The Difference in a Linear Skull Fracture on the Frontal Bone With and Without a Helmet

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INTRODUCTION:

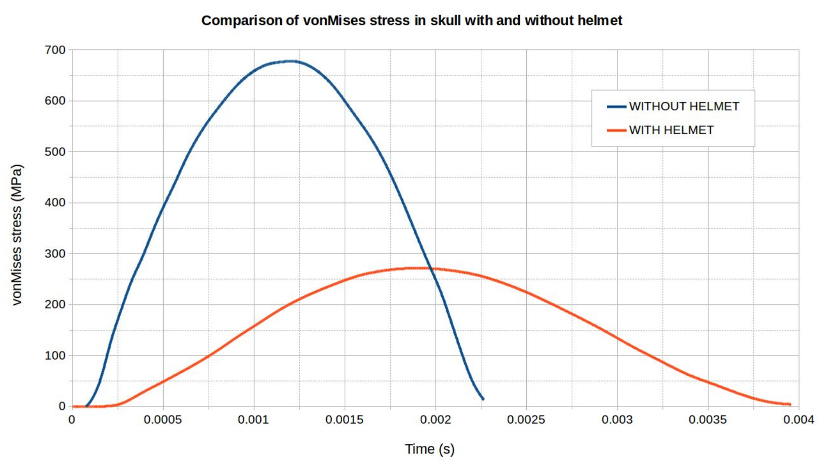
In 2016, it was found that California had the highest number of publicly owned, private and commercial motorcycles registered in the United States. Because California has the largest number of registered motorcycles in the US, there is an inevitability of having an increased number of motorcycle accidents in the state. According to the CDC, also known as the Centers for Disease Control and Prevention, there has been a steady rise in motorcycle fatalities since 2001. Research has shown that helmets saved over 1800 lives in 2016 and reduced the risk of death by 37% and the risk of head injury by 69%. A motorcycle helmet consists of certain materials that protect the head where the outer shell of a motorcycle helmet redistributes the force in order to protect the skull and objects from piercing it. The crushable inner liner of the helmet also limits the force of impact absorbing energy that would otherwise reach the head or even worst the brain. Although we are focusing our approach on motorcycle accidents in particular, it is applicable to different situations in everyday life such as bicycle helmets and construction helmets.

For the most part, wearing a helmet in the event of a motorcycle collision significantly reduces the pressure of the impact and, therefore, minimizes the fatality of the injury on motorcyclists. However, in some cases, wearing a motorcycle helmet does not necessarily prevent most of the traumatic injuries that have been reported from motorcycle accidents. The leading causes of death from motorcycles accidents are the Injuries on or relating to the head. For this reason, our goal is to analyze the mechanism that causes one of the most common injuries from a motorcycle accident, skull fracture. Some types of skull fractures include linear, depressed, and basilar; a skull fracture range from a small hairline fracture to a more detrimental blow that could cause a more fatal injury. Some common locations of skull fracture include frontal, parietal, and temporal bone. For our simulation, we decided to focus on the amount linear stress needed to cause a skull fracture in the frontal lobe of the skull.

PRIOR METHODS:

In a prior method study conducted by John Lloyd, a Research Director at the College of Engineering at the University of Tampa, he conducted an experiment that compared ten different helmet models and the amount of most effective in protecting against skull fractures, concussion, and subdural hematoma. In Lloyd's publication, "Biomechanical Evaluation of Motorcycle Helmets: Protection against Head and Brain Injuries," he built a "standard test apparatus for impact testing of protective headwear" except it was changed to test for both linear and angular headform kinematics. His apparatus consists of neck assembly mounted to a fly arm that held a Hybrid III head; the head is where the helmets were placed during the simulation. The flying arm would then project in the inputted angle (ex. angular or linear) of the force onto a "100 mm thick concrete overlay" that is suppose to represent the road. Using the apparatus, he tested ten different helmet types of common models by impacting the helmet once in the frontal or occipital region at 18.5 mph. It was found that the Scorpion T510 helmet experienced the least amount of pressure than the rest of the other helmets with the Daytona skull cap not offering sufficient enough protection from occipital and lateral impacts at the specified velocity. It was shown that most of the helmets however, do not protect as efficiently against subdural hematoma, concussions and fractures as previously hoped for. The Scorpion T510 helmet was the only one to sufficiently offer protection against these head injuries. Overall, this study was able to answer the question of how efficient a motorcycle helmet is able to protect the skull depending on its shape, and conclude that they do not meet the standards to help safeguard against head trauma in a case of a motorcycle accident.

Another prior method simulation was conducted by Ahmed Hussain, an application engineer at SimScale, called “Impact Analysis of Skull with and without Helmet”. The goal of this experiment was to simulate a nonlinear data analysis of different impacts of a human skull and analyze the von Mises stress felt on the skull. Hussain used SimScale, a computer aided engineering platform used to perform simulations, in order to map out the impact force felt on the skull. In order to replicate a skull hitting the pavement during a motorcycle accident, he created a wall of concrete on SimScale that the computer modeled skull with and without the helmet would be projected against. He used an initial velocity of 6.944 m/s and had the skull crash against a wall. The final results showed the von Mises stress on the two skulls. It was shown that the skull without the helmet experienced a much higher stress value than the one with the helmet. The graphs also show that even though the area under the curve is the same, indicating the same amount of force was applied to the skull, the graph with the helmet shows that the stress was distributed over a longer amount of time meaning absorption of pressure and stress did occur. This study helped show that wearing a helmet offers much more protection than without since a “decrease of nearly 35% of acceleration was achieved” simply by wearing a helmet.



SPECIFIC APPROACH:

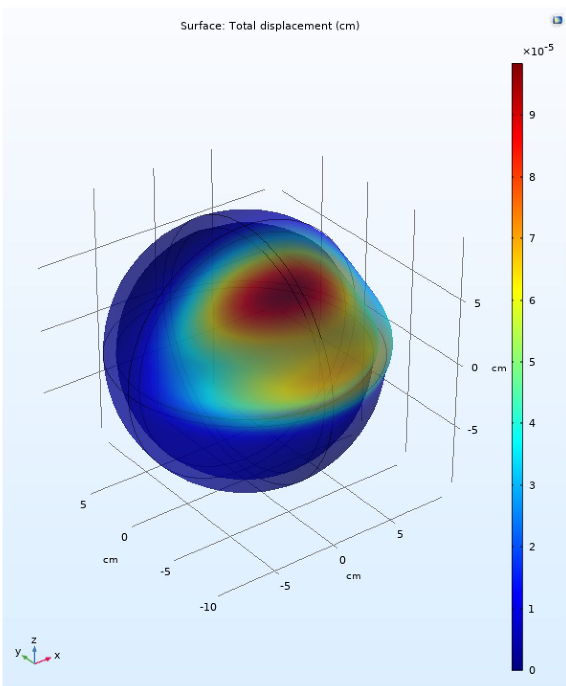
To demonstrate the effectiveness of helmet protection, we analyzed the mechanism of skull fracture with and without a helmet. However, we are focusing our analysis on linear impact on frontal skull fracture, excluding other angular impact configurations and excluding the viscoelasticity of skin as a factor and any brain/cerebrospinal fluids. We found that linear impacts are the most common type of impact for skull fractures and the initial common fracture location is on the frontal bone.

In order for our data to represent the general motorcycle population, we gathered statistics and dimensions of common materials of motorcycle In terms of circumference, the average skull of an adult male was found to be 54 to 57 cm. Therefore, the radius of the skull is approximately 8.5 to 9 cm. We determined polystyrene EPS and carbon fiber to be the two common materials that make up the helmet. The thickness of the layers of the skull, foam, carbon fiber layer are respectively: .65, 3.11, 1.5 cm. Using literature values for the properties of materials, we used COMSOL to model the human skull as well as the skull with the layers of the helmet. The material properties from literature are:

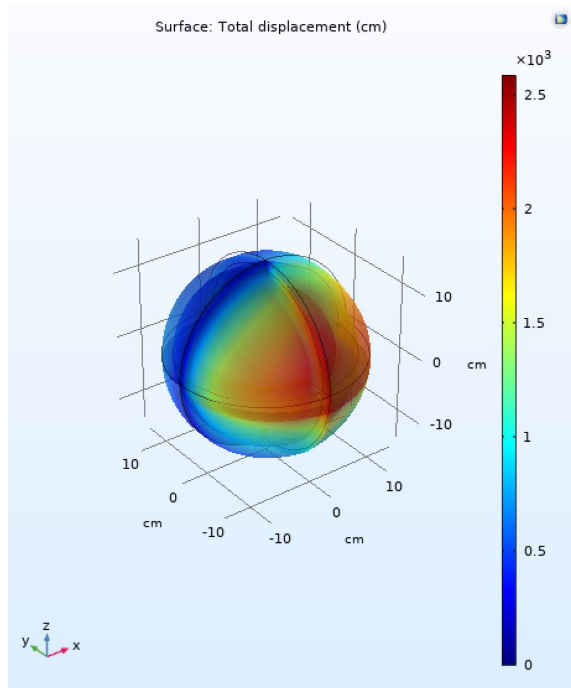
Property	Polystyrene EPS Foam	Carbon Fiber Outer Shell	Skull
Density (kg/m^3)	100	1.43	1.5
Young's Modulus (MPa)	80	52	5000
Poisson's Ratio	.1	.07	.3
Yield Stress	48	48	110
Ultimate Stress	.439	55	110

In order to create our model, simplifications were made by using a sphere for the skull and two layers of hollow spheres to simulate the full-face helmet. A boundary load of -200 N/m^2 and -500 N/m^2 will be applied in the y-direction and z-direction respectively to the top front hemisphere of the model to target the frontal bone with the rest of the faces being held as fixed constraints. With the loads and constraints applied, we applied different forces and pressures in different directions in attempt to determine the amount it would take for the skull to fracture.

RESULTS AND DISCUSSION:



[Figure 1] Total displacement of skull



[Figure 2] Total displacement of skull and helmet

Although it was not possible to simulate the point at which the skull fractures, we were able to analyze the amount of pressure needed to permanently deform a skull and compare it to the pressure needed to deform the skull with the addition of a standard motorcycle helmet. From our simulation we got two graphs, one for the total displacement of the skull and one for the total displacement of the skull and helmet. It was unnecessary to include the graph with the von Mises stress, as the displacement graph was similar. In the first graph, the stress is more localized and indicated by the darker red circle and there is a greater displacement shown by the deformation of the sphere with a maximum displacement value of 9.743e-5 cm. On the second graph, the stress is more dispersed along the sphere and there is a smaller amount of deformation on model with a maximum displacement value of 5.92e-5 cm. From this, we were able to conclude that the helmet greatly decreases the force felt on the skull by absorbing and dispersing the force of impact felt in a motorcycle collision. The polystyrene layer works to absorb the impact by compressing when it is met with force. The top two layers that mimic a motorcycle helmet absorb most of the impact that should be felt by the skull, leaving the inner layer (the skull) intact.

When creating the model of the skull and skull and helmet in COMSOL, the model needed to be simplified in order for us to run the simulation. Because of this, we were not able to add some layers. We chose a mechanical model for our physics which did not allow us to add a layer of separation between the helmet and skull. This would exclude certain factors such as hair, skin, and air that would separate the skull from the helmet and add additional cushioning. We also based our dimensions the skull of an adult male and the materials and dimensions of the skull on common motorcycle sizings. This also may vary the data as skull sizing varies among genders as well as materials and thicknesses vary among motorcycle helmets. However, using standard helmet and skull dimensions, materials, and properties, we were able to show that there is a significant benefit to wearing motorcycle helmet as it greatly reduces the likelihood of skull trauma and of receiving a linear skull fracture.

<u>RESPECTIVE CONTRIBUTIONS:</u>

Michelle Nguyen: Background Research, Prior Methods, Methodology, Written Report

Chelsea Lang: Background Research, COMSOL Simulation, Methodology, Written Report

Matthew Woods: COMSOL Simulation, Written Report

Manisha Prakash: COMSOL Model, Written Report

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