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Stability Analysis of Hossack Suspension Systems in High Performance Motorcycles

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Abstract : A motorcycle's front end links the front wheel to the motorcycle's chassis and has two main functions: the front wheel suspension and the vehicle steering. Up to this date, several suspension systems have been developed in order to achieve the best possible front end behavior, being the telescopic fork the most common one and already subjected to several years of study in terms of its kinematics, dynamics, stability and control. A motorcycle telescopic fork suspension model consists of a couple of outer tubes which contain the suspension components (coil springs and dampers) internally and two inner tubes which slide into the outer ones allowing the suspension travel. The outer tubes are attached to the frame through two triple trees which connect the front end to the main frame through the steering bearings and allow the front wheel to turn about the steering axis. This system keeps the front wheel's displacement in a straight line parallel to the steering axis. However, there exist alternative suspension designs that allow different trajectories of the front wheel with the suspension travel. In this contribution, the authors investigate an alternative front suspension system (Hossack suspension) and its influence on the motorcycle nonlinear dynamics to identify and reduce stability risks that a new suspension systems may introduce in the motorcycle dynamics. Based on an existing high-fidelity motorcycle mathematical model, the front end geometry is modified to accommodate a Hossack suspension system. It is characterized by a double wishbone design that varies the front end geometry on certain maneuverings and, consequently, the machine's behavior/response. It consists of a double wishbone structure directly attached to the chassis. In here, the kinematics of this system and its impact on the motorcycle performance/stability are analyzed and compared to the well known telescopic fork suspension system. The framework of this research is the mathematical modelling and numerical simulation. Full stability analyses are performed in order to understand how the motorcycle dynamics may be affected by the newly introduced front end design. This study is carried out by a combination of nonlinear dynamical simulation and root-loci methods. A modal analysis is performed in order to get a deeper understanding of the different modes of oscillation and how the Hossack suspension system affects them. The results show that different kinematic designs of a double wishbone suspension systems do not modify the general motorcycle's stability. The normal modes properties remain unaffected by the new geometrical configurations. However, these normal modes differ from one suspension system to the other. It is seen that the normal modes behaviour depends on various important dynamic parameters, such as the front frame flexibility, the steering damping coefficient and the centre of mass location.

Keywords : nonlinear mechanical systems, motorcycle dynamics, suspension systems, stability
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