

Motorcycle Stability Control - The Next Generation of Motorcycle Safety and Riding Dynamics

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ABSTRACT

Anti-lock Braking Systems (ABS) for motorcycles have already contributed significantly to the safety of powered two-wheelers (PTW) on public roads by improving bike stability and controllability in emergency braking situations.

In order to address further riding situations, another step forward has been achieved with Motorcycle Stability Control (MSC) system. By combining ABS, electronically combined braking system (eCBS), traction control and inertial sensors even in situations like braking and accelerating in corners the riders' safety can be improved. The MSC system controls the distribution of braking and traction forces using an algorithm that takes into account all available vehicle information from wheels, power train and vehicle attitude. With its ability to control fundamental vehicle dynamics, the MSC system will be a basis for further development and integration of comprehensive safety systems.

The contribution of ABS towards motorcycle safety has been confirmed by numerous international research studies, making it the safety technology with the highest possible benefit for motorcycles available today. Recent investigations by Bosch accident researchers show the contribution of the MSC system to further increase the safety benefit for motorcycle riders by extending the acceleration and braking control functions to cover more riding situations. The MSC systems could avoid more than every 3rd accident with casualties involving a motorcycle in Germany.

This paper focuses on these new motorcycle technologies developed with centralized system architecture and their safety benefits in preventing and mitigating motorcycle accidents with injuries and fatalities.

CITATION: Lich, T., Block, W., Prashanth, S., and Heiler, B., "Motorcycle Stability Control - The Next Generation of Motorcycle Safety and Riding Dynamics," *SAE Int. J. Engines* 9(1):2016.

INTRODUCTION

In many regions over the world two-wheelers are the main mode of transportation. As a result, by 2023, more than 160 million two-wheelers will be produced annually with nearly 90 percent made in China, India and South East Asia [1]. Their relatively low prices and costs of ownership as well as lower fuel consumption than passenger cars contribute to their popularity, especially in emerging countries in Asia and Latin America. On the other hand, motorcycle riders face a high risk of getting injured or killed in traffic accidents. According to the latest Global Road Safety Report from the World Health Organization (WHO), approximately 1.3 million people die in road traffic accidents worldwide. Out of that the huge amount of 312,500

(23%) are riders of powered two- or three wheelers (Figure 1). Especially, regions like South East Asia and the Western Pacific are affected by these high numbers of fatalities [2].

The total amount of motorcycle riders involved in fatal accidents has been increasing over the last fifteen years; putting motorcycle accidents increasingly in the focus of road safety activities worldwide [2]. Therefore, traffic safety for users of powered-two/three wheelers becomes more important in the future.

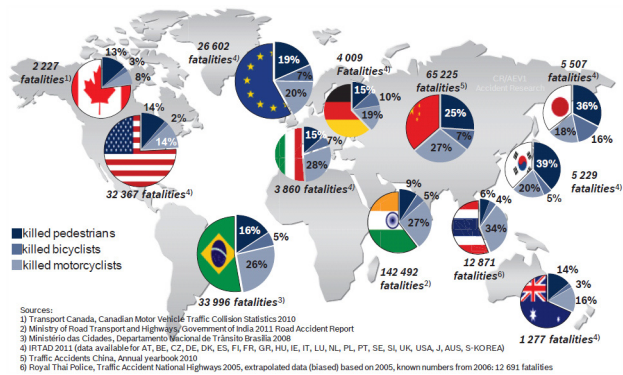


Figure 1. Traffic fatalities by type of road user

In order to improve the safety of two-wheeler riders, three basic pillars can be addressed: road infrastructure, rider behaviour and vehicle safety equipment. Whereas improvements in road infrastructure like separate lanes for two-wheelers and the continuous education of riders with regard to wearing proper safety equipment like helmets are of undisputed importance, this paper focuses on electronic systems to improve the bike's safety itself like motorcycle ABS and Motorcycle Stability Control.

The benefit of motorcycle ABS has been proven in various studies worldwide including the Insurance Institute for Highway Safety (IIHS) in the United States, Swedish Road Administration (Vägarverket) and a Bosch analysis in Germany and India, recently. The IIHS study showed that motorcycles above 250cc equipped with ABS are 37% less likely to be involved in fatal crashes [4].

A study of the Swedish Road Administration came to the conclusion that 48% of all severe & fatal PTW accidents above 125cc could be avoided due to PTW ABS [5].

And a Bosch analysis on German accident data estimates that at least 26% of all motorcycle accidents with injuries or fatalities in Germany could be prevented if all bikes were fitted with an ABS, and in further 31% of the cases the average collision speed could be reduced by two thirds [6]. A study conducted by Bosch using in-depth-accident data in India out from rural accidents came to the conclusion that approximately every 3rd accident involving a motorcycle could be avoided by PTW ABS [7].

Motorcycle ABS is becoming a standard among motorcycles in developed countries like Europe, Japan and the US. Increasingly motorcycles in emerging markets are also equipped with ABS systems. In order to further improve the bikes safety beyond the benefits of the motorcycle ABS Bosch introduced the newly developed Motorcycle Stability Control (MSC) in 2013. Much like a passenger car ESC, the Motorcycle Stability Control system is also based on ABS technology, but adds new hardware and algorithms to significantly increase the functionality and benefits.

The objective of this paper is to show the technology behind the MSC system and its relevance in real world accidents. Findings from accident research built a baseline for this technology and will be

discussed in more detail including a benefit estimation of its accident avoidance potential. Furthermore technical requirements and implementations will be discussed.

ACCIDENT ANALYSIS AND BENEFIT ESTIMATION

In 2007 Bosch's accident research group conducted an investigation to find out further needs for powered two-wheeler safety technologies. Analysis of the accident situation brought out that further safety is needed especially while riding through a curve. Furthermore a benefit assessment was gathered afterwards.

Data Sources

The accident situation is reported in official traffic accident statistics. For Germany the Federal Statistical Office provides an annual report which is officially available throughout the year [8]. This report contains comprehensive data on traffic accidents such as number of crashes and number of injured or killed persons. Nevertheless such a report is not sufficient for detailed analysis or moreover for benefit assessment on accidents involving PTW. Therefore micro-accident data out of in-depth accident investigation is used. Such data is collected and stored in the GIDAS database (German In-Depth Accident Study) [9].

Accident Situation

According to official statistics 641 user of PTW were killed on German roads in 2013. Thereof are 568 motorcycle riders (>125cc). Overall this is a share of ~19% of all traffic fatalities in Germany (3,336 fatalities). Whereas total traffic fatalities in Germany decreased since 2000 by more than 50%, powered two-wheeler accidents decreased less significant. The share of powered two-wheeler accidents of the total thus increased from ~15% to ~19% in the same timeframe (Figure 2).

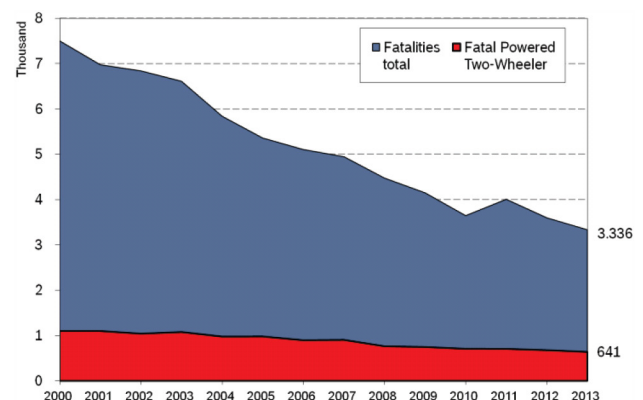


Figure 2. Traffic fatalities total and user of PTW in Germany since 2000

For more information about accident causal factors on national level i.e. characteristics of accident site, a special investigation was done in 2011. This data was provided by the Federal Statistical Office [8] within a special inquiry conducted by Bosch.

According to this in 2011, overall 4,009 people died in a traffic accident and 778 were users of a PTW (708 used a motorcycle >125cc).

Having a closer look on the characteristic of the accident site it can be seen that nearly every 2nd (46%) PTW user died while riding through a curve. Figure 3 shows this in detail (Share of killed PTW users by characteristic of the accident in Germany in 2011).

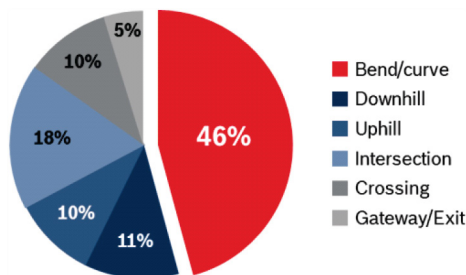


Figure 3. PTW rider fatalities by characteristic of accident site in Germany in 2011 (n=778).

One main cause of motorcycle accidents is speeding in general and in particular while riding through a curve, as well as inadequate steering technique of the rider. When a rider realizes that a curve (subjectively) is being passed with too much speed, the rider typically tends to overreact while he applies the brakes. Hence loss of lateral cornering force, especially for the front wheel, is the result and a fall down happens. Such loss of control, or officially driving accident, typically leads to further impacts with possibly severe or fatal injuries. Figure 4 shows that driving accidents are the main accident type in fatal PTW accidents in Germany.

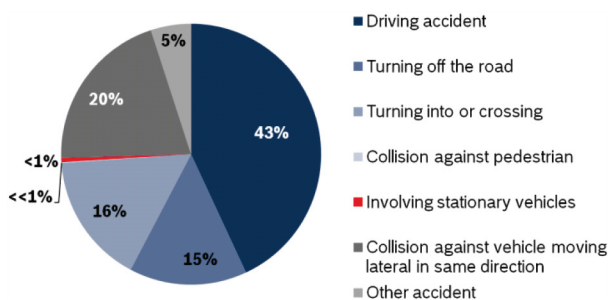


Figure 4. PTW rider fatalities by type of accident in Germany in 2011 (n=778).

Overall 43% of all fatal PTW accidents are loss of control accidents in which active safety technologies such as ABS and MSC technology could avoid or at least mitigate the accident. It is claimed that this type of accident will be less in future assuming a full penetration of ABS/MSF technology. Therefore an investigation from Bosch accident research was made to estimate the avoidance potential of the MSC braking functionality by using GIDAS data.

Methodology for Benefit Assessment

The baseline for the analysis is a sample of 3,167 powered two-wheeler accidents with casualties in the GIDAS database (2001 till 2012). To be representative, the data is extrapolated to a national

level using the following three parameters: type of accident (7 accident types defined in [8]), location (urban, rural or highway) and severity (slight, severe or fatal).

The benefit of the MSC braking functionality was determined by re-calculation of the collision speed assuming a brake intervention of the rider, hence reconstructed data is required. In a first step the data was filtered according to its relevance and verified that all required information is available. The following information was considered:

- Measured braking distances according to traces or reconstruction
- If fall-down: distance between fall-down and impact as well as braking distance till fall-down
- Curve radius
- Street surface and condition at time of accident
- Friction at time of accident
- Reconstructed initial speed and collision speed

Cases in which the maximum velocity was exceeded were excluded from the investigation.

Applying all criteria's for the remaining benefit assessment 2,165 PTW accidents w/ injuries were available (set to 100%). MSC belongs mainly to curve related accidents, thus all cases were excluded if the radius was >150 m. As a result it can be concluded that a share of 16% of all accidents with casualties involving a PTW in Germany happens in a curve - in other words every 6th PTW accident with casualty in Germany occurs in a curve. Within this share of accidents a retrospective analysis was done to determine typical rider behaviour. The result is shown in Figure 5 and underlies the assumption that a first rider reaction is a brake intervention.

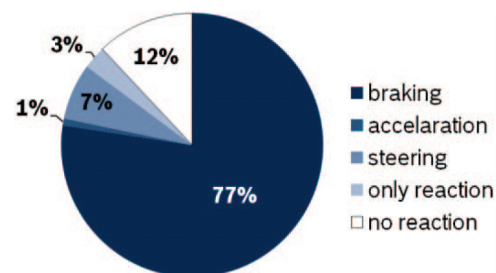


Figure 5. PTW rider reaction in curve related accidents with casualties in Germany (n=328).

Within a single case evaluation of the braked cases a closer look was done on the manoeuvre which lead to the collision thereof following scenarios were identified:

1. Slipping wheel caused by over-braking
2. Upright moment lead to road departure. This was caused by over-braking.
3. Road departure caused by too modest braking
4. Collision with a vehicle, animal or object although braking (including oncoming traffic)