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

The Influence of a Passive Rider on the Open Loop Dynamics of a Bicycle

A. L. Schwab, and J. D. G. Kooijman
Laboratory for Engineering Mechanics
Delft University of Technology
Mekelweg 2, NL 2628 CD Delft, The Netherlands
email: a.l.schwab@tudelft.nl jodikooijman@gmail.com

J. P. Meijaard
Mechanical Automation and Mechatronics
Faculty of Engineering Technology
University of Twente
Enschede, The Netherlands
email:j.p.meijaard@ctw.utwente.nl

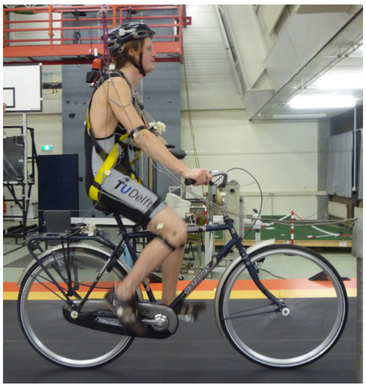
Abstract

The bicycle is an intriguing machine as it is laterally unstable at low speed and stable, or easy to stabilize, at moderate to high speed. During the last decade a revival in the research on dynamics and control of bicycles has taken place [1]. Most studies use the so-called Whipple model [2] of a bicycle. In this model a no-hands rigid rider is fixed to the rear frame. However, we know from experience that some sort of control is required to stabilize the bicycle and/or carry out tracking operations. This control is either done by steering or by performing a set of upper body motions. The precise control used by the rider is currently under study [3, 4].

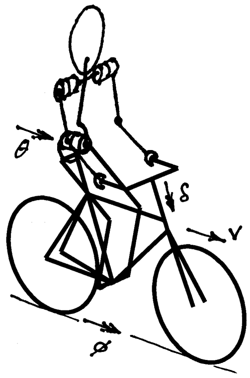
This paper addresses the influence of a passive rider on the lateral dynamics of a Whipple-like model. In this model the arms of the rider are connected to the handlebar and the rider can use both steering and lateral upper body motion for control. From observations of bicyclist riding on a large treadmill [3, 4] two major and distinct rider postures can be identified. The first is a rider on a city bicycle where the posture is upright with the arms hinged at the elbows and where the upper body does not move back and forth, Figure 1a. The second is a rider on a sportive touring bicycle where the posture is such that the upper body is leaning forward, the arms are stretched and where the upper body is able to twist, that is, rotate about its vertical axis, see Figure 1c.

Models can be made where neither posture add any degree of freedom to the system other than the extra degree of freedom for the lateral upper body motion. In both models, Figure 1b and 1d, the legs are rigidly connected to the rear frame and the upper torso is allowed to move laterally with respect to the rear frame by means of a single hinge located at the saddle. The model for the first, upright, posture is shown in Figure 1b. Here the upper arms are connected to the torso by a single hinge and the lower arms are connected by universal joints at the elbows and by ball joints at the handlebar. In the model for the second, leaned forward, posture, see Figure 1d, the arms are stretched and the upper and lower arms are modelled as one rigid body each, connected by universal joints to the torso and by ball joints to the handlebar. The upper body is allowed to pitch and twist. The geometry and mass properties of the two bicycles and the rider used in this study where measured by the procedure as described in [5].

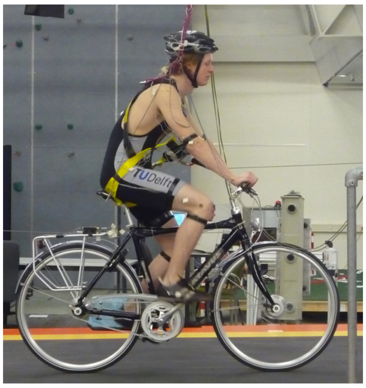
For both postures the open loop, or uncontrolled dynamics of the bicycle-rider system is investigated by examining the eigenvalues and eigenmotions in a forward speed range of 0 to 25 km/h. It is shown that such a passive rider can substantially change the eigenvalues compared with those where the no-hands rider is rigidly attached to the rear frame, the original Whipple model.



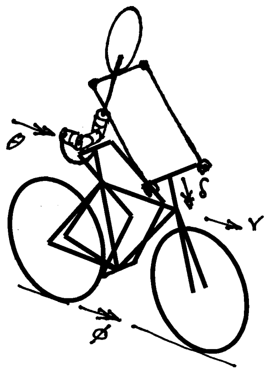
(a) Upright rider posture on a city bicycle.



(b) Model for a bicycle rider combination with an upright rider posture.



(c) Leaned forward rider posture on a sportive touring bicycle.



(d) Model for a bicycle rider combination with a leaned forward rider posture.

Figure 1: Two distinct rider postures and their Whipple like models. Degrees of freedom are the forward speed v, rear frame lean angle ϕ, upper body lean angle θ, and steer angle δ.

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