

# MATERIAL STUDY FOR DESIGNING PORTABLE HELMET

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## Abstract

Actually, the helmet was available since so many decades. It was actually in battle for protecting people in the battle. It was made by iron. But nowadays, the helmet are use in so many areas like building, cycling, horse-riding, snowboarding, boxing, motorcycle rider. In this paper, the main focus is on motorcycle helmet. The helmet is the most common safety equipment used by the motorcyclist. Due to high fatality of two-wheeler, it was felt that there was need to look at improving the safety of the motorcyclist in the country. However, due to the problem of storage, bulky and heaviness of the helmet certain riders prefer to not wear them. Looking at this set of difficulties faced by the rider and their pillions, the aim is to research into the helmet in order to make compact, lighter and safe. At this stage, a different material is studied.

**Keywords:** - Fatality, Flexible, Resilient, Cushion

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## 1. INTRODUCTION

In India according to the Society of Indian Automobile Manufacturers (SIAM) for the year of 2015-16 a grand total of 2.04 Cr<sup>[10]</sup> Vehicles were sold and brought to the market. Of that, the market share of various types of vehicles is as follows

1. 27lac of private vehicles,
2. 6lac of commercial vehicles
3. 1.6 cr of two wheelers

So from the statistics we can see that around 80 percent of the vehicles sold in the last year itself are 2 wheelers. Looking at the nation record of crime bureau, it was seen that around 1.41lac, people are killed on the road due to road fatalities, and around 4.77 lac people are injured in road traffic. According to the million-death study, it is seen that road fatalities has become one of the top ten reasons for the causing death in India in 2013. Also in the age of 5-14 its ranked 6<sup>th</sup>, for 15 to 49 it is 4<sup>th</sup> and for all age road fatalities is 8<sup>th</sup> most common reason for the cutting short of life span. In addition, a further segregation into the study shows that, among the total road fatalities, motorized two wheelers form the 29 % of the number.

Looking at such a high fatality of the two-wheeler, it was felt that there was a need to look at improving the safety of the motorcyclist in the country. Currently, Helmet is the most common safety equipment used by the motorcyclist. However, due to the problem of Storage, bulky and heaviness of the helmet certain riders prefer to not wear them even if they are given the freedom to do so.

Looking at this set of difficulties faced by the rider and their pillions we decided to research into the topic of how we could make the helmet lighter as well as compact so that it's easy to carry and store.

## 1.2 Review of Research and Development in the Subject

The World Health Organisation (WHO) recommends wearing the helmet as it can reduce the risk of death in case of an accident of a motorcyclist and its pillion by almost 40% and the risk of severe injury by over 70%<sup>[10]</sup>. When motorcyclist laws are enforced effectively, helmets wearing rates can be increased by 90%. Also requiring the helmet to meet the safety standards can effectively reduce the impact of a collision to the head in the event of a crash.

According to the US national Highway Traffic safety Administration, of the motorcyclist Fatalities 3/4<sup>th</sup> are due to head injuries. It has been observed that after the implementation of the strict helmet laws there is a trend of decrease in motorcyclist fatalities. In a study conducted by University of Pennsylvania, it was seen than after the state repealed the helmet law, the fatalities in the state went up by nearly 66%. From this data one can see, that helmet does really prove to be effective in containing the injuries to the rider.

However it is seen in the country even after the implementation of the mandatory laws for wearing the helmet, it is the pillion rider never wears one. One of the reason is obviously that it is not mandatory for him/her, but also how do you store the second helmet is also an issue that is to be dealt with.

Hence, it will come up with an idea of, what if the helmets are made inflatable. The inflatable helmets would be ready to inflate on the go. Wherein the pillion can just fill the air by a hand pump or at an air station, and when the ridding is done they can deflate it and store the helmet in the storage compartment. This will greatly help in reducing the trouble of carry the helmet around. Hence, increase the chances of riders carrying them around as well as keeping a spare for the pillion as well.

## 2. OVERVIEW OF HELMET

The helmet is made by the different materials in different layers. The outer layer is called the Shell which is normally hard. After the shell, there is EPS liner. Then, it is fit padding which is normally uses foam. And finally, retention system which hold the helmet on the head.

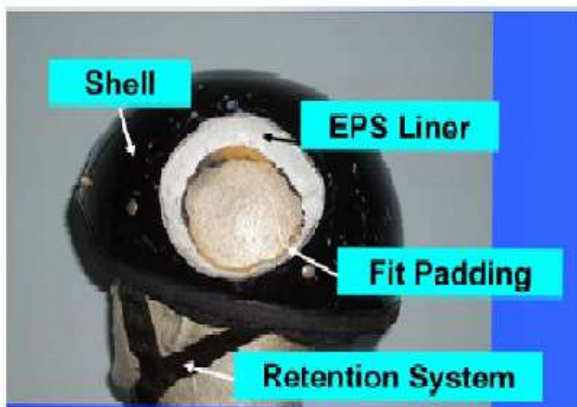


Fig 1: Helmet components

### Expanded Polystyrene Liner (EPS)

When the EPS liner crushes, it will absorb more energy. Actually, it will not store energy and act like a spring that it will rebound. But, in case of accident the head move inside the helmet in up-down direction. Shake the brain so many times. Due to which, it will not store energy and will be negative point in this case. This material is absorbs kinetic energy of moving head and generate a small amount of heat as foam collapse<sup>[9]</sup>.

### Outer Shell

Outer shell acts as a shield when it comes to contact with any sharp object. This will greatly help to not to reach the penetration to the next layer that is EPS liner. When sliding on the road, it protect against abrasion. Outer shell will absorb energy when accident happens. It will flex in polycarbonate helmet or it will flex, crush and delaminate in fiberglass composite helmet.

### Fit Padding

Actually, padding is necessary for keep the helmet on rider's head properly. It will help to make the helmet more comfortable to wear. In shortly, it is act as safety of helmet.

However, the padding absorbs a small amount of force in case of crash. Nowadays, helmet is design to deform in case of crash. The helmet is made of hard foam and plastic, crumple in case of impact. It will dissipate force of impact in invent of crash. Due to this, rider should replace their helmet after any impact. Padding is mostly use for comfort and on head purpose.

### Retention System

The main purpose of the retention system is to hold the helmet properly on the head. If this system not tight properly then helmet can slightly movable which is hazardous while accident happen.

### 2.1 Brain Injury

The study of human head is also important point while designing the helmet. The outer layer of head is called skull. After this, dura mater. Then, arachnoid mater. After arachnoid mater, there is sub-arachnoid space. After this, pia mater is present. At last, brain is present.

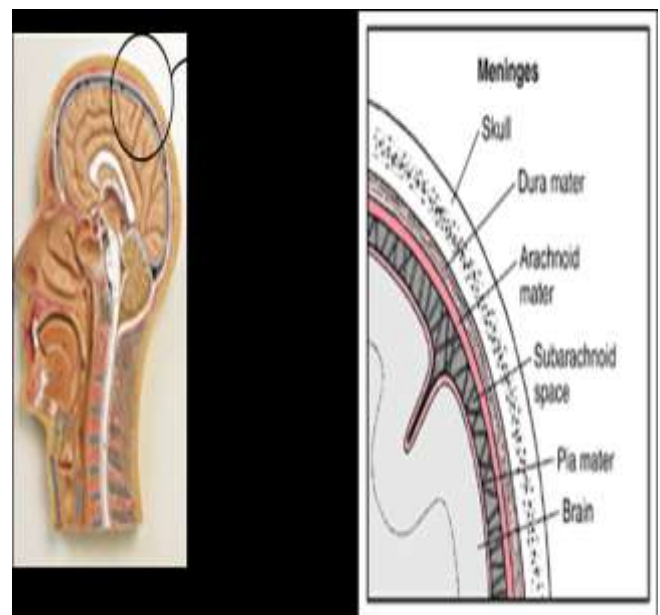


Fig 2: Sagittal view of Human head and Meninges

Brain basically present in the skull within the Cervical Spinal Fluid (CSF) and protective membrane called as Dura. In case of crash, the skull will stop suddenly when hit to hard object. In the skull, brain is not stops suddenly. Brain is keep moving with collision to the inside of skull. If this collision is most severe, brain injuries like shearing of brain tissues, bleeding and swelling occurs. When collision is severe, the bleeding is trying to squeeze through any opening like eyes, base of skull. In this project, study of different material play an important role while designing and developing the safe & flexible helmet.

### 3. STUDY OF MATERIALS

In this approach, discuss about the existing material use and the newly discover material for helmet. The materials are the Silicone foam, D3O material, Sorbothane, PXCM, Microlattice material, Silicone gel, LLNL's material. Study this materials and note down their properties.

#### 3.1 Silicone Foam

Silicone foam has most resilient properties. It has low compression set<sup>[2]</sup>. It is ultraviolet and ozone resistant. It is flexible and resilient in hot and cold condition. Due to which, it act like excellent gasket and cushion material<sup>[6]</sup>.



Fig 3: Silicone foam

- **Material Properties of Silicone Foam**

1. It has operating temperature range of 55<sup>0</sup>c to 200<sup>0</sup>c.
2. It's hardness value is 13
3. The density is 256 g/cm<sup>3</sup>.
4. Tensile strength is 1.2 N/mm<sup>2</sup>.
5. Compression set is 5%

#### 3.2 D3O Material

It is the polyurethane material. It contains poly-boro-dimethyl-siloxane which is liquid substance. This substance act in their raw state like flow freely when moving slow, but when the force will apply, it get lock together for absorbing shock and disperse energy. When returning toward the flexible or original state. This material uses in snowboarding and motorcycle rider's suit<sup>[8]</sup>.



Fig 4: D3O material

The D3O materials are also use in following areas like,

1. Military
2. Work wear
3. Medical
4. Sport including snowboarding, baseball, cricket, volleyball, tennis, boxing.
5. It can also use in shoes.
6. For packaging like case for electronic devices.

The D3O formable foam includes D3O (LITE) which are lightweight, comfortable. Its temperature is suitable for cushioning and protection purpose. The D3O formable foam has best properties that is the shape of material can be reshape for wide applications.

- **Properties for D3O Formable Foam**

1. It has density of 90-110 kg/m<sup>3</sup>.
2. It's hardness value is 32
3. Tensile strength is 1.30 MPa.
4. Compression set is 29%

#### 3.3 Sorbothane Material

Sorbothane is use in many industrial applications. It is use to personal computer by pack around the hard drive and noisy spinning component. It is use for dampen vibration transmission from vibrating hardware. NASA has used this material for isolating vibration in the Air force memorial<sup>[1]</sup> it is currently use with insole and heel pad for absorbing impact during the sport activities like football, cricket. It provides better protection against lower limb injury cause by continuous motion during the game. Sorbothane are solid in their normal state. But, when the force will apply, it will come to liquid state and flow freely and small amount of heat is generated.

- **Material Properties of Sorbothane**

1. It has density of 81.91 lb/ft<sup>3</sup>.
2. Its tensile strength at break is 100 psi.
3. Optimum performance temperature range is -20°F to 140°F.
4. Compression set is 6%.

#### 3.4 Phase Transforming Cellular Material

The phase transforming cellular material is developing by the Purdue University with the collaboration of general motor<sup>[3]</sup> this new energy absorbing material has 3D printed and uses in the areas from earthquake engineering to football helmet. Its look like honeycomb structure which can be used for various application by scaling to different sizes. In that application, one can be utilise in helmet to reduce head injury. Another application is that, it can be used in the building wall to dampen earthquake force. Actually, it is 3D printed for which it is less expensive. It is reusable. The various length scale of PXCM material use to integrate energy absorption. This material is not ready to use for commercial applications.

### 3.5 Microlattice Material

It is synthetic porous metallic material consist of ultra-light metal foam. It has a very low density that is  $0.9 \text{ mg/cm}^3$ . It is known as lightest material. It was developed by scientist and researcher from California in Nov.2011<sup>[5]</sup>.



**Fig 5:** Microlattice material

It is use as thermal and vibration insulators and also use as battery electrode and catalyst support. It is use in spring like storage device because of its ability to return to their original state after compress. It is use in automotive and aeronautical field for developing extremely lightweight and efficient structure.

### 3.6 Silicone Gel

Silicone gel includes individual polymer molecules which were interconnected. In this way, silicone are yield when impact to hard surface. It is most resilient material and absorb thermo-mechanical stress<sup>[7]</sup>.



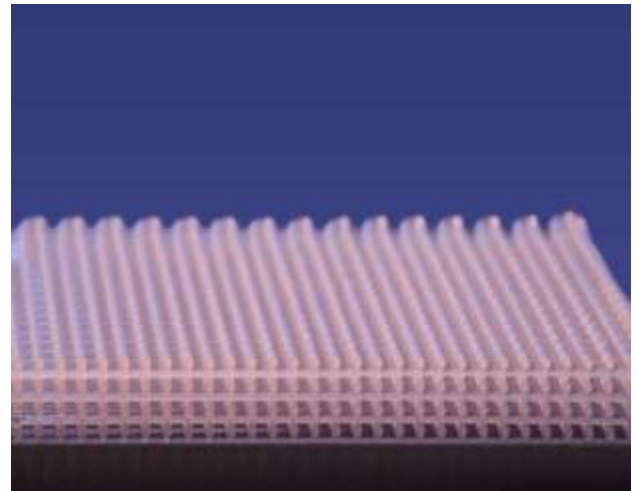
**Fig 6:** Silicone gel sheet

- **Key Features of Silicone Gel**

1. It is having addition curing system.
2. It has elastic modulus range of 5kpa-50kpa.
3. It having temperature range of  $-50^{\circ}\text{c}$  to  $200^{\circ}\text{c}$
4. Specific density is  $0.97 - 0.99 \text{ g/cm}^3$
5. Thermal conductivity is  $0.2 \text{ W/mK}$

### 3.7 LLNL's Energy Absorbing Material

This material is use for padding and cushioning. Gels are relatively heavy than the padding. Its performance can also be affected by temperature. It has limited range of compression, because of lack of porosity. Foam is lighter and compressible but its performance not proper due to inability of controlling the size, shape and placement of voids during foam manufacturing process. To neglecting or overcoming the above problem, the scientist discovered a new material which is use for cushioning purpose. It's having many properties and behaviours that neglect the problem which mention above, through additive manufacturing also known as 3D Printing<sup>[4]</sup>.



**Fig 7:** LLNL's material

It can be used in many applications like shoes and helmet and also in aerospace application.

## 4. RESULT AND CONCLUSION

At this stage, two materials are selected which are D3O and Sorbothane. The D3O materials have different categories i.e. FF001, FF002, FF003, FF004, FF005. In first category i.e. FF001, it has energy return at 4.2J is 44% and impact protection of 27KN. In the second category i.e. FF002, it has energy return at 4.2J is 43% and impact protection of 28KN. In the FF003, it has energy return at 4.2J is 36% and impact protection of 23KN. In the FF004, it has energy return at 4.2J is 33% and impact protection of 16KN. In the FF005, it has energy return at 4.2J is 33% and impact protection of 6KN. Then, Sorbothane material has properties at different stages of the hardness value which is called durometer (shore 00). At hardness of 30, the resilience test rebound height is 11%. At hardness of 50, the resilience test rebound height is 15%. At the hardness of 70, the resilience test rebound height is 29%. From the overall properties of D3o and Sorbothane material, the best suitable material for helmet to be designed will be D3O and Sorbothane material. It is proposed to model the helmet based on material finalized in this study<sup>[11]</sup>. Further, it will be simulated in order to validate the result<sup>[12]</sup>.

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