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Modification in The Design of Two-Wheelers Helmets for Improved Comfort of Indian Riders

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ABSTRACT

Existing helmets consist of the durable exterior which is of light-weight (polycarbonate, carbon fibre or composite fibre), its shielding is made up of polystyrene layers together with a comfortable padding of urethane. These helmets are used to protect the rider's head during crash but it becomes difficult to wear helmets in summer for longer durations due to a rise in temperature and poor ventilation mostly in Asian countries as it increases the stress level of the riders. Thus there is an urgent need for modifications in the design of the helmet which can provide improved thermal comfort with superior visibility, better aerodynamic shape in addition to reduce discomfort due to accumulation of carbon dioxide and to provide good relief against bad weather. 3D model of the existing and proposed helmet is designed on CAD software (solid works) and a comparison of the existing and proposed model with all features is performed on ANSYS software. In the present work, CFD simulation was also used which shows that in the proposed design there is improved flow of air inside the helmet which will increase the comfort level of the users against heat and humidity.

Keywords: Helmet; Comfort; Design; CFD; User-centered; Simulation.

INTRODUCTION

Due to the rapid increase in population, rise in fuel prices, congestion in traffic and limitation of parking space, two-wheelers are becoming a preferred mode of transportation generally in low and middle-income countries where ownership of four-wheelers and user rates are generally much lower as compared to high-income countries. However, the risk of driving two-wheeler vehicles is high due to the weaknesses of such vehicles, including poor stability, unstable speed and lack of protection facilities, frequent traffic accidents etc. such vehicles cause high casualty rate (Lin, 2020). Severe accidents and fatal injuries to the head and neck are the main causes of death among riders and pillion of two-wheelers. Causalities due to head injuries rise up to 70% of deaths (Palanivendhan et al., 2020). Head and brain injuries during traffic collisions can be avoided by using proper helmets hence the wearing of the helmets are mandatory to protect head injury for both rider and pillion of two-wheelers (Yadukul et al., 2016). The existing helmets consist of the durable exterior which is of light-weight (polycarbonate, carbon fibre or composite fibre), its shielding is made up of polystyrene layers together with a comfortable padding of urethane and softer foam material is provided for appropriate fit and for the reduction in noise level (Nakatsuka and Yamamoto, 2014). The thickness of polystyrene layers is often about one inch and is used to absorb shocks during impact and is also used to redistribute energy form impacts from the head. The role of the shell is to keep the liner in proper position and to offer support points for different accessories of the helmet like strap, wind visor, etc. Helmets offers safety against impact but reduce the flow of air over the head and may affect the dissipation of heat from head to the surroundings and further increase the stress associated with the accumulation of heat (Pang et al., 2013). This thermal stress will lead to the rise in temperature of the head and will consequently responsible for the sense of discomfort and excessive production of sweat to the users (Van Brecht et al., 2008). Various researchers reported that a significant amount of heat can be lost from the head irrespective of the small surface area of the head which is almost 10% of the total surface area of the body (Okamoto-Mizuno et al., 2003; Mündel et al., 2007, Wimer, 2009). The results obtained from study of heat transfer properties of helmets suggested that there is an adverse effect of helmets on the circulation of air over the head and for this reason, many users are not comfortable to wear helmets irrespective of the various measures and fine imposed by the government agencies (Pang et al., 2013). Designers are recommended to consider the comfort parameters in detail while designing a helmet for riders of two-wheelers. Thermal properties, protection against weather, physical appearance, absorptivity/permeability, temperature rise, mass distribution, size and shape, the volume of the helmet, visual aspects, speech and sound factors, maintenance and compatibility of the helmets are the 12 important factors that are to be given due considerations while designing helmets (Hickling, 1986). In recent years considering these comfort factors the two-wheelers helmet industries have proposed and undergone significant changes in the styles and models for use by the riders of the two-wheelers and are more varied than ever before. Helmets cover the entire head, as well as the top of the neck and it provides a protective-section along the cheek-bones to encompass the jaw and the chin. These full-face helmets although covers and protect the entire head against any causalities but it has certain limitations like the increase in interior heat, reduction in peripheral vision and produce a sense of isolation (Fernandes and Sousa, 2013). Among these limitations the most important concern in wearing a helmet is the rise in temperature inside the helmet. Hsu et al., (2000) reported that in hot countries during sunny days with no wind, the temperature often rises to about 500 C which is simply unbearable. There is a need for helmet which meets the requirement of thermal comfort, adjustable interior, better visibility and pleasing aesthetics (Vincent et al, 2018). This paper presents a project on the redesign of the helmet shell for improving its thermal properties and other parameters considering comfort factors for the riders by the provision of two scoop vents on the top, grooves at the side with projection at the top of the visor on the helmet.

MATERIALS AND METHODS

PARTICIPANTS

The survey conducted in this research took place at multiple sites in the two districts – Ghaziabad and Gautam Buddh Nagar of Uttar Pradesh India – spanned over a three month period in 2017. Interview venues included local two-wheeler shops, metro parking and helmet shops. The inclusion criteria were male motor-cyclists, over 18 years of age, who were familiar with the use of two-wheelers helmets. The sample size was 100 participants from both districts and subjects were informed about the protocol and need of the study as they volunteered for the investigation of the helmet.

QUALITATIVE SURVEY

Participants were invited to provide their feedback on the self-administered questionnaire (SAQ) regarding various parameters which include data of demographics (gender, age, ethnicity, stature, and weight), the purpose of riding (entertaining, contesting, commuter), seven qualitative requirements of the helmet (inside temperature, weight, vision, scratch resistance, inside foam, aerodynamic shape and prevention against dust/rain), helmet fit assessments and costs. The average time required to complete the survey is about 15 minutes and were recorded on a ten-point scale. On a scale from 1 to 10 participants were requested to rate their (participant) satisfaction (Chandra and Chandna, 2014) when wearing a two-wheeler helmet assuming 10 is highly satisfied and 1 highly unsatisfied. Before completing the survey, participants were provided with three mostly used helmet models of 58 cm head size. Participants were asked to choose their preferred model and to assess its requirements. It was concluded that there is a need for modification in the design of helmet taking into considerations of thermal comfort, aerodynamic shape, improved visibility, discomfort due to CO_2 with prevention against dust and rain.

DESIGN SUGGESTIONS

Initially the 3D designing of the existing helmet for medium size (58 cm head size) which is mostly used by Indian riders was designed on solid-works software and presented in figure 1 using the specifications provided by the Bureau of Indian standards (B.I.S.) it was observed that there are no provisions of air-vents, large frontal area and no hearing aid on the existing helmet based on this survey it was furthermore concluded that inside temperature and aerodynamic shape are also the major concern among the listed variables hence these parameters are taken into consideration for modification in the design of the helmet in the subsequent section of this paper. The 3D designing of the modified helmet for medium size (58 cm head size) with specifications inner diameter 202 mm, outer diameter 205 mm, length 365 mm, width 240 mm and height 194 mm (Balakrishna et al., 2020) is designed as provided in figure 2. Following changes are proposed in the design of the full face existing helmet taking into account comfort of users.

Figure 1. Existing full face motorcycle helmet

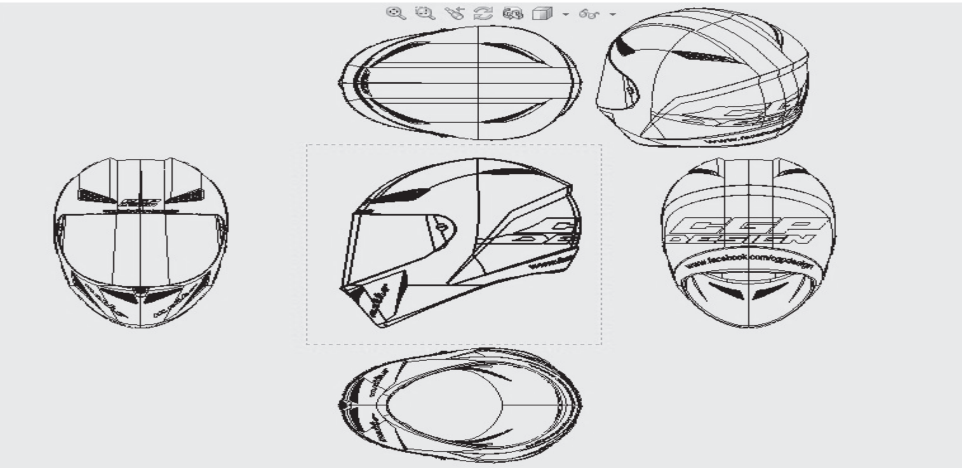

Figure 2. Different views of modified helmet

PROVISION OF TWO SCOOP VENTS

Various researchers indicated that dissipation of heat through helmet increases when it contains more vents (Reischl, 1986; Abeysekera et al., 1991; Holland et al., 2002). It is assumed that the thermal comfort of the helmet can be enhanced by providing vents for circulation of air through the helmet by taking advantage of the convective mode of heat transfer. The two-scoop ventilation at the top in the helmet is presented in figure 3. The proposed vent scoop should be of a small height about 10-20 mm and angled to minimize solar radiation and water entry. The study conducted by Pinnoji and Mahajan (2006) indicates that the ventilation channels grooved in liner foam are not detrimental to the dynamic performance of the two-wheeler helmet.

Figure 3. Modified full face motorcycle helmet with scoops at the top

PROVISION OF SIDE HOLES/GROOVES

As there is an urgent need of removing excess heat there is also a requirement of removal of an exhaled CO2 since helmet encases the head while riding (Aldman et al., 1981, Chinn et al., 2003, Brühwiler et al., 2003). The introduction of these small side vents as shown in figure 3 will have one an important contribution in reducing the discomfort due to accumulation of exhaled CO2 since the peak allowed concentration of CO2 in any workplaces can be 0.5%. These vents between chin cover and visor will also help in eliminating the hearing problem in the helmet.

Figure 4. Modified full face motorcycle helmet with side holes/grooves

PROVISION OF PROJECTION ON VISOR

The riders of two-wheeler will generally prefer a 'visor' or 'peak' at the front of the helmet as it provides relief against the dust, dirt, sun (glare), bright light and it will also serve the purpose of deflecting overhanging foliage (Ramireddy et al., 2020). Rigid projections (figure 5) outside helmets shell is recommended with limitation not to protrude more than 0.20 inch (5 mm) as these projections provide additional benefit to the rider and also prevents the entry of dust, dirt, and rain inside the shell. So the introduction of the projection restricts the entry of water in the rainy season to some extent and will be far better than the existing model. The aim of suggested changes in the design was to improve the dissipation of heat and will meet the other requirements as well as comfort of the users of existing helmets. However, it is possible that the proposed changes in the design of existing helmets may alter the structural integrity. Hence before the implementing the proposed changes discussed in the design of the existing helmet a comparison between the existing and modified helmet in terms of structural integrity, performance and flow of air is recommended. The numerical simulation on (static structure test and CFD analysis of the existing and modified helmet) is performed on ANSYS software to examine and compare the two models and to check whether these parameters are within the permissible limits.

Figure 5. Modified full face motorcycle helmet with projections at the top

RESULTS AND DISCUSSIONS

Human description evaluation with helmets was used to compare the strength and other properties of the existing and modified helmet on ANSYS (14.3) which was computationally used to examine the 3D models of an existing and modified helmet.

STATIC PRESSURE TEST

For static pressure, testing pressure of 25 MPa is applied on one side of the helmet and accordingly, the comparative results for total deformation, equivalent stress, and equivalent strain are shown in Figures. 6-8. Zone of maximum deformation is shown in red colour whereas the blue region has minimum deformation. Figure 6 shows that maximum deformation is 6.9435e5 m and minimum deformation of 6.6777e5 m in the existing helmet it shows that maximum deformation is 6.3699e5 m and minimum deformation is 5.6755e5 m in a modified helmet. The results reveal that maximum deformation in a modified helmet is lower than that of minimum deformation of an existing helmet and it also shows that deformation is more uniform in case of the modified helmet. Thus the proposed changes in the design do not have adverse effect on the strength of the modified helmet. Figure 7 represents that maximum equivalent strain

strain is 0.41715 and minimum equivalent strain is 3.2492e-2 in the modified helmet. The results of figure 7 reveal that the maximum equivalent strain is slightly higher for a modified helmet. It again shows that the proposed changes in the design do not affect the strength of the modified helmet. The different colors represent the variation of equivalent strain in an existing and modified helmet.

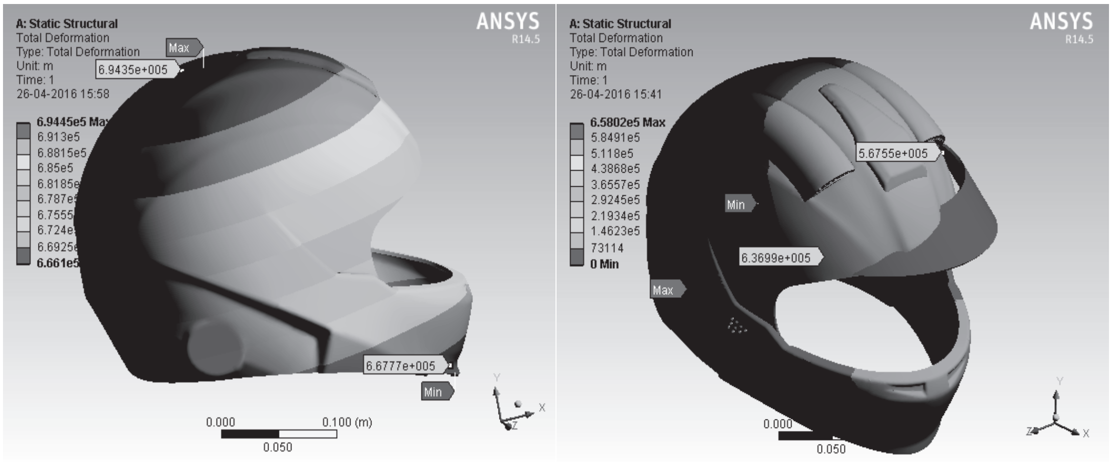

Figure 6. Comparison of total deformation on the existing and modified model

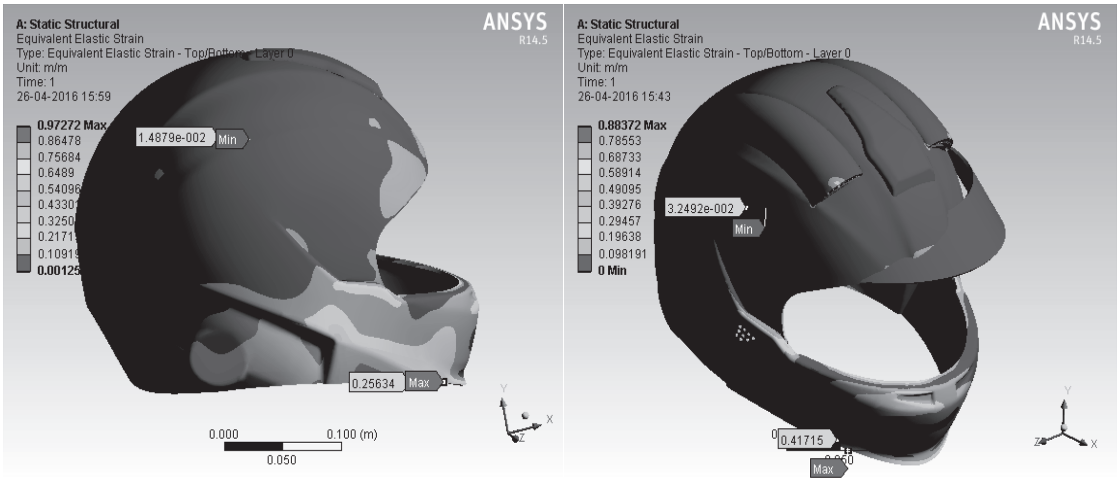

Figure 7. Comparison of equivalent strain on the existing and modified model

The different colors represent the variation of equivalent stress in an existing and modified helmet. Figure 8 illustrate that maximum equivalent stress is 3.4901e10 Pa and minimum equivalent stress is 1.5034e9 in the existing helmet it also shows that maximum equivalent stress is 1.6801e10 Pa and minimum equivalent stress is 2.9494e9 Pa in the modified helmet. The result of Figure 8 indicates that maximum equivalent stress is slightly lower for a modified helmet. The strength does not differ too much under proposed changes and the results are under permissible limits given by the BIS standards. Hence with proposed modifications; the helmet passed the static pressure test for total deformation, equivalent stress, and equivalent strain.

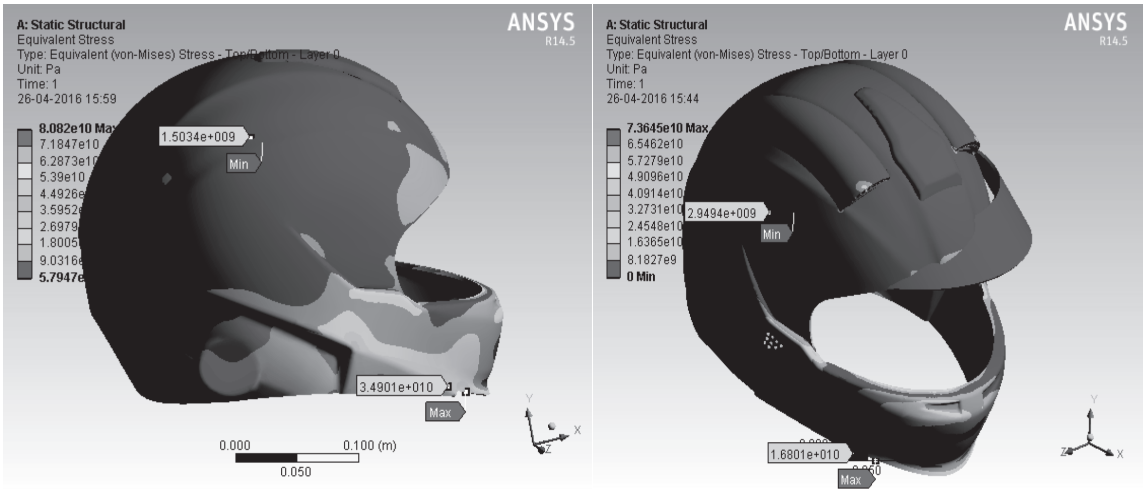

Figure 8. Comparison of equivalent stress on the existing and modified model

CFD SIMULATION

CFD simulation and its analysis were performed on ANSYS. The same k-ε model was selected to solve the 3D steady Reynolds averaged Navier-Stokes equations since this model is the same which was generally applied in the area of sports science (Zaïdi et al., 2010, Beaumont et al., 2017). CFD Fluent analysis was performed on the human manikin to identify the region where inlets and outlets of the ventilation vents can be provided. It was observed that in actual driving conditions the air exhaled by the rider will recirculate multiple times inside the helmet thus increasing the level of CO2 content and thus resulting in the discomfort of the user of the helmets. Figure 9 demonstrates the detached airflow at the rear of the helmet. This detached airflow may be attributed due to the spherical shape of the helmet. Due to flow separation behind the neck region wake formation was observed at the rear of the neck, at the bottom edges of the helmet and sides of the neck. As vortices are created where the flow is separated and hence high stagnation pressure was created over the visor, neck, and chest frontal area further low-pressure zone was created on the sides of the neck and shoulders.

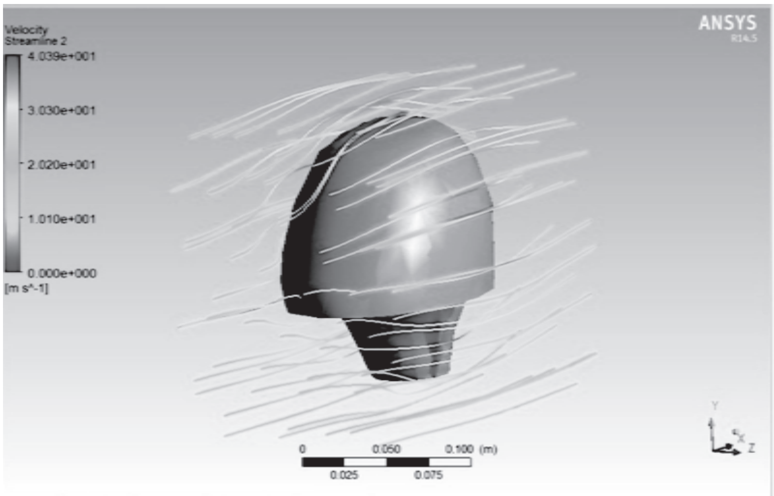

Figure 9. Streamlining air flow across the helmet

This pressure distribution over the helmet and manikin was applied to decide on the optimal position of the grooves for ventilation. The inlet ventilation zone was provided over the forehead region since it creates a high-pressure zone over this region. The negative pressure region on the lower end of the side liner facilitates the suction of the air from the forehead region and the low pressure at the back is assumed to act as an outlet. Therefore the design of the liner was modified to provide ventilation grooves as the air flows through the gap between the chin guard and the visor. This airflow splits the vortex and permits some air to escape and also supply fresh air to the user of a helmet. To reduce the consequence of the ill effect of dust and other impurities the grooves were modified taking into the comfort consideration of the rider and these grooves were also used to increase the velocity of the air since temperature decreases with the increase in the velocity of air. The grooves provided in the helmet has an advantage that the wake created between chin guard and chin was reduced. Therefore the level of comfort of the rider was increased with better circulation and less turbulence of air this improved air circulation reduces CO_2 concentrations drastically and rider can breathe fresh air.

CONCLUSIONS AND SCOPE OF FUTURE WORK

The primary purpose of helmet is to protect the head of rider and pillion during accidents while driving two-wheeler. At present different types of helmets with specific applications are available to user but these helmets have certain limitations like heat transfer properties and other comfort requirements of the users. Present study recommended the changes in the design of the existing helmet with improved features to reduce discomfort of the users' with few significant remarks, which need to be emphasized.

- A motorcycle helmet should be conceptually designed, modeled and developed to meet the requirement of riders by considering ergonomic and thermal comfort.
- Introduction of small side vents helps in reducing hearing and inner discomfort condition due to the accumulation of exhaled CO_2.
- The results obtained through ANSYS are in close tolerance with the B.I.S standards.
- The routing of the scoop vents and grooves should be fine-tuned to improve the rider comfort.

Physical testing of the modified helmet under various loading conditions is recommended. It is also suggested that the study of the modified helmet should be performed taking into the effects of crosswinds and influence of head position on the aerodynamic drag. Additionally feedback related to thermal and comfort parameters of the modified helmet from riders and pillions would add value to the design provided in the present study. Air filters can be introduced to reduce dust accumulation and pollution effects, different shapes of grooves can be tested other than circular to reduce dust accumulation problem and the truncated shape concept can be introduced to eliminate flow separation.

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