Development and evaluation of advanced seat and helmet for safer motorcycle users

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Abstract. The purpose of this research is to develop the prototypes of advanced motorcycle seat and protective equipment of compulsory helmet wearing through experimental evaluation. In this prototype, suitable sensors for detecting pillion, strapping chin and wearing helmet of motorcycle users are integrated with the existing motorcycle and helmet. These sensors were developed and investigated through the experimental testing procedures. For the evaluation of pillion seat sensor, the hip of dummy hybrid III 50th percentile male was used with the discrete values of mass on the sliding machine at each position of pillion seat. To conduct the experimental evaluation of strapping chin and wearing helmet conditions, the EN960 european standard headform were used at each position. Consequently, the functional detective range of the developed prototypes are identified and specified at pillion seat, chin strap and helmet wearing conditions. Additionally, these results are planned to develop an advanced system for supporting motorcycle users and increasing awareness of injury reduction.

1. Introduction
Motorcycle is very popular mode of transport in Southeast Asia [1, 2] because the motorcycle has agility, convenience and effectiveness in city traffic conditions such as the inaccessible public transportation. However, motorcycle is the least safe form when compared with other transportations because of its lack of protection around the rider with greater chances of severe injuries in case of crash. In fact, 34% of total road traffic deaths was caused by motorcycle accidents in Southeast Asian region which was one of the highest when compared to any other region of the world. Thailand uses a great number of motorcycles and confronts with high rate of motorcycle user fatalities and injuries. It is well accepted that the road traffic accident occurs due to at least one of the three elements: human error, road and environment defects or vehicle defects [3].

In the past, the technology and innovation were continuously developed to have sustainable growth in Japan motorcycle industries [4]. However, the safety innovation is one of the key factors that can protect from the road accident such as motorcycle AFS (Adaptive Front-lighting System) [5], smart helmet [6-11]. For the smart helmet, various sensors are used to detect the wearing condition of rider. Such system can enforce only the rider to wear the helmet. Therefore, the system should be compulsory for both rider and pillion to wear the helmet for protection of their severe injuries or death. In another user enforcement in passenger car, warning technologies were developed for enforcement of the driver and passenger such as seat belt reminder (SBR).

Even though the safety technologies and innovation were developed to protect road users from accident, such evaluation should be conducted for their limitation and characteristics to inform the
related users and organization. For example, the control variation of antilock brake system (ABS) for motorcycles were evaluated in term of benefit and effectiveness from 350 real-world accidents using various parameters such as collision speed, initial speed distance of falling to collision point and braking distance etc. [12]. In addition, 13 motorcycle models with and without ABS technology during 2003–2008 were compared with fatal crashes per 10,000 registered vehicle years in order to understand the effectiveness of such technology and innovation [13].

Therefore, the purpose of this research is to develop and evaluate the prototypes of advance motorcycle seat and protective equipment for enforcing helmet wearing through the experiment.

2. Development of advanced seat and helmet
In this research, the prototypes of advanced motorcycle seat and helmet was developed. It consists of two main parts, i.e. pillion and helmet parts. The ergonomics of human and operating conditions of motorcycle users were considered in this development. The suitable sensors were attached with helmet and seat in order to detect the pillion, strapping chin and wearing a helmet. Moreover, the selected sensors should be integrated and combined in the existing motorcycle and helmet.

2.1. Detection of the pillion
These consists of flex sensor and press pad mechanism. The attachment of flex sensor 2.2” inches length with resistance 70 Ohm as shown in figure 1(a) is used to detect the pillion presence by the flex sensor bending due to mass gravity. Flex sensor is attached by superglue and double-sided of tape. Press pad mechanism is attached above the flex sensor as shown in figure 1(b, c) and used to distribute the mass of pillion at pillion seat. Press pad mechanism is designed by considering the width of human sit bones to ensure that flex sensor is bent while the pillion sitting on the seat [14].

![Figure 1. Attachment of flex sensor and press pad mechanism.](image)

2.2. Detection of the strapping chin and wearing helmet
These consists of flex sensor and infrared sensor. The same flex sensor 2.2 inches length in the detection of the pillion are used and attached by the super glue and double-sided tape at the left side of chin strap. Flex sensor is used to detect the strapping chin curve of motorcycle users. To detect the wearing helmet condition by motorcycle users, the infrared sensor was attached inside the helmet at the position of ear by superglue and double-side tape. The detection of infrared sensor is 2 to 30 cm of distance and 35 degree of detection angle. The attachment of flex and infrared sensor are shown in figure 2.

![Figure 2. Attachment of flex and infrared sensor.](image)
3. Experimental evaluation

The experimental evaluation were performed in the laboratory by using the hip of dummy hybrid III 50\textsuperscript{th} percentile male and EN960 standard headform. The complete hip of dummy hybrid III and EN960 european standard headform were accomplished by CNC milling machine, which are made from high-density foam. The dummy hybrid III and EN960 european standard headform are the most widely used crash test dummy in the world for the evaluation of automotive safety restraint systems in the frontal crash test. They are also used to evaluate the protective helmet under repeatability of testing conditions.

3.1. Pillion seat

The experiment setup as shown in figure 3, are composed of hip of dummy hybrid III, mass, sliding machine and tape ruler. The hip of dummy hybrid III was used for evaluating the pillion seat sensor. The sliding machine is pressed on a hip of dummy hybrid III via H-point. The discrete value of mass is usually applied on the pressed sliding machine to represent the mass of motorcycle users. The tape ruler is attached on the floor to indicate the positions of pillion seat.

![Figure 3. Experiment setup of pillion seat sensor.](image)

In the experimental procedure, the veracity of the experimental results relies on a precision of mass and position of pillion seat. Therefore, the mass and position of pillion seat should are measured to achieve their precision values under calibration. The positions of pillion seat were divided as shown in figure 4, by measuring in the X direction from the end of pillion seat as the reference point (R). The input parameters for the experimental cases are given in table 1.

![Figure 4. The positions of seat evaluation.](image)
Table 1. Experimental cases of pillion seat sensor with input parameters.

| Test cases | Position (cm) | Mass (kg) |
|------------|---------------|-----------|
| 1          | $X_1 = 10$    | 30.8      |
| 2          |               | 40.8      |
| 3          |               | 50.8      |
| 4          |               | 60.8      |
| 5          |               | 70.8      |
| 6          |               | 80.8      |
| 7          | $X_2 = 20$    | 30.8      |
| 8          |               | 40.8      |
| 9          |               | 50.8      |
| 10         |               | 60.8      |
| 11         |               | 70.8      |
| 12         |               | 80.8      |
| 13         | $X_3 = 30$    | 30.8      |
| 14         |               | 40.8      |
| 15         |               | 50.8      |
| 16         |               | 60.8      |
| 17         |               | 70.8      |
| 18         |               | 80.8      |

3.2. Strapping chin and wearing helmet

The EN960 European standard headform was used for evaluating the strapping chin and wearing helmet sensors. The plane of EN960 headform as shown in Figure 5, are composed of BB’ plane, AA’ plane, reference plane and basic plane. The BB’ plane (2.54 cm from reference plane) is the additional plane in order to analyze the problem of interest. These planes are deemed to correspond to the level of the lower edge of the headband of helmet.

![Figure 5](image.png)

In the experimental procedure, a helmet is worn with headform as shown in Figure 6, by placing the helmet leading edge as the same level with BB’ plane and AA’ plane. Meanwhile, there are three strapping chin characteristics i.e. fit, slack and release conditions. The round gauge [15] with cylinder diameter of 2.54 cm was used to represent the gap measurement between the chin of headform and chin strap with slack condition. In the experimental preparation, the size of headform should have the same fit condition with the size of helmet. To conduct the experimental work, the input parameters for the experimental cases are given in Table 2.
5. **Data recorder**

The data recorder was used to record the output of resistance change of the sensors. The sampling rate at 0.5 Hz is used for monitoring and recording the data.

5. **Experimental results**

To identify and specify the pillion seat, the chin strap and wearing helmet conditions, the resistance change of the sensors was principally considered.

5.1 **Pillion seat**

The resistance change of pillion seat sensor at $X_1 = 10, X_2 = 20$ and $X_3 = 30$ cm positions are shown in figure 7. Before applying the mass on the seat, the resistance of the sensor starts from 35 Ohm. Position $X_1$, in the graph can be seem that the resistance was not changed with 30.8 kg and unequal changed with 40.8, 50.8, 60.8, 70.8 and 80.8 kg. In the position $X_2$ the result indicated that the resistance was greatly changed equally with 30.8 to 80.8 kg. However, the resistance was changed from 30.8 to 80.8 kg in the position $X_3$, which was lower than that in the position $X_2$.

5.2 **Strapping chin and wearing helmet**

The resistance of strapping chin and wearing helmet sensor are shown in figure 8. Before strapping chin and wearing a helmet, the resistance of the sensors start from 64 Ohm and 211 Ohm respectively. For the strapping chin and wearing a helmet at AA’ plane and BB’ plane conditions, it seems that the resistance values of fit and slack conditions were changed from the original to low value. Whereas the resistance of releasing chin strap condition was higher than that of fit and slack conditions. The different resistance value is the indicator of strapping or unstrapping chin conditions. In term of wearing a helmet, the resistance was changed from the original to low values.
Figure 7. The resistance change of pillion seat sensor.

Figure 8. The resistance change of strapping chin and wearing helmet sensor.
6. Discussion
The evaluation of advanced seat and helmet in this research was performed by the static experiment. Actually, the daily motion of sitting position in motorcycle is variable. The motorcycle users might adjust the position to sit on the seat and change the position of wearing helmet. However, the system could be conducted in the dynamic experiment in the future.

7. Conclusion
In this research paper, an experiment is performed to evaluate the functional detection range of pillion seat, chin strap and wearing helmet sensor by using the hip of dummy hybrid III 50th percentile and EN960 headform standard.

The parameters to evaluate the pillion seat are sitting position and mass. From the results, the resistance of pillion seat sensor at the end range of seat are change unequally. It is the chance that the pillion seat sensor cannot indicate the pillion is presence.

For strapping the chin, the evaluation parameter is the style wearing condition. From the result, the resistance is not constant due to the adjustment of helmet with the headform. After adjustment, it can indicate the use of chin strap by the fit and slack conditions. Also the sensor can indicate the unstrapping chin condition.

The wearing position does not affect the wearing helmet condition. However, it can indicate a wearing of helmet and unhelmet with all rotated conditions.

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