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Motorcycle's Helmet Design

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***Abstract*— More than 80 percent of all motorcycle crashes result in injury or death to the motorcyclist. Per mile driven, a motorcyclist is 16 times more likely to die in a crash than an automobile driver. Wearing a motorcycle helmet reduces that risk by almost one-third (29 percent). Wearing a helmet is the single most critical factor in preventing or reducing head injuries among motorcycle drivers and passengers. First, about half of all serious motorcycle accidents happen when a car pulls in front of a bike in traffic. These accidents typically happen at very low speeds, with a typical impact velocity, after all the braking and skidding, below 40 kmph. Actual crash speeds are slow, but the damage isn't. The energy is proportional to the height from which the rider falls—not his forward speed at the time. A high-speed crash may involve a lot of sliding along the ground, but all modern full-face helmets do an excellent job of protecting you from abrasion. Helmets hit a flat asphalt surface (75-85%) Helmets do hit curbs a small percentage of the time, but usually after sliding along on the road first. The aim of this study is to find the Vibrational deformation using a motorcycle helmet including different material. The material considered for the analysis are polycarbonates and polypropylene is most commonly used engineering material but having certain limitations and to overcome those we have taken an alternative material for design and analysis point of view i.e. carbon fibre. The most commonly used materials for motorcycle helmet are Fiber reinforced plastic, Polypropylene and other plastic materials out of which find that the carbon fibre is best suited for helmet material for high impact of helmets this result shows that the helmet deformation was higher with the polypropylene material with maximum frequency, while helmet constructed via carbon fiber had less deformation rate with less frequency The comparison of material also shows the reflection of the above three points that carbon fibre can be better and best suited for helmet design and analysis.**
Keywords—*Deformation, Reinforced.*

I . Introduction

A. Origin of Helmet

The origins of the crash helmet date back to the Brooklands race track in early 1914where the medical officer, a Dr Eric Gardner, noticed he was seeing a motor cyclist with head injuries about every 2 weeks. He got a Mr Moss of Bethnal Green to make canvas and shellac helmets stiff enough to stand a heavy blow and smooth enough to glance off any projections it encountered. He presented the design to the Auto-Cycle Union where it was initially condemned, but they later converted to the idea and made them compulsory for the 1914 Isle of Man TT races, although there was resistance from riders [1].

Gardner took 94 of these helmets with him to the Isle of Man, and one rider who hit a gate with a glancing blow was saved by the helmet. Dr Gardner received a letter later from the Isle of Man medical officer stating that after the T.T. they normally had "several interesting concussion cases" but that in 1914 there was none.

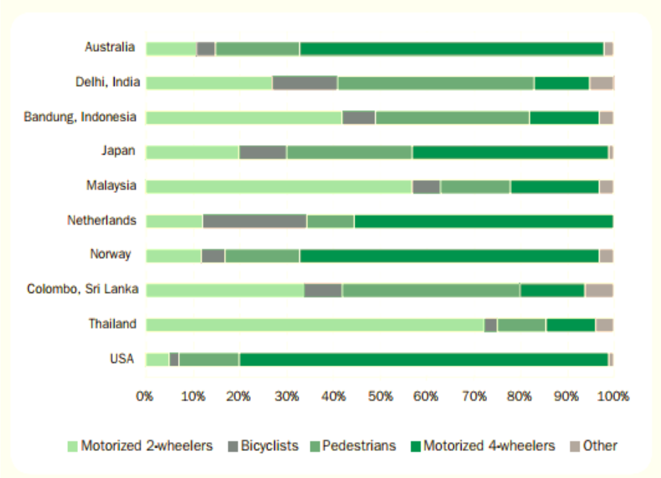


Fig1: World report on road traffic injury prevention.

B. Types and Different Styles of Helmet

There are various styles of helmets which afford different protection. The four most common types are [2]:

Full-face helmets: These helmets offer facial protection in addition to impact protection. Their principal feature is a chin bar that extends outwards, wrapping around the chin and jaw area. Extending above the jaw, there is a vision port that allows the wearer maximum range of sight, in line with the requirements for peripheral and vertical vision.

Fig 2: Motorcycle Full Face Helmets

Fig 3: Open Face Helmets

Fig 4: Half head helmet

Fig 5: Tropical helmet

Open-face helmets: Open-face helmets give standard protection from impact with their hard outer shell and crushable inner liner. Compared to the full-face type, they offer only limited protection for the jaw and chin area. They may or may not have retractable visors to protect the eyes.

Half-head helmets: These helmets provide protection by means of a hard outer shell and a crushable inner liner. They do not offer protection for the chin or jaw area and are rarely equipped with visors. The half-head helmet may or may not have ear flaps attached tothe retention system.

Helmets for tropical use

These are helmets specifically designed for South Asian and South-East Asian countrieswith extremely hot and humid climates. They are actually half-head helmetswith ventilation holes to provide a maximum flow of air so as to reduce the heat.Their extreme lightness of weight is achieved by using semi-rigid vacuum-formingPVC material.

C. Composite Materials as an Advanced Material of Manufacturing for The Rigid and Robust Design of Helemt

A composite material (also called a composition material or shortened to composite, which is the common name) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure [4]-[9]. More recently, researchers have also begun to actively include sensing, actuation, computation and communication into composites, which are known as Robotic Materials.

Typical engineered composite materials include:

- mortars, concrete.
- Reinforced plastics, such as fiber-reinforced polymer.
- Metal composites.
- Ceramic composites (composite ceramic and metal matrices).

D. Available Products of Composite Material

Fiber-reinforced composite materials have gained popularity (despite their generally high cost) in high-performance products that need to be lightweight, yet strong enough to take harsh loading conditions such as aerospace components (tails, wings, fuselages, propellers), boat and scull hulls, bicycle frames and racing car bodies. The new Boeing 787 structure including the wings and fuselage is composed largely of composites. Composite materials are also becoming more common in the realm of orthopedic surgery. Carbon composite is a key material in today's launch vehicles and heat shields for the re-entry phase of spacecraft. It is widely used in solar panel substrates, antenna reflectors and yokes of spacecraft. Furthermore, disk brake systems of airplanes and racing cars are using carbon/carbon material, and the composite material with carbon fibers and silicon carbide matrix has been introduced in luxury vehicles and sports cars[10][11][12].

E. Physical properties of composite materials

The physical properties of composite materials are generally not isotropic (independent of direction of applied force) in nature, but rather are typically anisotropic (different depending on the direction of the applied force or load). For instance, the stiffness of a composite panel will often depend upon the orientation of the applied forces and/or moments. Panel stiffness is also dependent on the design of the panel. For instance, the fibre reinforcement and matrix used, the method of panel build, thermoset versus thermoplastic, type of weave, and orientation of fibre axis to the primary force [13].

In contrast, isotropic materials (for example, aluminium or steel), in standard wrought forms, typically have the same stiffness regardless of the directional orientation of the applied forces and/or moments.

The relationship between forces/moments and strains/curvatures for an isotropic material can be described with the following material properties: Young's Modulus, the shear Modulus and the Poisson's ratio, in relatively simple mathematical relationships. For the anisotropic material, it requires the mathematics of a second order tensor and up to 21 material property constants. For the special case of orthogonal isotropy, there are three different material property constants for each of Young's Modulus, Shear Modulus and Poisson's ratio—a total of 9 constants to describe the relationship between forces/moments and strains/curvatures[13][14].

Techniques that take advantage of the anisotropic properties of the materials include mortise and tenon joints (in natural composites such as wood) and Pi Joints in synthetic composites.

II LITERATURE REVIEW

F.M. Shuaeib, A.M.S. Hamouda, S.V. Wong, R.S. Radin Umar, M.M.H. Megat Ahmed [1], studied and verify the suitability of the expanded polypropylene (EPP) foam as a liner for motorcycle helmet and to perform helmet design optimization. This EPP foam has a multi-impact protection performance and also has a potential for ventilation system improvement due to its resiliency

Chia-Yuan Chang, Chih-Hsiang Ho, San-Yi Chang [2], used the survey data collected from the class to develop a microeconomics (demand) model to predict the sales when our products hit the market. By solving the optimization coupled with the engineering and marketing model, we propose a product family featuring 3 different products targeting commuters, amateurs, and professional racers.

Praveen Kumar Pinnoji, PuneetMahajan [3],investigated and enhanced the evaporation of sweat alternative designs of the helmet. CFD simulations were performed in FLUENTTM to determine the velocity of air flow in the proposed helmet models.

N.J. Mills and A. Gilchrist [4] investigated the performance of bicycle helmet for oblique impacts with a simulated road surface. The linear and rotational accelerations of a head form, were measured. The peak rotational accelerations, the order of 5krad s-2 when the tangential velocity component was 4 m s-1, were only slightly greater than in comparable direct impact tests. Oblique impact tests were possible on the front lower edge of the helmet, a site commonly struck in crashes, without the head form striking the 'road'.

N.J. Mills and A. Gilchrist [5]used Finite Element Analysis (FEA) for bicycle helmets making oblique impacts with a road surface, to evaluate the linear and rotational accelerations of the head form.

Afshari, A. &Rajaai, S. M. [6], In their study, used models of motorcyclists helmet and the human head, two cases of head impact with a rigid surface are simulated by Finite Element Analysis; first, the impact of the head protected by the helmet and then, that of the unprotected head. In each simulation, impact parameters such as HIC, mass center velocity of the head, and pressures produced in the brain are calculated and corresponding parameters are compared with each other

N.J. Mills, S. Wilkesb, S. Derlerc , A. Flischd [7], used Finite Element Analysis to predict the rotational and linear acceleration of a Hybrid II head form, representing a motorcyclist's head, in such impacts, considering the effects of friction at the head/helmet and helmet/road interfaces.In these impacts, the higher velocity component normal to the road caused high frictional forces on the helmet shell, eventually causing it to roll on the road. The peak head form rotational accelerations, at some impact sites, were potentially injurious. The most effective method of reducing head rotational acceleration could be a reduction in the linear acceleration limit of the helmet standards.

N.J. Mills [8], introduced a safety helmet assessment and rating program (SHARP) for motorcycle helmets sold in the UK. The mechanics behind the part of the scheme that uses a rigid-sphere head-plus-helmet model to estimate the peak head form acceleration in oblique helmet impact tests is assessed and the approximations exposed. It was concluded that the derived oblique impact test results, based on an inappropriate mechanics model, are meaningless. Consequently, the helmet star ratings are not related to head protection levels.

MazdakGhajari and UgoGalvanetto [9], Developed and validated the Finite Element (FE) model of a commercially available helmet in the LS-DYNA crash code.The solution to an analytical model of the helmeted head form drop test suggested increasing the mass of the head to include the effect of the body in detached-head impacts. The added mass was calculated using the full-body impact results and applied to the Hybrid III head form. The modified head impact results corroborated the idea of the added mass.

Chawla, SandeepKadam, Singh S .P. [10],optimized a helmet. First a discrete dynamic model of a helmet has been proposed for modeling the free fall of the helmet from a height of 2m. The model was solved using RungeKutta method. The model was then used for optimization. The objective of optimization is to minimize 'time bound peak acceleration' which is taken as an injury criterion representing the effectiveness of the helmet.

M. Aiello , U. Galvanetto& L. Iannucci [11], simulated experimental impact tests on a commercially available motorcycle helmet and to develop a virtual design tool. The mechanical properties of the shell and the foam liner of the helmet were estimated from existing material data taken from the open literature. The material data were adjusted to match the temperature conditioning of each impact test condition.

Forero Rueda, Manuel A.; Cui, Liang; Gilchrist, M. D. [12]used Finite element simulations in ABAQUS/Explicit to model a realistic helmet model during standard helmeted rigid head form impacts and helmeted head model (UCDBTM) impacts.

F.A.O. Fernandes, R.J. Alves de Sousa. [13] In this work concepts related to head impact protection and energy absorption are explained. The materials that are typically used in impact situations and new design concepts are also approached. In a non-restrictive and never up-to-date report, a state-of-art review on road helmets safety is done, with a special insight into brain injury, helmet design and standards.

Peter Halldin and Sven Kleiven[14]initiated the work to design a new helmet test oblique or angled impact test method a helmet test method that can measure the rotational energy absorption in a helmet during an angled impact. This paper presents a short summary of possibilities and limitations on how to build a helmet test method that can measure the rotational energy absorption in a helmet during an angled impact.

MazdakGhajari, Gaetano Davide Caserta, Lorenzo Iannucci and UgoGalvanetto [15] investigated the modeling of a honeycomb reinforced helmet in Ls- Dyna environment. The ECE 22.05 standard impact tests are simulated in the front, top and rear regions of the helmet, and the numerical outcomes are compared to experimental results. Overall, the model realistically reproduces the impact response of the helmets. Particularly good agreement with experimental results is observed from impacts in the front and rear regions, against the kerbstone anvil.

Shishodia. B. S, Sanghi. S, Mahajan. P [16] studied to find the best turbulence model for predicting air flow in the gap between the head and the helmet. The numerical experiment on simple pipe flow shows that SpalartAllmaras S-A model performs better than the standard two equation models when the flow is in the laminar or transition regime and performs almost the same as the other two equation models in the turbulent regime. The flow between the head and the helmet is not a standard geometry for which the Reynolds number at which the flow becomes turbulent is well established and hence the need for a proper model performing well in all regimes.

V. C. Sathish Gandhi, R. Kumaravelan, S. Ramesh, M. Venkatesan, M. R. Ponraj [17],analyzed the helmet with all the standard data. The simulation software 'ANSYS' is used to analyze the helmet with different conditions such as bottom fixed-load on top surface, bottom fixed– load on top line, side fixed–load on opposite surface, side fixed–load on opposite line and dynamic analysis. The result shows that these values are concentrated in the retention portion of the helmet. These results have been compared with the standard experimental data proposed by the BIS and well within the acceptable limit.

TasnimFirdaus Ariff1, Muhammad EzurinJalil [18], improved the design of the inner shell of a motorbike helmet using coconut husk. Modeling of the inner shell of the motorbike helmet is done by using CATIA software. Finite Element Analysis (FEA) is used in analyzing its performance using method from ANSYS software with the determined properties from series of mechanical testing. The outcome from the mechanical testing shows that this coconut fiber composite is strong with some properties of elasticity in it. This material has shown to have better stress absorption compared to Expanded Polystyrene Styrofoam (EPS).

Tyler Lawrence Shaw [19], The helmet consists of an array of elastomeric rubber dampers in addition to the traditional crushable foam cushion. In this thesis, the design of the Omni Directional Suspension (ODS) helmet and its potential to mitigate brain injury are discussed. Due to the nature of the ODS helmet design, it is expected that the technology will perform comparatively better than conventional designs in low-energy impacts, in which concussion or Mild Traumatic Brain Injury (MTBI) is the most common injury.

Nermin M. Aly and Ali Marwa A. [20] studied experimentally the protection performance of new laminated composite shells compared with that of an Acrylonitrile Butadiene Styrene (ABS) shell. It was illustrated that, the laminated composite shell reinforced with the polyester/glass woven fabric and glass fiber mat achieved the best performance, can sustain impact loads and provide better protection to the head from penetration.

Edward B. Becker, Denis V. Anishchenko, Stephanie B. Palmer [21],investigated how two different helmet test standards, reflecting different demands of impact management, affect helmet protective performance in impacts at varying levels of severity. The results further demonstrate that the M2010/DOT helmets have significantly superior impact management in higher severity impacts.

Saroj Kumar Biswal, S.M.ShahrukhRais, Karanam Krishna [22], in this study a standard motorcycle helmet is designed using CATIA V5.0. Two materials i.e. Acrylonitrile butadiene styrene (ABS) and Poly vinyl chloride (PVC) are being used for dynamic analysis. The impact test analysis is performed on the helmet using ANSYS at different speeds ranging from 50-70kmph. Peak acceleration and Head Injury Criterion values derived from the head form are used to assess the protective performance of the helmet. The stresses, strains and deformations formed are evaluated. Results are compared for the prediction of material that would be suitable for the preparation of helmet.

Tso-Liang Teng, Cho-Chung Liang and Van-Hai Nguyen [23],in their study performed a shock absorption test in accordance with the EN1078 standard to evaluate the energy absorption capability of a helmet on the market. Then, the finite element analyses of helmet impact tests modelled using LS-DYNA software. To verify the accuracy of the model, the simulation results were compared with experimental data. Finally, an innovative design of helmet model with semispherical cone liner was considered in this study. To assess the dynamic energy absorption of this helmet, a simulation was performed in accordance with the EN1087 standard for shock absorption tests.

III METHODOLOGY

A complete Finite Element Analysis consists of three stages:

A. Pre-Processing

a) Part module- First of the helmet is created in part module with different bodies.

b) Property module-CATIA has built-in system of units. All input data must be specified in consistent units.For the present analysis we have used SI (mm) system of units for which the material taken is composite in nature.

c) Mesh module- Now the meshing is done using this module, for the present analysis the node-modified quadratic tetrahedron element type is used. One more important parameter to be considered is the mesh size for the present work meshing size is taken as Default.

d) Requesting data output- Finite element analyses can create very large amounts of output. Ansys allows controlling and managing this output so that only data required to interpret the results of simulation are produced.

e) Applying Boundary Conditions-In modal analyses, boundary conditions are applied to those regions of the model where the displacements and/or rotations are known. Such regions may be constrained to remain fixed (have zero displacement and/or rotation) during the simulation or may have specified, nonzero displacements and/or rotations.In this model the helmet is fixed from the bottom to have the vibrational effects on the components of the piston.

B. Finite Element Solver

After the pre-processing is done the job is submitted for the analysis.

C. Post-processing with Ansys/CAE

Graphical post-processing is important because of the great volume of data created during a simulation. When the job completes successfully, are ready to view the results of the analysis with the Visualization module. Select Results from the menu that appears to enter the Visualization module. Ansys opens the output database by the job and displays a fast plot of the model. Ansys provides the different maximum to minimum deformation in different colors for better understand, and analyzing the results.

D. Modeling Procedure

The geometric perimeters are taken with referral to the numeric and empirical formulae which are mentioned previously and the boundary conditions of the helmet is taken in such a way that it can be fixed from the bottom part to have the vibrational effect on it. The meshing of the helmet is done in the same software for which we had chosen a 4 node parabolic octree-tetrahedron element is selected with element size of default. Finally the material property is defined and then the analysis is done in ANSYS modal analysis workbench to obtain the best possible results. The flow chart shows the simulation procedure for the whole analysis.

E. The Catia Software

CATIA V5 is a powerful software package yet has a relatively short learning curve. One of the reasons for the short learning curve is that it is fully Windows compatible and the processes are consistent across the workbenches, toolbars and tools. If you learn the basics of a particular workbench the same process can be used for more complex problems. Several tools are used in more than one workbench.

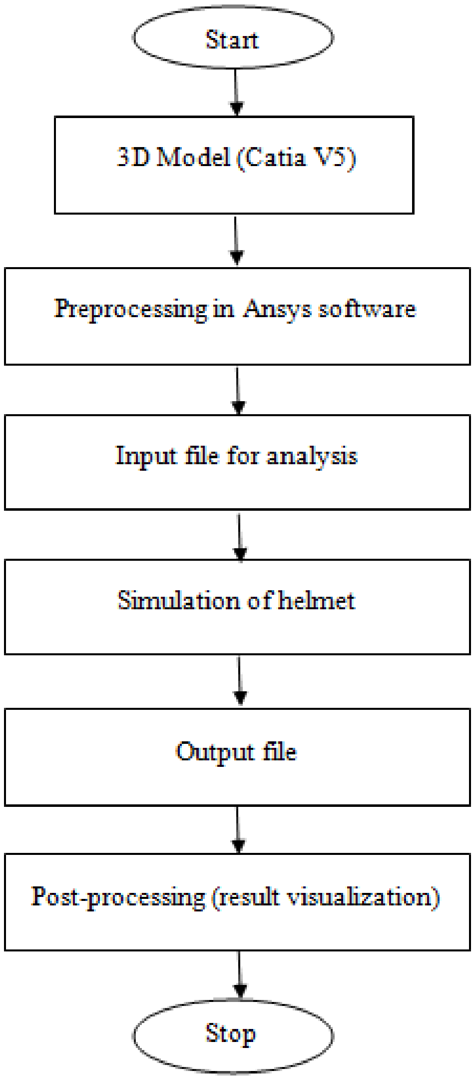


Fig.6: Modeling Process of Motor cycle helmet.

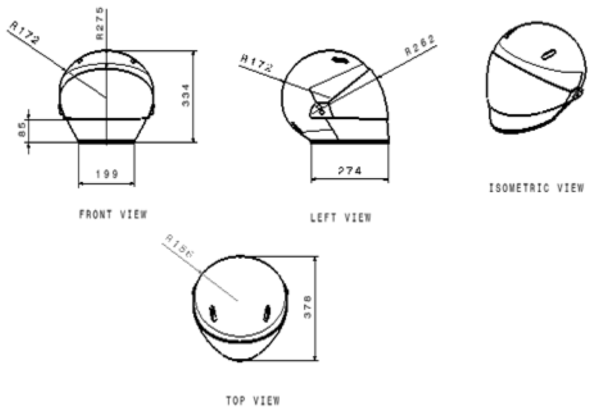


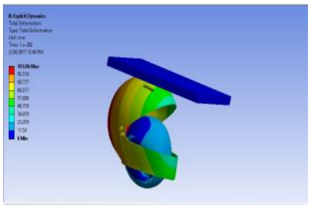
Fig.7: Helmet modal with dimensions

IV RESULT ANALYSIS

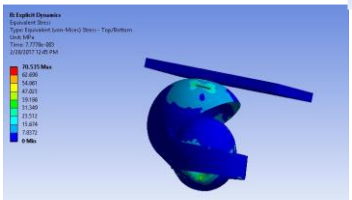
For this process two main material types had been used such as outer shell constructed through polypropylene and carbon fiber. A deformed plot shows the manner in which the component is deforming. On the basis of above discussions a computer aided model using CATIA software is prepared and after that the boundary conditions are employed by fixing giving a fixation at the bottom of the helmet in ANSYS Modal workbench further the material properties are given and lastly the whole model is computed to find Natural frequencies and deformation.

A. Impact Analysis

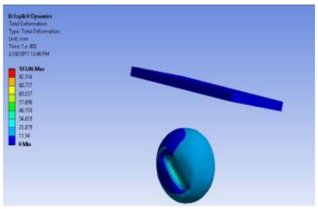
In order to test the efficiency of the helmet to prevent head injuries an impact test is performed for which a 3D model assumed to be human head was placed inside the helmet. The properties assigned to the model were. It can be seen that during the impact the maximum deformation caused in the helmet was about 104mm and the maximum stress was 70.53 MPa. It can be seen from the image above that during the impact there is a slight deformation in the side of the skull. This is due to the fact that during impact head tries to come out of the helmet during which it strikes with the side walls of the helmet.



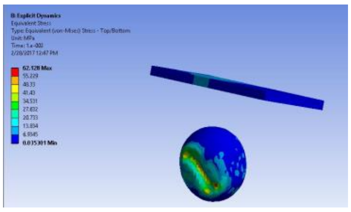
Deformation of helmet on impact



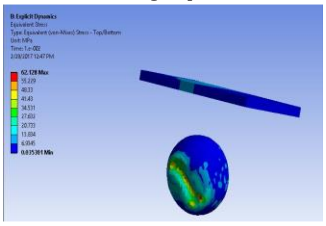
Stress on helmet on impact



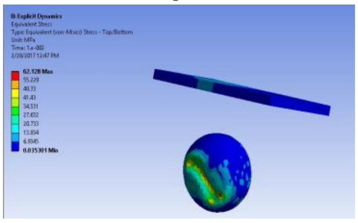
Deformation of Skull inside helmet during impact



Stress on skull inside helmet during impact



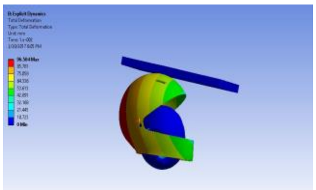
Deformation of brain inside helmet during impact



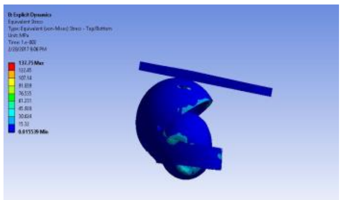
Stress in brain inside helmet during impact

Fig. 8: Impact Analysis on the Polypropylene Helmet

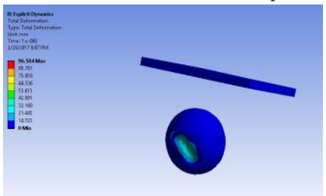
Figure 8 shows the impact analysis on Polypropylene Helmet as well as Figure 9 shows the impact analysis on the Carbon Fiber Helmet.



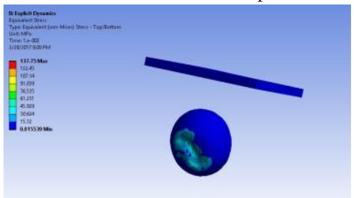
Deformation of helmet on impact



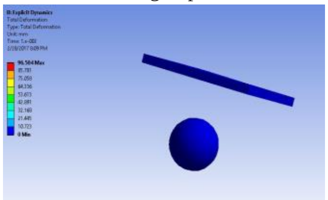
Stress on helmet on impact



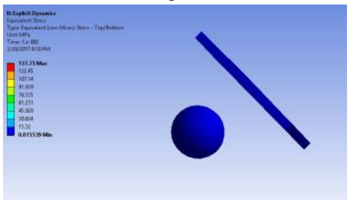
Deformation of Skull inside helmet during impact



Stress on skull inside helmet during impact

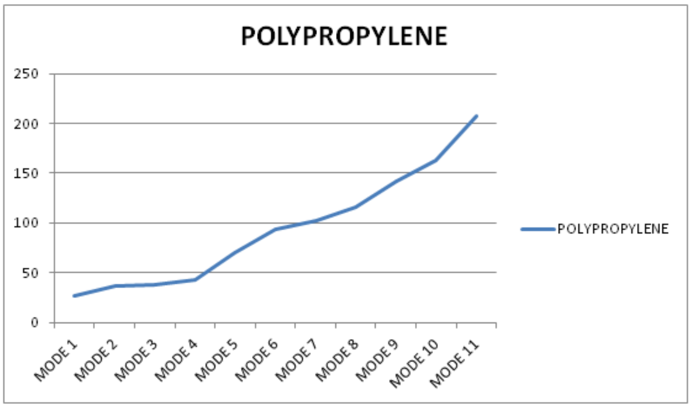


Deformation of brain inside helmet during impact

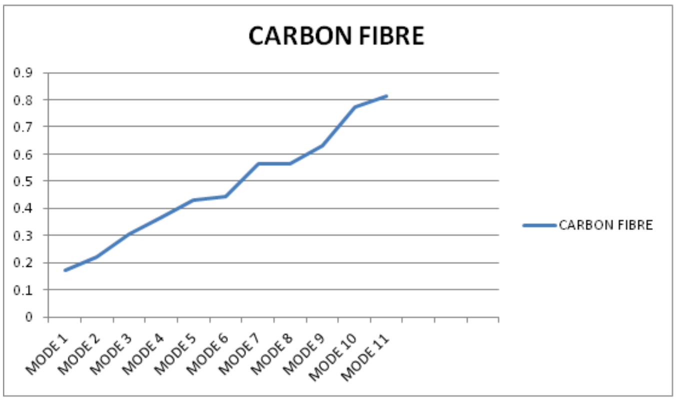


Stress in brain inside helmet during impact

Fig. 9: Impact Analysis on the Carbon Fiber Helmet



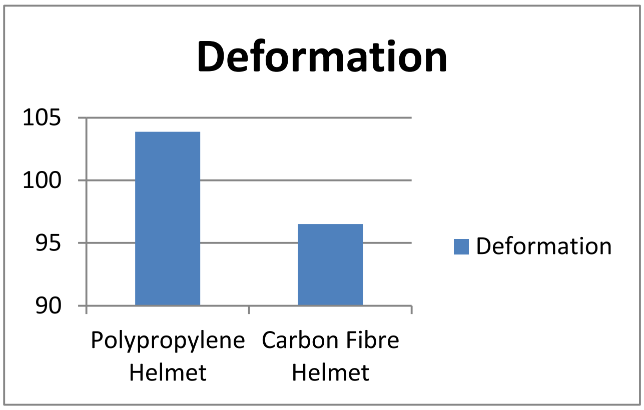
Graph 1: Frequency of Helmet with Polypropylene



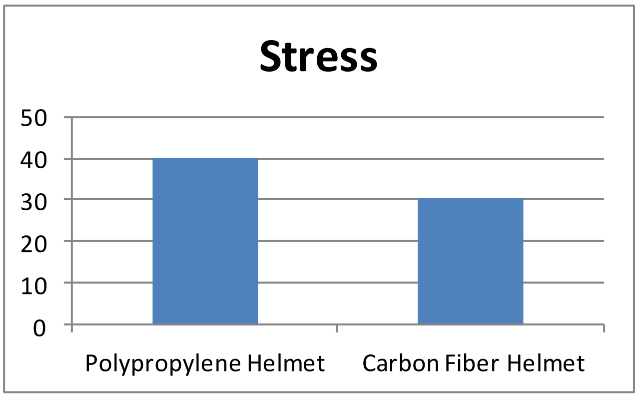
Graph 2: Frequency of Helmet with Carbon Fibre

Table 6.4: Total deformation and stress in both the helmet

Helmets	Total Deformation	Stress
Polypropylene	103.86 mm	39.86 MPa
Carbon Fiber	96.50 mm	30.62 MPa



Graph 3: Deformation in both helmets due to impact



Graph 4: Stress on both helmet due to impact

VI CONCLUSION

While doing study over project, used two materials first was polypropylene and second one was carbon fiber and found different level of deformations over different frequencies. Based on the result following conclusion can be drawn:

- While putting helmet on first condition the polypropylene reacts on 26.134Hz frequency and deformation ranges from 0 min. to 77.664Max.
- Carbon fiber on first stage the frequency obtained 0.17396Hz and deformation ranges from 0 min to 48.287Max.
- The all over frequency on helmet with polypropylene shell ranges from 26.134Hz to 207.09Hz.
- The all over frequency on helmet, with carbon fiber shell ranges from 0.17396Hz to 0.81238Hz.
- The comparative deformation over helmet with polypropylene shell was found 77.664 to 139.72Max while those in carbon fiber shell helmet were 48.287min to 95.425max.
- The visor/face shield for the helmet made with carbon fiber was made with glass material and as can be seen it deforms at lower frequency
- The visor/face shield for the helmet made with polypropylene was made with polycarbonate and as can be seen it can endure frequencies of much higher range
- Impact analysis is performed to test the efficiency of the helmet in preventing head injuries
- In the case of helmet with polypropylene material it can be seen that the maximum deformation occurring is 103.86 mm which in the case of helmet with carbon fiber material is 96.5 mm only.
- It can also be seen that the deformation and stress caused to the skull during the impact is much more in the case of helmet made with polypropylene material than with the carbon fiber material

- According to the literature the critical stress on the brain is considered to be 100 KPa. So from the result it can be concluded brain in both helmets is under safe zone

Thus this result shows that the helmet deformation was higher with the polypropylene material with maximum frequency, while helmet constructed via carbon fiber had less deformation rate with less frequency, also the helmet constructed via carbon fiber is more efficient at preventing head injuries rather than the helmet constructed via polypropylene, by the result of this obtained that carbon fiber is better material than the polypropylene. The carbon fiber material contains good strength and durability to form in any shape.

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