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Study of Design and Analysis of Motorcycle Helmet

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Abstract*: Each year, nearly 900 individuals perish from head injuries, and over 50,000 sustain severe injuries due to the absence of helmets. This paper reviews various approaches for the conceptual design of a motorcycle helmet aimed at enhancing structural comfort, visibility, and safety, while also considering adjustable interior form to accommodate the rider's ergonomics. The use of a new material called Fiberglass Reinforced Plastic (FRP) is also explored. The analysis involves the use of the simulation software ANSYS to evaluate the helmet. A maximum force of 150 N is applied to the helmet to assess its performance under static and dynamic conditions. The simulation focuses on parameters such as total deformation, strain energy, and von-Mises stress across different scenarios in static conditions*

Keywords: Motorcycle Helmet, Composite Material, Safety, ANSYS.

I. INTRODUCTION

It is challenging for middle-class individuals to afford luxury cars for their daily needs, making two-wheeler motorcycles essential. Consequently, motorcycle usage is steadily increasing in India. As most accidents in India involve two-wheelers, ensuring the safety of motorcycle riders is paramount. The use of a protective helmet is one effective measure to prevent head injuries in motorcycle crashes. Helmets have been shown to significantly reduce the risk of head and brain injury by 70 to 88% and facial injury to the upper and mid-face by 65%. However, wearing helmets is challenging in countries like India due to discomfort in tropical climates. Despite the Indian Motor Vehicle Act mandating the use of helmets while riding, people often opt for open-face helmets, which offer less protection compared to full-face helmets. There is a need for motorcycle helmets that provide good thermal comfort, visibility, safety, and an adjustable interior head form. Proper ventilation is crucial for the rider's safety and comfort, ensuring adequate heat transfer and airflow. A quality helmet not only enhances the riding experience by reducing wind noise, windblast, and deflecting objects but also contributes to comfort in changing weather conditions and reduces rider fatigue.

In order to understand basic structure of helmets we must know some of the basic definitions and terminologies used in helmets.

1. Two-Wheeler-A two-wheeler can be defined as a two wheeled motor vehicle with or without detachable side car. General term used for this is Motorcycle.
2. Protective Helmet-A helmet primarily intended to protect the wearer's head against impact. A helmet is a type of safety measures used in various sections of the dangerous segments of use. A helmet is used in different sectors such as road safety as a safety gear while two-wheeler driving, industrial work etc.
3. Shell-It is the most rigid part of the helmet which gives its general shape. A hard part of the helmet, which provides the strength and toughness, to the whole of a helmet structure.
4. Protective Padding-Protective padding is a soft material placed to absorb the impact shocks and its energy. As the name suggests it protects the head of the person who is wearing the helmet through shock reduction through its soft padding.
5. Comfort Padding-The material is similar in nature to the protective padding; this type of padding is provided to provide comfort to the person who is wearing it. To provide comfort is the whole sole purpose of this type of padding.

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6. Retention System-A system which keeps the helmet and head at a stable position is called retention system. It includes devices which are there for adjustment of the system or comforting the person who is wearing it.
Chin Strap-It is a strap which is placed under the jaw to support the chin for proper stable position of the head.
Chin Cup-It is a cup like structure in the chin strap which holds the chin for proper position.
Peak-Peak is an extension of the shell which is covered throughout the helmet.
Lower Face Cover-It is an integral, detachable and movable part of the helmet which covers the lower part of the face.
Protective Lower Face Cover-It is an integral, detachable and movable part of the helmet which covers the lower part of the face which is intended to protect the chin of the rider from impact.
Non-Protective Lower Face Cover-It is an integral, detachable and movable part of the helmet which covers the lower part of the face and it does not protect the chin of the rider from impact.
7. Visor-Visor is that transparent part of the helmet through which a rider is able to see. It is a protective screen for the eyes.

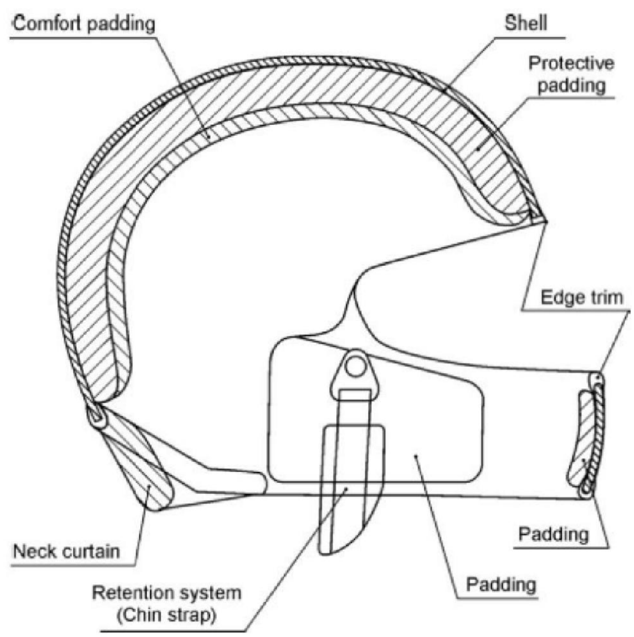

Figure 1:Structure of Helmet

II. LITERATURE REVIEW

V. C. Sathish Gandhi et. al. conducted a study titled "Analysis of Motorcycle Helmet under Static and Dynamic Loading" published in the International Journal of Mechanical, Aerospace, Industrial, and Mechatronics Engineering in 2014. The design and analysis of the helmet were performed using ANSYS software for both static and dynamic conditions, considering various scenarios. The results indicated that the chin (retention system) side of the helmet experienced less strain energy and deformation, which is crucial since head injuries in accidents involving motorcycles can be severe. Therefore, special attention should be given to the chin side of the helmet to reduce the risk of serious injuries to the rider.

P. Viswanadha Raju et. al. presented a study on the "Design of Streamlined Motorcycle Helmet with Enhanced Head Protection." They conducted fluid flow analyses to understand the flow behavior inside the helmet and proposed modifications to improve the flow for better rider comfort. Impact analysis was also performed to ensure that the modified helmet meets the impact absorption test specifications set by the Bureau of Indian Standards (BIS).

N. J. Mills, et. al. conducted a study on"FEA of Oblique Impact Tests on a Motorcycle Helmet." The study estimated that the peak head rotational acceleration during oblique impacts to the side of the helmet, which commonly occurs in motorcycle falls, could reach 15krad s-2. Such acceleration levels could lead to rotational head injuries.

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S. K. Mithun, et. al. worked on the conceptual design of a motorcycle helmet to improve thermal comfort, ergonomics, and safety. Their project aimed to design a helmet with adjustable interior form, enhanced thermal comfort, visibility, and safety features based on user requirements. The design process included GEMBA study, user surveys, QFD, PDS, and detailed design incorporating adjustable head form, air vents, and exhaust fans for thermal comfort. They also created a full-scale working model and tested it for functionality.

Praveen K. Pinnojiet. al presented "Two-Wheeler Helmets with Ventilation and Metal Foam" in the Defence Science Journal. They investigated the dynamic performance of three different helmets: one with an ABS shell, another with metal foam, and the third with a single groove in the liner foam for ventilation. Impact analyses were conducted at 10 m/s velocity using LS-DYNA. The study found that the presence of a groove in the liner foam did not significantly affect pressure and stresses in the brain, which were measured to evaluate ventilation improvements. They also compared the dynamic performance of a helmet with a metal foam outer shell to that of a helmet with an ABS material shell.

Tamilmaniraj.Vet. al. discussed the importance of improving the strength of motorcycle helmets through materials and designing a closed surface with less ventilation for safety during crashes. However, this design may not be suitable for asthma patients who cannot wear closed helmets for long periods. To address this, they designed a helmet using SOLIDWORKS surface modeling and analyzed it using ANSYS and CFD Fluent 14.5 workbench. They developed a model for engineering optimization and used survey data to predict sales when the product is launched. They also conducted a literature survey to refine their cost estimation model by aligning customer demand with design and manufacturing processes.

Asiminei AG, et. al. conducted a study on the impact of bicycle helmet material properties on head protection during an impact. They used finite element analysis to understand how bicycle helmets protect the head during impacts, with a focus on helmet optimization and improvement. The study used MSC Marc Mentat finite element software to describe the relationship between helmet mechanical parameters and the risk of head injury. The results showed a reduction in head linear acceleration and stress, indicating the protective effect of different materials studied, with anisotropic foam showing superior behavior.

Keith Norris et. al. analyzed the performance of foams used in hurling helmets. They tested energy-absorbing materials to determine the optimal thickness and density of foam in the helmet. Static tests were conducted on a compression test machine, while dynamic tests were carried out on a drop test rig. The results were analyzed using LabView and TEMA analysis software. Finite element analysis was used to model the foams statically and dynamically, with ANSYS implicit solver and ANSYS/LS-DYNA, respectively. The study aimed to determine the best density and thickness of foam for hurling helmets.

Jingshu Wu, et. al. analyzed helmet impact velocity experimental data and studied factors influencing impact velocity. They aimed to verify if a tolerance of +/- 3 percent of mean velocity is feasible and allows at least 95 percent of impacts to fall within the proposed range. Statistical methods were applied to design impact velocity tolerances, incorporating calibration procedures and data variances from several laboratories.

M.A Shamsudin et. al. (2020) designed an open mould suitable for the hand lay-up technique of the Kenaf fiber with epoxy resin adhesion. The analysis of the mould designed by using CAD is to study its mechanical properties such as plasticity. The analysis shows the critical part of the moulding is at its center where the deformation happened. The mould will return to its original shape when the force applied is removed due to the maximum value for shear and equivalent elastic strain did not reach 0.4 m/m which will cause silicon rubber material to tear and failed [9].

Sajjad Pakzad et.al. (2021), intending to identify the minimum stress transmitted to the helmet during an impact, used Rhino software to model a helmet with honeycomb liner and outer shell and then analyzed it in Abaqus software. Due to the fact that the size of various parts of the head is different in people, so for more comfort and safety, the use of a customized helmet is emphasized. To design and make a customized helmet, the materials used in designing the helmet are ABS and PETg filaments, which can be used in 3D printing. These two materials have been analyzed with four compositions for the liner and the shell of the helmet. The results show that the best combination of the helmet with Minimum stress transmission and appropriate plastic strain due to impact is the helmet case with honeycomb liner of PETg and a shell made of ABS [13].

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Kongwat, Suphanut et. al. (2022) research investigates the structural performance of commercial motorcycle helmets in Thailand for head injury prevention using finite element analysis via LS-DYNA. The helmet structural model was firstly validated under impact analysis by comparing with the test according to the TIS 369-2557 standard. The finite element results showed that the difference in maximum acceleration was only 4.8%. The protective efficacy of the helmet structure was then studied and analyzed by simulation under various velocities and impact angles according to three cases of accidents. The structural strength was investigated by assessing energy absorption, HIC, and AIS. The worst case was caused when high impact speeds and angles were applied, which showed the highest impact force and HIC. It also enabled a 100% probability of head damage according to AIS 2+, which causes fatality to passengers during impact accidents. The safest conditions in terms of head injury severity occurred when the impact angle was 45 degrees. Finally, at least 75% energy absorption of foam was further recommended for safety design to reduce head injury from motorcycle accidents [16].

III. RESEARCH GAP IDENTIFICATION

The research gap in the designing and development of two-wheeler helmets encompasses several areas that warrant further investigation. Firstly, there is a need for comprehensive studies on the incorporation of advanced materials and technologies in helmet design to enhance safety without compromising comfort. Exploring innovative materials with superior impact absorption properties, lightweight characteristics, and durability could significantly improve helmet performance. Additionally, research could focus on the integration of smart technologies such as sensors for impact detection, communication systems, and augmented reality displays to augment the overall protective capabilities of helmets. Furthermore, there is a research gap in understanding the human factors associated with helmet usage. Studies should investigate user behaviors, preferences, and the factors influencing helmet compliance among riders. This could involve exploring the design features that promote user comfort, ease of use, and aesthetic appeal to encourage consistent helmet-wearing habits.

Moreover, there is a need for research on the environmental impact of helmet materials and manufacturing processes. Sustainable and eco-friendly materials should be explored to reduce the ecological footprint of helmet production. Life cycle assessments and eco-design approaches can be employed to evaluate the environmental impact of helmets from raw material extraction to disposal.

Lastly, there is a gap in research concerning the standardization and regulation of helmet designs. Investigating the efficacy of existing safety standards, exploring the need for updated regulations, and developing international standards could contribute to creating a safer environment for two-wheeler riders. Overall, addressing these research gaps would lead to the development of more effective, user-friendly, and sustainable two-wheeler helmets, ultimately enhancing rider safety.

IV. PROBLEM STATEMENT

The helmet can protect vehicle riders from severe injuries during traffic accidents. Traffic injuries have only quite recently been recognized as a major public health problem in developing countries. Also, serious bicycle accidents have increased in the last two decades. Traffic injuries often involve severe cases and require critical care that eventually causes high medical costs and economic losses. Such burdens would be prolonged if the victims consequently sustain disabilities. In order to reduce deaths and traumas of traffic accidents, the helmet act for motorcyclists and bicyclists was enacted in many countries. Some countries even enforced helmets use to be nationwide. The global share market of the helmet is difficult to estimate. However, due to some helmet acts and enforcements, also it is believed that consumers usually replace helmets periodically. The market is assumed to be large enough to run a new series of products. And the product levels should be determined. For example, it is not easy to get into the high-performance helmet market which is shared by several specific brands. To design a functional helmet, it is important to analyze the structure of helmets. The main helmet components are the foam linear (EPS, PU, PP, PE, Pb, PVDC, or integral skin) and the shell (Thermoplastic or Composite). Basically, the function of the foam is to absorb most of the impact energy, while the function of the shell is to resist the penetration of any foreign object from touching the head and resulting in direct skull damage and to distribute the impact load on a wider foam area thus increasing the foam linear energy absorption capacity. Usually, manufacturers design their helmets based on experimental verification. During the experimental verification, the helmet must absorb the energy of the impact such that the head form acceleration shall exceed certain predetermined values (300g). The shell must resist the penetration of a falling 600 conical anvil with a specific dimension. The criterion is that the spike does not touch the head form on the helmeted-head form test setup. This penetration test is the main criteria for shell thickness determination and, in fact, results in a helmet with a thicker shell and consequently a weight of about 6-8 times as compared to the foam liner.

If a thicker shell is chosen, the strength will increase, unfortunately, as well as cost and weight. Or an alternative material should be considered. It is very important to check out all of the local regulations of the target market. Violations of laws and standards may result in re-design and unexpected delays and costs.

V. CONCLUSION

In this paper discussed shed light on various aspects of helmet design and analysis, particularly in the context of motorcycle and bicycle helmets. The research emphasizes the importance of optimizing helmet materials and designs to improve safety and comfort for riders. From predicting mechanical properties and enhancing head protection to analyzing foam performance and impact velocity, these studies provide valuable insights for the ongoing development of helmets. By leveraging advanced engineering tools and methodologies, researchers can continue to refine helmet designs, ultimately reducing the risk of head injuries in various impact scenarios. Continued research in this area is crucial to advancing helmet technology and ensuring the safety of individuals engaging in activities where helmets are necessary.

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