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OPTIMIZATION OF A LARGE TRANSPORTABLE VACUUM INSULATED CRYOGENIC VESSEL BY USING CAD/CAE TOOLS

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ABSTRACT:

The denotation "cryogenics" is defined as the study of a liquefied gas at very low temperature (below −150°C), as well as how materials perform at the aforementioned temperature. In this case, the cryogenic fluid is methane, which presents very good flammable qualities allowing it to be used as a new fuel and energy source. This project is deals with design and analyzes a large transportable vacuum insulated cryogenic vessel that will be attached to a truck in order to keep, maintain and transport by road liquid methane. 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. The CAD software Pro/Engineer (creo-2) is used to visualize the models for the chosen designs. In addition, the finite element module ANSYS WORKBENCH 15.0 is used to obtain results of mechanical analyses in order to determine if the stresses are within margins. Finally this project concludes which is most suitable material at different loading conditions.

Key Words: CREO, ANSYS WORKBENCH 15.0, transportable vacuum insulated cryogenic vessel.

1. INTRODUCTION

This project is aimed at the design and analysis of a transportable cryogenic vessel composed of several parts. Methane is kept in an inner vessel covered by an outer jacket of the same shape. Between both vessels, a vacuum insulation system is located. There are also beams which are used as connections between the inner vessel and the outer jacket and these are designed, analyzed and optimized in order to obtain stress values within margins. Apart from this, the project also addresses the frame to which vessels are attached, as well as its supports, which are the connections between the vessels and the frame. Finally, pipes and valves are taken into consideration in order to complete the design of the cryogenic vessel. This project is structured around two parts. The first part contains a background on me

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thane, the truck with the hook-lift mechanism and the insulation system. The second part focuses on the design and finite element analysis of the cryogenic vessel assembly.

2. DESIGN AND ANALYSES OF THE PARTS OF THE CRYOGENIC VESSEL

2.1 CAD DESIGN TOOL (CREO)

In each part, the value of the safety factor, which comes from the ratio between the yield strength and the maximum stress value, is given. The tensile strength is not considered for this calculation as criteria for failure, because the finite element module only considers the lineal behaviour of materials. Therefore, it is assumed that if the model stands the stresses and loads with the yield strength as criteria, it stands them with the tensile strength, since the yield strength is lower than the tensile strength.

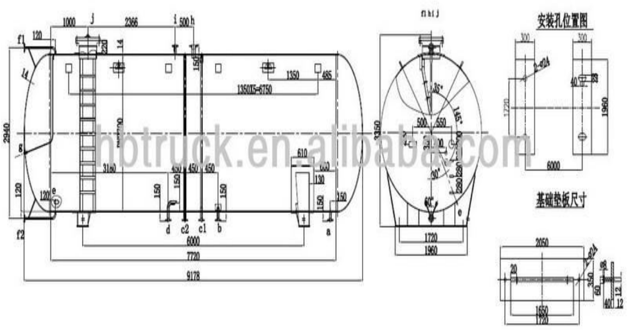

Fig 2.1Reference model

The main function of the inner vessel is to keep the methane at a temperature of -162ºC. Figure 2.2 shows an overall view, where it is possible to observe the symmetric shape of the inner vessel. It has three symmetry planes. The main dimensions are a length of 3320 mm, a width of 1900 mm and a height of 1100 mm.

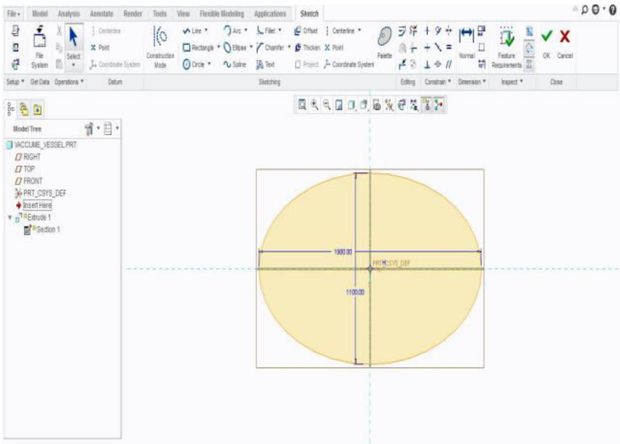

Fig 2.2 Designing front part of vessel using CREO

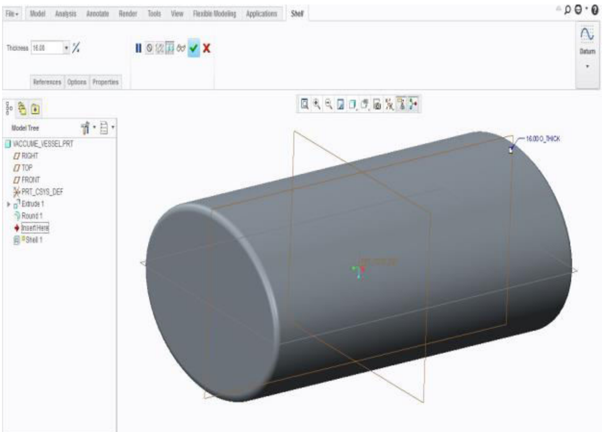

Fig 2.3 Creating round edges of vessel using CREO

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Above Figure shows two rounds in the edges. The purpose of these features is that the rounds reduce the stress concentrations where the inner vessel has sharp corners. The space between the horizontal edge at the top part of the surge plate and the inner vessel is an opening whose function is to let gases flow through. Thus, the pressure has the same value at all positions in the inner vessel. The distance from the top edge to the horizontal edge of the surge plate is 700 mm. The surge plates cover an area of approximately 70 % of the cross-section area of the inner vessel.

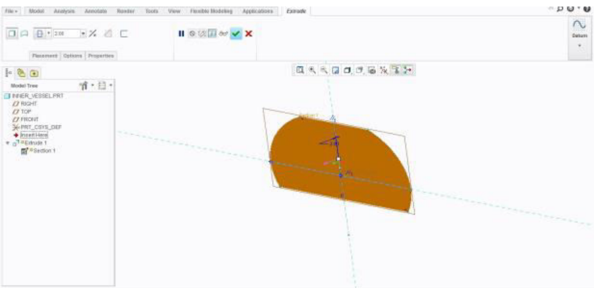

Fig 2.4 Creating surge plates of vessel using CREO

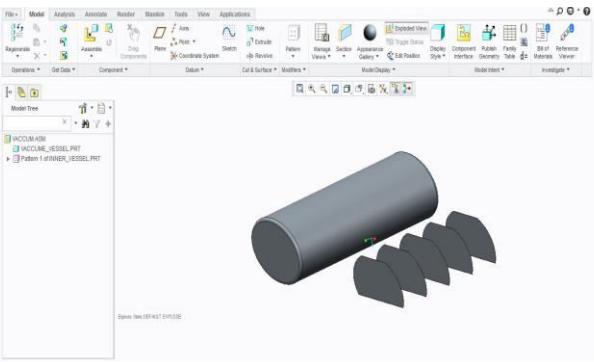

Fig 2.5 Inserting inner plates

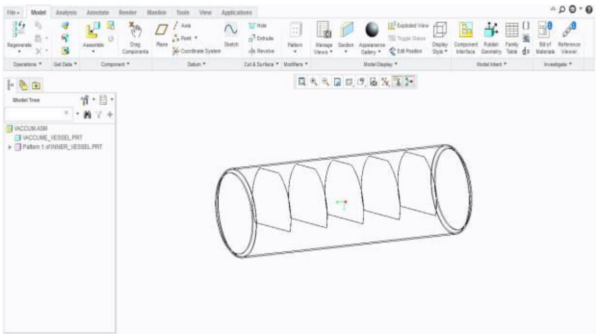

Fig 2.6 Wire frame model of the vessel assembly

2.2 FINITE ELEMENT ANALYSIS

2.2.1 Structural Analysis

Model imported from pro-e tool in IGES format is shown in the figure below.

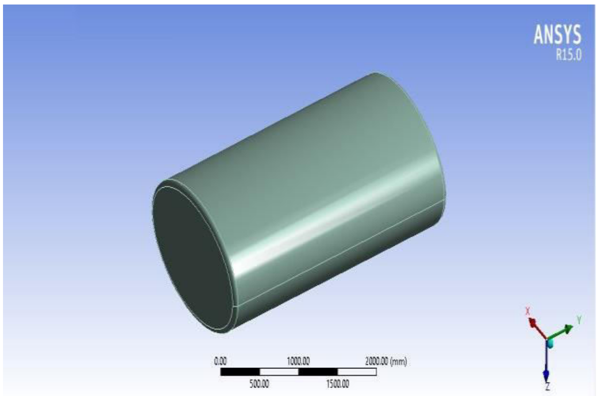

Fig 2.7 Imported Model View in Ansys

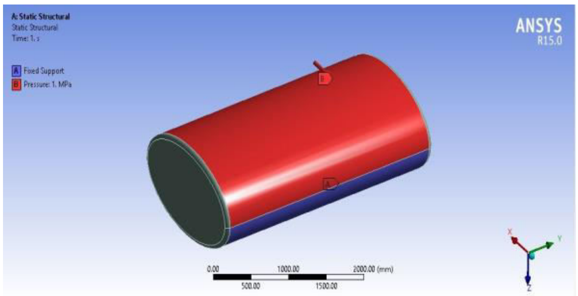

Fig 2.8 Selecting geometry asign material properties

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The resulting figures of the material are shown below.

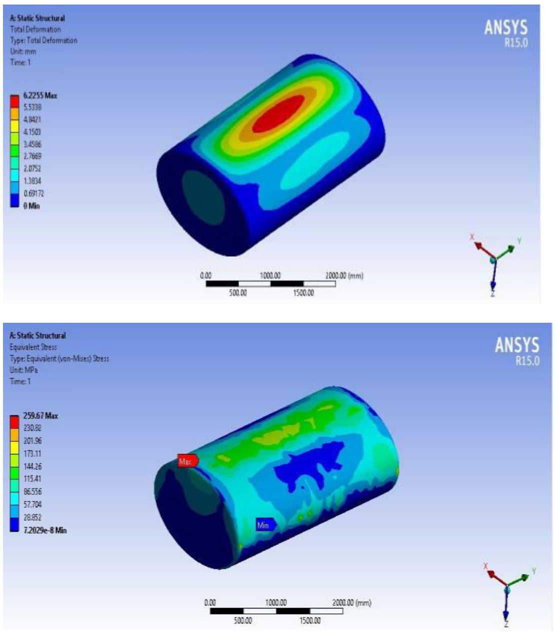

Fig 2.9 deformation and stress figures of carbon steel-AISI 1040

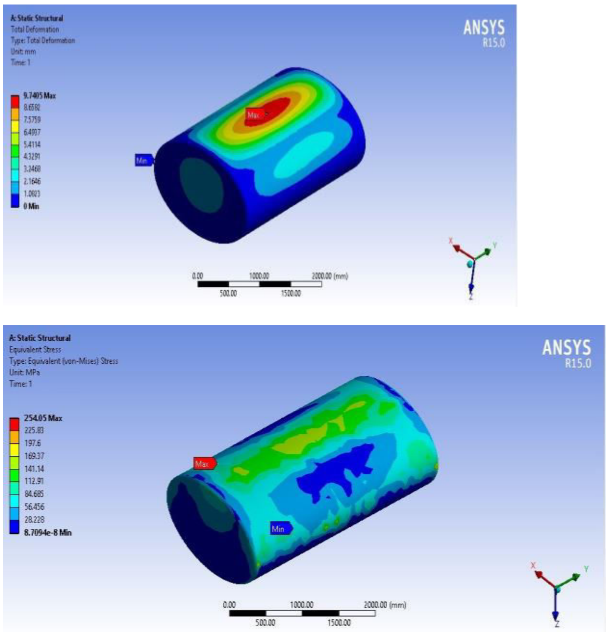

fig 2.10 deformation and stress figures of MONEL-400

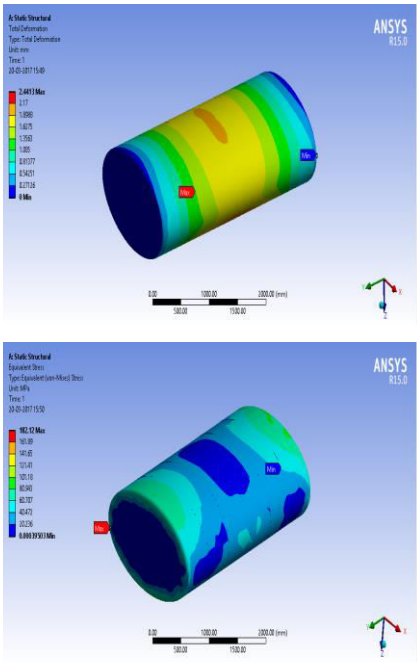

fig 2.10 deformation and stress figures of Al-2024

2.2.2 Thermal Analysis

The model imported and temperature on the outer surface of the vessel is shown in the figure below.

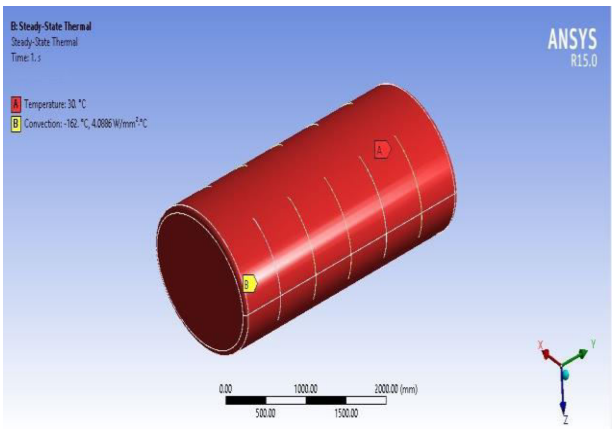

fig 2.11 Temperature on outer surface of imported model

Thermal analysis results of the materials are shown in the following figures.

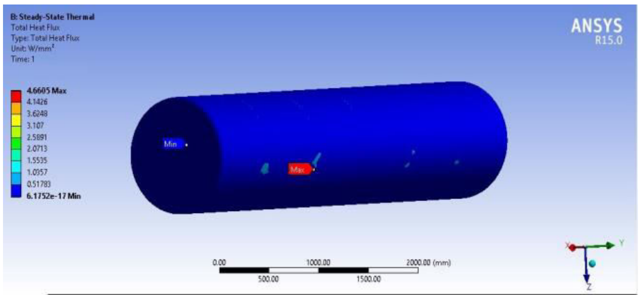

fig 2.12 Total heat flux of CARBON STEEL AISI-1040

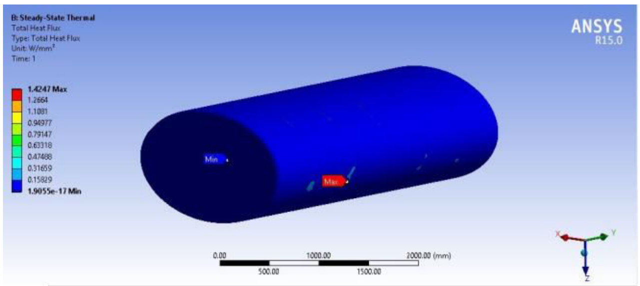

fig 2.13 Total heat flux of MONEL-400

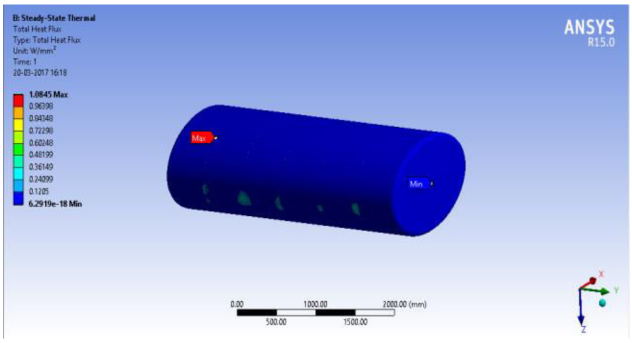

fig 2.14 Total heat flux of AL-2024

From the above all results we can say all temperature and heat flux values are mostly near values for both stainless steel and al2024 materials.

3. RESULT

In this chapter resuls were discussed. The results are shown in graphical manner.

Table 3.1 Results obtained for different materials

	STAINLESS STEEL	CARBON STEEL AISI - 1040	Monel - 400	Al-2024
Deformation(mm)	6.45	6.2255	9.7405	2.4413
Stress(Mpa)	259.67	259.67	254.05	182.12
Safety factor	1.1168	1.361	1.5745	1.7845

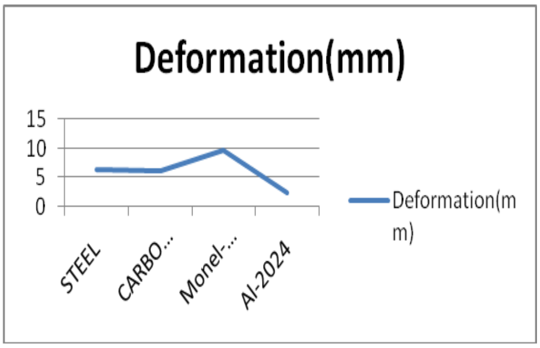

fig 3.1 Deformation comparision of different test materials

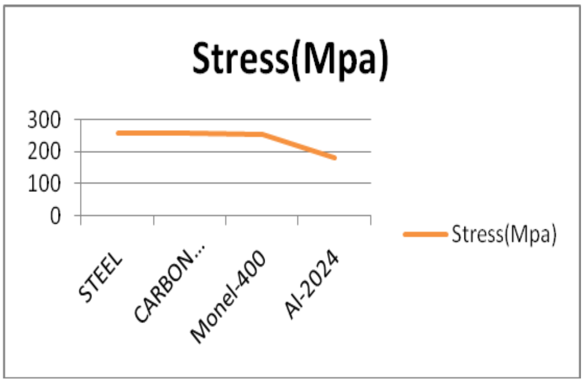

fig 3.2 Stress comparision of different test materials

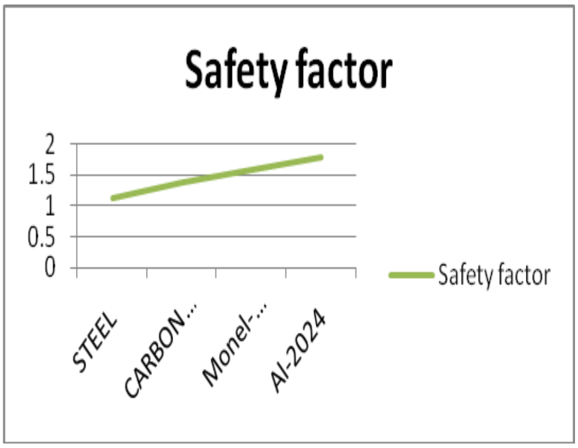

fig 3.3 Safety Factor comparision of different test materials

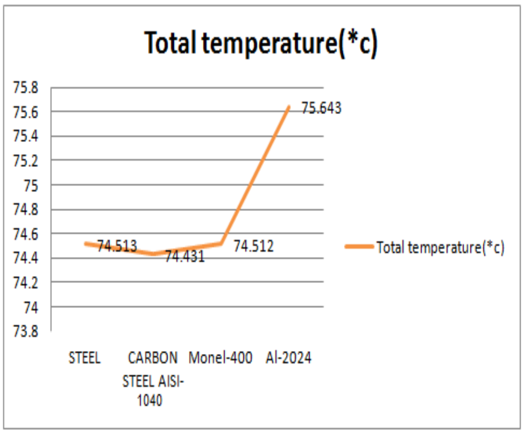

fig 3.4 Total Temperature comparision of different test materials

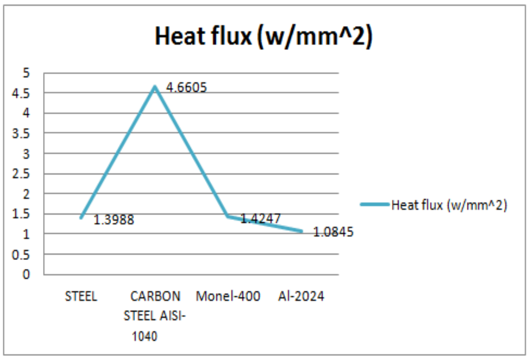

fig 3.4 Total Heat Flux comparision of different test materials

4. CONCLUSION

In this project first we took one cryogenic vessel with stainless steel material, our aim in this project is reducing the internal stresses while applying real-time boundary conditions on the object to do this first we have to check our object with existing material. Designed one cryogenic vessel with inner vessel by using cad tool (pro-e/creo-2), to analys we imported it into cae tool (ansys workbench) then applied real time boundary conditions on it. We got stress 259Mpa and safety factor is 1.1, to reduce the stress and increasing the strength of the object we also checked another three materials those are carbon steel AISI-1040 and monel-400 and al-2024, in this case carbon steel AISI-1040 not satisfied our requirement but monel-400 and al-2024 satisfies. In real time we cannot say by only single analysis our material can be replace by existing that’s why we have to check another analysis also We did thermal analysis also on this object, we applied temperature on outer surfaces and convection on inner surfaces and calculating all the results like total temperature, heat flux, heat flux in x,y,z directions.. From all the results we can say the both materials have same results in heat flux and total temperature (approximately). Now we can say al-2024 material is the best material for cryogenic vessels.

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