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Study of Structural behaviour of SS 316 Water Tank using ANSYS Workbench under Hydrostatic Pressure

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ABSRACT. Stainless steel alloys exhibit various properties like high thermal resistance, corrosive resistance, high flexibility, strength and high hardness. They act as a replacement for the concrete water tanks and a partial replacement on plastic water tanks which have been used for ages. Among those alloys, Stainless Steel 316 (SS 316) is significantly used to fabricate water tank thanks to its mechanical and thermal properties. In this study, the strength parameters and structural behaviour of SS 316 water tank under hydrostatic pressure was explored. SS 316 specimen was tested manually and analysed by using ANSYS Workbench. The steel tank was analysed using ANSYS Workbench by static structural analysis. Based on the results, the structural design of the steel tank will be proposed. In order to enhance the serviceability of the SS 316, the water is filtered before storing in the water tank. The outcomes can be beneficially used for designing water tank.

Keywords – Stainless Steel, SS 316, ANSYS Workbench, tensile strength, hydrostatic pressure, Static structural analysis, Rapid sand filter

I. INTRODUCTION

The rapid increase in population demands housing facilities. The interconnection between population and housing seems obvious. A water storage tank is an essential in every housing. Storage containers are commonly built in a cylindrical shape, and conical-cylindrical combined tanks. The construction of conical-cylindrical tanks is dominated by using either steel, conventional reinforced concrete or partially pre-stressed concrete. The decision to select the most proper construction material for conical-cylindrical tanks depends on various factors: structural performance, material cost, life service, material availability and cost of labour works . The main advantages of reinforced concrete tanks over steel tanks are that they provide high resistance to compression stresses and have long service life (up to 50 years) compared to steel tanks (up to 20 years) . The main disadvantages of reinforced concrete tanks are related to the low tensile strength and the large thickness required to satisfy design requirements, which leads to a significant increase in its weight. The weight of steel tank is 1/03 times lighter than the weight of the concrete tank. Also the installation of the steel tanks is takes a minimal time period which is 1/3 times less than the time taken for the construction of concrete tanks. Despite the advantage of using reinforced concrete as a construction material for storage tanks, steel tanks are widely used in North America and European countries over the last 25 years. The fact that steel storage tanks are leak-free structures and they also provide high tension resistance and lighter own weight compared to reinforced concrete counterparts. There are various grades of stainless steel alloys among them selecting the most suitable one for the steel tank construction was quiet a challenge as there where lot of features considered. Stainless steel 304 (SS 304) and Stainless steel (SS 316) are considered to be more ideal after few studies based on the composition and mechanical properties od the stainless steel which are similar in most aspects. Though SS 304 offers the standard corrosion resistance, formability, strength, and easy maintenance, SS 316 is more preferred among them for a steel water tank construction due to it is vastly superior corrosion resistance to chlorides and acids.

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Stainless steel with high molybdenum content is beneficial for construction of steel tanks, where greater corrosion resistance is essential. Hence SS 316 is much appropriate choice for steel tank construction. In order to increase the life time of the steel tank, the hardness of the water stored in the water tank can be filtered by the means ofRapid sand filter system. The only concern about steel as a construction material is that it is sensitive to geometric imperfections, buckling, and corrosion problems which are to be considered in the future.

This study evaluates the structural behaviour of alloy, SS 316, which is widely used in industry and construction industry. The evaluation is done by laboratory testing of the SS 316 Specimen and software analysis of the steel tank using ANSYS Workbench. The ANSYS Workbench is a tool used for stimulation and analysing various interacting data on the designed geometry. It helps in obtaining analytical solutionsfor different aspects like complex geometrical shape, different and new material properties and diverse boundary conditions of the problem easily. Designing of the geometry is done using Solidworkswhich is platform for designing 2D and 3D geometrical models similar to CAD. The analysis of the tank is done by a method, Static Structural analysis. The static structural analysis in ANSYS Workbench has become popular by it is usefulness and user friendly support practice in every analysis. The aim of this study is for predicting the behavioural characteristics and properties of steel, as they play vital role in designing of the steel water tank.

II. STAINLESS STEEL 316 (SS 316)

2.1. Chemical Composition of SS 316:

Stainless steel 316 has an amount of molybdenum which helps in reducing corrosion. So, resistance to corrosion is achieved. SS 316 is immune to grain boundary carbide precipitation which makes it suited to use in heavy gauge. Stainless steel contains an amount of titanium around 0.5% which prevents carbide precipitation and protects metal from corrosion.The composition of the SS 316 is shown in Table 1.[1]

Table 1. Composition of Stainless Steel 316.

ELEMENT	PERCENTAGE %
C	0.0 –0.07
Mn	0.0 – 2.0
Si	0.0 – 1.0
P	0.0 – 0.05
S	0.0 – 0.02
Cr	16.50 – 18.50
Mo	2.0 – 2.5
Ni	10.0 – 13.0
F	Balance

2.2. Properties of SS316:

The proof stress and elongation are 200 MPa and 40%. Hardness Brinell value is 215. The tensile strength of SS 316 bar and a section of thickness up to 160mm thick is 500-700 MPa. The 8 g/cm^3 of SS 316 has a melting point and modulus of elasticity value of 1400^{0}C and 193 GPa. It has a thermal and electrical conductivity of 16.3 W/m.K and 0.74 x 10^{-6}Ω.m. It also has a thermal expansion of 15.9 x 10^{-6}/K. Though SS 316 has a yield strength comparatively less than its own tensile strength, the value is compensational when compared to other grades of steel. Stainless steel 316 has excellent corrosion resistance when exposed to a range of corrosive environments and media.Stainless steel 316 has good resistance to oxidation in intermittent service to 870°C and in continuous service to 925°C. However, continuous use at 425-860°C is not recommended if corrosion resistance in water is required. Stainless steel 316 is readily brake or roll formed into a variety of parts. It is also suited to stamping, heading and drawing but post work annealing is recommended to relieve internal stresses. Cold working will increase both strength and hardness of Stainless steel 316. All common hot working processes can be performed on Stainless steel 316. Hot working should be avoided below 927°C. The ideal temperature range for hot working is 1149-1260°C. Post-work annealing is recommended to ensure optimum corrosion resistance. Through heat treatment of SS 316 make it more resistant to corrosion and oxidation.[2][3]

2.3. Supremacy of SS 316

Grade 316 stainless steel is both tough and versatile. The 316 stainless steel has a stronger resistance to various chemical agents that might damage or corrode 304 stainless steel. Steel with higher levels of molybdenum (up to 6%) appear in oil-platform components. When temperatures get higher, 316 stainless steel gets tougher. Though it remains just as easy to fabricate as SS304, it will not harden under heat treatment. Salt water can be especially damaging to metals. Salt will even compromise the protective oxide layer of grade 304 stainless steel, resulting in rust. For the processes involving chlorides, grade 316 stainless steel is ideal. Grade 316 has especially better resistance to salt and chloride pitting. Pitting corrosion can occur when stainless steel alloys, such as grade 304 stainless steel, come into contact with salt-rich water. Chloride resistant metals, like SS316, are

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essential to use for naval applications or anything involved with chloride. For instance, grade 316 stainless steel can withstand caustic solutions and corrosive applications such as vapour degreasing or many other parts cleaning processes. Hence grade 316 stainless steel is more advantageously for the manufacturing of stainless steel.[4][13]

III. RAPID SAND FILTER SYSTEM

3.1.Design and specifications of Filter System

The hardness of water stored in the tank plays a vital role in the maintenance and life time of the in the tank due to salt deposition. In order to reduce hardness, a filter system is installed with the steel tank.A 2HP motor is used for pumping water from underground up to a height of 12m. The filter system is located at a height of 12m from ground level. The diameter of the pipe connecting the pump and filter system having a flow rate of 0.67m/s is 1.5 inch. The filter system consists of two layers. The layers are fine aggregate (0.014-0.024-inch tk) and coarse aggregate (0.024-0.04-inch tk). This filter system is designed to filter large suspended particles of size (usually < 0.1-1 Nephelometric Turbidity Unit) in the bore well water. The water from the pump enters the filtering system having a discharge of 1.8 LPS. The filter of 1.5 m² area can filter 2.053 LPS. The water after filtration enters the pressure pump which pumps the water to the steel tank at a pressure of 3-7Kg/cm². Capacity of residential metallic tank is 2000 L.[5][6] The sectional view of the filter system designed by Auto CAD Software is shown in figure 1.

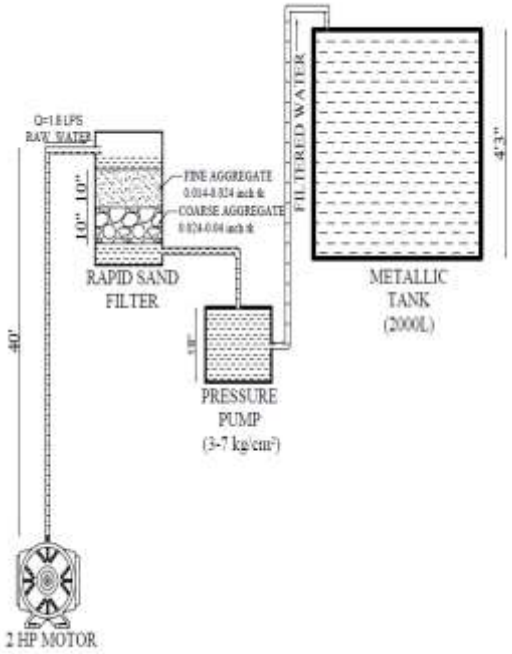

Figure 1. Sectional view of the filter system.

3.2.Process of Filtration

The water flowing at a rate of 0.67 m/s enters the filtering unit and passes through the fine aggregate (0.0014-0.0024-inch tk) in which the larger suspended particles and dispersed particles of size more than 100 nm get filtered. When the semi filtered water gets through the coarse aggregate (0.0024-0.04-inch tk) which filters particles of volume 1 cm³ with edges of 10 nm. The rapid sand filter filters flocculant chemicals such as colloids, suspended particles and pathogens up to 90% and then water enters the pressure pump in order to get pumped to the metallic tank. The particles and impurities that have been trapped in the gravels have to be manually cleaned. The pipes connected at the edges of the tank transports the filtered water to all the pipelines.[7][8]

IV. TENSILE TEST OF SPECIMEN

4.1.Laboratory test using UTM

Tensile test has a significant impact on the mechanical properties. In this study, tensile test was performed according to the Indian StandardASTM E8for the tensile test specimen, the dog bone specimen which undergoes the effect of changing laboratory conditions in the Universal Testing Machine (UTM). The specimen rod initially before performing tensile test in UTM machine is shown in Figure 2. Initially the load pointer was set at zero by adjusting the knob.Small elongation of the specimen was measured by fixing the dial gauge. The mean diameter and the length of the specimen is measured using vernier before the application of load. Automatic graph recorder was set The control valve was slowly turned to an open position to get the desired loading rate. With increase in load, the pointer goes backwards from stationary position and the specimen fails. The specimen rod after the failure in the test is shown in Figure 3. The readings are recorded until the specimen fails. The tensile test laboratory report and graph is shown in Figure 4.

Figure 2. Specimen rod before testing.

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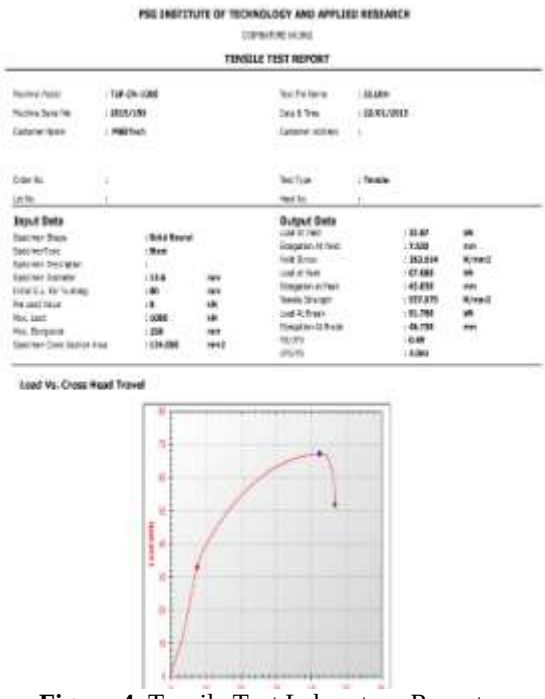
Figure 3. Specimen rod after testing.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TENSILE TEST REPORT

Input Data

Output Data

Load Vs. Cross Head Travel

Figure 4. Tensile Test Laboratory Report.

4.2. Analysis using ANSYS

The specimen rod of having dimensions of the dog bone specimen used for the tensile testingwithout the grips was designed using Solidworkssoftware as shown in Figure 5. The analysis of the specimen was done using ANSYS workbench by creating a setup of procedures. The analysis carried is static structural analysis. After importing the Solidworksmodel, the material property is choose followed by the creation of mesh.[9] The force is set up in accordance to the force applied in UTM machine, the boundary conditions, the direction of the action of the force are defined and to obtain the solution.[10][11] At one of the end, a fixed support was given and at the other end the load was applied. The stress distribution after the analysis by applying minimal value of force is shown in Figure 6.

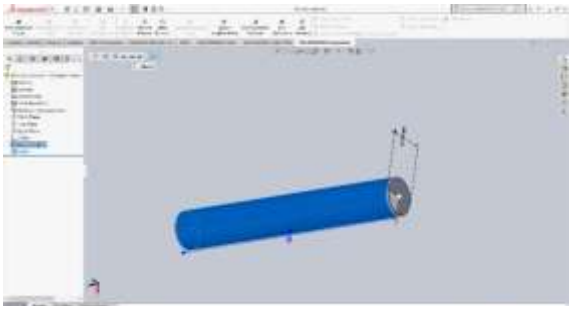

Figure 5. Specimen model using Solidworks.

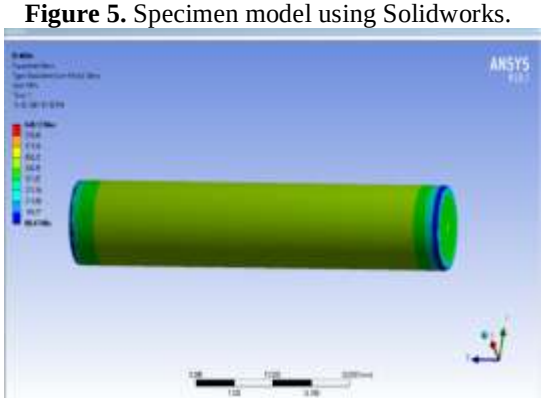

Figure 6. Stress analysis using ANSYS.

V. ANALYSIS OF STAINLESS STEEL 316 (SS 316)

5.1.Modeling of SS316 Steel tank in solid works

Solidworks softwareis a computer-aided solid modelling tool used to make 3D engineering designs.The basic model of a steel tank was sketched and designed using the Solidworks.[12] The modelling was done using various toolslike sketch tool, extruded cut tool and revolve tool for the rough dimensions, diameter 50 inches, height 65 inches and having a thickness of 0.80 inches. The model of the steel tank designed using the Solidworksis shown in Figure 7.

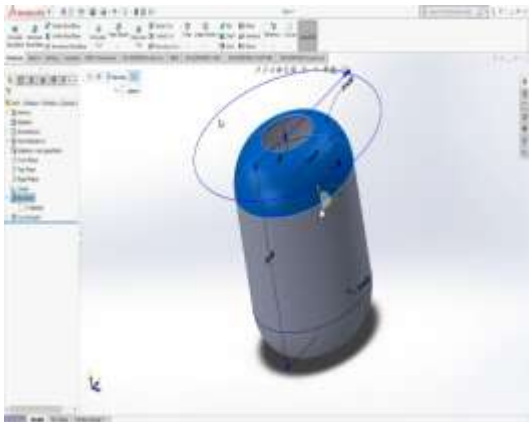

Figure 7. Steel tank model using Solidworks software.

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5.2.Analysis of SS 316 in ANSYS Workbench

ANSYS Workbench is a new modern interface which is used for efficient engineering simulations of the geometrical engineering designs. Accuracy in analysing strength, toughness, elasticity, fluid flow and other attributes are the main features that encourage the analysis using the ANSYS Workbench. It helps in modal analysis to determine and predict various robust simulations accurately and efficiently. In this paper static structural data is used for the analysis. Static analysis determines the simulation changes due to eternally applied load which causes stress, strain, deformation, forces etc.There are conventional stages of ANSYS to be fulfilled for the structural analysis of the steel tank which includes geometrical models, meshing, setup and so on. The static structural workbench format is shown in Figure 8.

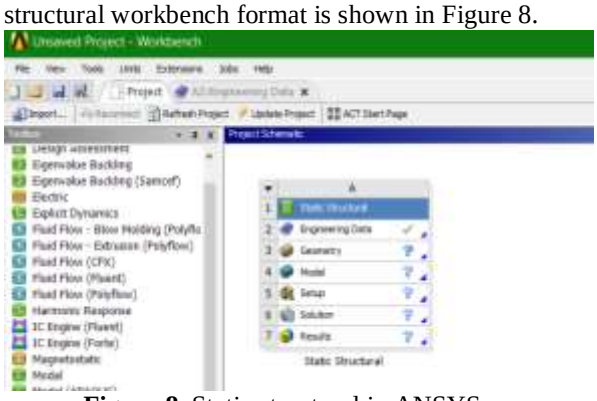

Figure 8. Static structural in ANSYS.

5.2.1. Engineering data

Selection of the mechanical properties of the element is the initial step. The property of the material was selected by defining in the engineering data. The required data of SS 316 is filteredfrom the engineering data sources library. The engineering data defined as Stainless steel is shown in Figure 9.

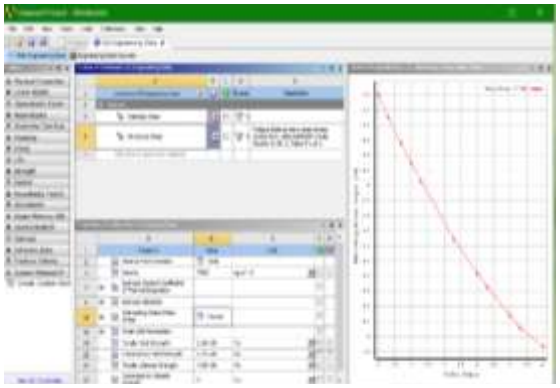

Figure 9. Engineering data in ANSYS.

5.2.2. Geometry and Mesh

The steel tank model designed using Solidworks software platform is imported as geometry in the Workbench. Furthermore, using of suitable mesh type, based on the original geometry is a very important step. The efficiency and the accuracy of a simulation is greatly influenced by the mesh. This mesh geometry is breaks the entire domain geometry into small pieces each representing an element. The effective mesh is created by having a fine span angle length, resolution value 7 and the minimum edge length 20.32 mm. After defining the mesh a web layer is formed for the steel tank as shown in the Figure 10.

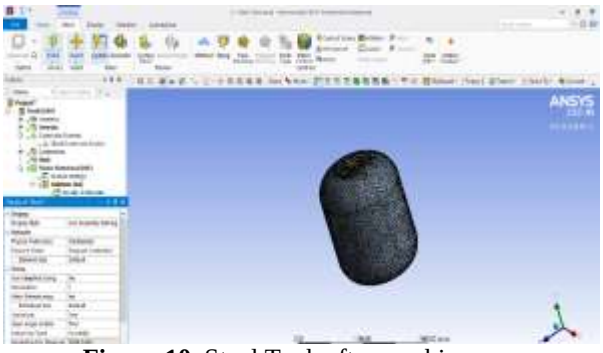

Figure 10. Steel Tank after meshing.

5.2.3. Setup and solution

After the meshing process, the analysis established the ANSYS prototype and the values for the hydrostatic pressure analysis.Hydrostatic pressure is the pressure exerted by fluid at a point under the influence of gravity. The workbench window when the hydrostatic pressure is zero initially shown in Figure 11. The values of hydrostatic acceleration as 9.81 m/s^2in the Y-coordinate,density of water as 1000 kg/m^3 and the height of the tank as 65inches are defined in the global coordinate system to analyse the hydrostatic pressure that acts on the steel tank. The values defined for the analysis of hydrostatic pressure on the steel tanks is shown in Figure 12.

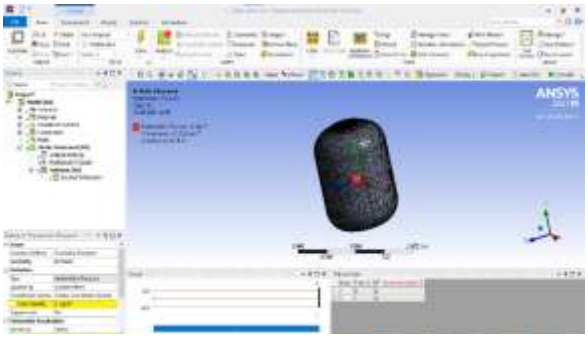

Figure 11. Workbench setup when the pressure is zero initially.

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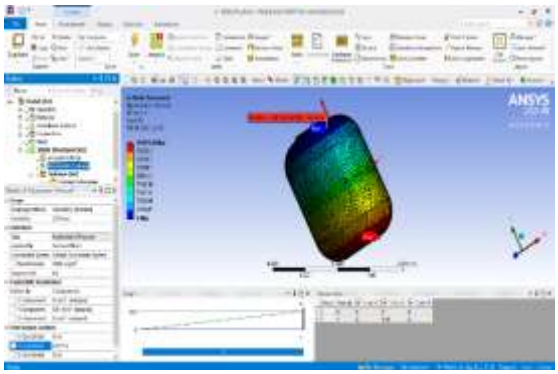

Figure 12. Workbench setup after the values for hydrostatic pressure analysis are defined.

VI. RESULTS AND INFERENCES

6.1. Tensile test of SS 316 specimen rod

The tensile test was performed to collect data from actual steel samples, and the results were used in simulation to accurately study the hardening behaviour of the steel being simulated. ANSYS Workbench was used to analyse tensile stress distribution over the membrane surface under different strain loading conditions where the material behaviour under tension load is established. The material property of SS 316 analysed using ANSYS under the boundary condition of Static Structural type confer the property of the specimen with direct measurements ofultimate tensile strength, breaking strength, maximum elongation and reduction in area. From these measurements Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics were determined.The ANSYS simulation results were referenced to the actual tensile test results and it was found they are comparable.

6.2.Hydrostatic pressure of SS 316 Steel Tank

Hydrostatic pressure increases proportional to depth from its surface as increase in weight of fluid exerts downward force from above. In Ansys the Hydrostatic pressure load stimulates the pressure that is exerted by the water stored in different receptacle. This boundary conditions is available in Static structural, Explicit Dynamics and Transit structural of Ansys analysis type. A static structural analysis determines the displacements, stresses, strains, and forces in structures caused by loads. In order to study the hydrostatic property on material SS 316, stimulation of hydrostatic pressure is executed which determines the force of fluid applied to the surface of the container and the ability of the receptacle to withstand the pressure, from which its material property is been examined. The result of the hydrostatic pressure analysis of steel tank in ANSYS Workbench is shown in Figure 13.

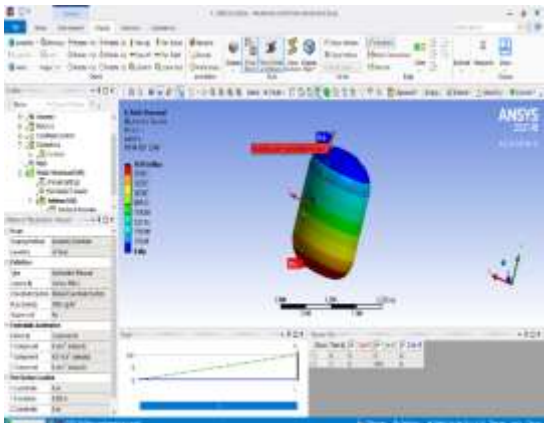

Figure 13. Hydrostatic pressure analysis in ANSYS.

VII. CONCLUSIONS

- Investigation of the SS 316 steel water tanks was carried out by using static structural method in Ansys Workbench Software.
- In this paper analyses for the tensile test of the specimen and the hydrostatic pressure of the tank was done.
- The analysis results of the above study will be helpful incalculating the most suitable thickness of the tank and the structural design of the same.

Acknowledgement

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