Analysis of effects of a motorcycle pre-crash braking system using in-depth crash data and drive-through data: a case study

Giovanni Savino, Simone Piantini

I. INTRODUCTION

Motorcyclist safety will remain an important issue for society because motorcycle usage is expected to increase in the coming years, especially in cities affected by traffic congestion problems.

Recent studies have reported on the progress of Pre-Crash Braking (PCB) systems on motorcycles, showing that higher automatic decelerations now seem more viable. In particular, the experiments conducted by Merkel *et al.* [1] suggested that automatic decelerations of up to 5 m/s^2 may be sustained by normal riders, whereas previous studies had assumed a more conservative value of 3 m/s^2. A consequence of the higher deceleration produced by PCB is a greater reduction in impact speed, which potentially leads to larger benefits in terms of injury mitigation. Another way to increase the effects of PCB is to deploy the system earlier than the moment when the collision becomes inevitable [2], an approach that is in accordance with the opinions of expert riders provided in a previous field study [3]. Here, the authors define PCB 'late intervention' as a deployment produced when a collision between the host powered two-wheeler (PTW) and opponent car cannot be avoided with any manoeuvres involving accelerations of up to 1 g. When assuming a max. acceleration of 0.7 g for the avoidance manoeuvres, the deployment of PCB would occur earlier in time. This triggering condition is defined as 'early intervention'.

This paper presents the analysis of a case study aiming to assess the effects of: (i) a modified triggering threshold; and (ii) a modified automatic deceleration for a PCB system.

II. METHODS

In order to verify the potential effects of a PCB, we performed 2D numerical simulations of the pre-crash phase of a selected crash case. The inputs of the simulations were obtained by merging two sets of data: one obtained from the in-depth crash investigation, the second one obtained from drive-through data using instrumented vehicles at the actual crash site. The data included the trajectories of the vehicles, their speeds and the actual avoidance manoeuvres employed, such as braking or swerving. The suitable crash case was selected from the InSAFE database, an ongoing in-depth crash study being conducted by the University of Florence in the metropolitan area of Florence (Italy) [4]. The main selection criteria were: (i) PTW impacting against another vehicle; (ii) PCB system would have applied, as described in [5].

Notwithstanding a careful in-depth crash investigation, the pre-crash phase is always affected by uncertainties. In that regard, drive-through data provided valuable information about real-world crash situations that was used to confirm the realism of the reconstructed trajectories, which were then input into our subsequent computer crash simulations. Drive-through experiments were conducted adopting the test protocol presented in [6], and pre-crash trajectories of the PTW and the opponent vehicle were recorded in real traffic conditions. Both PTW and opponent car were equipped with Differential Global Position System (DGPS) units for accurate position measurements. For our crash case, six runs were performed at the actual crash site. Consistency of the drive-through data was first assessed, followed by an analysis of coherence between pre-crash trajectories obtained in the drive-through experiments with those obtained during the accident reconstruction phase. Then, a set of computer simulations was performed also assuming a PCB equipping the host motorcycle and using the validated pre-crash trajectories. Different combinations of triggering thresholds (early and late intervention) and automatic deceleration values (0.3 g and 0.5 g) were tested, and results were compared with the baseline case in which PCB did not intervene.

Finally, according to the motorcyclist injury risk function developed by Ding *et al.* [7], the risk of MAIS3+F injuries was assessed.

G. Savino (e-mail: giovanni.savino@unifi.it; tel: +390552758695) is Assistant Professor and S. Piantini is Postdoctoral Research Fellow in the Department of Industrial Engineering at University of Florence in Italy.

III. INITIAL FINDINGS

The selected case study (ID-84) took place at night at a traffic-light intersection and with moderate traffic flow. A passenger car was approaching from a side street at the right-hand side of the host PTW. The PTW was moving fast and hit frontally into the left side of the car, without any evident braking action. Impact speeds were 57 km/h and 12 km/h for the PTW and the passenger car, respectively. Following the crash, the rider was admitted to hospital for a serious polytrauma (Injury Severity Score, ISS = 24).

The results of the simulations showed that a late intervention of the PCB with deceleration of 0.3 g could have produced an impact speed reduction of 3.2 km/h. Assuming an automatic deceleration of 0.5 g, impact speed reduction could have been 5.4 km/h. Similar effects were obtained with early intervention of the PCB system at low deceleration, whereas the combination of early intervention and higher deceleration could have produced an impact speed reduction of 8.6 km/h (Table I).

Fig. 1. Case-study crash conditions.

Fig. 2. Real-world trajectory overlap.

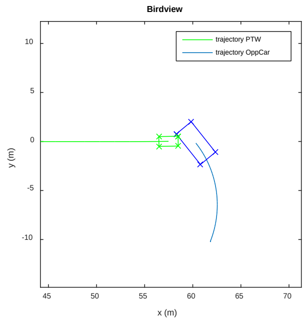

Fig. 3. 2D software simulation.

TABLE I
CHANGES IN THE PTW IMPACT SPEED WITH DIFFERENT TRIGGERING THRESHOLDS

	Baseline	0.3 g / late	0.5 g / late	0.3 g / early	0.5 g / early
TTC [s]	0.34	0.35	0.35	0.52	0.53
PTW impact speed [km/h]	57	53.6	51.5	51.5	48.2
PTW impact speed reduction [km/h]	-	3.2	5.4	5.4	8.6
Relative speed reduction [km/h]	-	3.2	5.4	5.4	8.6
MAIS3+F injury risk [%]	13.7	12.8	12.2	12.2	11.3

TTC = time to collision

IV. DISCUSSION

For a preliminary assessment of the potential effects of a PCB system, we used in-depth crash data and drive-through data to obtain realistic trajectories for the computer simulations of a selected crash case. A series of drive-through events showed consistency in the approaching trajectories for both PTW and passenger car, and a good coherence with the trajectories identified during the crash reconstruction phase of the in-depth investigation. Our reference PCB system was intended as a last resort solution meant to reduce the consequences of the impact rather than to avoid it. The case study showed that, assuming the more conservative 'late intervention' of PCB, an increase in the automatic deceleration of 0.2 g produced an impact speed reduction 1.7 times greater. It also showed that similar improvement was achieved with an early intervention of the PCB while keeping a baseline deceleration of 0.3 g. However, if future experimental tests can confirm the possibility of combining higher deceleration value and 'early intervention', PCB may achieve an impact speed reduction 2.7 times greater than what was estimated in previous studies considering the more conservative intervention parameters. In terms of MAIS3+F injury risk, PCB was estimated to produce a reduction of 2.4%, which may lead to 18% casualty reduction under the assumption of 100% penetration.

V. REFERENCES

[1] Merkel, N., *et al.*, IFZ conference, 2018.
[2] Savino, G., *et al.*, *Trans on Int Transp Systems*, 2016.
[3] Savino, G., *et al.*, *IMechE*, Part D, 2012.
[4] Piantini, S., *et al.*, IRCOBI, 2012.
[5] Savino, G., *et al.*, *Traf Inj Prev*, 2014.
[6] Savino, G., *et al.*, ESV Conference, 2017.
[7] Ding, C., *et al.*, *Accid Anal Prev*, 2018.