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Influence of the Front Suspension on the Transient Dynamics of Motorcycles on Braking

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Abstract

The front suspension layout has crucial influence on the vertical and lateral dynamics of the motorcycle. The most widely used front suspension is the telescopic fork.

Alternatives offer some advantages, which can be verified through steady-state analysis. But those front suspensions have never found broad application in racing-oriented motorcycles. Instead, many riders claim to miss control on braking. To understand this criticism better from a scientific point of view, the focus of this work is set on the transient dynamics of motorcycles in the braking maneuver, which was inspired by the publication of Tony Foale [1].

For an analytical analysis, a simple and linear multibody-model is developed (Figure 1). It consists of three bodies. The model represents a simplified motorcycle with a rigid chassis body and two massless and ideally stiff wheels of the same diameter, an abstract front suspension and a direct connection between chassis and rear wheel. To keep the model as general as possible, the front suspension is represented by its instantanious center and a wheel related, linear spring (k) and damper (c) unit.

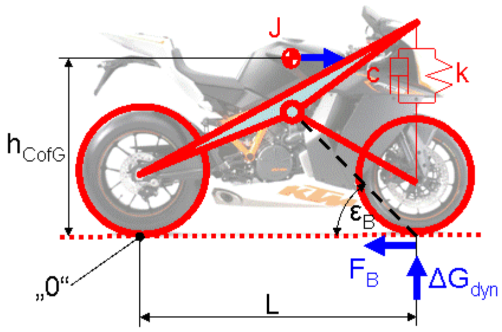

Figure 1. Front wheel load during sudden brake force variations.

For a first approach, the adhesion limits of a tyre are not considered.

Under this conditions, the transfer function between the braking force, which is the output created by the rider, and the dynamic front wheel load, can be formulated as

$$\frac{\Delta G_{dyn}}{F_B}(j\omega) = L(k + j\omega c)\frac{h_{CofG} + L\tan(\varepsilon_B)}{kL^2 + cL^2 j\omega - J_0\omega^2} - \tan(\varepsilon_B)$$

with J_0: Motorcycle inertia around point "0".

Out of this equation, the system answer to a sudden brake force variation can be calculated by the inverse laplace transformation through correspondence tables. The results for typical motorcycle data are illustrated in Figure 2.

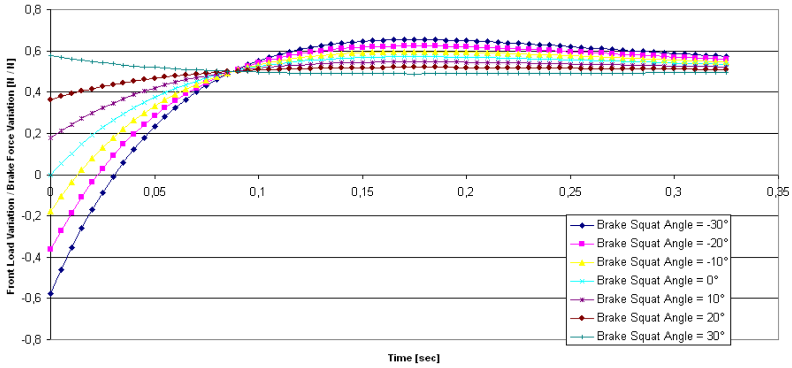

Figure 2. Front wheel load during sudden brake force variations.

These results suggest that a front suspension with a highly negative squat angle, like the telescopic fork, initially unloads the front, before loading it up to the steady-state dynamic load. Vice versa, a highly positive squat angle initially creates a very high wheel load on a quick brake force increase, which is later fading down to the stationary value. Opposite effects can be expected for a brake force decrease.

It can further be considered that there is a relation between the current wheel load, the thereby transmittable braking force and the tyre slip, which is usually described through the tyre model. This means generally, that at a constant brake force, the adhesion coefficient and thereby the slip is reduced by higher wheel loads.

The conclusion ,is, that a highly negative squat angle offers reduced grip on initial braking, as the dynamic wheel load is applied with a delay. Vice versa, on instant brake release or grip loss the dynamic wheel load increases due to the squat kinematics. This can help to safe a possible front wheel slide.

For a more realistic analysis, multibody simulations with VI motorcycle have been used. They are performed for three different front suspensions, which have different brake squat angles.

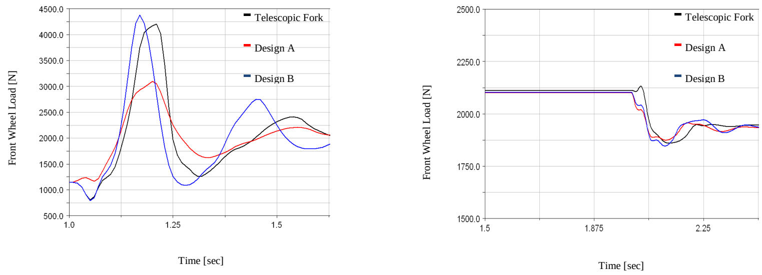

Figure 3. Wheel load due to sudden brake force increase (left) and decrease (right) for different front suspensions.

Indeed, the results show the same tendencies expected from the simple model. Additionally, they show the relation to other effects, like the rear suspension movement and the influence of a complex tyre model, which were neglected in the simple model.

As a conclusion of this study, on the one hand additional objective weight was given to the subjective criticism of many alternative front suspensions, often mentioning the missing feeling for the front on braking. The main goal, to deepen the understanding for this criticism from a scientific point of view, was reached. On the other hand, out of this aspect it will be possible to develop evaluation criteria for new generations of front suspensions, which might find more sympathies from the riders.

[1] T. Foale, *Motorcycle Handling and Chassis Design, 2nd Edition*, Tony Foal Designs, Spain, 2006.