Bicycle Dynamics during Critical Braking Manoeuvre on Road Surfaces with High Friction

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1 INTRODUCTION

Nose-over accidents have a significant share among single-bicycle crashes [1,2]. One of the main reasons is the small wheelbase and high center of gravity compared to motorcycles which have been studied extensively [3-5]. Rear wheel lift-off ending up in a nose-over accidents have been described in detail analytically [6,7].

Modelling of accidents is complex due to the large number of influencing boundary conditions. In order to get a deeper understanding of bicycle dynamics prior to and during nose-over accidents, several uncritical and critical braking maneuvers have been executed and compared (uncritical braking maneuvers, rear wheel lift-off, nose-over). In addition, collisions with hard obstacles have been included in the study, since they are often combined with nose-over accidents.

2 EXPERIMENTAL SETUP

To execute the above described investigations, a test bike has been set up with a remote control for driving and braking via an App on a mobile phone. The brakes were actuated by the brake levers, similar to a standard bike. The brake levers, in turn, were actuated via bowden cables by pneumatic cylinders, driven by compressed air. With this setup reproducible and variable brake scenarios could be carried out [8].

On the bike, a crash test dummy is positioned, locked into upright driving position, with bonds that release under the forces acting during a crash.

The bike is equipped with several sensors: 3D acceleration sensors (in seat post position / handle bar), 3D angular rate sensors, pressure sensors in the brake system and various wheel speed sensors.

3 PROCEDURE

With the test bike described in chapter 2, several braking situations have been studied (see Figure 1) based on the sensor data that have been recorded during the scenarios.

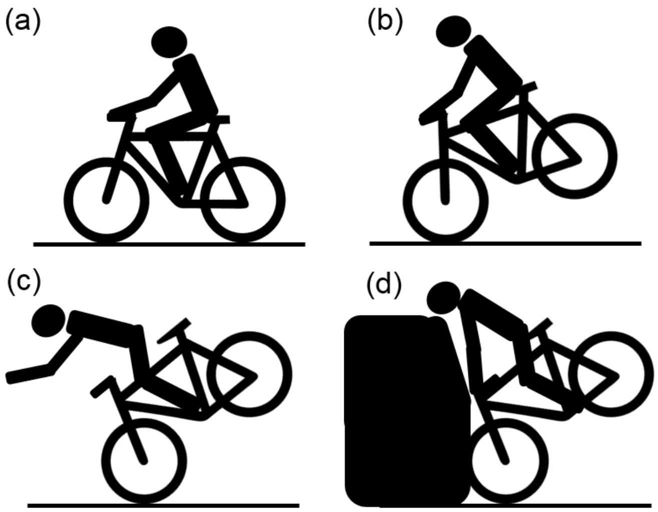

Figure 1: Braking and accident scenarios. (a) normal, uncritical braking; (b) braking with rear wheel lift-off, (c) braking with nose-over; (d) collision with a hard obstacle.

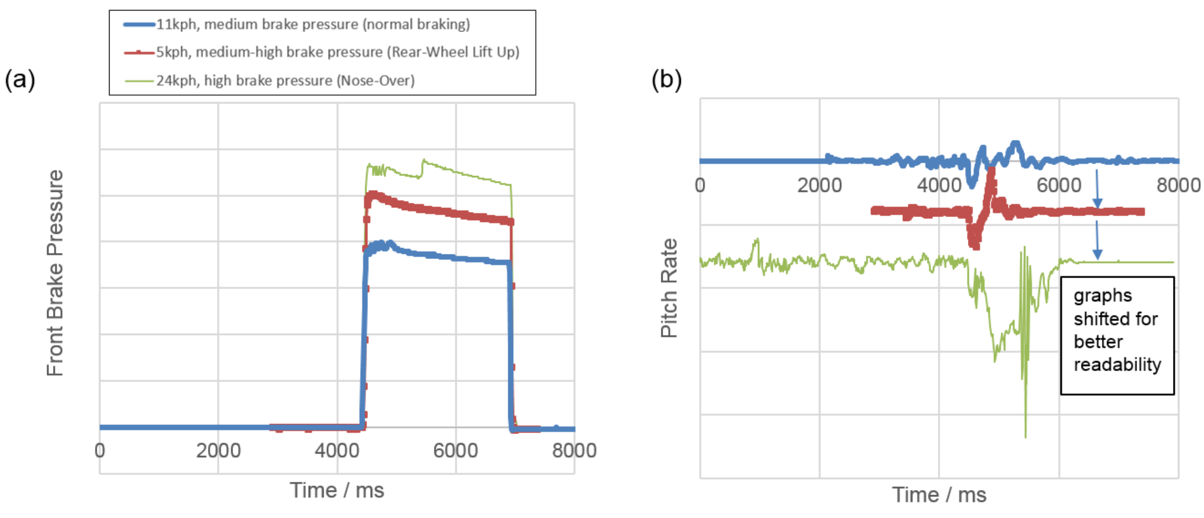

Figure 2: (a) exemplary brake pressure profiles (b) pitch rate for shown brake scenarios

3.1 Results

In Figure 2(a), some exemplary brake pressure profiles are shown. The different brake scenarios are easily differentiable via the measured pitch rate (Figure 2 (b)), at least after initial pitch due to suspension of the fork compression. For instance, the rear wheel lift-off shows very characteristic pattern, even though the speed of the bike was only 5 kph compared to 11 kph during the standard braking scenario in the same graph. It can also be seen that the whole nose-over motion from brake input start to crash onto ground takes less than 500 ms.

Accelerations of several g's have been observed during these braking maneuvers, especially when hitting the floor after nose-over, whereas up to 100 g were observed when crashing unbraked against a hard obstacle.

4 CONCLUSIONS

In order to get a better understanding of bicycle dynamics prior to and during single-bike crashes, different braking scenarios were analyzed, including normal braking, rear wheel lift-off and nose-over. The movement of the bike as well as braking interventions were remotely controlled over the air. The bike was equipped with several sensors, including wheel speed sensors, 3D accelerometers and gyros, and brake pressure sensors. On the bike, a Crash Test Dummy was fixed in the rider position. In addition to the braking maneuvers, crashes against hard obstacles have been included. The data can be used for a better understanding of the physics during a crash event. Additionally, simulation models can be verified with the created set of data.

REFERENCES

[1] K. Bauer, S. Schick, A. Wagner, K. Khou, S. Peldschus and A. Malczyk, *Untersuchungen zur Schutzwirkung des Fahrradhelms*, German Insurers Accident Research, UDV, Berlin, 2015.

[2] O. Maier, M. Pfeiffer, C. Wehner, J. Wrede, "Empirical Survey on Bicycle Accidents to estimate the Potential Benefits of Braking Dynamics Assistance Systems", *Proceedings, International Cycling Safety Conference 2015*, Hannover, Germany, 15-16 Sept. 2015.

[3] D. J. N. Limebeer and R. S. Sharp, Bicycles, motorcycles, and models, *IEEE Control Syst. Mag*. 26(5) (2006), pp. 34-61.

[4] J. P. Broker, P. F. Hill and B. S. Abrams, *Bicycle accidents: Biomechanical, engineering, and legal aspects*, Lawyers & Judges Pub. Co., Tucson, 2006.

[5] S. Werner, W. Newberry, R. Fijan and M. Winter, "Modeling of Bicycle Rider Collision Kinematics", *Proceedings, SAE World Congress*, Detroit, USA, 5-8 March 2001.

[6] G. P. Bretting, H. P. Jansen, M. Callahan, J. Bogler and J. Prunckle, "Analysis of Bicycle Pitch-Over in a Controlled Environment", *SAE Int. J. Passeng. Cars – Mech. Syst.* 3(1) (2010), pp. 57-71.

[7] D. L. Metz, "Road Bicycle Dynamics in the Presence of Idealized Roadway Irregularities", *Proceedings, SAE World Congress*, Detroit, USA, 13-15 April 2010.

[8] F. Dauer, "Requirements for a test environment and a driving situation catalogue for bicycle driver systems", *Proceedings, International Cycling Safety Conference 2016*, Bologna, Italy, 3-4 Nov. 2016