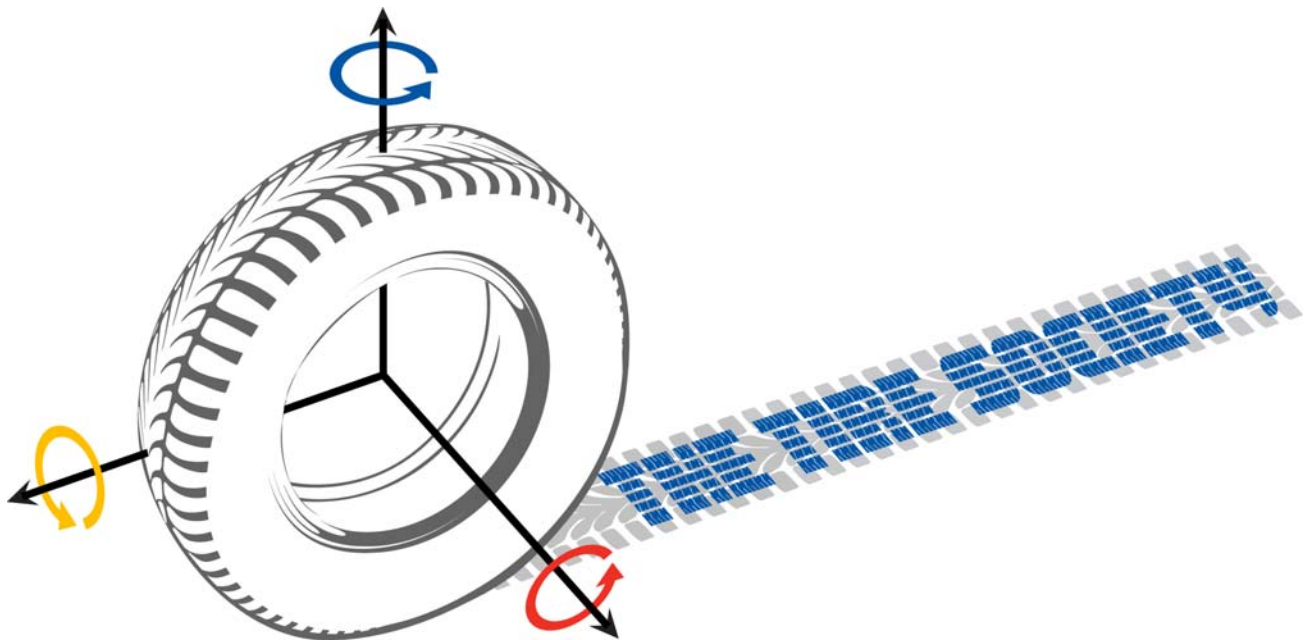


30th Annual Meeting and Conference on Tire Science and Technology

Program and Abstracts



**September 13-14, 2011
Hilton Akron/Fairlawn Hotel
Akron, Ohio**

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30th Annual Meeting and Conference on Tire Science and Technology

Hilton Akron/Fairlawn Hotel, Akron, Ohio, USA

Day 1 – Tuesday, September 13, 2011

All Technical Sessions located in the Akron/Summit Ballroom

7:00 AM	Registration – until 5:00PM (Foyer)	
8:00 AM	Conference Opening (Akron/Summit Ballroom)	Saied Taheri, Conference Chair
8:10 AM	Welcome (Akron/Summit Ballroom)	Dale Moseley, President
8:15 AM	Keynote Address (Akron/Summit Ballroom): Does Re-Inventing the Automobile Include Re-Inventing the Tire?	Terry Connolly, Director of Tire & Wheel Systems, GM
8:45 AM	Session 1: Friction & Wear	James Cuttino, Session Chair
8:50 AM	1.1 Analysis of the Influence of Driving Dynamic Parameters on Tire Marks	Gunther Seipel
9:15 AM	1.2 An Analytic Thermo Dynamical Approach to Friction of Rubber on Ice	Klaus Wiese
9:40 AM	1.3 Lab Test Based Wear Performance Prediction of Tread Compounds	Frank Schmerwitz
10:05 AM	Break (Refreshments - Foyer)	
10:15 AM	Session 2: New Light on Tire Technology 1 (Student Competition)	Marion Pottinger, Session Chair
10:20 AM	2.1 A Novel Approach for Thermomechanical Analysis of Stationary Rolling Tires within an ALE-Kinematic Framework	Anuwat Suwannachit
10:45 AM	2.2 Anti-Lock Brake System Control Using an Innovative Intelligent Tire-Vehicle Integrated Dynamic Friction Estimation Technique	Kanwar Bharat Singh
11:10 AM	2.3 Accelerometer Measurements of Tire Carcass Vibrations and Implications to Tire-Pavement Noise	Tyler Dare
11:35 AM	2.4 Interaction of Anti-Lock Braking Systems with Tire Torsional Dynamics	John Adcox
12:00 PM	Luncheon; Provided by The Tire Society (Conrad Ballroom) Tire Society Distinguished Achievement Award Presentation	Steve Vossberg, Selection Committee Chair
1:30 PM	Session 3: New Light on Tire Technology 2 (Student Competition)	Kory Smith, Session Chair
1:35 PM	3.1 An Implicit to Explicit FEA Solving of Tire F&M with Detailed Tread Blocks	Zhao Li
2:00 PM	3.2 Measurement of Water Film Thickness Due to Sipe Edges of Studless Tire	Akihiro Takim
2:25 PM	3.3 Evaluation of the Holistic Method to Size a 3-D Wheel-Soil Model	Timothy Reeves
2:50 PM	3.4 Observation of Water Behavior In the Contact Area Between Porous Rubber and Mating Surface During Sliding	Yusuke Minami
3:15 AM	Break (Refreshments - Foyer)	
3:30 PM	Session 4: Rolling Resistance	Patrick Keating, Session Chair
3:35 PM	4.1 On Road Fuel Consumption Testing to Determine the Sensitivity Coefficient Relating Changes In Fuel Consumption to Changes in Tire Rolling Resistance	Calvin Bradley
4:00 PM	4.2 How Low Can We Go - A Study on Minimum Rolling Resistance	Timothy Rhyne
4:25 PM	4.3 Tire Fuel Efficiency – Rolling Resistance, Traction, Tread Wear – the Optimum Oil to Get You There	Steven Tranguch
4:50 PM	End of Tuesday's Technical Sessions – Closing Comments	
5:30 PM	Reception (Conrad Ballroom)	(Cash Bar / Hor d'oeuvres)
6:30 PM	Dinner Awards Banquet (Conrad Ballroom)	
7:00 PM	Awards Presentation: 2010 Superior & 2011 Student Paper	Gary Tubb, Award Chair
7:20 PM	Dinner Speaker: Future Space Exploration Technology Challenges	Donald Palac, NASA Glenn
8:00 PM	Adjourn	

30th Annual Meeting and Conference on Tire Science and Technology

Hilton Akron/Fairlawn Hotel, Akron, Ohio, USA

Day 2 – Wednesday, September 14, 2011

All Technical Sessions located in the Akron/Summit Ballroom

8:00 AM	Registration – until 12:00PM (Foyer)	
8:00 AM	Opening/Announcements (Akron/Summit Ballroom)	Saied Taheri
8:10 AM	State of the Society	Dale Moseley
8:30 AM	Session 5: Finite Element Analysis (FEA) Part 1	Mohammed Sobhanie, Session Chair
8:35 AM	5.1 Optimized and Robust Design of Tires Based on Numerical Simulation	Michael Kaliske
9:00 AM	5.2 Investigating Applicability of the Meshfree Method to the Structural Analysis of Tires	Takehiro Noda
9:25 AM	5.3 Effectiveness of Tetrahedral Finite Elements in Modeling Tread Patterns for Rolling Simulations	Harish Surendranath
9:50 AM	Break (Refreshments - Foyer)	
10:05 AM	Session 6: Finite Element Analysis (FEA) Part 2	Josh Herron, Session Chair
10:10 AM	6.1 Prediction of Temperature Distribution of Steady State Rolling Tires	Emily Ledbury
10:35 AM	6.2 An Enhanced Finite Element Tire Model for Vehicle Crash Simulations	Emmanuel Bolarinwa
11:00 AM	6.3 Effects of Road Surface Texture to Tire Structural Borne Noise	Xianwei Meng
11:25 AM	Plenary Lecture (Akron/Summit Ballroom) The State of Research on Smooth, Safe, and Quiet Pavements in the U.S.	Steve Karamihas , U. of Michigan Transportation Research Inst
12:00 PM	Lunch – On your own	
1:15 PM	Session 7: Modeling & Simulation	Victor Li, Session Chair
1:20 PM	7.1 Pull: The Science of a Nuisance	Marion Pottinger
1:45 PM	7.2 Efficient Acquisition of Tire Data and Its Application in Vehicle Handling Simulation	Henning Olsson
2:10 PM	7.3 Nonlinear Viscoelastic Constitutive Law for Unvulcanized Carbon Black Filled Rubbers	Mahmoud Assaad
2:35 PM	Break (Refreshments - Foyer)	
2:50 PM	Session 8: Testing	Randy Cooper, Session Chair
2:55 PM	8.1 Advances in Fully Automatic Splice Quality Monitoring	Oliver Scholz
3:20 PM	8.2 Development of the Measurement Method of a Rotating Tire Surface Strain	Ryoji Hanada
3:45 PM	8.3 Tire Testing - Meeting the Needs of Tomorrow	James Cuttino
4:10 PM	Break	
4:15 PM	Session 9: Tire Road Contact	Xianwei Meng, Session Chair
4:20 PM	9.1 Experimental and Computational Studies of Contact Mechanics for Tire Longitudinal Response	Jacob Kidney
4:45 PM	9.2 Towards Tire-Road Contact Stresses and Pavement Design	Morris De Beer
5:10 PM	Closing remarks (Akron/Summit Ballroom)	
	End of Conference	

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.

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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:

JOURNAL ASSOCIATE EDITORS:

Axel Becker	<i>Continental AG</i>	Hannover, Germany
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In addition to the Executive Board, many members volunteered their time to put together the 2011 conference.

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Program Chair: Saied Taheri	<i>Virginia Tech University</i>
Assistant Chair: Lin Kung	<i>Nexen Tire</i>

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<i>James Cuttino</i>	<i>Camber Ridge, LLC</i>
<i>Josh Herron</i>	<i>Hankook Tire Company</i>
<i>Patrick Keating</i>	<i>Yokohama Tire</i>
<i>Victor Li</i>	<i>The Goodyear Tire & Rubber Company</i>
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The 2012 Conference...

Program Chair: Lin Kung	<i>Nexen Tire</i>
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The 2012 conference committee would appreciate your assistance and suggestions. A call for papers will be issued to attendees of the 2011 conference and will be available online. Visit www.tiresociety.org for updates.

Keynote Address



Terrence E. Connolly

General Motors, Detroit, MI, USA

Terrence (Terry) E. Connolly was appointed director for General Motors' Tire and Wheel Systems Group in October, 2008. In this role, he has been responsible for tire application engineering and wheel development across GM's brands and regions.

Terry has over 30 years of sustained contributions in engineering and business functions for General Motors. He began his career with Pontiac in 1979 focusing on chassis and powertrain development and has progressed through various technical positions in the vehicle and supply industry, including: Product Engineering Manager for Chevrolet Corsica/Beretta/Cavalier, Director of Program Management for Delphi Chassis, Chief Engineer for Chassis Systems at Delphi, Director - GMNA Product Safety Center, and GM Vehicle Integration Center Director - where he became a prime motivator for growth of vehicle integration knowledge in GM. Also in a recent role leading GM's Energy Center, Terry managed GM's fuel economy development and labeling activities. These experiences in energy, safety, and chassis control development bring him a somewhat unique perspective on the function tires deliver. In June 2011, Terry became the head of GM's Suspension, Chassis Structure, and Fastening engineering groups.

After growing up in central New York, near Syracuse, Terry received a Bachelor of Science degree in Mechanical Engineering from Princeton University in 1979. He earned a Master's degree in Business Administration from Stanford University in 1984.

He lives with his wife and three boys in Rochester, MI and is an active participant in his family's activities, including regularly coaching sports teams and chairing Cub/Boy Scout Troops, and the Ojibwa Scout District. As with many GM leaders, he is also an automotive enthusiast, re-living his youth through vehicle restoration projects!

Does Re-Inventing the Automobile Include Re-Inventing the Tire?

Pressures on automobile "re-invention" have huge prominence in virtually every country worldwide. There is a resulting stream of hybrids, electric cars, natural gas, fuel cells, etc coming to market; and depending on one's perspective these may evolve to a dominant market share in the near future. The automotive industry has not seen this much differentiation in vehicles since the fledgling industry included brands like the Detroit Electric and Stanley Steamer! Regardless of whether these technologies are indeed the "re-invention" or whether the internal combustion gasoline engine remains as the mainstay of propulsion – there is enormous pressure on improvement in parasitic losses, an area where the tire is conspicuous!

But those same fickle consumers of fuel economy want acceleration, stopping distance, and evasive maneuvering well beyond where even the highest performers were a decade ago. And the propulsion advances may focus the customer on smoothness and refinement more than ever before. Indeed the "re-invention" goes well beyond energy/environmental issues and into connectivity, safety, vehicle controls, and even dives deeply into how consumers use their vehicles.

In everyone's vision, tires will remain the linchpin of every dynamic characteristic in an automobile. The tire industry has a long and positive history of continuous incremental improvement benefiting the vehicle. Productive vehicle and tire business relationships/approaches were mostly cemented decades ago. But is some of this same stability going to disable "re-inventing the tire"? Vehicle manufacturers have a deep list of challenges (rolling resistance is only one!) for the tire industry. Finding solutions to some of these long-standing problems, and finding them fast, may be as critical to your business as it is to the automotive business!

Luncheon Presentation

Tire Society Distinguished Achievement Award



Takashi Akasaka (1925–2010)

Dr. Takashi Akasaka is the second recipient of the Tire Society Distinguished Achievement Award. This bi-annual award recognizes outstanding contributors to tire science and technology. A presentation is being given in his honor, to be accepted by his son Dr. Shuichi Akasaka.

A lifetime of achievement in tire science and technology and a record of contributions by Dr. Akasaka, along with his mentorship of additional researchers that went on to also contribute to this field of knowledge make him an ideal choice for this award.

Dr. Akasaka conducted and published contributions to tire research for over 50 years, beginning immediately after his undergraduate education in the 1940s and extending into the 21st century. He published 12 books and over 94 refereed papers dealing with applied mathematics and mechanics. Akasaka contributed many articles to the Tire Science and Technology journal. Furthermore, he encouraged and mentored many students who went on to become well respected, lifelong tire science researchers themselves, such as Doctors Shunichi Yamazaki and Kazuyuki Kabe. He received his doctorate degree based on his work with the role of cord inextensibility in cord-rubber composite behavior from the University of Tokyo at the age of 37. He did much of his work while a lecturer and professor at Chuo University.

His many insightful publications dealing with mechanical properties of cord-rubber composites first appeared in a series of internal university reports written during the 1950s. He developed sufficiently accurate but also simple equations for the various elastic constants of a single ply as well as for multiple-ply laminates of cord and rubber. Dr. Akasaka went on to apply these cord-rubber composite descriptions by modeling many different aspects of tire behavior. His knowledge of physics and skill in mathematics enabled him to develop analytical models that provide insight and understanding of the dominant physical mechanisms, thereby making tire design more physically understandable. He was also comfortable in the laboratory, using experimental methods to observe behaviors and corroborate models. Tire topics he addressed include tire cross-section natural shape, tire frequency response, cord compressive failure due to cornering, standing waves at high speed, hydroplaning, irregular wear, cornering properties and tire-to-ground contact pressure distribution.

Dr. Akasaka served as an associate editor from the beginnings of the Tire Science and Technology Journal until very recently, 1973-2008. As an invited speaker he delivered the Plenary Address at the 1984 conference.

In view of his long, proficient and distinguished career it is most appropriate to award The Tire Society Distinguished Achievement Award to Dr. Takashi Akasaka.

Dinner Speaker



Donald T. Palac

NASA John H. Glenn Research Center, Cleveland, OH, USA

Donald T. Palac is an engineering project manager for NASA John H. Glenn Research Center's research into nuclear surface power for the U.S. Space Exploration Policy. He joined the NASA staff in 1987.

His project management experience includes space transportation systems development, spacecraft and upper stage development, hypersonic access to space research, and electric propulsion and power research and development. He led development of the Discovery mission proposal that eventually became the Dawn spacecraft, and oversaw the development of Mars Pathfinder flight experiments from NASA Glenn. Prior to joining NASA, he served as an officer in the U.S. Air Force managing DOD spacecraft/launch vehicle integration, and was a Test Director for Defense Support Program early warning spacecraft initial on-orbit testing.

Don has a Bachelor of Science degree in Aeronautical and Astronautical Engineering from Purdue University, a Master of Astronautics degree from the Air Force Institute of Technology, and a Master of Business Administration degree from California State University at Dominguez Hills.

Future Space Exploration Technology Challenges

Expanding human presence beyond Earth orbit will require innovation, since the challenging environments that will be encountered are so unlike familiar terrestrial parallels. Interplanetary space itself offers temperature and radiation extremes that challenge the survival of electronics and humans. Every potential destination in the solar system has its own unique challenges, ranging from fine, sharp-edged dust that statically clings and vacuum-bonds to surfaces, to low gravity that upsets all paradigms for calculation of surface firmness and traction. NASA is currently reformulating its plans for future exploration beyond low orbit. Some of the most interesting and likely destinations will be reviewed, to include the technology challenges of the voyages and the destinations.

Plenary Lecture



Steven M. Karamihas

University of Michigan Transportation Research Institute

Steve is a senior research associate in UMTRI's Vehicle Systems and Control Group. He has dealt primarily with the interaction of vehicles and roads. His first major research project involved the coupling of vehicle dynamic loading and pavement response to predict the effect of truck characteristics on pavement life. Mr. Karamihas has also been heavily involved in the measurement and interpretation of longitudinal road profiles. He conducted a two-year research study of the effect of road roughness on automotive ride quality, user perception of pavement performance, and truck dynamic wheel loads. In this study, he was instrumental in developing an algorithm for estimating automotive ride comfort from measured longitudinal road profile, which became the latest version of the Ride Number. He has also conducted numerous studies of the factors that affect accuracy and repeatability of longitudinal road profile measurement.

Mr. Karamihas has expended considerable effort disseminating research findings on the measurement and interpretation of longitudinal road profile. Together with Mike Sayers, he developed the Little Book of Profiling and RoadRuf (specialized software for analyzing road profiles) for a pilot National Highway Institute (NHI) short course. Specialized versions of the course have been delivered several times for state and federal working groups.

Mr. Karamihas also operates the heavy vehicle suspension-parameter-measurement facility at UMTRI, where he has tested over 120 heavy vehicle suspensions. In addition, he has analyzed data from on-road heavy-vehicle ride tests and laboratory heavy-vehicle tilt-table tests. He earned bachelor's and master's degrees in mechanical engineering from the University of Michigan.

Areas of expertise: Vehicle Dynamics, Vehicle Parameter Measurement, Road Roughness

The State of Research on Smooth, Safe, and Quiet Pavements in the U.S.

This presentation describes recent and on-going U.S. research initiatives within the pavement community for improving pavement surface characteristics. This research examines the effect of pavement unevenness and surface texture on safety, noise, ride comfort, and durability with the goal of providing the public with improved pavement surfaces. The presentation discusses the state of practice in road surface measurement and characterization, the use of surface characteristics measurements as feedback during the pavement manufacturing process. The presentation summarizes recent research on the relationship between pavement texture and the potential trade-off between noise reduction and safety, and the coming transition to new standard pavement texturing methods.

The presentation concludes with a call for greater cooperation between the pavement research community and the Tire Society.

Analysis of the Influence of Driving Dynamic Parameters on Tire Marks

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Tire marks play a central role in the reconstruction of traffic accidents, as they can provide valuable information about the vehicle's trajectory, initial speeds or the steering and braking input of the driver. How the latest changes in vehicle and tire technology influence the applicability of these methods has not yet been completely ascertained. Changes in tire mark characteristics of modern vehicles due to chassis control systems or new types of tires can be observed. The research project described in this paper focuses on the analysis of tire marks under controlled conditions using a mono-wheel setup to permit a selective variation of different driving dynamic parameters without mutual influence. The long-term goal is to find a model for the development of tire marks which allows predicting the influence of specific driving dynamic parameters on the occurrence of tire marks. This model may be applied in accident reconstruction tools. A literature review has been performed to find evidence for the development of tire marks and to identify relevant parameters for their occurrence. Currently no explicit mathematical model showing the influence of tire forces or slip on the occurrence of tire marks is available. Many authors describe the development process mainly related to frictional heating of the pavement and tire tread wear. Based on these assumptions, a mathematical formula has been developed which allows the calculation of the dissipated friction energy within the contact patch as a function of the tire forces, the longitudinal slip and the side slip angle. The main hypothesis deduced from this formula is that the strength of a tire mark depends on the amount of this friction energy independent of the varying parameter. To verify this hypothesis, experiments have been conducted with variation of wheel load, longitudinal slip, sideslip angle and tire type. First results indicate a correlation between tire mark characteristics and dissipated friction energy. Nevertheless, modifications of the description model and additional tests with respect to different tire/road combinations and the influence of environmental factors are necessary. Further improvements of the tire mark analysis methodology focus on the refinement of methods to detect and quantify the visibility of tire marks.

An Analytic Thermo Dynamical Approach to Friction of Rubber on Ice

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The presented investigation is motivated by the need of performance improvement of winter tires, based on the idea of innovative “functional” surfaces. Current tread design features focus on macroscopic length scales. The potential of microscopic surface effects for friction on wintry roads has not been considered extensively yet.

We limit our considerations on length scales for which rubber is rough in contrast to a perfectly smooth ice surface. Thereby we assume that the only source of frictional forces is the viscosity of a sheared intermediate thin liquid layer of melted ice. Rubber hysteresis and adhesion effects are considered to be negligible.

The height of the liquid layer is driven by an equilibrium between the heat built up by viscous friction, energy consumption for phase transition between ice and water and heat flow into the cold underlying ice. Additional microscopic squeeze out phenomena of melted water due to the rubber asperities are also taken into consideration. The size and microscopic real contact area of these asperities are derived from roughness parameters of the free rubber surface using Greenwood-Williamson contact theory and compared with the measured real contact area.

The derived one dimensional differential equation for the height of an averaged liquid layer is solved for stationary sliding by a piecewise analytical approximation. The frictional shear forces are deduced and integrated over the whole macroscopic contact area to result in a global coefficient of friction. The boundary condition at the leading edge of the contact area is prescribed by the height of a “quasi liquid layer” which already exists on the “free” ice surface.

It turns out that this approach meets the measured coefficient of friction in laboratory. More precisely, the calculated dependencies of the friction coefficient on ice temperature, sliding speed and contact pressure are confirmed by measurements of a simple rubber block sample on artificial ice in laboratory.

Lab Test Based Wear Performance Prediction of Tread Compounds

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Wear performance of tires is given by a combination of the wear resistance of the tread material and the mechanical load of the rubber in the tire road contact. The known key parameters for wear rate are frictional energy, tread temperature and surface characteristics. For efficient tread compound development reliable and cost effective test methods are requested, which can predict the field relevant wear performance at lab scale. Although several lab test methods are well known for a long time, in practice the rating of compounds via vehicle testing contradicts lab prediction in quite a few cases.

The object of this paper is an improvement of lab prediction by an enhanced approach. Choosing a suitable contact pressure and slip angle as well as the temperature of the tread of a lab wheel, a steady state abrasion process can be realized and the repeatability of the measurement is improved. An important prerequisite for field relevant tread compound ranking is the usage of the same magnitude of the wear rate at lab scale as the wear rate of the tire in service. Therefore the friction mechanics is realistically mapped from tire conditions to the lab scale and a significantly better prediction of compound wear performance is achieved.

A Novel Approach for Thermomechanical Analysis of Stationary Rolling Tires within an ALE-Kinematic Framework

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It is widely known that rubber components in tire structures exhibit their inelastic behavior, like rate dependency and hysteresis, during rolling operations. The resulting internal dissipation is well recognized as the main cause of temperature rise, which changes mechanical properties and eventually the performance of car tires. Despite the fact that a variety of computational techniques for thermomechanical analysis of tires in stationary rolling contact have been suggested over the last three decades, most of them are extracted from the same modeling concept originally presented by Whicker et al.¹ A partition of the overall simulation process into three major steps (mechanical, dissipation and thermal module) is well accepted. Unfortunately, within this modeling concept the authors inevitably encounter the same problem with the calculation of energy loss in the second module since the behavior of rolling tires is only assumed to be nonlinear elastic in the first mechanical step. To this point a number of empirical solutions have been suggested. The application of linear viscoelastic constitutive relations is only found in a few publications, which is, however, not an appropriate choice if large deformations are concerned.

To avoid the problems with conventional approaches mentioned above, a new simulation technique is developed and presented in this contribution. Different from the existing approaches, the dissipative behavior of rolling tires is directly characterized by a finite-strain thermoviscoelastic constitutive model with options for specific rubber phenomena like frequency and temperature-dependent response. The simulation is performed within the Arbitrary-Lagrangian-Eulerian (ALE) kinematic framework, which allows for an efficient finite element implementation, such as a local mesh refinement of the contact region and time-independent formulation of the weak presentation of momentum balance. For the computation a three-phase staggered scheme is suggested. First the mechanical subproblem is solved using the developed thermoviscoelastic constitutive equations. Deformations and dissipation rates are then transferred to the subsequent thermal phase for the solution of heat equations. Finally, in the third step material history is treated by solving the advection equations using Time-Discontinuous Galerkin method within the spatially fixed finite element mesh.

¹ Whicker, D., Browne A. L., Segalman, D. J., and Wickliffe, L. E., "A thermomechanical approach to tire power loss modeling," *Tire Sci. Technol.*, Vol. 9, 1981, pp. 3-18.

Anti-Lock Brake System Control Using an Innovative Intelligent Tire-Vehicle Integrated Dynamic Friction Estimation Technique

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The contact between the tire and the road is the key enabler of vehicle acceleration, deceleration and steering. However, due to changes to the road conditions, the driver's ability to maintain a stable vehicle maybe at risk. In many cases, this requires intervention from the chassis control systems onboard the vehicle. Although these systems perform well in a variety of situations, their performance can be improved if a real-time estimate of the tire-road contact parameters (ranging from kinematic conditions of the tire to its dynamic properties) is available. This paper presents the implementation strategy for a real-time tire-road contact parameter estimation methodology using accelerometric (tri-axial) signals from an intelligent tire. Through post-processing of the acquired acceleration signals, it is possible to determine in real-time, information about the dynamic vertical load exerted on the tire and the tire slip angle. An observer developed using the sliding mode approach is used to make an estimate of the lateral and longitudinal tire forces. This method strictly uses measurements from sensors potentially integrable or already integrated in current production vehicles (yaw rate, longitudinal /lateral accelerations and steering wheel angle). An Extended State Observer (ESO) has been developed to make an estimate of the vehicle's longitudinal velocity and lateral velocity and hence the slip-ratio (assuming wheel rotational speed information is available from the ABS unit). An artificial neural network (ANN) based data fusion approach, combining the intelligent-tire information with the observer information was used to make a real-time estimate of the tire-road friction coefficient. Considering the strong interdependence between the operating road surface condition and the instantaneous forces and moments generated; this real time estimate of the tire-road friction coefficient is expected to play a pivotal role in improving the performance of a number of vehicle control systems. In particular, this paper focuses on the possibility of enhancing the performance of the ABS control by using the additional information provided by the intelligent tire. In order to achieve the aforementioned objectives, the design and implementation of a Fuzzy/Sliding Mode/Proportional Integral (Fuzzy-SMC-PI (FSP)) control methodology is proposed. The performance of the proposed system was evaluated through simulations on a series of braking maneuvers, emphasizing on jump - μ conditions. The results show significant improvements in the stopping distance of a vehicle equipped with an intelligent tire based FSP controller as compared to a vehicle equipped with a standard ABS.

Accelerometer Measurements of Tire Carcass Vibrations and Implications to Tire-Pavement Noise

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There are many analytical and finite element models for predicting vibration of a tire carcass. However, experimental verification of these models is limited because of the difficulties involved in measuring vibration near the contact patch of the tire. In this research, a set of experiments were conducted using a micro-accelerometer mounted against the tire carcass, in the center of the tread pattern. The tire was mounted on Purdue University's Tire-Pavement Test Apparatus, a machine that allows precise measurements of tire noise and vibration as the tire rolls over samples of actual pavement. Microphone and accelerometer signals were recorded simultaneously to determine the influence of pavement parameters on tire-pavement noise generation mechanisms. The vibration measurement and signal processing techniques are verified by comparing the results to previously published studies using accelerometers and laser Doppler vibrometers. The relationship between vibration characteristics and noise was investigated as a tire rolls over contraction joints in Portland cement concrete pavements. It was found that although there is a loud impulsive noise generated when the tire contacts a joint, there is much less change in the vibration levels. Therefore, increased tire-pavement noise due to contraction joints not solely the result of increased carcass vibration, and other mechanisms must also be involved.

Interaction of Anti-Lock Braking Systems with Tire Torsional Dynamics

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A tire's torsional dynamics couple the responses of wheel/hub inertia to that of the ring/belt inertia. Depending on the effective stiffness, damping and mass distribution of the tire, the ensuing deflections between the wheel and the ring can cause significant errors in the estimation of the tire's longitudinal slip from wheel speed measurements. However, this remains the established approach for constructing anti-lock braking (ABS) control algorithms. Under aggressive braking events, the errors introduced by torsional dynamics may significantly affect the ABS algorithm and result in less than optimal braking performance.

This paper investigates the interaction of tire-torsional dynamics and ABS control using a comprehensive system model that incorporates sidewall flexibility, transient and hysteretic tread-ground friction effects, and the dominant dynamics of a hydraulic braking system. It considers a wheel/hub acceleration-based ABS controller that mimics the working steps of a commercial ABS algorithm. Results from multiple sensitivity studies show a strong correlation of stopping distances and ABS control activity with design parameters governing tire/wheel torsional response, and the filter cutoff frequency of the wheel acceleration signals used by the controller.

An Implicit to Explicit FEA Solving of Tire F&M with Detailed Tread Blocks

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A detailed tire rolling model (185/75R14) using the implicit to explicit FEA solving strategy is constructed. High-quality hexahedral meshes of tread blocks are obtained with a combined mapping method. The actual rubber distributing, non-linear stress-strain relationship of rubber and bilinear elastic reinforcement are modeled to avoid a departure from the reality. A tread rubber friction model obtained from a Laboratory Abrasion and Skid Tester (LAT 100) is applied to simulate the interaction of the tire with the road. The F&M (force and moment) behaviors of tire cornering subjected to a slip-angle sweep of -8 to 8 degree are studied. To demonstrate the efficiency of the proposed simulation, the computed F&M are compared with results by the implicit solver as well as experimental results from a MTS Flat-Trac Tire Test System. The computed cornering forces agree well with experimental results. Furthermore the footprint shape and contact pressure distribution of several cornering conditions are investigated.

Measurement of Water Film Thickness Due to Sipe Edges of Studless Tire

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Water on an icy surface is wiped by the rubber edges of sipes of studless tires. However, it is said that the water on the icy surface forms a thin film rather than being removed completely. Relatively few studies have been reported on the contact condition of the rubber edges and the formation of a film of water due to wiping. In this study, the frictional properties and the contact areas of model sipes of studless tire were measured. In addition, the thickness of water film formed on the surface was also estimated by the optical interferometry method. Three types of styrene butadiene rubber with different levels of hardness were used as rubber specimens. The experiment was conducted by varying both the number of rubber edges and the slope angle between a glass disk and the rubber specimens. As a result, it was found that the contact area between the glass disk and the rubber edges with a slope angle of 0° tended to increase as the sliding speed increased. In the case of a slope angle of 0° , the coefficient of friction of single and double edges tended to decrease; however, the coefficient of friction of triple edges showed an upward trend. The thickness of the water film formed after the surface was wiped ranged from 0.98 to 1.46 μm , which increased as the slope angle became enlarged.

Evaluation of the Holistic Method to Size a 3-D Wheel-Soil Model

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The problem of a tire operating on deformable terrain requires extensive computational effort to simulate. Much of the effort goes into simulating the behavior of the soil because the soil response is three dimensional, dynamic, and nonlinear due to material behavior and large deformation. In order to reduce computational times as much as possible it is important to use no more soil volume than necessary. This gives rise to the need to determine an appropriate soil size, a process which itself has the potential to consume significant computational resources. A holistic method to size a dynamic 3-D wheel-soil model has been proposed previously with a demonstration of its effectiveness for a particular case. The method involves the simultaneous adjustment of all soil dimensions to find a large enough size to capture all significant soil deformations while not wasting computational resources on the simulation of unneeded material. The method is efficient because it requires significantly fewer simulation runs than would be required to treat the soil dimensions separately. While the method was effective for the case presented previously, this work has shown the method's applicability to a broader range of wheel-soil simulation problems. It has been tested with varying wheel aspect ratios, wheel sizes, loads and gravitational fields. The influence of these parameters on the effectiveness of the method has been evaluated and adjustments to the proposed method have been recommended. Also observations have been made regarding changes in the final required soil size with respect to changes in the parameters.

Observation of Water Behavior in the Contact Area Between Porous Rubber and Mating Surface During Sliding

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Porous rubber is often used as the tread rubber of studless tires because of its higher coefficient of friction on icy surfaces, which is due to the larger real contact area resulting from its lower elastic modulus.

It is also said that the real contact area is increased by the water absorption into the pores. Relatively few studies have been reported on the water behavior around the pores.

The purpose of this study was to clarify the effect of pores during sliding under wet conditions. As a result the absorption of water into the pores was not observed in this model. The pore contained an air bubble during the sliding. The water flow circumventing the air bubble above in the pore was also observed.

On-Road Fuel Consumption Testing to Determine the Sensitivity Coefficient Relating Changes in Fuel Consumption to Changes in Tire Rolling Resistance

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Tire rolling resistance is one of the primary forces opposing motion on passenger vehicles. New regulations appearing around the world will provide consumers information on tire rolling resistance. The linear relationship between fuel savings and rolling resistance has been previously demonstrated. Extensive testing in real world driving conditions has validated previous models. The result is a measured sensitivity coefficient for North American usage, which relates the changes in vehicle fuel consumption of E10 gasoline to changes in rolling resistance. This sensitivity coefficient is shown to not be significantly different between a compact car, a medium sized sedan and a full sized pickup truck. Results provide a simple and robust way for end consumers to predict the impact of tire choice on their fuel consumption and CO₂ emissions using tire label information.

How Low Can We Go - A Study on Minimum Rolling Resistance

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Tire rolling resistance has been a topic of study since the invention of the pneumatic tire. Currently there is a heightened interest due to the need to minimize fuel consumption of vehicles and the introduction of regulations regarding both the maximum allowable rolling resistance and consumer labeling for rolling resistance.

The question arises as to how low tire rolling resistance can go. Obviously if lossless materials are developed, the answer is zero. This is considered an unlikely event and thus the material loss properties are fixed in this study knowing that reduction in material loss will reduce rolling resistance proportionally.

This paper attacks the other part of the rolling resistance equation, the deformation part. The current paradigm of the steel belted radial tire is assumed. The minimum deformations required for the function of the tire are established and the assumption is made that all other deformations are parasitic and can in theory be eliminated. Analytical expressions for the necessary deformations are developed and the functional relationship for minimum rolling resistance is determined. The conclusions are substantiated by FEA simulations.

Tire Fuel Efficiency – Rolling Resistance, Traction, Tread Wear – the Optimum Oil to Get You There

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The North America (NA) tire industry is waiting for the labeling and consumer information portions of the tire fuel efficiency rule. The rules and labels have already been decided for Europe and Japan.

The final rule on tire fuel efficiency, mandated by the Energy Independence and Security Act of 2007 (EISA), was issued in March 2010, requiring consumer grades for rolling resistance, traction and tread wear.

Our paper will demonstrate by the proper selection of process oil, to optimize the levels of the three parameters of rolling resistance, traction, and tread wear, although diametrically opposite, can be achieved.

The paper will briefly touch on regulatory history; tire performance labeling in place, forecasted labeling for NA; present tire performance, and the effect of oil aromaticity to meet fuel efficiency standards.

Optimized and Robust Design of Tires Based on Numerical Simulation

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In this paper, a numerical approach to analyze tires based on a multi-objective optimization with special consideration of uncertainties is presented. Within the optimization, which uses evolutionary algorithms, the evaluation of a 3D Finite Element tire model in the steady state rolling situation is performed. In order to obtain a reliable and high quality design, data uncertainty caused e.g. by variation of production conditions of tire components as well as incomplete information concerning loading have to be considered. Modeling epistemic uncertainty, which results from fragmentary or dubious information, requires the application of the uncertainty model fuzziness.

Among several design goals, this study is looking at durability as an example. An improvement is achieved by the consideration of two objective functions: one is focusing on the reduction of wear and the other on providing a resistance to fatigue. The wear performance is strongly influenced by the distribution of contact pressure in the contact zone. Therefore, a criterion for obtaining optimal contact pressure ratios in the tire footprint is formulated. Within the second objective function, the occurrence of a fatigue crack is investigated by the evaluation of, for example, the strain energy density as a simple criterion. Additionally, in the proposed optimization concept the robustness measure is implicitly included. The robustness measure is defined as a ratio of the variation of uncertain simulation input parameters versus the variation of uncertain structural responses. Thereby, a high variation of uncertain input parameters leading to a minor variation of uncertain structural responses indicates a high robustness of the tire design. In order to improve the numerical efficiency of the proposed design approach, a response surface approximation based on artificial neural networks is applied.

Investigating Applicability of the Meshfree Method to the Structural Analysis of Tires

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In contrast to the finite element method (FEM) which is widely utilized in the tire industry nowadays, some alternative methods have been proposed by academic communities since the last decade or so. The meshfree method is one of those new methodologies. That is originally intended to get rid of the burden of creating the mesh which is inherent in FEM, namely the meshfree method relies on the point data rather than the mesh, which makes it quite easier to discretize the geometry. In addition to those modeling issue, it has been found that the meshfree method has several kinds of advantages over FEM in handling geometrical nonlinearities, continuities, etc. In accordance with those emerging possibilities, the authors have been conducting research on the matter. This paper describes the results of the authors' preliminary research on the applicability of the meshfree method to tire analyses, which include the theoretical outline, the strategy of tire modeling, numerical results, comparisons with results of FEM, and conclusions.

Effectiveness of Tetrahedral Finite Elements in Modeling Tread Patterns for Rolling Simulations

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Generating structured hexahedral finite element meshes on tread patterns is a challenging and laborious task due to the complex pattern geometry. However, creating good quality tetrahedral meshes on these geometries is relatively straightforward and can be fully automated. Despite the convenience and time saving, analysts have long avoided tetrahedral elements due to inadequate contact stress accuracy, which is critical for pattern wear prediction.

Recent advances in contact formulation and element technology have vastly improved the accuracy of contact stresses predicted by tetrahedral meshes. This paper presents a comparative study between the results predicted by tetrahedral and hexahedral meshes under slow rolling conditions. Comparisons are presented for footprint solution quantities like contact stresses, slip etc. as well as global solution quantities like lateral force and residual aligning torque.

Prediction of Temperature Distribution of Steady State Rolling Tires

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Tire heating is caused by hysteresis effects due to the deformation of tire rubber during operation, and frictional heating due to the friction between the tire and the road surface. Tire temperatures can depend on many factors, including tire geometry, inflation pressure, vehicle load and speed, road type and temperature and environmental conditions. In this paper, a thermal-mechanical finite element analysis (FEA) is presented in order to predict the stress/strain and temperature distribution in static and rolling tires. The proposed approach has three analysis modules: deformation, dissipation, and thermal modules. Each module solves a particular aspect of the analysis. The deformation module performs a finite element stress analysis to determine the strain and stress distributions within the tire for different vehicle weight, speed, inflation pressure and road friction. In the dissipation module, the heat source is calculated from the strain distribution and the hysteresis of the material. In the thermal module, the heat transfer analysis is done with a 2D steady state model including the hysteresis heat generation obtained from the dissipation module, and the thermal boundary conditions. The calculated footprint pressures, strain energy density, and the steady-state temperature distributions in the tire key areas are obtained, and compared with experimental data available in the literature.

An Enhanced Finite Element Tire Model for Vehicle Crash Simulations

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Over the years finite element (FE) tire models have been successfully utilized in the area of tire design, tire research and vehicle performance. This is largely due to the improvements in hardware computational facilities and the continuing emergence of user friendly commercial FE codes, which have encouraged the use of such models for a wide variety of applications. Despite these developments, the application of appropriate FE tire models for extreme conditions such as those experienced during vehicles sudden impact with roadside hardware is still not widely used. One reason may be concerns that crash simulations do not fully replicate real crash events. As vehicle behavior during such impact event is often influenced by the interaction of the tire with roadside hardware, existing tire models are not sophisticated enough to handle such extreme situations which are well beyond normal tire operating conditions. In view of this, the current study aims to develop an enhanced tire model that provides a realistic tire behavior representation for vehicle crash simulations. The modeling methodology in terms of the geometrical details, material characterization, and tire failure mode implementation is discussed. The comparison between FE vehicle model predictions using the enhanced tire model and some crash test results are also presented.

Effects of Road Surface Texture to Tire Structural Borne Noise

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Road surface characteristic is one of most important factors affecting tire structural borne noise performance. Past experience learnt that roughness of the road surface, texture and pattern such as cross cut rain groove etc can make tire road noise performance very different. This study is to characterize road surface as input to tire FEA model and predict tire dynamic response and spindle force. The surface roughness can be described as power spectrum density (PSD) random input and the cross-cut rain groove as predefined displacement spectrum. Depending on road surface textures, tire dynamic stiffness characterizes tire road noise performance better than tire spindle force transmissibility.

Pull: The Science of a Nuisance

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All tire constructions exhibit some inherent offsets in forces and moments, generically called pull forces. When radial tires became the predominant tire construction, pull forces became a nuisance to both tire and automotive manufacturers. Over the last four decades the science has become essentially complete, but confusion still occurs and scientific work is repeated. This results partially because there is not a comprehensive reference uniting the existing information. This paper is a comprehensive reference dealing with effects, measurement, sources, and how a frustrated service person can decide what is really going on within the context of a service facility.

Efficient Acquisition of Tire Data and Its Application in Vehicle Handling Simulation

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Tire force and moment data can be collected from laboratory testing or track testing using wheel force transducers. The data is then used to generate semi-empirical tire models. Examples of the two methods are presented and differences in the results between the two methods are discussed.

With novel simulation methodology, tire models have then been used to successfully predict vehicle handling characteristics. The influence of tire design changes on overall vehicle performance can quickly be evaluated both in terms of on-center stability and at the limit balance.

Nonlinear Viscoelastic Constitutive Law for Unvulcanized Carbon Black Filled Rubbers

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Rubber engineering design analysis requires a fundamental understanding of the mechanical behavior of polymers, especially in its unvulcanized state. It necessitates the establishment of a three-dimensional constitutive material law which accounts for the observed mechanical behavior. This law is required to produce realistic descriptions of the viscoelastic performance in a mathematically simple form that is easy to implement in engineering applications. This paper describes the theory of the Tschoegl-Chang-Bloch time-dependent nonlinear viscoelastic constitutive law. The experimental verification of this law is provided under different deformation fields and multiple load steps. Laboratory test procedures to obtain the parameters required to describe the material under consideration are provided in detail. A recursive form of the constitutive law, suitable for finite element application, is derived and coded in the FE commercial code ABAQUS via the user subroutine UMAT. Comparisons between the experimental observations, the theoretical results, and the numerical data are drawn for simple test models examined under creep or shear relaxation conditions. The excellent agreements observed indicate the suitability of the governing law in analyzing viscoelastic problems of unvulcanized carbon black filled rubbers.

Advances in Fully Automatic Splice Quality Monitoring

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The tire building process is still dominated by numerous manufacturing stages involving human interaction or supervision. One recurring task is the subsequent application of various material layers on the tire building drum. Currently point-laser triangulation sensors are used to monitor the material overlap, or splice, in usually three locations to detect gross manufacturing faults. The operator is required to visually inspect and if necessary correct problems.

With the transition to more automated tire production, fully automatic monitoring of the tire building process is a requirement. The application of sheet-of-light measurement at multiple stages of the tire building process allows complete 3D acquisition of the entire material layer for all layers, providing data significantly beyond splice measurement alone.

This paper presents a sheet-of-light based tire building measurement system, suitable for fully automatic monitoring of the layer application on the building drum. The operating principle is demonstrated along with data gained on a tire building machine. The various measurement possibilities with the availability of full 3D material data are discussed as well as the advantages and drawbacks associated with the design choices depending on the prerequisites given by existing machinery.

Development of the Measurement Method of a Rotating Tire Surface Strain

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To know the surface strain of a rotating tire at high speed has been requested from the former, not only to design the tire construction or tire material but also to verify FEM analysis results.

We adopted Sampling Moiré Method to measure the rotating tire sidewall strain when cornering and braking. This method, taken by two separate cameras at the same time the portion attached with grid sheet and analyzed the images can be gained the 3D shape. With this method, we can measure the tire deformed shape and surface strain with practical accuracy. To verify this, we measured two tires with different construction. The two results are clearly different, the measurement method was validated.

Tire Testing – Meeting the Needs of Tomorrow

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As new federal mandates, testing protocols, and efforts to improve safety come into play on the passenger car, light truck, and heavy trucking industries, the need for expanded tire testing capabilities becomes more and more evident. Incremental improvements have been made to existing testing configurations, with belt systems leading the way. Unfortunately, most existing systems have disadvantages and constraints that are accentuated by the higher loads, steer rates, and other testing conditions now demanded by the industry.

This presentation will discuss a new tire testing facility being developed in the Charlotte, NC region with the input of eight industrial affiliates from the automotive and tire industries. The facility takes the best features of current tire testing machines while eliminating many of the challenges. The result is a modular machine which advances testing capabilities such as high speed and high rate of steer dynamic testing, testing on paved surfaces, wet traction testing, high torque applications and cleat testing. In addition, the facility will allow quantification of the effects of ambient conditions on tire grip. Overall machine design and facility layout will be discussed, as well as time frame for construction.

Experimental and Computational Studies of Contact Mechanics for Tire Longitudinal Response

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Longitudinal traction and braking response of a tire is an important performance feature for vehicle applications. This presentation examines basic tire mechanics issues governing tire longitudinal response to drive and brake torque changes in dry surface conditions. The role of footprint contact response to longitudinal force change in traction and braking is examined. The interaction of local contact phenomena and global tire response is evaluated. The influence of tread pattern features on contact behavior is illustrated. Both experimental and computational evaluations of footprint response are presented. The evolution of mu-slip force development is examined and related to local contact behavior. Aspects of tire longitudinal response for steady state as well as transient conditions are examined. The significance of synergistic application of both experimental and computational tools in tandem is illustrated in clarifying the basic mechanics of tire longitudinal response.

Towards Tire – Road Contact Stresses and Pavement Design

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Optimization of road pavement design, especially towards the surface of the pavement, requires a more rational approach to modeling of truck tire-road contact stresses. Various road surfacing failures are given in this paper as examples, and it is shown that the traditional civil engineering tire model represented by a single uniformly distributed vertical contact stress of circular shape is inadequate to explain this type of surface failure. This paper therefore discusses the direct measurement of three dimensional (3D) tire pavement contact stresses using a flatbed sensor system referred to as the "Stress-In- Motion" (SIM) system. The SIM system (or device) consists of multiple conically shaped steel pins, as well as an array of instrumented sensors based on strain gauge technology. The test surface is textured with skid resistance approaching that of a dry asphalt layer. Full-scale truck tires have been tested since the mid- 1990s and experience shows that 3D tire contact stresses are non-uniform and the footprint is often not of circular shape. It was found that especially the vertical shape of contact stress distribution changes, mainly as a function of tire loading. In overloaded/underinflated cases, vertical contact stresses maximize towards the edges of the tire contact patch. Higher inflation pressures at lower loads, on the other hand, result in maximum vertical stresses towards the center portion of the tire contact patch. These differences in shape and magnitude need to be incorporated into modern road pavement design. Four different tire models were used to represent a single tire type in order to demonstrate its effect on road pavement response of a typical South African pavement structure. Only applied vertical stress was used for the analyses. It was found that road surface layer life can reduce by as much as 94 percent as a result of simply using a different tire model on the same pavement structure.

The Tire Society, Inc.

30th Annual Meeting and Conference on Tire Science and Technology

September 13-14, 2011
Hilton Akron/Fairlawn Hotel
Akron, Ohio

Schedule Overview (detailed schedule inside)

Day 1 - Tuesday, Sept 13

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

Day 1 Presentations: Akron/Summit Ballroom

8:00a ... **Opening:** *Saied Taheri,*
Program Chair

8:10a ... **Welcome:** *Dale Moseley,* President

8:15a ... **Keynote Address:**
Terry Connolly,
Director of Tire & Wheel Systems, GM

8:45a ... **Friction & Wear:** 3 Presenters

10:05a . **Break / Refreshments**

10:15a . **Student 1:** 4 Presenters

12:00p . **Lunch:** *Provided,* Conrad Ballroom
**Distinguished Achievement
Award Presentation**

1:30p ... **Student 2:** 4 Presenters

3:15p ... **Break / Refreshments**

3:30p ... **Rolling Resistance:** 3 Presenters

4:50p ... **Day 1 Technical Sessions
Closing**

Awards Banquet: Conrad Ballroom

5:30p ... **Reception**

6:30p ... **Dinner Banquet**

7:00p ... **Best Paper Awards:** *Gary Tubb,*
Awards Chair

7:20p ... **Dinner Speaker:** *Don Palac,*
NASA Glenn

8:00p End of Day 1

Day 2 - Wednesday, Sept 14

8:00a **Registration** (half day)

Day 2 Presentations: Akron/Summit Ballroom

8:00a **Opening:** *Saied Taheri,*
Program Chair

8:10a **State of Society:** *Dale Moseley,*
President

8:30a **FEA I:** 3 Presenters

9:50a **Break / Refreshments**

10:05a . **FEA II:** 3 Presenters

11:25a . **Plenary Lecture:**
Steve Karamihas ,
U. of Michigan Transportation
Research Inst.

12:00a **Advisory Board Meeting**

12:00a **Lunch Break**

1:15p ... **Modeling & Simulation:**
3 Presenters

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

2:50p ... **Testing:** 3 Presenters

4:10p ... **Break**

4:15p ... **Tire Road Contact:** 2 Presenters

5:10p ... **Closing Remarks**