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Study of Design of a Conceptual Helmet

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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. Based on the user survey, Quality Function Development and Product Design Specification 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. Motor cycle helmet is conceptually designed, modeled 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: Thermal comfort, Exhaust fan.

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. 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 counter measures 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%.

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. Objective is to carry out literature survey on the design requirements of the helmet, safety standards, ergonomics of the motorcycle riders and to conduct questionnaire survey to understand the requirement of the motorcycle rider helmet.

LITERATURE REVIEW

Helmet can protect vehicle riders from severe injuries during traffic accidents. Traffic injuries have only quite recently been recognized as a major public health problem in developing countries. Also, serious bicycle accidents have increased in the last two decades. The global share market of helmet is difficult to estimate. However, due to some helmet acts and enforcements, also it is believed that consumers usually replace helmets periodically. The market is assumed to be large enough to run a new series of products. And the product levels should be determined.

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. 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, modeled 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.

To design a functional helmet, it is important to analyze the structure of helmets. The main helmet components are the foam linear (EPS, PU, PP, PE, Pb, PVDC or integral skin) and the shell (Thermoplastic or Composite).

The helmet must be designed to provide the user with the most lightweight, form fitting system, while meeting other system performance requirements. This can be achieved through a complete analysis of the system requirements. The advanced helmet development process for developing aircrew helmets includes the utilization of several emerging technologies such as laser scanning, computer aided design (CAD), and computer generated patterns from 3-D surfaces, laser cutting of patterns and components, and rapid prototyping (stereolithography). Advanced anthropometry methods for helmet development are also available for use. The use of these advanced technologies will minimize errors in the development cycle of the helmet and molds, and should enhance system performance while reducing development time and cost.

A new helmet design with an exterior elastic skin, capable of moving independently from the hard layers underneath, could decrease brain injuries from motorcycle accidents when the rider's head hits the road or a vehicle with a glancing blow.

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METHODOLOGY

Literature survey has been carried out to know the requirement of the helmet, safety standards and ergonomics of the motorcycle riders wearing helmet. Ergonomics study on the helmet has been carried out. Questionnaire survey has been carried out to understand the requirements of the motor cycle rider helmet. Questionnaire was prepared and a pilot survey was conducted. Some irrelevant and confusing questions are avoided and the questionnaire was refined. Data analysis is done with SPSS software. Descriptive statistics is used for analysis.

Questionnaire survey

A survey is used to collect data of consumers' preference to buy a motorcycle helmet. There are 24 questions in the survey and questions are prepared on a 5 point likert scale. Questions are prepared based on the objective of the study and the response are collected.

A pilot survey of the questionnaire prepared was randomly distributed among 30 peoples. As per the suggestions of respondent, some irrelevant questions are removed and the questionnaire was refined, then the main survey was conducted.

Sample size and Technique

The population considered is 500. A random sampling was done with an expected proportion of 0.1 from the population and at 95% confidence level and margin of error as 5%.A printed questionnaire were issued. The response data collected were recorded in spreadsheet. The response obtained was 215

The sample size is found out using the formula

$n= N/(1+Ne^2)$

where, n= sample size, N=population, e= margin of error at 95% confidence level

RESULTS AND DISCUSSION

literature is reviewed on the design requirements of the helmet, safety standards, ergonomics of the motorcycle riders and the following design considerations are made in making the helmet.

Design Criteria

Reduce the risk of mild traumatic brain injury (MTBI)

Three key features designed with the intent of reducing the risk of MTBI.

I. Side and facial protection— of the impacts that were analyzed, over 70% of those that resulted in MTBI were from a blow to the side of the head, face, or mandible area.

II. Increased Shell Offset – the distance from the helmet shell to the wearer's head gives the helmet to manage the types of impacts that cause MTBI without compromising its response at higher energy levels.

III. Carefully-designed Shell Shape –the shell extends into the mandible area, and it has been computer designed around the head's anatomical center of gravity.

Stability and Fit

I. The stability of the helmet on the wearer's head is critical to keeping the protective system in its intended place, where it can best protect the athlete.

II. A properly fit helmet is key to player protection.

Comfort

I. Ventilation

II. Ear Channel — allowing for much easier donning and doffing than traditional football helmet designs.

III. Lightweight — producing a lightweight product without compromising protection

Structure of Helmet

A good design starts from a throughout understanding about the concept of a new product. Fig. 1 shows the common parts of a helmet. A brief description for the function of each part is also given to highlight their importance in the design process.

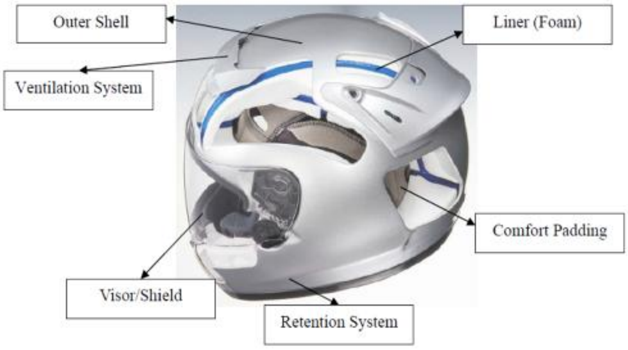

Fig.4.1 Components of a helmet

Visor

The visor is made of a strong and transparent material, e.g. polycarbonate, and is designed to protect the face of the rider from wind, dust and insects. In addition, the visor is equipped with a water- and scratch-proof coating.

Manufacturing a distortion-free visor including a reliable opening mechanism not only calls in a manufacturer's development strength, but is equally dependent on the right production technology.

Outer Shell

During an accident, the hard outer shell has to both absorb and disperse the impact. At present, outer shells are generally made of thermoplastics or fibre-reinforced polymer (FRP), a composite material consisting of a synthetic resin reinforced with, for instance, fibreglass.

Comfort Padding

Despite its rounded shape, an EPS liner is much too hard to guarantee a good fit. The comfort padding, which consists of a sufficiently firm synthetic foam pad covered with a skin-friendly fabric, is thus all the more important.

Ventilation System

The system ensures fresh air is ducted into the helmet and exhaled air and humidity are vented out.

Retention System

A special synthetic-fibre chin strap that fulfils the strict breaking- and tensile-strength requirements serves to secure the helmet firmly on the head of the rider. The retention system is attached to the helmet with strong metal rivets.

Liner(Foam)

The liner protects the wearer's head by absorbing the remaining force of the impact that was

already partially absorbed and dispersed by the outer shell. The liner located on the inside of the shell is made of lightweight and highly impact-absorbing EPS (expanded polystyrene).

Standards for Helmet Strength

Different countries have their own standards for helmet tests, and the ASTM F1446-95a [1] helmet standard had been the most-used standard in the world. All of the standards require helmets to pass lab tests where they are placed on an instrumented head form, turned upside down and dropped for a measured distance onto flat or hemispherical anvils. Drop distances vary but are generally between one and two meters. For the helmet to pass, the instruments inside the head form must register less than 300 g's during the impact, or in some cases less than 250 or even 200 g's. The most-used three helmet testing standards, CPSC, ASTM F1447 and Snell B-95, are compared in table 1. It is obviously that Snell uses more severe criterion for helmet test

Table 4.1

Helmet test criteria for CSPC, ASTM F1447 and Snell B-95 [2]

	CPSC	ASTM F1447	Snell B-95
Drop height on flat anvil	2.0 m	2.0 m	2.2 m
Drop height on hemispherical anvil	1.2 m	1.2 m	1.5 m
Head form weight	5 kg	5 kg	5 kg
Failure threshold	300 g	300 g	300g

Standard for Head Protection

Criterion used to measure the performance of the helmet for head injury prevention is not only the head acceleration. Another criterion is the Head Injury Criterion (HIC). HIC is a measure of the severity of an impact and takes into account its duration as well as its intensity. The criterion is based on the results of research into the effects of impacts on the human head. HIC is defined by the following integral formula

$$HIC = \max\left\{\left[\frac{\int_{t_1}^{t_2} a(t)dt}{t_2 - t_1}\right]^{2.5}(t_2 - t_1)\right\}$$

Where 'a' is the head form center of gravity acceleration and t_1 and t_2 are chosen so that the HIC is a maximum. The requirement for helmet protection is that HIC should less than 1000.

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. User can tighten or loosen the inner foam as per his requirement.

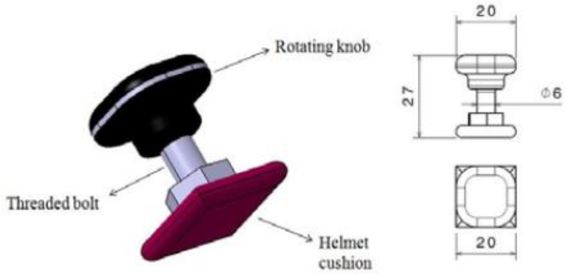

Fig. 4.2 Manually adjustable foam

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 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. 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.

Fig. 4.3 Ergonomic analysis of helmet with 50th percentile male dummy

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 shows the velocity contours inside the helmet.

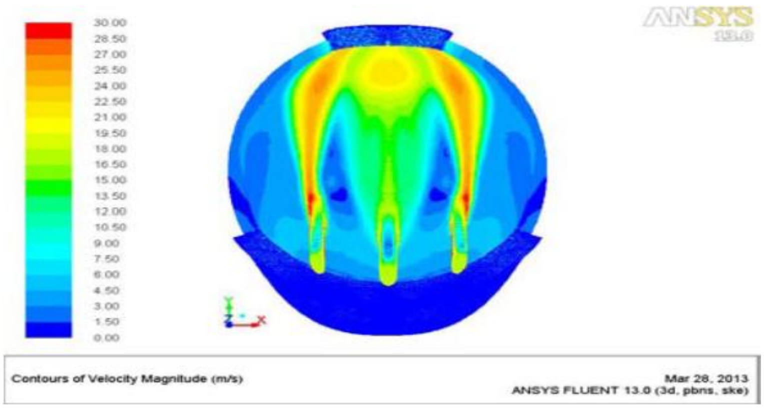

Fig. 4.4 velocity contour without exhaust fan

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 10 C reduction of temperature has been noticed due to introduction of exhaust fan in the rear side of the helmet. The figure shows the velocity contours from the top view of the helmet.

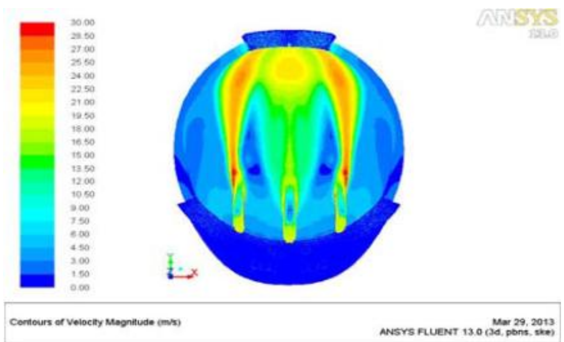

Fig.4.5 velocity contour with exhaust fan

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COMPARISON OF RESULTS

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.

CONCLUSION

- 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

Questionnaire analysis

Questionnaire is prepared and distributed among the selected population the data is collected and the data is analyzed using SPSS software descriptive analyzes is made on the collected data. Based on the results the objectives are reached.

A question regarding the rating of helmets which are available in the present market is asked and the response is obtained as shown in the bar chart.

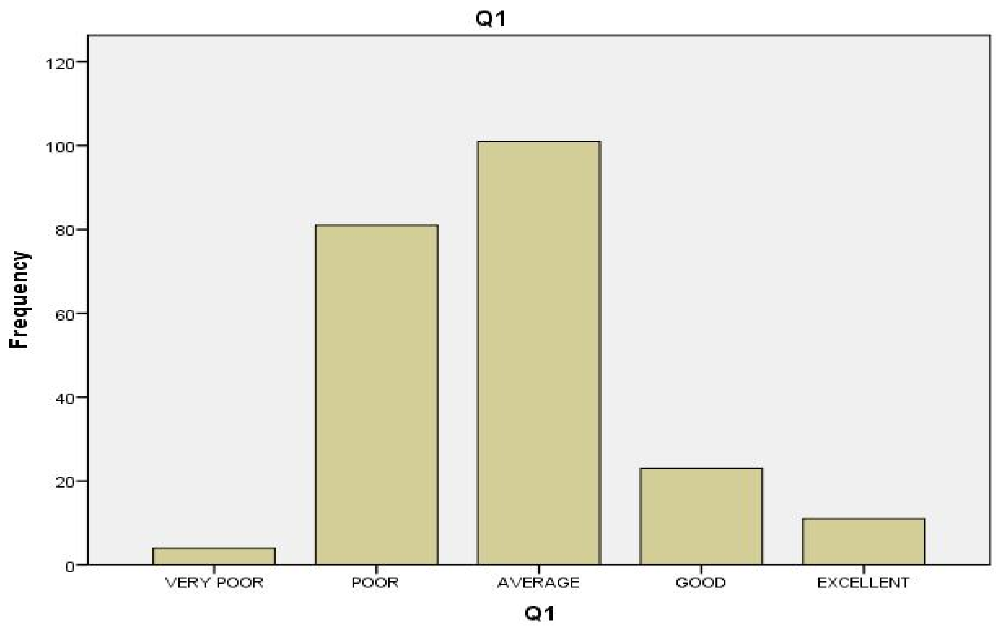


Fig. 4.6 Bar chart showing rating of helmet

220 peoples responded to the questionnaire and 1.8% rated as very poor 36.8%, 45.9%, 10.5%, 5% rated as poor, average, good, excellent respectively on viewing this results we can conclude that customers are not happy with the helmets which are available in the market change in design is required for the helmet.

Question regarding the visibility from the helmet is asked and the response is obtained as shown in the bar chart.

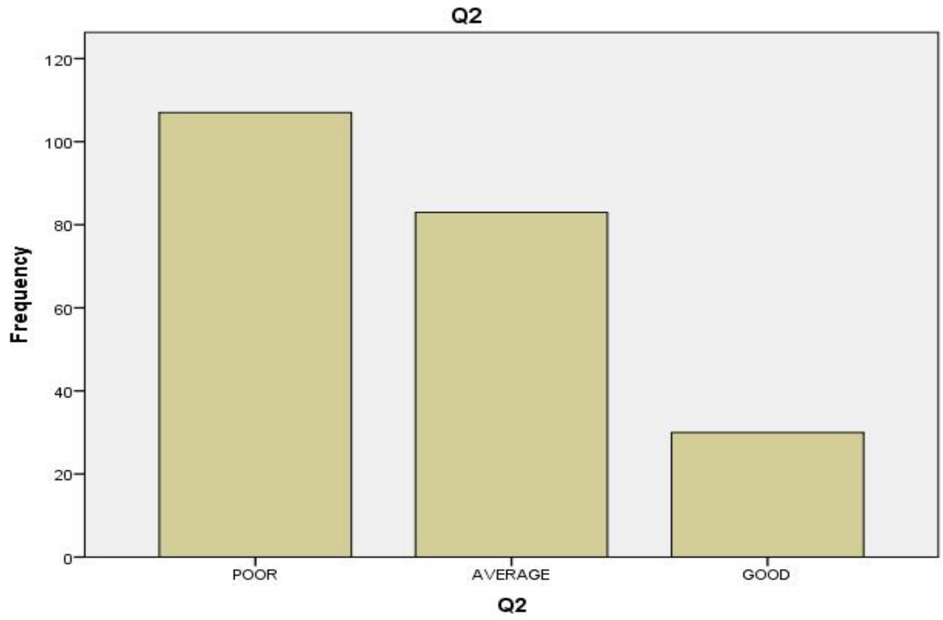


Fig. 4.7 Bar chart showing rating of visibility from helmet

Questionnaire was prepared on 5 point likert scale containing very poor, poor , average, good, excellent scale. Among 220 response 48.6% rated as poor 37.7%& 13.6% rated as average, good respectively. No one rated as very poor and excellent on closely analyzing the data we can see that visibility is poor we need to consider design changes containing visibility.

Question about the comfort provided by the currently available helmets is asked and the response is obtained as shown in bar chart. Among 220 response 5% rated as very poor 38.6%,38.2%,16.4%,1.8% rated as poor, average , good, excellent respectively. On analyzing the result we can see that comfort level average or below average so change in design is requires so as to accommodate more comfort.

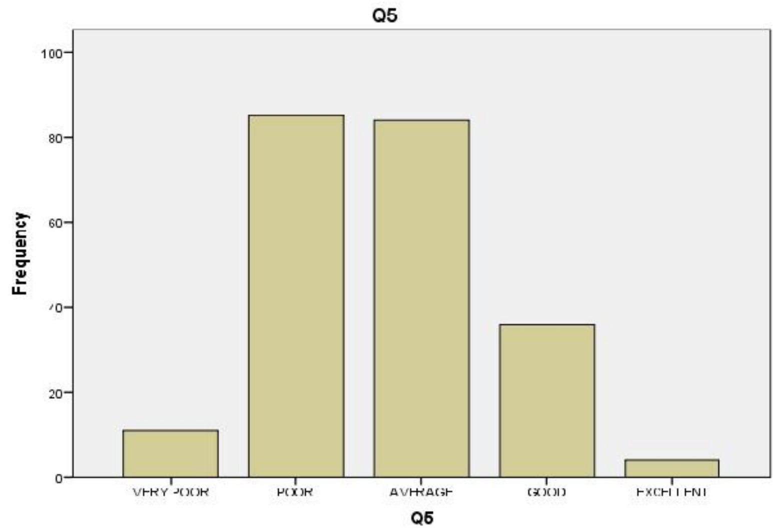


Fig. 4.8 Bar chart showing rating comfort provided by helmet

A question is asked that hearing is affected while wearing the helmet and the response among the people are collected and obtained as shown in the bar chart.

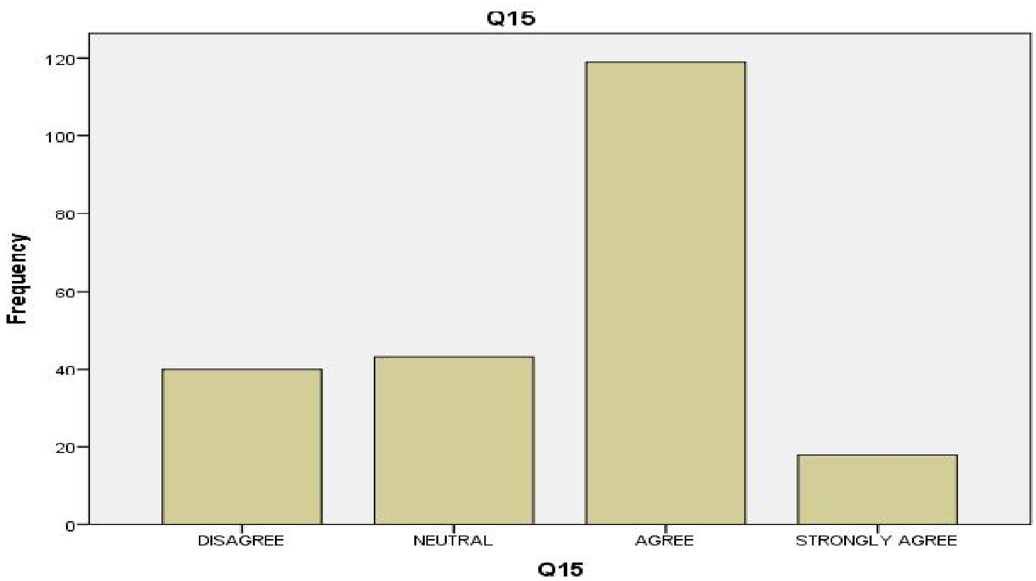
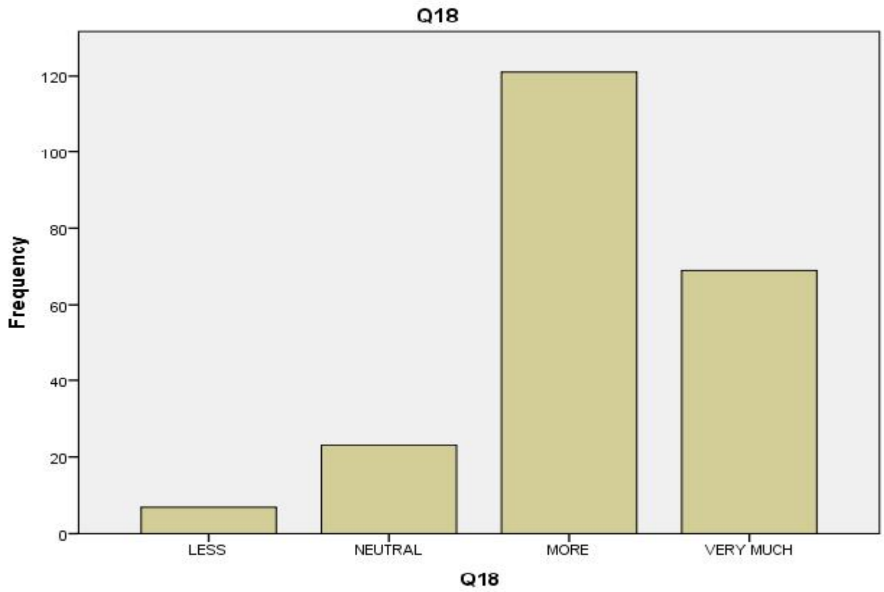


Fig. 4.9 Bar chart showing response rate regarding hearing ability

Among 220 response 18.2% disagree the statement 19.5%,54.1%,8.2% responded as neutral, agree, strongly agree respectively no one responded as strongly disagree on viewing these data we can conclude that hearing is affected while wearing helmet so design changes are needed in accordance to rectify this problem.

Question regarding the effect of thermal stress caused by the helmet is asked and the response are obtained as shown in the bar chart. Among 220 response 3.2% responded as less 10.5%, 55%, 31.4% responded as neutral, more, very much no one responded as very less from these response we can say that the thermal stress caused by the helmet are high so we have to make a change in the design in order to reduce the thermal stress.



4.10 Fig. Bar chart showing response rate of effect thermal stress

Question regarding the effect of contact stress caused by the helmet is asked and the response are obtained as shown in the bar chart.

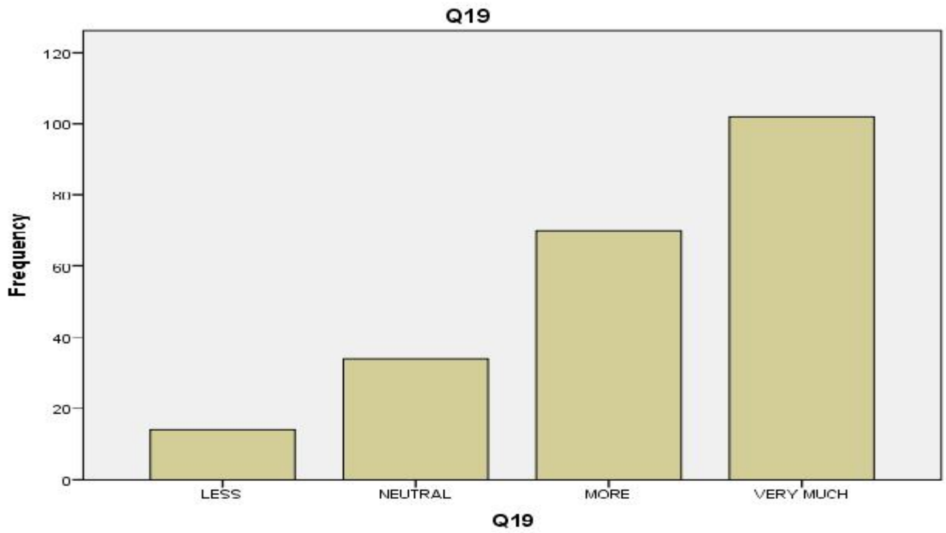


Fig. 4.11 Bar chart showing response rate of effect contact stress

Among 220 response 6.4%responded as less 15.5%, 31.8%, 46.4% responded as neutral, more, very much no one is responded as very less from these responses we can say that contact stress caused by the helmet is very much so we have to change the design in order to reduce the contact stress.

CONCLUSION

Literature is reviewed on the design requirements of the helmet, safety standards, ergonomics of the motorcycle riders and the following design considerations are made in making the helmet. Design requirements are identified and corrected by literature review data's are collected about the design requirements , safety guards , ergonomics of the motorcycle. Design considerations including stability, fit , comfort and safety are made. 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 User can tighten or loosen the inner foam as per his requirement. The CFD analyses for the different cases such as without exhaust fan and with exhaust fan conditions are performed using FLUENT solver. 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.

- 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

The questionnaire survey is analyzed questions regarding comfort, visibility, hearing ability, thermal stress, contact stress is analyzed on SPSS the response rate are determined from the analyzes it is found that the comfort, visibility, hearing ability, thermal stress, contact stress which are not in a favorable range so change in design considerations are recommended in order to minimize these problems.

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