Tire model to include road irregularities on handling

REFERENCES

[1] Bakker E., Nyborg L., Pacejka H.:
Tyre Modelling for Use in Vehicle Dynamics Studies.
SAE paper 870421, 1987.

[2] Haug E. J.:
Computer Aided Kinematics and Dynamics of Mechanical Systems.
Allyn and Bacon, Boston ..., 1989.

[3] Hirschberg W.:
Reifenkräfte-Programmodul DTIRE.
Bericht EF-29/90, Steyr-Daimler-Puch Fahrzeugtechnik GesmbH., Graz.

[4] Hirschberg W.:
Simulation der Dynamik von allradgetriebene Fahrzeugen.
Fortschritte der Fahrzeugtechnik; Bd. 11, Braunschweig: Vieweg 1992

TIRE VERTICAL FORCE DESCRIPTION FOR VEHICLE HANDLING SIMULATIONS (ABSTRACTS)

A.W. Parsons[1] and A.H.O. Janssen[2]

1) Goodyear Technical Center Luxembourg
2) University of Technology Eindhoven

Tire vertical and longitudinal dynamics play an important role in the handling performance of vehicles. For most modeling applications these characteristics can be adequately described using simple spring-damper representations. For certain classes of handling simulations however, an improved description of the tires response may be required. This presentation gives an outline of a tire model to describe vertical force reactions to road irregularities and wheel spindle displacements. The model is designed to be computational simple for inclusion in mathematical models for handling simulations whilst giving an acceptable response description for frequencies up to 100Hz.

An empirical modeling technique has been chosen as the objective was primarily to provide a good description of tire characteristics rather than to give insight into the physical behavior of the tire itself. Parameters for the model are derived from a series of simple laboratory tests and both the modeling technique and the experimental methods for parameter identification can be applied equally well to the description of longitudinal force response.

In order to provide an accurate representation of tire response, even in this low frequency range, it was found necessary to include three elements in the empirical model. Each of these elements describes a physical aspect of the tires reaction to road surface irregularities. From experiment these have been found to be essentially independent and must therefore be described and derived separately. These are:

1. Tire eigenfrequencies and stiffness/damping characteristics.

2. A two part description of contact patch dynamics including:
   - Description of stiffness over contact surface.
   - Tire/road contact geometry.

TIRE STIFFNESS/DAMPING DESCRIPTION:

The model consists of a spring/mass/damper system describing the tire static spring and damping values together with a modal system describing the first eigenmode of the tire itself. Parameters are derived from test data where modal analysis is performed on a rotating tire with vertical or longitudinal inputs applied at the spindle. This test method results in a model valid for the condition where the tire contact patch is displaced as one point. The single-point-following model derived this way can be used directly in vehicle simulations provided the road surface profile inputs are not short in wavelength compared to the tire contact patch and provided input frequency content does not exceed the range for which the modal description is valid.(0-100Hz.)

In order to produce a model for the more general case of road inputs and specifically one accepting impact type irregularities it is necessary to depart from the single point contact description and to include the effects of a finite contact length in the model.

CONTACT PATCH DESCRIPTION:

a) Stiffness distribution over contact area:

The assumption of a single contact point between the tire and the road will produce inaccurate results when the road surface irregularities to be used in the simulation are short in wavelength compared to the actual tire contact region. Several possible solutions exist to overcome this problem including calculating simply an equivalent road surface profile by averaging over a finite length. Due to its peculiar combination of pneumatic and structural stiffnesses however, the radial tire does not react in a uniform manner to the road surface along the contact length. To produce correct tire response in time domain simulations the solution chosen was to represent tire-road contact via a weighting function designed to approximate the actual distribution of total tire stiffness over the contact area.

The convolution of this weighting function with the road surface profile is then used to calculate an equivalent input to the single point contact model. This has the advantage over the simpler method of road surface averaging of giving a better description of the non-linear response of a tire as an obstacle traverses the contact region.

b) Tire-road contact geometry:

Due to its finite inflation pressure and relatively high bending stiffness of the radial tire tread region the deformed shape in the contact region will not follow discontinuities in the road surface. The tire therefore acts as a low pass filter to the actual road surface spectra for high frequency inputs. As both the mass/spring/damper tire description and the weighting function approximation for stiffness distribution are derived assuming continuous contact this effect must be described by including an additional function into the tire model.

The actual deformed shape of the tire in the contact region will be a non-linear function of the normal contact force,tread bending stiffness,as well as the height and length of the obstacle being enveloped. For the modeling of contact with discontinuous road surfaces a smoothing function, derived from tests using a series of defined obstacles, is applied to the road surface profile before the convolution with the weighting function is performed. As the deformed shape is assumed to be independent of tire rolling speed but dependant on the wavelength of the obstacle, its effect is that of a frequency domain low-pass filter acting on the road surface, with a cut-off frequency dependant on tire velocity and with non-linear amplitude characteristics. Due to limitations in the frequency range of the current model the smoothing function applied to the road surface profile is also used to fulfill a second function. This is to ensure that the combined filtering effects of the road surface smoothing and the weighting function description of the tire contact region eliminate high frequency inputs to the mass/spring/damper system for which calculated responses would be in error.

The tire model described has been found to provide a good description of tire response in the frequency range for which it was designed. Calculation time remains acceptable allowing its inclusion in the handling simulation models for which it was intended and the improvement in accuracy over simple spring/damper representations is significant.