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Numerical Assessment of Motorcyclist Accident

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Abstract – *Road traffic accidents cause one of the highest numbers of severe injuries. Virtual human body models play an important role to assess the injuries during impact loading especially for scenarios, where complex dynamical loading is taken into account. It concerns mainly vulnerable road users, where motorcyclists are addressed. The risk of fatal injuries connected to motorcycle usage is still one of the biggest among all modes of transportation. Due to a complicated interaction between a motorcycle and an opposite vehicle during their crash, the virtual approach is an optimal way towards a crash reconstruction. The presented work shows the exploitation of virtual a human body model in the injury assessment during the motorcycle against car accident using the virtual approach by the numerical simulation. The study exploits an existing human body model as a helmeted motorcycle rider, couples it to a motorcycle model and runs a simulation, where the motorcycle impacts an opposite vehicle according to a real case. Injury assessment and comparison to the real case is analysed. The paper shows the advantages of the virtual approach in a complex impact scenario reconstruction in order to optimize the personal protective equipment for injury risk reduction in future transport.*

Keywords: Motorcycle, accident, human body model, real case, injury assessment

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1.0 INTRODUCTION

World Health Organization (WHO) monitors that every year the lives of approximately 1.25 million people are cut short as a result of a road traffic crash (WHO, 2017). Between 20 and 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury. Nearly half of those dying on the world's roads are so-called vulnerable road users: pedestrians, cyclists, and motorcyclists including two-wheeler riders (European Road Safety Observatory, 2016). The number of traffic accident fatalities of motorcycle passengers in the ASEAN countries has increased in the past 10 years (Yasuki, 2018).

Whilst the passengers' vehicle safety is well ensured by fulfilling the conditions and regulations such as the New Car Assessment Programme (NCAP), the crash testing protocol for the motorcycle riders is not established so far. Since the kinematics of the motorcycle rider is complex, the virtual approach to assess the rider's behavior and the injury risk seems to a suitable tool for the accident reconstruction, the injury prediction and the future rider's protective equipment development and optimization. Standard ISO 13232 configurations (International Organization for Standardization, 2005) were already numerically assessed and compared to real experiments (Mukherjee et al., 2001). The numerical simulation, as a tool for a motorcyclist's injury protection, was proposed by Barbani et al. (2014). Virtual simulation was also previously used to assess particular rider's human body part injuries (Toma et al., 2010).

The current paper analyse the full real accident case reconstruction as the first step for personal protective equipment development and optimization by the virtual approach. For the virtual approach towards accident reconstruction followed by the injury description, one needs to have a validated human body model. The paper exploits the existing scalable virtual human body model (Vychytil et al., 2014; Hynčík et al., 2017), couples it to a virtual motorcycle model and assesses the consequences of the traffic accident based on a real case.

2.0 METHODOLOGY

The current safety of passenger vehicles is ensured by the certification process, where the hardware dummies are used to assess the injury risk. Before the process of certification, each vehicle shall be optimized, where the virtual simulation is a common approach. However, the vehicles pass the criteria just for standard impact scenarios, such as frontal and side impact. This is also a problem for two-wheeler vehicles, where the impact kinematics and the rider loading are complex. Considering also future challenges of autonomous vehicles with a non-standard seating configuration and variability of human population, one can take into account virtual simulation using scalable human body models. The present paper shows the virtual numerical approach towards motorcycle accident reconstruction and so defines the way for future safety systems and personal protective equipment optimization.

2.1 Accident Reconstruction

Accident reconstruction is one of the major sources of getting detailed information on the accident, its process and its consequences. The accident reconstruction is useful to feed in-depth accident databases to have detailed data for safety system optimization in as many impact scenarios as possible. The analysed motorcycle accident took place at the intersection. The opposite vehicle stopped on the red traffic light and the motorcycle impacted the rear end of the car. The accident configuration is presented in Figure 1.

There were two vehicles participating in the accident. The other vehicle was a BMW 318i Cabrio (Figure 2 left) with dry mass equal to 1370 kg. The passenger car was occupied by one person, the driver with mass equal to 70 kg. Therefore, the total mass of the other vehicle including the driver was 1440 kg. The motorcycle was represented by the maxi scooter Suzuki Burgman 200 (Figure 2 right) with dry mass equal to 161 kg. The rider was 66 years old having 171 cm of the height. The rider's mass was equal to 70 kg, so the total mass of the motorcycle including the driver was 241 kg. The impact speed reported by the accentologist team was equal to 55 ± 5 km/h.

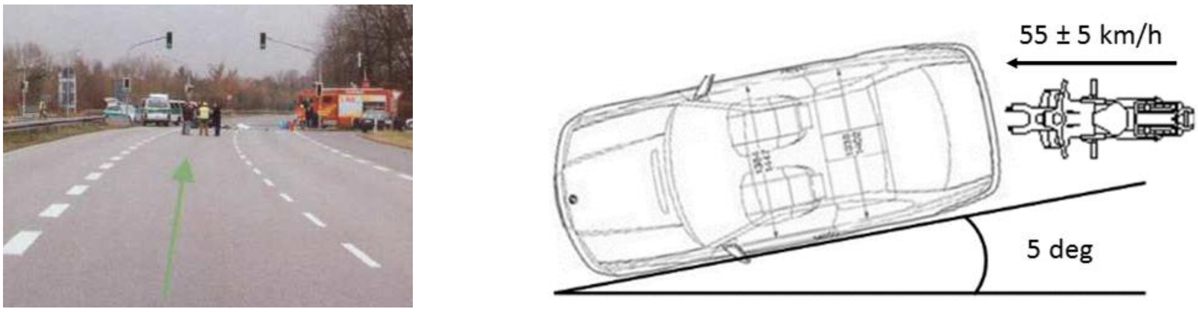

Figure 1: Accident configuration (left – accident case documentation from Biomechanics and Accident Analysis Group (n.d.), right – sketch for simulation setup)

Figure 2: BMW 318i Cabrio (Accident by car, 2011) and Suzuki Burgman 200 (Trade motorcycles, 2015)

The motorcycle rider suffered serious injuries, namely the massive head and brain injuries, the delocalization of the skull base from the spine, serial rib fractures, the ripped aorta and the massive collarbone/sternum fractures. The injuries described by the maximum abbreviated injury scale (MAIS) (Gennarelli, 2008) were 6 for the head, 6 for the neck, 5 for the thorax, 5 for the abdomen and 1 for the extremities. Severest injuries of the scooter rider were the massive head and brain injuries, the delocalization of the skull base from spine, serial rib fractures, the ripped aorta and massive collarbone/sternum fractures.

2.2 Numerical Modelling

The chosen accident scenario was analysed in detail (Biomechanics and Accident Analysis Group, n.d.). Both involved vehicles were reconstructed to have their numerical models. The Suzuki motorcycle model (Trade Motorcycles, 2015) was developed from scratch based on the multi-body approach with elastic joint placed on the front fork (Ambrósio & Dias, 2007). Since there is no specific model for the opposite vehicle (Accident by car, 2011) available, another existing finite element model (National Crash Analysis Center, 2018) was trimmed to have a particular dimension and mass.

Whilst the opposite vehicle driver is involved in the total mass of the opposite vehicle, the motorcycle rider was developed by scaling the existing virtual human model Virthuman (Hynčík et al., 2013; Vychytil et al., 2014) to the particular dimensions (66 years, 70 kg, 171 cm) and coupled to the personal protective equipment represented by the numerical helmet model (AGV – T2) (Ghajari et al., 2011; Ghajari et al., 2013; Hynčík et al., 2017) coupled to the head by the symmetrical contact between the helmet foam and head and by the chinstrap (Figure 3 and Figure 4).

The human body model was positioned to the motorcycle sitting position and coupled to the motorcycle having a sliding contact to the structure holding the handlebars by the stiffness equal to 9.36 kN/m (Happee et al., 2008) with the limiting force equal to 350 N for each hand (Mathiowetz et al., 1985). Then, the numerical models representing the participants (motorcycle, motorcycle rider and opposite vehicle) were positioned according to the accident configuration (Figure 3 and Figure 4). The passenger car was placed at 5 degrees with zero speed. The initial velocity of the motorcycle was set to 55 km/h with its vector lying in the vertical longitudinal plane and the simulation was run in the VPS numerical environment.

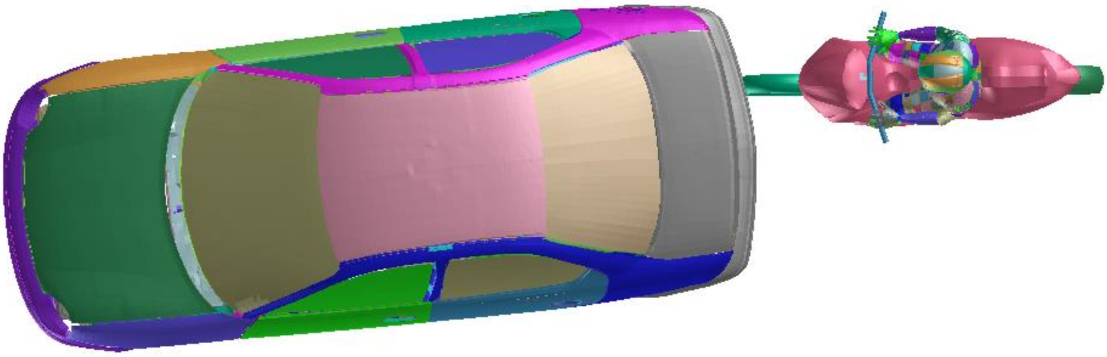

Figure 3: Models of vehicles in accident scenario – top view

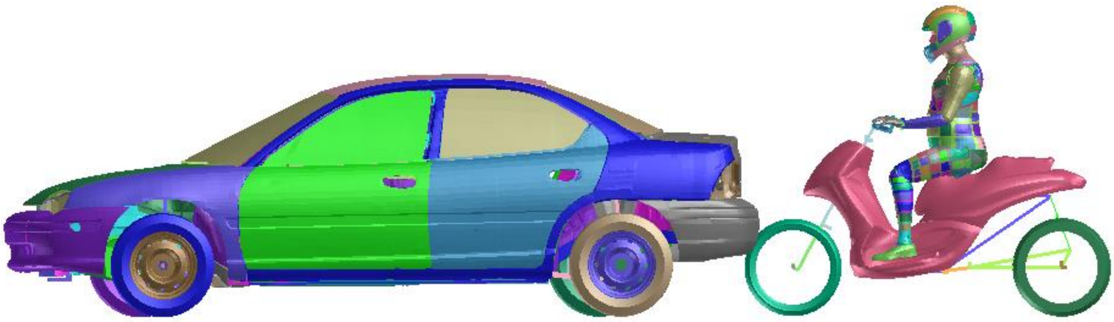

Figure 4: Models of vehicles in accident scenario – side view

3.0 RESULTS AND DISCUSSION

The first 300 ms of the accident was simulated and the results were compared to the real accident (Figure 5 and Figure 6). One can see that there are similar deformation patterns in both the real accident and the simulation results. The weak point of the numerical results is a shallow deformation of the car upper back, which resulted in the lower head acceleration because the head impact is not so direct. This is an issue to be fixed by incorporating a real car model for the particular accident scenario simulation.

The kinematics of the accident participants can be observed in Figure 7. In the first phase of the crash, the wheel contacted the rear bumper of the car. The contact induced the bending of the elastic joint placed on the fork and caused the wheelbase shortening. Figure 5 and Figure 6 show a good correlation between the real and the virtual deformations. In the next phase, at 35 ms, the motorcycle rider started to slide from the seat and the rider's hands lost the connection with the handlebars. At 55 ms, the full vehicles' deformations appeared and the chassis of the motorcycle stopped the linear movement of the rider and caused the rotation of the body around the handlebars. The whiplash appeared before the impact of the head to the rear window at 105 ms, which brought a serious neck injury. The rotational movement finally caused the impact of the head to the rear window at 150 ms.

Figure 5: Accident case documentation (Biomechanics and Accident Analysis Group, n.d.)

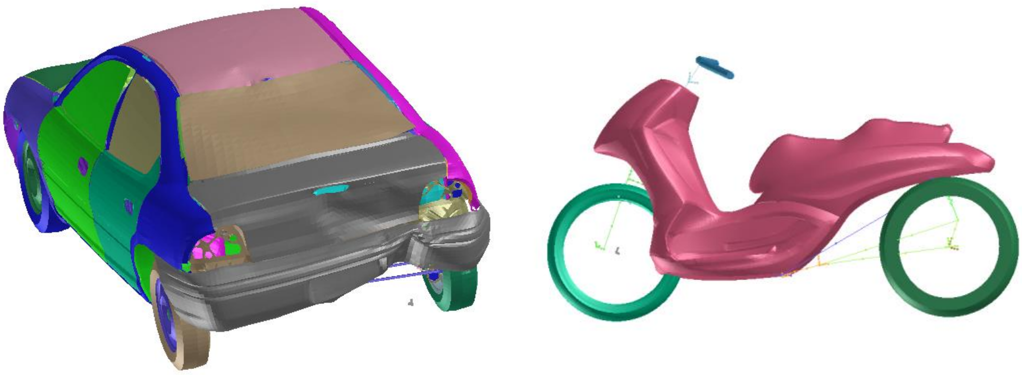

Figure 6: Accident results by numerical simulation

The injury criteria were assessed for all major body parts (head, neck, thorax, abdomen, pelvis, legs) according to the EuroNCAP (MECAS ESI, 2016), where the red colour means the high injury risk, the orange colour means the marginal injury risk and the yellow colour means the acceptable injury risk. Green colour means the low (or no) injury risk. The highest injury risk at the time of the major contact to the car appeared in the neck (by the red colour in Figure 7 and Figure 8) and the abdominal part (by the orange colour in Figure 7 and Figure 8), which is compatible to the real injury report. Table 1 compares the numerical results to the real injuries. In the numerical simulation, also the lower extremities suffered a high injury risk. On the other hand, the head didn't suffer a high injury risk, which could be caused by utilization of highly protective helmet model (AGV T2) for the case simulation.

Figure 7: Accident kinematics

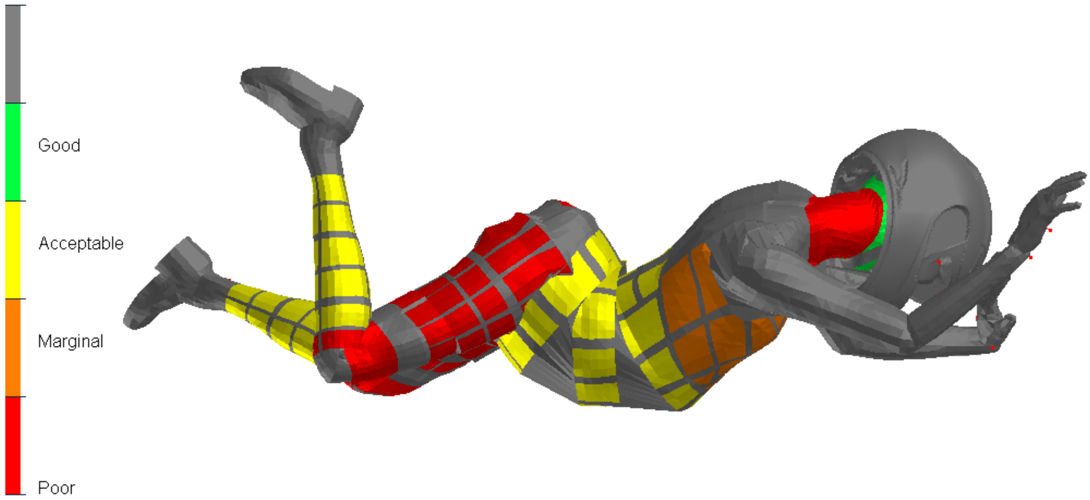

Figure 8: Injury risk prediction

Table 1: Comparison between the numerical results and the real injuries

Body part	**Degree of injury (MECAS ESI, 2016) by numerical simulation**	**MAIS from accident report** (Biomechanics and Accident Analysis Group, n.d.)
Head	Green (Good)*	6 (Fatal)
Neck	Red (Poor)	6 (Fatal)
Thorax	Orange (Marginal)	5 (Critical)
Abdomen	Yellow (Marginal)	5 (Critical)
Extremities	Yellow / Red (Marginal / Poor)	1 (Minor)

**The head was seriously injured in the real case. The numerical simulation results might be influenced by the used model of the helmet.*

4.0 CONCLUSION

The paper demonstrates the virtual approach towards a real case accident analysis with the injury criteria assessment. The chosen crash identified from the accident database is modelled by coupling an FEM passenger car, an MBS motorcycle and a model scaled to the particular anthropometry. The human body model is equipped by a helmet as a usual motorcycle personal protective equipment. The virtual simulation allows recreating the kinematics and the dynamics of the motorcycle driver during the accident. The assessment of the injury criteria shows good correlation and so the opportunity for future use of the virtual human body model especially in scenarios, where both the kinematics and loading are complex. However, the realistic vehicle model is necessary to have high predictability of the numerical simulation.

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