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Modelling Tyre Rubber Materials for High Frequency FE Analysis

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Abstract : Automotive tyres are gaining importance recently in terms of their noise emission, not only with respect to reduction in noise, but also their perception and detection. Tyres exhibit a mechanical noise generation mechanism up to 1 kHz. However, owing to the fact that tyre is a composite of several materials, it has been difficult to model it using finite elements to predict noise at high frequencies. The currently available FE models have a reliability of about 500 Hz, the limit which, however, is not enough to perceive the roughness or sharpness of noise from tyre. These noise components are important in order to alert pedestrians on the street about passing by slow, especially electric vehicles. In order to model tyre noise behaviour up to 1 kHz, its dynamic behaviour must be accurately developed up to a 1 kHz limit using finite elements. Materials play a vital role in modelling the dynamic tyre behaviour precisely. Since tyre is a composition of several components, their precise definition in finite element simulations is necessary. However, during the tyre manufacturing process, these components are subjected to various pressures and temperatures, due to which these properties could change. Hence, material definitions are better described based on the tyre responses. In this work, the hyperelasticity of tyre component rubbers is calibrated, using the design of experiments technique from the tyre characteristic responses that are measured on a stiffness measurement machine. The viscoelasticity of rubbers are defined by the Prony series for rubbers, which are determined from the loss factor relationship between the loss and storage moduli, assuming that the rubbers are excited within the linear viscoelasticity ranges. These values of loss factor are measured and theoretically expressed as a function of rubber shore hardness or hyperelasticities. From the results of the work, there exists a good correlation between test and simulation vibrational transfer function up to 1 kHz. The model also allows flexibility, i.e., the frequency limit can also be extended, if required, by calibrating the Prony parameters of rubbers corresponding to the frequency of interest. As future work, these tyre models are used for noise generation at high frequencies and thus for tyre noise perception.

Keywords : tyre dynamics, rubber materials, prony series, hyperelasticity
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