Wheel Shimmy and Delayed Tyre Models

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Shimmy is still a difficult, hard-to-predict vibration phenomenon of rolling wheels. Although it usually appears with low probability, it may cause serious accidents on aircrafts, articulated buses, trailers, motorcycles, bicycles, even on strollers, shopping carts, wheel-chairs.

Brief description of low degree of freedom models of shimmying wheels is presented. When the wheels are rigid relative to other parts of the supporting structure, the complex shimmy phenomena can be described by single-contact-point models. These models can predict the loss of stability of stationary rolling, and the simple geometric nonlinearities of these systems lead to Hopf bifurcations, which are typically subcritical. Even isolated unstable periodic motions may exist for certain realistic parameters. The prediction of the isolated unstable self-excited vibrations is difficult at the design stage, and even extensive experiments may fail to identify them. This becomes even worse when Coulomb friction exists at the king pin of these structures, which can be modelled as another strong nonlinearity in the system. Analytical studies extended with AUTO-07p numerical bifurcation analysis of such systems are carried out to construct bifurcation charts while the rolling condition is also checked for the contact force between the wheel and ground. Parameter domains are identified, where bistability occurs, that is, where stable stationary rolling and violent shimmy may coexist.

The violent shimmy motion is often chaotic, but certain parameter combinations may also result in transient chaotic motions. This means that the stationary rolling is globally stable, but the transient motions are temporarily chaotic and the length of the transient motions can be predicted with the methods of chaos theory or extensive numerical simulations only.

The wheel is modelled to be soft relative to the supporting structure if there is a pneumatic tyre on the wheel and the classical creep force theory usually gives satisfactory results regarding possible shimmy. In these cases, however, a certain time delay effect becomes relevant in the corresponding stretched-string-like tyre models. The stability charts obtained by linear stability analysis present various bifurcation phenomena. These are checked by experiments on a test rig and also by numerical simulation that involves the partial sliding of the tyre in the contact region as a nonlinear effect. The sense of the Hopf bifurcations are compared to various shimmy models including the classical single-contact-point ones. Double Hopf bifurcations leading to quasi-periodic oscillations are also investigated. The applied numerical methods are optimized for convergence and also for possible application in real-time control strategies. The idea of micro-shimmy is also identified as a phenomenon where the small-amplitude tyre oscillations lead to increased heat, noise and as a consequence, to increased fuel consumption.