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Design and Analysis of Hydrogen Storage Tank with Different Materials by Ansys

Design and Analysis of Hydrogen Storage Tank with Different Materials by Ansys

S. Senthil Kumar [1], C.Bibin[1], [2]M. Ramachandran

[1]Dept. of Mech. Engg, RMK College of Engg and Technology, Chennai

[2]MPSTME, SVKM'S NMIMS University, Dhule 425405, Maharashtra, India
umailbibin@gmail.com

Abstract. Pressure vessels are used for large commercial and industrial applications such as softening, filtration and storage. It is expected that high-pressure hydrogen storage vessels will be widely used in hydrogen-fuelled vehicles. Progressive failure properties, the burst pressure and fatigue life should be taken into account in the design of composite pressure vessels. In this work, the model and analysis of hydrogen storage vessels along with complete structural and thermal analysis. Liquid hydrogen is seen as an outstanding candidate for the fuel of high altitude, long-endurance unmanned aircraft. The design of lightweight and super-insulated storage tanks for cryogenic liquid hydrogen is since long identified as crucial to enable the adoption of the liquid hydrogen. The basic structural design of the airborne cryogenic liquid hydrogen tank was completed in this paper. The problem of excessive heat leakage of the traditional support structure was solved by designing and using a new insulating support structure. The thermal performance of the designed tank was evaluated. The structure of the tank was analyzed by the combination of the film container theory and finite element numerical simulation method. The structure of the adiabatic support was analyzed by using the Hertz contact theory and numerical simulation method. A simple and effective structure analysis method for a similar container structure and point-contact support structure was provided. Bases for further structural optimization design of hydrogen tank will be provided also. The analysis will be carried out with different materials like titanium, nickel alloy and some coated powders like alumina, Titania and zirconium oxide. The results will be compared with that.

Keywords. hydrogen, storage vessels, model and analysis, liquid hydrogen, airborne, cryogenic

1. Introduction

The intemperate use of fossil fuels has led to gradually increasing drastic environmental pollution and energy crisis. Numerous research works have recently been carried out on looking for renewable resources as a replacement for conventional fossil fuels. Hydrogen has been recognized as the superior option for the future energy industry because of the characteristics of unlimited supply, zero-emission of greenhouse gases, and high energy efficiency. Hydrogen storage has become one of the predominant technical barriers limiting the widespread use of hydrogen energy. Safe, high-efficiency and economical hydrogen storage technique is a key to ensure a favourable run of hydrogen fuel cell vehicles. Among many hydrogen storage patterns including high-pressure gaseous storage, cryogenic liquid storage and chemical hydrogen storage, high-pressure gaseous storage has become the most popular technique. The basic requirements for the design of storage vessels are safety, reliability and economy. However, the composite pressure vessels may work under the high-pressure and high-temperature environment. Conventional metallic pressure vessels cannot longer be competent for the rigorous need for high strength and stiffness weight ratios. Therefore, the composite filament wound technology was introduced to improve the performance of the storage vessels. Generally, the composite materials are used for fabrication of pressure vessels by placing them in different orientations for different layers and in a common orientation within a layer. These layers are stacked in such a way to achieve high stiffness and strength. The design of the composite vessel as a fundamental research work relates the physical and mechanical properties of materials to the geometric specifications.

1.1. Liquid Hydrogen Storage

Storage and transportation of hydrogen as a liquid is another possibility. The cryogenic hydrogen is to be stored in specially insulated vessels at (-) 252.880C. The energy required to liquefy hydrogen (gas at 300oK and 1 bar pressure) is about 47 MJ / kg of hydrogen. The energy also is dependent on the size of the plant. With improved technologies and small plants involving magnetic regenerative liquefaction about half of this energy may be adequate. Thus, energy required for bulk storage and transport cryogenic liquid hydrogen gas can be about 10 to 20% lower. Like hydrogen in gaseous form, the liquid hydrogen also has the tendency to diffuse into the material of construction at high pressures and make them brittle. To check this problem of embrittlement, the storage vessels may be made of FCC (as the material of construction) with special insulation, comprising double-walled with the vacuum in between, opacifiers and multi-layer insulations.

Fig: 1.1 Hydrogen stored as a liquid

1.2. Cryogenic Storage

Liquid hydrogen is stored in cryogenic tanks at 21.2 K at ambient pressure. Because of the low critical temperature of hydrogen (33 K), the liquid form can only be stored in open systems, as there is no liquid phase existent above the critical temperature. The pressure in a closed storage system at room temperature (RT) could increase to ~10^4 bar. The simplest liquefaction cycle is the Joule-Thompson cycle (Linde cycle). The gas is first compressed and it undergoes an isenthalpic Joule-Thomson expansion, producing some liquid. The cooled gas is separated from the liquid and returned to the compressor via the heat exchanger. The Joule-Thompson cycle works for gases, such as nitrogen, with an inversion temperature above RT. Hydrogen, however, warms upon expansion at RT. then cooled in a heat exchanger, before it passes through a throttle valve where For hydrogen to cool upon expansion, its temperature must be below its inversion temperature of 202 K.

1.3. Nano Structure Tube

Materials with a large specific surface area like activated or nano structured carbon and carbon nano tubes (CNTs) are possible substrates for physisorption. The main difference between CNTs and high surface area graphite is the curvature of the graphene sheets and the cavity inside the tube. In micro porous solids with capillaries, which have a width of less than a few molecular diameters, the potential fields from opposite walls overlap so that the attractive force acting upon adsorbate molecules is increased compared with that on a flat carbon surface. This phenomenon is the main motivation for the investigation of hydrogen-CNT interaction. Most work on the theoretical absorption of hydrogen in carbon nanostructures uses the Feynman (semi classical) effective potential approximation to calculate the adsorption potential or the grand canonical Monte Carlo simulation.

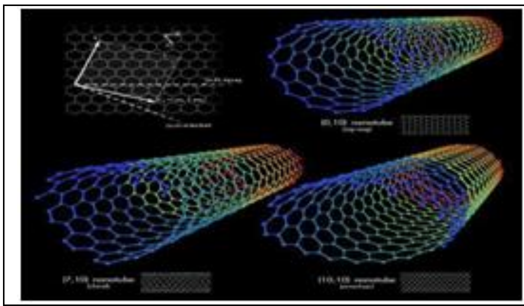

Fig 1.2 Carbon Nanotube

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1.4. Workbench Ansys

The Ansys software is used to analyse a given model. The Ansys consists of more number of libraries and module for the analysis.

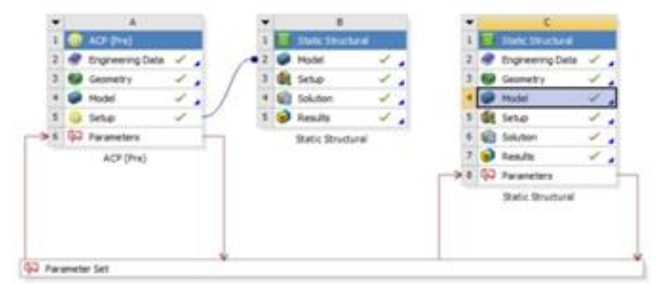

Fig: 1.3 WORKBENCH ANSYS

i. Mechanical APDL

ACP (Pre) is used to create the laminate i.e. the ply orientation and stacking different material. Loading conditions is done in static structural module and results are viewed in ACP (Post).

ii. Module

The Ansys workbench consists of several modules which help in the analysis of the multi-leaf spring.

- Engineering Data
- Geometry
- Model
- Setup
- Result.

The engineering data is used to feed the data like (young's modulus, Poisson ratio etc.) Ansys is like a black box the result depends upon what data is given. Geometry is used to create the 3D model of the object or import the model from other platforms such as creo5.0, catiav5, solid works etc. Para solid, IGES, STEP. The file is flexible when the model is being imported. The Model is used to create the mesh (hedraterdral, triangular). The nodes are classified based on the mesh type. Smaller the element size more accurate the results. In this module, the loading condition and boundary condition can also be defined based on which result converge. Setup (ACP) is used to create the composite material i.e. ply orientation, laminate direction, fibre direction. e viewed in ACP (Post) module. The module is used to create a solid model of the storage tank using different materials. In this module, the stack up the layer of the lamina is also created. Results module is used to display the output of the given input.

iii. Element Type

The tools used for simulation in Ansys 14.0 software. The software uses the element type to create a solid model. The element type which is suitable for the composite analysis is solsh190, solid185, solid186. Solsh190, solid185 uses 3D 8- node for solid structural data. Solid186 uses 3D 20-node for solid structural data which gives finer mesh thereby giving accurate results.Solsh190 is the default element type in Ansys workbench software. The Ansys software has plenty of tools and a suitable tool for creating and loading a composite is ACP (pre), ACP (post), Static Structural. The Fatigue tool is used for Flexural analysis of leaf spring.

Fig 1.4 Element type ANSYS

2. MATERIALS AND METHODS

2.1. DESIGN METHODOLOGY

Modelling and analysis of 3-D models of the tank were carried out using ANSYS FEA. The methodology includes the process of analysis and this project includes the process of numerical investigation and comparison with different materials and ceramic coated powders by Ansys.

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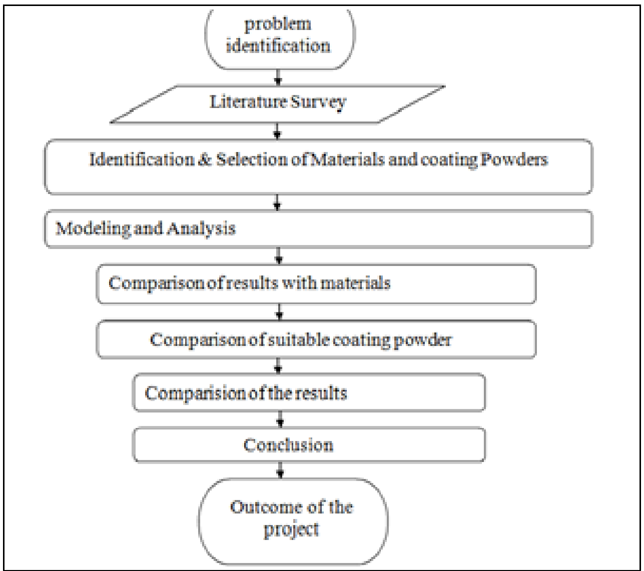

Fig 2.1 Flowchart of Methodology

2.2. MODELLING AND ANALYSIS

The analyses conducted during this contract are described in the following section. Cost analysis of emerging technologies is inherently an iterative process as the technology, designs, and performance are rapidly changing. Consequently, some of the analyses in this report are marked as preliminary to denote their interim status as of the report date, due to either on-going areas of investigation or shifting of DOE priorities. However, these preliminary analyses have significant value and are included to provide both status reporting and identification of cost drivers and manufacturing requirements.

2.3. DESIGN PARAMETERS

i. Titanium alloys

Unalloyed, commercially pure titanium has a tensile strength ranging from 275 to 590 MPa, and this strength is controlled primarily through oxygen content and iron content. The higher the oxygen and iron content, the higher the strength. Commercially alloyed titanium grades can range from a tensile strength as low as 600 MPa such as Ti-3A1-2.5V to a tensile strength as high as 1250 MPa (e.g. for the high strength alloy Ti-15Mo-5Zr-3AI).

Table 1: Mechanical properties of Titanium alloys

Mechanical properties	Titanium	Nickel	Zirconium
Density	4.50 g/cc	8.88 g/cc	
Hardness, Vickers	60	-	150
Tensile strength, Ultimate strength	220 MPa	317 MPa	330 MPa
Tensile strength, yield	140 MPa	59 MPa	230 MPa
Elongation at Break	54%	30%	32%
Modulus of Elasticity	116 GPa	207 GPa	94.5 GPa
Poisson's ratio	0.34	0.31	0.34
Shear Modulus	43 GPa	76 GPa	


Fig:2.3 titanium


Fig 2.4 Nickel


Fig 2.5 Zirconium

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3. RESULT AND DISCUSSIONS

3.1 *MODELLING* OF HYDROGEN STORAGE TANK

I. MODELLING OF NICKEL-ALUMINA

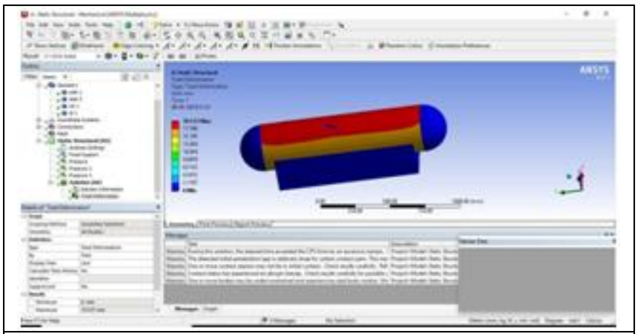

Fig:3.1 Deformation of Nickel-alumina

II. MODELLING OF TITANIUM-ALUMINA

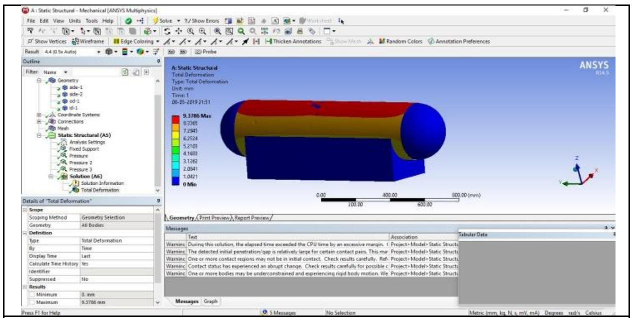

Fig:3.2 Deformation of Titanium-alumina

III. MODELLING OF TITANIUM-ZIRCONIUM

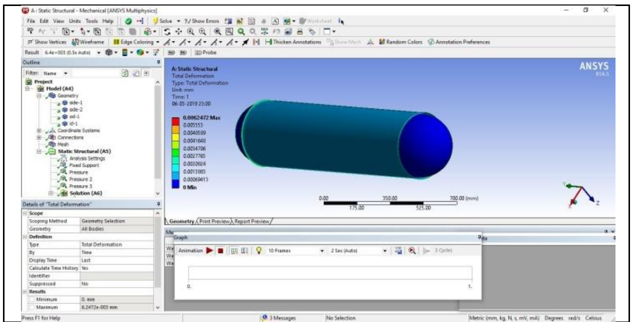

Fig:3.3 Deformation of Titanium-zirconium

IV. TOTAL DEFORMATION OF TITANIUM-ZIRCONIUM

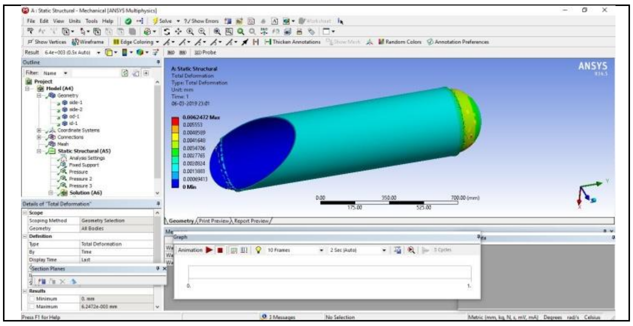

Fig 3.4 Cut section of titanium-zirconium

This shows the input data needed for the analysis and properties of the material chosen from the standard ANSYS Workbench Library. Engineering data of the material can be added when the properties are not available in the Library. This shows the solid model of the composite with fibre and matrix combined in it. The drop-off and cut off handles the global material handling of the composite. Drop-off method defines the ply's drop-off before or after the edge. The maximum equivalent strain produced in the peri-implant region was mostly within the range for bone augmentation. Under oblique loading, maximum von Mises stresses and the equivalent strain was more evident at the neck of the most distal implant on the loaded side. Under an axial load, the stress and strain were transferred to the peri-implant bone around the apex of the implant. Maximum tensile stresses that developed for either material were well below their fracture strength. The highest stresses were mainly located at the distobuccal region of the neck for the two implant materials under both loading conditions. Zirconium, Titanium and Hafnium are a group of metals with similar properties. Titanium and its alloys are increasingly used in both aerospace and chemical engineering. Zirconium and alloys based on it have important structural applications in certain nuclear reactors. These uses of Ti and Zr require that the designer has a good understanding of both their low-temperature plasticity and their high-temperature strength.

4. Conclusion

Both Zirconium and titanium are strong, long-lasting, corrosion-resistant metals that are ideal form any demanding projects. In most cases, either one would work. Titanium is more expensive, but the demand for Zirconium is increasing, which may lower the cost of titanium. So many industries, such as in dentistry, now prefer Zirconium because of its low electrical conductivity and better hypoallergenic properties**.**

Table 2: Comparisons of Results

MATERIAL USED	COATING USED	THICKNESS (mm)	PRESSURE (bar)	DEFORMATON (mm)
NICKEL	ALUMINA	4	600	9.38
TITANIUM	ALUMINA	4	600	19.54
TITANIUM	ZIRCONIUM	4	600	0.00625

Zirconium are strong, durable and resistant to a variety of chemicals. Titanium, however, weighs a fraction of what steel weighs. To have the same strength with less weight, titanium seems like an ideal combination. The biggest drawback to titanium is the price. The superiority of titanium over steel will cost you. But oftentimes, another similar metal often gets overlooked: Zirconium. Zirconium and titanium do share many desirable characteristics, most notably their durability and corrosion resistance. Zirconium's strength, corrosion resistance and durability make it ideal for use in pipes, fittings and heat exchangers, steel alloys, coloured glazes, bricks, ceramics, abrasives, flashbulbs, lamp filaments, artificial gemstones and some deodorants. Zirconium is also used in surgical instruments, jewellery, lab crucibles, television glass, surgical instruments and catalytic converters. Zirconium's lack of attracting particles make it a popular option for use in nuclear power plants. At one time, Zirconium was even used to treat poison ivy, before skin irritations became linked to possible side effects. This work may also help identify and develop similar hydrogen storage systems. To be a mainstream source of fuel, hydrogen must be stored safely and efficiently. Conventional high-pressure storage tanks can be dangerous and are too big and heavy for certain applications, such as hydrogen-based fuel cells in automobiles. Hydrogen-storage materials, however, incorporate hydrogen safely and compactly and temporarily hold large quantities of it that can be recovered easily under safe, controlled conditions. A hydrogen-storage material must be able to store hydrogen quickly under normal conditions that are without very high temperatures and pressures

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