



Cite This Article: Yogesh Avula, Sateesh Kumar & K. Govardhan Reddy, "Design & Analysis of Folding/Unfolding of Missile Fin", International Journal of Advanced Trends in Engineering and Technology, Special Issue, January, Page Number 58-65, 2018

Abstract:

An aerospace vehicle has been conceived having two foldable fins to stabilize the vehicle during flight. Mission plan requires the fin to be folded during the process of vehicle deployment and subsequently unfold at the onset of cruise flight. The kinematic shaping of connecting rod is carried out such that it passes through a small sized cut out in the vehicle body during its motion, with least clearance. The flight vehicle has a control flap at the trailing edge of the fin which is unfolded along with the fin. Transmission of rotary control motion has been possible through a universal joint connecting the actuator and the flap in flight conditions. The kinematic and dynamic analysis has also been carried out to estimate the time of opening. Functional test of fin unfolding is carried out and unfolding time is measured from the test is compared with prediction. Strains induced during locking of fin are measured and compared with the simulation of fin locking by transient dynamic analysis.

Key Words: Missile Fin, Aerospace Vehicle, Dynamic Analysis, Fin Locking & Rotary control Motion

1. Introduction:

A fin is a thin component or appendage attached to a larger body or structure. Fins typically function as foils that produce lift or thrust, or provide the ability to steer or stabilize motion while travelling in water, air, or other fluid media. Fins are also used to increase surface areas for heat transfer purposes. Fin is located at the tail end of missile to stabilize. Fins are used on missile to provide this stability and control direction. It works in the same way as placing feathers at the tail of an arrow. The purpose of putting fins on a missile is to provide stability during flight, that is, to allow the missile to maintain its orientation and intended flight path. The purpose of missile fins is to stabilize missile and help it continue in a certain direction without wobbling, falling, flipping over or suddenly changing direction. The fins also help control the speed of the missile as it lifts into the air. Without fins, a missile would be much less aerodynamic, which would interfere with the missile ability to shoot high and straight into the air. For a missile to be successful, it must have fins that can help the missile keep its intended trajectory.

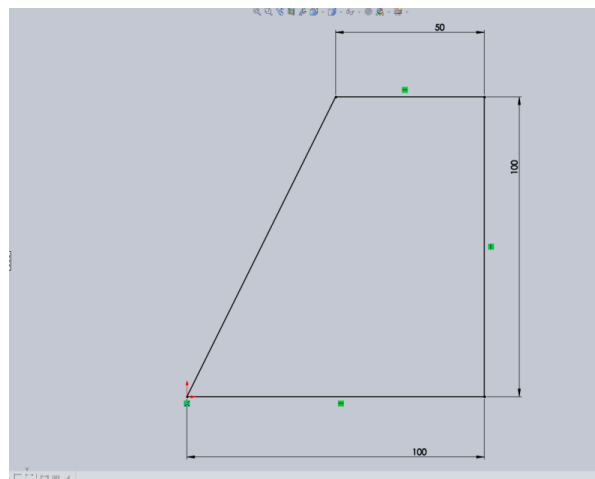
2. Designing and Modeling of a Fin Components:**A. Plan form shape of the fins:**

Figure 1: Plan form of Fin

B. Material Selection & Thickness of Fin:

Table 1: Material selection & thickness for fin

Material	Thickness
Titanium alloy	2.771 mm
Aluminium alloy	7.7159mm
Steel alloy	2.81744mm

The materials in general usage for the construction of missiles are Aluminium alloy, Titanium alloy, Steel alloy. Because of high temperatures encountered by missiles flying at high supersonic and hypersonic speeds, other type of materials is coming into more common Usage.

Table 2: Output Parameters of fin materials

Materials	Root Thickness	Approx. Weight of fin
Ti alloy	2.771 mm	50.25 gms
Al alloy	7.7159mm	37.97gms

Steel Alloy	2.81744mm	112.42ms
-------------	-----------	----------

From the above aluminium has less weight but root thickness is more and steel ally has more mass and less thickness. So, titanium alloy is suitable for fin among three titanium alloy can withstand high loads. Load = 250 N, $Y_{cp} = 54\text{mm}$, Material $\rightarrow$ Ti alloy [Commercially Pure CP-Ti UNS R50400 (SS)], Thickness: Root $\rightarrow$ 3mm, Tip $\rightarrow$ 1.5mm.

C. Design of Unfolding Mechanism:

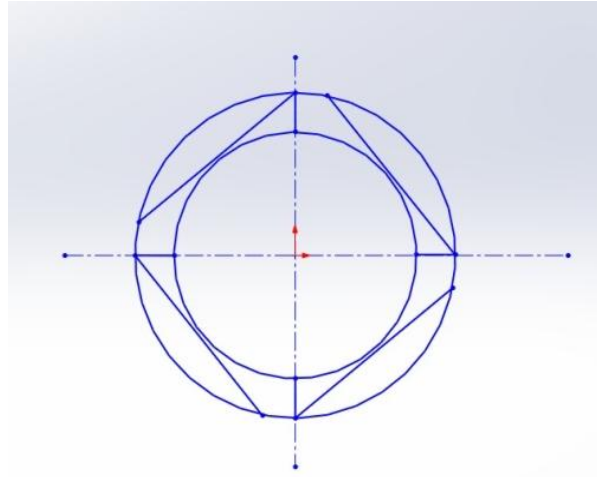


Figure 1: Folding of fin the launcher tube

The dimensions of above Fig is:

Hinge Axis=15mm

Launch tube Diameter=240mm

Fin=100mm

Missile Diameter=200mm

From these dimensions we found Fin folding angle as 110° which is an optimal angle which can exactly fit into the launcher tube, more than this angle is not possible to take in to launcher tube.

D. Design of Springs:

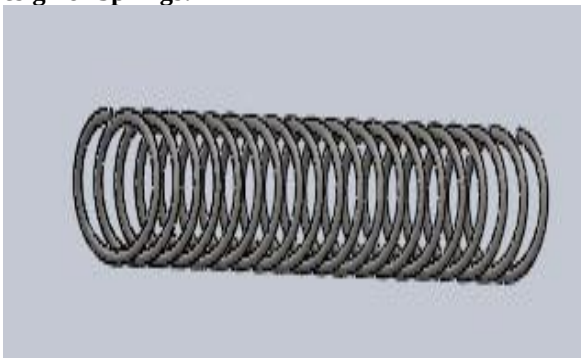


Figure: Modeling of Compression spring

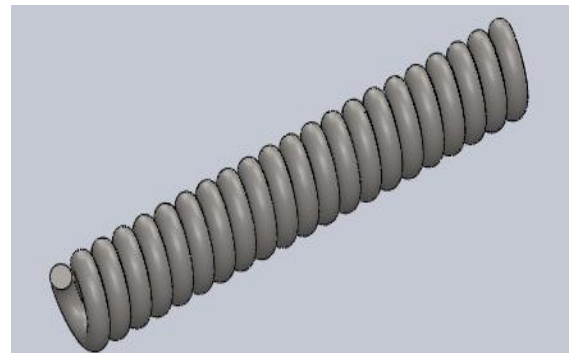


Figure 2: Modelling of Torsion Spring

E. Design of Bracket:

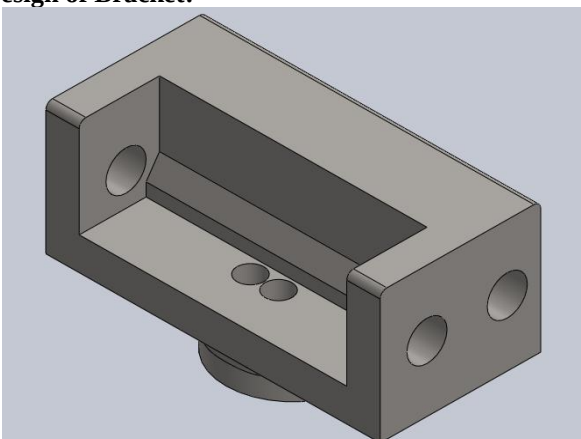


Figure 3: Modelling of Bracket

F. Design of Locking Pins:

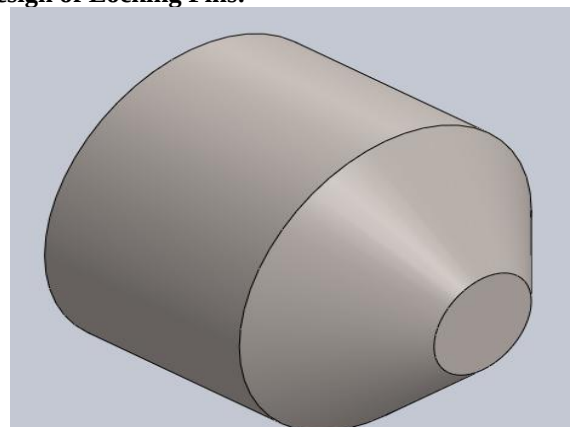


Figure 4: Modelling of Locking pins

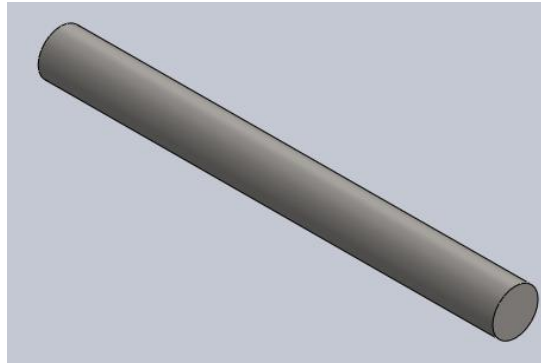
G. Design of Shaft:

Figure 5: Modeling of Shaft

Table 3: Weights of parts according to materials

Name	Material	Mass in gms
Fin	Ti Alloy	52 gms
Bracket	Steel Alloy	10 gms
Springs	Steel Alloy	6 gms
Shaft	Steel Alloy	2 gms
Pins	Ti Alloy	1 gm

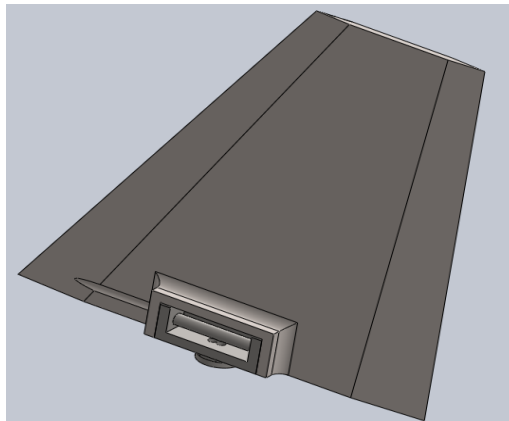
H. Assembling of All Parts:

Figure 6: Assembled Part

3. Step by Step Process of Analysis of Assembly of Fin by Ansys:

A. Building a Model: Job name a name that identifies the ANSYS job. When you define a job name for an analysis, the job name becomes the first part of the name of all files the analysis creates.

Command(s): /FILNAME: final 2

GUI: Utility Menu>File>Change Job name

Import solid works geometry file (parasolid file) by using the following menu path

File → Import → Para solid → select file (Assem 2.x-t)

Plot → volumes

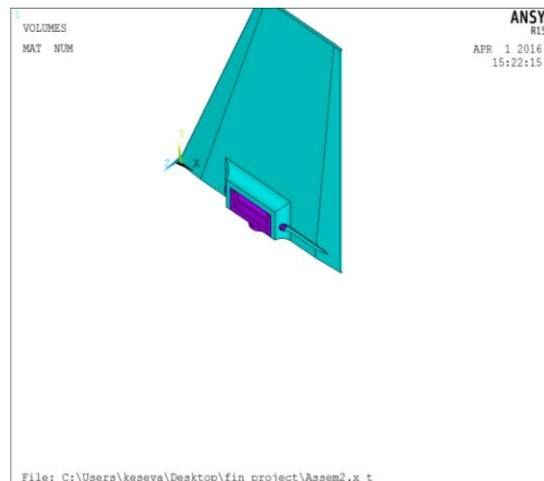


Figure 7: Imported Fin assembly from solid works to ANSYS

Then you use the PREP7 preprocessor to define the element types, element real constants, material properties, and the model geometry. ANSYS main menu – Preferences Select – STRUCTURAL – ok

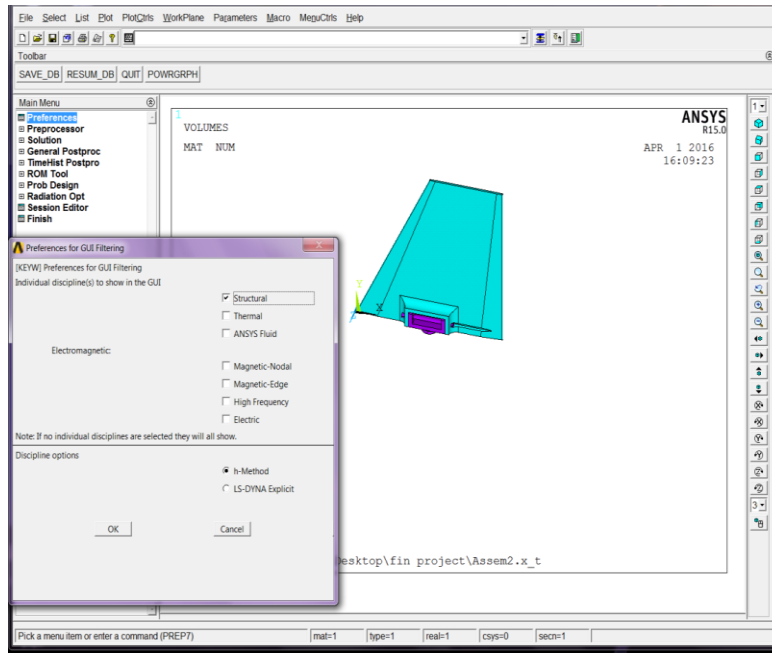


Figure 8: Selecting the structural analysis

The ANSYS element library contains more than 100 different element types. Each element type has a unique number and a prefix that identifies the element category: BEAM4, PLANE77, SOLID96, etc. The following element categories are available,

The element type determines, among other things, The degree-of-freedom set (which in turn implies the discipline-structural, thermal, magnetic, electric, quadrilateral, brick, etc.) and Whether the element lies in two-dimensional or three-dimensional space. For defining the element space,

Preprocessor → element → type → add/edit/delete → add → close

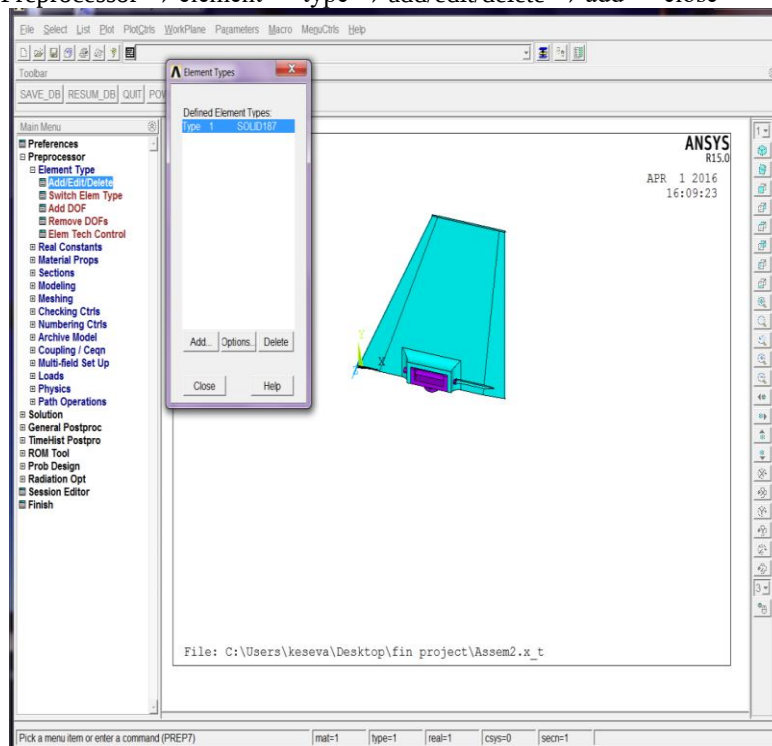


Figure 9: Selecting element type

4. Defining Element Properties for Titanium Alloy for Fin & Pin, Steel Alloy for Bracket & Shaft:

Preprocessor → Material Props → Material Models → Structural → Linear → Elastic → Isotropic,

A. For Titanium Alloy Material:

Give

Young's Modulus (EX): 1.1E+011Pa

Poisson's Ratio (PRXY): 0.3

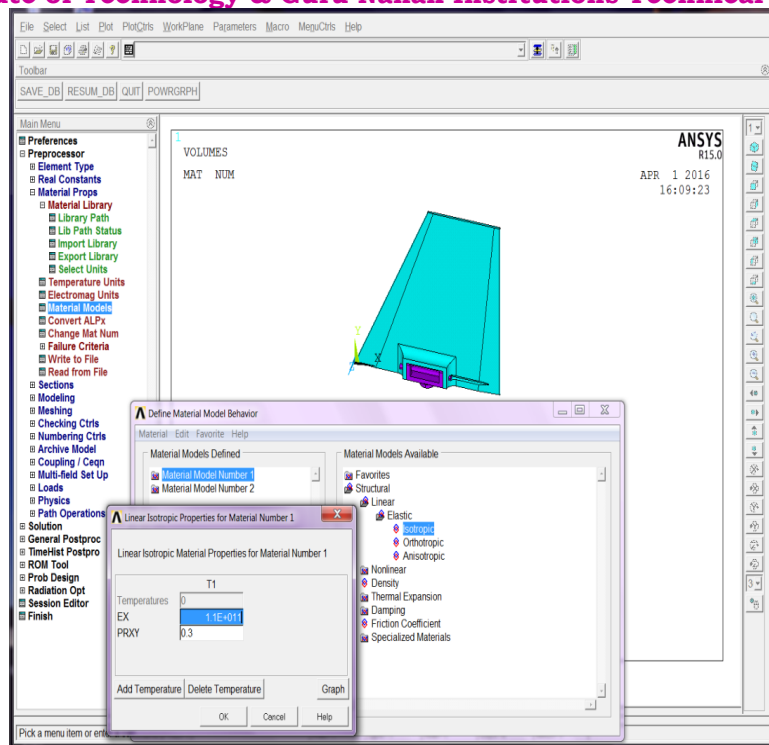


Figure 10: Giving the properties of Young's Modulus & Poisson's Ratio for Titanium Alloy material

B. For Steel Alloy material:Young's Modulus (EX): $2.1 \text{ E}+011 \text{ N/m}^2$

Poisson's Ratio (PRXY): 0.3

within brackets [1].

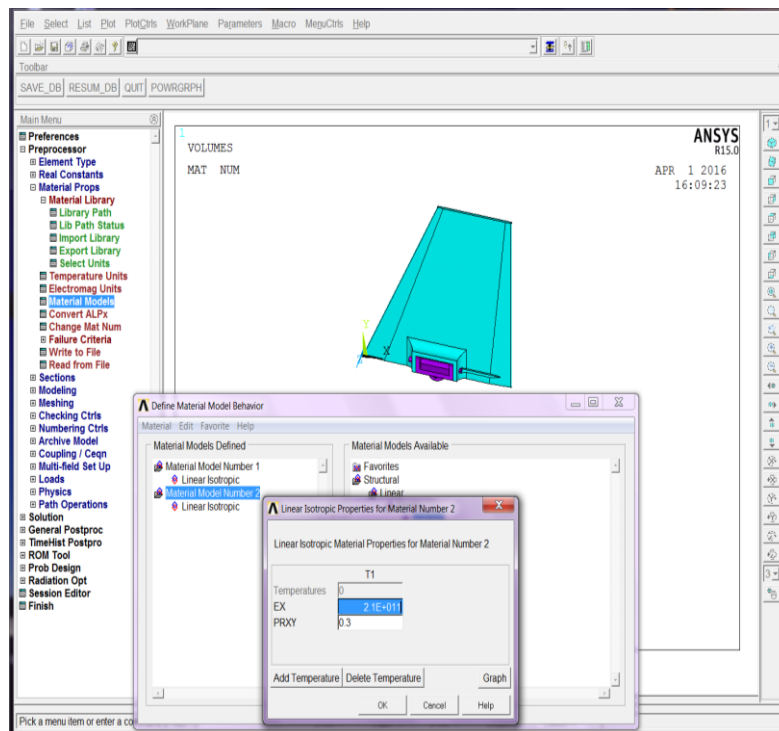


Figure 11: Giving the properties of Young's Modulus & Poisson's Ratio for Steel Alloy material

5. Meshing and Applying Boundary Conditions:

preprocessor → Meshing → Mesh Tool → smart size → 6; Mesh Volumes → Pick volume → OK

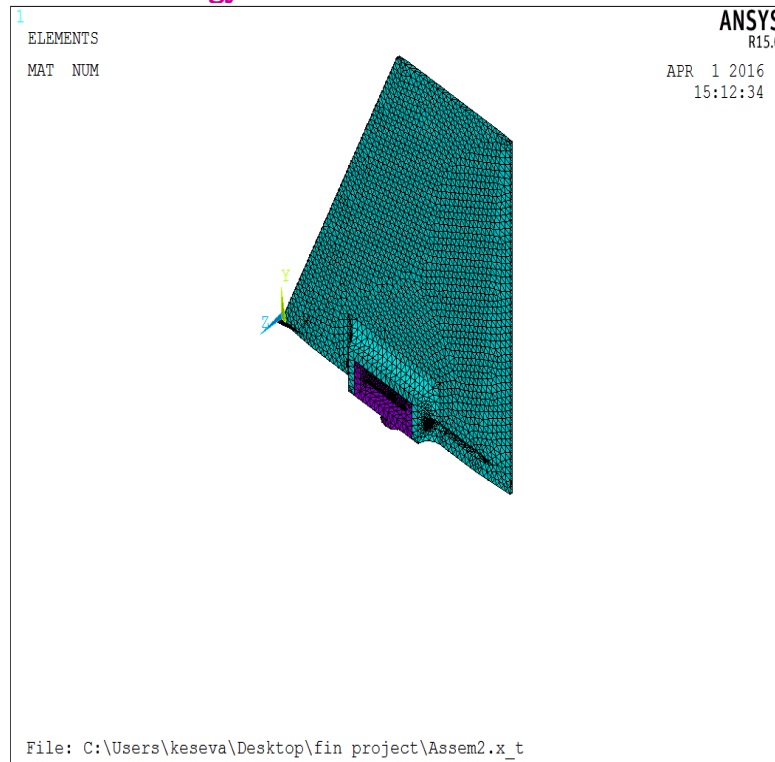


Figure 12: Meshing process for assembly

Two important load-related terms you need to know are load step and sub step. A load step is simply a configuration of loads for which you obtain a solution. Sub steps are incremental steps taken within a load step.

Load = 250 N

Menu path for apply load for the volumes

F, NODE (0.05, 0.05, -1.5)FZ, 250

Then go to Solve → Current LS → OK

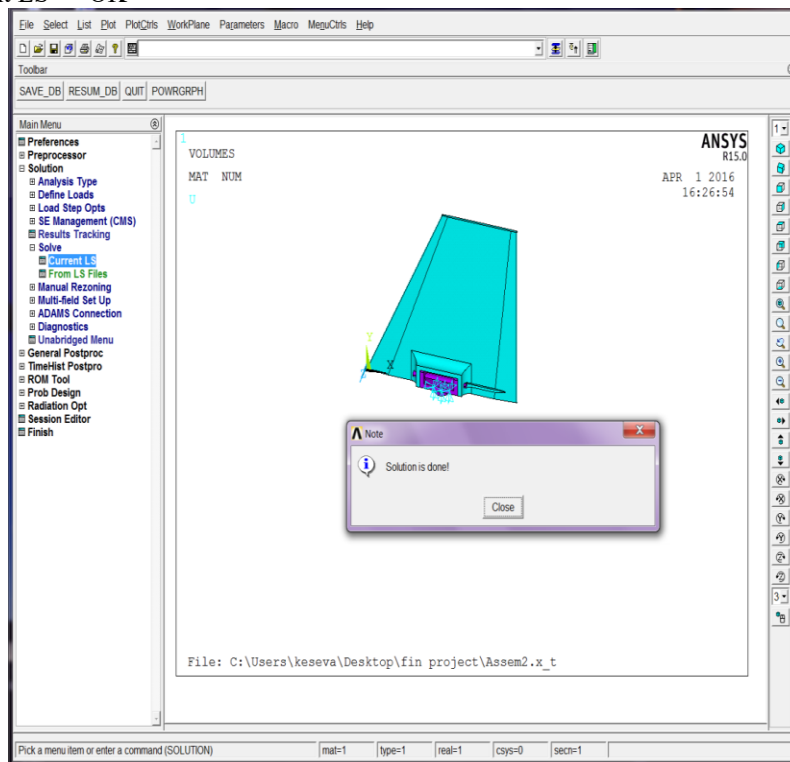


Figure 13: Solution of the Assembly of fin

General Postproc → Query Results → sub grid solution → Pick any one displacement → apply → Ok

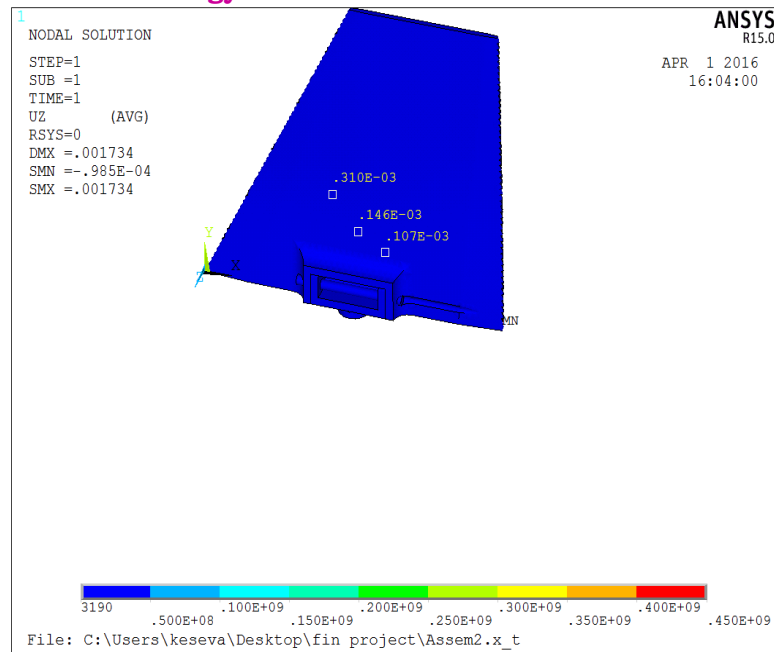


Figure 14: Checking displacement at a point

General Postproc → Query Results → sub grid solution → Pick any one displacement → apply → Ok

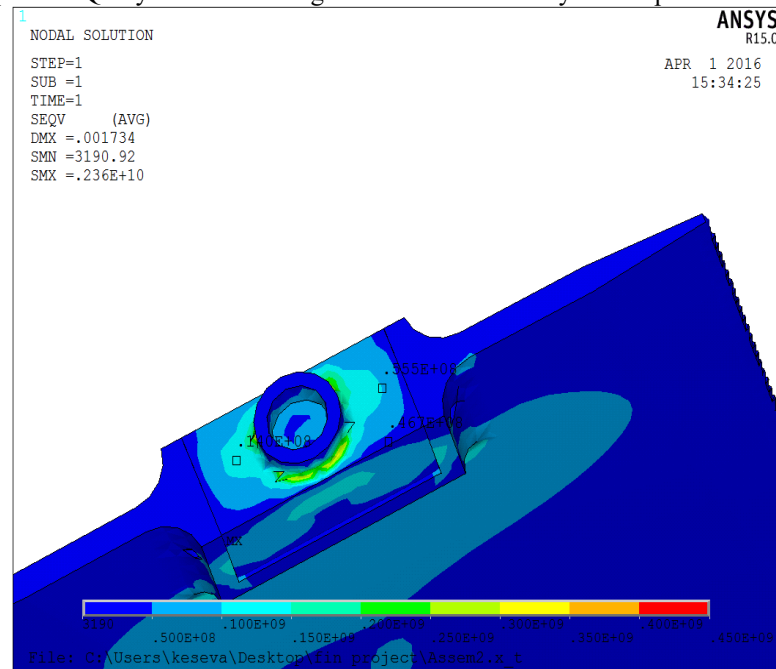


Figure 15: Checking stress at a point

Stress;
$$\sigma = \frac{m *}{l}$$

Where

$$m = p * l$$

P= Load applied=250 N

l = distance from which load acting on surface=50mm

y=t/2=3/2=1.5mm=distance of extreme fibre from neutral axis

b=100mm=section width

d=3mm= section depth

By substituting the above value

$$\text{Stress; } \sigma = 0.83 * 10^8 \text{ N/m}^2$$

6. Conclusion:

As Control Surface/Fin is one of the critical components in the missile, structural design of Fin will be done by considering various aspects such as Strength, Stiffness etc. In this project, Fin is designed which is capable of taking all Aerodynamic load during its service. Unfolding mechanism also designed to facilitate the launch tube for compactness with

International Journal of Advanced Trends in Engineering and Technology**Impact Factor 5.965, Special Issue, January - 2018****1st International Conference on Innovations in Mechanical Engineering (ICIME-2018)****On 5th & 6th January 2018 Organized By****Guru Nanak Institute of Technology & Guru Nanak Institutions Technical Campus, Hyderabad**

minimum protrusions. All the components in this fin assembly having sufficient factor of safety to include uncertainties in load, material etc.

7. Future Scope:

Fin unfolding mechanism is very critical in respect of unfolding time. Unfolding mechanism can be simulated and time will be estimated using ADAMS software. Fin assembly can be fabricated and unfolding time can be tested. Structural Load test on the fin can be done to validate the design.

8. References:

1. M. C. Meijer. Aeroelastic prediction methods in supersonic flows for missile design. MSc dissertation, University of the Witwatersrand, (2014)
2. Solid Works Flow Simulation (2010)
3. M. J. Lighthill. Oscillating airfoils at high Mach number. Journal of the Aeronautical Sciences, Vol. 20, No. 6, pp 402-406 (1953)
4. H. Ashley. and G. Zartarian. Piston theory - a new aerodynamic tool for the aeroelastician. Journal of the Aeronautical Sciences, Vol. 23, No. 12, pp 1109-1118, (1956)
5. A. C. Chabalko. Identification of transient nonlinear aeroelastic phenomena. PhD thesis, Virginia Polytechnic Institute and State University, (2007)
6. J. J. Mc Namara, A.R. Crowell, P.P. Friedmann, B. Glaz and A. Gogulapati. Approximate modeling of unsteady aerodynamics for hypersonic aeroelasticity. Journal of Aircraft, Vol. 47, No. 6, pp 1932-1945(2010)