Australian Journal of Basic and Applied Sciences, 11(11) August 2017, Pages: 30-40

AUSTRALIAN JOURNAL OF BASIC AND APPLIED SCIENCES

ISSN:1991-8178 EISSN: 2309-8414
Journal home page: www.ajbasweb.com

Design And Structural Analysis Of Missile Nose Cone

[1]M. Sreenivasula reddy and [2]N. Keerthi

[1]*Mechanical Engineering, AITS, Rajampet, AP*
[2]*Assistant Professor, Mechanical Engineering, AITS, Rajampet, AP, Annamacharya Institute of Technology and Sciences (Autonomous) Rajampet, Kadapa, Andhrapradesh-516126*

Address For Correspondence:
M. Sreenivasula reddy, Mechanical Engineering, AITS, Rajampet, AP,
E-mail: sreenivas5046@gmail.com

ARTICLE INFO

Article history:
Received 18 June 2017
Accepted 28 July 2017
Available online 20 August 2017

Keywords:
missile nose cone design, Titanium Ti-6Al-4V, Titanium Ti-6Al-6V-2SN, titanium grade 1, structural loads, impact loads, CATIA, ANSYS.

ABSTRACT

A new nose cone concept that promises a gain in performance over existing conventional nose cones is discussed in this paper the term nose cone is used to refer to the forward most section of a rocket, guided missile or aircraft. The cone is shaped to offer minimum aerodynamic resistance. Nose cones are also designed for travel in and under water and in high-speed land vehicles Given the problem of the aerodynamic design of the nose cone section of any vehicle or body meant to travel through a compressible fluid medium (such as a rocket or aircraft missile or bullet), an important problem is the determination of the nose cone geometrical shape for optimum performance. This project evaluates missile nose cone is analysis using the materials are Titanium Ti-6Al-4V most commonly used alloy. Titanium Ti-6Al-6V-2SN Titanium grade 1 the remainder titanium. These are significantly stronger than commercially pure titanium. While having the same stiffness and thermal properties a structural-loaded, a pressure sudden impact loads and a foam nose-cone concept Results from analysis of the nose cone are used in structural analysis performed with ANSYS. A naval model is designed for the concepts of blunt nose cone and analyzed with the commercial software CATIA. The nose concept conforms to the requirements for structural integrity, weight, functionality.

INTRODUCTION

Current warfare techniques include many technical advances. In the news, one often hears of "smart" bombs, satellite communications, GPS (Global Positioning System), radar, and guided missiles. A guided missile is an unmanned explosive-carrying vehicle that moves above the earth's surface in a flight path controlled by an external or internal source. There are many kinds of guided missiles, but all have the same ultimate function: destroy enemy "targets", i.e., personnel, tanks, vehicles, airplanes, ships, and weapons, including attacking missiles. In modern usage, a missile is a self-propelled precision-guided munition system, as opposed to an unguided self-propelled munition, referred to as a rocket (although these too can also be guided). Missiles have four system components: targeting and/or missile guidance, flight system, engine, and warhead. Future fighter aircrafts will have supersonic cruise and high angle of attack and capability to maneuver in the flying path. new missiles must be developed, which are more maneuverable and have less static margin than those are in use. A missile with less aerodynamic resistance could be used. The nose control, as the name suggests, is realized by angular deflection of a section of or whole of missile’s nose in the flow field off the missile’s centerline to create a pressure difference between the windward and leeward sides of the nose. The design of the nose cone section of missile to travel through a compressible fluid medium and important problem is the determination of nose cone geometrical shape and material used to it for optimum performance. Such tasks requires the definition of solid of revolution shape that experiences minimal resistance to rapid motion trough such a fluid medium, which consists of elastic particles. This difference produces aerodynamic control

To Cite This Article: M. Sreenivasula reddy and N. Keerthi., Design And Structural Analysis Of Missile Nose Cone. ***Aust. J. Basic & Appl. Sci.,*** *11(11): 30-40, 2017*

forces and moments relative to missile's mass center to enable the missile to attain a certain angle of attack, it is superior due to its better aerodynamic characteristics, shorter response time and increased effectiveness and maneuverability. Moreover, the control forces and moments produced by nose deflection increase rapidly with Mach number increasing, which makes it an ideal method for controlling supersonic and hypersonic missiles. a concept of moveable nose and tail for actively steering aircraft, particularly, rocket-craft under different atmospheric and operating conditions. In the recent years space vehicles like rockets, reentry vehicles regardless their unique designs needed control surfaces at hypersonic speeds. Low-radius leading edges are subject to much greater aerodynamic heating than blunt edges, such as those on the Space Shuttle, and they thus will reach temperatures that may exceed 2000°C during reentry. Available thermal protection materials will not survive such extreme temperatures and new materials are required for advanced thermal protection systems. The basic nose cone material majority of manufactures were more comfortable with the known life limitations of structural metal, in particular the Aluminum alloys, primarily used by the US manufacturers, these alloys have a tensile strength in excess of mild steel, but the drawback is their susceptibility to corrosion. The composite materials, although being out standing in their strength to weight characteristic have some drawbacks in the cost of raw materials, storage and available data on structural life limitations in addition to requiring in many instances, expensive methods of non-destructive inspection. In our study, to know the observable behavior of these materials, which are used for making cone nose of an aircraft model commonly there are many shapes like conical, elliptical, O-give (tangent), parabolic and blunt cone. Among which we have chosen blunt cone shape because of less mean shear stress distribution and lowest tip temperature. It is concentrated firstly on deformation of nose cone under the air pressure of 18700 (Pa) and secondly the comparison of the materials mentioned above with their capability to withstand when the cone section of aircraft travelling at a height of 40km, which experiences the temperature around 800 0C through a compressible fluid medium. Based on the shape the air intensity may be directed around the nose by balancing the force with whole body, when the air intensity exerts on the nose, it is subjected to some stresses, strains also along with the deformation.

A missile can be divided functionally into 8 sections: radome, guidance, warhead, autopilot, dorsal fins, rocket motor, steering control and control surfaces. These missile sections are described below.

1. *Radome:*

A housing made of ceramic material similar to the household "Corningware" and located at the front end ("nose") of the missile. Here are some radomes on the production line. The radome is non-metallic to act as an electromagnetic (EM) "window" for radar or heat-seeking EM devices located inside the missile. Radar (Radio Ranging and Detection), transmits EM pulses that bounce off the target and return to the radar set to provide target location, direction and speed.

2. *Guidance:*

A system that receives radio information from its launch controller (a computer, not a human), directing it to launch the missile and calculate its most efficient path to the target. The Guidance system also transmits all missile functions back to its launch controller for continuous monitoring of missile subsystem performance.

3. *Warhead:*

A system containing missile internal "homing" radar and an explosive surrounded by thousands of serrated iron pieces or otherdestroying material, depending on the nature of the anticipated target. As the missile approaches ("homes in on") the target, its internal radar electronically "sees" and locks onto the target to guide the missile towards it. Not all missiles have this "homing" radar. If not, its launch control must continuously direct it to the target.

4. Autopilot:

A system that provides missile location, direction, velocity and "attitude" (up, down sideways, etc.) and the capacity to change its motion via the Control Surfaces (see below). The Autopilot contains an antenna to receive and transmit information to its home controller. It also contains a battery that supplies electrical power to the missile electronic and microprocessor components. &bnsp; Transmissions to and from the missile must be encoded and decoded to prevent electronic spying by other countries' surveillance radars.

5. Dorsal Fins:

The fins, along with the missile body, provide surfaces against which air exerts pressure. These dorsal surfaces are used by the Control Surfaces (see below) to change the direction and attitude of the missile.

6. Rocket Motor:

A mixture of solid chemical fuels. When ignited, the chemicals propel the missile from its launcher into space.

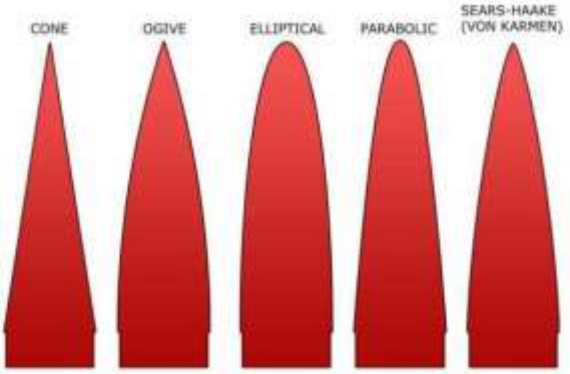
7. Steering Control:

A system that electrically changes the Control Surfaces (see below) that change the missile motion. It reacts to information sent to it by the Autopilot (see above).

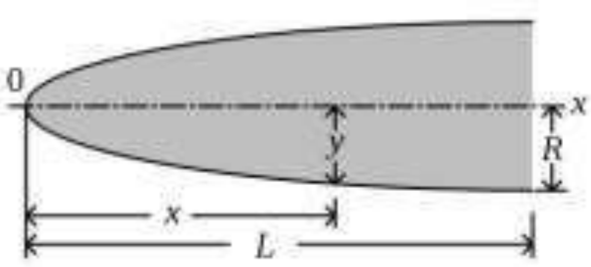
8. Control Surfaces:

These are four "fins" that act against air resistance to change the direction of the missile.

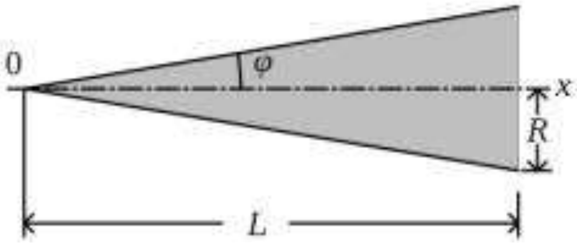
2.0 Types of missile nose cone:



In all of the following nose cone shape equations, L is the overall length of the nose cone and R is the radius of the base of the nose cone. y is the radius at any point x, as x varies from 0, at the tip of the nose cone, to L. The equations define the 2-dimensional profile of the nose shape. The full body of revolution of the nose cone is formed by rotating the profile around the centerline *(C/L)*. Note that the equations describe the 'perfect' shape; practical nose cones are often blunted or truncated for manufacturing or aerodynamic reasons.

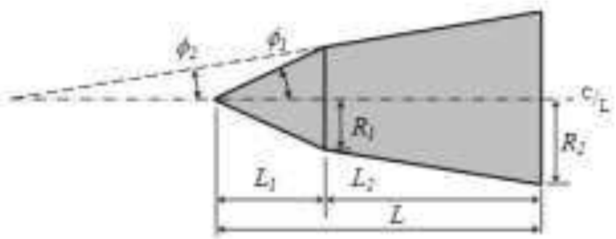


2.1 Conical:



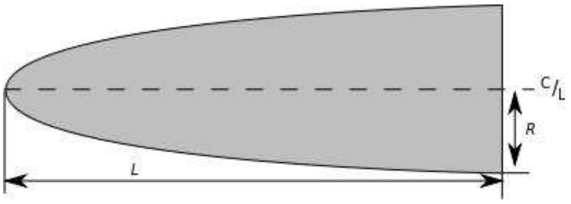
A very common nose-cone shape is a simple cone. This shape is often chosen for its ease of manufacture, and is also often (mis)chosen for its drag characteristics.

2.2 Bi-conic:



A bi-conic nose cone shape is simply a cone with length L_1 stacked on top of a frustum of a cone (commonly known as a *conical transition section* shape) with length L_2, where the base of the upper cone is equal in radius R_1 to the top radius of the smaller frustum with base radius R_2.

2.3 Elliptical:



The profile of this shape is one-half of an ellipse, with the major axis being the centerline and the minor axis being the base of the nose cone. A rotation of a full ellipse about its major axis is called a prolate spheroid, so an elliptical nose shape would properly be known as a prolate hemispheroid. This shape is popular in subsonic flight due to the blunt nose and tangent base. This is not a shape normally found in professional rocketry, which almost always flies at much higher velocities where other designs are more suitable. If *R* equals *L*, this is a hemisphere

A Rocket is a vehicle which acquires push by the response of the rocket to the discharge of plane of quick moving liquid fumes from rocket engine. Solid fuel rockets make their fumes by the ignition of strong charge grain. The subsequent gasses are extended through the spout whose capacity is to change over this inward weight into a supersonic fumes speed. Rocket engine fumes are shaped altogether from force conveyed inside of the rocket before use. Rocket motors work by activity and response. Rocket motors push rockets forward by ousting their fumes the other way at fast. Rockets depend on energy, airfoils, helper response motors, gimbaled push, force wheels, diversion of the fumes stream, charge stream, turn, and/or gravity to help control flight.

Rockets are moderately lightweight and intense, fit for creating expansive increasing velocities and of achieving amazingly high speeds with sensible productivity. Rockets are not dependent on the climate and work extremely well in space. Rockets for military and recreational uses go back to at any rate 13th century China. Significant logical, interplanetary and modern utilization did not happen until the 20th century, when rocketry was the empowering innovation for the Space Age, including setting foot on the moon. Rockets are presently utilized for firecrackers, weaponry, launch seats, dispatch vehicles for simulated satellites, human spaceflight, and space investigation.

Substance rockets are the most widely recognized sort of high power rocket, commonly making a rapid fumes by the burning of fuel with an oxidizer. The put away force can be a basic pressurized gas or a solitary fluid fuel that disassociates in the vicinity of an impetus (monopropellants), two fluids that suddenly respond on contact (hypergolic fuels), two fluids that must be touched off to respond, a strong mix of one or more fills with one or more oxidizers (strong fuel), or strong fuel with fluid oxidant (half and half charge framework). Concoction rockets store a lot of vitality in an effortlessly discharged frame, and can be exceptionally perilous. Notwithstanding, watchful configuration, testing, development and utilization minimizes dangers.

India has made tremendous studies in launch vehicle technology to achieve self-reliance in satellite launch vehicle program with the operationalization of PSLV and GSLV. To minimize the aero acoustic and aerodynamic loads on the vehicle, the slanted strap on nose cone with 25^0 on the free side and straight on the interference side are selected based on various studies. The change in pressure rise on core will be more for slanted nose cone. But the zone of influence is more in regular nose cones. Appreciable weight savings are possible through the integral section design which also develops high resistance to buckling loads. This method improved performance through smoother exterior surfaces by reduction in number of attachments and non-buckling characteristics of skin. Design of structural components has to meet specific requirements which influence the complexity of its structure and the materials used in its construction. Aluminum**,** blended with small quantities of other metals is used on most types of aircraft because it is lightweight and strong. AA2014 aluminum alloy is an aluminum-based alloy often used in the aerospace industry.(1) It is easily machined in certain tempers, and among the strongest available aluminum alloys, as well as having high hardness.

3.0 Objectives:

As an unpowered glider nose cone design has an emphasis on the minimization of drag. This requires certain streamlined shapes for the vehicle surface. This geometrical requirement dictates shapes and sizes; however Mach number is used to restricted geometry of the nose cone. In current rocket-propelled ballistic missiles of the ICBM type employing fuel propellants, geographical considerations dictate a range of as much as 5000 miles. To attain such long ranges, it is necessary to propel the missile to an extremely high altitude. At the peak of its ascent, the missile will reach a level well above the earth’s atmosphere and at the upper level of the ionosphere, where the absolute pressure is almost zero and the resistance to the forward flight of the missile is almost nil. Once the thrust of its rocket engine is exhausted and the missile has reached this high altitude, it follows a free falling trajectory course towards the target, obtaining no lift from wings or similar surfaces.

4. 0 Literature data:

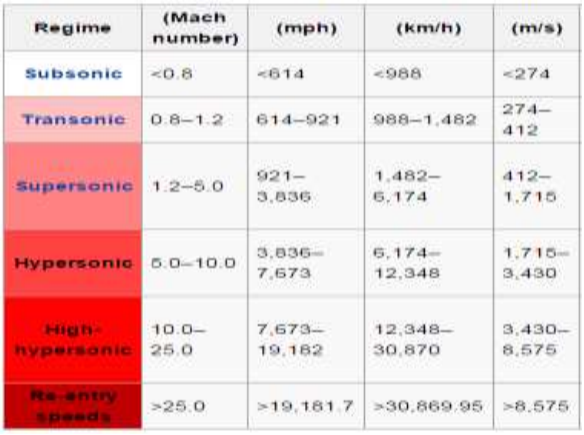
During initial stage upward flight to the ionosphere, the speed of the missile is not great enough to pose any serious thermal problems. However, at the altitude of 50 miles, the absolute pressure begins to increase progressively during descent, until the earth’s surface is reached. At the present time, missiles reentering the air layer during downward flight, attain speeds equal to Mach 5 or 3700 miles per hour, and in the near future, missiles are expected to be designed which will attain speeds as high as Mach 18, equivalent to approximately 13,000 miles per hour. These heating rates being produced by the high temperature of the air boundary layer ahead of the missile resulting from the compression of air, which temperature can be as high as 12,000 F. at 11,000 Mph. It is seen, therefore, that a challenging problem in the design of intercontinental missiles is the tendency of the atmosphere to burn them up as they descend towards the earth. At the extreme speeds with which the missiles descend through the atmosphere, they suffer aerodynamic heating and abrading due to the extremely high skin temperatures developed in and by the air boundary layer immediately encompassing the missile, and this condition is increasingly critical and greatly aggravated at high Mach numbers as to constitute a serious thermal barrier. It is obvious that the missile must have a low drag-to weight ratio during its upward flight through the atmosphere. reentry into the its descent towards the earth, a high drag-to-weight ratio is required to reduce the speed of the missile and consequently its heating rate. However, the downward speed of the missile must not be reduced to the point where it can be intercepted. for that purpose blunt nose cone is useful for hypersonic speeds .blunt cones are less drag resistance and produced less shock waves at high speed ranges.

5.0 Methodology:

In general, the constraints and goals for atmospheric reentry conflict with those for other high speed fligh application. During reentry a high drag blunt reentry shape is frequently used. Blunt which minimize the heat transfer by creating a shock wave. Mainly these missile nose cone designs are based on Mach number.

$$\text{Mach number} = \frac{U}{C}$$

U = Local flow velocity
C = Speed of the sound in the medium



Regime	(Mach number)	(mph)	(km/h)	(m/s)
Subsonic	<0.8	<614	<988	<274
Transonic	0.8–1.2	614–921	988–1,482	274–412
Supersonic	1.2–5.0	921–3,836	1,482–6,174	412–1,715
Hypersonic	5.0–10.0	3,836–7,673	6,174–12,348	1,715–3,430
High-hypersonic	10.0–25.0	7,673–19,182	12,348–30,870	3,430–8,575
Re-entry speeds	>25.0	>19,181.7	>30,869.95	>8,575

A tactical missile is from 5 to 20 feet long, 6 inches to 1 foot in diameter, and weighs from 200 to 2,000 pounds. The size is determined by the expected distance to the target (longer distances require more fuel capacity) and the type of target (bigger, heavier targets required more explosive). 'Most' of the missile body is made of a titanium alloy, which provides high strength and low weight. Inside the missile are hundreds of electronic, digital and mechanical subsystems that perform thousands of operations to guide the missile from its launcher to its target. A tactical missile travels at about the speed of sound (700 mph), but some travel almost twice that speed. Each missile costs tens to hundreds of thousands of dollars. Its flight time is measured in seconds.

In summary, a guided missile is a combination of electrical, digital and mechanical parts segregated into sections. Each section has specific functions that must operate accurately and safely; otherwise, the missile mission is electronically aborted and the missile is destroyed. Internal controls monitor each function to assure proper coordination among parts. This information is radioed to the launch controller, so that it knows at all times how well each part of the missile is performing to achieve the missile's ultimate goal of destroying the target.

Classification Of Guided Missiles:

A number of different classifications of guided missiles are possible. However, the most usual is the one in which the position of launch and the position of the target are used for classification. This is most widely used as these positions more or less designate the general requirements or specialties of the missiles used. The four general categories of missiles are:

- A Surface-to- Surface Missiles (SSM)
- A Surface-to- Air Missiles (SAM)
- A Air-to- Air Missiles (AAM)
- A Air-to- Surface Missiles (ASM)

Missiles can be launched from ships, planes and the ground at targets located on ships, planes and the ground; hence, the classifications as ground to ground Tow, ship to ground Cruise, ground-to-air Stinger, air-to-ground Amraam, Apache, ship-to-air Standard Missile, and so forth. Some missiles attack targets at long distances - thousands of miles - like the ICBM (Intercontinental Ballistic Missile). These are "strategic" missiles. Other missiles are used offensively or defensively over shorter distances - from a few to a few hundred miles. These are "tactical" missiles. Missiles can have weird configurations:

I will describe, first, missile parts and their functions, second, missile deployment, and finally, how a missile is launched to intercept and destroy its target.

5.1 material used and properties:

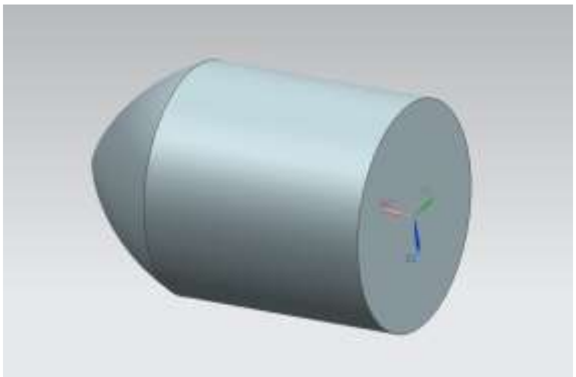
In this present generation mainly considered all aspects to choose materials like used in aerospace application. That material is

Ti-6Al-6V-2Sn

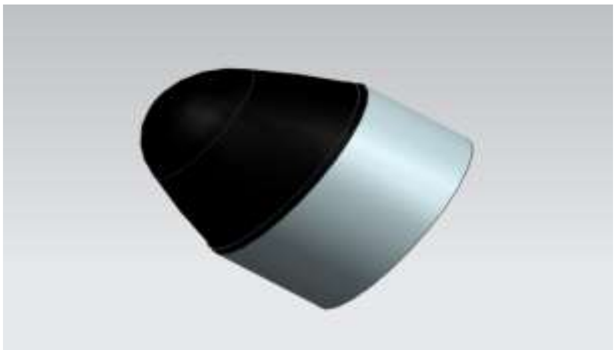
- This material is also known as 6-6-2-Titanium
- Alpha-Beta alloy
- Superior strength and stiffness
- Solid corrosion resistance, medium welding and fabrication ability Excellent material for rocket and air craft casing and artillery parts for improved ductility and strength
- Mainly heat treatment with in the range of nearly 850-950^0 C.

5.2 Modeling and Analysis:

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches. CATIA is able to read and produce STEP format files for reverse engineering and surface reuse.



MODEL-1



MODEL-2

5.3 Structural Analysis:

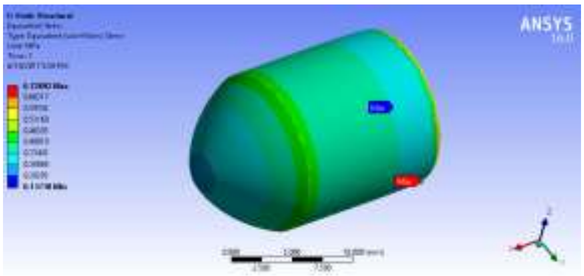
After the aerodynamic analysis was completed, values regarding the loading of the nose cone were resolved. From this loading data, structural analyses were able to be completed to strengthen designs and prove their ability to resist these pressures. As each nose cone design is fundamentally deferent from each other, they can not all be analyzed by employing the same method. Tests have been selected in order to produce either comparable results or essential data for each design type. Much like CFD, computer assisted engineering software can use Finite Element Analysis (FEA) to provide numerical solutions to the mechanical environment. This allows for models to be analyzed as to their physical strengths and weaknesses in the virtual environment. As loads are introduced to a structure, FEA can calculate the resulting stresses and deformations. By inputting material properties for each specific model, FEA can accurately produce solutions

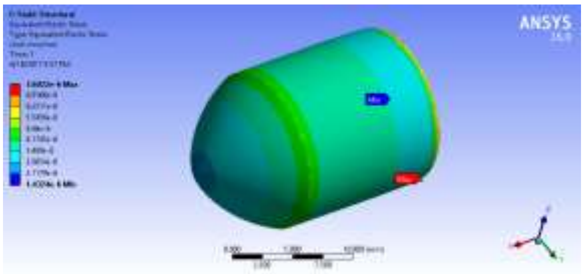
After the aerodynamic analysis was completed, values regarding the loading of the nose cone were resolved. From this loading data, structural analyses were able to be completed to strengthen designs and prove their ability to resist these pressures. As each nose cone design is fundamentally deferent from each other, they can not all be analyzed by employing the same method. Tests have been selected in order to produce either comparable results or essential data for each design type. Much like CFD, computer assisted engineering software can use Finite Element Analysis (FEA) to provide numerical solutions to the mechanical environment.

This allows for models to be analyzed as to their physical strengths and weaknesses in the virtual environment. As loads are introduced to a structure, FEA can calculate the resulting stresses and deformations. By inputting material properties for each specific model, FEA can accurately produce solutions providing necessary information about the design.

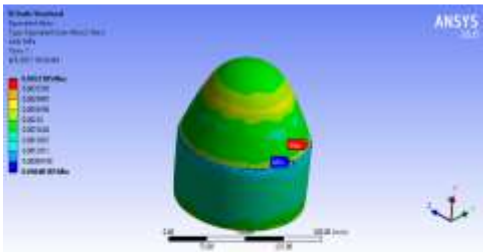
Three of the four designs were selected for a structural analysis. The design that was not selected was the foam nose. This was because the material properties could not accurately be analyzed in the FEA solver ANSYS, therefore the foam nose analysis was conducted in the experimentation phase. The three designs that were selected were the Spring-Loaded Nose, the Inflatable Nose and the Rubber Nose. The Spring-Loaded Nose is a rigid mechanical structure, so the benefits in using FEA compared to bench-top testing are clear. Internal stresses and deformation effects can easily be calculated using a numerical solver. The Inflatable Nose was not analyzed using FEA but simply the inside pressure was resolved. The Rubber Nose was analyzed using FEA to provide an initial design. Since the Rubber Nose is to be constructed out of a synthetic urethane rubber, the specific material properties are unknown and the numerical solver only provided approximate solutions for deformation effects.

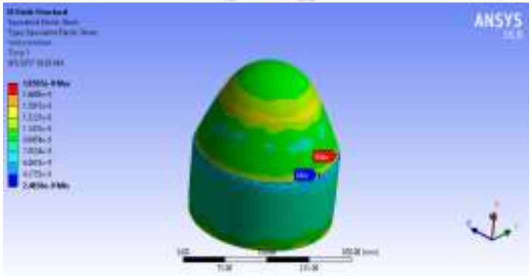
5.3.1 Static structural analysis of model 1:





5.3.2 Static structural analysis of model 2:

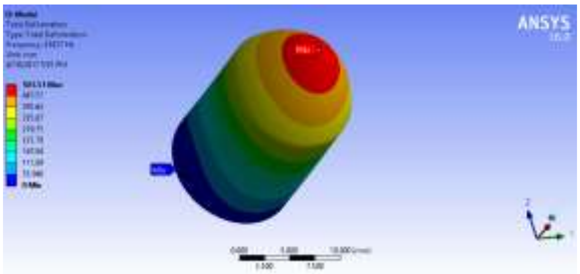


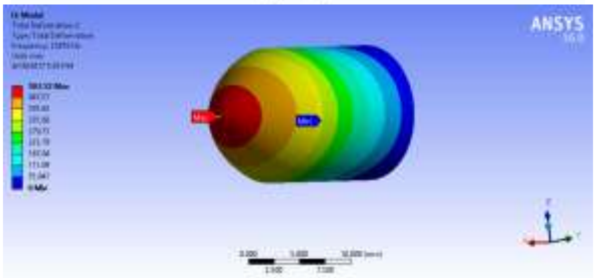


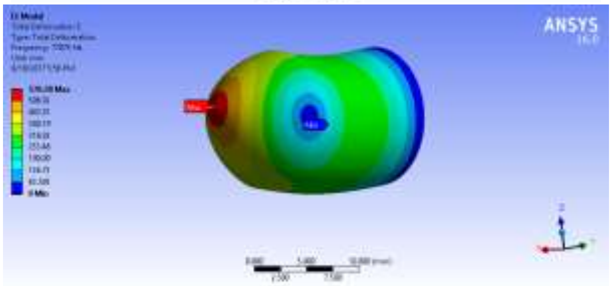
3.5 Model analysis:

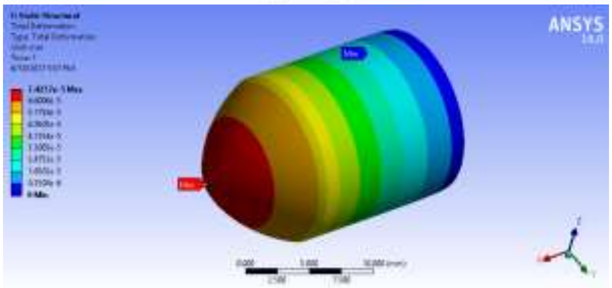
Modal analysis to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It also can be a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis. Modal analysis to determine the natural frequencies and mode shapes of a structures. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. They are also required if you want to do a spectrum analysis or a mode superposition harmonic or transient analysis.

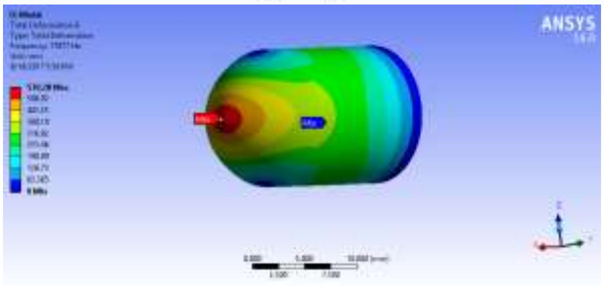
5.4.1 Modal analysis of model 1:



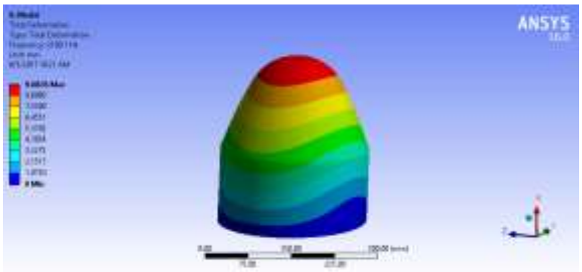


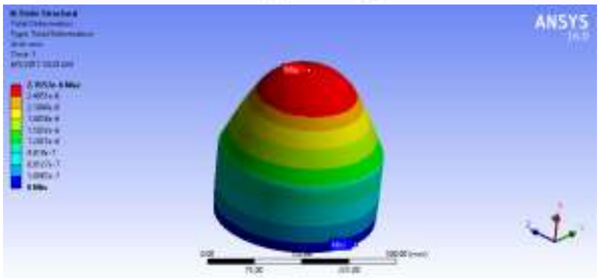


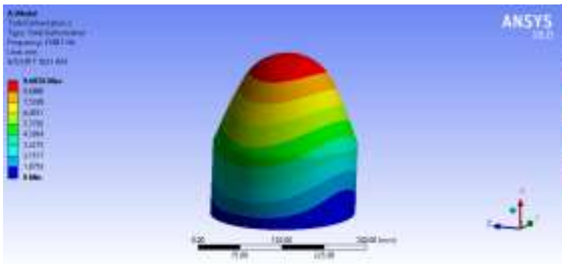


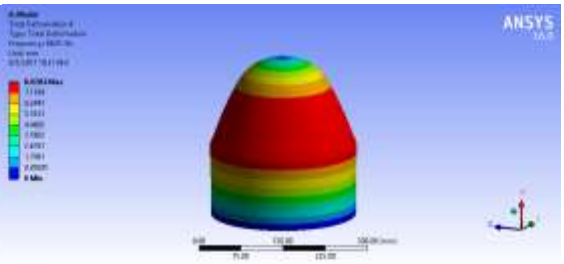


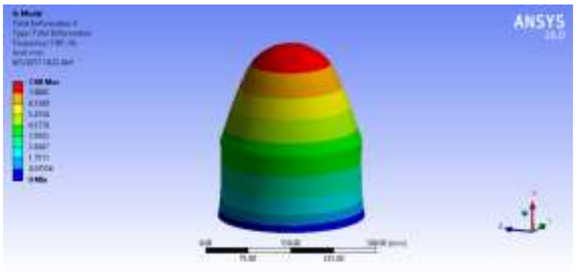
5.4.2 Modal analysis of model 2:











RESULTS AND DISCUSSION

The above figures (model 1 and model 2), explaining About the testing phase with air pressure of 40 MPa at a Height range around 60 Km under the static condition by using ANSYSv16 software package, where the model of nose cone of which is made by the different materials like Aluminum alloy and titanium alloys. The above figures represent the size of deformation changes from maximum range to minimum from extreme edge of nose (Tip) to contour towards back side of nose respectively. Then it bring Proper idea to compare the materials under constant air Pressure and constant height in the static position of the nose Cone in ansysv16. The deformation of missile nose cone analyzed at various time intervals like 1,30,60,90 and 120 sec. The table shows the maximum and minimum deformations attained in the different time intervals.

	MODEL 1		MODEL 2	
	Max	Min	Max	Min
Equivalent stress	o.72892	0.13718	0.0037185	0.00048
Equivalent strain	7.6022e-6	1.4324e-6	1.8595e-8	2.4856e-8
Total deformation (static structural)	7.4257e-5	0	2.7057e-6	0
Total deformation (Model)	503.51	0	9.6826	0

Conclusion:

From the above results are obtained from ANSYS software and design is done using CATIA v5 software. And with the help of ANSYS software done structural analysis and model analysis .so the results are model 2 is better values compared to model 1 by using of Titanium alloys.

- Titanium Ti-6Al-4V is less deformation value *77.256 mm* and high withstand value in von misses stress and less weight 15.948 kg comparing with two other materials
- Equivalent elastic strain is max in titanium grade 1
- Titanium Ti-6Al-4V is better suitable material to missile nose cone compared to aluminum, stain less steel and some other materials.

REFERENCES

Analysis of blunt nose cone with ultra-high temperature ceramic composite TPS materials N.Sreenivasa babu, Dr. k.Jayathritha rao (International journal of innovative research in science, engineering and technology)

Aerodynamic characteristics of a missile components P. Sethunathan, A. Anupriya, K. Hema prabha, T.S. Vaishnavi (International journal of research in Engineering and Technology)

Design of an air craft nose cone and analysis of deformation under the specified conditions with different materials using ANSYS P.Venkata suresh,K.Ayyappa,V.Anjalee kumari,M.Koteswararao, J. Venumurali (International journal of Engineering research and Technology

Cheng, S Chin, 2014. “Design and Analysis of Composite Rocket Motor Casing “, William Atmodihardjo, Lok W Woo1 and Ehsan Mesbahi Chin et al. Robomech Journal, 2: 4.

Sheikh Naunehal Ahamed, Jadav Vijay Kumar, Mohammed Mushraffuddin, Parimi Shrawini, **“**Modeling and Analysis of Rocket Outer Shell”**,** international journal of scientific & technology research, 3: 4.

Mashiro Kanzakia, Atthaphon Ariyairtb, Kazuhisa Chibab, Koki Kitagawac, 2015. ToruShimadac “Conceptual Design of Single-stage Rocket Using Hybrid Rocket by Means of Genetic Algorithm”, Asia-Pacific International Symposium on Aerospace Technology, APISAT2014, science direct.

Zhu Hao, Tian Hui, Cai Guobiao, Bao Weimin, 2015. “Uncertainty analysis and design optimization of hybrid rocket motor powered vehicle of subortial flight”, Journal of aeronautics January.

The paper, 2014. “Optimal design for hybrid rocket engine for air launch vehicle” by Ihnseok Rhee, Changjin Lee, Jae-Woo Lee journal of aeronautics.

The paper “ Flow Analysis and Optimization of Supersonic Rocket Engine Nozzle at Various Divergent Angle using Computational Fluid Dynamics (CFD)” by Karna S. 2014. Patel IOSR Journal of Mechanical and Civil Engineering.

The paper “Modeling and Analysis of a Rocket Based Combined Cycle Rocket Nozzle” by A Kalyan Charan, D Madhava Reddy, 2014. CH Rakesh IOSR Journal of Mechanical and Civil Engineering.

The paper “Analysis of dual bell rocket nozzle using computational fluid dynamics” by balaji krushna.p, p. srinivasarao, b. 2013. balakrishna International Journal of Research in Engineering and Technologynov.

The paper 2012. “Analysis of Thrust Coefficient in a Rocket Motor” by PBose, K M Pandey International Journal of Engineering and Advanced Technology.

DetlefK uhl“ 2002. Thermo mechanical Analysis and Optimization of Cryogenic Liquid Rocket Engines” journal of propulsion and power.

Soon-Heum Ko, Sangho Han, Jin-ho Kim and Chongam Kim “Integrated Rocket Simulation of Internal and External Flow Dynamics in an e-Science Environment” Journal of the Kor ean Physical Society.

Ten-See Wang “Unified Navier-Stokes Flowfield and Performance Analysis of Liquid Rocket Engines” journal of propulsion and power