Transport and Communications, 2022; Vol. II.
ISSN: 1339-5130
DOI: 10.26552/tac.C.2022.2.2

Motorcycle Crash Tests - Literature Review

Marek Jaśkiewicz[1], Damian Frej[1], Antoni Bankowski[1*]

[1]Kielce University of Technology, Al. Tysiaclecia Panstwa Polskiego7, 25-314 Kielce, Poland
[*] Corresponding author: abankowski@tu.kielce.pl

Abstract More and more motorcycles appear on the roads, which can be seen, for example, on the basis of statistic data presented by the Central Statistical Office. The data shows that every year there are more newly registered motorcycles and that there are many road accidents involving two-wheelers. The following work presents a review of the existing literature related to crash tests of motorcycles and dummies. The paper presents the standards according to which the tests are carried out, various crash tests and the stands on which the tests were carried out. The paper presents and describes a dummy used in motorcycle crash tests and presents the differences between its construction and the construction of the Hybrid III dummy.

Keywords motorcycles, crash tests, safety

JEL R41

1. Introduction

Motorcycles are becoming an increasingly popular means of transport. In Asian countries, they constitute a significant number of vehicles in road traffic. In European countries, there is also an increase in interest in two-wheelers and an increasing number of them on the roads. The increase in the number of motorcycles can also be seen from the increase in the number of new two-wheelers registered in Poland. Based on the data provided by the Central Statistical Office, it can be seen that there are new motorcycles in Poland every year.

Due to the increasing number of motorcycles, road incidents involving motorcycles have begun to be investigated and analyzed, because motorcycles do not have as many safety systems as vehicles, and the driver and passenger are not protected to the same extent as vehicle users. 28% of victims of all road accidents are motorcyclists [6].

The paper presents dummies used in motorcycle crash tests and discusses the literature on motorcycle crash tests.

2. Crash test dummies

In motorcycle crash tests, dummies are not tested on people's stands for safety reasons. Hybrid dummies were mainly used for the study [16]. People involved in crash testing motorcycles decided to develop an anthropometric dummy adapted to testing two-wheelers. As a result of this idea, the MATD 1 dummy (Motorcyclist Anthropometric Test Device) was developed and created [1]. The dummy is presented in Figure 1. The dummy was made as a result of modification of the Hybrid III dummy.

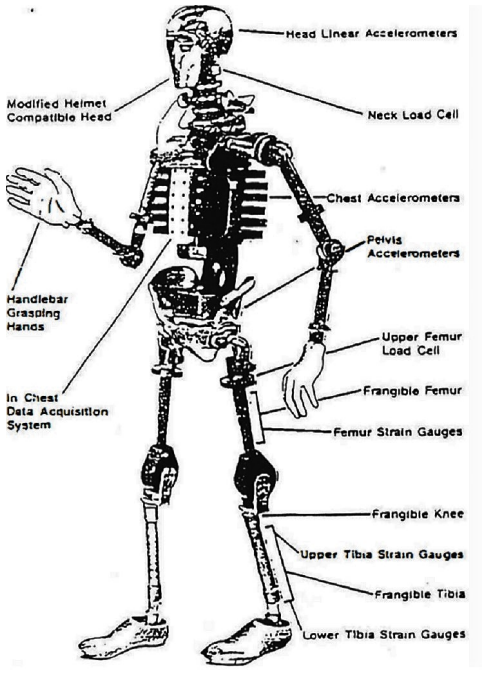

Figure 1. Dummy MATD 1 [1]

The dummy had built-in sensors that allowed for wireless data collection [1,10]. The standard Hybrid III dummy's femurs and tibias were replaced with brittle bones equivalent to human bones, and knee joints were created to simulate the possibility of ruptured ligaments, in order to observe accidental injuries and to better represent the movement of

limbs during a crash. Figure 2 shows the fractured femur of the MATD dummy.

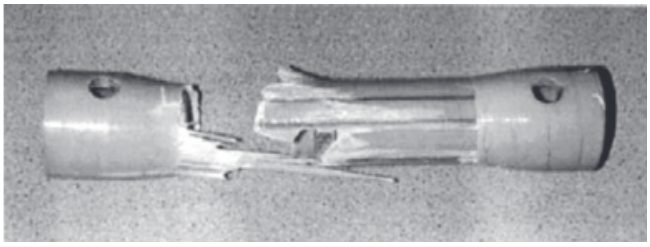

Figure. 2. The femur of the MATD dummy cracked during the crash test [10]

Modifications also included the hands, MATD 1 allowed for better placement of the hands on the steering wheel of the vehicle. Despite the fact that a motorcycle crash dummy has been specially designed, hybrid III dummies are often used for testing. On the basis of tests with the use of dummies, it is checked what injuries occur within the limbs, head and spine [1,2,3,4,5,6,8]. The use of maenkins and crash tests can increase safety

3. Crash tests of motorcycles and vehicles

Crash tests of motorcycles are carried out on special stands. Usually, these are special tracks on which the motorcycle moves on a trolley [7,8,10,11]. An example stand is shown in Figure 3. The Figure shows a motorcycle placed on a special rack that moves along a prepared track.

Figure. 3. Motorcycle crash test bench [11]

Motorcycle crash tests are usually carried out according to the ISO 13232 standard. The standard applies to two-wheeled motorcycles. The standard outlines test and analysis procedures, moreover, it specifies the type of vehicle the motorcycle collides with, whether both vehicles are in motion, the type of motion the motorcycle is moving before the impact, and it specifies that the motorcycle is to move at a constant speed. The standard also defines which dummies should be used for testing and how they should be placed on the vehicle. The standard describes the occurring injuries and their division into individual areas of the body. Based on the analyses, the standard defines different types of collisions between a motorcycle and a passenger vehicle and the angle at which the collision occurred. The collision configurations of a motorcycle and a vehicle are shown in Figure 4.

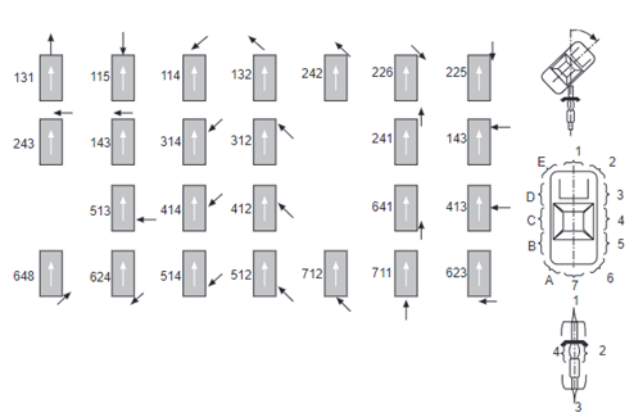

Figure. 4. Shock configurations for motorcycle with vehicle according to ISO 13232 [10]

Based on the ISO 13232 standard, simulation tests are performed first, and then tests performed on full-size test stands. Figure 5 shows a crash test performed according to configuration 413 of the ISO 13232 standard. The test was performed at a speed of 48 km/h and the effectiveness of the airbag on the motorcycle was checked [10].

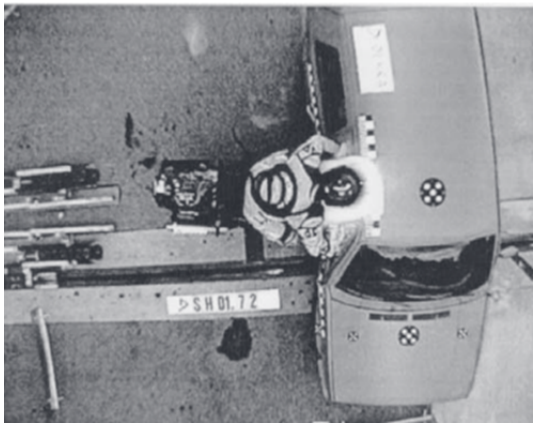

Figure. 5. Collision of a motorcycle with a passenger vehicle in configuration 413 according to ISO 13232 [10]

Many studies discuss whether a helmet adequately protects a motorcyclist's head during a collision with a vehicle or during a fall [2, 3, 4, 5]. Direct investigations collect information on the displacement and acceleration that occur during the event. In addition, medical reports about the injuries sustained by the driver of the vehicle are also analyzed. Based on this work, it can be seen that helmets largely prevent loss of life and reduce the risk of serious skull injuries. Crash tests of motorcycles allow for the development of newer and newer solutions that increase the safety of motorcyclists [8]. The tests allow to determine the forces acting on both vehicles and the motorcyclist. The motorcycle hitting the side of the vehicle had a speed of about

DOI: 10.26552/tac.C.2022.2.2

50 km/h. During the test, the initial position of the driver's head and its displacement relative to the trunk were determined using a high-speed camera. In addition, during the test, the impact of the padding inside the helmet on the victim was checked. The conducted research showed what part of the kinetic energy of the motorcyclist's body, dissipated during the accident, depended on the course of deformation of the vehicle body at the point of impact of the motorcyclist's head and the helmet, and on the type of helmet lining material.

Motorcycle crashes are based on vehicle crash tests [14]. One of the studies using a motorcycle collision was a study to determine whether the measurements recorded by a high-speed camera will be consistent with the data recorded by the acceleration and angular velocity sensors placed in the black box inside the vehicle [12, 13]. The impact of a motorcycle against the side of a passenger vehicle was recorded. The crash test is shown in Figure 6.

Figure. 6. Crash test recorded with a high-speed rotating camera at 1000 frames per second [7]

Data from the camera were processed using a film analysis program, while data from the sensors were analyzed using mathematical relationships [15]. Based on these two analyses, the authors concluded that the measurement results are consistent with each other because the position of the Figure resulting from the calculations was consistent with what the camera recorded on the video. The results of the analysis are shown in Figures 7 and 8.

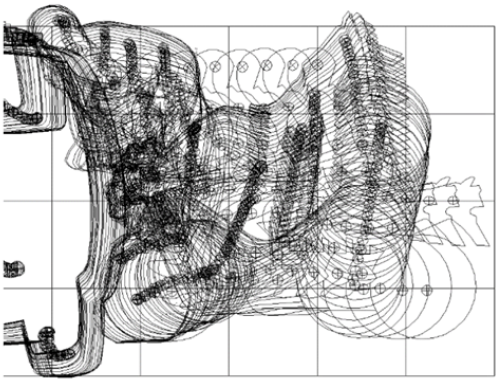

Figure. 7. Impact analysis based on time-lapse analysis of film [7]

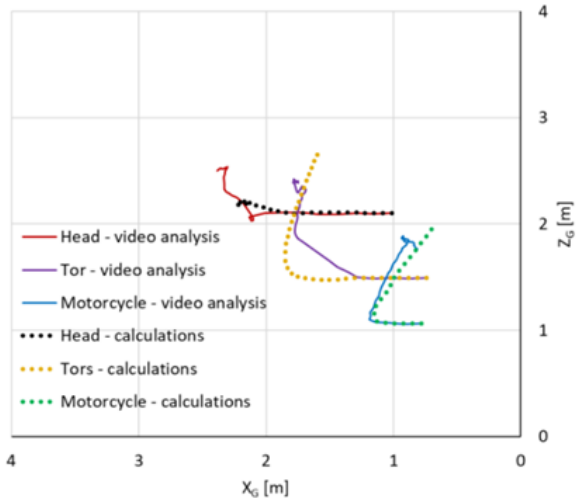

Figure. 8. Crash analysis based on the calculation method [7]

3.1.Crash tests for motorcycles with road barriers

In addition to examining road accidents involving a motorcycle and a vehicle, collisions of motorcyclists with energy-intensive barriers are also investigated [9, 17, 20, 21, 22, 23.24]. Such events usually occur outside urban areas and are usually caused by excessive speed of the driver, loss of control of the vehicle during maneuvers. During the tests, the impact on concrete and metal protective barriers was tested. The test was performed at a speed of 60 km/h. A Hybrid III dummy representing a 50th percentile male was used for the study. During the test, the motorcycle hit the protective barriers at different angles. Figure 9 shows the stand with the motorcycle properly tilted. During the tests, the displacement and acceleration of individual parts of the body, in particular the head, were measured. The forces that occur when colliding with barriers were also measured.

Figure. 9 Crash test bench with road barriers [9]

Based on the observation of collisions, it was noted which injuries occur most often and what are their causes. Based on the research, it was proposed to modernize the

barriers in order to increase the safety of motorcyclists. Further studies have been carried out that have shown that changes in barriers can increase the safety of drivers.

4. Conclusions

There are more and more motorcycles on the road and their riders account for almost one-third of all road fatalities. For this reason, it is important to research the issues related to motorcycles as much as possible. Thanks to such research, it is possible to introduce changes in vehicles, protective clothing and road infrastructure in order to increase the safety of two-wheelers.

REFERENCES

[1] James A. Newman, John W. Zellner, Kenneth D. Wiley, "A motorcyclist anthropometric test device MATD." proceedings of the International IRCOBI Conference on the Biomechanics of Impacts, IRCOBI, 1991

[2] Michael Van Auken, John W. Zellner, Terry Smith, Nicholas M. Rogers, "Development of an improved neck injury assessment criteria for the ISO 13232 motorcyclist anthropometric test dummy." 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV). No. 05-0227. 2005.

[3] Antonio Maria Catena, Michele Treglia, Luigi Tonino Marsella, Marcello Locatelli, Enrica Rosato, Abuzar Kabir, Martina Bonelli, Cristian D'Ovidio, "When the Helmet Is Not Enough: Forensic Multidisciplinary,Reconstruction of a Deadly Motorcycle Accident", Diagnostics, Volume 12, 2022

[4] Carolina Chaves Gama Aires, Heitor Tavares De Araújo, Rosa Rayanne Lins De Souza, Aída Juliane Ferreira Dos Santos, Ricardo José De Holanda Vasconcellos, Belmiro Cavalcanti Do Egito Vasconcelos, "Relationship between the use and types of helmets with facial injuries-a prospective study", Revista do Colégio Brasileiro de Cirurgiões, Volume 49, 2023

[5] Mercy Lorlonyoa Amegah, Emmanuel Kofib Adanu, Thomasa Kolawole Ojo, Shaibuc Bukari, Filibertod Asare-Akuffo, "Exploration of motorcyclists' red-light running and helmet use at signalized intersections in Ghana", Traffic Injury Prevention, Volume 24, pp. 94 - 97, 2023

[6] Fritjof Gidion, Jolyon Carroll, Nils Lubbe, "Motorcyclist injuries: Analysis of German in-depth crash data to identify priorities for injury assessment and prevention", Accident Analysis and Prevention, Volume 163, Article number 106463, 2021

[7] Tomasz Pusty, Miroslaw Gidlewski, Leon Prochowski, "Methods for determining the physical quantities describing the vehicle movement and the driver during a road accident", IOP Conference Series: Materials Science and Engineering. Volume 1247. No. 1, 2022

[8] Tomasz Pusty, Miroslaw Gidlewski, Leon Prochowski, "Experimental research aimed at determining the force and energy of the impact of motorcyclist's head against a motor car side during a road accident" International Journal of Safety and Security Engineering, Volume 8, pp. 20-30, 2018

[9] Steffen Peldschus, Erich Schuller,Jens Koenig, Marcus Gaertner, David García Ruiz, Alberto Mansilla, "Technical bases for the development of a test standard for impacts of powered two-wheelers on roadside barriers." Proceedings of the 20th Enhanced Safety of Vehicles Conference. 2007

[10] Alexander Berg, Peter Rücker, Jens König, "Motorcycl crash tests—an overview". International Journal of Crashworthiness, Volume,10, pp. 327-339, 2005

[11] Leon Prochowski, Tomasz Pusty, "Analysis of motorcyclist's body movement during a motorcycle impact against a motor car side" Journal of KONES, Volume 20, pp. 371-379, 2013

[12] Marek Guzek, Zbigniew Lozia, "Possible Errors occurring during Accident Reconstruction based on Car "Black Box" Records", World SAE Congress and Exposition. Detroit, Michigan USA, 2002

[13] Marek Guzek, Zbigniew Lozia, "Analiza dokładności rekonstrukcji wypadku drogowego wykorzystujących zapisy samochodowej „czarnej skrzynki". II Konferencja Naukowo-techniczna "Rozwój techniki samochodowej a ubezpieczenia komunikacyjne", 2004

[14] Filip Dąbrowski, Mirosław Gidlewski, "Front and Side Crash of Cars in Motion – comparative analysis of experimental and modelling test results", Zeszyty Naukowe Instytutu Pojazdów Politechniki Warszawskiej, 2015

[15] Paweł Buraczewski, Jerzy Jackowski, "Porównanie metod określania parametrów ruchu pojazdu podczas zderzenia z przeszkodą", XXXI Seminarium Kół Naukowych Wydziału Mechanicznego, 2012

[16] Marek Jaśkiewicz, Rafał Jurecki, Karolina Witaszek, Darek Więckowski, "Overview and analysis of dummies used for crash tests". Zeszyty Naukowe Akademia Morska w Szczecinie, Voulme 35, pp. 22-31, 2013

[17] Denis Wood, Colin Glynn, Darren Walsh, "Motorcycle-to-car and scooter-to-car collisions: speed estimation from permanent deformation", Proceedings of the Institution of Mechanical

DOI: 10.26552/tac.C.2022.2.2

Engineers, Part D: Journal of Automobile Engineering, Volume 223, pp. 737-756, 2009

[18] K. S. Tan , Shaw Voon Wong, Megat Ahmad, "Effects of layout design changes on frontal crash behaviour of small motorcycles." International Journal of Crashworthiness Volume 22, pp. 111-128, 2017

[19] Dario Vangi, Carlo Cialdai, "Evaluation of energy loss in motorcycle-to-car collisions", International journal of crashworthiness, Volume 19, pp. 361-370, 2014

[20] F. Alexander Berg, Peter Rücker, Marcus Gärtner, Jens König, Raphael Grzebieta, Roger Zou "Motorcycle impacts into roadside barriers-Real-world accident studies, crash tests and simulations carried out in Germany and Australia". In Proceedings of the Nineteenth International Conference on Enhanced Safety of Vehicles", 2005

[21] Raphael Grzebieta, Mike Bambach, Andrew McIntosh, "Motorcyclist Impacts into Roadside Barriers Is the European Crash Test Standard Comprehensive Enough?", Transportation research record, Volume 2377, pp. 84-91, 2013

[22] Mike Bambach, Rebecca Mitchell, Raphael Grzebieta, "The protective effect of roadside barriers for motorcyclists", Traffic injury prevention, Volume 14, pp. 756-765, 2013

[23] Allison Daniello, Hampton Gabler, "Fatality risk in motorcycle collisions with roadside objects in the United States", Accident Analysis & Prevention, Volume 43, 2011,

[24] Hussein Jama, Raphael Grzebieta, Rena Friswell, Andrew McIntosh, "Characteristics of fatal motorcycle crashes into roadside safety barriers in Australia and New Zealand", Accident Analysis & Prevention, Volume 43, 2011

[25] Esmaeil Mohammadi, Sina Azadnajafabad, Mohammad Keykhaei, Ali Shakiba, Sepideh Ebrahimi Meimand, Sedighe Hosseini Shabanan, Pouya Mahdavi Sharif, Mohammad Hossein Asgardoon, Mehdi Shafieian, Zahra Ghodsi, Seyed Taghi Heydari, Rasha Atlasi, Alireza Ansari-Moghaddam, Mahdi Sharif-Alhoseini, Gerard M O'Reilly, Vafa Rahimi-Movaghar,"Barriers and factors associated with the use of helmets by Motorcyclists: A scoping review", Accident Analysis & Prevention, Volume 171, 2022.