FINITE ELEMENT ANALYSIS ON DIFFERENT MATERIALS FOR MOTORCYCLE HELMET SHELL

Intakhab khan[1] (0000-0001-9006-4224), Aditya shinde[2], Shresth Khandelwal[3], Vinay sah[4], Narendiranath Babu T

[123] Student, School of Mechanical Engineering, Vellore Institute of Technology, Vellore, Tamilnadu, India

[4]Associate Professor, School of Mechanical Engineering, Vellore Institute of Technology, Vellore, Tamilnadu, India

intakhab.khan97@gmail.com, adsh314@gmail.com, shresthkhandelwal3@gmail.com, vinaysah96@gmail.com,

---***---

Abstract - *In order to protect the rider from the severe injury and deaths during accidents the helmets play a vital role. The main objective of the helmet is to prevent the brain from any damage since it is the most crucial part of our body, so the helmet must be designed in such a way that it has the required toughness so as to resist fracture during impact. In our research materials like Acrylonitrile butadiene styrene (ABS), Polycarbonate, Polycarbonate with 30% glass and epoxy glass fibre are used and are evaluated for helmet shell using Finite Element Analysis (FEA). The strength analysis was done using FEA and the proper Factor of Safety (FOS) was kept to prevent failure. The standards of Federal Motor Vehicle Safety Standards (FMVSS) No. 218 were used which also satisfies the new Bureau of Indian Standard (BIS) standards for helmets which has been applied from January 2019 and has been used to analyze the helmet with the help of which we found out the optimum material and thickness as per the results.*

As per the results obtained the glass fibre with 4 mm thickness was obtained safe and as per the regulations of BIS. ANSYS 18.0 software was used for FEA and Solidworks was used for solid modelling.

To increase the thermal comfort of the rider during the summer season the holes were made for the air circulation since wearing helmets during the summer season is difficult and as per the results it was obtained that within the shell there was decrement of 5℃ as compared to the initial condition.

Key Words: *ANSYS, BIS, Finite Element Analysis, FMVSS, material, Helmets, Impact, SolidWorks, Toughness.*

1. INTRODUCTION

Helmet helps riders save their lives from traffic accidents by protecting them from severe head injuries. One of the major reasons of fatal injuries or death by traffic accident is people not wearing helmet, mainly because people feel uncomfortable while wearing helmet and our focus is on solving the issues regarding helmet design. Traffic injuries is now considered as major public health problem in India. Traffic injuries leads to high medical costs and finances. After the helmets acts and enforcements it is believed that that the person replaces the helmets periodically so the market is large. Main concern is that most of the people feel reluctant to wear helmet due to its thermal discomfort, ventilation issues, its ergonomics etc. A new helmet is designed in which chin side of the helmet has been optimized so that minimum force will be transmitted to the head [1].We selected various materials and examined their properties and analysed them through FEA and then the thickness of the helmet is minimized so that less force is induced on the head and at the same time weight of the helmet is reduced and cost cutting has been done[2].We see that our designed helmet holds good for impact tests at reduced weight and at the same time factor of safety is not compromised [5]. We then focussed on thermal comfort of the rider. Thermal comfort is achieved by providing holes to the inner surface of the helmet so that heat flux would be more and a significant temperature reduction is observed. Also, there will be forced convection to reduce the heat generated ([4], [6]). Ergonomics of the helmet is improved and the slot, groove is applied to improve the air flow and reduce stress inside the helmet [3].

1.1 Literature review

According to study done by Gandhi et al.(2014) when the BIS standard of 19.5 kN force is applied to test the helmet in static and dynamic loading, it showed that least strain energy and deformation has occurred in chin side of the helmet, which means that maximum force will be imparted to the head [1]. As the thickness of the outer shell of helmet increases and the velocity of the helmet increases the force induced on head increases, so the thickness should be optimized while designing the helmet[2].As work done by Praveen et al(2008) who used CFD to analyse the air flow through the helmet and concluded that the helmet with groove of 14 mm × 14 mm along with a slot of 48 mm× 7mm is optimum at 7 m-s velocity, it increases the air flow in the helmet head gap and the head will experience lower stress and force[3].It is seen that a good linear relationship exists between forced convective heat loss and wind speed (0

Km/hr – 80 Km/hr), making predictions of forced convective heat loss behaviour easier based on a limited number of measurements[4].Theoretically helmet mass can be optimizing up to 700gms; but without compromising safety practically the mass of the total helmet assembly having EPS protective padding can't be reduced below 850gms[5].It was also observed that 36°C is a crossover temperature beyond which if the air inlet temperature is increased, the microclimate in helmet is not found comfortable for rider. So, for providing better thermal comfort to the rider, improved air ventilation in helmet is must [6].

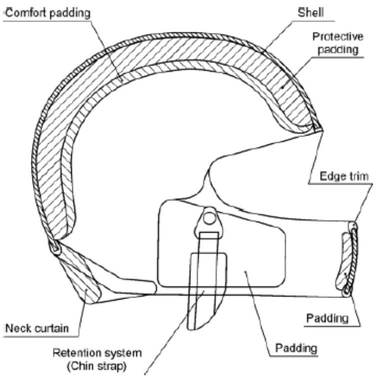

Chart-1: Internal components of Helmet

Above "Chart-1" shows the internal component of the Helmet according to the BIS standard. Our focus is on rider safety so we have concentrated on shell design and its optimization which can withstand the shear load in static and dynamic condition ensuring rider safety.

2. DESIGNING

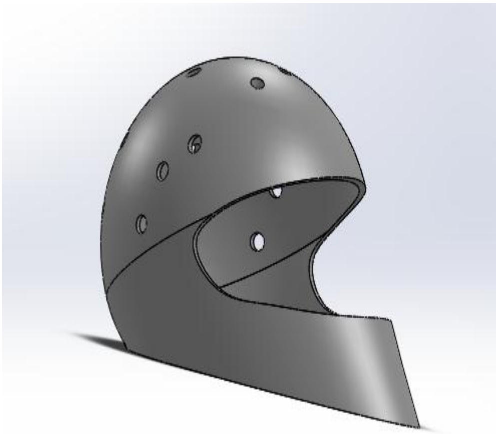

Chart-2: Solid modelling

Solidworks was used to model the shell of the helmet. The dimension was kept in such a way that it satisfies the BIS standards as shown in "Chart-3".

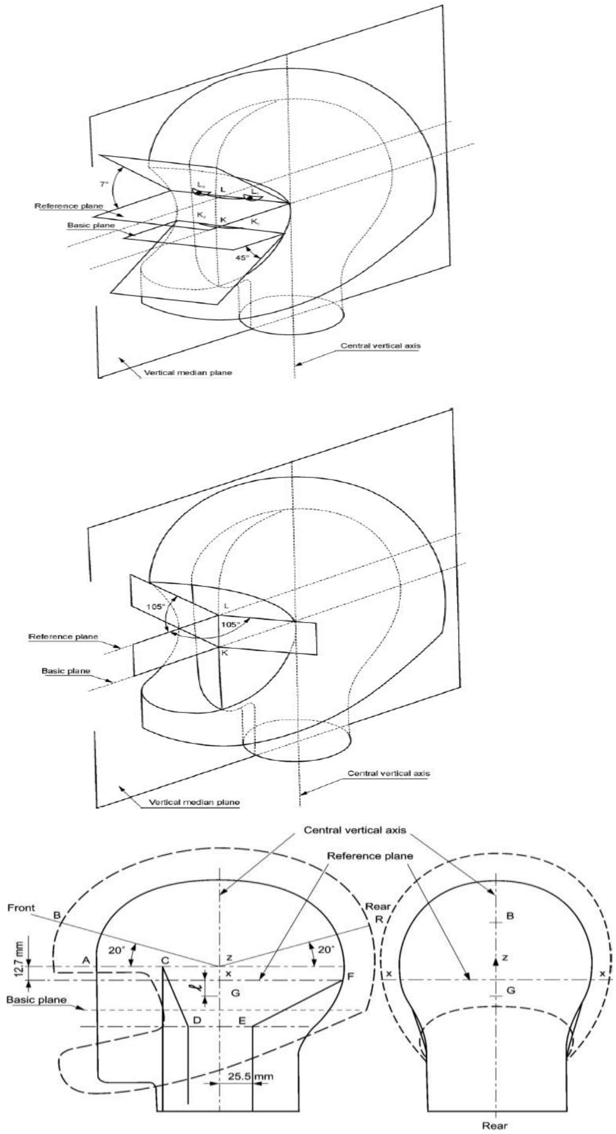

Chart-3: Design considerations as per BIS standard

3. MATERIAL USED

Table-1: ABS- Properties

Property	Minimum Value (S.I.)	Minimum Value (S.I.)	S.I. Units
Density	1.27	1.38	Mg/m^3
Elastic Limit	99.2	132	MPa
Young's Modulus	13.5	21.4	GPa
Poisson's Ratio	0.3182	0.3487	

Table-2: Polycarbonate properties

Property	Value (S.I.)	Units
Density	1.21	Mg/m^3
Yield Strength	6100	psi
Young's Modulus	380000	psi
Poisson's Ratio	3.5	

Table-3: Epoxy glass fibre

Property	Minimum Value (S.I.)	Minimum Value (S.I.)	S.I. Units
Density	2.55	2.6	Mg/m^3
Poisson's Ratio	0.21	0.23	
Elastic Limit	2750	2875	MPa
Young's Modulus	72	85	GPa
Thermal Conductivity	1.2	1.35	W/m.K
Thermal Expansion	4.9	5.1	$10^{-6}/K$

The "Table-1", "Table-2" and "Table-3" shows the properties of the material we have used in the analysis.

4. METHODOLOGY

Finite element analysis was done using ANSYS software in which different materials were analysed and material with best results were optimized so as to reduce weight. And thermal analysis was done so as to check the heat flux and the temperature drop along the material thickness and area with maximum heat flux were identified.

4.1 Strength analysis

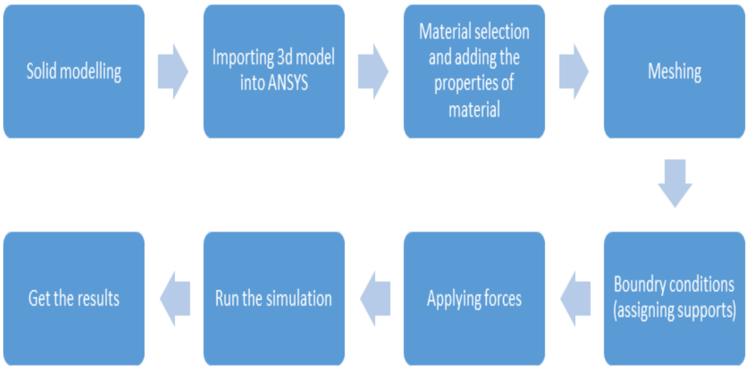

Chart-4: Steps for strength analysis

The solid model made was imported in ANSYS as a STEP file then different materials were used which were either directly used or the material properties were added as per the need of evaluation. Then the meshing was done which is a discretization process of diving the whole product into smaller elements and the governing equations are found for every element and the nodal results are represented in the results. So as to get the results the boundary conditions like the fixed support was given the base part of the helmet was fixed and the force was applied from the top and front so as to check the possible stress generation and so as to check the FOS. The 19.5 KN of force was applied as per the FMVSS 218 standard which has to be applied in all the direction (one direction at a time) so as to check the quality of helmet [1].

4.2 Thermal analysis

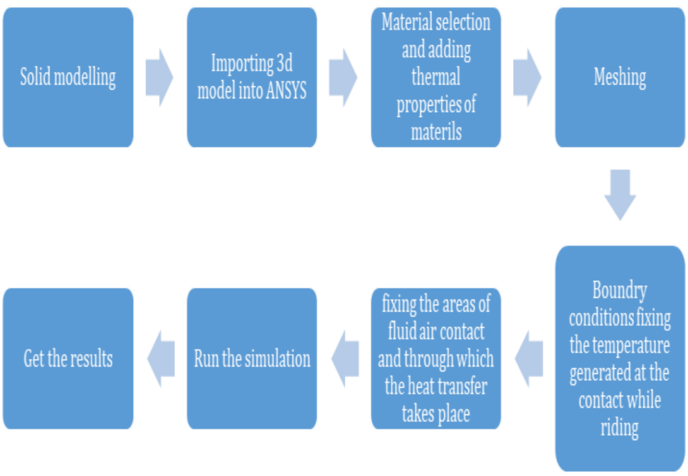

Chart-5: Steps for thermal analysis

The solid model made in SolidWorks which was finalized after the strength analysis was imported into ANSYS for thermal analysis. The material properties were inserted and meshing was done the boundary conditions like the internal surface temperature, ambient temperature and the surfaces which is in contact with air was mentioned so as for convection through those surfaces. After that simulation was done so as to solve the governing equation and then the results were drawn out for maximum heat flux and temperature drop across the thickness of the helmet.

5. RESULTS AND DISCUSSION

5.1 Strength analysis

5.1.1 ABS material

At first the helmet was made up of 10mm thickness and the ABS was used for the analysis. We got the FOS to be very less and the helmet will fail under the load of 19.5 KN on the top surface as shown in the "Chart-6".

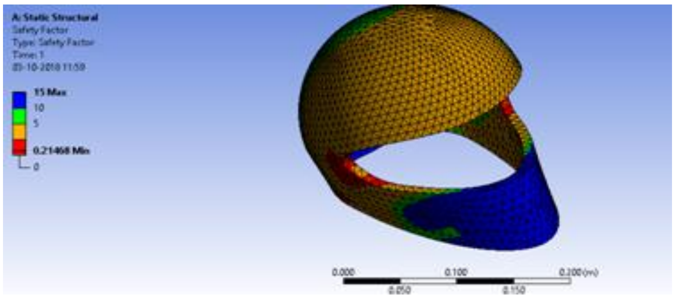

Chart-6: FOS for ABS material

5.1.2. Polycarbonate

Then the polycarbonate with 10 mm thickness was analysed under the 19.5 KN force on the top surface but the FOS was very low as shown in the "Chart-7" and hence this material also cannot be used since it will fail

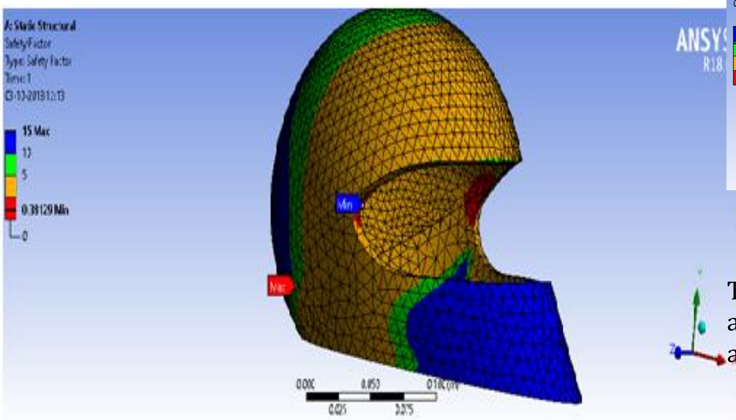

Chart-7: FOS for polycarbonate

5.1.3 Polycarbonate with 20% glass

When the polycarbonate with 20% glass with 10mm thickness was analysed for FOS it was observed very low as shown in the "Chart-8".

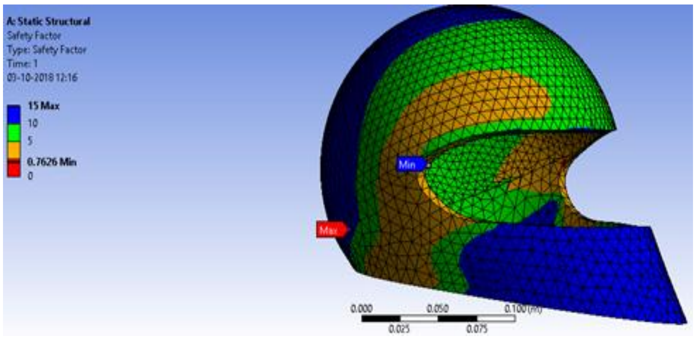

Chart-8: FOS for Polycarbonate with 20% glass

5.1.4 Epoxy Glass fibre

When the glass fibre was analysed with 10mm thickness the FOS was observed high as shown in the "Chart-9".

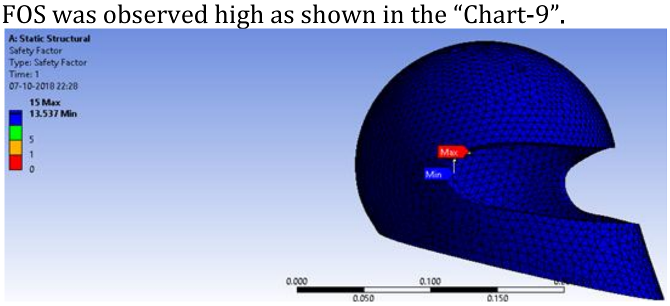

Chart-9: FOS for epoxy glass fiber

Since the FOS was observed high and so as to reduce the weight the thickness was reduced to 8mm and structural analysis was done.

We got the FOS to be decreasing as shown in the "Chart-10" but even after that the helmet was observed safe.

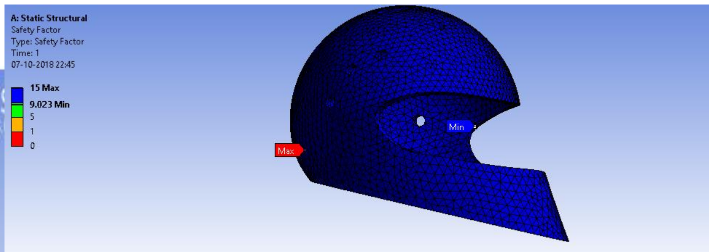

Chart-10: FOS of epoxy Glass fibre with 8mm thickness

The thickness was further reduced to 5mm and strength analysis was done even after that we got FOS around 4.7955 as shown in the "Chart-11".

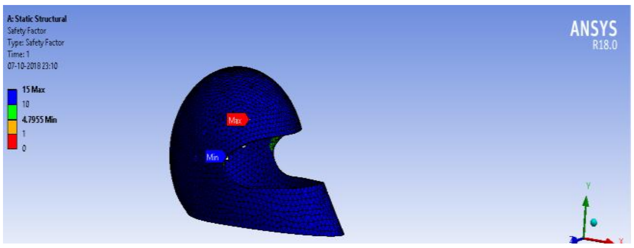

Chart-11: Epoxy glass fibre with 5mm thickness

The thickness was further reduced to 4mm and some fillets were added and strength analysis was done even after that we got FOS around 3.7992 as shown in the "Chart-12".

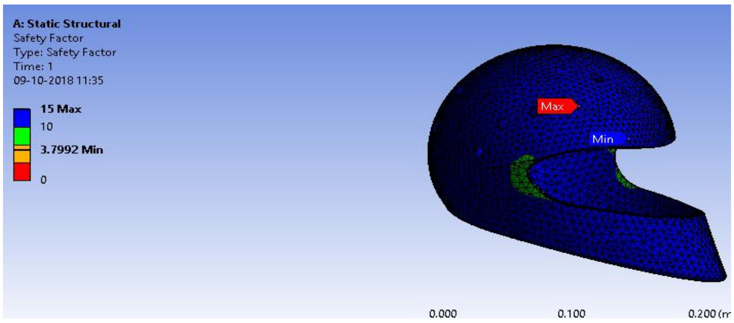

Chart-12: Epoxy glass fibre with 4mm thickness and fillets at the base

Then the front horizontal force was applied so as to protect the jaw and face of the rider as per the FMVSS the 19.5 KN was applied and we got the FOS as shown in the "Chart-13".

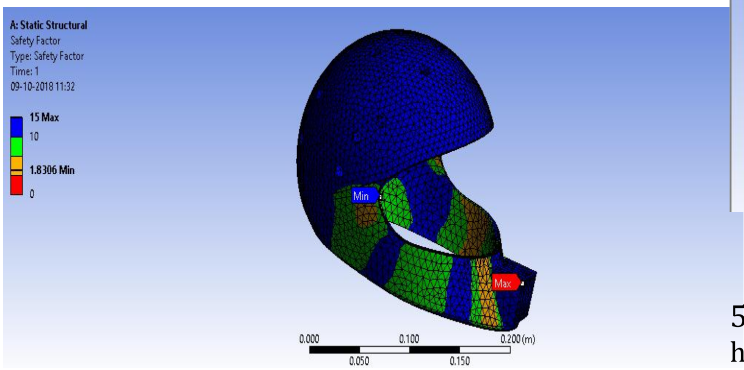

Chart-13: Epoxy glass fibre with 4 mm thickness during frontal horizontal force.

"Chart-13 "shows that the design was safe under all the conditions according to the standards.

5.2 Thermal analysis

For the convective heat transfer coefficient of 100 W/m²K and as we are sing thermal conductivity of E Glass fibre as 1.35 W/m-C and steady state, Ambient temperature as 22°C and head maximum temperature of 35°C as per the analysis done we got the following results as shown in the "Chart-14" and "Chart-15" of temperature distribution and heat flux respectively.

5.2.1 Thermal analysis of glass fibre with 4mm thickness without holes in the shell

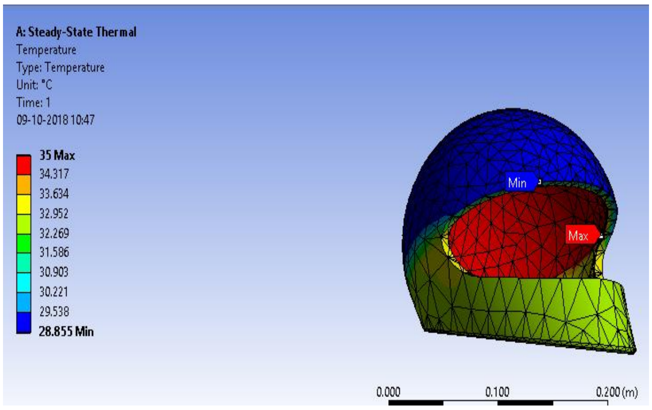

Chart-14: Temperature distribution

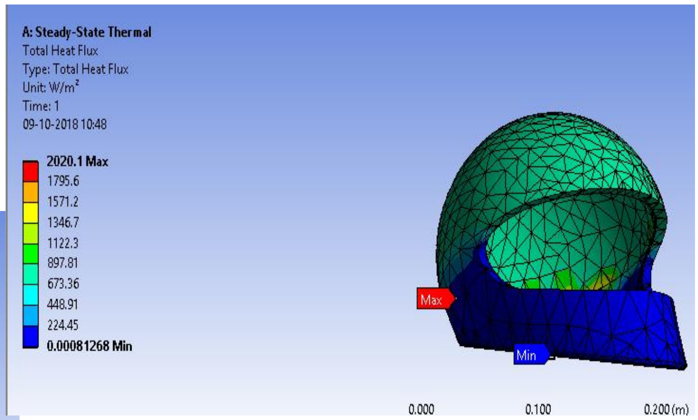

Chart-15: Heat flux

5.2.2 Thermal of shell with 4mm thickness and with holes

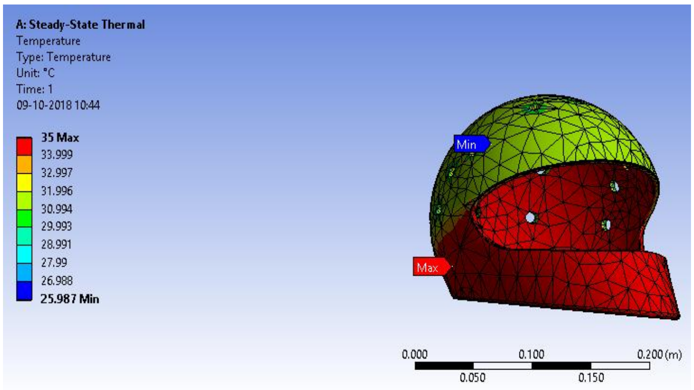

Chart-16: Temperature distribution

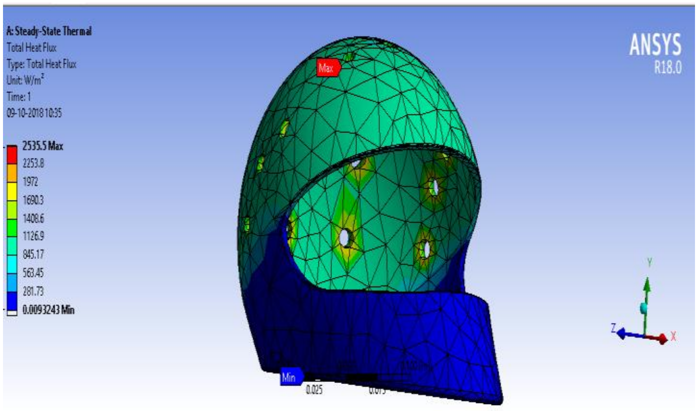

Chart-17 Heat flux

6. CONCLUSION

Different materials like Acrylonitrile butadiene styrene (ABS), Polycarbonate, Polycarbonate with 30% glass and epoxy glass fibre are analysed and their properties have been studied and the new design of the helmet has been made with 1mm fillet which was safer than those without fillet, the thickness and FOS of the helmet is optimized, final weight of the helmet is 980 grams. The 19.5 KN force was applied and the glass fibre with 4mm thickness and 14 holes was found to be safe under the condition required as per BIS standard. The FOS obtained was 3.799 when the rider meets the accident and the load is on the middle part of the helmet. FOS was 1.8306 when rider falls along his face. The thermal analysis is done and results show that without holes the temperature gradient was 7 degrees and the heat flux was 2020.1 W/m2 and when the holes were made the temperature gradient was increases to 10 degrees and the heat flux increased to 2535 W/m2, hence we can conclude that the heat transfer was improved by making the holes and the thermal comfort was increased.

REFERENCES

[1] Gandhi, V.S., Kumaravelan, R., Ramesh, S., Venkatesan, M. and Ponraj, M.R., 2014. Performance Analysis of Motor Cycle Helmet under Static and Dynamic Loading. Mechanics and Mechanical Engineering, 18(2), pp.85-96.

[2] Amit Waghmare and E. Rajkumar, 2016, "Application of Reverse Engineering and Impact Analysis of Motor Cycle Helmet",Indian Journal of science and technology,Vol 9(34)

[3] Pinnoji, P.K., Haider, Z. and Mahajan, P., 2008. Design of ventilated helmets: computational fluid and impact dynamics studies. International journal of crashworthiness, 13(3), pp.265-278.

[4] Bogerd, C.P. and Brühwiler, P.A., 2007. Heat transfer of full-face motorcycle helmets. ENVIRONMENTAL ERGONOMICS XII, p.208.

[5] Joshi, A.A., Gore, R.G. and Sundaram, K., 2014. Experimental Optimization of Thickness of Protective Padding for Two-wheeler Rider's Helmet. In Applied Mechanics and Materials (Vol. 612, pp. 139-143). Trans Tech Publications.

[6] Shishodia, B.S., Sikri, S., Sanghi, S. and Mahajan, P., 2018. Air flow, heat transfer and impact study of ventilated and non-ventilated full-face motorcycle helmet. International journal of crashworthiness, 23(2), pp.124-133.

[7] K Naresh, Y Ramdas, Sk.Habibul Rehaman, M Dushyanth,"Design of Helmet and Fracture Analysis to identify the Crack Formation", International Journal of Innovations in Engineering and Technology, vol-6, Issue no-4, pp- 27-30, 2016

[8]. Amal Thomas, Dr.P.Suresh , J. Anish Jafrin Thilak N.Subramani. "IMPACT ANALYSIS ON COMPOSITE HELMET BY USING FRC AND GLASS FIBER BY USING ANSYS." 2017. International Research Journal of Engineering and Technology (IRJET).

[9]. Pinnoji, Praveen K., Zafar Haider, and Puneet Mahajan. "Design of ventilated helmets: computational fluid and impact dynamics studies." 2008. International journal of crashworthiness13.3: 265-278.

[10]. Patel, Rajesh, and Dinesh Mohan. "An improved motorcycle helmet design for tropical climates."1993. Applied ergonomics 24.6 : 427-431.