The University of Akron
College of Engineering and Polymer Science

THE 54th TIRE MECHANICS SHORT COURSE

In conjunction with the 43rd Tire Society Annual Conference

September 9-13, 2024 University of Akron Student Union, Akron, Ohio, USA

This five-day educational and developmental course will provide engineers and scientists with an in-depth, intense study of the latest developments surrounding tire engineering. The course is designed for practicing engineers, chemists, and scientists who are concerned with tires and vehicles and who have an engineering or science background at the bachelor-of-science level.

The basic and practical aspects of the mechanics of pneumatic tires will be introduced by internationally renowned experts in tire mechanics. Extensive and detailed course notes prepared by each instructor will be provided for all participants along with a 700-page e-book, ***The Pneumatic Tire***, edited by Professors A. Gent and J. Walter.

Those who complete this course will receive a **Tire Mechanics Short Course Certificate** from The University of Akron.

Tire Society will offer course attendees a one-year membership, including online journal access and a $100 discount towards a Play-on-Demand replay of the Tire Society Conference, held concurrently with the Course. Current Tire Society members enrolling in the course will receive a $150 discount on the course tuition.

Monday, September 9, 2024
9:00-9:30
WELCOME AND INTRODUCTION

Dr. Xiaosheng Gao
Department of Mechanical Engineering
The University of Akron, U.S.A.

9:30-16:30 (Complimentary lunch 12-13:00)
TIRE COMPONENTS, TIRE COMPOUNDS AND TIRE MATERIALS

Dr. Annette Lechtenböhmer
Goodyear Innovation Center, Luxembourg (Retired); Associate Editor of Tire Science and Technology

This lecture gives an overview of the tire components, the demands on their compounds and the use of materials in these compounds. It attempts to make the connection

between the role of components in a tire, the compound requirements of these components and the raw materials and cure which results in the desired compound properties. The lecture wants to close the loop between the raw materials and reinforcements used, the compound properties, tire preparation and cure, and final tire properties. The lecture will cover:

1. A Short Introduction
2. Components of a tire and demands
3. Tire compounds and their materials, including polymers, fillers, additives, sulfur, and curatives
4. Tire structures and composites, textile cords, wire, carcasses, beads, and belts
5. Processing, including mixing, calendaring, and extrusion
6. Tire building

Tuesday, September 10, 2024
9:00 – 16:00 (12:00-13:00 Complimentary Lunch)
THE TIRE AS A VEHICLE COMPOMENT

Dr. Gerald Potts (presenter)
GRP Consulting, Akron, OH, USA
Dr. James Cuttino
Yokohama Corporation of North America, Cornelius, NC, USA

Today's pneumatic tire must serve four functions: (1) support a moving load;(2) generate steering forces; (3) generate driving and braking forces; and (4) provide isolation from road irregularities. In examining the complex mechanism involved in satisfying the four requirements, participants will study the tire's importance in determining overall vehicle performance; for no matter what level of complexity is designed into a vehicle, its only communication with the road is through its tires, which must be tough and strong, yet flexible. The following topics will be covered:

1. Basic Functions
2. Lateral Force Tire Models
3. Cornering Transients
4. Vehicle Ride Characteristics

Wednesday, September 11, 2024
9:00 - 16:00 (12:00-13:00 Complimentary Lunch)
IMPACT OF RUBBER AND REINFORCEMENT PROPERTIES ON TIRE FOOTPRINT AND MECHANICS

Dr. Mahmoud Assaad
Senior Technical Advisor, Endurica, Findlay, OH, USA
Global Tire Performance Prediction, Computational Mechanics

The Goodyear Tire & Rubber Company (Retired), Akron, OH, USA

The viscoelastic behavior of the rubber compounds and the reinforcing cords influences the stability of the tire footprint shape. Additional physical properties such as the strain dependency of both constituents and their thermal stability contribute to the contact pressure distribution. The resultant tire forces and moments transmitted to the vehicle are measured using tri-axial force pin transducers or pressure-sensitive mats. The interaction between the materials' behavior and the tire global response controls the mechanics of tire readability and wear characteristics. The following topics will be discussed:

1. Mechanical properties of Rubber
   Elasticity and Viscoelasticity
   Strength of rubber compound
   Payne, Mullins Effects
   Energy Dissipation
   Strain Energy Release rate
   Neural Network (Feed Forward-Back Propagation) based constitutive model for rubber material.
2. Fibers and cords: load-displacement, creep, stress relaxation, and shrinkage
   Impact of steel wires & polymeric cords on tire performance, Reinforcement adhesive coatings and processing
3. Tire transient force & moment response to slip angle sweep.
   Footprint characteristics.
   F&M measurement.
   Cornering stiffness.
   Small-medium-large slip angle regimes.
4. Tire applications
   How tires age and how to measure aging in tires.
   Tire electric resistance.
   Tire pressure loss over time-impact of liner material and thickness.
   Tire post cure inflation.
   Tire digital twin technology.
   Monitor health of tire using Continuum Damage Mechanics (CDM)

Thursday, September 12, 2024
9:00-16:00 (12:00-13:00 Complimentary Lunch)
VIRTUAL TIRE MODELING FOR IMPROVED PERFORMANCE

Dr. Ronald Kennedy
Center for Tire Research, The University of Akron and Virginia Tech. Blacksburg, VA, USA (Retired); Associate Editor of Tire Science and Technology

Simulations are increasingly being used in companies' virtual design processes to develop a tire more effectively and efficiently with desired performance attributes. These

simulation methods run the gamut from simple empirical or analytical models to highly detailed finite element models. These increasing levels of modeling will be described along with examples, with extended focus on the finite element modeling method. Various finite element modeling techniques will be shown as part of the tire performance simulation examples. The lecture will cover:

1. Tire load transfer, cord force, and tire shape mechanics and model representations
2. Review of tire performance modeling methods of increasing complexity, with examples
    - Empirical
    - Analytical
    - Physically based Numerical
3. Brief introduction to tire finite element analysis (FEA)
4. Application of FEA to tire performance prediction.
    - Tire/road contact and forces (static, rolling, cornering)
    - Rolling resistance
    - Tread wear
    - Durability
    - Hydroplaning

Friday September 13, 2024
9:00 - 12:00
TIRE SUSTAINABILITY AND ENVIRONMENT

Dr. Annette Lechtenböhmer
Goodyear Innovation Center, Luxembourg (Retired); Associate Editor of Tire Science and Technology

This lecture gives an overview of the many aspects around tire sustainability with its challenges to such a highly developed product as a tire. It includes an overview of government regulations, life-cycle analysis, new tire materials, end-of-life considerations, recycling of rubber and rubber reclaim. Equally, the environmental impact of tires is also discussed, and topics include noise, rolling resistance (energy saving), treadwear particles, airborne dust, tire emissions and leaching of tire substances.

(12:00-13:00 Complimentary Lunch)

13:00 - 15:00
APPLICATIONS OF ARTIFICIAL INTELLIGENCE (AI)
Dr. Mahmoud Assaad
Senior Technical Advisor, Endurica, Findlay, OH, USA

Global Tire Performance Prediction, Computational Mechanics
The Goodyear Tire & Rubber Company (Retired), Akron, OH, USA

The field of Artificial Intelligence (AI) is used to generate models capable of predicting the mechanical behavior of polymeric materials using input data. These computational models are based on biological neural networks (NN) with the ability to approximate unknown functions in interpolation or extrapolation manner. Consequently, they can be used to model complex relationships between inputs and outputs. The class of recurrent NNs has a memory and thus can present time in an implicit fashion. They are used to simulate the time dependent response of viscoelastic reinforcing cords. The classical Feed-Forward NNs propagate data linearly from input to output and are used primarily to approximate the strain energy function of the rubber. Both classes of NN are investigated through numerical experiments: time delay Elman, Jordan, and Finite impulse response are introduced and used to predict the viscoelastic (creep) behavior of a polymeric cord. The Feedforward Backward propagation driven by the first/second strain invariants with volume change ratio is used to establish the rubber constitutive material law. It is demonstrated that the neural network yields higher accuracy with much better curve fitting than the classical polynomial (Invariant based), and Ogden (Stretch based) strain energy functions.

15:00 – 15:30
COURSE EVALUATIONS AND DISTRIBUTION OF CERTIFICATES

Dr. Xiaosheng Gao
Department of Mechanical Engineering
The University of Akron, Akron, OH, USA

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Biographical Notes

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Dr. Mahmoud C. Assaad

In 1983, Dr. Assaad earned his Ph.D. degree in Engineering Science and Mechanics as major and Applied Mathematics as minor from Iowa State University, Ames, Iowa. In 1979, he received a M.S. degree in Structural Engineering from the same university. In 1990, he received a M.S. degree in Polymer Science from The University of Akron (Akron, Ohio). In 1983, he joined The Goodyear Tire & Rubber Company. His current research interests include development of multi-physics simulation of tire performance including structural, thermal, and oxidative response. He is a lecturer at the Goodyear Institute of Technology. He was an Adjunct Assistant Professor in the Civil Engineering Department at The University of Akron and was also a lecturer at The University of Toledo. He Coauthored the composite segment of The Pneumatic Tire e-book, taught short courses on Plastics and Elastomers in Engineering Design in Italy, Luxembourg, and Germany. He was an invited speaker to the Gordon Conference on Fibers Science and to the 2009 “The Annual Workshops Materials’ Days at the University of Rostock”, Germany.

Dr. Assaad was a recipient of the special Achievement Award from NASA for his meritorious accomplishments, dedicated work, and special efforts. He was the Winner of the “2008 Create the Future Design Contest” in the machinery/equipment category and served as a technical chairman for the 26th Anniversary of The Tire Society Conference. Dr. Assaad holds over 60 U.S., patents and trade secrets in U.S., and Europe.

Dr. James F. Cuttino

Dr. Cuttino is the Director of Tire Development and Testing at Yokohama Corporation of North America. In that role, Jim supervises the development of tires for both the Original Equipment and Replacement markets as well as the related testing activities. Prior to joining Yokohama, Jim was the Director of Tire Technologies and Product Line at LINK Engineering, where he oversaw the conceptualization and development of new tire testing equipment, business development related to tires, and tire testing services. He received his BS and MS degrees from Clemson University in 1985 and 1987, and began his career at Michelin Americas R&D Center before returning to school to earn his Ph.D. in Precision Engineering at NC State University. Over the next 14 years he taught Mechanical Engineering at The University of Alabama and UNC Charlotte, where he started the Motorsports and Automotive Research Center. Jim left teaching in 2009 to start Camber Ridge, a first of its kind tire testing facility designed to improve accuracy and fidelity in tire testing. He subsequently sold the technology to LINK Engineering in 2017.

Dr. Cuttino is the Chair of the SAE Truck and Bus Tire Committee along with having served on numerous organizing committees for the SAE, the Clemson Tire Conference, and others. Dr. Cuttino was the Keynote Speaker at the 2017 American Society for Precision Engineering Annual Meeting and

received an SAE Best Paper Award at the 2013 SAE Commercial Vehicle Conference. He is the author of nine patents.

Dr. Xiaosheng Gao

Dr. Xiaosheng Gao received his PhD from Brown University in 1998 with a major in solid mechanics and two minors: one in materials science and the other in applied mathematics. He then worked as a postdoctoral research associate at the University of Illinois at Urbana-Champaign. He joined the University of Akron as an assistant professor of Mechanical Engineering in January 2001 and became an associate professor in 2006 and professor in 2011.

Dr. Gao's research is in the broad area of mechanics of materials and structures with emphasis on numerical modeling and simulation. His primary research effort focuses on modeling the processes of damage and fracture of engineering materials and structures under static and dynamic loadings as well as under environmental influences. Through the years he has worked extensively on developing mechanism-based models to address the transferability of fracture criteria from laboratory specimens to structural components. This research bridges the macroscopic continuum mechanics and the microscopic aspects of materials science. The results provide guidelines for safer and more economic design and operation of high-performance engineering structures and components.

Dr. Gao has authored over 100 peer-reviewed publications. His research has been presented numerous times at national and international conferences and workshops and has attracted funding from multiple federal and state agencies as well as industrial sponsors. He has served on the editorial board of several international journals, served as a panelist/reviewer for various funding agencies such as NSF, DoD, DoE, etc., and served as a reviewer for over 30 international journals. He received the Office of Naval Research Young Investigator award in 2002 and was elected as a Fellow of the American Society of Mechanical Engineers in 2013.

Dr. Ronald Kennedy

Dr. Ron Kennedy served as the Managing Director of the Center for Tire Research (CenTiRe), an industry/university consortium involving Virginia Tech, The University of Akron, and tire and tire-related companies. Before joining CenTiRe, he worked for 37 years in the tire industry at Firestone, Bridgestone/Firestone, and Hankook Tire performing tire finite element methods development and software programming, simulation systems development, advanced tire design, and tire factory uniformity studies. His work has covered the range of tire performance areas, manufacturing, and design. Dr. Kennedy is currently an Associate Editor of the Journal of Tire Science and Technology. He has numerous technical publications and presentations and has been awarded the Arch T. Colwell Merit Award from SAE, the Tire Society Superior Paper Award and an Honorable Mention Award, the CEO Award and President's Award from Bridgestone/Firestone. Dr. Kennedy was the Plenary Speaker at the 2017 Tire Society Conference and gave the Keynote Address at the 2018 ACS Rubber Division Meeting. Ronald Kennedy received his BS and MS degrees in Engineering Mechanics from the University of Wisconsin, and his Ph.D. in Mechanical Engineering from The University of Akron.

Dr. Annette Lechtenböhmer

Annette Lechtenböhmer, a citizen of Germany, finished her studies of chemistry at Westfälische Wilhelms-Universität Münster, Germany, with a Ph.D. in Physical Chemistry in 1981. After two post doctorates, she was employed at the Goodyear Innovation Center in Luxemburg, she filled positions within compounding and compound testing. She achieved the title of Senior Research Associate of Material Science. During her 35 years of experience in the rubber industry, she has accumulated profound knowledge of compound development, compound testing and test principles, viscoelasticity, compound processing, testing for material modelling and structure of tires, quality control and production. Her positions required close cooperation with other steps of tire development, production, tire design, construction, raw material suppliers, and scientific institutes and universities.

In addition to her industry experience, she taught at Universität Hannover on “Tire Technology” for many years and lectured on “Elastomer Technology” at Luxemburg University. She holds several Patents and Trade Secrets. She is a member of Tire Society, German Chemical Society and German Rubber Society. She retired from Goodyear in 2020 but maintains her dedication to promote rubber and tire science. She continues teaching and serving as an Associate-editor of the Tire Science and Technology Journal. In June 2022, she was presented an award from the German Rubber Society at the International Rubber Conference for her special performances in research, technology, and economy.

Dr. Gerald Potts

Dr. Gerald Potts obtained his Ph.D. degree in Mechanical Engineering from Kansas State University. Upon graduation in 1970, he joined the Firestone Tire and Rubber Co. as a Research Scientist and Group Leader of the Dynamics Research Laboratory. In 1978, he became the Manager of Tire/Wheel Testing Systems at MTS Systems Corporation where he led the initial development of the Flat-Trace â tire test machine. Two years later, he was employed by the General Motors Institute as an Associate Professor of Mechanical Engineering teaching Vehicle Dynamics and Mechanical Vibrations. In the meantime, he established his own company, G.R. Potts Associates, Inc. From 1984 to 1991, then becoming President of TMSI specializing in tire high speed uniformity test systems, tire rolling resistance testers, On LEVEL tire test systems and vehicle crash testing. In 2013, he sold TMSI to MESNAC Americas, LLC, and remains as President of TMSI LLC. Dr. Potts has traveled and lectured to engineering groups, world-wide, having delivered a Plenary Lecture at the 2006 Indian Rubber Institute Conference in Cochin, India. He holds ten patents, has been an Adjunct Professor of Mechanical Engineering at The University of Akron since 1974, and was awarded a Lifetime Achievement Award by Tire Technology International at the 2014 conference and Exhibition in Cologne, Germany.