Bicycle and Motorcycle Dynamics 2010
Symposium on the Dynamics and Control of Single Track Vehicles,
20 - 22 October 2010, Delft, The Netherlands

Modeling of a Motorcycle using Multi-Body Dynamics and Its Stabilization Control

S. Murakami
Graduate School of System Design and Management
Keio University
4-1-1 Hiyoshi, Kohoku-ku, 223-8526 Yokohama, Japan
e-mail: s.murakami@z5.keio.jp

S. Zhu
School of Medicine,
Keio University

H. Nishimura
Graduate School of System Design and Management,
Keio University

Abstract

In this paper, a new rider-motorcycle system including front and rear suspensions [1], [2], [3] is modeled using multi-body dynamics, and then the stabilization control system is designed based on the multi-body dynamics model. We have already modeled the rider-motorcycle system taking into account of the lean angle of the rider's upper torso [4], [5], however, including the front and rear suspensions will be necessary for dynamical analysis of a motorcycle during braking in a turn or straight running.

A dynamical model of the nonlinear twelve-degree of freedom rider-motorcycle system derived as shown in Figure 1. In addition to the lean motion of the rider's upper torso: θ_{wx} rotating around the x-axis of the rear frame of the motorcycle, the steering angle: δ and the rotation of the front and the rear wheel, this model includes the compression length of the front suspension: l_{UD} and the compression angle of the rear suspension: ψ, which are restrained with a spring and a dumper respectively. The rider's upper torso is connected to the handle with a spring and a dumper.

A front-steering assist control [5], [6], [7] stabilizes the motorcycle against applied impulse disturbance on the front wheel. For driving in a straight line at low speed, references [6] and [7] have experimentally verified stability with this control. Figure 2 shows a simulation result of the front-steering assist control during rear braking in a turn; (a) roll angle, (b) steering angle, (c) tu-

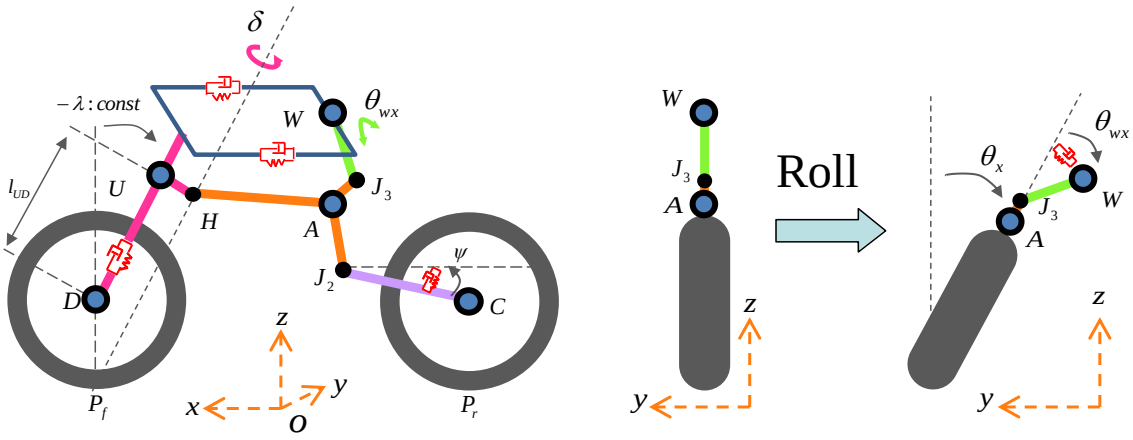

Figure 1 Dynamical Model of a rider-motorcycle system

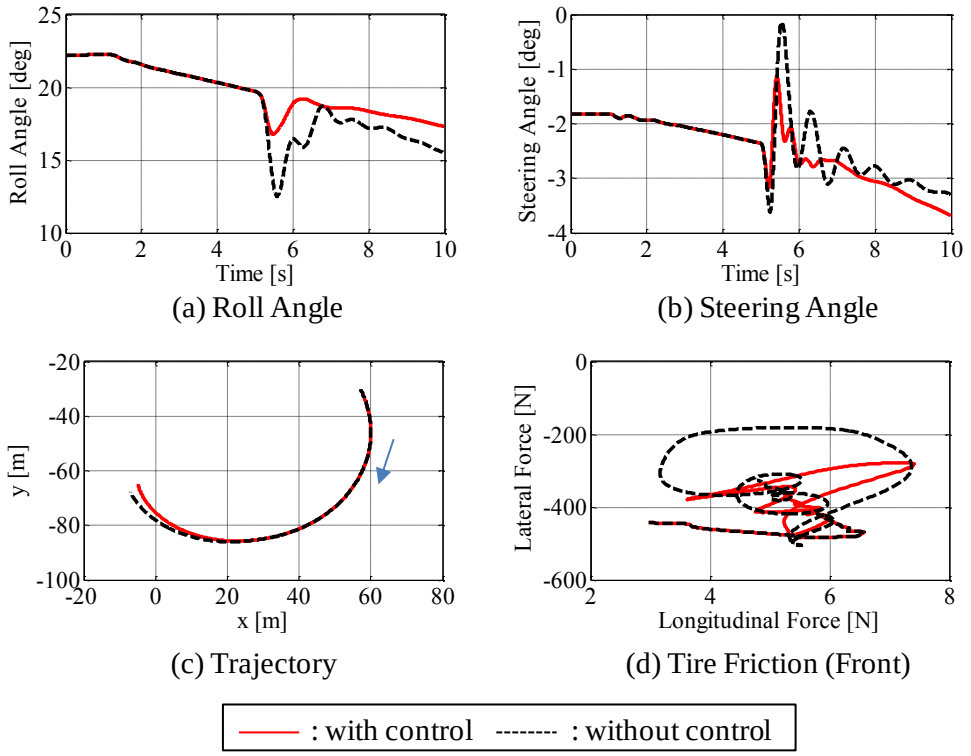

Figure 2 Simulation result with and without a steering assist control during rear braking in a turn

rning trajectory and (d) tire friction force. In the simulation, the speed of the motorcycle is decelerated from 50 km/h to 30 km/h, and 10 Nm of impulse disturbance is given to the steering torque. The controller [5] designed for steady circular turning aims to stabilize the motorcycle against applied impulse disturbance on the front wheel even during rear braking in a turn. With the derived dynamical model, we adopt the front-steering assist control to braking situations and show further investigation of the stabilization control using simulation.

References

[1] V. Cossalter and R. Lot, "A motorcycle multi-body model for real time simulations based on the natural coordinates approach", *Vehicle System Dynamics*, 2002, vol. 37, No.6, pp. 423-447.

[2] R. Lot and M. DA LIO, "A symbolic approach for automatic generation of the equations of motion of multibody systems", *Multibody dynamics* **12** (2004), pp. 147-172.

[3] R. S. Sharp, S. Evangelou and D.J.N. Limebeer, "Advances in the modeling of motorcycle dynamics", *Multibody dynamics* **12** (2004), pp. 251-283.

[4] T. Katayama, A. Aoki, and T. Nishimi, "Control Behavior of Motorcycle Riders", *Vehicle System Dynamics* **13** (1988), pp. 211-229.

[5] S. Zhu and H. Nishimura, "An Attitude Stabilization Control System for a Motorcycle (A front-steering assist control for steady-state circular turning at the low speed)", *Transactions of the Japan Society of Mechanical Engineers*, Series C, Vol. 75, No. 753 (2009), pp. 1336-1345.

[6] Y. Kamata, H. Nishimura, System Identification and Attitude Control of Motorcycle by Computer-Aided Dynamics Analysis, *JSAE Review*, Vol. 24, No.4 (2003), pp. 411-416.

[7] Y. Kamata, H. Nishimura, H. Iida, System Identification and Front-Wheel Steering Control of Motorcycle, *Transactions of The Japan Society of Mechanical Engineers*, Series C, Vol. 69, No. 688 (2003), pp. 3191-3197.