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Design of Air Receiver for Pneumatic Devices Used in Machining Fixtures

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ABSTRACT: The design of air receiver pressure vessels plays a critical role in ensuring the safe and efficient operation of various industrial processes that Based on compressed air systems. This comprehensive study deals into the aspects of designing air receiver pressure vessels, considering the factors that influence their structural integrity, performance, and compliance with relevant standards.

The initial section of this research outlines the fundamental principles underlying the need for air receivers in compressed air systems. The role of these vessels in stabilizing pressure fluctuations, separating moisture and contaminants, and enabling a continuous and reliable supply of compressed air. Subsequently, the study explores the regulatory landscape governing pressure vessel design, with a focus on international standards such as ASME Boiler and Pressure Vessel Code, European Pressure Equipment Directive, and other pertinent guidelines.

The core of the research revolves around the mechanical design considerations in creating a robust and efficient air receiver. This is detailed examination of factors like material selection, thickness calculations, stress analysis, and fatigue assessment. Special attention is given to the choice of materials, taking into account factors such as corrosion resistance, temperature variations, and the specific application requirements of the air receiver.

Furthermore, the study delves into the intricate balance between maximizing the volumetric efficiency of the air receiver and ensuring its structural reliability. The impact of design parameters, such as diameter, length, and orientation, on the vessel's performance is analyzed through advanced simulation techniques and empirical validations. Additionally, the research investigates the implications of varying operational conditions, exploring how factors like temperature, pressure, and cyclic loading can influence the longevity and safety of the air receiver.

The safety aspects of air receiver design are a paramount concern throughout this study. An in-depth analysis of pressure relief mechanisms, emergency venting, and fail-safe features is presented, ensuring that the designed pressure vessel adheres to the highest safety standards. The research also investigates the implications of potential failure modes, providing insights into risk mitigation strategies and preventive measures.

this research offers exploration of the design considerations for air receiver pressure vessels. By integrating mechanical engineering principles, material science, and regulatory insights, the study provides a valuable resource for engineers, designers, and stakeholders involved in the development and operation of compressed air systems. The findings presented here contribute to the ongoing enhancement of safety, efficiency, and reliability in industrial applications on air receiver pressure vessels.

I. INTRODUCTION

Air receiver pressure vessels play a crucial role in various industries where compressed air is utilized for powering pneumatic tools, equipment, and processes. These vessels serve as storage units for compressed air, providing a buffer to accommodate fluctuations in demand and ensuring a steady supply of compressed air to different applications. In this

essay, we will explore the introduction of air receiver pressure vessels, their design, functions, regulations, and their significance in industrial settings.

The concept of storing compressed air dates back to the early 19th century when industrialization spurred the development of pneumatic tools and machinery. Initially, compressed air was stored in simple containers such as barrels or wooden tanks. However, as industrial processes advanced and the demand for compressed air increased, the need for more efficient and reliable storage solutions became evident. These vessels were designed to safely store and distribute compressed air, thereby enhancing the efficiency and productivity of various industrial processes. The pressure vessel is part of the pressurized equipment playing a significant role in many industries, especially for storage purpose. As the manufacturing technology advances, their uses have expanded rapidly throughout the world [1].

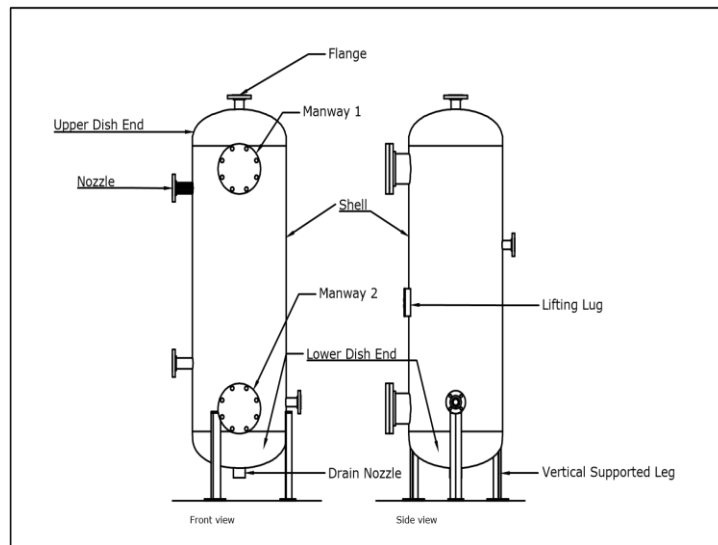


Fig 1: Schematic diagram of Air Receiver

Air receiver pressure vessels are typically cylindrical in shape and are constructed from materials such as steel or aluminium. The design of these vessels takes into account factors such as maximum allowable working pressure, volume capacity, and safety considerations. The vessels are equipped with inlet and outlet connections for the intake and distribution of compressed air, as well as safety valves and pressure gauges to monitor and control pressure levels. Pressure Vessels are subjected to testing procedures, including hydrostatic testing, to verify their strength and durability under pressure. Welding techniques are also critical in ensuring the integrity of vessel seams and joints.

Air receiver pressure vessels serve multiple functions in industrial settings, including:

1. **Storage:** The primary function of air receiver pressure vessels is to store compressed air generated by air compressors. These vessels provide a reservoir of compressed air that can be drawn upon to meet varying demand levels.
2. **Pressure Regulation:** Air receiver pressure vessels help regulate the pressure of compressed air by absorbing fluctuations and maintaining a steady supply to downstream applications. This ensures consistent performance and prolongs the lifespan of pneumatic equipment.
3. **Condensate Management:** As compressed air cools, moisture condenses within the system, leading to the accumulation of condensate. Air receiver pressure vessels are equipped with drains and separators to remove moisture and contaminants, preventing corrosion and damage to downstream components.
4. **Energy Efficiency:** By storing compressed air during periods of low demand and releasing it when needed, air receiver pressure vessels contribute to energy efficiency by reducing the workload on air compressors and minimizing energy consumption.

II. LITERATURE REVIEW

For design of process equipment as Air Receiver, Various design methodologies becomes helpful and guiding in development of the equipment[2].

Here learned about Design and Analysis of Vertical Pressure Vessel from research paper title “Design and Analysis of Vertical Pressure Vessel using ASME code and FEA technique”. In this project they are designing a pressure vessel using ASME section VIII and Division 2, designing a closed container to find the required thickness of the shell, head, nozzle and leg support by author Niranjana S. J., Smit Vishal Patel, Ankur Kumar Dubey [3].

From research paper “Finite Element Modelling and Analysis of Pressure Vessel” by author Rohitkumar S. Biradar in 2022. In this research paper various mechanical studies have been done, such as tensile, impact, flexural, and hardness. For the same geometrical parameters of the steel pressure vessel, FE Analysis of Structural Steel pressure vessel is carried out, and stresses for internal pressures are determined [4].

We come to know about Design and Analysis of Pressure Vessel according to ASME code. In research paper title “Design and Analysis of Pressure Vessel” published in 2019. In this research paper the design a pressure vessel according to ASME standards and do thermal analysis on the pressure vessel made up of different types of materials by varying the shell thickness of the vessel for various ambient temperature [5].

The research paper “Guidelines for Pressure Vessel Safety Assessment” published by Sumio Yukawa in 1990. In this research paper they provided a technical overview and information on metallic pressure containment vessels and tanks. The intent of the document is to provide OSHA (Occupational Safety and Health Administration) personnel and other persons with information to assist in the evaluation of the safety of operating pressure vessels and low pressure storage tanks[6].

We learned in design of pressure vessel safety is the primary consideration, due the potential impact of possible accident from research paper title “Structural Design of Air Receiver Using ASME Code” by author Manish Kumar Gupta. This paper describes its basic structure, stress characteristics and the engineering finite element modeling for analyzing, testing and validation of pressure vessels under high stress zones [7].

III. DESIGN OF AIR RECIEVER

In these research over the design of Air receiver was carried out with the help of ASME Codes, and standards.

For Material of Construction, SA 516 Gr70 was utilized referring properties from ASME section II Part D Table 1A [8]

Minimum Tensile Strength= 485 MPa

Minimum Yeild Strength= 260 MPa

Maximum allowable stress up to 250° C = 138MPa

Now,

$$R = \frac{D_i}{2} = \frac{2000}{2} = 1000 \text{ mm}$$

The vessel may be corroded after some years of use, so we have to consider the corrosion allowance. Just so that the shell can serve the purpose in safe condition even after the outer layer is corroded.

Therefore, the new Radius will be:

$$R = R_i + CA = 1000 + 3$$

$$R = 1003 \text{ mm}$$

Thickness Of Shell Under Internal Pressure Can be calculated by (For circumferential stress),

$$t = \frac{PR}{SE - 0.6P}$$

.... (ASME Section VIII, Subsection A (UG 27)) [9]
the vessel to get overall acting pressure.

Now, thickness due to internal pressure is calculated

We have to calculate static head due to fluid in

$$t = \frac{PR}{SE - 0.6P}$$

$$= \frac{1.2(1000+3)}{(138 \times 1) - 0.6 \times 1.2}$$

$$t = 8.76 \text{ mm}$$

This is minimum required thickness.

But while designing, we have to consider corrosion allowance.

So, design thickness will be,

$$t_d = t + CA$$

$$= 8.76 + 3 \text{ mm}$$

$$t_d = 11.76 \text{ mm}$$

But this size will not be available in the market. So, we have to choose nominal dimensions.

$$t = 12 \text{ mm}$$

Now checking vessel for external pressure

1. Outer Diameter to Thickness ratio:

$$D_o = D_i + 2t$$

$$= 2000 + (2 \times 12)$$

$$D_o = 2024 \text{ mm}$$

Here we have to consider corroded thickness in do/t ratio

$$t = t_{\text{nominal}} - CA$$

$$= 12 - 3 = 9 \text{ mm}$$

$$\text{Now, } \frac{D_o}{t} = \frac{2024}{9} = 224.88$$

$$\text{Here, } \frac{D_o}{t} > 10$$

Hence, we will use

ASME Sec VIII Subsection A UG 27(c)(1)

2. Length to Outer Diameter ratio:

$$L = 5000 + 2 \times \frac{500}{3}$$

$$= 5333.33 \text{ mm}$$

$$\frac{L}{D_o} = \frac{5333.33}{2024} = 2.63$$

3. Calculating Factor A:

For Factor A referring

ASME Sec II Part D Subpart 3 Figure G

We got,

$$\text{Factor A} = 0.00012$$

4. Calculation of Factor B:

For Factor B referring

ASME Sec II Part D Chart CS-2 [10]

From graph,

The Factor is lying in the left region of the graph where there is no intersection of Factor A line with curves of modulus of elasticity.

We cannot get Factor B for Factor A = 0.00012 and

$$E = 200 \times 10^3$$

Therefore, we have to calculate Allowable Pressure with the help of Factor A only.

5. Calculations for allowable pressure:

$$P_a = \frac{2AE}{3\left(\frac{D_o}{t}\right)} = \frac{2 \times 0.00012 \times 200 \times 10^3}{3(224.88)} = 0.0711 \text{ MPa}$$

We know that, External atmospheric pressure is 1 Bar

$$\text{i.e. } P_{atm} = 1 \text{ Bar} = 0.1 \text{ MPa}$$

And, allowable external pressure calculated for this vessel is 0.0711 MPa

$$\text{i.e. } P_a = 0.0711 \text{ MPa} = 0.7 \text{ Bar}$$

$$\text{Here, } P_a < P_{atm}$$

Therefore, we can conclude that the vessel is failing against external pressure.
Now, we have to make the pressure vessel safe against external pressure.

There are 2 ways:

1. Increasing the shell thickness.
2. Adding stiffener ring to shell.

In our case, the optimum solution is to add stiffener ring to shell

Therefore we use Barshell type Stiffener.

$$L = 533.33 \text{ mm}$$

$$\text{So, } L_{\text{new}} = \frac{L}{2} = 266.66 \text{ mm}$$

$$\text{Therefore, } \frac{L_{\text{new}}}{D_o} = \frac{266.66}{2024} = 1.317 \quad \text{and} \quad \frac{D_o}{t} = 224.88$$

Calculating Factor A:

For Factor A referring ASME Sec II Part D Subpart 3 Figure G

We got,

$$\text{Factor A} = 0.00022$$

Calculation of Factor B:

For Factor B referring ASME Sec II Part D Chart CS-2

From graph,

$$\text{Factor B} = 24 \text{ MPa}$$

Find Allowable External Pressure

$$P_a = \frac{4B}{3\left(\frac{D_o}{t}\right)} = \frac{4 \times 24}{3(224.88)}$$

$$P_a = 0.142 \text{ MPa} \quad \text{and} \quad P_e = 0.1 \text{ MPa}$$

$$P_a > P_e$$

Therefore, we can say that the vessel is now safe for external atmospheric pressure.

Thus, the design is safe and we can take the thickness of sheet material of which the pressure vessel is going to be fabricated as 9 mm.

IV. RESULTS

Provided thickness & size of shell, head & nozzle of air receiver are sufficient to take internal pressure of 1.2 Mpa. This is because required thickness & size values as per ASME Codes.

Hence design of air receiver for given internal pressure is safe according to ASME code section VIII Div1.

Complete pressure vessel is analyzed in ANSYS using axi-symmetric analysis . Maximum Allowable Pressure Is Greater Than Atmospheric Pressure So Pressure Vessels Safe Against Assumed Thickness.

V. CONCLUSION

In conclusion, the design and engineering of Plant Air Receiver is a complex and challenging project that requires a thorough understanding of pressure vessel design and the ASME code.

As a final year Mechanical engineering student, this project has provided me with valuable hands-on experience in applying theoretical knowledge to real-world engineering problems.

The process of calculating the thickness of the shell for both internal and external pressure has allowed me to gain a deeper understanding of the factors that must be considered in pressure vessel design, such as material properties, operating conditions, and safety margins.

this project has been a valuable learning experience that has allowed me to apply my technical knowledge and skills to a real-world engineering problem. It has provided me with insights into the complexities of pressure vessel design and the importance

of following industry standards, while also highlighting the significance of teamwork and collaboration in engineering projects. I am confident that the knowledge and experience gained from this project will be beneficial as I transition into a professional career in mechanical engineering

Overall conclusions based on present study are as below:

- 1) Pressure vessel is designed and analyzed for the given internal pressure.
- 2) ASME Code is effectively used for the safe structural design of air receiver.

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- [10] ASME Code Section II Part D Chart CS-2.



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