

Finite Element Analysis of Protective Helmets using Different Material Parameters

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ABSTRACT: Numbers of road accidents are increasing as the number of vehicles are increasing in the roads. About 30% of the total road accidents accounts for the motorcycle accidents. Total deaths of such motorcycle riders are mostly due to inappropriate safety measures adopted by the riders and one of which is not using helmets or using faulty helmets. As per a statement by helmet manufacturer about 90% of total helmets in India use faulty helmets. This paper deals with the critical review of helmets that are available in the market and how are they performing to the standards of different testing scenarios. A comparative analysis has also been done taking four different materials and analysing how they perform on a similar loading condition. The main purpose of this paper is to give an insight on how the materials perform on given conditions and which will be a comparatively better option to be chosen.

KEYWORDS: Helmet, Crash Test, Motorcycle Accident, FEM, Ansys, PEEK, Polycarbonate, Polyester, PPA.

I. INTRODUCTION

Helmet is a protective gear used to wear on head when doing some hazardous work. Helmets are used while riding motorcycles, industry works, construction works etc. a helmet generally consists of a shell of a very hard and tough material which is covered by certain padding for shock absorption and comfort. In order to understand basic structure of helmets we must know some of the basic definitions and terminologies used in helmets.

1. Two Wheeler-A two wheeler can be defined as a two wheeled motor vehicle with or without detachable side car. General term used for this is Motorcycle.
2. Protective Helmet-A helmet primarily intended to protect the wearer's head against impact. A helmet is a type of safety measures used in various sections of the dangerous segments of use. A helmet is used in different sectors such as road safety as a safety gear while two wheeler driving, industrial work etc.
3. Shell-It is the most rigid part of the helmet which gives its general shape. A hard part of the helmet, which provides the strength and toughness, to the whole of a helmet structure.
4. Protective Padding-Protective padding is a soft material placed to absorb the impact shocks and its energy. As the name suggests it protects the head of the person who is wearing the helmet through shock reduction through its soft padding.
5. Comfort Padding-The material is similar in nature to the protective padding; this type of padding is provided to provide comfort to the person who is wearing it. To provide comfort is the whole sole purpose of this type of padding.
6. Retention System-A system which keeps the helmet and head at a stable position is called retention system. It includes devices which are there for adjustment of the system or comforting the person who is wearing it.
Chin Strap-It is a strap which is placed under the jaw to support the chin for proper stable position of the head.
Chin Cup-It is a cup like structure in the chin strap which holds the chin for proper position.

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Peak-Peak is an extension of the shell which is covered throughout the helmet.

Lower Face Cover-It is an integral, detachable and movable part of the helmet which covers the lower part of the face.

Protective Lower Face Cover-It is an integral, detachable and movable part of the helmet which covers the lower part of the face which is intended to protect the chin of the rider from impact.

Non Protective Lower Face Cover-It is an integral, detachable and movable part of the helmet which covers the lower part of the face and it does not protect the chin of the rider from impact.

7. *Visor*-Visor is that transparent part of the helmet through which a rider is able to see. It is a protective screen for the eyes.

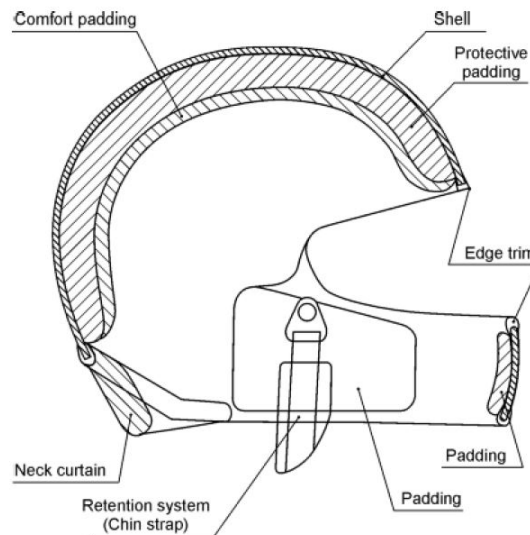


Fig.1 Construction of a Helmet

II. REVIEW OF HELMETS USED ACROSS THE WORLD

There are several organisations which do test the helmets using different criteria, few of the global leaders of the helmet testing lab are DOT, SNELL, ECE, SHARP, crash etc. In this review we are using the data from CRASH testing lab.

RANK	HELMET	MATERIAL	WEIGHT
1	Shark Explore-R	Shark Composite Material	1.783 kg
2	Shoei X-Spirit III	Fibreglass and Polyester resin	1.350 kg
3	Shoei GT-Air (UNECE Reg 22)	Fibreglass reinforced Polyester resin	1.426 kg

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4	SparX S-07	Acrylonitrile Butadiene Styrene (ABS)	1.644 kg
5	LS2FF323 Arrow	Fibreglass	1.668 kg
6	HJC FG-17	Fibreglass + polyester resin	1.618 kg
7	Shark Evoline	Composite Material	1.807 kg
8	Shark Vision R	NA	1.695 kg
9	HJC IS-16	Polycarbonate Composite	1.703 kg
10	Zeus ZS-2100B	Acrylonitrile Butadiene Styrene (ABS)	1.737 kg

Table 1. Rankings of Helmets by CRASH testing lab

From the above table it is clear that this data shows that composites are widely used and is very responsive as the needed quality of helmet is concerned. This is followed by some polyester resins and then fibreglass, Acrylonitrile Butadiene Styrene and Polycarbonate is somewhere in between the line.

III. DESIGNING AND MATERIAL PROPERTIES

Designing of the model has been done in CATIA with a shell thickness of 1mm and head diameter of 170mm. the actual idea of this design is to check the performance of different materials under same loading conditions and design. This will provide us a comparative idea of the materials and their suitability.

PROPERTY	PEEK	POLYCARBONATE	POLYESTER	PPA
Density(kg/m ³)	1310	1200	1400	1100
Young's Modulus (Pa)	3.6 e+009	2.4 e+009	4.41 e+009	2.2 e+009
Poisson's Ratio	0.3779	0.37	0.33	0.4
Bulk Modulus (Pa)	4.914 e+009	3.0769 e+009	4.3235 e+009	3.6667 e+009
Shear Modulus (Pa)	1.3063 e+009	8.75 e+008	1.6579 e+009	7.8571 e+008
Tensile Yield Strength	1.1032 e+008	6.55 e+007	5.5861 e+007	6.9 e+007
Compressive Yield Strength (Pa)	1.379 e+008	8.27 e+007	2.588 e+009	0
Tensile Ultimate Strength (Pa)	3.4474 e+009	2.2063 e+009	1 e+008	2.0684 e+005
Compressive Ultimate Strength (Pa)	3.4474 e+009	1.6547 e+009	3.0002 e+0010	0

Table 2. Properties of PEEK, Polycarbonate, Polyester and PPA material

The designing of the model given below in the figure has been designed in CATIA. The main purpose that the design serves is to be tested upon loading conditions and their variations when the material parameter changes. The design given below is a testing model that has been created by taking accounts of the actual designs of the helmets that are being used in today's world.

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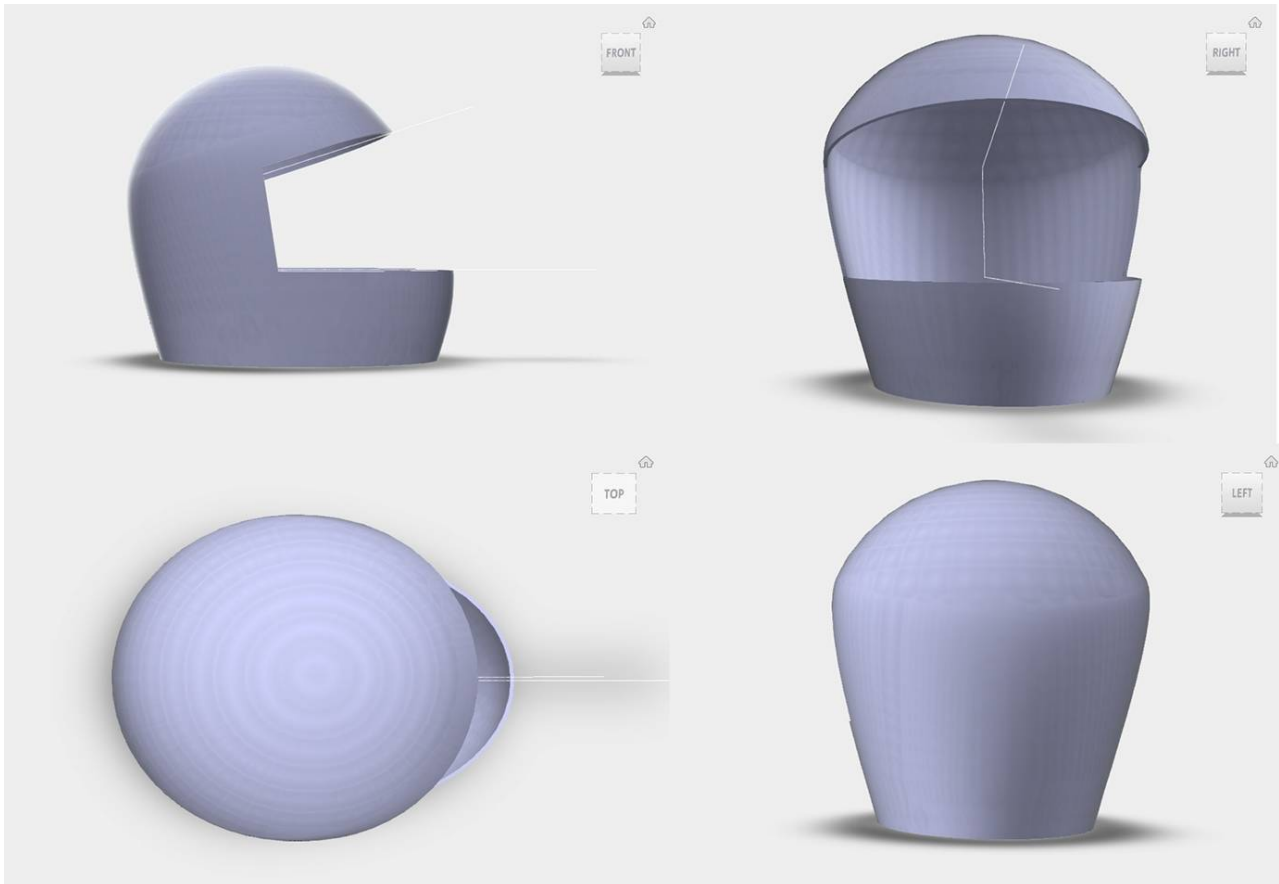


Fig.2. Different views of the model

IV. EXPERIMENTAL RESULTS

After analysing the model of our helmet we need to study the results that have been observed through the analysis. The analysis was done on ANSYS 17 for deformation and stress for four different types of material which are Polyether ether ketone (PEEK), Polycarbonate, polyester, and Polyphthalamide (PPA). This analysis will give a comparative aspect on the performance of the four materials.

The figure below is the analysis result for PEEK material. The fig.3 (a) shows the stress generated in the model when a load of 200N was applied. The maximum stress observed was 14314 Pa and the minimum stress was 1.0584×10^{-16} Pa. When we talk about the deformation of the body in fig.3 (b), the maximum deformation was 1.0747×10^{-8} m and the minimum deformation was 0 m.

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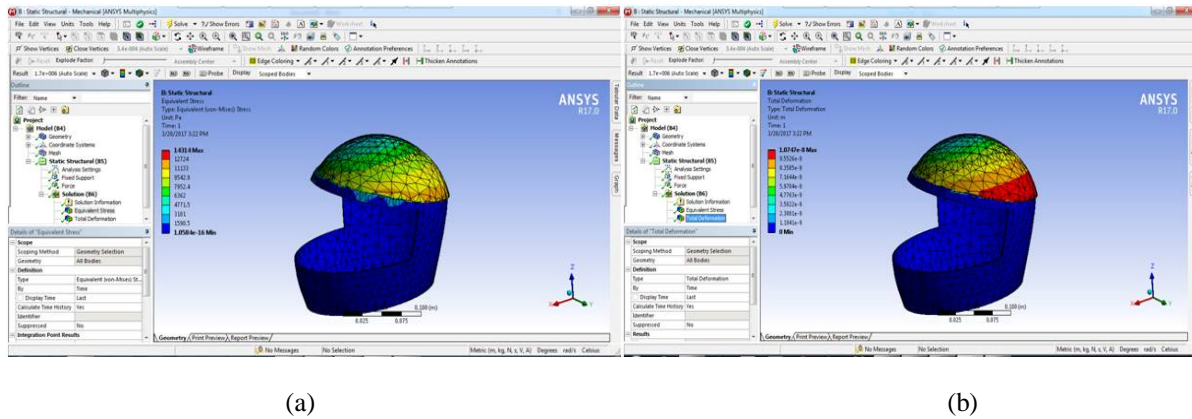
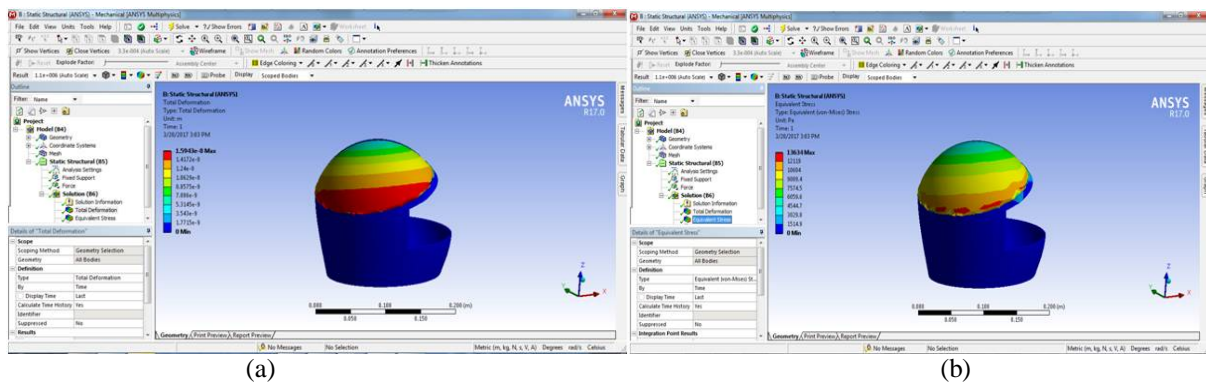


Fig.3. Stress and Deformation report of PEEK material

Then after doing the analysis for PEEK material we changed the material parameters as of Polycarbonate material. The maximum and minimum stress observed was 13634 Pa and 0 Pa respectively which is given in fig. 4(a). The deformation result was 1.5943 e-8 m for maximum value and 0 mm for the minimum value, fig. 4(b) shows the result for deformation.



(b) Fig.4. Stress and Deformation report of Polycarbonate material

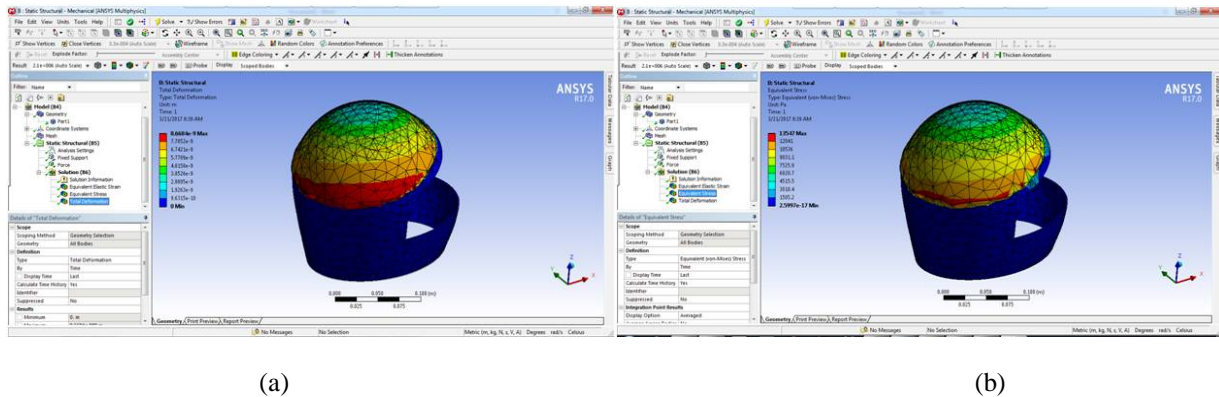
The third material that we analysed was polyester. The stress results as shown in fig. 5(a) is 13547 Pa for maximum stress and 2.59997 e-17 Pa for minimum stress, the results for deformation was 8.6685 e-9 m for maximum value and 0 m for minimum value.

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Vol. 6, Issue 5, May 2017



(b) Fig.5. Stress and Deformation report of Polyester material

The last material that we analysed was PPA. The maximum stress observed was 13546 Pa and the minimum was 2.1924×10^{-16} Pa, for the deformation the maximum value was 1.0877×10^{-8} m and minimum value was 0 m as described in fig.6 (a) and (b).

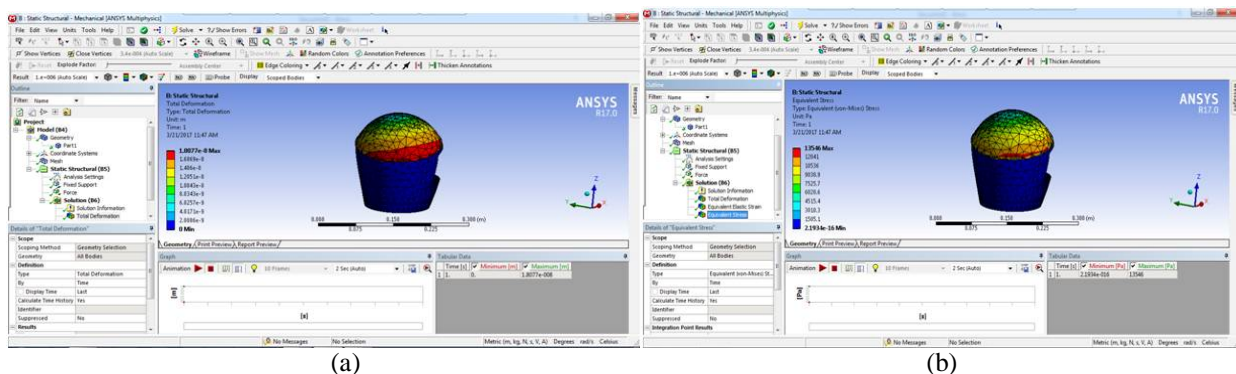


Fig.6. Stress and Deformation report of PPA material

The compilation of all the above results has been tabulated below and has been discussed in the conclusion section of this paper.

MATERIAL	STRESS (Pa)	DEFORMATION (m)
PEEK	14314	1.0747×10^{-8}
POLYCARBONATE	13634	1.5943×10^{-8}
POLYESTER	13547	0.8668×10^{-8}
PPA	13546	1.8077×10^{-8}

Table 3. Stress and deformation result of the four different materials used

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Vol. 6, Issue 5, May 2017

V. CONCLUSION

In this paper we reviewed and analysed about different type of materials and models for deformation and stress test in order to get results for better performance characteristics. The analysis we did for 4 different materials, the highest stress observed was for PEEK material (Polyether ether ketone) and the lowest was for PPA (Polyphthalamide) and the deformation that we observed was highest in PPA (Polyphthalamide) and lowest in polyester. From the above condition we can state that the materials which were imparted to a minor load of 200N was to just check on to the performance of the materials and their deformation, the important aspect for a helmet is its deformation against the applied load. The minimum deformation observed was of the polyester material amongst the tested four materials and implies to be a better suitability for the use as helmets.

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