Study of the Potential of Medium Carbon Steel as Main Pressure Vessel Material: A Literature Study

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Abstract. The application of pressure vessel technology in various industrial sectors is a common thing that often happens. This is caused by the main function of the pressure vessel which plays a very important role in industrial jobs. As a result, there has been an increase in the cost of making pressure vessels, especially in terms of workmanship. Medium carbon steel is one of the materials that is esasy to obtain and inexpensive. However, the common material of pressure vessels is seamless steel. The purpose of this study is to analyze the potential of medium carbon steel as the main material for pressure vessels. This type of research was a literature review. This study explores the properties of medium carbon steel which was then compared to the characteristics of the pressure vessel. The results of the study show that medium carbon steel can be the main material for pressure vessels.

Keywords: main material; industrial; cracking.

1 Introduction

A pressure vessel is a closed container by the function of storing high-pressure liquid or gas at a higher pressure than atmospheric pressure [1]. Pressure vessel is a further application of the special pressure tank function to withstand high pressure with a minimum pressure of more than 15–3000 Psi [2]. Pressure vessels are widely applied in industries such as petrochemical, gas and nuclear, and home activities [3]. The safety factor is the main variable that must be considered when making a pressure vessel [4]. However, the manufacturing process of a pressure vessel requires large costs both in terms of materials and manufacturing processes.

Medium carbon steel is widely applied in industry in many forms due to its low cost and easy forming process [5]. Medium carbon steel is easy to obtain, making it a material used by many engineers. Another advantage is that medium carbon steel has high strength. However, medium carbon steel has mechanical properties that will decrease after welding due to the increase in C content which forms the martensite phase. This condition has brittle properties, is susceptible to cracking, and decreases ductility [6].

This article study aims to analyze the potential of medium carbon steel as the main material for pressure vessels. The study of medium carbon steel is interesting because it is easy to

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obtain, has good mechanical properties, and is relatively cheap. The application of medium carbon steel as the basic material for a pressure vessel is considered appropriate because of the high cost of making a pressure vessel.

2 Literature Review

Pressure vessel

A pressure vessel is a cylindrical or spherical vessel that is specifically designed to store and hold liquids, gases and pressurized fluids where the pressure inside is usually greater than the pressure outside the vessel [7],[8]. Pressure vessels applied in industry include nuclear and thermal power plants, chemical industry, aerospace, deep sea, and liquid storage [9]. The main considerations in making a pressure vessel are material selection, design and model analysis [10]. The main components that need to be considered in making a pressure vessel are head, shell, opening, support.

The safety factor is one of the important factors in making pressure vessels. There are 3 main components that must be considered in safety factors, namely (1) the level of confidence in pressurized equipment; (2) technological and human deficiencies; and (3) equipment hazard level [11].

Medium-carbon steel

Fe-C can be classified into several phases, namely (1) phase a (Ferrite) which has a unit cell body-centered cubic (BCC) with soft, easy to deform and ductile properties; (2) g phase (Austenite) which has unit cells face-centered cubic (FCC) with good easy deformation and forming properties; (3) the d (Theta) phase also has a unit cell BCC; (4) the Fe3C (Cementite) phase has hard and brittle properties; and (5) the a+Fe3C (Pearlite) phase is a mixed phase of ferrite and cementite with properties between ferrite and cementite [5].

Medium carbon steel is a material with the main composition of iron (Fe) and carbon (C) with a content of 0.3 – 0.6% [12], [13] and may contain manganese (Mn) ranging from 0.6% to 1 .65%) [14]. Medium carbon steel has other properties that can be hardened, welded, and easily machined [15]. The use of carbon steel medium for pressure vessels often experiences material degradation and high temperature corrosion, so surface treatment is required [16]. Testing of welding results has an important role in steel inspection for pressure vessel applications [17].

3 Methods

This research method uses a literature review with the steps (1) Planning the review; (2) Conducting the review; and (3) Report the review.

Planning a review

The review planning study is intended to construct urgency from the study literature on pressure vessels with medium carbon steel materials. This study covers the standards for making the right pressure vessel? Potential properties of carbon steel medium as the main material for pressure vessels? And the need for treatment of the main ingredients?

Conducting a review

Most of the review materials are scientific articles from trusted journals indexed by Scopus and so on. A total of 60 articles were reviewed. Based on the results of the study, there were 32 articles that were relevant for literature review material.

Reporting the review

The results of the study are then synthesized to answer the research questions. The results of the study are contained in an explicit report regarding the use of carbon steel medium as the main material for pressure vessels.

4 Results and Discussion

Results

The main problem in pressure vessel failure is in the welded steel crack tip area and the fatigue crack mechanism in the weld [18]. This is caused by changes in the mechanical properties of the medium carbon steel metal being welded. Changes in mechanical properties that occur are due to the addition of carbon content which makes the welding results brittle, so that there is the potential for cracking.

Metals such as tool steel 1.2709 because the metal provides tensile strength above 1900 MPa after thermal treatment with a bond between the tension support and the vessel wall as a solution to the problem of leaks in pressure vessels [19]. If a potential weld crack occurs, one alternative solution that can be used is the temper bead technique [20].

Post Weld Heat Treatment (PWHT) Quenching the results of welding medium carbon steel using palm oil can be one solution to maintain the properties of medium carbon steel because it can maintain ductility [21]. Quenching with marula oil can increase the tensile strength, yield strength and hardness of moderate carbon steel, but decreases ductility [22]. Another way is to add chromium to medium carbon steel to increase its strength [23].

The choice of a multi-layered hollow spherical vessel shape is assumed to have (1) the advantages of constant temperature and pressure loads; (2) heat transfer and stress evolution across the vessel wall are axisymmetric and stable; (3) the material properties are homogeneous in each wall layer; and (4) the layers in the vessel wall are perfectly bonded to each other [24].

Discussion

The factors that are taken into consideration in making a pressure vessel are (1) the material's resistance to corrosion; (2) strength to pressure; (3) costs; (4) nature of fabrication; (5) design; (6) vulnerability to temperature and fire protection; and (7) material service life [25].

Basically, carbon steel such as SA-36 and SA-283 materials can also be used for pressure vessels with the consideration that (1) they are not used to contain deadly liquids or gases; (2)

not for unfired steam boilers; and (3) the plate thickness has a maximum strength of 5 ls in [26].

Medium carbon steel will experience an increase in hardness after quenching and will gain an increase in ductility after the tempering process, resulting in high strength steel [27]. The quenching temperature often applied for medium carbon steel ranges between Ac1 (725^{o}C) and Ac3 (725^{o}C) [28].

Medium carbon steel is widely used because it has good strength, mechanical properties that can be improved, and can be machined, welded, and hardened [29]. In applications in pressure vessels, carbon steel is being used because it has good tensile properties, has good toughness, has the ability to be easily welded, and has good resistance to brittleness [28]. However, medium carbon steel has problems with cracking easily [30].

Increasing the strength and ductility of medium carbon steel by quenching and tempering can also cause brittleness and premature damage due to student stress [31]. However, medium carbon steel which has gone through a quenching and tempering process has been widely used for pressure vessel construction because it has high strength [32].

5 Conclussion

Medium carbon steel has the advantage of its strong properties and low price. This makes desang carbon steel very widely used in various technologies. However, the potential for medium carbon steel to be applied in pressure vessels still has many considerations. The main advantage is the aspect of ease of acquisition and relatively cheap price. However, once welded, medium carbon steel has many properties that are not good for pressure vessels. This can be overcome with PWHT.

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