38th Annual Business Meeting and Conference on Tire Science and Technology

MOBILITY FRONTIERS

Program and Abstracts

September 10-11, 2019
Hilton Akron/Fairlawn Hotel
Akron, Ohio

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Over the past decade, Tyre Asia − the flagship publication of Asian Business Media (ABM) − has grown as the most authentic voice of the global tyre industry. From raw materials, manufacturing processes, and technological breakthroughs, to finished goods and aftermarket, it is a source of knowledge for decision-makers to drive their business. The bi-monthly magazine features patrons of the industry as well as mid-management, researchers, scientists, engineers, and corporate leaders. Tyre Asia organises one of the most influential biennial conferences--the Asian Tyre & Rubber Conference (ATRC)--for the tyre and allied industry, providing a platform to share industry trends and networking opportunities.

UKI Media (Tire Technology International)

Tire Technology Expo 2020 promises to be the most exciting gathering of tire manufacturing experts. Visitors, exhibitors and conference delegates will come to Hannover, Germany February 25-27 and enjoy a networking opportunity unrivalled within the tire-manufacturing sector.

Over three days, delegates will have the opportunity to see presentations from speakers picked from the world's leading experts on tire manufacturing. Presentations will cover the very latest developments for the tire manufacturing industry. This high-profile conference, coupled with one of the industry's largest exhibitions, makes this not only a prestigious event to attend but also a priority for all involved in the tire-making process.

38th Annual Meeting and Conference on Tire Science and Technology

Day 1 – Tuesday, September 10, 2019

All Sessions take place in Akron/Summit Ballroom

7:00 AM	Registration (until 5pm)		
8:00 AM	Welcome		**Gerald Potts** *President of the Society*
8:10 AM	**Keynote Speaker**	*Will the Tire Society Rise to Meet the Challenges Created by Future Mobility*	**Robert Asper,** Director, Core System Engineering – Bridgestone Americas Inc.
9:10 AM	Opening Remarks		**Anudeep Bhoopalam** *Program Chair*
9:15 AM	**Session 1: Tire Performance**		**Gautam Barot,** *Kumho Tires*
9:20 AM	1.1	The Effect of Bending and Shear Deformation of Belt on the Tire Cornering Stiffness Characteristics	**Gibin Gil** *Hankook Tire Co. Ltd.*
9:45 AM	1.2	Analysis and Prediction of Tire Cornering Properties for Different Inflation Pressure Based on Deflection Control	**Lu Dang** *Jilin University*
10:10 AM	1.3	Generation of Flexible Ring Tire Models Virtually using FEA: Application to FTire and Dynamic Cleat Simulations	**Yaswanth Siramdasu** *Hankook Tire Co. Ltd.*
10:35 AM	1.4	Developing a Monster Tire	**Ron Tatlock,** *BKT USA Inc.*
11:00 AM	Networking Break		
11:20 AM	**Session 2: New Light on Tire Technology**		**Yusheng Chen,** *Cooper Tire & Rubber*
11:25 AM	2.1	A Novel Approach for the Viscoelastic Treaded Tires Simulation Using Localized Tread Pattern Coupling with Stationary Rolling Tire Structure	**Thirumal Alagu Palanichamy** *Leibniz Universität Hannover*
11:50 AM	2.2	Simulation Analysis of Tire Inflation Pressure Loss Coupled with Temperature Field and Oxidation Reaction	**Liu Ji** *Jiangsu University*
12:15 PM	Lunch (Provided)		
1:30 PM	**Session 3: New Light on Tire Technology**		**Yaswanth Siramdasu,** *Hankook Tires*
1:35 PM	3.1	Prediction and Validation of an Agricultural Tire-Soil Interaction Using Advanced Modeling Techniques	**Zeinab El-Sayegh**, *University of Ontario Institute of Technology*
2:00 PM	3.2	Modeling Vibration Induced Tire-Pavement Interaction Noise in the Mid-Frequency Range	**Sterling McBride** *Virginia Tech*
2:25 PM	3.3	Development of a Characterization Method of Tire Handling Dynamics Based on an Optical Measuring System	**Chao Liu,** *TU Dresden*
2:50 PM	Networking Break		
3:10 PM	**Session 4: Supplier Technology**		**Jan Terziyski,** *Nexen Tire*
3:15 PM	4.1	Analysis of Self-Heating, Standing Wave Development, and Fatigue During Regulatory High-Speed Testing Protocols	**Will Mars** *Endurica*
3:40 PM	4.2	Tire Performance Simulation and Durability Evaluation using ANSYS	**Jin Wang,** *Ansys*
4:05 PM	4.3	New Methods for Assessing Tire-Related Vehicle Interior Noise	**Peter Schaldenbrand,** *Siemens*
4:30 PM	4.4	Enhanced Fiala Tire Model for Durability Simulation	**Chris Coker,** *Altair*
5:00 PM	Reception		
6:00 PM	**Awards Banquet**	*Dinner Speaker: "Time versus Space in Urban Mobility"*	**Pierre Lefevre,** *CTO - Coast Autonomous*
8:00 PM	Close of Day 1		

Day 2 – Wednesday, September 11, 2019 All Sessions take place in Akron/Summit Ballroom			
7:30 AM	Registration (until 5pm)		
8:00 AM	Opening Remarks		**Anudeep Bhoopalam** *Program Chair*
8:05 AM	**Session 5: Experimental Technologies**		**Matt Schroeder,** *Cooper Tire & Rubber*
8:10 AM	5.1	A Study of the Effect of Tread Design Changes on Tire Patch Dynamics at High Speeds Through Use of a Dynamic Contact Force Measurement Rig	**Matt Van Gennip** *A&D Technology*
8:35 AM	5.2	Tread Block Force and Displacement Measurements during Rolling Contact Testing on a Stationary Machine	**Bruce Rusnak** *TMSI LLC*
9:00 AM	**State of the Society**		**Gerald Potts,** *President of Society*
9:20 AM	**Panel Discussion - Tire Industry Realignment Necessities for Mobility Market Trends**		**Ric Mousseau** *General Motors*
10:10 AM	Networking Break		
10:40 AM	**Session 6: Emerging Technologies**		**Corissa Lee** *Exponent*
10:45 AM	6.1	Vision on a Digital Twin of the Road System for Future Mobility	**Michael Kaliske** *TU Dresden*
11:10 AM	6.2	Machine Learning Guided Discovery of New Compounds	**Brandon Kelly** *Goodyear Tire & Rubber*
11:35 AM	6.3	Advanced Antenna Simulation Tools for Intelligent Smart Tires	**CJ Reddy,** *Altair*
12:00 PM	Lunch (Provided)		
1: 15 PM	**Plenary Lecture** *"Autonomous Vehicles: The Good, the Bad and the Ugly"*		**Srikanth Saripalli,** *Co-Director, Center for Autonomous Vehicles and Sensor Systems - Texas A&M University.*
2:20 PM	**Session 7: Simulations**		**Timothy Davis** *Goodyear Tire & Rubber*
2:25 PM	7.1	Finite Element Modeling and Critical Plane Analysis of a Cut and Chip Experiment for Rubber	**Chris Robertson** *Endurica*
2:50 PM	7.2	A Study of the Influence of Waveforms on Fatigue Crack Growth Characteristics of Tyre Tread Rubber using Finite Element Analysis	**Prasenjit Ghosh** *HASTERI*
3:15 PM	7.3	Durability Evaluation in Elastomers using Fracture Mechanics	**Mario Garcia,** *TU Dresden*
3:40 PM	Networking Break		
4:00 PM	**Session 8: Friction**		**Gobi Gobinath** *Goodyear Tire & Rubber*
4:05 PM	8.1	Using a New 3D-Print-Method to Investigate Rubber Friction Laws on Different Scales	**Jan Friederichs** *RWTH Aachen University*
4:30 PM	8.2	Dynamic Behavior of Fractional Viscoelastic Tire Tread Blocks on Pavement	**Arne Leenders** *Leibniz Universität Hannover*
5:00 PM	Close of Conference		**Anudeep Bhoopalam** *Program Chair*

About The Tire Society

The Tire Society was established to disseminate knowledge and to stimulate development in the science and technology of tires. These ends are pursued through seminars, technical meetings and publication of the journal, Tire Science and Technology. The Society is a not-for-profit Ohio corporation managed by a duly elected Executive Board of tire industry professionals who serve on a volunteer basis.

In addition to the Journal Editor, the associate editors volunteer time to contribute to the peer review process associated with publishing manuscripts in the Tire Science & Technology Journal:

The Tire Society Executive Board is also supported by an Advisory Board:

In addition to the Executive Board, many members volunteered their time to put together the 2019 conference.

CONFERENCE COMMITTEE:

Program Chair: Anudeep Bhoopalam, *Giti Tire R&D Center – North America*
Co-Chair: Meysam Khaleghian, *Texas State University*
Conference Committee Chair: Jim McIntyre, *Bridgestone Americas Tire Operations*

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Yaswanth Siramdasu	*Hankook Tire & Technology Co, Ltd*
Yusheng Chen	*Cooper Tire & Rubber Company*
Jan Terziyski	*Nexen Tire*
Matt Schroeder	*Cooper Tire & Rubber Company*
Corissa Lee	*Exponent*
Timothy Davis	*The Goodyear Tire & Rubber Company*
Gobi Gobinath	*The Goodyear Tire & Rubber Company*

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STUDENT PAPER JUDGES:

Yaswanth Siramdasu	*Hankook Tire & Technology Co, Ltd*
Yusheng Chen	*Cooper Tire & Rubber Company*
James Valerio	*Hankook Tire & Technology Co, Ltd*
Dennis Kelliher	*Hankook Tire & Technology Co, Ltd*
Qian Li	*Cooper Tire & Rubber Company*
Madhura Rajapakshe	*Bridgestone Americas Tire Operations*

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The 2020 Conference
Conference Dates: September 9th & 10th 2020

(Note: this is Wednesday and Thursday the week of Labor Day)

Program Chair: Meysam Khaleghian, *Texas State University*
Co-Chair: Matthew J. Schroeder, *Cooper Tire & Rubber Company*

The conference committee would appreciate your assistance and suggestions. A call for papers will be issued to attendees of the conference and will be available online. Visit www.tiresociety.org for updates.

Keynote Address

Robert Asper
Director – Core System Engineering, Product Development
Bridgestone Americas Tire Operations

Robert Asper is Director of Core System Engineering in the Product Development division of Bridgestone Americas. He currently has responsibility for the engineering of products throughout the Americas including current product development, the research of tire mechanics and the engineering of new concepts. Robert oversees a diverse team of talented engineers at Bridgestone's Americas Technical Center in Akron, Ohio.

Robert has worked in the tire industry for over 20 years and has spent much of that time in the research and development areas. Robert holds a Master of Science in Mechanical Engineering from the Pennsylvania State University. Robert joined Bridgestone in 1998 as a member of its Advanced Tire Technology team focusing on research of tire vibration and the application of simulation of tire performance in tire design. Robert has held management roles of increasing responsibility in tire design, tire research, technology and product innovation.

Title of Talk:

Will the Tire Society Rise to Meet the Challenges Created by Future Mobility?

Plenary Lecture

Dr. Srikanth Saripalli
Gulf Oil/Thomas A. Dietz Career Development Professor II
Texas A&M University

Srikanth Saripalli is the Co-Director for Center for Autonomous Vehicles and Sensor Systems (CANVASS) at Texas A&M University and the Gulf Oil/Thomas A. Dietz Career Development Professor II in Mechanical Engineering. His research focuses on robotic systems: particularly in air and ground vehicles and necessary foundations in perception, planning and control for this domain. He is currently interested in developing and deploying autonomous shuttles on campus and in cities. In his lab (http://unmanned.tamu.edu) he is developing fleets of autonomous vehicles that are shared and electric. He has deployed these autonomous shuttles on a hotel campus and is currently deploying these shuttles on Texas A&M campus and in downtowns. He is also interested in developing such autonomous shuttles for mobility challenged and para transit applications. On the other end he is interested in developing autonomous 18-wheeler trucks for long-haul freight movement.

Title of Talk:

Autonomous Vehicles: The Good, the Bad and the Ugly.

Over the past year, we have successfully deployed autonomous shuttles in downtown Bryan and are currently on track to deploy them in Corpus Christi and Ft. Bragg. In this talk, I will give an overview of our algorithms that made these shuttles possible -- estimation, localization and control algorithms. They must satisfy multiple requirements:

1) navigate in GPS-denied environments
2) sense and avoid obstacles
3) able to determine interesting phenomenon.

In this talk, I will give an overview of our algorithms on combining vision with inertial measurement unit and GPS for accurate state estimation of the vehicle. I will describe our algorithms for mapping using thermal, visual and LIDAR sensors that enable autonomous navigation in various challenging conditions. A major portion of the talk will be on applications of the above algorithms to real vehicles and the lessons that we have learned i.e. what worked and what didn't and how we should go about building such systems. I will also talk about how we can go from these deployments to "truly" autonomous vehicles.

Banquet Speaker

Pierre Lefevre
Chief Technology Officer, Coast Autonomous

Pierre Lefevre has long been recognized as one of the leading experts in the fields of robotics, 3d mapping, and autonomous vehicles. His pioneering work over the past twenty plus years has led to significant advancements in all three fields. His opinions with respect to autonomous vehicles are sought after by governmental rule-making authorities, commercial vehicle manufacturers and technology companies and the academic community.

In 1995, Pierre took the lead in developing the first connected car to Microsoft CEO Bill Gates which resulted in the delivery of the Microsoft Clarion AutoPC in 1998. In 2000, long before the successful introductions of Uber, Lyft, and Grab, Pierre developed a fully automated reservation platform to operate a fleet of more than 2,000 taxis across the City of Paris (01 Taxi). In 2005, Pierre led the only European team to enter the DARPA Grand Challenge of autonomous vehicles. In 2007, Pierre and his team returned to the DARPA Grand Challenge and developed a new cutting-edge technology stack that did not rely on GPS and emphasized low cost sensors. In 2011, Pierre delivered the world's first commercially available autonomous shuttle which has subsequently won numerous awards and successfully transported more than 100,000 passengers in trials across North America, Europe and Asia.

Today, as CTO of COAST Autonomous, a California-based company, Pierre successfully continues his game-changing and award-winning work. Pierre leads an elite team developing highly-accurate indoor and outdoor 3d mapping, commercial-ready vehicle automation and remote supervision systems on various vehicle platforms focusing on urban mobility solutions. In 2017, Pierre delivered the first autonomous shuttle to Hong Kong, and in 2018, Pierre and Coast demonstrated the first autonomous vehicle, the P-1, on Broadway in heart of New York's Times Square. In addition to deployments on college campuses, later this year, Pierre will be showcasing Coast's technology at two major internationally recognized sporting events in the United States and Asia.

Title of Talk:

Time Versus Space in Urban Mobility.

<u>Panel Discussion</u>
Tire Industry Realignment Necessities for Mobility Market Trends

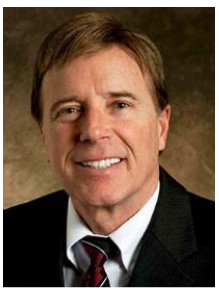
Forces acting on the tire industry will require realignment of how tires are engineered, manufactured, and sold. The realignment will be driven by changes in vehicle configurations, requirements, cost, and also by environmental concerns. For instance, autonomous vehicles will require more robust tires and real-time health monitoring. Electric vehicles under development are heavier than equivalent fossil fueled vehicles. OEM's are compressing development vehicle development schedules, driving increased use of simulation to support virtual tire modeling. Environmental issues to address sustainability and tire recycling are also a concern. The list goes on. Representatives from the tire industry, vehicle OEM's, test laboratories, and academia will provide their perspectives on these issues.

Moderator: Ric Mousseau, Lead Tire Modeling Engineer, General Motors.

Dr. Mousseau received his Ph.D in Mechanical Engineering from the University of Michigan. He served in the Mechanical Engineering departments at the universities of Michigan and Toledo and has worked in the automotive and tire industries and for the US Army TACOM. Dr. Mousseau has volunteered in many roles with the Tire Society, including, President, Vice President, Secretary, XCOM Member at Large, Program Chair, and Associate Editor. He has authored over 30 publications on tire mechanics and vehicle dynamics. In his free time, he enjoys being with his family, running, hiking, golf, and photography.

Robert Asper, Director of Core Engineering, Bridgestone Americas Inc., USA

Keynote Speaker Robert Asper is Director of Core System Engineering in the Product Development division of Bridgestone Americas. He currently has responsibility for the engineering of products throughout the Americas including current product development, the research of tire mechanics and the engineering of new concepts. Robert oversees a diverse team of talented engineers at Bridgestone's Americas Technical Center in Akron, Ohio.



Bruce Lambillotte, Vice President of Technical Consulting, Smithers.

Bruce Lambillotte is responsible for product and process-specific technical consulting activities involving a wide variety of polymer products. These include performance analyses, formula reconstructions, failure mode analyses and product development. Most recently, Mr. Lambillotte was the General Manager for Smithers' Akron Laboratories. Prior to joining Smithers, he was employed by Continental General Tire Inc. in various product development areas. He has worked in the rubber industry for over 40 years and holds a Bachelor of Science in Chemistry and an MBA.

Remi Olantunbosun, Professor of Mechanical Engineering, University of Birmingham, UK.

Dr. Olatunbosun is a Senior Fellow at the University of Birmingham, where he obtained his PhD, and an Adjunct Professor at the University of Lagos. Formerly Head of the University of Birmingham Vehicle Dynamics Laboratory. Dr. Olatunbosun has a long history of successful collaborative research and consultancy with the automotive industry in the UK and Nigeria. He has authored over 100 peer-reviewed research papers. Recently he has been working on the development of intelligent tires for application in chassis control and on multi-chamber tires for low rolling resistance.

Greg Smith, Senior Engineer-Virtual Submissions, The Goodyear Tire and Rubber Company, USA.

Dr. Smith began his career at Jaguar Land Rover, where he founded the Tire CAE and Modelling team. The recipient of the 2016 Tire Technology International Young Scientist Prize, Dr. Smith joined Goodyear in 2016 and is currently responsible for developing a new virtual tire submissions process to facilitate a CAE driven, collaborative tire development method with Goodyear's OEM customers.

The Effect of Bending and Shear Deformation of Belt on the Tire Cornering Stiffness Characteristics

Gibin Gil[1], and Sujin Lee[1]

Email: gibingil@hankooktire.com

In radial tires, the belt structure plays a role of minimizing the lateral deflection of carcass, which has significant influence on the cornering and wear properties of a tire. The deflection of the carcass affects the magnitude of tread block deformation when the tire is under a slip angle. As a result, it can change the cornering stiffness characteristics of the tire, especially when the vertical load is high.

During tire development, a tire design engineer tries to find the optimal belt ply angle which satisfies the various performance requirements simultaneously. But, it is not an easy task because the effect of belt angle change is different depending on the tire size. There have been many attempts to construct mathematical model that represents the structural properties of the belt package. It includes the string-based model and the beam on elastic foundation model. But, in many cases, only the in-plane bending of belt is considered and the shear deformation is not taken into consideration.

In this study, the effect of belt angle change on belt stiffness is analyzed using a mathematical model based on Timoshenko beam theory. This model can account for the bending and shear deformation of the belt structure at the same time. The analysis results show how the contribution of bending and shear is changed depending on the tire size. Then, the effect of belt ply angle change on cornering stiffness is investigated by means of the brush model including belt flexibility. The prediction by the brush model is compared to the measurement using Flat-trac machine and the validity of the model is discussed.

[1] Hankook Tire Co., LTD., 50, Yuseong-daero 935beon-gil, Yuseong-gu, Daejeon, 34127, Korea

Analysis and Prediction of Tire Cornering Properties for Different Inflation Pressure Based on Deflection Control

Lihong.Sun[1,2], **Dang.Lu[1]**, and Bing.Li[2]

Email: sun.lihong@giti.com

Changing tire pressure will affect the tire's mechanical characteristics, and then affect the vehicle performance. The influence of tire pressure must be taken into account in high precision tire models. In the past, there have been a lot of studies on the change of tire mechanical properties and modeling methods under different inflation pressures, such as the improved Magic Formula/Swift tire model that can handle inflation pressure changes. By processing a large number of tire test data under different inflation pressures, an empirical model is obtained, but a large number of tire tests will lead to a high cost and it also does not help us to understand the mechanism.

In previous studies, most tire tests are based on load control, where they change the inflation pressure while keeping the load unchanged, the contact patch, the carcass and belt stiffness will be changed at the same time, which complicates the cornering characteristics. In this study, we use the method of deflection control. In this condition, the contact patch is well maintained. The effect of tire inflation pressured is simplified to that of structure stiffness and averaged contract pressure change.

In our study, the effect of tire inflation pressure on cornering properties when tire deflection kept at different value was systematically observed, and the prediction model as well as its test scheme were also proposed. Through the test validation, it shows that this prediction method not only has a good accuracy, not less than 95%, but also can reduce the amount of test conditions by half or more.

[1] State Key Laboratory of Automotive Simulation and Control, Jilin University Nanling Campus, 5988 Renmin Street., Changchun, Jilin Province, People's Republic of China 130025

[2] GiTi Tire (China) R&D Center,Hefei,Anhui Province, People's Republic of China 230601

Generation of Flexible Ring Tire Models Virtually Using FEA: Application to FTire and Dynamic Cleat Simulations

Yaswanth Siramdasu[1], Kejing Li[1] and Robert L Wheeler[1]

siramdasu@hankook-atc.com

Flexible ring and semi empirical ring based tire models, like commercially available products FTire, CD-Tire and MFSWIFT, are used as standard tools for simulating and predicting vehicle ride harshness, handling, traction, and durability performance. These models represent the tire mathematically as a combination of fundamental vertical, torsional, and lateral dynamic stiffness components with fidelity needed to assess the effect of tire designs on the aforementioned performances. The determination of these stiffness components are typically acquired after tires are built and through extensive physical testing. This approach is expensive and limits the ability to address these performances during the virtual stages of design. A virtual process is introduced and demonstrated in this study using high fidelity FEA of the tire to generate a FTire model.

For estimation of tire dynamic stiffnesses, rolling tire cleat test data at various speeds and loads are required for most ring models. Although this method produces reliable models, the parameterization is not time and cost effective and prone to test rig imperfections. From a system dynamics point of view, the flexible ring tire dynamic stiffnesses correspond to frequencies of lower order vibration modes of the tire, which are excited under these cleat tests. The corresponding modal frequencies are easily measured on non-rolling conditions however they have been shown to produce models with stiffness values higher than those from corresponding cleat test frequencies. Multiple previous studies attribute this to material softening within the tire when transitioning from non-rolling to rolling conditions. In this work, the concept of bimodal modulus is utilized towards accurate prediction of FE rolling modal frequencies. Then the associated FE modal frequencies are used towards characterizing dynamic stiffness of FTIRE model. The developed FTIRE model is validated with dynamic cleat data.

[1] Hankook Tire and Technology - America Technical Center

Developing a Monster Tire

Ron Tatlock[1]

Email: Ron.Tatlock@bkt-tires.com

Monster Jam, an international motorsport, is the biggest abuser of tires in the world. For their Monster Trucks they needed monster tires capable of doing monstrous things. Special application tires were needed for their 12,500 lbs. machines that incorporated durability, high traction, reinforced side walls, and reduced weight. Incorporating all these elements into one tire was a daunting task, but BKT Tires' engineers were up to the challenge.

BKT engineers came true to the task. The BKT tire weight was reduced 46% from their existing tire. By Lightening the total weight of the vehicle, the truck was able to do much more fun maneuvers to entertain the crowds.

The engineering on the strength of the sidewall and bead gave the tire ability to handle 20G plus landings.

The depth of the cleat was reduced at the correct angle to eliminate throw of mud into the crowds.

New tread and sidewall compounds were developed to provide cut and tear resistance as the truck rolled over metal scrap.

These changes have also been incorporated into BKT's OTR and Ag tires to provide better performance in the fields, construction zones, and on the road. The engineering and design helped reduce compaction, carry heavier loads, and transport loads at higher speeds.

The continued partnership between BKT and Monster Jam is mutually beneficial. BKT can produce a higher quality tire for customers, and Monster Jam can beat new world records and perform more jaw-dropping stunts than ever before.

[1]BKT USA Inc.

A Novel Approach for the Viscoelastic Treaded Tires Simulation Using Localized Tread Pattern Coupling with Stationary Rolling Tire Structure

Thirumal Alagu Palanichamy[1], Udo Nackenhorst[1], Anuwat Suwannachit[2] and Maik Brinkmeier[2]

Email: thirumalalagu.palanichamy@ibnm.uni-hannover.de

Tires with detailed tread pattern cannot be treated within Arbitrary Lagrangian Eulerian (ALE) relative kinematic framework due to its axisymmetric constraint whereas the fully Lagrangian approach results in enormous computational time. In literature, there are many numerical approaches developed for treaded tires simulation. But there is still a big scope to develop a versatile numerical method which can treat detailed tread pattern with the major requirements of computationally cost effective and maintaining physically reliable predictions.

In this work, a new approach based on coupled ALE – Lagrangian is followed in such a way that the detailed tread pattern (Lagrangian) is coupled to the ALE tire base structure. This interface coupling would enforce the tread pattern to follow the material points in ALE base structure and also the surface traction equilibrium along the interface. Such interface coupling overcome the limitation of Global - Local approach (one-way coupling) where the feedback to the tire structure is not considered.

To gain computational efficiency, the tread pattern is localized only at the footprint which is in two-way coupling and a single pitch at the non-contact region (trailing edge) would be modeled as one-way coupling (Global – Local). With the synchronization of the pitch movement, the history variables of the pitch would be tracked and switched back to two-way coupling when it enters the leading edge zone.

To verify this coupled framework and for the comparison of the computational effort, the axisymmetric Grosch model and tire model results of fully ALE kinematic framework and fully Lagrangian framework are compared with the coupled framework results.

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Simulation Analysis of Tire Inflation Pressure Loss Coupled with Temperature Field and Oxidation Reaction

Chen Liang[1], **Liu Ji[1]**, Owen Li[2], Xinyu Zhu[1], Guolin Wang[1]

Email: jiliu940126@foxmail.com

Tire inflation pressure loss would be inevitable during the service time of a tire. IPLR (Inflation Pressure Loss Rate) is used to estimate the tire inflation pressure retention performance. A lower IPLR means that tire has a better capacity in maintain tire inflation pressure, which will effectively reduce rolling resistance and vehicle exhaust emissions. Some scholars have done a lot of research on the tire inflation pressure loss under static state and proposed the IPLR prediction model based on Ficklaw. On the basis of previous studies, the rubber oxidation reaction and tire temperature field were added to simulate the tire pressure inflation loss under free rolling conditions.

The oxygen inside the tire will oxidize with the rubber during the diffusion process, and the reaction is more intense at high temperatures. Oxidation would accelerate the gas diffusion rate. After considering the oxidation reaction of rubber, the prediction accuracy of the IPLR model has been effectively improved.

The diffusion coefficient and solubility coefficient are the most critical parameters in the IPLR model. According to mass transfer theory, the diffusion coefficient and solubility coefficient of gas are closely related to temperature. During the rolling process, the tire will be in a non-uniform temperature field due to the hysteresis effect of the rubber. In this paper, the interpolation algorithm is used to combine the tire temperature field model and the inflation pressure loss model to provide a simulation method for predicting tire inflation pressure loss under free rolling conditions.

Compared with standard IPLR test, the difference between the tire IPLR test and the simulation result is within 10%. It can be seen from the temperature field result of the tire that the gas diffusion and oxidation reactions in the shoulder region are remarkable. The method of this paper will effectively reduce the amount of gas passing through the region, which will also reduce the degree of the oxidation reaction and improve the tire inflation pressure retention performance of the tire.

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Prediction and Validation of an Agricultural Tire-Soil Interaction Using Advanced Modelling Techniques

Zeinab El-Sayegh[1], Fatemeh Gheshlaghi[1], Mirwais Sharifi[1] and Moustafa El-Gindy[1]

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This paper focuses on modeling and validation of an agricultural tire size 220/80-B16 over clayey loam. The tire is modeled using a Finite Element Analysis (FEA) technique and validated against experimental measurement in static and dynamic responses. The clayey loam is modeled using Smoothed-Particle Hydrodynamics (SPH) technique and calibrated against experimental terramechanics measurements. The tire-terrain interaction is then computed using node-symmetric node-to-segment contact with edge treatment.

The rolling resistance coefficient of the agricultural tire running over clayey loam is computed at different operating conditions including tire longitudinal speed, inflation pressure, vertical load and soil moisture content. The effect of the operating conditions on the tire rolling resistance coefficient are discussed and investigated. Experimental testing of the agricultural tire over clayey loam are also carried out at similar operating conditions to those of the simulations. The experimental results are then used to validate the results obtained from FEA-SPH simulations. The results obtained in this research will further be used to better understand the tire-terrain interaction.

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Modeling Vibration Induced Tire-Pavement Interaction Noise in the Mid-Frequency Range

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Tire-Pavement Interaction Noise (TPIN) is one of the main sources of exterior noise produced by vehicles traveling above 50 kph. The dominant frequency content is typically within 500-1500 Hz. Structural tire vibrations are among the principal TPIN mechanisms.

In this work, the development of a new cylindrical shell model for simulating the vibratory response of a rolling tire is introduced. Starting with the classic Donnell-Mushtari-Vlaslov (DMV) theory for thin shells, the equations of motion are simplified. A new equation with a dominant radial behavior is derived.

The model is then extended to account for orthotropic structural properties, in an effort to accurately replicate those of an actual tire. Non-uniform structural properties along its transversal direction are used to account for differences between its sidewalls and the belt. The effects of rotation and inflation pressure are also included in the formulation. Finally, the process to compute the tire's response is presented.

Modes along the transversal direction and propagating waves along its circumferential direction are assumed. Resulting Frequency Response Functions (FRF) of the structural model are analyzed and validated. The tire's normal surface velocities are then coupled with a Boundary Element Model (BEM) to compute the radiated noise.

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Development of a Characterization Method of Tire Handling Dynamics Based on an Optical Measuring System

Chao Liu[1], Jan Kubenz[1, 2], Günther Prokop[1], Julian Diehl[1], and Peter Hoffmann[1]

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The tire is the only component connecting the vehicle body and the ground. All the tire forces and moments are generated at the tire contact patch, and then transferred through the linkages in the suspension to the vehicle body. In this way, tire forces and moments change the vehicle movements. It is of great importance to characterize the tire behavior as for a solid and trustworthy total vehicle simulation.

In the total project of “Parameter Street” – a systematic parameterization methodology for the total vehicle dynamics in Vehicle Testing Center at TU Dresden, the characterization of tire handling dynamics plays a key role. Compared with general tire force and moment (F&M) measuring method, it gives a detailed insight into the generation of tire F&M characteristics by measuring the tire carcass deformation during static and side slip maneuvers.

A tire observation system with two GOM optical measuring instruments was established to characterize the tire carcass deformation of the standing and rolling tire. Structural parameters of tire carcass flexibility have been identified based on a polynomial physical tire model with help of measured bending curves of tire carcass. A good correlation of the measured and estimated tire force and moment has proved the validity of the developed characterization method.

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Analysis of Self-Heating, Standing Wave Development, and Fatigue During Regulatory High-Speed Testing Protocols

William V. Mars[1], Govind Paudel[2], Jesse D. Suter[1] and Christopher G. Robertson[1]

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Tire speed ratings derive from regulatory testing in which tire structural integrity is validated over a series of steps with successively increasing speed. For the FMVSS 139 high speed standard, there are 4 half-hour duration speed steps at 80, 140, 150 and 160 kph. Speed ratings from T through Y may be attained through the UN ECE R30 regulation high speed testing. For either protocol, a tire must demonstrate the ability to operate without failure at high speed for 20-30 minutes. After the test, "there shall be no evidence of tread, sidewall, ply, cord, innerliner, belt or bead separation, chunking, broken cords, cracking, or open splices".

A workflow for simulating regulatory high speed durability performance has been developed based upon: 1) recent improvements to the Abaqus steady-state transport formulation that now permit converged solutions to be obtained at high speed (including after the development of standing waves in the tire) and 2) Endurica DT self-heating and incremental fatigue simulations that account for thermal effects and for damage accumulation occurring due to a schedule of load cases.

For each step of the high-speed procedure, steady state structural and thermal solutions are first computed. Crack growth is then integrated for each potential critical plane through each step of the test until failure is indicated. Standing waves are shown to induce significant self-heating and damage, rapidly limiting high speed performance. The simulation is executed on both a flat surface and on the regulation specified 1.7 m diameter road wheel.

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Tire Performance Simulation and Durability Evaluation using ANSYS

Mario A. Garcia[1], **Jin Wang[2]**, Deepak Hasani[2], Grama Bhashyam[2], Guoyu Lin[2], Michael Kaliske[1]

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In recent years, the importance of using numerical simulations to improve the service life and performance of rolling tires have grown within the tire industry. However, until now, there is no common approach which combines durability, tires and numerical analysis. This contribution seeks to demonstrate a method to evaluate tire durability using ANSYS. At this point, a finite element model of a tire is analyzed in a steady state rolling framework. Moreover, using a submodel technique, a crack is inserted and so-called material forces (generalized energy release rate) can be employed to determine the crack sensitivity in specific scenarios, with respect to defined fracture criteria of the rubber compounds.

Tire performance is assessed applying standard maneuvers like free rolling, cornering or camber angle, these are computed using an Arbitrary Lagrangian Eulerian (ALE) formulation, where the capabilities of transferring the analysis into transient analysis or multiphysics simulations are highlighted. This implementation makes use of a dedicated ANSYS Customization Toolkit (ACT), which simplifies the user interaction and offers a vast set of options for editing the analysis parameters. Numerical examples are presented for validation, where the application of boundary conditions into the submodel is discussed in detail. Concluding remarks and a foresight of the different capabilities of this novel framework close this presentation.

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New Methods for Assessing Tire-Related Vehicle Interior Noise

Peter Schaldenbrand[1]

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When assessing tire-related vehicle interior noise, the traditional method has been to use a sound pressure microphone positioned at the driver ear. An A-weighted decibel value is calculated to indicate the sound level in the interior of the vehicle. Unfortunately, the decibel level does not always provide a complete picture of the vehicle interior sound quality. There are several sound phenomena that are not captured in a decibel value.

In this presentation, newer sound assessment methods, including loudness, roughness, fluctuation strength, articulation index, and sharpness will be discussed as they can be applied to describe and quantify tire-related vehicle interior sound quality.

[1] Siemens PLM Software, Inc.

Enhanced Fiala Tire Model for Durability Simulation

Chris Coker[1]

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This paper details a new tire model available in Altair MotionSolve. This tire model can be used to generate durability loads and evaluate secondary ride with better accuracy than a simple point-follower road contact method. It utilizes the Fiala model for forces and moments, a reduced set of input parameters when compared to high fidelity tire models. A description of the model is provided, along with some comparisons with physical test data.

[1] Altair

A Study of the Effect of Tread Design Changes on Tire Patch Dynamics at High Speeds Through Use of a Dynamic Contact Force Measurement Rig

Matthew Van Gennip[1], Kazuki Okamoto[2], Kohei Miyanishi[2], and Hideaki Kashimata[2]

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The dynamic effects at the tire contact patch is one of the most difficult areas of a tire to measure. Generally, only the total forces at the tire axle are captured during tests. There are a few methods for identifying the force distribution at the tire contact patch, but these methods are limited to static tests or dynamic tests at slow speeds under non-repeatable conditions, such as with vehicle testing.

Due to this limitation, A&D Company, Limited has developed a tire testing machine named the Dynamic Contact Force Testing Rig (DCFR), to measure the dynamic force distribution at the contact patch at high speeds and under reproducible conditions. Preliminary studies have shown that minute changes in shear stress and pressure distribution can be measured consistently.

This study observes the dynamic force distribution for a high-performance tire (Fig. 2) under a variety of test conditions – varying normal load, pressure, camber, slip angle, and slip ratio. The tire tread is altered manually by siping additional longitudinal and lateral slits in the existing tread pattern. The tests are repeated for each tread pattern – stock tire tread, additional longitudinal slits, and additional lateral slits. The change in force distribution is compared along the longitudinal, lateral, and vertical axis. The results show how small changes in tread design can influence tire performance.

Being able to measure the contact patch dynamics will expand the mobility frontier and lead to new innovations across the entire field. Potential fields of research include developing new tires for electric vehicles that can withstand the higher torque demands and not wear out as quickly, reducing tire rolling resistance by investigating the many smaller components that contribute to rolling resistance, and increasing tire model accuracy by better understanding the tire road interaction, just to name a few. The applications are not limited to the tire; also extending to the vehicle suspension. By measuring the contact patch dynamics under various conditions, the optimization of the suspension can be improved.

[1] A&D Technology, Inc; 4622 Runway Blvd., Ann Arbor, MI, 48108

[2] A&D Company, Limited; 1-243, Asahi, Kitamoto-shi, Saitama, 364-8585, Japan.

Paper 5.2

Tread Block Force and Displacement Measurements During Rolling Contact Testing on a Stationary Machine

Bruce M Rusnak[1], Savyasachi Gupta[1], and Mark Herman[1]

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Tire tread wear is a function of the frictional energy between the tire and the road surface. Measuring the forces and displacements of individual tread blocks as the tire rolls provides the data for deriving frictional energy. The means for measuring the forces and displacements of individual tread blocks in a reproducible way and analyzing the data is time-consuming. The sheer volume of data needed to define the contact patch requires precision placement of the contact patch to the measuring probe.

Using a TBR tire on a stationary frame machine capable of applying vertical loading with independent control of speed, camber, slip, and rotational angle for two full revolutions of the tire provides proof-of-concept testing. Multiple time-series slices of Fx, Fy, Fz, Dx, and Dy measurements from a 36-probe array were recorded into an SQL database. Queries provide a means for retrieving just the data needed for analysis in calculating scrub energy to be correlated with treadwear patterns on a given tire design.

[1] TMSI, LLC, 9073 Pleasantwood AVE NW, North Canton, OH 44720

Vision on a Digital Twin of the Road System for Future Mobility

Michael Kaliske[1], Ronny Behnke[1], and Ines Wollny[1]

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Innovative trends like autonomous cars and smart vehicles gain increasing attention and will form a new mobility technology. At the same time, the appearance of smart tire systems will give rise to a better tire performance, better vehicle control and the enhancement of nowadays, intelligent systems for autonomous vehicles. In contrast, innovations for the road system, which has to carry the increasing traffic loads, are rare in recent years. However, in order to solve the current and future challenges of mobility, related to road transport, like durability, safety, efficiency, ecology, cost etc., the potential of innovative trends and digitalization of all interacting components – vehicle, tire and road – should be used and will change the industrial ecosystem and the paradigm of transport in human life!

The vision of a Digital Twin of the road system, which is the digital/virtual image (reality model in space and time) of vehicle, tire and roadway, enables in future, among others, pioneering condition predictions of the single components from manufacturing over service until failure state, targeted traffic control, optimal synthesis of building materials and structures, interfaces to automated driving and emission reductions. The Digital Twin of the road system contains and combines all available and relevant information about the system "road of the future" from physical evaluations and modeling as well as from informational and traffic data (real-time sensor data by vehicle, tire and road sensors, data models, etc.). The contribution presents the current state of research, tasks and challenges towards the Digital Twin of the road system as well as the potential of the Digital Twin for future mobility.

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Machine Learning Guided Discovery of New Compounds

Brandon Kelly[1], Bernadette Crookston[1], Nihat Isitman[1], Craig Burkhart[1]

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We present a process for using machine learning to guide the development of new compounds. This process relies on the interaction of compounding experts with machine learning and optimization algorithms. Our approach begins with the definition of chemical and compounding features, which are input to a machine learning model that provides predictions of physical properties and their variability. These probabilistic outputs are then used to make recommendations on compound properties. In this talk we will discuss the implementation of our process, its performance, and its role in adaptive design.

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Advanced Antenna Simulation Tools for Intelligent Smart Tires

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Intelligent and smart tires are being developed by all tire companies across the world by integrating various sensors in to the tire. This technology includes Tire Pressure Monitor Systems (TPMS), Radio Frequency Identification (RFID) etc. TPMS allows for monitoring pressure and temperature of the tire in real time. RFID allows for identification of individual tires for supply chain logistics, performance tracking etc.

Both these sensors and others normally include an integrated antenna that converts the information into an electromagnetic signal which is then radiated. Typically, a receiver in the dashboard receives and demodulates the signal and displays the tire status to the driver and/or transmits to a central location using another antenna on the vehicle in case of fleet management.

For the antennas embedded in the tire unit needs to be functional in the proximity of various metallic structures such as rim, tire carcass etc. Design of tire embedded antennas should take in to account these effects to be efficient to transmit required signal level to dash board of the car. In this talk, various case studies will be presented on such antenna designs using advanced electromagnetic simulation tools. Case studies also will be presented on design and simulation of vehicle mounted antennas that transmit tire and other data to fleet control stations.

[1] Altair

Finite Element Modeling and Critical Plane Analysis of a Cut and Chip Experiment for Rubber

Christopher G. Robertson[1], Mark A. Bauman[1], Jesse D. Suter[1], Radek Stoček[2,3], and William V. Mars[1]

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Rubber surfaces exposed to concentrated, sliding impacts carry large normal and shearing stresses that can cause damage and the eventual removal of material from the surface. Understanding this cut and chip (CC) effect in rubber is key to developing improved tread compounds for tires used in off-road or poor road conditions.

In order to better understand the mechanics involved in this cut and chip process, an analysis has been made of an experiment conducted on a recently introduced device, the Coesfeld Instrumented Chip & Cut Analyser (ICCA), that repetitively impacts a rigid indenter against a rotating solid rubber wheel. The impact process is carefully controlled and measured on this lab instrument, so that the contact time, normal force, and shear force are all known.

The numerical evaluation includes finite element analysis to determine the stress and strain fields during impact, as well as critical plane analysis using the Endurica CL fatigue life solver to determine the fatigue response of the specimen surface. The modeling inputs are experimentally-determined hyperelastic stress-strain parameters, crack growth rate laws, and crack precursor sizes for carbon black filled compounds wherein the type of elastomer is varied in order to compare natural rubber (NR), butadiene rubber (BR), and styrene-butadiene rubber (SBR).

The simulation results are consistent with the relative CC resistances of NR, BR, and SBR measured using the ICCA, and they confirm that CC damage can be understood in terms of fundamental rubber fracture mechanics characteristics.

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A Study of the Influence of Waveforms on Fatigue Crack Growth Characteristics of Tyre Tread Rubber Using Finite Element Analysis

P. Ghosh[1], R. Mukhopadhyay[1], and R. Krishna Kumar[2]

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Rubber products are mostly subjected to cyclic fatigue loading in service. On prolonged exposure to cyclic loading, damages initiate at the intrinsic defect site in micro levels and subsequently propagate, leading to catastrophic failure. Therefore, the material that offers better resistance towards fatigue crack growth (FCG) is suitable for a durable product. FCG characteristics of rubber compounds depends on many factors like constituent material (rubber, filler etc.), environmental and operational conditions (loading amplitude, loading pattern etc.). To simulate the realistic service condition of a product, the choice of loading pattern is the key factor and emerged as a very important research topic in recent times. The present work focused on effect of loading pattern on FCG characteristics of tire tread rubber compounds.

In the present study, FCG characteristics of 100% Natural Rubber (NR) compound was measured in a Tear & Fatigue Analyzer (TFA) using double edge notched pure shear specimen. Fatigue loading was applied using sinusoidal and pulse waveforms over a wide range of tearing energy level. Pulse mode recorded a very high crack growth rate (~10 times) than that of Sine mode at equivalent tearing energy level.

In order to understand the mechanics of higher crack growth rate in pulse mode, finite element analysis (FEA) of pure shear specimen was performed wherein FCG experimental conditions were used as boundary conditions. FE analyses were carried out using both linear and non-linear viscoelastic material model. Non-linear viscoelastic FEA results revealed that viscous energy dissipation at the crack tip is much less in the case of pulse mode which is in support of higher FCG rate in pulse mode as observed in the experiments.

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Durability Evaluation in Elastomers Using Fracture Mechanics

Mario A. Garcia[1], Jad Khodor[1], Bo Yin[1], Michael Kaliske[1]

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In the design of tires, durability plays an important and critical role. Its theoretical prediction using finite element simulations and the energy release rate has been lately improved using more advanced numerical techniques. This contribution presents the current developments in the evaluation of cracks by using two main and different methods.

The first one is a discrete approach based on the computation of material forces, which are non-Newtonian forces that act on an inclusion within a homogeneous body. In a cracked body, the material force acting on the crack tip is the crack driving force. This force can be used to determine the crack propagation direction and the energy release rate.

The second approach is a smeared approximation of the crack by means of phase-field method, which does not depend on any explicit criterion to evolve fracture, including crack initiation, propagation, branching, kinking and arrest.

Good agreements are obtained by comparing the results of simulations and experiments. Furthermore, the meeting point of these two different formulations is found in the determination of a fracture criteria in elastomers and the degradation of the resistance against fracture as a function of representative parameters like time, temperature, and velocity, among others.

A first set of numerical examples are presented in a finite strain framework, where hyperelastic and viscoelastic material models are used. The good agreement in results from both approaches is discussed. Moreover, specific examples for the analysis of durability in tires are carried out. Conclusions and important remarks close this presentation.

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Using a New 3D-Print-Method to Investigate Rubber Friction Laws on Different Scales

Jan Friederichs[1], Felix Hartung[2], Tobias Götz[3], Lutz Eckstein[1], Daniel Wegener[1], Michael Kaliske[2], Wolfram Ressel[3]

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Rubber friction is a complex phenomenon that is composed of different contributions – hysteresis friction, adhesion, viscous friction and interlocking effects. As it always consists of a friction pairing, the road surface topology has a main impact on the adhesive and sliding characteristics in the rubber-road-interaction. New manufacturing processes offer the means to develop road surfaces specifically. Additive production processes with polymer material have already shown first successes, but limiting factors to fit the characteristics of asphalt have been the reproduction of the microstructure and long-term stability of the texture.

By using a modified 3D printing method on the basis of Selective Laser Melting with stainless steel it is possible to create any desired surface up to a resolution of 20 µm. In this work, several metallic surfaces with different micro and macrostructures and a reproduction of an asphalt section have been built for two separate purposes. Firstly, the rubber road interaction has been analyzed and compared for metal and asphalt. Secondly, theoretical friction laws have been investigated with synthetic surfaces of different harmonic wavelengths and the influence of water on the friction coefficients is regarded separately for macro and micro structured surfaces. For this aim, the friction coefficients have been measured with a linear friction test rig with different rubber samples in dry and wet condition.

A multiscale approach for friction properties on different length scales (frequency clusters) has been implemented to accumulate the micro- and mesoscopic friction into a macroscopic friction coefficient. On each length scale, a homogenization procedure generates the friction features as a function of slip velocity and contact pressure for the next coarser scale. The applicability of the homogenization method with respect to the space between adjacent frequency clusters has to be verified in advance. Within the multiscale approach, adhesion implemented as non-linear traction separation law is assumed to act only on microscopic length scales. By using the finite element method (FEM), the sensitivity of the influencing factors like macroscopic slip and load conditions are investigated by a simulative approach and tested against the real friction characteristics.

With regard to the interlayer properties, the friction loss from dry to wet conditions cannot be explained by loss of adhesion alone. Hysteresis has to be affected as well. A possible hypothesis for this are trapped water pools in the texture. The road surface is effectively smoothed and thus hysteresis reduced. To verify this hypothesis, a hysteretic friction model is calibrated to dry measurements. The cavities in the modeled texture are then filled incrementally to simulate various amounts of trapped water. By comparing the simulated friction with wet measurements, the amount of trapped water is quantified.

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Dynamic Behavior of Fractional Viscoelastic Tire Tread Blocks on Pavement

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The component of vehicle tires that contacts the road is the tire tread. It consists of several tread blocks with different shape and can be realized by siped structure to improve the traction on the pavement in particular in wet, icy or snowy road. The blocks are usually made of elastomer materials, which possess viscoelastic behavior. Elastomers show time-dependent and dissipative properties and their deformations vary in temperature, velocity and frequency or external excitations. Viscoelastic material is often described by the generalized Maxwell-Wiechert-model, whose parameters, often realized as Prony series, characterize the stiffness and damping properties. Another model with a much smaller set of parameters is the approach of fractional viscoelasticity. Fractional viscoelastic models can allow a better approximation of the real deformations of elastomers.

Each single tire tread block shows periodically frictional impacts with the pavement. The contact configurations and transitions among stick and slip or impact and detaching can be formulated as a linear complementarity problem, whose solution estimates the local contact forces. We propose to simulate transient deformations of a tire tread block by developing a discretized fractional model. The focus is on the deformation process of a tread block with siped structure on pavement for frictional contact. The simulation results are compared to measurements on a high velocity linear testing bench. The contact forces of the frictional contact for different road surfaces and also the deformation process of siped tread blocks, where self-contact can occur, are investigated. The qualitative comparison between results out of simulations and experiments shows a fair agreement.

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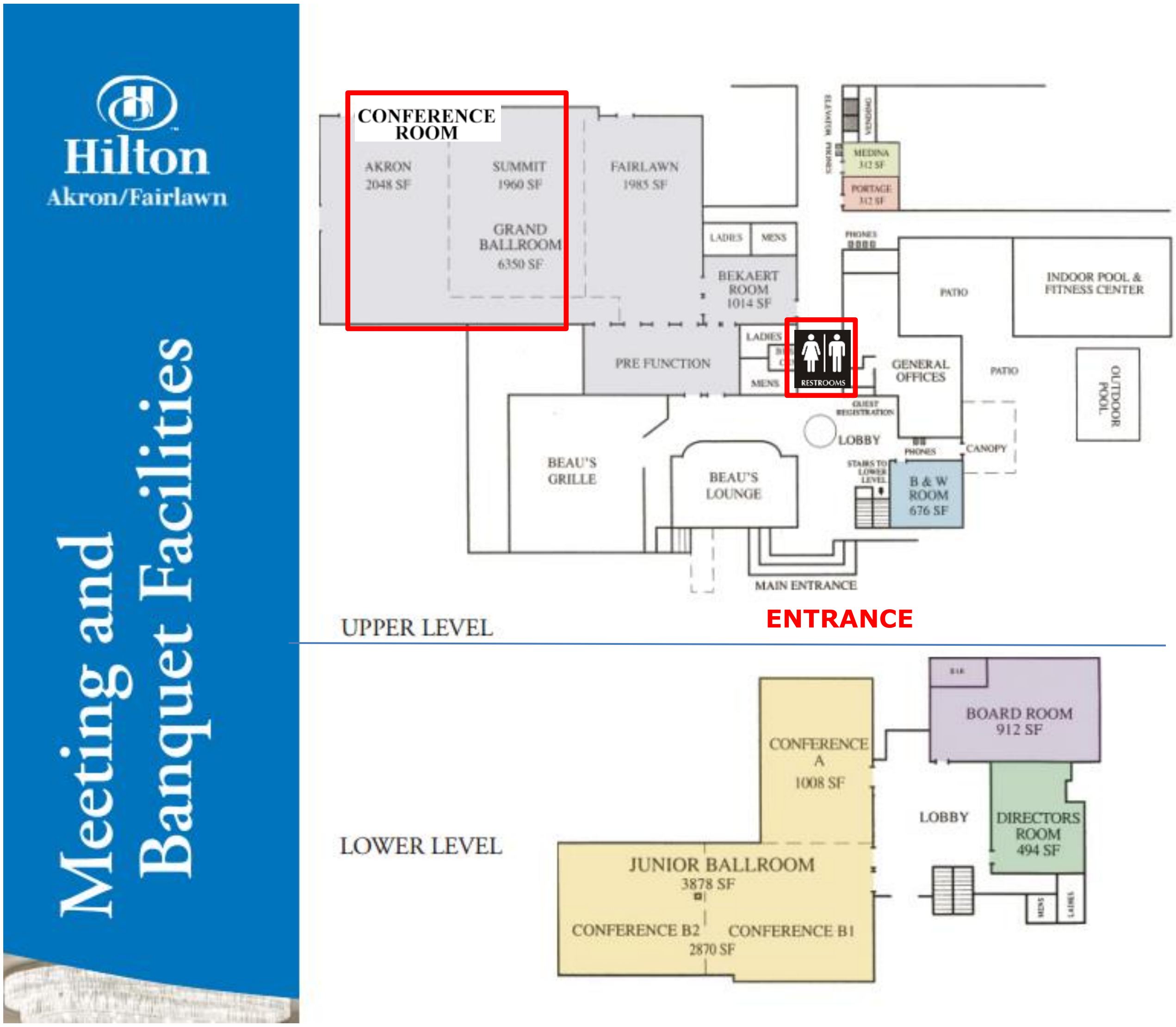
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The Tire Society, Inc.

38th Annual Business Meeting and Conference on Tire Science and Technology

September 10-11, 2019
Hilton Akron/Fairlawn Hotel
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Schedule Overview (detailed schedule inside)

Day 1 - Tuesday, Sept 10	
7:00a	Registration: Foyer (all day)
	Day 1 Presentations: Akron/Summit Ballroom
8:00a	**Welcome** *Gerald Potts*
8:10a	**Keynote Address** *Robert Asper, Bridgestone Americas*
9:10a	**Opening** *Anudeep Bhoopalam, Conference Chair*
9:15a	**Tire Performance** *3 Presenters*
11:00a	*Break/Refreshments*
11:20a	**New Light on Tire Technology I** *2 Presenters*
12:15p	*Lunch (Provided)*
1:30p	**New Light on Tire Technology I** *3 Presenters*
2:50p	*Break/Refreshments*
3:10p	**Supplier Technology** *3 Presenters*
5:00p	Reception: Conrad Ballroom
6:00p	Banquet: Conrad Ballroom
7:00p	**Banquet Talk** *Pierre Lefevre, Coast Autonomous*
8:00p	Close of Day 1

Day 2 - Tuesday, Sept 11	
7:00a	Registration (half day)
	Day 2 Presentations: Akron/Summit Ballroom
8:00a	**Opening** *Anudeep Bhoopalam, Conference Chair*
8:05a	**Experimental Technologies** *2 Presenters*
9:00a	**State of Society** *Gerald Potts*
9:20a	**Panel Discussion**
10:20a	*Break/Refreshments*
10:40a	**Emerging Technologies** *3 Presenters*
12:00p	*Lunch (Provided)*
1.15p	**Plenary Lecture** *Srikanth Saripalli, Texas A&M University*
2:20p	**Simulations** *3 Presenters*
3:40p	*Break/Refreshments*
4:00p	**Friction** *2 Presenters*
5:00p	**Closing Remarks**