Biomimicry Inspired Motorcycle Helmet Design Concept

Nayhel Sharma[1], Rahul Vaishya[2]

[1, 2]PEC University of Technology, Production Department, Sector 12, Chandigarh-160012, India

Abstract: ***Everyday men, women and children suffer head injuries in road accidents. It is observed that Motorcycle Helmet plays a significant role in reduction of head injuries. One of the major functions of the helmet is to protect the human head from Impact force Injuries. This work aims in designing a motorcycle helmet using bio-mimicry as an inspiration and as a concept.***

Keywords: Helmet Design, Bio-mimicry

1. Introduction

Motorcycles and scooters are popular and provide an important means of transportation in both developing and developed countries. In motorcycle traffic accidents, the human head is exposed to loads exceeding several times the loading capacities of its natural protection. The human head is very vulnerable to injury, often with severe consequences. It is particularly susceptible to acceleration/deceleration and rotational forces because it is freely mobile in three dimensions and occupies a relatively unstable position, being secured by neck muscles and ligaments. One of the effective countermeasures to prevent head injuries in bicycles and motorcycle crashes is the use of a protective helmet. The beneficial effects of helmets in direct impact are well documented and helmets have been found to decrease the risk of head and brain injury by 50% [1] [2]. It is shown that for direct impact situations, an injury reduction of circa 30% to 90% can be achieved [3] the main mechanical parameter that causes head injuries is assumed to be its linear acceleration [4]

Bio-mimicry – Nature as our mentor. For any human engineering or design problem we face today, the chances are good that over the last billion or so years nature has devised and optimized at least one elegant, holistic, sustainable solution. Bio-mimicry actively seeks out those best-in-class designs and "manufacturing" methods and applies them to today's pressing needs. Bio-mimicry can improve businesses by helping them find nature's best ideas and then imitate these designs and processes to solve problems [5]

2. Literature Survey

In motorcycle traffic accidents, the human head is exposed to loads exceeding several times the loading capacities of its natural protection [1]

2.1 Composition of Helmets

This section contains a review of the literature on the impact behavior of motorcycle helmets. First the composition of motorcycle helmets in general is discussed followed by a discussion of the functions and material behavior of each component separately. Finally the specifications of the motorcycle helmet to be modeled will be presented.

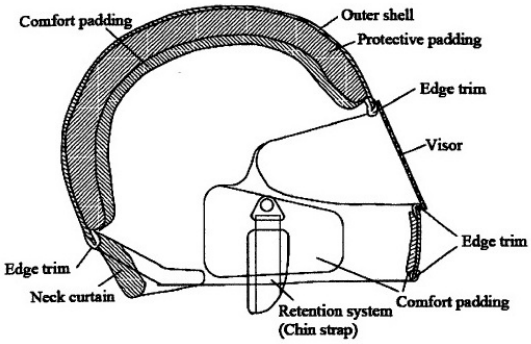

Figure1: Illustrates the individual components of a full-face motorcycle helmet [3]

This figure shows that the shell of a helmet consists of three different layers: the comfort padding linner, the protective padding liner and the outer shell. The purpose of these layers will be discussed in the next three sections. A chinstrap is used to prevent loosing the helmet prior to and during an impact.

2.1.1 Comfort padding liner

The comfort padding liner has direct contact with the head and is fixed to the protective padding liner over a large area. The purpose of the comfort padding liner is to increase the wearing comfort of the helmet and to provide a perfect fit on the head. It consists of lower density, flexibility, open-celled polyurethane or PVC foams and is often faced with a cloth layer. A possible injury reducing effect by means of reducing the relative motion between the skin of the head and the skull is caused by shearing in the comfort padding linner [3].

2.1.2 Protective padding liner

The protective padding liner, or impact liner, is situated between the comfort padding liner and the outer shell. A small part of the liner is often glued to the outer shell. The protective padding liner is the main impact energy absorbing component of a helmet. It usually consists of expanded poly-Styrene (EPS). This is thermoplastic foam [3].

2.1.3 Outer Shell

The outer Shell of a motorcycle helmet has three main functions: the distribution of the impact load over a large area, the prevention of penetration of sharp edged objects and the prevention of injury as a result of abrasion along a rough object [3]. It is made from polymers reinforced with fibers (glass, carbon or Kevlar) or thermoplastics like ABS or polycarbonate [6].

Two types of material are used in outer shells of motorcycle helmets [3]:

- Rubber reinforced thermoplastics (RRT)
  -Rubber toughened poly carbonate (PC)
  -Acrylonitrile Butadiene Styrene (ABS)
- Thermosetting fiber Reinforced Plastics (FPR)
  -Carbon Fiber Reinforced Plastics (CRP)
  -Glass Fiber Reinforced Plastics (GRP)

2.2 Biomimicry (Concept):

Bio-mimicry or bio-mimetic is the examination of nature, its models, systems, processes, and elements to emulate or take inspiration from in order to solve human problems. The term *bio-mimicry* and *bio-mimetic* come from the Greek words bios, meaning life, and mimesis, meaning to imitate [5] Literature and article survey gave the following ideas and concepts.

1. "Cats have elastic spines, their spines can contract like springs and that helps them when they fall." The skeleton of the cat allows it to absorb shocks to its forelimbs because it has no direct skeletal connection between its collarbone and vertebral column.
2. "Mountain rams have necks like shock absorbers; the impacts of heads can be heard for miles." A mountain ram's thick, bony skull and soft padding in between the vertebrae prevents serious injury.
3." Bones have holes in the dense areas, this makes them stronger, like the femur in our body, it gives them more structure." Bones achieve an even distribution of mechanical tension through the efficient use of material. Its adaptive structural design optimizes strength, resilience and material for a wide variety of load conditions.
4. "Hedgehogs spines not only jab predators – they also function as shock absorbers if hedgehog falls from a height."

2.3 Helmet constitutive modeling

Helmet outer shell:
A motorcycle helmet has two major parts, namely: the outer shell and the energy absorbing liner. The outer shell, the main purpose of which is to prevent penetration of helmet by sharp objects is made from glass fiber etc. In the FE analysis the outer shell is assumed to be made of glass fiber, reinforced plastic and modeled as a homogeneous isotropic elastic material: its properties are [2]

Table1: Material properties for helmet shell

Part	*Density (tones mm $^{-3}$)*	*Young's modulus (N mm $^{-2}$)*	*Poisson's ratio*
Shell	2.0E - 09	80.0E + 03	0.3

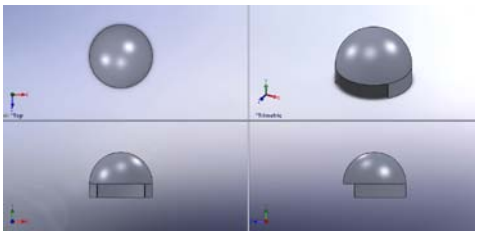

Figure 2: Helmet shell [6]

Table2: Material properties for helmet padding [6]

Part	*Density (kg/m^3)*	*Young's modulus (Gpa)*	*Poisson's ratio*
Padding	28-34	1.5e^{-3}	0.05

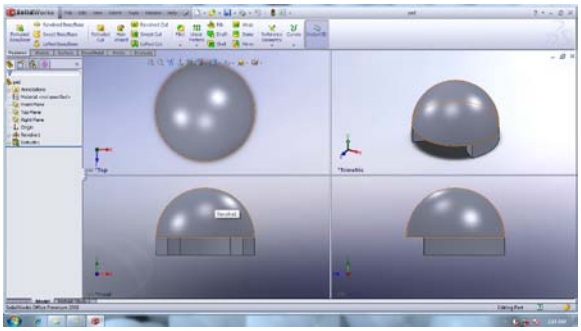

Figure 3: Padding [6]

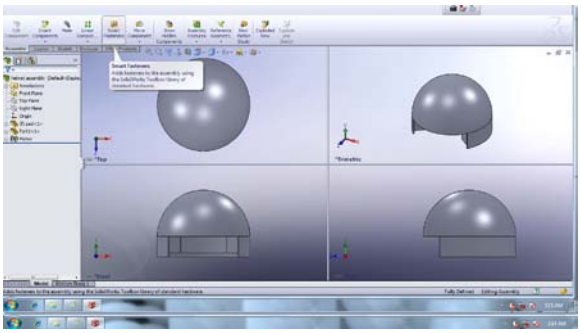

Figure 4: Complete Helmet assembly [6]

2.4 Bio-mimicry inspired concepts which can be used in helmet design

The new helmet will consist of multi layers. Each layer having its own advantage inspired from nature. The new helmet Design will use same Materials and material properties so that it can be compared in various Helmet tests [1]

2.4.1 Multi layered Shell

Snail has multi layered scales. As shown in figure 5

Figure 5: Multi layers of scales in snail for protection

Multi layers of single thickness are better than single layers as proved by Min Huang (2005) [7]. As in regular helmets the outer shell has only one layer, this new helmet will have 3 layers.

2.4.2 Multi Layered modified Padding

The padding will also be of multi layers. One of the layers will use Hedgehogs spines as a design concept.

Figure 6: "Hedgehogs spines not only jab predators – they also function as shock absorbers if hedgehog falls from a height."

3. Conclusion

The study shows that the Motor cycle helmet serves as a protective measure in case of an accident. The motorcycle helmet consists of three basic parts the outer shell, the inner padding and the liner. Studies show that the liner has negligible role in protection of the human head. The outer shell which is hard is the first layer to absorb the impact however majority of the impact energy is absorbed by the padding. Bio-mimicry an important tool for design which uses nature as its mentor can be used to design a helmet. Multi layers of outer shell can be used instead of single layer of same thickness. In padding which is again made with pillars in it in resemblance to spines. Studies have shown that multi layers are better in case of ballistic helmets. The idea is to design a motorcycle helmet inspired from bio-mimicry and test it through finite element method. In past various helmets have been tested through finite element method [8].

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Author Profile

Er. Nayhel Sharma received BTech Degree in Mechanical Engineering from Chandigarh engineering College, Mohali (Punjab Technical University) in 2010 and is currently pursuing M.E in Industrial Design Engineering (Production Dept.), PEC University of Technology, Chandigarh. His area of interest is Industrial Design.

Prof. Rahul Vaishya is currently Assistant Professor in PEC University of Technology, Chandigarh in the Production engineering Department. He has Experience of more than 12 years in teaching. He has various Research publications under his name. His key areas of interest are Non-Conventional, CNC Machines, FRP.