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Design And Analysis Of Indusrtial Safety Helmet Using Composite Material

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Abstract-*Today safety of site engineers and workers is of a prime concern to various industries like manufacturing, construction & power industry. New standards are being set for the safety of the employees in different accidental scenarios like fall from height, slip/trip/fall injuries, fall of object from height. There are many cases of fatal incidents daily due to injuries to head. To protect person from such injuries, use of safety helmet by personal working on site has become mandatory according to OHSAS 18001[Occupational Health and Safety Assessment Series]. Hence the mechanical properties of safety helmet must withstand the stresses during accidental situations. Use of composite materials in industry has exponentially increased due to their properties like strength & hardness. The aim of present research is analyses of industrial safety helmet using composite material having better mechanical properties than the existing materials being used. This project discusses the overview of safety helmet constructional features, composite materials, classification and selection of appropriate composite material. Afterwards manufacturing of product will be done using suitable manufacturing method with proposed composite material. The mechanical tests such as compression test, impact test and tensile test will be carried out on the prototype and existing models. The results of these tests will be compared with the FEA results using ANSYS.*
Keywords: *ANSYS, Composite material, compression test, Industrial safety helmet, OHSAS*

I. Introduction

All helmets attempt to protect the user's head by absorbing mechanical energy and protecting against penetration. Their structure and protective capacity are altered in high-energy impacts. 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. Every year many workers are killed or seriously injured in the construction, manufacturing and power industry because of head injuries. Wearing an appropriate safety helmet significantly reduces the risk of injury or even death. Protective headwear could save your life. At present strength of the helmet using industry is less due to improper selection and filling of material, uneven pressure distribution and blow holes. The aim of the project is to increase the strength of industrial helmet shell by using composite material. The safety helmet selected should satisfy certain performance requirements including shock absorption, resistance to penetration. To achieve this an improvement in shell material by using composite material will be studied in this project.

II. Literature Review

Ankuloria [1] determined that when the glass fiber concentration increased in the processed ABS from 5 ,10, 20, 30 wt%, the tensile strength, tensile modulus was improved but strain value lowered. Increasing the concentration of glass fibers also shows better bond between ABS and SGF. 12]

Yusuke Miyazaki [2] discovered that when foaming ratio of the liner and the shell-thickness were varied, indicated that there is an optimum combination where the shell part fails without the liner bottoming, improving the shock absorption ability of a helmet.

1Anil Kumar. K [3] carried out mould flow analysis on helmet by using plastic advisor which is a module in pro/E. He found that the Nylon 4-6 plastic is good instead of ABS plastic and impact ABS plastic for manufacturing safety helmets by injection moulding process.

Terry Smith [4] carried out three-dimensional finite element models [FEM] of the helmet components and the test head form were developed using MSC software and material properties were estimated. He concluded that there are a number of currently available materials from which energy absorbing [EA] liners could be fabricated that could improve the impact performance of the existing HGU-84/P helmet. FEA can be an effective tool for the analysis and design of both new and existing helmet designs.

S. P. Soe [5] discovered that cellular structure-based inner liners, manufactured via additive manufacturing processes, have exciting potential towards improving bicycle helmet safety.

N. J. Mills [6] performed Finite-element analysis [FEA] for bicycle helmets making oblique impacts with a road surface, to evaluate the linear and rotational accelerations of the headform. It was found that The predicted peak headform rotational accelerations depended on the impact site and direction, and became nearly constant for a tangential velocity component.

Alyssa L. DeMarcoa [7] performed Sixty-five drop tests against the side of 10 different beanie helmets onto a flat anvil at impact speeds of 0.9–10.1 m/s. She found that acceleration attenuation improved with increasing thickness of the energy-absorbing liner. Helmet responses varied with foam thickness, foam material and possibly shell material.

Helmy Mustafa [8] carried out the experimental impact test is carried out using 2-wire drop test facility in accordance to the AS/NZS 2063:2008. The result obtained from numerical model correlated well with those from physical drop impact test.

F.L. Tan [9] Designed helmet cooling system using phase change material [PCM] to absorb and to store the heat produced by the wearer head so as to achieve comfort cooling for the wearer. The PCM helmet cooling system is simple and has potential to be implemented as a practical solution to provide comfort cooling to the motorcycle riders.

Bernd Fuernschussa [10] investigated the safety performance of jockey helmet shells made out of carbon fibre. Four different shell types were produced with the same prepreg material. It was found that two-patterned shell with the five layers [2P5] showed the best overall performance impact sites with smaller curvatures showed higher energy absorption

Katherine M. Breedlove [11] Six models of football and six models of lacrosse helmets were tested using a drop tower at three prescribed velocities and six locations on the helmets. Features of football helmet design provide superior protection compared to lacrosse helmets.

S.G. Kulkarni [12] found that carbon fiber composites can provide higher ballistic protection at a reduced weight than the composites used in the current helmets. Polymer matrix nanocomposites, especially those reinforced by carbon nanotubes, can potentially offer the highest ballistic protection.

Mayank Singh Rajput [13] carried out numerical simulations to determine the impact resistance of Personal Armor System Ground Troops [PASGT] helmet. The KEVLARs helmet is able to resist a 9 mm full-jacketed bullet travelling at 358 m/s.

A. GILCHRIST [14] used a simple mathematical model to explain the results obtained when helmets are hit on the top. He concluded that while the helmets perform adequately during top impacts, the protection given at the sides, front and back of the helmet is so poor that a redesign is necessary.

Yeh-Liang Hsu [15] done experiments to established to simulate the conditions of a head wearing a helmet. By using better insulation techniques & adequte ventillation can improve the thermal properties of safety helmet.

Amal Thomas [16] carried out impact analysis on GFRP composite helmet using ANSYS. composite fibers have been successfully reinforced with the epoxy resin by simple and inexpensive hand lay-up technique. Reinforcement of composite fibers have good and comparable mechanical properties as conventional composite materials

Occupational health and safety council manual-2004, Hong kong [17]. This manual provides guidance of basic knowledge about safety helmet.

M. S. EL-Wazerya [18] developed E-glass fiber with random oriented reinforced polymer composite by hand lay-up technique with varying fiber percentages [15%, 30%, 45%, and 60% by weight percentage]. The influence of glass fiber percentage on the mechanical properties such as tensile strength, bending strength and impact strength was investigated. The mechanical property such as hardness, tensile strength and flexural bending strength of polyester resin has been improved by a great extent due to the presence of glass fiber reinforcement.

Divakar H [19] tested ABS laminates with multiple layers of glass fibers for tensile, compression and bending according to the standard procedures. With addition of the glass fibre properties tensile & compression properties are enhanced gradually. Inclusions of glass fibre have enhanced the tensile and compressive strength but reduced the bending strength of ABS.

C.Elanchezhian [20] carried out fabrication and investigation of fiber composites and compares it with GFRP and CFRP used separately. Mechanical behaviour of the composite is obtained by testing the composite laminates for tensile , flexural and impact. The tensile strength and flexural strength of CFRP composite is the relatively more than GFRP. Impact strength of GFRP composite is which is quite high than CFRP. Orientation angles of fibres play an important role in the mechanical behaviour of CFRP and GFRP.

III. Selection Of Composite

Selection of material is a step in the process of designing any physical object. The main goal of material selection is to increase the material properties and to minimize cost in the context of product design, while meeting product performance goals. The selection of the best material for a given application starts with properties of

material and costs of candidate materials. The performance of an engineering component is limited by the properties of the material of which it is made, and by the shapes to which this material can be formed[3].
The material used for shell must withstand stresses due to

1. Impact strength due to fall of heavy object from above
2. Compressive force due to entrapment of wearer in confined space
3. Fall of safety helmet from working height

Materials commonly used for shell material
• High density polyethylene [HDPE]
• Acrylonitrile-butadiene-styrene [ABS]

For safety helmet impact strength and compressive strength of material is of prime importance. Other mechanical properties such low density, high tensile and flexural strength are also important.

Material should also possess other properties such as electrical nonconductivity, withstanding working temperature, low water absorption, corrosion resistant.

Based on these criteria different material data is collected from commercial websites validating ASTM standards. It is seen that the polycarbonate composite with 10% glass reinforcement gives optimum material properties for safety helmet.

3.1. Selection of matrix material

First criteria for selection-High impact strength

From fig.3, it can be seen that ABS and Polycarbonate are two lightweight materials which have higher impact strength than HDPE. So, these materials are feasible for safety helmet manufacturing. Further it can be seen that polycarbonate has higher impact strength than ABS.

Fig. 3 Notched Izod impact strength [ASTM D256]

Second criteria-High compressive strength

From the data in table.2; it is clear that ABS has high compressive strength than polycarbonate.

Third criteria-High hardness

From the data in table:2 it is clear that Polycarbonate has better hardness than ABS.

Both ABS and polycarbonate has better tensile strength, low density and low raw material cost. Out of which polycarbonate has better mechanical properties than ABS.

So we select polycarbonate as matrix material for the proposed composite material.

3.2. Selection of reinforcing material

Mechanical behavior of glass and carbon fiber reinforcement on composites:

Glass fiber and carbon fiber are generally used as a reinforcing material in plastics. These carbon reinforced plastics are named as CFRP similarly the glass fiber reinforced plastics are named as GFRP. Let's discuss the result of glass and carbon fiber reinforcement into composites[20].

-Impact strength of GFRP composite is quite high when compared with the CFRP composite.
-The tensile strength of CFRP composite is the relatively more than GFRP composite.
-The percentage elongation of CFRP in tensile testing is found to be less than that of the GFRP composite. Therefore, the GFRP composite withstands more strain before failure in tensile testing than the CFRP composite

-The flexural strength of CFRP composite is the relatively more than GFRP composite [20].
From the above discussion it is clear that for impact load applications GFRP are more suitable than CFRP. Glass fiber though doesn't increase impact strength, but it improves other mechanical properties such as compressive strength and hardness.

So we select glass reinforcement in the proposed composite material.

3.3. Selection of final composite material

After selection of matrix material and reinforcement material data is collected for ABS, HDPE and their composites for comparing their mechanical properties. Also other advanced engineering materials are compared with the proposed material.

	Property	HDPE	ABS	ABS 10GFRP	ABS 10CFRP	PC	PC10GFRP	PC10CFRP	NYLON66
Essential properties for safety helmet	IZOD impact, notched[j/cm]	**0.77**	2.23	0.765	0.52	3.2	**1.25**	0.817	1.02
	Rockwell hardness R	**49**	107	104	106	119	**117**	117	114
	compressive strength[MPA]	**20**	95	95	NA	70	**95**	NA	46.3
Desired properties for safety helmet	Youngs modulus[GPA]	**0.927**	2.3	3.66	7.36	2.39	**3.6**	11.3	2.52
	Tensile yield stress[MPA]	**26**	43.3	58	75	60	**64**	108	71.5
	Ultimate tensile strength[MPA]	**21.3**	38.5	59	79	63	**67**	112	72.7
	density[kg/m3]	**970**	1060	1140	1120	1200	**1270**	1280	1140
	Flexural yield strength[MPA]	**29.2**	67	87.4	98	90	**108**	179	94.4
	Raw material price/kg	**85**	90	90	90	80	**80**	80	150

Table. 2 Material mechanical properties data

From the data collected it is clear that Polycarbonate with 10% glass reinforcement gives better mechanical properties than other polymers and composites. It is also the much better than existing HDPE material. Hence, we select polycarbonate with 10% glass reinforcement as final material.

IV. Anlysis Using Ansys

For theoretical analysis of the current model & proposed composite model; ANSYS software is used. A prototype of helmet shape outer shell is prepared in the form of half hollow hemisphere in Catia and imported in ANSYS. A sample compressive load of 2000N is applied from the top to both the prototype. The dimensions are taken from HDPE make safety helmet available in market.

Sample dimension: 200mm inner dia, 205mm outer dia, 2.5mm thickness.

Property	HDPE	PC 10GFRP
Youngs modulus[GPA]	1.03	3.6
tensile yield stress[MPA]	26	64
Ultimate tensile strength[MPA]	27	67
density[kg/m3]	970	1270
compressive strength[MPA]	20	95

Table 4: Properties of HDPE vs. PC composite

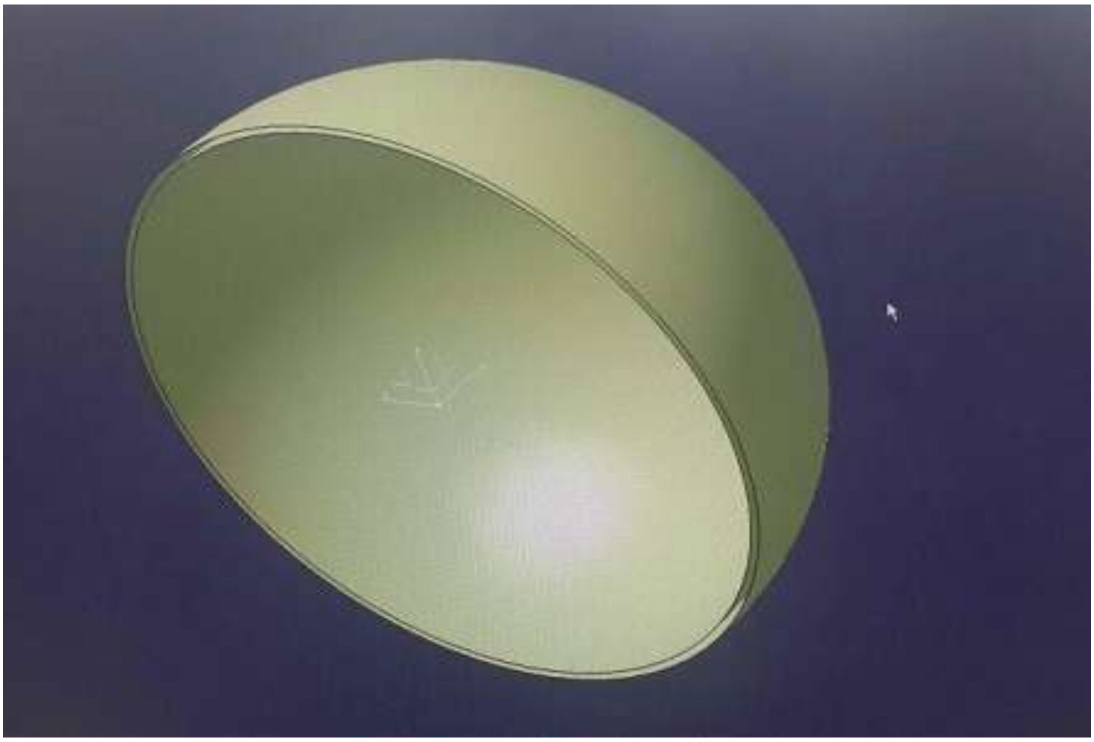

Fig.5. prototype of safety helmet shell in catia

4.1. ANSYS: Equivalent stress

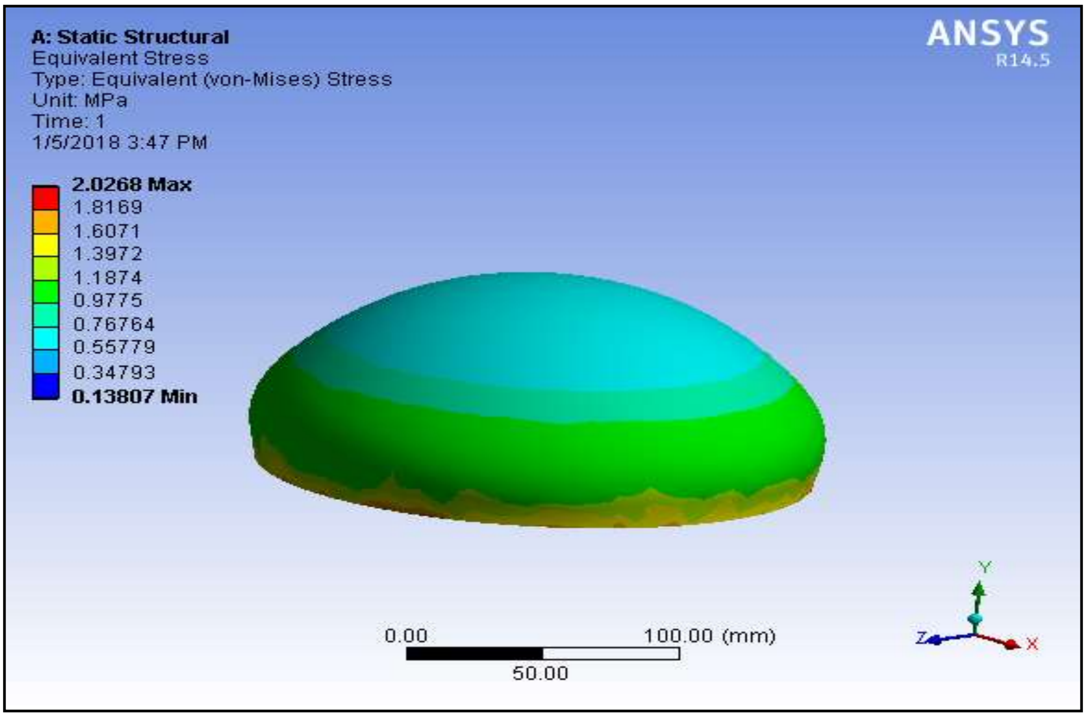

Fig.6. Equivalent stress distribution in HDPE prototype.

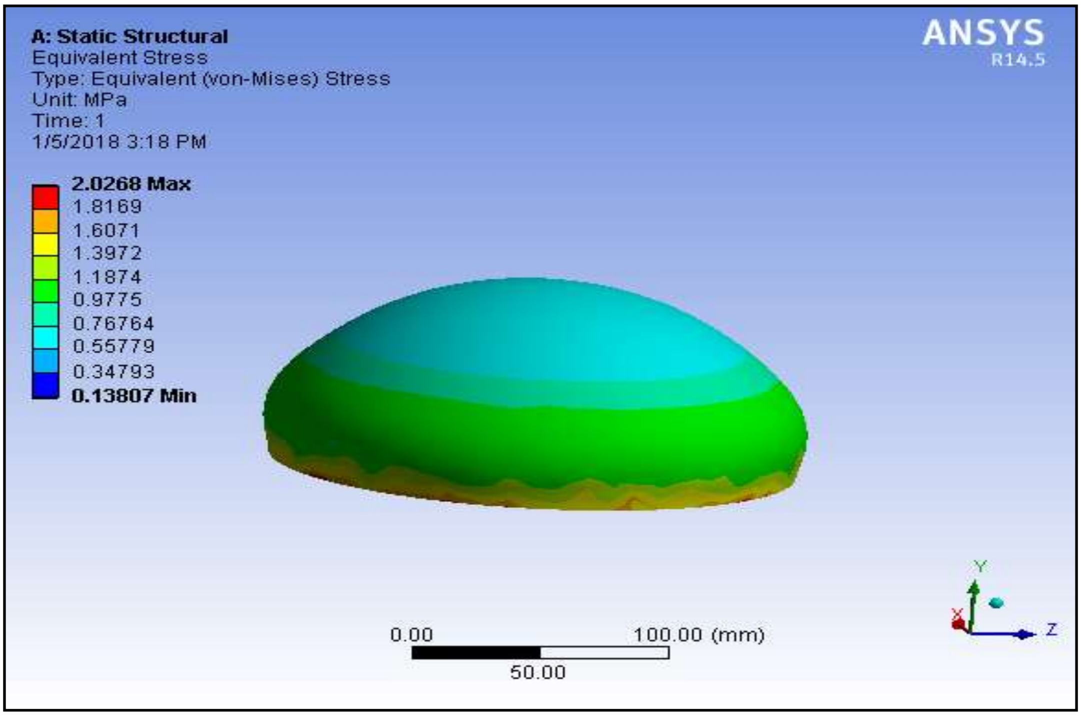

Fig.7

Equivalent stress distribution in Polycarbonate composite prototype.

4.2. ANSYS: Equivalent elastic strain

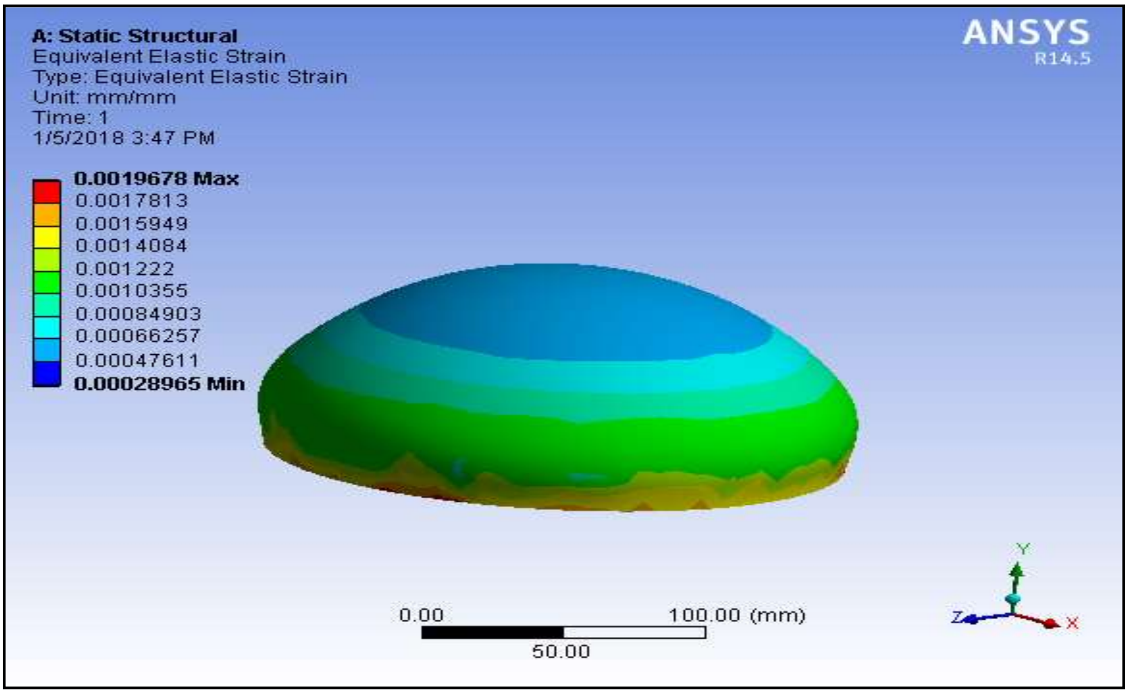

Fig.8. Equivalent elastics strain distribution in HDPE prototype.

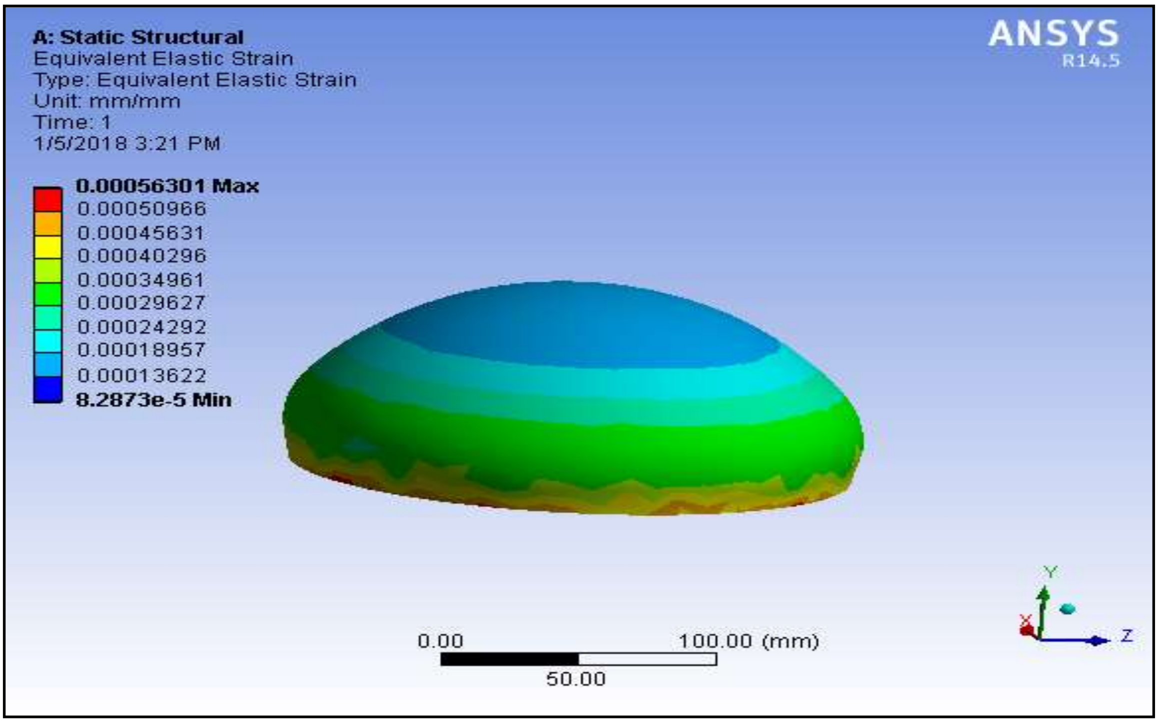

Fig.9 Equivalent elastics strain in Polycarbonate composite prototype.

4.3. ANSYS: Total Deformation:

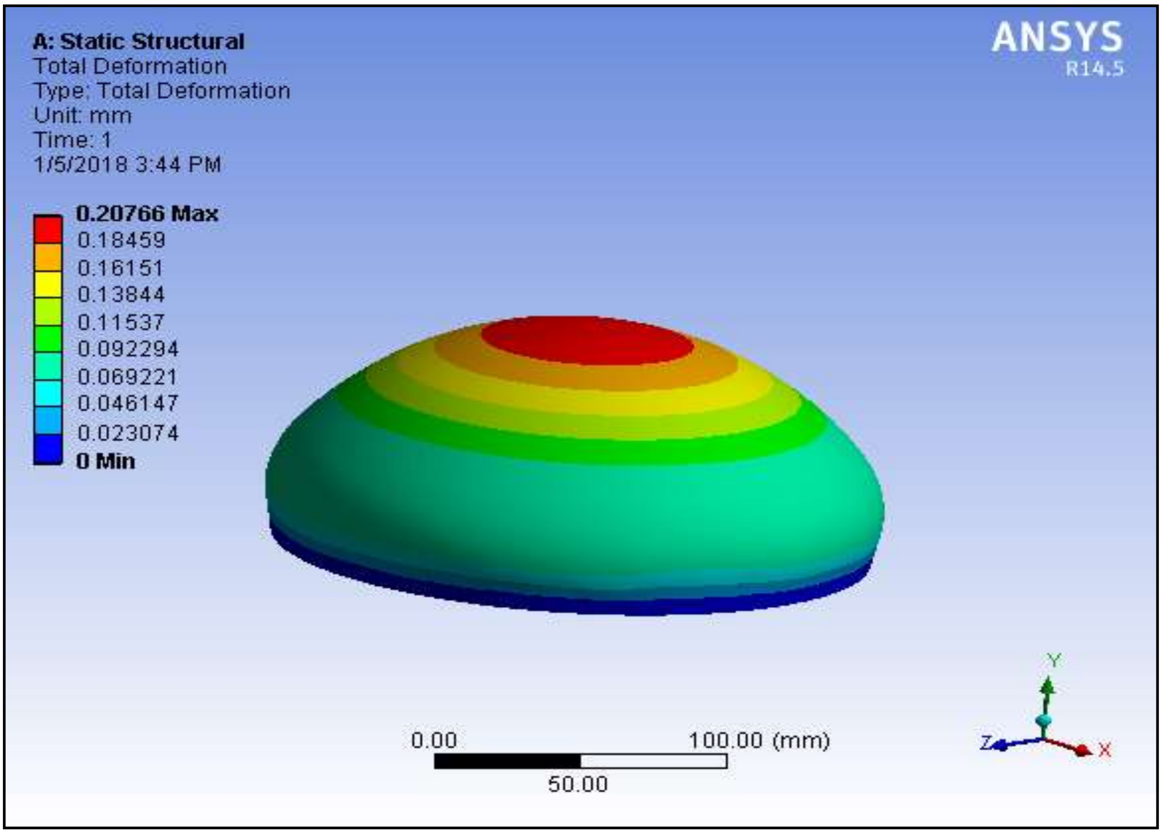

Fig.10 Total distribution in HDPE prototype.

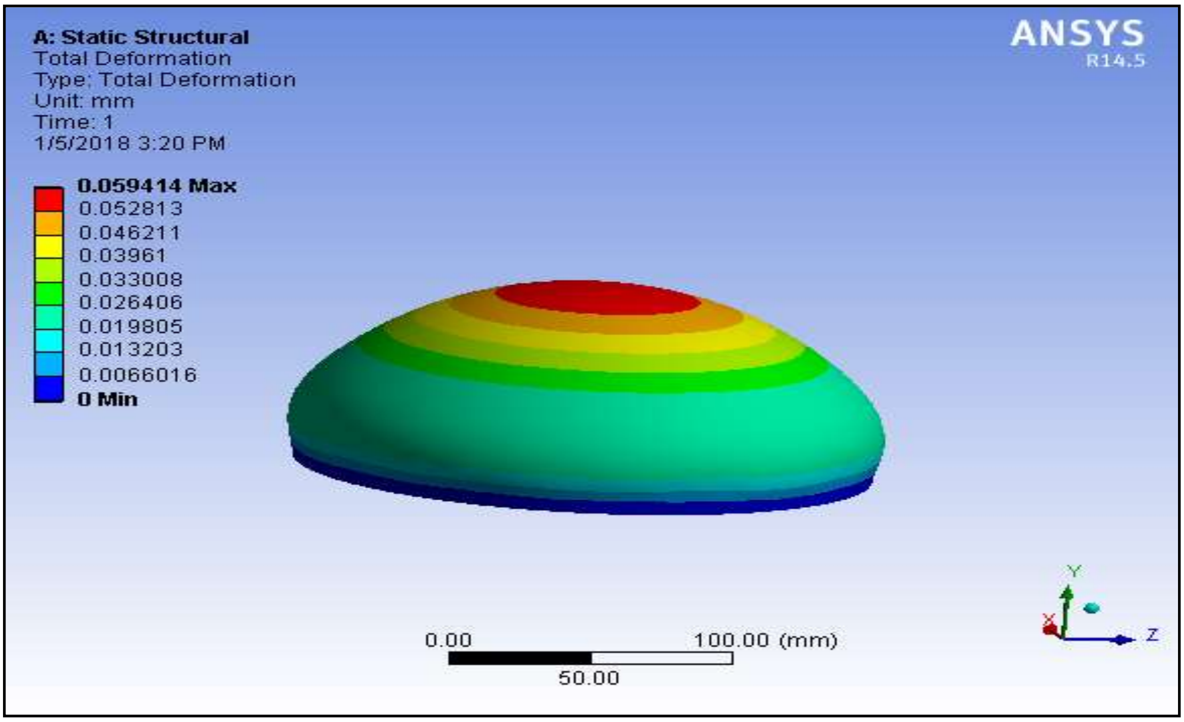

Fig.11. Total distribution in polycarbonate composite prototype.

V. Conclusion

Since both the geometries are same and same load is applied; the equivalent stress distribution is same in both the cases. But the equivalent max strain in polycarbonate composite is 0.00056 mm/mm which is less than the max strain 0.0019mm/mm in HDPE. Max total deformation in polycarbonate composite is 0.059mm which is less than total deformation 0.207mm in HDPE.

Hence in the preliminary ANSYS test show that the polycarbonate composite with 10% glass reinforcement possess better mechanical strength than the traditional HDPE material.

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