Design and Analysis of Large Transportable Vacuum Insulated Cryogenic Vessel

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Abstract - This project is aimed to study, design and analyze a large portable vacuum insulated cryogenic vessel that will be attached to a truck in order to keep, maintain and transport by road liquid methane at a temperature of -162 °C. Considerations such as different pressure loads, dimensions, materials as well as their mechanical properties, constraints, masses, insulation systems and weather-environmental conditions are made in the mechanical analysis. Furthermore, calculations and dimensions satisfy the requirements given by following the standards SS-EN 13530-1: Cryogenic vessels - Large transportable vacuum insulated vessel; Part 1: Fundamental requirements and SS-EN 13530-2: Cryogenic vessels - Large transportable vacuum insulated vessel; Part 2: Design, fabrication, inspection and testing. The CAD software Pro/Engineer (Creo1.0) is used to visualize the models for the chosen designs. In addition, the finite element module in ANSYS is used to obtain results of mechanical analyses in order to determine if the stresses are within margins.

Key Words: CAD, Pro/Engineer (Creo1.0) and Cryogenics

1. INTRODUCTION

Cryogenics is the study of the production and behavior of materials at very low temperatures (below −150 °C, −238 °F or 123 K). A person who studies elements that have been subjected to extremely cold temperatures is called a cryogenics. Rather than the comparative temperature scales of Celsius and Fahrenheit, cryogenicists use the absolute temperature scales. These are Kelvin (SI units) or Rankine scale (Imperial and US units). Most of the common applications of the cryogenics are, they can be used as rocket fuels, coming to the mechanical applications, As these all are the sub-zero gases or fuels these can used in the precession engineering of the mechanical components. For E.g. fits and tolerances of the mechanical components such as piston and piston rings, these components are to be précised correctly otherwise the efficiency of the machine will reduced. Using cryogenics such typical tolerances can be set. Considerations such as different pressure loads, dimensions, materials as well as their mechanical properties, constraints, masses, insulation systems and weather-environmental conditions are made in the mechanical analysis.

Transportable Vacuum Insulated Cryogenic Vessel.

1.2 CRYOGENICS

Cryogenics

The branches of physics and engineering that involve the study of very low temperatures, how to produce them, and how materials behave at those temperatures.

Cryobiology

The stem of biology involving the study of the effects of low temperatures on organisms (most often for the purpose of achieving cryopreservation).

Cryosurgery

The branch of surgery applying very low temperatures (down to -196 °C) to destroy malignant tissue, e.g. cancer cells.

Cryonics

The emerging medical technology of cryo-preserving humans and animals with the intention of future revival. Researchers in the ground seek to apply the results of many sciences, including cryobiology, cryogenics, theology, emergency medicine, etc. "Cryogenics" is sometimes erroneously used to mean "Cryonics" in popular culture and the press.

Cryo-electronics

The field of research regarding superconductivity at low temperatures.

Cryoethics

The study of the ethical implications surrounding cryonics. Focuses on the reasoning behind which one would want to preserve their body at below freezing temperatures due to life-threatening conditions that may be cured or prevented in the future.

Transportable Cryogenic Vessels

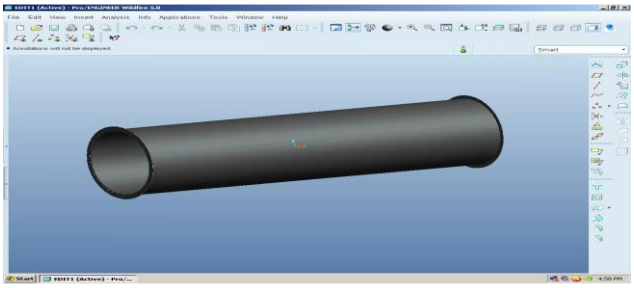
Consideration & Advantages of Transportable Vessel over Stationary Cryogenic Vessel.

Cryogenic gasses/ fuels can even be transported to remote areas where production unit cannot be established. Using the transportable cryogenic vessel the contents can be transported to the seismic prone areas. Transportable vessels are of different sizes so the fuel can be migrated as per the requirements

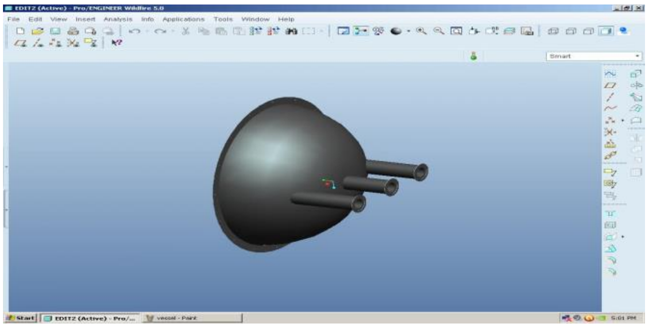
2. Design Considerations

I. Load during the pressure test
II. Chemical effects
III. Thermal conditions
IV. Material properties
V. Inspection of Material

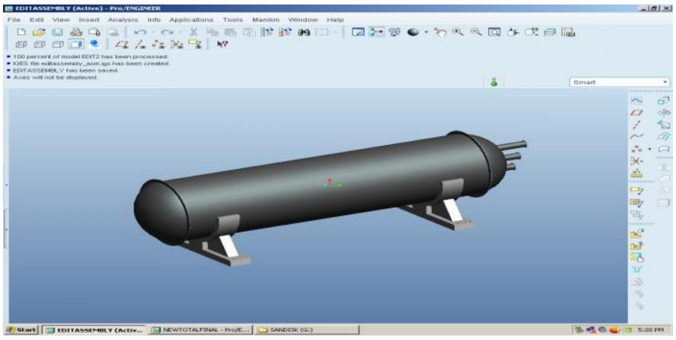
2.1 Modelling of the Cryogenic Vessel



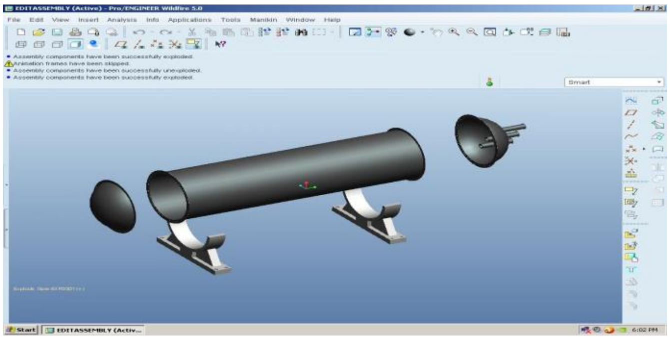
Vessel Shell Modelled Using Pro/engineer.



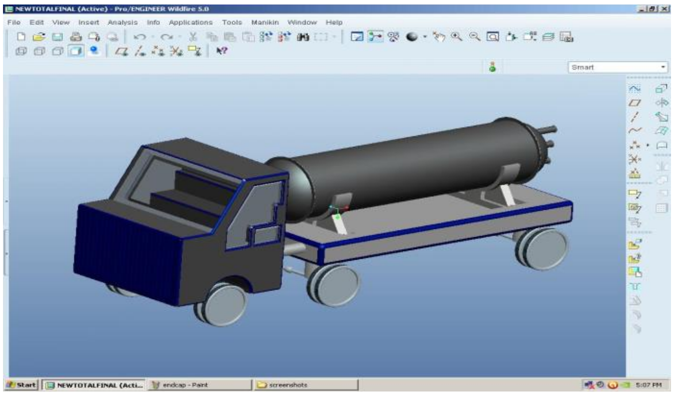
Terscopic End of the Vessel



Cryogenic Vessel Assembled On the Supports

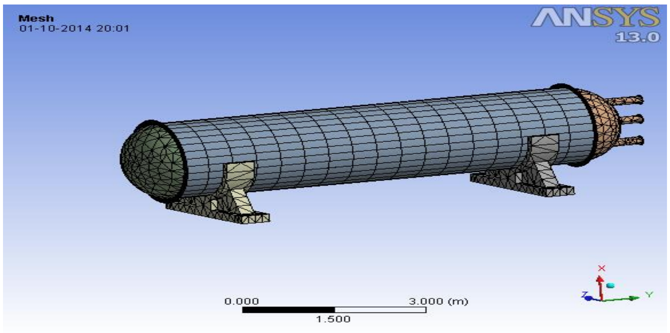


Exploded View of Vessel Assembly

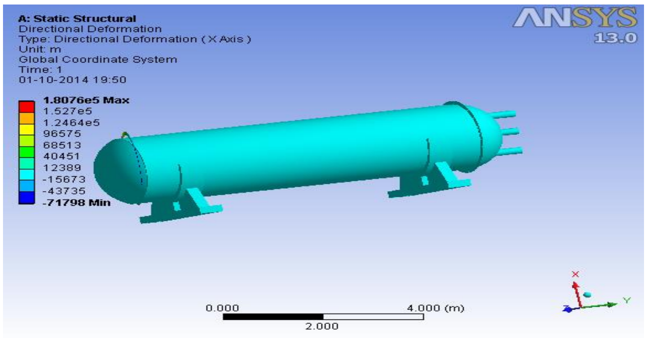


Final Assembly of Transportable Cryogenic Vessel.

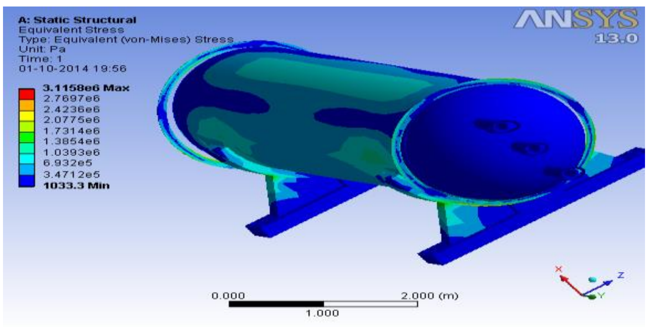
2.2 Analysis In Ansys



Mathematical model of the Cryogenic Vessel



Deflection/ Directional Deformation



Static Structural Equivalent Stress

3. RESULTS

Theoretically calculated wall thickness (s) = $s/D \leq 0.25$ then maximum allowable wall thickness will be = 6.25 cm
Case -2: If $s/D > 0.25$ then the maximum allowable wall thickness/ peaking will be = 7.95 – 9.7 cm
Theoretically calculated developed stresses (max) = 4.115 N/mm^2
Deformation (max) = 1.95 m
Deformation (min) = 0.83 m
Stress Results Calculated in Ansys

I. For steel tensile stress = 0.58 N/mm^2
II. For titanium stress = 3.115 N/mm^2

4. CONCLUSIONS

Hence with the above data and the calculations the fabrication and manufacturing of the vessel can be done, by the above results we can come to a conclusion that titanium can be used to manufacture the vessel because it can withstand higher pressures compared to steel when in alloy form (Ti, Ni alloy). Even Ti can be operated under sub zero temperatures as corrosion resistance is much higher comparing with steel and aluminum. Cost of manufacturing will be high when compared with steel but titanium vessels have better life span.

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