43rd Annual Conference and Business Meeting on Tire Science and Technology

Beyond the Surface: Models, Materials, and Manufacturing

Speakers and Abstracts

September 11th – 13th, 2024

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Invited Speakers

Keynote Address

Rob Williams
President
Hankook Tire America

Title of Talk:
Adapting to Change: Leveraging Technology as a Catalyst for Innovation.

Mr. Williams has been serving as Senior Vice President of Commercial and Consumer Sales since 2022 for Hankook tire America. In January 2023, Williams was appointed to President for Hankook Tire America, overseeing the U.S. and Canada regions. He leads four departments and direct teams including the Tennessee Plant and TBR sales department, a role he's held since joining Hankook in January 2019. Williams has 33 years of tire and automotive experience. Prior to joining Hankook, Williams, served as Vice President of Automotive Car Care Centers for AAA Carolinas. He also served in operations and sales roles at Michelin, as the Region Director for Commercial Sales & Operations and then developed to Vice President of Commercial Operations. Earlier in his career, he also worked for Goodyear Tire & Rubber as a District Manager – Consumer Division. Williams is a graduate of Virginia Commonwealth University with a degree in Business Administration and Management and currently resides in Mt. Juliet, Tennessee, with his wife and two children.

Plenary Lecture

Tom Ebbott
Vice President
Endurica, LLC

Title of Talk:
Modeling, Materials, and the Move Towards Virtual Product Development

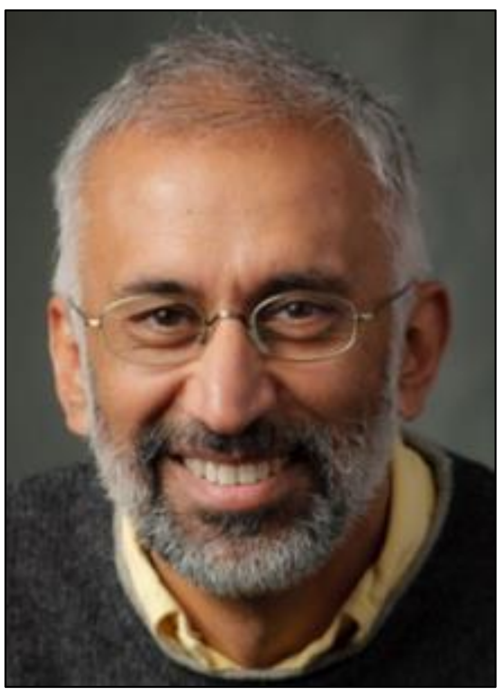
Tom received his PhD from the University of Wisconsin with a research topic of fracture and crack growth in polymers. He is a tire industry veteran known for his leadership in driving advances in modeling, simulation and workflows across a global organization. He joined Endurica in 2022 after a 35-year career at Goodyear. While at Goodyear, he held various technical and leadership positions with experience in product development, technology development, modeling and simulation, and materials characterization. He was a major contributor to multiple technical partnerships. He also enjoyed a two-year assignment at Goodyear's technical center in Luxembourg as the Manager of Computational Mechanics. He has published many technical papers and received numerous awards for his technical achievements.

Banquet Speaker

Anand Jagota
Professor & Bioengineering Chair
Lehigh University

Title of Talk:
Controlling Adhesion and Friction of Soft Interfaces by Meso-Scale Structures

Discoveries of unique adhesive and frictional properties in biological attachment systems have, over the past two decades, demonstrated how near-surface architecture at lengths between the molecular (a few nm) and continuum (mm) scales can be used to achieve interesting and unique surface mechanical properties. This has spurred considerable research activity in design of meso-scale, near-surface architecture (typically at micron to mm length scales). This talk will present some of our group's contributions to this field, including design and understanding of film-terminated fibrillar structures for adhesion enhancement, switching by a crack-trapping mechanism, shape-complementary interfaces for controlled adhesion and friction, and enhancement of elasto-hydrodynamic friction by surfaces with periodic modulation of properties.



Anand Jagota is Professor of Bioengineering and Professor of Chemical and Biomolecular Engineering, and Vice-Provost for Research at Lehigh University. His training is in Mechanical Engineering, from IIT Delhi for undergraduate studies and Cornell University for graduate work. He worked for nearly 15 years as a materials scientist at the DuPont company and moved in 2004 to Lehigh University. His research interests are in interfacial mechanical properties.

Oral Presentations

Estimation of Feasible Ranges of Tyre Characteristics for Vehicle Lateral Dynamics using a Tyre Resizing Tool

Mathias Lidberg[1], Xin Li[2]

[1]Fraunhofer-Chalmers Centre, Gothenburg, N/A, Sweden.

[2]Volvo Cars Corporation, Gothenburg, N/A, Sweden

Abstract

For vehicle original equipment manufacturers (OEM), determining the optimal tyre dimensions in the early phase of vehicle development is a challenging and costly task. In this phase, there are great uncertainties in vehicle parameters and there is a large variety of tyre dimensions and tyre lines to choose from.

Balance needs to be achieved among packaging space and some core vehicle attributes such as ride comfort and yaw stability. Battery electric vehicle has further reduced the tuning window. To make a robust and accommodative vehicle platform, large number of wheels and tyre inputs corresponding to various dimensions and tyre lines need to be assessed. There are several studies on the assessment of virtual tyre designs in the early vehicle design process. However, the gap of communicating the feasible range of tyre/vehicle characteristics still exists.

The aim of the study is to establish a methodology to communicate desired tyre characteristics that enables joint-development between vehicle OEM and tyre manufacturers in the early phase of a vehicle project.

Presenting Author Biography

Dr. Mathias Lidberg is a Researcher at Fraunhofer-Chalmers research center in industrial mathematics. Prior to PhD studies, he was an Engineering Analyst and Project Manager with Mechanical Dynamics Inc. (now Hexagon). His primary research area is integrated powertrain and chassis control. Currently, he is working on tire CAE for electric vehicles and he is also teaching graduate and post-graduate students his course in Handling Dynamics and Control. Furthermore, Dr. Lidberg is the co-founder of one start-up company in the automotive area.

Viscoelastic Material Constants Calibration Procedure using Optimization for FE Analysis

Sairom Yoo, Yongsu Kim, Kideug Sung

NEXEN Tire, Seoul, Gangseo-Gu, Republic of Korea

Abstract

In tire finite element analysis (FEA), the definition of material properties is essential for obtaining accurate results. In the case of rolling resistance analysis that requires high precision, the definition of viscoelastic material affects the accuracy of the analysis. Abaqus, a commercial finite element analysis program, provides the Prony model as a viscoelastic material model. Prony model material constants are obtained by curve fitting the storage modulus E' and loss modulus E" from experiment with Dynamic Mechanical Analysis (DMA). If the experimental results are directly applied without going through the calibration procedure between the experiment and FE analysis, the FE analysis may produce unexpected results. These errors are caused by the storage modulus E' and loss modulus E" being fitted with experimental errors, so the FE analysis material behavior does not match the experiment. Therefore, in this study, to compensate for this problem, we used Bayesian optimization technique based on the stress-strain hysteresis curve, as well as storage modulus E' and loss modulus E" data, to obtain viscoelastic material constants verified through finite element analysis. This approach aims to obtain viscoelastic material constants that are validated through finite element analysis, compensating for potential discrepancies between experimental data and finite element analysis results.

Presenting Author Biography

PhD in Mechanical Engineering from Korea Aerospace University, Nexen Tire, Central Research Institute, Design Analysis Team Researcher

Computational Analysis of Rubber-Snow Interaction: Incorporating Advanced Snow Models and Experimental Validation

Ahmad Moeineddin, Jakob Platen, Julian Meyer, Michael Kaliske

Institute for Structural Analysis, TU Dresden, Dresden, Saxony, Germany

Abstract

Understanding the complex interaction between rubber and snow is vital for enhancing tire traction in winter conditions. Therefore, it is necessary to enhance the understanding of the process that occurs during contact between the tire tread and snow, particularly during sliding. Recognizing the inherent complexities of these interactions, especially under varying applied loading rates, a dual methodology is employed: detailed computational simulations and experimental validation. To capture the diverse behaviors exhibited by snow, an advanced elastoplastic constitutive model at finite strains is utilized. This model is enriched by an implicit gradient damage enhancement to replicate the brittle nature of snow under high loading rates. After calibration against established experimental benchmarks, the proposed material model is shown to demonstrate a suitable alignment with observed behaviors. Further computational simulations provide insights into different examples of the rubber snow interaction, while experimental data is used to validate our approach. This affirms the potential of the proposed framework as a robust tool for modeling the intricate interaction between rubber and snow.

Presenting Author Biography

Michael Kaliske was born in Hamburg, Germany. He graduated from University of Hannover and Swansea University. He was working as research fellow at Institute for Structural Analysis (University of Hannover) 1991-1999. He got his Ph.D. in 1995 and Habilitation in 1999. Subsequently, he joined Continental and was Head of Mechanics and Simulation Development Department until 2002. In 2002, he was awarded the Chair of Structural Mechanics at University of Leipzig (2002- 2008). Since 2006, he is Director of the Institute for Structural Analysis at Technische Universität Dresden. Further responsibilities are Secretary of the “International Association of Applied Mathematics and Mechanics” (GAMM) since 2009, President of the “German Association of Computational Mechanics” (GACM) 2017-2020 and Vice-President of the “International Association for Computational Mechanics” (IACM) since 2022, among others. Michael Kaliske is interested in modelling and simulation of structural behaviour at different length scales as well as its multi-physical characteristics.

Predicting Tire Performance on Asphalt from Indoor Measurements

Henning Olsson, Marco Furlan, Matthew Strang

Calspan, Buffalo, NY, USA

Abstract

Indoor tire testing provides a controlled environment to obtain highly repeatable and consistent data across a wide range of test conditions. However, concerns arise regarding the difference between the road surface of indoor facilities—typically sandpaper—and real-world asphalt. This difference in surface roughness results in variations in tire force curves, affecting the peak friction and the slip/cornering stiffness. Therefore, tire models derived from indoor testing data must be adjusted to accommodate these differences to produce accurate and reliable vehicle simulations on asphalt.

In this study, we propose a novel indoor testing methodology to predict the change in tire performance when transitioning from sandpaper to asphalt surfaces, eliminating the need to retest tires on asphalt. This approach exploits the repeatability and accuracy of indoor testing to develop a predictive estimate of the tire performance change (such as Magic Formula scaling factors) for asphalt based purely on indoor measurements.

Presenting Author Biography

Having spent the last 15 years in the tire testing industry, Henning is well-versed in all aspects of tire testing and modelling. At Calspan, Henning contributes to the team by supporting customers in their tire research projects and leading R&D projects to further enhance Calspan's tire testing and modelling capabilities. Henning has a B.S. in Engineering from Dartmouth College and a M.S. in Automotive Engineering from the Royal Institute of Technology in Stockholm, Sweden.

Wheel Slips Explained by Aristotle's Circle

YI LI

GCAPS, Alton, VA, USA

Abstract

Two rigid bodies in point contact are deemed non-slip relative to each other if there is zero relative velocity at the contact point between them. This criterion becomes invalid when at least one of the bodies in contact is deformable. That results in challenges in describing the slip of a rolling tire, which is a deformable body in contact with the road forming an area rather than a point contact. The commonly used term "tire slips" in vehicle and tire dynamics would more appropriately be named "wheel slips" because they are just a way to describe the wheel's motion, not the tire's. The definition of tire(wheel) slips adopted across modeling and testing has intrinsic inconsistency. This fact needs to draw more attention from the tire science community.

This study addresses the inconsistency problem by examining relevant definitions in standards such as ISO 8855, SAE J1024, and TYDEX, alongside adaptations made by indoor test machine implementations. Furthermore, it demonstrates the limitations of the standard tire slip definitions for motorcycle tire kinematics, which deal with the large camber case.

The paper presents a unified and rigorous geometric framework for longitudinal, lateral, and spin slip (including turn-slip and camber slip). Inspired by Aristotle's wheel paradox, it introduces the concept of Aristotle's circle to help better depict the various global slips exhibited by deformable rolling bodies, such as tires. It also opens a new window to examine the combined slips. The objective is that the refinement and generalization of wheel slip definitions within the realm of tire science can provide a solid foundation to solve the inconsistency problem discussed above.

Presenting Author Biography

Dr. YI LI is the lead Modeling and Simulation Engineer for the Global Center for Automotive Performance Simulation (GCAPS). His expertise in tire mechanics and mathematical modelling, coupled with his background in dynamics, drives innovation and excellence within the organization. He has the aspiration of becoming both a theoretical expert and a hands-on practitioner in the field.

Experimental Method for Reproducing Self-Sustained Longitudinal Tire Vibrations

Carlo Lugaro[1], Yi Li[2], Dirk Engel[3]

[1]Siemens Digital Industries Software, Helmond, Noord-Brabant, Netherlands.
[2]GCAPS, Alton, VA, USA. [3]HAW Hamburg, Hamburg, Hamburg, Germany

Abstract

Exceeding the maximum friction potential between a vehicle wheel and the road often results in pronounced vibrations, in this context referred to as “power-hop”. This phenomenon typically occurs during driving off, particularly when excessive driving torque is applied to the driven wheels. These vibrations, interacting within the vehicle powertrain, impact vehicle comfort and may cause component damage. They are centered at approximately 10 Hz, subject to vehicle and tire characteristics in different operating conditions.

Past investigations have involved real-world testing as well as simulation on full-vehicle level, alongside proposed mitigation strategies. This paper will give an overview on the past research. Moreover, it introduces an experimental approach aimed at reliably replicating these vibrations on a flat belt tire testing apparatus. Through integration with theoretical frameworks, a deeper comprehension of the underlying physics is achieved, reflecting the actual state of the investigations.

Furthermore, a theoretical model elucidates the primary contributors within the powertrain to this phenomenon. It is found that the vibrations stem from energy transfer at the tire-road interface when the tire operates beyond its peak friction point. This results in a nonlinear, marginally stable system, that produces limit cycle oscillations. The tire slip characteristics dictate the amplitude, while the drivetrain natural frequencies determine the frequency of the vibrations.

Presenting Author Biography

Carlo Lugaro is a research engineer at Siemens Digital Industries Software. Carlo and his team at Siemens develop the theories and models that are implemented in the Simcenter Tire product. He also actively participates in research projects focused on tire and vehicle dynamics. In his career, he has been previously involved in the development of control systems for vehicle stability as well as for autonomous driving. Carlo received his MSc degree in mechanical engineering at the Polytechnic University of Turin in Italy.

Influences of Multiple Design Parameters on Vibration Characteristics of a Rolling Non-pneumatic Tire with Honeycomb Spokes

Zhou Zheng[1], Shanshan Chen[2]

[1]Soochow University, Suzhou, Jiangsu, China.

[2]Pan Asia Technical Automotive Center Co. Ltd, Shanghai, Shanghai, China

Abstract

A three-dimensional finite element (FE) model was developed for a rotating non-pneumatic tire (NPT) with honeycomb spokes of 15.8° cell angle using the Abaqus software in order to predict its dynamic responses under certain operating conditions. The validity of this FE tire model was confirmed by comparing predicted responses with published results, considering similar overall and component dimensions as well as identical operating scenarios. These include the peak stresses developed in the honeycomb spokes and the overall vertical deflections of the tire under normal loads varying from 2-4 kN. Parametric studies considering multiple material and geometric design parameters were subsequently conducted using the verified FE model so as to evaluate their effects on the vibration responses of the NPT rolling over a cleat, including variation in the overall vertical displacement of the tire as well as its normal forces acting on the road. The results suggest that natural frequencies and vibration amplitudes of the dominating modes of vibrations are more sensitive to the geometric design parameters, particularly those related to the spokes and shear-band. The results could offer important guidance for tuning the honeycomb tire design for better ride and noise performance.

Presenting Author Biography

Zhou Zheng holds a Ph.D. degree in Mechanical Engineering from Advanced Vehicle Engineering Research Center of Concordia University (Canada), under the supervision of Prof. Subhash Rakheja and Prof. Ramin Sedaghati. His research focuses on the structural design and dynamics of both pneumatic and non-pneumatic tires. Zhou is committed to overcoming technical barriers to the application of non-pneumatic tires in high-speed vehicles. Recognized for his academic excellence, he has been honored with the International Excellence Award from Concordia University, a National Scholarship, Outstanding Dissertation Defense Award, and the Outstanding Young Scholar Award from Soochow University.

An Efficient Method to Predict Tyre Life using ADAMS and RWUP Data

Harsha Vardhan M, Raghupathi S, Praveen P, Sameer Telote

Mahindra and Mahindra, Chennai, Tamil Nadu, India

Abstract

Tyre replacement is a major cost of ownership for the car users after it is worn. To reduce the cost of ownership to end users, there is a target tyre life to be met so that it is acceptable to most of the users. Currently the only method followed to check the tyre life is to run the vehicle till it achieves the target tyre life or till it wears out completely. This is a tedious and time-consuming activity as this process involves running the vehicle for several months to calculate the target tyre life.

In addition to this, tyre wear is dependent on various factors such as the vehicle type, front wheel drive or rear wheel drive, electric vehicle or internal combustion vehicle, wheel alignment, tyre placement in front left or right or rear left or right etc.

In this paper, a simple model to predict the tyre life based on the work done by the tyres is discussed in detail.

Considering all the variables, a model to predict the work done by each tyre using ADAMS simulation in a certain duty cycle is done. The predicted work done was verified with the actual work done of the tyres using the wheel force transducer measurements. Based on these measurements, the tyre life was extrapolated for each wheel using the known tyre wear model for the given work done. Actual tyre life by regular method of running the vehicle for complete tyre life is also done and reverified with the predicted tyre life.

Presenting Author Biography

Harsha Vardhan is an accomplished and diligent professional with over 10 years of experience in the areas of Engineering, Research & Development, and Product Design, currently working as Lead Engineer at Mahindra and Mahindra Pvt Ltd along with strong organizational and time management skills while maintaining profitable communications and interpersonal relationships

Sensitivity Analysis and AI based tuning of Tire Parameters for Enhanced Vehicle Handling Performance

Lakshmi S[1,2], V Krishna Teja Mantripragada[2,1], Vipan Kumar Basan[2], Krishna Kumar Ramarathnam[1]

[1]Indian Institute of Technology Madras, Chennai, Tamil Nadu, India.

[2]JK Tyre and Industries, Mysuru, Karnataka, India

Abstract

Tires play an important role in vehicle performance, comfort and safety. Meeting an OEM's vehicle target characteristics by tyre manufacturers is often costly and time consuming involving multiple iterations. The aim of this research is twofold. First, a global sensitivity analysis of tire parameters on handling objective metrics and second, to tune tire parameters using artificial intelligence to meet target metrics. The study employs experimental data collected from three tires and a SUV vehicle. Through rigorous parameter estimation techniques, the tire and vehicle parameters are estimated to accurately represent their respective characteristics. Exploiting high-performance compute simulation capabilities, a global sensitivity analysis with thousands of virtual tires is performed to study the influence of tire parameters on vehicle handling objective metrics such as gradients, deadbands etc for different ISO handling tests. Unlike conventional sensitivity analysis methods which focus on local sensitivity and few test cases, conditional variance based global sensitivity analysis is performed to elucidate the intricate relationship between tire characteristics and vehicle handling performance providing valuable insights for vehicle dynamics optimization and enhancing overall driving safety and comfort. The vast amount of datasets generated for sensitivity analysis are further utilised to train an artificial intelligence agent that predicts the optimal tire parameters that can satisfy the given handling objective metrics. Finally, a user-friendly GUI is developed that employs the AI agent to tune the tire parameters.

Presenting Author Biography

Dr. Krishna Teja is Deputy Manager at Product Development Centre of JK Tyres, involved in development of advanced technologies in areas of manufacturing analytics, driver-vehicle interactions, tire-vehicle integration, data-driven and model-free automotive control systems employing artificial intelligence and other state-of-the-art techniques. In addition to his impactful industry role, Dr. Teja contributes to the academic realm as an Adjunct Faculty at the prestigious Indian Institute of Technology Madras. His commitment extends to guiding numerous graduate and post-graduate theses, reflecting his passion for nurturing the next generation of talent. His work on tire-vehicle interactions has earned publications from the reputed Vehicle System Dynamics journal and is featured by the MathWorks. Dr Teja is an undergrad alumnus of NIT Trichy and holds PhD from IIT Madras.

A Novel Application of Intelligent Tire in Semi-active Suspension System of Cars

Delei Min, Yintao Wei

Tsinghua University, Beijing, Beijing, China

Abstract

Intelligent tires attract increasing attention in both smart car industry and tire sector, while commercialized application of the former in real smart car chassis is seldom. In this paper, a novel application of intelligent tire in semi-active suspensions is present to improve vehicle ride comfort. Using an intelligent tire sensor to reflect the tread band vibration, a road unevenness classification method that is based on tread band vibrations is proposed and implemented in the control algorithm of a semi-active suspension with a magnetorheological damper (MRD). An improved rigid-flexible coupling ring tire model that can be served as the simulation environment for tread band vibration is established to analyze the rolling contact between tire and uneven road. The simulation for vibration bench tests indicates the influence of road levels and driving speeds on the tread band vibration. The tests conducted on the hardware testing platform, including an intelligent tire and a 1/4 vehicle vibration bench with a semi-active suspension, further demonstrate the insensitivity of tread band vibration signals to MRD control current, providing a prerequisite for accurately classifying road levels during suspension control. The comparison of different machine learning algorithms indicates the effectiveness of using the decision tree algorithm for road classification. Furthermore, a hardware architecture is proposed in this paper for real-time communication between wirelessly transmitted intelligent tire acceleration signals and a suspension controller, achieving online classification of road levels and adaptive adjustment of the optimal control parameters for the semi-active suspension. The experimental results prove the advantage of the proposed method and the potential of extending this new method to classify other uneven roads such as the bump is studied, which demonstrates the possibility and basis for developing more complex general chassis control systems that include intelligent tires.

Presenting Author Biography

Yintao Wei, a tenure Professor in Tsinghua University, School of Vehicle engineering & Mobility. Got PhD in 1997 from Harbin Institute of Technology, and had visiting experience as an AvH fellow in several Europre Univeristies including Univeristy of Hannover, AAchen, and TU Dresden. Professor Wei recent research interests focus on Smart chassis and tires.

Overcoming Sensor Limitations Induced by Battery Life Requirements in Intelligent Tires

Roman Son[1], Sparsh Sharma[1], Kanwar Bharat Singh[2]

[1]The Goodyear Tire & Rubber Company, Colmar-Berg, Mersch, Luxembourg.

[2]The Goodyear Tire & Rubber Company, Akron, OH, USA

Abstract

Intelligent tires, equipped with tire-mounted sensors, have emerged as a transformative force in the automotive industry. These sensors provide real-time data on tire health, road conditions, and vehicle performance. However, their efficacy is constrained by battery life limitations. To address this challenge, a range of strategies has been devised to enhance the reliability and accuracy of intelligent tire systems. These strategies encompass edge computing, event-driven sensing, selective sampling, sensor fusion, and adaptive algorithms. By synergistically integrating these approaches, we can optimize the output of intelligent tire systems across diverse applications.

In this paper, we introduce a novel load estimation methodology that leverages a combination of these strategies. Initially, we present static tire load estimation algorithms alongside tire autolocation techniques. Subsequently, we propose a fusion strategy that unifies both algorithms, yielding simultaneous results for static tire load and tire autolocation. Furthermore, we extend this approach to incorporate vehicle inertial measurement unit (IMU) data, enabling dynamic load estimation for each tire. Remarkably, this extension obviates the need for ongoing inputs from tire-mounted sensors during extended periods of driving.

Validation results underscore the effectiveness, reliability, and accuracy of our proposed methodology, positioning it as a promising advancement in the field of intelligent tire systems.

Presenting Author Biography

Roman Son received his master's degree in Mechanical Engineering from Bauman Moscow State Technical University. He further pursued a master's degree in Automotive Engineering from Hanyang University in Seoul, Korea, in 2018. His research interests lie in machine learning, signal processing, vehicle dynamics and control. Currently, he is engaged in developing algorithms for intelligent tires at The Goodyear Tire & Rubber Company.

Tire/deformable Terrain Interaction Model for Longitudinal Slip Based on Stress Distribution

Dang Lu, Xiaofan Wang, Haidong Wu

School of Automotive Engineering, Jilin University, Changchun, Jilin, China

Abstract

Unlike the contact between tires and paved road, the tire/deformable terrain interaction is more complex, often involving traction, compaction resistance, sinkage, and other factors. The study of tire driving performance on deformable terrain is of great significance to off-road vehicle design and development. Finite element modeling seems a good approach to investigate tire/terrain interaction, and its capabilities have been demonstrated well. In addition, different kinds of tire models are developed in order to realize vehicle dynamics simulation and analysis on deformable terrain. Among them, the stress distribution on the tire-terrain interface is the basis of tire modeling, and its characteristics is complicated under the influence of tire sinkage and slip/skid, which makes it difficult to make a reasonable expression of the tire model. In this research, the stress distribution characteristics on the wheel-terrain interface was investigated based on the finite element analysis of tire longitudinal slip/skid. It has been found that a clearer change rule of stress distribution can be obtained by adopting the loading method of fixed sinkage. The stress distribution presents three characteristics under different slip/skid degree, corresponding to the slip, little skid and large skid states respectively. Then, the stress distribution model applicable to three slip/skid states was established after simulating sink and shear tests and obtaining soil characteristic parameters. On this basis, the tire-deformable terrain interaction model for longitudinal slip was further established. The verification shows that the model has a high prediction accuracy, where the errors of the longitudinal force, the vertical force and the torque are respectively 0.1%, 4.4%, and 1.1%, showing that this model can have a good expression of the in-plane characteristics of tires on deformable terrain.

Presenting Author Biography

Xiaofan Wang is a PhD candidate at the College of Automotive Engineering, Jilin University, China. Her research interests include tire dynamics, tire/terrain interaction and structural design theory and numerical analysis of non-pneumatic tires. She has participated in tire modeling, vehicle dynamics simulation analysis, mechanical studies of tire/terrain interaction, development of tire test rig for deformable terrain, and theoretical modeling and simulation analysis of non-pneumatic tires and other projects.

Development of Sound Source Identification for the Reduction of Tire Tread Noise

Yuki Hayashi

Toyo Tire Corporation, Itami, Hyogo, Japan

Abstract

Nowadays, the regulation of vehicle pass-by-noise requires high level quietness. And the electric vehicles have gained popularity and they are very quiet on the road except for tire noise. So, the demand for low noise tire has become increasingly high. Under these circumstances, in order to achieve both more aggressive tire exterior design and lower tire noise, we are trying to identify the causes of tire tread noise through sound source identification tests.

Acoustic holography is one method for identifying the source location of tire tread noise. However, since this method assumes free-field propagation during the calculation process, it does not consider the effects of acoustic reflections on the tire and road surface.

Therefore, the location of the sound source could not be determined, or the results sometimes differed from what was expected by tire tread pattern design.

Therefore, in order to consider the influence of the sound field environment around the tire, we tried a method that combines actual measurement test and numerical simulation. First, sound pressure was measured using multiple microphones at actual measurement test. Next, using an acoustic space model that simulates this actual measurement test environment, frequency response function [Pa/(m^3/s)] between the multiple sound source points set near the tire contact patch and the microphone was calculated by acoustic FEM. Finally, by performing inverse matrix calculation on the sound pressure and frequency response function, the strength at each sound source points were calculated as volume velocity. Here, the frequency response function considered the effects of reflections on the tire and road surface, so the calculated volume velocity also takes these effects into account. The results obtained in this way were compared with the results from acoustic holography, and it was confirmed that the identification of the sound source could be more clearly.

Presenting Author Biography

Yuki Hayashi joined Toyo Tire Corporation in 2020. As an engineer in the Advanced Technology Development Department, he is involved in performance research related to tire NVH. Through actual measurements and simulations, he focuses on how to measure tire noise and how to reduce it.

High-Strength Mechanism of Hydrogenated Styrene-Butadiene Rubber Using Coarse-Grained Molecular Dynamics Simulation

Shuichi Karatsu

Toyo Tire Corporation, Itami, Hyogo, Japan

Abstract

Recently, the automotive industry has focused on the development of electric vehicles. Tires installed on electric vehicles are expected to be more susceptible to wear due to increased vehicle weight and high torque during acceleration. Styrene-butadiene rubber (SBR) has been widely used as tire tread rubber owing to its exceptional elasticity, mechanical strength, and abrasion resistance. Rubber made by adding hydrogen to SBR (hydrogenated SBR) is known to achieve higher tensile strength and elongation at break in the stress-strain curve than conventional SBR rubber. In this study, I elucidated the mechanism of increased strength of hydrogenated SBR by using coarse-grained molecular dynamics simulation.

SBR and hydrogenated SBR polymers were modeled based on the entanglement density obtained from experiments. After cross-linking simulations to create rubber models, uniaxial tensile simulations were performed. The stress–strain curves obtained from the simulations show that hydrogenated SBR exhibited higher tensile strength and elongation at break than SBR. This result is qualitatively consistent with the experimental result.

Two factors are considered contributing to the increase of tensile strength and elongation at break for hydrogenated SBR. One is an increase in entanglement density. It increases entropic elasticity and affects the improvement of the tensile strength. The other is the uniformity of crosslinking. Uniform crosslinking prevents stress concentration of hydrogenated SBR and the break point during elongation become large.

Presenting Author Biography

Shuichi Karatsu joined Toyo Tire Corporation in 2018 and worked at the Central Research Center to develop new rubber materials for tires. From 2019, he moved to Advanced Technology Development Department where he has been focusing on the physical properties and improving the performance of rubber materials through material simulation.

Vibroacoustic simulation for the prediction of exterior noise of truck tires

Dario Garofano, Dario Dotolo

Prometeon Tyre Group, Milan, Italy, Italy

Abstract

In the last years, the introduction to the market of electric vehicles and a new labeling system introduced by the European Commission raised a strong interest in the noise produced by the tire-road interaction. The reduction of noise emissions became a strong challenge for the tire manufacturers that are constantly in need of developing new simulation tools capable of predicting the noise emitted by a tire. In this paper, the application of a simulation methodology capable of predicting the noise performance of a tire is shown and validated by means of experimental data. The experimental activities consisted of the acquisitions of noise produced by special truck tires made up of a particular tread pattern in which a single geometric feature is analyzed in each configuration, in a near field indoor condition.The simulation process aims to faithfully reproduce the procedure of the experimental test and involves the use of non-linear explicit finite element analysis followed by a vibroacoustic simulation to account for the radiated noise by structural vibrations and fluid-pumping.

Presenting Author Biography

After Master's degree in Design and Production Mechanical Engineering, I worked as a Post Graduate Researcher at Federico II University for 9 months. At the end of this period, I was hired in Prometeon Tyre Group in December 2021 as an R&D Modeling Specialist Engineer, position that I occupy still now.

Optimizing Tire Mold Performance with Advanced Nickel-Phosphorus Composite Coating

Pooya Nikbakhsh

Dalhousie University, Halifax, NS, Canada

Abstract

Tire molds play a critical role in determining the quality and appearance of automobile tires. When tire mold defects occur under high temperatures, high pressure, or chemical reactions during vulcanization, the quality and appearance of the tires will be affected.
Additionally, demolding the tires becomes more challenging, as the product can stick to the mold, causing potential damage during removal. This problem leads to increased material costs, production delays, and wasted labor.
Certain nickel polyalloys such as Ni-P-PTFE and Ni-P-BNh have been adopted in the molding and stamping industries for their superior anti-galling properties. boron nitride is an artificial material that comes in many structural forms and hexagonal BN is a popular structure which is used as solid lubricant with excellent anti-friction properties. These materials offer excellent thermal stability and solid lubrication, which can enhance the durability and performance of the molds.
The nickel-phosphorus hexagonal boron nitride composite coating goes a step further by providing semi-permanent protection and anti-sticking properties to the mold. This innovative coating aims to mitigate the challenges associated with tire mold defects.
Laboratory experiments have shown that the coating possesses superior anti-friction, roughness, hardness, and corrosion resistance properties. By improving these characteristics, the coating helps prolong the lifespan of the mold and enhances the overall efficiency of the tire manufacturing process.
This advancement in mold technology has the potential to revolutionize the tire production industry, offering manufacturers an effective solution to common challenges while improving the quality and consistency of their products. With its ability to minimize defects and enhance performance, the Ni-P-BNh composite coating represents a promising development for the future of tire manufacturing.

Presenting Author Biography

Being involved in entrepreneurship programs at Dalhousie University has given me the opportunity to build strong relationships with a diverse network of scientists and professionals around the world. Through participation in various events, collaborative projects, and interactions with industry experts, I have developed a wide and valuable network. I am excited to leverage these skills and connections in my future career.

Appearance and Evaluation of Fatigue Waves on Rubber samples in relation to sliding friction

Maximilian Feldwisch[1], Michael Hindemith[1], Pavel Ignatiev[2], Burkhard Wies[2], Matthias Wangenheim[1]

[1]Leibniz University Hannover, IDS, Hannover, NI, Germany.

[2]Continental Reifen Deutschland GmbH, Hannover, NI, Germany

Abstract

The appearance of Fatigue waves on rubber samples sliding over corundum surfaces was investigated using the High Speed Linear Friction Tester (HiLiTe) at the IDS. Initially the operational parameters combined with different rubber compounds at which the waves reproducibly occur have been determined and the wave propagation in relation to the sliding distance was documented. Using the compound showing the most distinctive wave pattern, the operational parameters as well as the corundum surface have been varied for following measurements to determine the influence of parameters on wave patterns.
Measured data include the coefficient of friction, abrasive wear and additionally thermal image recordings as well as 3d scans of the specimen. Thermal images and 3d scans were used to find correlations between the surface temperature of the specimen and the wave patterns.

Presenting Author Biography

Max is in the second year of his M.Sc. study program in Mechanical Engineering at Leibniz University Hannover, Germany. Before he finalized his B.Sc. degree also at Leibniz University.

Towards the Absolute Tire Performance Prediction with the Enhanced Parallel Rheological Framework including Payne and Mullins Effect.

Gautam Sagar[1], Anuwat Suwannachit[1], Dong Zheng[1], Maik Brinkmeier[1], Kristin Fietz[1], Carsten Hahn[1], Bhaskar Chaturvedi[2], Paul Wagner[1]

[1]Continental Reifen Deutschland GmbH, Hannover, Niedersachsen, Germany.

[2]Continental Tire the Americas, Auburn Hills, Michigan, USA

Abstract

The complex material behavior of filler-reinforced rubber in tires under cyclic loading is well-documented, influenced by factors such as strain rate, amplitude, temperature, and loading history. Previous efforts in tire performance prediction predominantly utilized finite element simulations with hyperelastic material models combined with Prony series – a linear viscoelastic material model, which inadequately captured the dynamic behavior of rolling tires. A variety of nonlinear viscoelastic material models have been proposed in the last decades. Among others, a quite general framework for the class of nonlinear viscoelasticity, called Parallel Rheological Framework is also available in ABAQUS. As the demand for accurate tire performance simulation under real-world service conditions continues to rise— encompassing factors like tire efficiency in lower ambient temperatures and performance across the tire's lifespan—the significance of employing non-linear viscoelastic models becomes increasingly pronounced.

This contribution employs the non-linear viscoelastic modeling approach based on the Parallel Rheological Framework. The original constitutive model is further enhanced by the new creep law. The calibration procedure is developed to fit the model to the material response in a wide frequency, temperature and amplitude ranges, while the Mullin effect is also taken into account. The material model is implemented in the in-house finite element code of Continental Tire. In this study, the comparison of rolling resistance performance prediction using linear and non-linear viscoelastic model to cover a wide range of frequency and strain amplitude is presented. The results show significant improvement in prediction quality using non-linear viscoelastic models. The tire simulation also shows the impact of tire conditioning/history and high speed on tire characteristic which are important for car manufacturer. Moreover, recognizing the viscoelastic properties of textile reinforcements, this study incorporates these effects into cord material models, resulting in significantly enhanced tire performance prediction across various textile materials.

Presenting Author Biography

Dr.-Ing. Gautam Sagar received his Bachelor in Mechanical Engineering from India (2002), Masters in Virtual Engineering from France (2004) and his Ph.D. in Computational Mechanics from Germany (2009). During his PhD he worked on constitutive material models of Shape Memory Alloys. During 2004 - 2005 he worked at Bajaj Auto (R&D), India. From 2009 through 2011 he worked for Airbus (R&D) where he contributed to the development of different part of A350. He joined the Continental Tires R&D Center, Hannover, Germany in 2011, where he has been involved in developing different simulation methods for tire performances and constitutive material models.

Predicting the Friction of 3D Printed Samples on Snow

Michael Hindemith, Rebecca Berthold, Matthias Wangenheim

Institut of Dynamics and Vibration Research, Hannover, Lower Saxony, Germany

Abstract

The friction of a tire on snow depends significantly on the driving conditions and the snow and tire parameters. At our institute, it is possible to produce snow tracks with different densities and temperatures. Reproducible friction tests are conducted on the tread block level on these snow tracks on a linear rolling test rig, the RepTiL (Reproducible Tread Block Mechanics in Lab).

A new process combining simulation and 3D printing was used to produce tread block samples in order to obtain pre-deformed samples. The samples were previously simulated in ABAQUS in order to be able to reproduce realistic deformation of the samples. The deformed shapes of the samples were extracted from ABAQUS and subsequently used for 3D printing these shapes as sample geometry. The influence of these deformations effect simulation and experimental results in a similar manner. The experimentally determined coefficient of friction changes by up to 50% due to the extracted deformation of the samples and the snow parameters.

Machine learning methods such as feature extraction and principal component analysis are used to create multiple linear regression models for the influence of the test conditions on the friction test results. Furthermore, dependencies of the parameters are shown and prediction models are determined for deformed shape of the samples and different snow properties.

Presenting Author Biography

- Born 03.02.1988 in Jena, Germany - 2008 to 2016 Study of mechanical engineering at Leibniz University Hannover with the degree Dipl.-Ing. - Since 2017 Research engineerat the Institute for Dynamics and Vibration Research (IDS) - Research area in the field of contact mechanics and elastomer friction - Research focus is on the investigation of the friction of tire tread blocks on snow

Critical Plane Analysis of Surface-proximal Fields for the Simulation of Mechanochemical Wear

William Mars[1], Thomas Ebbott[1], Ethan Steiner[1], Lewis Tunnicliffe[2]

[1]Endurica, Findlay, Ohio, USA.

[2]Birlca Carbon, Marietta, Georgia, USA

Abstract

A scheme for multi-field analysis of the consequences of sliding asperities on a rubber surface has been developed. The analysis considers: 1) the multiaxial mechanical fields set up via the asperity contact, 2) the thermal field set up due to friction and heat generation,
3) the material property fields that evolve due to thermochemistry, and 4) the growth of crack precursors near the sliding interface. Considering these fields, the scheme produces an estimate of the variation with depth of fatigue damage/residual life, from which may be derived the wear rate for a given set of conditions.

Presenting Author Biography

Will Mars is the founder and president of Endurica LLC.

Investigation of Variation in Buffed Tire Profiles on Worn Wet Grip Results

Eric Pierce, Taylor Floyd, James Jagodinski

Smithers, Pearsall, TX, USA

Abstract

Wet traction performance is a crucial aspect of overall tire performance. Traditionally, wet traction testing has been conducted on new tires providing a benchmark for one point in the product lifecycle. However, expected wet traction performance throughout the lifespan of a tire adds another layer of concern. Traditional methods for wearing a tire through mileage accumulation are costly and time-consuming. Creating artificially worn tires by removing tread rubber through buffing and grinding can be a viable alternative that allows for quicker and cost-effective testing.

This research aims to better understand the sensitivity of wet braking performance as it relates to variations of tread depth and profile within boundaries of allowable tolerances for buffed tires. By testing part-to-part repeatability, we investigated the variation of wet grip performance index between multiple specimens of tires of the same design. Replicates were buffed to different profiles and then tested using a traction trailer in accordance with UNECE R117 wet grip procedures. Insights from this study show that variations in buffed tire tread profiles can have an impact on wet grip performance index and should be considered.

Presenting Author Biography

Eric Pierce is a Principal Engineer covering the Smithers Winter Test Center in Brimley, Michigan, and the Treadwell Research Park in Pearsall, Texas . He specializes in overseeing engineering projects related to winter testing, wet traction, tire buffing, noise testing, on-vehicle testing, and quality. He has specific expertise in wet and winter traction testing for passenger, light truck, and truck tires. He has previously worked as a Lab Manager for the Center for Tire Research at Virginia Tech. Eric is a member of ISO Workgroup 8 for measuring snow and ice grip performance, the Industry Advisory Board for the Center for Tire Research, and the SAE Truck and Bus Military Industry Tire Task Force. He is also sub-chairman for the ASTM F09.10 Tires Committee on Equipment, Facilities, and Calibration. He earned his Bachelor of Science in mechanical engineering from Virginia Polytechnic Institute and State University.

High Fidelity Wet Handling Tire Models for Advanced XiL Vehicle Development: an Efficient Workflow from Precise Real Condition Measurements Towards the Next Level of Simulation Realism

Carlos Nerini[1,2], Nicolas Carabetta[1]

[1]WOM Testing Technologies, Turin, Torino, Italy.

[2]Danisi Engineering, Nichelino, Torino, Italy

Abstract

Vehicle dynamics development is one of the most strategic workflows to improve, on the path towards a safer, more sustainable and more efficient mobility in the years ahead. The realism of tire digital twins is key to reach these global goals and is critical to increase overall vehicle programs efficiency.

On the other hand, most of the tire data for F&M modeling comes from the laboratory, where there are evident limitations in reproducing with realism tire-road interaction on ice, wet, or damp surfaces, for instance. However, where else do we find more realistic data than in reality?

This work shows the latest advancements of tire measurement technologies in the real condition with particular focus on wet asphalt tire-road grip modelling. A real case study is shown in which vehicle systems can be developed in an advanced human in the loop wet simulation environment built from precise tire measurements of the real world.

Presenting Author Biography

Carlos Nerini is the Managing Director and Co-Founder of WOM Testing Technologies, an innovative start-up for the mobility industry. He lives at Torino where he also works as Tire and Vehicle Dynamics senior Consultant collaborating with global customers. He started his career working for the PSAGroupe as a tire engineer. He then moved to Brazil, where he joined the vehicle dynamics team as a chassis simulation engineer. He ended his collaboration with the OEM in the role of performance engineer, being responsible for vehicle dynamics road testing, subjective/objective evaluation and tuning of tires and chassis components. His career has been closely related to applied research, contributing to the science of vehicle dynamics with publications in different journals of the field. In 2018, he founded the Vehicle Interaction Measurement Research Project and he is currently professor of vehicle dynamics within the Faculty of Engineering of the University of Buenos Aires

Coupled Multiphysics Strategy to Monitor the Health of Rubbery Structures Using Endurica Tools

Mahmoud Assaad[1], Ed Terrill[2], Jonathan Martens[2], Jesse Suter[1], Tom Ebbott[1], Will Mars[1]

[1]Endurica, Findlay, OHIO, USA.

[2]ARDL, Akron, OHIO, USA

Abstract

When exposed to air, the long polymer chains of a rubbery object react with the oxygen molecules to form oxygenated functional groups which weaken the material and make it more susceptible to cracking. Higher temperature accelerates the diffusion of oxygen and the mechanisms of the ensuing chemical reactions. The property degradation of the oxidative rubber is manifested by embrittlement of its stiffness, reduction of its maximum chain extensibility, and accelerated crack initiation and propagation. In this paper, a process is developed to measure the oxygen permeability, solubility, and oxygen consumption rate to map the state of oxygen concentration. These properties are updated for elevated temperature generated by the structural dynamic deformation. The fracture energies (T_0, T_c) are also measured at the relevant aerobic and thermal conditions and updated into Endurica DD/DT modules to predict the overall durability and lifespan of the rubber components. To fully demonstrate this crucial Multiphysics mechanism in material design and engineering applications, two tire types (PCR, TBR) were analyzed using FE models in Abaqus. The predicted performance and longevity are compared for the aerobic and anaerobic conditions.

Presenting Author Biography

Mahmoud C. Assaad Senior Technical Advisor, (Endurica) Senior R&D Associate, Goodyear (Retired) Adjunct Assistant Professor, University of Akron. Ph.D. - Engineering Science & Mechanics (Major) and Applied Mathematics (minor) Iowa State University (ISU), Ames, Iowa – 1983 M.S. - Structural Engineering; (ISU) – 1979 M.S. - Polymer Science from the University of Akron, Ohio. – 1990 Diplome d'Ingenieur Civil-Section Travaux Public, Universite' de Saint-Joseph, Ecole Superieure d'Ingenieur, Beirut, Lebanon – 1976 Co-author of the Composite segment of The Pneumatic Tire book. Taught short courses on Plastics and Elastomers in Engineering Design in Pisa-Italy, Mersch-Luxembourg, Garmisch-Partenkirchen and Hamburg Germany. Recipient of special Achievement Award from NASA for his meritorious accomplishments, dedicated work. Winner of the "2008 Create the future design contest" in the machinery/equipment category Received "Superior paper award".

Sponsor mini symposia on tires: Vienna (2013), Glasgow (2018). Technical chairman for the 26th Tire Society conference. Hold over 70 patents and trade secrets, Author of 25 publications

Improvements Afforded by Real-time Cornering Stiffness Estimation for Autonomous Driving.

Vamsi Vegamoor, Sanjay Balaga, Kanwar Bharat Singh

Goodyear Tire & Rubber Company, Akron, Ohio, USA

Abstract

Autonomous vehicles and advanced driver assistance systems have become prevalent in many parts of the world today. These vehicles rely on a variety of perception systems and sensors to understand the environment and to estimate their own state. However, most autonomous vehicles do not actively incorporate tire characteristics into their control systems. In this paper, we focus on the cornering stiffness parameter for tires. Tire stiffness is incorporated into a wide range of dynamics models used in vehicle controllers but is often a static value that is obtained through system identification experiments performed on a given vehicle. In reality, a tire's cornering stiffness varies with the wear state of the tire, load on the tire, as well as tire pressure and temperature. By implementing a real- time cornering stiffness estimation technique as part of the lateral controller for a simulated autonomous vehicle, we demonstrate the improvements in controller performance afforded by the real-time estimate as opposed to a static value. This is corroborated through validation with a variety of vehicle types using the high- fidelity vehicle models in CarSim and TruckSim. In this way, we demonstrate the utility of tire intelligence in one of the core functions for autonomous driving.

Presenting Author Biography

Dr. Vamsi K. Vegamoor received his undergraduate degree in mechanical engineering from Texas A&M University (Qatar campus) in 2016 and consequently completed his MS (2018) and PhD (2021) from Texas A&M – College Station, USA. His graduate work was funded by U.S. Department of Transportation through a mix of grants as well as the Dwight Eisenhower Transportation Fellowship from the Federal Highway Administration. His research interests lie in cooperative platooning, V2X, vehicle control, sensor fusion and advanced driver assistance systems. Since 2021, he has been working with The Goodyear Tire & Rubber Company company leading projects at a niche intersection of tire intelligence and automated driving.

End to End Data Driven Real Time Road Surface Condition Estimation Using Vehicle Dynamics Data

Vishal Hariharan, Kanwar Bharat Singh

The Goodyear Tire & Rubber Company, Akron, OH, USA

Abstract

Real time estimation of road surface estimation is a key enabler in accurately estimating tire road friction by providing information about the peak grip potential. Typically, friction is estimated through dynamics based recursive estimators by calculating the slip slope.
However, its efficacy is heavily constrained by the vehicle dynamic scenario. When the vehicle is cruising and there is little to no slip, these methods render ineffective due to the inability of present-day equipment and methods in either measuring or accurately estimating micro slip which ends up being crucial in distinguishing dry and wet scenarios for instance. To address this challenge, the correlations between vehicle dynamics scenario and the road surface condition needs to be learnt.
In this paper, we introduce an end-to-end data driven framework that correlates the statistical parameters of vehicle dynamics behavior to the road surface condition and perform classification into one of dry, wet, ice or snow condition. A sliding window approach is adopted where a 2 second window of accelerations, yaw rate and wheel speeds sampled at 100Hz are fed into a preprocessing module where statistical features such as mean, standard deviation, frequencies and amplitudes of first and second peaks of power spectral densities are computed for every vehicle dynamic input variable. The stacked statistical features are fed through an autoencoder like multi-layer perceptron neural network with training done on data obtained from real world maneuvers. Validation results emphasize the importance of providing the right features as input to the data driven model in obtaining reliable and robust results even in scenarios where traditional dynamics-based estimators fail, showing promise for accurate end to end data driven state estimators in the field of tire and vehicle dynamics.

Presenting Author Biography

Vishal Hariharan is an algorithm development engineer at the Goodyear Tire & Rubber Company. He received his Masters in Computational Science and Engineering at the Georgia Institute of Technology and Bachelors in Materials Science and Engineering at the Indian Institute of Technology Madras. His interests and area of expertise lies in using classical and data driven techniques to solve automotive engineering problems. Some of the key projects he has worked in the past include physics informed machine learning for developing fast numerical solvers, and pre-training graph convolutional neural networks for improved material property prediction.

Tire Mode Shape Classification using Physics-based Images and Convolutional Neural Network

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[1]Virginia Tech, Blacksburg, VA, USA.

[2]Goddard Earth and Science Technology and Research (GESTAR) II, Baltimore, MD, USA.

[3]NASA Goddard Space and Flight Center, Greenbelt, MD, USA

Abstract

Classifying mode shapes through vibration analysis plays a critical role in assessing and enhancing tire performance for noise, vibration, and harshness (NVH) purposes. With the emergence and proliferation of electric vehicles and the consequent absence of internal combustion engines, the tire NVH has gained more importance. In the automotive industry, understanding the natural frequency and mode shapes of radial tires in the 0-500 Hz range is important for improving road-tire Structure-Borne Noise (SBN) performance. Modal density is extremely high in this range. Efficiently characterizing and categorizing these modes based on the observed vibrational behaviors will help at the design stage and will be further useful for understanding, communicating, and comparing the vibrational behavior. It would save industry analysts time identifying modes and comparing modes between measured and predicted datasets, between two designs, and between different geometries. In general, it is necessary to repeatedly analyze the mode shapes for newly designed tires with a manual effort to detect a specific mode that can degrade a tire's performance in certain frequency ranges. This study aims to classify tire mode shapes by generating physics-based images from finite element models and eigenvectors that would be used for training and validating convolutional neural networks (CNN). The tire is discretized into sidewall and belt regions, and their corresponding physics-based images are generated with respect to modal displacement components in the cylindrical coordinate system. Two CNN models are built, one for classifying unloaded tire mode shapes while the second for classifying loaded tire mode shapes. Transfer learning is implemented from the unloaded tire classification CNN model to the loaded tire classification CNN model to enable faster training and higher accuracy with less data. Also, the tire mode shapes are categorized into diverse, representative groups such as axial, torsional, pitch, diametric and other bending modes

Presenting Author Biography

PhD Student at Virginia Tech and completed masters from Virginia Tech.

Estimating Normal and Tangential Forces in Tires through Flexible Sensors

Md Jarir Hossain, Shahba Tasmiya Mouna, Jae-Won Choi

University of Akron, Akron, Ohio, USA

Abstract

Measuring normal and tangential forces on tires is crucial for enhancing tire performance under various road conditions and environmental settings. The measurement of these forces has been challenging due to limitations in sensing technology related to rigidity, durability, and sensitivity. This research introduces an innovative method that utilizes flexible sensors made of ionic liquids to overcome the limitations. Through the utilization of the distinctive properties of ionic liquids, such as their flexibility, enhanced sensitivity, and exceptional stability, a multi-layer sensor has been manufactured. This sensor consists of five layers: two conductive layers with multi-walled carbon nanotube (MWCNTs)/polymer composite; a pressure-sensitive layer with an ionic liquid/polymer composite; and two outmost layers with an insulating/protective polymer. The pressure-sensitive layer is sandwiched between the electrode layers. The research evaluates the sensor's performance and efficacy under varied force conditions, demonstrating its capability to accurately measure both normal and tangential forces. Such measurements are vital for the development of intelligent tires, offering deeper insights into critical tire parameters such as braking or traction force coefficients, contact patch characteristics, vehicle dynamics, and road surface conditions leading to the improvement of safety, efficiency, and performance of tires.

Presenting Author Biography

Md Jarir Hossain is a Ph.D. student in the Department of Mechanical Engineering at The University of Akron, USA, where he also completed his Master of Science in Mechanical Engineering in 2023. Priorly, he earned a Bachelor of Science in Mechanical Engineering from Khulna University of Engineering & Technology, Bangladesh in 2020. Jarir’s academic journey is marked by a strong focus on additive manufacturing and sensor technology, particularly in the development and applications of 3D printed flexible sensors. His research aims to innovate in the field of smart materials, enhancing the functionality and integration of sensor technology in diverse environments.

Application of Virtual FTire in Tire Design and Development

Yaswanth Siramdasu[1], Gibin Gil[2], Jung-Sik Kim[2]

[1]Hankook Tire & Technology America Technical Center, Uniontown, OH, USA.

[2]Hankook Tire & Technology R&D Division, Daejeon, Korea

Abstract

At present virtual tools are leveraged to align initial tire design to OEM's handling requirements. However, the traditional approach is to conduct finite element rolling simulations to predict cornering, aligning stiffness, and relaxation length. A previous publication shared simple virtual methods for generation of FTire models [1]. Due to its computational simplicity in creation of a FTire model and physical meaning of derived FTire parameters, an alternative approach of using virtual FTire model for prediction handling metrics is explored. A set of 40 tire design changes typically made in tire development are selected and corresponding virtual FTire models are generated. The variation of belt out of plane bending, sidewall lateral and rotational stiffness, tread shear stiffness and other lateral FTire parameters are studied. This study aims to shed light on individual contributions of belt, sidewall, and tread to cornering stiffness and eventually help tire development engineer's knowledge base in tuning the appropriate parts of tire design.

Presenting Author Biography

Yaswanth Siramdasu presently working as Lead Engineer at Hankook Tire - American Technical Center. He earned his PhD from Virginia Tech, Masters from University of Alabama. His current areas of research are Tire Modeling and virtual tire parameterization towards tire/vehicle dynamics application

Poster Presentations

Traction Testing of Race Bicycle Tires

Jonas Gude, Michael Hindemith, Markus Brase, Jonas Becker, Matthias Wangenheim

Leibniz University Hannover, IDS, Hannover, NI, Germany

Abstract

Utilizing our High-Speed Linear Friction Tester HiLiTe we developed a methodology to test the traction of bicycle tires. While varying sliding speed, tire pressure and tire load we are able to obtain entire friction characteristics by evaluating static and sliding coefficients.
These characteristics can be used to assess the traction level of the tire for different driving conditions such as braking, accelerating or cornering. We are able to use different surfaces such as asphalt or cobblestone in dry and wet conditions. Furthermore ambient temperature as well as relative humidity can be controlled in a wide range.
In the course of the experiments we purchased a number of high performance tires as well as consumer tires form different brands. With these tires we performed a general analysis with respect to their sensitivity on parameters pressure, load, sliding speed before we compared the friction characteristics between the brands. As expected we see a clear dependency of the friction in terms of the tire pressure, due to the bike-specific tire design we can also identify a load dependency, which helps identifying ideal tire pressure levels for specific tire loads. With respect to the sliding speed most tires show a speed dependence for small velocities < 500 mm/s.
The comparison of all tires resulted in a surprisingly wide range of coefficient of frictions between 0.6 for the least performing tire to 1.2 for the best tire.

Presenting Author Biography

Matthias Wangenheim: since 2013 Head of Research Group "Contact Mechanics and Friction" at the Institute of Dynamics and Vibration Research, Leibniz University Hannover, Germany. Before, he held different engineering positions in automotive and aerospace industry. PhD in 2012 in the field of tribology, 2005 M.Sc. Degree in Mechanical Engineering at Leibniz University Hannover, Germany.

Road Surface Replication by Additive Manufacturing

Matthias Wangenheim, Michael Hindemith, Markus Brase, Jonas Becker

Leibniz University Hannover, IDS, Hannover, NI, Germany

Abstract

A common lab test method in tread compound development is evaluating the friction potential of rubber samples on different surfaces under varying conditions. While rubber samples can be vulcanized in nearly any shaped it can be challenging to get realistic road surfaces into lab. In the course of a B.Sc. thesis we utilized a resin-based 3D printer to manufacture asphalt-like surfaces. For 3 different materials (soft and hard thermoset and ceramics) we assessed the printing quality in terms of spatial resolution, dimensional restrictions and surface replication grade. In particular the latter was analyzed using a focus variation microscope to evaluate technical surface roughness parameters as well as surface power spectral density in comparison to the original surface. Furthermore we compared friction test results on original and replicated surfaces with promising outcome. In a last step we developed a replication strategy from surface imprints. Therefore the surface scan needs processing steps like negation, extrusion and multiple duplication to create larger artificial road pieces before it can be sent to the printer.

Presenting Author Biography

Matthias Wangenheim: since 2013 Head of Research Group "Contact Mechanics and Friction" at the Institute of Dynamics and Vibration Research, Leibniz University Hannover, Germany. Before, he held different engineering positions in automotive and aerospace industry. PhD in 2012 in the field of tribology, 2005 M.Sc. Degree in Mechanical Engineering at Leibniz University Hannover, Germany.

Research on Fast and Efficient Virtual Sample Delivery Method of Tire Mechanical Characteristics

Lu Dang, Yang Wenhao

State Key Laboratory of Automobile Simulation and Control, Jilin University, Changchun, Jilin, China

Abstract

A fast and efficient virtual sample delivery method of tire mechanical characteristics is proposed to address the problems of long development cycles and high test costs in the matching of tire and real vehicle mechanical characteristics. Firstly, a detailed finite element model is established according to the material distribution diagram and material properties of the tire. Secondly, under the premise of ensuring the simulation accuracy of the model, the detailed finite element model of the tire is simplified to a certain extent, and the dynamic friction characteristics between the tire tread and road surface are accurately expressed by implanting the friction model subprogram. Then, based on the simplified finite element model simulation, the cornering mechanical characteristics of the tire are obtained and combined with the proposed high-precision tire mechanical characteristics prediction method, the mechanical characteristics of the driving/braking and combined slip conditions with multiple and complex simulation conditions are quickly and accurately predicted. Finally, based on the tire handling stability data obtained from the finite element model and prediction method, the tire empirical or semi-empirical model can be identified, and the tire and vehicle mechanical characteristics can be iteratively developed. The fast and efficient virtual sample delivery method of tire mechanical characteristics can not only effectively shorten the development cycles and reduce the test costs, but also advance the development of tire mechanical characteristics to the design stage through the combination of finite element model and prediction method, and further improve the virtual sample delivery efficiency of tire models.

Presenting Author Biography

Dr. Yang Wenhao has been engaged in vehicle and tire dynamics research for a long time and has achieved certain achievements in tire dynamic simulation theory, tire finite element modeling method development, and tire mechanical characteristics prediction. Dr. Yang Wenhao has presided over and participated in many tire dynamics-related topics published 8 academic papers, and applied for 10 national invention patents in China.

Validation of New Design of Inner Drum Test Rig Conducted with a Cleat Test

Jonas Becker, Matthias Wangenheim, Markus Brase, Michael Hindemith

Institute of Dynamics and Vibration Research, Garbsen, Lower Saxony, Germany

Abstract

A cleat test was conducted to verify the basic functionality of the new inner-drum test rig at the Institute of Dynamics and Vibration Research at the Leibniz University Hannover. The inner diameter of the drum is 3.8 m (12.5 ft) and a passenger car tire has been used. Since the design of the hexapod, which houses the measuring cell and the flange for mounting tires, is relatively new, special attention is paid to its stiffness and whether the six force transducer provide sufficient sensitivity.
For this test a cleat was used at various speeds up to 160 kph (100 mph). The advantages of this test rig among other include a significantly higher sample rate or more than 10 kHz compared to state-of-the-art machines that offer a few 100 Hz. In addition, the drum itself has an opening for mounting a window which is made from zinc sulfide. This allows us to use our high speed IR camera and also our high speed camera for human visible light in parallel.
For this purpose, the cleat was positioned in such a way, that the impact point, where the tire gets in contact with the surface after rolling over the cleat can be recorded with both cameras.
In summary this poster should demonstrate if the results of a cleat test using the new hexapod are comparable to SAE J2370 conform measurements and that using optical sensors can expand our tool set to understand the tire behavior.

Presenting Author Biography

2013 - 2018 B.Sc. Mechanical Engineering at Leibniz University Hannover 2018 - 2022 M.Sc. Mechanical Engineering at Leibniz University Hannover since 2022 Ph.D student at the Institute of Dynamics and Vibration Research

Characteristics Analysis and Prediction of Road Adhesion Coefficient Based on Smart Tire

Dang Lu, Hao Yuan, Konghui Guo

Jilin University, Changchun, Jilin Province, China

Abstract

Road adhesion coefficient has an important effect on tire force, affecting the longitudinal driving and braking ability of vehicles, as well as lateral stability, so it is necessary to accurately predict the adhesion coefficient. At present, the prediction methods of road adhesion coefficient are mainly based on vehicle multi-sensor and vehicle dynamics model. However, a large number of sensors and ancillary equipment will lead to large costs, and the prediction requires the tire to be in a sliding state, and it is difficult to estimate the road adhesion coefficient before sliding, which makes it difficult for vehicle control to predict the safety threshold in advance. In this paper, the prediction method based on smart tire is used to fully collect tire information. The prediction of the road adhesion coefficient is simplified to the identification of road type, and the real-time adhesion coefficient is estimated by considering the changes of the adhesion coefficient in the process of tire pressure and speed. The relationship between the adhesion coefficient and acceleration characteristics of the road under different road complexity is systematically observed. This paper carries on the qualitative analysis of simulation, based on different types of asphalt pavement modeling and simulation, to determine its pavement adhesion coefficient. The acceleration characteristics of tire driving in a straight line were collected, and the asphalt pavement type was determined by wavelet multi-resolution analysis combined with machine learning method. Considering the influence of tire pressure and speed on adhesion coefficient in tire model, the effect of indirect prediction of road adhesion coefficient is realized. The results show that the road adhesion coefficient estimation based on smart tire can guarantee the prediction accuracy and improve the accuracy and adaptability of the electronic control system to different road surfaces under the premise of reducing the hardware requirements.

Presenting Author Biography

Hao Yuan is a PhD student from Jilin University, and is studying for his PhD with Professor Dang Lu. During my study, I mainly studied UniTire tire model, intelligent tire and related parameter prediction. During my study, I completed the six component force prediction project of intelligent tire. At present, relevant patents and papers are being submitted. The future research focus is to expand the application scenarios of intelligent tire combined with tire models.

Tire Camber-Turn Slip Combined Simulation Using Implicit and Explicit Finite Element Analysis

Hengfeng Yin, Dang Lu, Yandong Zhang, Haitao Min

Jilin University, Changchun, Jilin, China

Abstract

The mechanical properties of tire turn-slip mainly reflect the mechanical characteristics of tires driving at low speed when it has yaw angle velocity, and the acquisition of tire force like that is helpful to improve the expression accuracy of the tire model in the case of low speed and large turning angle. At present, the mainstream tire test bench does not have the ability to test the pure turn-slip of tires, and in the process of exploring the virtual sampling method of tires, tire suppliers use prediction and virtual data as the basis for the identification of tire models, the data acquisition of turn-slip can expand the expression range of tire models, furthermore, no researchers have publicly published the results of using finite elements to estimate the mechanical properties of tire turn-slip. With this motivation, in this paper, a tire camber-turn slip combined simulation method based on finite element implicit and explicit algorithms is proposed. Firstly, using the non-pattern tire model, implicit and explicit simulation methods for camber-turn slip combined conditions are designed based on ABAQUS software. Secondly, the mechanical characteristics of tire turn-slip under different loads and inclination angles and the distribution of tire forces in the contact patch using two simulation algorithms are obtained. Finally, the reliability of the linear characteristics of the simulation results is analyzed, and the influence trend of inclination angles on the turn-slip characteristics under the two algorithms is compared. It is concluded that the bias of the two algorithms has a good consistency on the influence trend of the inclination angles, and the data reliability of the two methods is high, and the mechanical characteristics of the turn-slip of the tire obtained by finite element simulation have the ability to estimate its mechanical properties.

Presenting Author Biography

Hengfeng Yin, a Ph.D. candidate in vehicle engineering at the School of Automotive Engineering, Jilin University, and mainly engaged in vehicle dynamics, tire dynamics and the application of tire dynamics in chassis electronic control systems.

High Speed Thermal Camera Images of Tire Tread Blocks in Dynamic Road Contact

Markus Brase, Matthias Wangenheim, Michael Hindemith, Jonas Becker

Leibniz University Hannover, Institute of Dynamics and Vibration Research, Garbsen, Lower Saxony, Germany

Abstract

A high speed linear friction tester can be used to investigate the friction behaviour between tire tread blocks and road surfaces. The friction is affected by the sliding speed, normal load, and also the contact temperature. Accurately recording the contact temperature can be challenging due to its highly dynamic nature.

Therefore, a new method has been developed to record the contact temperature of the entire tread block immediately after driving over the road surface using a high speed thermal imaging camera. The methodology involves using a mirror to view not only the contact temperature of the tread block but also the heat conduction in vertical direction. In addition to the general heat distribution, other effects such as abrasion and Schallamach waves are visualized by this method. The high speed linear friction tester, which is located in a climate chamber, supports speeds up to 10 m/s and normal loads of up to 1000 N. The high speed thermal camera images of the tread blocks presented, were recorded at 7000 Hz.

Presenting Author Biography

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Lab Grip Test Concept for Mars Rover Rubber Tire Tread

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Abstract

Vehicles on Mars or the Moon have to travel forward on different types of surfaces such as sand, gravel or rocks. Furthermore temperature changes are drastically between day and night, ranging on Mars from -150°C to +20°C (-238°F to 68°F) and on Moon from -160°C to
+130°C (-256°F to 266°F). In the course of a B.Sc. thesis we investigated how to adapt an existing test rig to these conditions. The steps towards a novel testing methodology were:

- Acquire representative surfaces for Mars and possibly Moon
- Adapt test rig to most likely tire kinematics of Mars rovers (derived from mining equipment)
- Develop a procedure to cool (and heat) both, rubber samples and surfaces, to relevant temperature ranges

The expected measurement results comprise traction potential in terms of temperature, load (tire pressure if pneumatic), speed, slip ratio. Furthermore the tread's wear behaviour can be assessed witrh respect to an expected mileage and its vulnerability to cut&chip effects.

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