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Design and analysis of industrial safety helmet

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Abstract

The safety of the workers is a valuable asset in every organization. A safety helmet is one of the personal protective equipment to ensure the user's head against the impact of heavy loads in work sites. This study presents the optimized design of the shell of locally used safety helmets in Nepal's industries and works sites. The study is based on the cohesive findings from qualitative and quantitative research. The interviews were carried out in Mahindra Auto Works Pvt. Ltd. and Dhulikhel Hospital. Questionnaire data were collected from Udayapur Cement Industries Ltd., Balaju Industrial Area and Patan Industrial Area, which helped identify the problems in Nepal's existing safety helmets. The issues identified were headache due to extra weight, insufficient ventilation, adjustment and fitting problem, insufficient peak, inadequate aesthetic look, tight chin strap. The data from Dhulikhel Hospital interpreted anatomy of head and was considered to proceed with the new design of helmet shell. The 3D design of the shell of the newly designed helmet and the existing helmet was done in SolidWorks, and their simulation was carried out in ANSYS Workbench 15. The comparison of old and new models was done for static, dynamic and compression test considering the varying cases and force magnitudes. This study concludes that the total deformation and equivalent stress of the new model were less than that of the old model.

Keywords: Personal protective equipment; Safety helmet; Chin strap; Peak

1. Introduction

The safety of the workplace is a crucial factor in determining the effectiveness and productivity of the worker. The ignorance of safety factor is prevailing, especially in the developing countries where labors face a significant loss [1]. Even when the safety equipment is given, they are mostly outdated. The industrial sector of the developing country is more prone to hazard and accident, and hence it requires the safety equipment which is up to meet the OSHA standard [2]. In response to overcoming the challenges posed by unsafe workplace, the work is focused on the helmets shell's design. A safety helmet is a type of helmet, used to protect the user's head from impact. The impact might be in the form of the falling object from the top or lateral side. It helps protect the head from debris, rain and electric shock and is mandatory in workplace environments, including industrial and construction sites. The oldest use of helmet was by the Assyrian soldiers in 900 BC [3]. The earlier year had used leather and bronze as helmet material [4].

The optimization of helmet design has been done over time, leading to the advanced safety helmet. The safety helmet, according to OSHA standard, uses the lightweight plastic as its material [5]. The same helmet can also be used in sports, rescue work, mountaineering, firefighter and transportation with some specified modifications [6]. The project aims to reduce the risk of serious head injury due to the impact of force and collision on the head. A safety helmet is designed to absorb a significant portion of impact energy, created during the collision of the impact load and helmet. The minor portion of the impact is transferred to the head during the collision. The design of the safety helmet is based on ANSI Z 89.1-1997 standard.

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2. Materials and method

High-density polyethylene (HDPE) is a chain of the hydrocarbon polymer prepared from the ethylene or petroleum, using a catalytic process [7]. HDPE has been chosen over other material because it can easily be molded and welded together. It has greater tensile strength compared to Acrylonitrile Butadiene Styrene (ABS) [8]. It is resistant to solvents and has a high density to strength ratio, making it ideal plastic for reusable and recyclable materials [9]. After the selection of material, research procedure was selected. Qualitative research was the initial stage of research which focused on open-ended and conversational communication. The interview session was carried out where open-ended questions were asked with 40 people from different sites, as mentioned above.

The basis for analysis was provided by this research method. Quantitative analysis was followed by the qualitative, which was meant to provide precise information, relevant to the problem. Questionnaires were prepared where responses are obtained from the self-completing questionnaire and online survey of the bike helmets. The Teku area was selected for a market survey where the helmets like H Ventra, Karma and general helmets were reviewed. The general type helmet was imported from China and had not followed any standard specification, which was an eye catching and serious issues encountered during the market survey. It was appalling and drew our attention to work further to resolve real-life problems. The data from Dhulikhel Hospital provided the basis for understanding human head anatomy and allergic materials to design a comfortable helmet. Nylon was identified as the most allergic material and required to be avoided, where design must be based on reducing traction force between the head and helmet.

Figure 1: Helmets shell design of new model.

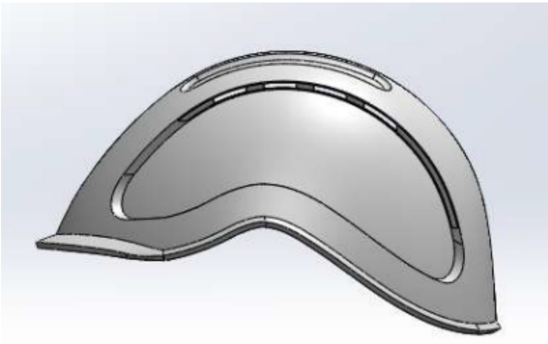

Figure 2: Right side view of new model.

2.1. Boundary and simulation condition

The simulation process's boundary condition was carried out considering the factor such as mesh, force, and fixed support applied on the helmet shell. Initially, the minimum edge length was less, and the mesh independence used in this work was not successful and took more time to mesh and generate a solution. So, the mesh was made fine for a quick solution. The force of 250 N was applied in a vertical direction to analyze the simulation. The force of 150 N, 350 N and 450 N was also analyzed under the same condition. The force of 250 N was applied in both directions in a compression test. Fixed support was applied at the edges and inner side for every case.

The simulation condition was carried out for static, dynamic (drop test) and compression test for the old and new model. The assumption is made for the analysis and is listed below:

- All forces are uniformly distributed throughout the helmet's shell.
- All forces are absorbed only by the helmet's shell.

3. Results and discussion

3.1. Design of optimized helmet shell

The problems were identified using the qualitative and quantitative information, and hence the design of the helmet shell was optimized, which could overcome the problems encountered during the study. The optimization was continued considering the factor such as safety, appearance, comfort and manufacturability. The helmet shell was designed (Fig. 1-3) and consisted of the below-listed features:

- There are four ventilation holes on each side to access the adequate flow of airstream and maintain the helmet's temperature.

Figure 3: Top view of new model.

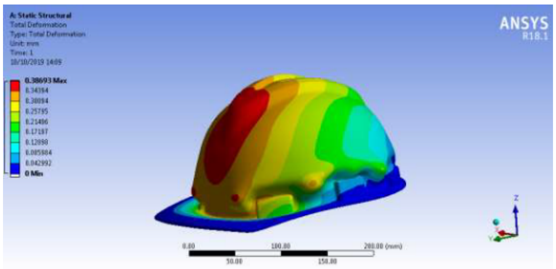

Figure 4: Total deformation of old model.

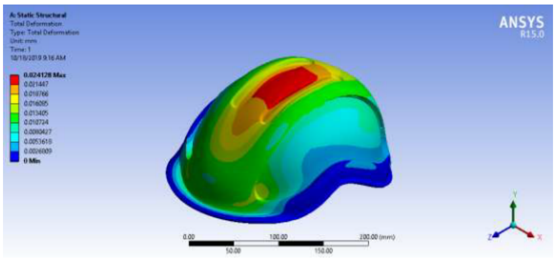

Figure 5: Total deformation of new model.

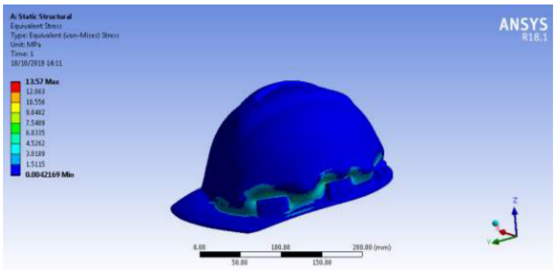

Figure 6: Equivalent stress of old model.

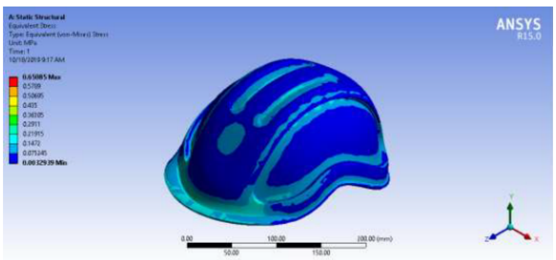

Figure 7: Equivalent stress of new model.

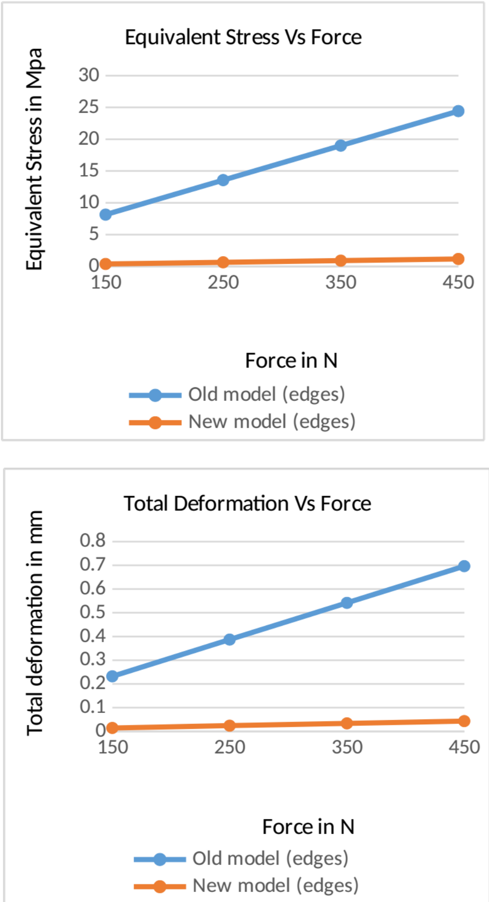

Figure 8: Equivalent and total deformation vs. force.

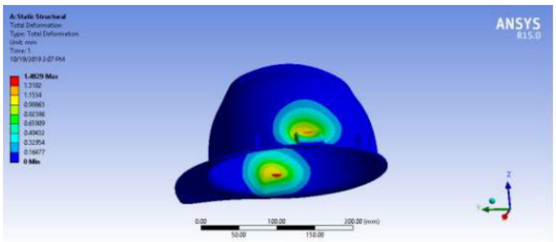

Figure 9: Total deformation of old model.

- The length of the peak is 2 cm, and it is less than the old model. It was done to provide maximum sight to users.
- The dome shape is changed to a slender dome shape according to the shape of the human head. It helps to decrease the height of the helmet.
- The back part of the helmet was further extended to protect the cerebrum part of the human head recommended by the doctor of Dhulikhel Hospital.
- The bump on the top and sides of the helmet induces more stress and protects head parts.
- The arc was provided on both sides of the helmet just above the ear, preventing ear pain.
- The brim of the helmet was made slight at an angle for rainwater management.

3.2. Simulation

The simulation was done for comparing the old and new model where the boundary conditions were discussed above.

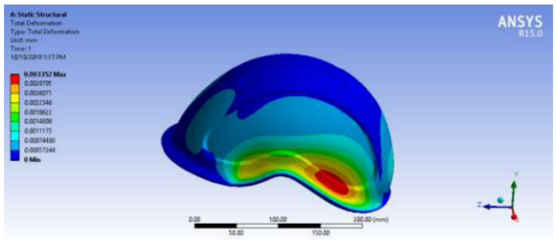

Figure 10: Total deformation of new model.

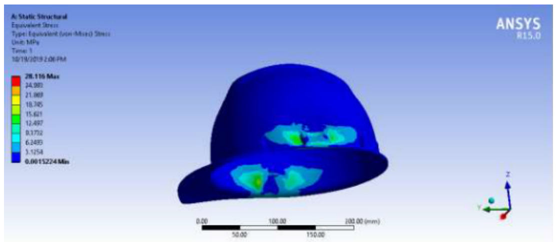

Figure 11: Equivalent stress of old model.

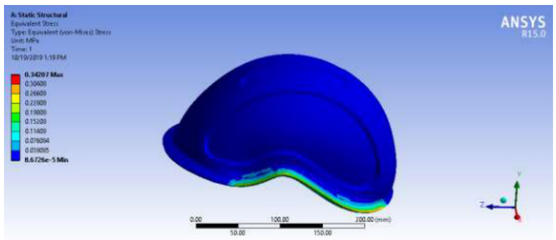

Figure 12: Equivalent stress of new model.

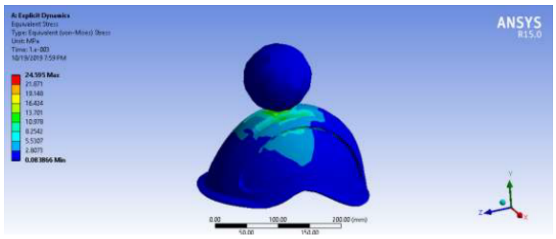

Figure 13: Equivalent stress of new model.

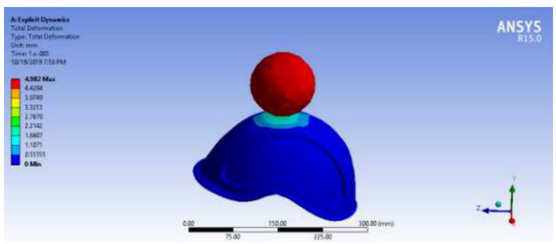

Figure 14: Total deformation of new model.

3.2.1. Case 1: Varying forces and fixed support on edges

In this case, we had applied the forces of 250 N in the vertical direction on V-section of old and new helmets. The fixed support was applied on the edges of helmet shell. It was done to calculate the equivalent stress and total deformation. Fig. 4 and Fig. 5 show the simulation result for total deformation, and Fig. 6 and Fig. 7 show the equivalent stress. The same condition was also tested for other boundary condition as mentioned above. The similar result was achieved by replacing the edge fixed support by inner fixed support, keeping all other condition same as it is shown in Fig. 8.

3.2.2. Case 2: Compression test

The force of 250 N was applied horizontally on both sides of the old and new model in a compression test. The fixed support was applied on the edges of the helmet's shell. The model was created keeping in mind the lateral loads which must take loads from lateral sides without deforming. Fig. 9-10 show total deformation of the old and new model. Fig. 11-12 show equivalent stress of the old and new model.

3.2.3. Case 3: Dynamic test of new model

The dynamic test was carried out for the new model. The grey cast iron ball of 5 kg mass was dropped on the helmet with the velocity of 5 m/s. Acceleration due to gravity was also considered. The value for total deformation and equivalent stress was calculated (Fig. 13-14). The equivalent stress under the allowable stress of the material and total deformation for the applied force was 2 mm.

4. Conclusion

The design optimization of industrial safety helmet shell ensures both safety and comfort. It is done in response to tackling the identified problem accompanied with the safety helmet. The research identified the core problems: extra weight, insufficient ventilation, adjustment and fitting problems, insufficient peak, inadequate aesthetic look, tight chin strap, and rigid suspension web. The helmet quality does not meet OSHA standard, and it poses the major threat on smooth workplace regulations. The paper is based on solving the problem associated with the helmet shell where other issues are supposed to be encountered in the near future by other research enthusiast. The minimum total deformation value was found to be 0.014477 mm (edges) and 0.0001261 mm (inner) for the force of 150 N.

In contrast, the maximum total deformation value was 0.043431 mm (edges) and 0.0003783 mm (inner) for the force of 450 N. The minimum equivalent stress value was found to be 0.39051 MPa (edge) and 0.0015623 MPa (inner) for 150 N force. The maximum equivalent stress value was 1.1715 MPa (edges) and 0.046868 MPa (inner) for 450 N force. The conclusion extracts the information that the new model has less equivalent stress and total deformation under both conditions of edge and inner face than the old model. The dynamic test and compression test, followed by a static test, also has less equivalent stress and total deformation for the new model than the old model.

Acknowledgments

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