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Influence of operating factors on modal characteristics of a rolling truck tyre

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A structural 3D tyre model is developed for estimating modal characteristics of a rolling truck tyre using LS-DYNA finite element analysis platform. The model takes into account the complex construction of a pneumatic tyre such as the multi-layered composite designs of carcass and belts as well as hyper-elastic rubber materials forming the tread and bead fillers. The validity of the structural tyre model was thoroughly examined via comparisons with reported experimental data in view of vertical and lateral forces, and aligning moment characteristics. The verified tyre model is subsequently employed to study its modal characteristics in terms of variations in vibration modes and frequencies of the pre-loaded pneumatic tyre structure considering ranges of loading conditions such as inflation pressure, normal load and rolling speed. The influences of these loading conditions are incorporated in the eigenvalue calculations via applying the large-deformation finite element theory, where a new term, known as the geometric stiffness matrix, is introduced to the material stiffness matrix of the system. This new term accounts for nonlinear geometric effects due to rotations of stresses arising from the loading conditions. A number of prior explicit dynamic simulations are thus necessitated in order to determine the stress state throughout the tyre model at circumstances when the modal characteristics are desired. This is achieved using LS-DYNA via the intermittent eigenvalue extractions during an explicit dynamic simulation at three distinct instants including: (i) Following tyre inflation in response to the internal pressure under given loading condition; (ii) following steady-state tyre deflection due to applied normal load; and (iii) following a given steady rolling speed. These permitted the analyses of variations in modal frequencies and deflection modes under applied inflation pressure, loading and rolling speed. The validity of the simulation results are established through demonstrating correlations of predicted natural modes and frequencies with the reported data for similar tyres. Furthermore, a computationally efficient algorithm is formulated and applied to facilitate model reformulations for parametric studies. The results showed significant contributions of all the operating factors considered, namely, inflation pressure, vertical load and rolling speed. Several pairs of conjugate mode frequencies were further detected for the inflated tyre due to symmetry. For the deflected tyre, however, each pair diverged to two distinct frequencies with one lower and other higher than the corresponding frequency of the tyre under inflation alone.

Biography

Subhash Rakheja is a professor of mechanical engineering at the CONCAVE Research Center, Concordia University, Montreal, Canada. He is a research chair in vehicular ergo-dynamics in Concordia University. Dr. Rakheja is a fellow of the CSME and of the ASME. He is the editor of the International Journal of Industrial Ergonomics and associate editor of the SAE Journal of Commercial Vehicles and International Journal of Heavy Vehicle Systems. He continues to serve in the Canadian Advisory Council on International Standards.

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