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Motorcycle control by variable geometry rear suspension

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Abstract

This work is about controlling the geometry of the rear suspension to reduce cornering weave oscillations associated with high performance motorcycles operating at high speeds. The main lateral oscillations in two-wheeled vehicles are “wobble” and “weave”. The wobble mode is a steering oscillation whose frequency is normally in the range $6-9$ Hz and varies little with speed. The weave mode is a fishtailing motion that involves mainly yawing, rolling and steering of the vehicle. At low and intermediate speeds it is well damped but becomes less damped as the speed increases, in straight running or under moderate lean angle conditions. The natural frequency is lower in heavier motorcycles and rises from zero at very low speed to somewhere in the range $2-4$ Hz. In cornering, the above lateral modes and the in-plane tyre deflections and suspension modes become coupled, as was first shown by Koenen [1]. The motorcycle becomes prone to resonant forcing when regular road undulations produce displacement forcing that is tuned to lightly damped modal frequencies of the machine. Moderate roll angles appear to represent the worst case conditions [2].

Conventional motorcycle rear monoshock suspension systems are designed to provide varying but predetermined leverage ratios between spring damper unit and road wheel, as the suspension travels to its limits. These characteristics are motivated and designed by static equilibrium considerations. Further variations of the leverage ratio can be superposed by utilising variable geometry arrangements in which the mechanical path along the suspension kinematic loop is combined with an actuator. The actuator will essentially act as a displacement controller and will interact with the conventional passive force-producing elements, spring and damper, to provide active control. The degree of their interaction will primarily be determined by the geometric design, and it will prescribe the actuator force and power requirements. Variable geometry suspension ideas have already been explored in [3, 4, 5, 6, 7] for cars and in [8] for motorcycles. In the case of motorcycles the participation of the rear suspension in weave oscillations implies the potential for an active variable geometry suspension to add damping to the weave mode.

The broad purpose of this research is to investigate the practicality and performance of a variable geometry suspension scheme in improving the cornering weave behaviour of modern high performance motorcycles. The suspension under consideration aims to incorporate four major characteristics. Firstly, due to packaging constraints, the operating space of the variable geometry system should be close in size to that of the standard passive system. Secondly, in order to reduce costs it should be possible to use much of the existing passive technology with easy retrofitting of any new parts. Thirdly, variation of the geometry should be done with low actuation forces and power so that actuators of reasonable size can be used. Fourthly, fail safe operation should be easily achievable.

The large perturbation performance of the variable-geometry-controlled motorcycle is studied by simulation. An illustration of such simulation results is shown in Figure 1.

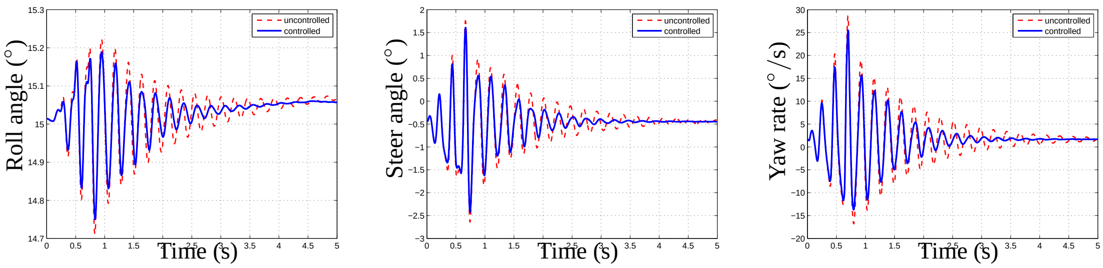

Figure 1. Transient behaviour of the roll and steer angles and the yaw rate for the uncontrolled (dashed line) and controlled (solid line) machine, in response to sinusoidal road forcing that begins at $t = 0$ and ends at $t = 0.623$ s, and has a peak amplitude of 5 mm. The forcing frequency is tuned to the weave mode. The forward speed is 75 m/s and the lean angle 15 deg.

References

[1] C. Koenen, “The dynamic behaviour of motorcycles when running straight ahead and when cornering,” Ph.D. dissertation, Delft University of Technology, 1983.

[2] D. J. N. Limebeer, R. S. Sharp, and S. Evangelou, “Motorcycle steering oscillations due to road profiling,” *Journal of Applied Mechanics-Transactions of the ASME*, vol. 69, no. 6, pp. 724–739, 2002.

[3] P. J. T. Venhovens, A. C. M. Knaap van der, and H. B. Pacejka, “Semi-active attitude and vibration control,” *Vehicle System Dynamics*, vol. 22, no. 5-6, pp. 359–381, 1993.

[4] N. J. Leighton and J. Pullen, “A novel active suspension system for automotive application,” *Proceedings of the Institution of Mechanical Engineers Part D-Journal of Automobile Engineering*, vol. 208, no. 4, pp. 243–250, 1994.

[5] D. Karnopp and S. G. So, “Energy flow in active attitude control suspensions: A bond graph analysis,” *Vehicle System Dynamics*, vol. 29, no. 2, pp. 69–81, 1998.

[6] Y. Watanabe and R. S. Sharp, “Mechanical and control design of a variable geometry active suspension system,” *Vehicle System Dynamics*, vol. 32, no. 2-3, pp. 217–235, 1999.

[7] W. J. Evers, A. Knaap van der, I. Besselink, and H. Nijmeijer, “Modeling, analysis and control of a variable geometry actuator,” in *2008 IEEE Intelligent Vehicles Symposium (IV)*. Eindhoven, Netherlands: IEEE, 2008, pp. 251–256.

[8] R. S. Sharp, “Variable geometry active rear suspension for motorcycles,” in *Proceedings of AVEC 2000*, Ann Arbor, MI, August 2000, pp. 389–395.