ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Coupled Field Analysis on a Re-Entry Vehicle

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ABSTRACT

The detail engineering design of a reentering space-vehicle heat shield requires the coordinated efforts. The predominant difficulty lies in the definition of thermal-mechanical properties of the heat-shielding material which encounters wide range of temperature conditions during its environmental life cycle. The conventional Reentry Vehicles use liners and foam bricks as insulators to resist the temperature of aerodynamic heating. These conventional liners and foam bricks can be replaced with insulating material which has good structural properties. This paper presents the coupled field analysis of conventional reentry vehicle using Zirconium Diboride (ZrB2) and Hafnium Diboride (HfB2) as insulating material. The coupled field analysis is carried out using finite element analysis software ANSYS. The analysis resulted that insulating material absorbs the temperatures before reaching the CFRP structure.

Key words: ***Re-Entry vehicle, Thermal Protection System, Coupled field analysis, ANSYS.***

INTRODUCTION

REENTRY VEHICLES

Manned Re Entry Vehicles are the compartments designed to support humans during their journey through space. They must contain the basic elements that astronauts need to live like air to breathe, water to drink, and food to eat. They also have to protect the astronauts from the cold of space and space radiation. These are well insulated and contain systems to adjust the internal temperature. There must be a way for the astronauts to secure themselves so they don't get jostled around during launch or re-entry; for this there are seats with strap systems. They also may need to strap themselves in a seat to work or bed to sleep when they are in space because they will be weightless. Capsules also have to be equipped with a way to communicate with mission control.

To design and build a vehicle that will survive re-entry through the Earth's atmosphere (or that of another planet) and impact on the surface one should have the knowledge of the forces of gravity and acceleration along with test design trials. Many early spacecraft that orbited the Earth landed on land or water (which is still quite a hard surface if you are travelling at high speed!). The Mercury, Gemini and Apollo spacecraft all landed in the water with the aid of parachutes. The Russian Soyuz spacecraft landed (and still lands) on land with the aid of parachutes and jet firings. The Mars Pathfinder crash landed on the surface of Mars in 1997 with the aid of parachutes and protected by airbags. The Huygens probe to the surface of Saturn's moon Titan (carried on board the Cassini spacecraft) must be able to land safely on land or water because the surface is unknown due Titan's thick clouds.

TYPES OF REENTRY VEHICLES

MANNED REENTRY VEHICLES

There have been many types of capsules developed by NASA. The Mercury capsule carried America's first astronaut, Alan Shepherd, into space and the other astronauts in the Mercury program. The Gemini capsule carried the second generation of astronauts into Earth orbit for longer stays and docking maneuvers. The Apollo capsule took astronauts to the Moon, and the Lunar Lander landed 12 astronauts on the surface. The Russian Soyuz capsule has launched and returned dozens of Russian cosmonauts from Earth orbit. Vehicles have not always been successful; one early Soyuz capsule lost three cosmonauts when it depressurized upon re-entry. The Apollo 1 capsule lost three astronauts on the pad during a test when a fire broke out in its pure oxygen atmosphere and the hatch

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could not be opened fast enough for the astronauts to get out. The international space station will have permanently docked to it one and, later, two Soyuz escape capsules (each holds 3 persons) for emergency egress. It will also have a crew return vehicle built by NASA called the X-38, which will serve as an emergency vehicle for all seven space station crewmembers. The X-38 is remotely controlled and, after re-entry, glides to a landing with the aid of parachutes and a Para foil.

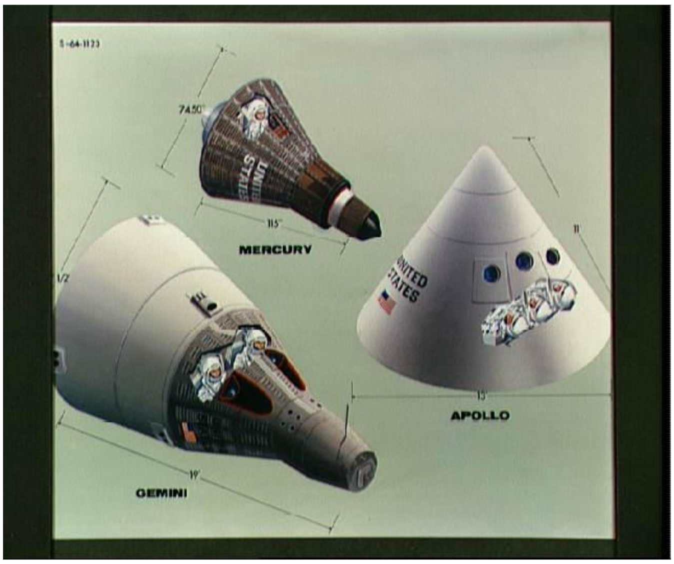

Fig. 1.1. Apollo Vehicle

UNMANNED REENTRY VEHICLES

Unmanned space probes have landed on Venus, the Moon, and Mars. The Russians sent eight Venere spacecraft to land on the surface of Venus beginning in 1970. The air pressure on Venus, extreme heat, and sulphuric acid atmosphere crushed and melted the probe within minutes. The last Lander, Venera 14, survived for 57 minutes (the planned design life was 32 minutes) in an environment with a temperature of 465° C (869° F) and a pressure of 94 Earth atmospheres. Early U.S. and Russian Moon Landers (the Surveyor and Luna programs, respectively) brought back images of the Moon before humans landed there.

Fig. 1.2. Lunar Surveyor

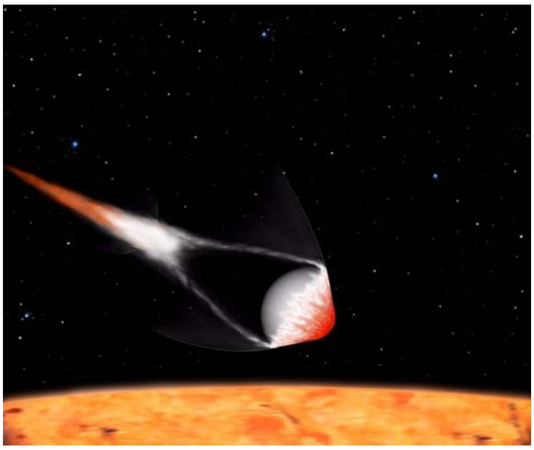

Fig. 1.3 Mars Viking Lander

GRAVITY AND MOMENTUM

Gravity is the force that attracts bodies to one another. The Sun's gravity holds the planets in their orbits, and the planets' gravity hold their moons in orbit around them. Gravity pulls all objects down to the surface of a planet (and holds us down so we do not float away!). Spacecraft launched at high speeds against the pull of gravity orbit the Earth and then fire jets to re-enter the atmosphere. Gravity does the rest of the work bringing them home.

“G-force” is a term used to express how many times the usual Earth gravity force an astronaut feels upon launch and upon re-entry when the speed creates the G-force. This is the feeling you have in a very fast roller coaster as you are being pushed back in your seat or in an amusement ride that spins and pins you against the wall. Early astronauts suffered from very high G-forces, making it hard to breathe or move. Today's shuttle astronauts experience only a few (2-3) G's upon launch and re-entry. The Russian cosmonauts, however, experience higher G's (6-7) upon launch and re-entry.

As objects fall, they pick up momentum or accelerate until they impact the surface. Planets with atmospheres will create friction (and heat) with the spacecraft, which will slow re-entry down a small amount. Spacecraft like the shuttle are designed to fly like gliders and land aerodynamically. Vehicles like the Soyuz and early NASA Mercury, Gemini and Apollo capsules used parachutes to help slow their fall. Both types of spacecraft have heat shields on their bottoms. In the Egg-astronaut activity, gravity and momentum are the major forces acting on the Vehicle.

PARACHUTES AND AIRBAGS

Most Vehicles use parachutes to help slow their descent, reduce their acceleration, and aid in a soft landing. The Soyuz spacecraft also fires jets immediately before impact to help reduce the force of the impact. The Mars Pathfinder used airbags in addition to parachutes and bounced along the surface before coming to rest. Both of these ideas make excellent additions to the egg-drop capsule and can be incorporated into students designs using string and plastic garbage bags for parachutes and inflated sandwich bags for airbags (freezer bags are even sturdier for high drops).

Fig. 1.4 Apollo Parachute

RE-ENTRY MOTION

Walking along the shore of a tranquil lake on a sunny, spring day, most of us have indulged in one of life's simplest pleasures: skipping stones. When the wind is calm, the mirror-like surface of the water practically begs us to try our skill. Searching through pebbles on the sandy bank, we find the perfect skipping rock: round and flat and just big enough for a good grip. We take careful aim, because we want the stone to strike the water's surface at the precise angle and speed that will allow its wide, flat bottom to take the full force of impact, causing it to skip. If we have great skill (and a good bit of luck), it may skip three or four times before finally losing its momentum and plunging beneath the water.

Returning from space, astronauts face a similar challenge. Earth's atmosphere presents to them a dense, fluid medium, which, at orbital velocities, is not all that different from a lake's surface. They must plan to hit the atmosphere at the precise angle and speed for a safe landing. If they hit too steeply or too fast, they risk making a big "splash," which would mean a fiery end. If their impact is too shallow, they may literally skip off the atmosphere and back into the cold of space. This subtle dance between fire and ice is the science of atmospheric re-entry.

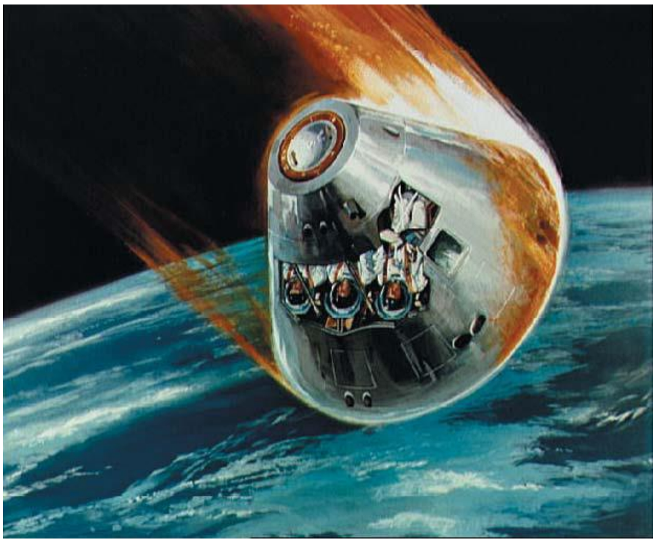

Fig. 1.5 Apollo Capsule Re-entry, An artist's concept

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TRADE-OFFS FOR RE-ENTRY DESIGN

All space-mission planning begins with a set of requirements we must meet to achieve mission objectives. The re-entry phase of a mission is no different. We must delicately balance three, often competing, requirements

- ✓ Deceleration
- ✓ Heating
- ✓ Accuracy of landing or impact

The vehicle's structure and payload limit the maximum deceleration or "g's" it can withstand. (One "g" is the gravitational acceleration at Earth's surface—9.798 m/s 2.) When subjected to enough g's, even steel and aluminium can crumple like paper. Fortunately, the structural g limits for a well-designed vehicle can be quite high, perhaps hundreds of g's. But a fragile human payload would be crushed to death long before reaching that level. Humans can withstand a maximum deceleration of about 12 g's (about 12 times their weight) for only a few minutes at a time. Imagine eleven other people with your same weight all stacked on top of you. The maximum deceleration a vehicle experiences during re-entry must be low enough to prevent damage or injury to the weakest part of the vehicle.

But maximum g's aren't the only concern of re-entry designers. Too little deceleration can also cause serious problems. Similar to a rock skipping off a pond, a vehicle that doesn't slow down enough may literally bounce off the atmosphere and back into the cold reaches of space. Another limitation during re-entry is heating. The fiery trail of a meteor streaking across the night sky shows that re-entry can get hot!

This intense heat is a result of friction between the speeding meteor and the air. To find out how hot can something get during re-entry, think about the energies involved. The Space Shuttle in orbit has a mass of 100,000 kg (220,000 lb.), an orbital velocity of 7700 m/s (17,225 m.p.h.), and an altitude of 300 km (186 mi.). In following section we showed that an object's total mechanical energy depends on its kinetic energy (energy of motion) and its potential energy (energy of position). If we have to get our calculators and punch in the numbers for the Space Shuttle, we'd find that it is

Total mechanical energy is E = $3.23*10^{12}$ joules = $3.06*10^{9}$ Btu

Let's put this number in perspective by recognizing that heating the average house in Colorado takes only about $73.4*10^{7}$ Btu/year. So, the Shuttle has enough energy during re-entry to heat the average home in Colorado for 41 years. The Shuttle has kinetic energy due to its speed of 7700 m/s and potential energy due to its altitude. It must lose all this energy in only about one-half hour to come to a full stop on the runway (at Earth's surface). But, remember, energy is conserved, so where does all the "lost" energy go? It converts to heat (from friction) caused by the atmosphere's molecules striking its leading edges. This heat makes the Shuttle's surfaces reach temperatures of up to 1477° C (2691° F).We must design the re-entry trajectory, and the vehicle, to withstand these high temperatures. As we'll see, we have to contend with the total heating and the peak heating rate.

The third mission requirement is accuracy. Beginning its descent from more than 6440 km (4000 mi.) away, the Space Shuttle must land on a runway only 91 m (300 ft.) wide. The re-entry vehicle (RV) of an Intercontinental Ballistic Missile (ICBM) has even tighter accuracy requirements. To meet these constraints, we must again adjust the trajectory and vehicle design. On the other hand, if a vehicle can land in a larger area, the accuracy constraint becomes less important. For example, the Apollo missions required the capsules to land in large areas in the Pacific Ocean much larger landing zones than for an ICBM's RV payload. Thus, the Apollo capsule was less streamlined and used a trajectory with a shallower re-entry angle. In all cases, designers adjust the trajectory and vehicle shape to match the accuracy requirement.

As you can see from all these constraints, a re-entry vehicle must walk a tightrope between being squashed and skipping out, between fire and ice, and between hitting and missing the target. This tightrope is actually

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International Journal & Magazine of Engineering, Technology, Management and Research
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a three-dimensional ***"re-entry corridor"*** shown in Figure 1.5, through which a re-entry vehicle must pass to avoid skipping out or burning up. The size of the corridor depends on the three competing constraints—deceleration, heating, and accuracy. For example, if the vehicle strays below the lower boundary (undershoots), it will experience too much drag, slowing down rapidly and heating up too quickly. On the other hand, if the vehicle enters above the upper boundary (overshoots), it won't experience enough drag and may literally skip off the atmosphere, back into space.

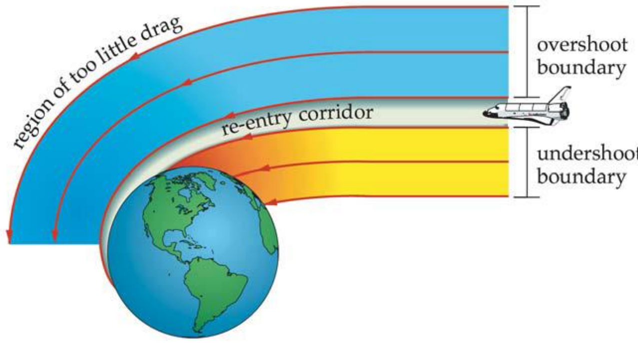

Fig. 1.6 Re-entry Corridor

The re-entry corridor is a narrow region in space that a re-entering vehicle must fly through. If the vehicle strays above the corridor, it may skip out. If it stays below the corridor, it may burn up.

RE-ENTRY PROCESS

Imagine one of Earth's many small, celestial companions (say, an asteroid) wandering through space until it encounters Earth's atmosphere at more than 8 km/s, screaming in at a steep angle. Initially, in the upper reaches of the atmosphere, there is very little drag to slow down the massive chunk of rock. But as the meteor penetrates deeper, the drag force builds rapidly, causing it to slow down dramatically. This slowing is like the quick initial deceleration experienced by a rock hitting the surface of a pond. At this point in the meteor's trajectory, its heating rate is also highest, so it begins to glow with temperatures hot enough to melt the iron and nickel within. If anything is left of the meteor at this point, it will continue to slow down but at a more leisurely pace. Of course, most meteors burn up completely before reaching our planet's surface. The meteor's velocity stays nearly constant through the first ten seconds, when the meteor is still above most of the atmosphere. But things change rapidly over the next ten seconds. The meteor loses almost 90% of its velocity—almost like hitting a wall. With most of its velocity lost, the deceleration is much lower—it takes 20 seconds more to slow down by another 1000 m/s.

We also define the ***"re-entry flight-path angle"***, which is the angle between the local horizontal and the velocity vector. (Note this angle is the same as the orbital flight-path angle, used earlier, but re-entry analysts like to use gamma, instead, so we play along.) Similar to, a re-entry flight path angle below the horizon (diving toward the ground) is negative, and a flight-path angle above the horizon (climbing) is positive. To truly understand the motion of a re-entering Shuttle, we have to start by listing what forces might affect it. After a bit of thought, we could come up with the following short list of forces to worry about:

- The force of gravity
- The force of drag
- The force of lift
- Other forces just in case

In the above paragraphs gravity is discussed, as described by Sir Isaac Newton, Drag and lift are two there forces that any object travelling through the atmosphere must deal with. "Other" forces cover us in case we forgot something.

Drag is a force that resists motion through the atmosphere. If you were to put your hand out the window of a fast-moving car and turn your palm into the wind, you'd feel the force of drag pushing back on your hand. The drag force acts in the direction opposite to your motion.

Lift is a force produced at a right angle to the direction of motion as a result of air moving over an object's surface. An object with the correct shape, such as an airplane's wing, will generate enough lift force to overcome the force of gravity and "lift" it into the air.

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For Shuttles, meteors, and ICBMs entering the atmosphere at near orbital velocities, it turns out that

- The re-entry vehicle is a point mass
- Drag is the dominant force—all other forces, including lift and gravity, are insignificant. (We'll see why this is a good assumption later).

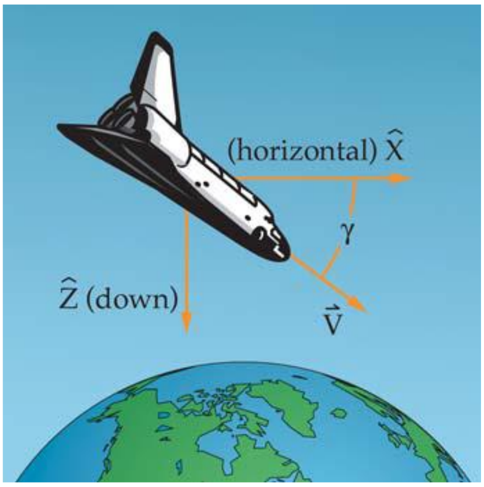

Fig. 1.7 Re-entry Coordinate System

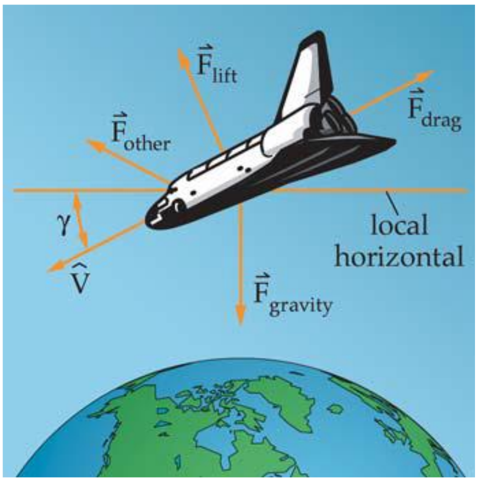

Fig. 1.8 Significant Forces on a Re entry Vehicle

VEHICLE SHAPE

The re-entry vehicle's size and shape help determine the ballistic coefficient (BC) and the amount of lift it will generate. Because adding lift to the re-entry problem greatly complicates the analysis, we'll continue to assume we're dealing only with non-lifting vehicles. In the next section, we'll discuss how lift affects the re-entry problem.

The hardest component of BC to determine for re-entry vehicles is the drag coefficient, C_D, which depends mainly on the vehicle's shape. At low speeds, we could just stick a model of the vehicle in a wind tunnel and take specific measurements to determine C_D. But at re-entry speeds approaching 25 times the speed of sound, wind tunnel testing isn't practical because no tunnels work at those speeds. Instead, we must create mathematical models of this hypersonic flow to find C_D. The most accurate of these models requires us to use high-speed computers to solve the problem. This approach is now a specialized area of aerospace engineering known as *computational fluid dynamics (CFD).*

Fortunately, a simpler but less accurate way will get us close enough for our purpose. We can use an approach introduced more than 300 years ago called *Newtonian flow*. Yes, Isaac Newton strikes again. Because Newton looked at a fluid as simply a collection of individual particles, he assumed his laws of motion must still work. But they didn't at low speeds. Centuries later, however, Newton was vindicated when engineers found his model worked quite well for flow at extremely high speeds. So the grand master of physics was right again—but only for certain situations. Figure 1.7summarizes these two approaches to analyzing fluid dynamics. Using Newton's approach, we can calculate CD and thus find BC.

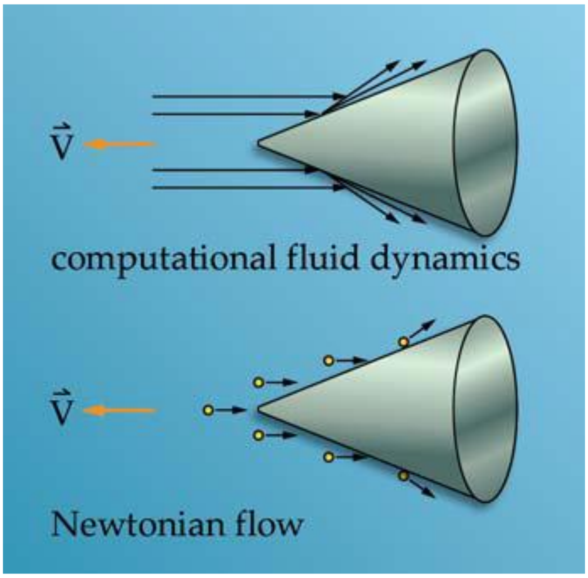

Fig. 1.9 Computational Fluid Dynamics (CFD) Versus Newtonian Flow

THERMAL-PROTECTION SYSTEMS (TPS)

As you know by now, during re-entry, things get hot. How do we deal with this massive heat accumulation without literally burning up? We use specially formulated materials and design techniques called thermal protection systems (TPS). We'll look at three approaches to TPS

- Heat sinks
- Ablation
- Radiative cooling

LITERATURE REVIEW

Aerodynamic and heat transfer analysis over spherical blunt cone

Agosh M C in his work "Aerodynamic And Heat Transfer Analysis Over Spherical Blunt Cone" has presented the computational simulations that were carried out on a spherical blunt body to determine the aero thermodynamic coefficients at various hypersonic mach numbers. The sea level conditions were assumed for the computational simulations. Computations were validated through a simulation of flow field around spherical blunt body at Mach numbers 6, 7 and 8.

Analysis of Blunt Nose Cone with Ultra High Temperature Ceramic Composite TPS Materials

N. Sreenivasa Babu, Dr. K. Jayathirtha Rao in their work "Analysis Of Blunt Nose Cone With Ultra High Temperature Ceramic Composite TPS Materials" has presented the Aerodynamic drag and heating are the crucial in the thermal stability of hypersonic vehicles at various speeds. The latest developments in the design of nose cone structure demands an effective Thermal Protection System (TPS) meets the need of the space research technology.

Simulating Vehicle Water Landing With Explicit Finite Element Method

John T. Wang1 and Karen H. Lyle in their work "Simulating Vehicle Water Landing With Explicit Finite Element Method" has presented the study of using an explicit nonlinear dynamic finite element code for simulating the water landing of a Vehicle was performed. The finite element model contains Lagrangian shell elements for the Vehicle and Eulerian solid elements for the water and air. An Arbitrary Lagrangian Eulerian (ALE) solver and a penalty coupling method were used for predicting the fluid and structure interaction forces. The Vehicle was first assumed to be rigid, so the numerical results could be correlated with closed form Solutions.

Aerothermodynamics Analysis of Space- Vehicle Phenomena

J. Muylaert, W. Kordulla, D. Giordano, L. Marraffa, R. Schwane in their work "Aerothermodynamics Analysis Of Space- Vehicle Phenomena" has presented aerothermodynamics is a key technology for the design and optimisation of space vehicles because it provides the necessary databases for, example, the choice of trajectory, guidance, Navigation and control, as well as for the thermal-protection and propulsion systems. This article presents its current capabilities with respect to flow Phenomena.

FINITE ELEMENT MODELING USING ANSYS MODELING IN ANSYS

ANSYS is popular commercial Finite Element Modeling (FEM) software that is capable of analyzing composite structures. ANSYS utilizes the principle of virtual work (PVW) as an alternative to solving the less convenient equations of equilibrium. PVW states that a virtual change of the internal strain energy must be offset by an additional change in external work for the applied loads. This principle allows for the derivation of structural matrices and general element formation.

ELEMENT SELECTION

The elements available in ANSYS which are capable of structurally modeling composite materials are: SHELL91, SHELL99, SHELL181, SHELL281, SOLSH190, SOLID46, SOLID185, SOLID186, and SOLID191. Since it was decided to use a solid geometry, an element requiring a volume mesh is needed. If the design did not contain the stabilizing core, only a skinned geometry would be required. This can be meshed with shell elements, SHELL99 being the most widely used for similar cases analyzing wind turbine blades.

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International Journal & Magazine of Engineering, Technology, Management and Research
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SOLSH190 was designed for simulating shell structures with a wide range of thickness (from thin to moderately thick). The element possesses the continuum solid element topology and features eight-node connectivity with three degrees of freedom at each node: translations in the nodal x, y, and z directions. Thus, connecting SOLSH190 with other continuum elements requires no extra efforts. A degenerate prism option is available, but should only be used as filler elements in mesh generation. The element has plasticity, hyper-elasticity, stress stiffening, creep, large deflection, and large strain capabilities.

Profile

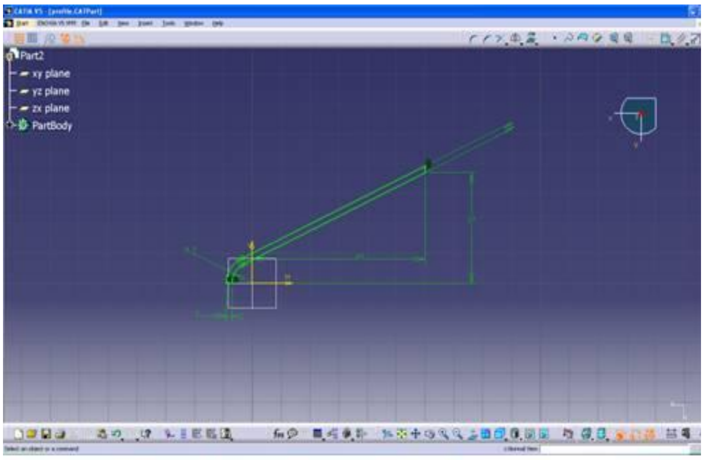

Fig. 4.2 Catia Wire frame model

The above profile is designed in CATIAV5 software by taking the reference dimensions from the reference

Meshed model-3d

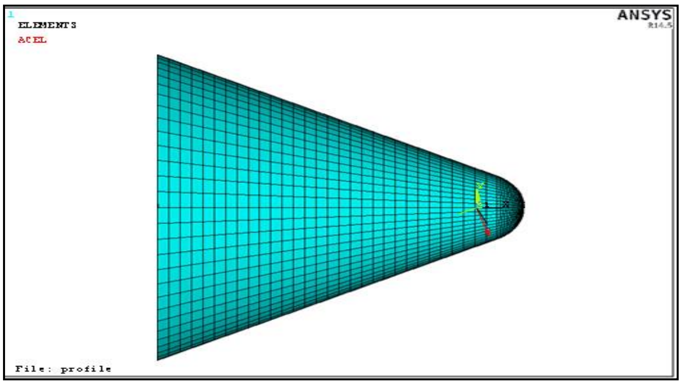

Fig. 4.3 Meshed model 3d

The above figure shows the mesh model of the nose cone where we did the mapped mesh for the nose cone

APPLIED BOUNDARY CONDITIONS

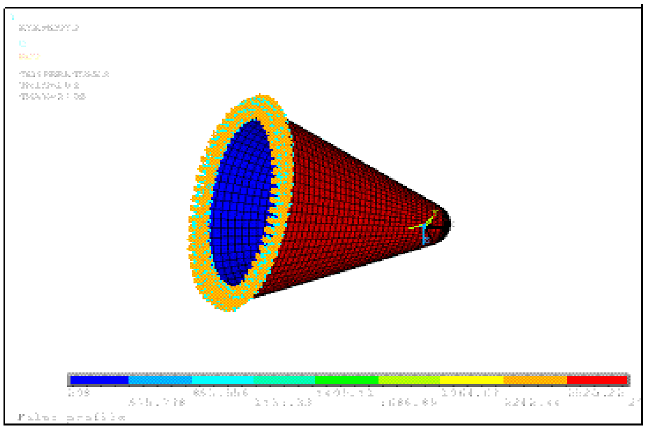

Fig. 4.4 Temperature loads

The figure shows the displacement loads which are applied as a fixed loads at the back side of the nose cone, the temperature loads are applied, minimum temperature as 298K inner side of the nose cone the maximum temperature as 2798 K outer side of the nose cone .

GRAVITY

The inertial force should be applied in the y-direction value is -30g(g-9.81n/mm) . This force is given because the Vehicle will be re-entering into the earth's atmosphere without any additional propulsion system

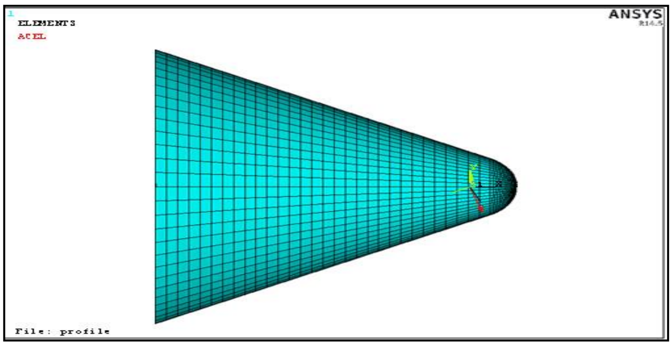

Fig. 4.5 Gravity direction

RESULTS AND DISCUSSION

DEFORMED AND UN DEFORMED SHAPE

Deformed shape (With Gravity) :-

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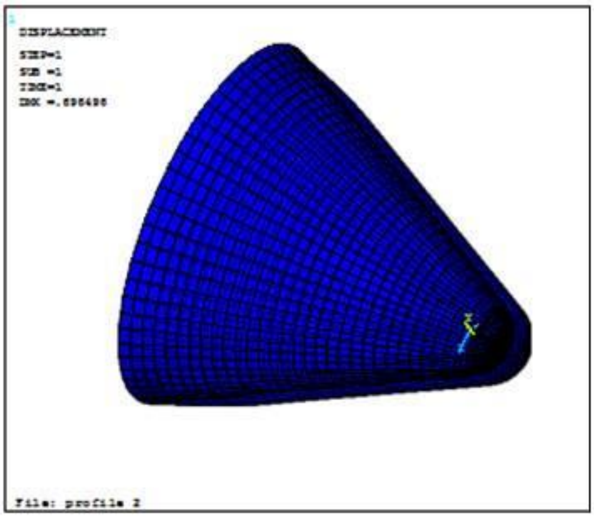

Fig. 5.1- Deformed+ Un Deformed Shape

STRESS DEFORMATION

Stress: - The force acting across a unit area in a solid material resisting the separation, compacting, or sliding that tends to be induced by external forces.

Strain: - Change in length of an object in some direction per unit undistorted length in some direction, not necessarily the same; the nine possible strains form a second-rank tensor.

STRESS REACTION WITH GRAVITY

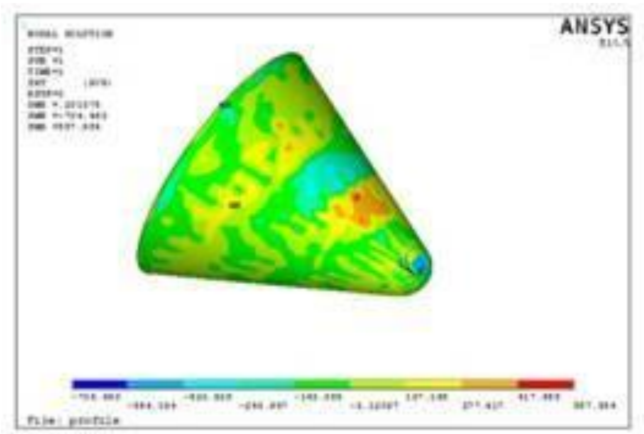

Fig. 5.2 Stress-X Direction with gravity

The above figure shows the stress area of the space cone which is effected more at the front side because the maximum temperature is applied at the front side upper layer of the space (i.e.., 2798K) here the stress is in x direction when the Vehicle is returning into the earth's atmosphere the force at the front side will be more effected than the end of the space cone section, so the more effected area is shown in red color decreases gradually to blue color where we can observe at the end section of the space cone structure is in blue color indicates the less stress affected area.

STRESS REACTION WITHOUT GRAVITY

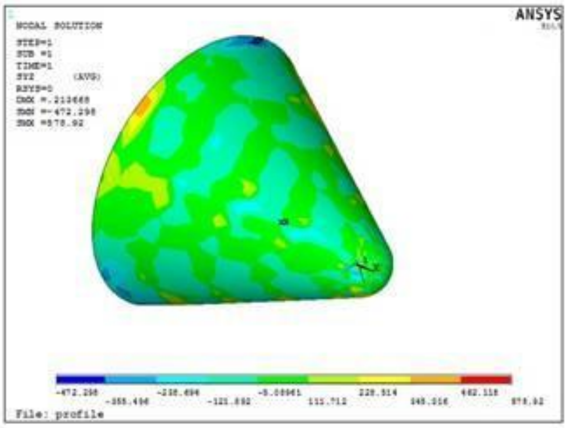

Fig. 5.3 Stress-X Direction without gravity

The above deformation of stress shows the difference between with gravity reaction and without gravity reaction if the gravity is applied on the nose cone the stress at X-direction will be more when compared to the stress reaction applied without gravity the legend table shows the clear difference between with gravity and without gravity of stress reactions at X-direction. If the gravity is applied on the nose cone the stress reaction is- 1760. Stress reaction without gravity is 1348.18

STRESS REACTION WITH GRAVITY

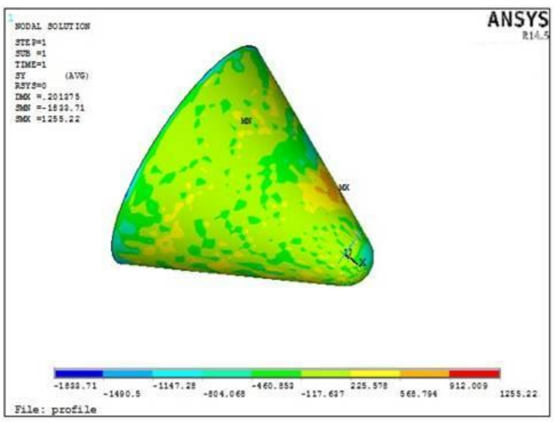

Fig. 5.4 Stress-Y Direction with gravity

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The above figure shows the stress area of the nose cone which is effected at the y direction because when the Vehicle is returning into the earth's atmosphere the force at the y-direction will be more, so the more effected area is shown in red color decreases gradually to blue color where we can observe at the end section of the space cone structure is in red color indicates the high affected stress area gradually decreases to the blue color but we can't observe the section because it is moving in the y-direction. The legend table shows the increment to the decrement clearly. The above reaction is when the gravity force is applied on the nose cone.

STRESS REACTION WITHOUT GRAVITY

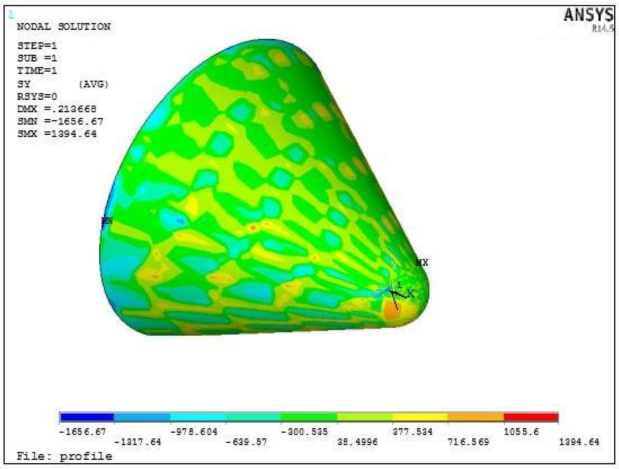

Fig. 5.5 Stress-Y Direction without gravity

The above reaction is when gravity is not applied on the nose cone structure there is a difference between when the gravity is applied, not applied on the nose cone in the Y-direction. The legend table shows the clear difference between stress reaction with gravity and without gravity. When the gravity is applied the stress at Y-direction -1394.64, if the gravity is not applied on the nose cone the stress at Y-direction varies with – 1255.22.

STRESS REACTION WITH GRAVITY

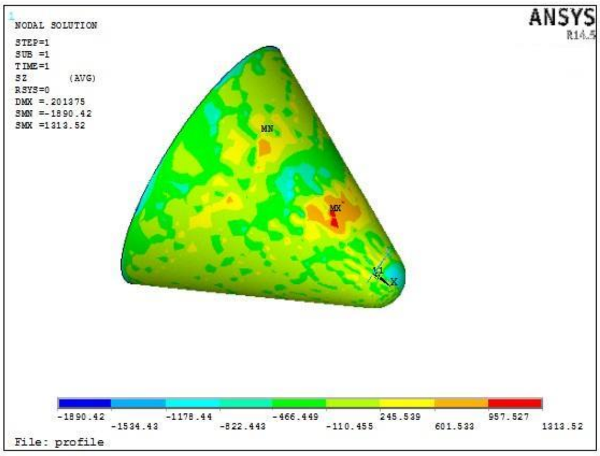

Fig. 5.6 Stress-Z Direction with gravity

The above figure shows the stress area of the nose cone which is effected more at the z direction i.e., when compared with the stress at X,Y –directions because when the Vehicle is returning into the earth's atmosphere the force at the z-direction will be more, so the more effected area is shown in red color decreases gradually to blue color where we can observe at the end section of the nose cone structure is in blue color indicates the less affected stress area gradually increases to the red color shown at the other surface of the nose cone. The legend table shows the increment to the decrement clearly.

STRESS REACTION WITHOUT GRAVITY

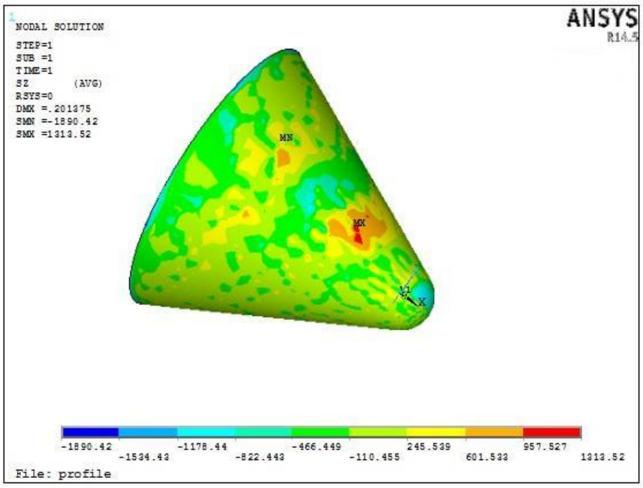

Fig. 5.7 Stress-Z Direction without gravity

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The above reaction of the stress shows when the gravity is not applied if we compare the reactions of stress at Z-direction when the gravity is applied and not applied on the nose cone structure there will be an difference by observing the legend table the difference can be shown by applying the gravity on the nose cone the stress reaction-1801.28, without gravity stress reaction on the nose cone structure -1313.52.

SHEAR STRESS DEFORMATION WITH GRAVITY

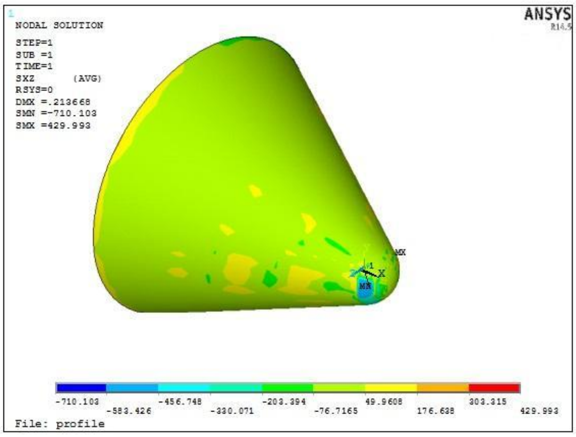

Fig. 5.8 Shear Stress-XY Direction with gravity

The above figure shows the shear stress area of the nose cone which is effected more at the starting surface because the direction is in xy , when the Vehicle is returning into the earth's atmosphere the force at the xy-direction will be more.

SHEAR STRESS REACTION WITHOUT GRAVITY

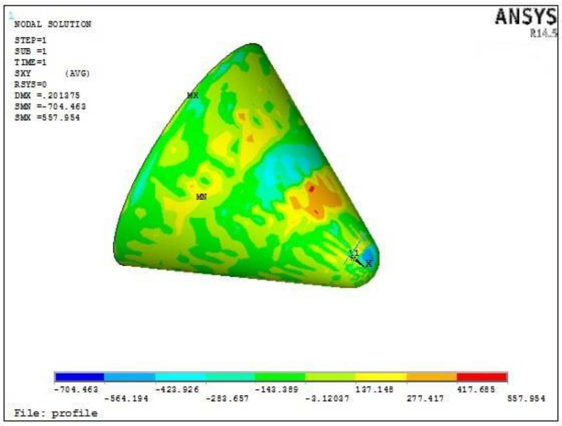

Fig. 5.9 Shear Stress-XY Direction without gravity

The above figure reactions are when the gravity is not applied on the nose cone structure by comparing both the shear stress reactions we can observe the difference. Shear stress reaction XY- 585.546 when gravity is applied, shear stress reaction XY- 557.954 when the gravity is not applied on the nose cone structure.

SHEAR STRESS REACTION WITH GRAVITY

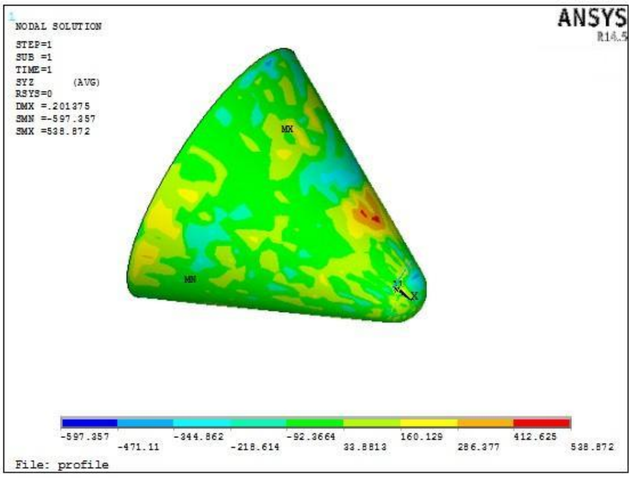

Fig. 5.10 Shear Stress-YZ Direction with gravity

The above figure shows the shear stress area of the nose cone effected because the direction is in yz top surface is shown in red color when the Vehicle is returning into the earth's atmosphere the force at the yz-direction (i.e.., upper surface) will be more effected the area is shown in red color decreases gradually to blue color where we can observe at the bottom surface of the nose cone structure in blue color indicates the less affected stress area gradually increases to the red color shown at the upper surface of the nose cone.

SHEAR STRESS REACTION WITHOUT GRAVITY

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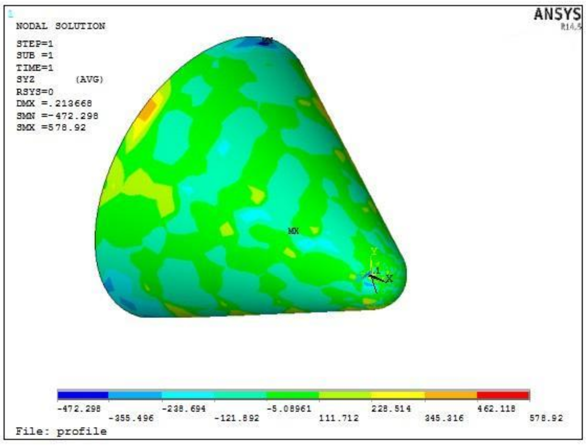

Fig. 5.11 Shear Stress-YZ Direction without gravity

The above reaction is when the gravity is not applied on the nose cone structure of the shear stress at the YZ-direction by observing the legend table the difference can be observed clearly if the gravity is applied on the nose cone structure the shear stress YZ-578.92, if the gravity is not applied the shear stress YZ- 538.872, the shear stress is more when the gravity is applied because the gravitational force is important while the Vehicle is returning into the earth's atmosphere.

SHEAR STRESS REACTION WITH GRAVITY

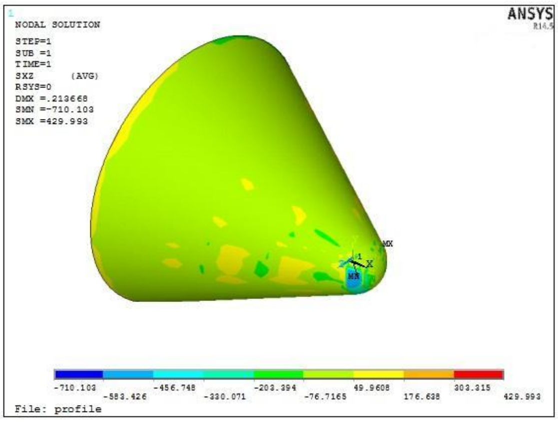

Fig. 5.12 Shear Stress-XZ Direction with gravity

The above figure shows the shear stress area of the nose cone which is effected is shown in red color when the Vehicle is returning into the earth's atmosphere the force at the xz-direction (i.e.., right surface) will be more, so the more effected area is shown in red color decreases gradually to blue color where we can observe at the bottom surface of the space cone structure is in blue color indicates the less affected stress area gradually increases to the red color shown at the right surface of the nose cone. The legend table shows the increment to the decrement clearly.

SHEAR STRESS REACTION WITHOUT GRAVITY

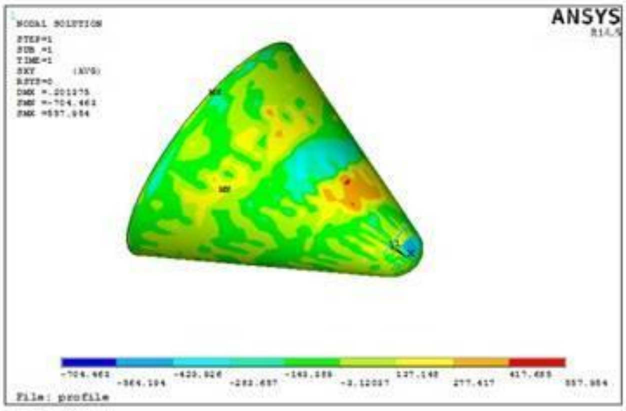

Fig. 5.13 Shear Stress-XZ Direction without gravity

The above reactions are when the gravity is not applied on the nose cone structure the legend table gives the comparison between when the gravity is applied and not applied on the nose cone structure of an shear stress –XZ direction. If the gravity is applied shear stress XZ- 429.993, gravity is not applied on the nose cone structure then the shear stress XZ-663.773.

VON-MISES STRESS

Von-mises stress: - Von Mises stress is widely used by the designers to check whether their design will withstand a given load condition. In this lecture we will understand Von Mises stress in a logical way.

Use of Von-Mises stress: - Von mises stress is considered to be a safe haven for the design engineer's .Using this information an engineer can say his design will fail, if the maximum value of Von Mises stress induced in the material is more than strength of the material. It works well for most of the cases, especially when the material is ductile in nature.

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VON-MISES STRESS WITH GRAVITY

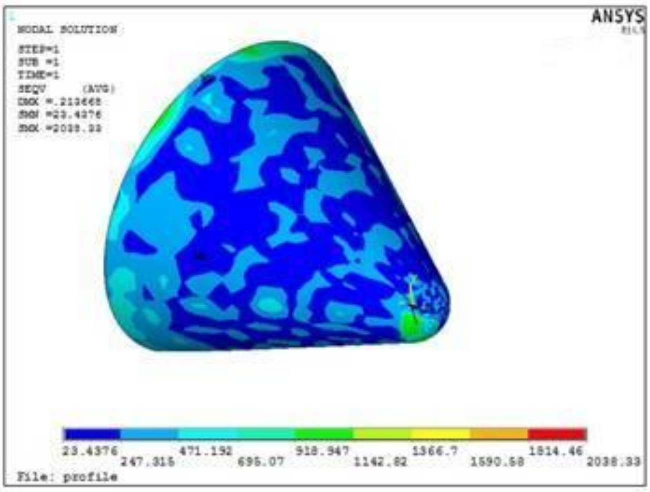

Fig. 5.15 Von-Mises Stress with gravity

The above reactions are the von-mises stress on the nose cone structure when the gravity is applied here the von mises stress is distributed on the whole body of the nose cone structure the failure section will be less affected in red colour the whole body is protected i.e.., the forces applied on the nose cone structure will be distributed failure area will be less on the nose cone structure. The above reactions are when the gravity is applied on the nose cone structure

VON-MISES STRESS WITHOUT GRAVITY

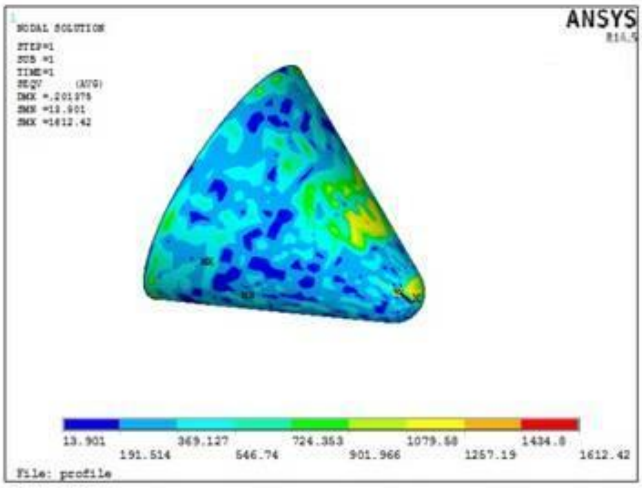

Fig. 5.16 Von-mises stress without gravity

The above reaction is obtained when the gravity is not applied on the nose cone structure the legend table shows the comparison between gravity applied and not applied on the nose cone structure with gravity the von mises stress blue color value- 23.4376, without gravity – 13.901 by applying gravity the von mises stress is stable on the nose cone structure.

DISPLACEMENT RECTIONS

DISPLACEMENT WITH GRAVITY

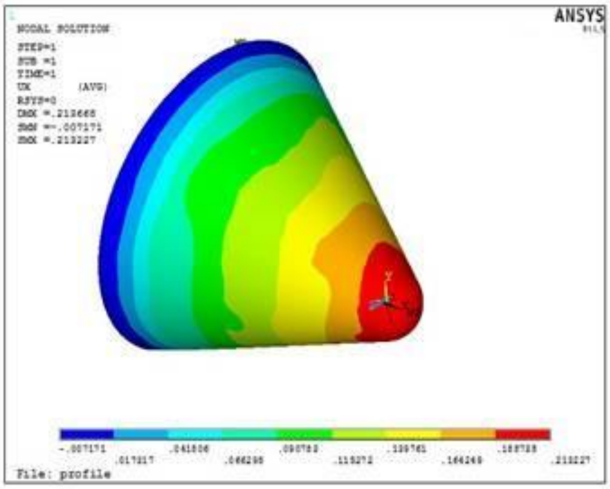

Fig. 5.19 Displacement X-direction with gravity

The above reaction is displacement through X-direction when gravity is applied on the nose cone structure here we can observe clearly the red color is more affected area on the front side of the nose cone because when the Vehicle is returning to the atmosphere the front side will be more affected, blue color is the less affected area on the nose cone structure observing the nose cone the blue color is at the end surface of the structure. The legend table gives more information of the affected forces on the nose cone structure.

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DISPLACEMENT WITHOUT GRAVITY

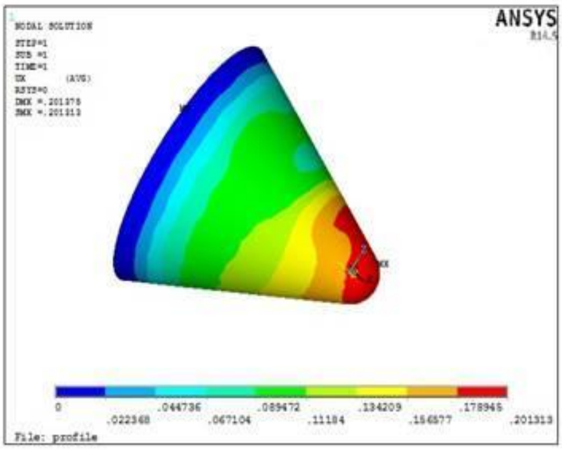

Fig. 5.20 Displacement X-direction without gravity

The above reaction is displacement through X-direction when gravity is not applied on the nose cone structure here we can observe clearly the red color is more affected area on the front side of the nose cone because when the Vehicle is returning to the atmosphere the front side will be more affected, blue color is the less affected area on the nose cone structure observing the nose cone the blue color is at the end surface of the structure. By comparing displacement with gravity and without gravity displacement at X-direction will be varied. Legend table shows the difference when the gravity is applied the reaction of displacement- .213227, without gravity the displacement reaction-.201313.

DISPLACEMENT WITH GRAVITY

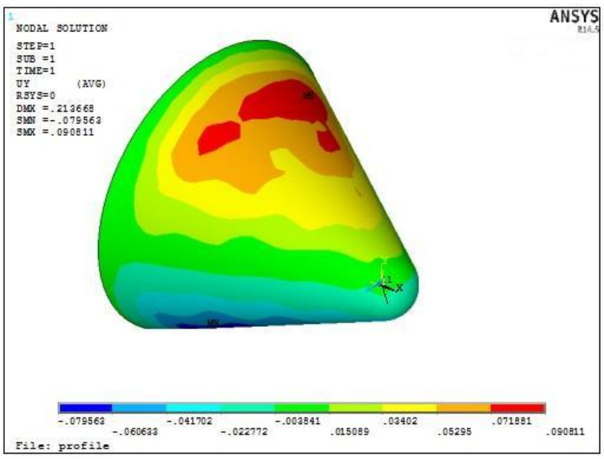

Fig. 5.21 Displacement Y-direction with gravity

The above reaction is displacement through Y-direction when gravity is applied on the nose cone structure, here we can observe clearly the red color is more affected area on the upper surface of the nose cone because when the Vehicle is returning to the atmosphere the upper surface will be more affected because the direction is through Y, blue color is the less affected area at the bottom surface of nose cone structure by observing blue color is at the bottom surface of the structure.

DISPLACEMENT WITHOUT GRAVITY

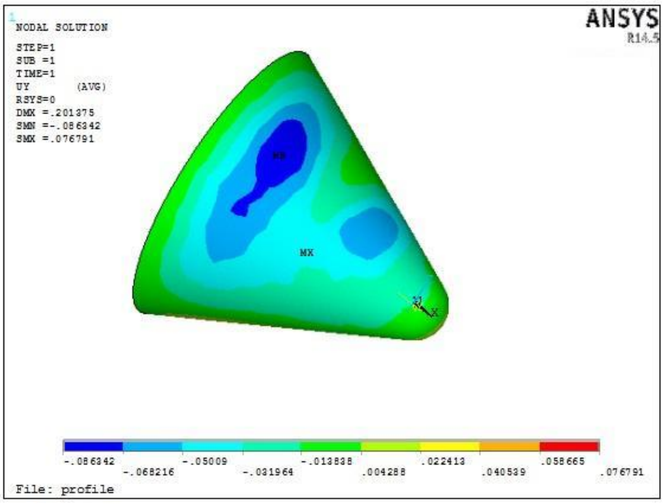

Fig. 5.22 Displacement Y-direction without gravity

The above reaction is displacement through Y-direction when gravity is not applied on the nose cone structure here we can observe the blue color means less affected area on the upper surface of the nose cone because when the Vehicle is returning to the atmosphere the right surface will be more affected because it is in the y direction, red color is more affected area on the nose cone structure observing the nose cone the at the right surface of the structure. By comparing displacement reactions with gravity and without gravity displacement at Y-direction will be varied. Legend table shows the difference when the gravity is applied the reaction of displacement-.090811, without gravity the displacement reaction-.076791.

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DISPLACEMENT WITH GRAVITY

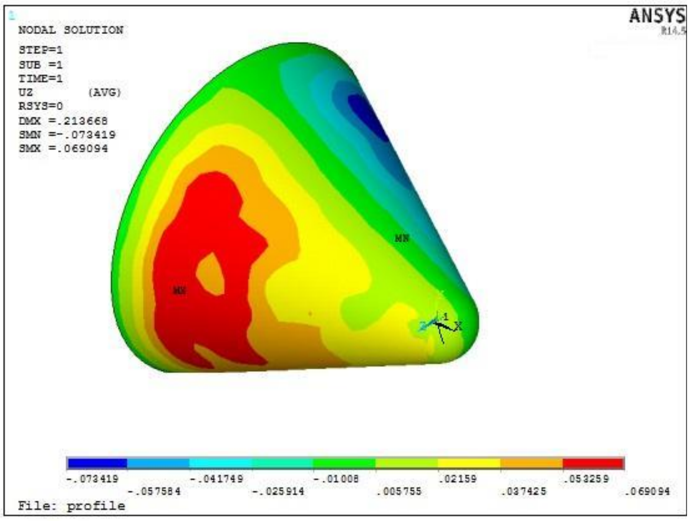

Fig. 5.23 Displacement Z-direction with gravity

The above reaction is displacement through Z-direction when gravity is applied on the nose cone structure, here we can observe clearly the red color is more affected area on the left side of the nose cone because when the Vehicle is returning to the atmosphere the left side will be more affected because the direction is through Z, blue color is the less affected area at the bottom right side of nose cone structure by observing blue color is at the right side of the nose cone structure.

DISPLACEMENT WITHOUT GRAVITY

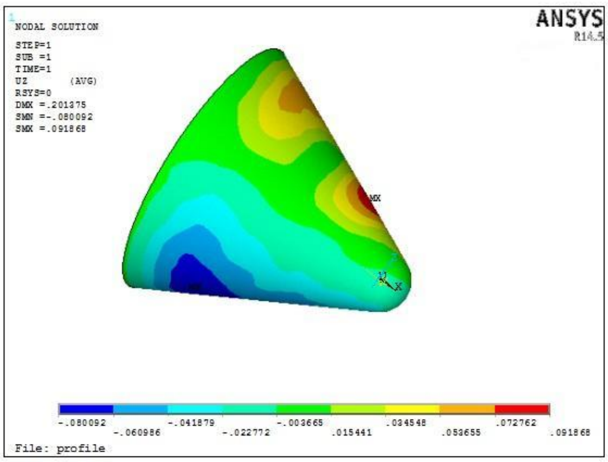

Fig. 5.24 Displacement Z-direction without gravity

The above reaction is displacement through Z-direction when gravity is not applied on the nose cone structure here we can observe the blue color means less affected area on the bottom surface of the nose cone because when the Vehicle is returning to the atmosphere the bottom surface will be less affected because it is travelling through Z direction, red color is more affected area on the nose cone structure observing the nose cone the at the upper surface of the structure. By comparing displacement reactions with gravity and without gravity displacement at Z-direction will be varied. Legend table shows the difference when the gravity is applied the reaction of displacement-.069094, without gravity the displacement reaction-.091868.

DISPLACEMENT WITH GRAVITY

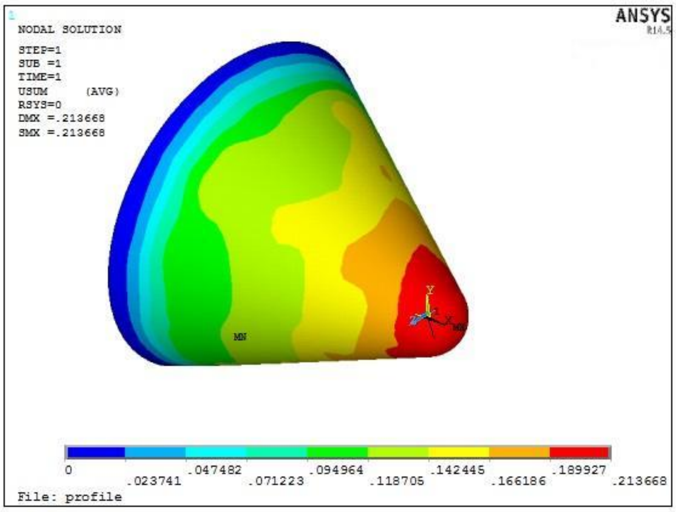

Fig. 5.25 Displacement Vector Sum with gravity

The above figure shows the displacement vector sum of the nose cone structure this shows when the gravity is applied on the structure gives the total sum of the displacement vector. By observing the above figure we can observe the red color area affected at the front place of the nose cone structure, blue color area at the end of the surface of the nose cone structure. Red color indicates more affected area when the Vehicle re-enters to the earth's atmosphere the forces will act at the front side of the nose cone structure because the Vehicle is re-entering into opposite direction of the gravity. The legend table shows the clear picture

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difference of increment to decrement forces acting on the nose cone structure.

DISPLACEMENT WITHOUT GRAVITY

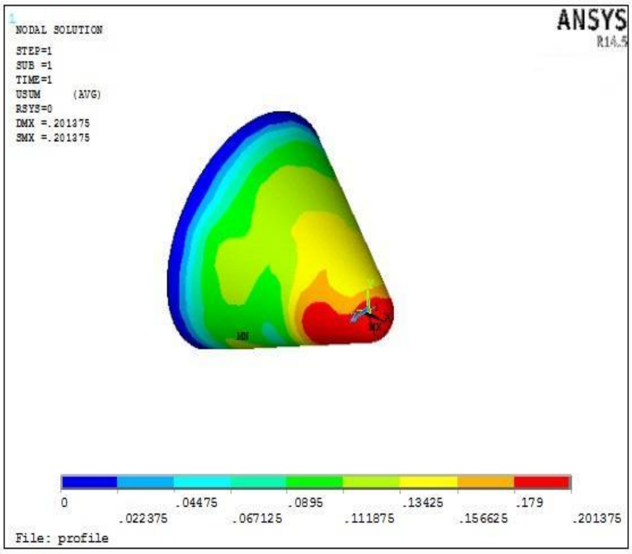

Fig. 5.26 Displacement Vector Sum without gravity

The above figure shows the displacement vector sum of the nose cone structure this shows when the gravity is not applied on the structure gives the total sum of the displacement vector. By observing the above figure we can observe the red color area affected at the front place of the nose cone structure, blue color area at the end of the surface of the nose cone structure. Red color indicates more affected area when the Vehicle re-enters to the earth's atmosphere the forces will act at the front side of the nose cone structure because the Vehicle is re-entering into opposite direction of the gravity. The legend table shows the clear picture difference of increment to decrement forces acting on the nose cone structure. This figure and the above figure shows the difference between gravity applied and without gravity we can see the difference through legend table when the gravity is applied on the nose cone structure the displacement vector sum-.213668, when the gravity is not applied on the nose cone structure the displacement vector sum-.201375.

NODAL TEMPERATURE

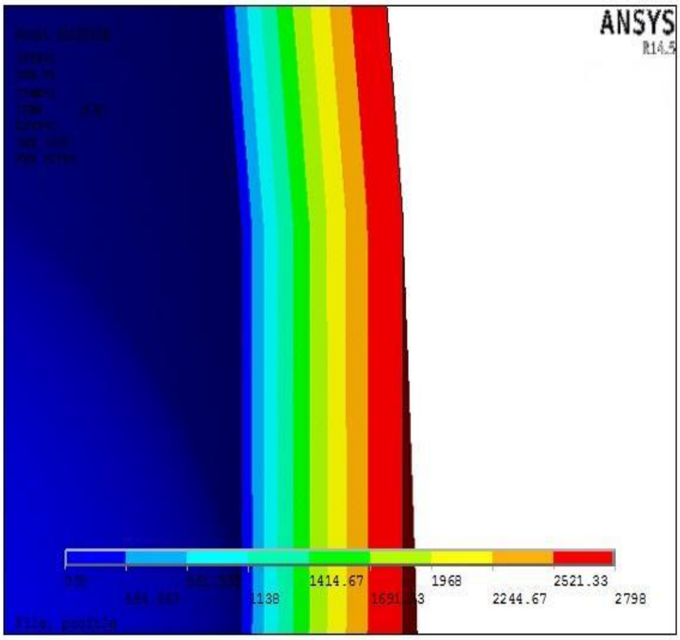

Fig. 5.27 Nodal Temperature

The above figure shows the nodal temperature of the nose cone as we have the minimum temperature at 298K maximum temperature at 2798 K the red color shows the high temperature area from 2798- 2520.22K shown from the legend table which is affected at the outer surface of the nose cone the blue color shows the minimum temperature from 575.778- 298 K shown from the legend table i.e.., inner surface of the nose cone where the human can survive and the equipment of the nose cone the decrement from red to blue shown clearly where the temperature decrement the orange color shows 2520.22- 2242.44K, the yellow color shows 2242.44-1964.67 K, the next decrement shows the 1964.67- 1686.89 K, the green color shows 1686.86- 1409.11 K, light green color shows the 1409.11- 1131.33K, cyan color shows the 1131.33- 853.556 K, light blue color shows the 575.778-853.556 K and at last the inner surface shows the minimum temperature from 575.778- 308 K. The legend table shows clearly decrement of outer surface through inner surface of the nose cone.

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COMPARISON OF RESULTS BETWEEN WITH GRAVITY AND WITHOUT GRAVITY

NAME	WITH GRAVITY	WITH OUT GRAVITY
Displacement Vector Sum	.213668	.201375
Displacement- X	.213227	.201313
Displacement –Y	.090811	.076791
Displacement –Z	.069094	.091868
Stress –X	1760.38	1348.18
Stress –Y	1394.64	1255.22
Stress –Z	1801.28	1313.52
Shear stress-XY	585.546	557.94
Shear stress-YZ	578.92	538.872
Shear stress-XZ	429.993	663.773
Von-moises stress	2038.33	16142.12

Table-5.1 Comparison of results between with gravity and without gravity

CONCLUSIONS

The above project shows the nose cone thermal and structural analysis where we can observe the deformed+ un deformed shape values are minimum, the stresses in X,Y,Z directions varied in the correct range , the shear stresses in XY,YZ,XZ directions varied in the correct range, the body temperature also varied from the outer surface to the inner surface of the nose cone i.e.., maximum to the minimum, but when we compare to the von mises stresses the failure rate is more to decrease that the thickness of the outer surface of the space cone can be increased then the failure rate can be decreased. The materials used for this nose cone are the carbon epoxy, hafnium diboride and zirconium diboride when we compare all these materials the carbon epoxy material can sustain the thermal protection system located in the inner surfaces of the CFRP.

THE FUTURE SCOPE OF THIS PROJECT

Is to decrease the stress levels at the outer surface of the nose cone. So, if we compare with the real model of the nose cone with all the supporting systems installed then the stress levels (i.e..,- von-mises stress) can be decreased. The other point is the LS-DYNA model, the Vehicle when returns to earth's atmosphere mostly fall into the seas. By applying appropriate material properties those stress levels can be analyzed. This also includes sudden cooling of the highly heated material. Another case will be of the Fluid – Structure and Thermal Interaction.

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