27th Annual Meeting and Conference on Tire Science and Technology

Program and Abstracts

September 15-16, 2008
John S. Knight Center
Akron, Ohio

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27th Annual Meeting and Conference on Tire Science and Technology

Day 1 – Monday, September 15

7:30 AM		**Registration**	
8:00 AM		**Conference Opening**	Hans Dorfi President of The Tire Society
8:10 AM		**Technical Program Opening**	Jim McIntyre, Conference Chair
8:15 AM		**Session 1: Wear / Friction**	John Luchini, Session Chair
8:15 AM	1.1	Influence of Pattern Void on Hydroplaning and Related Target Conflicts	Bernhard Röger, Burkhard Wies, Reinhard Mundl
8:40 AM	1.2	The Unified Approach to the Optimization of the Tread Pattern Shape and the Cross-Sectional Contour of Tires	Naoya Ageishi, Yoshihiro Tanaka
9:05 AM	1.3	Tire Dry-Traction and Rolling Resistance Dependency	Mohamed Kamel Salaani, Larry Evans, John Harris, James D. MacIsaac Jr.
9:30 AM		**Break**	
9:45 AM		**Session 2: Vehicle Dynamics**	Terrence Wei, Session Chair
9:45 AM	2.1	Winter Tires: Operating Conditions, Tire Characteristics and Vehicle Driving Behavior	Burkhard Wies, Helge Dörrie, Carsten Schröder
10:10 AM	2.2	Influence of Friction Heat on Tire Traction on Ice and Snow	Martin Giessler, Frank Gauterin, Burkhard Wies, Klaus Wiese
10:35 AM	2.3	Effect of Tire Wear on Tire Force and Moment Characteristics	Robert J. Pascarella, Donald F. Tandy, Jr., Joseph W. Neal, John M. Baldwin, Jackie D. Rehkopf
11:00 AM		**Break**	
11:10 AM		**Plenary Lecture:** Membrane Theory - Tire Design 101 and a Valuable Research Tool	Tim Rhyne - Michelin
12:00 PM		**Lunch – Box Lunch Provided**	
1:00 PM		**Session 3: Student Papers**	Barry Yavari / Osama Hamzeh, Session Chairs
1:00 PM	3.1	Dynamics of a Siped Tire Tread Block on Rough Surfaces	Stefan Ripka, Gunnar Gäbel, Matthias Wangenheim
1:25 PM	3.2	Experimental Determination of the Effect of the Surface Curvature on Rolling Resistance Measurements	Thomas Freudenmann, Hans-Joachim Unrau, Mohanad El-Haji
1:50 PM	3.3	Energy Based Methodology for Material Characterization	Ryan Kupchella, Jacob Kidney, Wade Hutchison
2:15 PM	3.4	A Three-Dimensional Hyper-Viscoelastic Constitutive Model for the Dynamic Response of Rubber	Min Liu, Michelle S. Hoo Fatt
2:40 PM		**Break**	

Day 1 (Continued)

3:00 PM		**Session 4: Noise, Vibration and Harshness**	Lin Kung, Session Chair
3:00 PM	4.1	Ride-Enhancing Belt for a Non-Pneumatic Bicycle Tire	Kundan Kumar, Gerhard Scharr
3:25 PM	4.2	Cavity Noise Sensitivity Analysis of Tire Contour Design Factors and Application of Contour Optimization Methodology	H. M. Park, S. R. Kim, S. W. Hwang, K. H. Noh, C. T. Cho
3:50 PM	4.3	Reduction of Groove Noise of a Tire Using Slot Resonators	Shu Fujiwara, Keita Yumii, Takanari Saguchi, Kenshiro Kato
4:15 PM	4.4	Explicit Transient Finite Element Modeling of High Speed Uniformity	Mohammed Sobhanie, Desheng Li, Greg Shteinhauz, Greg Johanning
4:40 PM		**End of Monday's Technical Sessions**	
5:00 PM		**Social Time / Gallery Tours** – Akron Art Museum	
5:30 PM		**Cash Bar / Hors d'oeuvres**	
6:45 PM		**Dinner:** NASA's New Rockets: An Overview of the Constellation Program and the Ares Launch Vehicles	Scott R. Graham NASA Glenn Research Center

Day 2 – Tuesday, September 16

8:15 AM		**Opening/Announcements**	
8:20 AM		**State of the Society**	Hans Dorfi President of the society
8:45 AM		**Break**	
9:00 AM		**Keynote Address**	Mark Emkes - Bridgestone Firestone North American Tire
10:00 AM		**Break**	
10:20 AM		**Session 5: Component-Level Modeling**	Marion Pottinger, Session Chair
10:20 AM	5.1	Structure and Parameterization of MF-Swift, a Magic Formula-based Rigid Ring Tire Model	Antoine Schmeitz, Willem Versteden
10:45 AM	5.2	CDTireMC: A New Physical Tire Model for Spindle Load Prediction of Motorcycle Tires Including Very Large Inclination Angles on Rough Roads	Axel Gallrein, Manfred Baecker
11:10 AM	5.3	Comfort and Durability Tire Model Validation	Xiaobo Yang, Sudhakar Medepalli
11:35 AM	5.4	The Impact of Tire Measurement Data on Tire Modeling and Vehicle Dynamics Analysis	Thomas Hüsemann, Mark Wöhrmann
12:00 PM		**Lunch - Provided (in Tent)**	
1:00 PM		**Session 6: Structural Performance**	Jan Terziyski, Session Chair
1:00 PM	6.1	Laboratory Measurement of Tire Flatspot	Neel K. Mani, Michael A. Berzins, John L. Turner
1:25 PM	6.2	Fracture Mechanics of Elastomeric Structures: Experiments, Modeling and Tire Simulation	Michael Kaliske, Bastian Näser
1:50 PM	6.3	Thermomechanics of 3D Crack Propagation in Amorphous Polymeric Solids; Application to Predicting Belt Separation Failure in Automotive Tires	Kenneth N. Morman
2:15 PM		**Break**	
2:25 PM		**Session 7: Durability**	Terry Ruip, Session Chair
2:25 PM	7.1	Enhancement of Tire Durability by Considering Physics Interaction Between Thermo-Mechanical and Air Flow Field	Kenshiro Kato, Toshiya Miyazono, Masashi Yamaguchi, Makoto Tsuruta
2:50 PM	7.2	3D Digital Imaging Correlation: Applications to Tire Testing	Russ A. Moser, H. Jim Sube, John L. Turner, Paul Zakelj
3:15 PM		**Closing remarks**	
3:25 PM		**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 that is managed by a duly elected Executive Board of Tire Industry professionals who serve on a volunteer basis.

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Paper Number 1.1

Influence of Pattern Void on Hydroplaning and Related Target Conflicts

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Reinhard Mundl
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Performance Prediction of Hydroplaning via coupling of CFD (computational fluid dynamics) and FE modeling has delivered a detailed insight into the local mechanisms and root causes of hydroplaning but is still very time consuming and extensive.

The goal of the presented work is the development of simple of rules of thumb and easy to understand models to give the tire designer a quick approach to optimize the hydroplaning performance of his design concepts including the target conflicting trade offs.

Based on DOE study covering basic winter and summer tread patterns and tread compounds taking into account interactions, total void, longitudinal and lateral void distribution has been varied. Experimental designs have been tested concerning longitudinal hydroplaning behavior on front and rear driven cars and lateral hydroplaning. Most important target conflicting performance criteria like wet and dry braking, noise, rolling resistance, winter traction and force and moment characteristics among others have been tested additionally.

Existing models using hydrodynamic pressure influences have been reviewed and extended. A simple to use development tool has been programmed to quantify pattern design to get a quick prediction of tire performance changes ("Void Slider").

[1] Presenting Author

Paper Number 1.2

The Unified Approach to the Optimization of the Tread Pattern Shape and the Cross-Sectional Contour of Tires

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Structural optimization procedures based on finite element analysis (FEA) have been successfully applied in the tire industry so far and one can easily find a number of examples in published papers. In most cases, these concern themselves with the determination of the optimized cross-sectional contour of tires, which is one of the key elements to the tire design. To the authors' knowledge, however, there is another important element of tire design to be considered – that is the tread pattern. Although the tread pattern affects a lot of functionalities of tires like wear, handling, etc., numerical optimization methods have been rarely used for the design of tread pattern, due to the complexity of numerical identification of the design element.

The purpose of this work is to develop an optimization algorithm which can understand mutual relationship between the tread pattern shape and the cross-sectional contour, and the contribution ratio of each design parameter. To attain this purpose, a pattern shape optimization algorithm is first established by combining the basis vector method, (a well-known shape optimization method), FEA, and the response surface method through the parametric assignment strategy of the design of experiment method. Next, an optimization algorithm is constructed that can define the contour design factors and the pattern shape design factors as design variables at the same time. This algorithm is applied for optimization problems of real tire design. Finally, a discussion and conclusions about this work are given.

[1] Presenting Author

Paper Number 1.3

Tire Dry-Traction and Rolling Resistance Dependency

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This paper analyses the relation between dry-traction mechanical properties and rolling resistance of tires. The research was conducted as part of the technical development phase of a tire rolling resistance rating system by the National Highway Traffic Safety Administration (NHTSA).

This aspect of the research focused on examining possible trade-offs between tire rolling resistance (related to vehicle fuel economy) and tire traction (related to vehicle safety). Twenty five tires of different constructions and manufactures were tested on a MTS Flat Trac® flat-belt machine to estimate force and moment mechanical properties. Rolling resistance was measured using the SAE J1269© recommended practice on a 1.707-m diameter indoor roadwheel. The mechanical properties measured consisted of stiffnesses, peak frictions, and moment arms at the tire footprint area. These are estimated for all the tires and fitted to generic empirical models.

Regression analysis showed that laboratory rolling resistance correlated well with mechanical properties and can be predicted with a correlation factor of 0.9. This is based on a normalization procedure with the 16-inch ASTM F2493-08© Radial Standard Reference Test Tire for passenger tires and Michelin LT245/75R16 Radial LT® for light truck tires. The results suggest that the proportion of energy lost in rolling might be due to greater proportions of elastic and frictional energy than is reported in the published literature. Moreover, a relation between traction properties and rolling resistance can be developed with correlation greater than 0.9 if the sample size of tires is larger, and rubber compound viscoelastic properties are included. This typical relation would play an important role in providing accurate analysis of the possible trade-off between traction mechanical properties and rolling resistance.

[1] Presenting Author

Paper Number 2.1

Winter Tires: Operating Conditions, Tire Characteristics and Vehicle Driving Behavior

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The modern development process of winter tires requires intense subjective and objective evaluation of the tire properties on the vehicle, but also requires knowledge about the influence of relevant tire characteristics on vehicle driving behavior.

It is important to understand the influences of ambient conditions, such as temperature, track surface (asphalt vs. corundum) and tire inflation pressure on tire behavior. Tire characteristic results of a parametric study, using a fully climate-controlled interior drum test stand will be presented. The effect on tire characteristics and the resulting vehicle behavior will be discussed using vehicle dynamics simulation. Furthermore the consequences for an optimal design of modern high performance winter tires will be presented.

[1] Presenting Author

Paper Number 2.2

Influence of Friction Heat on Tire Traction on Ice and Snow

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The internal drum test bench of the Universität Karlsruhe (TH) allows tire performance measurements under controllable conditions. In cooperation with Continental AG a research project was initiated to focus on traction on ice and snow surfaces. The test chamber was upgraded with a cooling system, surface conditioners and a snow production system.

As a major result of these experiments, a strong correlation of thermal conditions and transmittable forces has been discovered. Furthermore, a high-speed infrared camera was used to monitor the temperature increase of the tire surfaces under traction.

This paper presents the developed theoretical model, which describes the time dependent temperature increase in the contact zone. Based on this model, a formula to determine the thermal limiting curve of force transmission on ice and snow was derived. The computed curves were verified through comparison with experimental data.

[1] Presenting Author

Paper Number 2.3

Effect of Tire Wear on Tire Force and Moment Characteristics

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In physical testing of vehicles at or near their handling limit, shoulder wear occurs that is not typical of normal customer use. It has been observed for decades that this type of severe cornering induced tire wear can have a significant effect on the force and moment characteristics of tires. In this study, this shoulder wear effect was isolated by testing tires in a controlled environment and objectively assessed for a number of tires of various brands and sizes. This testing shows how a tire's lateral force and overturning moment capacities increase significantly as the number of runs on a tire accumulates. Additionally, one particular tire make and model was placed on a vehicle to acquire one thousand miles of normal customer driving and then evaluated under the same simulated load conditions. The results confirmed that, irrespective of a tire break-in procedure, the increases in lateral forces of the tire in limit handling maneuvers were a product of the test induced atypical shoulder wear generated during the limit handling maneuver.

[1] Presenting Author

Plenary Lecture

Membrane Theory - Tire Design 101 and a Valuable Research Tool

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Paper Number 3.1

Dynamics of a Siped Tire Tread Block on Rough Surfaces

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Within the contact zone between tire and road, all normal and tangential forces have to be transmitted. The tread block is the only tire component that is in direct contact with the pavement and therefore is of special interest.

The rolling process of a tire can be seen as a chronology of single contact events between tread block and road surface, whereas exact details of the contact situation are usually unknown. The surface texture of the pavement comprises a large range of surface wavelengths, leading to a small area of real contact and to complex contact conditions.

Under braking or acceleration, sliding friction occurs within the footprint, especially at the trailing area of the contact zone. The tangential forces depend strongly on the contact conditions (e.g. surface texture, sliding velocity, normal contact pressure, temperature, tread block geometry and on the existence of a lubrication film). An intermediate layer not only lowers the friction coefficient, but changes the whole contact situation. This effect is considerably existent for siped tire tread blocks, which react in a different manner than non-siped tread blocks.

Within this publication the dynamics of siped tread blocks in contact with rough surfaces are analyzed and a mechanical model is presented to explain the observed phenomena. The simulation results are verified by experiments.

[1] Presenting Author

Paper Number 3.2

Experimental Determination of the Effect of the Surface Curvature on Rolling Resistance Measurements

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Vehicle and tire manufacturers usually perform rolling resistance measurements on external drums with diameters of 1.71 or 2.0 meters. The rolling resistance measured on these test benches is higher than the actual rolling resistance measured on a flat surface. This deviation is caused by the drums' curvature. In 1979, S. K. Clark aimed to solve this problem by developing a formula, which converts the rolling resistance of a tire measured on a curved surface into the corresponding rolling resistance on a plane. This formula is still used until today in ISO and SAE standards.

To verify Clark's universally accepted formula, a research project was initiated at the Universität Karlsruhe. A combined test bench that allows measurements on two external drums of different diameter and a continuous flat track with the same wheel suspension was built up and came into operation. The rolling resistances of six different tires on the three surfaces were measured under variation of operational parameters, such as tire load and inflation pressure.

Comparison of converted values from measurements on external drums with flat track measurements showed the necessity for an upgrade of the existing formula. By conducting a multiple regression analysis, which took various tire properties and operational parameters into account, a modified formula was derived. Application of this new formula on the measurement data of the six tires as well as on further measurements showed excellent results.

[1] Presenting Author

Paper Number 3.3

Energy Based Methodology for Material Characterization

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Optical methods using digital image correlation (DIC) are utilized to develop rubber constitutive tests. Two and three dimensional DIC systems are employed to measure strains on rubber specimens subjected to uni-axial, planar and bi-axial stress states. A special membrane inflation test was developed and is described for providing the bi-axial constitutive data.

Deformation-induced material property changes for the three modes of testing are quantified using a concept based on energy dissipation. The constitutive test strain ranges for each of the three modes are separately selected to equalize the material states.

The methodology is applied to filled rubber compounds in order to characterize them in terms of hyperelastic behavior. Evaluation and comparison of several common hyperelastic models are given and application to finite element modeling of a structural rubber specimen is described.

[1] Presenting Author

Paper Number 3.4

A Three-Dimensional Hyper-Viscoelastic Constitutive Model for the Dynamic Response of Rubber

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The development of a constitutive model to describe the dynamic response of a filled rubber compound is presented in this paper. A series of cyclic tension tests were done on the rubber compound under mean strains ranging from 0.2 to 0.5, strain amplitudes ranging from 0.05 to 0.2, and strain rates ranging from 0.1 to 10s-1. The cyclic strain-controlled test results showed material rate-dependence and hysteresis, and this motivated the development of a phenomenological-based, hyper-viscoelastic constitutive model. A Zener model, i.e., a spring in parallel with a Maxwell element, was assumed. The total stress was decomposed into a rate-independent equilibrium stress and a rate-dependent overstress. The springs were modeled as NeoHookean, while the damper was defined by a nonlinear viscosity function. Material constants for the constitutive model were calculated from the cyclic tension test results. Cyclic tension tests were also performed on a sheet with central hole to check the accuracy of the constitutive model. The constitutive model was implemented into ABAQUS Standard by user-defined material subroutine. The FEA simulation of the rubber sheet with a central hole demonstrated relatively good agreement with the experimental data.

[1] Presenting Author

Paper Number 4.1

Ride-Enhancing Belt for a Non-Pneumatic Bicycle Tire

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Bicycling, for many environmentally conscious urban-dwellers in Europe, is a smart means of transportation. A tire designed to operate without requiring pressurized air could prove helpful in promoting the use of bicycles. But a non-pneumatic bicycle tire, generally, does not provide pneumatic-like performance and ride quality. This paper proposes a ride-enhancing belt, to be mounted on the top of a non-pneumatic bicycle tire, that can greatly improve the ride quality. The ride-enhancing belt is formed integrally as a ring structure consisting of two thick cylindrical coaxial layers separated by multiple circumferentially and laterally spaced hemispherical knobs. Soft and solid hemispherical knobs of the belt compress locally under impact loads thereby providing a softer ride. The virtual development of proposed belt is also discussed in this paper.

[1] Presenting Author

Paper Number 4.2

Cavity Noise Sensitivity Analysis of Tire Contour Design Factors and Application of Contour Optimization Methodology

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Cavity resonance noise of passenger car tires is generated by interacting excitation between a tire structure and the fill gas (Air), and generally lies in frequency range of 200~230 Hz. As such, this noise is strongly perceived and may be a serious source of driver annoyance. Thus, many studies regarding the cavity noise mechanism and its reduction have already been conducted.

In this study, we conducted a vibro-acoustic coupled analysis between a tire structure and an air cavity. Using this analysis, we can more accurately simulate the tire noise performance in the region of cavity resonance frequency. An analysis of the effects of variation of tire contour design factors was conducted, using design-of-experiment methods. Finally, a multi-objective optimization was performed, using in-house codes, to reduce cavity noise level while minimizing loss of other performances, such as ride comfort and handling, caused by the variations of contour. As a result of this optimization, we derived an optimized contour shape, which satisfied the multi-objective performances.

[1] Presenting Author

Paper Number 4.3

Reduction of Groove Noise of a Tire Using Slot Resonators

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Circumferential tire grooves form pipes in the contact patch and generate the nuisance noise, for which the fundamental natural frequency is approximately 1,000 Hz for passenger car tires. The frequency coincides with the peak of pass-by noise spectrum. Therefore, controlling the groove resonance is of a main motivation of this paper to reduce environmental noise.

If one lateral slot end is terminated in tread rib and if the other end merges to a circumferential groove, it is found that the slot performs as a side-branch or a Helmholtz sub-resonator to counteract to the pipe resonance. The slot parameters such as cavity volume and the change in section area, determine the resonant frequency and effectively influence on the acoustic characteristics of whole groove space. Optimal slot geometry is widely investigated by using numerical analysis and validated by experiments. It is shown that the proposed tread design can significantly reduce groove noise without sacrificing other performances.

[1] Presenting Author

Paper Number 4.4

Explicit Transient Finite Element Modeling of High Speed Uniformity

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Tire non-uniformity is one of the most important sources of undesirable vibration and noise at high speed. Reducing variations in tire manufacturing processes is essential for improving tire uniformity. In addition, one could design a tire that is less sensitive to inevitable variation affecting tire uniformity.

In high speed uniformity (HSU) measurement, a tire is rolled against a road wheel at a fixed axle height at high speeds. Tire non-uniformity causes a variation in the measured spindle forces. The harmonics of tire spindle forces are a measure of the tire uniformity at high speeds.

In this paper, the high speed uniformity (HSU) of a P205/65R15 passenger tire with an eccentric rim was modeled using ABAQUS explicit finite element code. The rim eccentricity was a known source of tire run-out.

The developed methodology was used to evaluate the HSU sensitivity of tire constructions by comparing the resulted spindle force variations. Four tire constructions are considered in this paper. These constructions represent a combination of soft/hard crown with a soft/hard sidewall. Simulation results are compared with the experimental data, showing consistent observations.

[1] Presenting Author

Guest Speaker: Tire Society Banquet

NASA's New Rockets: an Overview of the Constellation Program and the Ares Launch Vehicles

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Following a brief overview of NASA's Vision for Space Exploration, Mr. Graham will describe NASA's plans to develop new human and cargo launch vehicles for the Constellation Program. These new vehicles, Ares I and Ares V, will be used to return humans to the Moon in the next decade. Ares I is the Crew Launch Vehicle which will be used to launch humans into low earth orbit. Ares V is the heavy-lift cargo launch vehicle that will be used to launch the lunar lander and other cargo. The presentation will include a short video animations depicting how these new vehicles will be used for future lunar exploration missions. The Glenn Research Center's roles and responsibilities for Ares will also be discussed.

Paper Number 5.1

Structure and Parameterization of MF-Swift, a Magic Formula-based Rigid Ring Tire Model

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Vehicle dynamic simulations require accurate, fast, reliable and easy-to-parameterize tire models. For this purpose, TNO has developed MF-Swift in close cooperation with the technical universities of Delft and Eindhoven.

MF-Swift is based on the well-known Magic Formula model of Pacejka, but extending to higher frequencies (60-100 Hz), shorter wavelengths (>0.2 m), and rolling over obstacles, by adding a rigid ring and obstacle enveloping model.

During the development of MF-Swift, great emphasis was given to experimental validation using laboratory experiments, with a special emphasis on accuracy. With increasing use of MF-Swift in the automotive industry, easy and reliable parameterization has become more important. Therefore, recent efforts have focused on improving the parameter identification process, so that it can be conducted by non-specialists with measurements performed using common test facilities.

This paper will discuss the MF-Swift parameter identification process. It will discuss the theory behind the parameter identification procedure, rather than describing the measurement procedure in detail.

The main topics that will be considered are:
- Magic Formula slip model
- Masses and moments of inertia
- Tire overall stiffnesses
- Rigid ring sidewall stiffnesses and damping
- Residual stiffnesses
- Enveloping model
- Constitutive relations

[1] Presenting Author

Paper Number 5.2

CDTireMC: A New Physical Tire Model for Spindle Load Prediction of Motorcycle Tires Including Very Large Inclination Angles on Rough Roads

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The full vehicle simulation for durability analysis is a well established technique in the development process of passenger car manufacturers. The respective road surfaces are designed to generate representative spindle loads and typically include events that will induce large tire deformations.

For motorcycle tire models, the large deformation scenario is important for two reasons: The sidewall length of motorcycle tires is small compared to passenger car tires, translating into very low aspect ratios (in terms of sidewall length) and due to large inclination angles, the distance of the rim crown to the road surface can be quite small.

After a short overview of the standard modeling technique used by the CDTire model family for passenger car tires the new motorcycle tire model is introduced. Its parameter identification process is sketched, utilizing static and stationary measurements as well as cleat run measurements. Finally, some selected test rig validation results including cleat runs with high camber angles are compared to measurement results.

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Paper Number 5.3

Comfort and Durability Tire Model Validation

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A valid durability tire model has been highly expected to be applied for vehicle development for a long time. Many efforts from industry and academic sectors have been devoted to develop durability tire models capable of accurate road loads predictions. The fundamental questions associated with tire model applications are how accurate the currently available tire models are and should be? So far these questions have not been clearly answered. As a result, the application of durability tire model is still very limited.

In this study, a systematic validation of LMS comfort and durability (CD) tire models will be given by focusing on the measured tire data collection, bench test and full vehicle model prediction. Different road events will be considered in the validation process, including deterministic and random type events. It is expected that the study will answer the above mentioned fundamental questions and lead to a broad application of tire models in vehicle development process to enhance the product quality and reduce development cost.

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Paper Number 5.4

The Impact of Tire Measurement Data on Tire Modeling and Vehicle Dynamics Analysis

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Computer aided engineering tools play an important role in today's vehicle development process. Today, overall vehicle dynamics analysis and chassis component fatigue resistance investigations can be carried out without the need for existing prototype hardware versions of the corresponding vehicle.

An accurate tire model is a key element in precise modeling of the vehicle and its components. All forces acting on the vehicle (except for aerodynamic forces) are transferred via the tires. Therefore, the tire and its modeled characteristics have a major influence on the results of vehicle dynamics analysis.

At present, many tire simulation models are available for application in vehicle dynamics analysis. To obtain best possible performance from these models, a number of different tire measurements are required to support the tire model parameter identification process.

This paper presents a review of different tire simulation models and their required tire measurements. Depending on the test rigs used and the measurement procedures applied, the tire measurement results may be somewhat different. What is the impact of these differences on the tire modeling performance and the vehicle dynamics analysis output? This paper gives an answer.

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Paper Number 6.1

Laboratory Measurement of Tire Flatspot

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Tires flatspot when they remain loaded without rolling for a period of time. The magnitude of this flatspot and the speed with which it recovers due to subsequent rolling are influenced by the temperature, load and tire speed before and after flatspot.

Experience indicates that controlled measurement in the laboratory is the best way to measure the flatspot characteristics of tires. However, the laboratory test procedure must be based on the flatspot and recovery conditions the tire experiences in the field for the measurements to truly represent tire performance. Processing of the experimental data to compute the initial flatspot and its decay due to rolling also requires special care since the flatspot decays from the first revolution of the tire after flatspot. Effects of flatspot on a tire can be measured in many ways using low or high speed uniformity measurements or by measuring the radial runout of the tire.

This paper will address the issues involved in flatspot measurement of tires and also present mechanistic explanation of the influence of test conditions on flatspot.

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Paper Number 6.2

Fracture Mechanics of Elastomeric Structures: Experiments, Modeling and Tire Simulation

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Durability investigations for structures like the tire need to be based on physical foundations in order to yield reliable results. In this paper, fracture mechanics serves as basis for the investigation from the experimental and computational point of view.

With the material force method at hand, fracture mechanical investigations can be performed in a very efficient manner. Further, the theory of material forces is extended to materials with dissipative effects as found for rubber (rate-dependent and rate-independent inelasticity, Mullins effect). In the context of the finite element method, material nodal forces, representing the J-Integral at crack tips, can be computed on such complex structures as tires. A ranking between different tire designs is possible for the same material around the crack tip. In order to investigate the influence of different compounds, fracture mechanical material parameters (as given by Paris-plot) must be taken into account.

Fundamental experimental results as well as theory and implementation of the material force method for dissipative materials are shown in this contribution. To demonstrate the accuracy of the method and its applicability, the results of fracture mechanical material tests are reproduced and the durability of belt edges of a truck tire are investigated.

[1] Presenting Author

Paper Number 6.3

Thermomechanics of 3D Crack Propagation in Amorphous Polymeric Solids; Application to Predicting Belt Separation Failure in Automotive Tires

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Using the theoretical developments presented in this paper, a capability for the finite element analysis of rolling tires has been developed to aid in the evaluation of the conditions and mechanisms leading to belt edge separation (BES) failures in automotive tires. The model is capable of analyzing both real and hypothetical tire designs under different operating conditions from a detailed description of the cross-section geometry specifying those areas of differing mechanical and thermal properties and an accurate description of those properties. Given a set of operating conditions (load, inflation pressure, ambient temperature, etc.) and a steady-state driving cycle, the model is capable of predicting all of the mechanisms contributing to the BES tread separation failure including: tire inertia effects, material hysteresis and heat build-up, crack initiation and growth, tire pressure, loading and rolling speed.

Paper Number 7.1

Enhancement of Tire Durability By Considering Air Flow Field

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Rolling tire performance is frequently affected by multiple physics. For instance, dry handling is influenced by the tire temperature as a consequence of the heat generation by material viscosity and the heat transfer to ambient air. The general phenomenon is complex and even interactive in that the elasticity parameter affecting tire deformation is a function of the temperature and that the temperature depends considerably on the air flow on tire surface.

This paper refers to connecting the different physics of outside air flow and thermo-mechanical system of tire. Especially, the heat transfer across tire surface is focused from the view point of thermo-fluid dynamics. Macroscopic flow turbulence to accelerate the heat transfer is studied in a case study of the run-flat tire, where high temperature due to very large deformation is of a key issue. Numerical simulation is conducted in parallel to experimental works in assessing heat flow and temperature on the surface. It is shown that the proposed geometry of rib sidewall reduces the tire temperature and improves the tire life remarkably.

[1] Presenting Author

Paper Number 7.2

3D Digital Imaging Correlation: Applications to Tire Testing

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Three-Dimensional Digital Imaging Correlation (DIC) techniques are a viable method for measuring surface displacements and strains on tires. DIC provides the capability to measure the full-field non-contact tire surface deformation and strain state, which supports multiple objectives: validation of tire models based on finite element (FE) predictions, setting targets for improving FE predictions and providing insight into the tire deformation state under static and dynamic conditions.

A method for verifying the accuracy of the DIC measurement process is presented whereby a thin, rectangular test sample of rubber material is subjected to a combination of strains and rigid body motions of known amounts. Once the measurement technique is proven accurate with a simple specimen, the focus shifts to the objectives explained above. Tire surface strains will be discussed for purposes of validating model predictions of sidewall and belt edge strains. Several types of specimen geometries will be reviewed and their effect on material properties will be presented. Also, the DIC technique can provide insight into complex physical problems that may otherwise be very difficult to measure. Some examples presented here include tire sidewall standing waves at high speeds and strains near tread lugs of agricultural tires.

The DIC measurement method is an accurate, non-invasive full field technique for measuring in-plane surface displacements and strains of the magnitudes encountered in tire analysis. This technique serves many functions and has become a valuable tool for both tire testing and development.

[1] Presenting Author

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The Tire Society, Inc.

27th Annual Meeting and Conference on Tire Science and Technology

September 15-16, 2008
John S. Knight Center, Akron, Ohio

Overview (detailed schedule inside)

Day 1 – Monday, September 15

7:30 Registration

8:00 Opening Remarks: *Hans Dorfi*, President of The Tire Society

8:10 Program Opening: *Jim McIntyre*, 2008 Tire Society Program Chair

8:15 **Session 1**
Wear / Friction
3 presentations

9:30 Break (15 minutes)

9:45 **Session 2**
Vehicle Dynamics
3 presentations

11:00 Break (10 minutes)

11:10 **Plenary Lecture**
Speaker: *Dr. Tim Rhyne*
Michelin

12:00 **Lunch - Box Lunch Provided** (1 hour)

1:00 **Session 3**
Student Papers
4 presentations

2:40 Break (20 minutes)

3:00 **Session 4**
Noise, Vibration and Harshness
4 presentations

4:40 End of Technical Sessions

5:00 **Social Time / Gallery Tours**
At Akron Art Museum

6:45 **Dinner**
Speaker: *Scott Graham,*
NASA: Launch Systems Project Office

Day 2 – Tuesday, September 16

7:30 Registration

8:15 Opening/Announcements

8:20 **State of the Society**

8:45 Break (15 minutes)

9:00 **Keynote Address**
Speaker: *Mr. Mark Emkes*,
Chairman & CEO: Bridgestone Firestone North American Tire

10:00 Break (20 minutes)

10:20 **Session 5**
Component-Level Modeling
4 presentations

12:00 **Lunch - in tent** (1 hour)

1:00 **Session 6**
Structural Performance
3 presentations

2:15 Break (10 minutes)

2:25 **Session 7**
Durability
2 presentations

3:25 **End of Conference**