Modelling and Analysis of Foldable Motorcycle Helmet for Human Comfort

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Abstract
Riding a motorcycle gives rider the freedom of the open road. However, there are some serious dangers involved in it. Thus, motorcyclists need to take extra precautionary measures to protect their body. The foremost place to start out is by protecting the top. The head and brain are the most susceptible to injury during a motorcycle accident than any other body part. Wearing a helmet increases the chance of survival significantly over non-helmet wearers. From 2008 to 2010, there have been 14,283 motorcyclist fatalities and 6,057 of them involved the rider not wear a helmet. Also, in India, it’s absolutely compulsory for motorcycle riders to wear helmets under the Section 129 of the automobiles Act, 1988. The rule also states that a standard safety helmet should have a thickness of 20-25 mm, with quality foam to absorb the impacts. The most frequent reasons for not using a helmet were weight of the helmet (77%), discomfort due to the heat, pain within the neck and inconvenience to carry it due to its bulky nature. Our project aims at easing the neighbourhood of carrying the helmet by making it collapsible when not in use making it portable and convenient. The new helmet design will have a similar design to a normal motorcycle helmet but will have collapsible/foldable mechanism that reduces the volume of the helmet by 20% and thus making it less bulky. The new mechanism is such that it doesn’t compromise on the protection of the rider. This therefore increases the convenience of usage and also the portability aspect of the helmet. The main goal of the project is to develop a collapsible helmet design that features a considerably reduced space occupied by 20% while retaining all the characteristics of a standard helmet that’s available in the market. This will therefore encourage the riders to use helmets more often and hence decrease the number of deaths caused by road accidents.

Keywords: safety helmet, collapsible helmet, foldable mechanism

1. Introduction
Road accidents are one of the key reasons for death on this planet. Around 31 thousand people fail horrendously and 1.6 million people get hurt every year inside the ECMA Association as a brisk delayed consequence of street mishaps. Motorcyclists are less ensured against accidents than other vehicle customers since head defenders are the fundamental securing gadget while the inhabitants of a four-wheeler are made sure about through seat straps, airbags, and even by the general structure of the vehicle. Bicycle riders are more than various occasions bound to fail horrendously during a car mishap than vehicle inhabitants. In Portugal, 21% of road disasters were savage and 24.9% of street setbacks caused genuine injuries in the year 2011 were suffered by controlled two-wheeler (PTW) clients. Regardless, cruiser accidents speak to 14.6% of supreme road customer fatalities in the European Association, 12.1% in Australia, 9.4% in the USA, and 9.2% of full-scale traffic fatalities in Japan. Motorcyclists are at higher peril of injury in auto crashes and thus, the head is primary among the zones generally
presented to extraordinary and deadly injuries. Head injury is one of the major wounds that outcomes from bike mishaps. Thus, head injury is taken into account a serious explanation for death which accounts for up to 70% of the deaths. In this way protective cap utilization is the most indispensable thing in forestalling it and lessening the risk of serious wounds during crashes.

"Fábio A.O. Fernandes, Ricardo J.Alves de Sousa, Rémy Willinger, Caroline Deck (2013) have done a research on Finite Element Analysis of Helmeted Impacts and Head Injury Evaluation with a Commercial Road Helmet. The results were revealing that a high risk of moderate DAI was predicted and concussion emerged as a real possibility. Thus, these results reveal defects in the current motorcycle standards therein a licensed helmet cannot protect the user from sustaining brain injuries. Considerable work remains needed to enhance helmet standards, including ECE R22.05 and therefore the US DOT FMVSS 218, to make sure that helmets meeting these standards to protect the users from brain injuries like cerebral concussion and moderate DAI.” [1]

"David H Blanco, Alessandro Cernicchi and Ugo Galvanetto (2013) had a research on optimised innovative motorcycle helmet design. A computerized design optimization was performed using the software LMS Virtual. The objective of the study was to describe a design procedure based on engineering expertise, DOE and RSM for obtaining an optimized innovative design of safety helmets equipped with a cone liner. Moreover, accelerations and HIC at low and high temperature indicated a good overall performance.”[2]

V Gandhi VS, Kumaravelan R, Ramesh and Venkatesan (2014) made a report on Safety Assessment of motorcycle helmet using finite elemental analysis. The different tests were simulated to ensure the impact capacity of the helmet. The foam thickness played a very important role in the peak head form acceleration. When the foam thickness was increased, then the helmet passed all the tests and met the safety requirements of the regulation.[3]

"F.A.O. Fernandes, R. J. Alves de Sousa (2013) made a report on Motorcycle helmets- A state of the art review. This report tries to form a summary of the work administered by scientific community of road helmets safety. An state-of-the-art review on road helmets safety is completed with an insight into the brain injury, helmet design and standards in the non-restrictive and never up to date report.”[4]

"Marta Palomar, Estvaliz Lozano-Mngue, Marcos Rodríguez-Milln, Mara Henar Migulez, Eugenio Giner (2018) have done a research on Relevant factors within the design of composite Ballistic helmets. The Behind Helmet injury (BHBT), which is generated by the deformation of the inner face of the helmet and the back-face deformation (BFD), which is used in current standard testing methodologies due to its most measure in ballistic testing. Nevertheless, this paper signifies the mechanical parameter and the head trauma (BHBT) connection by studying various head injury criteria.”[5]

Saurabh Singh and Hrishabh Singh carried out a research using FEA for different material parameters. This paper deals with the critical review of helmets that are available in the market and how they are performing to standards of different testing scenarios. A comparative analysis has also been done taking four different materials and analysing how they perform on a similar loading condition. The main purpose of this work is to give an insight on how the materials perform on given conditions and help choose a better option while testing.[6]

In this research work the modified helmet has been modelled in such a way that it will occupy less space with negligible compromise on safety perspective.
2. Methodology:

2.1 Components of The Helmet

Motorcycle helmets are mostly made from quality materials. Among them, the most durable material that’s being used is carbon fibre. These materials and construction applied to a motorbike helmet must meet the requirements of Department of Transportation (DOT), Snell, and also the ECE. This is to make sure that these helmets can really protect the rider’s head in an accident. The six basic components involve to make a typical motorcycle helmet are very thin and hard outer shell, soft and thick impact-absorbing inner liner, comfort padding, retention system, visor and ventilation system. [7]

The fundamental effect retaining part is the foam liner, which is conventionally formed from polystyrene beads. Polystyrene foam incorporates an irregularity, it’s monetary to shape, and has great one-sway vitality ingestion. There is the solace foam inside the defensive top to stay out drafts and to permit a confined scope of cap sizes to suit an exceptional scope of head sizes. Cap shells are either injection moulded with ABS (Acrylonitrile Butadiene Styrene copolymer) or versatile toughened polycarbonate or formed with polyester thermosetting resin reinforced with optical fibre (GRP). [8] The table underneath summarizes the most distorting parts in a head protector. Understanding the structure of a motorcycle helmet is important for a motorcyclist. This is often necessary because one should understand how it might protect you while driving on the road. Driving skill is also important to keep the rider safe. One should be able to figure out what’s wrong and know which part to get replaced. The helmet parts are available in some motorcycle shops with different brands and styles. [9]

2.2 Design of standard helmet:

The 3D CAD model of the various pieces of the protective cap was treated on SOLIDWORKS, improving the strong model, so as to make the finite element analysis model. slight rearrangements were made to the model, making the model simpler to work however keeping up the general geometry as shown in figure 1.

![Figure 1: 3D medalling of standard helmet](image-url)
2.3 Modelling of foldable helmet:

To enable us to style a foldable helmet, we started with brainstorming stage. We were able to begin with many ideas for designing our foldable helmet. The following 2 shows various possibilities of foldable helmet.

![Figure 2: basic idea of the foldable helmet](image)

The primary and the main design of our helmet is shown within the figure 3. The preliminary design involved in sliding the helmet from the chin part. This design wasn’t considered as most of the impact acts upon the top front part of the helmet and need to model to be stable and be able to withstand the load acting upon the helmet. [10]

The second idea was to keep the top hat of the helmet intact and move the chin part and the rear bottom of the helmet towards the top part of the shell, giving us a minimum volume that will be occupied by the helmet and also making it easier to carry around when not in use as shown in figure 3.

![Figure 3: Iterative design](image)

To understand the various orientation of foldable helmet all the views are shown in figure 4. And in the figure 5 all the sub components are assembled then shown in isometric view.
view in the modelling software. After folding all the components, the foldable helmet model was so simple and occupy very less space as shown in figure 6.

Figure 4: Final model of foldable helmet with different orientation

Figure 5: 3D modelling of foldable helmet

Figure 6: Folded helmet
3. Results:

3.1 Static analysis of standard Helmet:

The maximum permissible limit of 19.5 kN (as per BIS standard) impact load is applied for this analysis. The following are the different conditions considered for this study.

a) Bottom fixed and load on top surface (Case 1)

b) Side fixed and load on opposite area (Case 2)

As per the standard condition, the bottom was fixed and load was applied on the top surface of the helmet. Because in practice, the helmet is fixed with our neck so it is considered as bottom fixed. If motorcyclist falls on the road, load mainly acts on the right, left and the top side of the helmet, so the load acting on the top side for the first case.[11] Figure 5.4 shows the deformation of the headgear. The majority of the deformation happens within part of the froth and the estimation of 1.0078mm as shown in figure 7.

For the second case, a side face was fixed and the load was applied on the contrary side of the substance of the protective cap. In case of a mishap, the head protector side face is the essential area of contact and the other inverse side of the cap is viewed as fixed. Figure 8 shows the deformation of the protective cap. The majority of the deformation happens on the lower side of the side on which the load was applied and the estimation of 8.9207mm.
3.2 Static analysis of foldable helmet

The same cases that were used in analysis of standard helmet was used in foldable helmet’s analysis too. The maximum admissible limit of 19.5 kN (according to BIS standard) sway load is applied for this investigation. The following are the various conditions considered for this investigation. For the foldable helmet three cases were taken for the analysis since it is not a monolithic structure.

a) Bottom fixed and load on top surface (Case 1)

b) Side fixed and load on opposite area (Case 2)

c) Various sides fixed and load on the joints (Case 3)

For the first case, the bottom was fixed and load was applied on the top surface of the foldable helmet. Because in practice, the helmet is fixed with our neck so it is considered as bottom fixed. If motorcyclist falls on the road, load mainly acts on the right, left and the top side of the helmet, so the load here is directly applied on the top side for the first case. Figure 9 shows the deformation of the headgear. The greater part of the deformation happens within part of the foam and the estimation of 4.563mm.
Figure 9: load on top for foldable helmet

For the second case, a side face was fixed and the load was applied on the contrary side of the essence of the foldable head protector. In case of a mishap, the headgear’s side face is the essential area of contact and the other inverse side of the cap is viewed as fixed and the different parameters like strain energy, stress and all-out deformation acquired from the investigation were talked about. Figure 10 shows the deformation for the applied load and the maximum deflection is 26.655mm.

Figure 10: side fixed and load on contrary side for foldable helmet
For the third case, a side with jig joint was to be fixed and the load was to be treated on the other jig joint of the foldable headgear. In case of a mishap, the helmet side face is the essential area of the contact, so the jig joint that we utilized must have the option to withstand the effect and the different parameters. Figure 11 shows the complete deformation of the protective cap. The maximum deflection is around 24.528mm.

![Figure 11: one jig is fixed and load on another jig](image1)

For checking one special condition, the top side was to be fixed and the load was treated on the rear part side of the foldable protective cap. As the rear of our helmet can be folded, it should have the option to withstand the effect and the different parameters. Figure 12 shows the complete deformation of the head protector. The maximum deformation happens for this condition is 0.678mm.

![Figure 12: top fixed and load on rear side for foldable helmet](image2)
All those deformation values are tabulated in table 1 for the comparison between standard and redesigned foldable helmet.

Table 1: comparison between standard and foldable helmet

| Test cases                                      | Standard helmet max. deformation (mm) | Foldable helmet maximum deformation (mm) |
|------------------------------------------------|---------------------------------------|------------------------------------------|
| Bottom fixed & Load on top surface             | 1.0078                                | 4.563                                    |
| Side fixed & load on opposite direction        | 8.9207                                | 26.655                                   |
| One jig joint fixed & load on front side       | -                                     | 24.528                                   |
| Top fixed & load on rear end                   | -                                     | 0.678                                    |

4. Conclusion

In this work, a standard motorcycle helmet and a foldable motorcycle helmet were modelled in 3D modelling software SolidWorks and analysis were performed in ANSYS software. This foldable helmet design has a considerable volume reduction of 51% from its original state, which will make it more portable and convenient. From the results the obvious standard motorcycle helmet is better in all three aspects except deformation which is having more compare to the standard helmet.

5. Future work

For the large deformation of the folded helmet can be modified with appropriate material in such a way that it has higher elasticity value to recover the deformation.

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