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Enhancement of Postura Motergo™: From an Ergonomic Motorcycle Test Rig to a Full-Scale Simulator

Wan Muhammad Syahmi Bin Wan Fauzi
Abdul Rahman Bin Omar
Helmi Bin Rashid
Motorcycle Engineering Technology Laboratory (METAL)
Faculty of Mechanical Engineering, Universiti Teknologi MARA
40450 Shah Alam. Selangor, Malaysia

ABSTRACT

Motorcycle road accidents have become a global transportation issue. In enabling scientific studies on indoor motorcycling, Postura MotergoTM motorcycle test rig was initially established by a group of researcher from the Motorcycle Engineering Technology Laboratory (METAL). Unique from other test rigs, the patented Postura MotergoTM was designed to be fully adjustable in order to replicate different type of riding postures. However, it is noticeable that the current design of Postura MotergoTM could be improved to further elevate users' experience into a full-scale simulator. The aim of this study was to enhance the features of Postura MotergoTM's test rig, adding to better fidelity and ensuring the design longevity and overall cost effectiveness provided by the newly enhanced motorcycle simulator. In improving the Postura MotergoTM, it can be divided into 2 categories: (i) Design Aspect Category (DAC), and (ii) Environmental Simulator Category (ESC). The DAC covers parts of Postura MotergoTM's test rig which is the main chassis, handlebars, foot-pegs, tank cover and the platform or base of the simulator. The ESC involves the enhancement of Human-Machine-Environment Interface (HMEI) elements. As of the methodology, state-of-the-art CATIA V5R20 software was extensively used in redesigning the Postura MotergoTM whilst the fabrication works were done in-house at the Machine Workshop, Faculty of Mechanical Engineering, Universiti Teknologi MARA, Shah Alam, Malaysia. As a whole, these categories ensured the complete construction of an immersive motorcycle simulator. Conclusively, by enhancing the Postura MotergoTM test rig, greater near-to-real motorcycling conditions could be simulated in a controlled laboratory setting and narrowing the fidelity and validity values. Thus, it enables the particular motorcycle simulator to contribute to various motorcycle ergonomics

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researches in the near future. Such matter would then be hoped to ultimately aid in reducing the global motorcycle road accident statistics.

Keywords: *Motorcycle, Ergonomics, Test Rig, Simulator, Enhancement*

Introduction

As a mode of transportation, road users in various Asian countries prefer motorcycles over four-wheeled vehicles. Characteristics of having an economic market price, good fuel consumption, but, most importantly easy to manoeuvre through congested roads; makes it as the preferred choice for them. However, motorcycle road accidents have become a global transportation safety issues where motorcyclists suffer mortality and non-fatal injury crashes [1]. In the last 7 years, the fatality rates from road accidents in Malaysia increased steadily by 4% per year, contributing to a number of deaths rising to 6745 in 2009 compared to 6000 for the past five years [2]. Besides that, road accidents have become a major cause of death around the world with a statistics of 31,000 death and 1,600,000 sustained non-fatal injuries in the European Union every year [3]. Henceforth, there is a need for continuous researches that propose for new countermeasures in overcoming this global phenomenon.

There are several factors documented to be the causation factors towards the occurrence of motorcycle road accidents. In examining these factors, as an alternative to real world assessment, researchers have utilized the option of utilizing motorcycle simulators or test rigs. A motorcycle simulator was invented to give actual experience while handling motorcycle in a controlled laboratory environment with the capability to compute the dynamic behaviour of the motorcyclist [4]. Suggestively, it is the safest way of handling the motorcycle due to the absence of real hazardous conditions from the real road. Furthermore, motorcycle simulator is also worth for studies on various types of fatigues and medical impairments [5]. Henceforth, motorcycle simulator has been and continuously developed nowadays for studies and further research on motorcycle accidents including motorcycle ergonomic niche area.

Currently, there are a lot of motorcycle simulators being developed all around the world such as Honda SMARTrainer Motorcycle Simulator [6], NIHON Motorcycle Simulator [7], and UNIPD Motorcycle Simulator [8]. Even so, for this study, a special interest was made on the Postura Motergo™, a revolutionary motorcycle test rig initially established by a group of researchers from the Motorcycle Engineering Technology Laboratory (METAL) of the Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM) [9-11]. Figure 1 shows the initial Postura Motergo™ test rig setup.

Figure 1: Postura Motergo™

The particular motorcycle test rig, similar with the other aforementioned motorcycle test rig or simulators, allows for studies on motorcycle or motorcyclist within a controlled and safe laboratory setting. The unique adjustability package of the Postura Motergo™ permits for the motorcycle test rig to be adjusted in order to cater for various motorcycling riding postures based on the Riding Posture Classification (RIPOC) system [12]. Nevertheless, fidelity and validity issues are always the main concern in motorcycle simulators related researches. Suggestively, based on Dr. Alex Stedmon's researches [13], for any studies that use a motorcycle simulator, it is best if the motorcycle simulator could provide a genuine motorcycling experience to the test subjects. As adjustable as it is, this issue is still of concern with respect to the Postura Motergo™. In improving the Postura Motergo™ test rig, two categories were mainly focused: (i) Design Aspect Category (DAC), and (ii) Environmental Simulator Category (ESC). The DAC covers the main parts of Postura Motergo™ within its chassis. The ESC involves the enhancement of Human-Machine-Environment Interface (HMEI) elements and surrounding environment. As a whole, these categories will ensure the complete construction of a newly enhanced and immersive motorcycle simulator mainly for research purposes.

There is a lot of enhancement that could be done in order to elevate the Postura Motergo™ to a new level of motorcycle simulator facility.

i. Design Aspect Category (DAC)

- From the perspective of the initial test rig, the cockpit design of the Postura Motergo™ is a rigid feature. The motorcycle cockpit is made up of; (i) handlebar (along with its components such as the triple clamps and top yoke), (ii) body (commonly houses the fuel tank), and (iii) seat/seating platform. Henceforth, in order for Postura Motergo™ to be able to replicate these cockpit designs features, it is strongly suggested that the current cockpit is redesigned. The newly designed cockpit features a simultaneous expendable and collapsible tank design. The goal here is to ensure the validity and fidelity of the new simulator design with respect to human operator's user experience while utilizing the simulator.

- It can be observed that the current Postura Motergo™ test rig does not provide any simulation system that links between the user input and the visual output. Currently, there is no throttling system, braking system and gear clutching system implemented on the test rig. For a simulator, especially in motorcycle simulation, these are one of the most important elements that should be integrated to the simulator so that it can provide a simulation interface between the user and the simulator. The idea is to develop a comprehensive system consisting of throttle system, gear clutch system and brake system and linking them with a 3D motorcycle gaming software. Hence, this system can provide a more realistic riding experience, where the Postura Motergo™ is connected with the gaming simulation.
- Initially, the Postura Motergo™ test rig used a simple spring and two rotational shafts in order to provide dynamic motions. However, due to its design limitation, the movement of the Postura Motergo™ was limited to only one static positioning with very minimal roll axis when being integrated with its base platform. Furthermore, due to the rigidity of this setup, it was found that it was rather physically challenging for the test subject to replicate similar dynamic motions of real world motorcycling on the particular motorcycle test rig. Therefore, the aim is to enhance the Postura Motergo™'s motion system by integrating more degrees of freedom (DoF) into the simulator setup using an electric motor.

ii. Environmental Simulator Category (ESC)

- The initial visual element of the setup only provided a flat screen in front of the test rig. For most of the available motorcycle simulators, they used a combination of 3 high quality LCD screens installed in front of them [8]. It is interesting to note that the use of 3 LCDs actually aids in simulating the speeding sensation during the simulation process. This is possible when the eye's side portions capture the perception of speed during the ride.

Therefore, by improving the current design and features of the Postura Motergo™ motorcycle test rig, fidelity and validity values of the particular motorcycle test rig could be further enhanced. Furthermore, such improvements could further stretch the design limitations of the Postura Motergo™, thus, enables the particular motorcycle test rig to contribute to various motorcycle ergonomics researches in the near future. Henceforth, it ensures design longevity and overall cost effectiveness.

Methodology

Table 1 shows the summary of the categories of works for this study. The research methodology was separated into 4 sub-methodology categories.

Table 1: Categories of Works

	Design Aspect Category (DAC)
Categories of Works	**Development of an adjustable tank cover by adapting Rib and Spine Chassis (RISC^{TM}) Concept** - The new tank design adapted from Rib and Spine Chassis (RISC^{TM}) concept provides an innovative expandable and collapsible motorcycle tank that can improve the replication of different types of motorcycle models.
	New simulation system - The newly developed simulation system shall highly improve the interaction between the human and the workstation. In this case, the subject and the simulator. The subject can control the simulator with his desire, whether to turn, brake, accelerate and change gear.
	Improvement of the motion system - The improvement of the DoF shall also give better riding motions. The consideration of 3 DoF in motion cues shall give better riding simulation as compared to the initial test rig setup.
	Environmental Simulator Category (ESC)
	Improvement of the visual elements - The improvement on the screen by having a 180° curved screen shall improve the speed sensation of the test subjects. During riding, the eye’s side portions shall capture the perception of speed. The side screens give actual speed to the subjects so that he or she does not feel slow as compared to actual riding scenario.

Development of an adjustable motorcycle tank cover

This research methodology focused on developing an adjustable tank cover utilizing Rib and Spine Chassis (RISC^{TM}) concept. Several methods were conducted as follow:

Literature assessment

Literature assessment was performed in acquiring the information regarding the motorcycle tank cover, obtained from the UiTM Online Library database.

Field study

The field study was crucial in identifying the design parameters in establishing the adjustable tank cover. Measurements of various tank cover from a variety of motorcycle models were taken. Subsequently, the average value of these measurements was taken in establishing the adjustable tank cover.

Conceptual design and concept selection

Based on the field study conducted, three (3) ideas and conceptual designs were generated. The selection of the best design was done via both Morphological Chart and Pugh Method.

Detail design

As for the design process, the chosen concept which was concept 3 was redesigned, using Computer Aided Design (CAD) software; CATIA V5R20. Via the software, accurate 3-Dimensional (3D) depiction of the concept was successfully generated. Figure 2 shows the 3D model of the adjustable tank cover utilizing the Rib and Spine Chassis (RISC^{TM}) concept. In contrast to the existing tank cover of the Postura Motergo^{TM}, this new design provides a fully adjustable feature in order to replicate different types of tank cover with respect to the motorcycle cockpit design.

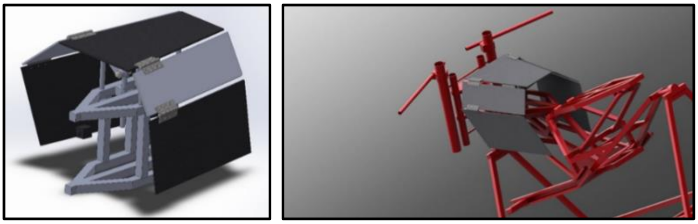


Figure 2: 3D model of the adjustable tank cover

Fabrication process

Fiber glass was used as the main material to fabricate the tank due to good complexity in fabrication before it becomes hardened as a single form. Fiberglass has pros such as anti-rust, durable, high fatigue limit and also can withstand shock or force during simulation process. The fabrication process was done at the workshop of Faculty of Mechanical Engineering, UiTM.

Development of new simulation system

This research methodology focused on developing a new simulation system for the Postura Motergo™. Several methods were conducted as follow:

Literature assessment

Literature assessment was performed in acquiring the information regarding the simulation system, obtained from the UiTM Online Library database.

Field study

There are several inputs and outputs to be considered in developing the simulation system. The following describes the inputs and outputs of the system:

i. Throttle Input – to increase and decrease the speed of the motorcycle.
ii. Front Brake Input – to stop the motorcycle using front brake.
iii. Rear Brake Input – to stop the motorcycle using rear brake.
iv. Steering Input – to steer the motorcycle during cornering.
v. Gear Input – to step up or step down the gear system of the motorcycle.
vi. Clutch Input – to enable the gear to be step up or step down.
vii. Motorcycle Gaming Software Output – to provide the medium of simulation system that will be projected onto the screen.

Concept system

Initially, the concept of the simulation controller system was done by modifying a Logitech MOMO Racing Wheel and attaching a motorcycle handlebar onto it so that it creates a counter-steering feeling (a physic terminology in motorcycle cornering) as shown in Figure 3. The design of this system is owned by an experienced motorcycle controller designer, Allan J.P. Beaton from IASystems based in the United Kingdom. A research collaboration was made with IASystems to design and fabricate this controller system.

Figure 3: Concept of modifying the MOMO Wheel with a handlebar

Detail design

To suit the simulation controller system design with the initial Postura Motergo™ test rig setup, several design changes were made specifically on the design mountings. This involved the usage of Computer Aided Design (CAD) software; CATIA V5R20. Figure 4 shows the controller system.

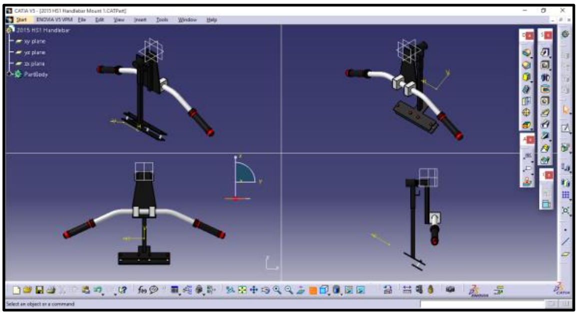


Figure 4: Design of the controller system

Procurement and fabrication process

Based on the research collaboration with IASystems, procurement and fabrication of the controller system named as HS1 Fullthrottle Motorcycle Controller was made due to the counter-steering effect embedded into the system. On 28th September 2015, the controller was successfully fabricated and delivered.

Improvement of the motion system

This research methodology focused on improving the motion system of Postura Motergo™. Several methods were conducted as follow:

Literature assessment

Literature assessment was performed in acquiring the information regarding the DoF, obtained from the UiTM Online Library database.

Concept redesign

Initially the pivot point was positioned incorrectly. As in real motorcycle riding, the pivot point was located at the contact point between the tires and the ground. The incorrect pivot point gave the wrong feeling in movement. Hence, in order to relocate the pivot point of the test rig, some modifications were done. Firstly, the design of the new pivot point was modeled using CATIA V5R20. Figure 5 shows the new design of the pivot point and base for the test rig.

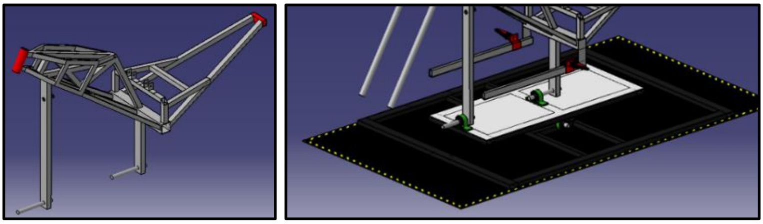


Figure 5: 3D design of the new pivot point and base for Postura Motergo™

Fabrication process

The fabrication process was done at the workshop of Faculty of Mechanical Engineering. As the improvement towards the DoF was done, the installation of motion system into Postura Motergo™ would be done. For the motion system, a special industrial collaboration was made between METAL and Timur Automation Engineering Sdn. Bhd. Since the Postura Motergo™ had undergone modifications on the DoF, where roll axis and pitch axis were enabled; hence, 2 DC motors were planned for the motion system. However, the quotation for 2 DC Motors was RM 28,000, which exceeded the budget limit. Thus, the author decided to install only single DC Motor, which controlled the roll axis DoF. The quotation for single DC motor was RM 19,000.

Improvement of the visual element

This research methodology focused on improving the visualization for the Postura Motergo™ during the simulation process. Several methods were conducted as follow:

Literature assessment

Literature assessment was performed in acquiring the information regarding the screen for simulator, obtained from the UiTM Online Library database.

Detail design

Based on literatures, most simulators used a 180° curve screen for their visual projection using 3 units of projectors. However, those available in the market are quite expensive. Therefore, an own 180° curve screen was designed and fabricated in-house. Figure 6 shows the 3D design of the curve projection screen using CATIA V5R20.

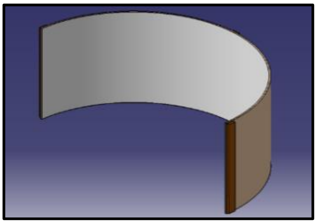


Figure 6: 3D design of the curve projection screen

Procurement and fabrication process

The main materials for the curve projection screen were 4’ x 8’ flexible plywood and 4’ x 8’ plain white Formicas layer. The fabrication process was done at the workshop of Faculty of Mechanical Engineering, UiTM. Since the single flat projection screen was enhanced to a curve screen, it was required to use multiple projectors in order to generate the side view of the visual. A survey on equipment was done to search the appropriate equipment to project multiple view of the visual element. 3 projectors (model: EPSON EB-X18) were procured along with a special software named Immersive Display PRO, an image mapping software that merged multiple display to fit the projection screen.

Result

As a result from this research, a newly enhanced Postura Motergo^{TM} simulator that linked between the different types of riding posture based on the RIPOC system was established.

Adjustable motorcycle tank cover

The Rib and Spine Chassis (RISC^{TM}) concept successfully provided the capability to replicate various motorcycle cockpit designs with respect to the Postura Motergo^{TM} motorcycle simulator. As noted, this adjustable tank cover concept emulated the motion of the human ribs during breathing i.e. to expand and collapse. Figure 7 shows the collapsed and expanded view of the adjustable tank cover utilizing the Rib and Spine Chassis (RISC^{TM}) concept. Figure 8 shows the final product of RISC^{TM} tank integrated into Postura Motergo^{TM}.

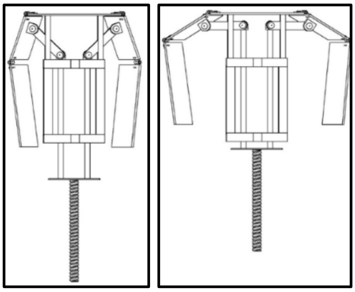


Figure 7: Collapsed and expanded view of RISC™ tank

Figure 8: RISC™ tank integrated to Postura Motergo™

In short, the Rib and Spine Chassis (RISC™) concept is a revolutionary new concept for tank cover design in motorcycle simulator setup. Via this concept, the existence and non-existence of a gap between the seat and the handlebar were simulated without making any changes on the current chassis design. Thus, it provided the test subject an accurate depiction of riding various motorcycle models. This new concept ensured the simulation of an immersive riding experience by the test subject in utilizing the Postura Motergo™ motorcycle simulator.

New simulation system

Procurement of the HS1 Full throttle Motorcycle Controller, a custom-made controller built by IASystems United Kingdom was done via an official distributor in Malaysia, Aman Semesta Enterprise. The HS1 controller was connected to a PC via a USB cable, and linked with motorcycle games such as Ride 2015, GP Bikes and Grand Theft Auto 5. Figure 9 shows the HS1 controller mounted to the Postura Motergo™.

Figure 9: Hs1 Full throttle Motorcycle Controller mounted

The HS1 controller was built based on a concept of the MOMO wheel car steering to provide counter-steering feelings. Six (6) P260 Vishay Potentiometers were used to control six inputs which were steering input, throttle input, front brake input, rear brake input, clutch input and gear input. These potentiometers were integrated with a custom built 3D printed Mechanical to Electronic (MTE) box converter. The function of the MTE box was to transfer the input given by the users, to the potentiometer, via different gear ratio for each input. The potentiometers were then connected to a BU0836X control board, manufactured by Leobodnar Company, United Kingdom. The board consisted of 32 input channels for the controller, and connected to the computer via a USB cable. The computer detected the board as a game controller that enabled the user to calibrate the input direct from the computer and ready to be used as a controller for many motorcycle games.

Improved motion system

Better and enhanced DoFs were integrated into a dynamic motorcycle simulator in order to truly replicate the dynamic movements of real world motorcycling. For this study, the selected DoFs integrated into the Postura Motergo^{TM} were roll, pitch and steering angle. A newly fabricated simulator platform, and a DC motor as shown in Figure 10, was integrated enabling the movement of roll and pitch angles. The DC Motor was controlled and programmed by using Programming Logic Controller (PLC). However, due to budget constraint, the DC motor for controlling the pitch angle was not available at the moment.

Figure 10: New platform for Postura Motergo^{TM}

Improved visual element

For this research, a 180° curve projection screen was successfully fabricated with 3 projectors and a special software named Immersive Calibration PRO that was procured and used to improve the visual element. Immersive Calibration PRO is image mapping software that offers the most advanced tools and algorithms for automatic alignment and soft-edge blending of multi-channel projection systems. It does support the most popular flight and racing simulators, yet can also be integrated into any projection system. Since the screen used for Postura Motergo™ was curved screen, the Immersive Calibration PRO was the most suitable software to combine multiple image projected by multiple projector into one single view, and mapping and wrapping it to fit the curved screen. Figure 11 shows the fabricated curve projection screen.

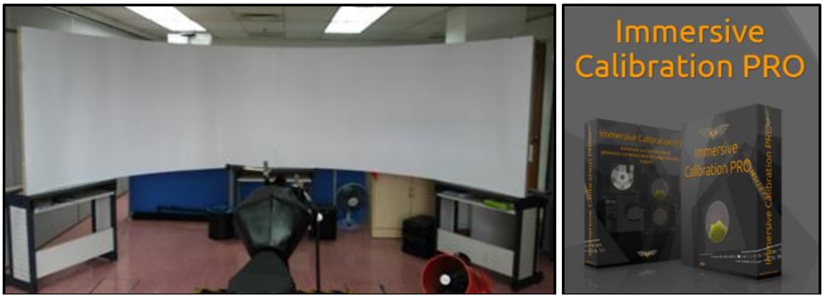
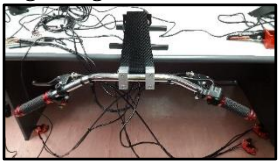


Figure 11: Curve projection screen and Immersive Calibration PRO

Comparison before and after enhancement

Table 2 shows the comparison between before enhancement and after enhancement of the Postura Motergo™.

Table 2: Comparison before and after enhancement

Before Enhancement	After Enhancement
Tank Design	
Rigid tank design 	Adjustable tank design 
Simulation System	
No simulation system and a real video was generated used  	New simulation system with a 3D gaming bike software  
Degree of Freedom and Pivoting	
Wrong pivot point and 1 DoF  	Correct pivot point and 2 DoF  
Visual Element	
Single projection screen and single projector  	Curve 180’ projection screen and 3 projectors  

This motorcycle simulator enables researchers, R&D personnel or manufacturers to do indoor lab studies that require the use of motorcycle with different riding postures. The main usage is to perform research, testing or experiments onto motorcyclist especially concerning riding postures and ergonomics. It also provides a safer and controlled environment to researchers and motorcyclist as for they do not need to ride on real roads with real hazards. Figure 12 shows the simulation and final testing of the simulator.

Figure 12: Simulation process using Postura Motergo™

Conclusion

Conclusively, the initial Postura Motergo™ test rig managed to be enhanced into a full-scale motorcycle simulator that was truly dedicated for motorcycle ergonomics research purposes. However, there were still vast rooms for improvement in concerning this particular motorcycle simulator. By enhancing the Postura Motergo™, greater near-to-real motorcycling conditions could be simulated in a controlled laboratory setting. This adds up better fidelity of a motorcyclist riding the simulator which is comparable with real riding experience. The newly enhanced motorcycle simulator could help researchers to conduct experiments regarding motorcycle area in a controlled laboratory, avoiding the real road hazards on the real road.

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References

[1] L. I. C. Sàrl and Villars-sous-Yens, "Global Status Report on Road Safety," Switzerland 2013.

[2] M. M. A. Manan and A. Várhelyi, "Motorcycle fatalities in Malaysia," *IATSS Research*, vol. 36, 10 February 2012.

[3] F. A. O. Fernandes and R. J. Alves de Sousa, "Motorcycle helmets - A state of the art review," *Accident Analysis & Prevention*, vol. 56, pp. 1-21, 7 March 2013.

[4] L. Nehaoua, H. Arioui, and S. Mammar, "Review on single track vehicle and motorcycle simulators," presented at the 19th Mediterranean Conference on Control and Automation, Aquis Corfu Holiday Palace, Corfu, Greece, 2011.

[5] S. L. J. a. A. H. Jamson, "The validity of a low-cost simulator for the assessment of the effects of in-vehicle information systems," 2010.

[6] J. Buchanan. (2008, 28 November). *Honda SMARTrainer*. Available: http://www.motorcycle.com/how-to/honda-smartrainer-86756.html

[7] T. Kishida and I. Kageyama, "A Study on Riding Simulator for Motorcycle," in *DSC 2007 North America*, Iowa City, 2007.

[8] V. Cossalter, R. Lot, M. Massaro, and R. Sartori, "Development and Testing of Assistant Rider Systems with the UNIPD Motorcycle Riding Simulator."

[9] W. M. S. W. Fauzi, "Thesis: Integrating Human-Machine-Environment Interface (HMEI) Elements into an Ergonomic

Motorcycle Test Rig to Replicate Near-To-Real Riding Scenario," Bachelor of Engineering (Hons) (Mechanical), Mechanical Engineering, Universiti Teknologi Mara (UiTM), 2014.

[10] M. H. Kamal, "Thesis: An Ergonomic Motorcycle Test Rig based on Motorcyclist Riding Posture Classification (RIPOC) System," Bachelor of Engineering (Hons) (Mechanical), Mechanical Engineering, Universiti Teknologi Mara (UiTM), 2014.

[11] H. Rashid, M. I. N. Ma'arof, A. R. Omar, S. C. Abdullah, and R. Jaafar, "Evolution of a New Adjustable Motorcycle Test Rig for Measuring Motorcyclist Fatigue during Prolonged Riding," *Advances in Human Aspects of Transportation: Part II,* vol. 8, p. 3, 2014.

[12] M. I. N. Ma'arof and I. N. Ahmad, "Proposed standard method for motorcycle nomenclature system," in *Network of Ergonomics Societies Conference (SEANES), 2012 Southeast Asian*, 2012, pp. 1-6.

[13] A.W. Stedmon, M.S. Young, and B. Hasseldine, "Keeping It Real or Faking It: The Trials and Tribulations of Real Road Studies and Simulator in Transport Research," in *Contemporary Ergonomics 2009*, Royal College of Physicians, London, UK, 2009.