Performance Analysis of EPS Foam of Various Densities to be as Inner Layer of Cricket Helmet

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CERTIFICATE OF RESEARCH

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DECLARATION

I at this moment declare that this thesis entitled "**Performance Analysis of EPS Foam of Various Densities to be as Inner Layer of Cricket Helmet"** is an accurate report of study carried out as ra requirement for the award of degree B.Sc. (Mechanical Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of Dr. Md. Zahid Hossain, Professor, MPE, IUT in the year 2022-2023.

The matter embodied in this thesis has not been submitted in part or whole to any other institute for the award of any degree.

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Despite my best efforts, I apologize sincerely for any mistakes that may have been included in this report.

Abstract

Cricket has been hailed as a "gentleman's game" since it was first played. The protection of players has become a major issue in recent seasons. Since the prevalence of information about concussions has grown, more and more athletes are donning protective gear. A rise in helmet use has been seen in skiing, snowboarding, and cycling, not only during official events. The helmet's popularity has grown over the last four decades, although it is still not required equipment for a batter. The need for safety standards and constraints to avoid such accidents has been emphasized due to the rising number of tournaments, the introduction of new game forms, and the development of improved modalities for injury diagnosis. The risks associated with cricket are lower than those of contact sports like ice hockey and American football. However, recent cases of head injuries disprove this theory and call for an investigation into the improved design and stricter usage of safety devices.

A non-contact sport like cricket raises more concerns than it does answers when it comes to the risk of brain damage. Some people are beginning to doubt the helmet's efficacy as a safety measure after recent fatalities involving helmet-wearers.

In this study, we worked on finding a new helmet design suitable for preventing sudden head injuries and a compatible material for the helmet shell to reduce the weight of the helmet as well reduce the impact on the head.

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Nomenclature

FRA	Frequency Response Analysis
HRA	Harmonic Response Analysis
CAD	Computer-Aided Design
SISO	Single Input Single Output
SIMO	Single Input Multiple Output
MIMO	Multiple Input Multiple Output
MISO	Multiple Input Single Output

CHAPTER 1

1.1 Introduction

Cricket is known to be the second most-played game after soccer worldwide with a fan base of 2.5 million people. The ever increasing interest in cricket demand the security of the players against any severe injury against the ball moving at a speed of 140-150km/h. Extensive study of the past injuries related to cricket suggest that helmet plays a vital role in ensuring the safety of the player. Continuous observation of the players inflicted with injuries ensures the potential development of the helmet is paramount for the players to continue their profession. Professional was introduced first in 1970’s which later passed through number of successive developments in their material and design [1]. It's reasonable that cricket's governing bodies would take swift action to address safety issues by introducing new helmet requirements in light of the high-profile injuries that have happened in recent years. Yet, it is crucial that the importance of eyesight in cricket is recognized by these modifications [2]. The distinguished parts of a cricket helmet are the grill, the shell, the padding, chin strap and neck guard. Shell is the dome like structure of a helmet that is usually made of carbon fiber, fiberglass and other raw materials. Beneath the shell there is the padding made of high density foam materials to attenuate the impact after a ball strikes the helmet. The net like portion in helmet is denoted as grill which provides the player prevention from craniofacial injury. The chin strap helps the helmet to remain attached to the head. The neck guard is to provide protection of the neck and back of the head region against a blow which might not strike perpendicular to the surface of the helmet [3]. As a result of bowlers deliberately aiming the ball towards batsmen's heads, cricketers used helmets to shield their heads and faces. Up to 160 kilometers per hour, the ball can go. To reduce the risk of a skull fracture or fatal head injury, modern helmets are designed to spread the ball's kinetic energy across a larger area upon contact. Most modern helmets include a hard outer shell and a softer inner lining to better distribute impact force and reduce head trauma. Typically, they will consist of a low-density polyethylene inside and a fiberglass or ABS (Acrylonitrile butadiene styrene) outside[4]. Even after gradual development of the foaming material of the helmet and design optimization, players seem to prefer a heavy helmet since a heavy one can provide room for development to make the helmet lighter. It is imperative to know different part of helmet and their functions to improve safety concerned issues. In order to lessen the force exerted on the skull and the probability of a fracture, head protection equipment is designed to slow the head's acceleration and disperse the impact load over a larger region. This is what modern cricket helmets are aimed at providing by combining a soft inner padding to soften the blow and absorb the energy of contact with a rigid outer shell to offer an impact face that distributes the impact force over a greater surface area [5]. Helmets play a vital role in ensuring the safety of cricket players, especially in reducing the risk of head injuries caused by impact forces. The selection of materials and design elements used in the construction of a helmet have a significant impact on its protective capabilities. Expanded Polystyrene (EPS) foam has emerged as an extensively used and effective energy-absorbing material in helmet production. The purpose of this thesis is to conduct a comprehensive analysis of the efficacy of different densities of EPS foam in cricket headgear. This study seeks to optimize the design of cricket helmets and improve player safety by systematically evaluating the impact attenuation characteristics and protective properties of different foam densities.

To lay the groundwork for the research, a comprehensive literature review will be conducted, including studies on head injury biomechanics, helmet design principles, and the function of EPS foam in impact attenuation. This review will improve comprehension of the current state of knowledge, identify research voids, and emphasize the importance of investigating the effect of EPS foam density on helmet performance. This study will employ a combination of experimental testing and numerical simulations as its research methodology. A series of impact experiments replicating genuine cricket ball impacts on headgear with differing densities of EPS foam will be conducted. Impact forces, head accelerations, and other pertinent parameters will be measured and analyzed in order to quantify the performance differences between the foam densities. In addition, computational modelling and finite element analysis will be employed to supplement the experimental results. These simulations will provide a comprehensive comprehension of the internal stress distribution, energy absorption capabilities, and deformation patterns within the helmet structure for varying densities of foam. Such insights will aid in elucidating the fundamental mechanisms that regulate the protective performance of the foam. This research is anticipated to yield beneficial results for both cricket headgear manufacturers and participants. This research seeks to determine, by comparing the impact attenuation properties of various foam densities, the optimal foam density that maximizes player safety without compromising comfort and usability. The findings will inform enhancements to helmet design and provide recommendations based on scientific evidence for the selection of appropriate EPS foam densities in cricket helmets.

The results of this thesis are anticipated to contribute to the expanding corpus of knowledge regarding cricket headgear design and player safety. The findings have the potential to influence cricket helmet manufacturing industry standards, regulations, and guidelines. In addition, the study will emphasize the significance of head protection in cricket and the function of EPS foam in reducing the risk of head injuries.

This thesis report's objective is to analyze the efficacy of different densities of EPS foam in cricket headgear through a combination of experimental and numerical studies. This research aims to improve player safety and advance cricket headgear design by shedding light on the impact attenuation characteristics and protective properties of various foam densities. The subsequent chapters will delve into the detailed analysis, experimental methods, results, and conclusions, leading to practical recommendations for cricket helmet manufacturers and cricket community stakeholders. This study's findings have the potential to have a substantial effect on the cricketing community. By identifying the optimal foam density that balances protection and comfort, manufacturers of cricket helmets can enhance their design and manufacturing processes, ensuring that players are adequately protected during gameplay. In addition, the evidence-based recommendations derived from this study can assist regulatory bodies, regulating bodies, and standards organizations in revising and updating cricket helmet safety guidelines. In addition, this thesis report functions as a rallying cry for additional research and innovation in cricket headgear design. While the present study concentrates on the analysis of EPS foam densities, additional material properties, design elements, and technologies can further improve helmet performance. This research's findings can influence future investigations and contribute to ongoing efforts to enhance cricket player safety. The ultimate purpose of this thesis report is to promote a secure environment for cricket players by reducing the risk of head injuries and their potential long-term effects. This research aims to advance the understanding and implementation of effective protective measures in cricket by conducting a comprehensive performance analysis of different densities of EPS foam used in cricket headwear. In conclusion, the subsequent chapters of this thesis report will provide a detailed analysis of the experimental methodologies, results, and conclusions derived from the performance analysis of cricket headgear containing EPS foam of varying densities. This research has the potential to influence the design of cricket helmets in the future, creating a safer and more secure environment for participants.

Figure1.1: Different parts of a helmet[6].

Number of studies prove that there is room for development for helmet in terms of material and design. This work specifically focuses on developing material and doing simulation on different available cricket helmet design to search for novelty which can later be used on other helmets also. Transient , modal and harmonic analysis was performed on developed model. Potential materials that seemed fit to reduce the weight of the helmet as well provide the strength was run under simulations to find out their usefulness. Accelerations at different parts of the helmet was also determined using the accelerometer to find the impact at different portions of the head due to varying speed of the ball. Frequency of the taken helmet and our simulated model's frequency didn't have much difference which ensures the validity of the developed model.

The model developed to run our necessary simulations was developed from a real life cricket helmet. The peak, faceguard and the inner lining of foam material were ignored since we were focused on finding the impact on shell. We used a couple of other models to make a comparative analysis of various shapes and see if different shapes manipulate the result of simulation. Results of aforementioned simulations on various shell shapes have been mentioned in the methodology section.

Modal and Frequency Response Analysis:

Understanding the dynamic response of a complex structure subjected to a given set of loading circumstances is often a challenging issue that cannot be solved using conventional analytical or numerical methods alone. It is quite challenging to develop a mathematical model that can faithfully represent the dynamic behavior of the individual parts and the whole system. Even if it is assumed that the structure has a global linear behavior, connections, joints, welding, etc. are often challenging to model. Particularly, a proper characterization of damping is difficult, if not impossible. The experimental path is typically used when trying to develop a decent model that faithfully represents the actual dynamic behavior. When constructing a model, it is necessary to interpret and analyze the data gathered from the structure's measurements so that it can accurately represent the structure's behavior under realistic settings. During this stage of identification, dynamic characteristics are analyzed and quantified. The field of structural dynamics known as experimental modal analysis gained a lot of traction in the 1970s and has since expanded into many other fields and applications, such as substructure coupling, model update, damage detection, and acoustics.

Either the dynamic reaction under free vibration circumstances (i.e., the free decay data) or the forced response under some external stress may be measured. In the case of ambient excitation, the external loading may be unknown or very difficult to define (e.g. wind exciting a bridge). In such a circumstance, evaluation is limited to the reaction. It is the ratios of responses to each applied force that are used to determine or regulate the excitation. If one is working in the frequency domain, one derives the frequency-response functions (FRFs); if one is working in the time domain, one derives the impulse-response functions (IRFs). Inverse Fourier transforms are often used to get the IRFs from the FRFs.

The dynamic equilibrium equation for a system with N DOF and viscous damping is

$[M]\{\ddot{x}\}+[C]\{\dot{x}\}+[K]\{x\}=\{f\}$ ………………………………….………………(1.1)

where (M, C, K) denotes the mass, damping, and stiffness matrices, respectively. The relationship between the complex amplitudes of response and the amplitudes of the applied forces may be established under steady-state circumstances and from the harmonic excitation case through a matrix [H] (the frequency response function matrix), such that X=[H]F. Response at coordinate j is related to force at coordinate k according to the receptance frequency response functions in [H]. It is given by

$$H_{jk}(\omega)=\sum_{r=1}^{N}\left\{\frac{rAjk}{\omega_r\varepsilon_r+i\quad(\omega-w_R\sqrt{1-\varepsilon_r^2}}+\frac{r^{A}jk}{\omega_{21}\varepsilon_r+i\left(\omega+\omega_r\sqrt{1-\varepsilon_r^2}\right)}\right\}\text{…………………(1.2)}$$

Here $r^{A_{jk}}$, ε_r, ω_r are denoted as residue, viscous damping and natural frequency respectively. A different version of 1.2 is

$$H_{jk}(\omega)=\sum_{r=1}^{N}\frac{r^{C}jk}{w_r^2-w^2+in_rw_r^2}\text{ ………………………………………………….…(1.3)}$$

Here we take $\omega=\omega_r$ which is denoted as modal constant. If we use the hysteric damping model, then FRF turns out to be like 1.3. Here n_r is defined as the hysteric damping ratio.

The time domain counterpart of (1.3) is the impulse response function, which is given by

$$h_{jk}(t)=\sum_{r=1}^{2N}r^{A}jk^{e^{s_rt}}\text{……………………………………………………..(1.4)}$$

Here $\boldsymbol{s_r=-\omega_r\varepsilon_r+i\omega_r\sqrt{1-\varepsilon_r^2}}$

The structure's behavior among the chosen points is represented by either (1.3) or (1.4), depending on whether one prefers to work in the time domain or the frequency domain. Using Fourier transformations, we may easily go from one domain to another.

The two major classification between the identification of the modal analysis are

- Data used in the time domain
- Data used in the frequency domain

For both free and forced response data, the time domain is always applicable (with or without knowledge of the forces). Only when the forces causing the vibration are understood can frequency domain approaches be employed.

Various approaches exist in case of determining modal analysis on the basis of input and output, some of which make use of data from just one response site, while others make use of data from many areas at once. The following categorization takes into account the fact that there may be a single force site or several force locations in each of those situations. These three approaches account for the vast majority of use.

- SIO, or single-input, single-output, means that there is just one input and one output.
- Single-input multiple-output (SIMO) models where numerous outcomes result from a single input.
- MIMO, or multiple-input, multiple-output, describes a system in which many outputs result from many inputs.
- Many-input, single-output (MISO) is a situation in which a single answer is generated despite the presence of multiple driving factors.

It is not feasible (or at least not straightforward) to state how many resonances are there in a given time period since the responses (time histories) inherently carry information about the frequency content, but this is 'hidden' in the time domain. Therefore, time domain techniques may detect several modes of vibration in a structure at once, as can MIMO techniques. Multi-degree-of-freedom (MDOF) techniques are a kind of this. When viewing data in the frequency domain, identification may be made mode by mode due to the visibility of resonance peaks. One term for these strategies is "single-degree-of-freedom" (SDOF) approaches.

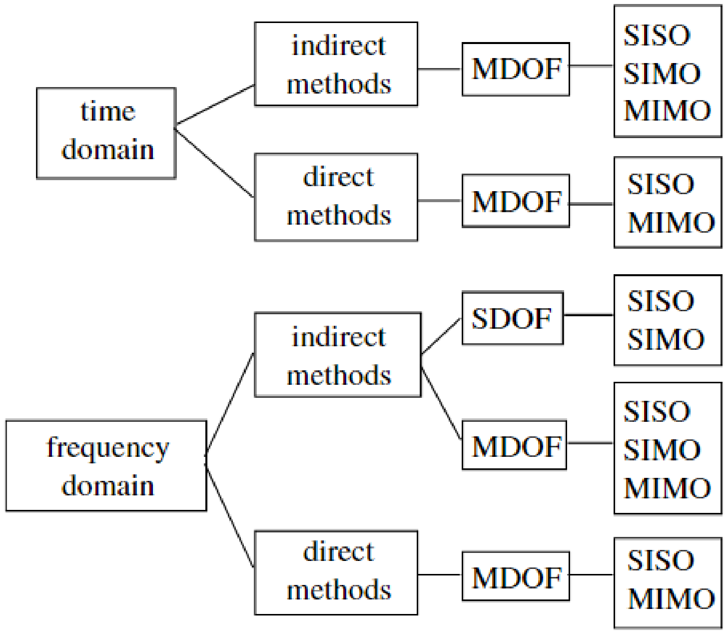


Figure1.2: Classification of modal analysis methods[7]

Many different methods have been developed over the years, particularly in the 1970s and 1980s, in addition to the very simple methods where basically the natural frequencies were evaluated directly from the peaks of the frequency response functions (FRFs) and the damping ratios were calculated by the half-power points method. Prior to the 1970s, the seminal contribution was made by Kennedy & Pancu (1947). By plotting the frequency response function in the complex plane, they discovered in 1947 that they could improve the resonant zones (the Nyquist plot). The plots have a circular form at the natural frequencies and are perfectly circular for a system with a single degree of freedom. This not only proves the presence of resonances, but also, with the help of a good curve-fitting procedure, allows one to determine the dynamic parameters of each resonance. The circle-fitting approach is an upgraded version of this procedure; it is user-friendly, requires little in the way of computation, and provides immediate results. The method is both adaptable and educational, but it is time-consuming due to the need to identify the dynamic features (the modal parameters) for each mode individually. When analyzing damping, the hysteretic model is often used, with the underlying assumption being that the contribution of the modes other than the mode under discussion is a(complex) constant [8].

Transient response/impact Test:

A numerical method is used to investigate the dynamic behavior of structures subjected to time-varying loads. This method is referred to as transient response analysis or time-domain analysis. It entails resolving the structure's equations of motion for a given period of time. The study determines the structural reaction, including displacements, velocities, and accelerations as functions of time, taking into consideration variables like inertia, damping, and stiffness**.**

Impact testing includes applying sudden, impulsive loads to a structure to assess how it will react to high-energy events like collisions or drop tests. This kind of study is critical for safety and durability evaluations in sectors like automotive, aerospace, and consumer products where understanding how structures sustain impact loads is crucial.

1.2 Literature Review

The record of severe head injuries in cricket in the 20's show that the death of Philip Hughes was the last recorded severe injury case. But a number of studies have been performed since then as a precautionary measure in helping not to recreate that tragic event. Besides , a number of injury cases don't get officially recorded [9]. Moreover, cases where the plyers get hit on the head even after wearing helmet, ball going through the pace between the peak and faceguard is not scarce. So, researchers have put forth their effort to avoid different possible injuries and their possible impact on the player's career. Dmityh.et.al [10] tried to find out the impact on human head due to strike made by a moving cricket ball thrown at different initial velocities. An experimental program was conducted to find the impact on head which was later validated using LS-DYNA software. Their work showed impacts on various points of human head both with helmet and without helmet and the reduction of impact on head due to wearing helmet. W.H.A.C. Wijerathna. et. al [11] tried to find the scopes of developing the design parameters of cricket helmet to increase the comfort of the player as well ensuring the protection of the head. They went through a number of literature reviews, videos containing the recent incident of abrupt injury on the field and interviews of both male and female player. The simplified statistics of this work showed that player wanted a lighter helmet, a better inner padding material and protection against neck injury. Toh Yen Pang.et.al [12] made a comparative analysis of various vent design of the helmet and tried to find the best fit for the player at various temperatures for most heat dissipation . Heat dissipation and gain of a head manikin was measured using ten K- thermocouples when the wind was made to blow over the head at the speed of 2.3m/s. The findings in their work prove that wearing helmet increase the head surface temperature around parietal region, extra holes provide thermal comfort during forced convection, space provided by the suspension strap assists in heat dissipation in parietal and occipital region. A. Subic.et.al.[5] worked on replacing the conventional faceguard made of steel with proposed polycarbonate grill which later came into large scale market production. They also proposed a slight change in the grill design to provide better support against suddenly gained speed. Manjul Tripathi.et.al.[13] tried to find the reduction of impact on head due to moving ball while establishing a comparison between drop test and air canon test. They categorized the injuries in terms of career-threatening and severe , which position of the players were more susceptible to injuries and cases when ball hits the head directly or slips through the gap between peak and faceguard. The statistical report drawn from a scenario comprised of 36 cases presented an overall picture of injuries related to cricket in craniofacial regions. Magnus Aare.et.al.[14] worked on finding the impact on a riot helmet due the effect of bullet which is more likely the impact of a moving ball over cricket helmet. They used finite element analysis (FEA) method to find the impact on the head wearing helmet to find the impact when bullet coming at different angles and how the shell strength manipulate the load on the head. Studied simulation data were regarding the stress in the cranial bone, strain developed in the brain tissue, pressure developed in brain, change of rotational velocity, translational and rotational acceleration. The findings in their study suggest that there should be gap between the skull and inside of the helmet otherwise the skull is more likely to get fractured and the oblique impact are most likely more harmful than the pure radical ones. P.Naresh.et.al.[15] worked on modification of the material of industrial helmet to improve its strength. After developing the 3D model in ProEngineer software they went for the impact analysis in ANSYS using S-glass, Carbon Epoxy, Polythene and Nylon4-6 while applying different amount of forces at each scenario. After comparing the stress and deformation value of all the materials against applied load of 25kg, S-glass showed the maximum deformation while carbon fiber had the highest stress developed. David Harman.et.al.[16]. David Harman.et.al. developed a realistic 3D model developed from MRI data after integrating mesh technique based on image using CAD geometry to study the impact of shock wave on head with helmet. Result of their study proved that shock waves are capable of inducing concussion and destruction of brain cells that can be minimized using customized helmet developed after data gathered after one's head scan data. Ben . W . Stone.et .al.[17] worked on finding the impact of load on head which applied in projectile. This work centered around finding the presence of rotational acceleration and its impact on frontal and lateral portions of the head. The experimental setup of the study consisted of a pressure canon throwing ball at 22 and 28m/s at specified locations of a certain head form and data collection was done using a high speed video camera and accelerometer. The findings of this result show3d that the ball deformation was significant at the frontal part of head. It was shown that during the loading period, the average linear acceleration was higher for frontal hits than for lateral impacts, perhaps because of changes in surface geometry leading to different ball deformation. Bernd Furenschuss.et.al.[18] worked on finding the safety of the sports helmet shell made out of carbon fiber taking jockey helmet as their subject of interest. Four different types of shells varying in layers and patterns were used to study their performance. The various shells were compared using peak deceleration from 2-wire drop testing. In order to learn more about the impact behavior, the researchers also assessed the Gaussian and Mean curvatures of the impact locations. During the typical impact test, the 2-patterned shell with 5 layers (2P5) performed the best. Ben Stone.et.al.[19] worked on finding if different positions of the used head form had any influence over the outcome of the performed experiment. This study focused on identifying whether 'Fixed' and the 'Free Suspended' position of the head form made any significant difference in the same experiment. Balls moving at three different speed were made to hid specified locations of the head form after throwing from a pressurized canon. Contact duration was calculated using high speed vide and peak acceleration of the ball was measured from the accelerometer. Lee Gabler.et.al.[20] validated the performance of wearable devices over head by following standard validation method . This study provides guidelines for validating the precision of head kinematic devices in a laboratory setting. Cornelis P.Bogerd.et.al.[21] tried to find the effect of helmet on cognitive performance under various ambient conditions. Temperature and preference of using the helmet was recorded after each study session . When comparing wearing a helmet to not wearing a helmet, we found that wearing a helmet was related with decreased comfort (p 0.001) and an increased impression of temperature (p 0.001). Post-hoc testing revealed no significant impact of helmet use on any of the other eight cognitive metrics. John Stock Strickland [22] intended on finding the protection gear of the mask of a softball player while getting a deeper look into the incidents of injury and frequency related to injuries in the facial region. Using an instrumented Hybrid III head form, impacts were measured at two speeds and four impact sites with a variety of protective situations, including six fielder's masks, one catcher's mask, and without any head protection at all (no mask). The majority of fielder's masks were shown to lower head accelerations, although not to the extent seen with catcher's masks. They averaged 36% and 49% reductions in peak linear and angular acceleration, respectively, for hits at 40 mph, and 25% and 42% reductions, respectively, for impacts at 60 mph. Fielders' masks with plastic frames have been shown to enable contact with the face when hit in the nose at high speed. The fact that different fielder's masks were found to have varying degrees of impact protection provided more evidence that certain design aspects, such as foam padding and frame attributes, had a role in this phenomenon. Saurabh Singh.et.al used different types of materials and models for deformation and tension testing were reviewed and analysed to improve performance characteristics. The materials were subjected to a minor load of 200N to test their efficacy and deformation; however, the most essential aspect of a helmet is its deformation against the applied load. Polyester showed the least amount of deformation among the four evaluated materials, indicating that it is more suitable for use as headwear [23]. Luca Di Landro.et.al gave some conclusions can be derived regarding the deformation mechanisms and energy absorption capacity of polystyrene foams and polycarbonate casings for protective helmets, as well as some design enhancement suggestions. Considering the primary mechanisms responsible for the energy absorption capacity, SEM analysis reveals that the crushing of EPS cells is not uniform through-thickness, but is instead localized at the borders between pre expanded beads, since pre-crushed cells are always present, even in non-deformed specimens [24]. Sk. Ahmed .et.al concluded that CATIA has also been used as a vital instrument for the design of "jet-fighter" aircraft, aircraft carriers, helicopters, tanks, and a variety of other weapons widely employed by the defense industry. Compared to Acryl nitrate Butadiene Styrene and Expanded Poly Styrene, Poly Carbon and Expanded Poly Styrene is the superior material for helmets because it is more resistant to stresses, strains, and deformation. Even though Poly Carbon has a lower density than Acryl nitrate Butadiene Styrene, PC can withstand greater amounts of tension and the helmet's mass is minimal [25]. Some K Bhudola.et.al proved that With increasing density, the quantity of energy absorbed by the foam increases, but there is a saturation point beyond which no more energy can be absorbed, and any further increase in density will result in an unnecessary increase in the specimen's weight.

In PC category foam, the majority of the energy is absorbed by the splitting of the foam and the deformation of the ABS exterior, whereas in CC configuration, the majority of the energy is absorbed by the deformation/compression of the foam as opposed to the failure. Comparing the energy absorbed by the PC and CC configurations, the CC configuration absorbs 9.2% more energy. The results demonstrated that as foam density increases, acceleration decreases and energy absorption increases up to a saturation point C foam demonstrated a 9.2% increase in energy absorption over PC foam. More energy is absorbed by the compression/deformation of the foam as opposed to failure, as is the case with PC samples with corrugated foam designs [26]. Mohammad Nasim.et.al conducted computational study where the experimental and simulated results of the resultant linear acceleration, as a function of time, measured at the center of gravity of the head form during linear impact experiments at sites P and B were compared. The greater maximal force observed during the experiments was a result of the impactor's direct contact with the MEP. Due to the low strain rate applied during the quasi-static compression, the struts did not fracture, but the samples were unrecoverable. The dynamic efficacy of various lattice liners has been investigated. In this investigation, a commercial helmet was utilized to compare the efficacy of lattice and EPS foam liners. In accordance with the helmet standard, EPS and PA12 lattice liners were coupled with a head form in order to simulate high-energy linear and oblique impacts. As a helmet liner, a lattice structure with high energy absorption capacity may not perform satisfactorily. In this paper, we investigated, for the first time to our knowledge, the potential of PA12 lattice structures to design energy absorbing and dissipating helmet liners based on the current standard ECE 22.06.Calculated results indicate that it can be difficult to select the optimal cell topology, tessellation method, and strut diameter for a lattice liner, as there must be an equilibrium between energy absorption capacity and rigidity [27].

Above mentioned all works tried to find the impact on head at large due to varying load occurred at different speed and tried to grasp the idea of injury occurrences so that better protective protection measures can be invented. It is evident from the studies that helmet shell material can still be improved which can be both feasible and lightweight. Moreover, injuries in the facial regions a player doesn't go unnoticed during various intense moments of the game. The cricket helmet still lacks the correct rigidity which will stop the balls from going through the gap between peak and faceguard. However, a fast moving ball could severe damage around the neck portion if the neck , back of the head and ears are not protected. This study focuses on material and design development since injuries in cricket are still prevalent.

1.3 Objective

After going the current and previous works regarding injuries in cricket we find that sufficient work has not been done to prevent abrupt injuries which may turn out to be fatal and can even terminate the career of a player.

The objective of this study is

- To find the best possible material for the helmet cushion as EPS
- To find a more compatible design of the cricket helmet
- To find scope in integrating novelty into any other helmet type

ADVANTAGES OF EPS OVER CONVENTIONAL FOAM

Expanded Polystyrene, or EPS, is a material that is frequently used in the manufacture of helmets. EPS is a strong, lightweight foam that offers superior impact protection. EPS is frequently used as the inner lining or core of helmets during production. Its function is to disperse and distribute an impact's force in order to lessen the possibility of head injuries. Because of its superior energy-absorbing qualities, EPS is the perfect material for building helmets. Helmets' EPS foam is made to compress upon impact, which reduces the amount of energy that is released during a crash. EPS helps to decrease the impact on the wearer's head by absorbing and spreading the force, lowering the risk of skull fractures, concussions, and other serious head injuries.

CHAPTER 2

2.1 Methodology

Before starting the analysis of the cricket helmet shell we developed the geometric model in Solidworks2021. After developing the model from areal life object and scaling down the measurements, we went for the simulation in ANSYS. We performed the simulation in ANSYS 2020.

The steps followed in methodology is depicted in the flowchart

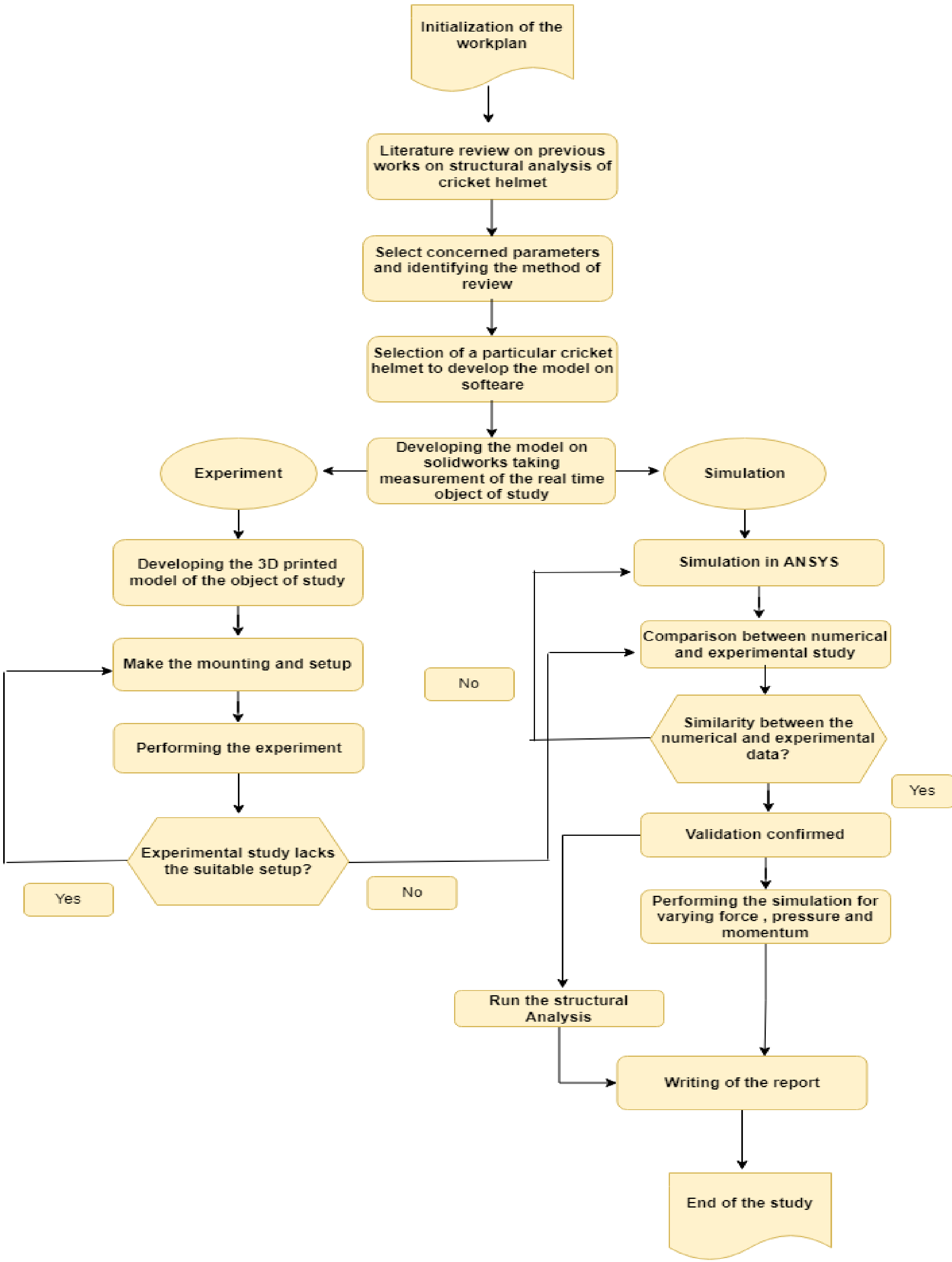


Figure 2.1: Flowchart showing steps of methodology

After going through comprehensive studies mentioned in literature review, the geometric model of the case of study was formed after scaling down the model measurements to 1:50 for the convenience of our simulation. Modal and transient analysis was done in ANSYS to find which analysis took the minimum amount of time to ensure the best mode of analysis.

Modal and transient response assessments are among the many simulation capabilities offered by the potent software suite ANSYS. In engineering and design, these studies are frequently used to comprehend the dynamic behavior of structures and systems. Depending on the ANSYS version we are using and the particular issue we are trying to solve, the precise information and options may change. When utilizing the program for these analyses, it is always advised to refer to the ANSYS documentation or look for supplementary resources for more in-depth instructions and help.

2.2 Geometry and Dimensions

Primarily the work we are doing is on the outer shell of the helmet, which is the cap. So we have taken the measurements of outer shell removing some parts from helmet by taking a plain surface of outer shell.

Modelling of helmet with Cushon

The model was done in Solidworks 2021 version. The dimension is taken according to the measurements

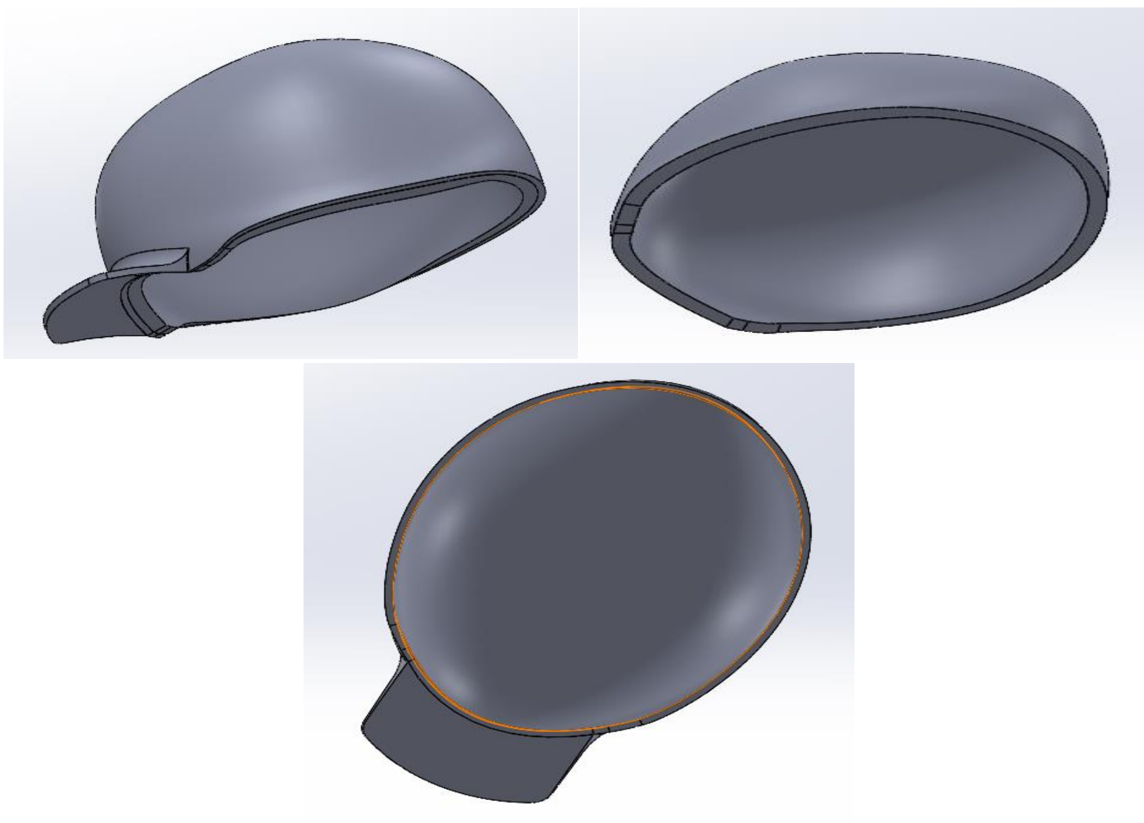


Figure 2: developed model, cushon and helmet shell.

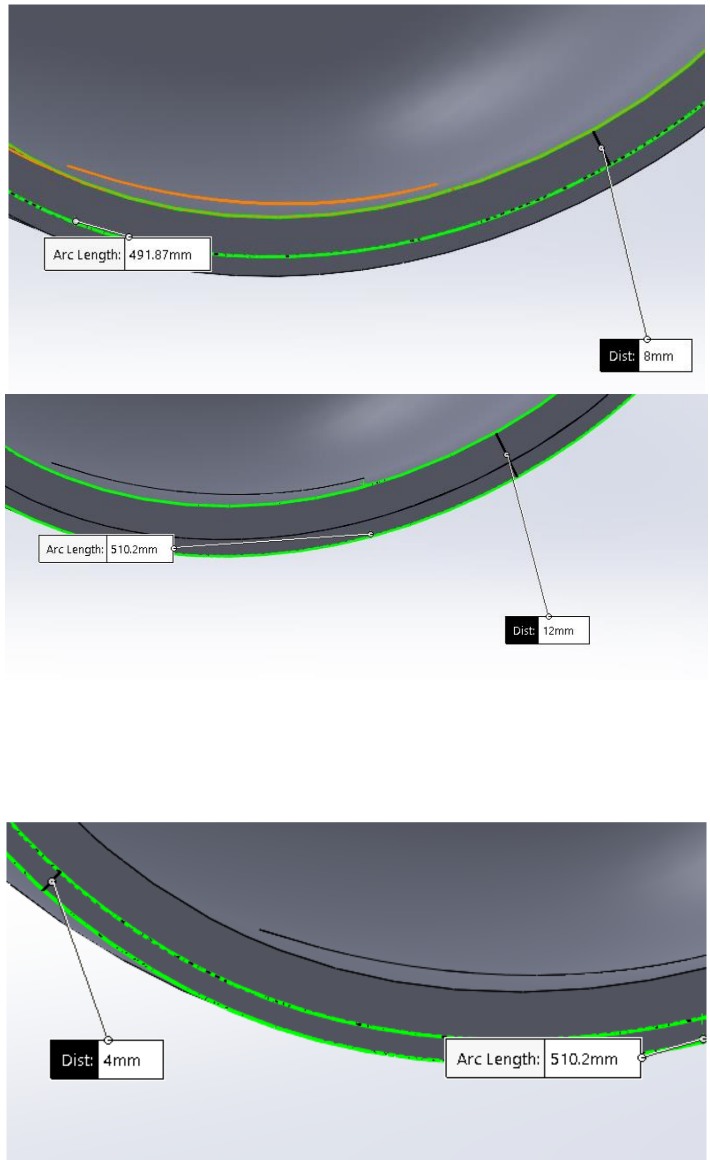


Figure 2.3: Thickness of the developed model(Cushon),total thickness of helmet and helmet outer shell thickness.

This is outer part of helmet its nearly a shape of existing common model of cricket helmet's outer shell.

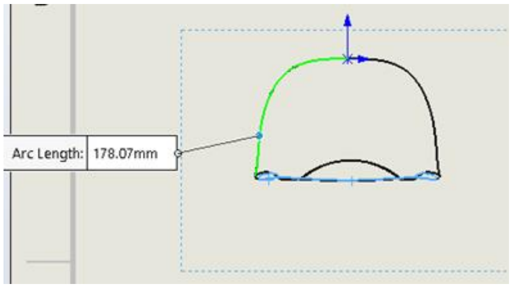


Figure 2.4: Dimensions arch of the model geometry

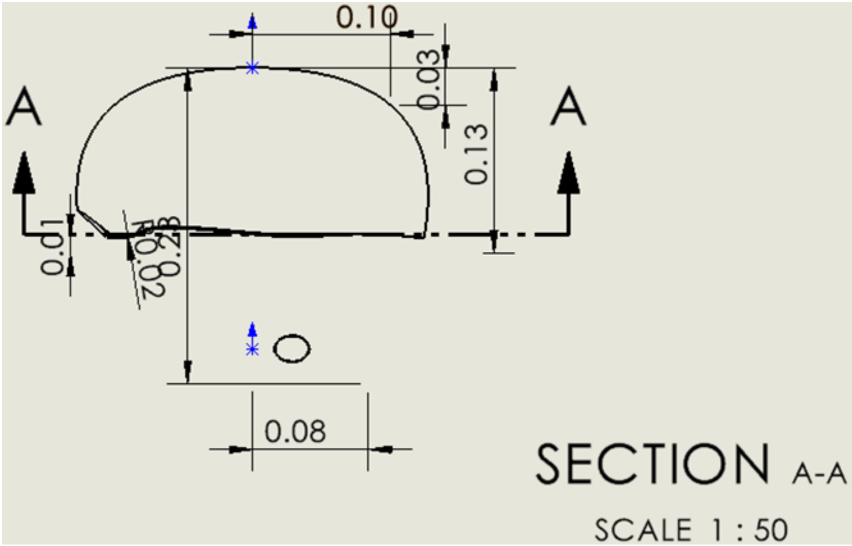


Figure 2.5: Dimensions of the CAD model of the helmet shell (Side View)

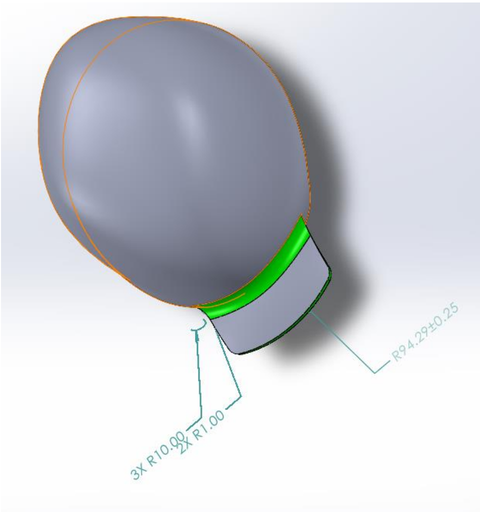


Figure 2.6 : Outer shell of helmet's model design and dimensions

The dimension are taken in scale 1:50

2.3 Material

The material which is used in helmet outer shell is basically Carbon Fiber, ABS and other composite materials.

Material properties of cap (outer shell) which is undergoing:

Material property		ABS PLASTIC	unit
Density	ρ	1.9	g.cm-3
Young's Modulus	E	183	GPa
Poisson Ratio	υ	0.26-.0.28	
Bulk Modulus	K	3.5	Pa
Shear Modulus	G	200-500	GPa
Thermal Expansion coefficient	α	10-5	K^-1

Table 2.1: Material properties of ABS PLASTIC

Calcium		Value	unit
Density		1550	kgm^-3
Poisson's ratio		0.31	
Young's Modulus		1.97E+10	Pa
Bulk Modulus		1.73E+10	Pa
Shear Modulus		7.53E+09	Pa

Table 2.2- Material properties of Calcium (head)

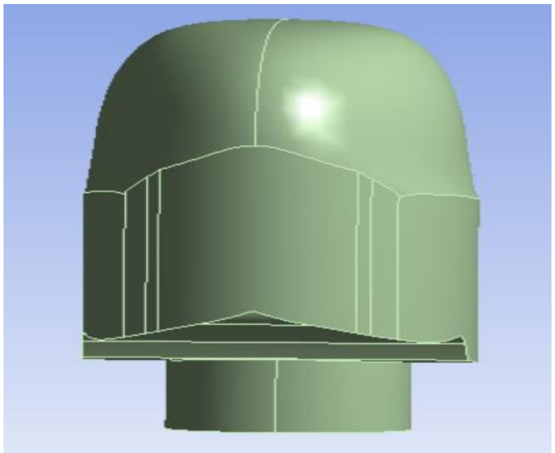


Figure 2.6 - Headform in which the Helmet will Fit And the material properties of Head. (developed in solidworks)

2.4 Simulation Setup

Simulation on the model was done in various boundary conditions and input .We have done the modal, Harmonic response and transient structural response in ANSYS 2020 workbench.

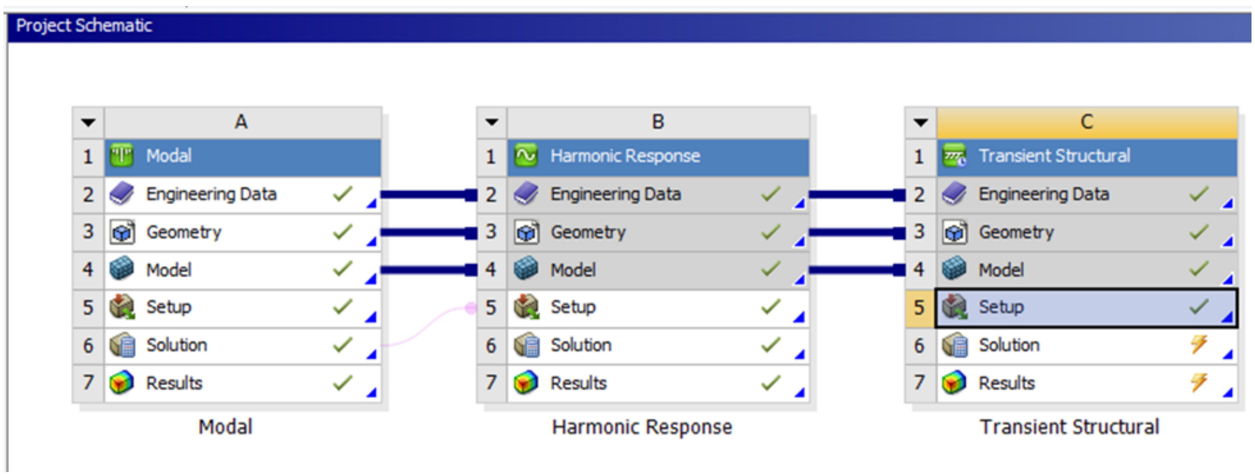


Figure 2.7: ANSYS 2020 workbench interface

The following steps were followed while running the simulation

- Step 1 Modal analysis
- Step 2 Transient Response (Impact test)
- Comparing results of total acceleration and deformation, directional deformation.

2.5 Engineering Data

Material properties for EPS

EPS 35		Value	unit
Density		35	kgm^-3
Poisson's ratio		0.01	
Young's Modulus		1.29E+07	Pa
Bulk Modulus		4.38E+06	Pa
Shear Modulus		6.43E+06	Pa

EPS 50		Value	unit
Density		50	kgm^-3
Poisson's ratio		0.01	
Young's Modulus		1.91E+07	Pa
Bulk Modulus		6.48E+06	Pa
Shear Modulus		9.43E+06	Pa

EPS 55		Value	unit
Density		55	kgm^-3
Poisson's ratio		0.25	
Young's Modulus		5.00E+09	Pa
Bulk Modulus		3.33E+09	Pa
Shear Modulus		2.00E+09	Pa

EPS 60	Value	unit
Density	60	kgm^-3
Poisson's ratio	0.01	
Young's Modulus	8.51E+06	Pa
Bulk Modulus	8.51E+06	Pa
Shear Modulus	1.23E+07	Pa

Table 2.3- Material properties of Input of engineering data for Different EPS

2.6 Geometry

We converted the design model from SOLIDWORKS 2021 into IGES file and then upload to the workbench ANSYS 2020 for performing the Modal, transient response. As impact test.

2.7 Meshing

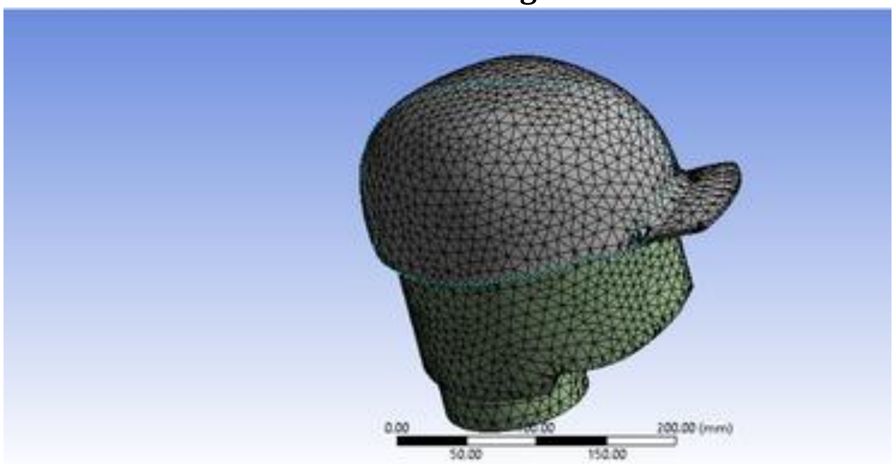


Figure 2.9: Meshing of the helmet and details

With a view to getting reasonable nodes and proper modal analysis meshing is the most important part. So for the better analysis we have taken the element size to be 10 mm for this model

Statistics	
Nodes	10223
Elements	5060
Mesh Metric	None

Figure 2.10: Nodes and elements

Here the numbers of elements are 10223 and the numbers of nodes are 5060.

2.7 Boundary Condition

We have taken certain point and place fixed and whole body sizing.The whole body of the model was done sizing.

- Fixed support:

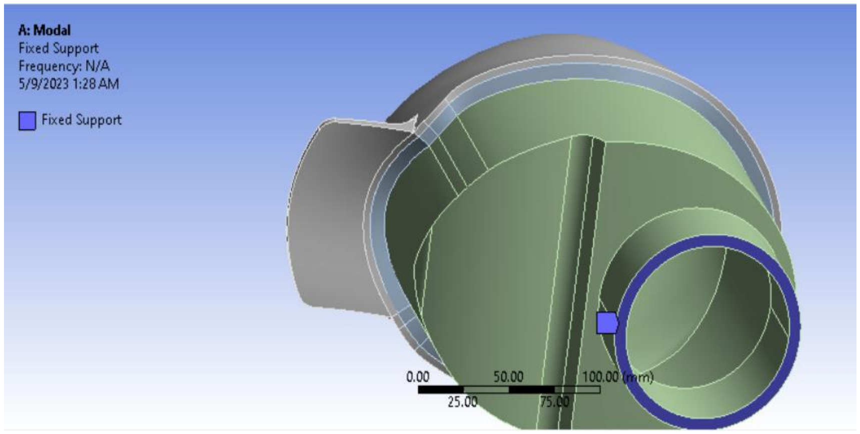


Figure 2.11: Fixed points in model

The Blue colour part are the fixed position for the model which was selected for the modal analysis.

2.8 Modal Analysis

Here we get the frequency of different mode and shapes for certain fixed points. For the better result and performance we have given the solver 6 modes and shape of modal analysis**.**

EPS 35		EPS 50		EPS 55		EPS 60	
Modal	Frequency	Modal	Frequency	Modal	Frequency	Modal	Frequency
1	216.55	1	215.94	1	216.81	1	215.51
2	319.4	2	318.61	2	320.41	2	318.03
3	817.4	3	850.37	3	879.55	3	855.16
4	840.76	4	851.89	4	1075.8	4	875.28
5	907.13	5	923.27	5	1089.6	5	934.66
6	1150	6	1162.2	6	1211.5	6	1167.7

Table 2.4- Frequency of 6 modes of 4 different EPS

2.9 Transient Response

Input

Because of analyzing the impact test on the outer part of helmet, transient response was done, as it shows the sudden change in the outer body of helmet , we get the very idea of deformation directionally or stress analysis because of a sudden pressure or force comes at it.

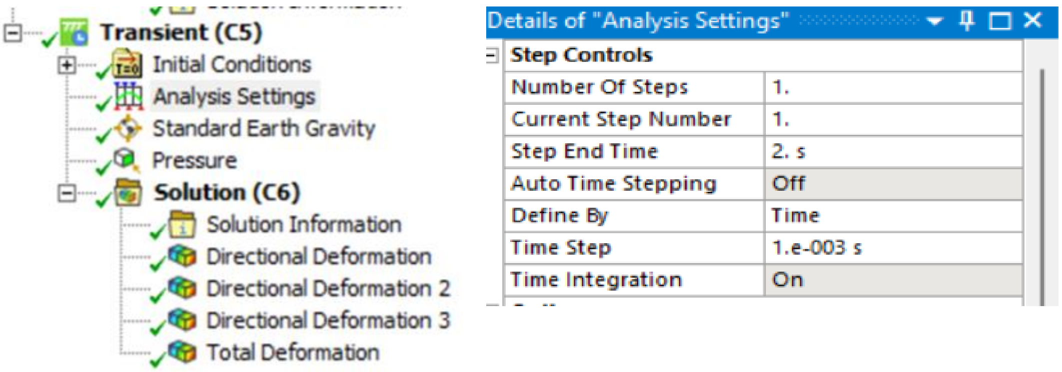


Figure 2.13: Transient structural response boundary condition

Initial conditions came from modal analysis data which were connected to transient response by ANSYS 2020

In analysis setting number of steps were taken 1, current step was 1,step end time was 2 sec ,auto time stepping was off.

The boundary condition we took here was central earth gravity

As it was for sudden impact 2000 N force was given for a certain fraction of time in between 1 sec which was 1.e-003 sec.

Force was given to a certain point because we assume the possibility of ball heating the helmet in a certain point at a time.

Impact of the ball on Helmet and Head:

mv-mu = F.t ; where mv momentum of cricket ball coming towards and F impulse of force.

Indifferent force in axis,same time steps and force in the particular face on same elements were taken

Tabular Data

	Steps	Time [s]	X [N]	Y [N]	Z [N]
1	1	0.	0.	0.	0.
2	1	5.e-002	0.	0.	0.
3	1	0.1	-2000.	0.	0.
4	1	0.15	0.	0.	0.
5	1	2.	0.	0.	0.
*					

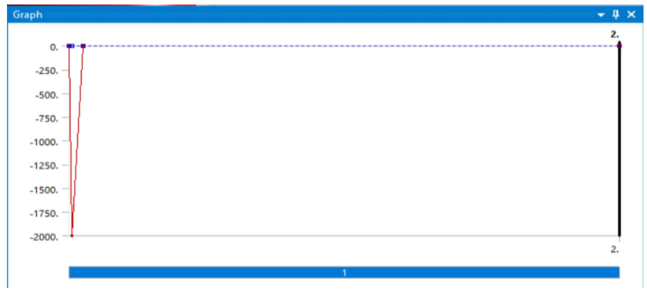


Figure 2.14: Force applied on helmet surface in transient response

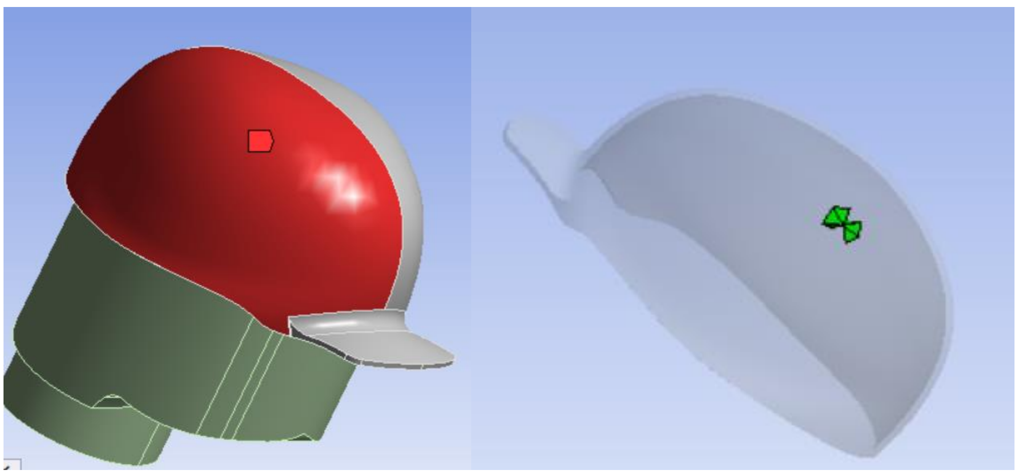


Figure 2.15-Pressure putting in helmet surface in Transient Response

Chapter 3

3.1Simulation Result

Modal Analysis (Mode and shapes)

In Modal analysis we get the differentsmodes shapes and dieformationon various axis on various frequency.

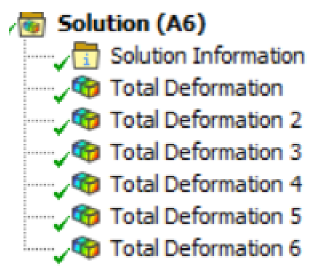


Figure 3.1: Solution bar in ANSYS during modal analysis

From the simulation, the natural frequency of the first mode is 216.7Hz, and the sixth mode is 1150 Hz. As the mode number increases so does the natural frequency. The mode shapes are also changing in the different axes. The first mode is bending in the Z axis. The second mode is bending in the X axis. A torsional or twisting mode can be seen in the Y axis. Rest of the modes are in the Z axis. A tabulated version of the modes is given in below.

Here, the analysis on the EPS 35,50,55,60 Cushon used in helmet which are given below:

EPS 35		
Modal	Frequency	mode shape
1	216.55	1st mode of bending in the Z direction
2	319.4	2nd mode of bending in the Z direction
3	817.4	3rd mode of bending in the Z direction
4	840.76	4th mode of bending in the Z direction
5	907.13	1st mode of bending in the X direction
6	1150	1st mode of twisting in the Y direction

EPS 50		
Modal	Frequency	mode shape
1	215.94	1st mode of bending in the Z direction
2	318.61	2nd mode of bending in the Z direction
3	850.37	3rd mode of bending in the Z direction
4	851.89	4th mode of bending in the Z direction
5	923.27	1st mode of bending in the X direction
6	1162.2	1st mode of twisting in the Y direction

EPS 55		
Modal	Frequency	mode shape
1	216.81	1st mode of bending in the Z direction
2	320.41	2nd mode of bending in the Z direction
3	879.55	3rd mode of bending in the Z direction
4	1075.8	4th mode of bending in the Z direction
5	1089.6	1st mode of bending in the X direction
6	1211.5	1st mode of twisting in the Y direction

EPS 60		
Modal	Frequency	mode shape
1	215.51	1st mode of bending in the Z direction
2	318.03	2nd mode of bending in the Z direction
3	855.16	3rd mode of bending in the Z direction
4	875.28	4th mode of bending in the Z direction
5	934.66	1st mode of bending in the X direction
6	1167.7	1st mode of twisting in the Y direction

Table 3.1: Modes and frequencies table according to axis in modal analysis

Deformation for each EPS density Helmet:

Deformation in modal analysis refers to the displacement or shape alterations that take place in a structure as a result of dynamic loads or vibrations. A popular finite element analysis program, ANSYS, offers the ability to conduct modal analysis and look at a structure's deformations.

The main goal of a modal analysis in ANSYS is to ascertain the structure's intrinsic frequencies and mode shapes. Natural frequencies are the frequencies at which the structure has a tendency to vibrate, and mode forms are the deformation patterns that correspond to each natural frequency.

EPS 35:

Total Deformation on overall Head and helmet:

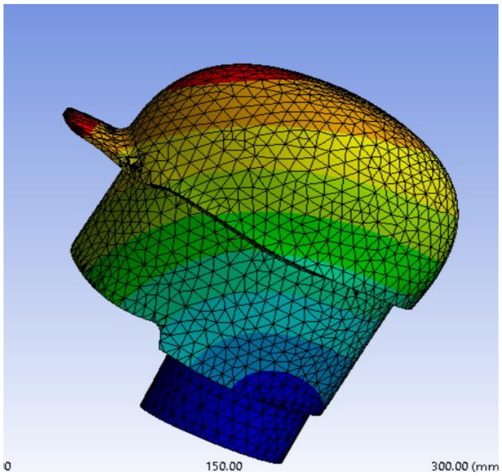


Figure 3.2- Deformation in overall structure For EPS 35

Total Deformation on Head:

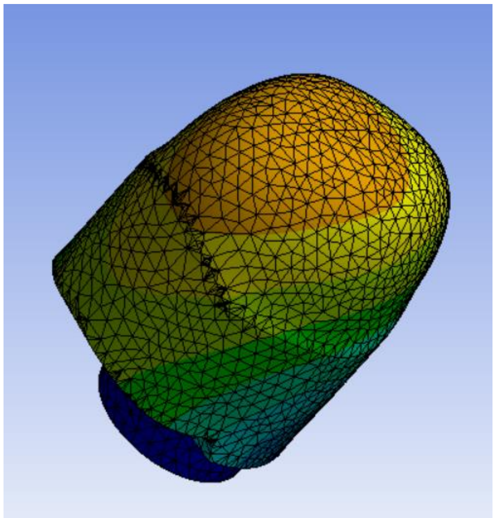


Figure 3.3- Deformation in Head

EPS 50:

Total Deformation on Helmet:

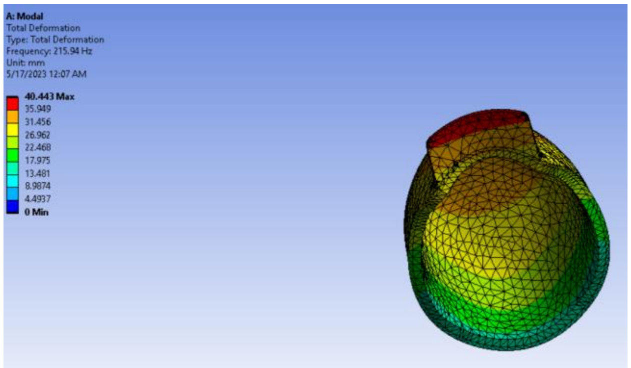


Figure 3.4- Deformation in overall helmet structure For EPS 50

Total Deformation on Head:

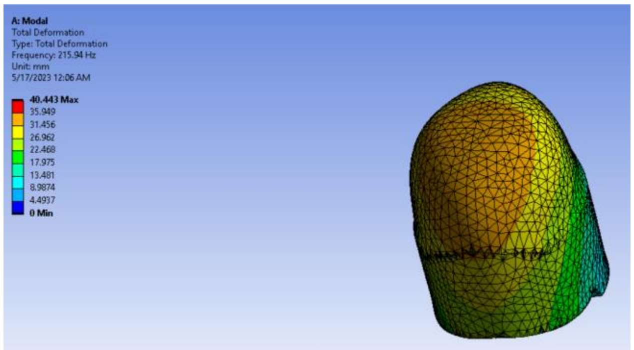


Figure 3.5- Deformation in Head

EPS 55:

Total Deformation on Helmet:

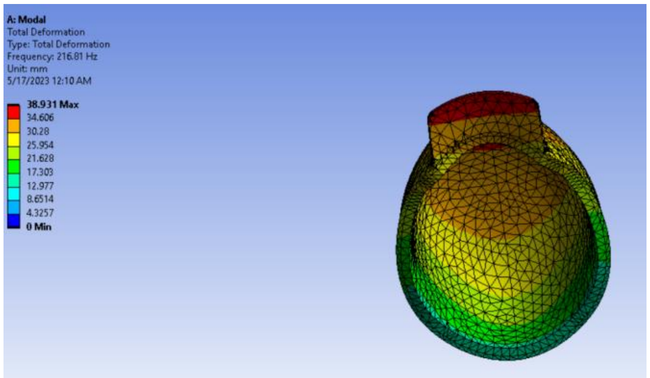


Figure 3.6- Deformation in overall helmet structure For EPS 55

Total Deformation on Head:

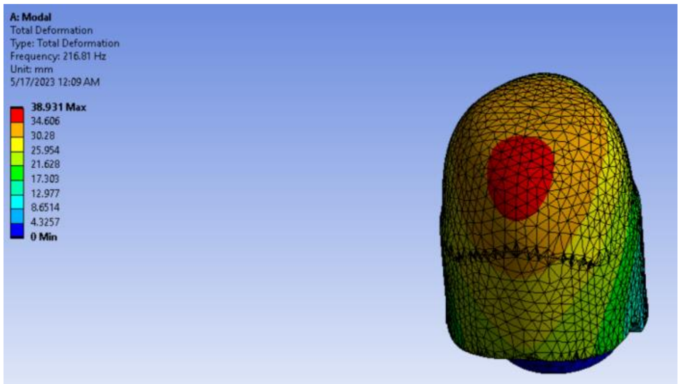


Figure 3.7- Deformation in Head

EPS 60:

Total Deformation on Helmet:

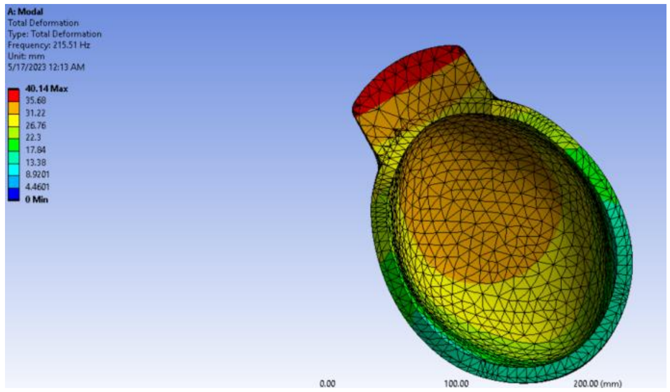


Figure 3.6- Deformation in overall helmet structure For EPS 60

Total Deformation on Head:

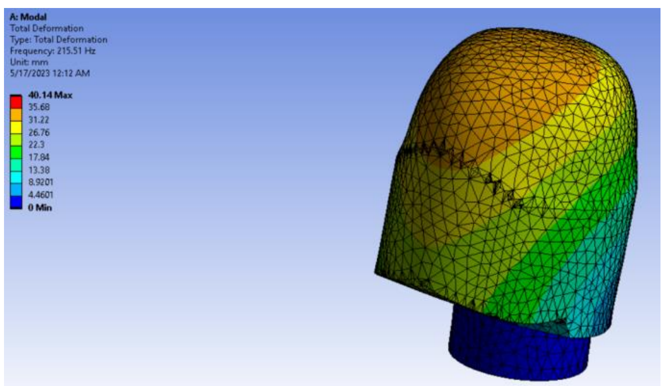


Figure 3.9- Deformation in Head

When external loads are applied to EPS (Expanded Polystyrene) foam of various densities, deformation refers to the shape or compression change that takes place. Lightweight and rigid EPS foam is frequently utilized in construction, packaging, and insulation applications.

Up until a point, EPS foam behaves elastically. In this range, the foam stretches when loaded but snaps back into place when the weight is released. The density of the foam determines the extent of elastic deformation. Higher density foam will experience less elastic deformation compared to lower density foam when subjected to the same load. When pushed to the same stress, higher density foam will flex less elastically than lower density foam.

EPS foam may experience plastic deformation after reaching its elastic limit. The shape and volume of the foam material change as a result of permanent plastic deformation. The density of the foam affects the degree of plastic deformation. Compared to lesser density foam, higher density foam is less prone to suffer substantial plastic deformation.

3.2 Transient Structural Response

We have done the transient response according to the modal

Under transitory loading, total deformation is the whole displacement or distortion that a structure experiences. It displays the total impact of displacement at every location in the structure. Understanding how the structure reacts and deforms to dynamic events like impact, vibration, or other time-varying loads requires careful analysis of total deformation.

Because of the pressure a certain effect have been happened in directional ways (X, Y, Z axis) For the pressure there is a certain amount of change in deformation at x direction

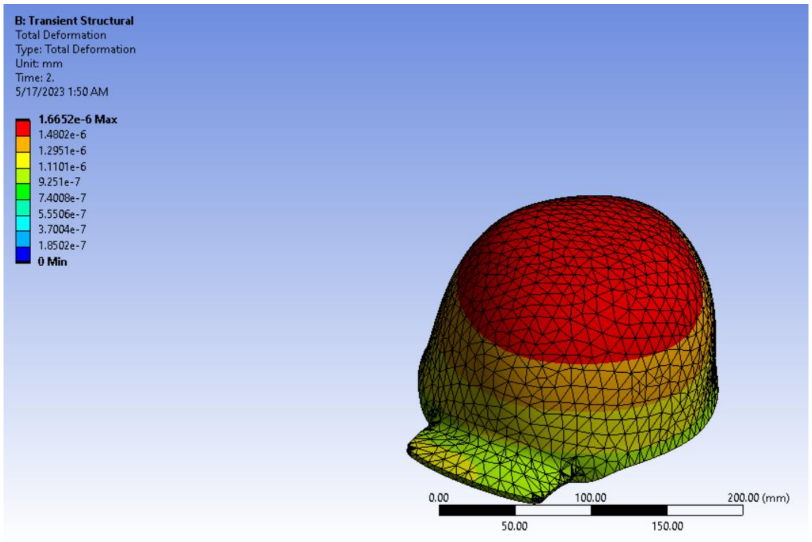


Figure 3.10- Directional deformation at X axis

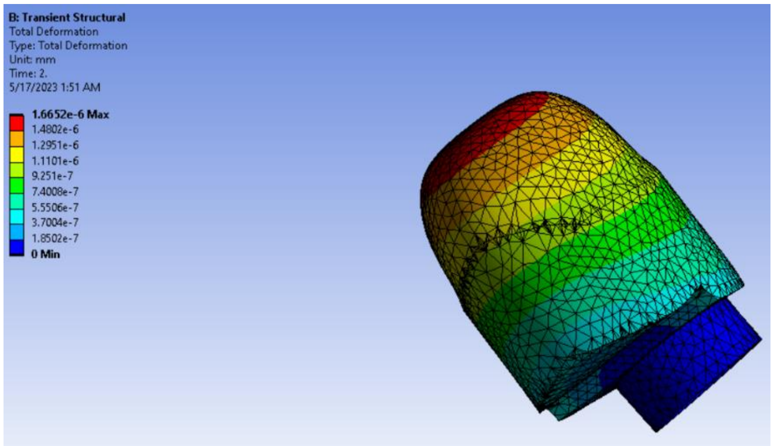


Figure 3.11- Maximum stress on the head

Here the maximum deformation is shown for the head particularly and helmet particularly. So effect of the force impact is visible.

Total acceleration is a measurement of the rate at which the velocity changes across a structure when transient loading is present. It displays the acceleration that each point experiences as a result of the dynamic forces that are being used. When evaluating a structure's dynamic response and its impact on the safety and comfort of its occupants, total acceleration is essential.

Total Acceleration:

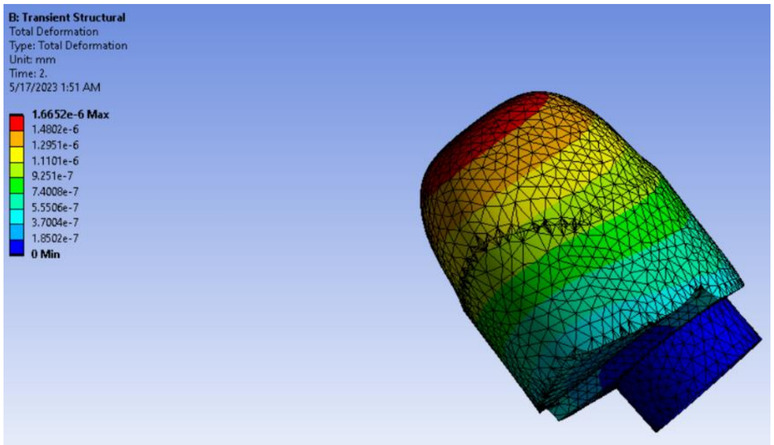


Figure 3.12- Maximum stress on the head

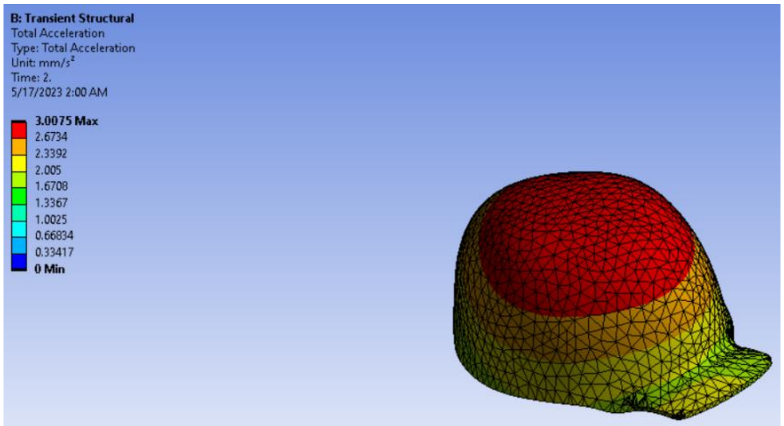


Figure 3.13- maximum acceleration shown on the helmet

Engineers can analyze the possibility for structural damage or human injury by analyzing total acceleration to determine critical acceleration zones, assess dynamic behavior of the system, and evaluate the dynamic behavior of the system. By integrating damping devices or changing the system's geometry to lower acceleration levels, it enables designers to optimize the structure's response to dynamic loads.

Basically the Four EPS 35,50,55,60 have the different magnitude of total deformation and total acceleration. To understand the detail in the diference its important to see the graphical value But the position or the elements are indifferent in those EPS helmet and head. that's why only the deformation and total acceleration of EPS 60 are shown.

3.3 Graph and Result Analysis:

Reviewing graphical representations or statistics that offer deformation and total acceleration values for each model would be helpful in understanding the specific distinctions between EPS 35, EPS 50, EPS 55, and EPS 60. Analyzing such data can reveal how these helmets function in various impact scenarios and how they might provide varied levels of protection.

Graph on directional deformation:

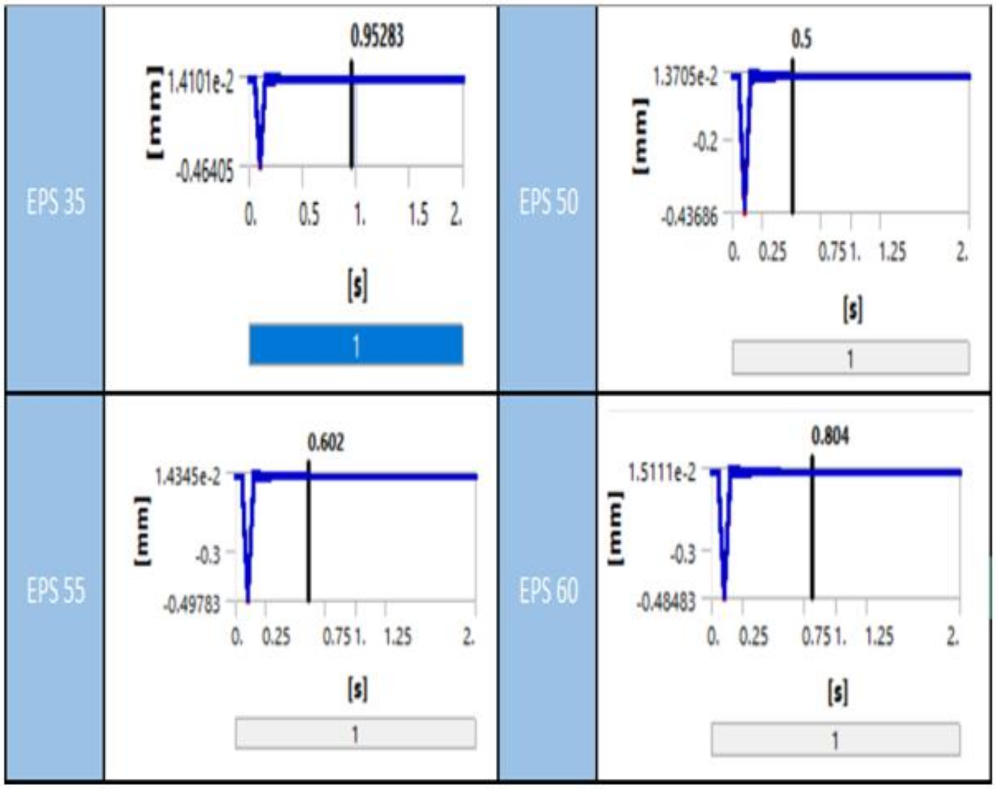


Figure 3.14- displacement vs time curve in Transient response

The relationship between the applied dynamic loads and the consequent decrease in vibration amplitudes or acceleration levels is represented by a vibration mitigation curve. It is a tool used to evaluate how well different vibration mitigation strategies or design changes reduce structural vibration.

Through the use of post-processing software, a graph illustrating directional deformation in transient structural response can be produced. Usually, the graph shows the amount and direction of deformation with time at various places or nodes inside the structure. In the figure the vibration mitigated curve of EPS 35,50,55,60 density in total deformation.The reduction in amplitude starts in four different time in four different graphs.So,the average displacement of four EPS density material Helmet are different.the better one is in EPS 50.

Graph on total acceleration:

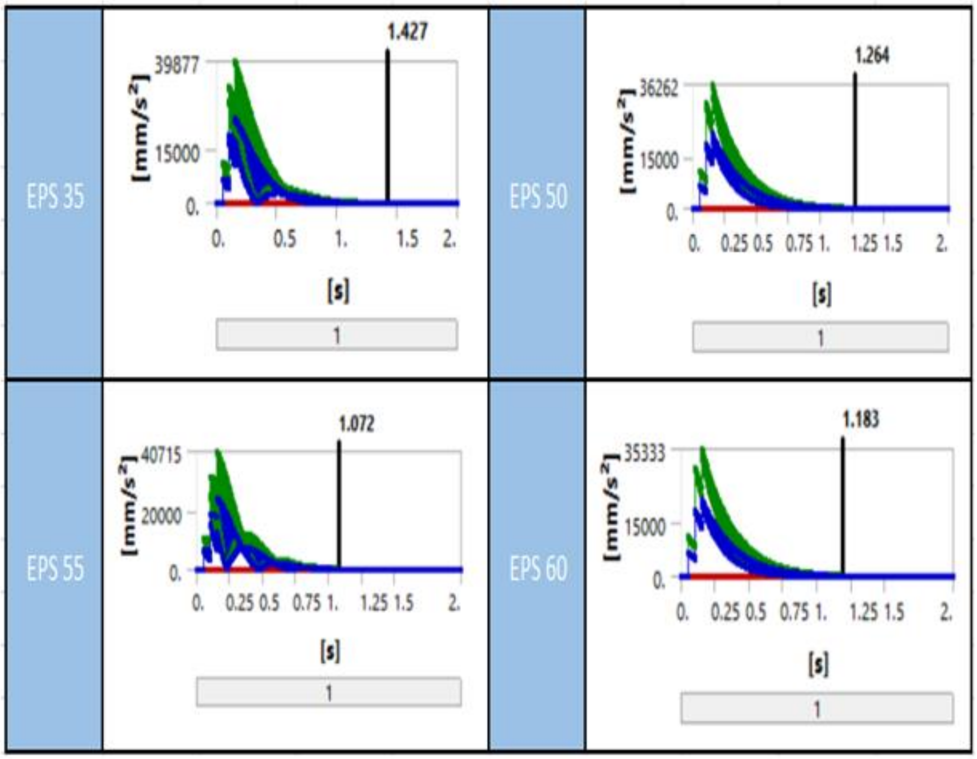


Figure 3.15- acceleration vs time curve in Transient response

Post-processing software can produce a graph that displays the total acceleration of the transient structural response. Typically, the graph shows the degree of acceleration over time at different places or nodes within the structure. By generating a graph of total acceleration, we can visually analyze how the structure responds to transient loads or impacts, identify regions with high acceleration levels, assess the temporal variations in acceleration, and evaluate potential structural vulnerabilities or risks.

In the figure the vibration mitigated curve of EPS 35,50,55,60 density in total acceleration.The reduction in amplitude starts in four different time in four different graphs.So,the average displacement of four EPS density material Helmet are different. the better one is in EPS 55.

3.4 Result

- Comparison between average acceleration and maximum acceleration in directional acceleration.

EPS Density(kg/m^3)	Time(s)	Maximum Acceleration(m/s^2)
35	.155	39.483
60	.152	35.333
50	.151	36.262
55	.151	40.715

EPS Density(kg/m^3)	Time(s)	Average Acceleration(m/s^2)
35	.151	23.747
60	.152	21.154
50	.151	21.669
55	.151	24.548

Table 3.2- Average acceleration and maximum acceleration in directional acceleration

- Comparison between average acceleration and maximum acceleration in total acceleration

EPS Density(kg/m^3)	Time(s)	Maximum Acceleration(m/s^2)
35	.153	33.809
60	.154	29.491
50	.153	28.470
55	.153	37.984

EPS Density(kg/m^3)	Time(s)	Maximum Acceleration(m/s^2)
35	.153	32.472
60	.154	28.357
50	.153	27.261
55	.153	37.343

Table 3.3- Average acceleration and maximum acceleration in total acceleration

The comparison of average acceleration and maximum acceleration in directional acceleration during the transient response study carried out with ANSYS offers important insights into the dynamic behavior of a structure or system under transient loading conditions.

By averaging the acceleration values over a given period of time, the average acceleration is determined. It shows the overall acceleration that the structure underwent during the transient response investigation. The average acceleration can be used to evaluate the structural reaction over time and is helpful in determining the typical degree of loading.

The highest magnitude of acceleration that was ever encountered during the transient response analysis is represented by the maximum acceleration, on the other hand. It draws attention to the highest loading levels and pinpoints crucial times or places when the structure is subject to the greatest acceleration. The maximum acceleration is crucial for determining the likelihood of structural collapse or damage.

The goal here was mainly to reduce the vibration mitigated amplitude early time as much as possible because sooner the vibration is reduced the better the outcome of the impact testing because we clearly focused on that.

Furthermore impact testing on helmet will be done by transient structural response by stress analysis ,by engaging force and Von Misses stress analysis.

EPS Density (kg/m^3)	Maximum Directional Acceleration (m/s^2)	Maximum Total Acceleration (m/s^2)	Minimum Directional Acceleration (m/s^2)	Time for total acceleration (s)	Time for total acceleration (s)
35	33.809	39.1483	-33.934	1.593	1.800
50	28.470	36.262	-28.811	1.612	1.362
55	37.984	40.715	-38.214	1.542	1.479
60	29.491	35.333	-29.777	1.603	1.792

Table 3.4- Acceleration data of different densities of EPS

EPS Density kg/m^3)	Maximum Total Deformation (m)	Maximum Directional Direction (m)	Minimum Directional Deformation (m)
35	.56	.014	-.47
50	.55	0.14	-.44
55	.53	.014	-.49
60	.55	.015	-.46

Table 3.5-Deformation data of various densities of EPS

At various time stages during the study, displacements or strains are frequently used to represent the structure's deformation. Based on the applied loads, the characteristics of the material, and the boundary conditions, the analysis determines the displacements and rotations of each node in the finite element mesh. Depending on the applied loads, material qualities, and structural parameters, the transient structural response's deformation can change over time. Understanding the behavior of the structure under dynamic loading circumstances and assessing its performance require a comprehensive analysis of the results.

It's important to keep in mind that the precise stages and methods may differ depending on the ANSYS version you're using, thus it's always advised to refer to the ANSYS documentation or user guides for thorough instructions and best practices.

Chapter 4

4.1 Discussion

Our model is undergoing a lot of changes in outer shape and materials but currently we are working on a certain material because we need to validate the simulation data.

We have done a modal analysis of harmonic response and transient structural response in ANSYS 2020.

In Modal analysis, we have seen the deformation in various Axis; our upcoming goal is to reduce the deformation in the highest possible way.

In transient response, the sudden impact test was done by giving a specific amount force or pressure, by that it was decided the change in deformation in the directional axis the model is going through.

Our primary focus is to mitigate the vibration curve in transient structural response.

When a helmet's cushion is padded with different densities of EPS and is simulated in ANSYS, it can yield valuable information on the performance and impact protection of the helmet. The behavior of complicated systems, such as helmet designs, can be studied and forecasted using the potent engineering simulation tool ANSYS.

4.2 Validation

For the model validation, experimentations are needed.

We have the nearly shaped helmet outer shell as our SOLIDWORKS model by which we can bring out the natural frequency, and after that, we can make a head dummy of a human, and helmet outer shell can be fixed with a head form/dummy and by using that we can analyze the further impact on head practically and compare them as well.

- Experimental CAD model:

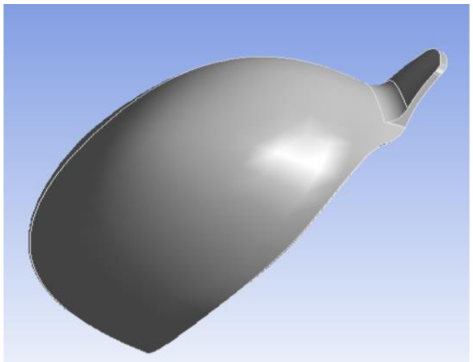
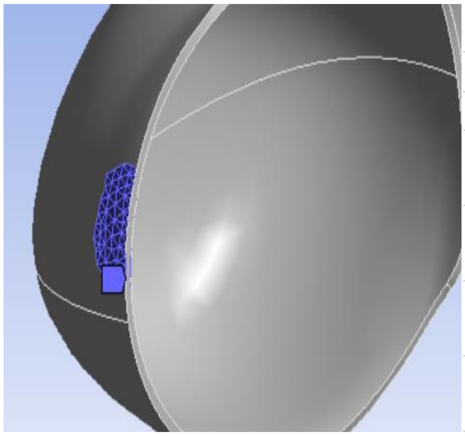


Figure 3.14-Experimental CAD model

- Boundary condition:



ABS	Value	unit
Density	1.04E-06	kgmm^-3
Poisson's ratio	0.399	
Young's Modulus	2.39E+03	mpa
Bulk Modulus	3.94E+03	mpa
Shear Modulus	8.54E+02	mpa

Figure 3.16-Fixed position in Helmet Table 3.6-ABS plastic material is used

- Meshing: nodes- 26282

  elements-559556

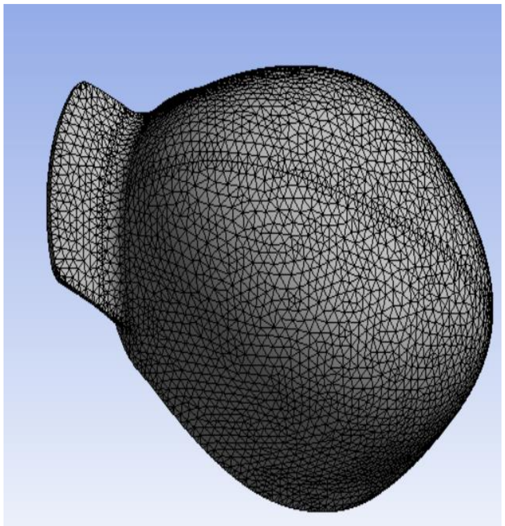


Figure 3.15 -meshing

RESULT:

Mode	Frequency
1	17.465
2	26.852
3	84.199
4	116.4
5	217.38
6	282.67

Table 3.7- results of modal frequency of experimental CAD model in Simulation

4.3 Experimentation

For validation of simulation results, it is necessary to experiment. We have yet to do any practical experiment, but soon it will be done.

The instrument list contains the electrodynamic vibration shaker, load and displacement sensors, oscilloscope, and frequency generator. They have been kept in a controlled environment to protect them from humidity, solar radiation, and other environmental components. The table below holds information such as the model number and name of each instrument and their use cases. Using this we will do the natural frequency testing and harmonic response for different modes. We can be able to calculate the deformation and stress if it is possible to bring a strain gauge and other equipment

Figure 3.17-Experimental Setup

Figure 3.18- Displacement Sensor

Figure 3.19- Impact Hammer

Impact Hammer: A typical tool used in engineering and testing applications to produce controlled impacts on structures or components is an impact hammer, also known as an impactor or an impulse hammer. It is made to provide a precise and quantifiable force pulse to gauge the target object's reaction.

The striking component of the impact hammer is linked to a handle or a mechanism that enables repeatable, controlled hits. The unique element usually consists of a mass that strikes the surface of the target item, frequently with a hardened point.

Displacement Sensor: A displacement sensor, also known as a linear position sensor or displacement transducer, is a device used to measure an object's linear displacement or position relative to a reference point. It provides information about the change in place along a single axis.

Displacement sensors are used in various applications across industries such as manufacturing, automation, robotics, and engineering. They are crucial in precise position control, dimensional measurement, quality assurance, and feedback systems.

DAQ Software: For the purpose of facilitating data collection and processing, DAQ software often provides a variety of features. These may consist of:

Device configuration: Users can define sampling rates, signal types, and input/output channels in the software to setup and set up the linked data acquisition devices.

Data acquisition allows the software to simultaneously gather data from a variety of sensors or equipment, frequently in real-time. This may involve recording voltage levels, temperature, pressure, strain, and other physical factors as well as analog or digital information.

Data From DAQ :

QUICK DAQ DATA		
SAMPLE RATE	4000	
MEASUREMENT TYPE	Autospectrum	
CHANNEL NAME	DT98387(00)A.in)-FFT	
X AXIS UNIT	Hz	
Y AXIS UNIT	g^RMS	
FREQUENCY	MAGNITUDE	PHASE
15.6	0.001	-127.98
62.5	2.94E-07	30.9315
82.1	4.52E-08	-99.876
128.9	9.28E-09	-78.98
209.4	1.92E-08	-36.67

Comparison between Simulation Data and experimental Data				
Simulation Value		**DAQ value**		**Error(%)**
Mode	Frequency	Mode	Frequency	
1	17.465	1	15.6	1.865
2	84.199	2	82.1	2.56
3	116.4	3	128.9	9.01
4	217.38	4	209.4	4.01

Table 3.7- Data acquired from SimpleDAQ table by experiment

The validated data are the first 3 modes of simulation and all other modes will be found near to simulation data. If we apply force to the different position with impact hammer.

4.4 Future Work

- To work with more EPS density and get validation Machine Learning.

4.5 Future Scope

- Our main focus is to Input Machine Learning related work in it.
- Testify the simulation with further details and improvement in the outer shape of the helmet
- the next works will be on the material change, we will work with different material for further improvement on the stress analysis and deformation

4.6 Conclusion

When a helmet's cushion is padded with different densities of EPS and is simulated in ANSYS, it can yield useful information on the performance and impact protection of the helmet. The behavior of complicated systems, such as helmet designs, can be studied and forecast using the potent engineering simulation tool ANSYS. In the outer shell or impact zones, where the force of an impact is anticipated to be higher, helmets often use a higher density EPS foam. Greater stiffness and higher density foam can offer improved protection against high-energy impacts.

Conversely, parts that need additional comfort and cushioning, such the inside padding of the helmet or regions that come into touch with the wearer's head, frequently employ lesser density EPS foam. Foam with a lower density is softer and better at absorbing shock from collisions with lower energy.

Manufacturers can strike a balance between protection, comfort, and weight by carefully inserting various densities of EPS foam inside the helmet. The mixture of densities guarantees that the helmet can efficiently deflect and disperse impact forces while maintaining a snug fit for the user.

So testing with Different density EPS is the primary Goal. testing with different density EPS is the primary goal when evaluating the performance of a helmet or any impact-absorbing cushioning material. The purpose is to assess how different densities of EPS foam affect the helmet's ability to absorb and distribute impact forces.By conducting tests with various density EPS foams, engineers and researchers can gather valuable data on the helmet's performance characteristics. These tests typically involve subjecting the helmet to controlled impacts or impact simulations to evaluate its ability to protect the wearer's head.

During the testing process, measurements are taken to assess factors such as acceleration, force, energy absorption, and deformation. These measurements help in understanding how the different density EPS foams respond to impacts and how they affect the overall performance of the helmet.

The goal is to find an optimal combination of EPS foam densities that provides the best balance between impact absorption, energy dissipation, and overall helmet performance. This involves analyzing the test results and identifying the density or combination of densities that offer the highest level of protection while still maintaining comfort and practicality.

4.7 References

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