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Design and Analysis of Motor Cycle Helmet for Improved Safety

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Abstract: ***Road accidents are one of the most common and unavoidable problems in our society which costs our precious lives. Helmets of poor quality only give the lack of security, so helmets with more improvised design become the priority for two-wheelers. Our paper aims to design and prototype safety helmets for motorcycles with innovative design, which facilitates the user to wear it more comfortably. In addition to that, we analyze the improved design and optimize it. As safety is the primary criterion for the customers, we aim to produce the helmets by additive manufacturing with a customized design enabling ventilation, lightweight and increased stiffness. Additive manufacturing helps to fabricate complex designs with a combination of different materials.***

We will incorporate a mechanism that does not allow the two-wheeler to unlock unless the rider has a helmet. The outer casing would be durable and protect the user against impact. We have also planned to integrate the technology, which gives SOS signals to the nearby hospitals when the vehicle undergoes an accident. This is done by incorporating accelerometers in the helmet, so once the value reaches a certain limit, the emergency message is sent. By conventional manufacturing technologies, making customized helmet is very difficult. But, on the other hand, additive manufacturing facilitates fabricating complex design, which can have integrated sensors for safety purposes. Impact test analysis and airflow analysis will be performed on the helmet to validate the design.

Therefore, in this paper, we are going to design and analyze the helmet with improved safety. Keywords: Helmet, motorcycle, optimization, safety, Fusion 360, Ansys, Arduino, 3D printing.

I. INTRODUCTION

Official data collected from the Govt. claim that about 29% of deaths were attributed to non-use of helmets and 70% of the accident occurred for two-wheelers. This information gives an insight that the people were not wearing helmets even though it was strictly instructed by the government. Most of the helmets in the market are of poor quality and some of them are made of thermocol. This acts as a big threat to the motorcycle riders and development in safety helmets along with technology is one of the major real-world problems faced in our society. It can be seen that unfortunately, the fatality rates due to road accidents are increasing every year

The solution of this problem is to make helmets of good quality, less weight and more security. It is easy in this developing world to design a helmet with locking technology that can compel the rider to wear it in order to start the vehicle. Sensors help in communication of essential information to nearby hospitals if any accident occurs to the rider by use of accelerometer and GPS/GSM module. Therefore, we have planned to design and analyze the helmet model and to manufacture using additive manufacturing to have more customized design ranging from various complexity. These include deformation, stress, strain, air flow analysis which validate the helmet design. The sensors are incorporated with the design in the aim to provide complete safety to the riders and making sure that they wear it due to its advanced as well as versatile nature.

II. METHODOLOGY

A preliminary study on the properties of helmet available in the current market is made first. Then, a CAD model of helmet is designed in Solidworks and imported to Fusion 360 for design optimization. This process tells about the parts which add extra material weightage for the helmet. So, the optimized helmet is further used to do analysis using Ansys. Deformation and stress analysis are made in Ansys and drop test is carried out in Solidworks. To study the air flow properties, an air flow simulation is carried out in Ansys fluent to make sure that the model is aerodynamically stable and it is preferred to use. This model is converted into STL file for the purpose of additive manufacturing in order to fabricate the helmet and obtain the prototype. The simulation to find the printing duration, printing orientation is made in Cura Ultimaker and then it is fabricated using FDM method. Then, the sensors ar

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A. Study On Properties Of Helmet

1) MATERIAL USED: Outer shell made from polycarbonate plastic, fiberglass, Kevlar and inner liner is made of expanded polystyrene

2) The given figure shows the current available helmet model in the market. 1> ABS
2> POLYCARBONATES
3> EXPANDED POLYSTYRENE (EPS)

3) Weight of helmet: 1400 to 1800 grams

4) Manufactured by injection moulding process using mould

5) Yield stress is around 1-1.32 MPa

6) Cost of helmet is about ₹ 900 to ₹ 1300

7) Side vision of minimum 45 degrees must be allowed

8) IS 4151 is the standard mark for Indian helmets for two-wheeler riding and is governed by the provisions of the Bureau of Indian Standards Act, 1986

9) ISI-certified helmets go through various stringent tests to prevent brain injuries. For example, the buckle is tested for a load of about 150 kilograms.

Figure 1. Study of current available helmet

B. Study On Different Materials For Making Helmet

PLA(Polyacitic acid) is easy to fabricate from cad model by material extrusion as well as easily recyclable, has low load bearing ability. It is used to fabricate complete prototype, best for making prototype, shows high impact characteristics and tensile strength of 27MPa. It is suitable for making inner layer of helmet.

Polycarbonate is a chain of carbon fibre resin which is woven to make helmet. It is very light, strong, durable but costlier compared to PLA. This is 30 times stronger than clear plastics. Its impact strength is about 600-850 J/m. It is best for real life application such as helmet.

Steel is used only for military applications. It cannot be used to cover face which is high impact zone and is ruled out because of lack of versatility. It can be printed only by DMLS technique which is very costly.

Toughness of PEEK(Polyethyle ether ketone) is twice that of polycarbonate. It has higher temperature and creep resistance compared to other polymers. This assures longer life and prevent damage to the head and is highly expensive. It has a high tensile strength of 100MPa. It can be 3D printed only at 400 Celsius.

ABS(Acrylonitrile butadiene styrene) is harder to print and costlier comparing to PLA. It is weaker, less rigid in nature and material deformation is higher than PLA. It offers resistance to strong impact.

III. DESIGN AND SIMULATION OF THE HELMET

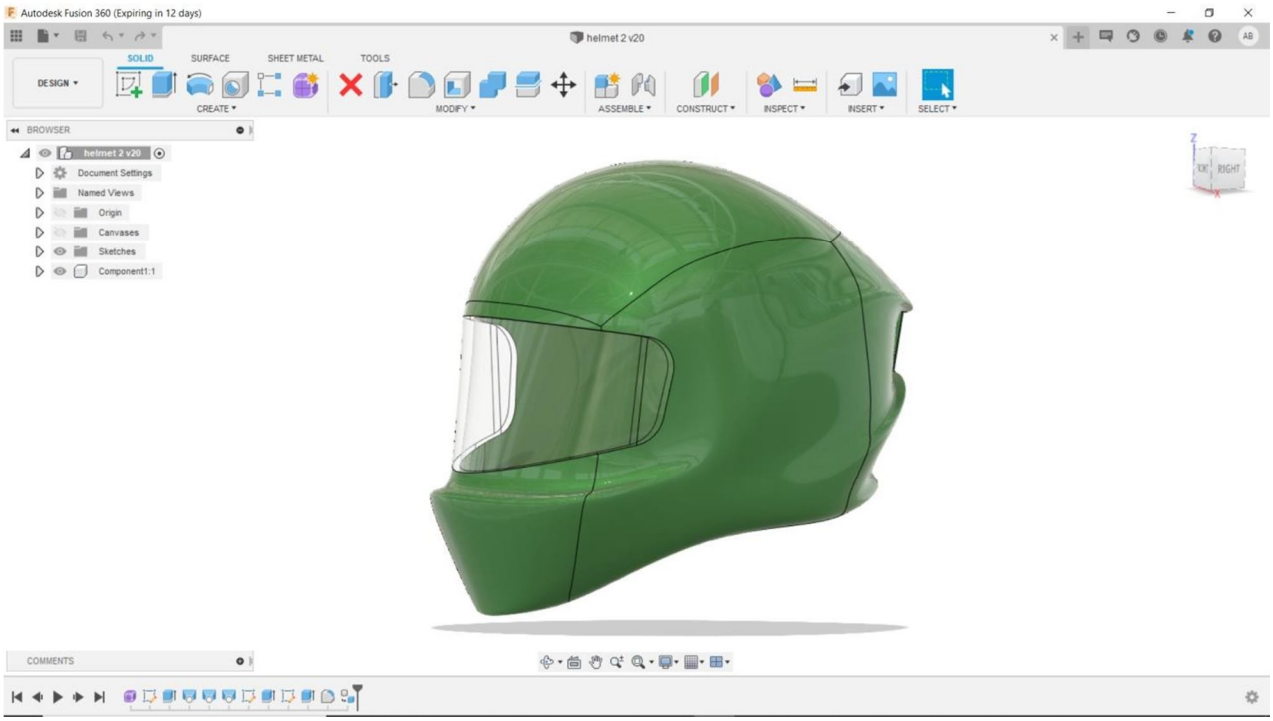

Figure 2. CAD model of helmet made in Fusion 360

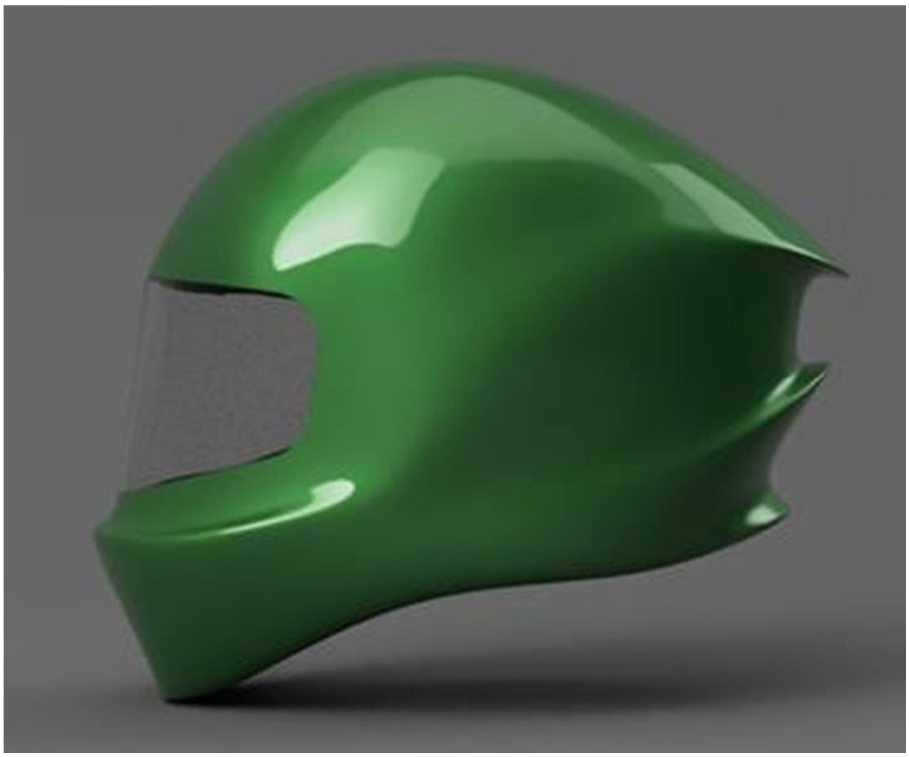

Figure 3**:** CAD model of helmet made in Fusion 360(Rendered image)

A. Design Optimization

1) A force of 1400N is applied at 6 points across the helmet

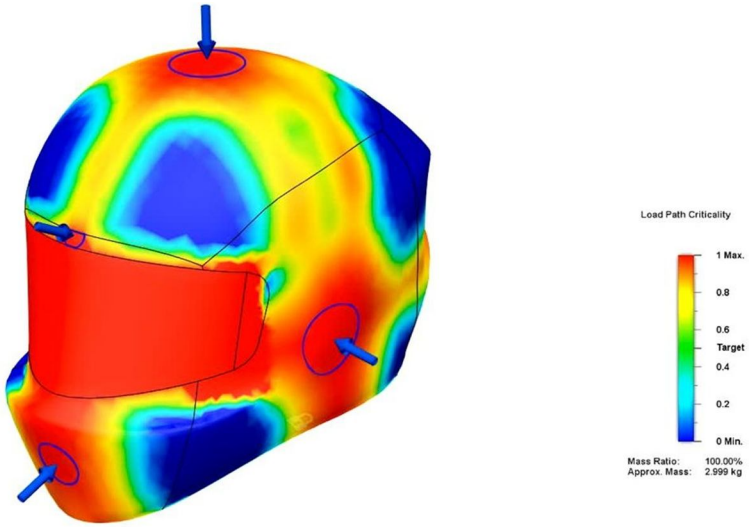

Figure 3. Force of 1400N applied on the helmet for optimization done in Fusion 360

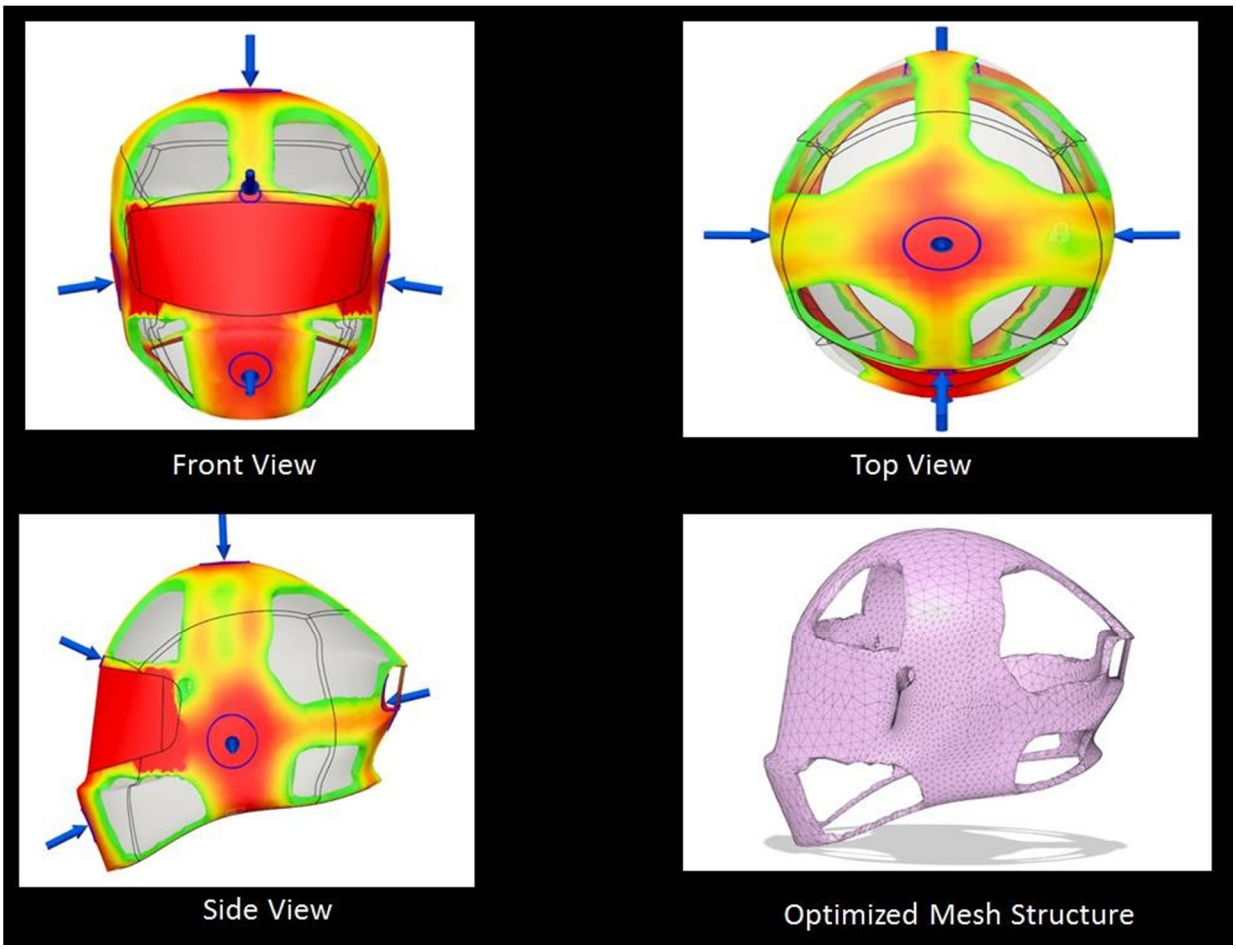

Figure 4. Isometric, Top, Front and Side views of optimized helmet

B. Structural Analysis For Optimized Helmet

1) For the structural analysis, a force of 1000N is applied on the optimized model

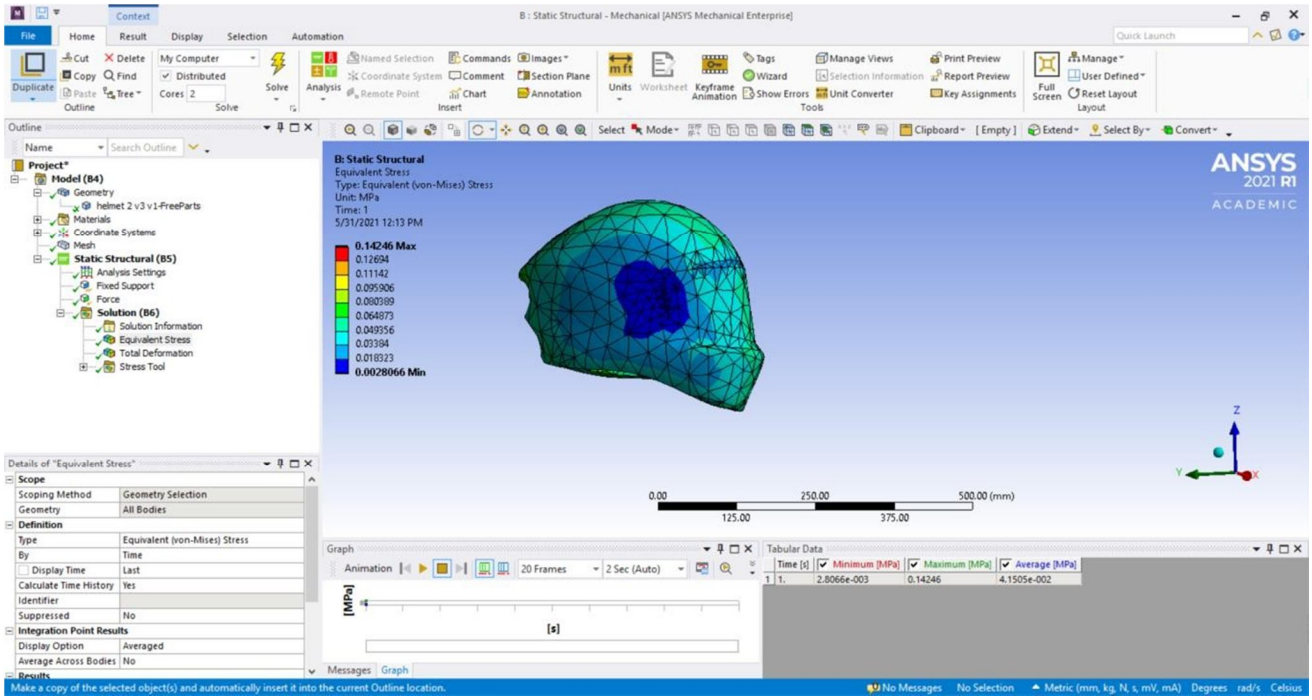

Figure 5. Structural Analysis (Stress analysis) in Ansys

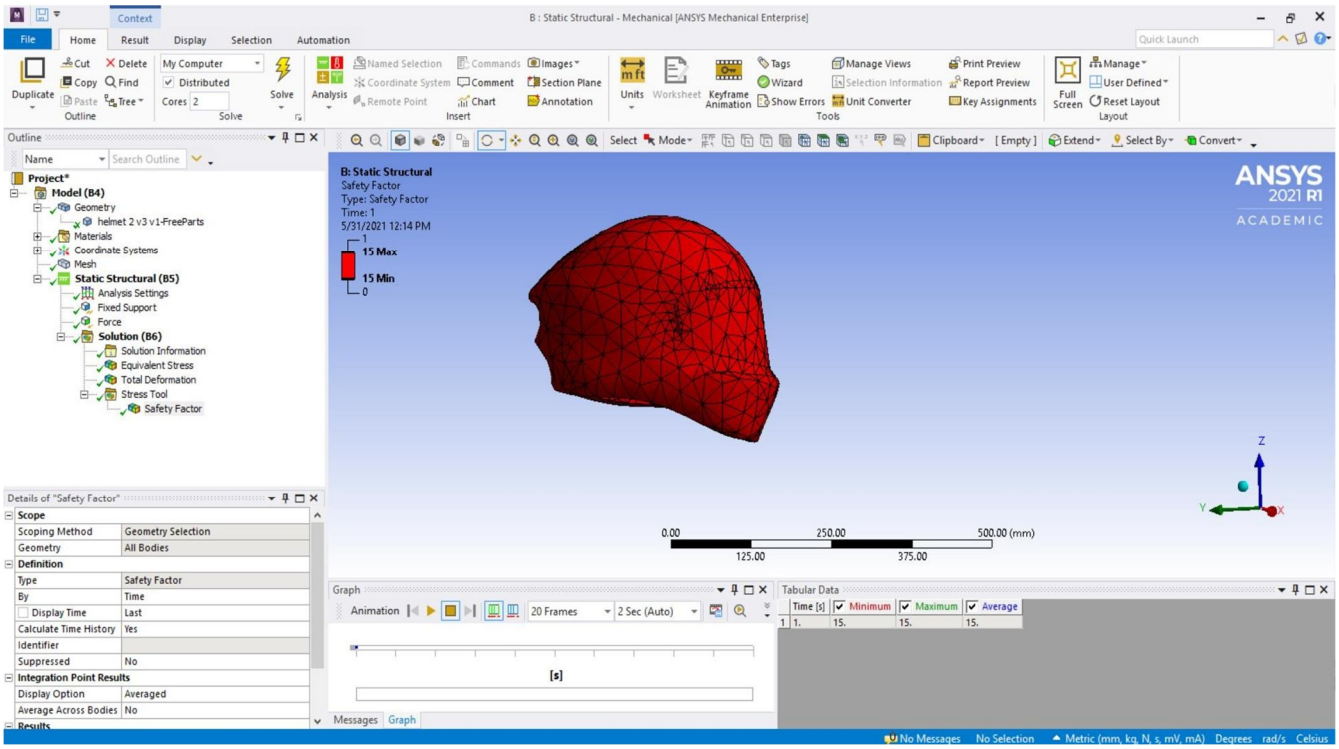

Figure 6. Structural Analysis (Factor of Safety) in Ansys

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C. Drop Test Analysis For Optimized Helmet Design

1) The drop test is performed for a maximum height of 10m

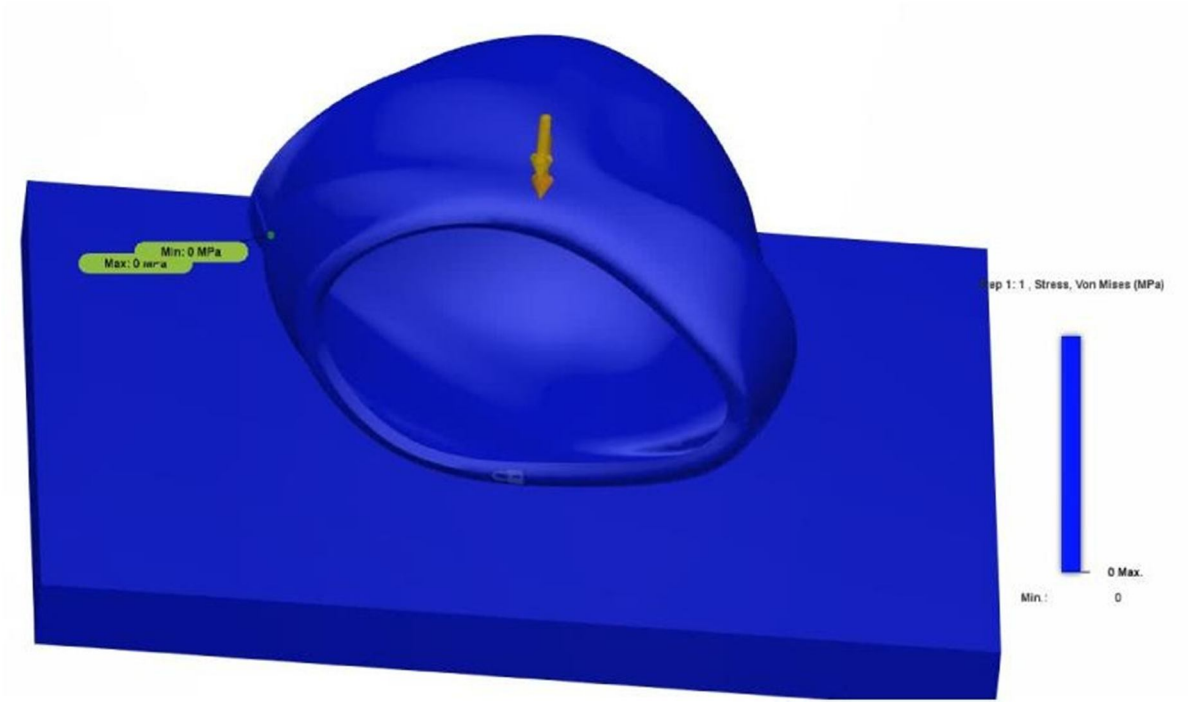

Figure 7. Initial conditions of the helmet before the drop in Fusion 360

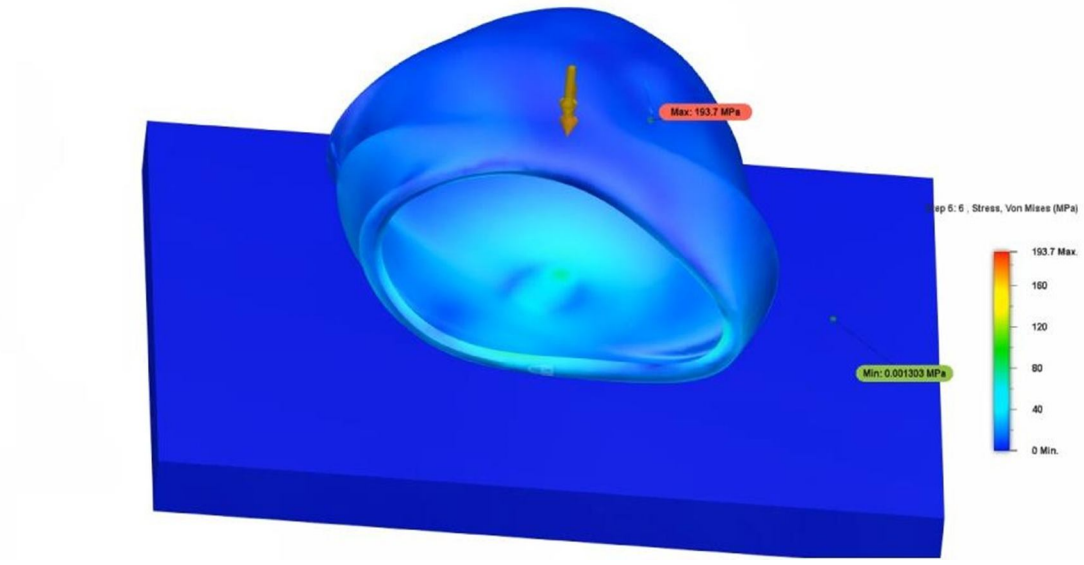

Figure 8. Final conditions of the helmet after the drop in Fusion 360

D. Stress And Strain Analysis Of Helmet In Fusion 360

A stress and strain analysis for the helmet was done in fusion 360. Two loads of 1400N were applied on both sides of the helmet.

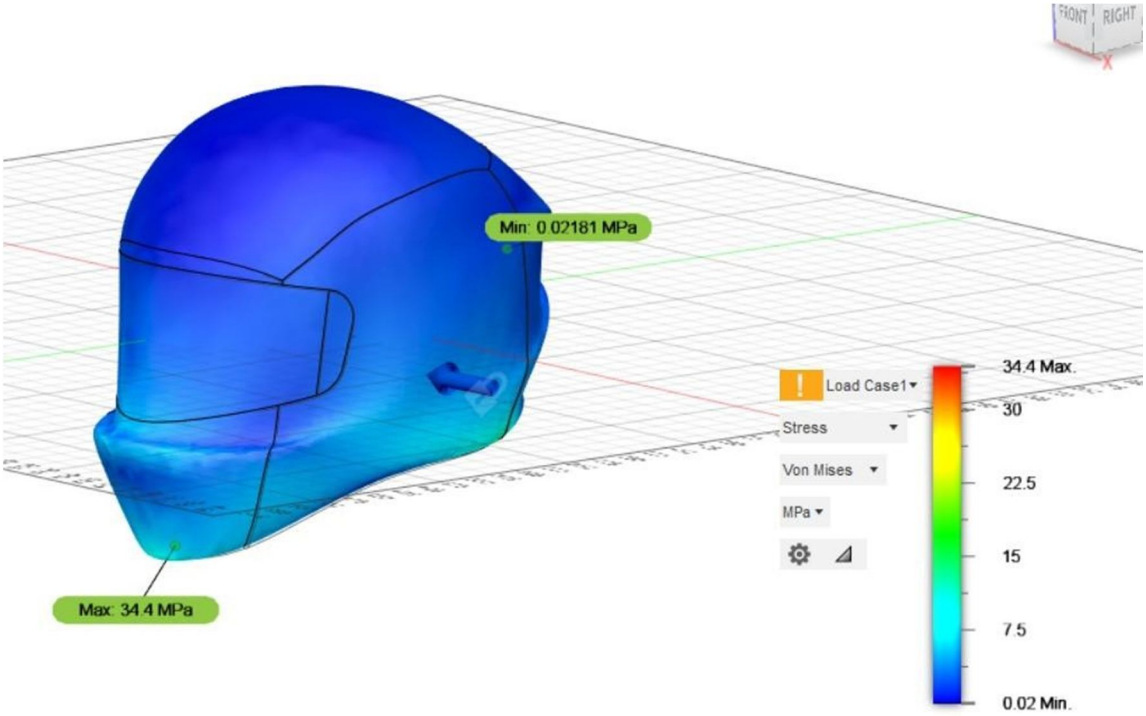

Figure 9. Max stress and min stress on the helmet

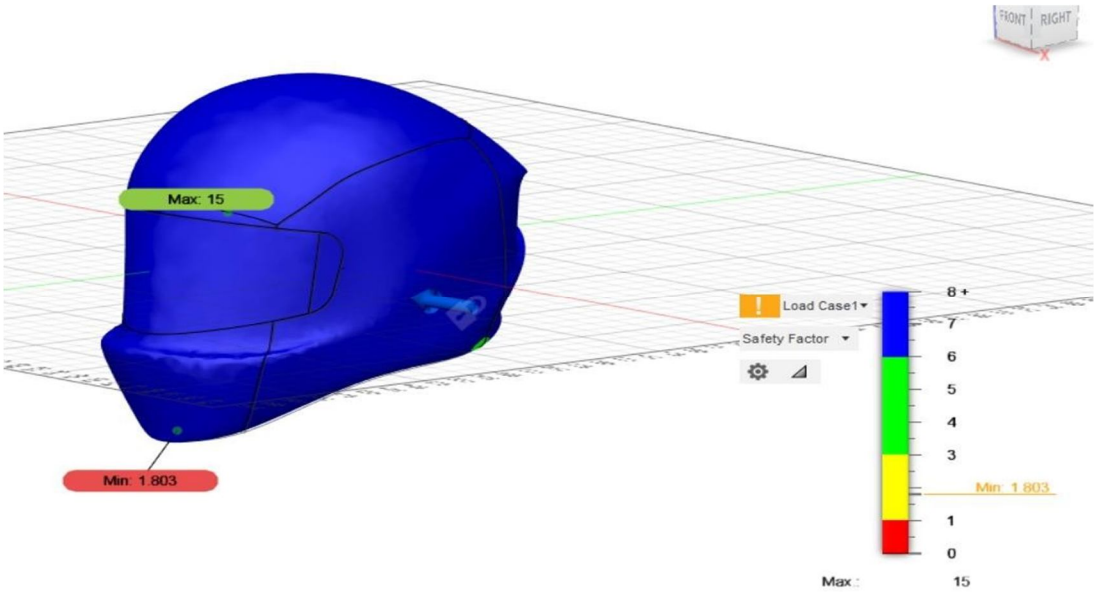

Figure 10. Maximum and minimum safety factor of the helmet

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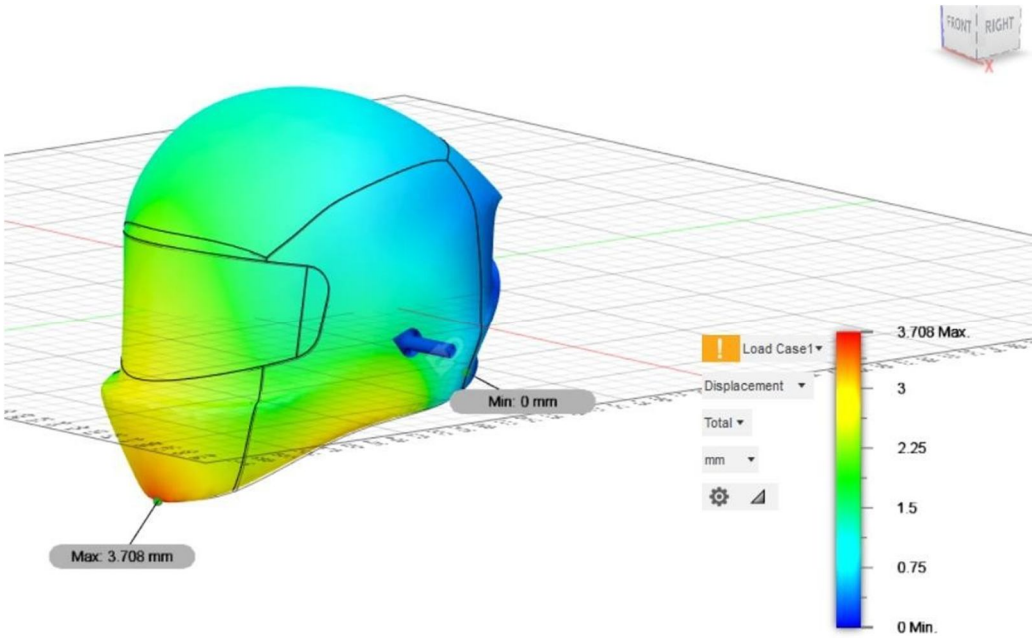

Figure 11. Maximum and minimum displacement of the helmet

E. Air Flow Simulation (Using SimScale)

Using simscale an external airflow analysis of the helmet was conducted. This analysis would help us optimize drag forces and pressure on the helmet while being used by the user during use on the motorcycle.

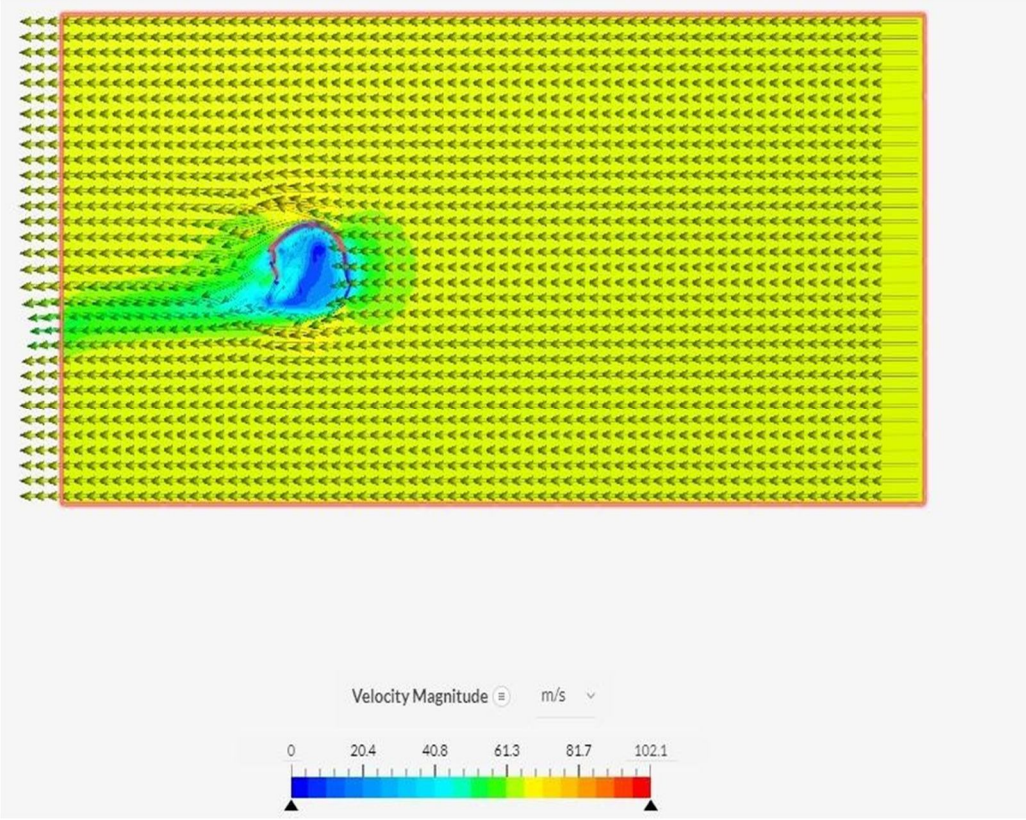

Figure 12. Velocity analysis by air flow simulation and result using velocity vectors

IV. ADDITIVE MANUFACTURING OF HELMET

Using additive manufacturing technique results are obtained with high dimensional accuracy. High strength and resistance to breakage can be obtained by this method. Can print complex shapes easily. Helmets will be printed in top-down approach where top most part is fabricated at the bottom of the build platform of the printer. The method will help to fabricate ***customised helmet*** based on dimension of the face obtained by scanning.

Cost of FDM machine is cheaper than conventional injection moulding machine which cost around 30 lakhs. AM helps to fabricate slots for adding sensors, which is not possible by conventional method

A. Fused Deposition Modelling

Extrudes molten thermoplastic filament and lays a thin bead of material side by side, one layer at a time. Part is fabricated by material extrusion. The method provides excellent strength-weight ratios. It also provides thermal and chemical resistance. Best am method for printing functional prototypes. Can easily fabricate the model from more than one material at same time

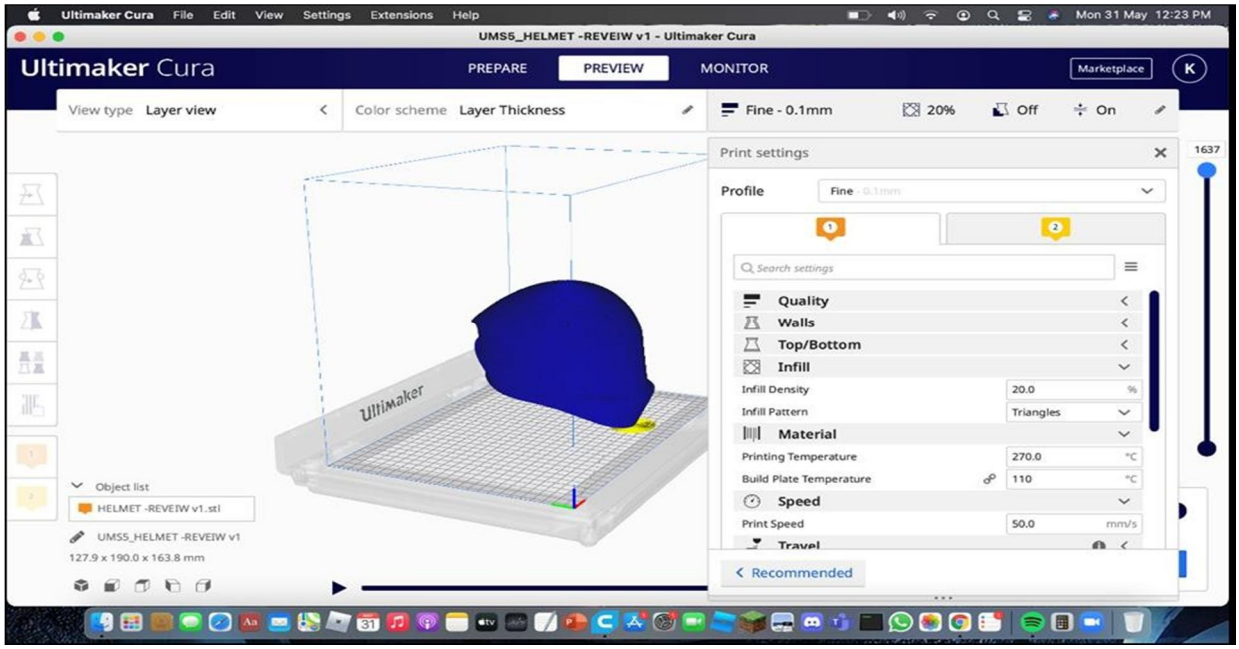

Figure 13. Slicing of the model CURA software and obtaining different parameters

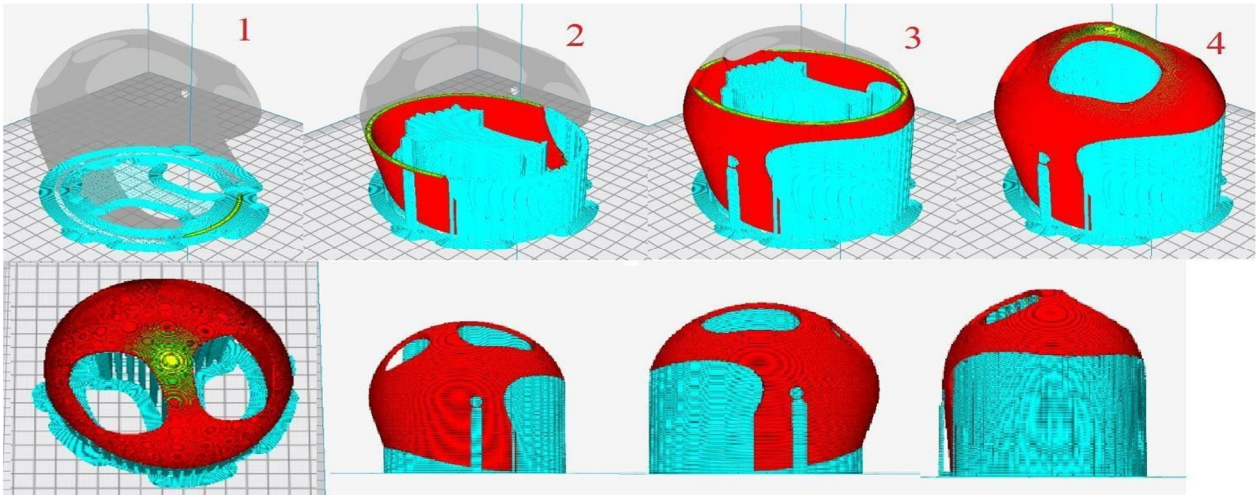

Figure 14. Layer by Layer manufacturing of helmets

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V. SENSORS AND CODES

A. *Components Used*

1) Arduino Uno
2) GSM Module
3) GPS Module
4) Accelerometer
5) Power Supply
6) Breadboard

The Arduino Uno is the brain of our project. It is a commonly used microcontroller and its processor basically uses the Harvard architecture where the program code and program data have separate memory. This fits our use case perfectly. This is used for our prototyping but can be replaced with a PLC or even a circuit board for mass production later on. GPS or Global Positioning System Module is used to detect the latitude and longitude of any location on earth along with the exact time. This data is received every second from satellite. It is used to track the location of the accident in our device from which we can get the coordinates.

GSM module or a GPRS module is a chip or circuit that will be used to establish communication between a mobile device or a computing machine and a GSM system, which in this case is our device. When an accident occurs, it is this module that is used to alert the hospital about the same with the help of the sim attached with the system. Accelerometer is a very basic electromechanical device used to measure acceleration forces. This is the sensor that will be used to detect the accident happening.

We will be monitoring drastic changes in velocity, acceleration and cross referencing it with GPS to determine if/when the accident occurs.

For prototyping we are using a breadboard but in the final product this can be eliminated by soldering of joints for better connection and reduced space consumption. In this circuit diagram, the Arduino Uno is connected to a stable DC power source and connected to the Display LCD, GSM and GPS module as well as the accelerometer as shown. Though the LCD is not directly needed for the function, its presence is used to track the data in the prototype.

This can then be used to send SOS to a hospital immediately after a crash. The location and the details of the person will be sent and hence the survival of a person is increased.

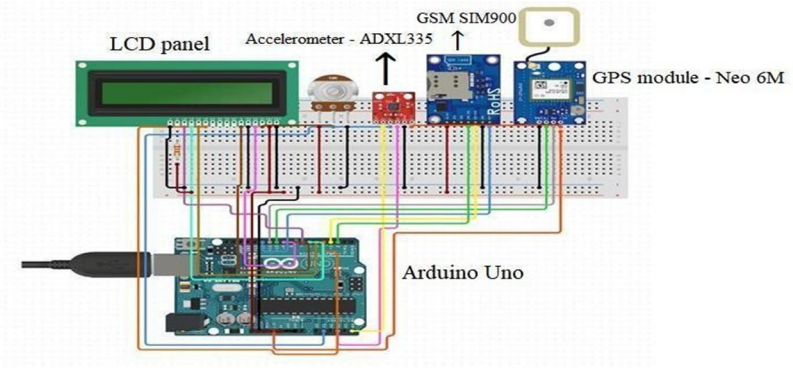

Figure 15. Circuit incorporated with the helmet

B. *Arduino Code*

The code logic applied in Void loop is given below(c++):

```
void loop()
{int value1=analogRead(x); int value2=analogRead(y); int value3=analogRead(z);
int xValue=xsample-value1; int yValue=ysample-value2; int zValue=zsample-value3; Serial.print("x="); Serial.println(xValue);
Serial.print("y="); Serial.println(yValue); Serial.print("z="); Serial.println(zValue)

if(xValue < minVal || xValue > MaxVal || yValue < minVal || yValue > MaxVal || zValue

< minVal || zValue > MaxVal)
        { get_gps(); show_coordinate(); lcd.clear(); lcd.print("Sending SMS "); Serial.println("Sending SMS"); Send();
        Serial.println("SMS Sent"); delay(2000); lcd.clear();
          lcd.print("System Ready");

    } }
```

VI. RESULTS AND DISCUSSION

It was found that **Polycarbonate** was the best material for the design as it shows high impact characteristics and tensile strength. Using design optimization the weight of the helmet was reduced by 36% from 2.4Kg to 1.9 Kg. The structural analysis results showed that factor of safety was 15 (which should be greater than 3 for better safety purpose) and stress value is 0.08 Mpa(should be less than 180 MPa for improved life cycle). The drop test showed a maximum displacement of 14mm and a stress of 190 MPa was induced. Slicing of the model was done layer by layer provided many parameters : such as printing time was 2 days and 2 hours, infill density- 20%, printing speed- 50mm/s, printing temperature- 270 C. The electronic circuit to send SOS to hospitals was determined and code was written using Arduino. Air flow analysis indicated that pressure of 2721 Pa was applied at velocity of 100m/s. Fused Deposition Modeling (FDM) was desired method for additive manufacturing of the helmet. Complex models can be made at reduced costs through this method. The overall projected manufacturing cost per helmet was between Rs 900 to Rs 1300.

VII. COCLUSIONS

Through this paper, motor cycle helmet with improved safety was designed and developed. The results obtained through analysis showed values within the desired limits. The optimized helmet shows lower deformations as compared to open face helmets and other design counterparts. The weight of the helmet has been reduced significantly, which can provide better comfort for the user. Using additive manufacturing, slots for fixing sensors and customization can be done effectively. Its unique design and nominal cost proved to be better than conventional helmets with substandard qualities. Hence, the optimized helmet was able to satisfy the problem statements defined. Along with the stated advantages, it can also be used in saving the lives of people in road accidents due to faster communications and better services. Thus, the helmet satisfies both technological and social causes.

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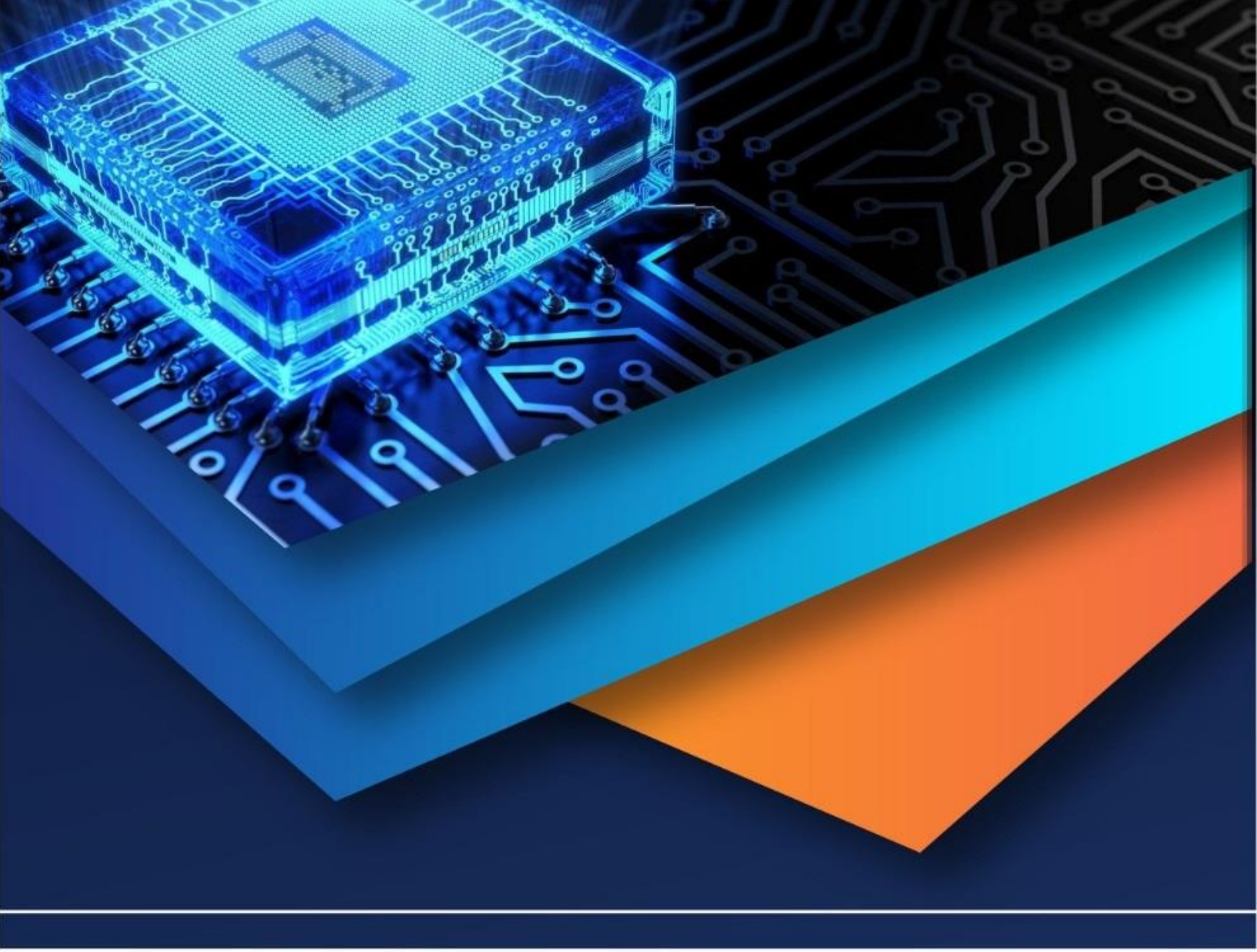

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