CONCEPTUAL DESIGN OF MOTOR CYCLE HELMET TO MEET THE REQUIREMENT OF THERMAL COMFORT, ERGONOMICS AND SAFETY

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Abstract

In recent times, due to rapidly growing population, traffic congestion and lack of parking space, two wheelers are the most popular mode of transportation. As per Indian traffic rules, it is mandatory to wear the helmet for safety while riding two wheeler. To provide safety for the rider, helmets are incorporated with lightweight plastic exterior, protective polystyrene layer and urethane comfort padding. It is very difficult to wear helmets for the longer duration in summer due to high temperature rise and lack of ventilation which increases the stress level of the humans. Since helmet designs are available in standard sizes and standard interior forms, it is difficult to fit for riders with different head shapes. There is a need for helmet which meets the requirement of thermal comfort, adjustable interior, better visibility and pleasing aesthetics.

In this project work an attempt has been made to conceptually design a motorcycle helmet for improved thermal comfort, visibility, safety with adjustable interior form considering rider's ergonomics. Initially, GEMBA study has been carried out on existing helmets to understand the design requirements, ergonomics and thermal comfort. Based on the user survey, QFD and PDS were generated and the product specifications were obtained to meet the requirement. Concept sketches were generated incorporating features like adjustable head form, air vents and exhaust fans for thermal comfort. Detailed design for the selected helmet concept and geometric model for the same has been created incorporating all the features as per the concept. A full scale working model of the helmet is built with all features, tested and demonstrated for its functionality.

Motor cycle helmet is conceptually designed, modelled and built incorporating features for improved thermal comfort, visibility and with adjustable interior form considering rider's ergonomics. Steady state airflow simulation on the helmet interior was carried out with a head form of rider (95 percentile male) to assess the air flow pattern and temperature distribution. It is found that exhaust fan provided on the rear end of the helmet along with air vents turned out to be a better possible configuration to extract the heat from the helmet.

Keywords: QFD, PDS, CFD, Thermal comfort, Exhaust fan

Nomenclature

T	Temperature	ºC / K
V	Velocity	m/s
ρ	Density	kg/m^3
μ	Viscosity	N-s/m^2, kg/m-s
R_e	Reynolds number	-

Abbreviations

ASHRAE	American Society of Heating, Refrigerating And Air-Conditioning Engineers
CFD	Computational Fluid Dynamics
QFD	Quality Function Deployment
PDS	Product Design Specification

1. INTRODUCTION

In recent times, due to rapidly growing population, traffic congestion and lack of parking space, two wheelers are the most popular mode of transportation .In the developing countries like India, it is very difficult to the middle class people to afford the luxury cars for daily needs. Hence the two wheeler motor cycles are very necessary for them. Due to this, the use of motor cycle is increasing steadily in India. In India most of the accidents includes the two wheelers, hence the safety of the motor cycle rider is most essential requirement. The two wheeler motor cycle rider is most likely to sustain serious injuries during the accidents. The human head is very vulnerable to injury. It is particularly susceptible to acceleration/deceleration and rotational forces because it is freely mobile in three dimensions and occupies a relatively unstable position, being secured only by the neck muscles and ligaments. One of the effective countermeasures to prevent head injuries in motorcycle crashes is the use of a protective helmet. The beneficial effects of helmets in direct impact are well documented and helmets have been found to decrease the risk of head and brain injury by 70 to 88% and facial injury to the upper and mid-face by 65% (Becker 1998, Mohan &Kothiyal 1984, Bowman et al 1982, Huston & Sears 1981) [1]. The traffic injury is recently recognized as one of the major health problems in the developing countries. Traffic accidents are more severe and require critical care that causes eventually high medical costs and economic losses. It may also cause permanent disabilities of the victim [2].

It is very difficult to wear helmets in the countries like India due to the discomfort they caused in tropical climatic conditions. According to the Indian motor vehicle act, the wearing of motor cycle helmet is mandatory while riding. Due to the discomfort caused by the present day helmets, people use to wear open face helmet which doesn't give more protection to the head and the face of the rider when compared to full face helmets. Hence there is an essential requirement of motor cycle helmet with good thermal comfort, visibility, safety and adjustable interior head farm. The proper ventilation is an important criterion for the safety and the comfort of the rider. As the rider exposed to the high speed stream of air, there should be proper heat transfer and air flow. A good helmet makes riding a motorcycle more fun, due to the comfort factor. It cuts down on wind noise on ears, windblast on face and eyes, and deflects bugs and other objects flying through the air. It even contributes to comfort from changing weather conditions and reduces rider fatigue.

2. PROBLEM DEFINITION

Helmet is one of the essential safely devices one can wear while riding a motor cycle. Helmets are effective in reducing the likely hood of Head Injury as well as their severity. It reduces the severity by reducing impact force. Increase in temperature inside the helmet interior increases the stress level and cause fatigue for the riders. At present helmets are available in standard sizes and it is difficult to fit the helmet for the different head shapes. Hence there is requirement of advanced helmet with better thermal comfort, fit, ergonomics, visibility and maintenance.

2.1 Definition of the Problem

To conceptually design motor cycle helmet to meet the requirement of thermal comfort and the ergonomics

2.2 Objectives

- To carry out literature survey on the design requirements of the helmet, safety standards, ergonomics of the motorcycle riders
- To carryout GEMBA study to understand the requirement of the motorcycle rider helmet
- To create the QFD and PDS for the design requirement of the helmet
- To generate concept sketches of the helmet with the provisions for air circulation and temperature monitoring inside
- To create a detailed design and geometrically model the selected concept incorporating all the accessories those are responsible for safety, thermal comfort and ergonomics
- To carryout CFD simulation to evaluate the temperature distribution and air flow pattern inside the helmet
- To carryout ergonomic study on the helmet for different head forms
- To build a scaled mockup model of helmet with all facilities

2.3 Methodology

- Literature survey has been carried out to know the requirement of the helmet, safety standards and ergonomics of the motorcycle riders wearing helmet
- GEMBA study has been carried out to understand the requirements of the motor cycle rider helmet
- QFD has been generated based on GEMBA study, merging customer's voice and technical requirements
- PDS has been generated based on the literature survey and QFD
- Conceptual sketches have been generated for helmet incorporating provisions for air circulation, adjustable foam to suit different head shapes and temperature control system
- Detailed design has been carried out for the selected conceptual helmet
- Geometric model of the selected conceptual helmet has been created using Autodesk alias and CATIA V5 as per detailed design
- CFD simulation has been carried out and evaluated the temperature distribution and air flow pattern inside the helmet using Ansys Fluent software
- Ergonomics study on the helmet has been carried out
- A mock up helmet has been made with all facilities and demonstration of its working

3. DATA COLLECTION QFD AND PDS

3.1 Product study

User survey has been carried out on the existing customers to study the comfort level, safety and ergonomics in the existing helmets. The detailed study has been carried out to understand the present day helmet in the market by consulting some of the helmet dealers. The expectations of helmet users and dealers are collected.

3.2 User study questioners

For users:

- Do you drive a car or traveled in a car?
- What is your opinion about the helmets which are available in the present market?
- What makes you to buy this particular helmet?
- How is the visibility from your helmet?
- How do you feel about your helmet during the night journey?
- How far your helmet is comfortable to you?
- What is the comfortable level you expect from the new generation helmets?
- Any accessories or facilities you are looking in the new generation helmets?
- How do you feel while riding in the winter, summer and rainy season?
- What is you expectation about the exterior of the helmet?

- Does the weight of your helmet is optimum or you are feeling more weight?
- Any other problem you are experiencing in your helmet?
- Anything in your helmet which you feel very comfortable?
- Anything in your helmet which you feel very difficult to use?

For dealers

- How many brands of helmet you are selling?
- Which brand is moving fast in the market and why?
- Which brand helmet is moving slowly and why?
- What type of helmet people like most?
- According to your which facility can improve the sales of the helmet?
- What is the main complaint in the helmet from the customers?
- Any accessories or facilities you are looking in the new generation helmets?
- Which helmet has got maximum facility and moving fast in the market?
- According to you which helmet has a good value for money?

3.3 Quality Function Deployment

Quality functional deployment is a method of transforming user needs into the design quality. It is a customer driven method which reduce the implementation time, promotes the teamwork and provides the documentation. In order to design a good product, the design team needs to know what the end user will expect from the product. Quality Functional Deployment is a systematic approach to design a product according to the requirement of the customer. Hence the QFD is a customer driven planning process. It causes the company to focus on the customer requirement. The steps involved in building QFD – "House of Quality" is.

- Go to GEMBA to understand the customer voice
- Identify the customer requirement through GEMBA study
- Get customer evaluation of demanded quality
- Priorities customer quality requirement
- Establish the technical description
- Develop relationship and interrelationship
- Conduct competitor assessment

According to the customer voice and technical voice, QFD matrix was developed.

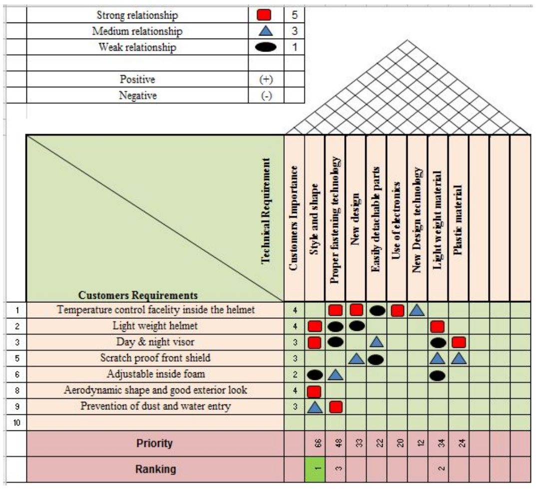

Fig. 1 QFD

As per QFD analysis results, maximum importance is given to the following parameters

- Temperature control facility inside the helmet
- Adjustable inside foam
- Visibility
- Size and shape
- Materials

3.4 Model Making

The full scale working model of the final concept of the helmet was made to check the designed features and to get a better understanding of the concept. The figure 2 shows the working model of full scale helmet.

The working model of the helmet has been made using Fiber reinforced plastic. The internal protective padding is made of Polystyrene and the comfort padding is made of Nylon cloth and Thermoplastics.

Fig. 2 Full scale model of helmet

Manually adjustable foam

Manually adjustable foam helps to adjust to the different head shapes. It consists of a rotating knob mounted on side of the helmet outer surface, threaded bolt and the cushion pad as in the figure 3. User can tighten or loosen the inner foam as per his requirement.

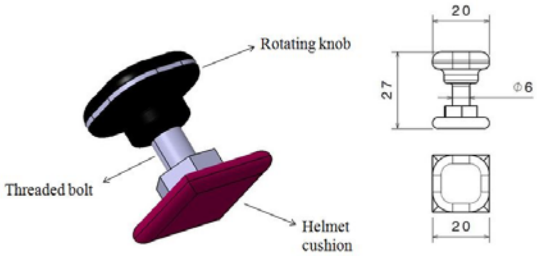

Fig. 3 Manually adjustable foam

Ergonomic study of the helmet

Ergonomic study of the helmet means, the validation of the designed helmet for its comfort, feasibility, visibility, ease of accessibility and exterior aesthetics The figure 4 shows the helmet with 50th percentile male dummy. It shows that, it is easy to access the helmet for 50th percentile head dummy. The gap between the helmet and the head fills with protective and the comfort padding.

Fig. 4 Ergonomic analysis of helmet with 50th percentile male dummy

4. MODEL CONSTRUCTION AND SOLUTION

4.1 Geometric modelling of the helmet, cushion and head foam

The selected helmet primarily designed in Autodesk Alias and then imported to Catia-V5.Geometry simplification was done to improve the ease of meshing. Fillets and radius of unimportant areas were removed. The head manikin is removed with the solid helmet using Boolean operation to create the fluid domain and cushion region inside the helmet. The figure 5 shows the half section of solid helmet with head form, helmet cushion and the manikin used for the analysis.

Fig. 5 Geometric model of Helmet, cushion and head

The three air vents are given at the top of the helmet to give air circulation inside the helmet. The air flow inside the helmet can be improved by installing a suitable exhaust fan in the rear side of the helmet. Hence in this proposed design of helmet an exhaust fan has been installed in the rear side of the helmet. The figure 6 shows the air flow passages provided inside the helmet.

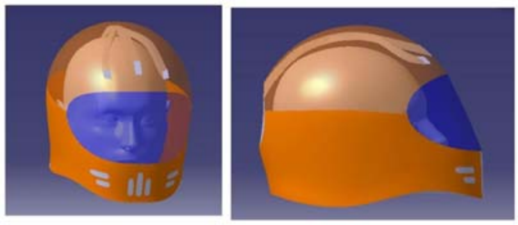

Fig. 6 Air flow passages inside the helmet

4.2 Discretisation of the Geometric Model

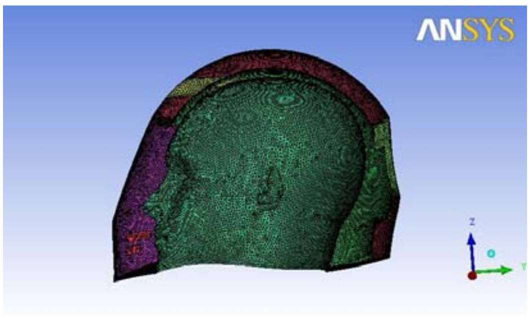

Fig. 7 Discretisation of the geometric model

The geometric model of the helmet and the interior was discretised using the pre-processor software ICEM CFD. The computational domain was made up of 732508 elements Figure 7, shows the discretised geometric model of the helmet.

4.3 Solution Using FLUENT Solver

The discretised model is imported in to the FLUENT data base for solving. The CFD analysis has been carried out to study the air flow pattern and temperature distribution inside the helmet. The air flow simulations have been carried out for two different conditions at the wind speed of 60km/h. The two conditions are:

- Without exhaust fan
- With exhaust fan

In FLUENT several setting and inputs are to be given before solving. The input details and solution settings are discussed below.

Defining Material Properties

The material for the helmet interior domain is selected as Air; the default air properties as given by Fluent are selected.

Solver settings

Table 1. Solver settings in FLUENT

Model settings	
Space	3D
Solver	3D-pressure based
Energy	Enabled
Viscous model	Standard k-ε turbulence model
Wall treatment	Standard wall functions
Solver controls	
Equations	Flow Turbulence Energy
Pressure-Velocity coupling	SIMPLE

Boundary Conditions

The different conditions are given for each case.

Table 2.Without exhaust fan condition

Surface	Boundary conditions	Input
Inlet	Velocity inlet	16.67 m/s
Outlet	Pressure outlet	0 gauge pr @305K temp.
Head manikin	Stationary wall, no slip	4.3 W/m2 Per K
Helmet outer shell	Stationary wall, no slip	Stationary –No slip
Helmet cushion	Stationary wall, no slip	Specified shear
Fluid	Air	1.225kg/m3 and 1.784X105kg/m-s

Table 3. With exhaust fan condition

Surface	Boundary conditions	Input
Inlet	Velocity inlet	16.67 m/s
Outlet	Pressure outlet	67.254Pa @ 305K temp.
Head manikin	Stationary wall, no slip	4.3 W/m2 Per K
Helmet outer shell	Stationary wall, no slip	Stationary –No slip
Helmet cushion	Stationary wall, no slip	Specified shear
Fluid	Air	1.225kg/m3 and 1.784X105kg/m-s

5. RESULTS AND DISCUSSION

The CFD analyses for the different cases such as without exhaust fan and with exhaust fan conditions are performed using FLUENT solver. CFD analysis is performed for the discretised interior domain for two cases. The results obtained from these simulations are discussed in this section.

Case 1 (Without exhaust fan condition)

Velocity contour shows the variation of the velocity inside the helmet. Here the air is flowing from the inlet to the outlet; hence the velocity at the path of the air is high when compared to the other parts of the helmet. This air velocity helps to take away the heat generated from the head which leads to increase in rider comfort. The figure 8 shows the velocity contours inside the helmet. The figure 9 shows the temperature distribution on the head.

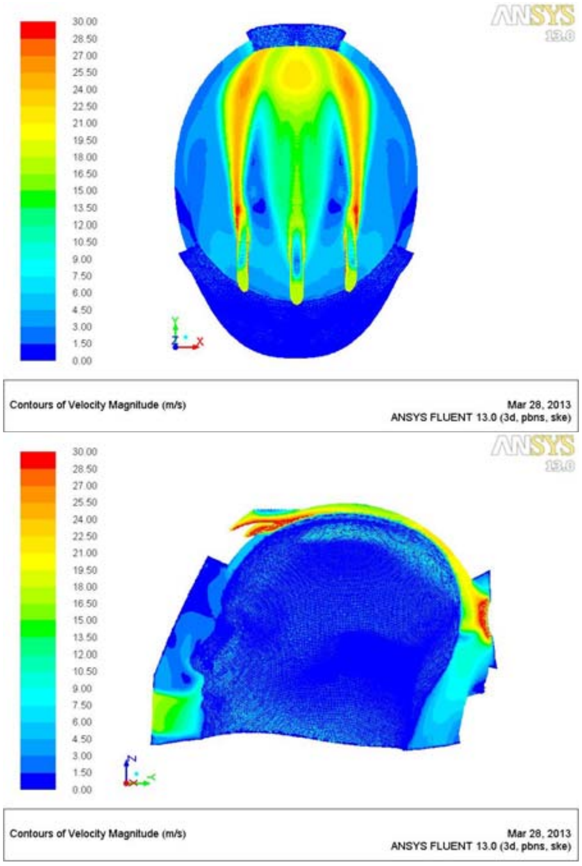

Fig. 8 Velocity contour from top and the side view of the helmet

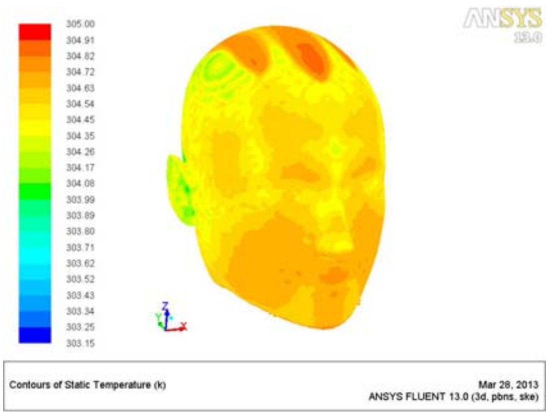

Fig. 9 Temperature distribution on the head

Case 2 (With exhaust fan condition)

In this case, there is no much difference in the velocity contours but there is a slight reduction in pressure and the temperature. The 1^{0} C reduction of temperature has been noticed due to introduction of exhaust fan in the rear side of the helmet. The figure 5.3 shows the velocity contours from the top view of the helmet.

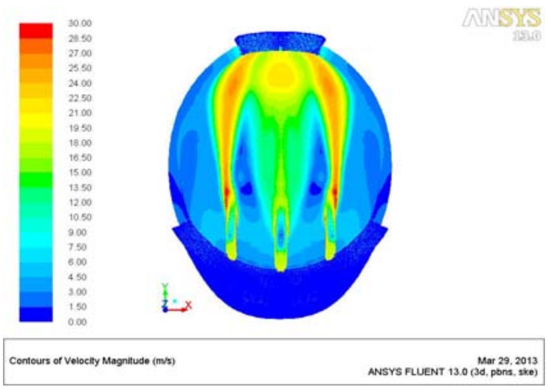

Fig. 10 Velocity contours from top view of the helmet

The figure 10 shows the temperature distribution on the head.

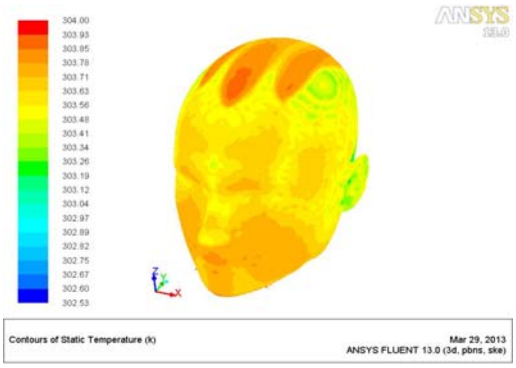

Fig. 11 Temperature distribution on the head

5.4 Pathlines

The contours for pathlines coloured by velocity for case 1 is shown in Figure 12 and 13**,** the air enters into the interior portion of the helmet through the vents provided at the front end. The pathlines for the same are observed and the flow is understood in the interior of the helmet.

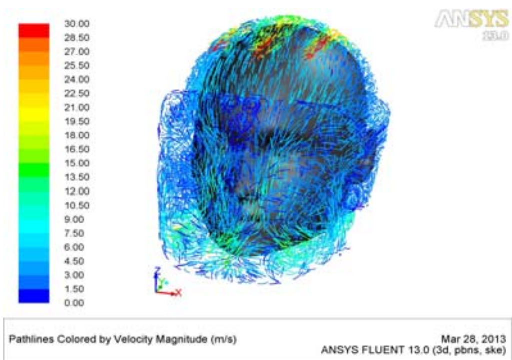

Fig. 12 Pathlines colored by static temperature

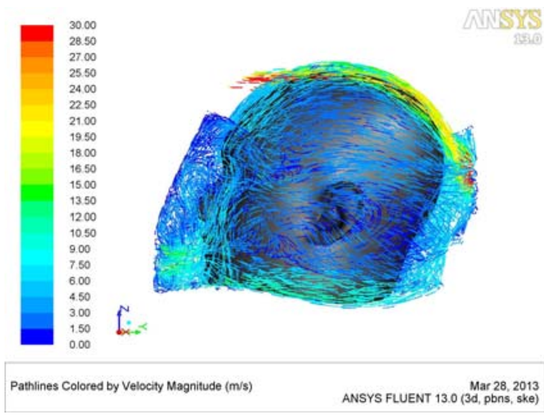

Fig. 13 Pathlines colored by static temperature

6. COMPARISON OF RESULTS

The results obtained from the steady state CFD analysis are compared in the following.

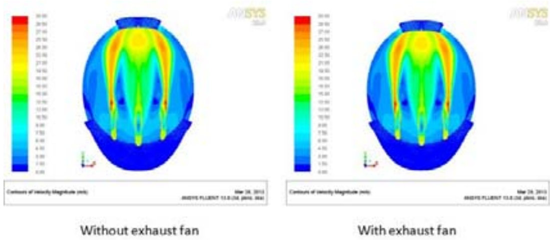

Fig. 14 Comparison of velocity contours

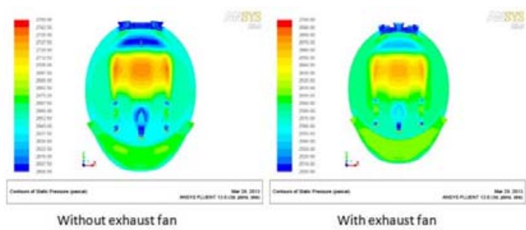

Fig. 15 Comparison of pressure contours

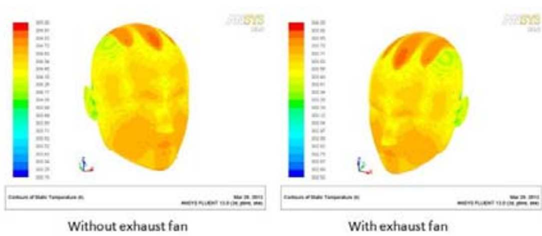

Fig. 16 Comparison of temperature distribution

It is hard to notice a difference in the velocity contours, but there is a slight difference in the pressure contours. The pressure inside the helmet during 'with exhaust fan condition' is lesser than the pressure at 'without exhaust fan condition'. There is a difference of 1o C temperature between the two cases. The temperature during 'with exhaust fan condition' is lesser than the first condition. It means the exhaust fan helps to reduce temperature by 10 C. During the long journey at high ambient temperature, the effectiveness of exhaust fan will increase due to increase in temperature inside the helmet.

7. CONCLUSIONS

- Motor cycle helmet has been conceptually designed, modeled and built to suite the requirement of riders by considering ergonomics and thermal comfort
- The proper ventilation and the exhaust fan reduces the thermal discomfort to the rider
- The adjustable head form helps to suit the helmet to the riders of different head shapes
- The visibility of the helmet has been improved by giving wide angle of visors

8. RECOMMENDATIONS FOR FUTURE WORK

- The selection of exhaust fan location can be carried out
- Structural analysis can be carried out to know the behavior of helmet during accidents
- Adjustable foam technology can be extended at the rear side of the helmet
- Suitability of blower fan instead/along with exhaust fan can be review
- Electronic devices can be incorporate to automate the exhaust fan
- Solar panel can be introduced to power the exhaust fan

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