Test Vehicles for Motorcycle Accident Reconstruction and Analysis

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Abstract

The research groups on "Vehicle Dynamics" at TU-Wien and on "Transportation Infrastructure Technologies" at AIT have been active since many years in the field of vehicle accident research. As part of this research, experimental work has been carried out especially on the interaction between the motorcycle and the rider. An instrumented motorcycle used and the results obtained are briefly reviewed. Recently a much more advanced motorcycle has been equipped with high-fidelity measurement systems. This vehicle is described in details and future applications as a tool to investigate and analyse motorcycle accidents are outlined.

Introduction

Since the dynamics of motorcycles, more generally termed "Powered Two-Wheelers" (PTW), is quite complex [1] and substantially different from passenger cars, also accidents of such vehicles are often difficult to analyse. Mathematical models and theoretical studies are the basis for understanding the dynamics of motorcycles in the pre- and the post-crash phase. However, important parameters to be used in conjunction with mathematical models need to be acquired by experiments. Measurements of the friction coefficient of a crashed motorcycle sliding on a concrete road surface may be mentioned as an example for such needed studies.

But not only basic mechanical properties are highly relevant for the analysis of a motorcycle accident. The interaction between the rider, the motorcycle and the environment is of utmost importance. In this context the handling of the brake system plays an important role. Without an anti-lock-system (ABS) the rider has to adjust the braking force according to the friction available between tire and road such that wheel lock is prohibited and sufficient deceleration is achieved. A complex chain of action and reaction is observed during an emergency braking manoeuver. Reliable data on the performance of motorcycle riders and the information needed to analyse motorcycle accidents with emergency braking manoeuvers in the pre-crash phase also rely heavily on experimental data on the rider's ability to control such a difficult manoeuver.

These are just two examples out of many others that motivate and justify experimental work in motorcycle accident research. Clearly, such studies need facilities, test stands and test vehicles. Some experiments can be carried out on test stands [2], some need a special test environment for safety reasons, but numerous experiments can only be carried out by a human test riders and real motorcycles to provide realistic data [3,4].

Previous instrumented motorcycle

In the past experimental studies have been carried out at TU-Wien by the first author to investigate the interaction between rider and motorcycle during emergency braking manoeuvers. For these experiments a mid-sized motorcycle (Honda CB 500) was instrumented with a measurement system to measure brake reaction times and braking deceleration. Both measurements were carried out at the same time. Figures 1 shows the instrumented motorcycle and the essential measurement components in use.

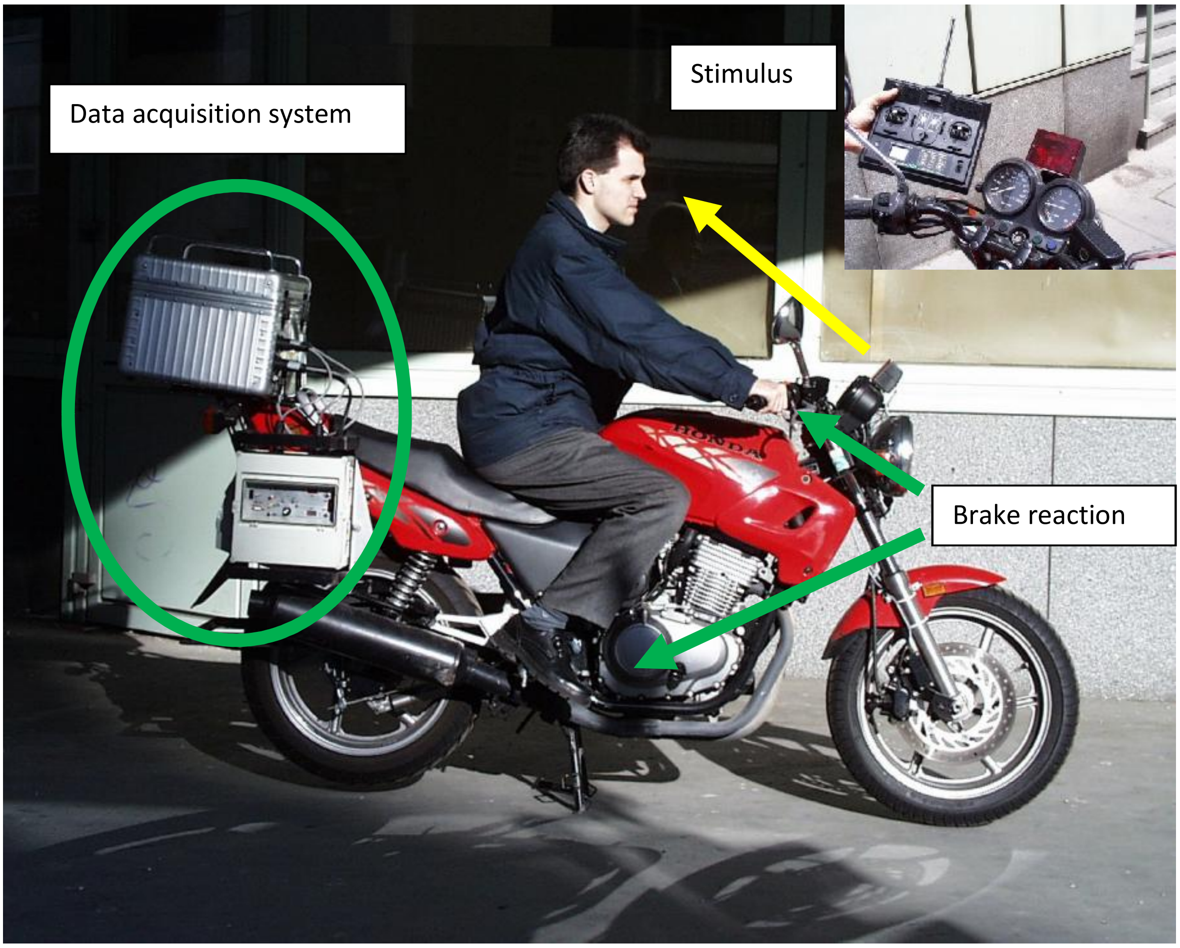

Figure 1: Instrumented motorcycle for measuring brake reaction times (front brake and rear brake) as well as braking deceleration in a simulated emergency braking manoeuver [3], [4].

With this test motorcycle a large number (several hundred) riders were tested and realistic data for brake reaction times and for braking deceleration were measured. Below, some of the results as published in [3] and [4] are shown.

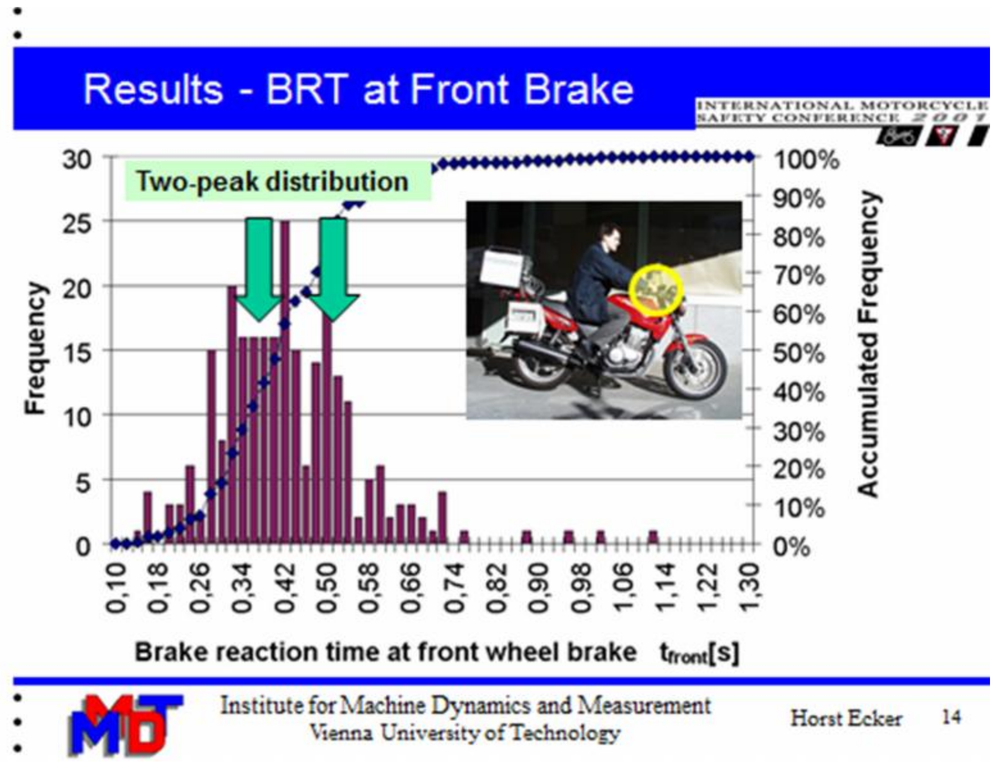

Figure 2: Measured Brake Reaction Times at the front brake for motorcycle riders, see [3].

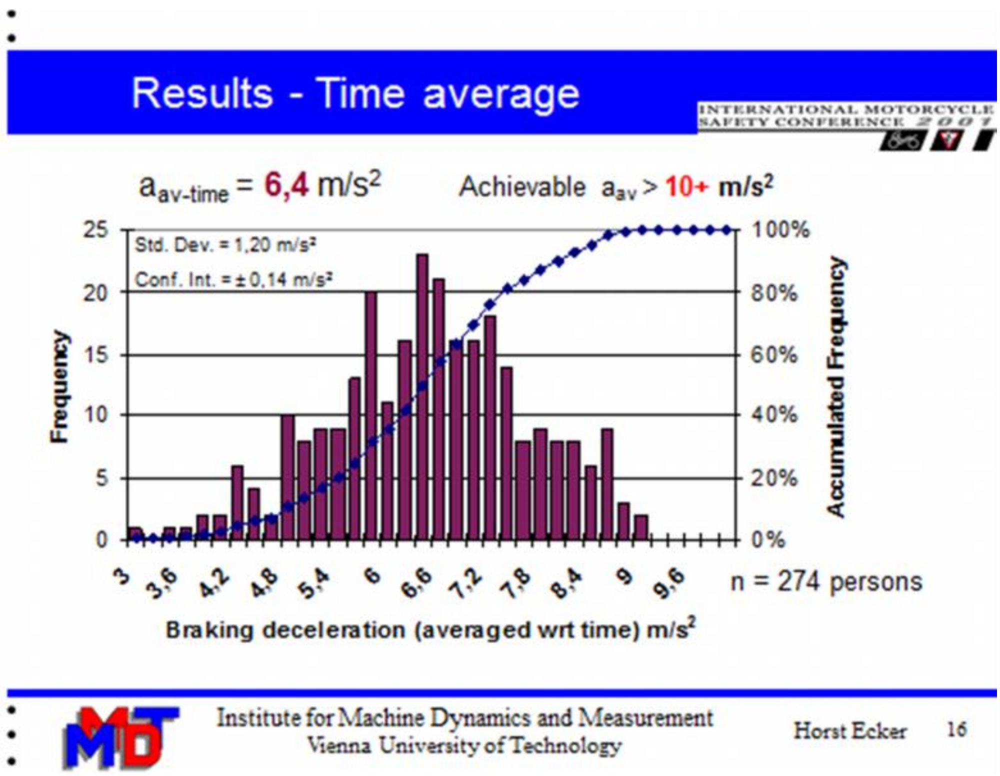

Figure 3: Measured braking deceleration of motorcycle riders, see [4] for details.

For these measurements, an external stimulus for the rider was triggered by a remotely controlled signal lamp on the dashboard of the motorcycle and this was the signal to initiate an emergency braking manoeuver. Started by the trigger signal, timers measured the time until the front brake and the rear brake was operated. Such the brake reaction time was measured. A 1-axis acceleration sensor was used to measure instantaneous values of the braking deceleration. The time series were then averaged during a post-processing step. All signals were recorded on an on-board laptop-based data acquisition system.

This measurement system of this test vehicle was further improved and it was equipped with brake force sensors so that instantaneous braking forces could be measured and analysed. The results showed very interesting driver behaviour and were especially useful to better understand and value the ability of untrained motorcycle riders to perform an emergency braking manoeuver, see [5].

Due to the modifications on the braking system, this vehicle was no longer registered and could not be operated in traffic anymore. The need to carry out driving studies in public traffic and moreover to use an up-to-date vehicle with recent technology (ABS, etc.) led to the decision to terminate the usage of this test motorcycle and start with a completely new vehicle and recent data acquisition technology.

MoProVe – An advanced general-purpose probe motorcycle for accident analysis

This section presents a highly specialized probe vehicle, which will serve as a mobile laboratory to analyse the interaction between the vehicle and the road, to investigate vehicle dynamics and vehicle safety. MoProVe (MOtorcycle PRObe Vehicle) is the result of a cooperation between Vienna University of Technology (TU-Wien) and Austrian Institute of Technology (AIT). It is based on a KTM „1290 Super Adventure“., see Fig. 4. This motorcycle is fully equipped with all currently available rider assisting systems like C-ABS, traction control, active suspension, etc., which rely on data signals from a variety of sensors. Therefore, it was possible to start from a rather high level, concerning necessary additional equipment.

Figure 4: MoProVe based on a KTM Super Adventure 1290. © KTM [6]

A unique feature of MoProVe are two additionally installed and independently operating measurement systems, see Figs. 5 and 6. These systems complement each other and allow a much more precise coverage of the vehicle's dynamic state and the interaction between bike and road and bike and rider. Key modules of both measurement systems are 6-axis motion sensors (IMU), GPS-antennas, CAN-interfaces and data loggers. Both systems record vehicle signals and data, like wheel speed, throttle position, brake system pressure. While system I is used and optimized for the vehicle motion in general (via double GPS-antennas and DGPS-station), the system II is used primarily for in-plane and out of plane motion of the chassis and the steering system.

Figure 5: VBOX 3i Dual Antenna Version. Vehicle dynamic measurement system I, © Racelogic [7]

Figure 6: Data logger, dashboard display and gyro sensor of measurements system II. © 2D Debus und Diebold Messsysteme GmbH [8]

It is very important to realize that MoProVe may be operated in traffic, since it is still a registered motorcycle, despite the extensive upgrade with measurement equipment. To record also the traffic situation and environment details, videocams are mounted additionally. In combination with high-resolution areal photographs and precise GPS-positions in-depth analysis of driving behaviour and safety issues in public traffic is possible.

At this time instrumentation of MoProVe is almost completed and measurements will be possible in the near future. However, measurement tests have been carried out already on a similar motorcycle with the actual measurement hard- and software and they have been very promising. Especially the dual antenna system has proven to be very accurate and reliable. It will be possible to measure the vehicle path with high accuracy, along with the other system parameters. Longitudinal acceleration and deceleration are measured in 3 axes as well as gyroscopic sensors measure the pitch-, yaw-, and roll-rate of the motorcycle.

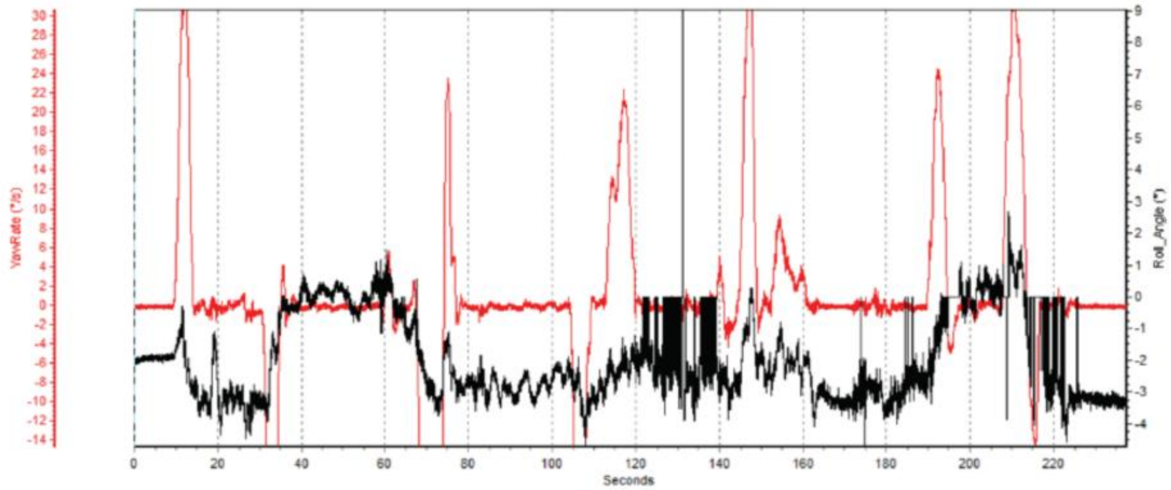

Figure 7: Raw signals of the yaw and the roll rate sensors from a test ride [9].

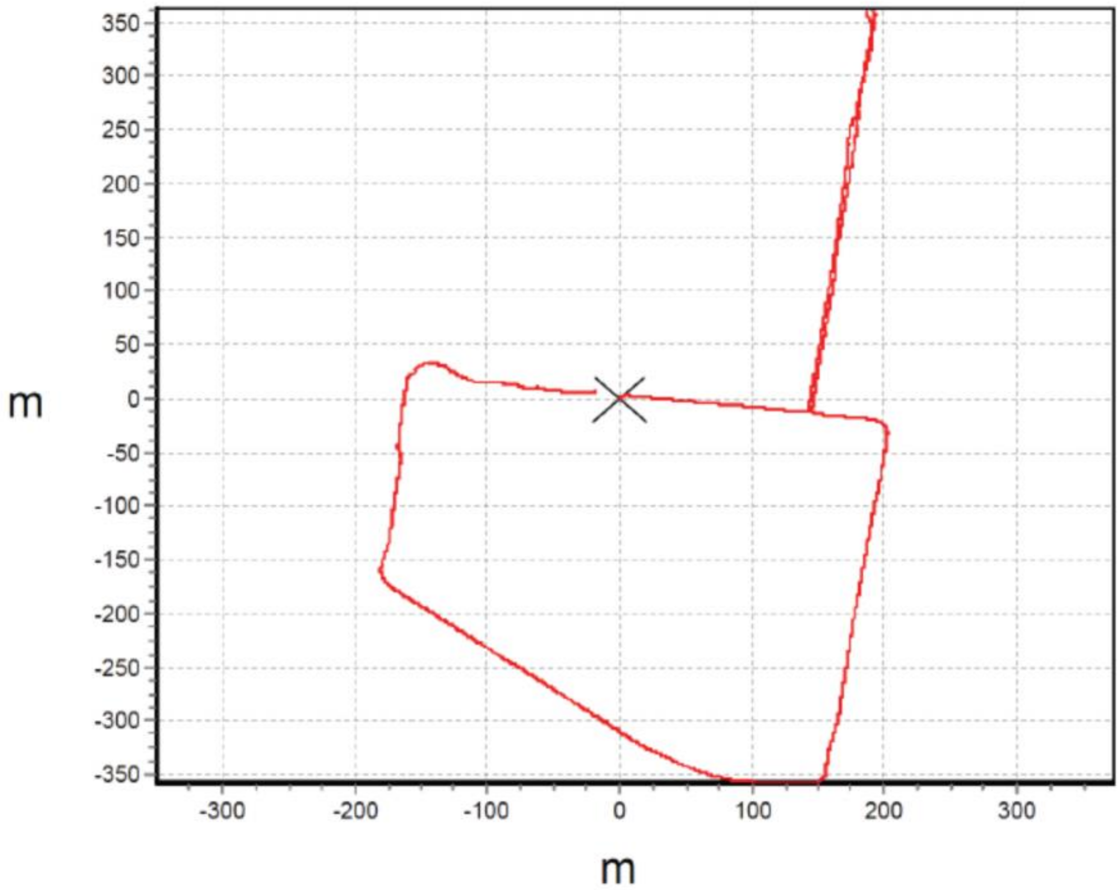

Figure 8: Track of a test ride with measurement system I. GPS-data plottet on a scaled grid [9]

Figure 7 shows raw measurement data from the yaw and the roll rate sensors from a test ride. The signals are of excellent quality and signal noise is relatively low. Therefore, even these critical but essential parameters in motorcycle dynamics can be analysed precisely. Obviously the time series still need to be further processed and to be merged with other signals to provide a meaningful output. The ultimate post-processing will also comprise an animation of the motorcycle motion in real time and in slow motion.

Figure 8 shows the track of a test ride, displayed to scale, based on GPS-signals. Note the nearly identical tracks in the upper part of the diagram, when the same road was driven up and down for an accuracy check. Measurement system I allows to merge GPS data and signals from the inertia measurement unit (IMU) to optimize signal quality. This is especially helpful when driving in city traffic, where GPS-signals may be weak or not existing as in tunnels or next to high-rising building.

Conclusion

Measurements with this instrumented motorcycle will enable in-depth accident studies by driving the path of accident victims at a lower speed, but recording all relevant dynamic parameters such that the full dynamic motorcycle system state is known at all times. By post-processing the measured data, it will be possible to extrapolate the system state to higher speeds, or other environment conditions. Thereby, accidents may be simulated by a combination of experiments and mathematical methods avoiding dangerous driving manoeuvers or driving situations which are impossible to reproduce. This experimentally new based investigation method will be a step further on in forensic science and a valuable method in traffic research.

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