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# Design and Impact Analysis of Motorcycle Helmet Using Composite Material

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**Abstract—***A helmet is a protective layer thatprevents head injuries during accidents. The impact energy absorption of motorcycle helmet is of critical importance to the survival of the motorcyclist during an accident. To safeguard the human life and to avoid sufferings and losses due to road casualties, the mechanical properties of the helmets must withstand the stresses during accidents hence the helmets as per standard IS-4151 has become mandatory. The use of composite materials in helmet applications has exponentially increased because of their better mechanical properties like impact strength, penetration resistance etc. In this paper FTIR, TGA and Mechanical tests (Tensile and Impact) are done on existing helmet's core shell samples. The purpose of this research is to develop a composite of Acrylonitrile Butadiene Styrene (ABS) and Carbon Fiber (CF) at different ratios to make the material for outer shell of helmet, afterwards the preparation of specimens for further analysis is done by suitable moulding method. Mechanical test such as Impact and tensile analysis were performed on the prepared samples along with the SEM analysis to study the morphology. The results of these testsarecompared with already existing helmet samples results and used to perform at simulated real loading conditions ondeveloped helmet model through ANSYS software.*

**Index terms***: Helmet, Impact analysis, Stress, Strain, Deformation, Epoxy, nylon6, ABS (Acrylonitrile butadiene styrene), CF(carbon fiber),composites of ABS and Carbon Fiber .*

## 1. Introduction

A helmet is a form of protective gear worn on the head to protect it from injuries. Helmets are widely used by twowheeler riders to protect their head during the accidents or falls. The Motorcycle helmets have a hard-outer shell that prevents penetration and distributes the impact force on a wider foam area, increasing the liner capacity to absorb energy and therefore reduce the load that reaches the head. Beside their energy-absorption capability, their volume and weight are also important issues, since higher volume and weight increase the injury risk for the user's head and neck. Helmets used for different purposes have different designs. For example, a bicycle helmet must protect against blunt impact forces from the wearer's head striking the road. A helmet designed for rock climbing must protect against heavy impact, and against objects such as small rocks and climbing equipment falling from above. Practical concerns also dictate helmet design: a bicycling helmet should be aerodynamic in shape and well ventilated, while a rock-climbing helmet must be lightweight and small so that it does not interfere with climbing. The Assyrian soldiers in 900BC used to wore thick leather or bronze helmets to protect the head from blunt object and sword blows and arrow strikes in combat. Soldiers still wear helmets, now often made from lightweight plastic materials. Since the1990s, most helmets are made from resin or plastic, which may be reinforced with fibers such as aramids. Here we will compare the properties of already existing materials used for making helmets core shell with our prepared samples through impact test and with the FEA results using ANSYS.

## 2. Material Identification and Composition

- **Fourier Transform Infrared Spectroscopy (FTIR)**

Material identification for comparison is done by FTIR it is a powerful tool for identifying the types of chemical bonds in organic and inorganic molecule by producing an infrared absorption spectrum that is like a molecular fingerprint. It is a very simple technique and is widely used for analysis and determination of plastics structure. The materials identified from FTIR are: -

**Figure 1. Nylon 6 (Sample 1)**

**Figure 2. Epoxy (Sample 2)**

- **Thermogravimetric Analysis (TGA)**

To determine the amount of filler content of existing samples Thermogravimetric Analysis (TGA) is done which will provide the exact amount of pure materials in the sample.

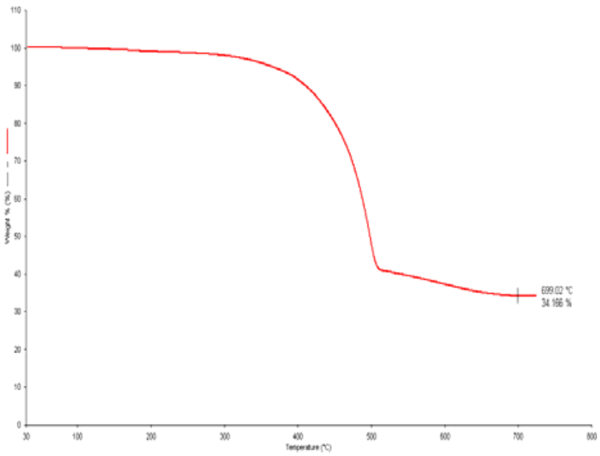

**Figure 3. Nylon6**

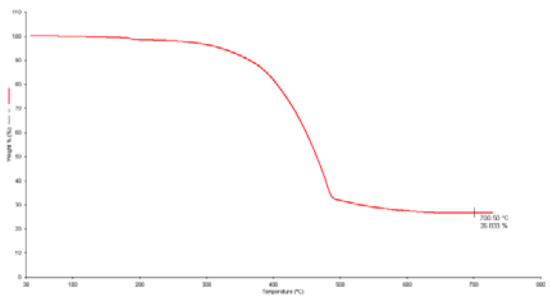

**Figure 4. Epoxy**

From the TGA results it is found that both the existing samples for the coreshell of helmets are not pure Nylon 6 has 34.16%fillers and Epoxy has 26.83%.

**3. Selection of Materials for Composite**

Types of materials used to make composite for core shell of helmetsare: -

- ACRYLONITRILEBUTADIENE STYRENE(ABS)
- CARBON FIBER(CF)

The composite of abs and cf is prepared at different ratios here abs is matrix material and carbon fiber is reinforcing material.

**4.Matrix Materials and Processing**

ABS copolymer (ABSTRON MIF45) was obtained from ANOOPAM INDIA Pvt ltd, New Delhi and Carbon Fiber (CF) spool of 6µm diameter was obtained from composite tomorrow, Vadodara.

The carbon fiber spool was cut into 1 to 2 mm fine fibers with the help of scissor, we can cut these fibers with the help of electronic fiber cutting machine also if available. Mixture batches of 5, 10 and 15 wt% CF and ABS were prepared. Next, these batches were pre-dried into a oven at 80$^{o}$C for 2 hours to remove any moisture content. After that the batches are one by one compounded into twin screw extruder with following setting:

**Table 1. TSE temperature of each zone**

| | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|---|
| Temp. ($^{o}$C) | 220 | 230 | 240 | 250 | 260 |

**Screw Speed:40 RPM**

The extrudate so formed is converted into pallets using palletiser. Next these pallets are used to make test specimen with the help of compression moulding machine at 250$^{o}$C and 100 psi for 10 minutes and then cooling. After that the specimen were shaped using contour cutter.

**5.SEM Analysis**

SEM analysis is done to study the morphology of samples prepared and to check distribution of fibersthrough the matrix. Since we have three different samples the distributions observed are :-

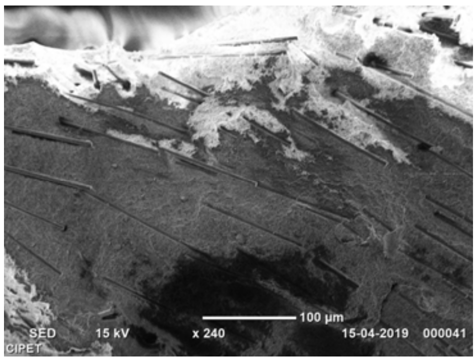


**Figure 5. ABS +5%CF**


**Figure 6. ABS +10%CF**

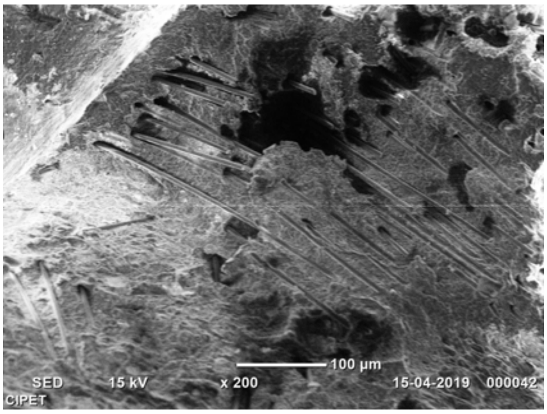


**Figure 7. ABS+15%CF**

From the figure results it can be seen that as we increase the percentage of fiber in the matrix the number of fibers in per unit volume of the matrix increases which causes increased interaction of polymer matrix and fiber reinforcement which is evident from test results as the tensile strength of the material is increased with increase in fiber.

## 6. Testing

### Mechanical Impact Testing (ASTM D 256)

This test is done to check the ability of material toresist the fracture under stress applied at high speed.

Specimendimensions(64.5mm*12.7mm*3.2mm),notch(2.54mm).

**Table 2. Physical properties of different material**

| **Material** | **Density ($g/cm^3$)** | **Izod strength (j/m)** | **Tensile Strength (MPa)** |
|---|---|---|---|
| NYLON6 | 1.18 | 26.23 | 48 |
| EPOXY | 1.5 | 38.54 | 27 |
| ABS+5%CF | 1.065 | 46.48 | 64.3 |
| ABS+10%CF | 1.09 | 50.23 | 77.5 |
| ABS+15%CF | 1.12 | 53.46 | 88.9 |

From the above results it is found that the composite materials prepared(at 15%cf) has more ability to resist the fracture under stress applied at high speed thanalready existing materials of core shell of motorcycle helmets available in market.

## 7. Design and Analysis of Helmet

In the present work impact analysis is performed on helmet by using ANSYS software. The model of helmet is prepared in SolidWorks software and it is imported in ANSYS software to perform analysis. Analysis is performed with five different materials i.e. nylon6,epoxy and composite of ABS/CF at different ratiosto predict the suitable material for replacing the existing materials for core shell of helmets. The dimensions are taken from the predefined standards for the manufacturing of helmets. The shell portion of the helmet is taken into consideration during analysis as it is the part exposed to the outer environment. A set of estimated results are found out by using the analysing software.

For designing a helmet model, the standard designing parameters are followed. .

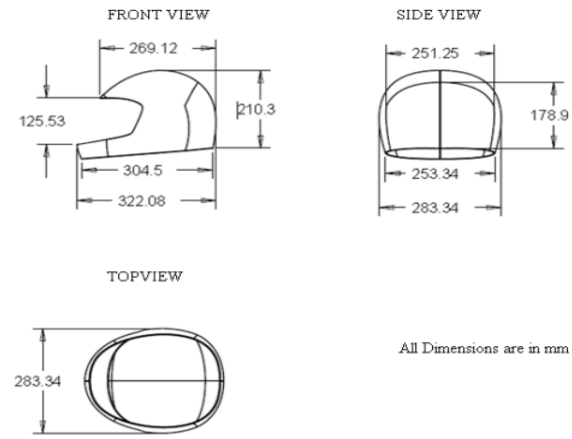


**Figure 8. Standard dimension of helmet**

Here are some of the figures showing equivalent stress developed on core shell of helmet at 80 km/h speed.

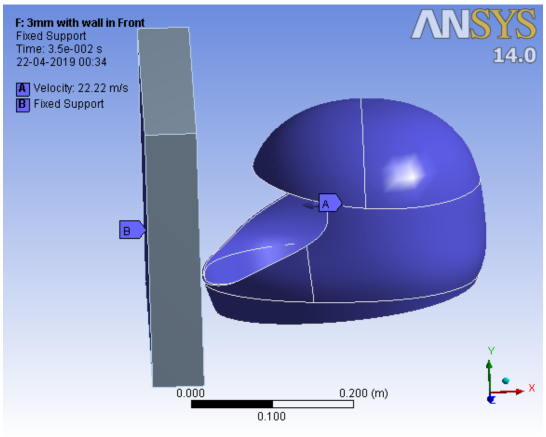


**Figure 9. Analysis condition in ANSYS**

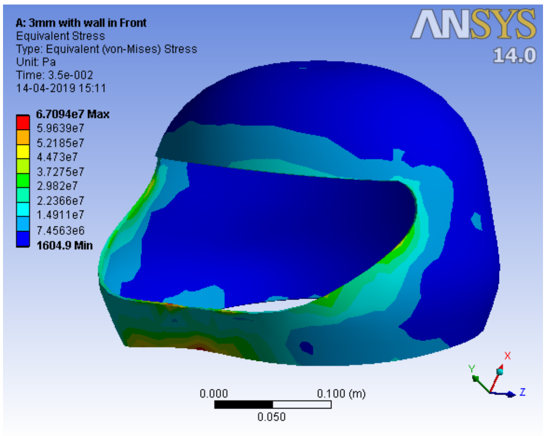


**Figure 10. Equivalent Von Mises Stress Nylon at 80 km/h from front**

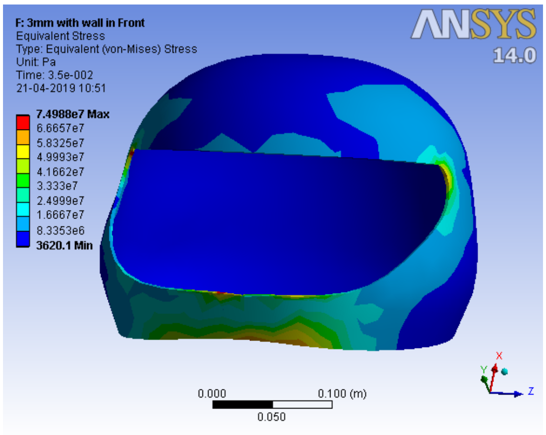


**Figure 11. Equivalent Von Mises Stress epoxy at 80 km/h from front**

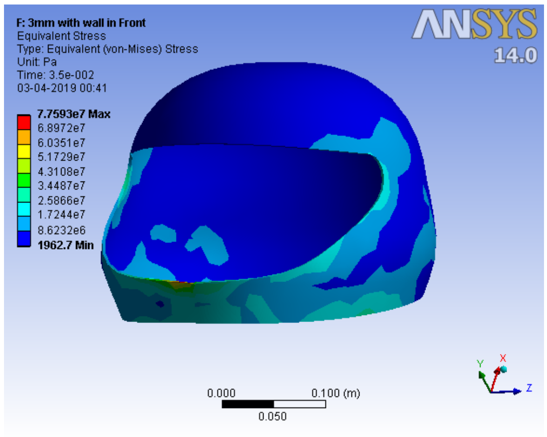


**Figure 12. Equivalent Von Mises Stress of ABS + 5%CF at 80 km/h from front**

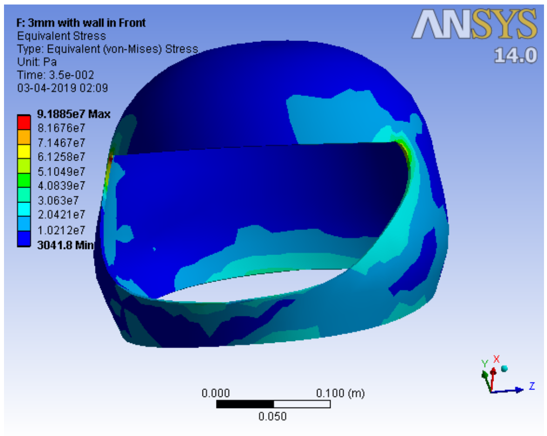


**Figure 13. Eq. Von Mises Stress of ABS+ 10%CF at 80 km/hfrom front**

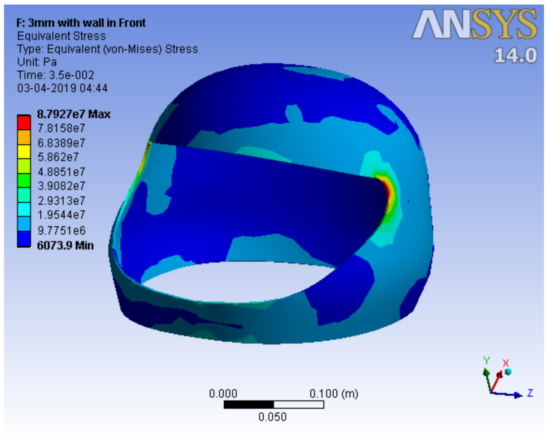


**Figure 14. Eq. Von Mises Stress of ABS+ 15%CF at 80 km/hfrom front**

The most common injury in car and motorcycle accidents is head injury. The comparison of von misses stresses, strain and deformations of nylon6,epoxy and composites of ABS/CF at different ratios at 80km/hr in front and side directions is presented. Depending on the results, prediction of suitable material for helmet is made. This provides a rough estimation for the material properties and its impact resistant values. The comparison is based on analysis done using ANSYS software. The ANSYS Parametric Design Language (APDL) is used to do the meshing. The constants, material properties are defined in this stage. Also the application of loads and the boundary conditions are properly checked to get effective results**.**

## 8. Results

- **Design Analysis**

**Table 3. Analysis result of collision from Front at 80 km/h**

| Materials | Stress (MPa) | Strain | Deformation(m) |
|---|---|---|---|
| Nylon6 | 67.09 | 0.043175 | 0.21077 |
| Epoxy | 74.988 | 0.033465 | 0.23551 |
| ABS+5%CF | 77.59 | 0.0151 | 0.20011 |
| ABS+10%CF | 91.88 | 0.0127 | 0.1752 |
| ABS+15%CF | 87 | 0.009 | 0.1351 |

**Table 4. Analysis result of collision from Side at 80 km/h**

| Materials | Stress (MPa) | Strain | Deformation (m) |
|---|---|---|---|
| Nylon6 | 40.086 | 0.022021 | 0.76578 |
| Epoxy | 58.417 | 0.32125 | 0.76357 |
| ABS+5%CF | 92.6 | 0.0209 | 0.65 |
| ABS+10%CF | 84.2 | 0.0144 | 0.63 |
| ABS+15%CF | 87.6 | 0.0112 | 0.21 |

**Table 5. Physical properties of Helmet core shell**

| Helmet Properties | | |
|---|---|---|
| Material | MASS(kg) | VOLUME($m^3$) |
| Nylon6 | 0.70632 | 5.9858 X $10^{-004}$ |
| Epoxy | 0.89787 | 5.9858 X $10^{-004}$ |
| ABS+5%CF | 0.63749 | 5.9858 X $10^{-004}$ |
| ABS+10%CF | 0.65246 | 5.9858 X $10^{-004}$ |
| ABS+15%CF | 0.67041 | 5.9858 X $10^{-004}$ |

## 9.Conclusion

1. From the results of impact analysis (Table 2) it is found that composite of ABSandCF has more ability to resist the fracture under stress applied at high speed than already existing materials of core shell of motorcycle helmets available in market(nylon6 and epoxy)
2. Composite of ABS and CF is better when compared to existing samples of nylon6 and epoxy in terms of stresses developed. Hence the shell part if manufactured with composite will be able to withstand large stresses as compared to nylon6 and epoxy. Composite of ABS and CF is also better than virgin abs in terms of strain and deformations occurred during colliding. Hence this material can be employed to provide lesserdeformations during accidents than existing models like nylon6 and epoxy.
3. From table 5 it is found that the weight of composite materials for making the core shell is less as compared to the weight of core shell prepared from nylon6 and epoxy available in market.

## 10.Acknowledgement

First of all I would like to take this humble opportunity to express my deep sense of appreciation to almighty god for his generous blessings and the undying strength bestowed upon me during this research project

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