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Analysis of the Biomechanical Interaction between Rider and Motorcycle by Means of an Active Rider Model

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Abstract

Compared with other vehicles like cars, the mechanical interaction between rider and his motorcycle is much closer. Dynamics of motorcycles is well understood [1] and even complex multibody models of real bikes have been realized [2]. But models which consider the influence of the rider on the dynamics of the man-machine system are restricted to upper body lean and artificial steering torques. To enable the analysis of issues like motorcycle ride comfort, safety and instable ride modes Biomotion Solutions has developed a biomechanical rider model for motor-cycle simulations which is capable of steering the motorcycle by moving the handlebars.

The Human Body Model: Based on anthropometrical data [3] we have implemented a 17 segment full body model. The model consists of 2 legs (foot, shank and thigh), a 3-parted trunk, neck head and two arms (hand, fore-arm, upper arm). Furthermore, each of these rigid bodies is coupled with a so-called wobbling mass which takes into account that human body tissue is not a rigid material. The consideration of wobbling masses [4, 5] is crucial - especially for ride comfort simulations.

Enabling Active Movement: To enable active steering movements we have implemented passive and active actuators into the model. The lower extremities, the trunk and head-neck are stabilized by passive impedances whose parameters are chosen according to literature values [6]. To enable the rider model to control the handlebars, shoulders and elbows are actuated via muscle moment generators. Their input is provided by our driver model controller which uses a look ahead measurement of the track (e.g. [2]) as feedback for the path control. Muscle moments are generated by PID-Controllers in the joints, which take the desired joint space configuration as set value. The heavier a motorcycle is, the more dominant the so-called countersteering with the handlebars is. Consequently we take the cornering via controlling the steering angle into account at first. Appropriate roll angles can be computed by PID-Controllers using as input the lateral track error of the bike's position and the yaw-angle, which describes the difference between the bike's direction and the curvature of the road trajectory. Both strategies can be superposed; PID-parameters have to be chosen carefully to allow for stable operation.

The Motorcycle Model: The motorcycle model is built as a 3d multibody system using SIMPACK as simulation platform. The bike consists of a fork mounted frontwheel connected to the steering axis by a 1 DOF (*degree of fredom*) prismatic joint. The steering is connected by a 1 DOF hinge joint to the frame. The swingarm mounted rear wheel has also 1 DOF of rotation. Parameters for inertia and masses were chosen in agreement with literature. As this configuration came out as too ideal to generate wobbling modes, we added some further DOF e.g. to describe the elastic properties and joint clearance.

Analyzing Safety Issues: Motorcycle and rider are a coupled system whose dynamics emerge from the interaction of both. Experienced riders are reporting possibilities to provoke or to damp down highly dangerous instable ride modes like weave or wobble. We used our rider model to analyze the rider-bike-system near weave mode. Riding with 60 meters per second a transient disturbance moment has been applied at the steering. The bike then showed a short latency time in which a negative damped oscillation showed up which finally led to exponential rising amplitude in yaw angle and to uncontrollable crashing. Furthermore we have analyzed the sensitivity of the weave

phenomenon to the seat cushion parameters ot to total muscular tension of the rider's body. The results predict strong influence of biomechanical factors on ride dynamics.

Figure 1. Phase space trajectories of the yaw. The man-machine system becomes unstable if the rider tries to hold the handlebars too tight (right figure).

Figure 2. The biomechanical rider is capable of handling tasks like straight running, cornering and even jumping (some animations can be found under www.biomotion-solutions.com/drivermodel).

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