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Experimental investigation on the shimmy phenomenon

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Abstract

Dynamic behavior of motorcycles, in terms of out of plane vibration modes, is strongly influenced by oscillations that can arise between the front and rear frames around the steering axis. Idealizing the behavior for a very large rear frame mass compared with the front frame, the shimmy phenomenon takes place [1].

This paper presents a basic experimental investigation on the shimmy phenomenon of a scooter front assembly. The tests were conducted at the DiME laboratory, adopting a test rig for different sets of parameters that influence the dynamic behavior of system.

The castor adopted for the investigation (Fig.1) is derived from a commercial scooter front assembly; it is joined to a rigid steel frame by means of a support that allows the castor to vertically translate and rotate around its steering axis the wheel rolls on a flat track belt [2].

The castor rake angle can be regulated by means of screw adjustment.

The vertical load, acting on the castor support, is set by means of a wire rope and a system of pulleys.

As the fork stiffness increased with the vertical load, due to the shortening telescopic suspension, the suspension springs were removed and replaced with rigid spacers. In this way, the influence of the vertical load and fork stiffness can be evaluated separately: indeed, they have opposite effects on the shimmy phenomenon. In particular, two castor configurations were considered, characterized by the maximum and the minimum extension of the fork respectively.

Finally, the castor was equipped with a 18 position (clicks) adjustable steering damper.

A basic survey was conducted to highlight the influence of some experimental parameters on the system dynamics; the tests were performed with different values of belt velocity for each castor configuration. The system was perturbed by hitting the handlebar extremity and noting if the shimmy oscillation arose; the steering damping was then tuned by setting the “click” in position where the system is stable.

Considering the force exerted by the steering damper, in the damper velocity variation range, approximately linear, a constant damping value was estimated for the first 9 damper positions. Taking into account the distance between the damper axis and the steering axis, the rotational damping coefficients σ, associated with each damper position click are:

click	0	1	2	3	4	5	6	7	8
σ [Nms/rad]	0.615	0.661	0.723	0.938	1.29	1.44	1.75	2.20	2.61

The investigation results are shown in the form of diagrams reporting the damping required to stabilize the system versus the belt speed, for the different castor configurations.

The castor configurations that were different from the nominal one were obtained by acting on the following parameters: the fork stiffness (both bending and torsional separately); the castor moment of inertia about the steering axis (I_c); the wheel moment of inertia (I_w), the rake (ε); the vertical load (N) and the tire characteristics.

As an example of results, Figure 3 shows the stability curve corresponding to the following parameter values: ε=27°; p=1.2 bar; I_c=0.37kgm2; I_w=0.324 kgm^2; maximum fork extension and two values of the additional vertical load: 20 daN and 40 daN.
It shows that the shimmy oscillation arises over a certain speed value and then, for greater speeds, thanks to the gyroscopic effect, it disappears [3] and no additional damping is required to stabilize the castor.
The upper curve (40 daN) in Figure 3 was adopted as a reference result and is reported in the other stability diagrams obtained by modifying one parameter at time to highlight and compare the influence of the modified parameter.
Figure 4 shows an FFT waterfall performed on the angular steering sensor signal, obtained for a given damping value and for different belt velocity values. The shimmy frequency has increased with an almost linear law from 5 Hz (at 10km/h) to 7 Hz (at 65 km/h) The straight line in the diagram represents the frequency which is synchronous with rotating angular speed.
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Figure 1 - Castor on belt rig

Figure 2 – Handlebar with steering damper

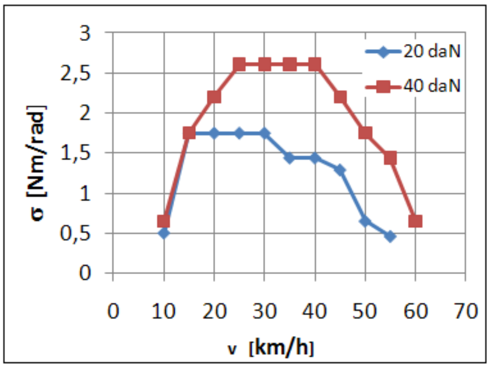

Figure 3 – Stability curve

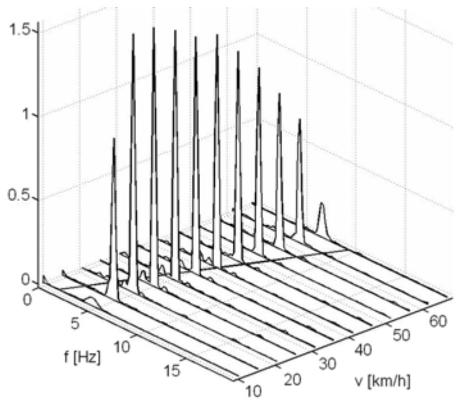

Figure 4 – FFT waterfall

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