On the self-excited chatter vibration in motorcycles

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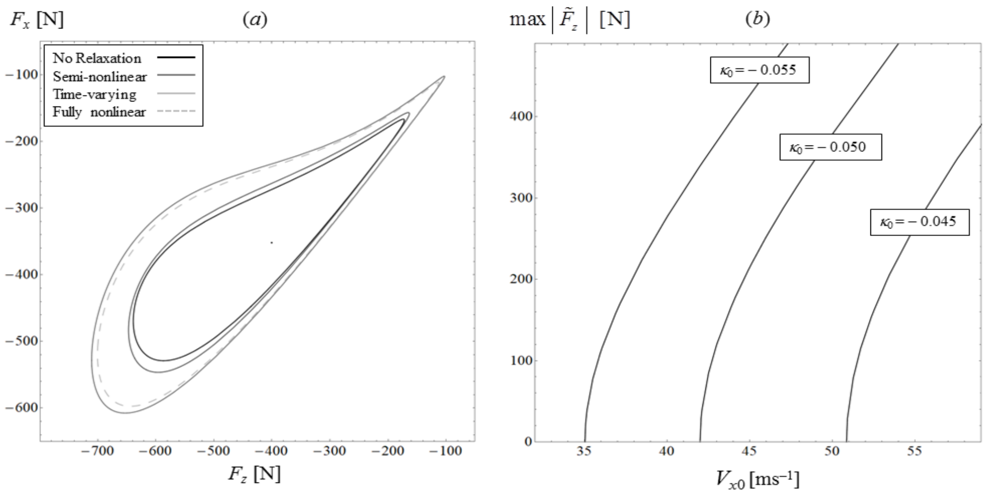
Abstract. This study is focused on the understanding of the nonlinear effects of tyre forces and chain geometry on motorcycle chatter, a self-excited oscillation arising at the rear wheel during heavy braking manoeuvres. In particular the post-bifurcation criticality is assessed, whether subcritical or supercritical, with respect to travelling speed.

Introduction

An instability exists in the rear suspension of motorcycles typically called 'chatter' that is experienced during heaving braking in the frequency range from 17 to 22 Hz. The causes and mechanisms of this self-excited oscillation have been studied with many focusing on the interaction between rear wheel speed and rear suspension travel, involving the 'driveline' mode [2,3]. Previous work has thoroughly investigated the phenomenon using linear methods showing that it is caused by out-of-phase interactions in the normal load and longitudinal tyre forces, with analogy to flutter in aeroelasticity [2]. The gradient of the characteristic function of the tyre force [3] was shown to play a fundamental role in the onset of chatter, and the geometry of the chain transmission in its amplification. It has recently been demonstrated that the roll angle enhances instability in an indirect way, affecting the characteristic function of the tyre force. Stability analyses in the above-mentioned studies were performed on linearized models, either minimal models [2] or large multi-body models [3].

This study looks to assess the post-bifurcation criticality, whether subcritical or supercritical, with respect to travelling speed. This also includes the contribution of tyre relaxation [3], since this aspect has not been investigated in-depth in previous studies. A two-dof minimal model is considered, including the nonlinear terms due to geometry, tyre characteristic function and tyre relaxation. To study the post-bifurcation behaviour and the existence of limit cycles, the harmonic balance method is adopted in combination with Floquet theory, aimed at identifying the most meaningful parameters in limit cycle generation, their amplitude and stability.



Results and Discussion

The nonlinear system without tyre relaxation is found to have a supercritical behaviour within the parameter domain of technological interest, with a single stable limit cycle (figure *a*: limit cycle in terms of longitudinal F_x and vertical F_z tyre forces, and effects of different tyre relaxation models; figure *b*: bifurcation diagram as a function of travelling speed, for different values of tyre slip coefficient κ_0, showing supercritical behaviour). The growth of the limit cycle soon after the linear stability boundary in any case is strong enough to overcome the limits of what could be acceptable for motorcycle stability. A sensitivity analysis is performed to identify the influence of each of the model parameters on the limit cycle amplitude, with the aid of bifurcation diagrams, confirming that the main driver of nonlinear asymptotic behaviour comes from the tyre force characteristic function. Tyre relaxation produces destabilizing effects both in the linear and nonlinear models, however, adopting realistic values of relaxation length, those effects are found to play a minor role.

References

[1] Sorrentino S., Leonelli, L. (2017) A. S. (1999) A study on the stability of a motorcycle wheel-swingarm suspension with chain transmission. *Vehicle System Dynamics* **55**(11):1707-1730.

[2] Leonelli, L., Cattabriga, S., Sorrentino, S. (2018) Driveline instability of racing motorcycles in straight braking manoeuvre. *Journal of Mechanical Engineering Science* C **232**(17):3045-3061.

[3] Pacejka, H. (2012), Tyre and Vehicle Dynamics. Elsevier Science.