Modelling tyre rubber materials for high frequency FE analysis of tyre noise

Bharath Anantharamaiah [1)] Stijn Jonckheere [2)] Francesc Xavier Montane [1)] JoanPuig [1)] Roger Mateau [1)] Elke Deckers [2)] Wim Desmet [2)] Juan J. Garcia [1)]

1) Applus IDIADA Group , L'Albornar, PO Box 20
Santa Oliva (Tarragona), 43710, Spain (E-mail: bharath.anantharamaian@idiada.com)
2) Mecha(tro)nic System Dynamics (LMSD), Leuven (Arenberg), Celestijnenlaan 300 - box 2420, Leuven, 3001, Belgium
3) Flanders Make – DMMS Core Lab, Gaston Geenslaan 8, Heverlee, Leuven, 3001 Belgium

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To predict the static and dynamic behaviour of the tyre, the material properties of the rubbers of a tyre play a key role. This work addresses the challenge – how to predict the tyre behaviour in case the rubbers properties are not available? Performing a test on every rubber (which is vulcanized) used in a tyre is time consuming and is not economical. This is because, such tests must be performed on every rubber samples with a certain geometry defined by relevant testing standards.

To overcome this challenge, the author has used a simplified axisymmetric tyre FE model to calibrate the rubber hyperelasticites (in the form of hardness that is expressed in rubber shoreA) and thus the static behaviour of the tyre, previously. Along with modal damping factors, that were estimated from modal tests, the dynamic responses of the tyre were also modelled in previous works. However, these properties were efficient to predict the tyre modal and noise behaviour of a free-free tyre up to 300 Hz only. In order to estimate the dynamic behaviour of the tyre at higher frequency, the material based damping or viscoelastic was necessary.

In this paper, the technique of the estimation of rubber viscoelasticities using their corresponding hardness values (in shoreAs) is discussed. This is carried out using a theoretical equation, that has been developed in house, that expresses a relation between the loss angle, Prony parameters and shoreA.

$$\delta = (\log_{10}(f) - \log_{10}(X_{offset}))^{p} + Y_{offset}$$

Once these parameters are estimated, they are employed in an FE tyre model, loaded radially with 5 kN force, to estimate the modal and acoustic behaviour up to 1 kHz. The performances observed in the simulations are compared with that from the test of a loaded real tyre.

From this work, it is clear that the definition of material based or viscoelastic damping is necessary in order to model tyre dynamic behaviour for higher frequencies. These definitions can be of several types, however in this work, it was defined as Prony series, specifically in terms of Prony pair/parameter. For every rubber of the tyre, these parameter values are estimated from fitting the experimental data, of the DMA test results of rubber for 300 Hz, with that of a theoretical equation, that allows a possibility of extrapolating the measured DMA test curves up to 1 kHz. While the experimental data is expressed as a mathematical relation between loss angle and rubber shore hardness, the theoretical expression establishes a relation between the loss angle and Prony parameters. Once the Prony parameters were determined using this technique, they were incorporated into FE simulation to model tyre modal and noise behaviour.

From the results of tyre modal simulations, it was observed that there was a good correlation in tyre PIs with test up to 1 kHz. From the results of output NTFs calculations, it was observed that there is a good match between the NTFs of test and simulation up to 450 Hz beyond which there is a constant drop of 10 dB up to 1 kHz in the simulations. As the future work, the objective is to impact/excite the treads closer to the contact patch to synthesize the rolling noise of the tyre using concatenation and convolution techniques. For this, the observed dB loss in the PI due to the impact at the point considered in this work may not be highly significant.

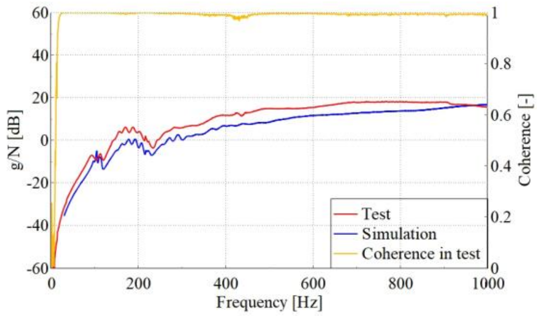

Fig. Comparison of point inertance measurement results of the loaded tyre between test and simulation. The Simulation model employed material based damping that were determined in this work

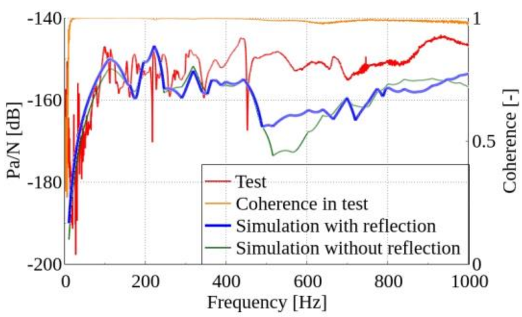

Fig. Comparison of test and simulation output NTFs for loaded tyre model with and without reflection due to setup components.