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DESIGN & DEVELOPMENT OF MANUFACTURING PROCESS FOR LPG PRESSURE VESSEL'S INNER SHELL WITH FIBER REINFORCED POLYMER (FRP)

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Abstract : With the introduction of polymer composites, design engineers have an increasing problem in establishing viable manufacturing methods with required features. Choosing the right manufacturing method is critical for achieving the necessary quality in polymer-based composite materials. The current study focuses on building a moulding technique to create the inner shell of a filament wound pressure vessel.

The effort entails developing and testing improved manufacturing processes in order to create an impenetrable cylindrical shell with no joints. Experiments will be carried out in this direction on moulding the inner shell by hand layup, centrifugal moulding method, and semi-compression moulding technique in order to choose the optimal production process among these. This project is entirely funded by "Rath Composite Industries Private Ltd." for their LPG storage tank production facility.

Keywords: *LPG, Fiber reinforce polymer (FRP).*

1. INTRODUCTION

COMPOSITE:

A composite is a microscopic mixing of two or more distinct materials, one of which is normally the continuous phase (matrix) and the other being the discontinuous phase (reinforcement).

SIGNIFICANCE OF COMPOSITE MATERIALS:

With knowledge of various types of composites and an understanding of how their behaviours are influenced by the characteristics, relative amounts, geometry/distribution, and properties of the constituent phases, it is possible to design materials with better property combinations than metal alloys, ceramics, and polymeric materials.

Many of our current technologies demand materials with odd combinations of qualities that traditional metal alloys, ceramics, and polymeric materials cannot provide. This is particularly true for materials used in aeronautical, undersea, and transportation applications. For example, aeroplane engineers are increasingly looking for low-density structural materials that are robust, stiff, abrasion and impact resistant, and not readily corroded. Better property combinations are created by the careful combining of two or more unique materials, according to this concept of combined action. There are several composites found in nature. Wood, for example, is made up of strong and flexible cellulose fibres that are surrounded and kept together by a stiffer substance known as lignin. Furthermore, bone is made up of the strong but flexible protein collagen and the hard, brittle mineral apatite.

In this application, a composite is a multiphase substance that is created intentionally rather than one that exists or develops naturally. Furthermore, the component phases must be chemically different and separated by a clear interface. As a result, most metallic alloys and

Many ceramics do not suit this criteria because their various phases result from natural events.

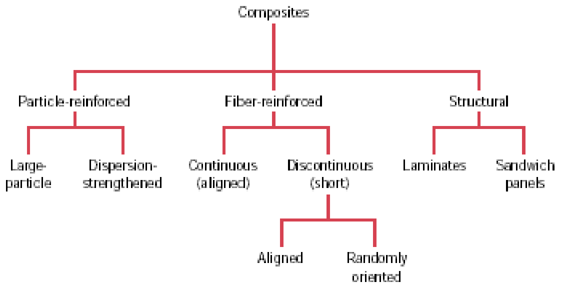
Scientists and engineers have cleverly blended diverse metals, ceramics, and polymers to create a new generation of remarkable materials while constructing composite materials. Most composites were developed to increase mechanical properties like as stiffness, toughness, and ambient and high-temperature strength.

THE PRESENT STATUS IN INDIA:

The use of composites in the Indian industrial sector is still in its early stages. However, only traditional techniques of fabricating FRP components, such as hand lay-up and spray-up, are in use. However, the quality of components generated by such technologies is inconsistent, i.e. repeatability, interchangeability, and homogeneity in component manufacturing are still in doubt. Other processes, including as centrifuging, compression moulding, resin transfer moulding, pulltrusion, filament winding, and so on, may be used to enhance this.

COMPOSITE CLASSIFICATION:

A simplified classification of composite materials with three primary divisions is shown in Figure. structural, fiber-reinforced, and particle-reinforced composites with at least two subdivisions each.



FIBER-REINFORCED COMPOSITES:

The main composites as far as innovation are those wherein the scattered stage (constant stage) is looking like a fiber. High strength or potentially firmness on a weight premise are in many cases plan goals for fiber-built up composites. These properties are expressed as far as unambiguous strength and explicit modulus boundaries, which relate to the rigidity to explicit gravity and modulus of versatility to explicit gravity proportions, separately. Low-thickness fiber and lattice materials were utilized to make fiber-built up composites with extremely high unambiguous qualities and modulus.

FRP DEFINITION:

Fiber Reinforced Polymer (FRP) Composites are portrayed as "a polymeric network built up by strands or other building up material."

FRP COMPOSITE CONSTITUENTS:

- Reinforcements
- Fillers
- Additives
- Resins (polymers)

NEED AND SCOPE OF THE PROJECT:

Choosing the right manufacturing method is critical for achieving the necessary quality in polymer-based composite materials. With the introduction of polymer composites, the challenge for design engineers is to develop viable production methods with desirable qualities. An effort is made in this project endeavour to establish a better manufacturing procedure.

This project's pressure vessel inner shell offers high strength, high corrosion resistance, high resilience to increased temperatures, fatigue resistance, and low weight. The inner shell may also be filament wounded and therefore utilised as an LPG storage tank.

2. LITERATURE SURVEY

Composite Pressure Vessels in Petroleum Industry: Status and Outlook

The use of composite pressure vessels in petroleum industry is one of the major areas of application of such vessels, particularly for storage and transportation of fuels. Existing studies related to this field have considered various types, designs and applications of composite pressure vessels. The current state of the art composite pressure vessels are light, safe, but unfortunately rather expensive compared to steel vessels. This is one of the main reasons why abroad introduction of composite vessels for liquefied petroleum gas (LPG) storage and transportation has not taken place yet. In this work the current status of composite pressure vessels in the petroleum industry is highlighted. Various existing models and studies of composite pressure vessels are discussed. Potential for application in the area of composite LPG cylinders is discussed.

Design, Fabrication, and Testing of Epoxy/ Glass-reinforced Pressure Vessel for High-pressure Gas Storage

The design, fabrication, and testing of an epoxy-glass reinforced polymer composite pressure vessel suitable for high-pressure gas storage have been reported. In this study composite pressure vessels are made up of aluminum alloy 6063 seamless liner and glass/epoxy composite reinforcement. The aluminum liner, which is developed by extruded aluminum tube of internal diameter 141 mm and wall thickness 4 mm, is subjected to super plastic deformation. Continuous glass fibers impregnated in epoxy resin are wound on the seamless liner by filament winding process. In this work, 10 pressure vessels were manufactured for 3.5 MPa service pressure with marginal safety of 3. Four pressure vessels were subjected to cyclic and burst test; the burst pressures were 10.9, 11.0, 11.0, and 13.0 MPa.

ANALYSIS OF AUTOMOBILE LPG CYLINDER USING COMPOSITE MATERIAL

As the usages of fossil fuels are increasing day by day as the numbers of automobiles on roads are increasing, this is contributing to the increasing levels of pollution in the atmosphere. Now the automotive industry is looking forward to promote the alternative fuels usage for automotive propulsion. In this sinerio LPG, CNG fuels are the immediate solutions to reduce the pollutants concentration in the atmosphere even though they are coming from fossil fuels. Composite materials can be utilized to design better storage systems at lower rates when compared to conventional metallic materials. FEA is implemented to the present problem to arrive it better solutions pertained to various geometries of pressure vessel made of E-GLASS/EPOXY composite. Providing solutions for the design of pressure vessel made of filament wound technology with Cylinder with spherical ends.

An Approach for Designing of Composite Gas Cylinder Using ASME Standard

This paper describes the use of ANSYS software for the replacement of the conventional stainless steel material of Liquid Petroleum gas (LPG) cylinder by a low density composite material named E Glass Epoxy for reducing the cylinders weight. In lieu of this, Finite element analysis package ANSYS has been used on composite cylinder subjected to an internal pressure. A case has been developed to study the stresses due to pressure loading inside the cylinder designed as per ASME standards. The results of stresses for steel cylinders were compared with the analytical solution available in the literature in order to validate the model and the software. The weight reductions were presented for steel, composites LPG cylinders and the variation of stresses throughout the cylinder made of steel and composites were studied. The current Indian Gas supply system makes the transportation of cylinders arduous due to the difficulty in moving the heavy stainless steel cylinders around the house for housewives. An alternative is required, which can produce the same result with less weight, that is, for the same amount of gas stored inside the cylinder the weight of the cylinder is reduced. The above project is a small step towards an user friendly concept taking into consideration practicality, utility as well as safety.

Finite Element Analysis of LPG

This project aims at reduction of weight of Liquid petroleum gas (LPG). So, the finite element analysis of Liquefied Petroleum Gas (LPG) cylinders made of Steel and Fiber Reinforced Plastic (FRP) composites has been carried out. Finite element analysis of composite cylinder subjected to internal pressure is performed. Layered shell element of a versatile FE analysis package ANSYS (version 14.0) has been used to model the shell with FRP composites. A number of cases are considered to study the stresses and deformations due to pressure loading inside the cylinder. First, the results of stresses and deformation for steel cylinders are compared with the analytical solution available in literature in order to validate the model and the software. The weight savings are also presented for steel, Glass Fiber Reinforced Plastic (GFRP) composites and Carbon Fiber Reinforced Plastic (CFRP) composite LPG cylinders. Variations of stresses and deformations throughout the cylinder made of steel, GFRP and CFRP are studied. A complex orthotropic mechanics of FRP composites has been studied and discussed in brief to have some understanding of behavior of FRP composites. In addition to that an introductory Finite Element Method has also been presented on the basis of which the cylinder has been analyzed.

3. METHODOLOGY

METAL USED FOR CASTING:

LM6 Aluminum Combination: LM 6 is a strain bite the dust projecting compound that is likewise appropriate for gravity and low tension projecting. This amalgam agrees with BS 1490, and practically identical composite sciences are utilized worldwide.

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Application: LM 6 is a high virtue combination utilized in castings with more slender, more convoluted segments. The composite is mediocre in strength and malleability. This composite is appropriate for sea fittings, water manifolds, and street transport applications on the grounds that to its solid consumption obstruction and extraordinary castability. Anodizing may further develop erosion opposition significantly further by passing on a shifted dark to brown colored layer on the projecting's surface. LM 6 is a high silicon aluminum combination that is particularly appropriate for welded castings.

Alloy Designation	Al Si 12	**Color code**	Yellow.
Short designation	LM 6	**Alloy Number**	N/A

MECHANICAL PROPERTIES		
Supplied in die cast form.	**Minimum**	**Maximum**
Tensile strength	--	280 MPa
0.2% Proof Stress	--	120 MPa
Impact strength (Charpy)	6.0 Nm	9.0 Nm
Elongation	2.0 %	5.0 %
Shear strength	--	--
Modulus of Elasticity x10^3	--	71 MPa
Fatigue Strength 5 x 10^8 cycles	70 MPa	138 MPa
Hardness BHN	85 max	85 max

PHYSICAL PROPERTIES	
Melting range	575 - 565° C
Density	2.65g / cm3
Coefficient of Thermal expansion	0.00002
Thermal Conductivity	0.34
Electrical Conductivity	37 % IACS

MOULD DESIGN:

Fig 1 first design for casting in 3d

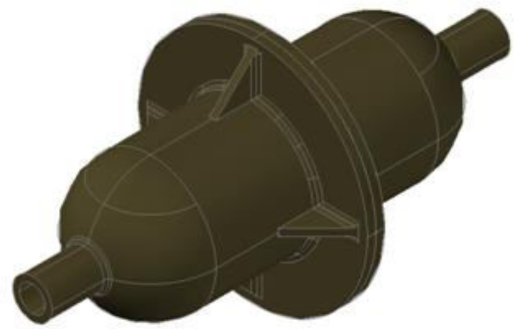

Fig 2 Second design for casting in 3d

Because of its many benefits, the casting technique is widely utilised in production. Molten material pours into any tiny portion of the mould cavity, allowing the casting process to create any complicated shapes, internal or exterior. Casting is feasible with any material, ferrous or non-ferrous. Furthermore, the instruments needed for casting moulds are basic and affordable. As a consequence, it is a suitable approach for trail production or small batch manufacturing. It is possible to precisely put the quantity of material necessary throughout the casting process. As a consequence, weight reduction in design is possible. Because castings are normally cooled from both sides, they are assumed to have directional qualities. Because of metallurgical reasons, some metals and alloys may only be handled by casting and not by any other technique such as forging. Castings of any size and weight, up to 200 tonnes, are possible. Casting in metalworking is emptying a fluid metal into a shape that has an empty office of the ideal structure and afterward permitting it to solidify. To complete the cycle, the cemented segment, otherwise called a projecting, is ousted or broken out of the shape. Casting is most frequently used to make complicated structures that would be troublesome or costly to make utilizing different systems.

Casting is a hardening interaction, which suggests that the cementing peculiarities oversees most of the projecting's qualities. Besides, most of projecting imperfections, like gas porosity and cementing shrinkage, emerge during hardening. Nucleation and gem development are the two phases of cementing.

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Strong particles foster inside the fluid during the nucleation stage. At the point when these particles create, their inside energy is not exactly that of the encompassing fluid, bringing about an energy interface between the two. Since the extra energy important to make the connection point surfaces requires the formation of the surface at this point of interaction, the material really undercools, or cools beneath its edge of freezing over, while nucleation happens. It then recalescences, or gets back to its frigid temperature, in anticipation of the precious stone development stage. Since a fractional connection point surface requires less energy than an entire circular point of interaction surface, nucleation happens on a prior strong surface. Fine-grained castings have prevalent characteristics than coarse-grained castings, which may be valuable. Grain refining or immunization, which is the demonstration of acquainting impurities with cause nucleation, may both produce fine grain structure. All of the nucleations portray a gem that creates as the intensity of combination is taken from the fluid until no fluid remaining parts. To upgrade the characteristics of the projecting, the heading, speed, and kind of development might be changed. Directional cementing happens when a material solidifies toward one side and keeps on setting at the opposite end; this is the most ideal kind of grain improvement since it empowers fluid material to make up for shrinkage.

OVERVIEW OFINVESTMENT CASTING: Investment casting, frequently known as lost wax projecting, is an accuracy projecting strategy used to make close net-molded metal items from basically any composite. Notwithstanding its long history in the formation of craftsmanship, the most pervasive utilization of venture projecting in late history has been the creation of parts requiring complex, commonly meager walled castings. While a definite clarification of the method is past the extent of this article, the consecutive periods of the speculation projecting interaction will be examined momentarily, with an emphasis on projecting from fast prototyping designs. The Investment casting cycle begins with the making of a conciliatory example that has a similar major mathematical structure as the last cast object. Designs are many times made utilizing speculation projecting wax shot into a metal wax infusion pass on. Manufacture of the infusion pass on could cost huge number of dollars and require numerous months. Subsequent to making a wax plan, it is gotten together with other wax parts to spread the word about a metal conveyance framework as the door and sprinter framework. The entire wax get together is then lowered in a clay slurry, stuccoed with sand, and dried. The method of plunging and stuccoing is gone on until a shell of 6-8 mm (1/4-3/8 in) is applied.

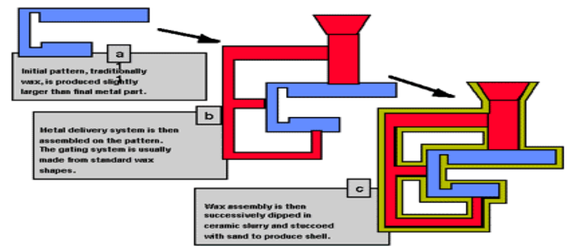

Fig 3 Casting

4. IMPLEMENTATION

METAL USED FOR FABRICATION:

Gentle steel (0.25% carbon) is the most frequently utilized and effortlessly welded constructing material, with the accompanying average mechanical characteristics (BS4360 Level 43A; weldable underlying steel): • Rigidity (N/mm2): 430 N • 230 N/m2 yield strength • 20% lengthening • 210 kN/mm2 pliable modulus • 130 DPN hardness No steel has a pliable modulus more prominent than gentle steel. In this way, in applications in which unbending nature is a restricting variable for plan (e.g., for capacity tanks and refining segments), high-strength prepares enjoy no upper hand over gentle steel. Plastic stream eases pressure focuses in gentle steel developments, which are not as fundamental in other, less-pliable prepares. Gentle steel's solidarity might be expanded by adding unassuming amounts (something like 0.1%) of niobium, permitting the development of semiskilled prepares with yield face up to 280 N/mm2. The yield point might be upgraded to 400 N/mm2 by expanding the manganese focus to generally 1.5%. This further develops strength maintenance at high temperatures and sturdiness at low temperatures. Erosion Opposition: Gear from gentle steel ordinarily is appropriate for taking care of natural solvents, except for those that are chlorinated,

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cold antacid arrangements (in any event, when concentrated), sulfuric corrosive at focuses more prominent than 88%, and nitric corrosive at fixations more noteworthy than 65% at surrounding temperatures. In any event, when mineral acids are very weaken, gentle prepares erode rapidly (pH under 5). Nonetheless, it is some of the time more savvy to use gentle steel and consolidate a huge consumption recompense on the thickness of the gadget. Gentle steel isn't appropriate when metallic defilement of the item isn't allowed. Protection from heat: Gentle steel might be used to a most extreme temperature of 550°C. Over this temperature the development of iron oxides and fast scaling utilizes gentle prepares uneconomical. For gear exposed to high loadings at raised temperatures, it isn't conservative to utilize carbon steel in cases above 450°C on account of its unfortunate drag strength. (Creep strength changes with time, with strain occuring under pressure.) Low Temperatures: The temperatures at which the change happens from flexible to fragile division depends on the steel arrangement, yet in addition on thickness. Financially, the expression "gentle steel" alludes to carbon prepares that are not covered by standard necessities. Carbon content of this steel might change from very low levels up to roughly 0.3%.

MOULD DESIGN:

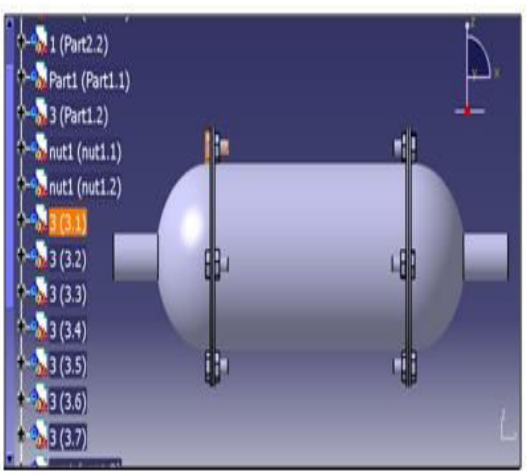

Fig 4 3d view for assembled parts

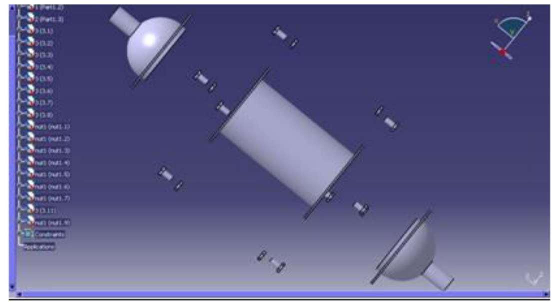

Fig 5 3d view of exploded parts

5. RESULTS AND DISCUSSION

Four mould designs were submitted in response to the "Rath Composite Industry" specifications in order to assess the manufacturing process's viability. Our design team suggested two casting concepts and two fabrication solutions.

DESIGNS FOR CASTING:

The first design for the mould (for centrifugal casting of pressure vessel inner shell) via the casting technique. There are various limits in this design for inserting the glass fibre in the mould. As a consequence, removing the inner shell of the LPG pressure vessel may be possible or difficult.

2ndDESIGN: This is the second design for the mould (for centrifugal casting of the inner shell of pressure vessels) via casting technique. The second design incorporates some fillets and eliminates sharp edges to lessen stress concentration efforts. This may result in the smooth removal of the inner shell of the LPG pressure vessel from the mould.

DESIGNS FOR FABRICATION:

1ST DESIGN: This is the design for the mould (for centrifugal casting of the inner shell of pressure vessels) via manufacturing procedure. The fabrication process is used to prepare the mould in order to make it easier to remove the component from the mould. The mould is divided into three sections, each having two hemispherical ends and a shell component.

2ND DESIGN: In this design, the mould is enhanced further by including apertures to make removing the component easier.

6. CONCLUSION

The firm accepted the second design of casting and the second design of fabrication among the four mould designs (Rath Composite Industries). The task was completed by splitting the seven people into two groups, one with four members for casting and the other with three members for fabrication. Thus, the moulds acquired from the casting and fabrication processes are utilised to produce the inner shell of the LPG pressure vessel by centrifugal casting by inserting the mould in the centrifuging setup. Thus, the experiment focused on improving the manufacturing process for the inner shell of an LPG pressure vessel.

Future work is the inner shell of the pressure vessel created from centrifugal casting might be further filament wounded and utilised as an LPG storage tank.

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