

On the non-linear behaviour of motorcycle shock absorbers

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Abstract: Motorcycle shock absorbers exhibit a non-linear behaviour characterized by hysteresis in the force–velocity diagram. The presence of hysteresis is the main obstacle in the identification of parameters and the development of computationally efficient shock absorber models. Gas compression, oil compressibility, mechanical compliance of chambers, and oil inertia are the most important causes of hysteresis. This paper deals with experimental research carried out on a twin-tube shock absorber equipped with pressure gauges in the chambers. A physical model is developed to explain the behaviour of the shock absorber from the measured pressures. The relevance of the various non-linear phenomena is discussed. The friction, hydraulic, and compliance parameters are identified from the measurements. The mathematical model fitted with the identified parameters is able to predict with accuracy the force generated by the shock absorber.

Keywords: shock absorber, motorcycle, identification, modelling

1 INTRODUCTION

The advanced simulation codes, which nowadays are used for virtual prototyping in automotive and motorcycle design [1], require computationally efficient models able to describe the relationships between effort variables (forces and torques) and flow variables (velocity and displacement) in the subsystems of the vehicle. Hence, specific models of tyres, suspensions' linkages, chassis, and shock absorbers are needed. This paper deals with shock absorber modelling.

If the force developed by a shock absorber were only a non-linear function of velocity, the identification of the parameters and the modelling of the shock absorber would be a simple task, because experimental data could be fitted by a curve. In fact, the force depends on piston position and acceleration as well, and the force–velocity characteristic shows a hysteresis loop, which cannot be fitted by means of a simple curve. For the same value of

velocity there are different values of force that depend on the time history of piston motion.

Some physical and black-box models have been developed to cope with hysteresis problems.

Duym and co-workers [2, 3] developed a complete model of the automotive shock absorber that takes into account details of flow across valves. They tested some shock absorbers with a frequency sweep and removed the hysteretic effects (which typically take place at the beginning of bound and rebound) by retaining only the samples in which acceleration and velocity have a different sign. The parameters of the model were successfully identified with optimization methods.

Allen *et al.* [4] in 2006 developed a model of a rotary damper for a heavy vehicle and highlighted the contribution to hysteresis due to entrapped gas.

In the field of motorcycle shock absorbers, Audenino and Belingardi in 1995 presented research dealing with a twin-tube shock absorber. They measured the external characteristics (force–velocity and force–position) and developed a mathematical model taking into account oil compressibility, oil inertia, and disc valve dynamics. They highlighted the importance of capacitance, which is caused by oil com-

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