Armadillo modelled foldable motorcycle helmet: A preliminary design concept for rider in Indonesia

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Abstract. Safety is an important thing while riding a bicycle or motorcycle. Using a helmet is one of the solutions to increase safety of the rider, but sometimes people are too lazy to bring the helmet because of its big size. In the present work, a foldable helmet adopting the Armadillo concept was proposed to make people feel more comfortable in carrying the helmet. The design also follows the safety standard required by the SNI (Indonesia National Standard). A locking system for the folding mechanism is discussed, and a honeycomb foam for impact absorber is considered in the design. As a result, the proposed foldable helmet can have a reduction volume of 23.75% compared with the non-foldable one. This work is expected to contribute to the innovative engineering design field.

1. Introduction
Motorcycle is one of the most popular transportation modes in Indonesia which has a very fast growth year by year. According to the Indonesian Central Statistical Agency, motorcycle users has reached around 113 million people in 2017 [1]. Moreover, nowadays, online transportation is participating in increasing the number of motorcycle users which has more than 22 million active users [2].

Based on the previous studies, it is revealed that, most of the traffic fatalities in Indonesia were caused by motorcycle accident [3-5]. The number of motorcycle injuries makes the Indonesian government think hard to provide safety when driving, the main safety tool for motorcycle and bicycle is a helmet [3]. Therefore, the government requires the motorcycle riders to always wear helmet when riding to improve safety. However, not all of the people strictly follow the rule while riding motorcycle. This is believed due to several reasons which one of them is because of the uncomfortable feeling of bringing a helmet with big size. The present work aims to propose a preliminary design concept of helmet for motorcycle rider in Indonesia by following the Indonesian National Standard (SNI) guidance. The focus is to maintain the strength of helmet while it can be foldable.

2. Foldable helmet review
Several design concepts of foldable helmet can be found either for motorcycle or bicycle rider. Here are the review of each design.

2.1. Morpher folding helmet
Morpher helmet concept is usually used for a bicycle. Its shape is shaped as some pieces of cut parts forming a helmet connected with an elastic membrane and having foam attached to each part. It works
by slashing and folding the helmet into part at the side. The detailed design is published in a US patent of number USD873495S1 [6].

2.2. Alpha/armadillo helmet
The Alpha helmet is a foldable helmet concept that is usually used for winter sports like skiing and snowboarding, and bicycle sports. The system is inspired by the ability of a pangolin to roll itself into a ball. When it is not in use, it is rolled into the back of the head, forming a curved shape that will circle around the neck and sit around the shoulder. Then, the internal structure is inspired by the honeycomb structure that is known to have the ability to absorb hard impacts [7].

2.3. Closca helmet
Closca helmet is a foldable helmet concept for bicycle rider. It is shaped as a circular cut in a horizontal direction that means the diameter of the cut part is decreasing as it reaches the top. It works similarly like a paper lantern. It is pushed down to make it folded and its shape becomes a cylinder and then it is pushed up to unfold the helmet. The structure comes with attached foam on each of the cut parts.

Those aforementioned helmet concepts are the available foldable helmet which has advantages and disadvantages. The Morpher folding helmet has a difficult part in the locking system which also will connect each membrane and needs more time in order to fold and unfold. The Alpha helmet has a honeycomb impact absorber as the internal structure as the positive point of this model. The Closca helmet has a circular cut in the horizontal direction which is the fold and the unfolding process will pull up or down which needs a good idea for the locking system to make the helmet steady in the unfolding position even the helmet not used by humans.

In the present work, a foldable helmet is designed by adopting and improving the alpha helmet or Armadillo helmet. The proposed concept applies a simple locking system because the Armadillo model requires a locking system which can lock all the curve shells either than the other design which needs more than one locking system. Meanwhile, the internal part uses honeycomb foam materials as an impact absorber which can make the helmet safer rather than just the shell then directly sponges.

3. Design methodology
According to the SNI guidance, several impact zones on the helmet body are defined as shown in Figure 1. The most dangerous impact zone when an accident occurs is in the jaw area. In order to reduce the risk of accidents specifically in the jaw area, a full-face foldable helmet is designed in the present work.

As mentioned before, Indonesia has the SNI guidance in order to create a new product. For a helmet product the SNI has defined three standard sizes which are small, medium, and large. In the present work, the large size is chosen for designing the foldable helmet to obtain a general size which commonly used by adults. The large size has a diameter of 580-620 mm based on the SNI.

As for the impact resistance, a helmet product should be able to hold a 300G (3000N) load according to SNI. The helmet should also weight less than 2 kg. Moreover, the helmet should also have a comfortable material that does not cause skin irritation and should be non-metal material. In general, the material for a helmet defined in the SNI standard should hold temperature in the range of 0 - 55°C [8,9].

4. Results and discussion
As it is mentioned above the model that is most likely possible to be added with extension is the Alpha helmet. The armadillo system is adopted to be a motorcycle helmet with the honeycomb internal structure and jaw extension [10]. The jaw extension is used to anticipate the injuries during the accident, because from Figure 1 the most impact zone is occurring in the jaw. The rough sketch/early idea of the adaptation design is shown in Figure 2.
The dimension of general part which is the inner circle diameter is 18 cm, outer circle diameter is 20 cm, and foam thickness is 1 cm. This helmet is divided into six components. One of the parts in the jaw and the other one is the lock system; the rest of the part is to generate the open face helmet.

The 2D helmet design that is proposed in the work is shown in Figure 3. The dimension of each part of helmet such as outer and inner diameter of part 0 is 25 and 23 cm diameter and angle of part 1 is 20 cm and 64 degrees, diameter and angle of part 2 is 20 cm and 65 degrees, diameter and angle of part 3 is 20 cm and 52 degrees, diameter and angle of part 4 is 24 cm and 30 degrees, diameter of part 5 is 8 cm.

From the 2D drawing, the 3D visualization is created and shown in Figs. 4 and 5. For the locking system of proposed helmet, the spring puller mechanism is introduced. A circular plate that has a hollow cylinder in the middle is used. In this locking system, the manufacturer put the spring inside the cylinder and there are five small cylinders to lock the helmet (see Figure 5(c)). In part one until part four of the helmet, it also has five holes in each part. The mechanism of the lock system is when the helmet is folded the five-cylinder of the lock system will enter the five-hole of the helmet part. The dimension of the lock system is outer and inner cylinder 4 cm and 3 cm key lock diameter is 8 cm and lock cylinder is 1 cm. In order to make the helmet more reliable and applicable, analyses on the strength of structure, vibration characteristics [11], fatigue life are therefore needed.
Figure 3. 2-dimensional drawing foldable helmet design.

Figure 4. (a) Unfolded helmet from corner perspective, (b) Unfolded helmet from side perspective.

Figure 5. (a) the proposed foldable helmet from corner perspective, (b) the folded helmet from side perspective, (c) the locking system component.

5. Conclusion
A preliminary design concept of foldable helmet based on Armadillo folding mechanism was introduced in this paper. The design has a jaw extension. The dimension of the proposed helmet applies the large size according to the SNI standard. The foldable helmet was developed in SolidWorks with six folding partitions. A locking system component is proposed. As a result of folding mechanism, the proposed
foldable helmet can give a volume reduction of about 24% compared with the non-folded one. As the future work, analyses on the strength of structure, vibration modes, fatigue life will be conducted.

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