Methods for elimination of crosstalk and inertial effects in bicycle and motorcycle steer torque estimation

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Applying forces to the handlebars of motorcycles and bicycles that result in a net torque between the front frame and the rear frame (and rider) about the steer axis provides the most authority of any other input for control of the lateral dynamics of the vehicles. It has also been postulated that haptic feedback is very important and may be essential for a human to balance a bicycle or motorcycle. Thus is it critical to understand how the steer torque plays a role in both the open loop and closed loop dynamics of the bicycle/motorcycle-rider system.

The first portion of the paper will be devoted to a review of steer torque measurements and modeling results. For example, the earliest measurements of steer torque were done on a motorcycle [1] with a manual scale. There have been various sensors designed since to measure steer torque with various degrees of range and accuracy.

The applied steer torque needed to control a motorcycle is generally much greater in magnitude than that of a bicycle. For similar maneuvers, motorcycles may require up to 50 Nm while bicycles require up to 10 Nm. Furthermore, the rider can easily apply moments to the handlebars up 20 times larger in magnitude than the steer torque. The sensors must be designed such that these other forces do not corrupt the much lower magnitude steer torque measurements.

There are several types of designs for measuring steer torque: force transducers at the hand-handlebar interface, torque transducers on or in the steer tube, and variations of secondary handlebars connected through transducers. The merits of each type of design are discussed in the paper.

We show that careful attention must be paid to any steer torque sensors which measure the strain at points between the hands and the front wheel contact point. Depending on the location along the steer axis where the measurement is made, the inertial effects of the front frame and handlebars between the sensor and the rider's hands must be accounted for. For bicycles, this is very important because the torques due to the inertial effects can be a high percentage of the actual applied torque. No previous steer torque measurements seem to take this into account.

Finally, we will describe the steer torque measurement sensor designed for an instrumented bicycle which attempts to account for many of the flaws of previous measurements. We include experimental results measuring headset bearing friction and show results for very accurate torque measurements in various bicycle maneuvers giving a qualitative and quantitative look at typical steer torque measurements.

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References

[1] R. A. Wilson-Jones. Steering and stability of single-track vehicles. In *Proceedings of the Institute of Mechanical Engineers (Auto Div)*, pages 191–199, 1951. Part 4.

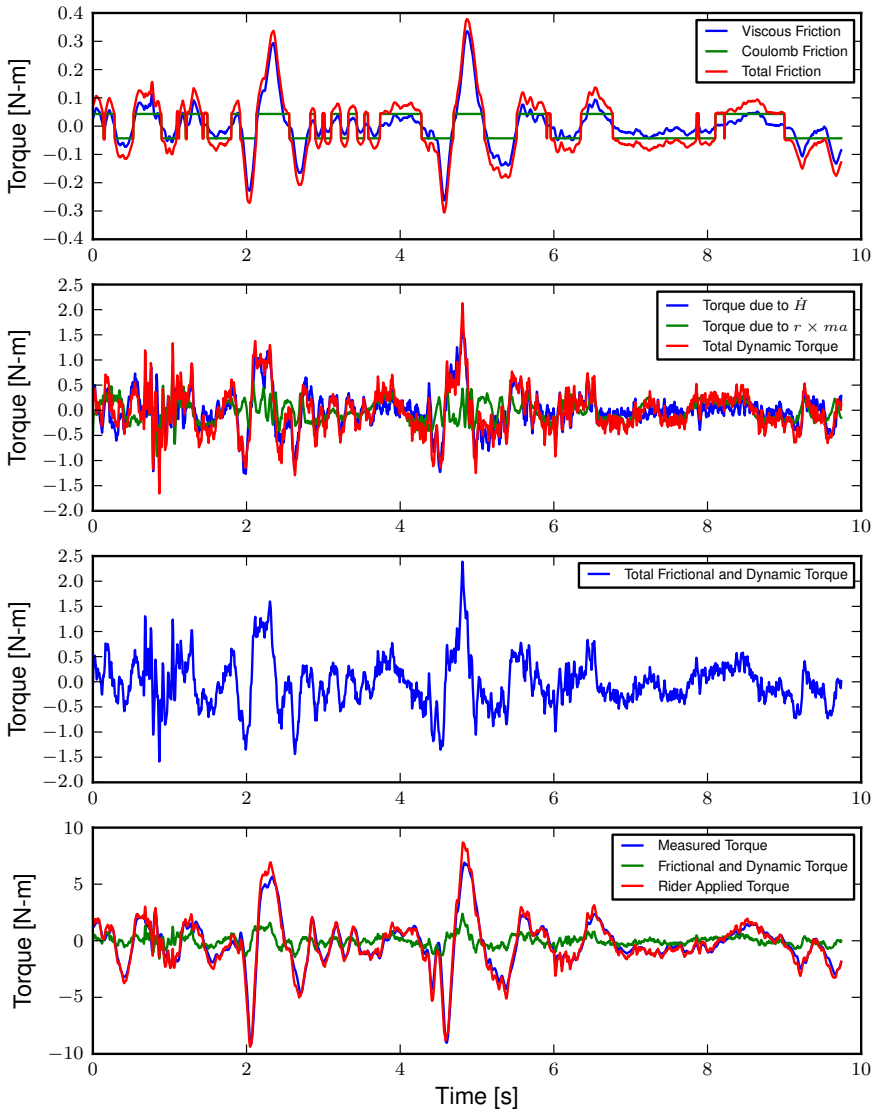

Figure 1: Steer torque components for run #700. The top plot shows the additive viscous and Coulomb friction. The total bearing friction during the run is less 0.3 Nm. The second plot shows the torque the rider must apply to overcome the handlebar inertia, which is the dominant moment. During peak accelerations the additive torque is as high as 1.5 Nm for this run. The third plot shows the total additive torque which is as large as 2 Nm. The last plot shows the difference in the measured torque and the rider applied torque. There are substantial differences, especially at the peaks.