Structural Analysis of Optical Locator System

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Abstract - *With the improvement in technology, the control and defensive systems employed in aircrafts have advanced positively over the years since the first flight. The weapon systems and avionics have upgraded to suit the latest multirole aircrafts with minimal dependency on the ground stations. Optical Locator System is one such system uniquely designed for defense aircrafts to carry out multirole missions without depending on ground-controlled interception systems. This OLS system allows an aircraft to detect and aim the targets, but unlike the traditional radar system, doesn't emit signals or leave any traces. The OLS which is usually mounted on supersonic aircrafts houses powerful optics in it. When the aircraft cruises at such high-speeds, the OLS body which is made of Zinc Selenium tends to deform under high forces. The current study focuses on calculating the force exerted on the body and consequently calculating stresses, deformation and other parameters.*

Key Words: **Defensive systems, optical Locator system, avionics, powerful optics, supersonic aircraft, zinc selenium.**

1. INTRODUCTION

The OLS system is usually mounted on fighter jets which attain Mach speeds at altitude around 35000 to 40000 feet. While cruising, an aircraft is said to be experiencing four forces. Primarily, thrust provided by engines and drag opposing thrust produced, lift generated by the wings and other control surfaces which is opposed by the weight of the aircraft. The drag force which opposes the motion of the aircraft is one dominant force which is the cause for deformation of systems mounted on the aircraft. Firstly, aerodynamic analysis is carried out on the body, where the co-efficient of drag (CD) is estimated. Later the obtained CD is substituted to the drag equation to obtain drag force acting on the body. Another approach is to calculate the varying pressure acting on different points of the body and map the pressure values onto the OLS body to obtain deformation. After analysing in perspective of both the methods, the results are compared and it was found that the design was safe on examining the safety factor contour.

2. DESIGN AND ANALYSIS

The OLS body was designed on the designing software Solidworks. It consists of a mount which is attached on to the aircraft, gasket, O-ring, and the hemisphere-shaped transparent dome. The dome is made of Zinc Selenium whereas the mount and gasket are of titanium alloy (Ti6Al4V).

The analysis was conducted on the software ANSYS, where it was meshed with hex dominant meshing and analyzed under Fluent.

The following boundary conditions at the inlet with pressure outlet and reference values were considered.

Table -1: Boundary Conditions

Inlet	Pressure far field
Gauge Pressure (Pa)	19400
Mach Number	3
Temperature (K)	216.7

Table -2: Reference Values

Area (m^2)	0.5925
Density (kg/m^3)	0.312
Enthalpy (j/kg)	309613.6
Pressure (Pa)	19400
Temperature (k)	216.7
Velocity (m/s)	884.97
Kinematic Viscosity (m^2/s)	4.557e-05
Thermal Conductivity (w/m-k)	1.952e-02

2.1 Properties of materials used for the OLS body

The material of the OLS dome is Zinc selenide, and for the supporting components like mount, gasket and O ring is Titanium alloy- Ti6Al4V.

Table -3: Material Properties

Material Name	Zinc selenide	Titanium Alloy
Density (kg/m^3)	5420	4430
Youngs modulus (MPa)	67200	114000
Poisson ratio	0.28	0.31
Tensile Yield Strength (MPa)	13	880

3. METHODOLOGY

Primarily, the turbulence model has to be decided. After some research, it was found that Spalart Allmaras and k-ω Shear Stress Transport (SST) suited our analysis. Spalart Allmaras is a turbulence model that is majorly known for solving aerodynamic problems like obtaining lift and drag co-efficient and forces while k-ω Shear Stress Transport (SST) model is employed to detect wall properties like temperature, pressure and boundary layer parameters. So, the OLS body mounted on the flight experience drag force which deforms the OLS body. The OLS body was enclosed in an enclosure of atmospheric air with the above-mentioned properties. Velocity of Mach 3 in terms of m/s had to be input to the solver. i.e. 1029m/s. But as altitude increases the speed of sound decreases. So, the speed of mach3 at an altitude of 40,000ft was found to be 885m/s. The flow is considered to be compressible as the inlet velocity is greater than 200m/s or mach0.6 In the Spalart Allmaras and k-ω Shear Stress Transport (SST) method, pressure-based solver and further a coupled scheme was chosen. The coupled algorithm solves the momentum and pressure-based continuity equations together avoiding longer calculating time. For high velocity and high turbulent compressible flow problems, the density is considered to be ideal and viscosity is switched on to Sutherland. The Sutherland law develops a relationship between dynamic viscosity and temperature yielding accurate and error less results over a wide range of temperatures. The inlet is considered to be pressure far field type wherein the user gets an option to directly input the Mach number velocity which is Mach 3, gauge pressure -19400Pa and operating temperature 216.7K at 40000ft altitude. The outlet is by default set to pressure outlet type.

The drag force is calculated by the equation,

$D = C_d * \rho * (v^2/2) * A$

D is the drag force

Cd is the o-efficient of drag

ρ is density

V is the velocity

A is the reference area of the body

4. MESHING

The meshing was done with a sphere of influence to capture the boundary layer properties effectively:

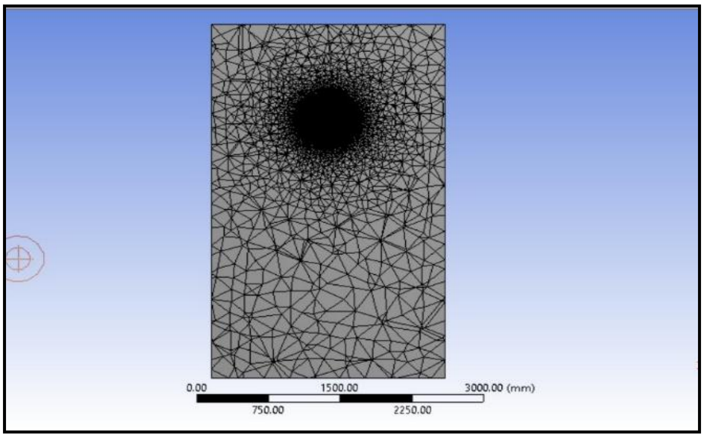

Fig -1: Mesh for Fluent Analysis

4. OUTCOME

The following results were obtained after the simulation in Ansys Fluent:

$C_d = 0.701$

$F_d = 50774.15$ N

4.1 Pressure contours are as follows:

The figure shows the contour of pressure where the shock wave can be noticed generated due to high speed.

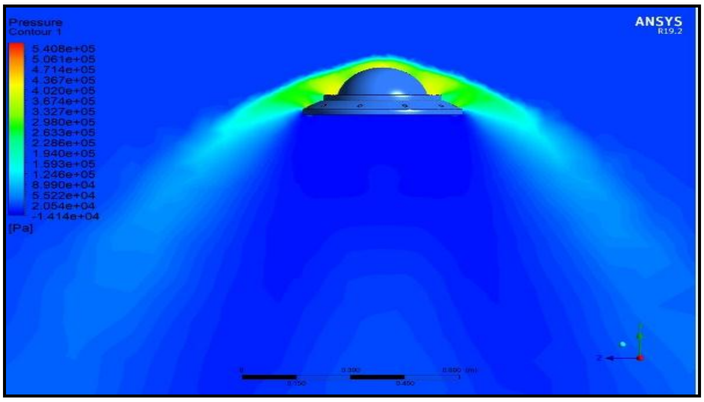

Fig -2: Pressure Contour over OLS

The maximum pressure on the body is 0.540 MPa

4.2 The Velocity contours are as follows:

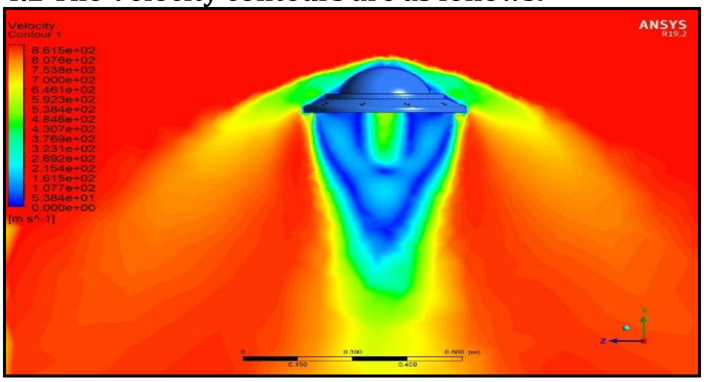

Fig -3: Velocity Contour over the OLS

4.3 The Temperature contours are as follows:

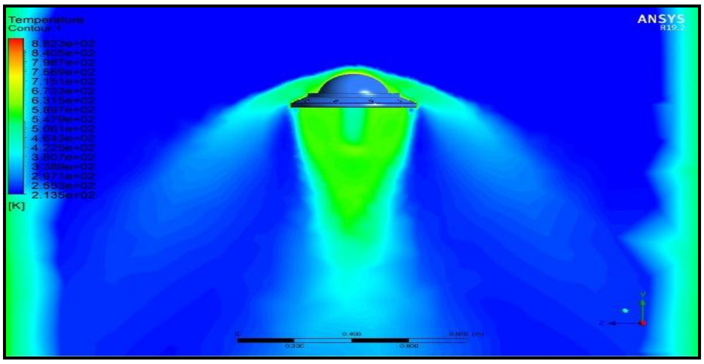

Fig -4: Temperature Contour over OLS

The maximum temperature surrounding the body was found to be 882 k

4.4 Temperature on the OLS body

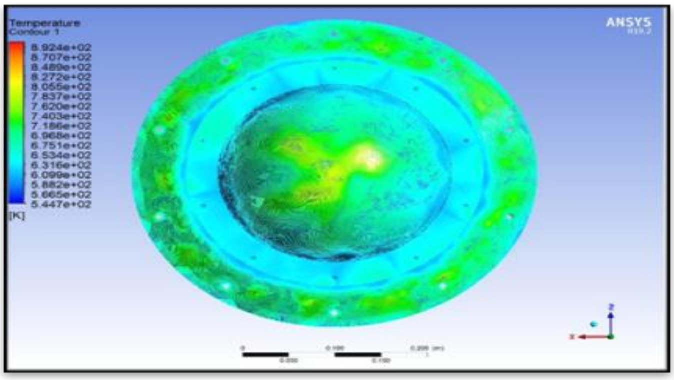

Fig -5: Temperature on OLS body

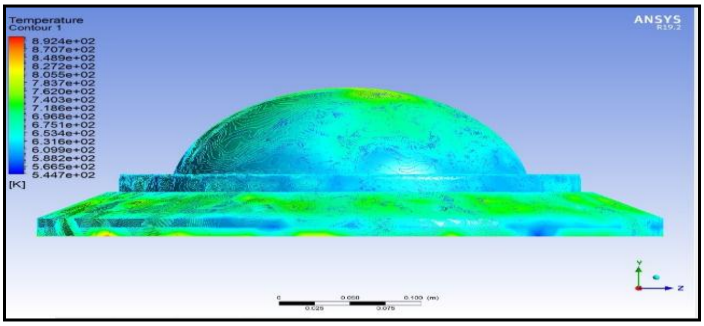

Fig -6: Temperature on OLS body (side View)

The max temperature of 892K was only found on some spots on the body, while the average temperature is 620K.

5 THE DEFORMATION IS CALCULATED IN TWO METHODS:

1. By applying the drag force on the body
2. By importing the pressure on the body

5.1 By Applying force on the body:

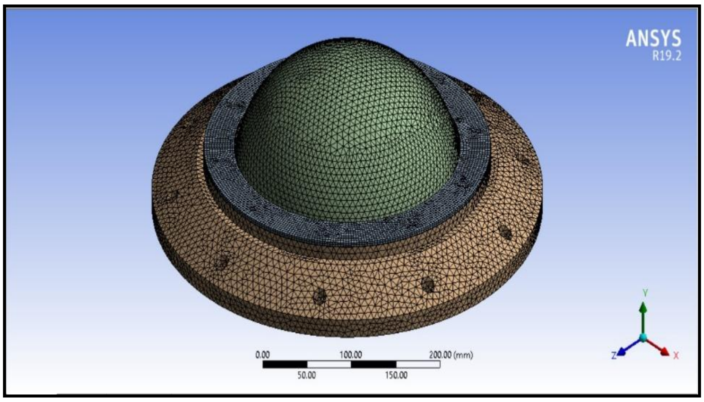

Fig -7: Mesh for Static Structural Analysis

5.1.1 Deformation

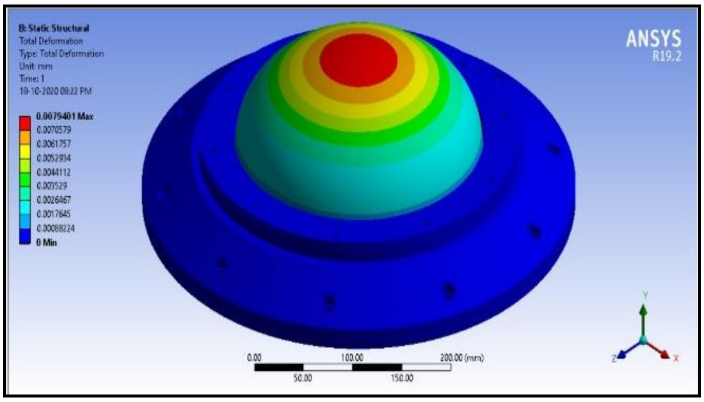

Fig -8: Deformation of OLS

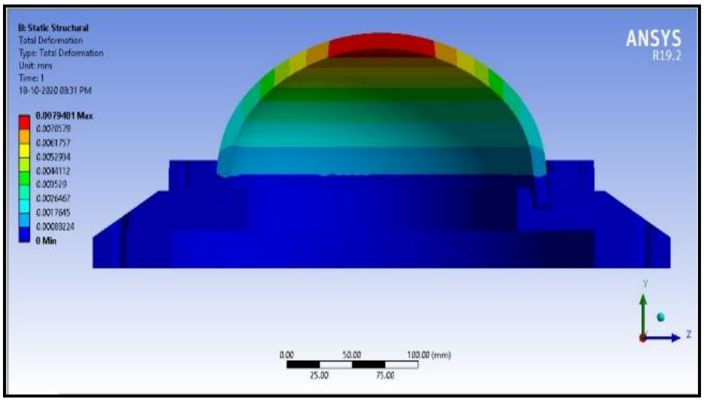

Fig -9: Deformation of OLS (Cross Section View)

The maximum deformation occurs at dome- 0.0079mm and minimum deformation occurs at gasket.

5.1.2 Von Mises Stress

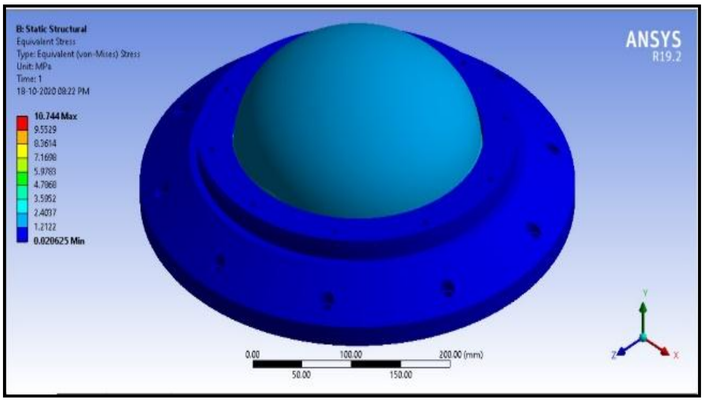

Fig -10: Von Mises Stress on OLS

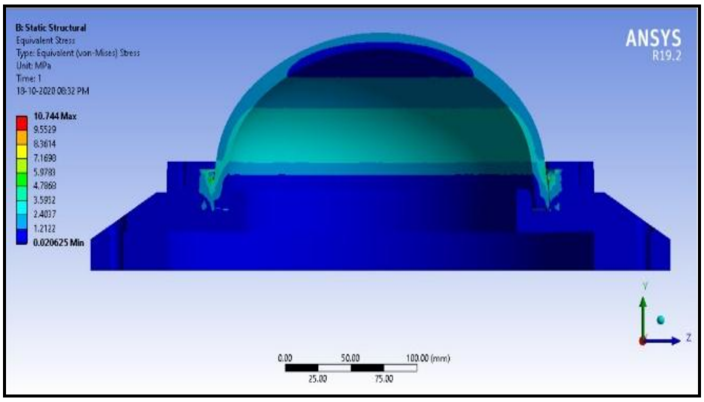

Fig -11: Von Mises Stress on OLS (Cross Sectional View)

The maximum Von Mises stress occurs at O ring 10.74MPa and Minimum occurs at mount.

5.1.3 Maximum Principal Stress

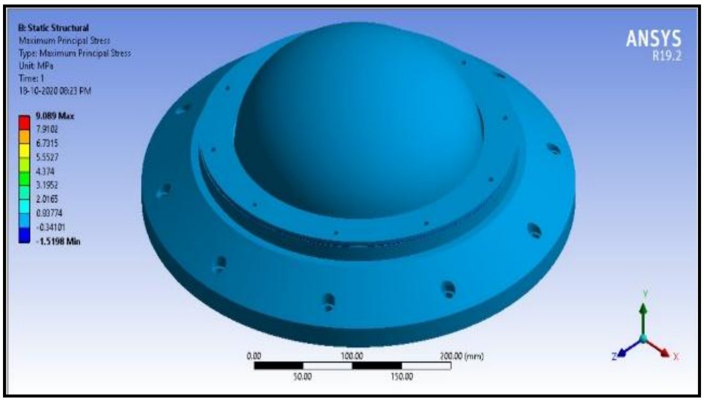

Fig -12: Maximum Principal Stress on OLS

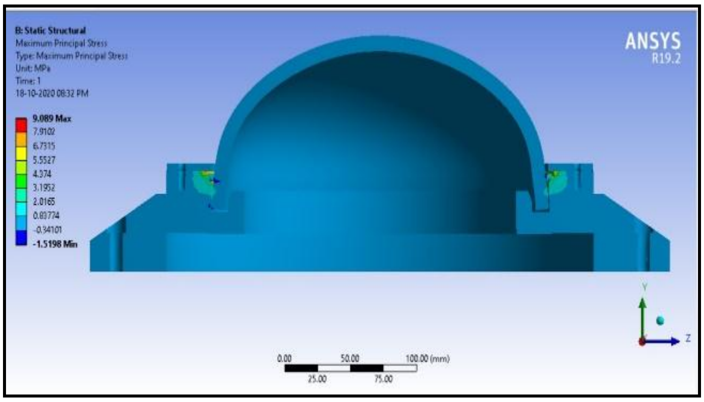

Fig -13: Maximum Principal Stress (Cross Section View)

The maximum principal stress occurs at O rings 9.089MPa and minimum at mount

5.1.4 Maximum Shear Stress

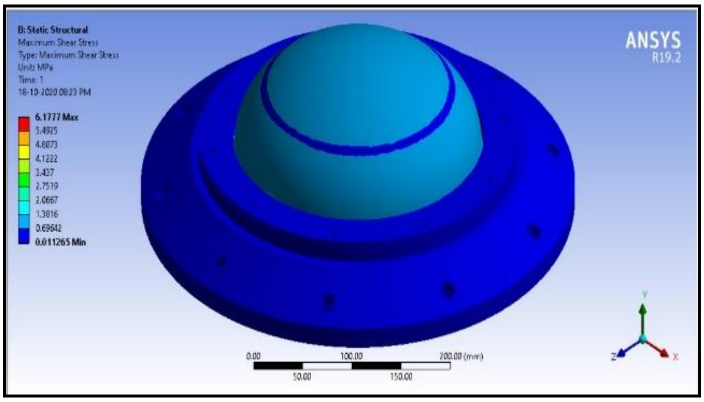

Fig -14: Maximum Shear Stress on OLS

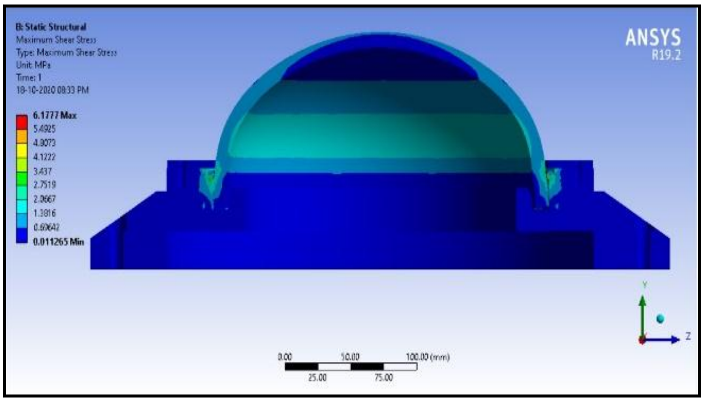

Fig -15: Maximum Shear Stress (Cross section view)

The maximum shear stress occurs at O ring- 6.177MPa and minimum occurs at mount

5.1.5 Safety factor

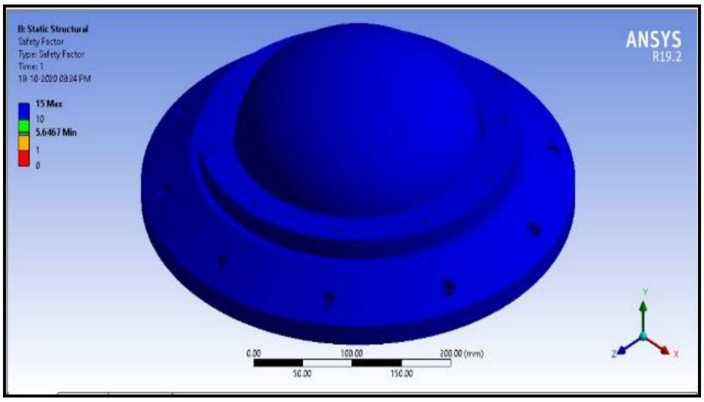

Fig -16: Safety Factor on OLS

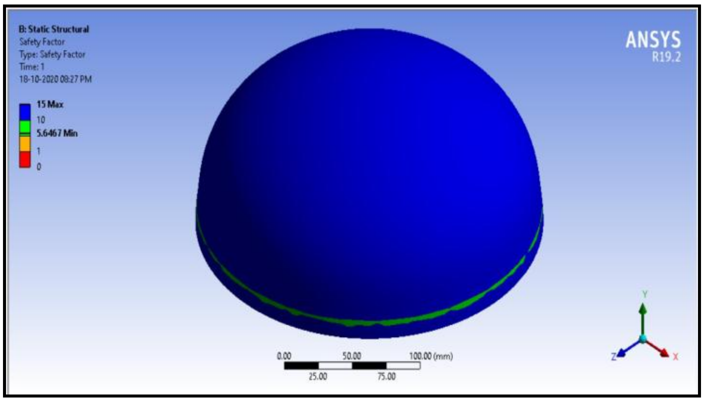

Fig -17: Safety Factor on OLS dome

The safety factor contour shows that the body possesses a minimum safety factor of 5.6 at any point. The minimum safety factor occurs on the edges dome.

Table -04 Results of OLS Body

Deformation (mm)	0.0079	
Equivalent Von – Mises stress (MPa)	10.74	
Maximum Principal Stress (MPa)	9.089	
Maximum Shear Stress (MPa)	6.177	
Safety Factor	Max: 15	Min: 5.646

5.2 By Importing Pressure on the Body

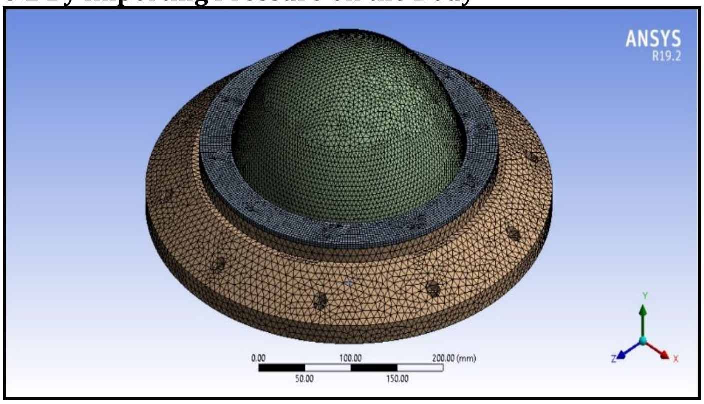

Fig -18: Mesh for Static structural Analysis

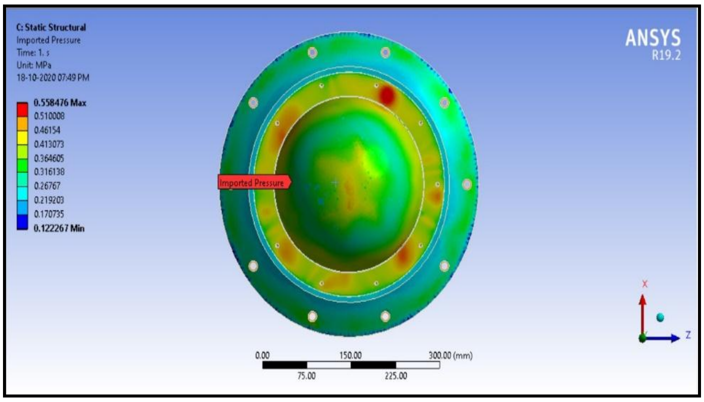

Fig -19: Pressure Imported from Fluent

5.2.1 Deformation

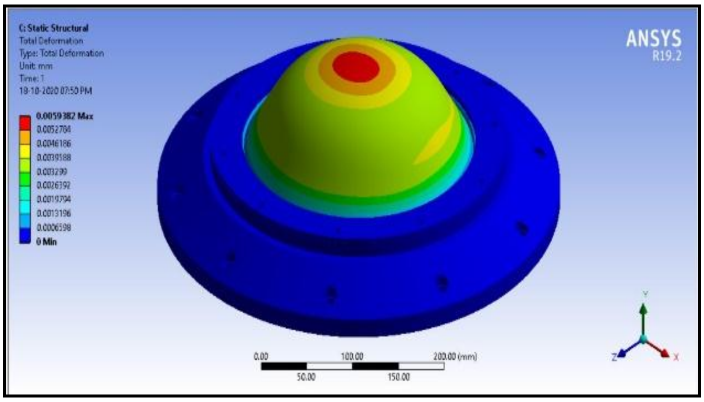

Fig -20: Deformation of OLS

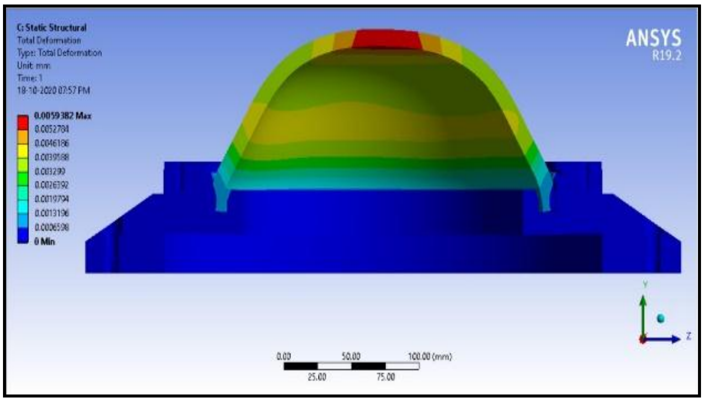

Fig -21: Deformation of OLS (Cross Section View)

Maximum deformation occurs at dome and minimum occurs at gasket

5.2.2 Von Mises Stress

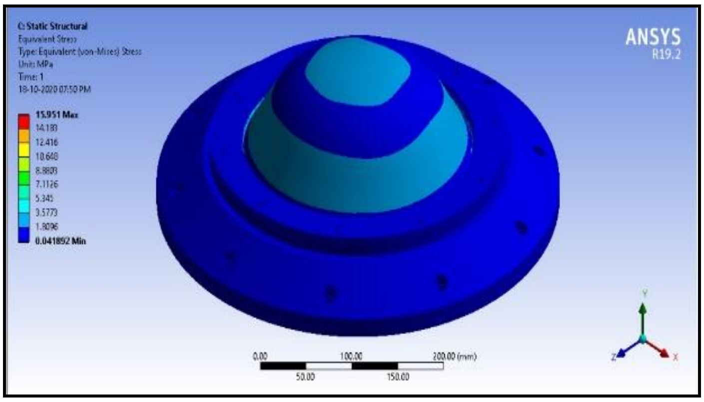

Fig -22: Von Mises Stress on OLS

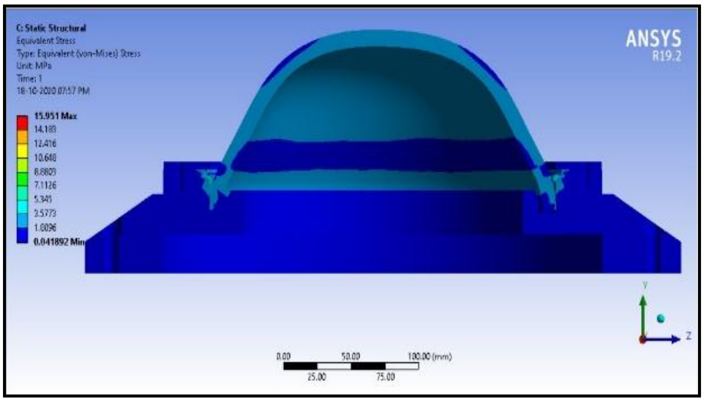

Fig -23: Von Mises Stress on OLS (Cross Section OLS)

Maximum Von Mises Stress occurs at O Ring 15.95 MPa and minimum occurs at the Mount

5.2.3 Maximum Principal Stress

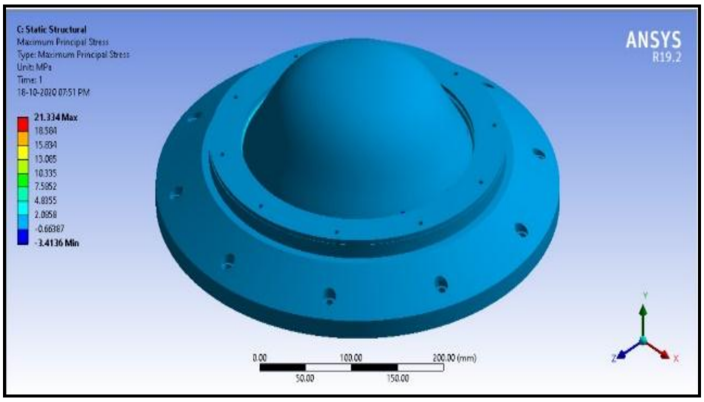

Fig -24: Maximum Principal Stress on OLS

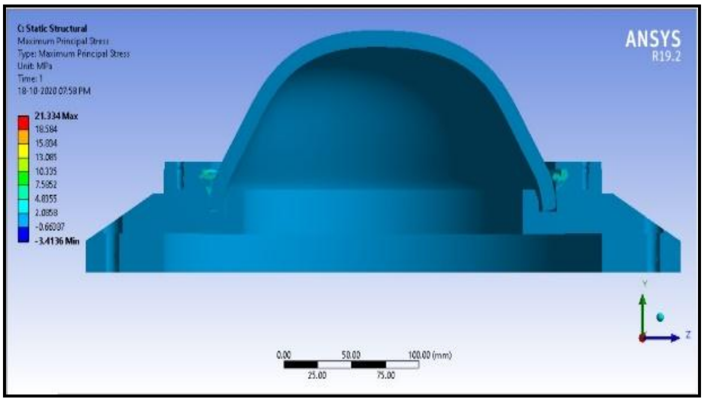

Fig -25: Maximum Principal Stress (Cross Section View)

Maximum principal stress occurs at O Ring 21.33MPa and minimum occurs at O ring

5.2.4 Maximum Shear Stress

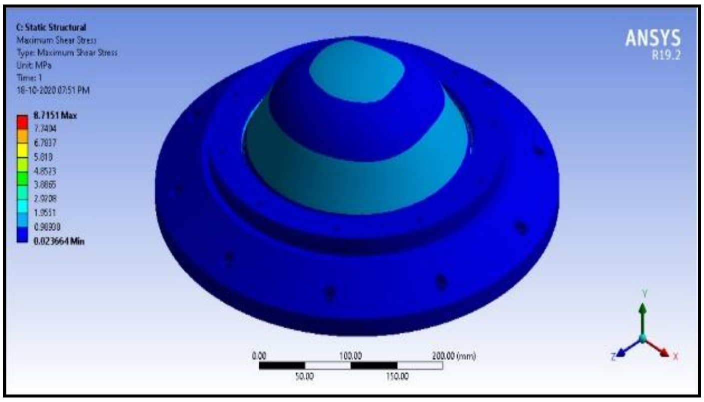

Fig -26: Maximum Shear Stress on OLS

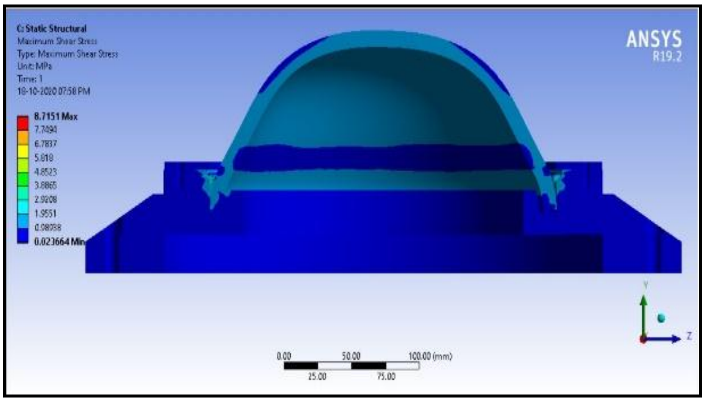

Fig -27: Maximum Shear Stress (Cross Section View)

5.2.5 Safety Factor

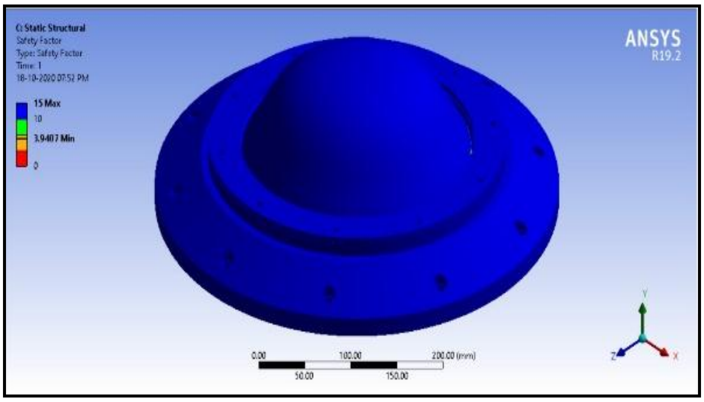

Fig -28: Safety factor of OLS

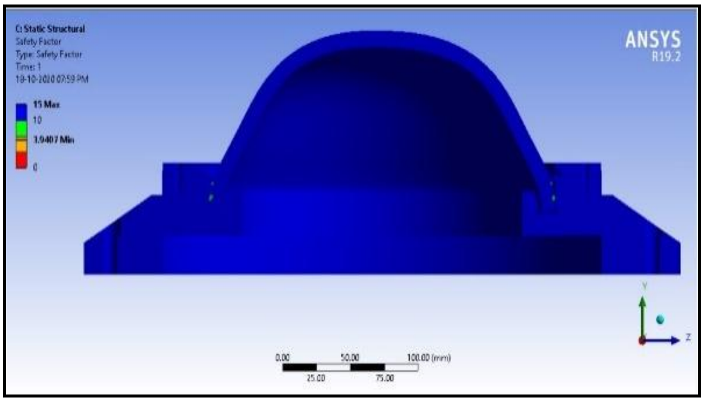

Fig -29: Safety Factor of OLS (Cross Section view)

The safety factor contour shows that the body possesses a minimum safety factor of 3.9 at any point.

Table -04 Results of OLS Body

Deformation (mm)	0.00593	
Equivalent Von – Mises stress (MPa)	15.951	
Maximum Principal Stress (MPa)	921.334	
Maximum Shear Stress (MPa)	8.7151	
Safety Factor	Max: 15	Min: 3.9407

6. CONCLUSIONS

Both the approaches, force approach and pressure approach, after analysis proved that the OLS body mounted on a supersonic aircraft cruising at 40000ft altitude in Mach3 speed undergoes deformation, but is safe with a minimum safety factor of 3.9 which is derived out of the pressure approach.

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BIOGRAPHIES

Chethan R Patil, born on 20 March 1999. He is currently pursuing 3rd year B. Tech Mechanical Engineering at Presidency University, Bengaluru. His major field of interests are Aerospace, Astrophysics and Aerodynamics. He has completed a Design Project at Indian Space Research Organization, ISRO, Bengaluru. He has also published a paper on Turbine blade cooling and a paper on Aerodynamic Analysis of airfoils.

Chaitanyaa K K, born on 21 November 1999. He is currently in his 3rd year Bachelors of Technology in Mechanical Engineering from Presidency University, Bengaluru, Karnataka, India. His major field of interests are Fluid mechanics, Aerospace and Thermal Sciences. He has Published a research paper on Heat Exchangers and a paper of Aerodynamic Analysis of Airfoils.

P. Selvaraj at present designated as Group Head, mechanical systems and facilities group of Laboratories for Electro Optics Systems, Indian Space Research Organization, Bangalore. He graduated in Metallurgical Engineering from Regional Engineering College, Trichy. He is thirty-three years experienced in Design and Development of Opto-Mechanical and Electro-Mechanical instrument systems for various satellites of India. He has many publications to his credit. He was awarded twice the ISRO excellence award.