Print ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Impact Scrutiny of a Glass Fibre Reinforced Polyester-Foam Sandwich Bike Helmet Using Fem

Karthigadevi Elangovan[1]*, Sohithanjan Gopisetty[2], Lokchandu Kummara[2]
[1]Technical Support Engineer, CAD Solutions, Coimbatore, Tamil Nadu.
[2]Deaprtment of Mechanical Engineering, Saveetha School of Engineering, Chennai, Tamil Nadu.
***Corresponding author: E-Mail: deviaerocrat@gmail.com, Tel: 09940657357**

ABSTRACT

In present days bike accidents are inevitable. Major bike crashes result in severe injuries or causes death to motor cyclist. Wearing bike helmet acts as a protector and reduces risk factor. The bike helmet should withstand high impact load, composite materials have that specialty. Now a day's composite materials are used in various applications mainly because of light weight, strength to weight ratio and design flexibility. Bike helmet is modeled in 3-D modeling software. A finite element analysis model is utilized to analyze dynamic responses at different impact velocities 40, 50, 60 km/hr and it is given in terms of impact load that faces helmet in all directions. The main aim of this paper is to attain a less weight helmet with a suitable material because it must be comfortable to the rider. To facilitate weight reduction the materials used are GFRP and PVC Foam as a composite laminates.

KEY WORDS: GFRP (Glass Fiber Reinforced Polyester), PVC (Polyvinyl Chloride), Impact load.

1. INTRODUCTION

The appliance of laminated composites are improved in all sorts of engineering applications especially in aerospace, sports, transportation and in marine also. A bicycle rider is tending have number of accidents and injuries due to high speed nature of motor cycles. Helmets are protective head gears wear by motorcycle riders for protection against injury in case of accident. They perform as face shields, provide ventilation and ear protection. Its main components are the shell and inner foam liner. The shell is usually hard and helps resist objects from piercing during impact thereby preventing direct injury on skull. The foam liner helps to absorb most of the impact energy. Most of the helmets are prepared from resins or plastics reinforced with fibers. Helmet protects bicycle rider head by absorbing mechanical energy and also protects against penetration. The structure and protective capacity are changed in high-energy impact. Besides energy-absorption capacity, their volume and weight are major problems that must be considered so as to reduce injury risk.

Normally, modern helmets are made from Acrylonitrile Butadine Styrene (ABS) plastics reinforced with glass or carbon fibres, fabric and foam interiors are placed in helmet to improve riders comfort .Its inner foam is soft, thick and conventionally made of expanded polystyrene foam (EPS) designed to cushion/crush on impact. Usually the outer shell is thin, hard and typically made of plastic or fibers such as fiber glass, polycarbonate, or Kevlar. FRP composites are described as multi-constituent materials that consists of reinforcing fibers rooted in a stiff polymer matrix. Thermosets are generally classified as a various range of polymers are used as the matrix to FRP composites. Examples of Thermosets are epoxy, polyester, etc. and for thermoplastics polyether-ether-ketone, olyamide resins. Generally, Glass-reinforced plastic or GRP is composite materials are made up of a polyester resin matrix and reinforced by thin fibers made of glass. Moreover, by applying compound layers of fiber on top of one another, each layer is stacked in various preferred directions, the stiffness and strength properties of the material is maintained. Mostly the plastic matrix permanently constrains the structural glass fibers to directions chosen by the designer. Composite materials have a significant number of failure modes, which probably is the reason that composite shells are able to absorb a greater section of the impact energy. Hence, a suitable material model should be used for them in FE models. Foam is defined as a cell based structure that has the capacity to deform at a relatively low stress level and absorb energy. The application of the foam is to prevent an object does not exceed a maximum acceleration limit.

2. MATERIAL PROPERTIES

For weight critical applications Glass Fiber reinforced Polyester composite material is selected. The Mass properties of the helmet are shown in Table.1. In this paper, shell is made of GFRP Sandwich laminates to improve the strength and reduces the weight. Material properties are given in Tables.2 & 3.

Table.1. Mass Properties of a helmet

Mass of Laminates/Kg	Volume/mm^3	Weight/ N
0.48	$4.7825e^5$	1950

Table.2. Properties of Glass fibre Polyester

Density/Kg/m^3	E_X/GPa	E_Y/ GPa	G_{XY}/GPa	G_{ZX}/GPa	μ_{XY}	μ_{ZX}
1620	14.02	4.5	2.03	1.93	0.245	0.165

Abbreviations. E_X, E_Y: Young's Modulus in X, Y direction; G_{XY}, G_{ZX}: Shear Modulus in X, Y, Z direction; μ_{XY}, μ_{ZX}: Poisson's ratio in X, Y, Z direction.

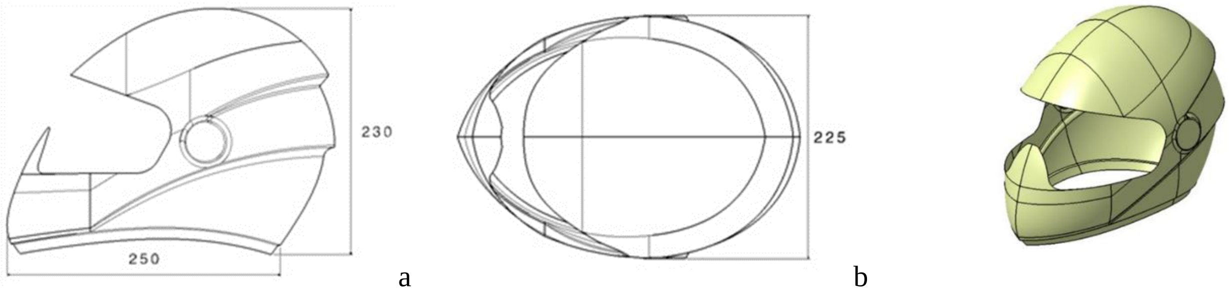
Table.3. Properties of Foam

Density kg/m^3	Poisson's ratio
80	0.3

Design of a Helmet: The 3-D Surface Model of a helmet is generated (Fig.1). The parameters of the helmet are shown in Figure.1a & b. The Surface thickness & layer thickness for the model is displayed in Table.4.

Table.4. Geometrical Parameters

Height/mm	Width/mm	Length/mm	Surface thickness/mm	Layer thickness/mm
230	250	225	3	10.44



a b

Figure.1. Surface model and its views of a helmet

Hybrid Composite Details: There are 11 layers of laminates are used to make a hybrid composite. Stackups are made up of a combination of PVC Foam and Glass Fiber reinforced polyester. The laminate layers are arranged in the orientation of 0° and 90°. It contains two layers of Glass Fiber Reinforced Polyester and one layer of Foam consecutively in order to built 11 layers. The layered section is shown in Fig.2.

Figure.2. Layered sections of a shell

Finite Element Analysis of Helmet: Finite element analysis method is used to predict stress acting on a helmet with an applied impact load. Speed is converted into Force by using Newton's Second Law of Motion shown in table.5,

$$F = ma \quad (1)$$

Velocity is converted into acceleration by using this formula,

$$a = \frac{dV}{dt} \quad (2)$$

$$a = \frac{V_1 - V_0}{t_1 - t_0} \quad (3)$$

Table.5. Speed Conversion

Speed /Km/hr	Force/N
40	278.63
50	348.11
60	418.08

Three different loading conditions are performed in this analysis, assume that,

Case-1: Left side of the helmet is fixed and Force is applied on opposite side.

Case-2: Front Side is fixed and Force is applied on Back side.

Case-3: Back side is fixed and Force is applied on Front side.

Deformation in Helmet: When a load or force is applied on the helmet it will get deformed. The deformation acting on a helmet with different loading condition for different cases is analyzed.

Case- 1 with different loading condition is shown in Fig.3. Case-2 with different loading condition is displayed in Fig.4. Case-3 with different loading condition is shown in Fig.5.

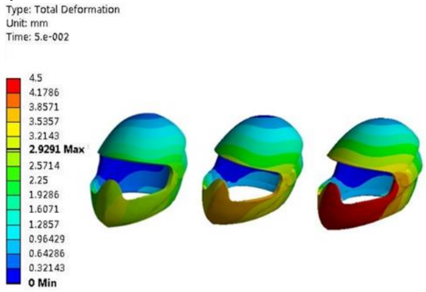
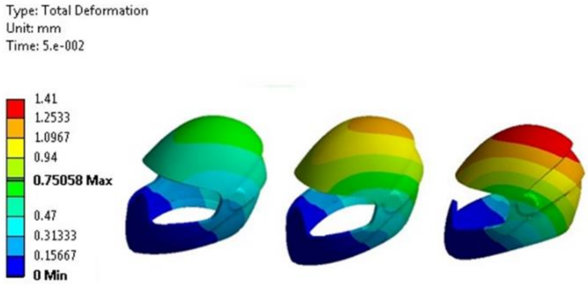


Figure.3. Deformation of different impact loads for case-1



Figutr.4. Deformation of different impact loads for case-2

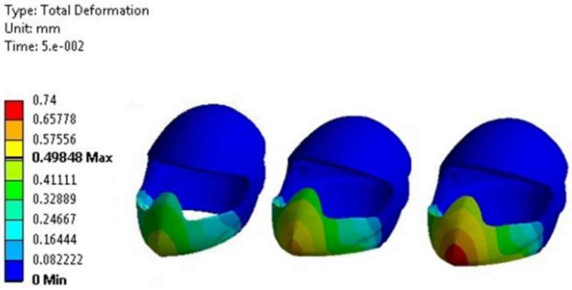


Figure.5. Deformation of different impact loads for case-2

Von-Mises Stress in Helmet: The Von-misses Stress is used to locate the resistance offered by the body. The stress acting on a helmet with different loading condition for different cases is analyzed.

Case- 1 with different loading condition is shown Fig.6. Case-2 with different loading condition is displayed in Fig.7. Case-3 with different loading condition is shown in Fig.8.

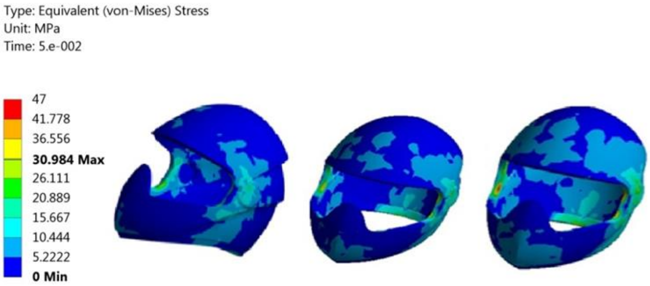


Figure.6. Von-Mises stress of different impact loads for case-1

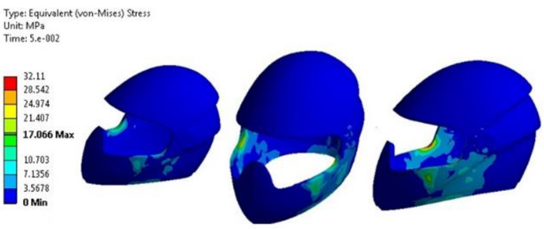


Figure.7. Von-Mises stress of different impact loads for case-2

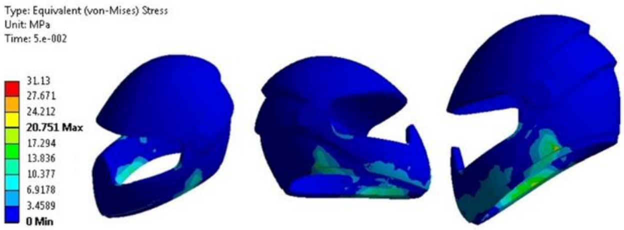


Figure.8. Von-Mises stress of different impact loads for case-3

3. RESULT AND DISCUSSION

The forces required to causing a particular injury are variable and very little quantitative information which exists about the magnitude of force, stress or strain that will cause a particular injury. The serious brain injuries will occur while hitting of a helmet on a road because of a contact between the helmet, head and the road surface. Three different loading conditions is performed for three different cases and their results deformation, stress, strain is shown in Table.6.

Table.6. Consolidate Simulation results of all cases

Cases	Impact Velocity/Km/hr	Total deformation/mm	Von-Mises stress/MPa	Von-Mises Strain/MPa
case 1	40	2.92	30.98	0.0036
	50	3.65	38.71	0.0046
	60	4.39	46.49	0.0553
case 2	40	0.75	17.06	0.0030
	50	1.17	26.03	0.0031
	60	1.41	32.11	0.0037
case 3	40	0.49	20.75	0.0027
	50	0.62	25.92	0.0034
	60	0.74	31.13	0.0040

Graphical representation of Total deformation and Von-Mises stress for case-1, case-2 & case-3 are shown in Figure 9 &10. In this representation we can find the difference in total deformation and Von-Mises stress for all cases.

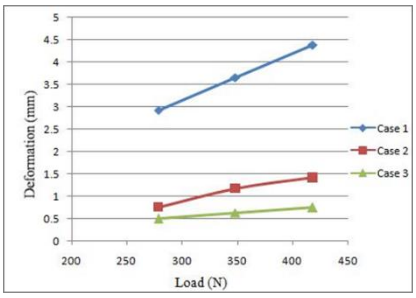


Figure.9. Load Vs Deformation

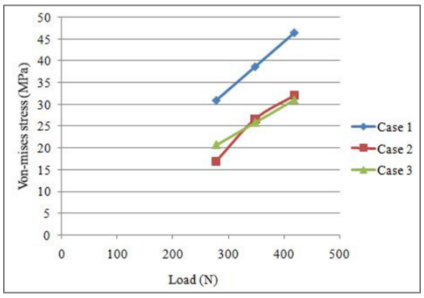


Figure.10. Load Vs Von-mises stress

Deformation of all the cases are plotted above, it shows that case-3 has less deformation so energy transfer to the head is high, which cause serious injuries.

4. CONCLUSION

From various case results it is stated that case-3 has absorbed less deformation. The head injury is very serious the rider meet an accident, in this case. Particular attention is required for a chin guard area, because a high proportion of the victims with head injuries continuous a fracture of the base of the skull, caused by a direct impact through the chin guard to the facial skull. So, special attention should be needed in front side of the helmet to reduce serious injuries.

5. ACKNOWLEGEMENT

We would like to express our thanks to Mrs. Ramya Deepak, Director, Dr.D. Dhanasekaran, Principal, Dr.G. Arukumar, HOD and Prof Pandian of Saveetha School of Engineering for encouraging us by providing facilities. Further we would like to thank Mr.J. Abdullah, CAD SOLUTIONS for this guidance.

REFERENCES

Afshari A, Rajaai S M, Finite element simulations investigating the role of the helmet in reducing head injuries, International Journal of Simulation modeling, 7 (1), 2008, 42–51.

Evans J.T and Gibson A.G, Composite angle ply laminates and netting analysis, The Royal society publishing, Proceedings of Royal society A, 458, 2028, 2002.

Gale A, Mills N J, Effect of Polystyrene Foam Liner Density on Motorcycle Helmet Shock Absorption, Plastics and Rubber Processing and Applications, 5 (2), 1985, 101– 108.

Gommers B, Determination of the Mechanical properties of composite materials by Tensile Test, Journal of composite materials, 32, 1998, 102 – 122.

Harding J and Welsh L M, A tensile testing technique for fibre-reinforced composites at impact rates of strain, J Mater Sci, 18, 1983, 1810–1826.

Harries K, Fatigue behavior of bonded FRP used for flexural retrofit, Proceedings of the International Symposium on Bond behavior of FRP in Structures, BBFS, 2005.

Irfan Sadaq S, Impact Test on Motor Cycle Helmet for Different Impact angles using FEA, International Journal of Engineering Trends and Technology, 12 (06), 2014.

Kingsbury H B, Rohr P R, Structure Characteristics of Motorcycle Helmets, Society of Automotive Engineers, Inc, No. 810372, 2014.

Kostopoulos V, Markopoulos Y P, Giannopoulos G, Vlachos D E, Finite element analysis of impact damage response of composite motorcycle safety helmet, J Compos Part B, 33, 2002, 99-107.

Lynn J C, Polymer composite characterization for automotive structural applications, Journal of Composites Technology and Research, 12 (4), 1990, 229–231.

Mauricio Donadon V, Brian Falzon G, Lorenzo Iannucci and John M Hodgkinson, A 3D micromechanical model for predicting the elastic behavior of woven laminates, Composites Science and Technology, 67, 2007, 2467–2477.

Mills N J, Gilchrist A, The Effectiveness of Foams in Bicycle and Motorcycle Helmets, Accident Analysis and Prevention, 23 (2–3), 1991, 153–163.

Nicolae Taranu, Gabriel Oprisan, Mihai Budescu, AlexandruSecu, IonelGosav, The use of glass fibre reinforced polymer composites as reinforcement for tubular concrete poles, Proceedings of the 11th WSEAS International Conference on Sustainability in Science Engineering, 2016.

Prasannasrinivas R, Chandramohan D, Analysis of natural fiber reinforced composite material for the helmet outer shell, International Journal of Current Research, 4 (03), 2012, 137-141.

Sathish Gandhi V.C, Kumaravelan R, Performance Analysis of Motor Cycle Helmet under Static and Dynamic Loading, Mechanics and Mechanical Engineering, Lodz University of Technology, 18 (0 2), 2014, 85–96.

Toma M, Njilie F E A, Ghajari M, Galvanetto U, Assessing Motorcycle Crash-Related Head Injuries Using Finite Element Simulation, Int.J. simul model, 9, 2010, 143 - 151.