Helmet-Riding to the Next Generation

Yuvraj1, G. Sai Venu Geethika2, Ayush Bakrewal3

1, 2, 3Vellore Institute of Technology

Abstract: A helmet is a type of head protection that is worn on the head. By decreasing the impact of a force or collision to the head, a helmet seeks to lessen the risk of significant head and brain injuries. The shell, EPS liner, Comfort liner, Cheek pads, Visor, and Retention or closing mechanism are the different sections of a helmet.

Metal foams are a type of cellular material that has a number of fascinating qualities, including high stiffness and low specific weight, as well as effective energy absorption. These distinct features make them suitable for a wide range of applications, from car bumpers to aircraft crash recorders.

Keywords: Helmet, Material Selection, CFRP, Bluetooth

I. INTRODUCTION

The Material Selection process for a product entails taking into account a variety of factors such as the manufacturing process, the environment, availability, function, form, cost, context of usage, and other factors. The designer is expected to include all of the relevant criteria while picking materials in order to provide a favourable user experience. It might also mean swapping out the current materials for something else that offers the same or better benefits.

We've also put some extra features in our helmet. For our helmet, we've designed an app illustration that can be connected through Bluetooth. We've added a few more functions to our helmet using this technology. They are as follows:

1) **Music:** While riding, the rider will be able to listen to music with minimum sound.
2) **Navigation:** The rider will be provided instructions on how to get to his desired location. It also informs about traffic and journey time.
3) **Speed Limiter:** If the car reaches 80 mph, he will be notified, allowing him to travel safely.
4) **Call Receiver:** Using the touch sensor on the left bottom, the driver will be able to accept or deny calls.

II. METHODOLOGY AND EXPERIMENTAL WORK

Helmet shells come in a variety of materials. The most frequent material utilised in the construction of helmets is fibreglass. Kevlar, Carbon Fibre Reinforced Polymer, Polycarbonate, Nylon 6,6, ABS are some of the other materials we're looking into for determining the best material to replace fibreglass.

We used the Ashby chart to compare different properties of our chosen materials and then compare them to see which one is the best suited material to replace the current use material (Fibreglass), but we can't pick and choose which properties to compare, so the properties chosen for comparison must be those that are essential for a motorcycle helmet.

The properties which we are taking into consideration to find a substitute for fibreglass are:

1) Density vs Young’s Modulus
2) Fracture Toughness
3) Hardness
4) Wear rate
5) Cost
III. CAD MODELLING / FEATURE ANALYSIS / LITERATURE REVIEW

Fig 1: 2D representation of helmet (top view, front view, side view)

Fig 2: Front view of 3D CAD helmet model

Fig 3: Side view of 3D CAD helmet model

Fig 4: Back view of 3D CAD helmet

Fig 5: Isometric view of 3D CAD helmet
Because of its features like lightweight and strong strength, fibreglass is one of the most commonly utilised materials for constructing helmet shells. As a result, we may determine the rankings of other materials by using it as a reference material.

| S.NO | MATERIALS                     | YOUNG’S MODULUS (E) (in GPa) | DENSITY (ρ) (in kg/m³) | PERFORMANCE INDEX E¹/³ /ρ |
|------|-------------------------------|-----------------------------|------------------------|---------------------------|
| 1    | FIBRE GLASS                   | 72                          | 1860                   | 2.24                      |
| 2    | POLYCARBONATE                 | 2.3                         | 1200                   | 1.14                      |
| 3    | CARBON FIBRE REINFORCED POLYMER | 110                        | 1550                   | 3.09                      |
| 4    | KEVLAR                        | 76                          | 1380                   | 3.07                      |
| 5    | Nylon 6.6                     | 2.52                        | 1140                   | 1.19                      |
| 6    | ABS                           | 2.3                         | 1060                   | 1.24                      |

Table 1: Comparing performance indexes based on Young’s Modulus and Density

From the above table, by comparing the performance indexes, it is visible that CARBON FIBRE REINFORCED PLASTIC (CFRP) is the most suitable material because of its good stiffness and light weight.

| RANK | MATERIALS                          | YOUNG’S MODULUS (E) (in GPa) | DENSITY (ρ) (in kg/m³) | PERFORMANCE INDEX E¹/³ /ρ |
|------|-----------------------------------|-----------------------------|------------------------|---------------------------|
| 1    | FIBRE GLASS                       | 72                          | 1860                   | 2.24                      |
| 2    | CARBON FIBRE REINFORCED POLYMER   | 110                         | 1550                   | 3.09                      |
| 3    | KEVLAR                            | 76                          | 1380                   | 3.07                      |
| 4    | POLYCARBONATE                     | 17.45                       | 1200                   | 2.16                      |
| 5    | Nylon 6.6                         | 2.52                        | 1140                   | 1.19                      |
| 6    | ABS                               | 2.3                         | 1060                   | 1.24                      |

Table 2: Arranging the materials based on their rank of performance indexes

| S.NO | MATERIALS                        | YOUNG’S MODULUS (E) (in GPa) | FRACTURE TOUGHNESS K_Ic (in MPa.m¹/²) | TOUGHNESS, G_c K_Ic²/E |
|------|----------------------------------|-----------------------------|----------------------------------------|------------------------|
| 1    | FIBRE GLASS                      | 72                          | 16                                     | 3.56                   |
| 2    | POLYCARBONATE                    | 17.45                       | 5.488                                  | 1.72                   |
| 3    | CARBON FIBRE REINFORCED POLYMER  | 110                         | 29.32                                  | 7.81                   |
| 4    | KEVLAR                           | 76                          | 24                                     | 7.57                   |
| 5    | Nylon 6.6                        | 2.52                        | 4.34                                   | 7.47                   |
| 6    | ABS                              | 2.3                         | 1.9                                    | 1.56                   |

Table 3: Comparing toughness of various materials
By comparing the toughness of various materials in the table above, it is clear that CARBON FIBRE REINFORCED PLASTIC (CFRP) is the best suited material due to its great toughness.

While CFRP has the highest toughness, Kevlar's (7.57) hardness is not far behind CFRP (7.81).

Table 4: Arranging materials in the order of their toughness

| RANK | MATERIALS                        | YOUNG’S MODULUS (E)(in GPa) | FRACTURE TOUGHNESS $K_{IC}$ (in MPa.m$^{1/2}$) | TOUGHNESS, $G_C$ $K_{IC}^2/E$ |
|------|---------------------------------|-----------------------------|-----------------------------------------------|-------------------------------|
| 1    | CARBON FIBRE REINFORCED POLYMER| 110                         | 29.32                                         | 7.81                          |
| 2    | KEVLAR                          | 76                          | 24                                            | 7.57                          |
| 3    | Nylon 6,6                       | 2.52                        | 4.34                                          | 7.47                          |
| 4    | POLYCARBONATE                   | 17.45                       | 5.488                                         | 1.72                          |
| 5    | ABS                             | 2.3                         | 1.9                                           | 1.56                          |

Table 5: Comparing wear rate of different materials

| S.NO | MATERIALS                        | HARDNESS, H (MPa) | WEAR RATE CONSTANT $K_a$ (1/MPa) (x10$^{-9}$) | WEAR RATE $(H \times K_a)$ |
|------|---------------------------------|-------------------|-----------------------------------------------|-----------------------------|
| 1    | FIBRE GLASS                     | 4500              | 0.022                                         | 0.1                         |
| 2    | POLYCARBONATE                   | 347               | 3.5                                           | 1.2145                      |
| 3    | CARBON FIBRE REINFORCED POLYMER| 310.5             | 1.35                                          | 0.4194                      |
| 4    | KEVLAR                          | 75                | 2.67                                          | 0.2                         |
| 5    | Nylon 6,6                       | 90                | 2.85                                          | 0.2565                      |
| 6    | ABS                             | 107               | 9                                             | 0.963                       |
### Table 6: Arranging materials according to their wear rates.

| Rank | MATERIALS                  | HARDNESS, H (MPa) | WEAR RATE CONSTANT $K_a$ (1/MPa) ($\times 10^{-9}$) | WEAR RATE ($H \times K_a$) |
|------|---------------------------|-------------------|---------------------------------------------------|-----------------------------|
| 1    | KEVLAR                    | 75                | 2.67                                              | 0.2                         |
| 2    | Nylon 6,6                 | 90                | 2.85                                              | 0.2565                      |
| 3    | CARBON FIBRE REINFORCED POLYMER | 310.5          | 1.35                                              | 0.4194                      |
| 4    | ABS                       | 107               | 9                                                 | 0.963                       |
| 5    | POLYCARBONATE             | 347               | 3.5                                               | 1.2145                      |

### Table 7: Comparing costs of different materials

| S. No. | MATERIALS                  | PERFORMANCE INDEX $E^{1/3} / p$ | COST($/kg) | NORMALISED COST $\dot{C}$ ($$/k$$) | PERFORMANCE INDEX $E^{1/3} / p\dot{C}$ |
|--------|---------------------------|----------------------------------|------------|-----------------------------------|-----------------------------------------|
| 1      | FIBRE GLASS               | 2.24                             | 15         |                                   |                                         |
| 2      | POLYCARBONATE             | 1.14                             | 7          | 0.467                             | 2.44                                    |
| 3      | CARBON FIBRE REINFORCED POLYMER | 3.09                        | 75         | 5                                 | 0.62                                    |
| 4      | KEVLAR                    | 3.07                             | 6.27       | 0.418                             | 7.35                                    |
| 5      | Nylon 6,6                 | 1.19                             | 2.56       | 0.17                              | 7.00                                    |
| 6      | ABS                       | 1.24                             | 3.5        | 0.233                             | 5.32                                    |
Table 8: Arranging materials in the order of their Performance Indexes when cost is included

From the previous table, CFRP came out to be the best material in terms of weight and stiffness. But, after considering the cost, Kevlar came out to be the best material.

IV. COST ANALYSIS

The different parts of our helmet include cheek pads, visor, shell, EPS lining, Comfort lining etc.

V. ADDITIONAL FEATURES OF OUR HELMET: APPLICATION ILLUSTRATION

![App demonstration of various features](image-url)

Fig 6: App demonstration of various features (Home page and music)
VI. RESULT AND DISCUSSION

A. From Table 1
1) When comparing the performance indices, it is clear that CARBON FIBRE REINFORCED PLASTIC (CFRP) is the most suitable material because of its good stiffness and light weight.
2) When comparing the performance indices, it is clear that CARBON FIBRE REINFORCED PLASTIC (CFRP) is the most suitable material because of its good stiffness and light weight.

B. From Table 3
1) When evaluating the toughness of various materials, it is clear that CARBON FIBRE REINFORCED PLASTIC (CFRP) is the best option due to its great toughness.
2) Although CFRP has the highest toughness, Kevlar’s (7.57) toughness is not much lower than CFRP’s (7.81).

C. From Table 5
1) When comparing the WEAR RATE, it is clear that KEVLAR is the most appropriate material due to its HIGHEST RESISTANCE TOWARDS WEAR AND TEAR UNDER SIMILAR CIRCUMSTANCES.
2) NYLON 6,6 and CFRP are ranked 2nd and 3rd, respectively, behind KEVLAR.

D. From Table 7
1) When comparing the COST, it is clear that KEVLAR is the most suited material due to its HIGHEST PERFORMANCE INDEX WHEN NORMALISED COST IS TAKEN INTO CONSIDERATION, as shown in Table-7.
2) NYLON 6,6 and ABS are ranked 2nd and 3rd, respectively, after KEVLAR.

We derive Young's Modulus – Density, Fracture Toughness – Density, and Wear rate – Hardness by comparing all the tables.

| Test                  | Material | Polycarbonate | Nylon 6,6 | ABS | Carbon Fiber Reinforced Polymer | Kevlar |
|-----------------------|----------|---------------|------------|-----|---------------------------------|--------|
| Young's Modulus – Density | 3<sup>rd</sup> | 5<sup>th</sup> | 4<sup>th</sup> | 1<sup>st</sup> | 2<sup>nd</sup> |
| Fracture Toughness – Density | 4<sup>th</sup> | 3<sup>rd</sup> | 5<sup>th</sup> | 1<sup>st</sup> | 2<sup>nd</sup> |
| Wear rate - Hardness | 5<sup>th</sup> | 2<sup>nd</sup> | 4<sup>th</sup> | 3<sup>rd</sup> | 1<sup>st</sup> |
| Cost                  | 4<sup>th</sup> | 2<sup>nd</sup> | 3<sup>rd</sup> | 5<sup>th</sup> | 1<sup>st</sup> |

Table 9: Summary of analysis of various properties
VII. CONCLUSION

In this work, we attempted to design a helmet made of a superior material to replace fiberglass, as well as to combine new functionality via a Bluetooth connecting device. Due to its low weight, high rigidity, strongest resistance to wear rate, and low cost, Kevlar was determined to be the optimum material for the job. Bluetooth headset, touch sensor to receive and deny calls, navigations with directions and traffic information, and a speed controller are among the extra features included to improve the rider’s safety and security. Because of its additional benefits not seen in traditional helmets, this helmet would be highly valuable for future generations.

Our model’s future scope of improvement would be to produce a long-lasting battery so that the user does not have to constantly charge it. Other features may be added, such as a riders tiredness detection system that alerts the user if someone is attempting to steal the helmet, and a locking system for the motorbike.

REFERENCES

[1] https://www.iosrjournals.org/iosr-jme/papers/NCRIME-2018/Volume-64.%2013-21.pdf
[2] Naresh, Poppathi & Krishnudu, D.Mohan & Hussain, Parwiz & Babu, A.V.Hari. (2015). Design And Analysis Of Industrial Helmet. International Journal of Mechanical Engineering Research. 5. 81-95.
[3] "Characterization of ABS composites reinforced short glass fiber” Ankul Oriya and Rohit Rajvaidya. IJRET [International Journal of Research in Engineering and Technology]-2015
[4] "Design and Analysis of Industrial Helmet”Anil Kumar and Y. K. Suresh babu. International Journal Of Computational Engineering Research, Vol-3, Issue-12-2013.
[5] "Ballistic Helmets - Their Design, Materials, and Performance against Traumatic Brain Injury” S.G. Kulkarni, X.-L. Gao, S.E. Horner, J.Q. Zheng, N.V. David. Composite structures-Elsevier. 2013.
[6] "Mechanical Properties of Glass Fiber Reinforced Polyester Composites” M. S. EL-Wazerya, M. I. EL-Elamy and S. H. Zoalfakarb. International Journal of Applied Science and Engineering 2016
[7] "Mechanical Characterization of Thermoplastic ABS /Glass Fiber Reinforced Polymer Matrix Composites” Divakar H, R Nagaraja and Guruprasad H L. International Journal of Engineering Research and Technology [IJERT] 2015
[8] Zhi Xiao, Li Wang, Yunfei Zhang & Chunhui Yang (2020): A study on motorcyclist head responses during impact against front end of vehicle, International Journal of Crashworthiness, DOI: 10.1080/13588265.2020.1779457
[9] Berg FA, Burkle H, Schmidts F, et al. Analyses of the passive safety of motorcycles using accident investigation and crash tests. In: Proceedings of the 16th International Technical Conference of the Enhanced Safety of Vehicles (ESV), Windsor, Canada; 1998
[10] N.J. Mills, A. Gilchrist, The Effectiveness of Foams in Bicycle and Motorcycle Helmets, Accid. Anal. & Prev. Vol 23, pp 153-163, 1991
[11] F.M. Shuaeib, A.M.S. Hamouda, M.M. Hamdan, R.S Radin Umar, M.S.J. Hashmi, Motorcycle Helmet Part II. Materials and Design Issues, Journal of Material processing Technology Vol 123, pp 422-431, 2002
[12] Motorcycle Industry Magazine October 2001 Survey on Helmet Market and Tools and Service
[13] Ashby Charts 
[14] https://www.azom.com/article.aspx?ArticleID=1951
[15] https://www.azom.com/properties.aspx?ArticleID=764
[16] Product Design for Manufacture and Assembly G. Boothroyd and P. Dewhurst, Boothroyd Dewhurst, Inc. 1989 Marcell Dekker, Inc. 1994
[17] https://www.azom.com/article.aspx?ArticleID=1992
[18] https://www.azom.com/article.aspx?ArticleID=1384
[19] https://www.azom.com/article.aspx?ArticleID=368
INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY
Call: 08813907089 📞 (24*7 Support on Whatsapp)