Organised by:

The Plastics and Rubber Institute Malaysia

IRC International Rubber Conference

KUALA LUMPUR CONVENTION CENTER

4-6 September 2018

www.irc2018.com

2018

In collaboration with:

International Rubber Conference Organisation

Malaysian Rubber Board

Malaysian Rubber Glove Manufacturers Association

Malaysian Rubber Products Manufacturers Association

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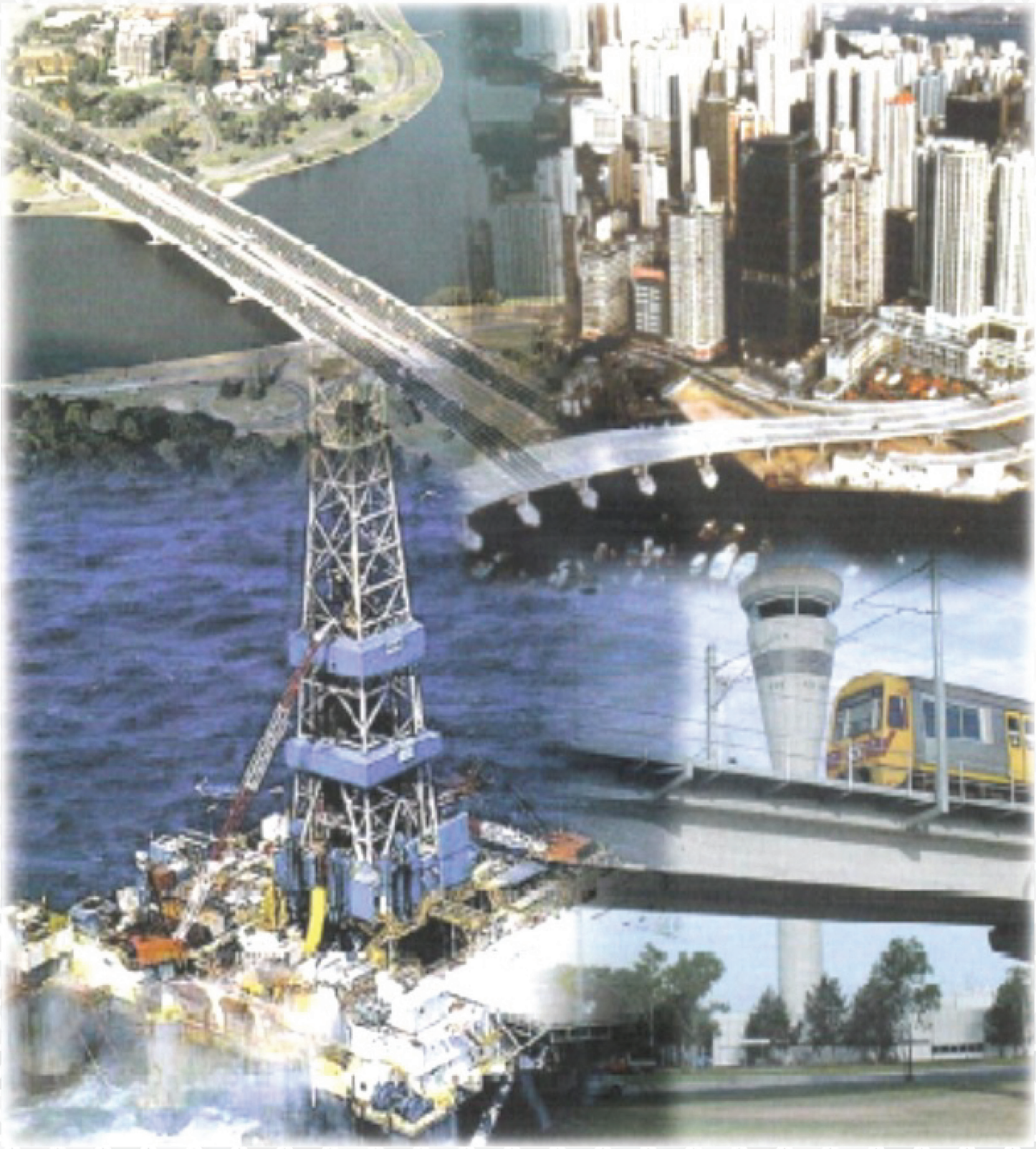

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▪ SMR 5	▪ SVR 10 / CSR 10
▪ SMR 20 CV	▪ SVR 10 CV
▪ RSS 1	▪ SIR 10 / SIR 20
▪ RSS 3	▪ ADS
▪ CSR 5L	▪ STR 10 / STR 20
▪ Skim Block	▪ SBR1502
▪ Latex Concentrate	▪ BR1220

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AWARDS & ACCOLADES

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Speakers

Dr. Zairossani Mohd Nor
Malaysian Rubber Board
Malaysia

Sudharshan Varadaraj
Elgi Rubber Company
India

David Stevens
TRIB
USA

Dirk G.H. Reurslag
VMI
Netherlands

Adam Gosling
TyreSafe
Australia

Rajiv Budhraja
ATMA
India

Dr. Ngeow Yen Wan (Roland)
Malaysian Rubber Board
Malaysia

Jos Uijlenbroek
Ferm RFID Solutions BV
Netherlands

Colin Clarke
Schill + Seilacher "Struktol"
Germany

David Willson
Retreading Business,
UK

Karun Sanghi
TRIA
India

Chin Hon Meng
TRMAM
Malaysia

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Conference Introduction

The Plastics and Rubber Institute Malaysia (PRIM) takes great pleasure in hosting this 3-day International Rubber Conference (IRC) 2018 under the auspices of The International Rubber Conference Organisation (IRCO). IRCO is an association of rubber societies from around the world. The primary objective of this conference is to offer a platform for professionals to share knowledge, network, and gain perspectives of trends and developments in rubber, with unique reference to the conference destination.

You will find enclosed with this booklet, the comprehensive programme schedule with a themed listing of presentation titles and speakers, as well as exhibition details. Approximately 150 papers from a diverse range of topics will be presented for further deliberation. These papers and their respective presenters originate from 20 countries globally including China, Czech Republic, Germany, India, Indonesia, Iran, Italy, Japan, the Netherlands, Philippines, Russian Federation, South Korea, Thailand, Turkey, Singapore, Slovakia, United Kingdom and United States of America. The domain of research encompasses upstream, midstream and downstream related to rubber development i.e. biotechnology, rubber sciences, rubber technology, applications, products, engineering, test methods, standard development, quality control, techno-economics, marketing as well as sustainability and environmental management.

The 9th International Rubber Glove Conference and Exhibition (IRGCE) is concurrently held with IRC 2018, upon successful collaboration between the IRC 2018 Organising Committee and the Malaysian Rubber Glove Manufacturers Association (MARGMA). IRGCE was inaugurated in 2002 to bridge the gap among the rubber glove industry players. A record number of 535 booths comprising 205 exhibitors from 14 countries are set-up for this exhibition.

In conjunction with IRC 2018, the Malaysian Rubber Board (MRB) Technical Workshop and the National Symposium of Polymeric Materials (NSPM) 2018 are further additional events taking place on the 3 and 5 of September 2018, respectively. The one-day MRB technical workshop is an interactive platform for discussing issues and challenges related to both midstream and downstream sectors of the rubber industry, while the NSPM 2018 is a premier national symposium that allows for networking among students, academicians and researchers in an exchange of their frontier research results.

On this note, we look forward to your participation in the abovementioned concurrent events. We wish you all a fruitful and pleasant week filled with inspiring and beneficial insights to be gained during these programmes alongside the conference. Do also take this opportunity to visit city highlights and have a memorable stay in Kuala Lumpur.

Dr Amir Hashim MD YATIM (Advisor)
Dr Yen Wan NGEOW, Roland
Veronica CHARLOTTE
Azlina PAWAN
Hui Mei LIM, Evelyn

Editorial and Publication
IRC 2018

Messages

Message from Organising Chairman

Selamat Datang, I wish to extend a warm welcome to all participants and delegates of the International Rubber Conference 2018 (IRC 2018) held in the capital city of Malaysia.

It has been a decade since Malaysia last hosted the International Rubber Conference *i.e.* the IRC 2008, successfully organised by the Malaysia Rubber Board. I take this opportunity to express our gratitude once again for their excellent effort in organising the previous event. The baton of being a member of International Rubber Conference Organization (IRCO) has now been passed on from MRB to The Plastics and Rubber Institute of Malaysia. Our gratitude to MRB for their continued support in rendering needed advice and assistance in organising the 2018 series.

PRIM has come a long way since its inception in 1960 as the Malaysian chapter of the former Institute of Rubber Industry, UK, and later PRI which subsequently merged with other professional bodies forming the current IOM3 headquartered in London. Our journey continues in playing a key role to promote and enhance the practice of polymer science and technology through education, training and related activities to fulfil the professional needs of the members and industry. For almost 60 years since its birth, PRIM has supported the rise of the Malaysian rubber industry to international importance.

PRIM is indeed privileged to organise the IRC 2018 under the auspices of the IRCO, an association of rubber societies worldwide which plans the calendar for the main international rubber conferences.

IRC 2018 is held in conjunction with the 9th International Rubber Glove Conference and Exhibition (9th IRGCE), which is a must visit bi-annual event for the medical care, oral dental, food handling, laboratories and other industrial handling users. "*Transforming Technology; Driving Innovation*" is the common theme for both events held at the renowned Kuala Lumpur Convention Centre.

IRC 2018 along with the 9th IRGCE will provide an excellent platform for rubber scientists, technologists, academicians and industrialists to share knowledge while exchanging ideas, technology and latest research findings, coupled with the interaction and networking at various social events throughout.

Up to press time, we have received a total of 155 conference papers from speakers originating from 22 countries. The conference will cover key topics including Novelty in Rubber; Science & Technology, Environmental/Green Technology and Sustainability; Latex Products; Tyres; Engineering and Automotive Products, *etc.*

On behalf of the Organising Committee, I would like to express our gratitude to all of you as well as various organisations for their kind participation and fervent support. We wish you successful deliberations at the conference. Last but not least, we urge you not to miss the opportunity to visit the joint exhibition, which is the largest rubber show by far staged in Malaysia.

Pak Kuen CHAN
Organising Chairman, IRC 2018

Message from PRIM President

Welcome to Kuala Lumpur, Malaysia and the International Rubber Conference 2018. Malaysia has previously hosted the IRC on a couple of occasions back in 1997 and more recently in 2008. Both these events were organised by the Malaysian Rubber Board hence this marks the first opportunity and privilege for the Plastics and Rubber Institute of Malaysia to play host, since taking over MRB's role as Malaysia's representative to IRCO in 2014.

ICR 2018 breaks new grounds in a different way. For the first time, the IRC in Malaysia will be held in collaboration with other major Malaysian rubber organisations and NGOs. IRC 2018 is also held in conjunction with the International Rubber Glove Conference and Exhibition, a bi-annual event organised by the Malaysian Rubber Glove Manufacturers Association who are also PRIM's principal partner for the IRC. As a co-host for both events, the Malaysian Rubber Export Promotion Council will conduct a series of talks and other activities to explain scholarships and career opportunities in the rubber industry to students in secondary schools and universities. The National Symposium on Polymeric Materials, an annual event principally for university post-graduate students to present their research, will also be held during the same period. This year, the organisers are Universiti Kuala Lumpur (MICET) and the event is sponsored by PRIM.

PRIM is grateful to its collaborators for their assistance in promotion, advise and participation in the various IRC Organising Committees. Above all, Malaysian Rubber Board has been most supportive. We wish to thank the Malaysian Rubber Product Manufacturers Association and the Institut Kimia Malaysia for involving representatives in the many committees, as well as Universiti Sains Malaysia and Universiti Kuala Lumpur (MICET) for their valuable contributions especially in the IRC Technical Committee. We thank the International Rubber Research and Development Board and member associations of IRCO for their assistance to promote IRC 2018 to their members. I reserve my last vote of thanks to MARGMA, our principal partner, who bankrolled IRC 2018 in making this conference a success with their participation and support. Finally, I personally wish to thank all volunteers from the various organisations who for their valuable time and expertise.

Once again we welcome our all participants from Malaysia and abroad with much gratitude. I wish you all a fruitful conference and pleasant experience.

Kai See PONG
President
The Plastics & Rubber Institute Malaysia

Programme Details

IRC INTERNATIONAL RUBBER CONFERENCE
4 - 6 September 2018
www.irc2018.com
KUALA LUMPUR CONVENTION CENTER

OVERALL EVENT SCHEDULE

Monday, 3 September 2018

Pre-Registration (Registration Counter, Level 3)

1000 to 1800	Pre-Registration for Speakers, Conference Participants and Exhibitors
0900 to 1530	MALAYSIAN RUBBER BOARD TECHNICAL WORKSHOP - http://irc2018.com/workshop/

Tuesday, 4 September 2018

Opening Ceremony (Plenary Hall, Level 1)

0800 to 1400	Opening Ceremony & Tour of Exhibition

Conference (Plenary Hall, Level 1)		Exhibition (Ground Floor)	
0800 to 0900	Registration for Speakers and Conference Participants Arrival of Guests-of-Honour	0800 to 0900 0900 to 1700	Registration for Trade Visitors Exhibition Open to Public & Trade Visitors
0900 to 1000	Opening Ceremony	0945 to 1300	Tour of Exhibition by Guest-of-Honour
1000 to 1030	Tea Break	1300 to 1400	MARGMA Press Conference at Press Centre
1100 to 1300	Tour of Exhibition		
1300 to 1400	Lunch		
1400 to 1740	**PLENARY LECTURES**		

Career Talks (Room 304-305, Level 3)		Conference Dinner (Hall 1 & 2, Level 3)	
1000 to 1600	Career Talks	1730 to 1900 1900 to 2200	Cocktails Reception & Photo Booth Conference Dinner

Wednesday, 5 September 2018

Conference (Plenary Hall, Level 3)		Exhibition (Ground Floor)	
0930 to 1700	Plenary Theatre - 9th IRGCE Conference	0900 to 1700	Exhibition Open to Public & Trade Visitors
0900 to 1730	Conference Room 1, 2, 3 & Room 302-303 - IRC 2018 Parallel Sessions *(CF1, CF2, CF3, & RM4)*		

Career Talks (Room 304-305, Level 3)

0930 to 1600 Career Talks

IRCO Committee Meeting & Dinner (Room 306, Level 3)

1730 to 2100 CLOSED MEETING - INVITED GUEST ONLY

Thursday, 6 September 2018

Conference (Level 3)		Exhibition (Ground Floor)	
0930 to 1700	Plenary Theatre - 9th IRGCE Conference	0900 to 1700	Exhibition Open to Public & Trade Visitors
0900 to 1700	Conference Room 1, 2, 3 & Room 302-303 - IRC 2018 Parallel Sessions *(CF1, CF2, CF3, & RM4)*		

NSPM (Room 306, Level 3)

0900 to 1700

IRC 2018 IRCO Student Prize Award (Room 306, Level 3)

1540 to 1600

9th IRGCE Closing Ceremony (Plenary Theatre, Level 3)

1650 to 1700 9th IRGCE Closing Ceremony

Friday, 7 September 2018

IRC 2018 Technical Tours - https://irc2018.com/social-program-2/

INTERNATIONAL RUBBER CONFERENCE, IRC 2018

3 September 2018 (Monday)
MRB Technical Workshop 2018
Venue: Room 304, KLCC

0830 – 0900	Registration	
0900 – 1520	PARALLEL SESSION	
	PRESENTATION	CLINIC SESSION (1000 – 1630)
	Topics: 1. Overview of A5 and A6 Programmes 2. Common Problems in Rubber Compounding Factories and Troubleshooting 3. Rubber-to-Metal Bonded Components: Attributes and Challenges 4. Specialty Rubber Application in Latex Based Product: Adhesive & Paint 5. RRIMfoam™: Deproteinised Natural Rubber Latex Slow-Recovery Foam 6. Awareness in Standard Development Related to Rubber and Rubber Products 7. Proficiency Testing Materials 8. MRB Testing and Services 9. TARRC Testing and Services 10. Product Certification Services by MRB	Focus area: a) Tyre Compound b) IRG /Engineering Product (Design, Consultancy, Testing, Compound, Processing) c) GRG Product (Compound and Processing) d) SMR Related Matter (Laboratories, Quality, Processing) e) Latex Product (Gloves, Adhesive, Paint) f) Product Certification (SMG and others) g) G-TAC$_R$ -Testing and Services for Rubber h) Specialty and New Rubber (EKOPRENA, PUREPRENA, LENR, Latex) i) Training & Publication j) Proficiency Testing Programme and Materials

Day 1: 4 September 2018 (Tuesday)
Venue: Plenary Hall, Level 1

0800 – 0900	Registration
0900 – 1000	Opening Ceremony
1000 – 1030	Tea Break
1100 – 1300	Tour of Exhibition by VIP
1300 – 1400	Lunch Break
1400 – 1440	Plenary Lecture 1 (P1) "State of the Rubber Glove Industry" *J.F. LOW, Denis* President, Malaysian Rubber Glove Manufacturers Association (MARGMA)
1440 – 1520	Plenary Lecture 2 (P2) "Gloves as Weapons of War in the Fight against Untreatable Infections" *W. TRUSCOTT* President of Truscott Medsci Associates
1520 – 1600	Plenary Lecture 3 (P3) "Rubber-to-Metal Bonded Components: Attributes and Challenge" *A. MUHR* Engineering Research & Design, Tun Abdul Razak Research Centre (TARRC)
1520 – 1540	Tea Break
1620 – 1700	Plenary Lecture 4 (P4) "Prospective Insights into Vulcanisation and Reinforcement of Rubber: Looking Forward to the Next Century" *Y. IKEDA* Director, Center for Rubber Science and Technology, Kyoto Institute of Technology
1700 – 1740	Plenary Lecture 5 (P5) "Sustainable Water Management for the Rubber Industry" *A.F. ISMAIL* Deputy Vice-Chancellor (Research and Innovation), Universiti Teknologi Malaysia
1930 – 2200	Conference Dinner

Technical Sessions– Programme at a glance
Day 2: 5 September 2018 (Wednesday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
0900 – 1040	Filled Vulcanisate	Rubber Engineering	Test Method and Standards Development	Rubber Sustainability
1040 – 1100	TEA BREAK			
1100 – 1240	Rubber Science	Rubber Applications	Test Method and Standards Development	Rubber Sustainability
1240 – 1340	LUNCH BREAK			
1340 – 1520	Rubber Blend	Rubber Applications	Specification and Quality Control	Rubber Sustainability
1520 – 1540	TEA BREAK			
1540 – 1720	Natural Rubber Science	Rubber Products	Test Method and Quality Control	Rubber Techno-Economics

Day 3: 6 September 2018 (Thursday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
0900 – 1040	Applications in Tyre	Rubber Engineering	Modern Natural Rubber Processing Technology	Novelty in Rubber
1040 – 1100	TEA BREAK			
1100 – 1240	Biotechnology and New Polymer Synthesis	Rubber Engineering	Rubber Marketing	Novelty in Rubber
1240 – 1340	LUNCH BREAK			
1340 – 1520	Materials Science in Tyre	Rubber Engineering - Seismic	Nanocomposites	
1520 – 1540	TEA BREAK			
1540 – 1720	Rubber Science	Rubber Products	Standards Development and Quality Control	IRCO Student Prize Giving Ceremony

Technical Sessions – Full Programme
Day 2: 5 September 2018 (Wednesday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
0900 – 0920	Invited Speaker Kyungho CHUNG A06: The Dual-Function of ZnO in Magneto-Rheological Elastomer Based on Ethylene/ Acrylic Elastomer (AEM) and Its Magneto-Induced Properties	Invited Speaker Liqun ZHANG B40: Ideal Microstructure for Super Tyre Performance: From Design to Performance	Invited Speaker Pinprayoon ORAWAN C07: Migration of N-nitrosamines from Rubber Gloves for Handling Food: Effect of Extraction Media	Invited Speaker Devaraj VEERASAMY E07: Sustainable Rubber Industry with Eco-Friendly Processing
0920 – 0940	Gon SEO A18: Preparation of Networked Silica-Filled SBR/BR Compounds with Improved Wet Traction and Rolling Resistance by Wet Masterbatch	Barnabas SHAW B21: Understanding the Cyclic Fatigue Behaviour of Filled HNBR Elastomers	Invited Speaker Victor CHAN C19: Feasibility Assessment on Condom Foil Opening Device (AONI Box)	Invited Speaker Susanna LIEBER A11: Hydrogenated Nitrile Rubber (Therban®) with Improved Oil Resistance and Low Temperature Flexibility
0940 – 1000	Nerissa Unielle QUENGA A27: Thermal and Viscoelastic Properties of Recycled Rubber-Derived Carbon (CRR) and Geothermal Brine-Derived Silica Fillers in Rubber Compounds	Keizo AKUTAGAWA B25: Nanomechanics on Non-Equilibrium Thermodynamics of Rubber-Like Materials	Hui Mei LIM C01: Integrating Theory of Copper Chelation, Latex Preservation and Oxidation in Natural Rubber Latex	Invited Speaker Wataru SAKAI E13: Spin-Trapping Analysis of Thermal Degradation Mechanism of Thermoplastic Polyester Elastomer
1000 – 1020	Luciano TADIELLO A55: Shape-Controlled New Nanofillers for Tyre Industry: Reinventing Rubber Compounds Properties with SmartNet Silica	Muhammad FAROOQ B29: Some Factors Affecting the Flex Life of Polybutadiene Rubber Vulcanisates	Yasuyuki HIRAKAWA C02: Trial Evaluation of Vulcanisation Depth of Thick Rubber Products by Terahertz Radiation	Abu Hassan AZIANA E05: Assessing Biodegradability of Epoxidised Natural Rubber Latex Films
1020 – 1040		Sanjoy DATTA B33: Study of Relationship between Fracture Energy and Redistribution of Processing Oil at Fracture Surface of Rubber	S.A.S. FARINIE C12: Standards Development at ISO/TC 45 Towards United Nation's Sustainable Development Goals	Suganti RAMARAD E03: Recycling Waste Tyres: Effect of Radiation Sensitisers and Electron Beam Irradiation of Properties of Reclaimed Waste Tyre Rubber
1040 – 1100	TEA BREAK			
1100 – 1120	Invited Speaker Anil K. BHOWMICK A36: Novel Forms of Carbon as Performance Enhancers for Rubber Vulcanisates	Invited Speaker Cornelis VAN DER AAR B22: Innovative EPDM Compounding for Optimal Ultimate Properties	Invited Speaker Jorge LACAYO PINEDA C10: Innovative Kinetic Approaches in Rubber Technology	Invited Speaker Sau Soon CHEN E06: Climate Actions for the Rubber Industry

Technical Sessions – Full Programme
Day 2: 5 September 2018 (Wednesday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
1120-1140	Invited Speaker Siby VARGHESE A48: Response Surface Methodology: A Tool for Assessing the Role of Compounding Ingredients in Peroxide Vulcanisation of Natural Rubber		Invited Speaker Pasaree LAOKIJCHAROEN C17: Development of Rubber Product Standards in Thailand	Invited Speaker Rabindra MUKHOPADHYAY E09: Green Mobility, Challenges and Opportunities for Automotives, Tyres and Related Industry
1140-1200	Mehdi RAZZAGHI-KASHANI A39: Physical Effects of Reinforcing Fillers on the Kinetics of Rubber Vulcanisation	Mustafa Kamal MAZLINA B24: Natural Rubber Modified Asphalt for Road Application	Amran Mohamad Khairul AKMAL C04: Flexure Testing Machine for Automotive Air Brake Hose and Hose Assemblies	Invited Speaker Naesinee CHAIEAR E12: Natural Rubber Latex Allergy: Cause, Control and Prevention
1200-1220	Akansha RATHI A54: Effect of Aromatic Oil on the sSBR/BR Blend Components Revealed Using BDS and PALS	Yasuhiro KAMEDA B31: New Kneading Advanced Mixing Rotor	Rizuan Mohd Ismail RIFDI C06: Equipment Development for Supporting Establishment of ISO 3821 towards Certification of Welding Hoses	Hans VAN HOEK E01: Challenges for Reuse of Passenger Car Tyres for a Circular Economy
1220-1240	Murat SEN A45: The Effect of Ionising Radiation on the Mechanical Properties of NBR Elastomers Reinforced By Lignin	Daniel SCHMIDT B46: Influence of Different Temperature Control Unit (TCU) Settings on Thermal Melt Homogeneity and Throughput in Rubber Extrusion Processes	Christopher ROBERTSON C16: Applying the Cutting Method to Quickly Quantify Elastomer Durability in the Laboratory for Compound Development and Quality Control	Paul SPEED E14: Sustainable Rubber through the Lens of Institutional Investors
1240-1340	LUNCH BREAK			
1340-1400	Invited Speaker Ulrich GIESE A09: Thermal Oxidative Ageing in Single and Two Phase Elastomer Systems - Kinetics and Spatial Evolution	Aik Hwee ENG B39: Advantages of Manufacturing and Using Natural Rubber Gloves	Invited Speaker Azemi SAMSURI C20: Technical Advisory Service (TAS)	Invited Speaker Eniya Listiani DEWI E10: The Potential of Natural Rubber Resources in Indonesia to Meet the Needs of World Rubber Products
1400-1420	Gustavo Ariel SCHWARTZ A04: Nano-Mechanical Structural Characterisation of Immiscible SBR/NR Blends	Invited Speaker Ranjit MATTHAN B41: Development and Evaluation of Non-Enzymatic (NE) Deproteinised Latex and Dry Natural Rubber Grades for Downstream Product Applications	Mohamed Resali Nur SALWANIE C14: Recent Developments in Data Analysis: Proficiency Testing (PT) Programme of Rubber and Rubber Products	Cristina BERGMANN E02: Influence of Process Oils Based on Renewable Sources on Key Properties of Tyre Treads

Technical Sessions – Full Programme
Day 2: 5 September 2018 (Wednesday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
1420-1440	Yuki TAKAHASHI A17: Study of Butadiene Rubber/Resin Composite by Using Nano-Palpation AFM	Sitisaiyidah SAIWARI B02: Thermoplastic Vulcanisates Based on Recycled Rubber from Waste of Natural Rubber Gloves and Polypropylene Blends: Effect of Maleic Anhydride as Compatibiliser	Dhavalkumar Narendrabhai PATEL C15: Novel Tools to Meet Analytical Challenges of Polymer Characterisation	Wencai WANG E08: A Novel Continuous and Green Technique for the Desulfurisation of Waste Tyre Rubber Using Multistage Screw Extruder: From Basic Research to Industrial Application
1440-1500	Naoki YAJIMA A24: Evaluation of Impact Absorbing Properties of Thermoplastic Elastomers	Abu Bakar ROHANI B23: Development of Wallpaper Adhesive from Specialty Natural Rubber Latex	Mohd Yusop MOHAMAD C21: Automotive Rubber Products: Related Regulations and Opportunity under WP29 Framework	Invited Speaker Choo Hin OON E15: Rubber Additives with RoHS Compliances Meeting Global Safety Standards
1500-1520	Mehmet KODAL A41: Mechanical, Rheological and Morphological Properties of NR/M-POSS Compounds	Siti Maizatul Farhain SALEHUDDIN B30: Burning Rate and Characterisation of Hydroxyl Terminated Natural Rubber/ Isophorone Diisocyanate/ Glycerol Propellant Composites		Invited Speaker Salvatore PINIZZOTTO E16: Sustainability and Growth In A Fast Changing Rubber Economy
1520-1540	TEA BREAK			
1540-1600	Invited Speaker Jitladda SAKDAPIPANICH A35: An Origin of the Outstanding Properties in Natural Rubber: Structural Characterisation of Natural Rubber Relating to Gel and Storage-Hardening Phenomena	Tao HAN B01: New NORDEL EPDMs Enabled by Advanced Molecular Catalyst (AMC)	Invited Speaker Rose Marie SALAZAR C05: Baseline Study on the Quality of Rubber Crumbs in Southern Philippines: The Role of Testing Laboratory in the Rubber Industry	Invited Speaker Kai See PONG D04: The New Rubber Economy: Expect the Unexpected
1600-1620	Abdullah NURULHUDA A30: Urea as a Single Denaturing Agent in Deproteinised Natural Rubber Latex	Kok Chong YONG B03: Antistatic Footwear Based on Epoxidised Natural Rubber: Optimisation of Formulation	Invited Speaker Haslina ABDUL KADIR C08: The Production and Certification of Reference Materials	
1620-1640	Sirirat KUMARN A37: Ammonia-Preserved Latex Stability Mechanism to Reveal a New *Hevea* Rubber Particle Microstructure Model	Chesidi HAYICHELAEH B04: Silanisation Efficiency of Silica/Silane in Dependence of Amines in Natural Rubber Based Tyre Compounds	Eshwaran Subramani BHAGAVATHESWARAN C03: Comparative Investigation of the Influence of Material Formulation on the Ageing Behavior of FKM, VMQ, EPDM and HNBR Elastomers for Sealing Applications	Invited Speaker Dar WONG D02: Global Economic Influences on Rubber Prices

Technical Sessions – Full Programme
Day 2: 5 September 2018 (Wednesday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
1640-1700	Siang Yin LEE A49: Novel Biocompatible Natural Rubber Latex Film Incorporated with Vegetable Oil Nanoemulsion as Plasticiser	Ibrahim NORAZURA B05: Application of Arrhenius Equation and Thermocouple Measurements in Predicting Curing Behaviour of Large Rubber Component	Kamaruddin Ahmad NAZIR C13: ISO/IEC 17025 Tyre Testing Laboratory for Mechanical (Tyre) Testing	Invited Speaker Choo Hin OON D07: Effect on Rubber Demand of New Technologies Particularly in Transport Related Industries
1700-1720		Jan KRUZELAK B06: Rubber Magnetic Composites with the Effect of Electromagnetic Radiation Shielding		

Technical Sessions – Full Programme
Day 3: 6 September 2018 (Thursday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
0900-0920	Invited Speaker Kannika SAHAKARO B10: Enhancing Filler-Rubber Compatibility of Silica Reinforced Tyre Tread Compounds Using Chemically Modified Natural Rubbers	Invited Speaker Alan TAN B42: Fatigue Analysis of Rubber Bushing under Multi-Block Duty Cycle	Invited Speaker Seiichi KAWAHARA A51: Mechanical Properties of Natural Rubber with Nanomatrix Structure	Changwoon NAH A20: 4, 4'-Bis(maleimidio) diphenylmethane: A Versatile Material for Enhancing Various Properties of Halogenated Isobutylene-Isoprene Rubbers
0920-0940	Abd. Rahim ROHAIDAH B11: Green Retreaded Tyres for Logistic Applications	Chenxi BAI B13: Research on Complete Sets of Industrialised Key Technologies of Synthetic Nature Rubber Chain	Benjamin ZIRNSTEIN A10: Leaving Traditional Routes for Flame Retarded Rubbers: Exploring New Pathways	Shibulal GOPI SATHI A40: A Novel Anti-Reversion Agent for the High Temperature Vulcanisation of Unsaturated Elastomers with Accelerated-Sulfur
0940-1000	Suppachai SATTAYANURAK B19: Synergistic Effect by High Specific Surface Area Carbon Black as Secondary Filler in Silica Reinforced Natural Rubber Tyre Tread Compounds	Kamaruddin SHAMSUL B34: Effect of Specialty Natural Rubbers for Engine Mount Application	Yuzhu XIONG A21: Study on the Surface Modification of Aramid Fibre and Properties of Modified Aramid Fibre Reinforced Natural Rubber Composites	Raa Khimi SHUIB A42: Self-Healing Natural Rubber: IT'S REAL AND IT'S COMING SOON

Technical Sessions – Full Programme
Day 3: 6 September 2018 (Thursday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
1000 – 1020	Bartlomiej JANOWSKI B44: Novel Functionalised Solution Styrene Butadiene Rubber for Winter Tyres Tread	Haibo YANG B35: Numerical Simulation of Flow of Rubber Compounds in Partially Filled Internal Mixer	Abd Rahim ABDUL HASIF A23: Natural Rubber (NR) Gloves Reinforced with Cellulose Nanocrystals: Preparations and Physio-Mechanical Characterisation	
1020 – 1040		Mohd Khairulniza MANSOR B36: Rubberised Roads: Constructions and Benefits		
1040 – 1100	TEA BREAK			
1100 – 1120	Chaendaekattu NARAYANAN A34: Variation, Heritability and Genetic Correlation of Growth and Wood Traits in Para Rubber Tree (*Hevea brasiliensis*) and Implications for Breeding	Invited Speaker James BUSFIELD B20: A New Constitutive Model for Carbon Black Reinforced Rubber in Medium Dynamic Strains and Medium Strain Rates Based on Fractional Derivatives	Invited Speaker Motoko KAWANO D06: Development Potential of Rubber Industry in Southeast Asia: Learning from Malaysia and Thailand	Invited Speaker Krisda SUCHIVA A53: Progress in Development of Electron Beam Vulcanised Natural Rubber Latex
1120 – 1140	Quanquan DAI A12: Synthesis of Polybutadiene with Controllable Microstructure Using a Rare Earth Organic Sulfonates Catalyst System	Yuki KIMURA B14: Study on Voxel Finite Element Analysis of Open Cell Polyurethane Foam	Siu Ming LEE D01: Malaysia's Rubber Gloves Export: The Role of Free Trade Agreements	Ramli ROSLIM A29: Natural Rubber Latex Slow-Recovery Foam for Shoe Insoles
1140 – 1200	Zhanbin FENG A38: A Robust, Self-Healable and Shape Memory Double Network Hydrogels	Hayato ONODERA B15: Thermodynamic Modeling for Compressible Hyperelasticity to the Microcellular Urethane	Aye Aye KHIN D05: Challenges with Export Rubber Latex Products in the ASEAN Market	Preeyanuch JUNKONG A43: Study on Guayule and Dandelion Natural Rubbers for Sustainability
1200 – 1220	Afina RUMIANTSEVA A57: Application of Different Lewis Bases for Development of New s-SBR Grades	Hayato NAKAHARA B16: Development of Anisotropic Hyperelastic Model for Fiber-Reinforced Rubbers Considering the Dispersion of Fiber Orientation Angles	Siu Ming LEE D03: An Analysis of Malaysia's Companies Participation in Condom Supply to Global Fund	Shipeng WEN A44: Graphene Aerogel/ Silica Hybrid Filler Reinforced SBR Nanocomposite with High Performance
1220 – 1240		Akihiro MATSUDA B17: 3-Dimensional Homogenisation Finite Element Analysis of Foamed Rubber		
1240 – 1340	LUNCH BREAK			

Technical Sessions – Full Programme
Day 3: 6 September 2018 (Thursday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
1340 – 1400	S.S. SALINA A13: Determining Crosslink Density of Tyre Treads and In-Service Tyres *via* Swelling Measurement	Invited Speaker Toshio NISHI B08: International Ultimate Behaviour Investigation of Various Elastomeric Seismic-Protection Isolators for Buildings	Invited Speaker Siby VARGHESE A47: Transparency of Latex Products: Effect of Prevulcanisation and Compounding Ingredients	
1400-1420	Paul BROWN A25: The Development of an Improved Understanding of Tread Wear and Its Prediction	Invited Speaker Azura A. RASHID B32: Comparative Studies on the Influenced of Types of Rubber and Carbon Black on Dynamic Properties of Anti Vibration Application	Invited Speaker Wirach TAWEEPREDA A50: The Effect of Field Natural Rubber Latex Pre-treatment with Cationic Exchange Resin on Latex Dipped Gloves Properties	
1420-1440	Yen Wan NGEOW A28: Wear Analysis of In-Service Tyres for Buses	Hamid AHMADI B12: Rubber Anti Seismic Systems for Protection of Structures and Non-Structural Elements	Mohd Rasdi FATIMAH RUBAIZAH A14: Alternative Microwave Coagulation and Its Effect on Raw Rubber Properties of Specialty Natural Rubber	
1440-1500	Nik Ismail NIK INTAN A32: Compounding Epoxidised Natural Rubber (ENR) Blends for Industrial Hose and Seal Applications	Farzad A. NOBARI B37: Recipe Optimisation and Characterisation of Elastomers Used as High Damping Seismic Isolation Materials	Wonho KIM A19: The Effect of Coagulant Types on Silica Dispersion of Compound Using WMB Technology	
1500-1520		Tan Teng OR B45: Application of Natural Rubber Product for Seismic Isolation of Civil Engineering Structures	Qinghong FANG A05: The Relationship between Crystallisation Behaviour and Processing Properties of Eucommia Ulmoides Gum and Natural Rubber Blend	
1520-1540	TEA BREAK			
1540-1600	Invited Speaker Anke BLUME A07: Effect of Electron Beam Irradiation on Structure and Properties of Styrene-Butadiene Rubber	Invited Speaker Nobuo MUROTA B26: An Experimental Study on Performance of High Damping Rubber Bearings under Long Period Earthquake Ground Motion	Invited Speaker Henri BURHIN C11: Rubber Process Analyser (RPA): Real Achievement, Limitations and Performance Assessment	IRCO Student Prize Giving Ceremony: Student Poster Presenter Student Oral Presenter

Technical Sessions – Full Programme
Day 3: 6 September 2018 (Thursday)

	Conference Room 1 (CF1)	Conference Room 2 (CF2)	Conference Room 3 (CF3)	Room 302-303 (RM4)
1600-1620	Invited Speaker Masatoshi TOSAKA A16: New Concept of Strain-Induced Crystallisation in Crosslinked Natural Rubber		Mohamed Yusof YUSNIWATI C09: Gel Content Evaluation for Various Grades of Epoxidised Natural Rubber (ENR)	
1620-1640	Xiaorong WANG A33: The Principle of Frequency-Strain Separability	C.A. AHMAD KIFLI B07: Performance Testing of Silica Filled Ekoprena® 25 Passenger Car Tyres	Sabri Zawawi ABU HASSAN C22: SMR and Its Quality Control	
1640-1700	Chantara Thevy RATNAM A56: Influence of Irradiation on the Thermal and Morphological Properties of Ethylene Vinyl Acetate/Waste Tyre Dust Blends in the Presence of Devulcanising Agents	Abdul Ghani RASSIMI B09: Green Tyres Based on Specialty Natural Rubber for Public Transportation	Supramaniam S. SHANMUGAM C23: Industry Driven Glove Standards Development	

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Plenary Speakers' Biography

Jau Foo LOW, Denis
PRESIDENT, MALAYSIAN RUBBER GLOVE MANUFACTURERS ASSOCIATION (MARGMA)

Denis Low Jau Foo, an MBA graduate from the Preston University, USA also holds a Graduate Diploma in Management from the International Professional Managers Association, London. He is currently handling the Corporate Affairs of Supermax Corporation Berhad (a world-class international manufacturer, distributor and marketer of high quality medical gloves) and with a passion for sales and marketing, he is also actively involved in it and is a Director of the Group. In line with the glove business, Denis Low is also the President of the Malaysian Rubber Glove Manufacturers Association (MARGMA). He is also a Board Member of the Malaysian Rubber Board (MRB/LGM) and a trustee of the Malaysian Rubber Export Promotion Council (MREPC). He is a well-known strategist and is regularly inducted into many think-tank sessions for the Malaysian government and numerous institutions.

Malaysia is the world leading producer and exporter of natural rubber (latex) and synthetic rubber gloves. Low is expected to talk about the challenges facing the glove industry and opportunities for continued growth, not just of the glove industry but also of the broader Malaysian rubber products manufacturing sector.

Dr Wava TRUSCOTT
PRESIDENT OF TRUSCOTT MEDSCI ASSOCIATES

Dr Truscott is President of Truscott MedSci Associates, an independent consulting and education advancement company. Her doctorate in Comparative Pathology is from the University of California, School of Medicine, emphasising Microbiology, Immunology and Pathology. Her employment history includes Kimberly-Clark, SafeSkin Corporation, Baxter and MIDECO, a medical device-testing laboratory. She has authored or co-authored over 90 articles and 6 book chapters including the microbiology section of the AAMI Sterilization Recommended Practices, the ANSI/AAMI/ISO 19930 on systemic toxicity testing, several ASTM 11.40 glove standards, and the Microbiology section of the recently published, IAHCSMM Endoscope Reprocessing Manual. Dr Truscott is a prominent advocate for infection prevention and safety in healthcare.

Dr Alan MUHR
FORMER HEAD OF ENGINEERING RESEARCH & DESIGN, TUN ABDUL RAZAK RESEARCH CENTRE (TARRC)

Dr Alan Muhr graduated in mathematics at the University of Cambridge in 1975 and went on to do a PhD and post-doctoral research at the University of Nottingham on polysaccharides.

He was recruited in 1983 by the Malaysian Rubber Producers' Research Association (now TARRC) to work with Prof. Alan Thomas on abrasion of rubber and its relationship to crack-growth characteristics, but involving also stress-strain behaviour, ageing, friction and lubrication, and the effects of rate and temperature on all of these.

Later he worked on the design principles of rubber engineering components, especially load-deflection behaviour and failure.

He became Leader of the Engineering Research & Design Unit at TARRC in 1999. Laminated rubber isolators, marine fenders, automotive mounts and bushings and structural energy dissipation systems have all featured in his research and publications on applications of rubber in engineering.

He co-founded the biennial European Conferences on Constitutive Models for Rubber.

He received the Melvin Mooney Distinguished Technology Award of the Rubber Division of the American Chemical Society in 2015 - the most prestigious award available to a rubber professional.

He has published papers on a wide range of rubber engineering and applications topics

Dr Alan Muhr will speak on "Rubber-to-metal bonded components: attributes and challenges" - The failure of rubber products in service and methods to prolong the service life of same.

Prof. Dr Yuko IKEDA
DIRECTOR, CENTER FOR RUBBER SCIENCE AND TECHNOLOGY, KYOTO INSTITUTE OF TECHNOLOGY

Prof. Yuko Ikeda hails from Kyoto, Japan and is attached to the Faculty of Molecular Chemistry and Engineering, Kyoto Institute of Technology (KIT) where she is also Director of the Center for Rubber Science and Technology. She reached her notable career landmark in 1995 when she was appointed as a professor at KIT, after obtaining her Doctorate in Engineering from Kyoto University (1994). She was also recipient of the international 29th Oenslager Award in 2014. Prof Ikeda's R&D work focuses on rubber and elastomer science and technology. Her current research topics are fundamental studies on sulfur crosslinking and reinforcement of rubbers by using new analytical methods. Characterisation of natural rubbers is also studied by using synchrotron X-ray analyses. Her expertise and active R&D work is manifested in more than 66 publications in high-impact journals, the latest involving reinforcing biofiller "lignin" for high-performance green NR nanocomposites in RSC Advances.

Prof. Yuko Ikeda is expected to give a critical review, including new insights, of the mechanism of sulfur crosslinking.

Prof. Datuk Dr Ahmad Fauzi ISMAIL
PROFESSOR AT FACULTY OF CHEMICAL AND ENERGY ENGINEERING, UNIVERSITI TEKNOLOGI MALAYSIA

Prof. Datuk Dr Ahmad Fauzi Ismail is attached to the Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia (UTM). He is currently the Deputy Vice Chancellor of Research and Innovation, UTM. His R&D work is centred on the development of polymeric, inorganic and novel mixed matrix membranes for water desalination, wastewater treatment, gas separation processes, a membrane for palm oil refining, a photocatalytic membrane for removal of emerging contaminants, development of haemodialysis membrane and polymer electrolyte membrane for fuel cell applications. He obtained his PhD in Chemical and Process Engineering in 1997 from the University of Strathclyde (UK) and has published more than 500 journal articles, authored six books, 45 book chapters, edited four books, four patents granted and 16 pending. Prof. Fauzi won more than 120 national and international awards: the most prestigious is the Merdeka Award in 2014. He is involved extensively in R&D&C for national and multi-national companies related to membrane-based processes for industrial application and currently, has two spin-off companies.

Prof. Datuk Dr Ahmad Fauzi Ismail will speak on purification of waste water using membrane purification technology . The rubber industry, upstream as well as downstream (latex products), are heavy users of water. Prof. Fauzi has developed a working model to recover waste water for re-use.

Abstracts

P1
State of the Rubber Glove Industry

J.F. LOW, DENIS

The Malaysian rubber glove industry has developed rapidly and steadily since its infancy in the 1980s when Malaysian entrepreneurs went to Taiwan to buy their first production lines. The ingenuity and innovations of the industry captains had brought many improvements to the rubber glove manufacturing processes. Meanwhile, the support of the Malaysian government had helped to nurture and grow the Malaysian rubber glove industry over the past few decades. With sheer grit and perseverance, the Malaysian rubber glove industry has grown from a small production base in the 1980s into the world's largest glove manufacturing hub today.

In this plenary address, statistics on the performance of the Malaysian rubber glove industry will be presented. The successful transformation and innovations over the past few decades will be summarised. The insights are expected to give the audience an overview of the past, present and future of the Malaysian rubber glove industry.

Keywords: rubber glove manufacturing; statistics; innovations

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P2
Gloves as Weapons of War in the Fight against Untreatable Infections

W. TRUSCOTT

When your daughter has a sore throat and high fever, you take her to the doctor or clinic where antibiotics would be prescribed. You are told she will be rapidly on the road to recovery. When your son trips and falls onto a stone during a neighbourhood soccer match, you clean the wound, add antiseptic, and cover it with a bandage. If it starts to show signs of infection, you take him to the doctor or clinic for an antibiotic. When grandfather acquires pneumonia, his physicians are quick to provide antibiotics in efforts to save his life. Over the last 8 decades, we have grown to accept antibiotics as "magic bullets" against infection as fundamental components of medical treatment. Unfortunately, that is not going to continue to be the case. This lecture will focus the current state of antibiotic resistance, our vulnerable ageing population, their impact on infection rates and severity, how this affects near future glove demands and the urgent need for infection prevention solutions.

Keywords: glove; infection; antibiotic; resistance; prevention

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P3
Rubber-to-Metal Bonded Components: Attributes and Challenges

A.H. MUHR

Based on 35 years of research aimed towards the design principles of rubber engineering components, the talk will address the remarkable attributes of rubber-metal composites. But their success has not been without serious challenges in manufacture. Engineers exploit the attributes of rubber-metal composites in a wide variety of environments and mechanical load conditions, each of which poses a challenge to achieve a satisfactory service life. The presentation will analyse these challenges, illustrated with examples from the field and the results of research.

Keywords: rubber-metal; composites; engineering

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P4
Prospective Insight into Vulcanisation and Reinforcement of Rubber: Looking Forward to the Next Century

Y. IKEDA

Sulfur crosslinking and reinforcement by filler are the two most important issues governing the property of rubber vulcanisates. Findings from millions of studies carried out to gain better understanding of these aspects have not served to systematically enlighten rubber engineers as well as rubber researchers. Our group has elucidated that nano-fillers clustering to a three-dimensional network in the rubbery matrix are the essence of rubber reinforcement. The remaining knowledge gap is the exact mechanism of sulfur crosslinking reaction of rubber. In this plenary address, sulfur crosslinking reagents are shown to play important roles not only to chemically link the rubber chains but also to control the resultant network morphology. Zinc is a main reagent for the roles. To verify our mechanism, the conventional accelerated vulcanisation of isoprene rubber is introduced, where bridging bidentate zinc/stearate complexes are identified to be the intermediate for the sulfur vulcanisation. Reinforcement effect of the network domain with a higher network-chain density is also identified to characterise an inhomogeneous network structure of rubber. These novel insights are expected to initiate a scientific guide for sustainable development of the rubber industry.

Keywords: sulfur vulcanisation; nano-filler reinforcement; network inhomogeneity

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P5
Sustainable Water Management for the Rubber Industry

A.F. ISMAIL[1#], D. VEERASAMY[2] AND J. JAAFAR[1]

The midstream and downstream sectors of the NR industry, specifically raw rubber and latex dipped goods manufacturing are highly water-intensive operations. Water tariff has also been increasing, hence to operate a profitable rubber product manufacturing industry it is vital to look for alternative water sources and to have a control of the water supply. The wastewater treatment systems popularly used by most glove factories are either one of these: an activated sludge system; sequential batch reactors; and the up-flow anaerobic sludge blanket (UASB). These systems incorporate physical, chemical and biological processes before discharging the treated wastewater, which must comply with DOE requirements. This paper deals with the utilisation of membrane separation process (MSP) to carry out a tertiary treatment which is a polishing process on the 'treated wastewater' (TWW) by microfiltration (MF), ultrafiltration (UF) and reverse osmosis (RO), and recycle the TWW depending on the extent of usage at the factory. Incorporation of the MF process which removes suspended solids including all types of bacteria, subsequently can be reused as general factory processing water, replacing water from the public utility board (PUB) with MF followed by UF processes. The water can be used for leaching of residual chemicals from the manufactured gloves, diluent for concentrated latex and for preparing chemical masterbatches for latex formulation, etc. *MF, UF and RO processes allow utilisation of TWW for high-end uses. Raw rubber processing effluents are usually treated by ponding or an activated sludge system, where BOD, COD and nitrogen values are considerably reduced before being discharged into water courses. These can be further polished by MF to remove suspended solids and reused as processing water. Utilisation of MSP on TWW enables cost savings from purchasing various grades of water, in regards to control of a factory's own processing water requirement as well as immunity from escalating PUB water tariff increases, while the factory qualifies to incorporate ecolabelling on their products. Ecolabelling signifies no damage to the environment as the processing water is reused. The maintenance of MSP systems is straight forward, by means of designated membrane cleaning procedure with specifications of duration and chemicals used, followed by periodical checks for membrane integrity to replace damaged membranes. The clogging of membranes is rare as the bulk of COD and BOD loads are systematically removed during chemical, physical and biological processes, before the MSP. The backwash and membrane cleaning wastewater from MSP is diverted to an effluent sump or equalisation tank which is the starting point of the wastewater treatment process for the factory's effluent. A recent case study carried out in a glove factory retrofitted with MSP on TWW saved 30% of its operating cost. Therefore, MSP is one of the feasible technologies available currently which can be utilised to attain sustainability in water management in the rubber industry.*

Keywords: midstream; downstream; water-intensive; activated sludge system; sequential batch reactors; up-flow anaerobic sludge blanket; tertiary treatment; microfiltration; ultrafiltration; reverse osmosis; treated wastewater recycling

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A04
Nano-Mechanical Structural Characterisation of Immiscible SBR/NR Blends

S. CERVENY[1,2], L. ORTEGA[2], L.A. MICCIO[1,2], M. MEYER[3], N. ISITMAN[3], C. SILL[3], S. WESTERMANN[3] AND G.A. SCHWARTZ[1,2#]

Due to its outstanding properties, natural rubber (NR) is usually blended with other elastomers, typically with styrene-butadiene rubber (SBR), to obtain desired characteristics in the resulting compounds. In this work, a systematic study of unfilled SBR/NR blends using a combination of experimental techniques is presented. On one hand, atomic force microscopy measurements show a clear phase separation with nearly spherical regions of SBR in a continuous matrix of NR. Moreover, a detailed analysis of the mechanical modulus with a resolution of a few nanometers, shows a radial variation of mechanical properties on the SBR islands. In addition to this, energy dispersive X-ray analysis measurements show a radial distribution of sulfur for the same regions which is most likely related to an uneven distribution of the crosslink density which explains the variations in the mechanical properties. These results are in agreement with macroscopic thermal and dielectric characterisation by means of differential scanning calorimetry and broadband dielectric spectroscopy, rationalised in terms of selective migration of the different additives between polymer phases.

Keywords: elastomers; blends; immiscible; nano-structure; phase separation

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A05
The Relationship between Crystallisation Behaviour and Processing Properties of Eucommia Ulmoides *Gum and Natural Rubber Blend*

Q.H. FANG

The effects of crystallinity on blend of Eucommia ulmoides *gum (EUG) and natural rubber (NR) on the processing properties were researched. The performance of the compound was characterised by mechanical properties and processability. Using the new technique, the experimental results showed that the processing properties of the blends were improved when an amount of EUG less than 50 phr was added into NR, the Mooney viscosity of blend decreases. It is concluded that processing properties of the blend is related to the change of microcrystals of EUG in the system.*

Keywords: *Eucommia ulmoides* gum; natural rubber; crystallisation; processability; blend

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A06
The Dual-Function of ZnO in Magneto-Rheological Elastomers Based on Ethylene/Acrylic Elastomer (AEM) and Its Magneto-Induced Properties

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A magneto-rheological(MR) material is a type of functional and smart material which has rheological and dynamic properties that can be stimulated by an external magnetic field. A magneto-rheological elastomer (MRE) is divided into isotropic (i-MRE) and anisotropic MRE (a-MRE) depending on the magnetic particles arrangement. In the i-MRE, carbonyl iron particles (CIPs) are randomly dispersed, while they form a chain-like structure in the a-MRE. However, magnetic particles are inorganic materials demonstrating poor compatibility with elastomers. Hence, the mechanical properties decreased and damping properties were impacted with the increasing content of magnetic particles. In this work, we explored a facile method which uses a zinc oxide (ZnO) filling ethylene/acrylic elastomer (AEM) matrix to prepare higher performance MRE. The metal-ligand crosslink structure had been measured by FTIR, XPS, while the tensile strength and dynamic properties were tested by a universal testing machine and rubber process analyser (RPA). The results showed that coordination crosslinks were formed by ZnO and it resulted in outstanding tensile strength and unexpected dynamic properties due to the coordination bonds between Zn^{2+} and amine group in the matrix. Also, ZnO could catalyse the interfacial reaction of carbonyl on the CIPs and amino group in the curing agent. ZnO not only reinforced the mechanical properties of MRE but also improved the magnetically-induced dynamic properties.

Keywords: magnetorheological elastomer; zinc oxide; metal-ligand crosslink; AEM

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A07
Effect of Electron Beam Irradiation on Structure and Properties of Styrene-Butadiene Rubber

A. BLUME

Crosslinking and chain scission occur simultaneously during irradiation of polymers and influence their properties in an opposite way. To characterise the radiation-induced changes and evaluate how they influence the performance of the polymer, quantification of these reactions is crucial. In this work, the effect of styrene-butadiene rubber (SBR) radiation curing with doses ranging from 25 kGy to 200 kGy, at room temperature and air atmosphere was investigated. The Charlesby-Pinner and Charlesby-Rosiak equations were used to characterise the curing process. Only the Charlesby-Rosiak equation gave good linear representation of the data and allowed to obtain the parameters, which characterise the irradiated SBR system: (i) gel dose, (ii) ratio between chain scission and crosslinking, and (iii) radiation yields of crosslinking and chain scission. These parameters showed that SBR is quite resistant to ionising radiation, where crosslinking predominates over chain scission. The effect of irradiation on in-rubber properties is discussed. An increase in radiation dose resulted in change of tensile strength, elongation at break, mechanical modules, hardness, glass transition temperature and thermo-oxidative stability. Freezing point depression experiments were also conducted. The depression of the solvent freezing temperature in swollen polymer gels provided information on polymer network and mesh size, staying in agreement with the crosslink density values.

Keywords: irradiation; crosslinking; chain scission; styrene-butadiene rubber; Charlesby-Pinner; Charlesby-Rosiak

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A09
Thermal Oxidative Ageing in Single and Two Phase Elastomer Systems - Kinetics and Spatial Evolution

U. GIESE

High performance in thermal-oxidative stability is an important requirement for modern rubber materials in several applications. To improve these properties and to predict the material behaviour especially under dynamic load, a detailed knowledge about the kinetics and the spatial evolution of the ageing process in dependency on temperature, time and sample composition is necessary. Concerning the spatial evolution of material changes, the DLO effect and stability against cracks are important factors. The present investigations are focused on the kinetics and the DLO-effect in single and two phase elastomer systems, consisting of different unmiscible polydienes and EPDM. Beside ATR-FT-IR spectroscopy and chemiluminescence the micro-indentation method is used to characterise the spatial material changes quantitatively. Data for lifetime prediction are generated by means of tear analyser measurements in dependency on the ageing status (DLO-effect) and ageing parameters like temperature and time.

Keywords: thermal-oxidative; stability; spatial evolution; lifetime prediction; tear analyser

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A10
Leaving Traditional Routes for Flame Retarded Rubbers: Exploring New Pathways

B. ZIRNSTEIN

Elastomers are used in a wide range of automotive and railway applications. However, a severe drawback of most rubbers are their high flammability. Therefore, flame retardants (FRs) are added to improve the performance in fire. Generally, rubber composites are filled with high amounts of mineral fillers such as aluminium trihydroxide (ATH) to fulfil fire safety regulations. These high loadings may cause deterioration of the physical properties of the material. This work shows the implementation of two new strategies to achieve the modern demands on non-toxic FRs and the reduction of fillers. The first approach was the implementation of multilayer graphene (MLG), acting as a multifunctional filler, reinforcing agent and FR. The second strategy was the combination of phosphorous-containing FRs with a potential new polymeric char promoting agent polyaniline (PANI).

The morphology of the rubbers and homogenous dispersion of MLG was investigated via *scanning/transmission electron microscope (SEM/TEM) micrographs. Characterisation* via *thermogravimetric analysis (TGA) led to a broader understanding of the decomposition. In order to determine the flame retardancy effect of these materials, a multi-methodical approach was selected. Limiting oxygen index (LOI) and UL-94 were used to quantify the flammability of the rubber composites. The cone calorimeter provided information about the fire behaviour in forced flaming conditions. By examining alternate FR formulations and their effect on mechanical and physical properties of the rubber, new insight into the range of applicable additives for rubber composites may be won.*

Keywords: flame retardant; graphene; carbon black; aluminium trihydroxide; filler

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A11
Hydrogenated Nitrile Rubber (Therban®) with Improved Oil Resistance and Low Temperature Flexibility

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Demand for rubber materials with excellent low temperature properties are increasing. Using a low temperature HNBR from ARLANXEO, Therban® LT, a glass transition temperature of -48°C can be achieved, but volume swell is significantly increased compared to standard Therban® copolymers. In 2016, a model for new polymer development with improved oil resistance and excellent low temperature properties based on solubility parameters was reported. The use of this model led to a new terpolymer, which has been commercialised, as Therban® ST 3107 VP. This new polymer has an outstanding balance of swell and low temperature properties, which is remarkable for HNBR grades. This excellent balance between volume swell and low temperature properties could be observed in reference fluids like IRM 903, as well as in different fuels and other media. Also, different filler types and plasticisers have been evaluated to identify optimal compound formulations for this new grade.

Keywords: HNBR; low temperature; fuel testing; new polymer structure

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A12
Synthesis of Polybutadiene with Controllable Microstructure Using a Rare Earth Organic Sulfonates Catalyst System

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The preparation of polymers with tailor-made microstructures and properties by controlling the regio- and stereoselectivity of diene polymerisation is an important research area in polymer science. A novel binary neodymium benzene-sulfonate catalyst composed of $Nd(C_6H_5SO_3)_3$ *and electron donors has been synthesised, and by activation with alkylaluminum,* cis-1,4 *polybutadienes containing changeable contents of* trans-1,4 *units have been prepared. Effects of the natures of electron donors and types of alkylaluminum on catalytic activity, content of* trans-1,4 *units, molecular weight and molecular weight distribution have been examined. The polymer obtained possesses stereo-block chain structure consisting mainly* cis-1,4 *sequences and variable contents of* trans-1,4 *chain segments. The ionic pair nature of neodymium (III) sulfonate,* i.e. $[Nd{\cdot}donors]^{3+}3[RSO_3]$-, *is inferred to account for the formation of* cis-1,4 *and* trans-1,4 *stereo-block chain structure.*

Keywords: polybutadiene; neodymium organic sulfonate catalyst; stereo-block

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A13
Determining Crosslink Density of Tyre Treads and In-Service Tyres via *Swelling Measurement*

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Physical properties of rubber vulcanisates are strongly dependent on crosslink density of the rubber compound and its distribution. Both tyre age and mileage affect its performance and this corresponds with changes in crosslink density of the rubber compound. This study on crosslink density of tyre treads based on epoxidised natural rubber uses the swelling measurement method. A comparison between crosslink density of precured tread to that of vulcanisates is reported. In addition, the crosslink density of worn tyre treads collected from in-service bus tyres during a road trial is evaluated. Precured tread possesses a higher crosslink density compared to the tread vulcanisate. Average crosslink density of epoxidised natural rubber vulcanisate is 0.69×10^{-4} *mol/cm*^{3}. *The crosslink density of precured tread is 10 % higher than the vulcanisate. The outer surface of precured tread has a slightly lower crosslink density compared to the inner surface of the tread. The average crosslink density of worn bus tyre samples is* 0.83×10^{-4} *mol/cm*^{3}, *comparable to those of precured tread.*

Keywords: crosslink density; epoxidised natural rubber; precured; tread; tyre

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A14
Alternative Microwave Coagulation and Its Effect on Raw Rubber Properties of Specialty Natural Rubber

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Coagulation of raw natural rubber (NR) is an essential stage to transform liquid latex to solid block rubber. This production process includes natural coagulation as well as chemical and physical coagulation. Natural coagulation, also referred to as auto-coagulation is unsuitable and has limited advantages in the preparation of solid block rubbers. Chemical coagulation via *acid addition (*i.e. *formic acid), is the typical method used in view of its economical advantages to smallholders and rubber processers. This method however poses difficulty in waste water treatment due to the high level of acidity and chemical oxygen demand. The physical method instead uses a coagulation agent which in turn is advantagous, involving a shorter process time. Futhermore, it is environmentally friendly with the absence of chemicals. The heat coagulation method is also adopted in the production of specialty natural rubber (*i.e. *ENR and DPNR)* via *steam coagulation as this is a suitable method due to the usage of non-ionic surfactants in the latex mixture. Steam coagulation uses a counter-current approach of latex and steam in a vertical coagulator. The latex distributes as a thin film below the inner surface of the coagulator. Upon contact with the steam injected at the bottom levels of the column, the latex forms coagulum. Inconsistent coagulum quality (milky serum) is the downside of the counter-current flow steam coagulation method. This study explores an alternative coagulation approach* via *microwave radiation in solidifying the specialty rubber to attain better quality control of the rubber material produced. Coagulation by means of microwave radiation has the ability to collapse the protective layer surrounding the rubber particles and generate an aggressive motion of collision causing rubber particles to aggregate and form coagulum. The effect of coagulation on raw rubber properties such as Mooney viscosity (V_R), gel content, epoxidation level, ring opening level, molecular weight (MW) and glass transition temperature (T_g) are evaluated to understand the variations with the conventional steam coagulation method.*

Keywords: microwave coagulation; ENR; DPNR; raw rubber properties

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A16
New Concept of Strain-Induced Crystallisation in Crosslinked Natural Rubber

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The requirement that the surface energy of nuclei must be lower than the usual folded-chain is demonstrated for strain-induced crystallisation of crosslinked natural rubber (NR), and the value is sown to be below the measurement limit. By quick extension, NR samples are crystallised at a predetermined crystallisation temperature (T_c) and a prescribed draw ratio (DR). The wide angle X-ray diffraction patterns during the subsequent stepwise heating process are investigated. Melting temperature (T_m) is found to depend solely on DR and to be independent of T_c. Average crystallite size in the chain direction ($<L_c>$) is found to be primarily determined by network-chain density and is also independent of T_c. As a result, the plot of T_m versus $1/<L_c>$ suggests that end-surface energy is negligibly low and estimated T_m is an approximation of the equilibrium melting temperature. These results indicate that strain-induced crystallisation of NR is primarily due to the formation of crystallites having such low surface energies. This new concept will innovate the understanding of strain-induced crystallisation, which has been believed to be an entropy-driven phenomenon for over 70 years since the 1940's.

Keywords: Gibbs-Thomson equation; chain folding; bundle nuclei; critical nuclei; conformational entropy

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A17
Study of Butadiene Rubber/Resin Composite Using Nano-Palpation AFM

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Butadiene rubber/resin composite (VCR) is a resin-reinforced rubber for tyre application. It is composed of high cis *butadiene rubber (BR) matrix and high crystallinity syndiotactic polybutadiene (SPB) resin, and the SPB is highly dispersed on the order of micrometers in the rubber matrix. SPB filler has a better reinforcement effect in comparison with conventional carbon black (CB). To figure out the reinforcement mechanism of the rubber, we investigated the structure and nano-mechanics of VCR and CB-filled rubber using nano-palpation atomic force microscope (AFM). Nano-palpation of vulcanised rubber samples was carried out under strain and their stress maps were obtained to visualise changes in morphology and the stress network structure. In CB-filled rubber, the oriented rubber molecular chains were found between CB particles. This suggested the super network structure of the bound rubber was formed through CB particle junction. On the other hand, observation of VCR clarified that the SPB fillers deformed and were oriented to the direction of deformation. At 200% strain, higher stress regions appeared in the matrix. These results showed that the SPB skeleton network was formed three-dimensionally with the bound rubber. The highly elastic network of VCR brings about stronger reinforcement in the rubber than CB.*

Keywords: butadiene rubber; AFM; polymer composite; structure; carbon black

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A18
Preparation of Networked Silica-Filled SBR/BR Compounds with Improved Wet Traction and Rolling Resistance by Wet Masterbatch

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The wet masterbatch (WMB) of silica-filled SBR/BR compounds is prepared with NK126 networked silica with organic networks among silica particles. The networked silica is added to a mixture of SBR and BR solution followed by vigorous stirring, recovery of silica-WMB with steam and drying. The silica content of SBR/BR compounds (R-WMB) obtained by mixing the silica-WMB with other additives varies from 50 to 120 phr. The properties of R-WMB compounds reinforced with NK126 networked silica of 80−100 phr are comparable to those of an SBR/BR compound mixed in dried state with a highly dispersive silica of 80 phr. Among them, R-WMB reinforced with 90 phr of networked silica shows the most improved rheological, cure, mechanical, dynamic and abrasive properties applicable to the preparation of tread rubber.

Keywords: SBR; BR; wet masterbatch; networked silica; reinforcement

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A19
The Effect of Coagulant Types on Silica Dispersion of Compound Using WMB Technology

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Currently, the development of silica WMB (wet masterbatch) technology for the production of high silica loading and well dispersed silica compounds is underway worldwide. However, emulsion WMB research generally focuses on improvements in physical properties according to the results of WMB technology application, however a detailed manufacturing mechanism is unavailable. This study investigates manufacturing conditions of ESBR/silica WMB, a kind of emulsion WMB. The effect of coagulant on the silica surface and the effect of coagulants remaining on the compound were investigated by evaluating the types of coagulants used in ESBR/silica WMB. As a result, it was possible to obtain excellent silica dispersion in compounds when calcium dichloride was used instead of sodium chloride and sulfuric acid coagulant for solidifying conventional synthetic rubber latex. However, both ESBR WMB compounds showed a disadvantage compared to the DMB (dry masterbatch, conventional mixing compound) as the crosslinking density of the WMB compound was lowered by the residual surfactant. Therefore, it can be confirmed that it is possible to develop an excellent silica compound by solving the problem of residual surfactant.

Keywords: ESBR/silica wet masterbatch; silica dispersion; latex/silica co-coagulation

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A20
4, 4'-Bis*(maleimidio)diphenylmethane: A Versatile Material for Enhancing Various Properties of Halogenated Isobutylene-Isoprene Rubbers*

C. NAH

Bismaleimides are addition type polyimide produced by the reaction between anhydride and diamines. These materials are generally used in the rubber industry as anti-reversion agents for accelerated sulfur vulcanisation or as co-agents for the peroxide curing. It is well established that the vulcanisation of halobutyl rubber with ZnO alone produces vulcanisates of low crosslink density and with accelerated sulfur exhibits reversion. To solve these problems, we used 4, 4'-bis *(maleimido) diphenyl methane (BMDM) as a multifunctional additive in the compounding recipe to enhance the crosslinking efficiency of the ZnO vulcanisation of halobutyl and also to improve the reversion resistance in the accelerated sulfur vulcanisation of halobutyl. Detailed cure studies using oscillating disc rheometer revealed that the state and rate of vulcanisation of the halobutyl rubbers with zinc oxide dramatically enhanced in the presence of BMDM. The crosslinking density, set property and thermal stability of the BMDM/ZnO vulcanised halobutyl rubber were also improved significantly. The isothermal DSC analysis have proved that the* in-situ *formed conjugated diene units* via *dehydrohalogenation from the halobutyl rubber with the maleic moieties of BMDM* via *Diels-Alder reaction is the primary reason for improved properties of the vulcanisates of the halobutyl rubber with BMDM.*

Keywords: bismaleimides; halobutyl rubber; Diels-Alder reaction; anti-reversion agents; oscillating disc rheometer

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A21
Study on the Surface Modification of Aramid Fibre and Properties of Modified Aramid Fibre Reinforced Natural Rubber Composites

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The surface modification of aramid fibre is carried out by ultraviolet (UV) irradiation and grafting of silane coupling agent for preparation of the modified aramid fibre/carbon black/natural rubber (NR) composite material. The results show that ultraviolet radiation can increase the oxygen functional groups on the surface of aramid fibre, and UV irradiation etching of fibre surface can significantly increase the mechanical interlocking ability between the fibre and rubber substrate. The aramid fibre is first modified by UV irradiation, and then grafted with silane coupling agent KH570. The surface of aramid fibre can be successfully introduced into the carbon-carbon double bond that can participate in the vulcanisation of the rubber. The surface activity and surface roughness of the aramid fibre are obviously improved by the joint action of UV irradiation and coupling agent grafting, and the interfacial compatibility of fibre and rubber matrix is improved. Compared with the unmodified aramid fibre/carbon black/NR composites, the 100% elongation stress of UV-modified aramid fibre/carbon black/NR composites, the 300% elongation stress and tear strength increase by 14.88%, 11.44% and 21.47%, respectively. The 100% elongation stress of KH570-UV-modified aramid fibre/carbon black/NR composites, the 300% elongation stress and tear strength increase by 24.70%, 22.43% and 48.69%, respectively.

Keywords: aramid fibre; surface modification; natural rubber composites

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A23
Natural Rubber (NR) Gloves Reinforced with Cellulose Nanocrystals: Preparations and Physio-Mechanical Characterisation

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In the rubber industry, amorphous silica has been widely used as a reinforcing filler in the past decades. However, production of silica involves the use of expensive yet hazardous chemicals and high processing temperatures. Recently, cellulose nanocrystals (CNCs) have attracted substantial interest as a promising reinforcement bio-nanomaterial in the development of green polymer composites. The attractive features of CNCs are their light weight, low cost, high surface area, high aspect ratio, renewability and biodegradability. Due to the high surface to volume ratio, CNC-based nanocomposites exhibit excellent mechanical and thermal properties in addition to being environmentally friendly. In this study, the reinforcing potential of wood pulp-derived CNCs in natural rubber latex (NRL) gloves was demonstrated. To produce NRL/CNCs composite gloves, the cellulosic nanofillers were compounded in the NRL suspension at varying concentrations of up to 5 per hundred of rubber (phr) and mixed uniformly prior to vulcanisation. A marked improvement in glove physio-mechanical properties was observed with ca. 400% increase in tensile strength at ~25 MPa compared to the neat glove at ~4 MPa. This could be attributed to strong interfacial interaction between both CNCs and latex matrices, resulting in rigid polymer chains which restrict rubber deformation. Microscopic images illustrate that all CNC particles were uniformly distributed over the latex film indicating good filler-filler interaction within the polymer matrix. The findings indicate CNCs' potential as an effective reinforcing nanofiller for natural rubber gloves with an enhancement in the tensile strength. Further efforts should be devoted to understanding the CNC-NR matrix interactions for control of the desired mechanical properties.

Keywords: NR glove; latex; CNCs; glove physio-mechanical

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A24
Evaluation of Impact Absorbing Properties of Thermoplastic Elastomers

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In this paper, impact absorbing properties of thermoplastic elastomers (TPEs) were investigated using an original drop weight impact testing machine. TPEs are physical mixtures of polymers (plastics and rubbers). TPEs are applied to numerous life-style products for its light-weight, cheap processability and absorbing properties. TPEs are applicable to various sports equipment, for the purpose of reducing fatigue and relieving injury contributed by the absorbing impact. For sports equipment, TPEs are applicable to grip of golf clubs, head-gear, protector, and so on. This includes baseball for example, where there is a possibility that players sustain serious injuries such as fractures. In these cases, TPEs are suitable materials for the protecting equipment such as the catcher gear and helmets due to their mechanical behaviour similar to rubber and the low odour level. Impact force and time are important factors to evaluate the impact absorbing properties. In this study, a drop weight impact testing machine for TPEs with real baseball weight were proposed. Impact force and impact time were measured with sheet-shaped TPEs specimens which was prepared by the Kraray Plastics Co.,Ltd.. As a result, impact absorbing properties of TPEs were evaluated experimentally.

Keywords: impact absorbing properties, TPE, impact force; impact time; fatigue

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A25
The Development of an Improved Understanding of Tread Wear and Its Prediction

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Good abrasion resistance has always been a key attribute for tyres. Legislation in many countries now also requires good wet grip and fuel economy performance from tyres. Laboratory evaluation of tread compounds provides valuable indications of tyre performance in regard to wet grip and rolling resistance but is however notoriously unreliable for wear. However, despite many laboratory based tests providing accelerated wear data under different conditions, there is no current standard laboratory based method that can accurately predict actual tread wear. In-service road trials remain the most accurate way of predicting the lifetime of a tyre tread. This paper presents a review of research into the complex processes associated with tyre tread wear and abrasion. It covers early investigative work of the mechanisms of wear and how this relates to recent work at TARRC where a technique visualising the surface micro layer of road worn tyre treads has been developed. Evidence for the breakdown of the rubber - rubber and rubber - filler networks is presented. Key differences observed in the surface microstructure of tread compounds assessed by laboratory abrasion techniques, as compared to road worn tyres, have helped explain the reasons behind the unsuccessful prediction of road-wear by laboratory methods.

Keywords: wear; tyre treads; networks

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A27
Thermal and Viscoelastic Properties of Recycled Rubber-Derived Carbon (CRR) and Geothermal Brine-Derived Silica Fillers in Rubber Compounds

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Carbon from recycled rubber (CRR) and silica (SiO_2) from geothermal brine have potential as sustainable and locally-sourced filler materials for rubber compounds. Thermal analysis was necessary to obtain the thermal stability and viscoelastic properties of rubber compounds reinforced with these two fillers. Thermogravimetric analysis (TGA) determined the critical degradation temperatures of the compounds as well as confirmed the composition of the compounded rubber samples, particularly the relative amounts of natural (NR) and butadiene rubbers (BR) in both. It showed that CRR-filled rubber exhibited three degradation peaks corresponding for NR, BR and carbon while the SiO_2-filled compound revealed only two peaks, for NR and BR. Dynamic mechanical analysis (DMA) was used to determine the viscoelastic properties of the compounds and revealed an increasing storage modulus for both compounds. Morphological analysis using a scanning electron microscope confirmed changes on the rubber-filler interaction which contributed to the increased performance of the compounds during DMA testing.

Keywords: carbon from recycled rubber; silica from geothermal brine; viscoelastic properties; DMA; TGA

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A28
Wear Analysis of In-Service Tyres for Urban Buses

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Tyre wear and tear significantly contribute to the presence of rubber debris in the environment. These materials may have health effects on mankind and such concerns have been raised by governmental organisations. Improving wear resistance of tyres would help reduce these environmental and health concerns. The focus of this work is optimisation of tyre wear performance using non-fossil based sustainable materials. The worn tyre tread surface of green retreaded tyres produced using a specialty natural rubber has been studied and evaluated. Application of optical microscope (OM), scanning electron microscope (SEM) and transmission electron microscope (TEM) techniques in studying tread surfaces and tread rubber debris were employed. Retreaded tyres were fitted with known tread compounds on commercial buses. The operating route of buses in this study encompassed selected urban roads in the Klang Valley. The worn tyre treads were collected and analysed after the tyres had achieved either a minimum tread depth of 3 mm or a mileage of approximately 30,000 km. 3D images of worn surface were developed using fine-focus control and stacking the micrographs taken with the OM. The micrographs of the worn treads were evaluated to ascertain a mechanistic insight into tread wear. The evaluation showed that some of the topographical features observed on worn tyre treads exhibited gross textures, known as Schallamach waves or pattern. The very tip of some of the patterns showed a definite liquid-like appearance as reported by Smith and Veith (1981).

Keywords: tyre wear; worn tyre treads; specialty natural rubber; Ekoprena®; retreaded tyre

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A29
Natural Rubber Latex Slow-Recovery Foam for Shoe Insoles

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A novel natural rubber latex (NRL) slow-recovery foam for shoe insoles with pressure-relief and shock-reduction properties has been successfully developed. Standard NRL foam and NRL slow-recovery foam were fabricated at three density levels. The indention hardness indicates that, NRL slow-recovery foam exhibited a lower hardness value compared to the standard NRL foam. The developed NRL slow-recovery foam insoles were observed to be able to retain an imprint for approximately 4−5 s when pressed, indicating its delayed-recovery property. The degree of bounce of a silica ball upon dropping onto the surface of NRL slow-recovery foam insoles was much lower compared to standard NRL foam insoles. This indicates the ability of the NRL slow-recovery foam insoles to absorb shock or down force energy efficiently compared to standard NRL foam insoles in each density level. Visualisation using a modern pressure mapping system (F-Scan) shows that the peak pressure area was at the heel followed by the metatarsal area. Comparison between conventional insoles, standard NRL insoles, commercial memory foam insoles (two brands) and NRL slow-recovery foam insoles confirms the developed NRL slow-recovery foam insoles resulted in better pressure-relief performance during both standing and running positions. This might be due to the ability of the material to conform to the shape of the foot, increasing the surface contact area between the foam and foot which consequently helps to redistribute body weight pressure efficiently. However, the peak pressure value of the NRL slow-recovery foam insoles increased slightly after the accelerated heat ageing test, possibly due to an increase in hardness of the foam.

Keywords: indention hardness; natural rubber latex slow-recovery foam; pressure-relief; shock-reduction; shoe insoles

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A30
Urea as a Single Denaturing Agent in Deproteinised Natural Rubber Latex

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Urea consists of a small organic molecule which is water soluble in large concentrations and integrates well with the hydrogen-bond network of water. Hence, the denaturation of proteins by urea is both well established and widely utilised. Protein denaturation of natural rubber latex (NRL) using urea is commonly carried out together with excessive use of surfactants comprising either sodium dodecyl sulphate or in combination with potassium laurate. These approaches tend to produce over stability in deproteinised NRL, which consequently affects film formation of latex on a glove dipping former. This study assessed the potential of urea as a single denaturing agent used in low (0.01 − 0.05%) and high (1 − 5%) concentrations. Correlation of low and high urea concentrations on the protein and nitrogen contents, chemical properties and green strength of the deproteinised NRL were evaluated. Properties of the deproteinised NRL treated with urea were observed to be markedly influenced by the urea concentration. The data obtained can be used to optimise loading concentration of urea for the preparation of deproteinised NRL with varying protein contents and physical properties for specialised applications.

Keywords: deproteinised; natural rubber latex; urea; protein; correlation

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A32
Compounding of Epoxidised Natural Rubber (ENR) Blends for Industrial Hose and Seal Applications

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Ekoprena® or epoxidised natural rubber (ENR) is generally modified to have no more than 50 mol % of epoxide in order to maintain elastic properties. Therefore, the degree of oil resistance improvement is limited. In this work, blending of ENR with other polar elastomers such as nitrile butadiene rubber (NBR) and neoprene (CR) were considered in order to improve oil resistance properties while maintaining its mechanical strength as well as dynamic properties. Effect of the blend ratios on oil swelling, mechanical properties and curing characteristics were investigated. The dynamic mechanical analysis (DMA) spectra showed a single damping peak for the ENR-50/NBR and ENR-50/CR blends, which suggests that ENR is miscible with both elastomers. The results indicate improved oil swelling property (up to 50%) with addition of 70 phr of NBR in the rubber blends. The modulus, tear strength and abrasion resistance of the rubber blends were slightly increased as the NBR component increased. It was found that addition of NBR had prolonged the cure and scorch time of the rubber blends. The above properties were also compared with a series of ENR-50/CR blends. Furthermore, some modifications on the filler loading and cure system had a significant influence on both hardness and compression set which are important characteristics for seal and hose applications apart from oil swelling.

Keywords: Ekoprena®; epoxidised natural rubber; ENR/NBR blend; ENR/CR blend; oil swelling; hose; seal

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A33
The Principle of Frequency-Strain Separability

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With a simple set of assumptions, the principle of frequency-strain separability of nonlinear dynamic rheological properties is established for filled elastomers. Specifically, these assumptions are: 1) a broad relaxation at the plateau zone; 2) a K-BKZ type constitutive equation; and 3) a negligible contribution from high harmonics. They all appear to be reasonable for filled rubbery materials. We also measured the rheological properties of a number of filled elastomers and showed that in both linear and nonlinear regimes the relationships between moduli (G' and G") and strain amplitude (g_0) in response to the frequency change display constant shifts along the vertical direction, leading to a striking superposition of the curves. In addition, we show that this frequency-strain separability can lead to many other superposed behaviours for measured dynamical properties, with important industrial applications.

Keywords: nonlinearity; dynamic properties; frequency-strain separability; filled rubbers

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A34
Variation, Heritability and Genetic Correlation of Growth and Wood Traits in Para Rubber Tree (Hevea brasiliensis) *and Implications for Breeding*

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Increasing global demand for rubber wood has necessitated breeding of vigorous rubber clones with high timber volume. Precise information on qualitative and quantitative genetic control of various traits is required for breeding. In a study with several clones, girth and specific gravity showed moderate genetic control. Timber traits like length, diameter and wall thickness of fibres showed moderate to strong genetic control. Paper and pulp traits like flexibility coefficient, Runkel ratio and slenderness ratio showed moderate to strong genetic controls. Girth showed a positive correlation with wall thickness and width of fibres indicating scope for indirect selection. Wood specific gravity was not correlated with growth and fibre length which will enable independent control on these traits. Hevea *breeding would need to consider improvement of rubber productivity and growth without having an adverse effect on important fibre traits. It would be beneficial to follow 'index-based' selection using variable economic weights for desirable traits. Families deviating from reported patterns (correlation breakers) can be utilised to combine growth vigour and long fibres. The information on genetics of fibre traits, vigour and specific gravity indicated that it is possible to breed rubber clones with a high yield and superior wood for various industrial purposes.*

Keywords: rubber tree; paper and timber traits; genetic improvement

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A35

An Origin of the Outstanding Properties in Natural Rubber: Structural Characterisation of Natural Rubber Relating to Gel and Storage-Hardening Phenomena

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The outstanding green strength of unvulcanised natural rubber (NR) was investigated, in relation to gel formation and storage hardening (SH) phenomena. SH is a progressive increase in hardness of a solid NR during storage, a critical factor affecting the processability of NR. This serious problem restricts the use of NR as the essential agricultural product of Thailand. So far, the actual mechanism of SH has not been fully clarified. The results suggested that proteins and Mg^{2+} ions are not important factors for SH, while phospholipids are responsible for SH of NR. It can be proposed that the interaction of phospholipids at the chain ends of NR is the origin of gel formation and SH of NR. It was found that the addition of hydroxylamine is an effective method for inhibition of gel formation and SH in NR by suppressing the formation of hydrogen bonds between phospholipids at chain ends of NR.

Keywords: natural rubber; green strength; storage hardening; phospholipids; hydroxylamine

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A36
Novel Forms of Carbon as Performance Enhancers for Rubber Vulcanisates

A.K. BHOWMICK

Understanding the fundamentals involved in the fabrication of rubber compounds is critical towards the development of high performance materials. Despite a plethora of work persuaded with many conventional carbon black fillers, work related to novel forms of carbon is gaining antecedence in recent years. Graphene, graphite, carbon nanotubes, carbon nanofibres, carbon nanodots, etc*. are attempted in rubber compounds. Lack of functional groups on the surface of pristine graphene and graphite often limits its interaction with an elastomer matrix. As a result, subtle interfaces are developed and inferior properties of the rubber compounds are registered. Thus, various strategies are adopted to control the dispersion of graphene, graphite and nanotubes in an elastomeric matrix through physical and chemical modifications. Once the dispersion is good, useful properties are obtained. Structure of various forms of unmodified and modified carbon was first analysed. These were then incorporated in a rubber matrix. The mechanical properties, dynamic mechanical properties, abrasion, permeability, electrical conductivity, adhesion* etc*. of ethylene vinyl acetate, natural rubber, styrene butadiene rubber , bromobutyl rubber and silicone rubber vulcanisates with and without the above nanofillers were determined. There was significant influence of the nanofillers on these properties. Wear loss was reduced in the dual filler nanocomposites by 33% (over the CB microcomposite) in less stringent and 75% under severe wear conditions. It was observed that the nanocomposites demonstrated a better gas impermeability (44%) compared to the neat bromobutyl rubber when the oxygen transmission rate was compared. Interestingly, these fillers give synergistic properties in carbon black filled rubber vulcanisates. Hence, various forms of carbon have potential to be future fillers for the rubber industry.*

Keywords: nanocomposites; rubber; nanofiller; gas permeability; modified carbon

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A37
Ammonia-Preserved Latex Stability Mechanism to Reveal a New Hevea *Rubber Particle Microstructure Model*

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The stabilisation mechanism of natural rubber (NR) latex from Hevea brasiliensis *was investigated to identify components involved in base-catalysed ester hydrolysis. Latex stability is thought to come from rubber particle (RP) dispersion in the serum, caused by negatively-charged species distributed on the RP surface. Mechanical stability time (MST) and zeta potential were measured to monitor field latices preserved in high and low ammonia and with the ester-containing components removed (saponified) at varied storage times. Amounts of ammonium salts of long chain fatty acids (LCFAs), produced from the transformation and hypothesised to be responsible for the RP repulsion, had higher fatty acid (HFA) numbers and evidenced by confocal laser scanning microscopy (CLSM) both qualitatively and quantitatively. The hydrolysable lipids and their LCFA products interacted differently with Nile red, which was a polarity-sensitive fluorophore used to re-emit characteristically. The results were confirmed by conventional ester-content determination utilising different extraction systems to reveal that the lipids hydrolysed were mainly polar lipids (glycolipids and phospholipids) on the RP membrane but not those directly linked to the rubber molecule. From these new findings and those already precedented, a new model for the* Hevea *RP in latex form is also proposed.*

Keywords: *Hevea brasiliensis*; latex stability; ammonia; rubber particle microstructure

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A38
A Robust, Self-Healable and Shape Memory Double Network Hydrogels

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Considerable attention has been focused on preparation of self-healing hydrogels in recent years due to inevitable appearance of cracks or fractures in hydrogels during application. Generally, self-healing hydrogels are prepared through either dynamic covalent reactions or non-covalent reactions. Although self-healing hydrogels can repair cracks automatically, it lacks mechanical strength (below 1 MPa). In this work, we synthesise a versatile double network (DN) hydrogel with two non-covalent crosslinked networks by multiple hydrogen bonding (H-bonding) interactions. The DN hydrogels were synthesised via *a heating-cooling photopolymerisation process by adding agar, N-acryloyl glycinamide (NAGA) and N-benzylacrylamide (NBAA) monomers as well as UV-initiators to a single water pot. P(NAGA-co-NBAA) was synthesised* via *UV-light polymerisation between NAGA and NBAA, forming strong intermolecular H-bonding network. Meanwhile, the intramolecular H-bonding network was formed between P(NAGA-co-NBAA) and agars. Such a double network enables high mechanical strength of the hydrogel (1.1 MPa), high self-healing efficiency (95%) and good shape memory ability. Additionally, the DN hydrogel was completely crosslinked by hydrogen bonds (H-bonds) without an extra potentially toxic chemical crosslinker. DN hydrogels find extensive applications in biomedical materials due to its excellent biocompatibility.*

Keywords: robust; self-healing; shape memory; multiple hydrogen bonding interactions

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A39
Physical Effects of Reinforcing Fillers on the Kinetics of Rubber Vulcanisation

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The influence of silica and carbon blacks on the vulcanisation kinetics of rubbers with sulfur curing system was investigated in more details. Contrary to previous literature, one single mechanism is introduced to explain kinetics of rubber vulcanisation in the presence of any filler type. It is demonstrated that in a wide range of filler loading, vulcanisation rate goes through a maximum, being enhanced at low filler contents but suppressed for higher loadings, regardless of the type of filler. Working mainly on highly-filled compounds, previous studies had only observed slowdown in kinetics of sulfur vulcanisation of silica-filled rubbers and acceleration effects for carbon black-filled rubbers. These observations are commonly attributed to acidic groups existing on the silica surface for the former case and easy dissociation of some accelerators when heated with carbon black and sulfur ring opening even without using accelerators for the latter case. Therefore, the black-filled compounds were normally thought to accelerate vulcanisation of rubber. Interestingly, it is here shown that for certain ranges of filler loading, silica is even able to promote the vulcanisation rate and carbon black to supress it, both following a single mechanism dependent on the filler content. It was discussed that not only the chemical nature of the filler, but also the physical phenomena originating from the filler-polymer and filler-filler interactions can alter both the kinetics and the degree of conversion in the vulcanisation of rubbers. For filler content being highly above the percolation limit, almost all the chains are in an immobilised state which could reduce the probability of reaction between macro-radicals (according to the collision theory in chemical reactions) which is represented by a rate constant. Therefore, a critical loading point was introduced after which the filler can decelerate vulcanisation of rubber regardless of the type and characteristics of filler. This critical point is related to the filler network as a physical effect, defined by wide-spread immobilisation of rubber chains. It was also shown that the nature of rubber vulcanisation is not changed by the type and concentration of filler and it obeys autocatalytic kinetics.

Keywords: silica; sulfur vulcanisation; kinetics; filler; filler-polymer interaction

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A40
A Novel Anti-Reversion Agent for the High Temperature Vulcanisation of Unsaturated Elastomers with Accelerated-Sulfur

S. GOPI SATHI

Vulcanisation of unsaturated elastomers like natural rubber (NR) with accelerated-sulfur is limited at high temperature due to reversion. One of the main reasons for the reversion is the breaking of the initially formed less thermally stable poly-sulfidic linkages during vulcanisation and the subsequent loss of the network integrity. Due to reversion, the mechanical performance especially the compression set properties of the accelerated-sulfur cured elastomers become inferior under elevated temperature. For many years, chemicals such as Perkalink 900, m-phenylenedimaleimide etc. *have been employed as anti-reversion agents to improve the reversion resistance for the sulfur vulcanisation of unsaturated elastomers. In the current investigation, 4, 4'*-bis *(maleimido) diphenylmethane (BMDM) was used as an anti-reversion agent for the first time to heal the reversion in an accelerated-sulfur vulcanised natural rubber. With the use of BMDM, it was possible to cure NR with accelerated sulfur without any reversion even at 180ºC for a period of 1h. The vulcanisation kinetics studies revealed that the use of BMDM does not alter the original vulcanisation characteristics of NR with the sulfur system. Moreover, the crosslink density of the vulcanisate of NR with accelerated-sulfur could be greatly enhanced with the use of BMDM. This enhanced crosslink density facilitates reduction of the set value of sulfur cured NR from 68% to 38% at 100ºC with the use of 5phr BMDM. Based on the curing analysis of neat NR with n-phenyl maleimide (NPM) and BMDM, two possible mechanisms have been proposed for the enhanced reversion resistance.*

Keywords: vulcanisation; reversion; natural rubber; sulfur cured; BMDM

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A41
Mechanical, Rheological and Morphological Properties of NR/M-POSS Compounds

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Tyre is a composite material made of rubber, rubber chemicals (vulcanising agents, processing aids, etc.*) and reinforcements located at pre-defined positions. Natural rubber (NR) is often used as a matrix in tyre manufacturing. NR is compounded with oils, fillers, crosslinking agents, antioxidants and processing aids. The most widely used reinforcing filler for NR is carbon black. Polyhedral oligomeric silsesquioxanes (POSSs) are the new generation of nanofillers allowing reinforcement and stabilisation of polymers. POSS nanoparticles have reactive and/or nonreactive organic side groups that are at crucial importance for controlling compatibility, solubility and reactivity between POSS and polymers. This study aims to investigate effects of POSS nanoparticles having reactive polar methacryl groups (M-POSS) on the mechanical, morphological and rheological properties of NR compounds. NR compounds were prepared in a laboratory two-roll mill and M-POSS content was selected at 1, 3, 6 and 8 phr. The curing step was carried out in a hydraulic hot press at 160ºC under 150 bar pressure according to their respective predetermined optimum cure times. Thermal properties, curing behaviour and cure characteristics as well as optimum cure time of the NR/OM-POSS compounds were analysed by a differential scanning calorimeter and moving die rheometer, respectively. Tensile properties of NR vulcanisates were determined using an Instron Universal Testing Machine (Model 3345) according to* ASTM D 412*. Morphology of the tensile-fractured surfaces of the composites was investigated on a scanning electron microscope (SEM). In conclusion, mechanical and rheological test results showed that M-POSS changed the vulcanisation mechanism of NR. SEM analysis indicates a homogeneous dispersion of M-POSS in NR compounds.*

Keywords: natural rubber; POSS; compounding; mechanical properties; morphological properties

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A42
Self-Healing Natural Rubber: IT'S REAL AND IT'S COMING SOON

R.K. SHUIB

Increasing numbers of new elastomeric materials being developed with the aim of improving its performance in challenging applications. Indeed to the properties of elastomeric materials which can sustain large deflections with little or no permanent deformation, rubbers still fail through fracture and fatigue processes. Self-healing rubbers are a new class of smart materials that have the capability to repair themselves and to recover functionality when they are damaged without the need for detection or repair by manual intervention of any kind. Emerging self-healing provides rubbers the capability to arrest crack propagation at an early stage thereby preventing catastrophic failures. In this work, a novel self-healing additive was developed and the concepts of mixing both covalent and reversible bonds to fabricate self-healing rubber was proposed. The results revealed that the developed self-healing natural rubber able to recover 80% of its initial mechanical properties in a minute and almost 100% in 10 minutes at room temperature without the aid of any external resources. The self-healing additive was develop using ready available industrial raw materials and the self-healing rubbers can be processed using typical rubber processing equipment. Some of the potential products that could benefit from the advantages of this materials are tyres, industrial rubber good, cable, hoses, belting, bearing, mounting and footwares.

Keywords: self-healing; natural rubber; crack; mechanical properties; recover functionality

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A43
Study on Guayule and Dandelion Natural Rubbers for Sustainability

P. JUNKONG

Natural rubber (NR) from Hevea brasiliensis *is a unique biopolymer which cannot be replaced by synthetic rubber. Because of the increasing global demand for* Hevea *NR as well as its biosecurity and biodiversity problems, the studies on other rubber yielding plants,* i.e.*, guayule (*Parthenium argentatum*) and rubber dandelion (*Taraxacum kok-saghyz*) have been resumed in order to maintain the sustainability of NR. It has been well known that the versatility of* Hevea *NR in industrial applications is ascribed to its outstanding tensile properties and excellent crack growth resistance, which are considered to be due to its strain-induced crystallisation (SIC). To determine the suitability of guayule and dandelion NRs as the alternatives to* Hevea *NR, it is of utmost importance to thoroughly evaluate their properties and SIC behaviours, particularly under the practical usage condition,* i.e. *repeated cyclic deformation. Here, the sulfur crosslinked guayule NR (S-GR) and sulfur crosslinked dandelion NR (S-DR) were subjected to the simultaneous wide angle X-ray diffraction and cyclic tensile measurements for the first time. S-GR and S-DR showed the distinguishable cyclic tensile properties and SIC behaviours. At the same stretching ratio, the lower crystallinity index, the lower average crystallites number and the greater breakage of physical crosslinking of aggregated non-rubber components in S-DR than S-GR were found to be the key factors, leading to the larger stress softening degree and hysteresis loss of S-DR upon cyclic deformation. The results will be useful to effectively utilise guayule and dandelion NRs as alternatives to* Hevea *NR in the rubber industry.*

Keywords: natural rubber; guayule, dandelion; *Hevea brasiliensis*; hysteresis

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A44
Graphene Aerogel/Silica Hybrid Filler Reinforced SBR Nanocomposite with High Performance

S.P. WEN

Graphene as the two-dimensional material and silica as the one-dimensional material have different reinforcement effects and functionality on the rubber composites. Therefore, the combination of the two fillers will generate more expectation on the performance of the rubber-based composites. In this research, graphene aerogels were first prepared during the reduction of graphene oxide. Afterwards, silica particles were added into the precursor solution of graphene aerogels. The silica particles were evenly dispersed on the walls of the graphene aerogels. The hybrid fillers were compounded with SBR to generate the composites. The composites showed improved mechanical, dynamic, electrical properties due to the synergistic effect of the two different fillers.

Keywords: graphene; reinforcement; SBR; silica; filler

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A45
The Effect of Ionising Radiation on the Mechanical Properties of NBR Elastomers Reinforced with Lignin

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This study aims to identify the effect of ionising radiation on mechanical stability of NBR elastomers reinforced and stabilised with lignin. For preparation of NBR elastomers, Kraynac 3330 is used as a main matrix. Lignin is obtained from OYKA A.Ş in its raw form. Other compounding ingredients were commercially used chemicals in rubber and tyre industries. In order to determine the effect of ionising radiation on NBR-Lignin elastomers, samples were irradiated with Co-60 gamma cell in air and room temperature of up to 80 kGy. The dose rate was 0.022 kGy/hour. It was observed that, gamma irradiation has a significant effect on tensile properties of 0.5 phr lignin containing NBR elastomer. The tensile strength of NBR-Lig0.5 is increased approximately 17% after 80 kGy irradiation. On the other hand, when the amount of lignin in the NBR mixtures are over 1 phr, tensile strength of elastomers does not change with irradiation. As a result of all these studies, it is concluded that lignin has a protective effect on mechanical properties of NBR elastomers during irradiation. 1 phr lignin can be used as an anti-rad for radiation exposed NBR elastomers without losing its mechanical properties.

Keywords: nitrile rubber; lignin; ionising radiation; mechanical properties

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A47
Transparency of Latex Products: Effect of Prevulcanisation and Compounding Ingredients

S. VARGHESE

Latex mixes which yield transparent films on drying are often preferred for products such as teats, soothers, tubing, rubber bands, certain type of gloves etc. *although transparency is not an important technological property for rubber products. Production of transparent rubber articles requires special attention in the choice of polymer and compounding ingredients. Sulfur, accelerators, activators* etc.*, in latex compounding have a marked influence on the transparency of a product. Other compounding ingredients employed and production techniques adopted also may influence transparency of vulcanisates. For obtaining maximum transparency, sulfur at the level of 1 phr shall be used and zinc oxide omitted. For achieving good ageing resistance with transparency, 1 phr of ZDC shall be used and while that requires good transparency irrespective of the ageing resistance, ZDC concentration can be reduced to the minimum. Solid ingredients shall be added as fine dispersions. Paraffinic oil and antioxidants SP do not influence transparency significantly. Viscosity modifiers at the level of 0.25 phr can be used, without any adverse effect on transparency. Fillers shall be avoided. Centrifuged latex and creamed latex gave films of comparable transparency. A substantial increase in transparency is possible by clarification of prevulcanised latex preferably by centrifuging and by heat treatment of the films. Ambient humidity decreases transparency. Products made by straight dipping are more transparent than those made by coagulant dipping.*

Keywords: latex; transparency; prevulcanisation; film; dipping

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A48
Response Surface Methodology: A Tool for Assessing the Role of Compounding Ingredients in Peroxide Vulcanisation of Natural Rubber

S. VARGHESE

Response surface methodology was used for assessing the role of various compounding ingredients like zinc oxide, antioxidant, coagent, oil and filler in peroxide vulcanisation of natural rubber. A Face Centred Central Composite Design (FCCD) with four factors at three different levels was used to obtain the relationship between vulcanisate properties and the level of ingredients. The four factors selected were filler/oil ratio and the amount of zinc oxide, antioxidant and coagent. The filler/oil ratio was kept constant throughout the experiment. The vulcanisates were evaluated for their mechanical properties like tensile strength, elongation, modulus (M100), tear strength, hardness, compression set (70 and 100ºC) and crosslink density. Regression equations were generated to model the properties of interest before response surfaces and contour diagrams were plotted.

Keywords: response surface methodology; regression equation; filler

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A49
Novel Biocompatible Natural Rubber Latex Film Incorporated with Vegetable Oil Nanoemulsion as Plasticiser

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This study investigates the potential of vegetable oil formulated into nanoemulsion (NE) as processing aids in natural rubber (NR) latex. A series of vegetable oil NE with particle size of 10.6-22.3 nm is formulated. To compare the effect of emulsion particle size, macroemulsion (ME) with particle size of 547.00 nm is also formulated. NR/ME films exhibit higher tensile stress than that of NR/NE films. Nevertheless, the tensile strengths of NR/NE films can be improved significantly from 7.7 MPa up to 17.5 MPa by increasing the incubation temperature of the latex. The antimicrobial properties of the NR latex films are investigated for their efficacy in preventing the adherence of tested Escherichia coli (E. coli) *and* Staphylococcus aureus (S. aureus) *and the viability assessment of the adherent tested bacteria. Results shows that NR-NE(P/S=7/3), can significantly kill the attached* S. aureus *with 92.5% reduction when compared to NR control, but none of the treated NR latex films shows significant log reduction in* E. coli. *All emulsions are found to be compatible with NR with low contact angles (< 90). Taken together, these findings indicate that vegetable oil nanoemulsions have the potential application as a renewable processing aids for NR latex films.*

Keywords: vegetable oil nanoemulsion; natural rubber latex; plasticisers; antimicrobial

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A50
The Effect of Field Natural Rubber Latex Pre-treatment with Cationic Exchange Resin on Latex Dipped Gloves Properties

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The current practice for concentrated natural rubber latex production involves reduction of magnesium ion (Mg^{2+}) with diammonium phosphate (DAP) before centrifugation. In the process, the chemical reaction between Mg^{2+} and DAP produces sludge as a waste product. In this research, cation exchange resins are used to solve this waste product problem in concentrated latex processing with removal of the Mg^{2+} ions from the field natural rubber latex instead of chemical precipitation. The natural rubber latex is contacted with a resin to increase solubility of the latex protein resulting in low protein concentrated latex. The method allows for manufacture of latex-based articles with reduced irritability to the skin. Latex thin films formed on the ceramic former were characterised for film morphology using scanning electron microscopy (SEM). The physical properties of latex thin films are found to meet the requirements of ASTM D-3578-91 *for natural rubber examination gloves.*

Keywords: latex; resin; glove; magnesium

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A51
Mechanical Properties of Natural Rubber with Nanomatrix Structure

S. KAWAHARA

Mechanical properties of natural rubber with nanodiamond nanomatrix structure (NR-ND) was investigated in relation to the distribution of nanodiamond inside a nanomatrix. The NR-ND was prepared by reacting nanodiamond with deproteinised natural rubber in the presence of a tert-butylhydroperoxide (TBHPO) / tetraethylenepentamine (TEPA) radical initiator at 30ºC in latex stage and subsequent drying. The morphology of the composite was observed by 3D transmission electron microscopy (TEM). The NR-ND prepared with an initiator exhibited a nanomatrix structure, whereas NR-ND prepared without an initiator displayed an island matrix structure. The nanomatrix was densely loaded with 15 nm or smaller-sized nanodiamond. The mechanical properties of NR-ND depended on the morphology. The stress at break and plateau modulus were 12 MPa and 1.19 $\times$ 10^6 Pa when NR-ND was prepared with a TBHPO/TEPA initiator and contains 25 w/w% nanodiamond, which were four and eight times higher than those of DPNR, respectively.

Keywords: nanodiamond; nanomatrix; natural rubber; DPNR; TEM

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A53
Progress in Development of Electron Beam Vulcanised Natural Rubber Latex

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Electron beam vulcanised natural rubber latex (EBVNRL) has been a subject of extensive research and development in the past due to its many attractive advantages over the conventional sulfur vulcanised natural rubber latex (SVNRL), viz. *absence of N-nitrosamines, low cytotoxicity, low allergenic proteins and low emission of toxic gases when burned. Thus, latex products made from EBVNRL would be safe to use and good for the environment. However, despite intense effort to develop EBVNRL and the products from it, commercial applications of EBVNRL still have not been realised. The major obstacles appear to be the high production cost and still unsteady properties compared to SVNRL. Improvement of ageing properties of EBVNRL is also in want. The latest technology for production of EBVNRL is based on irradiation of ammonia-preserved NR latex with the aid of a chemical to reduce irradiation dose by about five times in order to lower production cost. The so-called EB vulcanisation accelerator has been changed from n-Butyl acrylate (n-BA), which possesses strong and repulsive odour, to the almost odourless 1,9-Nonanediol diacrylate (NDDA). However, the presently developed EBVNRL still exhibits pungent smell of ammonia and the cost remains high. The present work reports further attempts to develop EBVNRL. Odourless EBVNRL has been developed by using TAPS-preserved NR latex instead of ammonia-preserved NR latex, with comparable tensile and processing properties. The EB vulcanisation accelerator was changed from NDDA to 1,6-Hexanediol diacrylate (HDDA). Thus, the cost of EBVNRL should decrease since HDDA is about 20 times less expensive than NDDA. The odourless EBVNRL developed was shown to be non-cytotoxic and free of allergenic proteins (Hev b1, Hev b3, Hev b5 and Hev b6.02). Laboratory prototypes could be made from the odourless EBVNRL developed including rubber glove, rubber teat, dental dam, finger cot and catheter. Factory trials for production of gloves, finger cots and rubber teats are being made with local manufacturers. The impact on environment and human health of gloves produced from the new EBVNRL developed were assessed in comparison with those of gloves produced from SVNRL NBR latex. It was found that gloves produced from the odourless EBVNRL developed exhibit significantly lower impact on environment and human health than gloves made from SVNRL and NBR latex.*

Keywords: latex; natural rubber; electron beam; vulcanise; irradiation

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A54
Effect of Aromatic Oil on the s-SBR/BR Blend Components Revealed Using BDS and PALS

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The focus of this research is on the aromatic process oil, which works as i) plasticiser, thereby decreasing mixing torque and the production cost of the final compound; ii) extender of free volume in the compound so that lesser amount of polymer is needed for the final compound. The precise mechanism of action of the oil to achieve this is still unclear. Therefore, the aim here is to understand the influence of mineral-based aromatic process oil (0 - 20 phr) on the s-SBR/BR (50/50 wt. ratio) blends in terms of its plasticisation and extension behaviour. A clearer understanding of the plasticisation behaviour is achieved using broadband dielectric spectroscopy (BDS) which can detect the changes in the effective glass transition temperature (T_{geff}) of each blend component. The extension behaviour is confirmed using positron annihilation lifetime spectroscopy (PALS) which indirectly measures the changes in the fractional free volume associated with the plasticisation of each blend component.

Keywords: aromatic process oil; S-SBR/BR blends; glass transition temperature; free volume; PALS

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A55
Shape-Controlled New Nanofillers for Tyre Industry: Reinventing Rubber Compounds Properties with SmartNet Silica

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The development of new rubber compounds for components of tyres aims to surpass the current trade-offs, and to consequently enlarge their application ranges. Great deal of work is spent on adjusting compound formulations in order to balance perfectly the desired set of properties. An alternative and complementary approach consist in developing brand new materials not with respect to those usually employed in tyre industry through collaborations with universities and research centers. In the frame of joint research programmes with Milano Bicocca University and Politecnico of Milano, Pirelli has developed a new class of silica-based fillers, namely SmartNet silica, featuring unique particle shape and tailored surface chemistry leading to unprecedented rubber compound properties. Rod-shaped, silica-like nanoparticles were obtained directly from a sol-gel approach or from natural clays modified by a mineral acid treatment, providing silanol groups on the surface. Mechanical behavior of rubber compounds demonstrated that the addition of SmartNet silica provided an advantageous balance between high and low strain reinforcement and hysteresis with a remarkable stability in a wide deformation and temperature range. This was related to the enhanced interfacial interaction with rubber, as well as to the size and self-arrangement of anisotropic particles into partially aggregated domains, including large areas of entrapped rubber.

Keywords: new materials; sol-gel approach; nanoparticles; rod-shaped; silica

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A56
Influence of Irradiation on the Thermal and Morphological Properties of Ethylene Vinyl Acetate/Waste Tyre Dust Blends in the Presence of Devulcanising Agents

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Attempts to recycle rubber for redesigning in its primary function include reclaiming, oxidative decoupling of rubber scrap and depolymerisation of rubber scrap. This paper describes the effect of irradiation on the morphological and thermal properties of ethylene vinyl acetate/waste tyre dust (EVA/WTD) blends in the presence of tetra methyl thiuram disulfide (TMTD), a multi-functional reclaiming agent and De-Link R, a devulcanising agent. The 90/10 EVA/WTD and EVA containing 4 phr TMTD and De-vulc were prepared using a Haake mixer at 140ºC and 50 rpm rotor speed. The blends were irradiated by using a 3.0 MeV electron beam (EB) machine at 0, 50, 100, 150 and 200 kGy irradiation doses. The blends were subjected to gel content, thermal stability, crystallisation, dynamic mechanical and morphological properties before and after irradiation. Results on gel content, differential scanning calorimetry, (DSC) and thermogravimetric analysis (TGA) revealed that in the presence of TMTD and De-Link R, EVA/WTD blends undergo irradiation-induced degradation along with irradiation-induced crosslinking. The tensile and morphological properties of the blends show evidence consistent with the above observations.

Keywords: irradiation; devulcanising agent; waste tyre dust; recycle rubber; thermal properties

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A57
Application of Different Lewis Bases for Development of New sSBR Grades

A. RUMIANTSEVA

It is well-known that the microstructure and molecular mass characteristics of solution butadiene-styrene polymers can simply be tuned to the desired direction, while products with narrow molecular mass distribution and required molecular masses can easily be produced. Besides others, (initiators, antioxidants, plasticisers, modifiers and branching agents), one of the most important factors here is the nature of Lewis bases. They serve as vinyl promoters and randomising agents and used for modification of the polymerisation initiator. In this regard, an actual problem is the choice of an optimal electron-donor system that allows changing the properties of the synthesised polymer in the desired direction. In the present work, we studied how Lewis bases with different structures influence the properties of rubbers as well as cured compositions. We compare our results with one of the typical commercial styrene-butadiene rubbers of SIBUR. The results indicate that tested selected Lewis bases allow for improved application performance of sSBR polymers produced for tyre treads. SIBUR sSBR oil-extended grades 2560-TDAE HV, 2560-TDAE F, 4040-TDAE, 3755-TDAE obtained using the selected Lewis bases, exhibit improved properties wet grip and rolling resistance compared with the basic grade 2560-TDAE. In conclusion, the use of alternative Lewis bases as vinyl promoters and randomising agents is a prospective means to improve the application performance of sSBR polymers produced for tyre treads. SIBUR takes into account increasing requirements for the quality of tyres. Considering modern trends as well as demands of our customers, SIBUR improves its own elastomers portfolio as a result of implementation of new research and development innovations.

Keywords: Lewis bases; sSBR; tyre tread; vinyl promoters; wet grip; rolling resistance

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B01
New NORDEL EPDMs Enabled by Advanced Molecular Catalyst (AMC)

T. HAN

EPDM synthetic rubber is the material of choice to manufacture various automotive parts due to its natural stability and resistance to heat, UV, and ozone. In addition, its polyolefinic nature results in consistent processing and good filler and oil acceptance for use in compounds ranging from automotive weather sealing, under-the hood belts and coolant hoses, roofing membranes, gaskets and other general rubber articles. Building on a fifty-year history of performance, Dow® Advanced Molecular Catalyst (AMC) and process technology advancements enable highly tailored design of EPDM molecular architecture including, composition, molecular weight and LCB. This results in capacity efficiency and sustainable production as well as increasing design options of the molecular features to tailor the performance for high in-use efficiency. This talk summarises a newly designed NORDELTM EPDM product and its potential applications. The EPDM polymer structure, compound formulation and mixing performance, compound rheology, vulcanisation characteristics, and mechanical property improvements are discussed.

Keywords: EPDM; NORDEL; synthetic rubber; advanced molecular catalyst

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B02
Thermoplastic Vulcanisates Based on Recycled Rubber from Waste of Natural Rubber Gloves and Polypropylene Blends: Effect of Maleic Anhydride as Compatibiliser

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Recycled rubber from waste of natural rubber gloves (R-WNRG) was prepared via *thermo-mechanical devulcanisation using diphenyl disulfide (DPDS) as devulcanising aids. Then, thermoplastic vulcanisates (TPVs) based on R-WNRG and Polypropylene (PP) blends were prepared. Maleic Anhydride (MA) was used as a chemical modifier in the TPVs and it was found that the TPVs mechanical and rheological properties improved with increasing MA content. Furthermore, it was confirmed by SEM morphological properties that increasing MA content decreased the spherical dispersed vulcanised rubber domains to a smaller size in the continuous PP matrix. The MA content at 80 meq was the optimum content for improvement of phase compatibility of R-WNRG/PP TPVs.*

Keywords: thermoplastic vulcanisates; waste of natural rubber gloves; devulcanisation

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B03
Antistatic Footwear based on Epoxidised Natural Rubber: Optimisation of Formulation

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Epoxidised natural rubber (ENR) has been identified as an environmentally friendly and sustainable material for antistatic footwear. This study sets out to optimise the concentration of a non-black antistatic agent by determining both electrical conductivity and percolation threshold of ENR composites. Eight composites with different concentrations of antistatic agent ranging between 2.5 to 50.0 phr were produced using a two-roll mill. It was found that electrical conductivity of the ENR composites increased as the concentration of antistatic agent increases. The conductivity ranges from 8.43 × 10^{-10} up to 8.65 × 10^{-6} S.cm^{-1} and the percolation threshold was obtained at 30 phr of antistatic agent. Transmission electron microscope images were used to visualise the dispersion of antistatic agent in the host matrix and showed a good distribution of antistatic agent that forms a continuous electrical conductive network. These results demonstrate non-staining and good electrical properties contributing to potential application of ENR for antistatic footwear.

Keywords: epoxidised natural rubber (ENR); antistatic; conductivity; transmission electron microscopy; footwear

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B04
Silanisation Efficiency of Silica/Silane in Dependence of Amines in Natural Rubber Based Tyre Compounds

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Silica-silane technology for low rolling resistance tyre compounds requires efficient bridging between the silica surface and rubber molecules through silanisation and coupling reactions. The presence of diphenylguanidine (DPG) as a secondary vulcanisation accelerator is also needed to catalyse the silanisation reaction between the alkoxy groups of silane coupling agents and the silanol groups on the silica surface. However, DPG can liberate toxic aniline under high mixing temperatures and therefore safer alternatives are required. This study investigates the influence of amines with different structures, i.e. *hexylamine (HEX), octadecylamine (OCT), cyclohexylamine (CYC) and dicyclohexylamine (DIC) on the primary silanisation reaction rate constant in a model system and on interfacial compatibility of practical silica-reinforced NR compounds. Compared to the system without amine, the amines clearly increase the reaction rate constant for which linear aliphatic amines work better than the cyclic one, in agreement with the values of chemically bound rubber contents as observed in the rubber compounds, due to better accessibility of the amines towards the silica surface. The shielding effect of amines with long alkyl-chain leads to more hydrophobicity, resulting in good physical interaction between silica and rubber. Herein, the compound with OCT shows the lowest filler-filler interaction (Payne effect) and the highest filler-rubber interaction as indicated by high bound rubber content and low heat capacity increment.*

Keywords: natural rubber; silica; amine; silanisation; silane

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B05
Application of Arrhenius Equation and Thermocouple Measurements in Predicting Curing Behaviour of Large Rubber Component

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Curing large rubber components like bridge bearing pads, dock fenders and solid tyres pose a few problems. Firstly surface rubber compound is overcured while the interior rubber compound is undercured. This discrepancy in cure state is simultaneously confounded by a misjudgement on undercure observation of porosity in fully cured compound. This misjudgement and misinterpretation is somewhat surprising. Operators of continuous extruded profile microwave oven and heating oven have cleverly separated these two requirements. Porosity is treated independently by incorporating dessicant chemical like anhydous calcium oxide to overcome the evaporation of water from compounding ingredients. Unpublished data by the researchers of this current research reported here has shown that curing of EPDM chips faced similar porosity problem in well cured chip compound in an autoclave unless a dessicant like anhydrous calcium oxide at 2 phr was added. Optimal curing is treated separately based on rheometric data and examination of heat penetration. In this current research the assortment of cure is examined closely. ASTM ACS1 *natural rubber and 50 phr carbon black, and MBTS-accelerated sulphur cure system is used as the basis for collecting rheometric data in a oscillating disc rheometer. It has been shown that the reciprocal of $t_{90}-t_2$ can be a proxy of rubber crosslinks. Thus Arrhenius plots of log $t_{90}-t_2$ versus reciprocal of Kelvin temperature are successfully constructed. The concept of fractional cure is introduced in that curing at any temperature in the desired range (120 to 180) for a specific time will contribute towards a fraction of the cure. Curing is achieved both in the temperature ramp-up and 'cooling' stage. Summation of fractional cure to achieve a 100% cure is explored for the least heated region. Thermocouples are inserted in appropriate regions to assess coolest region. Arrhenius plots help in designing accelerator combination for different parts of the rubber component. Case study of a large rubber component in a factory has shown the interior rubber compound is way above the necessary cure. A function written in R statistical package is presented and source code can be used by any interested parties. Using this R function graphical plots of optimal, undercure, or overcure are presented. Proposal of extending the present study to include porosity control simultaneously and an inexpensive way of incorporating temperature measurement using a robust Raspberry pi 3 supervisory computer aided data acquisition (SCADA) is made for future research.*

Keywords: Arrhenius plots; rubber compound; optimal curing; porosity; R statistical package

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B06
Rubber Magnetic Composites with the Effect of Electromagnetic Radiation Shielding

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Electromagnetic (EM) radiation is emitted from a number of appliances used in everyday life (laptops, TV sets, mobile phones, microwave ovens and other commonly used electronic devices). Electromagnetic radiation waves from these devices can interfere with other electronic appliances which leads to the lowering of their efficiency and malfunction in some cases. The acting of these factors can also affect functions of the human body, mainly when organisms are subjected to their exposure for longer periods. The most common symptoms are headaches, irritability, insomnia, fatigue, failure of attentions which may be the reason of more serious illnesses. Therefore the need for electromagnetic radiation shielding of electronic and radiation sources due to the increasing amount of such devices is inevitable. Application of magnetic soft ferrites into the polymer matrices leads to the preparation of materials with the effects of electromagnetic radiation shielding. Rubber magnetic composites tested in this work were prepared by incorporation of magnetic soft manganese-zinc ferrite into rubber matrix based on acrylonitrile butadiene rubber. The aim was to investigate the influence of magnetic filler content on the crosslinking, physical-mechanical and shielding properties of the rubber magnets. The results showed that although the tensile strength showed a decreasing trend with increasing contents of magnetic filler, the tested composites are able to efficiently shield the harmful electromagnetic radiation in the selected frequency range. The biggest preference of these materials is their ability to shield the electromagnetic radiation by absorption mechanisms.

Keywords: electromagnetic radiation; ferrites; magnetic filler; composite; absorption mechanisms

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B07
Performance Testing of Silica Filled Ekoprena®25 Passenger Car Tyres

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There is an increasing demand for tyres with improved performance, safety and green characteristics such as good wet grip, as well as reduced rolling resistance and noise. The application of epoxidised natural rubber 25 (Ekoprena®25) with silica in tyre tread compounds has shown promising laboratory results for tyre performance. This study evaluates the actual performance of a passenger car tyre by utilising a complete system of silica filled Ekoprena®25 as its tread component. Passenger car tyre prototypes of size 195/55R15 85V with silica filled Ekoprena®25 tread were successfully produced. The prototype tyres are tested for wet grip, rolling resistance and external noise according to UNECE R117 *requirements as well as fuel consumption, exhaust emission, ride and handling performances based on vehicle manufacturers' validation methodology. The comparison is made with similar type, size and pattern of a commercially available control tyre. The results show that the prototype tyre with silica filled Ekoprena®25 tread offers excellent wet grip with improvements in rolling resistance and external noise reduction. The prototype tyre also allows for better fuel consumption and exhaust emission performance as well as ride and handling characteristics when compared to the similar commercial control tyre.*

Keywords: Ekoprena®25; passenger car tyre; wet grip; rolling resistance; noise

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B08
International Ultimate Behaviour Investigation of Various Elastomeric Seismic-Protection Isolators for Buildings

T. NISHI

In recent years, various types of elastomeric isolators are used for seismic isolated buildings in many countries around the world. International standard for elastomeric seismic-protection isolators, ISO 22762 *was first developed in 2005. This standard consists of three parts (Part 1: Test Methods, Part 2: Application for Bridges-Specification and Part 3: Application for Buildings-Specification). The second edition was published in 2010 and currently,* ISO 22762 *is being revised through systematic review to issue the 3rd edition in 2018. This paper describes breaking tests results of elastomeric isolators to investigate ultimate property (breaking limit) of isolators used for buildings around the world. Ultimate property is one of the most important performance of elastomeric isolators and these test results must be useful for our proposal of the introduction of classification system (classification of isolators according to their performance) to* ISO 22762 *in the near future. Breaking tests were carried out for 11 isolators (2 linear natural rubber bearings, 5 lead rubber bearings, 4 high-damping rubber bearings) produced in 5 countries. The isolators had diameters around 800mm with total rubber heights around 160mm. They were tested with increasing shear strain under constant compressive stress using multi-axial testing system in National Centre for Research on Earthquake Engineering in Taiwan. At the tests, compressive stress was 6.0N/mm^2 to 15N/mm^2 corresponding to nominal compressive stress recommended by the manufacturers. Test results showed that all of the isolators had high flexibility in horizontal direction although it depended on the isolators. The breaking strain was distributed between 300% to 450% or more.*

Keywords: seismic; rubber; shear strain; isolator; bearing

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B09
Green Tyres Based on Specialty Natural Rubber for Public Transportation

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Growing concerns on environmental issues could be a challenge for the rubber industry. This study on green tyres based on specialty natural rubber for public transportation incorporates a usage duration of six months or mileage of about 30,000km. The approach applies a formulated compound based on specialty natural rubber for tyre manufacturing as well as wear rate data collections and projected life analysis. Twelve commercial buses are equipped with tested tyres at drive axles for the study. The green tyre based on specialty natural rubber shows a better wear rate and calculated projected life. The average wear rate of green and control tyres are 0.20 mm /1000 km and 0.30 mm /1000 km respectively. The projected life for a green tyre is 50,000 km compared to that of the control tyre which is 35,000 km. This indicates a potential advantage of specialty natural rubber green tyres with reduced tyre replacement frequency, resulting in transportation with a lower carbon uptake.

Keywords: green tyre; specialty natural rubber; wear rate; projected life

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B10
Enhancing Filler-Rubber Compatibility of Silica-Reinforced Tyre Tread Compounds Using Chemically Modified Natural Rubbers

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One of the alternatives for silane coupling agents that are normally applied for silica-reinforced tyre tread compounds for low rolling resistance tyres is the utilisation of chemically modified rubber to enhance filler-rubber interfacial compatibility. A key parameter that governs the properties of silica-reinforced rubber compounds is filler-rubber interactions. Different chemically modified natural rubbers, i.e. *natural rubber grafted with 3-octanoylthio-1-propyltriethoxysilane (NR-g-NXT), epoxidised natural rubber (ENR) and epoxidised low molecular weight natural rubber (ELMWNR), have been independently tested. All types of modified rubbers show their potential to be used as compatibilisers for silica-reinforced rubber compounds as observed by the improved processability and enhanced mechanical as well as dynamic properties compared to the system without any compatibiliser. The use of state-of-the-art* bis-*(3-triethoxysilylpropyl) tetrasulfide (TESPT) at its optimum loading remains superior but the application of these chemically modified rubbers with a small amount of TESPT and sulfur compensation results in properties that reach the levels obtained with TESPT. Moreover, the NR-based compatibiliser/TESPT combinations provide environmental benefits from the use of renewable material-based compatibilisers and a reduced amount of ethanol emitted from TESPT silane coupling agent during processing.*

Keywords: natural rubber; silica; compatibilisation; modified rubbers; tyre compounds

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B11
Green Retreaded Tyres for Logistic Applications

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Green retreaded tyres based on specialty natural rubber have been evaluated in road trials using tankers and cargoes for logistic applications. The study involves vehicles travelling in highway and federal state road routes at East Central and the Southern peninsular of Malaysia. The green retreaded tyres based on Ekoprena® rubber were tested on tankers at trailer positions with four drive axles. The Ekoprena® green tyre was also tested at the first and second drive positions of the tankers at selected areas. Ekoprena® green retreaded tyres at trailer positions indicate variable performances according to axle positions. At the drive position, Ekoprena® and control tyres have comparable tyre performances. These tyres were tested up to 75% wear with a calculated projected life of 49,000 km. The evaluation of road trials show that the performance of Ekoprena® is fairly similar to the control commercial retreaded tyres with an added advantage of using a renewable resource material, having a positive impact on the environment.

Keywords: specialty natural rubber; Ekoprena®; retreaded tyre; tanker; trailer

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B12
Rubber Antiseismic Systems for Protection of Structures and Non-Structural Elements

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This paper reviews the past four decades of TARRC's activities directed towards the development of rubber-based antiseismic devices. The scope includes high damping natural rubber isolators, used for the first base-isolated building in the USA in 1985, and auxiliary viscoelastic energy dissipation devices which, in 2000, became Europe's first example of enhancing damping for earthquake protection of a building. Components based on rubber have also been developed to protect non-structural elements. Rolling-ball rubber-layer isolators provide base isolation of light weight objects. A recent innovation has been a composite rubber/masonry infill for minimising earthquake damage to the masonry as well as controlling the seismic performance of the RC moment resisting structures by offering auxiliary energy dissipation. The composite rubber/masonry infill is capable of interacting in a controllable way with the reinforced concrete frame, thus optimising a combination of strength, deformability and energy dissipation capacity in three orthogonal directions. The paper concludes by describing TARRC's testing capability, including biaxial shear and compression/tension at a wide range of scales, from material to full scale laminated bearings.

Keywords: rubber antiseismic devices; viscoelastic energy dissipative devices; seismic isolation; Masonry infill seismic protection

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B13
Research on Complete Sets of Industrialised Key Technologies of Synthetic Nature Rubber Chain

C.X. BAI

The research team has carried out investigations on synthesising novel catalysts for synthetic rubber, controllable polymerisation, advanced engineering techniques and high performance modification which have solved the key scientific and engineering problems such as regulating microstructures and properties of new varieties of high performance synthetic rubber, optimal design of production processes and development of core devices. Subsequently, the complete set of industrialised technologies comprising great assortment of synthetic rubber−synthetic natural rubber and industrial production equipment with the largest capacity and low energy consumption have been developed. The products can entirely replace natural rubber for the first time and have been successfully used in all steel radial truck tyres, which open up a broader market space for rare earth-based isoprene rubber. On the basis of the above research, the key technologies investigation of synthesising low cost and high purity isoprene monomer based on one-step olefin−aldehyde gas phase reaction using a cheap C4 resource have been conducted. In addition, the three dimensional space structural heterogeneous supported metal catalysts and its magnifying technology have been successfully exploited, forming a 100000 tonnes/year full sets of isoprene monomer industrialisation technology with short process flow, little by-products and low cost.

Keywords: rare earth catalyst; isoprene; *cis*–polyisoprene

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B14
Study on Voxel Finite Element Analysis of Open Cell Polyurethane Foam

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Establishment of design method of the macroscopic stress-strain relationship of open cell foam have been required because of its complicated microstructures. In this study to consider microscopic structure and matrix properties, a material design method of mechanical behaviour of the open cell polyurethane foam using the voxel finite element analysis was proposed. An original voxel finite element analysis code was developed based on the Fortran programing language on the Linux system. The finite-strain hyperelastic model was applied to matrix of the polyurethane foam. The Mooney-Rivlin model was adopted for the potential energy function of the hyperelastic model. To obtain mechanical properties of the matrix, solid specimens of polyurethane were prepared originally. The material parameters of the matrix were identified from the tensile loading test results of the solid specimens. To evaluate effectiveness of the computational voxel model, some voxel finite element model were prepared for numerical simulations. Microstructures of the open cell polyurethane foam were given by the CT-scanning system. Finite element models constrained by the original microstructural configurations were applied to numerical simulations. Also, the periodic finite element models based on the modified microstructural configurations of which relative density were same as the original models, were applied to the simulation. From the numerical results, design performance of the simulation code for open cell polyurethane foam were performed. Initial stiffness and plateau stress of the open cell polyurethane foam were investigated by the simulated results.

Keywords: stress-strain; Mooney-Rivlin; hyperelastic; polyurethane; voxel finite element

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B15
Thermodynamic Modeling for Compressible Hyperelasticity to the Microcellular Urethane

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In this paper, applicability of the thermodynamic modeling for compressible hyperelasticity to the microcellular urethane was investigated. This microcellular urethane has been applied to the shock absorbing parts of a car suspension system. The mechanical behaviour and fatigue properties of these parts are important issues in the point of mechanical design. The stress-strain relationships of the microcellular urethane show temperature dependency and strain-rate dependency. Therefore, the thermodynamic contributions to the mechanical behaviour is necessary to the engineering design of this microcellular urethane. Static compression tests and cyclic compression tests of cylindrical microcellular urethane specimens were conducted to investigate material properties. Mechanical dissipation energy was converted into thermal energy under the cyclic deformation. In this study, an original FEM code for the compressible hyperelastic material was developed. Formulations for finite element analysis was derived from the first principle of thermodynamics. The analysis results had a good agreement with the results of compression tests. The temperature change inside the specimens caused by repeated deformation was modeled. Thermal properties of the microcellular urethane were given by the cyclic compression tests. The temperature calculated by this model showed a good agreement with the results of the cyclic compression tests.

Keywords: urethane; formed rubber; microcell; hyperelasticity; FEM

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B16
Development of Anisotropic Hyperelastic Model for Fibre-Reinforced Rubbers Considering the Dispersion of Fibre Orientation Angles

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In this paper, a numerical analysis model of the fibre-reinforced anisotropic hyperelastic model considering fibre dispersion was developed. The fibre-reinforced rubbers show non-linear elastic characteristics and they depend on the direction of the fibres. The fibre-reinforced rubbers have two families of reinforcing fibres in the materials. The analysis model was developed by applying a fibre-reinforced structural model introduced by Holzapfel and Gasser to fibre-reinforced rubbers. By using the developed model, mechanical characteristics of the rubbers were shown numerically. Analysis results of fibre-reinforced rubbers indicate the anisotropic behaviours and different responses depending on the dispersion of fibre orientation angles. Displacement of the rubber reduced while rigidity increased as the fibre directions were close to the tensile direction. Also, the results confirm the smaller the fibre dispersions, the greater effects of fibre orientation angles. Mechanical response of the material approached isotropic behaviour as dispersion increased. The developed analysis code took into account the effects of fibre dispersion and orientation angle. Results of the numerical analysis encourage the applicability of the anisotropic hyperelastic model considering fibre dispersion like fibre-reinforced rubber materials.

Keywords: hyperelastic model; anisotropy; fibre dispersion; fibre-reinforced rubber

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B17
3-Dimensional Homogenisation Finite Element Analysis of Foamed Rubber

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In this study, 3-dimensional homogeneous finite element analysis of a truncated octahedral unit cell which consisted of hyperelastic beams was conducted to predict macroscopic mechanical characteristics of foamed rubbers considering its microscopic structure. The homogenisation theory was applied to original finite element analysis code and the unit cells for simulation were assumed to have the periodic boundary condition. An original finite-strain homogenisation FEM code for a hyperelastic model was developed. The truncated octahedral unit cell models were created using FEMAP developed by the Siemens PLM Software. The relative density of the homogenisation analysis was adjusted by width of the beams in unit cell models. The rubber matrix was assumed to be represented by the incompressible hyperelasticity. The Mooney-Rivlin model and incompressible condition were applied to the hyperelasticity. The material parameters of the Mooney-Rivlin model for foamed rubber matrix were identified by the tensile loading test results. Furthermore, compression tests of polyurethane foam having various relative densities were conducted to verify the applicability of analysis. The analysis results showed good agreement with the compression test results.

Keywords: homogenisation analysis; foamed rubber; hyperelastic material

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B19
Synergistic Effect by High Specific Surface Area Carbon Black as Secondary Filler in Silica Reinforced Natural Rubber Tyre Tread Compounds

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Carbon black was a conventional reinforcing filler for tyre tread compounds before the silica-silane technology came into play to offer the rubber tread lower rolling resistance, higher wet traction and similar abrasion or wear resistance. As the wear resistance influences mileage and is always a concern for silica-reinforced tyre tread compounds, this present study investigates the effect of carbon black at low amounts as secondary filler on the properties of highly dispersible silica-filled natural rubber (NR) compounds. Different loadings of carbon black N134 with high specific surface area and structure were used in substitution of silica in the compound formulation to keep the total filler content at the same level of 55 phr. When compared to a silica-filled reference compound, at an optimum ratio of silica/carbon black 45/10 phr, the silica/carbon black-filled NR shows a higher cure rate index, higher bound rubber content, modulus, tangent delta at -20ºC and 0ºC indicative for wet traction of tyre treads made thereof, and abrasion resistance, while maintaining similar ultimate tensile properties and tangent delta at 60ºC indicative for rolling resistance of tyre treads.

Keywords: tyre tread; natural rubber; silica; carbon black

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B20
A New Constitutive Model for Carbon Black Reinforced Rubber in Medium Dynamic Strains and Medium Strain Rates Based on Fractional Derivatives

J. BUSFIELD

Research into the modelling of the viscoelastic properties of rubber like materials is very important particularly in the automotive and biomedical sectors. The observed behaviour includes significant non-linear effects such as hysteresis and cyclic stress softening during loading. Previous work has shown that none of the commonly used viscoelastic constitutive models can fit a wide range of typical stress-strain data satisfactorily, for natural rubber elastomer compounds loaded under the typical operating conditions. This paper examines the behaviour of typical materials, filled with different amounts of carbon black that are used in automotive spring type applications. The cyclical loading behaviour of these materials are fitted over the engineering strain range using a new constitutive model based on fractional derivatives. This is used due to its ability to predict hysteresis with a memory of the previous load history. This model is able to represent all the different mechanical responses of a filled rubber. It includes nonlinear elasticity, hysteresis and other strain history effects. This model is then implemented in a fractional derivative viscoelastic constitutive law adopted in a user material subroutine (VUMAT) in the finite element software Abaqus.

Keywords: modelling; viscoelastic properties; hysteresis; nonlinear elasticity; carbon black

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B21
Understanding the Cyclic Fatigue Behaviour of Filled HNBR Elastomers

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The fatigue behaviour of HNBR is of industrial importance as it is often used as the elastomer under extreme environments such as those encountered in oil and gas applications. It is frequently the case that elastomers are used at high strains, high strain rates, high pressures, over a wide temperature range and in contact with organic solvents. This combination of conditions makes their fatigue response hard to understand and even more difficult to predict. This paper aims to measure the various different aspects of this behaviour with the aim of characterising their performance under a combination of different behaviours. This paper uses cyclic fatigue tests and trouser tear tests done on high ACN content HNBR compounds with different filler contents under different conditions. These conditions include pre-ageing at a high temperature and/or in an organic solvent as well as testing at elevated temperatures. Using a fracture mechanics approach allows a model to be developed which can predict the energy required to propagate a crack and also predict the rate at which the crack will grow. This can be used to predict the service life of a part under these specific sets of conditions. Results from these tests were often subject to a large degree of experimental scatter especially after ageing and all show areas of transitional tearing behaviour between smooth tearing to knotty tearing. Other thermal characterisation tests were conducted to examine for example if any crystallisation of the polymer might arise which could alter the fatigue resistance. By understanding this behaviour, it is hoped that the toughest HNBR compound can be identified under specific testing conditions. The optimum material being one that features a permanent knotty tearing which would enhance the service life of these parts.

Keywords: fracture mechanics; fatigue; HNBR; crack; tearing

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B22
Innovative EPDM Compounding for Optimal Ultimate Properties

C. VAN DER AAR

EPDM is commercially available for over 50 years. The initial idea was to replace NR by EPDM in rubber applications, such as tyres for cars and bicycles, however it quickly became clear that EPDM rubber is not well suited to these applications and development of other more appropriate materials for this outstanding, synthetic rubber product was in order. Because of the excellent weathering resistance (EPDM is highly resistant to heat, oxygen, ozone, UV and water), opportunities to use EPDM in automotive and building and construction applications were explored and developed. As early as 1968, an EPDM roofing based on Keltan 720 (today renamed as Keltan 6460D) was applied by one of our earliest customers, i.e. *Hertel B.V. in Kampen (the Netherlands), carrying the brand name Herlatan®, which was based on a combination of the (brand) names of Hertel and Keltan. Worldwide, this is the oldest (evaluated) single ply EPDM-based roof, and it is still in service today, having been monitored now for several decades. Since the late 1960s, the world has changed dramatically and requirements on rubber articles have been increasing. Compounders have been getting common questions over the years including: How to achieve the best heat resistant EPDM compound (which meets* e.g. *requirement at 150ºC)?; Can one formulate a non-black EPDM compound with optimum UV resistance?; Could I achieve with EPDM a certain oil resistance?; Can I replace NR with EPDM and still meet the required dynamic properties?; Is it possible to get reasonably good properties with sustainable materials? The aim of this paper is to explain the background of the defined requirements, to clarify the various ageing mechanisms and theories, to explain the EPDM parameters influencing the ultimate properties and, finally, to present our experimental work done to answer the common questions.*

Keywords: EPDM; rubber application; ageing mechanism; dynamic properties

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B23
Development of Wallpaper Adhesive from Specialty Natural Rubber Latex

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Wallpapers are an interior decorational feature to improve the aesthetic appearance of homes and offices. Installation of wallpapers to an area creates the impression of a feature wall. Wallpaper adhesive for installation purposes are either wheat based or methyl cellulose. A wallpaper adhesive using specialty rubber latex was developed in the present study. Properties of peel adhesion, surface energy and sound absorption of the specialty rubber latex based adhesive were evaluated. Results demonstrated that peel adhesion of the specialty rubber latex based adhesive was higher than commercial wallpaper adhesives on all surfaces tested, namely concrete, gypsum board and plywood surfaces. Sound absorption coefficient in the range of 3000 to 4000 Hz regarded as most sensitive to human hearing was found to exceed 30 % to 40 % of this value in the specialty rubber latex based adhesive compared to commercial ones. Consequently, an upscale application of specialty rubber latex based adhesive for wallpaper installation on dry walls is recommended.

Keywords: specialty rubber latex; wallpaper adhesive; surface energy; peel adhesion

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B24
Natural Rubber Modified Asphalt for Road Application

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The asphalt binder is modified using natural rubber (NR) to improve its performance on street and highway pavements in an urban area setting. Natural rubber modified asphalt (NRMA) was prepared from a source of PG 60–70 asphalt. The rheological characteristics of NRMA were analysed upon subjection to different ageing conditions using a dynamic shear rheometer (DSR) according to the Superpave test protocol. The presence of NR was also investigated by a thermogravimetric analyser (TGA) and infrared (IR) spectroscopy. Results showed that NR modification improved conventional properties of the base bitumen i.e. *penetration, softening point and temperature susceptibility. Based on the results obtained from the DSR test, NR reduces temperature susceptibility and facilitates polymeric modification using a highly elastic network within the bitumen. This elastic network increases viscosity, stiffness and elastic behaviour of the NRMA contributing to improved rutting resistance at a high temperature.*

Keywords: asphalt; pavement; temperature susceptibility; rutting

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B25
Nanomechanics on Non-Equilibrium Thermodynamics of Rubber-Like Materials

K. AKUTAGAWA

The new mechanical model of rubber-like materials was proposed to characterise the stress-strain response as a function of time and temperature. Two parameters of an attractive energy, and an internal variable, are newly introduced to describe the departures from the equilibrium thermodynamics of rubber elasticity. The mathematical mechanical model can reproduce the entropy and energy components on stress with various conditions such as the degree of crosslinks, the extent of swelling, the temperature dependence and the strain rate dependence. It also offers physical insights represented by the quantitative molecular structural parameters such as the number of non-bonding interactions and its potential energy. As a conclusion the energy component can be associated with the non-bonding potential energy of the dipole-dipole interaction (0.3 - 0.9 kJ/mole) and the steric interaction to rotation about the chain backbone (16 - 20 kJ/mole). This model can cover a wide range of mechanical properties so that it can represent the behaviours observed in real world applications. Hence, it will be expected to contribute the computer simulation in rubber science and technology and give us a hint to design the advanced rubbery materials as fast as possible, at a minimum fraction of the cost.

Keywords: stress; strain; mechanical model; thermodynamics; energy

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B26
An Experimental Study on Performance of High-Damping Rubber Bearings under Long Period Earthquake Ground Motion

N. MUROTA

Long-period earthquake ground motion is one of most highlighted topics in earthquake engineering. Among typical characteristics of the ground motion is the long period contents in its motion, which will have a large influence on the behaviour of structures with long natural period, such as high rise buildings or seismically isolated buildings by resonance effect. Another consideration is the long duration of the motion which may continue over five minutes. As the seismic isolation is a design concept to reduce the seismic force transmitted to the structure by supporting it with a flexible element installed between the base, or sometimes middle story of the buildings, and superstructures to decouple from the ground motion during earthquakes by means of their flexibility in shear deformation. The most popular isolation devices are seismic rubber bearings, with layers of alternating rubber and steel plates, and among several types of seismic rubber bearings, high-damping rubber bearings (HDR, hereafter) provides both restoring force and damping characteristics prepared by high-damping rubber compound. During shear deformation of the HDR, energy dissipation occurs by the friction between rubber-polymers and fillers, such as carbon or resin. The dissipated energy is transferred as heat, and increases temperature of the rubber itself. And the energy dissipation characteristics and stiffness of HDR have temperature dependencies. The higher the temperature, the lower the energy dissipation and shear stiffness. Therefore, during the long-period earthquake, special attention has to be paid to the deterioration of energy dissipation and the shear stiffness. Lower stiffness and energy dissipation will lead to amplification of shear deformation and may exceed design displacement of the bearings. In this study, the performance of HDR under long-period earthquake was evaluated by several long duration repeated loading tests, and the change of the stiffness, damping, and energy dissipation characteristics were investigated. For comparison, same testing was conducted with lead rubber bearing (LRB). The change in the properties of HDR was relatively small compared with LRB. Secondly, based on the test results, design formulae of degradation factors for shear properties under repeated loading was developed, which was expressed by the parameter of cumulative shear strain and increase of temperature. The numerical simulation of the seismically isolated structure was conducted in single degree of freedom system with/without degradation factors, and the results were compared. Although the result of HDR with degradation factors show larger displacement, the difference is considered to be relatively small.

Keywords: rubber bearing; high-damping; seismic; shear deformation; energy dissipation;

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B29
Some Factors Affecting the Flex Life of Polybutadiene Rubber Vulcanisates

M. FAROOQ

Flex life of three different polybutadiene rubber (BR) grades has been measured, in this study. Firstly, flex life of the polybutadiene rubber grade with highly linear chains was found to be higher than those of the linear and long branched chain structures. The viscosity of the uncured rubber compounds and rheometry measurements were carried out using Mooney viscometer and oscillating disc rheometer, respectively. The mechanical properties of the cured rubbers like tensile strength, modulus, elongation at break, stored energy density and tear energies were also measured for all the grades used and then the flex life were also compared. The hardness and crosslink density of all the cured compounds were measured and correlated with the flex life of the cured rubbers. A similar study for the unfilled rubber compounds of very similar viscosities were also carried out and it was found that the flex life of the highly linear grade of the rubber had the longest flex life, the long branched chain structure was intermediate and that of linear grade rubber possessed the shortest flex life. There was a correlation between the flex life and torque of the rubber compounds.

Keywords: flex life; torque; hardness; crosslink density; polybutadiene rubber

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B30
Burning Rate and Characterisation of Hydroxyl Terminated Natural Rubber/Isophorone Diisocyanate/ Glycerol Propellant Composites

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Hydroxyl terminated natural rubber (HTNR) was synthesised from deproteinised natural rubber (DPNR) to get a low molecular weight natural rubber as a potential propellant binder. DPNR was first purified, followed by depolymerisation via *a chemical method using cobalt acetyl acetonate and treated with a reducing agent to introduce hydroxyl at the chain terminals to give HTNR. The HTNR was formulated with isophorone diisocyanate (IPDI) using four different mole ratios of NCO/OH which were 0.5, 1.0, 1.5 and 2.0 with a constant amount of glycerol as a chain extender. Propellant composite samples were prepared based on formulation of 68% of ammonium perchlorate, 15% of aluminium and 17% of binder. The samples were cured in an oven at 60ºC for a week to give composite propellants. Molecular weight of HTNR was determined using gel permeation chromatography (GPC) and its molecular weight was found to be 9,816 gmol^{-1}. Fourier transform infrared (FTIR) analysis indicated that the HTNR contains hydroxyl group with new peaks at 3411 cm^{-1} (OH symmetrical stretching). Further analysis on rubber binder resulted in formation of urethane bond at 3438 cm^{-1} (OH and NH), 1708 cm^{-1} (C=O), 1515 cm^{-1} (N-H, C-N), 1307 cm^{-1} (N-H, C-N) and 1216 cm^{-1} (O=C-O-C). The propellant composite samples were tested for bomb calorimeter and burning rate to observe the propellant performance. It was found that combustion energy increased with increasing mole ratios while burning rate resulted otherwise. Overall, HTNR shows a potential as a propellant binder.*

Keywords: hydroxyl terminated natural rubber; binder; hydroxyl group; FTIR; bomb calorimeter

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B31
New Kneading Advanced Mixing Rotor

Y. KAMEDA

Some designed rotors are key factors to achieve better properties. This new rotor shows achievement of uniformity in temperature and good distribution performance. In addition, this rotor exhibits high productivity performance. Mixing data will be presented to indicate an advantage in comparison with other rotors.

Keywords: mixer; rotor; mixing; rubber; flow

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B32
Comparative Studies on the Influence of Types of Rubber and Carbon Black on Dynamic Properties of Anti-Vibration Application

A.A. RASHID

Comparative studies on the influence of material properties on dynamic properties for anti-vibration application in automotive industries were carried out. In this research study, two factors were investigated; (i) different types of rubber (ii) different types of carbon black, based on semi-EV sulphur cure system. The cure characteristics were determined and rubber compounds were vulcanised at 165°C. The tensile properties of rubber compounds, compression set, fatigue test, static stiffness (K_s), dynamic stiffness (K_d) and tan delta were measured. The frequency sweep was tested for K_d and tan delta with amplitude ±0.05 mm and the results were plotted at 15, 45 and 100 Hz. The EPDM rubber compound showed the high value of scorch time (ts_2) and optimum cure time (tc_{90}) while a high bond energy in the rubber polymer structure can be correlated to the cure characteristics. The results show that, higher modulus and rigidity of rubber contribute to the higher values in K_s and K_d results. However, for tan delta, NBR rubber compound shows a higher value indicating the greater damping coefficient. Hence, the selection depends on effectiveness of the materials to accomplish energy absorption and dispersal. Since similar loadings of CB at 50 phr were used for different types of carbon black, higher surface area of carbon black has higher contribution in modulus and rigidity. The N220 type of carbon black showed higher K_s, K_d and tan delta values as required for anti-vibration applications. The inherent materials characteristics play a major role in the automotive application.

Keywords: anti vibration; rubber; carbon black; dynamic property

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B33
Study of Relationship between Fracture Energy and Redistribution of Processing Oil at the Fracture Surface of Rubber

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Cured natural rubber (NR), compounded at two different paraffin oil concentrations, 5 and 10 phr are subjected to a standard tensile loading at two different strain rates of 10 and 100 mm.min^{-1} to study effects of the variables on fracture energy. First, the fracture energy of the samples as a function of oil concentration and strain rate are determined. Additionally, the generated fractured surfaces are subjected to spectroscopic investigation using attenuated total reflection (ATR) Fourier transform infrared (FT-IR) spectroscopy. The study is focused on determination of a characteristic absorbance peak height for paraffinic oil, concentrated on the fractured surface, independent of the distance from the tip of the initiating notch. The results of these IR analyses are then related to fracture energy to define the relationship between redistribution of oil during the tensile fracture processes. Similar trends are found for both the fracture energy and IR absorbance peak heights independent of oil content and varied strain rates. The strain rate and fracture energy are found to be inversely proportional, whereas fracture energy and IR peak height response are directly proportional. The IR peak height is also proportional to the oil concentration.

Keywords: fracture energy; strain rate; oil concentration; peak height quantification

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B34
Effect of Specialty Natural Rubbers for Engine Mount Application

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An engine mount secures the engine of a vehicle to its chassis. Successful application of elastomeric mounts as vehicle engine mounts has been observed over the years. Epoxidised natural rubber (ENR) and deproteinised natural rubber (DPNR) are specialty rubbers with potential for application in the development of engine mounts. In this study, a blend comprising natural rubber (NR) and butadiene rubber (BR) was used to produce the Original Equipment Manufacturer (OEM) parts. Epoxidised natural rubber (ENR25 and ENR50) and deproteinised natural rubber (DPNR) developed by Malaysian Rubber Board were used and compared with NR by evaluating both physical and mechanical properties of the rubbers with different filler loadings. The physical properties of NR exhibited excellent results as opposed to other rubbers. However, a blend of ENR25 and BR reflected good compression set at 100ºC for 96 hours. The performance of an engine mount comprising a blend of ENR50 and BR is promising in reference to excellent mechanical properties over that of other rubbers. Dynamic stiffness and damping characteristics of the engine mount play an important role to achieve vibration isolation with acceptable engine motion control in a vehicle engine mount system. It is perceived that engine mounts produced with a blend of ENR50 and BR can improve vibration effects in dynamic conditions.

Keywords: engine mount; natural rubber; epoxidised natural rubber; deproteinised natural rubber; vibration

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B35
Numerical Simulation of Flow of Rubber Compounds in Partially Filled Internal Mixer

H. YANG

The fact that the internal mixers are only partially filled with rubber compounds brings a great challenge to the simulation of the flow in it. In the simulation of partially filled flow, the free surface of rubber compounds must be traced to determine the occupied space of rubber compounds. In this study, the volume of fluid (VOF) method and the dynamic mesh technology of computational fluid dynamics (CFD) were used to simulate the flow of rubber compound in a partially filled internal mixer. There is a common problem that the interface between the air phase and the rubber compound phase becomes ambiguous and finally the two phases mixes together as computation proceeding when using the VOF method. To solve this problem, we manually re-meshed the flow field every 18 degrees, according to the calculated transient location of the rubber compound. Thus, we obtained the transient distribution of the rubber compound in the internal mixer as the rotors rotated. The flow of rubber compounds in non-intermeshing counter rotating internal batch mixers equipped with traditional 2:1 rotor and new 4:1 rotor over the course of mixing was simulated using POLYFLOW software. The resulting velocity profiles were used to calculate the paths of material points in order to make a quantitative comparison of the mixing efficiency between the two rotors. Statistical results indicate that the shearing-type new 4:1 rotor is more effective and efficient than traditional 2:1 rotor in distributive mixing, while keeping high efficiency of the dispersive mixing.

Keywords: internal mixer; interface; CFD; flow; transient distribution

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B36
Rubberised Roads: Constructions and Benefits

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Asphalt plays an important role in the construction of flexible pavements due to its binding properties. Increases in traffic loading with variation of the climatic environment and insufficient degree of maintenance causes accelerated deterioration of road structure. These roads show early signs of pavement distresses or failures such as permanent deformation, cracking, ageing and stripping which directly affects the roads performance and durability. From practical experiences it is proved that the modification of asphalt binder with polymer additives, offers several benefits. In the present work, properties of modified asphalt by natural rubber is assessed and compared to the conventional asphalt. The mechanical characteristics of asphalt mixes are determined by using the Marshall test. The analysis of the study found that Marshall properties of modified asphalt at an optimum level increased remarkably and exhibited a positive response on the stability, stiffness and voids which are potentially due to increase in properties of adhesiveness and cohesiveness. Natural rubber may also serve as an additive of asphalt mixture for aggregate coating material. In conclusion, natural rubber modified asphalt offers the potential of durable and longer lasting roads.

Keywords: natural rubber; asphalt; Marshall test; flexible pavement; deformation

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B37
Recipe Optimisation and Characterisation of Elastomers Used as High Damping Seismic Isolation Materials

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Elastomeric materials are used in different structures as base isolation components for decades now. Since the beginning, lack of knowledge sharing between civil engineers, polymer engineers and scientists has slowed down the process of developing more effective and long lasting base isolation materials. In recent years however, newly established collaboration helps to develop high damping and high performance rubber bearings with increased lifespan and reduced costs. We are trying to renew our formulation to increase damping properties while other mechanical, dynamic and thermal properties still meet the specifications required for bearings and isolation materials. As the first step we have started the detailed characterisation of the currently used formulation which is based on natural rubber. We have tried to optimise the ratios of natural rubber, chloroprene rubber and/or styrene butadiene rubber to reach the best damping and ageing performance while improving or at least maintaining other mechanical and thermo-mechanical properties. In addition to routine tests like mechanical test, hardness, compression set, density and thermal ageing we have attempted to obtain detailed information regarding cure characteristics and network structure of the elastomeric material using both moving die rheometer (MDR) and rubber process analyser (RPA). Cure characteristics are in close relation with the network structure of rubbers and can help to estimate their dynamic and mechanic performance. As the second step and to deepen our investigation we decided to use material testing system (MTS) since this system can provide reliable data related to dynamic, mechanic and durability aspects. As a result of this detailed analysis, we have prepared a reference point in the way to optimise this formulation and develop new ones.

Keywords: high damping, seismic; elastomer; dynamic; bearing; isolator

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B39
Advantages of Manufacturing and Using Natural Rubber Gloves

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Natural rubber (NR) latex was the first rubber material used for the commercial production of rubber gloves. Today, NR gloves still command a sizeable market share worldwide. From the manufacturers perspective, it is easier to produce NR gloves because the latex contains much lower surfactant content than most of the synthetic latexes, making it less foamy which in turn leads to a lower product defect rate. In addition, the leaching time is also shorter with lower chemical discharge in the effluent water. It has good wet gel strength properties, which are important for maintaining the film integrity during the latex processing such as leaching, beading and drying. NR latex can be fully vulcanised in latex state, and therefore the product quality is less susceptible to temperature fluctuations in the curing oven. The use of prevulcanised NR latex could also lead to a more consistent product quality. Unlike synthetic gloves, which normally require slower and gradual drying, NR latex films can be dried with a single oven temperature. The latex shelf life of raw latex and pot life of compounded latex are also much longer than synthetic latexes. From the user's perspective, NR gloves are generally softer and more elastic than the synthetic gloves, which provide good comfort, low hand fatigue and good tactile sensitivity to the user. They are also more durable, have good resistance against polar solvents such as alcohol. The tear resistance of NR gloves is the highest among the common rubber glove materials. In addition, NR gloves also have the ability to reseal a small hole when punctured by a sharp object. These offer an extra barrier protection to the user. NR gloves are generally cheaper than most synthetic gloves except for PVC gloves, which are neither durable nor environmentally unfriendly. As NR gloves are produced using NR latex which is a plant based material, they are low carbon foot-print products and biodegradable. Therefore, the use of NR gloves helps to reduce the impact of global climate change.

Keywords: natural rubber; glove; wet gel strength; elastic; synthetic gloves

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B40
Ideal Microstructure for Super Tyre Performance: From Design to Performance

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Energy use due to automobile tyres accounts for more than 6% of the world's total energy consumption and ~5% of all carbon dioxide emissions. We designed and fabricated a next-generation, energy-saving advanced elastomer (AE) based on a macromolecular assembly strategy. This AE delicately balances rolling resistance, wear resistance and wet-skid resistance, addressing the so-called "magic triangle" that has plagued the tyre industry for more than a century. This AE crosslinks anionically synthesised hydroxyl-terminated solution-polymerised styrene-butadiene copolymers with highly symmetric isocyanates and polyols to generate a uniform network by macromolecular self-assembly. Remarkably, compared with those of widely commercialised elastomer nanocomposites tailored for green tyres, the wear resistance, rolling resistance and wet-skid resistance of this AE are improved by 94.6%, 69.8% and 13.8%, respectively. This AE affords a new opportunity for the large scale application of next generation high performance automobile tyres that will, in part, resolve a serious global energy and environmental crisis.

Keywords: advanced elastomer; assembly; magic triangle, high performance, green tyre

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B41
Development and Evaluation of Non-Enzymatic(NE) Deproteinised Latex and Dry Natural Rubber Grades for Downstream Product Applications

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The attributes of the non-ally deproteinised rubber enables applications where protein allergy is not the prime consideration. The process development of ammonia-free and nitrosamine-free latices, including prevulcanised latices, for customised end-use applications is provided. The properties obtained through modifications by grafting, epoxidation, single-walled carbon nanotube (SWCNT) incorporation, which enhance adhesivity, impermeability, conductivity and dynamic properties is discussed. Applications of the latex and solid rubber grades in downstream latex and dry rubber as a sustainable alternative to some conventionally available natural and synthetic rubber grades is presented.

Keywords: deproteinised rubber; protein allergy; sustainable; natural; synthetic

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B42
Fatigue Analysis of Rubber Bushing under Multi-Block Duty Cycle

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Bushings are often made of rubber materials and are usually of complex shape. The main purpose is usually to act as cushions between more rigid members. Although not considered structural members, bushings reduce impact loadings on the main members and thus becomes an integral part of the structure. Fatigue life prediction of bushings is necessary to assure safety and reliability. These parts are usually subjected to very complex loadings and duty loadings of bushings are multi-axial in nature. Road loading signals are used for fatigue life evaluation and for rubber components, a full strain history is needed for damage calculations. The scale and combine method for linear fatigue analysis cannot be used for rubber components. Thus, a procedure for estimating the strain history using a series of finite element (FE) load cases or load vectors is presented. The procedure takes into account material and kinematic nonlinear behaviour by using interpolation methods. With a full estimated strain history, fatigue life prediction of the rubber component is done using critical plane analysis in the rubber. Fatigue life prediction provided by FE-safe/rubber as well as Abaqus to determine critical failure locations.

Keywords: bushing; fatigue life, rubber; finite element; strain history

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B44
Novel Functionalised Solution Styrene Butadiene Rubber for Winter Tyres Tread

B. JANOWSKI

It is important for rubbery polymers that are used in winter tyres tread, to have proper glass transition temperature (T_g) and good compatibility with fillers, such as silica. It is well known that the filler in rubber compounds should be well dispersed throughout the rubber, in order to improve various physical properties as a result of enhanced interactions between polymer and silica or carbon black leading to a significant decrease of rolling resistance and heat build-up in tyres, correlating to a reduced vulcanisate hysteretic energy loss. Very often however, the improvement in rolling resistance results in the deterioration of the wet grip. In this work we present results of studies on model winter tyre tread compounds properties based on new functionalised low T_g sSBR with balanced rolling resistance and wet grip.

Keywords: winter tyre; tread; glass transition; rolling resistance; wet grip

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B45
Application of Natural Rubber Product for Seismic Isolation of Civil Engineering Structures

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Earthquake is one of the most destructive natural disasters that brings catastrophic effects on affected areas. While structural engineers have well-documented guidelines for earthquake resistant designs, the fundamental of the conventional approach remains the same; and that is to design a structure that resists frequent yet minor earthquakes without apparent damage. In large earthquakes, the structure is allowed to suffer controlled damage without collapse. Thus, repair works are required after such tremors and sometimes, demolition becomes the only viable option when the structure is beyond repair. Seismic isolation offers as an effective method in reducing the earthquake response of civil engineering structures such as buildings and bridges. High damping rubber bearing (HDRB) is probably the most practical seismic isolator that has been widely used in the United States, Europe, China and Japan. Compared to some other isolation systems, HDRB has little or no maintenance requirement after installation besides having higher re-centering capacity. The advancement of material engineering in the rubber industry has enabled rubber to be used in heavy engineering applications. Rubber is an extremely resilient material. It possesses flexibility in most of its mechanical properties. The rubber technology nowadays is so advanced that rubber can either possess very low stiffness to absorb impact energy, or higher stiffness to cater for a large loading. Besides, a specially formulated rubber compound allows for energy dissipation, which is an added advantage to the base isolation system. In some complex engineering applications such as seismic isolation, the rubber behaves intelligently in that it possesses distinctive characteristics under various loading conditions. Thus, rubber is an effective material for structural control. It changes the way a structure or a building reacts to vibration forces. The most challenging reality of any world-class rubber manufacturer is not only in the production know-how but most importantly, the testing counterpart. Investment in a testing facility is of no less importance compared to the production technology. In 2017, Doshin Rubber had successfully obtained its CE Marking (European Conformity certification) in high damping rubber bearing for seismic isolation, which brings a direct impact on Doshin as one of the leading specialists in seismic devices in the world. This paper deals with the application of highly damped rubber in real projects for seismic mitigation as well as the way forward for the industry. The technology of using natural rubber in high damping seismic isolators has been accomplished by the authors, with successful installation of such a system in a hospital building in Indonesia, a country with active earthquake history. This paper includes information on many other real projects in seismic isolation by the authors, and the advancement of testing facilities and requirements in relation to the reliability of HDRB.

Keywords: natural rubber; seismic isolation; high damping rubber bearing; earthquake; structure

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B46
Influence of Different Temperature Control Unit (TCU) Settings on Thermal Melt Homogeneity and Throughput in Rubber Extrusion Processes

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Nowadays a major point of research is focused on the increase of the throughput of rubber extrusion processes, maintaining a constant product quality. The aim to increase throughput is in competition with the thermal melt homogeneity. Increasing the throughput by a higher rotational speed leads to a strong thermal melt inhomogeneity. This effects the product quality in many ways; temperature peaks leads to scorching in the extruder, the flow behaviour in the die is unstable and the course of vulcanisation is influenced. To improve both throughput and thermal melt homogeneity, the influence of different TCU−Settings are examined with a 60mm rubber extruder. While the screw temperature mainly influences the throughput, the thermal melt homogeneity at the screw tip can be significantly influenced with different temperature profiles along the barrel. Raising the screw temperature leads to a higher throughput but the melt still lacks thermal homogeneity. This can be compensated with a suitable temperature combination along the barrel.

Keywords: rubber extrusion; thermal melt homogeneity; temperature control unit

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C01
Integrating Theory of Copper Chelation, Latex Preservation and Oxidation in Natural Rubber Latex

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When SMR scheme was conceived, the oxidation resistance was conceptualised as an important control parameter. Plastic Retention Index (PRI) was introduced and served as important criteria for controlled coagulation. It was soon observed that high copper and manganese content would invariably cause low PRI. A causative link was implied but the origin and precipitation route remained unexplored. In natural rubber field latex and latex concentrate, zinc diethyl dithiocarbamate (ZDC) was first introduced and practised in Sri Lanka, followed by the work of Krishnaswamy in Guthrie Plantation group in the use of tetramethyl thiuram disulphide (TMTD) for preserving field and latex concentrate. In 1975 Firestone successfully used sodium diethyl dithiocarbamate (SDC) as the primary preservative for their prolonged running time in centrifuges. All these three chemicals have similar chemical structure - the dithiocarbamyl group. Ng and Ong soon discovered that TMTD preserved field latex has a downside. Skim latex from centrifugation had a low PRI and high copper content. Careful study of latex serum by ultracentrifugation and their reaction of solid TMTD, ZDC, and SDC established the causative link between copper precipitation and poor PRI. Latex preservation and oxidation (low PRI) can thus have a common link which is the formation of copper chelate in the serum phase. This research advances an integrating theory of copper chelation, latex preservation, and oxidation. Two additional known preservatives zinc pyridinethione (ZP) and 1,2-benzisothiazoline-3-one (BIT) from archived information in Lembaga Getah Malaysia were tested alongside TMTD. First the concentration of copper was established at about 20 micromolar concentration based on latex weight. Then the commonly practised dosage of 125ppm TMTD was recalculated to yield 520 micromolar. Since this is the effective concentration used in practice this concentration was used as the criterion on which other preservatives were judged. A multiplication factor was also introduced based on the number of molecules necessary to chelate one molecule of copper. It was found that copper in serum was drastically reduced by the introduction of TMTD, BIT, and ZP using AES-ICP method. VFA was measured for all the three latex preserved with the above chemicals. TMTD was found to be superior to BIT and ZP. While BIT and ZP were equally chelating copper they were found to be inferior to TMTD in the control of latex quality as measured by VFA. The current research has not addressed the reasons for their relative effectiveness. Oxidation results (PRI) was tested but the results were more erratic indicating the complex nature of the oxidation process. Based on the current research a screening procedure for testing the effectiveness of preservatives is proposed.

Keywords: copper chelation; dithiocarbamyl; PRI; VFA; latex concentrate

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C02
Trial Evaluation of Vulcanisation Depth of Thick Rubber Products by Terahertz Radiation

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An estimation of vulcanisation depth of thick rubber products is performed using terahertz (THz) time-domain spectroscopy. The sample is styrene-butadiene rubber (SBR) based cylindrical products with a diameter of 35 mm and a thickness of 20 mm and vulcanised under the pressure of 10 MPa and the temperature of 150 degree Celsius. In order to clarify the vulcanisation effect, no carbon black (CB) is included in the sample, because the apparent THz absorbance of CB is extremely large compared with polymers and other additives. The thick sample is sliced parallel to the upper and lower heating plates of the cure mould into six thin specimens with the thickness of a few mm to construct the THz absorbance imaging. In this study, the sample at optimum cure time (T_{90}) is firstly investigated. As the results, we find that the coefficient of variation (CV) of the THz absorbance distribution is suitable for evaluating vulcanisation degrees at each depth position. The experimental result showing the specimen located around the centre of the thick sample has the maximum CV suggests more active cure reaction is processing than that at the neighbourhood of the heating plates.

Keywords: THz; vulcanisation depth; thick sample

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C03
Comparative Investigation of the Influence of Material Formulation on the Ageing Behaviour of FKM, VMQ, EPDM and HNBR Elastomers for Sealing Applications

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The present study investigates basic mechanical and sealing relevant property changes under accelerated ageing, with an aim to determine the influence of different structures on ageing and to correlate structure-property changes with sealing performance. Fluoro-elastomer (FKM), silicone rubber (VMQ), ethylene propylene diene rubber (EPDM) and hydrogenated acrylonitrile butadiene rubber (HNBR) are chosen. All the formulations were targeted to exhibit a comparable hardness of 70 Shore A, however achieving the target with different combinations of crosslink density and filler fraction to generate different structures. For example, properties of highly crosslinked EPDM with 33 phr of carbon black and less crosslinked EPDM with 65 phr of carbon black are compared. To investigate the influence of ageing with respect to the material formulation, basic properties such as hardness, crosslink density, tensile tests and dynamic mechanical analysis are studied for each rubber based on standard test specimens. Later on, sealing relevant properties such as compression set, leakage rate and stress relaxation are studied using the model O-rings. Basic material properties together with sealing relevant properties help in understanding the long-term structure-property-performance of the materials. Results from the experiments appear promising to judge the long term sealing performance of the O-rings.

Keywords: o-rings; structure-property relationship; ageing

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C04
Flexure Testing Machine for Automotive Air Brake Hose and Hose Assemblies

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The brake system is an important aspect of vehicle safety in avoiding accidents. Typically, an air brake system is applicable for commercial vehicles including buses, trucks, tractors and trailers. There is a concern that brake defects occur more often than brake failure. Therefore, full compliance with the Society of Automotive Engineers (SAE-J1402) *is crucial in order to reduce brake defects during manufacturing. A flexure testing machine was developed recently to test the flexing hose durability in actual conditions at an air pressure of 1 MPa in accordance to* SAE-J 1402. *The standard requires for the hose to be continuously flexed for 1 million cycles without leaking. The machine would stop if the hose leaks or otherwise progress until the cycle is completed. Evaluation of the machine was conducted using crosschecks with an accredited laboratory offering the same test. The results confirm that the machine developed was comparable with other accredited laboratory equipment. Resultantly, the development of this flexure testing machine supports its application in industry to ensure production of safe hoses.*

Keywords: vehicle safety; hose brake; flexure testing machine; hose durability

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C05
Baseline Study on the Quality of Rubber Crumbs in Southern Philippines: The Role of Testing Laboratory in the Rubber Industry

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Laboratory testing results are key objective evidences providing assurance on the quality and quantity of materials in a sample. These data serve as guidelines in assessing manufacturing practices as well as provide leverage for processors to command better price for their rubber products. The establishment of natural raw rubber testing laboratory by the Department of Science and Technology IX (DOST IX) provides an opportunity to initially evaluate the quality of rubber in Southern Philippines to determine conformance to the specifications of PNS ISO 2000:2015 *for Standard Philippine Rubber (SPR). Samples of natural raw rubber (crumbs) obtained from five (5) participating rubber processors were tested using the* ISO 1656:2014 *method for nitrogen determination, Philippine National Standard (PNS)* ISO 2007:2007 *for Initial Plasticity, PNS* ISO 2930:2015 *for Plasticity Retention Index, PNS* ISO 247:2015 *for ash content, PNS* ISO 249:2015 *for dirt content and PNS* ISO 248-1:2015 *for volatile matter. Results show that 87 percent of the 78 rubber samples labelled as SPR 20 meets the minimum requirements while 13% of the samples did not meet the requirements of the Standard for dirt content and Plasticity Retention Index. SPR 5 rubber shows consistent results with only 1 of 27 samples failed for Plasticity Retention Index. The study provided an evidence-based glimpse of the state of the quality of rubber crumbs in Southern Philippines.*

Keywords: Standard Philippine Rubber; raw natural rubber; rubber testing laboratory

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C06
Equipment Development for Supporting Establishment of ISO 3821 *towards Certification of Welding Hoses*

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The National Key Economic Area (NKEA) is defined as an important driver of economic activities that contributes towards the Malaysian economic growth measurable by the National Gross Income (NGI). Through this initiative of NKEA, the dry rubber products workstream has identified hoses as one of the priority products under selected product categories to increase Malaysian export values to RM 20 billion by 2020 as well as to decrease importation of dry rubber products. Product certification has been singled out as one of the most effective tools to accelerate the acceptance of the products worldwide. One of the products selected under this economic activity is welding hose, used to convey common fuel gas, i.e. *acetylene which is known for its high flammability during welding process. Hence, it is important to test welding hose for its flexibility in order to ensure that the hose is free from leakages.* ISO 3821 *(Gas welding equipment − Rubber hoses for welding, cutting and allied processes) is a standard that specifies the technical guidelines for welding hoses. The standard does not specify the types of equipment to be used for testing hose flexibility at sub-ambient temperature. The equipment has to be developed in-house from scratch in order to comply with the specification stated in* ISO 3821. *One of the equipment developed is low temperature chamber which is used to conduct cold flexibility test on welding hoses at -25° ± 3°C. This paper shall elaborate on the development of low temperature chamber in order to conduct cold flexibility test for welding hoses following* ISO 3821. *With the successful development of the machine; the certification of welding hose to* ISO 3821 *could now be accorded to local hose industry in order to help them grow and to penetrate the international market.*

Keywords: welding hose; *ISO 3821*; product certification; equipment development

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C07
Migration of N-nitrosamines from Rubber Gloves for Handling Food: Effect of Extraction Media

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Rubber gloves are used in a variety applications including food handling purposes. In order to assess possible exposure of the wearers to N-nitrosamines as well as possible release of N-nitrosamines into food coming in contact with these gloves, effects of extraction media are investigated. Artificial sweats (both alkaline and acid solutions), artificial saliva, and some food simulants are used for the extractions and twelve N-nitrosamines including NDMA, NDEA, NDPA, NDiBA, NDBA, NPIP, NPYR, NMOR, NEPhA, NMPhA, NDiNA, and NDBzA are analysed using GC-TEA. By using different extraction media, the levels of released N-nitrosamines and N-nitrosatable substances are different leading to the differences in judgement for compliance to the EU Directive. By comparison with data of daily intake of N-nitrosamines from food, the intake of N-nitrosamines migrating from gloves used for food handling under the most unfavourable circumstances could lead to the excess in dietary intake. Therefore, potential risks associated with the use of rubber gloves for food handling are considerably high.

Keywords: N-nitrosamines; N-nitrosatable substances; rubber gloves

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C08
The Production and Certification of Reference Materials

H. ABDUL KADIR

Certified reference materials (CRMs) are widely applied to ensure the reliability of analytical data and contributes towards establishment of the accuracy and traceability of chemical measurements. However, some types of reference materials may not be readily available, and the possibility of producing them in house has to be considered. General steps required in production of a certified reference material based on ISO 17034 *typically include collection or synthesis of material, sample preparation (including homogenisation, stabilisation, bottling* etc.*), homogeneity testing, stability assessment and value assignment (characterisation). The process begins with the definition of the material to be produced and obtaining a sufficient amount of raw material with the desired properties. The materials have to be homogeneous and stable in order to ensure that CRMs delivered to the laboratories are the same and this cannot be compromised. This work is often made at the sample preparation stage. Thorough control of homogeneity and stability are essential for certification of reference materials and to ensure validity of the certificate for each bottle of a batch throughout a defined shelf-life. Once the material has been determined to be stable and homogeneous, it is divided into portions and packaged appropriately for intended use. Subsequently, the material is analysed for the analyte(s) of interest for certification purposes, after which the certificate of analysis can be prepared. There are several accepted methods for characterising and producing certified values of certified reference materials. This paper will elaborate on the more widely accepted methods for characterising and producing certified reference materials that include certification using one definitive method, certification through inter-laboratory testing and certification using at least two independent methods. It is also imperative that a certified reference material be continually monitored for stability throughout its useable lifetime.*

Keywords: certified reference material; homogeneity; stability; certification

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C09
Gel Content Evaluation for Various Grades of Epoxidised Natural Rubber

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Epoxidised natural rubber (ENR) is a modified formulation of natural rubber (NR) with the introduction of an oxygen atom to the unsaturated molecule of NR, well known to react readily with peracids. This chemical reaction produces oxirane, the epoxide compound consisting of three-membered ether in a cyclic form. The mass fraction of intermolecular ether increases, leading to gel formation which is insoluble. ENR's high gelling property affects its application as a high gel content in raw rubber causes difficulty in processing, particularly mixing. There is no standard test method at present for the determination of gel content in ENR. Most gel content determination reported in literature are a result of in-house test methods. ISO 17278:2013 *Rubber, Raw Natural – Determination of the Gel Content of Technically Specified Rubber (TSR) was published in 2013. The precision statement was established through interlaboratory crosschecks using low viscosity rubber. This study will focus on development of a sound test method through comparison of two available test methods (in-house and ISO test method) to establish a reliable test method for the intended purposes. Resulting outcome will provide valuable information regarding gel content determination for various in-house grades of ENR and commercial ENR (Ekoprena®) using both test methods. Ekoprena® 25 (automatic process) with its high range Mooney viscosity was analysed to evaluate gel content consistency. The variation in gel content is also evaluated for ENR analysed using untreated and treated toluene at various soaking times.*

Keywords: epoxidised natural rubber; gel content; test method; validation

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C10
Innovative Kinetic Approaches in Rubber Technology

J. LACAYO PINEDA

Kinetics in rubber technology is mainly associated with vulcanisation, crystallisation, and glass transition. Different approaches and examples are presented here for these topics. Rheology and Differential Scanning Calorimetry (DSC) are valuable methods for characterising vulcanisation kinetics in both basic and advanced modes. Fast-Scanning DSC (Flash-DSC) opens new possibilities for kinetic studies of both glass relaxation and crystallisation in rubber.

Keywords: kinetics; differential scanning calorimetry; rubber technology; glass relaxation; crystallisation

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C11
Rubber Process Analyser (RPA): Real Achievement, Limitations and Performance Assessment

H. BURHIN

After 27 years of existence, it is important to review the achievement of RPA in the field of elastomer and rubber compound characterisation. It is now clear that the RPA has been found highly efficient to analyse uncured compound properties as is was initially design for. This efficiency was proven for compound development, quality control and troubleshooting. We can list for instance green tyre tread compound mixing, extrusion and injection moulding. Although not initially envisaged, raw elastomer testing is now one of the most important uses of the RPA in the world. It is extensively used not only by polymer suppliers but also compound producers. The RPA polymer characterisation covers Average Molecular Weight (AMW), Molecular Weight Distribution (MWD), Long Chain Branching (LCB) and polymer shear stability. It is in testing "after cure" properties that the RPA has been found the least capable. Accurate viscoelastic properties of cured rubber compounds require a perfect knowledge of the sample shape factor which can only be provided by proper solid Dynamic Mechanical Analyser (DMA). Some other manufacturers have promoted substantial improvements over the original design but rare are those who have undoubtedly proven the effectiveness of their design. For potential RPA customers, it is therefore essential to proceed to a very careful and thorough evaluation of the claimed performance of commercially available RPA before final acquisition. This can easily be achieved by testing known (elastomer or thermoplastic) reference materials in key area of the instrument testing scope.

Keywords: rubber process analyser; RPA; molecular weight; chain branching; dynamic mechanical analyser

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C12
Standards Development at ISO/TC 45 – *Towards United Nation's Sustainable Development Goals*

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Technical Committee (TC) 45 under the International Organization for Standards (ISO) was formed in 1947, along with formation of ISO to develop standards for rubber and rubber products. Its first meeting was held in 1948 in the United Kingdom and has evolved progressively to retain a top position among other committees producing standards annually. The main objective of standardisation is to assist in the development of quality, safe and reliable products, while facilitating international trade, by eliminating technical barriers to trade. Trade and standards are key elements in addressing issues on sustainability. ISO's commitment in contributing towards sustainable development in standardisation activities, has led to publication of more than 21,000 standards for various sectors that provide practical tools for all dimensions of sustainable development; i.e environmental, societal and economic. The United Nations, in September 2015 adopted a set of goals to protect the planet and ensure global prosperity. Standards development at ISO/TC 45 *are guided by these goals in ensuring sustainability of the rubber industry. In view of this, standards development at* ISO/TC 45 *has published new standards for business growth as well as to support sustainability. This presentation focusses on the roles of* ISO/TC 45 *in developing innovative and sustainable standards for rubber, rubber products and testing services. Apart from that, it also describes the processes involved in proposing an ISO standard to ensure sustainability of the rubber industry by providing quality and competitive products while facilitating free and fair trade. Standardisation allows for technological, economic and societal benefits leading to harmonisation amongst various global stakeholders within the rubber industry.*

Keywords: standards; sustainable; *ISO/TC 45*; rubber

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C13
ISO/IEC 17025 *Tyre Testing Laboratory for Mechanical (Tyre) Testing*

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RRIM Tyre Testing Laboratory (RRIM TTL) is a Malaysian government-owned laboratory that meets the requirements of SAMM Accreditation Scheme and complies with MS ISO/IEC 17025. *RRIM TTL has been in operation since 1978 and is located at the Rubber Research Institute Experiment Station, Sungai Buloh, Selangor, Malaysia. Its main function is to support the tyre industry in producing high quality products that meet national and international standard requirements. It is an independent facility that conducts tyre testing for the tyre industry in Malaysia as well as ASEAN countries and has become a reference point and centre for tyre testing laboratories to government bodies for implementation of tyre-related regulations. Currently the RRIM TTL is a hub for tyre testing following UNECE Regulation No. 117 in Malaysia. The regulation applies to new pneumatic tyres of classes C1, C2 and C3 with regards to sound emissions, rolling resistance and adhesion performance on wet surfaces (wet adhesion)1. The laboratory endeavours to be a centre for testing tyres following this regulation by adding a new testing equipment to perform the rolling resistance test. The equipment is currently undergoing a laboratory alignment programme with IDIADA Spain as reference laboratory, to enable tyre testing and provide valid results for labelling in accordance with* ISO 28580 *requirements. Competency of the current rolling resistance equipment is established through crosschecking with other machines from commercial and accredited laboratories. This paper elaborates results of rolling resistance coefficient (RRC) obtained from the cross-check programme. Further, increasing market demand for a number of key tests including endurance, high speed capability, plunger energy and bead unseating in meeting the requirements of* MS 1394 *and* MS 149 *for new and retread tyres of Classes C1, C2 and C3 including L categories (motorcycles) are also highlighted. RRIM TTL conducts tests for research and development purposes to tyre manufacturers in Malaysia comprising dimension measurement, footprint measurement, extended mechanical test and rolling resistance test.*

Keywords: tyre; mechanical (tyre) testing; rolling resistance

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C14
Recent Developments in Data Analysis: Proficiency Testing (PT) Programme for Rubber and Rubber Products

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The Malaysian Rubber Board (MRB) is among Proficiency Testing (PT) Providers for rubber and rubber products that use the online data analysis i.e. *e-Precision system developed based on* ISO/TR 9272 *(Rubber and rubber products – Determination of precision for test method standards) to estimate precision of test methods by means of inter-laboratory tests. However,* ISO/TR 9272 *which is technically equivalent to* ASTM D4483 *(Standard Practice for Determining Precision for Test Method Standards in the Rubber and Carbon Black Industries) prior to the year 2000 has been found to contain some technical errors and must be replaced. The errors in* ASTM D4483 *have been fixed and enhancements added with publication of* ASTM D4483*:* 14a *(Standard Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries). However, due to the copyright enforcement by ASTM in 2000,* ASTM D4483: 14a *cannot be used to correct the errors in* ISO/TR 9272*. Hence, a replacement document is needed. The recent publication of* ISO 19983: 2017 *(Rubber -- Determination of precision of test methods) replaces the* ISO/TR 9272*. This paper elaborates the technical evaluation of two different standards namely the* ISO 19983: 2017 *and* ASTM D4483: 14a *for estimating precision of test methods by means of the PT Programme. The determination of a precision statement following the two standards would be explored and demonstrated. Results obtained from this technical evaluation will be used by MRB to implement a new approach in analysing data obtained from the PT programmes online, for precision determination.*

Keywords: e-Precision; *ISO 19983:2017*; *ISO/TR 9272*; *ASTM D4483:14a*

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C15
Novel Tools to Meet Analytical Challenges of Polymer Characterisation

D.N. PATEL

Polymeric materials are abundant in our modern societies and cover a broad range of applications in areas such as automobiles, textiles, packaging, electronics, to name just a few. This increasing complexity in applications has driven the need to produce highly complex polymeric materials. The emerging complex synthetic biopolymers, novel polymers, and polymer additives with a structural and compositional diversity presents unique challenges for characterisation of modern polymers. Additionally these products are also difficult to dispose of due to their poor biodegradability. The consequence of this has caused the push towards green chemistry and the need to fully characterise new polymer systems to evaluate potential environmental consequences. The analytical scientists are deploying a wide range of analytical tools to keep pace with modern polymer chemistry. In particular, mass spectrometry has become increasingly important to the polymer industry following the introduction Electrospray Ionisation (ESI) and Matrix Assisted Laser Desorption Ionisation (MALDI) for atmospheric systems. Measuring many aspects of the polymer including repeat units, end groups, chain length, poly dispersity and back bone structure supplies polymer chemists with critical information. In this presentation, mass spectrometry based key analytical solutions for polymer characterisation that meet specific challenges faced by the polymer industry will be discussed with specific application examples.

Keywords: mass spectrometry; characterisation; environmental consequences; polymeric material; biodegradability

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C16
Applying the Cutting Method to Quickly Quantify Elastomer Durability in the Laboratory for Compound Development and Quality Control

C. ROBERTSON

The long-term fatigue performance of a tyre, hose, bushing, or other elastomer application is governed by the fatigue crack growth behaviour of its compounds, but these fundamental properties are not routinely characterised due to the complex and time-consuming testing procedure involved. A new rapid method will be described in this presentation. The intrinsic strength (fatigue threshold), T_0, and the ultimate tear strength, T_c, bracket the fatigue crack growth power law response of an elastomer. By assigning appropriate crack growth rates of 10^{-10} and 10^{-2} mm/cycle to T_0 and T_c, respectively, the intermediate eight decades of crack growth behaviour can be estimated. Both T_0 and T_c can be evaluated within a few hours using a commercial instrument which employs the cutting method of Lake and Yeoh (G.J. Lake and O.H. Yeoh, Int. J. Fracture 14, 509 (1978)), making this method appropriate for implementing in the rubber laboratory for compound development and quality control. This approach will be demonstrated using new results for carbon black filled natural rubber (NR), styrene-butadiene rubber (SBR), and butadiene rubber (BR) with widely dissimilar fatigue crack growth rate characteristics along with literature data for other elastomers.

Keywords: crack growth; SBR; NR; BR; fatigue

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C17
Development of Rubber Product Standards in Thailand

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As a global producer of natural rubber (NR) and rubber products, Thailand continues exploring ways to improve products quality and increase exports. The implementation of Rubber Product Standards in Thailand started a couple of decades ago. Since then the development of rubber product standards has been carried out in collaboration with several organisations i.e. *The Thai Industrial Standards Institute (TISI), Rubber Authority of Thailand (RAOT), Department of Science Service (DSS), The Federation of Thai Industries (F.T.I.), Mahidol University, National Metal and Materials Technology Center (MTEC) and other Thai universities and research institutes. This talk will cover the importance of standards in increasing the competitiveness of Thai rubber industries and the expansion of activities to support Thai rubber industries in terms of developing new rubber products standards and providing more testing facilities. Examples of research and development involving creation of new standards will be included.*

Keywords: rubber products; standards; Thailand

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C19
Feasibility Assessment on Condom Foil Opening Device (AONI Box)

V. CHAN

ISO 4074 *requires the test lab examiners to open foiled-condoms manually and strictly prohibits the assistance of any sharp tools, such as, scissors. It is believed that the prohibition for sharp tools is a result of the shortcoming on the current design of available equipment which can cause damages to the condom when used improperly or carelessly. However, the manual opening practise is inefficient and labour intensive. The monotonous action of this practice can cause exhaustion which can potentially lead to chronic muscle diseases to the test lab examiner and thereby increasing the chance for human error. As such, the intention of prohibiting the assistance of sharp tools can eventually backfire. Because of this, there is an obvious reason for a new design on the opening equipment for foiled- condoms. AONI box is an Assisted Opening Normalised Instrument (AONI) made to enable the test lab examiners to open foiled-condoms efficiently and effortlessly without the risk of damaging the condoms. The AONI box is a square, packet-sized plastic instrument which contains a station steel blade and a guiding rail mechanism that prevents the condom from meeting the blade. The cutting action is done when the AONI box user pulls the condom out from the retrieving end of the box. The scope of this paper is to assess the feasibility of the AONI box as an ISO 4074 allowable Assisted Opening Normalised Instrument for condoms.*

Keywords: foiled-condoms; AONI box; *ISO 4074*

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C20
Technical Advisory Service (TAS)

A. SAMSURI

Technical Advisory Service (TAS) provides technical assistance and advice that grants solutions to technical problems that arise in the rubber products manufacturing sectors or the like. The extent of TAS provided can range between small, medium or large tasks depending on the nature of the problems. Troubleshooting on factory problems that arise from poor quality control practice is an example of a small TAS enquiry. Solving problems associated with production line or processing can be considered as a medium task and setting up a new factory or turn around factory problems are examples of a large task. The time scale to solve a problem is dependent on its nature. There are cases where the problems can be solved merely by giving words of advice without having to conduct any laboratory work. In some cases it may involve small scale experimental work while in some cases extensive R&D work is required. One may need to engage TAS when you have problems of not meeting the right results and expectations in your productions. Last, but not least promoting rubber and/or rubber products can be considered as Technical Advisory Service as well. This paper discusses some typical cases of TAS work providing solutions to problems encountered by the rubber products manufacturing factory and the rubber industry in general.

Keywords: rubber industry; technical advisory; trouble shooting; factory; experimental work

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C21
Automotive Rubber Products: Related Regulations and Opportunity under WP29 Framework

M.Y. MOHAMAD

The automotive industry plays an important role and has emerged as the single-largest consumer of natural rubber, in the form of tyres of motor vehicles, fan belts, engine and exhaust mountings, tubes, hoses, seals, grommets as well as other parts and accessories. Since the application of these rubber products are very much related to the motor vehicles, thus this situation will require measurement of the performance, standard test methods and specifications in order to established the quality of the rubber products in use and yet it is safe to be used by the consumers. Road Transport Department of Malaysia has been appointed and nominated by Ministry of Transport Malaysia (MOT) to act as the Approval Authority in Malaysia to spearhead implementation of technical requirements of motor vehicles used on the road. Since 4th April 2006, Malaysia has become a Contracting Party to the 1958 Agreement in which Malaysia has been using the UN Regulatory framework under the World Forum for Harmonisation of Vehicle Regulations (WP29) as a main reference for technical regulations in Malaysia. The implementation and harmonisation of UN Regulation in Malaysia encourage the domestic automotive industry to upgrade the current approach in tandem with the international standards. This reflects that Malaysia is serious in ensuring the safety of vehicles and authenticity of automotive products in Malaysia. As of July 2017, there are one hundred (100) UN Regulations adopted and used as a technical basis and requirement of motor vehicle compliance which is regulated through the Vehicle Type Approval (VTA) process. Apart from that, out of one hundred (100) UN Regulations there are six (6) UN Regulations related to the tyres of motor vehicle requirement and specification. Further, there are three (3) Malaysian Standards (MS) which have been referred to and adopted under domestic legislation Motor Vehicle (Construction and Use) Rules 1959. As the leading agency responsible for the enforcement and implementation of technical regulations with regards to tyres of motor vehicle, Road Transport Department (RTD) is always dynamic in improving the implementation mechanism through holistic approaches by establishing collaboration networks between various government agencies and the domestic automotive industry to achieve aspirations targeted by the government.

Keywords: automotive; Malaysia Standards; UN Regulation; Road Transport Department; harmonisation

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C22
SMR and Its Quality Control

S.Z. ABU HASSAN[1#] AND H.H. ISHYAM[1]

Standard Malaysian Rubber (SMR) scheme was developed by the Malaysian government to ensure high quality of SMR produced. To achieve this objective, the Malaysian government through Malaysian Rubber Board (MRB) regulates the SMR scheme since its inception in 1965. MRB is responsible for SMR surveillance and inspection activities for SMR producers and authorised SMR testing laboratories to ensure sustenance and quality of SMR produced. SMR is a technically specified rubber (TSR) produced only in Malaysia. MRB ensures certification of every SMR issued through a rigorous process. This regulatory process ensures the quality of SMR marketed locally and globally. SMR quality assurance undertaken by MRB includes SMR producers and SMR laboratories. The certification of SMR producers ensures consistent production quality. The accreditation process is mandatory for SMR laboratories to ensure technical competency and feasibility in conducting SMR tests. This paper presents the latest approach adopted by MRB in strengthening SMR surveillance and inspection activities through an information and communications technology (ICT) application and SMR inspection improvement through implementation of the RIF system to ensure production of SMR with consistent quality.

Keywords: SMR scheme; surveillance; inspection; RIF system

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C23
Industry Driven Glove Standards Development

S. S. SHANMUGAM

Natural rubber latex cleanroom gloves have been widely used in various industries, that process or assemble critical environmental products, typically in a cleanroom environment. Such industries include the electronic semiconductor, disk drive, storage media and avionics industries. Quite recently, other industries that have embraced natural rubber latex cleanroom gloves include LCD, TFT, bio medical, bio technology, nanotechnology and pharmaceutical manufacturing concerns. This segment of gloves has been identified as the growth sector for coming years, with an average of 18% growth y-o-y. To date, the specifications for natural rubber latex cleanroom Class 10 , Class 100 and Class 1000 gloves has been set by the rare manufacturers and accepted by end users. However, with an increase in cleanroom gloves producers and end users, there is now a dire need to streamline the specification of the Class 10, Class 100 and Class 1000 natural rubber latex cleanroom gloves. A common yardstick of measure was sorely lacking in the natural rubber latex cleanroom glove industry. The Industry represented by Malaysian Rubber Gloves Manufacturers Association (MARGMA), hence initiated an effort to resolve this need. This paper addresses the methodology employed in this Industry driven standard development, leading to the publication of ISO 20437: 2017. *This was achieved by defining the critical parameters that describe a cleanroom glove. These critical parameters, are method and equipment specific, hence this specification will include the applicable test methods. In the cleanroom industry these parameters are known as particulate counts, ionic content, total non-volatile residue and organic residue. Principal manufacturers' capabilities has to be matched with the global required standards of the major end users. Such an exercise involved procuring, testing and establishing a baseline data of critical parameters that determines the specification of a cleanroom glove. Yet again, it has to be synced with the requirements of the major end users , without sacrificing quality and unit costs..*

Keywords: glove standards; natural rubber latex; cleanroom; glove industry

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D01
Malaysia's Rubber Gloves Export: The Role of Free Trade Agreements

S.M. LEE

Malaysia has an established ranking as world leading exporter of rubber gloves. There is, however, rising competition from countries such as Thailand, China and Indonesia. This study examines the determinants of Malaysia rubber gloves export in particular with bilateral and regional FTA partners and/or top twenty export destinations in 1989-2013 (29 countries, 25 years). A modified resource-based manufactured export gravity model is estimated using Poisson-pseudo maximum likelihood estimations (PPML). The results show that manufacturing value added and importers GDP are significant determinants while distance (another key variable) is insignificant in rubber gloves export flows. Malaysia significantly exported more rubber gloves to ASEAN after FTA has taken effect. Although Malaysia exports to all FTA partners increase generally in absolute terms, non-FTA countries (such as USA and Germany) relatively absorbed more of Malaysian gloves for selected bilateral FTA partners and ASEAN-China. Malaysia may explore further opportunities to export Malaysian gloves to large, high income importing countries though new FTAs or ASEAN+X (extension of ASEAN) regional FTAs. At the same time, exporters should also fully tap into the current importing countries with FTAs in effect.

Keywords: FTA; Malaysia; ASEAN; PPML; glove; export

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D02
Global Economic Influences on Rubber Prices

D. WONG

Over the years, the U.S. Dollar has been the main influence on global commodity prices. After the digestion of U.S. tax reform and public trading of Saudi Aramco, where would the crude be heading? How will this affect the rubber prices? Following the tapering of European stimulus towards end 2018, we will highlight the Asia outlook respectively to Dollar trend, and prepare you for an effective hedging on the market volatility of rubber prices.

Keywords: commodity; volatility; price; rubber

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D03
An Analysis of Malaysian Companies Participation in Condom Supply to Global Fund

S.M. LEE

As the world's largest exporter of condoms, Malaysia's supplies of condoms to Global Fund to Fight AIDS, tuberculosis and malaria (Global Fund) recipients are valued at about USD37 million which is about 41% of the total USD91 million condoms procured for the period of 2008 - 2013. This is despite the backdrop of encouraging local production of health commodities in Africa and encouraging participation of local African manufacturers to be qualified suppliers. There has also been reported instances of poor quality products supplied and breach in procurement procedures. This study identifies the country characteristics and product characteristics of Malaysian firms supply of condoms to the Global Fund programme. The study also contributes in providing decision-makers and suppliers (not only limited to Malaysian suppliers) on the important country and product characteristics in the supply of condoms besides increasing information to potential applicants for tender called by Global Fund. Random effect estimation is conducted on unbalanced panel data of Malaysia's supply of condoms to Global Fund recipients in 44 countries for the period of 2008 - 2013. In terms of country characteristics, HIV prevalence and African countries were significantly positive, while being a fragile state (World Bank classification), health expenditure per capita and number of physician per 1,000 people were insignificant. For product characteristics, quantity purchased and average quantity divided by distance between Malaysia and recipient countries were significantly positive while average unit price of below USD0.07 were significant but average unit price of below USD0.02 were insignificant (average price based on past literature of procurement for Global Fund). The increased analysis and discussion of these countries and product characteristics based on data available in public domain (for increased transparency) has a noticeable effect towards a more efficient supply process where suppliers or aspiring suppliers may supply condoms for a social cause to the recipients in countries that need them with product characteristics most required, thus also contributing to more efficient tender and supply processes.

Keywords: Malaysia; condom; global fund

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D04
The New Rubber Economy: Expect the Unexpected

K.S. PONG

Recent natural rubber price trends may appear confusing to many observers. Data and reports by various rubber organisations, including ANRPC and IRSG, indicate a seasonal short-supply of natural rubber vis-à-vis *demand. By as much as 600,000 tonnes at one stage. Yet the price of natural rubber went even lower in recent months. What are the reasons behind this? High natural rubber prices in 2016 and during 2010-2011 sent the message more rubber should be planted to support demand. Over-planting by traditional rubber producing countries and also new comers led to an over-supply situation that persists to this day as the newly planted trees mature. Newcomers to the industry have lower costs and continue to produce even as the traditional producer countries complained of low prices and took measures to restrict supply. Prices of synthetic rubber also showed uncharacteristic volatility. The main rubber consumption sector, tyres, is impacted by new technologies and market trends, particularly in vehicle production and demand. Impending demise of the internal combustion engine, rise of electric vehicles (EV), car sharing, ride sharing, autonomous cars and new tyre technology are all going to have an impact on this. The author explores possible scenarios based on recent reports and studies.*

Keywords: natural rubber; volatility; price; synthetic rubber

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D05
Challenges with Export for Rubber Latex Products in the ASEAN Market

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Approximately 90% of world natural rubber (NR) supplies are produced by the top four NR exporting countries, particularly Thailand, Indonesia, Malaysia and Vietnam. Challenges with export and uncertainties of rubber latex products in the ASEAN market are influenced by many factors. All these issues have driven the motivation for this study in aiming to investigate the factors affecting export of rubber latex products, to analyse relationship between export prices, production and exchange rates for export purposes and to predict the export of rubber latex products by selected ASEAN countries. Data from 1999 to 2016 utilises the panel data analysis and Granger homogeneously causality test for estimations. Estimations reveal that the independent variables, namely export price and production exhibit a significantly positive relationship while exchange rate indicates a negative correlation. To conclude, Indonesia and Malaysia are estimated to have decreasing trends of NR export. Inversely, Thailand and Vietnam are predicted to exhibit increasing trends of NR export. The novelty of this study concerns effective enhancement and stability of NR production in the ASEAN market despite challenges arising from the global market integration.

Keywords: export; rubber latex products; panel data; ASEAN countries

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D06
Development Potential of Rubber Industry in Southeast Asia: Learning from Malaysia and Thailand

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This paper discusses the development potential of resource production and resource-based manufacturing of rubber industry in Malaysia and Thailand. Two countries have been leaders in the production of natural rubber. After 1997/98 crisis, the production and export of manufactured products grew in both countries. The analysis of NR producing (upstream segment), processing (midstream segment) and rubber-based manufacturing (downstream segment) find the different timing and sectoral composition in the development of the rubber sector of two countries. Despite such differences, the two countries share a development pattern in one important respect. This paper will clarify the fact that the public sector played a crucial role in the development of the upstream segment, while the successful development of the downstream segment largely depends on innovative activities of private entrepreneurs to explore niche international markets for specialised rubber products. However, endeavours toward the sustainable development require a more targeted approach for channelling available resources, seeking technological upgrading and coordinating new players or different linkages. As a result, I will present some key findings from this study and finally we can obtain certain insights about economic prospects of resource-rich countries in Southeast Asia from the experiences of both Malaysian and Thai rubber industries.

Keywords: Malaysia; Thailand; upstream; rubber industry; downstream

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D07
Effect on Rubber Demand of New Technologies Particularly in Transport Related Industries

C.H. OON

The rubber industry especially that of synthetic rubber (SR) and synthesised chemicals are closely related to our environment. Synthetic chemicals used by rubber polymer related industries can be a concern if it is not managed in the proper manner. Automotive industries emit combustive polluted air and factories that synthesise chemicals used by rubber industries are of concern to the complex eco-environment system and its effects on human health. This paper covers a list of chemicals commonly used in industry over the past decades and reviewing their potential "life span" in relation to human health, particularly towards carcinogenic properties. What will be the direction of growth of these chemical industries in the near future? Will there be any new and safer chemicals, to be introduced as a replacement in the next decade?

Keywords: rubber industry; synthetic; chemical; human health; carcinogenic

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E01
Challenges for Reuse of Passenger Car Tyres for a Circular Economy

H. VAN HOEK

Circular Economy represents a major challenge, particularly in the elastomer world. In previous times, the quality of recycled rubber was rather poor, limiting its application range and quantities. New technologies for higher quality recycled elastomers need to be developed in order to make reuse of tyre rubber for new tyres a reality. A challenging technology is devulcanisation of rubber. In the strict sense of the word, this is reversion of the vulcanisation, leading to a material with the same property profile as the starting one. In the case of tyres, the challenge is to develop a universal generic procedure suitable for the different polymers and compounds used in these products. Another issue is the application of the devulcanised rubber: processing as well as compounding have to be adjusted to achieve the best properties, including maximum improvement of the lifetime of the blend of devulcanised and virgin rubber. A complicating factor is, that tyre development continues in parallel with new technologies; in particular the (partial) replacement of well-known carbon black as reinforcing filler by the new silica-silane technology for the tyre tread. Important properties as wear, rolling resistance and wet grip have improved considerably, leading to a better fuel economy of the vehicles and a longer life time of the tyres. An overview is presented of latest developments in car tyres elastomer recycling, with special emphasis on achievements and limitations in view of the parallel developments in tyre technology.

Keywords: circular economy; devulcanised; elastomer; recycling; passenger car tyres

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E02
Influence of Process Oils Based on Renewable Sources on Key Properties of Tyre Treads

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There are several trends that will affect tyre materials in the upcoming years, like intensified emission and tyre labeling regulations, sustainability with respect to recycling and purchasing of raw materials in a world of rising population with increased demand for personal transport. The raw materials trend is concentrated on renewable products for example rubber derived from latex of dandelions, bio-derived process oils and fillers like pyrolysis black, rice husk or micro-cellulose. Efforts to reduce environmental footprint of tyres have been intensified in recent years. Developing more eco-friendly products represent a central research subject for many scientists and tyre manufacturers. The present paper reports the influence of process oils based on renewable sources on key tyre properties, like rolling resistance, wet grip and abrasion by investigating the compatibility of these new materials in different polymer matrices, varying the vinyl groups and functionalisation in S-SBR. The new bio-based product developed does not show influence on sulfur vulcanisation compared to traditional process oils and can achieve significant improvements in tyre tread performance.

Keywords: bio-based process oils; sulfur vulcanisation; rolling resistance; S-SBR

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E03
Recycling Waste Tyres: Effect of Radiation Sensitisers and Electron Beam Irradiation of Properties of Reclaimed Waste Tyre Rubber

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Non-degradable waste tyre generation around the world is growing at an alarming rate. Diversifying the recycling route of these waste tyres is essential to solve the problem. To address the issue, this study utilised radiation sensitisers and electron beam irradiation to enhance the poor properties of reclaimed waste tyre rubber (RTR). The RTR and radiation sensitisers were mixed in the internal mixer followed by electron beam (EB) irradiation with doses ranging from 50 to 200 kGy. Radiation sensitisers loading was fixed at 4 wt%. The degradation and stability in RTR were studied in term of mechanical and morphological properties. Electron beam irradiation revealed the presence of radical stabilising and scavenging additives within RTR which retards the crosslinking process in RTR. Though chain scissions were predominant; study showed the replacement of S-S and S-C bonds with stronger and stiffer C-C bonds ensures the retention of RTR properties upon irradiation. However, RTR still suffered from further oxidative degradation from irradiation in air. Radiation sensitisers, trimethylol propane triacrylate (TMPTA) and tripropylene glycol diacrylate (TPGDA), were used to accelerate the irradiation induced crosslinking in RTR. Presence of radiation sensitisers leads to simultaneous improvement in toughness and tensile strength of RTR. Elastic capacity of RTR phase was restored and interfacial adhesion enhanced in the presence of radiation sensitisers. These findings validated the feasibility of using ionising radiation for recycling inferior waste polymers into higher quality material.

Keywords: waste tyre; recycling; reclaimed tyre rubber; electron beam irradiation; radiation sensitisers

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E05
Assessing Biodegradability of Epoxidised Natural Rubber Latex Films

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Natural rubber latex (NRL) is a green material with potential for various rubber product applications such as tyres, belts, gloves and foam. Addition of rubber chemicals and other additives to NRL improves its processability and enhances its properties for purposes of these applications. Research on chemical modification of NR through the epoxidation reaction dates back to the 1980s. Chemical modification of rubber polymer chains through the epoxidation process produces a unique molecular structure that comprises an epoxy group as a replacement of the double bonds in the NR polymer backbone. The resultant material i.e. epoxidised natural rubber (ENR) exhibits enhanced properties such as lower gas permeability, better oil resistance, increased glass transition temperature (Tg) and polarity. In line with these value-added properties, there exists unlimited potential to diversify the use of ENR in its latex form (ENRL) such as in dipped goods and foam products. This work investigates the biodegradability of ENRL products namely, ENRL films in a controlled composting environment under laboratory conditions. The degree of biodegradation was measured based on carbon dioxide produced by microorganisms in aerobic conditions. The physical and chemical changes of the ENRL films were observed using a scanning electron microscope (SEM), Fourier-transform infrared spectroscopy (FTIR), gel permeation chromatography and physical weight loss. The microbial population involved in the biodegradation process was quantified using a molecular identification technique.

Keywords: epoxidised; natural rubber latex; biodegradation; carbon dioxide; microorganisms

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E06
Climate Actions for the Rubber Industry

S.S. CHEN

As of October 2017, 169 nations have agreed to be bound to the terms of the Paris Agreement, an international treaty that seeks to limit global temperature rise to 1.5ºC above pre-industrial level. The 04/2017 press release of World Metrological Organisation (WMO) confirmed that the year 2016 recorded 1.1ºC above the pre-industrial period, which is 0.06ºC above the previous record set in 2015. Existing climate actions directed at reducing greenhouse gas emissions have not been able to effectively curb the upward trend in global temperature rise, arrest the rate of global warming and combat climate change. As climate change impacts become widespread, it is increasingly obvious that equal precedence should be accorded to climate change adaptation and climate resilience. The ISO 14080 *standard that is currently under development has adopted a holistic definition on climate action as any initiative to achieve climate change measures or goals based on mitigation and/or adaptation. The standard provides guidance on the characteristics of a framework for development of methodologies that can evaluate, quantify and track climate action. To motivate investments in climate actions whether from the public or private sectors, it is imperative to have methodologies that establish their effectiveness. Hence, a host of activities that exists in the life cycle of a product present opportunities for introduction of climate actions. These actions are not confined to only technological and innovation options but also development of tools that will objectively assess their effectiveness in the sustainability agenda. The natural rubber industry has a sphere of influence that span across many sectors, from agriculture to manufacturing to service and waste management. Plausible climate actions need not focus primarily on reducing greenhouse gas emissions. The industry should keep tap with climate change impacts on their value chain in preparation of possible disruption of upstream or component supplies, or changing specification of customers in response to climate change-related phenomenon and events. Taking climate actions is not always about preparing for potential damage. Climate actions can encompass exploring opportunities for business diversification and expansion into areas beyond the norm to enable social, economic and environmental systems to cope with the climate change impacts. Addressing climate change by mitigating emissions while strengthening adaptive capacity to remain resilient to the impacts are good strategies for today's business to remain in business. The Sustainable Development Goals (SDGs) 2030 of the United Nations-Transforming our world: the 2030 Agenda for Sustainable Development should not be viewed as goals intended only for policy makers. SD Goal 13 on Climate Action warrants proactive participation from the industry sectors, among them the rubber industry for business sustainability.*

Keywords: climate change; sustainability; rubber industry; life cycle; gas emissions

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E07
Sustainable Rubber Industry with Eco-Friendly Processing

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Environmental degradation at raw rubber processing (RRP) factories (latex concentrate and block rubber production) have been threatening sustainability of the rubber industry for several years. Issues related include, malodour, high effluent volume discharge with high organic load thus incurring a high cost for treatment, scarcity of water for processing, valuable bio-materials from latex and natural rubber serum not being extracted, valuable skim latex turned into low grade rubber, and lacking avenue for value addition to cuplump field grade rubber. Low rubber prices and escalating operating costs with a diminishing revenue dictated the closure of many RRP factories. To overcome this scenario, a paradigm shift has been envisaged since 2005 with the exploration of modern processing techniques. This paper outlines utilisation of the membrane separation process (MSP), a technology researched and evaluated by the Malaysian Rubber Board which has been systematically formulated into zero waste technology and can be adopted to mitigate environmental problems, the extraction of pharmaceutical raw material from natural rubber serum, value addition to cuplump field grade rubber, to generate additional income and discharge clean water which can be reused. The adoption of zero waste technology would lead to a sustainable rubber industry.

Keywords: rubber processing; sustainability; paradigm shift; membrane separation process; zero waste

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E08
A Novel Continuous and Green Technique for the Desulfurisation of Waste Tyre Rubber Using Multistage Screw Extruder: From Basic Research to Industrial Application

W. WANG

With the rapid development of the automotive industry, waste tyres have been posing significant health and environmental concerns. In China, the main ways for reusing waste rubbers include tyre retread, production of reclaimed rubber, application of ground tyre rubber (GTR), and pyrolysis. Most of the waste tyres are recycled to produce reclaimed rubber, which is viewed as the third rubber raw materials in China, and the production reached 4.6 million tonnes in 2016. However, the traditional industrial method brings about heavy environmental pollution, high energy consumption, and high safety risks. Based on the basic research on different desulfurising method, such as the mechanical, thermo-mechanical, supercritical carbon dioxide, twin-screw extruder, and traditional chemical method, we identified the desulfurising mechanism of GTR, established the responding relationship among mechanism of desulfurisation, conditions of desulfurisation, structure of reclaimed rubber, and performance of reclaimed rubber with excellent processing and mechanical properties. Through computer simulations, research of thermal conductivity of GTR, and the permeability of softer to the GTR, etc. *we independently developed complete technique and equipment for continuous and green desulfurising production of reclaimed rubber using a multi-stage extruder. Supported by the national 863 Plan, Beijing University of Chemical and Technology (BUCT) independently develops complete technique and equipment for continuous and green desulfurising production of reclaimed rubber using a multi-stage extruder, which realises the environment friendly, energy saving, security, simple and continuity in the production of reclaimed rubber from ground rubber. The final reclaimed rubber exhibits excellent performance, and the technology was identified by the neutral authority organisation as the international leading level. The technique and equipment have realised industrialisation with several types according to the output: 300kg/h, 500kg/h, and 800kg/h, and have been widely using in several Chinese companies and exported to the European Union (Slovakia), accompanying obvious social and economic benefits.*

Keywords: waste tyres; desulfurisation; reclaimed rubber; ground tyre rubber

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E09
Green Mobility, Challenges and Opportunities for Automotives, Tyres and Related Industry

R. MUKHOPADHYAY

Road congestion, urban sprawl and air pollution are among the most important challenges being faced by cities today; indeed, green objectives have been introduced in the majority of cities. Green mobility is a key sector for green economic growth. Mobility is at the heart of economic development and social wellbeing; it spans from individual and public transportation to goods transportation and logistics. Trends like urbanisation, an ageing society and digitisation highly influence mobility. Mobility and transportation have a huge impact on use of our resources by creating 22% of global gas emissions according to IEA.

*Presently, the tasks for automotive developments are being summed up into the minimisation of negative attributes, such as environmental problems, traffic accidents, and the maximisation of positive elements such as comfort and convenience for future human being. This paper will provide an overview of challenges and opportunities for the tyres, automotives and related industry, working towards green mobility through focus on: A new ecosystem of collaborative partnership among regulatory innovation frontier (government), business innovation frontier (cross industry value chain) and technical innovation frontier (automotive industry); Decoupling natural resources used and environmental impact from economic growth; Usage of advanced material like functionalised solution SBR, functionalised carbon black, highly dispersible silica, environment friendly silane coupling agent, part replacement of carbon black/silica with nano fillers (*eg. *nano clay, carbon nano tubes, silicon carbide, graphene, rubber nano particles, nano fibres* etc*) including carbon black/silica-latex master batch and polymer-fibre composites; Design for Environment (DFE): New concept development, selection of low impact materials, reduction of material, optimisation of production techniques, efficient distribution system, reduction of environmental impact in the user stage, optimisation of initial life time, optimisation of end of life system; Resource optimisation with 4R Strategy (reduce, re-use, recycle and renewable); smart manufacturing marries information, technology and human ingenuity to bring about a rapid revolution in the development and application of manufacturing intelligence to every aspect of business; Cleaner production to increase overall efficiency and reduce risk.*

Keywords: green mobility; efficiency; smart manufacturing; resource; technology

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E10
The Potential of Natural Rubber Resources in Indonesia to Meet the Needs of World Rubber Products

E.L. DEWI

Rubber is a strategic commodity in Indonesia since Indonesia is one of the world's largest producers of natural rubber. Unfortunately, more than 85% of raw rubber is exported, while the remaining 15% is used domestically thus the price of rubber is declining by the year. Government strives to increase natural rubber consumption by increasing its added value into engineering rubber products. To produce engineering rubber products, there must be a touch of technology ranging from the formulation of rubber compounding to the manufacturing process of its products. Two engineering rubber products that consume natural rubber as their main material are aircraft retreading tyres and rubber air bags, but in Indonesia it is still imported until now. The consumption for retreaded aircraft tyres in Indonesia reaches nearly 5000 tyres per year for Boeing 737-800/900 aircrafts, possibly various types of aircrafts require about 60,000 tyres per year. While the need for rubber air bags are as many as 1500 pieces, which for the manufacture requires 500 kg of natural rubber per rubber air bag. Mastering the technology of these rubber products will increase the consumption of natural rubber 925,000 kg per year. Besides transportation and maritime applications, the is a need for rubber products as health devices, especially from natural rubber latex. In the future, development of smart rubber is expected for many applications all over the world. However, natural rubber is a critical substance or raw material that cannot be substituted by other materials.

Keywords: rubber; Indonesia; retread; aircraft tyres; consumption

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E12
Natural Rubber Latex Allergy: Cause, Control and Prevention

N. CHAIEAR

Natural rubber NRL (NRL) can be found in many health care products. It has been extensively used in the manufacture of medical gloves because it is a very durable and flexible material giving wearers a high degree of dexterity, sensitivity and microbiological protection. Hev b *6.02 was the occupational sensitiser of NRL gloves amongst healthcare workers (HCW). There are 13 known* Hevea *latex allergens,* Hev b *1 through* Hev b *13. The 13 allergenic* Hevea *proteins are involved in a broad range of activities in the rubber tree, including rubber biosynthesis, disease resistance, structure, and housekeeping.* Hev b *1, 2, 3, 4, 5, 6.02, 7.01 and 13 have been identified as the most highly sensitising of the* Hevea *allergens. To date there are sufficient reports confirming that most allergens cause latex allergy to HCW come from* Hev *1 to 13. NRL proteins have the potential to cause asthma and dermatitis. Although rare, more serious allergic reactions such as anaphylaxis are also possible. The amount of NRL exposure needed to induce sensitisation is unknown. NRL proteins can cause type I (immediate) hypersensitivity. In addition, the products manufactured using NRL proteins contain other chemicals that can cause irritant reactions / type IV (delayed) hypersensitivity reactions. Irritant reaction caused by chemical additives in the gloves, sweating/occlusive effects of the gloves, or skin contamination caused by incorrect glove use. Once the irritant agent has been identified and its use discontinued, the symptoms will disappear and not recur. Type IV allergic reactions or allergic contact dermatitis. This is an allergic response to the chemical additives, known as accelerators, used in the manufacture of NRL gloves. The signs and symptoms may be indistinguishable from those of irritant contact dermatitis, and so diagnosis will require clinical assessment. A type IV allergic response occurs between 10 to 24 hours after exposure and can get worse over the subsequent 72 hours. The allergens can be identified by patch testing using some suspected allergens. Upon discontinuation of NRL gloves containing identified additives in gloves, the symptoms will disappear. Type I allergic reaction is an immediate allergic reaction to NRL proteins. In rare cases it can result in anaphylactic shock. Skin prick test with NRL allergens or blood test of NRL-specific antibodies will probably support diagnosis. Best means of preventing this reaction is to avoid using or being exposed products containing NRL. Using low-protein, powder-free, single-use NRL gloves in the workplace is unlikely to lead to new cases of NRL allergy. Individuals with an existing NRL allergy should take NRL-avoidance measures. Individuals with an existing NRL allergy is not at a significant risk if colleagues use either low protein, powder free NRL gloves or non NRL gloves. An exception might be if the affected employee has anaphylaxis.*

Keywords: natural rubber latex; medical gloves; contact dermatitis; allergens; accelerators

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E13
Spin-Trapping Analysis of Thermal Degradation Mechanism of Thermoplastic Polyester Elastomer

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Generally, polymer materials, including plastics, fibres and elastomers, are degraded by various factors, such as heat, UV light, mechanical stress, oxygen, water, radiation, and so on. It is widely believed that the degradation reaction of polymer materials proceeds through certain radical intermediates. However, most of the suggested radical reactions were estimated inductively by product analysis using spectroscopic analysis which cannot selectively detect the radical species, such as UV-Vis, FT-IR, or NMR spectroscopy, or structural investigation, such as GPC and MS. On the other hand, an electron spin resonance (ESR) spectroscopy is a useful and unique method for studying radicals, because ESR method can detect the radical species sensitively and assign its molecular structure. However, the major difficulty even when ESR is used for degradation analysis is the very short lifetime of the radical intermediates; the radical intermediates at room temperature or higher are easily deactivated by recombination as the temperature rises. For this problem, we applied a spin-trapping method to the degradation analysis of some polymer materials, poly(butylene terephthalate) (PBT) and PBT-related thermoplastic polyester elastomer (TPEE), and could detect some intermediate radical species successfully[1,2]. In the spin-trapping method, the produced short-lived radical species during the degradation is trapped by the spin-trapping reagent, and it becomes possible to measure ESR spectrum to analyse the molecular structure of the original intermediate radical species. For the TPEE[2], the thermal degradation of poly(butylene terephthalate)-co-poly(ethylene oxide) (PBT-co-PEO) under air was investigated, and it was found that the thermal degradation process of PBT-co-PEO starts around 120ºC producing two radical intermediates, $\bullet CH_2$- and -O-$\bullet CH$-CH_2- resulting from a homolysis at carbon-carbon bonds in the PEO unit and a hydrogen abstraction (or dehydrogenation) at an alpha carbon neighbour to the ester linkage, respectively. In this paper, we further discuss the oxygen effect on the thermal degradation of PBT-co-PEO using spin-trapping method by comparing the results both under air and nitrogen. The results revealed that the thermo-oxidation reaction occurs on the PEO unit above 120ºC and the PBT unit undergoes thermal degradation by long annealing at 120ºC. It was concluded that these radical intermediates are the key factor for thermal degradation of PBT-co-PEO elastomer. We will discuss in detail using the results from ESR measurements but also from GPC and TGA and demonstrate that the spin-trapping method by ESR is a new candidate for the degradation analysis and may enable the causal treatment for polymer materials including rubbers.

Keywords: electron spin resonance; thermal degradation; spin-trapping; thermoplastic polyester elastomer; PBT-*co*-PEO

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E14
Sustainable Rubber through the Lens of Institutional Investors

P. SPEED

New Forests is one of the largest global timber industry management organisations (TIMOs). TIMOs collate capital from institutional investors to invest in the forest asset class through co-mingled managed funds. New Forests' Asian fund also invests in rubber plantations. Currently TIMOs manage about USD 55 billion / 12 million hectares of forests globally[1]. The total institutional investment pool is estimated at USD 131 trillions[2]. Institutional investors are putting increasing pressure on fund managers to ensure that the investments made adhere to international best practice standards in governance and environmental and social management. International best practice standards are often measured through achieving compliance with voluntary international standards or third-party certification schemes. In New Forests' case, these are the International Finance Corporation (IFC) Performance Standards and the Forest Stewardship Council (FSC) Certification. Managing plantations (rubber or timber) to achieve these standards brings with it additional costs: direct, indirect and opportunity. Certification can also be used to bring benefits through a reduction in operational and reputational risks. In timber, FSC certification can bring additional product price benefits in the right markets and it is hoped this might be reflected too in rubber supply chains in the future. Our presentation will explore the structures for institutional investment, available certification schemes, costs associated with these and end use markets that would benefit from certified 'sustainable' rubber.

Keywords: rubber plantation; institutional investor; new forests; global timber industry; sustainable

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E15
Rubber Additives with RoHS Compliances Meeting Global Safety Standards

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The rubber industry especially that of synthetic rubber (SR) and synthesised chemicals are closely related to our environment. Synthetic chemicals used by rubber polymer related industries can be a concern if it is not managed in the proper manner. Automotive industries emit combustive polluted air, and factories that synthesise chemicals used by rubber industries are of concern to the complex eco-environment system and its effects on human health. This paper covers a list of chemicals commonly used in industry over the past decades and reviewing their potential "life span" in relation to human health, particularly towards carcinogenic properties. What will be the direction of growth of these chemical industries in the near future? Will there be any new and safer chemicals, to be introduced as a replacement in the next decade?

Keywords: rubber industry; synthetic; chemical; human health; carcinogenic

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E16
Sustainability and Growth in a Fast Changing Rubber Economy

S. PINIZZOTTO

Industrialisation and urbanisation in emerging economies, sustainability regulation and policies, changing demographics and consumer preferences, rise of new technologies (digitisation, IoT, Industry 4.0) trigger trends in the automotive industry that have the potential to radically change the mobility industry. Global vehicle sales will continue to grow although at a slower pace. Decreasing importance of private vehicle ownership, car sharing will account for up 9% of new vehicles by 2030. The future of electrified vehicle adoption will be shaped by consumer pull and regulatory push factors with electrified powertrains comprising up to 50% of new car sales in 2030. Within a more complex and diversified industry landscape, incumbent players will simultaneously compete on multiple fronts and cooperate with competitors in the mobility ecosystem. For the tyre and rubber value chain, business as usual will not deliver the expected changes. A responsive and flexible industry is needed to evolve its business model. Acceptance of changes reinforce the industry's ability to work for the future and gain advantage of the arising opportunities. Rubber production in Southeast Asia increased from 6.8 million metric tonnes in 2000 to over 13 million metric tonnes in 2018, doubling in the last 17 years. Over 2 million ha's of industrial-scale and smallholder monoculture rubber plantations have been established during the last decade across the globe. Equivalent to 548 football fields per day or 23 fields per hour. Southeast Asia and Southwest China are the epicentre of this expansion. There has also been a shift from rubber agroforest to rubber monoculture. Climate change and unpredictable weather patterns impacted rubber producers and businesses alike, making the value chains dysfunctional, resulting in heavy losses. To keep sustaining the global rubber chain, the main focus must be at the bottom of the value pyramid, the small growers. Although in theory rubber can be made profitable, in reality producers are unable to do so owing to low prices. However, with an open and sincere dialogue, value chain players may find better ways towards adopting sustainable and profitable practices. The rubber production segment can promote sustainable development through a carefully managed supply chain inclusive of smallholdings.

Keywords: sustainability; rubber production; automotive industry; industrial-scale; smallholders

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AP01
Properties of TPU Composition Mixed with Non-Halogen Flame Retardant

J. W. LEE

The flame retardants give a delayed ignition of flammable polymeric materials and prevent the spread of fire by the addition of compound with a large flame retardant effect such as halogen, phosphorus, nitrogen, and a metal hydroxide compound. The flame retardant must satisfy the various requirements, including low incidence of toxic combustion gases, mixed with the polymer material, mechanical properties of product. Recently, it focuses in not only flame retardant effect, but also development of product with low hazardous gasification, low heat generation, low corrosion, recycling for eco-friendly because the environmental problem has emerged. In this study, we studied thermal and mechanical properties that are revealed when PCD (Polycarbonate diol) type TPU and non-halogen flame retardant (Phosphate, Aluminum phosphinate and nitrogen type) mixed. Especially, we focused about minimising reduction of mechanical properties and improving thermal properties according to add flame retardants.

Keywords: flame retardant; TPU; delayed ignition; non-halogen; PCD

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AP02
Development of Mixing Method with SUMILINK® 100 and SUMILINK® 200 for Various Types of Rubber Composition

T. NOBUOKA

We have successfully developed novel coupling agents (SUMILINK® 100 and SUMILINK® 200) which improve CB dispersion of natural rubber (NR) compositions in consequence of interaction and/or reaction of the coupling agents with both NR and CB. Since their launching, some tyre manufacturers have been using them to develop novel fuel efficient tyres. Recently we have developed effective mixing techniques for various types of rubber compositions such as NR/SiO_2 and BR/CB with SUMILINK® 100 and SUMILINK® 200. In this presentation, we will report details of these new mixing techniques and the plausible mechanism.

Keywords: coupling agents; CB dispersion; NR; SUMILINK

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AP04
Micro-Compounders Utilised in Laboratory Scale Rubber Formulation Development

M. KODAL

Laboratory-scale mixing devices, which serve as cost and time efficient research facilities, provide possibilities of processing few grams of material and are capable of continuous or batch processing with the same thermal environment as a conventional extruder. Micro-devices can be used as fast screening tools in the field of polymer and rubber-based nanocomposite development. In this study, three different micro-compounders (All Xplore micro-compounder models, The Netherlands) with different maximum torque values were used. Several screw speeds were applied to evaluate the performance of dispersion and distribution of the reinforcing agents in rubber compounding. Ethylene-propylene diene monomer (EPDM)/carbon black (100/50 and 100/100 wt/wt%) and natural rubber (NR)/carbon fibre (100/30 wt/wt%) were mixed in three micro-compounders at different processing conditions to investigate carbon black dispersion and carbon fibre length variation and dispersion qualities in rubber matrices. EPDM with different viscosities were prepared to determine viscosity limits of the machines. Finally, the immiscible natural rubber and nitrile butadiene rubber (NBR) blends were mixed in again in the three micro-compounders at different processing conditions based on the viscosity handling capacities.

Keywords: EPDM; nanocomposite; micro-compounders; viscosity

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AP05
Effects of POSSs on the Adhesion between Silicone Rubber and Reinforcing Fabric Cords: Comparison of POSS and Resorcinol Formaldehyde Latex (RFL)

M. KODAL

Surface modification of fabric cords with resorcinol formaldehyde latex (RFL) which has a negative environmental effect due to its toxicity and application by the industry to improve the adhesion between rubbers and the fabric cords. Thus, this study was aimed to investigate the replacement of RFL application with poly(hedral oligomeric silsesquioxane) (POSS) which is known to be non-toxic. Octamaleamic acid-POSS with reactive polar groups; metacryl-POSS with only polar groups and octavinyl-POSS with neither polar nor reactive groups were used in this study. The presence of multiple double bonds that provides the grafting of POSSs to the silicone molecules during the crosslinking and the existence of polar and/or reactive groups that can interact with the reinforcing fibres of Kevlar and Rayon by physical and chemical interactions are the criteria used in the selection of POSS. Banbury mixing and compression moulding processes were used due to their industrially applicability. The optimum crosslinking conditions of model recipe (time and temperature) were determined by rheometer and differential scanning calorimeter (DSC) analyses. The fibre/silicone compound adhesion was investigated by strip-adhesion tests and the thermodynamic work adhesion (TWA) was calculated by using the surface free energy components of the compounds and fibres that were measured by contact angle measurements. The correlations between strip adhesion strength values and the TWA were studied to understand the adhesion mechanism.

Keywords: adhesion; POSS; silicone; fibres; fabric cords

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AP06
Modification of Natural Rubber Latex with New Titanium Dioxide Photocatalyst on Quartz Substrate

P. THEAMSAWADE[1] AND J. SAKDAPIPANICH[1#]

Many attempts have been made in the past to modify natural rubber (NR) to impart specific properties for use in a wide range of applications. Hydroxyl terminated natural rubber (HTNR), a modified form of NR with low molecular weight and bearing reactive functional terminal groups, is a versatile material which can be easily reacted to yield NR-based applications. Previous work used titanium dioxide (TiO_2) film coated on glass substrate as photocatalyst in photochemical decomposition of deproteinised natural rubber latex (DPNR). It was found that light energy was lost in the photo-chemical degradation process when glass was used as a substrate, because glass substrate has wavelength cutoff in the UV region. To further improve the efficiency of the photochemical degradation, TiO_2 films coated on glass and quartz were prepared and compared. They were characterised with respect to structural properties and surface morphology using XRD and AFM. It was found that the photocatalytic efficiency of TiO_2 coated on quartz substrate was higher than that on glass, based on the reduction of molecular weight of DPNR. The mechanism of formation of HTNR was elucidated. The molecular weight of the resulting NR was characterised by gel-permeation chromatography (GPC). The microstructure of the HTNR latex was analysed by Fourier-transform infrared spectroscopy (FT-IR) and nuclear magnetic resonance spectroscopy (NMR). It was found that FT-IR spectra showed a clear characteristic band at 3,300 cm^{-1} corresponding to hydroxyl group. Moreover, ^{1}H-NMR and ^{13}C-NMR spectra of HTNR showed small signals at the chemical shifts of 3.74 and 72.84 ppm, assigned for hydroxylated methine proton and carbons of HTNR, respectively. Based on the present finding, it was concluded that the HTNR was successfully prepared by photo-chemical degradation of NR latex using TiO_2 film coated on quartz as a photocatalyst.

Keywords: TiO_2 film; photochemical degradation; quartz; photocatalytic efficiency

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AP07
Impact of Geometric Isomers and Non-Rubber Components on the Mechanical Properties of Natural and Synthetic Polyisoprene Rubber Latices

N. PAYUNGWONG[1] AND J. SAKDAPIPANICH[1#]

The influence of geometric isomers and non-rubber components (NRC) on the mechanical properties of natural rubber (NR) and synthetic cis-*1,4-polyisoprene (IR) latices was investigated in this study. Both NR latex from* Hevea brasiliensis *and synthetic IR latex consist of* cis-*1,4-polyisoprene as a major molecular structural unit with different geometric isomeric impurities. NR latex consists of many NRCs such as proteins, lipids, carbohydrate and inorganic compounds, affecting their mechanical properties directly. Nuclear Magnetic Resonance Spectroscopy (NMR) and Fourier-Transform Spectroscopy (FTIR) techniques were used to confirm the quantity of different geometric isomers in NR and IR rubbers of the respective latices. Differential Scanning Calorimetry (DSC) revealed the influence of the geometric isomers on the various thermal properties of the rubber. Branching were removed from the rubber molecules after purification as reflected in a reduction of molecular weight in the NR from gel permeation chromatography (GPC). The influence of NRCs on mechanical properties was investigated from two aspects (i) blending synthetic IR with various amount of NR gel and (ii) adding NRCs into the synthetic IR latex compounds and using these two for dipping. The mechanical properties of the dipped latex film were investigated by tensile testing. Results revealed that the mechanical properties of the rubber strongly depend on the amount of geometric isomer in both NR and IR latices and also on the presence of NRCs in the matrix of IR.*

Keywords: geometric isomers; non-rubber; natural rubber; synthetic polyisoprene latex; blending

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AP08
Preparation of Puncture Sealing Agent for Car Tyres Suited for Use over Wide Temperature Range

J. WIRIYANANTAWONG[1] AND J. SAKDAPIPANICH[1#]

Puncture sealing agent made from natural rubber latex is a chemical which is introduced into a car tyre to seal up the puncture area from the inside. This study shows the development of a puncture sealing agent for use over a wide temperature range, especially from -40 to 60ºC. In this work propylene glycol (PG) was used instead of ethylene glycol (EG) as an anti-freeze agent, to allow the sealing agent to remain fluid under freezing temperature and hence, prevent the rubber particles therein from aggregating and remain functional. A saponified natural rubber (SPNR) latex is used because it is able to suppress latex particle coagulation while it is being forced out of the container through orifice containing the puncture sealing agent. This is confirmed by viscosity and MST measurement and the material has a good tack property. It was found that the stability of the puncture sealing agent is affected by the particle size of the latex particle within the system. A suitable ratio of SPNR latex: terpene resin emulsion: PG of 40:20:40 is critical in ensuring good applications of the sealing agent.

Keywords: puncture sealing agent; saponified natural rubber; anti-freeze agent; stability

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AP09
*Elucidation of Rubber Biosynthesis in Guayule (*Parthenium argentatum *Gray)*

Y. NAKAZAWA

Natural rubber, comprising high molecular weight cis-*1,4-polyisoprene, is a unique plant material produced as a biopolymer. Although more than 2,500 plant species likely to have the potential to synthesise natural rubber, commercial natural rubber production depends exclusively on* Hevea brasiliensis*. Therefore, new or alternative plant resources for natural rubber production are indispensable to ensure a reliable supply of natural rubber.* Parthenium argentatum *Gray, commonly known as guayule, is a promising plant resource for natural rubber production. However, the biosynthetic mechanism and accumulation machinery of rubber in guayule are still unclear. In this study, to investigate the biosynthesis and accumulation of rubber in guayule, we developed a microscopic technique by combining spectral confocal laser scanning microscopy (SCLSM) with a fluorescent reagent for the in situ detection of the* cis-*polyisoprene in guayule. We finally identified the specific cells for rubber biosynthesis and accumulation in parenchyma tissue in guayule stembark.*

Keywords: natural rubber; guayule; rubber biosynthesis;

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AP10
In Situ *TD-NMR Study on Sulphur Crosslinking Reaction of Isoprene Rubber*

M. KOSUKE[1], P. JUNKONG[2] and I. YUKO[2#]

Rubber materials are indispensable for our daily lives, and used in various applications such as automobile tyres, seismic isolation rubber, airplane tyres and so on. Vulcanisation using sulphur is an important crosslinking method for rubber which has been widely used. The formation of two-phase network structures in vulcanised rubbers has been investigated by our research group. In this study, the network structure of sulphur crosslinked isoprene rubber was characterised using time domain nuclear magnetic resonance (TD-NMR) measurement in situ. As a result, Carr-Purcell-Meiboom-Gill pulse sequence was confirmed to be suitable for analysing the sulphur crosslinked isoprene rubber network. The mobility of the rubber chains during the vulcanisation reaction was followed, and the progress of crosslinking reaction was evaluated in details. This TD-NMR method will be useful for the studies on the network structure, dynamics and kinetics.

Keywords: vulcanisation; in situ analysis; time-domain nuclear magnetic resonance; dynamics

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BP01
Evolution of Payne Effect of Silica-Filled Natural Rubber in Curing Process

J. WU

Vulcanisation is the key process for the final properties of elastomers due to the relationship between curing condition and viscoelastic behaviour. This study focuses on the variations in the dynamic behaviour of silica-filled natural rubber caused by crosslinking. Rubber samples with different degree of curing (DOC) are prepared by thermal quenching in crosslinking process. The strains sweep mode is used to study the Payne effect. The Kraus model is used to fit the test data, which is widely used to describe the Payne effect. The relationship between the parameters of Kraus model and DOC is obtained in small strain (<10%). The storage modulus in small strain amplitudes (usually < 0.01%) is proportional to DOC, however, the storage modulus in large strain amplitudes does not vary with DOC. The characteristic value of the strain amplitude is shifts to large strain and the maximum loss modulus decreases with the increment of DOC, when the loss modulus reaches its maximum value. Besides, the deviation between Kraus model and experiment is obtained when the strain is larger than 10%, whereby the loss modulus increases with the increment of strain amplitude. The deviation decreases when DOC increases. The mechanism for this deviation is discussed and the interaction between silica filler and rubber chain might be responsible for the observed deviation.

Keywords: vulcanisation; crosslinking; dynamic behaviour; Kraus model; Payne effect; natural rubber

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BP02
A Light Colour Natural Rubber for Pacifier Production from Saponified Natural Rubber Latex

S. KAEWSIKOUN[1] AND J. SAKDAPIPANICH[1#]

Natural rubber (NR) latex is used in manufacturing dipped goods such as condoms, balloons and gloves due to its high tensile strength, high elasticity and excellent green strength. However, the presence of non-rubbers in NR latex inevitably imparted undesirable colour to the products, for example, in NR baby pacifiers. This has somewhat limited the range of light coloured NR latex products compared to those made from silicon rubber. The present study attempts to produce a special NR latex that will yield light coloured dipped products. It has been known that rubbers from saponified NR latex (SPFL) and sodium hydroxide treated rubber give light coloured products while those from deproteinised rubber latex (DPFL), urea-treated and conventional centrifuge latices give darker coloured products. Traditionally, sodium metabisulphite has been used to lighten colours of rubber products due to its ability to inhibit enzymatic browning effectively. Only very low nitrogen content was detected in SPFL and DPFL indicating a very low level of residual proteins in the rubber. These latices were pre-vulcanised with t-butyl hydroperoxide (t-BHP), dipped and post-vulcanised. The colour of the product remained light when the tensile strength was fully developed. Significantly, the modulus (hardness) of the post-vulcanised SPFL product is comparable to those of commercial grade baby pacifiers made of silicon rubber.

Keywords: saponified natural rubber; pacifier; light colour; deproteinised rubber latex; silicon rubber

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BP03
Hydroxylation of Skim Rubber Latex via TiO_2 Photocatalytic Reaction

K. AMORNJIARASAK[1] AND J. SAKDAPIPANICH[1#]

Natural rubber (NR) latex is widely used in many applications such as footwear, conveyer belts and especially, tyre tread. However, NR has the limits of their usage due to the inert hydrocarbon nature, so some polar reactive groups like hydroxyl group was modified onto the molecular main chain. In this work, skim rubber latex was hydroxylation via photocatalytic reaction using titanium dioxide (TiO_2) as a catalyst under ultra violet (UV) irradiation. The TiO_2 was prepared by spin-coating technique, followed by calcination at 550ºC for 1 hour. Subsequently, the functionalisation of skim rubber latex samples was investigated in the presence of appropriate TiO_2 film. The chemical structures of functionalised skim rubber latex were characterised by FTIR and 1H NMR techniques. It was found that the hydroxyl functional group in skim rubber was clearly observed when irradiation of at least 5% under low UV power was carried out in the presence of small amount of hydrogen peroxide (H_2O_2) for 1 hour.

Keywords: skim rubber latex; hydroxylation; photocatalytic; FTIR; 1HNMR

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CP01
Long Term Life Prediction of Dust Cover Made of Chloroprene Rubber Using the Four Parameter Recovery Models

H.S. LEE

Rubber-like materials are widely used in many industries, and are often installed in mechanical systems. Such materials are used as dampers, dust covers, and other important system parts. Lifetime, durability, and reliability are considered in the design of rubber-like materials. Lifetime prediction of rubber material is very important in the design process; however, it is difficult to do because of the changing properties under complex operational environments such as temperature, vibration, and mechanical loads. The highly accelerated life test (HALT) is generally used to predict the lifetime of rubber materials. We conducted tensile tests with chloroprene rubber (CR) dust cover material, and compared the experimental data with the function data obtained from the recovery rate curve based on the successive zooming genetic algorithm (SZGA) method. We also verified the fitted recovery rate curve using the two parameter models and four parameter models in terms of the mean square error (MSE). The life of a dust cover for the retained target tensile strength (80%) was calculated. Finally, using the Arrhenius model, we predicted the quantitative long term life prediction method for a rubber dust cover made of chloroprene rubber (CR), and obtained four parameters from the SZGA method.

Keywords: chloroprene rubber; dust cover; lifetime; Arrhenius model; SZGA

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CP02
Viral Penetration Test for Medical Gloves and Male Condom

Q.Y. TAI

There are rising concerns over transmission of infectious agents through barrier materials such as those used in medical gloves and male condom. In order for both medical gloves and male condom to be medically claimed as being effective barrier protections, appropriate laboratory tests shall be performed. The viral penetration test is a pass/fail test that evaluates the viral penetration resistance characteristics of both medical gloves and condom. The test is recognised by the FDA and is performed in compliance with ASTM F1671 *for medical gloves and* US FDA CDRH & ISO 23409 *(Annex G) for male condom.*

Keywords: medical gloves; male condom; viral penetration test

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CP03
Relationship between Crystalline Formation and Microstructure of Poly(ethylene-co-vinyl acetate) with Different Vinyl Acetate Contents

S.S. CHOI

Poly(ethylene-co-vinyl acetate) (EVA) is a copolymer of ethylene and vinyl acetate, and its properties depend on the VA contents. EVA has crystalline structures due to its ethylene sequences and the crystallinity usually increases as the ethylene content increases. In general, crystalline structures of polymeric materials are analysed using X-ray diffraction (XRD) and differential scanning calorimetry (DSC). In XRD pattern of a polymer having crystalline structures, the crystalline structures appear at small angle region and their peaks are overlapped with the broad amorphous peak. DSC thermogram of a polymer shows melting point and enthalpy change. EVA can have crystalline structures of [110] and [200] of the ethylene sequences. Since microstructures of EVA can be diffentiated with the VA sequencing, the crystalline structures may be affected by the microstructures. Hence, crystalline structures of EVAs with the same VA content can be different. In this study, crystalline structures of EVAs with different VA contents were analysed using XRD and DSC, and relationship between the analytical results of XRD and DSC was investigated. Difference in the crystalline structures of EVAs with similar VA contents was also examined in terms of the difference in the microstructures.

Keywords: crystalline; microstructure; poly(ethylene-co-vinyl acetate); EVA; DSC; XRD

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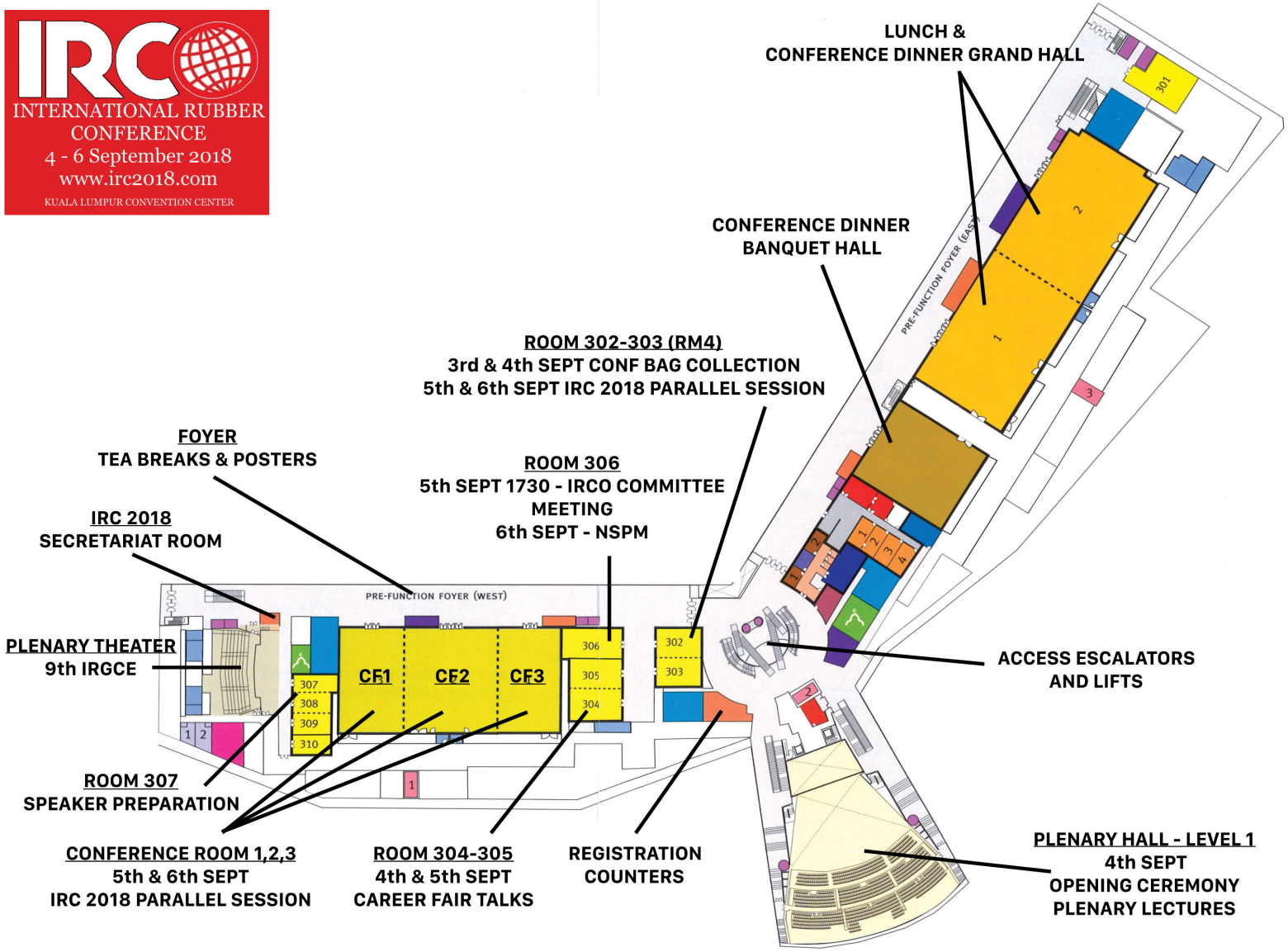

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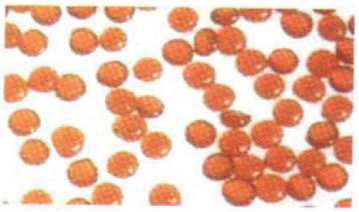

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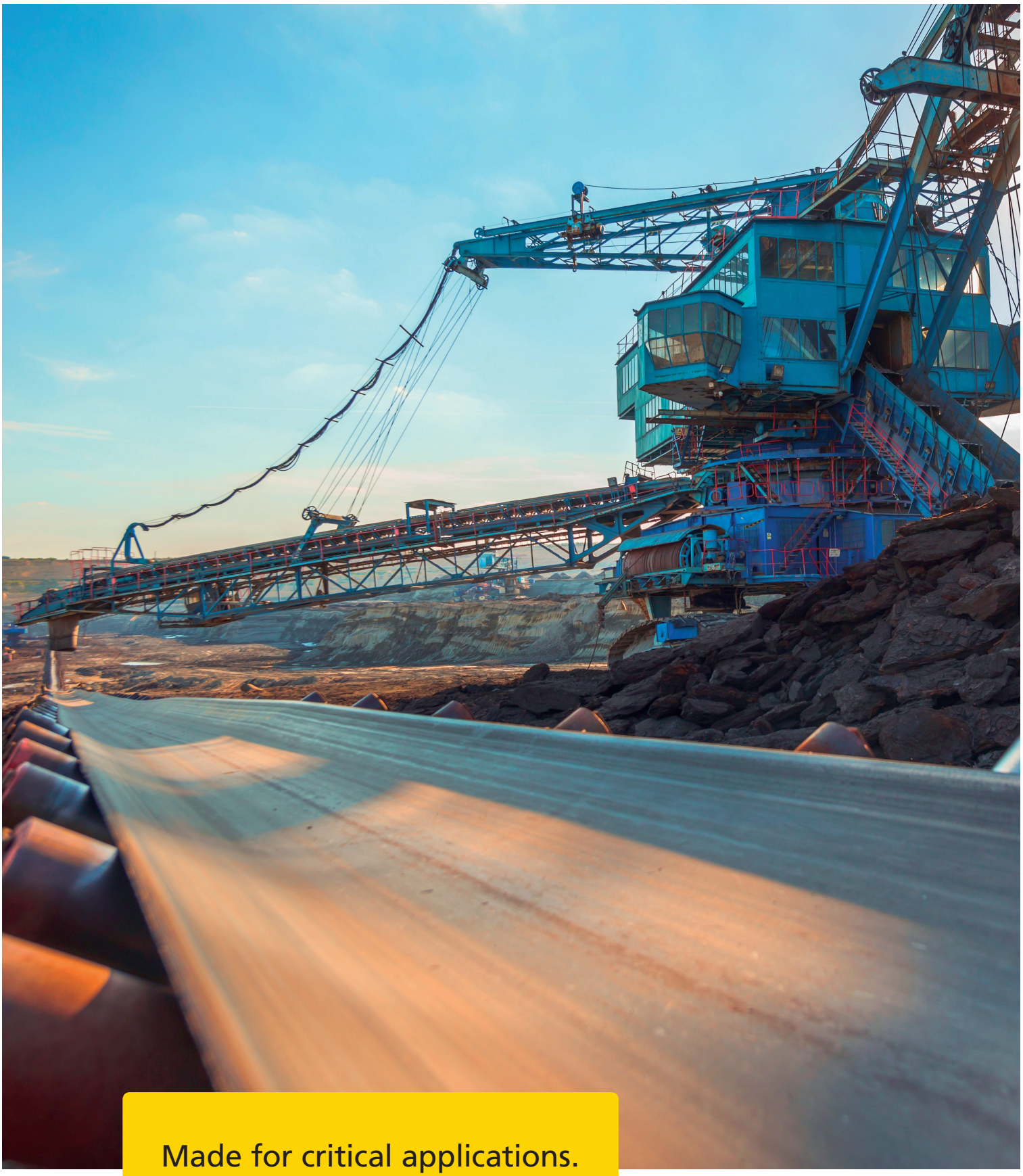

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