Design of Pressure Vessel For Nitrogen Gas Storage

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Abstract- *High pressure rise takes place in the pressure vessel and it has to withstand or bear against severe forces. The pressure vessels are designed with great safety because its failure may cause great loss of property and life. Some of the major factors are taken into consideration while designing of safe pressure vessel. This writing focuses on figuring out the safety parameters for allowable working pressure. The calculations for allowable working pressures are carried out by using "Pressure Vessel Design Manual by Dennis Moss", third edition. The chances of exploitation of the pressure vessel can occur at maximum pressure and it is the element (vessel) that only can withstand that pressure. Efforts are made in this paper for designing the Pressure Vessel using ASME codes and IS standards and to find out which one is more safe.*

Keywords- Pressure vessel, working pressure, high pressure, ASME codes, IS code

I. INTRODUCTION

Pressure Vessels are the containers or pipelines used for storing, receiving or carrying the fluids under pressure. These pressures are substantially different from the atmospheric pressure.

Pressure vessels can be dangerous, and destructive accidents have occurred in the past many years (since its being first developed and used) of their development and operation. Consequently, designing of pressure vessel, its manufacturing, and operation are monitored by engineering authorities who are assisted by legislation. These are the reasons, because of which the pressure vessel is defined in various means across the world.

The parameters such as material for vessel, maximum safe operating pressure and temperature, factor of safety, corrosion allowance and minimum design temperature (for brittle fracture) are always to be taken into consideration. The testing of vessel construction is performed using Non-destructive Testing (NDT) technics or methods, such as Ultrasonic testing, Radiography, and Pressure tests. As name implies, the Hydrostatic test uses water, where as Pneumatic test uses air or another gas. The Hydrostatic test is the safest method, because if a fracture occurs while testing, it releases very less amount of energy (when rapid depressurization occurs, water has the property that does not rapidly increase its volume, unlike gases like air, which fail explosively).

In most countries,vessels over a certain size and pressure limit, is mandatory to be built according to a formal code. United States have their own code or standard, ASME Boiler and Pressure Vessel Code (BPVC) for designing Boiler and Pressure Vessel. An authorized inspector is required for verification and validation of every new vessel constructed and also each vessel has a nameplate with related information about the vessel, such as manufactured by, manufactured for, working pressure, maximum temperature, minimum design metal temperature, date of test, year of fabrication, radiography, stress relief, its registration number (through the National Board), and ASME's official stamp for pressure vessels . The name plate makes the vessel identifiable and officially an ASME Code vessel.

II. PROBLEM STATEMENT

The failure of Pressure Vessel, which describes why failure has occurred, can be classified into four major categories.

Each failure has a reason why and how which can be identified from its history. The vessel may have failed through corrosion fatigue, because the material chosen was wrong.The designer must be as familiar with categories and types of failure and also must be familiar with categories and types of stresses and loadings. Ultimately they are all related.

- Material- Incorrect Material selection; defects and faults in material.
- Design- Insufficient or incorrect design data; design methods; inadequate shop testing.
- Fabrication- Quality control is poor;
  Fabrication procedures such as welding, etc. are improper.

III. CODE SELECTION

There are various standards or codes used for vessel design, but in this review paper we have selected two standards ASME Section VIII Division 2 and IS 2825 for our design of pressure vessel.We will be designing the components as per these two standards and by comparing them we'llfind out which one is more safe and suitable for working of vessel.

IV. METHODOLOGY

- Studying different components of pressure vessel.
- Nitrogen gas production.
- Design of pressure vessel according to standards.

V. LITERATURE REVIEW

1. Apurva R. Pendbhaje, MaheshGaikwad, Nitin Deshmukh, Rajkumar Patil, "Design and Analysis of Pressure Vessel"

This design and analysis of pressure vessel is presented in this technical paper.Withstand or bear against severe forces. The pressure vesselsare designed with great safety because its failure may cause great loss of property and life. Some of the major factors are taken into consideration while designing of safe pressure vessel. This writing focuses on figuring out the safety parameters for allowable working pressure. The chances of exploitation of the pressure vessel can occur at maximum pressure and it is the element (vessel) that only can withstand that pressure. Pressure vessels are usually havingspherical or cylindrical vessel shell with dome ends. Because of simplicity in manufacturing of vessel shells and making better use of the available space generally cylindrical vessels are preferred. This paperdescribes the selections of ASME VIIII division 2. The standard of material use is explained in this chapter. From the observation we come to know that all the pressure vessel components are selected on basis of available ASME standards and the manufacturers also have to follow the ASME standards while manufacturing the components. This makes easy to the designer and helps in designing the components as per standards. Due to this aspect of design the Development Time for a new pressure vessel isgreatly reduces and saves a lot of time.

2. A. Dhanaraj1, Dr. M. V. Mallikarjuna2, "Design & Stress Analysis ofa Cylinder with Closed Ends Using Ansys"

The pressure vessels (i.e. closed cylinders or tanks) are used to store fluids under pressure. The pressure vessels are designed with great care because the failure of the vessels inservice or operation may cause loss of life and property.
The material of pressure vessels may be brittle such that cast iron or ductile such as plain carbon steel or alloy steel. Vessel failures can be grouped into four major categories, which describe why a vessel failure occurs. For initialization of the design of pressure vessel therequirementsin terms of standard technical specifications along with various requirements that are secular from the market are required to be known. The design of a pressure vessel is more of a selecting a proper procedure, precise selection of its components rather designing individual component. The selection of components for pressure vessel is simple, but the selection should be done accurately, a superficial change in selection will result into a different pressure vessel altogether from what is aimed to be designed.

3. Shyam R. Gupta, Chetan P. Vora, "A Review Paper on Pressure Vessel Design and Analysis"

There are various fields where Pressure vessels are used such as nuclear and thermal power plants, process industries and chemical industries, in space and ocean depths, and fluid supply systems in industries. Loss of life, health hazards and damage of property are the results of the failure of pressure vessel. Due to practical applications, pressure vessels are often provided with openings of various shapes, sizes and positions. From above discussion, we can conclude that, to studythe stress concentration, the effect of change in size, position, location of the opening in pressure vessel are essentially required, the researcher did not studied the position and location of the opening on cylinder in past and there is no code provision for such design.

VI. DESIGNING OF COMPONENTS

We have designed the following components in accordance with ASME section VIII division 1 and 2. The reason behind selecting both the ASME code is as follows:

ASME BPV Code Sec. VIII Divisions

Division 1

- Exact analysis of local thermal and fatigue stresses are not required.
- Safety factor of 3.5 against tensile failure and 1.25 for 100,000 hour creep rupture.
- Can design pressures below 3000 psi (but usually costs more than Div.2 above about 1500 psi).

Division 2

- Requires more analysis than Div.1, and more inspection and monitoring, but allows thinner walled vessels.
- Safety factor of 3.0 against tensile failure.
- Can design temperatures less than 900°F (outside creep range).
- More economical for high pressure vessels, but fewer fabricators available.

Now, Let us see the components we will be designing according to above ASME codes:

I. Shell
II. Heads
III. Nozzles
IV. Manhole
V. Gaskets
VI. Supports

Till Now, We have successfully designed the two components i.e. Shell and Head.

Design Of Shell

Thickness of Shell (t_s)

$$t_s = \frac{P \times Ro}{(S\eta - 0.6P)} + c$$

$$t_s = \frac{1.1767 \times 1320}{177.142 \times 0.85 - 0.6(1.1767)} + 3$$

$$t_s = 13.36\ mm \cong 14\ mm$$

where,

c = Corrosion allowance = 3 mm
η = Joint efficiency = 0.85
R_o = Outer shell radius = 1320mm
P = Design pressure = 12kgf/cm^2
P = 1.1767 N/mm^2

$$S = \text{Allowable stress} = \frac{\text{Ultimate stress}}{\text{Factor of Safety}}$$

$$S = \frac{620}{3.5} = 177.142\ N/mm^2$$

I_D = Internal diameter of shell = $D_o - 2(t_s)$
= 2640 – 2(10)
= 2620mm

Design Of Torispherical Head

Stress intensification factor (W)

$$W = \frac{1}{4[3 + \left(\sqrt{\frac{Rc}{Ri}}\right)]}$$

$$W = \frac{1}{4[3 + \left(\sqrt{\frac{2640}{264}}\right)]}$$

W = 1.5405

Thickness Of Torispherical Head (t_h)

$$t_h = \frac{P \times Rc \times W}{2 \times S \times P} + c$$

$$t_h = \frac{1.1767 \times 2640 \times 1.7706}{2 \times 177.142 \times 1.1767} + 3$$

$$t_h = \frac{4785.544764}{416.8859} + 3$$

$$t_h = 14.47\ mm\ or\ 16\ mm$$

$$t_h = 16\ mm$$

Where,

R_c = Crown radius = D_o
R_i = Knuckle radius = 0.1 D_o

VII. CONCLUSION

In this paper we have designed the shell and head of the pressure vessel using ASME Section VIII division 1 as well as division 2.We have found that our design considerations are correct and can be used for working of the vessel. We are designing the rest of the components and that results will be included in our next paper.

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