FEM Analysis of Glass/Epoxy Composite Based Industrial Safety Helmet

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Abstract: Recently, the use of fiber reinforced polymer in every field of engineering (automobile, industry and aerospace) and medical has increased due to its distinctive mechanical properties. The fiber based polymer composites are more popular because these have high strength, light in weight, low cost and easily available. In the present work, the finite element analysis (FEA) of glass/epoxy composite based industrial safety helmet has been performed using solid-works simulation software. The modeling results show that glass fiber reinforced epoxy composite can be used as a material for fabrication of industrial safety helmet which has good mechanical properties than the existing helmet material.

Keywords: Fiber reinforced polymer, glass fiber, safety helmet, finite element analysis (FEA).

1. INTRODUCTION

A composite material is obtained when two or more materials are combined together to form a new material which has better properties than the individual one. A composite has basically two components matrix and the reinforcement. The main function of matrix to transfer the load to the reinforcement and binding the reinforcement together and the main function of reinforcement is to hold the load. Depending upon the matrix material, composites are classified as metal matrix, polymer matrix, and ceramic matrix composite. Depending upon the reinforcement, composites are particulate composite and fiber composite [1-2]. Fibers are classified as synthetic and natural fibers. Synthetic fibers are the man-made fibers that are prepared by raw materials obtained from nature. Synthetic fibers include glass, carbon, aramid, rayon, nylon, metallic fibers etc. The most commonly used fiber is glass fiber which has several advantages such as high strength, high chemical resistance, good insulating properties and low cost.

Helmets are used to protect head by absorbing impact energy and secure against damage. Various types of helmets that are used to protect head from injuries depend upon its uses such as ballistic helmets, motorcycle/bicycle helmets and industrial helmets. The main property of any type of helmet is to absorb the impact energy. Along with this property, a safety helmet should be light in weight and low volume since light in weight and low volume do not cause any pain or problem to the workers head and neck. V. Kostopoulos et al. [3] investigated the impact damage
response of a composite motorcycle safety helmet using hydrodynamic finite element code on LS-DYNA3D software. The authors concluded that the dynamic response of carbon and glass woven mat is nearly same but the Kevlar woven mat helmet respond is better than the glass and carbon. Ariff et al. [4] analyzed and modeled inner shell of a safety helmet fabricated by using coconut fiber reinforced epoxy composite. CATIA and ANSYS were used for finite element analysis and compared the mechanical properties with existing safety helmet material which was expanded polystyrene Styrofoam (EPS). The authors concluded that developed coconut fiber reinforced epoxy composite shell had better stress absorption capability, eco-friendly in nature and it had low cost as compared to expanded polystyrene Styrofoam (EPS). Murali et al. [5] fabricated the industrial safety helmet using jute/banana/sisal fiber reinforced epoxy composite by hand layup technique. The authors concluded that the developed jute/banana/sisal fiber reinforced epoxy composite had better strength (53.06 J/m) and less weight (252 gm) as compared to acrylonitrile butadiene styrene (ABS) which has impact strength of 50J/m and weight 370 gm. Natsa et al. [6] fabricated a military helmet using coir fiber reinforced epoxy resin composite. Seven specimens were fabricated having 20%, 40%, 50%, 60%, 70%, 80% and 85% coir fiber content in the composite and their mechanical properties were investigated. The specimens having a fiber content of 70% and 28% resin offered remarkable properties having impact strength of 8.733 J/mm². Bernd et al. [7] investigate the helmet shell developed by using carbon fiber. Four different helmet shells was developed using same carbon fiber. The number of fiber layers and fiber pattern was differing. The analysis of impact behavior of helmet shell was performed using the Gaussian curvature and the mean curvature method in CATIA V5. The 2-wire drop test was showed that two-patterned shell with five layers has the best impact behavior then other three helmet shells. Satish Gandhi et al. [8] carried out the performance analysis of motor cycle helmet under static and dynamic loading. The helmet model was designed using Pro-E software and the simulation was performed using ANSYS software. Under different situations 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. For static analysis the maximum deformation was 6.2263 mm and maximum strain energy was 111.94 joules and for dynamic analysis the total deformation was 12.147 mm. The authors concluded that situations as bottom fixed load on top surface and side fixed-load on opposite line has undergone less strain energy and deformation. Alessandro Cernicchi [9] carried out modeling of composite shell of helmet using Finite Element Model. The author investigates the Mechanical properties of composite helmet shell using Halpin-Tsai equation. The experimental results are satisfactory when compare with theoretical results. In the present work, the simulation of industrial safety helmet made of S-Glass/epoxy composite has been carried out using the solidworks simulation software.

2. MATERIAL AND METHODS

In the present work, CAD-embedded solidworks version 12 simulation software has been used to model industrial safety helmet. Material for helmet has been taken as S-glass reinforced epoxy composite. As the main load in helmet is impact load, the drop test has been simulated in the software environment. Different surfaces of the safety helmet have been simulated separately. All the surfaces were discretized with fine meshing. The simulation results were compared with the results of existing helmet material (i.e. polypropylene).
3. RESULT AND DISCUSSION

First, the model of industrial safety helmet shown in figure 3 has been imported to the solidworks simulation software environment. The helmet model is drawn in four surface parts. In solidworks surface has been selected and the material of helmet as s-glass and entered the properties of s-glass shown in figure 4. The drop test is performed to analyze the industrial safety helmet and the mesh element was taken in triangular form with mesh size 4.4472 mm. Smaller the mesh size better the simulation results obtained. The Generated mesh elements, Von-misses stresses and strain developed during simulation are shown in figure 3, figure 4 and figure 5 respectively.

![Helmet model](image1.png)
Fig. 2 S-Glass properties

Fig. 3 Generated Mesh Elements
The maximum von-mises stress produced when the load stroked the helmet is 194.4 N/mm² and the yield strength of the industrial helmet of S-Glass material is obtained as 0.4 N/mm². The
maximum value of strain is $1.001 \times 10^{-3}$ and the minimum value of strain is $4.487 \times 10^{-19}$ which is obtained from the simulation results. As shown in figure 6, the red zone shows the maximum stress area and the blue region has minimum stress area.

Various authors focused their study on the finite element analysis using different software of safety helmet developed by combination of different natural and synthetic fibers. The industrial safety helmet fabricated using natural fiber (coconut/banana) has more stress ($0.0828$ KPa) absorption capability and more displacement ($6.89 \times 10^{-2}$ mm) than the existing industrial safety helmet material made of polypropylene [10].

| Material of helmet                      | Von-mises stress (N/mm$^2$) | References |
|----------------------------------------|-----------------------------|------------|
| S-Glass Epoxy Composite                | 194.4                       | Present work |
| Polypropylene                          | $4.4 \times 10^{-15}$       | [10]       |
| Acrylonitrile butadiene styrene        | 37.291                      | [11]       |

Table 1. Comparison the analyzed results of S-Glass Epoxy composite helmet with Existed Helmet Material

4. CONCLUSION

In the present study, the simulation has been carried out using solidworks simulation for the industrial safety helmet. The conclusions drawn from the study are as:

1. The S-Glass epoxy composite has more capacity to absorb the stresses than the polypropylene and acrylonitrile butadiene styrene (ABS).
2. The maximum stress reached is $194.4$ N/mm$^2$ which is within permissible limit of yield stress of the material used for helmet i.e. glass/epoxy composite. At this maximum stress, the maximum displacements produced are $1.172$ mm.
3. Simulation results show the S-Glass fiber epoxy composite can be used to replace the existing industrial safety helmet because of its better mechanical properties and less in weight characteristic.

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