REPORT OF RESEARCH RESULTS

(a) Title: Investigation on Helmet Structural Performance under Severity of Motorcycle Accidents in Thailand

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(c) Summary: Include the outline and conclusions of the research

Motorcycle accidents mainly cause a high number of injuries and fatalities compared with other road traffic accidents. A motorcycle helmet is essential in preventing motorcyclists' head injuries from impacting other objects. However, the motorcycle helmet sufficiently requires high structural performance in terms of strength and energy absorption to prevent the severity of motorcycle accidents. This research aims to investigate structural performance for head injury prevention of a motorcycle helmet in Thailand by accessing the acceleration, energy absorption, and Head Injury Criteria using the finite element analysis via LS-DYNA. The model validation was firstly performed based on impact analysis according to TIS 396-2557 standard. The results showed that the finite element model perfectly represented the test, in which maximum acceleration and Head Injury Criteria were different by only 4.84% and 5.52%, respectively. It also found that the comfort padding significantly reduced the impact force and injury from side impact only, and it was excluded from the finite element model because this project was mainly concerned with the front and top impacts of the helmet structure. Furthermore, the protective efficacy of helmet structure was also studied based on three cases of the accident: skidding, collision with the footpath, and skidding to collide with the footpath under various velocities and impact angles. Abbreviated Injury Scale was adopted to assess the probability of injuries. The skidding to collide with the footpath was the worst case because the results clearly showed the highest impact force at helmet structure, and it allowed a 100% probability of head injury according to level 2 of the Abbreviated Injury Scale. Finally, the energy absorption of foam component at least 75% was further recommended to design the helmet structure for reducing the head injury from impact accidents.

(d) Aim of Research

The current research aims to employ a nonlinear explicit dynamic on finite element analysis via LS-DYNA program to investigate the strength of motorcycle helmet structure in Thailand according to impact, severity, and different scenarios of traffic accidents that frequently occur in Thailand.

Several cases for motorcycle accidents based on real conditions of traffic accidents are considered and taken into analysis such as sliding on a rigid wall, applying tangential velocity for impact simulation, and collision with a sharp stopper on the footpath. All cases considered in this research uses finite element modelling, an advanced technique for simulation to confirm that the strength requirements are higher than official regulations. The head injury on a motorcyclist is also examined using Head Injury Criteria (HIC) and Abbreviated Injury Scale (AIS) to evidently assess the motorcycle helmet performance such as injury prevention and lightweight design.

(e) Method of Research & Progression

The research methodology was firstly the literature review on types of helmet structure, motorcyclist accidents, and regulation of helmet structural investigation. Then, the components of the helmet structure were performed by the tensile test to acquire mechanical properties for simulation based on the finite element technique. The helmet structure was also tested according to the TIS 369-2557 standard to obtain the results and compare them with the finite element model for validation. The results found that the FE model had enough accuracy in representing the actual behavior. A helmet model was then modified to simulate various conditions of impact accidents for evaluating the HIC and AIS. The crashworthiness performance of the helmet structure was finally investigated, and summarized the research findings.

(f) Results of Research

An impact test of a motorcycle helmet structure with a flat anvil according to the TIS 369-2557 standard was firstly performed for the validation procedure to compare with the simulation results. The open-face helmet model was created using SolidWorks, and was divided into three parts: shell, foam, and comfort padding (Figure 1). All components were assigned as a deformable structure with the tetrahedral type of solid element, with only three degrees of freedom per node (only translational in three directions). The meshing procedure was done based on Hypermesh and then exported to simulate the impact test using nonlinear explicit dynamics via LS-DYNA. The results from the test and FE models were recorded and compared based on the TIS 396-2557 criteria (Figure 2). The results were significantly different when the helmet caused the first impact with the anvil at 1 ms because the chin strap was neglected in the finite element model. Furthermore, the acceleration during the impact simulations clearly showed the same tendency as the test, which can confirm that the simulations had sufficiently accurate results to represent the test.

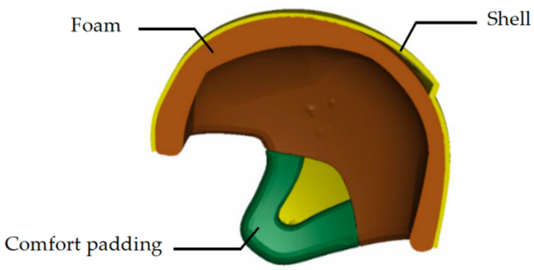

Figure 1 Helmet structural model and its components.

The efficacy of the finite element model for helmet structure was next investigated for damage and head injury under three cases: sliding, collision with a footpath, and skidding to collide with a footpath. Cases of sliding and collision with a footpath directly represent an accident when colliding with an object or vehicle. The motorcyclist then falls to the road until the helmet and head impact the road surface or edge of the footpath. Skidding to collide with a footpath combines the effect of sliding until impact with the sharp edge of the footpath. Since a motorcycle accident causes falling behavior until impacting with an object that is similar to a projectile profile, both the head impact and velocity impact angles were employed to simplify the problem. The head impact angle (Figure 3a) defines the angle on a horizontal line of the headform to describe the impact direction from 0 to 90 degrees. The impact velocity angle (Figure 3b) assigns the direction of the model to impact with the object along with normal and tangential velocities. Initial velocities of 27, 30, and 47 kph were applied to the model for all investigations, because 27 kph is the velocity specified according to TIS 369-2557 standard, while 30 and 47 kph are the average velocity and mean speed for lost control of motorcycles, respectively.

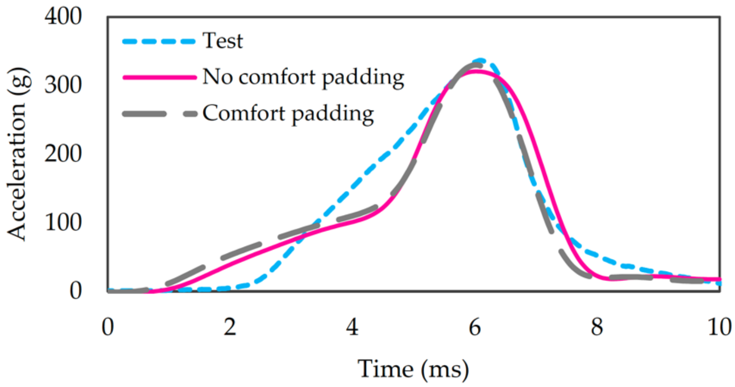

Figure 2 Acceleration during impact test according to TIS 369-2557.

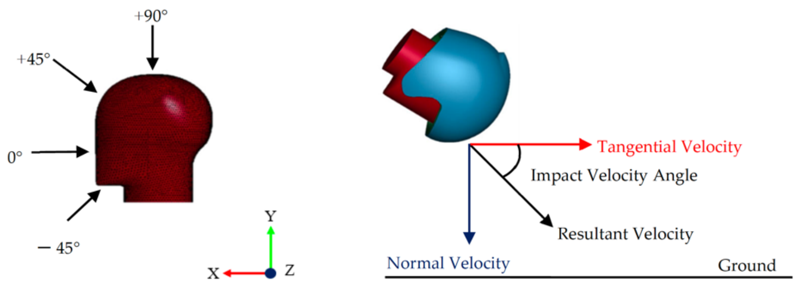

Figure 3 Angles for assigning to the model. (a) Head impact; (b) impact velocity.

All studies examined the head protection performance of motorcycle helmet structures under three cases of accidents with different initial velocities and impact angles. Firstly, the lost control speed (47 kph) caused the most severe head injury due to the high peak acceleration, and the probability of head injury for all cases was 100% according to AIS 2+ (Figure 4). The severity of injury was different for all three cases depending on the characteristics and behaviors in each case. An initial velocity of 27 kph at 30 and 45-degree impact angles seemed to be the most effective condition, because the probability of head injury was lower than 60% for all cases, except for 30 degrees in case II. The low impact angles caused an impact area at the top surface of the helmet only and increased the HIC because other surfaces had not absorbed the impact energy. The other impact angles varied based on each impact condition. Impact angles of 60 and 75 degrees also caused high peak acceleration for all cases, because the helmet had a collision with a footpath only, without sliding effects, and was not included for further comparison. However, the defined velocity for those helmet regulations (7.5 m/s or 27 kph) showed safe situations for head injury. In contrast, higher velocities (30 and 47 kph) were associated with more severe injuries, even though those speeds are typically used for driving nationwide.

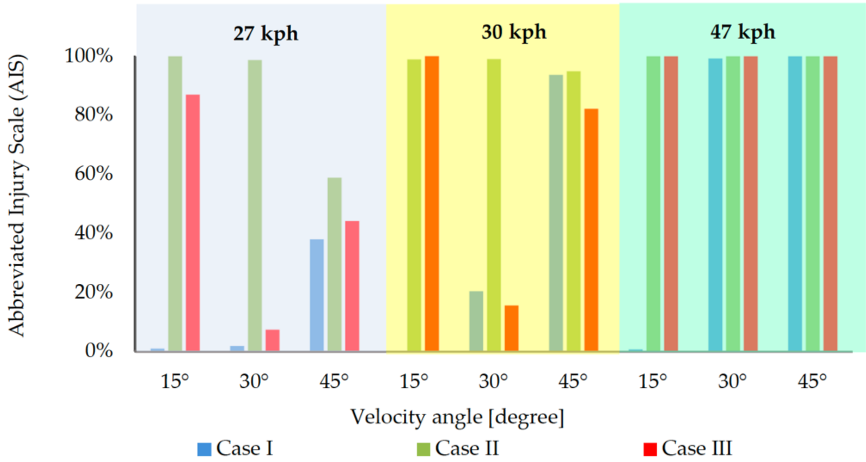

Figure 4 Probability of head injury according to AIS 2+.

The energy absorption of foam components is also a pivotal point to evaluate in terms of the performance of helmet protectability during accidents. The results were compiled with the probability according to AIS 2+. The highest energy absorption was observed when the impact angles were 30 and 45 degrees at an initial velocity of 27 kph. In all cases present, the foam absorbed over 75% of the energy, effectively reducing the impact of accidents' head injury probability. Thus, the helmet structure should be designed by mainly considering the energy absorption of the foam component, which can enable the most efficient performance for head protectability and reduce the severity of head injury in the event of impact accidents.

(g) Future Areas to Take Note of, and Going Forward

This work proposes the critical points to investigate in terms of helmet structural performance for head protectability using a finite element model via LS-DYNA. The simulation results show that the helmet model represents the characteristics of the impact test well according to the TIS 369-2557 standard, and comfort padding had no significance in reducing head injury by evaluating energy absorption. The helmet structure was then analyzed under different initial velocities and impact conditions. The lost control speed (47 kph) presented the overall results of head injury for all cases, because the highest peak acceleration and probability of head injury was 100% according to AIS 2+. Impact angles also affected injury severity due to the characteristics of sliding and impacting in each case. The velocity impact angles of 30 and 45 degrees seemed safe compared with the others, since the high energy presences and head severities were less than 100% based on AIS 2+ criteria. Furthermore, foam was the most effective component in the helmet structure to reduce head injury by absorbing the impact energy. Head injury severity was less than 100% when the energy absorption of the foam was over 75% of the total energy. Thus, designing the foam component to absorb at least this much energy is recommended for an efficient motorcycle helmet that can reduce the risk of head injury and severity in impact accidents. The chin strap should be included in the model for investigating and examining the characteristics and behaviors of head injury and helmet structural performance in future work.

(h) Means of Official Announcement of Research Results

This research has been *published into international academic journal with acknowledge the financial supports from Mitsui Sumitomo Insurance Welfare Foundation Research Grant 2021*. The publication is listed as follows:

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