36th Annual Business Meeting and Conference on Tire Science and Technology

Program and Abstracts

September 12-13, 2017
Hilton Akron/Fairlawn Hotel
Akron, Ohio

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36th Annual Meeting and Conference on Tire Science and Technology

Day 1 - Tuesday September 12, 2017

All Sessions take place in Akron/Summit Ballroom

7:00 AM		Registration (Fairlawn Hilton until 5pm)		
8:00 AM	10	Welcome (Akron/Summit Ballroom)		Randy Jenniges, *President of Society*
8:10 AM	60	**Keynote Speaker**		
			The Future of Mobility: How Customer Requirements will Shape Tire Technology	**Dr. Juan Botero** *Continental AG* *VP Sales, OE Passenger & Light Truck Tires, The Americas Tire Division*
9:10 AM	5	Opening Remarks		Joshua Herron, *Conference Chair*
9:15 AM	5	**Session 1: Tire Performance**		**Brian Steenwyk,** *Bridgestone*
9:20 AM	30	1.1	3-D Modal Analysis of a Loaded Tire	Ipar Ferhat *Virginia Tech*
9:50 AM	30	1.2	Experimental Investigation of the Tractive Performance of Pneumatic Tires on Ice	Emilio Jimenez *Virginia Tech*
10:20 AM	20	Break / Refreshments		
10:40 AM	5	**Session 2: Material Technology**		**Janice Tardiff,** *Ford Motor Co.*
10:45 AM	30	2.1	A Study of Compounding and Mixing methodology for Good Performance of EPDM in Tyre Sidewalls	Zhaoya Qiu *ARLANXEO USA*
11:15 AM	30	2.2	Characterizing the Intrinsic Strength of Natural Rubber / Butadiene Rubber Blends	Chris Robertson *Endurica*
11:45 AM	30	2.3	Modified Soybean Oil as a Processing Oil for SBR Tire Tread Compounds	Olena Shafranska *North Dakota State Univ.*
12:15 PM	75	Lunch (Provided)		
1:30 PM	5	**Session 3: New Light on Tire Technology**		**Celal Batur,** *Univ. of Akron*
1:35 PM	30	3.1	A Calculation Aero-Acoustic Study of Spokes of an Isolated Non-Pneumatic Tire	Mufeng Huang *Jiangsu University*
2:05 PM	30	3.2	Designing a New Dynamic Mechanical Analysis (DMA) System for Testing Viscoelastic Materials at High Frequencies	Roja Esmaeeli *University of Akron*
2:35 PM	30	3.3	On Isogeometric Analysis for Tire Simulation at Steady State Rolling	Mario A. Garcia *Univ. Dresden*
3:05 PM	20	Break / Refreshments		
3:25 PM	5	**Session 4: New Light on Tire Technology**		**Bart Kimble,** *Goodyear*
3:30 PM	30	4.1	Tire Contact Stress/Health Assessment using Acoustic Emissions	Arash Nouri *Virginia Tech*
4:00 PM	30	4.2	Tire particle emissions: demand on reliable characterization	Maria E. Dalmau *Technische Universität Ilmenau*
4:30 PM	30	4.3	The Effect of Rubber Hardness and Tire Size on Tire-Pavement Interaction Noise	Tan Li *Virginia Tech*
5:00 PM	60	Reception		
6:00 PM		**Awards Banquet**		
			Racing toward perfection (R2P) 50+ Years of Winning at Team Penske	**John Moloney** *General Manager - Penske Racing Team*
8:00 PM	5	Close of Day 1		

Day 2 - Wednesday September 13, 2017

All Sessions take place in Akron/Summit Ballroom

7:30 AM		Registration (Fairlawn Hilton until 5pm)		
8:00 AM	5	Opening Remarks		Joshua Herron, *Conference Chair*
8:05 AM	20	**State of the Society**		Randy Jenniges, *President of Society*
8:25 AM	5	**Session 5: Simulations**		**Kejing Li,** *Hankook Tire Co.*
8:30 AM	30	5.1	Accounting for Thermal Effects in Tire Durability via a Critical-Plane-Analysis-compatible Microsphere Model	Will Mars *Endurica*
9:00 AM	30	5.2	Effect of cam parameters in the tandem cam enveloping model on short obstacles using DOE approach	*Vikas Birajdar* *Kettering Univ./GM*
9:30 AM	30	5.3	Optimization of tire design and construction parameters for cornering stiffness of temporary spare tires in passenger car vehicle category	Deepti Soni *JK Tyre*
10:00 AM	20	Break / Refreshments		
10:20 AM	5	**Session 6: Simulations**		**Chris Robertson,** *Endurica*
10:25 AM	30	6.1	On the development of creep law for rubber in the Parallel Rheological Framework	G. Sagar *Continental*
10:55 AM	30	6.2	Viscoelastic Material Calibration Procedure for Rolling Resistance Calculation	Pablo Zitelli *Fate Tire*
11:25 AM	90	Lunch (Provided)		
1:00 PM	60	**Plenary Lecture**		
			Tire finite element modeling - how we got where we are and where we are headed.	**Dr. Ron Kennedy** *Managing Director - Center for Tire Research (CenTiRe)*
2:00 PM	5	**Session 7: Tire Vehicle System**		**Yusheng Chen,** *Cooper Tire*
2:05 PM	30	7.1	Tire Vibration Considerations in Vehicle Based Tire Testing	Anton Albinsson *Chalmers University of Technology,*
2:35 PM	20	Break / Refreshments		
2:55 PM	5	**Session 8: Experimental Technologies**		**Matt Schroeder,** *Cooper Tire*
3:00 PM	30	8.1	Actual Measurement of Inner Surface Deformation of Tire during Getting Over Steps	Tomoaki Iwai *Kanazawa University*
3:30 PM	30	8.2	Characterization of Thermal Influences on Tire Force and Moment Properties	Henning Olsson *Calspan*
4:00 PM	30	8.3	Experimental Measurement of In-plane Rolling Tire Vibrations Using High Speed Imaging	Meghashyam Panyam *Clemson/Michelin*
4:30 PM	5	Close of Conference		Joshua Herron, *Conference 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 2017 conference.

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The 2018 Conference
Conference Dates: September 11 & 12th 2018.

Program Chair: Nathan Billy, *Nexen Tires*
Co-Chair: Anudeep Bhoopalam, *Giti Tire*

The 2018 conference committee would appreciate your assistance and suggestions. A call for papers will be issued to attendees of the 2017 conference and will be available online. Visit www.tiresociety.org for updates.

Keynote Address

Dr. Juan Botero
Vice President Sales, Original Equipment, Passenger & Light Truck Tires,
The Americas
Tire Division
Continental AG

Dr. Juan Botero is Vice President of Sales for the Passenger & Light Truck Tires original equipment business in the Americas. He has held this position since July 2016. In this role, he is responsible for the regional marketing and sales strategies of the original equipment business. He oversees an international team for sales, controlling, product development, supply chain management and quality.

Dr. Botero joined Continental in 2007 as a Tread Pattern Mechanics engineer at the global tire R&D center in Hanover, Germany. Over the last ten years with Continental, he has held management roles of increasing responsibility based in Japan, Germany, Singapore and USA. His areas of expertise include tire mechanics, product development, strategic procurement and key account management.

Dr. Botero earned a Master of Science in Mechanical Engineering from University of Los Andes in Bogotá, Colombia and also holds a Ph.D. in Mechanical Systems Engineering from Technical University Milan, Italy. He has been a Roberto Rocca Doctoral Fellow at the Massachusetts Institute of Technology.

Title of Talk: The Future of Mobility: How Customer Requirements will Shape Tire Technology

Plenary Lecture

Dr. Ron Kennedy
Managing Director, Center for Tire Research (CenTiRe)

Ron Kennedy is currently the Managing Director of the Center for Tire Research (CenTiRe), an industry/university consortium involving Virginia Tech, the University of Akron, and tire and tire-related companies. In his position he provides administrative oversight, communication with industry members and faculty, and promotion of the Center.He also has the great opportunity to work with graduate students as they pursue their tire related studies.

Before joining CenTiRe three years ago, Ron worked for 37 years in the tire industry at Firestone, Bridgestone/Firestone, and Hankook Tire performing tire finite element methods development and software programming, simulation systems development, advanced tire design, and tire factory uniformity studies. His work has covered the range of tire performance areas, manufacturing, and design.

Ron has been actively involved in the Tire Society during his career, serving as conference program chair, awards committee member and chair, and currently as an Associate Editor of the Tire Science & Technology journal. He has given several presentations at Tire Society conferences, winning a Superior Paper Award and an Honorable Mention Award for his work in tire finite element modeling. He has also received the Arch T. Colwell Merit Award from SAE for work from his PhD dissertation on 3D steady state rolling tire finite element development, and the CEO Award and President's Award from Bridgestone/Firestone.

Ron received his BS and MS degrees in Engineering Mechanics from the University of Wisconsin, and his PhD in Mechanical Engineering from the University of Akron.

Title of Talk: Tire finite element modeling - how we got where we are and where are we headed

Banquet Speaker

John Moloney
General Manager, Penske Technology Group

Title of Talk: Racing Toward Perfection (R2P) 50+ Years of Winning at Team Penske

3-d modal analysis of a loaded tire

Ipar Ferhat[1], Pablo A. Tarazaga[1], Rodrigo Sarlo[1]

1 VAST LAB, Virginia Tech, Blacksburg, VA

Email: ipar@vt.edu

Modal analysis of tires has been a fundamental part of tire research that has been conducted to capture the dynamic behavior of a tire. An accurate expression of tire dynamics leads to an improved tire model and a more accurate prediction of the tire behavior in real life operations. Therefore, the main goal of this work is to improve the tire testing techniques and data range to obtain the best experimental data possible with the current technology.

With this goal in mind, we propose novel testing techniques such as piezoelectric excitation, high frequency bandwidth data, and non-contact vibration measurement. High-frequency data enables us to capture the coupling the wheel and tire as well as the coupling between airborne and structure-borne noise. Piezoelectric excitation eliminates the dynamic coupling of shakers and the inconsistency of force magnitude and direction of impact hammers as well as added mass effect. Non-contact vibration measurements using 3-d scanning laser doppler vibrometer (SLDV) is much superior comparing to accelerometers due to no mass loading, a high number of measurement points in all 3-d, and high sensitivity.

In this work, a modal analysis is carried out for a loaded tire in a static condition. Mode shapes of the tire are obtained for the 3-d geometry of the tire using the stitching capabilities of the 3-d SLDV. Since tires are highly curved structures, vibration measurement of the entire structure helps us identify the mode shapes in a most accurate way comparing to the 2-d mode shapes commonly studied.

Experimental Investigation of the Tractive Performance of Pneumatic Tires on Ice

Emilio Jimenez[1], Corina Sandu[1]

1 Advanced Vehicle Dynamics Laboratory, Virginia Polytechnic Institute and State University

Email: jimeneex@vt.edu

The investigation is motivated by the need for performance improvement for pneumatic tires in icy conditions. The pneumatic tire is the only force-transmitting component between the terrain and the vehicle under normal operation. Therefore, it is critical to grasp the understanding of the contact mechanics at the contact patch under various surfaces and operating conditions. This paper aims at enhancing the understanding of the tire-ice contact interaction through experimental studies and a semi-empirical Advanced Tire-Ice Contact Model (ATICM) for a pneumatic tire traversing over solid ice. A design of experiment has been formulated that gives insight into the effect of operational parameters, specifically: tire tread type, slip ratio, normal load, inflation pressure, ice surface temperature, and traction performance. The temperature distribution in the contact patch is recorded using a novel method based on thermocouples embedded in the contact patch. Temperature rise from simulations are validated against temperature distribution measurements at the contact patch under various operating conditions using K-Type thermocouples. As shown by both, the simulations from the Advanced Tire-Ice Contact Model and the test data, a rise in temperature was observed from the leading edge to the trailing edge of the contact patch. The drawbar pull is also measured at different conditions of normal load, inflation pressure, and ice temperatures. The measurements were conducted using the Terramechanics Rig at the Advanced Vehicle Dynamics Laboratory (AVDL). This indoor single-wheel equipment allows repeatable testing under well-controlled conditions. The data measured indicates that, with the appropriate tread design, the wheel is able to provide a higher drawbar pull on smooth ice. With an increase in ice surface temperature, a wet film is observed, which ultimately leads to a significant decrease in traction performance.

A study of compounding and mixing methodology for good performance of EPDM in tyre sidewalls

Philip Hough[1], Niels van der Arr[1], Zhaoyao Qiu[2]

1 ARLANXEO The Netherlands, Urmonderbaan 22, 6167 RD, Geleen, Netherlands
2 ARLANXEO USA LLC, 111 RIDC Park West Drive, Pittsburgh, PA 15243

It has long been a focus of development activity, both in academia and by industry to exploit the inherent properties of dissimilar elastomers in blends, thereby aiming to achieve compositions that demonstrate the beneficial characteristics of each of the blend polymers. One application that has received particular attention over the years is tyre sidewalls, and in particular the possibility of blending EPDM into sidewall compounds to give ozone protection.

EPDM is a terpolymer of ethylene, propylene and a diene, and is characterized by having a fully saturated polymer backbone, giving it excellent resistance to ozone and oxidative aging. In contrast, diene elastomers such as natural rubber and polybutadiene have high levels of unsaturation along their polymer main chains, which makes them susceptible to chain scission through chemical degradation. It is therefore necessary to protect diene elastomers, which is generally achieved through the use of free radical scavengers, often in combination with migrating waxes.

Protective systems based on paraphenylene diamines (PPD’s) are very effective and are used extensively for tyre sidewall protection, but as free radical scavengers their effectiveness becomes depleted through the service life of the tyre. Other potential drawbacks are that PPD’s cause discoloration and are thought to be potentially hazardous both human health and to the environment through contamination of water systems.

Compared with conventional PPD protective systems, it has been shown that blends of EPDM in typical tyre sidewall compounds can give similar or improved protection against ozone and oxidative aging, and offers further advantages in that it is safe to human health and the environment, is non staining and does not lose its effectiveness as a protective system throughout the service life of the tyre.

However, despite the obvious benefits, blending EPDM into typical tyre sidewall compounds is not without its challenges. Differences in the polarity and solubility of natural rubber, polybutadiene rubber and EPDM mean that the elastomers are not miscible when mixed together and will form polymer phase dispersions that are susceptible to preferential mixing of fillers, processing oil and the cure system towards the more compatible NR/BR polymer phases. When coupled with the relatively low inherent curing activity of EPDM, this can lead to the dispersed EPDM phase having a low state of cure with a reduced level of filler reinforcement, resulting in inferior physical properties of the cured compound.

By combining identified best practice for compound design and mixing methodology with selected grades of Keltan EPDM, it has been possible to achieve ozone protected tyre sidewall compounds that closely match the physical properties of a typical NR/BR sidewall compound. Additionally, the presence of EPDM in the sidewall compound gives superior properties after heat aging, and tear analyzer studies have indicated the potential for reduced energy dissipation, which could lead to tyres having improved rolling resistance.

Paper Number 2.2

Characterizing the intrinsic strength of natural rubber / butadiene rubber blends

WV Mars[1], R Stocek[2], C Kipscholl[3]

1 Endurica LLC, Findlay, Ohio, USA
2 PRL Polymer Research Lab, Zlín Czech Republic
3 Coesfeld GmbH & Co. Dortmund, Germany

Email: wvmars@endurica.com

Tire applications require rubber compounds capable of enduring more than 108 cycles without crack growth. One strategy for evaluating candidate compounds is to measure the intrinsic strength. The intrinsic strength is the residual strength remaining in the material after the strength-enhancing effects of dissipation in crack tip fields are removed. If loads stay always below the intrinsic strength (taking proper account of the possibility that the intrinsic strength may degrade with ageing), then cracks cannot grow. Using the cutting protocol proposed originally by Lake and Yeoh, as implemented on the Coesfeld Intrinsic Strength Analyzer, the intrinsic strength for a series of filled NR/BR blends typical of tire applications is determined. The protocol features a series of decreasing cutting rates that validate against potential rate dependence of the result, and that produces curves showing the dependence of cutting energy on tearing energy. The intrinsic strength is extrapolated from the curve corresponding to the lowest cutting rate. The proposed experimental procedure executes quickly and repeatably, and provides insight into the molecular parameters thought to govern long-term durability, as well as the prospects for long-term durability of a rubber compound in service.

Paper Number 2.3

Modified soybean oil as a processing oil for SBR tire tread compounds

Olena Shafranska[1], Dean C. Webster[1], Bret J. Chisholm[1], Sean McFarlane[2], Janice Tardiff[2]

[1] North Dakota State University, NDSU Dept. 2760, P.O. Box 6050, Fargo, ND
[2] Ford Motor Company, Dearborn, Michigan 48124

Email: Olena.shafranska@ndsu.edu

Soybean oil (SBO) was modified with polystyrene via a radical graft polymerization reaction for use as a processing oil in tire tread compounds. Styrene-butadiene (SBR)/polybutadiene (BR) rubber compounds with silica and carbon black, containing different processing oils including naphthenic oil (NO), aromatic oil (AO), SBO, polystyrene-modified SBO (SBO-PS) were formulated, vulcanized and tested. The curing behavior, mechanical properties and dynamic properties were investigated. The cure test results showed that all SBO-based rubber have shorter scorch time and cure window than the NO- and AO-based rubbers.

The tensile tests demonstrated that partial and complete replacement of NO with SBO leads to reduced tensile modulus, but increased elongation of rubber. For the rubbers compounded with SBO-PS and with a 50/50 mixture of NO/SBO-PS, tensile strength and elongation were higher than for the NO-based rubber. The same tendency was observed if SBO- and SBO-PS-based rubbers were compared with AO-based rubbers. SBO-PS-based rubbers demonstrated better tensile properties than AO-based rubbers and far better properties than an SBO-based rubber. In the tear resistance test and Durometer hardness test, SBO-PS contained rubbers showed similar properties to NO-contained rubber.

The dynamic mechanical analysis (DMA) of SBO-PS-containing rubbers demonstrated that use of this compound in the tire tread is expected to improve both rolling resistance and wet traction, if compared to an AO-based rubber. The modification of soybean oil with grafted polystyrene is a promising way to make a processing oil which can replace petroleum-based processing oils with bio-based renewable oils in tire tread compounds with improvement of their properties.

Paper Number 3.1

A Calculation Aero-Acoustic Study Of Spokes of an Isolated Non-Pneumatic Tire

Mufeng Huang[1], Haichao Zhou[1], Kaiqiang Li[1], and Guolin Wang[1]

1 School of Automotive and Traffic Engineering, Jiangsu University, Jiangsu, China

Email: marvinhuang@qq.com

With the progress of noise control of engines and the rise of new energy vehicles, the severity of tire noise is increasingly highlighted. Recently, the Non-Pneumatic Tire (NPT) has drawn attention because of its novel structure design that surpasses traditional tires in anti-explosion, maintenance-free and low rolling resistance. However, with an open-side structure and violent air impact at the flexible spokes, an NPT emits greater aerodynamic noise than a pneumatic tire during high speed rolling, which results in an adverse effect on riding comfort of vehicles.

The arrangement and the edge shape features of flexible spokes in an NPT play important roles in generation of aerodynamic noise. In this study, the aerodynamic flow around NPTs, which are in contact with the ground, rolling at speed of 80km/h, and with different edge shapes and arrangement patterns of spokes are investigated using the Reynolds-Averaged Navier-Stokes (RANS) method and Large-Eddy Simulation (LES). Then, the far-field aerodynamic noise of different NPTs are calculated using FW-H (Fowcs Williams-Hawkings) equations in the acoustic model of ANSYS-Fluent. The influence of spoke arrangements and edge shapes on the flow pattern and aerodynamic noise is analyzed. And based on which, we propose an optimized design of spokes, which can enhance the aero-acoustic performance of NPTs.

Paper Number 3.2

Designing a New Dynamic Mechanical Analysis (DMA) System for Testing Viscoelastic Materials at High Frequencies

Roja Esmaeeli[1], Elisha Dale[1], Chiran JBR[1], Anatoliy Torchilo[1], Megan Staimer[1], Celal Batur[1], Siamak Farhad[1]

1 Mechanical Engineering Department, University of Akron, Akron, OH, United States

E-mail: sfarhad@uakron.edu

The aim of this study is to design a new DMA test system that can operate at frequencies as high as 10 kHz with strain amplitudes sufficient for tire application of rubbers. The goal is to make the range of the test broad enough to eliminate the use of Williams–Landel–Ferry (WLF) equation in determination of rubbers mechanical properties. For this purpose, the state-of-the-art technologies to achieve high frequencies and strain amplitudes are studied and the DMA system is optimized for only rubbers used for tires. The conventional DMA test systems cannot effectively operate at high frequencies as needed for accurate prediction of tire wet traction. In addition, the conventional DMA systems are designed to operate for testing a broad range of viscoelastic materials; hence, one can achieve a more optimum system design by making the range of testing materials narrow to tire rubbers and making the range of frequencies wider. The design process including the design of each components of the DMA system as well as instrumentation and control of the system is presented in this paper. Moreover, calculation of required power and applied force to the test system is quantified in this study.

On isogeometric analysis for tire simulation at steady state rolling

Mario A. Garcia[1] and Michael Kaliske[1]

1 Institute for Structural Analysis (ISD), Technische Universität Dresden, Dresden, Germany

Email: michael.kaliske@tu-dresden.de

The use of Isogeometric Analysis (IGA) in industrial applications has increased in the past years. One of the main advantages is the combination of a Finite Element Analysis with the capability of representing the exact geometry by means of Non-Uniform Rational B-Splines (NURBS). This framework has proven to be an efficient alternative to standard FEA in solid mechanics and fluid dynamics, in cases where sensitivity to geometry is found. The numerical simulation of rolling tires requires a proper discretization for the curved boundaries and complex cross-sections, which often leads to the use of higher order or cylindrical elements. As remeshing operations are numerically costly in tire models, IGA stands as an important alternative for the modeling of rolling tires.

In this contribution, an arbitrary Lagrangian Eulerian formulation is implemented into IGA in order to provide the basic tools for the numerical analysis of rolling bodies at steady state conditions. The solid basis of the formulation allows the employment of standard material models, but tire constructive elements, like reinforcing layers, require special attention. Streamlines are constructed based on the locations of the integration points and, therefore, linear and nonlinear viscoelastic models can be implemented. Numerical examples highlight the advantage of requiring less degrees of freedom for an accurate description of the geometry.

Tire contact stress/health assessment using acoustic emissions

Arash Nouri[1], Seyedmeysam Khaleghian[1], and Saied Taheri[1]

1 Department of Mechanical Engineering, Center for Tire Research (CenTiRe), Virginia Tech, Blacksburg, Virginia

Email: anouri@vt.edu

A non-contact tire health monitoring method based on air-coupled acoustic emissions is presented in this paper. The proposed method has two primary goals; recognizing the tire type, and determining the condition of the tire. In this study, the resulted acoustic emissions from the contact patch of different tires were measured by an acoustic sensor. Each Tire emits a characteristic signature response, significantly dominated by material properties, tread pattern, sidewall stiffness, and etc. In order to accurately and reliably monitor the tire condition, a high-fidelity characteristic signature contact patch response should be extracted. A procedure has been developed to extract the signature response of each tire contact patch, which is presented in the first part of the paper. After defining characteristic mutual features for the signature response, a statistical analysis is used to select the most significant features. The selected features are then used in a machine-learning based approach to determine the type and condition of a tire in a measurement. Three types of tires were used in this study, which were tested using an instrumented vehicle (VW Jetta) that was prepared for this purpose. Results confirm that the proposed process is able to detect the types of tires and their conditions.

Paper Number 4.2

Tire particle emissions: study of experiment designed to assess a statistical characterization

María E. Dalmau[1], Klaus Augsburg[1], Kristian Höpping[1], Felix Wenzel[1], Valentin Ivanov[1]

1 Automotive Engineering Group, Department of Mechanical Engineering, Technische Universität Ilmenau, Ilmenau, Germany.

Email: maria-eugenia.dalmau@tu-ilmenau.de

Tire emissions are recently becoming an important topic in environmental science and among visionary automotive engineers. According to a study in PM10 traffic emission values, recorded by the Dutch Emission Inventory, tires can contribute up to 49% of the total emission in a diesel LDV. This share will be increased soon regarding the fast spreading of electric vehicles. It is also expected to have future worldwide regulations in tire particle emissions. Therefore, deep understanding of the mechanisms involved in tire wear and emissions and their reliable physical/chemical characterization should be assumed as an urgent task nowadays.

With the aim to contribute to a trustworthy characterization of tire wear and emissions, this paper presents both (i) analysis of state-of-the-art in this field and (ii) experimental collection and analysis of particles from a rotating tire under a variety of driving (by setting toe angle, brake pressure and velocity) and boundary (by setting vertical load and tire pressure) conditions. To realize this goal in an efficient way, exhaustive samples of particles in a new developed test box have been drawn under an experiment designed for this particular purpose. The box includes a fan and a secondary repository capable of collecting all the particles emitted and re-suspended. Statistical treatment of the data was carried out according to DOE theory.

Chemical and morphologic characterization by scanning electron microscope was accomplished in order to reveal possible insight in the wear process. The tire profile and the weight of the collected particles were measured to account for the rubber losses and easily evaluate the efficiency of the proposed collection method. The obtained results give the basis for further methodologies for experimental assessment of tire emissions under different testing conditions.

The effect of rubber hardness and tire size on tire-pavement interaction noise

Tan Li[1], Ricardo Burdisso[1], and Corina Sandu[1]

1 Department of Mechanical Engineering, Virginia Tech, Blacksburg, VA 24061

Email: L@vt.edu

Tire-pavement interaction noise (TPIN) is a dominant noise source for passenger cars and trucks above 25 mph (40 km/h) and above 43 mph (70 km/h), respectively. TPIN is generated due to the excitations of the tread pattern and pavement texture. For the same tread pattern and pavement texture at the same speed, TPIN might also be influenced by the tire structure, e.g., the tread rubber hardness and tire size. In the present study, forty-two tires with different rubber hardness and/or tire size were tested at five different speeds (45-65 mph, i.e., 72-105 km/h) on a non-porous asphalt pavement (a section of U.S. Route 460, both eastbound and westbound). An On-Board Sound Intensity (OBSI) system was instrumented on the test vehicle to collect the tire noise data at both, the leading edge and the trailing edge of the contact patch. An optical sensor recording the once-per-revolution signal was also installed to monitor the vehicle speed, and, more importantly, to provide the data needed to perform the order tracking analysis in order to break down the tire noise into two components. These two components are: the tread pattern noise and the non-tread pattern noise. For the non-porous asphalt pavement tested, the non-tread pattern noise increases with rubber hardness by ~0.23 dBA/Shore A. The tire carcass width (section width plus two times section height) influences the central frequencies of the non-tread pattern noise spectrum; the central frequencies decrease as the tire carcass width increases.

Paper Number 5.1

Accounting for thermal effects in tire durability via a critical-plane-analysis compatible microsphere model

H Wang[1], YT Wei[1], JD Suter[2], MA Bauman[2], **WVMars**[2]

1 e-Rubber Tech. Co., Ltd., Department of Automotive Engineering, Tsinghua University, State Key Laboratory of Automotive Safety and Energy, Beijing, China.
2 Endurica LLC, 1219 West Main Cross, Suite 201, Findlay, Ohio, USA

Email: wvmars@endurica.com

Because rubber has low thermal conductivity, the mechanical energy dissipation occurring during tire rolling can manifest as a significant internal temperature rise. Steep thermal gradients develop between the inside of the tire and the external surfaces through which heat energy exits. This work demonstrates how temperature effects can be systematically considered when computing tire durability via critical plane analysis. Dissipation during tire rolling is computed via a microsphere model that samples, for each element centroid, the individual deformation experiences of a representative set of material line elements and material surface elements. Each material line element may undergo uniaxial deformations, and each surface element may undergo shearing characterized by the angle occurring between two parallel slip planes. The dissipation contributions of all line and surface elements are computed and integrated over the microsphere domain to produce a final dissipation rate for every element centroid. This information is then used in a thermal FEA to compute the temperature distribution in the tire. The fatigue life at each point in the tire is finally computed via Critical Plane Analysis, taking into account the temperature sensitivity of the crack growth rate law. The calculations are illustrated with results from a truck tire.

Effect of cam parameters in the tandem cam enveloping model on short obstacles using DOE approach

Vikas Birajdar[1], Madhu Kandampadath[1], Javad Baqersad[1], Mohammad Behroozi[2]

1 Kettering University
2 General Motors

Understanding the dynamics of a tire rolling on an uneven arbitrary road surface has always been a challenge for ride engineers. In numerical ride models, a realistic road enveloping algorithm is required to filter the geometries of an uneven arbitrary surface and accurately predict the road load forces on the axle. Prediction and calculation of effective road surface is more challenging with varying obstacle dimensions. A two dimensional, five degree of freedom rigid ring ride model has been developed at Kettering University (KUTire) based on rigid ring and tandem cam enveloping models. Selection of generalized cam parameters for uncompromising accuracy and improved runtime performance is a challenge through a specific ride simulation. A DOE approach is used to identify dominant control factors related to the tandem cam enveloping model which significantly affect the enveloping response. The accuracy of KUTire enveloping model is compared with experimental cleat test from low to high speeds. DOE results suggests an optimization direction for selection of cam parameters set in which a similar test-to-simulation correlation is achieved with improved computational efficiency. Further this study shows the predictions are robust against noise factor such as tire and road.

Paper Number 5.3

Optimization of tire design and construction parameters for cornering stiffness of temporary spare tires in passenger car vehicle category

Deepti Soni[1], Abhishek Bhatnagar[1], and Kartik M Shah[1]

1 J K Tire & Industries Ltd., Tech Center, Raghupati Singhania Center of Excellence, 437, Hebbal Industrial Area, Mysuru – 570016, Karnataka, India

Email: deepti.soni@jkmail.com

Tire plays a vital role in handling response, ride and stability aspects of the vehicle. These parameters are evaluated by subjective and objective testing on the testing track. Such evaluation requires lot of resources like expert driver, vehicle, instruments to measure objective parameters, certified test tracks etc. There are many parameters like tire design, construction, material etc. that influence the characterization of ride and handling. Therefore, this process of evaluation will be time consuming and expensive as effect on ride and handling need to be studied with different combination of the tire design & construction parameters.

The purpose of the present study is to use finite element analysis to simulate F&M. Design Of Experiment (DOE) is applied to identify and optimize critical parameters to have better handling (cornering). Hypermesh, ABAQUS (FEA) and Flat track machine have been utilized for FEM modeling and optimization respectively.

This paper summarizes simulation studies with the help of finite element analysis and some real time experiments to understand the effect of individual parameters of the ride and handling characteristics. These are part of this paper in order to derive the optimum tire design for R&H characteristics.

Paper Number 6.1

On the development of creep law for rubber in the parallel rheological framework

G. Sagar[1], D. Zheng[2], A. Suwannachit[2], M. Brinkmeier[2], K. Fietz[2], C. Hahn[3]

[1] Performance Prediction & Virtual Development, Continental AG, Jaedekamp 30, 30419 Hannover, Germany
[2] Mechanics & Simulation Development, Continental AG, Jaedekamp 30, 30419 Hannover, Germany
[3] Truck Tire Mechanics, Continental AG, Jaedekamp 30, 30419 Hannover, Germany

E-mail: gautam.sagar@conti.de

It is widely known that filler-reinforced rubber in tires shows a very complicated material behavior when subjected to cyclic loadings. One of the most interesting effects for rolling tires is the nonlinear rate-dependent behavior, which is implicitly linked to the amplitude dependency of dynamic stiffness (Payne effect) in the frequency domain. This effect, however, cannot be described by a conventional linear viscoelastic constitutive law, e.g., the Prony series model. A variety of nonlinear viscoelastic material models has been proposed in the last decades. Among others, Lapczyk et al. (2012) recently proposed a quite general framework for the class of nonlinear viscoelasticity, called Parallel Rheological Framework (PRF) which is followed by ABAQUS. The model has an open option for different types of viscoelastic creep laws. In spite of the very attractive nonlinear rate-dependency, the identification of material parameters becomes a very challenging task, especially when a wide frequency- and amplitude-range is of interest. This contribution points out that the creep law is numerically sound if it can be degenerated to the linear viscoelastic model at a very small strain amplitude which also significantly simplifies model calibration. More precisely, the ratio between viscoelastic stress and strain rate has to converge to a certain value; i.e. the viscosity in linear viscoelastic case. The creep laws implemented in ABAQUS are discussed in detail here, with a focus on their fitting capability. The conclusion of the investigation consequently gives us a guideline to develop a new creep law in PRF. Here, one creep law from ABAQUS that meets the requirements of our guideline has been selected. A fairly good fit of the model is shown by the comparison of the simulated complex modulus in a wide frequency and amplitude range with experimental results.

Viscoelastic material calibration procedure for rolling resistance calculation

Pablo N. Zitelli[1], Gabriel N. Curtosi[1], and Jorge Kuster[1]

1 FATE, Av. Blanco Encalada 3003, Buenos Aires, Argentina 54 11 4725-8100

Email :pzitelli@fate.com.ar

As tire engineers we are always interested in predicting Rolling Resistance using tools like numerical simulation and tests. When a car is driven along, its tires are subjected to repeated deformation leading to energy dissipation as heat. Each point of a loaded tire is deformed as the tire completes a revolution. The tire flexibility intended to absorb surface unevenness and develop a contact patch leads to energy dissipation which causes Rolling Resistance, besides the friction force in the mentioned contact patch. Rolling Resistance mainly depends on the viscoelastic energy dissipation of the rubber materials used to manufacture the tires. In order to obtain an accurate amount of dissipated energy, a good understanding of the material mathematical model and its behavior is mandatory. For this reason we developed a calibration procedure. To obtain a good Rolling Resistance calculation method it's necessary to calibrate all the rubber compounds of the tire at different temperatures and strain frequencies. In order to validate the calibration procedure we perform simulations to evaluate the error between tests and models. For implementing the calibration procedure in the finite element models of rolling tires, we briefly describe a procedure to take into account change in properties due to temperature during the simulations.

Paper Number 7.1

Tire vibration considerations in vehicle based tire testing

Anton Albinsson[1], Fredrik Bruzelius[1], Schalk Els[2], Bengt Jacobson[1], Egbert Bakker[3]

1 Chalmers University of Technology, Gothenburg, Sweden
2 University of Pretoria, Pretoria, South Africa
3 Volvo Car Group, Gothenburg, Sweden

Email: anton.albinsson@chalmers.se

Vehicle based tire testing can potentially make it easier to reparametrize tire models for different road surfaces. A passenger car equipped with wheel force transducers, optical slip angle sensors and dynamic camber angles sensors on each wheel was used to measure all input and output signals of the Standard Tire Interface (STI) during a ramp steer maneuver at constant velocity at AstaZero proving ground. In these measurements, large lateral force vibrations are observed for slip angles above the lateral peak force. Clear peaks are seen in the frequency spectrum of the lateral force signal at 50Hz and at multiples of this frequency. These vibrations can lower the average lateral force generated by the tires and it is therefore important to understand which external factors that influence these vibrations.
A Ftire model parameterization of the tires fitted to the vehicle in the vehicle based tire testing is used to investigate these vibrations. The Ftire model is parameterized based on standard tests used for Ftire parameterization by a commercial tire testing company. Some model parameters are changed to better fit the out-of-plane cleat tests. A simple suspension model is used together with the tire model to conceptually model the effects of the suspension on the vibrations. The sensitivity of these vibrations to different operating conditions is also investigated together with the influence of the testing procedure and testing equipment, i.e. vehicle and sensors, on the lateral tire force vibrations. The simulation results show that these vibrations can lower the average lateral force generated by the tire for the same operating conditions. The results imply that it is important to consider the lateral tire force vibrations when parameterizing tire models which do not model these vibrations. Furthermore, the vehicle suspension and operating conditions will change the amplitude of these vibrations and must therefore also be considered in maneuvers in which these vibrations occur.

Paper Number 8.1

Actual measurement of inner surface deformation of tire during getting over steps

Tomoaki Iwai[1], Ryota Imaizumi[1], and Yutaka Shoukaku[1]

1 Kanazawa University, Kakuma, Kanazawa, Ishikawa 920-1192, Japan

Email: iwai@se.kanazawa-u.ac.jp

Prediction and estimation of tire deformation is one of the most important factors for tire design. Soft wear simulation is often used to estimate how tire deforms however there are many reports about tire deformation. On the other hand, it is difficult to observe actual tire deformation during driving because tire deforms when the tire contact with mating road surface.
We have developed stereo vision using two cameras installed on tire wheel to observe inner surface deformation of tire. This method is able to measure the 3-dimensional deformation of tire inner surface by tracking feature points. In this study actual tire deformations are observed when a car gets over several steps with different heights. We will also discuss the influence of air pressure on the inner surface deformation.

Paper Number 8.2

Characterization of thermal influences on tire force and moment properties

Henning Olsson[1], David Gentz[1], Matthew Strang[1]

1 Calspan Corporation, 4455 Genesee St, Buffalo, New York 14225

Email: henning.olsson@calspan.com

Tire force and moment properties play a critical role in the safety and performance of today's road vehicles. Tire performance metrics such as cornering stiffness and coefficients of friction are often used to understand tire behavior from a vehicle dynamics perspective. These metrics are often derived from physical testing or computer simulation at different operating condition, such as load, slip and inflation pressure.
In physical testing, one aspect of the tire's operating condition that cannot be directly controlled is the tire temperature. In this study, extensive instrumentation was used to measure the temperature of different tire components such as tread, sidewall, inner liner and bead area during different operating conditions. From these measurements, the effect of temperature on the tire's force and moment properties could be identified. It was found that force and moment properties are affected in different ways depending on the distribution of the temperature within the tire.
This paper presents the effect of temperature level and temperature distribution on tire stiffness and grip properties. It also discusses how these identified variations in tire performance due to temperature affects tire data and tire models used in vehicle simulation studies. Finally, examples of test procedures suitable for this type of characterization are discussed.

Paper Number 8.3

Experimental measurement of in-plane rolling tire vibrations using high speed imaging

Meghashyam Panyam[1], Beshah Ayalew[1], Timothy Rhyne[2], Steve Cron[2], and John Adcox[2]

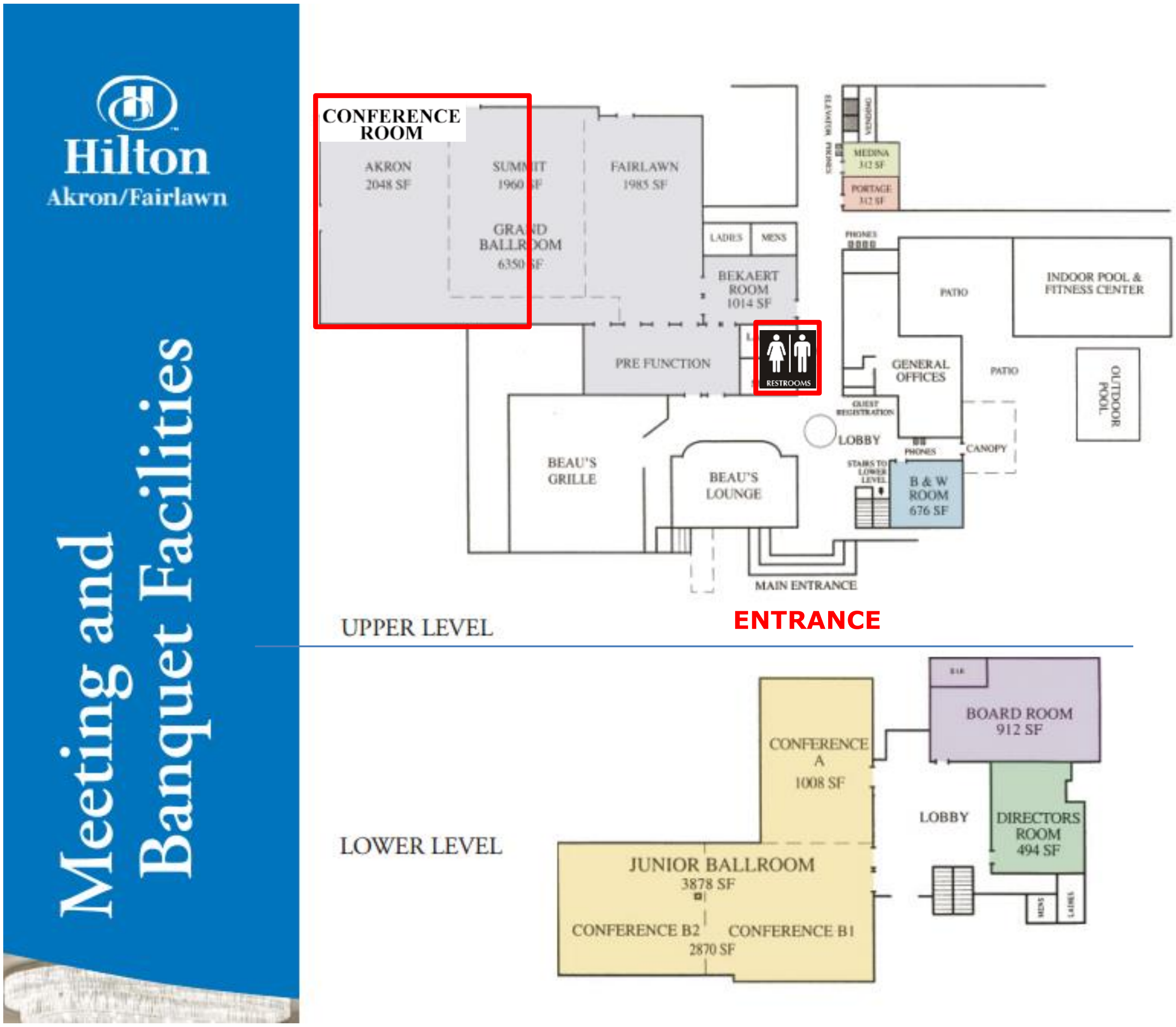
1 Department of Automotive Engineering, Clemson University International Center for Automotive Research (CU-ICAR), 5 Research Dr., Greenville, SC 29607
2 Michelin Research Corporation, 515 Michelin Rd, Greenville, SC 29605

Email: mpanyam@g.clemson.edu

This paper presents a novel experimental technique to measure in-plane deformations and vibration modes of a rotating non-pneumatic tire subjected to obstacle impacts. The tire is mounted on a modified quarter-car test rig which is built around one of the drums of a 500 HP chassis dynamometer at Clemson University's International Center for Automotive Research. A series of experiments are conducted using a high-speed camera to capture images of tire subject to static vertical loads as well as the event of the rotating tire contacting a cleat attached to the surface of the dynamometer drum. The resulting images are processed using a 2D digital image correlation algorithm to obtain in-plane radial and tangential deformation fields of the tire under static and dynamic excitations. The Dynamic Mode Decomposition algorithm is implemented on the deformation fields to extract the dominant frequencies that are excited in the tire upon contact with the cleat.

It is observed that the deformations and the modal frequencies estimated using this method are within a reasonable range of expected values. In general, the results indicate that the method used in this study can be a useful non-contact tool in measuring in-plane deformations of rolling tires without the need for additional sensors and wiring.

Venue Map



Hilton
Akron/Fairlawn
Meeting and Banquet Facilities
CONFERENCE ROOM
AKRON
2048 SF
SUMMIT
1960 SF
FAIRLAWN
1985 SF
GRAND BALLROOM
6350 SF
LADIES
MENS
BEKAERT ROOM
1014 SF
RESTROOMS
PRE FUNCTION
MEDINA
312 SF
PORTAGE
312 SF
PATIO
INDOOR POOL & FITNESS CENTER
GENERAL OFFICES
PATIO
OUTDOOR POOL
LOBBY
CANOPY
BEAU'S GRILLE
BEAU'S LOUNGE
B & W ROOM
676 SF
MAIN ENTRANCE
ENTRANCE
UPPER LEVEL
BOARD ROOM
912 SF
CONFERENCE A
1008 SF
LOBBY
DIRECTORS ROOM
494 SF
LOWER LEVEL
JUNIOR BALLROOM
3878 SF
CONFERENCE B2
CONFERENCE B1
2870 SF

The Tire Society, Inc.

36th Annual Business Meeting and Conference on Tire Science and Technology

September 12-13, 2017
Hilton Akron/Fairlawn Hotel
Akron, Ohio

Schedule Overview (detailed schedule inside)

Day 1 - Tuesday, Sept 12

7:00a....***Registration:*** Foyer (all day)

Day 1 Presentations:
Akron/Summit Ballroom

8:00a....***Welcome:***
Randy Jenniges, President

8:10a....***Keynote Address***
Dr. Juan Botero
Continental Tire, The Americas

9:10a... **Opening:**
Joshua Herron, Conference Chair

9:15a.... **Tire Performance**
2 Presenters

10:20a... ***Break / Refreshments***

10:40a... **Material Technology**
3 Presenters

12:15p... ***Lunch(Provided)***

1:30p ... **New Light on Tire Technology I**
3 Presenters

3:05p ... ***Break / Refreshments***

3:25p ... **New Light on Tire Technology II**
3 Presenters

5:00p ...Reception: Conrad Ballroom

6:00p ...**Banquet: Conrad Ballroom**

8:00p ...Close of Day 1

Day 2 - Wednesday, Sept 13

7:00a... ***Registration*** (half day)

Day 2 Presentations:
Akron/Summit Ballroom

8:00a... ***Opening:***
Joshua Herron, Conference Chair

8:05a.....**State of Society:**
Randy Jenniges, President

8:25a... **Simulations I**
3 Presenters

10:00a. ***Break / Refreshments***

10:20a. **Simulations II**
3 Presenters

11:25a... ***Lunch(Provided)***

1:00p... **Plenary Lecture**
Dr. Ron Kennedy
CenTiRe

2:00p... **Tire Vehicle System**
2 Presenters

2:35p... ***Break/Refreshments***

2:55p... **Experimental Technologies**
3 Presenters

4:30p... **Closing Remarks**