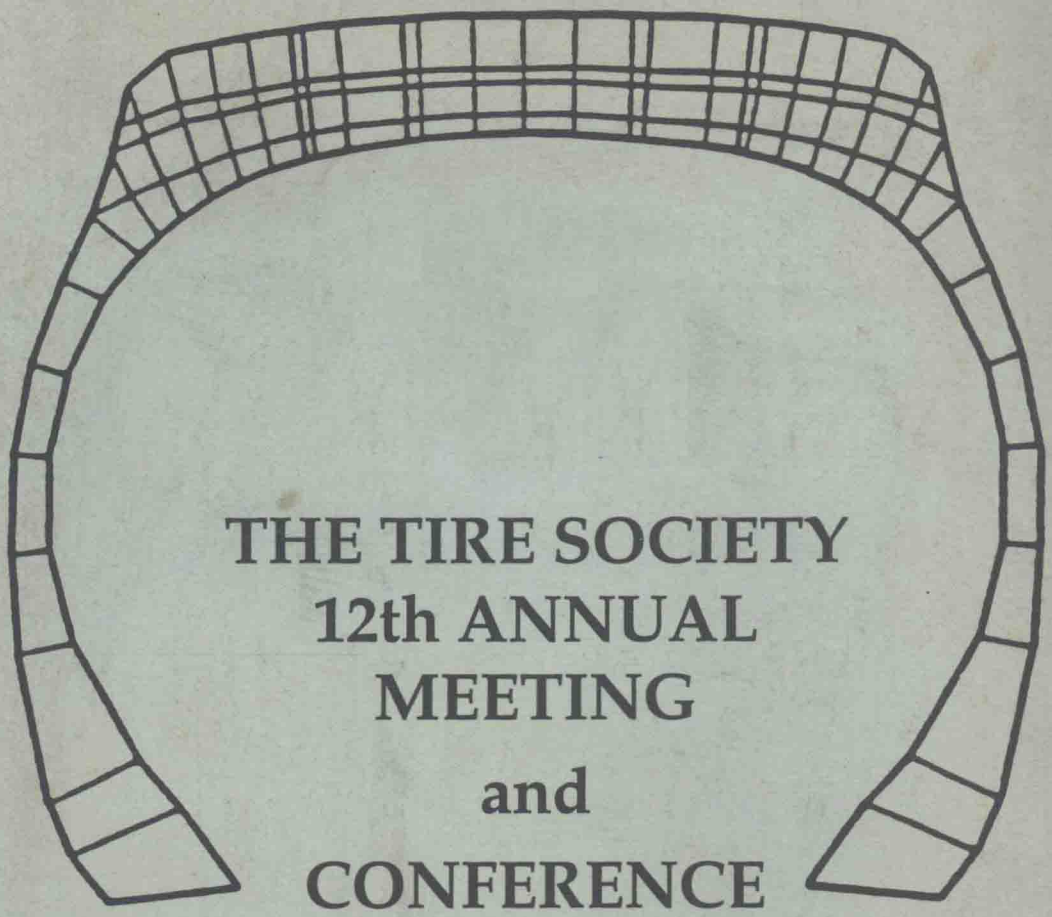

THE TIRE SOCIETY
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PAPER #1

TIRE ROLLING LOSS COMPUTATION WITH THE FINITE ELEMENT METHOD

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ABSTRACT

This paper describes a process for the prediction of rolling resistance in tires. A new Directional Incremental Hysteresis (DIH) theory describing the hysteretic behavior of carbon black filled rubber is presented. The steps required to implement this material model, within a Finite Element (FE) model, and then predict tire rolling resistance are described.

The material model using the DIH theory is a strain based model which includes an incremental formulation to deal with non-sinusoidal cycles within tires. The material model is also enhanced by a directional formulation which is active in situations where the strain tensor has a substantial change in direction with minimal change in magnitude.

Experimental work used to determine the parameters of the material model for specific compounds is outlined. Some example DIH parameters are listed by compound application.

The DIH theory within the FE method is then used to predict rolling resistance for a specific tire design. The results are compared to experimental data taken using SAE J-1269. The value of the tire rolling resistance is predicted within a few percent. In addition, the sensitivity of the tire to changes in load and inflation pressure are predicted and compare favorably with the experimental results.

PAPER #2

INFLUENCE OF RIM RUN-OUT ON THE NONUNIFORMITY OF TIRE-WHEEL ASSEMBLIES

Loh-Yi Chang
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ABSTRACT

This paper presents measurements of nonuniformities of rims. A membrane model and Finite Element Analysis are then being used to compute the contribution to the nonuniformity signal of the tire-wheel assembly. Finally, the findings are compared to experimentally obtained values for tire-wheel assemblies.

PAPER #3

A MATHEMATICAL MODEL FOR TIRE/WHEEL ASSEMBLY BALANCE

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ABSTRACT

A mathematical model is developed to calculate the weight required on a tire/wheel assembly to balance wheel non-uniformity effect such as the lateral runout. A finite element model of a tire mounted on a rigid wheel is used to simulate the free spinning about a skewed axis. The result showed that Euler's equation of motion in rigid body dynamics can be used to calculate the imbalance caused by wheel lateral runout. This equation is then put in a Monte Carlo model to simulate a production distribution. The model can be used to define tire and wheel specification limits, to predict return rates, and to analyze returned assemblies. The verification of the model and result of the Monte Carlo simulation are presented.

PAPER #4

FEM SIMULATION OF THE TIRE/RIM SEATING PROCESS

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ABSTRACT

Finite Element studies have been conducted in the past which involved the simulation of the tire/rim seating process under a variety of sophisticated loading conditions up to and including full 3-D loading with braking and cornering considered. However, the seating of the tire against the rim due to inflation pressure alone is an important and interesting phenomenon in its own right and time spent examining this 2-D seating case in more detail is well spent. This study will limit itself to this simpler 2-D case as three modeling strategies are compared for their applicability. Parametric results and frictional effects will be examined using the most accurate of these modeling techniques.

PAPER #5

FORCE TRANSMISSIBILITY OF HEAVY TRUCK TIRES

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ABSTRACT

This paper reports on a recent laboratory study of force transmission in modern radial truck tires. The experiments are conducted with the tire on a fixed axle and in contact with a flat surface. Single frequency displacement cycles are applied to the loaded tire footprint. The dynamic force transmitted through the tire is measured at the fixed axle. Fast Fourier transform signal analysis is employed to extract the displacement and force amplitudes, whose ratio is defined as the transmissibility. The experiments showed inflation pressure and tire load to have little effect on force transmissibility.

A single-degree-of-freedom tire model is described which uses easily measured tire parameters and reproduces the transmissibility data quite well.

This work was done because of interest in the influence of tire dynamics on pavement loading by heavy vehicles. Of particular interest is the comparison of force transmission in conventional and wide base radial truck tires, included in the paper.

PAPER #6

MODELLING TIRE PERFORMANCE DURING ANTILOCK BRAKING**

Joe Padovan*
Pat Padovan

ABSTRACT

Antilock brake systems (ABS) are employed to prevent loss of vehicle control during periods of high rates of braking. To date, most investigations on ABS have concentrated on performance in maintaining vehicle stability. This presentation will focus on developing an understanding of their effects on tire performance, i.e.,

- potential temperature buildup in the tread region
- potential wear - abrasively and thermally induced
- tire axle spinup and down cycling under various road conditions
- effects of tire size, loading and geometry on overall performance
- establish controllability at varying operational speeds.

Such work will be complemented by several benchmark studies.

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PAPER #7

NATURAL FREQUENCIES AND MODE SHAPES OF TIRES WITH MASS NON-UNIFORMITY

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From 1987 to 1992, a series of papers were published on the free vibrations of nonuniform tires with emphasis on stiffness non-uniformity. The purpose of this paper is to present the results of the vibration analysis of nonuniform tires due to mass non-uniformity and to show that in certain ranges of the parameters the vibration modes are localized.

The receptance method is used to determine the natural frequencies and mode shapes of tires that deviate from perfect axisymmetry due to mass non-uniformities. The tire is modeled as a ring on an elastic foundation. Unlimited number of non-uniformities located around the tire are allowed in the model. Two parameters are considered and discussed in this work: the magnitude of the mass(es) and their relative location.

For demonstration purposes, numerical results on natural frequencies and mode shapes are presented for up to two mass non-uniformities. Interesting phenomena such as loci veering and crossing, and mode localization and transition are reported. Considering the magnitude of the attached masses as the controlling parameter, loci veering is observed. On the other hand, loci crossing occurs when the relative location of the masses are the controlling parameter. Mode localization and transition may occur in both cases.

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PAPER #8

THE EFFECTS OF DYNAMIC STRAIN AMPLITUDE AND STATIC PRESTRAIN ON THE PROPERTIES OF VISCOELASTIC MATERIALS

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ABSTRACT

The dynamic material properties of viscoelastic materials are known to be sensitive to a variety of environmental factors. A great deal of attention has been given to the characterization of the effects of temperature and frequency. However, for thorough design of structures which utilize viscoelastic materials, it is often necessary to characterize the properties of the materials as a function of dynamic strain amplitude and static prestrain, as well as temperature and frequency. Included in this paper is a description of test techniques utilized to characterize these properties, presentation of sample properties, and discussion of the applicability of the data to the design of structures.

PAPER #9

UNEVEN WEAR OF TYRES

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ABSTRACT

Advances in tyre construction have given major increases in tyre life over the past twenty years, mainly by increasing the lateral stiffness, and thus reducing slip during cornering. However, this general increase in tyre life has tended to highlight the problem of uneven wear.

In the present paper, several new techniques are described which have been developed to study treadwear distribution:

- Measurements of wear distribution in long-term road tests, using both linear potentiometer and laser scanning techniques.
- Measurements of the forces, and calculation of the slip between the tyre and the road surface, using a triaxial sensor fitted flush with the surface
- Thermal imaging, to indicate regions where frictional work is high
- Finite element analysis, to calculate the work done against friction
- Rapid technique for determining the wear distribution in tyre tread patterns, by the abrasion of multicoloured paint films

These techniques are evaluated, and their results compared. Taken together, they indicate some of the causes of uneven tyre wear, and may be used to identify tyre design and service features which contribute to this problem.

PAPER #10

SCALE-AREA RELATIONS IN THE EVALUATION OF TIRE WEAR

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ABSTRACT

Scale-area relations, a technique suggested by fractal geometry, are used to study patterns in tire wear. The technique is based on measuring the areas of worn surfaces from topographic data sets, by covering the surfaces with a patchwork of triangles. The triangle area represents the scale of measurement. For each coverage exercise the triangles; areas are kept constant. Multiple covering exercises are performed with a progression of triangles of different areas. The apparent, or measured, surface area for each coverage exercise is normalized, to find the relative area, by dividing the projected area. The scale-area relations are recorded on a plot of the log of the projected area versus the log of the triangle area.

A tire was specially prepared with two different tread patterns. Wear was generated using a tire test machine with a flat surface covered with medium (80) grit Safety-Walk@ abrasive. The wear program consisted of three test sequences of approximately 250 km. each, at a rated load and pressure with cyclic steering angle from +4 to -4 degrees.

Topographic data was acquired on the original tire tread surface and on the worn surface after each wear sequence. The topographic data was collected using scanning laser profilometry on a 120x140 grid with spacings of 1.27mm.

The scale-area plots all had three distinct regions. At large scales the relative areas were close to one, i.e., the measured areas and the projected areas were approximately the same. On the unworn tires, at areal scales similar to the square of the tread spacings, the relative areas began to increase. This scale, where the relative areas begin to deviate significantly from one, is known as the crossover scale (Brown et al. 1992). The crossover scales diminished markedly for the first two wear intervals then increased to their original levels in the third. The second region, at scales just below the crossover scale, is characterized by a constant increase in the log of the relative area with respect to a decrease in the log of the scale. This region extends for one to two decades of scales. The slope of the plot in this region can be related to the fractal dimension and is indicative of the intricacy of the topography over this scale range. The slopes of the plots from data on the worn tires were found to remain close to that of the unworn tires for the first two wear intervals then they decreased dramatically on the third interval. The third region exists at the finest scales where the slope decreases. It is not clear if this decrease in slope is indicative of multi-fractal behavior or is an artifact of the measurement method (might be resolved by the point spacing).

Based on the assumption that an even distribution of footprint pressure would correlate with even wear, this analysis suggests an hypothesis, which could be stated as: "tread pattern with unifractal behavior should produce more regular wear than a pattern with multi-fractal behavior.

PAPER #11

EFFECT OF TIRE ROLLING LOSS ON VEHICLE FUEL CONSUMPTION

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ABSTRACT

Empirical data published since 1925 suggest that a linear relation exists between tire rolling loss and vehicle fuel consumption. The background of this relation is discussed. It is then updated to include current passenger cars and trucks and finally transformed into a simple rule that would allow an estimate of the fuel savings achieved by tire rolling loss reductions.

PAPER #12

CONCEPTS IN HYDROPLANING ANALYSIS

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ABSTRACT

In the last two decades analytical simulations have become the dominant engineering tool for studying design performance and behavior. Even though analysis technology is rapidly expanding its problematical base, fluid-flexible structure interaction continues to elude current solution methods.

Hydroplaning is a significant fluid structure interaction problem faced by the tire industry. Hydroplaning exists when the fluid (water) flowing through the tread has sufficient energy to lift the tire from contact with the road.

In this paper, a concept for a decoupled solution of fluid-flexible structure interaction problems is presented. This is based on linking the fluid energy states from FIRE, a commercial Computational Fluid Dynamics software package, with the structural energy states from an explicit finite element structural software program. A critical factor in this solution is the moving flow boundaries and opening/closing flow channels available in FIRE. Variable convergence criteria minimizes the effects of decoupling the flow from the structural response. An advantage to this approach is the utilization of existing technologies.

PAPER #13

IMPORTANT EFFECTS OF NATURAL RESONANCES IN TIRE DESIGNING

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ABSTRACT

Many tire performance characteristics are the result of associated natural resonances of the tire structure. Specific performance features, including ride quality and high speed capability, will be related to tire radial natural resonances. In particular, for original equipment radial passenger tires, objectionable or excessive boom frequency levels during subjective ride evaluation will be shown to be the result of coupling between the interior vehicle dimensions and the first vertical natural resonance of the tire structure. Secondly, the acoustical cavity resonance of the tire/wheel assembly will be investigated whereby, its specific characteristics will be discussed. Finally, the importance of radial natural resonances of the tire will be related to high speed capability. Also, it will be demonstrated how Finite Element Analysis can be employed to predict critical speed and standing waves.

PAPER #14

STATIC FRICTIONAL CONTACT OF THE SPACE SHUTTLE NOSE-GEAR TIRE

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ABSTRACT

A computational procedure has been presented for the solution of frictional contact problems for aircraft tires. The Space Shuttle nose-gear tire was modeled using a two-dimensional laminated anisotropic shell theory with the effects of variation in material and geometric parameters, transverse-shear deformation, and geometric nonlinearities included. The contact conditions were incorporated into the formulation by using a perturbed Lagrangian approach with the fundamental unknowns consisting of the stress resultants, the generalized displacements, and the Lagrange multipliers associated with the contact and friction conditions. The contract-friction algorithm was based on a modified Coulomb friction law. The elemental arrays were obtained by using a modified two-field, mixed variational principle. The modification consists of augmenting the functional of that principle by two terms: the Lagrange multiplier vector associated with nodal normal and tangential contact load intensities and a regularization term which is quadratic in the Lagrange multiplier vector.

Experimental measurements were made to define the response of the Space Shuttle nose-gear tire to inflation pressure loads and to combined inflation pressure loads and static normal loads against a rigid flat plate. These experimental results describe the meridional growth of the tire cross section due to inflation loading, the static load-deflection characteristics of the tire, the geometry of the tire footprint under static loading conditions, and the normal and tangential load intensity distributions in the tire footprint for the various static vertical loading conditions.

Numerical results were obtained for the Space Shuttle nose-gear tire subjected to inflation pressure loads and combined inflation pressure and contact loads against a rigid flat plate. Comparisons were made between the experimental measurements and the numerical results.

PAPER #15

APPLICATION OF GLOBAL/LOCAL APPROACH TO 3-D TIRE ANALYSIS USING ABAQUS

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ABSTRACT

During the last decade, the finite element method has been widely used in the tire industry to improve tire design and minimize the need for prototypes. Despite the quantum jump in computing power and availability of numerous general purpose finite element codes, procurement of the detailed localized stress/strain information is still a time-consuming and challenging job. To resolve this problem, a so-called global/local approach has proved to be very useful.

In this paper, the application of global/local approach using ABAQUS for the determination of contact area and pressure, evaluation of tread pattern design, and failure analysis is explored. The results are compared to those obtained using a conventional method for demonstrating the superiority of this approach.