ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Volume 11 Issue 01 January 2024

Development of Cost Effective Surgical Helmet

[1] Rashmi Uddanwadiker, [2] Prajwal Tamhane, [3] Ujjwal KumarZhende, [4] Alankar Ramteke

[1] [2] [3] [4] Mechanical Engineering department Visvesvaraya National Institute of Technology, Nagpur, India [4] Orthopedic Surgeon, Wockhardt Hospital Nagpur

Corresponding Author Email: [1] rvuddanwadikar@mec.vnit.ac.in, [2] prajwal.tamhane.9@gmail.com, [3] ujjwalkumarzhende@gmail.com, [4] alankar.ramteke@jointplacementclinic.com

Abstract*— Cost Effective Redesigning of Surgical Helmet was aimed to address the issue of the high cost of surgical helmets while maintaining their necessary features to prevent infection transmission between medical staff and patients. The project involved redesigning and creating a prototype surgical helmet with cost-effectiveness as the primary consideration. The study considered change of manufacturing processes, materials used, and part geometries to reduce cost without sacrificing the helmet's effectiveness. The project's objective was to develop a bi-directional biologic prevention and protection surgical helmet that met all requirements at a lower cost. The results of this study could lead to increased availability of surgical helmets in medical settings, ultimately improving patient and medical staff safety.

Keywords*— Protection, healthcare, fogging, ventilation, fluid.

I. INTRODUCTION

The primary objective of this study was to develop a cost-effective surgical helmets using 3D-printing technology and lightweight materials, with the aim of improving the accessibility and quality of personal protective equipment (PPE) for healthcare workers. The study included (i) identifying the key design features and materials needed to develop a costeffective and high quality surgical helmet using 3D printing technology. (ii) Evaluating the comfort, and mobility of healthcare workers using the redesigned surgical helmet during their daily duties. (iii) Assessing the impact of the cost-effective redesign of surgical helmets on the reduction of the risk of infection and other occupational hazards among healthcare workers. (iv) Providing recommendations for PPE manufacturers to develop new and innovative PPE designs that prioritize comfort, mobility, and affordability.

Several studies have been conducted on redesigning surgical helmets to improve their effectiveness, comfort, and cost-effectiveness. Development of a New Surgical Helmet for Optimal Protection and Comfort by N. Schmid et al.[1] aimed to develop a new surgical helmet that offers optimal protection and comfort to healthcare workers. A. Long et al.[2]in his study Development of a lowcost surgical helmet for use in resource-limited settings used locally available materials and simple manufacturing techniques to produce the helmet. Another study on Evaluation of a New Surgical Helmet by R. L. Reid et al.[3] designed prototype to decrease fogging and improve comfort. In the paper Design and evaluation of a prototype surgical helmet with fluid-capturing ability by S. K. Jha et al [4] the researchers used a 3D printing technique to produce the helmet and tested its effectiveness in capturing fluid splashes. An Anthropometric Study of Head for Designing Ergonomic Helmet by M. Andriani, A. Widyanti, Yassierli, R. Pramanda, and Suheri [5] discussed the method of measuring head dimensions and the importance of accurate measurements for head circumference, length and width, as they are crucial for designing helmets that fit comfortably and provide adequate protection.

II. METHODOLOGY

Based on the data exploration and feedback from healthcare professionals who use surgical helmets regularly, a CAD model was prepared; the data and the dimensions were taken from anthropometrics data from the research paper. Figure 1 shows the CAD model of first prototype which was found to be inefficient for placement of ventilation system.

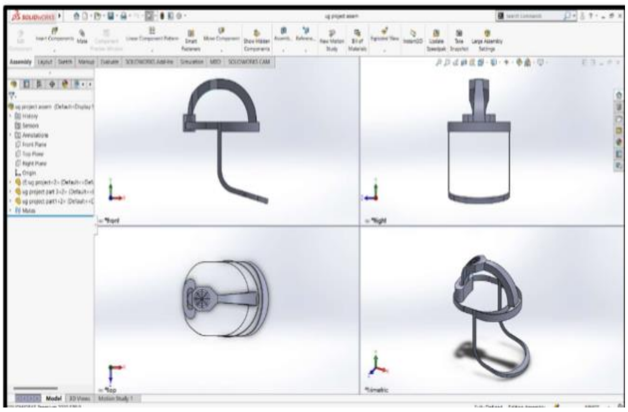

Fig. 1. Cad Model Showing Different Views of the Helmet

Another model with proper space for ventilation and placement of fan was designed and is as shown in the figure2.

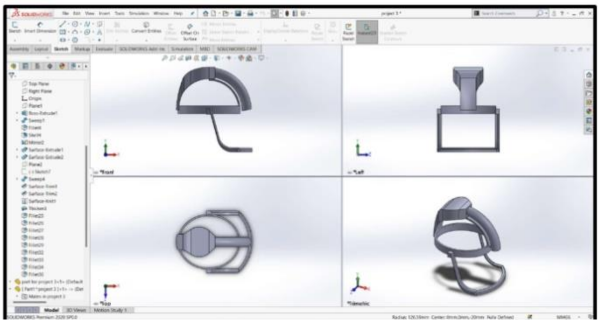

Fig. 2. Cad Model of Final Helmet Prototype

Based on the design, the product was manufactured and made of high-strength polycarbonate material, which is also used in the production of helmet. This material has been tested and proven to withstand impact. Figure 3 shows the manufactured part.

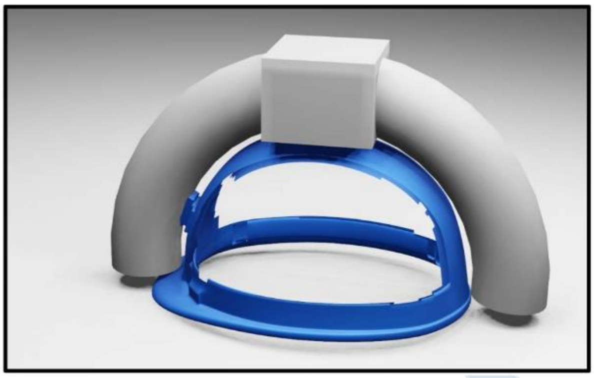

Fig. 3(a). Top view of the Final product

Fig 3(b). Padding and Strap Provided Below the Helmet

The helmet shell is the main body of the surgical helmet and is made of a lightweight, high-strength material. The inner surface has Shell Padding. The helmet padding is made of a soft, cushioning material that is designed to provide comfort and protect the wearer's head. The helmet straps are used to secure the helmet to the wearer's head.

The surgical helmet has been designed with a ventilation system that helps to reduce heat buildup and keep the wearer cool during long procedures. Ventilation system includes a fan, a battery to run the fan and a duct system. The Rechargeable Lithium Battery is used which needs 12.6V charging voltage and 600mA charging current. Further the fan used is centrifugal flow DC Blowers with expected life 70,000 Hours (L10) at 25˚ C, with an input Power of 3.48 W.

III. CFD ANALYSIS ON VENTILATION SYSTEM

For the CFD analysis the next step is to import the model created into SolidWorks which resembles the domain for analysis in ANSYS workspace. The imported geometry is split into two parts; one representing fan surroundings and other represents the duct. Named selections are created to generate inlet surface and two outlet surfaces. Meshing is a critical step in computational fluid dynamics (CFD) simulations, and it involves dividing the computational domain into a finite number of smaller elements or cells. The process of meshing helps to create a discrete approximation of the continuous domain, which can then be used to numerically solve the governing equations of fluid flow. The geometry is meshed using hexa-dominant meshing method with the body sizing 0f 5 mm for duct zone as shown in the fig4 and the fan surrounding is meshed using default meshing with the sizing of 1mm with 134528 Cells 301576 Faces and 33198 Nodes.

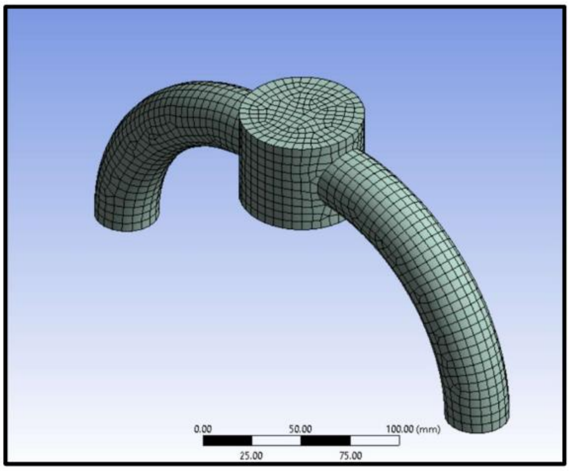

Fig. 4. Meshed Model of Duct Showing Inlet and Outlet

Constraints which are necessary to get required solution of problem are called as boundary conditions. Boundary condition for this case is as follows– The speed of air at inlet is set to 0.15 m/s normal to the surface. The pressure outlet conditions are assumed 44 MPa at the outlets. Fan surroundings are provided with the rotating motion of speed 2500 RPM.

The setup is then initialized and run for 10000 iterations. The fan used is 50 mm centrifugal fan and given a rotary motion. The analysis is conducted for the following conditions:

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Volume 11 Issue 01 January 2024

1. Pressure surrounding the domain as atmospheric pressure
2. Inlet air flow from top of the housing with velocity of 0.15m/s
3. The fan is rotating with the 2500 RPM
4. No slip conditions at the remaining walls

The velocity contour and the residual curves showing the convergence conditions are shown in figure 5.

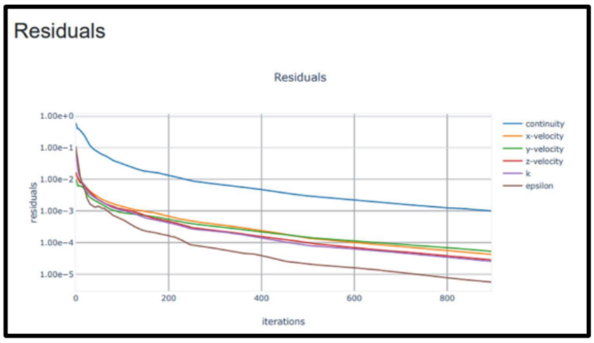

Fig. 5(a). Residual Curve Showing the Convergence During Solution

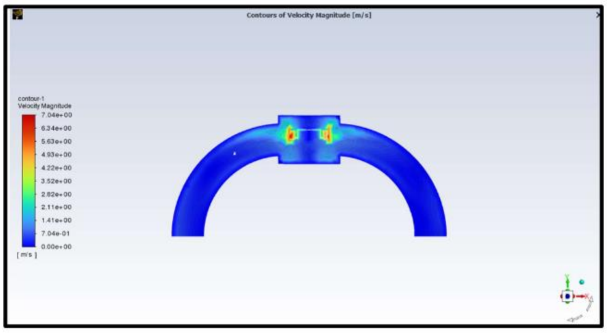

Fig. 5(b). Velocity Contour Showing the Working of Centrifugal Fan

Velocity output at both the outlet is observed as follows. Area-Weighted Average Velocity Magnitude $outlet_1$ - 0.20293766 m/s $outlet_2$ - 0.38753121 m/s. The results obtained from the CFD analysis were verified and validated using the experimentation on the manufactured product.

The results obtained after assembling the helmet, duct and fan system are recorded as shown in fig 6. The airflow from the $outlet_1$ (front duct) using anemometer is resulted in 0.28 m/s, and from the $outlet_2$ (duct at back) is observed as 0.41 m/s. The error is minimum and acceptable.

Fig. 6. Flow Measurement Using Anemometer

IV. CONCLUSION

The use of lightweight materials and 3D printing technology makes the helmet comfortable, adjustable, and cost-effective. It can provide healthcare workers with secure and effective protection while performing their duties. However, the study has some limitations, including a small sample size, and further evaluation is required to assess the helmet's durability and effectiveness in different clinical settings. Overall, while the redesigned surgical helmet shows promise in addressing the limitations of traditional helmets its cost effectiveness has a market potential and impact on reducing the risk of infection among healthcare workers.

REFERENCES

[1] Schmid, N., et al. "Development of a New Surgical Helmet for Optimal Protection and Comfort." Journal of Occupational Health, vol. 62, no. 1, 2020, pp. 1-8.

[2] Long, A., et al. "Development of a low-cost surgical helmet for use in resourcelimited settings." Journal of Medical Engineering & Technology, vol. 44, no. 1, 2020, pp. 34-40.

[3] Reid, R.L., et al. "Evaluation of a New Surgical Helmet Prototype Designed to Decrease Fogging and Improve Comfort." Journal of Occupational and Environmental Hygiene, vol. 16, no. 9, 2019, pp. 646-654

[4] Jha, S.K., et al. "Design and evaluation of a prototype surgical helmet with fluidcapturing ability." Journal of Medical Devices, vol. 13, no. 3, 2019, pp. 1-9.

[5] Andriani, M., et al. "An Anthropometric Study of Head for Designing Ergonomic Helmet." International Journal of Engineering and Technology, vol. 9, no. 2, 2017, pp. 160-165.