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Linear Analysis of a Cryo Propellant Tank

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***Abstract*— There are many stages for satellite launch vehicles. Among them cryo stages use fuels or oxidizers at low temperatures. Propellants are stored in propellant tanks. Tank will be subjected to pressure loads. A cryo propellant tank having liquid hydrogen was modelled axisymmetrically using ANSYS. Linear analysis is performed on it. From the results it was obtained that the equivalent von Mises stress exceeded ultimate tensile strength.**

***Keywords*— Propellant, linear analysis, yield strength, axisymmetric modeling, plane 82.**

I. INTRODUCTION

The fuel and an oxidizer in the launch vehicles are stored in propellant tanks. Common materials used for the tank are aluminum, alloy steel, titanium and stainless steel. Tanks can be spherical in shape, cylindrical in shape with half ellipses at the ends, and in irregular shapes. The tanks having cryogenic propellants should be thermally insulated.

In this paper finite element modelling of a tank containing liquid hydrogen tank is done using ANSYS. Plane 82 element was used for the model. Linear analysis was done in the tank. Hoop, meridional and von Mises stresses and radial displacement in the tank were found out.

II. CONFIGURATION OF LH2 TANK

Since liquid hydrogen is having very low density, tank should be bulky. AA2219 copper rich aluminium alloy is used for the tank. It is cylindrical with spherical end domes. There is a cylindrical shell, end domes, end rings and manhole reinforcement rings for the tank. Fig 1 shows the full tank depicting the parts. Fig. 2 shows a dome petal of the tank. At the weld regions of dome, a thickness of 4.4 mm is provided. Away from welded regions of the dome, thickness is reduced to 2 mm. Fig 3 & 4 shows the developed view (inside) of cylindrical shell & section A-A of cylindrical shell respectively. At the weld regions of cylindrical shell, a thickness of 7 mm is provided. Away from weld regions of the shell, thickness is reduced to 2mm. The cylindrical shell and domes are connected by using Y-shaped rings. Fig. 5 shows the cross section of the end ring.

At the centre of fore end dome, a manhole cover is provided. Fig. 6 shows the cross section of manhole reinforcement ring to which the manhole cover is welded to.

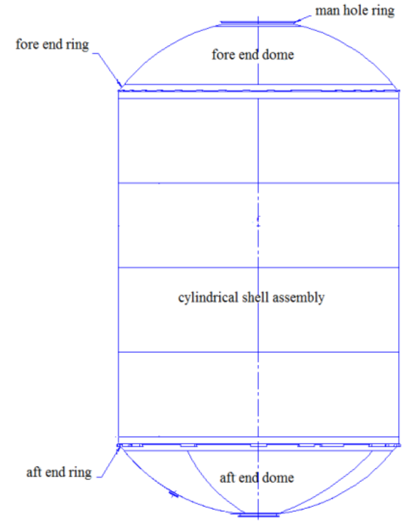

Fig. 1 LH2 tank assembly

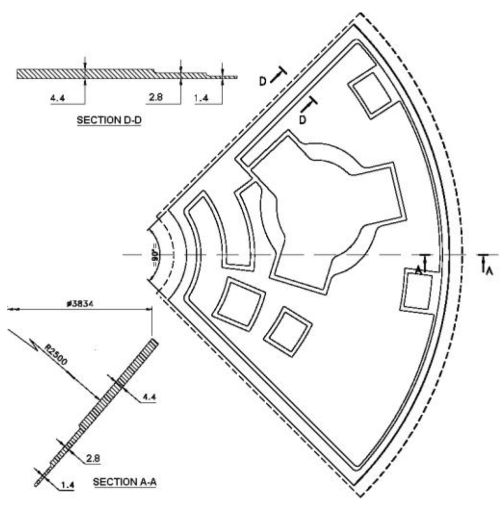

Fig. 2 Typical dome petal

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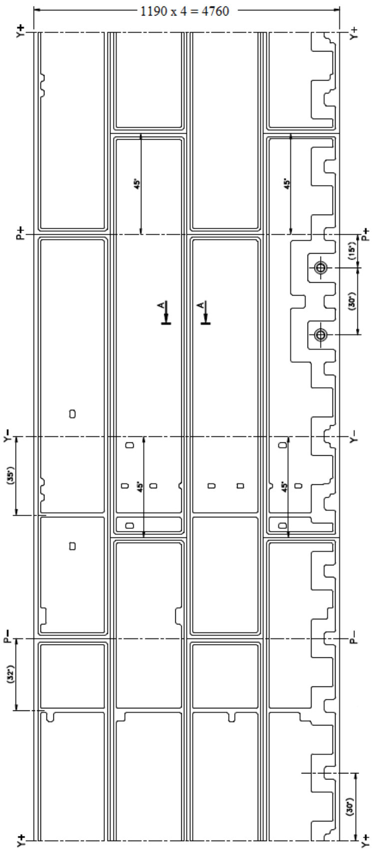

Fig. 3 Developed view (inside) of cylindrical shell

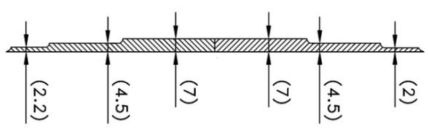

Fig. 4 Section A-A of cylindrical shell

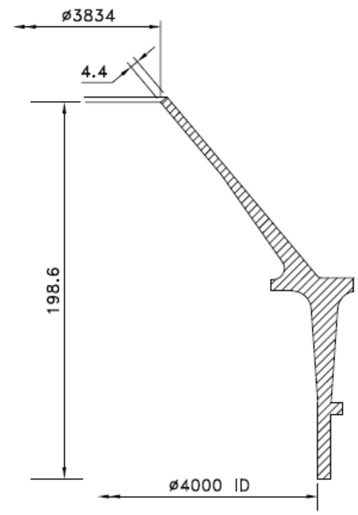

Fig. 5 Cross section of end ring

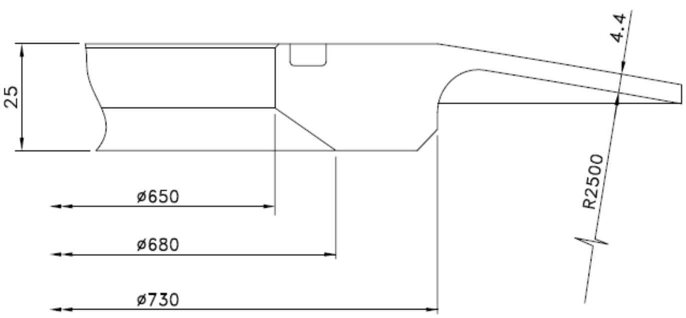

Fig. 6 Cross section of manhole reinforcement ring

III. AXISYMMETRIC MODELLING

The axis of symmetry is global cartesian Y axis. +X direction is taken as the radial direction.

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Axisymmetric PLANE 82, 2-Dimensional, 8 noded structural solid elements were used for the model. Only half portion of the tank is modeled because of symmetry. An internal pressure of 3.4 bar was applied. At the global cartesian Y axis, few nodes were constrained in X direction. Also few nodes at the bottom of the aft end ring were constrained in Y direction. The tank with boundary conditions is shown in Fig.7. Fig. 8 shows the internal pressure distribution in the tank. Table 1 gives the material properties of tank.

TABLE I
MATERIAL PROPERTIES

Property	Value
Young's modulus	71000MPa
Poisson's ratio	0.33
Tangent modulus	1420MPa
Yield strength	350MPa
Ultimate strength	440MPa

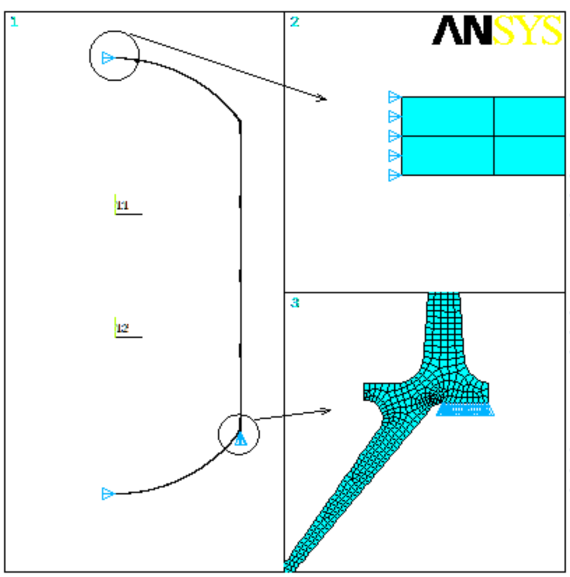

Fig. 7 FE model of tank

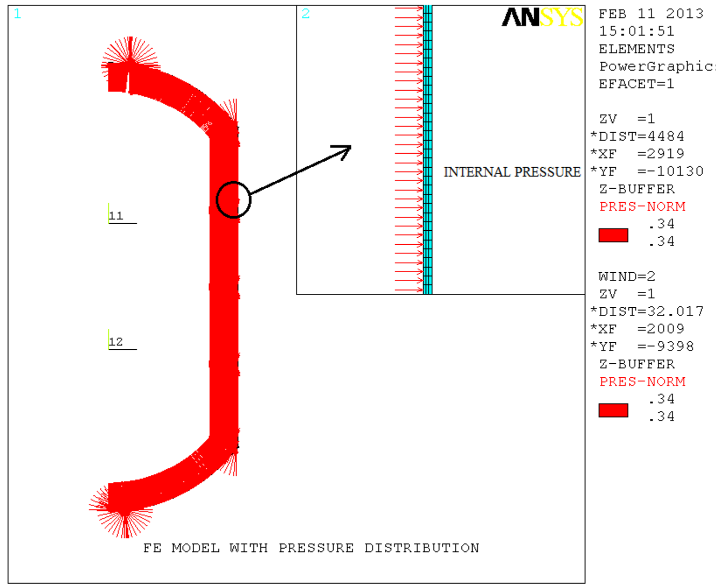

Fig. 8 Pressure distribution

IV. Results And Discussion

After performing the linear analysis following results were obtained. Fig. 9 shows the deformed shape of tank. Fig. 10, 11 and 12 shows the hoop, meridional and equivalent(von Mises) stress plots respectively. Fig. 13 shows the radial displacement of the tank. Table 2 shows the results.

TABLE II
ANALYSIS RESULTS

Parameters	Values
Hoop stress	354.813MPa
Meridional stress	160 to 180MPa
Maximum equivalent stress	671.677MPa
Maximum radial displacement	8.244mm

- Maximum equivalent stress is located at the chemical milling step at the manhole to fore end dome portion where thickness variation of 2.8 mm to 1.4 mm was there.
- The hoop stress, meridional stress and radial displacements matched with the classical solution.

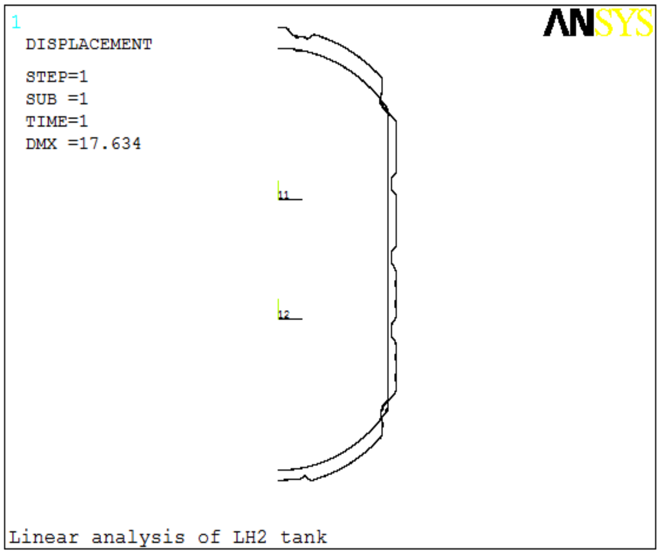

Fig. 9 Deformed shape of LH2 tank

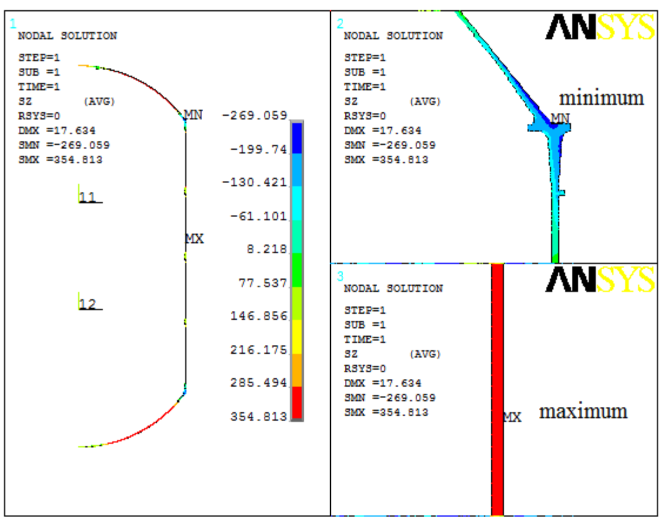

Fig.10 Hoop stress distribution

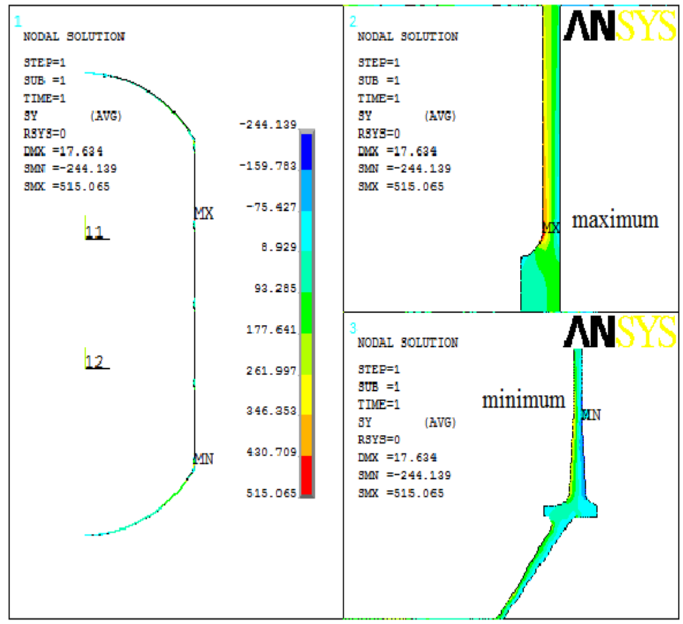

Fig. 11 Meridional stress distribution

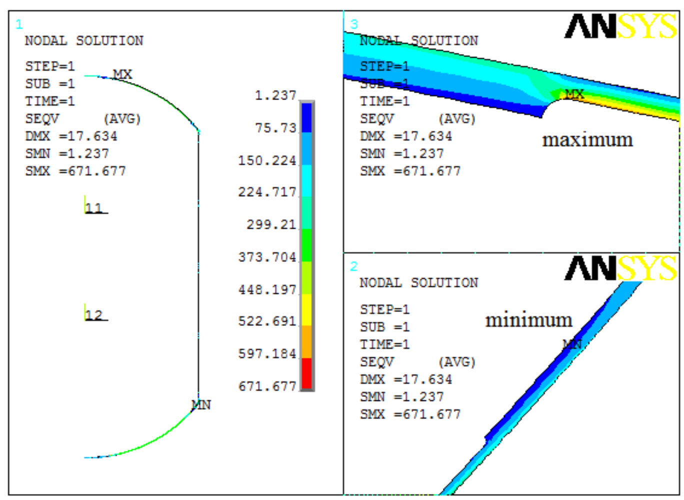

Fig. 12 Equivalent stress

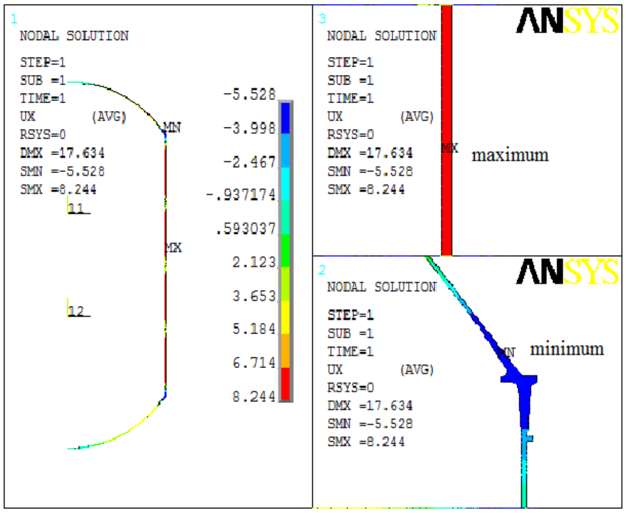

Fig. 13 Radial displacement

V. CONCLUSION

The von Mises stress in the tank is 671.677 MPa. This value is greater than the yield strength of the material, i.e, 350 MPa, as well as the ultimate strength i.e, 440 MPa.

The tank is more prone to failure at the chemical milling step in the manhole to dome portion. Therefore as the equivalent von Mises stress has exceeded the ultimate tensile strength, the tank will undergo failure. Hence the tank should be redesigned.

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