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Review TMET

Failure Analyses of 16 mm Thick SA 516 GR 70 Auto Clave

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Abstract

With the acceleration of global industrialization, there is a demand for high-or low-pressure storage of liquids or gases. Because of the complicated operating conditions that will inevitably encounter a possible hazard, pressure vessel design is a critical responsibility. Previous failure studies have revealed that the presence of local loads and discontinuities increases pressure vessel fracture. As a result, a detailed examination of pressure vessel steel from the standpoint of fracture is essential. During service or production, internal, surface, semi-elliptical cracks in pressure tanks and pipes are occasionally observed. A manufacturing fault, such as slag inclusion, cracks in a weldment, or heat impacted zones caused by uneven cooling and the presence of foreign particles, can cause a fracture within a component. Fatigue and fracture as a result Such crack investigations necessitate the estimation of stress intensity factors for a wide range of crack forms and sizes encountered. In this project, we are designing a pressure vessel using ASME section VIII and Division 2 to determine the thickness of the shell, head, nozzle, and leg support. The entire vessel has a uniform thickness. Pro-e 2.0 was used to model the pressure vessel, was used to mesh it. The meshing is done with a 2D Quad element, and the analysis is done with ANSYS Software 11 for two separate instances, working pressure and maximum operating pressure, with a fatigue study, and the result is 106. Finally, the entire model is theoretically validated, with results that are within acceptable limits. Because the pressure is higher than that of the surrounding environment, it is hazardous and, in some cases, fatal. A few pressure vessel instances Pressure vessels hold a considerable amount of energy; the higher the working pressure-and the larger the vessel-the more energy released, resulting in a greater magnitude of damage, disaster, or danger in the case of a rupture.

Keywords: ASME Code, Pressure vessels (Auto Clave) failure; Reliability; SA 516 GR 70, Analytical Calculation, Thermal Analysis.

INTRODUCTION

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This document provides an overview of pressure vessels and low-pressure storage tanks from a technological standpoint. This overview and information are meant to assist in identifying potentially harmful conditions and determining the level of safety for ongoing operations. The vessels and tanks under consideration are significantly larger metallic vessels used to hold liquids and gases at varying temperatures and pressures.

Despite the fact that pressure vessels designed to one of the recognized design codes have an excellent safety record, recent incidents raise worries about their continued reliability and safety, particularly when combined with the current trend of extending service life. A significant majority of the boats inspected in recent inspection procedures for various sorts of applications indicated cracking and damage. These findings will be examined in greater depth later in this publication.

PRODUCT DETAILS

Identification of the Material

Inexpensive carbon steel is the most prevalent type of steel due to its low cost and ability to give material qualities for a variety of applications. Mild steel has a carbon content of 0.005 to 0.25 percent, making it ductile and malleable. Because of its low carbon content, mild steel has a poor tensile strength. To lower the rate of cooling, thick parts may need to be preheated. Steel grades for pressure vessels, boilers, heat exchangers, and any other vessel that carries a gas or liquid at high pressures are available in a variety of steel grades. Gas cylinders for cooking and welding, oxygen cylinders for diving, and many of the enormous metallic tanks found in an oil refinery or chemical factory are all examples. There are numerous substances and liquids that can be kept and treated under pressure.

ASTM A516 Grade 70 has great notch toughness and is used in both pressure vessels and industrial boilers. It is an excellent choice for service in lower than ambient temperature applications, has excellent notch toughness, and is used in both pressure vessels and industrial boilers. When compared to ASTM A516 Grade 65, it has a higher yield and tensile strength and can work at lower temperatures. It's perfect for the oil, gas, and petrochemical industries' rigorous standards. Pressure vessel shows in the Figure 1 part (a) and (b). And Table 1 shows the Description of the pressure vessel.

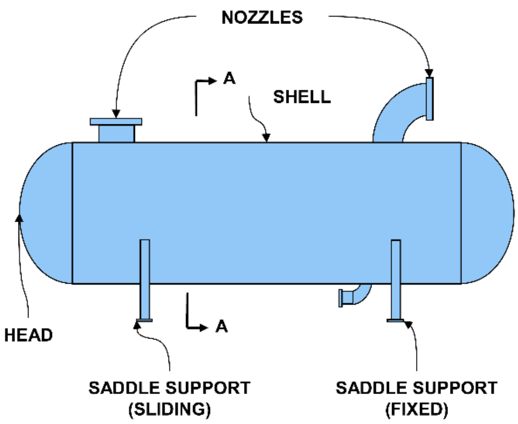

Figure 1. (a) Pressure Vessel.

Figure 1. (b) Pressure Vessel.

Table 1. Description of the pressure vessel

Column Head	Material	SA 516 Grade 70
1	Outer Radius	994 mm
2	Inner Radius	915 mm
3	Minimum Wall Thickness	79 mm
4	Working Pressure	9.93 MPa
5	Working Temperature	60°C
6	Yield Point	262 MPa

MATERIALS

Steel

Mild steel is a carbon steel with a low carbon content. It's also referred to as "low carbon steel." The quantity of carbon in mild steel is normally 0.05 percent to 0.25 percent by weight, though this varies depending on the supplier.

Higher carbon steels, on the other hand, are usually classified as having a carbon content ranging from 0.30 percent to 2.0 percent. If any extra carbon is added to the steel, it is classified as cast iron.

Mild steel has less carbon than high carbon and other steels, making it more ductile, machinable, and weldable. However, this also means that hardening and strengthening through heating and quenching is almost impossible.

Mild steel is a popular consumer steel because of its affordability, weldability, and machinability Figure 2 shows the mild steel. Table 2 shows the ASTM A516 mechanical properties.

Figure 2. Mild Steel.

Table 2. ASTM A516 mechanical properties

Parameters	Value	Unit
Tensile strength	485–620	MPa
Yield strength	Inner Radius	915 mm
Elongation in 200 mm (min)	Minimum Wall Thickness	79 mm
Elongation in 50 mm (min)	Working Pressure	9.93 MPa

Pressure Vessel Steel Plate Grades:

- A516 60
- A516 70
- A516 60/65/70 + HIC
- P355 NL2
- P355 NH
- P460 NL2
- A387 5, 11, 12 & 22
- 16Mo3 ASTM/ASME A516 70 + HIC 6 mm 100 mm

Boiler Plates

- German made–often Dillinger but also some Thyssen and Cableco
- EN10204 3.1 or 3.2 certification
- Thickness 6–200 mm
- Width–1.5 m, 2 m, 2.5 and 3 m
- Length Up to 12 m

CATEGORIES OF FAILURE IN PRESSURE VESSEL

Material—inadequate material selection; flaws un the material Inadequate shop testing; erroneous design data; imprecise or inappropriate design procedures. Poor quality control; incorrect or insufficient fabrication operations, such as welding; and heat treatment or shaping methods. Changes in service condition caused by the user; unskilled operations or maintenance employees; and upset situations are all examples of service issues. The following are some examples of services that demand specific consideration in terms of material selection, design details, and fabrication methods:

- Fatigue (cyclic)
- Fragile (low temperature)
- Excessive heat
- A high level of shock or vibration
- Hydrogen, ammonia, compressed air, caustic, chlorides, and hydrocarbons are among the contents of the vessel.

TPYES OF FAILURE

1. Elastic deformation, also known as elastic instability or elastic buckling, is prevented by vessel design, stiffness, and material qualities.
2. At low or moderate temperatures, brittle fractures can occur. Brittle fractures have occurred in vessels made of low carbon steel with small flaws during hydrostatic testing in the 40–50°F range. Excessive plastic deformation—The ASME Section VIII, Division 2 main and secondary stress limitations are designed to prevent excessive plastic deformation and progressive collapse.
3. Stress rupture-Creep deformation caused by fatigue or cyclic loading that leads to progressive fracture. Creep is a time-dependent event, whereas fatigue is a cycle-dependent behavior.

Plastic instability-Incremental collapse (cyclic strain accumulation or cumulative cyclic deformation); cyclic strain accumulation or cumulative cyclic deformation is incremental collapse. Plastic deformation causes the vessel to become unstable as a result of cumulative damage High strain-low cycle fatigue occurs in low-strength, high-ductile materials and is strain-dependent. Stress corrosion—Stress corrosion cracking occurs in stainless steels due to chlorides, and caustic service can also cause stress corrosion cracking in carbon steels. Material selection is critical in these services. Corrosion fatigue occurs when corrosive and fatigue effects are present at the same time. Corrosion can shorten the life of a component by pitting the surface and spreading cracks. The main factors are material selection and fatigue characteristics.

LITERATURE SURVEY

Noraphaiphipaksa, N., Poapongsakorn, P., Hasap, A., & Kanchanomai, C. (2020) [1]. A pressure vessel's sight ports can be used to examine the liquid level. Because a sight port is made up of several components (such as the body frame, gasket, sight glass, cover frame, bolt, and nut), each one is crucial to the pressure vessel's performance. Under high-stress conditions, a pressure vessel's sight port may fail due to faulty design and/or installation. In this work, the hydrostatic test was employed to evaluate a pressure vessel at simulated service pressure. Failures due to plastic deformation of the cover frame and water leakage were discovered during the hydrostatic test. Finite element analysis was used to investigate the root cause of these issues (FEA). The pressures on the cover frame were revealed to be higher than the material's limits due to improper geometries and placements of apertures, reinforced pad, and sight ports (i.e., SUS316 stainless steel). As a result, FEA was utilized to design and test a new pressure vessel with rounded apertures, shorter and thicker sight ports, and a larger reinforced pad There was no evidence of water leakage or failure in any of the new pressure vessel's components after the hydrostatic test.

Niranjana, S.J., Patel, S.V., & Dubey, A.K. (2018, June) [2]. Using ASME Section VIII and Division 2, you will design a closed container to estimate the required thickness of the shell, head, nozzle, and leg support. The entire vessel was given a uniform thickness. Pro-e 2.0 was used to model the pressure vessel, while Hyper mesh 6.1 was used to mesh the data. The meshing was done with a 2D Quad element, and the analysis was done with ANSYS Software 11 for two separate cases: working pressure and maximum operating pressure, with a result of 106. Finally, the entire model is theoretically validated, yielding values within an acceptable range.

Anbazhagan, A.S., Anand, M.D., & Milton, G.A. (2012) [3]. The design of wind and seismic equipment is a crucial necessity in the oil and gas industry. Oil and gas plants are often located distant from residential areas. However, if a strong earthquake or wind occurs, this will result in a tragedy due to equipment failure, as these plants handle a variety of hazardous poisonous process fluids and gases. Many disasters have occurred in various businesses around the world as a result of excessive wind and earthquake effects. In this research, we looked at how horizontal pressure vessels should be designed to handle severe external wind and seismic forces, as well as what design considerations should be made to avoid vessel failures. Because this is not a common industry practice at the moment, the finite element-based design technique is advised. The fabrication industry as a whole is taking an analytical approach. That could be why some pressure vessels fail despite being designed to do so. The downside of the analytical method is that we cannot visualize specific stresses during design, hence there is a large risk of over and under design. One of the main motivations for building a strong solution through this study article is to address this issue. In addition, there is no industry-wide FEM-based design approach to follow to determine the adequacy of this design under all specified loading conditions, the allowed stresses are examined and reported using ASME SECVUIDIV-I, ASME DIV-II, IS-875, and IS-1893 code standards. The obtained results meet the requirements of international codes and standards, as well as industry norms.

Kusmartono, D., & Nugroho, G. (2019, November) [4]. This paper uses the 3D Extended finite element method to handle the problem of determining the stress intensity factors (SIF) of semi-elliptical fractures in the shell and knuckle area of a pressure vessel (XEFM). Crack width will be adjusted dependent on crack depth while keeping the elliptical ratio constant. The numerical strategy for the SIF calculation of a pressure vessel semi-elliptical fracture is shown to be very efficient, and the modelling specifics of the sub-structuring methodology used in the analysis are explained. According to the findings, cracks in the shell have a higher potential to propagate than cracks in the knuckle area, although having the same geometry. This is owing to the fact that tensile stress dominates at the shell, whereas compressive stress dominates at the knuckle.

Kusmartono, D., & Nugroho, G. (2019, November) [5]. This paper uses the 3D Extended finite element method to handle the problem of determining the stress intensity factors (SIF) of semi-elliptical fractures in the shell and knuckle area of a pressure vessel (XEFM). Crack width will be adjusted dependent on crack depth while keeping the elliptical ratio constant. The numerical strategy for the SIF calculation of a pressure vessel semi-elliptical fracture is shown to be very efficient, and the modelling specifics of the sub-structuring methodology used in the analysis are explained. The findings reveal that cracks in the shell had a higher potential to propagate than cracks in the knuckle area, although having the same geometry. This is owing to the fact that tension in the shell is dominated by tensile stress, whereas stress in the knuckle area is driven by compressive stress.

Noraphaiphipaksa, N., Poapongsakorn, P., Hasap, A., & Kanchanomai, C. (2020) [6] A pressure vessel's sight ports can be used to examine the liquid level. Because a sight port is made up of several components (such as the body frame, gasket, sight glass, cover frame, bolt, and nut), each one is crucial to the pressure vessel's performance. Under high-stress conditions, a pressure vessel's sight port may fail due to faulty design and/or installation. In this work, the hydrostatic test was employed to evaluate a pressure vessel at simulated service pressure. Failures due to plastic deformation of the cover frame and water leakage were discovered during the hydrostatic test. Finite element analysis was used to investigate the root cause of these issues (FEA). The pressures on the cover frame were revealed to be higher than the material's limits due to improper geometries and placements of apertures, reinforced pad, and sight ports (i.e., SUS316 stainless steel). As a result, FEA was utilized to design and test a new pressure vessel with rounded apertures, shorter and thicker sight ports, and a larger reinforced pad.

Patel, B.C., Gupta, B., & Choubey [7], In fracture mechanics, the stress intensity factor (K) is used to more correctly estimate the stress condition ("stress intensity") near the crack tip produced by an inaccessible load or residual stresses. The current study explains how to analyses critical fracture toughness criteria such as stress intensity fracture. The goal of this research is to determine the mechanical properties of pressure vessel materials IS 2062 and SA 516 Gr-70 in thicknesses of 12, 16, 18, and 20 mm, as well as the critical stress intensity factor of a disc-shaped compact specimen DC(T) with a crack/width ratio of 0.5., as recommended by ASTM E-399.

Dixit, S., & Chaudhari, V. (2020) [8]. The goal of this research is to use a finite element approach to predict the fracture behaviour of SA 516 pressure vessel steel. Tensile and compact tension specimens were made according to ASTM requirements for experimental testing. Tensile and fracture testing were used to determine mechanical and fracture parameters, respectively. The phenomenological cohesive zone model is employed because it is fundamentally based on fracture energy and ductile resistance. Fracture growth is simulated by gradual degradation of cohesive materials in front of the crack tip. The required cohesive characteristics, such as cohesive strength and cohesive energy, are calculated using experimental data. Different cohesive laws and fracture process zone heights are investigated. For selected steel, a cohesive zone model with a continuous cohesive law was determined to be suitable. The 0.05 mm fracture process zone height was found to be suitable for the steel under investigation.

Palekar, A., Kompelli, P., Mayekar, N., Shembekar, A., Kurane, R., Mahatale, R., &Bharadwaj, S. (2016) [9]. Pressure Vessels are closed containers that are used to store fluids at temperatures and pressures that are different from ambient. They're utilized as reactors, convertors, regenerators, and splitters, among other things. Cylinders, spheres, and cones are the most common types of pressure vessels, with cylinders being the most common. Pressure vessels have a main body or shell, a head, saddles, and nozzles, among other features. Mono-Layer Cylindrical Pressure Vessels and Multi-Layer Cylindrical Pressure Vessels are available. Shrink fitting is used to make Multi Wall Pressure Vessels, which are a form of Multi-Layer Pressure Vessel. When fluids are retained in such critical conditions, the vessel's shell thickness is increased, with a high thickness associated with it. The building of a pressure vessel presents its own set of challenges, such as bulkiness and high material costs. Multi Wall Vessels are utilized to alleviate these problems. Shrink fitting is the process of fitting a thermally inflated shell over a normal-temperature shell. To get the desired interference, the system is cooled. This interference produces the requisite compressive stresses within the shells, which are employed to counteract the fluids' tensile stresses. For the same internal pressure, this minimizes Hoop's stresses, resulting in a smaller shell than that of a Mono Wall Pressure Vessel. As a result, both material cost and quantity are optimized. The purpose of our project is to look at Multi Wall Pressure Vessels and code calculations for the shell based on ASME Section VIII, Div. 1 and Div. 2 for a case study of a Pressure Vessel with a specific internal pressure. Validation of code calculations is also part of our work, which is done with the programmer ANSYS APDL 15.0.

Patel, B.C., Gupta, B., & Choubey [10], To more precisely anticipate the stress condition ("stress intensity") around the crack tip induced by an inaccessible load or residual tensions in fracture mechanics, the idea of the stress intensity factor (K) is commonly employed. The current study focuses on the comparison of experimental and numerical residual stress evaluations. Factor affecting the severity of stress (K). The mechanical properties of pressure vessel materials IS 2062 and SA 516 Gr-70 with different thicknesses of 12, 16, 18, and 20 mm, as well as the critical stress intensity factor of disc shaped compact specimen DC(T) with a crack/width ratio of 0.5 as suggested by ASTM E-399, are tested using experimental and numerical techniques.

Dixit, S., Chaudhari, V., & Kulkarni, D.M. (2020) [11]. Using a combined experimental–simulation method, the current study investigates the fracture behavior of SA 387 and SA 516 pressure vessel steels. Mechanical and fracture parameters are determined using tensile and fracture testing. Within the XFEM framework, a cohesive model is created for fracture investigations of pressure vessel steels. To model a fracture, continuous degradation of the elements is taken into account, and a reasonable criterion for selecting cohesive parameters is suggested (i.e., cohesive stiffness, cohesive strength, and cohesive energy). Simulations are used to investigate the effects of traction separation laws (exponential, partly constant, and constant). The simulation results are validated using experimental data. Among the chosen traction separation laws, it was discovered that partially constant and constant traction separation laws are appropriate for SA 387 and SA 516 pressure vessel steel, respectively. The fracture surface morphology analysis has also confirmed that SA 387 steel has less fracture resistance than SA 516 steel.

Sharma, S., & Samal, M.K. (2020) [12]. The purpose of this research is to see how loading rate affects the dispersion of cleavage fracture toughness data in SA516 Gr.70 steel in the ductile-to-brittle transition temperature (DBTT) regime, as well as the temperature dependence of the data. This steel is a high-strength carbon steel that is used to make nuclear pressure vessels, transportation casks, and pipelines, among other things. For integrity analysis in radioactive environments, the ASTM E1921 concept of master curve is used, and the reference temperature T0 is produced using experimental data. When fracture specimens are evaluated in a modified split Hopkinson pressure bar (SHPB) test setup, the goal of this study is to see how T0 changes as the loading rate increases. The fracture tests were carried out on sub-sized single-edged notched bend specimens utilizing a custom developed SHPB type test rig at a loading rate of 700 m/min. SHPB test results were compared to those obtained with a lower loading rate of 0.5 m/min. According to the results of the studies, the median value of fracture toughness, as well as the scatter in fracture toughness, increases with temperature in the DBTT regime for both loading rates.

Patel, D.M., & Kumar, B. (2014) [13]. The nozzles or valves in a pressure vessel contain several intake and outlet apertures. The design specifications of these valves may differ in one pressure vessel. Because these valves generate a geometric discontinuity in the pressure vessel wall, stress can build up around the valve or nozzle. Because of the high stress concentration, there is a risk of vascular junction failure. As a result, a detailed stress distribution analysis for the pressure vessel is required. The use of the finite element approach to determine the limit pressure at various locations on a pressure vessel saves time and eliminates tedious mathematical labour in problematic geometries. As a result, it is critical to verify the outcome. Experiments were carried out on an oblique nozzle (450 degrees with the shell axis) and the findings were used to confirm the finite element results. Test for distortion by measuring the change in diameter of the vessel after it has been pressured with water. The Twice elastic slope method and the Tangent intersection method are used to estimate the limit load of a cylindrical vessel with an oblique (450) nozzle.

Pratama, J., Fitriyana, D.F., Siregar, J.P., & Caesarendra, W. (2020) [14]. A pressure vessel is a container used to hold pressurised fluids such as oil, gas, or other chemical fluids. It is commonly utilised in the oil, gas, and chemical sectors. Finite element analysis is now widely utilised to lower the high cost of pressure vessel testing prior to the production process. However, additional validation is required to confirm the simulation's conclusions and the pressure vessels' safety. The notion of distortion energy is employed as a validation method in this work, which is based on material properties and behaviour. Finally, determine whether the pressure vessel can be used for production or if it requires refinement for safety. The study's findings revealed that while the theory of distortion energy can be utilised as a validation tool for finite element analysis on pressure vessels, it does not guarantee safety. As a result, extra validation methods are required to ensure that the pressure vessel detailed in this study is safe. The cost study revealed that using failure theory in conjunction with other mathematical methods can reduce pressure vessel testing costs, albeit some tests are unavoidably expensive.

Farzam, M., Malekinejad, P., & Khorashadizadeh, M. (2009) [15]. The new generation of ultrasonic devices that use Phased Array technology can easily gather information about the kind, size, shape, and location of flaws in items. This inquiry compares the findings of an ultrasonic test performed on a storage vessel using Phased Array technology with environmental factors such as corrosion to determine the type of defect with 100 percent certainty. Inspections demonstrate that the discovered cracks in the shell metal were caused by hydrogen driven cracking, and calculations show that if the hydrogen diffusion through the metal is stopped, the cracks will not expand. As a result, if an appropriate coating is placed to the interior of the vessel to prevent hydrogen diffusion, it is expected that the pressure vessel can continue to operate normally and under frequent observation.

DESIGN CALCULATIONS

The pressure vessel has been constructed to meet all ASME requirements. The minimum thickness of the shell required was calculated using cylindrical shells with longitudinal joints.

T = PR/SE-0.6P + Corrosion Allowance T = PR/SE-0.6P + Corrosion Allowance

- Where t is the shell's minimum thickness, P is the internal design pressure, R is the shell's inner radius, S is the material's maximum permitted stress value, and E is the vessel's joint efficiency.
- The minimum thickness of the pressure vessel for external pressure was calculated using:

$$Pa = 4 \times B/(3 \times Do/t)$$

- Where Pa is the external pressure on the pressure vessel, B is the factor for maximum design metal temperature, do is the outside diameter of the pressure vessel and t is the thickness of the shell for external pressure.
- The following calculation is used to compute the minimum thickness for the dished end for internal pressure.

t = PD/2SE–0.2P + Corrosion allowance t = PD/2SE–0.2P t = PD/2SE–0.2

- T is the minimum thickness necessary for the dished end, P is the internal design pressure, D is the shell's inner diameter, S is the material's maximum permitted stress value, and E is the joint efficiency.
- Due to external pressure, the minimum thickness of the dished end is computed [16].

OBJECTIVES

- To investigate current literature of Pressure Vessel failure.
- To identify various reasons/cases of Pressure Vessel failure
- To use software to assess the failure of AC.
- To validate the experimental data with software or analytical results.

CONCLUSIONS

The American Society of Mechanical Engineers defines pressure vessels in Section VIII, Div. 1. The interior design condition, (1) pressure; (2) temperature, affects the code of practice. Tank capacity, type, shape, external design condition, and head type are all limited in the simulation. The external temperature is adjusted to 250°C, while the inside temperature ranges from 0°C to 600°C, with 200°C increments. The American standard likewise has the greatest requirement for external thickness, with 3.36518mm for the head and 5.45026 mm for the shell. This is backed by the notion that it is preferable to assume more than less. It's also worth noting that not every internal design condition is always superior to the outward state. The pressure can come from an external source or from the direct or indirect application of heat. In addition, a progressive failure model was used in this study to run several hydrogen storage vessels burst simulations, which were compared to experimental results on displacement and pressure from two modelling attempts: the first, based on a mixed FE model, is fully adapted to future optimization trials due to its low execution time, and the second, based on a solid model, contributes greater accuracy on the stresses.

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