IOP Conference Series: Materials Science and Engineering

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To cite this article: Sanjaya Kumar Kar *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **402** 012055

IOP Conf. Series: Materials Science and Engineering **402** (2018) 012055 doi:10.1088/1757-899X/402/1/012055

New design and fabrication of smart helmet

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Abstract. We propose a new design of a smart helmet. It is easy-to-fabricate and can be mass produced on a large scale. Its casing will be made out of carbon fiber for increased durability. A cooling towel will be integrated in the helmet to keep the wearer comfortable. Vents, with the mechanism to open/close them at the user's convenience, have also been incorporated into the design. A front light (for night time use), indicators, brake lights and a GPS unit have been incorporated into the design as well. All will be controlled via a Bluetooth unit. An audio unit (using bone-conducting headphones) can be used to play music or listen to directions. All electronics on board will be powered via a battery unit, the casing for which will be moulded within the case itself.

1. Introduction

There are an estimated 5000 professional cyclists in the city of Chennai alone. One of the most important gear for a professional cyclist is the helmet. There is a range of helmets available to choose from, including the smart helmets available now-a-days. However, the prices of such helmets are too high, and it is difficult to mass produce them. With the advent of bicycle helmets, the rate of fatal accidents (involving head injuries) has drastically reduced. A helmet safeguards the head against injuries caused due to falling off from the cycle and impacting the ground. Smart Helmets are a cycling gear which uses an Electronic Circuit in conjugation with the helmet to provide a range of features - navigation, audio, etc. The aim of the project is to develop a new design and manufacture a Smart Helmet for Cyclists using composite materials (a hybrid of FRP and Carbon Fiber) and integrating the required electronic circuits for Navigation, Audio, Lighting, Indication, Etc.

2. Methodology of the Project

2.1. Components of a Helmet

The helmet consists of 3 major components, namely Shell, Liner and Strap

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1) Shell – the outer covering of the helmet, which gives the helmet its structure. This layer offers the protection and stability to the helmet design. The Shell is made from a composite material, one of the most common ones being GRP (Glass Reinforced Plastic)

2) Liner - The liner is the most important part of the helmet, the foam layer where the energy of the crash is managed. Bicycle helmet liners are mostly moulded in Expanded Polystyrene (EPS) foam.

3) Strap - Helmet straps are generally made of nylon or polypropylene. They all look similar, but vary considerably in fabric, surface finish, weave and other subtle characteristics. [1]

2.2. Materials used for making helmet shells

Commonly used materials: GRP, ABS, FRP, Kevlar (for high grade helmets) [2][3]

GRP (Glass Reinforced Plastic) – this material is made by mixing glass fibers in a plastic resin. The resulting mix is quite strong, durable and easy to mould. It is more expensive than ABS. however, it is the most commonly used material for manufacturing helmets.

ABS (Acrylonitrile Butadiene Styrene) – this is a thermoplastic polymer. Though it is the cheapest material (and was once widely used in making helmets) this material has been found to degrade in the presence of sunlight, thus losing its stability and durability.

FRP (Fiber Reinforced Plastic) – this material is made by mixing fibers of different length or different composition in a resin of plastic. The resulting mix is strong, durable and stable.

Kevlar – military grade bullet-proof material. Used only for high grade helmets (for use in mountain biking)

The material we are going to use in our design is a hybrid combination of FRP and Carbon fiber. While the base of the shell will be fabricated from FRP, an external layer of carbon fiber will be moulded to give it greater strength and durability.

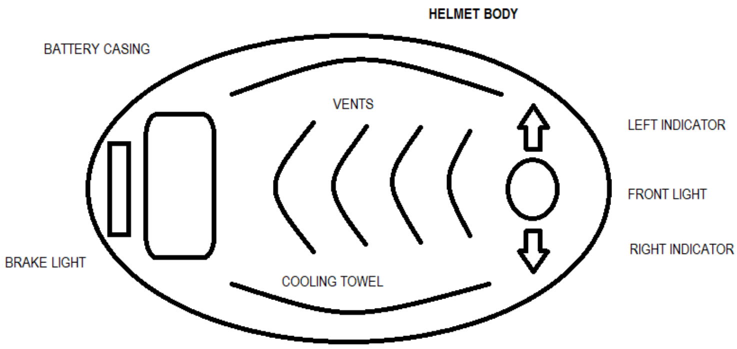

Figure 1. Block Diagram of Helmet (Top View)

2.3. Helmet safety standards

2.3.1. B-90A B-90C Snell test Snell standard is for helmets that are being sold in US and have predefined standards that a helmet has to fulfil in order to be sold in the states. There are various types of sub-standards also depending upon the type of cycling use. The standard vary from B90A to B90C. [4]

Snell test has various factors on which a helmet is tested:

1) General: It focuses on the points like both the internal and external surfaces should be smooth and all the projections on the outer shell should offer minimal frictional resistance to tangential force.

2) Material: The material used for the production of helmet should be durable and should not be harmed by environmental factors like exposure to rain, sunlight, dust etc. Also material should not support any type of bacterial or fungal growth.

3) Finishing: The internal as well as the external finishing of the helmet should be smooth and should not include any projection of material which could be uncomfortable or dangerous for the user.

4) Retention system: This rule states that the design of helmet should be simple and should not include any non-essential features which can degrade the main objective of the helmet.

5) Vision: The helmet should not hinder the vision of the user in any form and user should have a clear vision of at least 110 degree.

2.3.2. EN 1078 standard It is a helmet standard for the helmets that are being sold in Europe continent.

It test helmet on factors like field of vision, shock absorbing properties and the ease of use including ease of strapping and unstrapping the helmet.

2.4. Common Testing Methods

2.4.1. Impact Test This test involves a series of controlled impacts where the strength of a helmet is tested in order to check whether the helmet is safe for user. Standards are already set by various controlling agencies lie Snell and DOT. The tensile strength of helmet can be measured with the help of various experiment like Flat, Hemisphere, kerbstone, Roll bar, Edge or a Horseshoe type which simulate different impact surfaces.

2.4.2. Positional Stability (Roll-Off) Test In this test helmet is mounted on the mould upside down at an angle of 135degrees. Before the commencement of test the helmet is placed and properly mounted on the mould with the help of helmet strap and buckles. In the test a wire is attached to the rear end of the helmet and is then forward so it runs free towards the front. The other free end of the rope is then loaded with 4g weight resting on the top and then the weight is dropped from prescribed height (height prescribed in Snell standard) and dropped to a halt. After the test the rotational of helmet is noted from the previous position of helmet. If the amount of the deflection is less than the prescribed value then the test is a success and if the amount of deflection exceeds the prescribed value then the test is considered to be a fail.

2.4.3. Dynamic Retention Test This test is conducted to test the strength of chin strap and jaw piece. The helmet is placed securely over the head mount with the help of strap and is locked. The jaw piece is loaded with a load and is suspended for approximately one minute. Other way of conducting this test is to attach a load to the strap of the helmet and then the load is allowed to fall. If the load is able to break or displace the strap from its original position then the test is considered to be a fail otherwise the test is pass. The success of test is highly depend upon the standard upon which the helmet is being tested as the amount of load and the drop height is different for each and every test while the failure criteria being the same.

2.4.4. Shell Penetration Test The shell penetration test applies to cycling helmets to test the strength and the hardness of the outer shell. The main objective of the outer shell is to prevent and penetration of foreign objects into the liner and provide addition strength to the helmet. Shell penetration test is conducted in order to check the hardness of the helmet and its ability to resist the penetration of foreign objects in the helmet. In this test the helmet is mounted upside down on a head mount and is dropped on various shaped objects (generally shaped as a sledge, triangular and circular shapes). [5]

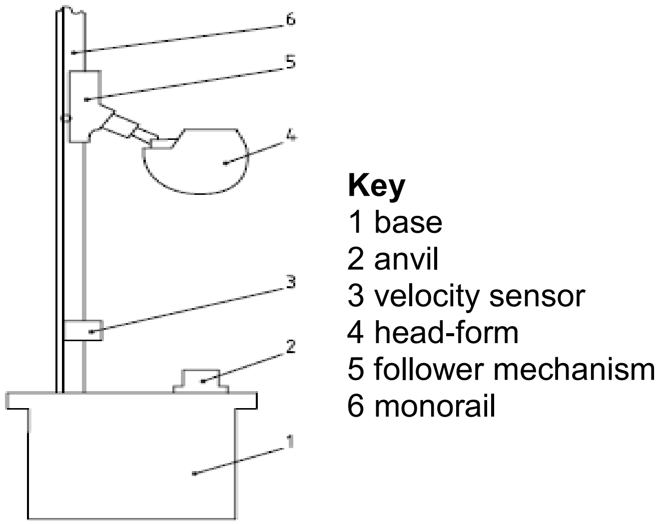

Figure 2. Impact Test Setup.

2.5. Electronic Components to be integrated

Arduino - A microcontroller, it will be used to connect all the components and make them function according to the code input. We are using nano arduino because of its small size which can easily be fitted into the helmet

Accelerometer - the device will register the acceleration and any force impacted on the helmet.

GSM Module - it will store an emergency number, which will send a pre-typed message to the number stored in the case of any eventuality. It will allow faster response time for emergency services.

Bluetooth Module - used to link up all the electronics in the helmet with the smart phone app and to exchange data between the Smartphone app and arduino.

LED - used for lighting and indication purposes.

Passive IR Sensor - used to detect if the helmet is worn on the head or not. If the helmet is worn, the IR sensor will register the signal and turn on all electronic circuits.

Bone-conducting Earphones - these earphones will be attached to the back of the wearer's ear. These earphones conduct sound via the auditory canal bone, thereby leaving the ears free to register ambient noise.

Battery - powers up the electronic circuits.

Given below is the basic block diagram of the electric circuit we're designing [6][7]

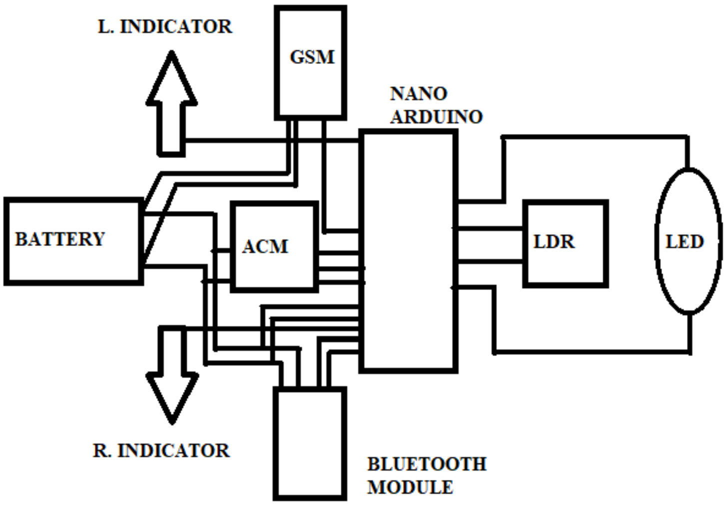

Figure 3. Basic Block Diagram of Circuit

3. Experimental Results

3.1. Design of the helmet

We have created the design of the helmet in the SolidWorks 2018 software. The design of the helmet was generated with spline curves and other basic drawing features like circles and lines. After getting a rough helmet shape the design was made more aerodynamic by removing various wanted surface area of helmet. The removal of area resulted not only in better aerodynamics of the helmet but also resulted in considerable decrease in the overall weight of the helmet. Features like extrude cut were used in material removal. The design of helmet can be viewed in figure 6. **[3]**

Ramachandran Manickam "Analysis of Mechanical Properties of Glass and Carbon Fiber reinforced polymer material", March 2015

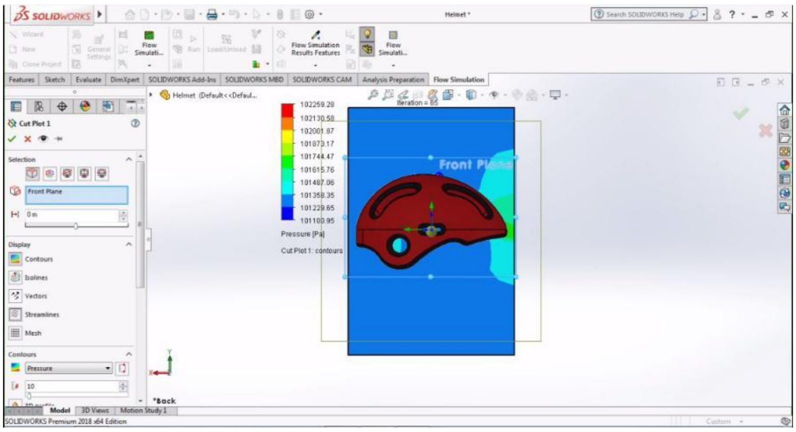

Figure 4. Side Profile of Helmet

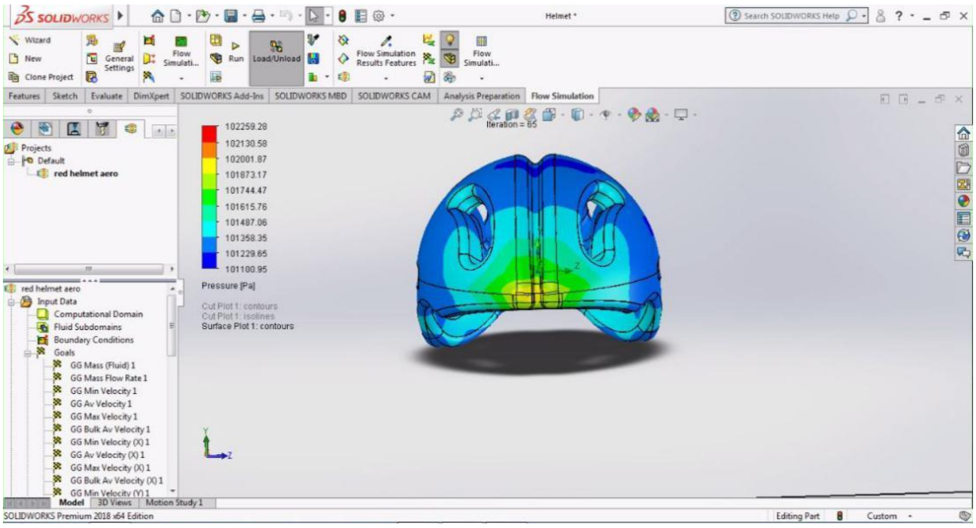

Figure 5. Result of Impact Test on Helmet

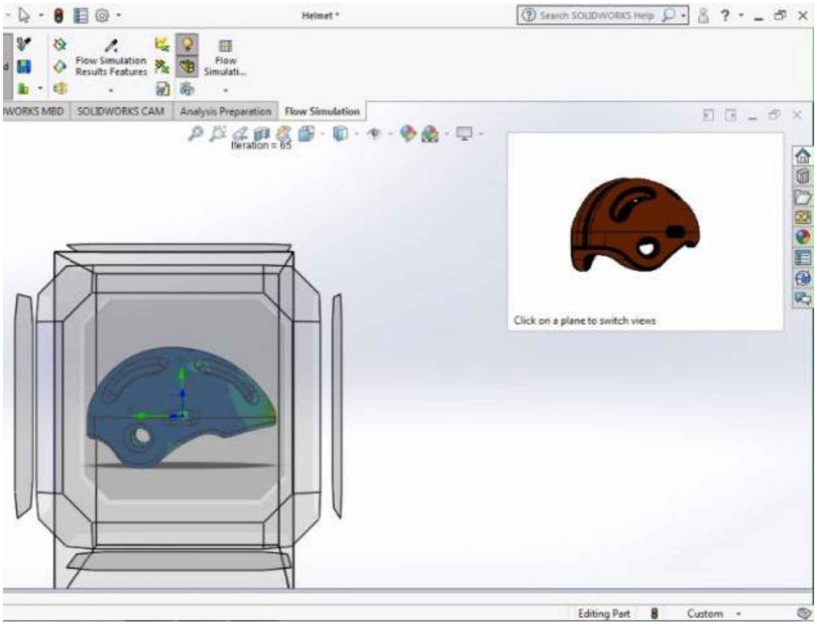

Figure 6. Design of Helmet

3.2. Force analysis of the helmet

Analysis of the helmet was also performed on SolidWorks 2018. The material selected for the outer shell of the helmet was carbon fiber. After selection of material various analysis tests were run like impact test and test for aerodynamics. Tests were also conducted for helmet at various different angles and positions in order to accurately predict the behaviour of helmet in dynamic conditions. The result of impact test obtained has been shown in figure 5.

With the help of fluid and flow analysis the amount of Drag and Downforce received at a speed of 20 km/h was also studied and suitable changes were made to the design of the helmet. The values of Drag and Downforce received have been shown in form of graphs in figure number 9. The flow tests helped us to understand the resistance offered by helmet under dynamic conditions and help us to identify the areas generating maximum resistance in order to improve the drag to its minimum; the result of air flow test can be seen in figure number 7.

In order to more effectively study the design of the helmet, helmet was put under static and dynamic testing at the same time this helped us to evaluate and precisely find out the point which are majorly responsible for creating vortex and instability in the helmet in dynamic state. The result of differentiated testing can be seen in figure 8 and the effect and the strength of vortex can be viewed in figure 4.

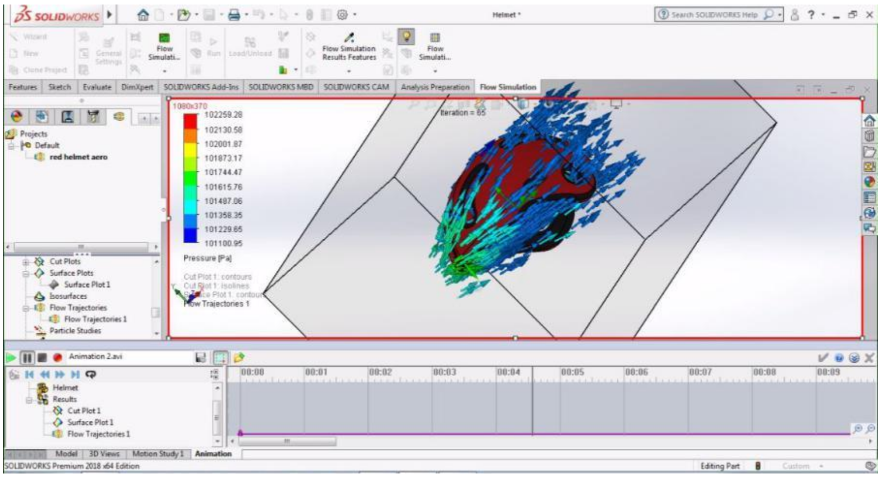

Figure 7. Air Flow Analysis of Helmet

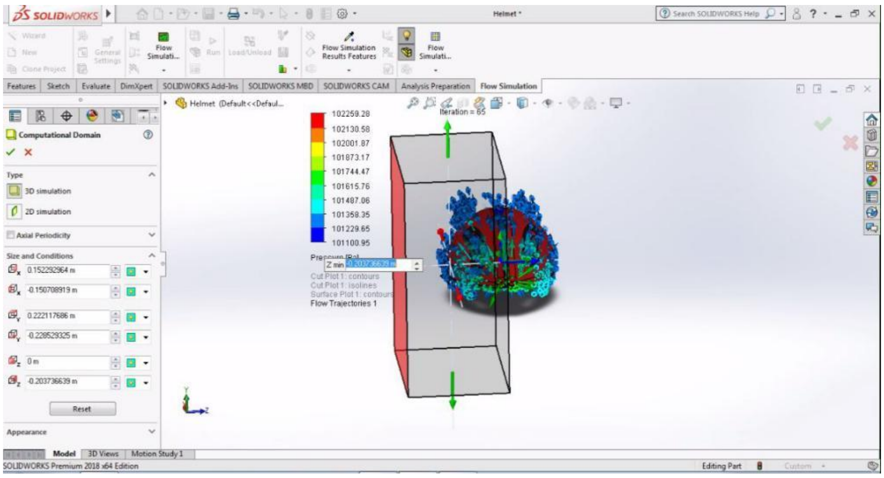

Figure 8. Down Force Analysis of Helmet

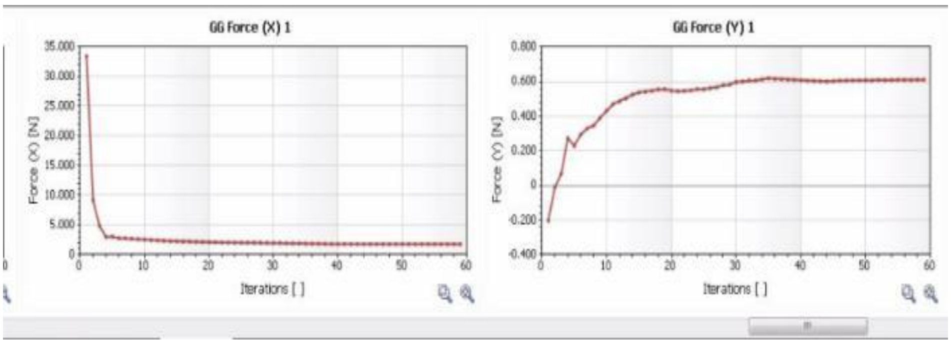

Figure 9. Graph showing Drag and Downforce Analysis

3.3. Smartphone application

We have created a Smartphone App that will link the electronic circuitry of the helmet with the mobile and will allow the user to control the helmet's electronic components via the mobile app. The app was coded and created using MIT app inventor 2. [7]

The features of the application are as follows:

1) Voice activation enabled for indicators

2) Online Navigation – Google Maps

3) Emergency Number setting enabled

4) Bluetooth Connectivity Enabled

5) Alarm Timer – for setting duration of ride

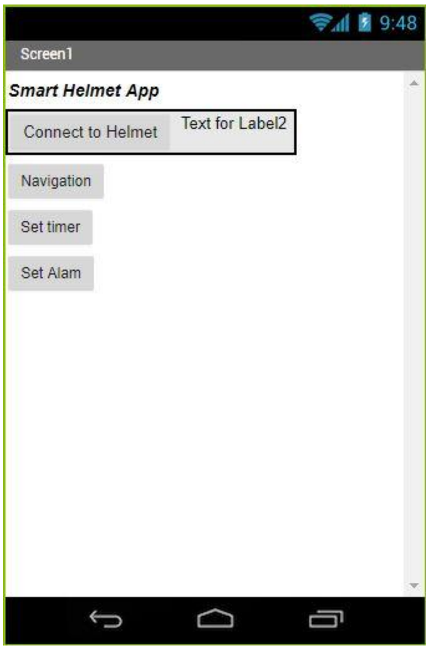

Figure 10. Screenshot of Home Page of Mobile App

4. Scope of the project

There are an estimated 5000 professional cyclists in the city of Chennai alone. One of the most important gear for a professional cyclist is the helmet. There is a range of helmets available to choose from, including the smart helmets available now-a-days. However, the prices of such helmets are too

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high, and it is difficult to mass produce them. The helmet has a huge market for professional cyclists worldwide.

5. Conclusion

We aim to design and manufacture a Bicycle Helmet of high quality using a hybrid of FRP and Carbon Fiber (for high strength and durability at lower costs) and the electric circuit for automatic accident detection and notification (to the authorities), navigation, audio, lighting, etc. All this at a lower cost than the high-end helmets presently in the market. We aim to make our design capable of mass production, so that it is affordable to everyone.

6. References

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