Journal of the Society of Automotive Engineers Malaysia
Volume 2, Issue 3, pp 231-244, September 2018
e-ISSN 2550-2239 & ISSN 2600-8092

Motorcycle Accident Scenarios and Post-Crash Kinematics of Motorcyclists in Thailand

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ORIGINAL ARTICLE — Open Access

Article History:

Received
15 May 2018

Received in revised form
31 Jul 2018

Accepted
10 Aug 2018

Available online
1 Sep 2018

Abstract – *This paper unveils a classification of motorcycle accident data in Thailand to identify common accident scenarios and impact parameters for multibody dynamics simulation of motorcycle crashes. The simulation results were analysed in terms of kinematics of riders and passengers as well as head impact locations. Motorcycle accident data revealed that rolling over without any contact with other vehicles was the most common scenario, while the side swipe was the most common type of crash involving other vehicles. The majority of accidents involved passenger cars with riders' age ranging between 10-29 years. Serious and severe injuries accounted for 20% of the total number of casualties whereas minor abrasions and bruise accounted for 41%. Four common accident scenarios were identified together with a range of impact speeds, impact angles and impact points to generate impact conditions for multibody simulations. The simulation results revealed two patterns of global kinematics including (i) the rider together with the child pillion passenger were laterally projected towards the other vehicle as the other vehicle hit the lateral side of the motorcycle; and (ii) the rider together with the child pillion were launched forward in the direction of impact when the front wheel of the motorcycle hit the other vehicle. The vehicle hood was found to be the most frequently impacted area by the rider's and child passenger's head. The car windshield was the second most frequently impacted location for the rider's head. For pick-up truck, the passenger window was the second most frequent area of impact. There was a moderate number of A-pillar contact on the car but such a situation was rare for the pick-up truck.*

Keywords: Motorcycle accidents, accident scenario, post-crash kinematics, head impact location

Journal homepage: www.journal.saemalaysia.org.my

1.0 INTRODUCTION

Road traffic fatalities among vulnerable road users are intolerably high especially in the Southeast Asia (SEA) region. World Health Organisation (WHO) reports that accidents involving powered two wheelers (PTW) in SEA accounts for 34% of overall road fatalities. This figure was as high as car occupant fatalities as shown in Figure 1 (WHO, 2015).

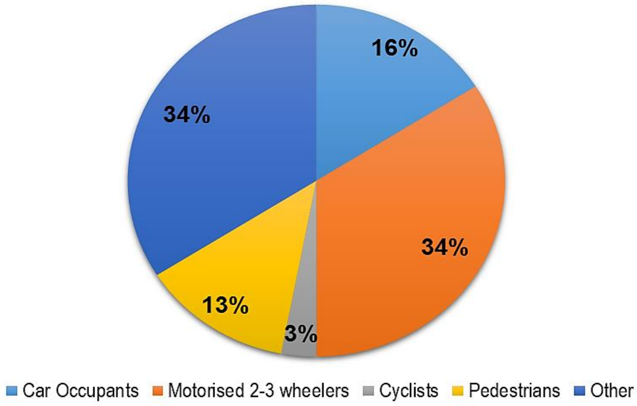


Figure 1: Southeast Asia traffic deaths by road user category (WHO, 2015)

It is without doubt that the motorcycle is the most popular mode of transportation in Thailand. As of 30 January 2017, there were 55% of motorcycles registered for both public transport and personal use (Department of Land and Transport, 2017). Road fatalities involving PTW make up the highest proportion in Thailand. In total, it constituted 73% of traffic deaths in the country (WHO, 2015). There have been concerns about PTWs raised by road safety organizations around the world as evidenced in various international forums and conferences, leading to a prioritization of PTW safety (Rohit, 2016; WHO, 2017).

Current motorcycle accident data analysis is limited in Thailand. A detail analysis of motorcycle accidents was, nevertheless, published in 2001 (Kasantikul, 2001). The latest accident information on the number of motorcycle accidents and fatalities dates back to 2012 (Kantipong, 2015). It is vital to analyse the current available motorcycle accident data. An updated typical motorcycle accident scenario should be identified. However, macro accident data have been inadequate to produce effective vehicle-related safety solutions or countermeasures. Typical post-crash kinematics and injuries sustained by motorcyclists and pillion passengers during crash are also important in order to support improvements of countermeasures and vehicle design.

Some researchers have used multibody dynamics simulation to virtually generate pedestrian and cyclist accidents which subsequently provided understanding of kinematics and injury mechanisms of the pedestrian/cyclist (Otto, 1989, 2004; Fiest et al., 2009; Untaroiu et al., 2009, 2010; Watson et al., 2009; Magriet et al., 2012). Otto et al. (1989, 2004) used simulations to reconstruct real world accidents involving pedestrians and cyclists. They posited the use of throwing distance as a reconstruction method. On the other hand, Utaroiu et al. (2009, 2010) developed an advanced methodology that combined multibody simulations and an optimisation technique for identifying the adult and child pedestrians' pre-impact postures and vehicle speeds. Fiest et al. (2009) also used combined approaches of multibody simulation and finite element simulation to investigate the relevance of rotation-induced head injuries to pedestrians hit by a large flat-front vehicle. In addition, Watson et al. (2009) and Magriet et al. (2012) also employed multibody dynamics model as a tool to study cyclist's kinematics during crash. They found that the head impact of cyclist was further rearward than the pedestrian. The head impact angles were also different although the head impact velocity was similar.

Due to limited in-depth motorcycle accident analyses available in Thailand, multibody dynamics simulations have been employed to generate various accident cases based on accident scenarios and parameters identified through real world accidents. Results of these simulations have enabled analysis of kinematics and head impact location of both rider and child pillion passenger. The goal of the current study is to classify available motorcycle accident data in Thailand and identify common motorcycle accident scenarios and parameters for multibody dynamics simulations. In addition, the kinematics of riders including head impact locations during a crash have been analysed using results of multibody dynamics simulations.

2.0 CLASSIFICATION AND IDENTIFICATION OF MOTORCYCLE ACCIDENT SCENARIO

2.1 Classification Approach

Motorcycle accident data were obtained from the Road Accident Victims Protection Co. Ltd. (RVP). RVP is an insurance company that insures almost 80% of motorcycles in Thailand. In addition, RVP employs online accident report. Each claim is recorded online in RVP's database including the date and time of accidents, types of accident, details of accident occurrence, age and type of casualties, details of injury and types of vehicle involved. The detailed description of accidents depends largely on the insurance claim surveyors. The total number of motorcycle accidents were 293,544 in 2014 and 321,998 in 2015. All data were coded by the research team and were classified according to types of motorcycle crash, types of other vehicles involved in the accidents, number and age range of riders and passengers involved in the accidents and levels of injury severity. Accident scenarios were identified from only the cases that involved other vehicles. Accident parameters were also specified for further analysis.

2.2 Results of Motorcycle Accident Classification

Based on the accident information recorded by RVP, eight types of crash were specified including Loss-of-control/Roll over, Rear-end Collision, Head-on collision, Sideswipe collision, Fixed object collision, Pedestrian and animal collision, collision at Intersection right angle and collision of more than two vehicles. Figure 2 shows the distribution of motorcycle accidents for each type of crash. Motorcycle loss-of-control or roll over with no collision with other vehicles had the highest proportion of 59% in both years. Sideswipe was the second highest, accounting for 32.5% in 2014 and 28.6% in 2015. On the other hand, pedestrian/animal collision accounted for 4.7% and 5.9% in 2014 and 2015 respectively.

Figure 3 shows the proportion of other vehicles (OV) involved in an accident with motorcycles (MC) (excluding pedestrian/animal collision). It was found that passenger cars constituted the highest proportion of OVs which were 42% and 40% in 2014 and 2015 respectively. Motorcycle/bicycle was the second highest with 37% and 40% in 2014 and 2015 respectively. Pick-up truck accounted for 15% in both years.

The majority of casualties were to the riders, accounting for 80% while passengers accounted for 20%. The portion was the same for both years. Figure 4 shows the proportion of riders and passengers for each age range in 2014 and 2015. It is obvious that the age ranges of 10-19 and 20-29 years old accounted for similar percentage around 21% in 2014 and 22% in 2015. The 10-29 age range accounted for almost 44% of rider population. Involvement of passengers aged between 10-19 years old in motorcycle accidents was higher than the other age groups. It accounted for 29% and 31.5% of the total number of motorcycle passengers in 2014 and 2015 respectively. It is important to note that the age range of 0-6 years old accounted for 10% of the total number of pillion passengers involved in motorcycle accidents. This clearly indicates that there was a significant number of child pillion passengers in such accidents.

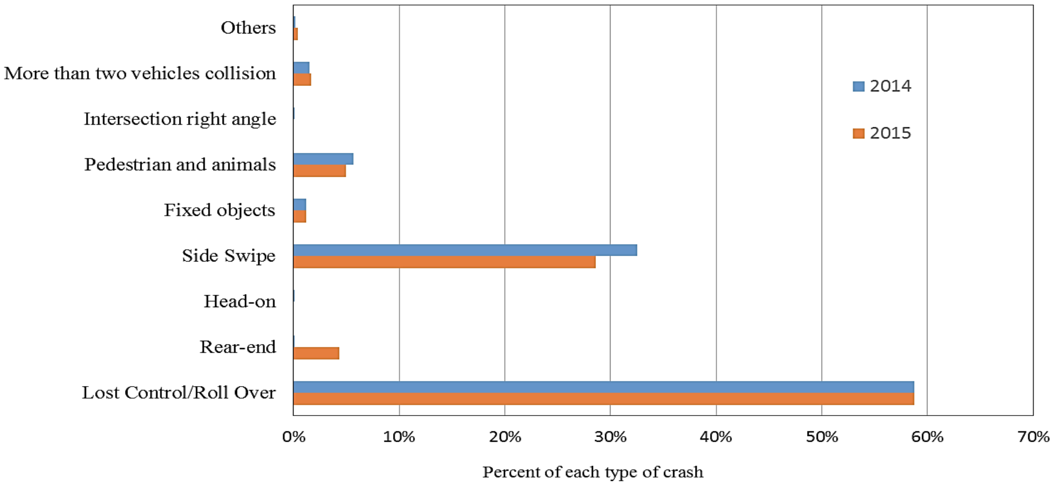


Figure 2: Comparison of motorcycle accidents classified by type of crash for 2014 and 2015

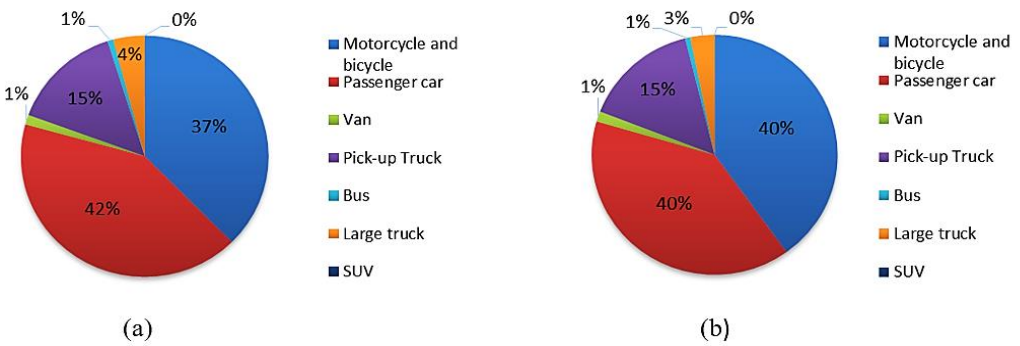
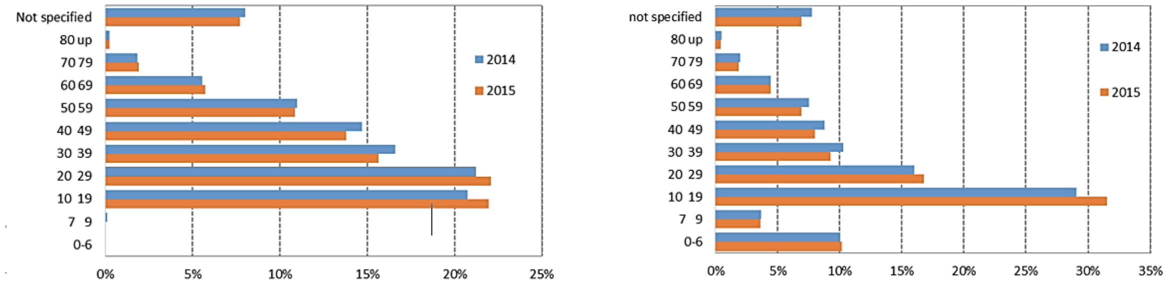


Figure 3: Other vehicles involved in accidents with motorcycle in (a) 2014 (b) 2015

The levels of injury were categorised into five levels including fatal/death, severe, serious, moderate and minor. This was interpreted based on the injury details recorded by RVP claim surveyors. The criteria used to interpret levels of severity are presented in Table 1. The criteria were also specified in relation to AIS scale (AAAM, 2008). Figure 5 shows the proportion of levels of injury sustained by the victims. It should be noted that the number of deaths indicated in these records involved only those who died at the scene. Serious and severe levels of injury (equivalent to AIS3-AIS5) constituted 20% of the total number of casualties. Minor injuries accounted for 34% and 41% in 2014 and 2015, respectively.

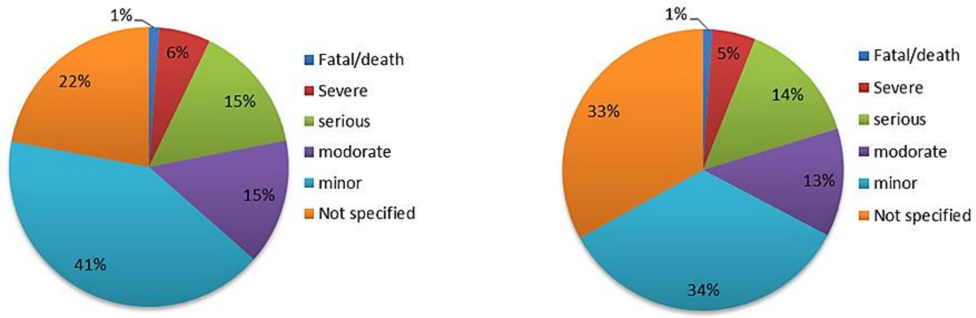


(a) (b)

Figure 4: Proportion of (a) rider (b) passenger population for each age range in 2014 and 2015

Table 1: Criteria for interpretation of levels of injury in relation to AIS scales

Level of Injury	Example of Injuries	AIS Scale Equivalent
Fatal/Death	Death	6
Severe	Open fracture or extensive fracture, unconscious more than 6 hours, multiple rib fractures, aortic injury, liver rupture, lung rupture	4-5
Serious	Broken femur, broken rib, invert fracture, unconscious for 1- 6 hours. Spleen or kidney rupture	3
Moderate	Skin laceration with 10 or more stiches or broken bone (tibia/arm), small crack on head, no need for hospital admittance	2
Minor	Minor skin laceration without stitching or skin contusion	1



(a) (b)

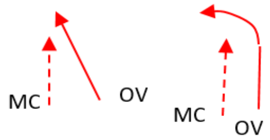
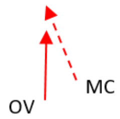
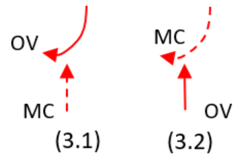
Figure 5: Percentage of each level of injury in (a) 2014 and (b) 2015

Although the majority of motorcycle accidents revolved around the rider losing control or rolling over, this type of accidents did not involve other vehicles. Since this study aims to understand involvement of other vehicles in order to effectively develop vehicle related safety solutions, this type of crash (loss of control, roll over) was not considered for subsequent analysis. The second highest type of crash was sideswipe which accounted around 30-33%. Accidents of the sideswipe type were considered for identification of accident scenario and further studies.

2.3 Identification of Accident Scenarios and Parameters

From the accident records, the sideswipe type of crash usually occurred when the motorcycle or vehicle was changing lane, overtaking, turning to the other road at the T-Junction or from small alley or taking a U-turn. They were summarised into four accident scenarios as illustrated in Table 2.

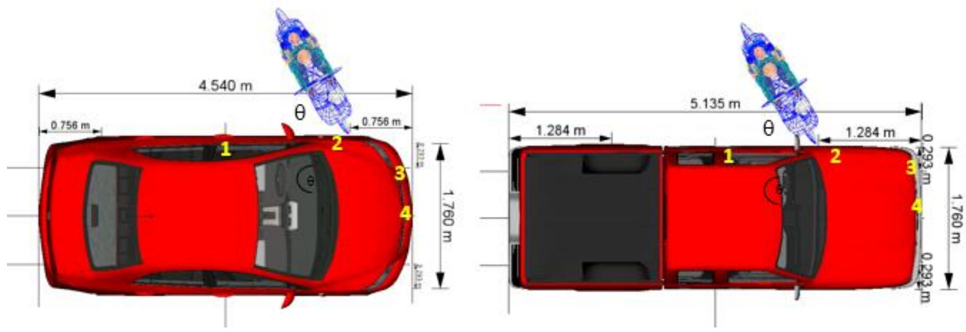
Table 2: Common accident scenarios

Accident Scenario	Diagram
1. Other vehicle (OV) was changing lane, overtaking a motorcycle (MC) or turning left across the path of MC. For this scenario, MC was moving towards the lateral side of OV.	
2. MC was changing lane, overtaking an OV or MC was moving across the path of OV. For this scenario, OV was moving towards the lateral side of MC.	
3. A vehicle was taking U-turn or turning right at a junction. For this scenario, the vehicle travelling crashed straight into the lateral of vehicle that was taking U-turn.	
4. MC was turning left from an alley or at a T-junction across the path of OV. For this scenario, OV was moving towards the lateral side of MC.	

From a total of four accident scenarios, two impact configurations emerged which were: (a) MC impacting the lateral side of OV; and (b) OV impacting the lateral side of MC. In order to generate possible accident cases using multibody simulations to cover all identified accident scenarios, three scenario parameters were specified. They included Impact Point, Impact Angle and Impact Speed. A sedan passenger car and a pick-up truck were selected as OVs for subsequent studies using the multibody simulations. In addition, the motorcycle type considered in this study was the step-through type with engine capacity below 125cc and a maximum speed of 90 km/h.

2.3.1 Impact Configuration A: MC Impacting Lateral Side of OV

This impact configuration represented Scenario 1 and 3.1. MC was travelling on straight road and the OV moved across the path of MC. The speed of the MC was usually greater than the OV. From the accident reconstruction data and the data studied by Kasantikul (2002) and Karnjanapollert et al. (2018), the range of motorcycle impact speed suggested for this study was 20 to 60 km/h. As in the reconstruction and data analyses in Kasantikul (2002) and Karnjanapollert et al. (2018.), the OV impact speed range was 20 to 30 km/h while taking a U-turn or turning right at a junction. However, if the OV was changing lane, the speed of OV was higher and about the same as the MC. Four impact points were selected as shown in Figure 6 for both car and pick-up truck. The Scenario Parameters are summarised in Table 3. For impact points 1 and 2, the impact angles selected were 30°, 45°, 60°, 90°, 120° and 150°. Only 120° and 150° were selected for impact points 3 and 4 since an impact angle greater than 180° did not represent the scenario of interest. The angle was measured counter-clockwise from the reference line (axial axis of the OV) to the centre line of the MC. The MC speeds were 40, 50 and 60 km/h and OV speeds were 20, and 30 km/h. Additional lane changing scenarios are illustrated in column A3 of Table 3. Altogether, there were 208 impact conditions.



(a) (b)

Figure 6: Impact points on the OV (a) a passenger car (b) a pick-up truck

Table 3: Scenario parameters for impact configuration A

Scenario Parameters	A1	A2	A3 (Addition For Lane Changing)
Type of OV	Sedan & Pick-up truck	Sedan & Pick-up Truck	Sedan & Pick-up Truck
Impact points	Lateral 1 & 2	Front 3 & 4	Lateral 1 & 2
OV impact speeds	20, 30 km/h	20, 30 km/h	40, 50 km/h
MC impact speeds	40, 50, 60 km/h	40, 50, 60 km/h	50 km/h
Angle (°)	30°, 45°, 60°, 90°, 120°, 150°	120°, 150°	30°, 60°
Number of cases	144	48	16
Total number of cases		**208**	

2.3.2 Impact Configuration B: OV Impacting Lateral Side of MC

This impact configuration represents Scenarios 2, 3.2 and 4 of which the OV was travelling on straight road and the MC moved across OV. The scenario parameters are summarised in Table 4. Three impact points on MC were specified at the rear wheel (R), mid of wheelbase length (M) and front wheel (F) as shown in Figure 7. Impact angles of 30°, 45°, 60° and 90° were selected. Three OV speeds of 40, 50, 60 km/h, and three MC speeds of 20, 30, 40 km/h were selected. The total number of impact conditions were 216.

Table 4: Scenario parameters for impact configuration B

Scenario Parameters	B
Type of OV	Sedan & Pick-up truck
Impact points	Front (F), Mid(M), Rear (R)
OV speeds	40, 50, 60 km/h
MC speeds	20, 30, 40 km/h
Angle (°)	30°, 45°, 60°, 90°
Number of cases	**216**

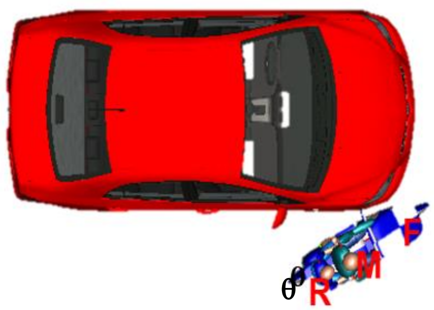


Figure 7: Three impact points on MC including rear wheel (R), mid of wheelbase length (M) and front wheel (F)

3.0 KINEMATICS OF THE RIDER AND THE PILLION PASSENGER

PC-Crash software was employed to perform multibody simulations for each impact condition defined in Tables 3 and 4. A total of 424 simulation cases were conducted. Since the number of child pillion passengers in Thailand was as high as 1.3 million (Save the Children Thailand, 2014), the child pillion passenger was also considered in this study. Kinematics of the rider and the child passenger as well as their head impact locations were investigated as follows.

3.1 Overall Kinematics

All simulations generated for impact configuration A (MC impacting OV) showed similar overall kinematics as exemplified in Figure 8. When the front wheel of the motorcycle hit the OV, both rider and child passenger were flung towards the impact point until the rider's body hit the MC cover and handlebar. The upper body still moved forward but the movement of the lower body was blocked by the MC handlebar. The rider's head was then hurled forward and impacted the vehicle structure. When the MC impacted at point 2 at a small angle, the rider and passenger did not impact the OV as shown in Figure 8. The child hit the rider's back and both were thrown together. The child's head mostly did not impact the OV. However, secondary impact to ground was possible for the child.

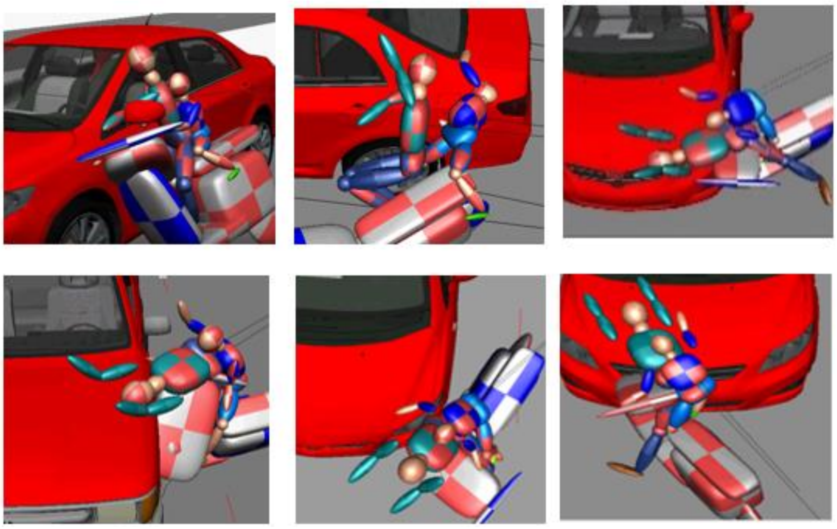


Figure 8: Typical kinematics obtained from simulations with MC impacting OV

All simulations generated for impact configuration B (OV impacting MC) showed similar overall kinematics as exemplified in Figure 9. When the OV impacted the MC, the rider and child passenger were projected towards the OV front. If the impact point was at the front wheel (F) of MC which was before the sitting position of the rider, the rider and child passenger had no impact with the OV. They fell onto the ground. However, if the impact points were at the mid of wheelbase length (M) or at the rear wheel (R), the head and upper body then impacted the vehicle front areas such as the hood, the bumper and the windshield. The child's movement after impact was similar to the rider. The location of head impact depended on the impact angle and speed.

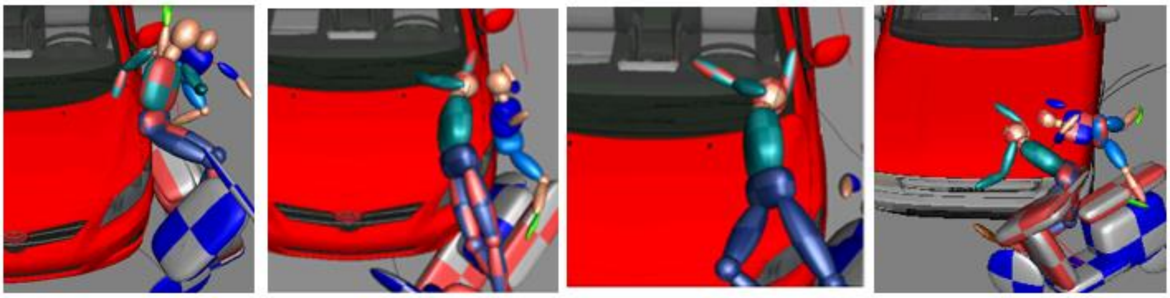


Figure 9: Typical kinematics obtained from simulations with OV impacting MC

3.2 Head Impact Locations

Various head impact locations were recorded for all 424 multibody dynamics simulations for both the passenger car and pick-up truck.

3.2.1 Motorcycle-Car Collision

The distribution of rider head impact locations on the car is shown in Figure 10. "No impact" refers to cases where there was no head contact to the OV.

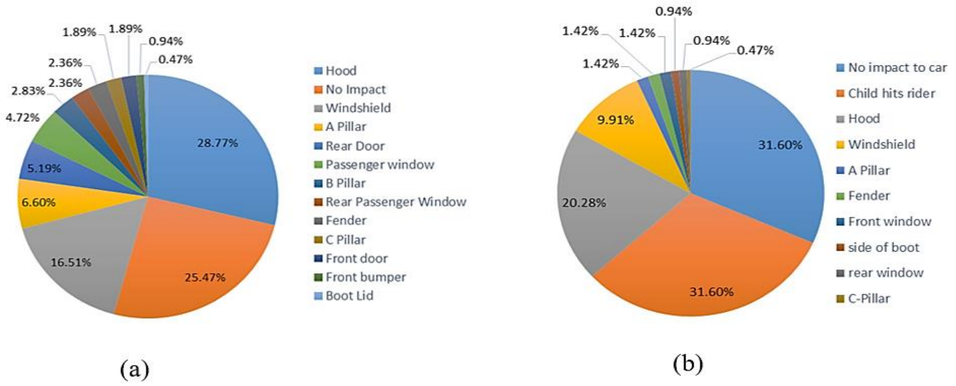


Figure 10: Percentage of head impact at various locations on a car (a) for the rider and (b) for the child passenger

The simulation results showed that the hood registered the highest proportion with 28.77% of all rider's head impacts. The windshield was the second at 16.51% and A-Pillar was at 6.6%. Figure 11(a) shows the five most frequent locations of rider's head impact and contribution of the number of impacts for each impact pattern. Simulations of OV impacting MC (impact configuration A) and MC impacting OV (impact configuration B) contributed the same amount of rider's head impact to the hood. As for the windshield location, simulations with impact configuration B contributed almost 86%. However, for A-pillar and passenger window, simulations with impact configuration A contributed more than 90%.

As regards child passenger's head impact location in Figure 10(b), it was found that a child pillion passenger mostly hit the rider's back. There was also a high number of no head impact cases. Apart from these two situations, the percentage of child's head impacting the hood was 20.28% and windshield was at 9.91%. These figures mainly involved impact configuration B as shown in Figure 11(b).

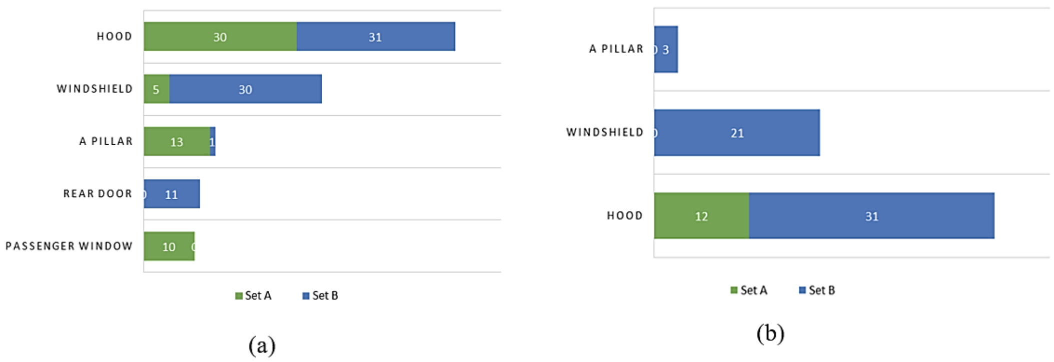
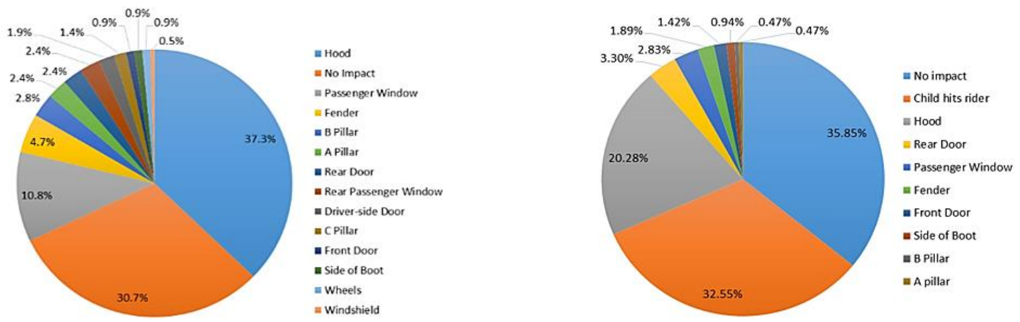


Figure 11: Proportion of head impacts on a car contributed from each impact configuration (a) the rider (b) the child

3.2.2 Motorcycle-Pickup Truck Collision

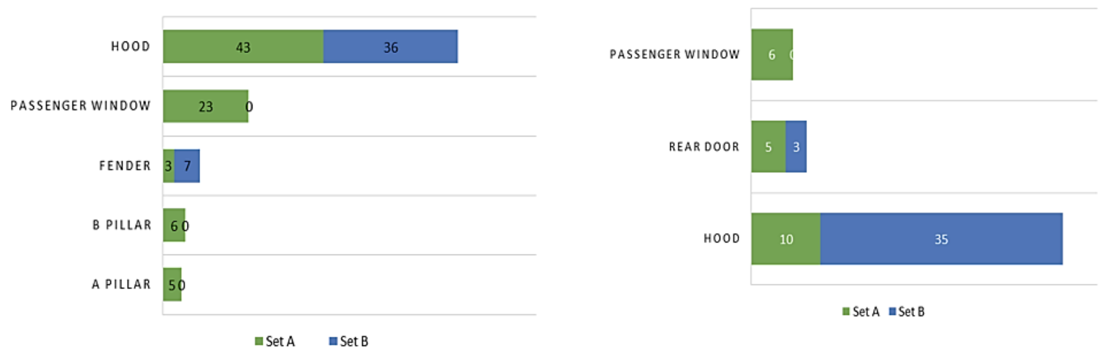
The distribution of rider's head impact locations for the pick-up truck is shown in Figure 12. Similar to MC-Car collision, the hood was the most frequently impacted by the rider's head. It accounted for 37.3%. Passenger window and fender accounted for 10.8% and 4.7% respectively. A-pillar and B-Pillar registered the same percentage of 2.4%. It was noticed that the rider's head rarely impacted the windshield. Figure 13(a) shows the five most frequent locations of rider's head impact and the number of impacts in each impact configuration. Simulations with impact configuration A contributed higher rider's head impacts than simulations with impact configuration B. The number of head impacts on passenger window, A-pillar and B-pillar locations was derived from simulations with impact configuration A only.



(a) (b)

Figure 12: Percentage of head impact at various locations on a pick-up truck (a) for the rider and (b) for the child passenger

Most of the simulated cases recorded no impact of the child passenger's head to the pick-up truck. 32.5% of simulations resulted in the child's head impacting the rider's back. The pick-up truck's hood was the most frequent location for the child's head impact. Simulations with impact configuration B contributed 72% for the pick-up truck's hood area.



(a) (b)

Figure 13: Proportion of head impacts on the pick-up truck contributed from each impact configuration for (a) the rider (b) the child passenger

Simulation results obtained from both MC-Car collision and MC-Pick-up truck collision revealed moderate proportion of head impacts with A, B and C pillars which featured high strength components. The head that impacts to these locations has high risk of severe injury.

3.3 Limitations

The PC-Crash software for multibody simulations employed in this study cannot provide information on injury. In this study, only kinematics information was available. It would have been more beneficial to combine the multibody simulation with finite element analysis to study the detailed injury mechanism as suggested by Fiest et al. (2009). The other limitation was the use of a single-sized young passenger. The distribution of head impact locations might change if the rider is physically taller. Additional simulations with various sizes of riders and pillion passengers will make the results more representable of real-world cases. They can then support the revision of pedestrian safety assessment protocol to cover the evaluation for motorcyclist safety.

4.0 CONCLUSION

In this study, classification of the motorcycle accident data was successfully performed. When considering accidents involving other vehicles, the majority of cases were sideswipe. The passenger car was the most frequent vehicle type involved in motorcycle accidents. The most common age group of riders in motorcycle accidents ranged between 10 to 29 years. Serious and severe injuries (equivalent to AIS3-AIS5) accounted for 20% of the total number of casualties while minor abrasion and bruise accounted for 41%. This information was employed for development of multibody dynamics models. A passenger car and a pick-up truck were selected as Other Vehicles for crash simulations. The rider height was selected to represent a young rider of the mentioned age group. Four accident scenarios were then identified. These included the other vehicle changing lane or overtaking a motorcycle, motorcycle changing lane or overtaking the other vehicle, either other vehicle or motorcycle taking U-Turn and motorcycle turning left from alley while the other vehicle was travelling straight. Impact speed, impact point and impact angle were employed to generate possible impact conditions to cover all specified accident scenarios.

The simulations in the study revealed two patterns of global kinematics. When the other vehicle impacted the motorcycle, the rider and child pillion passenger were laterally projected towards the other vehicle. When the motorcycle impacted the other vehicle, the rider and the child passenger were flung forward together. The rider impacted the vehicle structure while the chance of child impact was low. The hood the highest proportion of head impacts for the rider and child. The windshield had the second highest proportion of head impacts for the car. The passenger window was another common location for head impacts for both the car and the pick-up truck. Moderate proportion of A-pillar contact was recorded for motorcycle-car collision. This can lead to high risk of severe injuries. Child’s head often hit the rider’s back when the motorcycle impacting the other vehicle. The simulations should include different sizes of riders to improve the results which can support the feasibility of revising vulnerable road user safety assessment protocol of NCAPs.

ACKNOWLEDGEMENTS

The authors would like to thank the Road Accident Victims Protection Co Ltd (RVP) for allowing the use of their motorcycle accident data and Proactive Co. Ltd. for providing the PC-Crash software.

REFERENCES

AAAM (2008). *Abbreviated injury scale (AIS) 2005 – Update 2008*. Barrington, IL: Association for the Advancement of Automotive Medicine (AAAM).

Department of Land Transport Thailand (2017). *Government open statistical data*. Retrieved from www.data.go.th

Fiest, F., Gugler, J., Arregui-Dalmases, C., del Pozo de Dios, E., López-Valdés, F., Deck, C., & Willinger, R. (2009). *Pedestrian collisions with flat-fronted vehicles: Injury patterns and importance of rotational accelerations as a predictor for traumatic brain injury (TBI)*. Paper presented at the 21st International Technical Conference on the Enhanced Safety of Vehicles Conference (ESV), Stuttgart, Germany.

Kantipong, K. (2015). *Thailand motorcycle accident situation.* Paper presented at the 70th Session of UNECE Road Safety Forum. Retrieved from http://www.unece.org/ fileadmin/DAM /trans/doc/2015/wp1/ECE-TRANS-WP1-2015-Presentation-13.pdf

Karnjanapollert, P., Koetniyom, S., & Carmai, J. (2018). *The use of multibody dynamics simulations to investigate motorcyclist kinematics and injuries in accidents*. Paper presented at the 14th International Conference of Automotive Engineering, Muang Thong Thani, Pak Kret, Thailand.

Kasantikul, V. (2002). *Motorcycle accident causation and identification of countermeasures in Thailand: Volume I: Bangkok study*. Retrieved from http://www.mosac.eu/public/file/Kasantikul%20Motorcycle%20Accident%20Research%20in%20Thailand%20-%20Bangkok%202002.pdf

Magriet, V.S., Stefanie, H., Radarius, C., & Fredriksson, R. (2012). Cyclist kinematics in car impacts reconstructed in simulation and full scale testing with Polar dummy. *Proceeding of International Research Council on Biomechanics of injury (IRCOBI)*, 800-812. Retrieved from http://www.ircobi.org/wordpress/downloads/irc12/pdf_files/85.pdf

Otto, D. (1989). *Injury mechanism and crash kinematics of cyclists in accidents-an analysis of real accidents*. Paper presented at the 33rd Stapp Car Crash Conference, Warrendale, PA, USA.

Otto, D. (2004). *Use of thrown distances of pedestrians and bicyclists as part of a scientific accident reconstruction method*. Paper presented at SAE 2004 World Congress & Exhibition, Detroit, Michigan. USA.

Rohit, B. (2016). *Powered two wheelers safety in the South East Asian-region.* Paper presented at Europe-Asia Road Safety Forum 2016. Retrieved from https://www.unece.org/fileadmin/DAM/trans/doc/2016/wp1/ECE-TRANS-WP1-73-Presentation-7e.pdf

Save the Children Thailand (2014). *The 7% Project, 2014*. Retrieved from http://www.7-percent.org/about/

Untaroiu, C., Meissner, M., Cradall, J.R., & Takahashi, Y. (2009). Crash reconstruction of pedestrian accidents using optimization techniques. *International Journal of Impact Engineering*, *36*(2), 210-219.

Untaroiu, C., Cradall, J.R., Takahashi, Y., Okamoto, M., Ito, O., & Fredriksson, R. (2010). Analysis of running child pedestrians impacted by vehicle using rigid body models and optimization techniques. *Safety Science*, *48*(2), 259-267.

Watson, J., Hardy, R., & Kayvantash, K. (2009). Understanding the nature of cyclist's head impacts. *Proceeding of International Research Council on Biomechanics of Injury (IRCOBI)*, 301-314.

WHO (2015). *Global status report on road safety 2015 – Supporting a decade of action.* Geneva, Switzerland: World Health Organization (WHO). Retrieved from http://www.who.int/violence_injury_prevention/ road_safety_status /2015/en/

WHO (2017). *Powered two- and three- wheeler safety – a road safety manual for decision makers and practitioner*. Geneva, Switzerland: World Health Organization (WHO). Retrieved from http://apps.who.int/iris/bitstream/10665/254759/1/9789241511926-eng.pdf