UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Design, Analysis and Fabrication of Pressure Vessel

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Bachelor of Manufacturing Engineering (Manufacturing Process)

By

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APPROVAL

This PSM submitted to the senate of UTeM and has been as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process). The members of the supervisory committee are as follow:

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ABSTRACT

This bachelor degree final project presents design, analysis and manufacturing of pressure vessel. In the design of pressure vessel safety is the primary consideration, due the potential impact of possible accident. There have a few main factors to design the safe pressure vessel. This writing is focusing on analyzing the safety parameter for allowable working pressure. Allowable working pressures are calculated by using PV Elite which comply with the ASME VIII, Rules of construction pressure vessel div 1. The corruption of the vessel are probability occur at maximum pressure which is the element that only can sustain that pressure. At the end of this project, a pressure vessel which is air receiver are fabricated and the procedure of manufacture are explained clearly.

ABSTRAK

Projek akhir sarjana muda ini mempersembahkan rekabentuk, analisis dan proses pembuatan pengandung tekanan. Di dalam aspek rekabentuk pengandung tekanan, perkara yg perlu dititik beratkan ialah keselamatan disebabkan keupayaan berlakunye kemalangan besar. Terdapat banyak factor yang yang perlu diambil kira dalam mereka bentuk pengandung tekanan. Di dalam penulisan ini hanya memfokuskan analisis terhadap had tekanan yang dibenarkan ketika pengandung tekanan beroperasi. Tekanan yang dibenarkan dikira dengan menggunakan PV Elite, sebuah perisian yang memenuhi kod peraturan membuat pengandung tekanan, ASME VIII. Kemungkinan kerosakan yang berlaku disebabkan elemen-elemen yang terdapat pada pengandung tekanan yang tidak dapat menampung had tekanan maksimum. Di akhir projek ini, salah satu jenis pengandung tekanan dibuat iaitu penerima udara dan prosedur pembuatan diterangkan dengan jelas.

DEDICATION

For my beloved Mother and Father

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First of all, I would like to thank Allah, The One nothing is absent from His knowledge, and also to the most important person in my life, Nabi Muhammad S.A.W. I would also like to thank Universiti Teknikal Malaysia Melaka along with Faculty of Manufacturing Engineering. A very appreciate to Akra Engineering Sdn. Bhd to give this opportunity to learn and provide all the equipment to fulfill the requirement of this project. I would like to thank my supervisor, En. Sivarao for his support and assistant engineer of Akra Engineering, En. Zaihasren b. Mohamad Zainal for his encouragement, suggestion, faith, confidence and assistance throughout the study. I would like to thank my project partner R. Ahmad Muhaimin b Humaidi and everyone who is involved in this project directly or indirectly.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

AESB	-	Akra Engineering Sdn. Bhd.
ANSI	-	American National Standard Institute
ASME	-	American Society Mechanical Engineer
ASTM	-	American Society Testing Material
BS	-	British Standards
ID	-	Internal Diameter
MAWP	-	Maximum Allowable Working Pressure
MDMT	-	Minimum Design Metal Temperature
OD	-	Outside Diameter
PDF	-	Portable Document Format
PG	-	Pressure Gauge
RV	-	Relieve Valve

CHAPTER 1
INTRODUCTION

1.1 Overview of Pressure Vessel

Tanks, vessel and pipelines that carry, store or receive fluids are called pressure vessel. A pressure vessel is defined as a container with a pressure differential between inside and outside. The inside pressure is usually higher than the outside. The fluid inside the vessel may undergo a change in state as in the case of steam boiler or may combine with other reagent as in the case of chemical reactor. Pressure vessel often has a combination of high pressure together with high temperature and in some cases flammable fluids or highly radioactive material. Because of such hazards it is imperative that the design be such that no leakage can occur. In addition vessel has to be design carefully to cope with the operating temperature and pressure.

Pressure vessel are used in a number of industries; for example, the power generation industry for fossil and nuclear power, the petrochemical industry for storing and processing crude petroleum oil in tank farms as well as storing gasoline in service station, and the chemical industry. Their use has expanded throughout the world. Pressure vessel and tank are in fact essential to the chemical, petroleum, petrochemical and nuclear industry. It is in the class of equipment that the reaction, separation and storage of raw material occur. In the same word, pressurized equipment is required for a wide range of industrial plant for storage and manufacturing purpose.

Pressure vessels are usually spherical or cylindrical with dome end. The cylindrical vessels are generally preferred because of they present simple manufacturing problem and make better use of the available space. Boiler, heat exchanger, chemical reactor and so on, are generally cylindrical. Spherical vessels have the advantages of requiring thinner walls for a given pressure and diameter than the equivalent cylinder. Therefore they are used for large gas or liquids container, containment buildings for nuclear plant and so on.

In the design of pressure vessel safety is the primary consideration, especially for nuclear reactor vessels, due the potential impact of a possible accident. In generally however, the design is a compromise between consideration of economics and safety. The possible risks of a given failure and its consequent are balanced against the effort required for its prevention; the resulting design should achieve an adequate standard of safety at minimum cost.

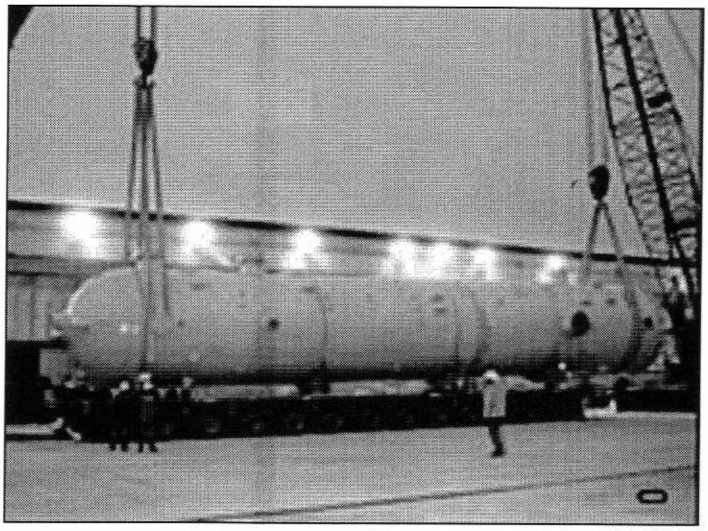

Figure 1.0: Pressure Vessel

1.2 Problem Statement

Vessel failures can be grouped into four major categories, which describe why a vessel failure occurs. Failures can also be grouped into types of failures, which describe how the failure occurs. Each failure has a why and how to its history. It may have failed through corrosion fatigue because the wrong material was selected! The designer must be as familiar with categories and types of failure as with categories and types of stress and loadings. Ultimately they are all related.

- Material- Improper selection of material; defects in material.
- Design- Incorrect design data; inaccurate or incorrect design methods; inadequate shop testing.
- Fabrication- Poor quality control; improper or insufficient fabrication procedures including welding; heat treatment or forming methods.

1.3 Objectives

The purpose of this project is to study the implementation and practices of pressure vessel designs. The objectives of this project are:

- To identify the pressure vessel
- To analyze the safety parameters for allowable working pressure using PV Elite which comply to ASME VIII standard.
- To fabricate the pressure vessel as per the reference standards

1.4 Scope

To ensure the objective is achieved, some of the important elements must be consideration. There is:

- Research about pressure vessel
- To analyze by using PV Elite at Akra Engineering Sdn Bhd.
- This project will be collaborate with Akra Engineering Sdn Bhd to provide the source and place to fabricate the pressure vessel.

Chapter 2

LITERATURE REVIEW

B.S. Azzam, M.A.A. Muhammad, M.O.A. Mokhtar et al (1996) was proposed a new design technique that enables rapid and efficient design calculations. This design method enables the designer of the composite pressure vessel to get readily the ultimate failure pressure of these vessels depending on the number of reinforced layers, layer thickness, fiber orientations, and materials. In this work a numerous of aluminum tubes have been wrapped by different number of composite layers made from different fibrous materials (glass, graphite and kevlar fibers). Then, these tubes have been used as pressure vessels which tested till the explosion failure. A comparison between the results of the experimental testing and the theoretical proposed design for these composite pressure vessels has been presented. This comparison has shown a good agreement between the theoretical and experimental analysis.

Shu-Ho Dai (1998) explain that the prediction of the occurrence of failure events for pressure vessels used in the process industry is a newly developing technology in the field of modern technical management of facilities. It is of great significance for ensuring safe and high efficiency operations in modernized large-scale and high parameter facilities of chemical, petrochemical, nuclear and electric power plants.

Changheui Jang et al. (1999) describes the pressure vessel integrity under a pressurized thermal shock using transient histories such as temperature, pressure and heat transfer coefficient, the stress distribution is calculated and then stress intensity factors are obtained for a wide range of crack sizes. The stress intensity factors are compared with the fracture toughness to check if cracking is expected to occur during the transient. Critical crack depth diagrams are prepared for each transient which is expected to initiate a pressurized thermal shock accident. Plant-specific analyses of the most limiting plant in Korea are performed to assure the structural integrity of the reactor vessel and the results are discussed.

Leta Y. Woo (1999) has mention that mild carbon steel with specification American Society for Testing and Materials (ASTM) A285 is a common material of construction for vessels in the petroleum and nuclear industries. Storage tanks were constructed between 1951 and 1956 from hot rolled carbon steel plate specified as ASTM A285 Grade B. Extensive analyses and experimental investigations have demonstrated tank integrity in full consideration of potential service induced degradation mechanisms, including stress corrosion cracking.

Vu D.K. and Staat M. (2007) published limit load formulae for circumferential defects overestimate the burst pressure for penetrating defects in pipes by the factor two in the short crack limit, because they only consider axial stress. Therefore, a class of limit load solution is discussed which takes the triaxial state of stress into account. The solutions for pressure loaded crack faces are improved analytically. Primal–dual limit analysis with the finite element method is used to adjust all solutions to numerical results. Limit loads are obtained for circumferential cracks of all sizes in thick-walled cylinders.

Yoneda, Makoto et al (2004) explain about a high temperature/high pressure vessel for treating a workpiece placed in the interior of the vessel at a high temperature and a high pressure, said vessel comprising: a cylindrical body, with piano wire wound under tension round an outer periphery of said cylindrical body; and lid members which tightly close axial openings of said cylindrical body so as to be disengageable from said openings, said cylindrical body comprising: an inner cylinder; a plurality of spacers arranged along an outer periphery surface of said inner cylinder; and an outer cylinder fitted on said inner cylinder through said spacers, wherein cooling water flow paths are formed each between adjacent said spacers, said cooling water flow paths extending from one end side to an opposite end side of said cylindrical body.

Giglio M. (2003) comparing two different methods for the construction of pressure vessel nozzles, designed with the same safety coefficient, according to ASME and VSR 1995 standards. It defines numerical and experimental analysis of behaviour under low-cycle fatigue for pulsating pressure. In particular, a nozzle with integral reinforcement, designed according to ASME standards, is compared to a nozzle with external reinforcement (applied reinforcement plate) designed according to VSR 1995 standards with the same safety coefficient. Strain gauge tests have been carried out on the plastic behaviour of the two structures in order to evaluate the expected fatigue life based on common criteria, using both the local strain and energetic approaches. At the same time, a FEM model of the nozzle with plate has been used to calculate numerically the expected fatigue life based on the same criteria. Finally, in order to identify the best system to exploit for design, comparisons are made of the fatigue life predictions, which are numerically and experimentally obtained and which are determined according to the standards of the two nozzle types to identify the better system.

J. Lewinski (2002) presents the problem of stress concentration in a cylindrical pressure vessel with ellipsoidal heads subject to internal pressure. At the line, where the ellipsoidal head is adjacent to the circular cylindrical shell, a shear force and bending moment occur, disturbing the membrane stress state in the vessel. The degree of stress concentration depends on the ratio of thicknesses of both the adjacent parts of the shells and on the relative convexity of the ellipsoidal head, with the range for radius-to-thickness ratio between 75 and 125. The stress concentration was analytically described and, afterwards, the effect of these values on the stress concentration ratio was numerically examined. Results of the analysis are shown on charts.

J. Schiedermaier (2004) explain about the economical and safe design of pressure vessels requires, besides others, also a detailed knowledge of the vessel failure behavior in the case of existing imperfections or cracks. The behavior of a cracked component under a given loading situation depends on material toughness. For ferritic steels, the material toughness is varying with temperature. At low temperature dominantly brittle fracture behavior is observed, at high temperature the failure mode is dominantly ductile fracture. The transition between these two extremes is floating.

D.H. Nash (2004) explain about the progress of pressure vessel technology over the years has been influenced by many important events. This paper identifies a number of milestones which have provided a stimulus to analysis methods, manufacturing, operational processes and new pressure equipment. The formation of a milestone itself along with its subsequent development is often critically dependent on the work of many individuals. It is postulated that such developments takes place in cycles, namely, an initial idea, followed sometimes by unexpected failures, which in turn stimulate analysis or investigation, and when confidence is established, followed finally by the emergence of codes ad standards. Starting from the industrial revolution, key milestones are traced through to the present day and beyond.

Ugur Guven (2007) present regarding the failure pressures of thick and thin walled cylindrical pressure vessels considering the Voce hardening law and plastic orthotropy effect are obtained. The solution presented is used to compare the failure pressures of copper and brass cylindrical pressure vessels.

Petrovic A. (2007) describe about the analysis of a cylindrical pressure vessel loaded by axial and transverse force on the free end of a nozzle. The nozzle is placed such that the axis of the nozzle does not cross the axis of the cylindrical shell. The method of finite element was applied to determine the state of stress in the cylindrical shell. The value obtained for stress in the nozzle region were used to determine the envelopes of maximum stress values, maximum values on this envelopes and distances between maximum values on envelopes and the outer edge of a nozzle. The different between stresses deduced from strain gauge readings on experimental and calculated stressed was maximum of 12%.

Najmi M. and Jahromi J. S.A. (2007) explain about the Cr–Mo steels which are widely used for pressure vessels in refineries and petrochemical plants, have a potential for hydrogen and temper embrittlement. During long-time service the embrittlement leads to decrease of the critical flaw size of brittle fracture and/or to the reduction of the remaining life of a pressure vessel. In this investigation the effect of high temperature and high pressure hydrogen on a vessel, made of 3Cr–1Mo low-alloy steel is studied. Inspections show that the only detected crack in the base metal is originally formed by welding defects and calculations show that it will not grow up. Therefore, it is predicted that the operation of the pressure vessel in normal condition and under regular supervision can be continued.

Price J. W. H. and Kerezsi B. B. (2002) describe the use of the ASME and British Standard codes to estimate the growth of cracks driven manly by thermal shocks. Repeated application of the thermal shocks may lead to crack ignition and crack growth. The ability to use current codes and standards to describe this type of crack growth is desirable. Areas of large conservation in the methods currently used in industry are identified and possible alternatives, less conservative approach are suggested. If the methods are fully applied, the possibility of crack growth slowing can be captured and the replacement of equipment with thermal shock cracking might be avoided.

Masuyama F. (2007) explain that creep-strength enhanced ferritic steels such as Gr.91, Gr.92 and Gr.122 have been introduced for power plant applications recently, and some have experienced creep failure in boiler tubes and thick wall components after several years of operation. In order to use these steels safely in power plants, establishment of creep life prediction and design factors for base metal and weldment is essential. In this paper, creep rupture strengths and lives obtained by means of uniaxial creep testing and internal pressure component testing for the above-mentioned high-strength ferritic steels are presented comparatively. Design life and weld reduction factors are discussed based on the data and on ASME criteria for establishing allowable stresses in the time-dependent temperature region.

Numerous boiler explosions took place through the late 1800s and early 1900s. This led to the enactment of the first code for construction of steam boilers by the commonwealth of Massachusetts in 1907. This subsequently results in the development and publication of the ASME Boiler and Pressure Vessel code in 1914 to standardize the design, manufacturing, and inspection of boiler and pressure vessel. The ASME and the ASTM (American Society for Testing Material) material specification merged in 1924. The first publication of section VIII 'unfired pressure vessel' appeared in 1925. The year 1928 saw the advance of welded pressure vessel. For higher pressure the welded shell were made thicker than 70 mm. these required nondestructive examination (NDE) before service. In 1934, a joint API-ASME Committee published the first edition of an unfired pressure vessel code especially for the petroleum industry. In 1952 these two separate code merged into a single code which is the ASME Unfired Pressure Vessel Code, Section VIII. The ASME Pressure Vessel Code, Section VIII Division 2 "Alternative Rules for Pressure Vessel "was published in 1968 and the original code became section VIII Division 1:"Pressure Vessel".(Cepluch, R.J. pressure vessel technology, 114, 1992).