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Comparative Analysis between SA-516 Gr 70 Material with SA-537 Class 2 Material in Shell Pressure Vessel Fabrication Process

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Abstrak

Bejana tekan adalah wadah yang dirancang untuk menampung cairan bertekanan, termasuk cairan dan gas dengan tekanan dan suhu yang bervariasi. Tekanan yang diberikan pada dinding dan badan bejana merupakan faktor penting yang harus dipertimbangkan secara cermat untuk memastikan kepatuhan terhadap standar desain internasional yang berlaku dan memprioritaskan keselamatan dan keamanan pekerja. Penelitian ini difokuskan pada bejana tekan untuk menyelidiki dampak suhu terhadap ketebalan cangkang agar memenuhi standar ASME. Penelitian ini menggunakan komponen cangkang yang terbuat dari bahan SA-516 Gr 70 dan SA-537. Eksperimen dilakukan dengan setiap bahan pada suhu 250°C, 235°C, dan 343°C, yang menunjukkan bahwa ketebalan bervariasi berdasarkan bahan dan suhu. Temuan penelitian menunjukkan kepatuhan terhadap standar ASME, karena ketebalan cangkang di semua uji coba melebihi minimum yang ditentukan dalam gambar.

Kata kunci: Bejana Tekan, ASME VIII DIV 1, *Shell*, suhu, tekanan

Abstract

A pressure vessel is a container designed to hold fluids under pressure, including liquids and gases with varying pressures and temperatures. The pressure exerted on the vessel's walls and body is a critical factor that must be carefully considered to ensure compliance with applicable international design standards and prioritize worker safety and security. This research focused on a pressure vessel to investigate the impact of temperature on shell thickness to meet ASME standards. The study utilized shell components made from SA-516 Gr 70 and SA-537 materials. Experiments were conducted with each material at temperatures of 250°C, 235°C, and 343°C, revealing that thickness varies based on material and temperature. The research findings demonstrate compliance with ASME standards, as the shell thickness in all trials exceeded the minimum specified in the drawings.

Keywords: Pressure Vessel, ASME VIII DIV 1, Shell, Temperature, Pressure

1. Introduction

PT X Batam is a manufacturing company focused on oil and gas fabrication, utilizing advanced production technologies for various processes. One of its primary products is the pressure vessel, a sealed metal container designed to hold fluids at conditions that differ from the ambient environment. These vessels are employed in specific applications based on their design and must operate within defined maximum allowable working temperatures and pressures to ensure safe operation [1]. Designers must carefully select load combinations to achieve a safe and cost-effective design, requiring a comprehensive understanding of different stress types and loading scenarios [2].

Pressure vessels come in various types, including storage tanks, reactors, heat exchangers, and separators. Storage tanks are typically used for holding liquids or gases at atmospheric pressure, while reactors facilitate chemical reactions under controlled conditions [3]. Heat exchangers transfer heat between fluids, and separators are designed to divide components of a mixture based on density differences [4]. Each type has distinct design requirements and operating conditions, emphasizing the importance of material selection and engineering analysis.

A pressure vessel consists of several main components, including the shell, heads, nozzles, and supports. The shell is the cylindrical body of the vessel that provides the primary containment for the fluids under pressure. It is critical because it must withstand the internal pressure exerted by the contained fluid while also resisting external loads, such as seismic or wind forces. The thickness and material of the shell are crucial for ensuring the structural integrity and safety of the vessel [5]. The heads, which cap the ends of the shell, also play an important role in maintaining pressure containment, especially in vessels that operate under high pressures [6].

This research focuses on the shell. It examines the effects of varying temperature parameters and shell thickness. The materials used in this study are SA-516 Grade 70 and SA-537 Class 2. The aim is to determine whether these specified parameters influence the thickness of the shell and whether the selected materials comply with ASME standards. This study will also examine a horizontal pressure vessel constructed in accordance with ASME Section VIII, Division 1 standards [7]. The vessel is designed to withstand both internal and external pressures, along with additional loads encountered during operation.

For this design, SA-516 Grade 70 and SA-537 Class 2 materials are recommended. SA-516 Grade 70 is a carbon steel plate specification well-suited for use in pressure vessels that operate under moderate to high-temperature conditions due to its excellent weldability and toughness [8]. Conversely, SA-537 Class 2 is known for its enhanced strength, making it ideal for critical applications that require superior material performance [9]. Understanding the differences between SA-516 and SA-537 is essential for material selection in pressure vessel design. While SA-516 Grade 70 is often favored for its cost-effectiveness and adequate performance under moderate conditions, SA-537 Class 2 is preferred in high-temperature scenarios due to its superior mechanical properties [10]. Therefore, new research comparing these two materials is still necessary to optimize material selection for specific applications, ensuring safety and performance in various operational contexts [11].

Additionally, the corrosion resistance of these materials plays a key role in their longevity. Proper treatments and protective coatings can significantly extend the service life of SA-516 Grade 70 in corrosive environments, making it suitable for a wide range of industrial applications [12]. A detailed comprehension of the properties and behaviors of these materials is critical for ensuring the safety and durability of pressure vessels across varying operating conditions [13]. Evaluating material properties and thickness is vital for enhancing pressure vessel safety and compliance with industry standards. Engineers must assess design pressure, operating temperature, and potential corrosion allowances, as outlined by the ASME Boiler and Pressure Vessel Code [1]. Ongoing research and innovation will be essential to optimize the use of these materials, ensuring they meet the demands of modern engineering practices [14].

In evaluating the integrity of pressure vessels, several non-destructive testing (NDT) methods can be employed. Radiographic testing (RT) uses X-rays or gamma rays to reveal internal flaws within materials [15]. Magnetic particle testing (MT) detects surface and near-surface defects in ferromagnetic materials [16]. Dye penetrant testing (PT) applies a liquid dye to reveal cracks by highlighting defects on the surface [17]. Eddy current testing (ECT) employs electromagnetic induction to locate surface flaws in conductive materials [18]. Each of these methods offers distinct advantages and is suited to different applications and material types.

In this analysis, the Dakota Ultrasonics MX-3 was selected as the NDT method due to its reliability and precision in measuring material thickness. The use of ultrasonic techniques allows for the assessment of structural integrity without causing damage. The Dakota MX-3 offers several advantages: it provides high accuracy and precision, essential for evaluating material thickness and detecting potential defects; features a user-friendly interface that simplifies operation; and is versatile enough to work with a range of materials and thicknesses. Its durable and portable design ensures reliability in challenging industrial conditions, while its rapid measurement capabilities facilitate timely decision-making, crucial in high-stakes environments.

2. Method

The research conducted follows a flow diagram, as illustrated in Figure 1. This research focuses on the use of SA-516 Grade 70N and SA-537 Class 2 materials for the shell of pressure vessels. SA-516 Grade 70N is a carbon steel specification designed for medium and low-temperature applications. Its enhanced strength and improved corrosion resistance, attributed to its carbon content, make it suitable for various environmental conditions [15 19]. In contrast, SA-537 Class 2, composed of carbon, manganese, and silicon, provides excellent low-temperature toughness and resistance to thermal variations, crucial for maintaining structural integrity during operation [9].

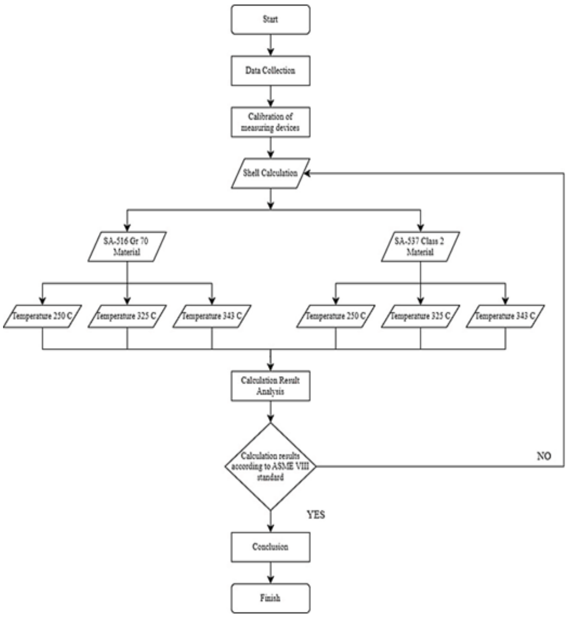

Figure 1: Flowchart analysis shell

The design and construction of pressure vessels must adhere to guidelines established by the American Society of Mechanical Engineers (ASME). The ASME Boiler and Pressure Vessel Code serves as a critical reference for ensuring the safety and reliability of pressure vessel operations [1]. Specifically, Section VIII, Division 1 outlines essential criteria for design, fabrication, inspection, and maintenance, significantly reducing the risk of operational failures [2]. Adhering to these codes is vital for ensuring that pressure vessels can withstand internal and external stresses throughout their service life [3].

To evaluate the shell thickness, this study employed the Dakota Ultrasonics MX-3, a precision ultrasonic micrometer. This device utilizes ultrasonic waves to accurately measure material thickness to within ±0.001 inch (±0.01 mm), making it effective for assessing the integrity of various materials, including metals and plastics [20]. Its capability to monitor corrosion rates is critical for ensuring the longevity and safety of pressure vessels, as corrosion can lead to catastrophic failures if not addressed [21].

Conducted at PT X Batam, the research involved a series of trials aimed at analyzing the impact of shell thickness under different temperature conditions (250 °C, 235 °C, and 343 °C), as shown in Table I. Calculations were performed in accordance with ASME DIV VII Section 1 standards to evaluate material performance and structural integrity under these specified operational parameters [4]. This comprehensive methodology aims to provide insights into optimizing pressure vessel designs for safety and efficiency in demanding industrial applications.

The results of this research are intended to contribute to a broader understanding of material performance in pressure vessel applications, facilitating better design practices that align with industry standards [22]. Future studies may focus on comparative analyses of alternative materials and their respective performance under similar conditions to further enhance safety protocols [23].

TABLE I

PARAMETER OF SA-516 GR 70 AND SA-537 CLASS 2

Parameter	Data
Code	ASME VIII Div 1
Design Pressure (P)	10 Mpa
Design Temperature (T)	250 °C, 235 °C, 343 °C
Fluid	Water
Vessel Inside Diameter (D)	200 mm

The numbers in the figure below indicate the points where thickness analysis is conducted on the shell. There are three points marked: Point 1 is located at the front near the head, Point 2 is at the midpoint between the supports, and Point 3 is at the back.

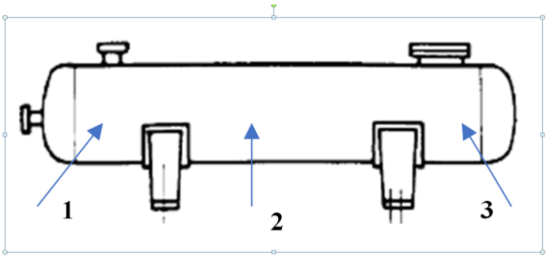

Figure 2: Shell part tested

The tables below present the parameters used for calculating the shell thickness. It includes three temperatures, each corresponding to a different thickness. The calculations are performed manually using a measuring instrument, with measurements taken at three points for each temperature, and each point measured three times.

TABLE II

SA-516 GR 70 EXPERIMENT

Temperature	Unit	Actual Thickness (mm)
250 °C	1	13
	2	13
	3	13
235 °C	1	18
	2	18
	3	18
343 °C	1	22
	2	22
	3	22

TABLE III

SA-537 CLASS 2 EXPERIMENT

Temperature	Point	Actual Thickness (mm)
250 °C	1	25
	2	25
	3	25
235 °C	1	18
	2	18
	3	18
343 °C	1	13
	2	13
	3	13

3. Results and Discussion

The analysis conducted on SA-516 Grade 70 and SA-537 Class 2 materials was performed at three points on each shell, with varying shell temperatures and thicknesses.

A. Thickness at 250°C

The table below shows the calculation results of SA-516 Grade 70 material at a temperature of 250 °C with a shell thickness of 13 mm. Among the three units measured, the largest value is found in unit 3.

TABLE IV

THICKNESS RESULTS OF SA-516 AT 250 °C

Location	Trial	Actual (mm)	Result (mm)	Average (mm)
Point 1	1	13	13.25	13.26
	2	13	13.25	
	3	13	13.29	
Point 2	1	13	13.25	13.20
	2	13	13.22	
	3	13	13.12	
Point 3	1	13	13.30	13.33
	2	13	13.34	
	3	13	13.34	
Average (mm)				13.26

The table below presents the calculation results for SA-516 Grade 70 material at a temperature of 250 °C with a shell thickness of 13 mm. Among the three units measured, the highest value is recorded in unit 3.

TABLE V

THICKNESS RESULTS OF SA-537 AT 250 °C

Location	Trial	Actual (mm)	Result (mm)	Average (mm)
Point 1	1	25	25.71	25.74
	2	25	25.74	
	3	25	25.78	
Point 2	1	25	25. 54	25.57
	2	25	25.56	
	3	25	25.57	
Point 3	1	25	25.84	25.86
	2	25	25.86	
	3	25	25.89	
Average (mm)				25.74

B. Thickness at 235°C

Table VI presents the results for SA-516 Grade 70 material at a temperature of 235 °C with a shell thickness of 18 mm. The values shown for each unit are relatively similar, with only minor differences. Table VII shows the results for SA-537 Class 2 material with a shell thickness of 18 mm. While the shell thickness is identical to that of SA-516 material, the resulting values differ.

TABLE VI

THICKNESS RESULTS OF SA-516 GR 70 AT 235 °C

Location	Trial	Actual (mm)	Result (mm)	Average (mm)
Point 1	1	22	18.16	18.25
	2	22	18.28	
	3	22	18.30	
Point 2	1	22	18.21	18.23
	2	22	18.24	
	3	22	18.24	
Point 3	1	22	18.27	18.29
	2	22	18.27	
	3	22	18.33	
Average (mm)				18.26

TABLE VII

THICKNESS RESULTS OF SA-537 AT 235 °C

Location	Trial	Actual (mm)	Result (mm)	Average (mm)
Point 1	1	13	18.26	18.27
	2	13	18.28	
	3	13	18.28	
Point 2	1	13	18.28	18.30
	2	13	18.30	
	3	13	18.33	
Point 3	1	13	18.34	18.35
	2	13	18.37	
	3	13	18.35	
Average (mm)				18.31

C. Thickness at 343°C

Table VIII presents the calculation results for SA-516 Gr 70 material with a temperature of 343 °C and a shell thickness of 22 mm. The results indicate that the first trial yielded a higher value compared to the other two trials. Table IX presents the calculation results for SA-537 Class 2 material with a temperature of 343 °C and a shell thickness of 13 mm. The results indicate that the values obtained in this test are higher than those from other tests. In Unit 1, the dominant value is significantly greater than the values in other units.

TABLE VIII

THICKNESS RESULTS OF SA-516 GR 70 AT 343 °C

Location	Trial	Actual (mm)	Result (mm)	Average (mm)
Point 1	1	22	22.71	22.75
	2	22	22.78	
	3	22	22.77	
Point 2	1	22	22.55	22.56
	2	22	22.57	
	3	22	22.56	
Point 3	1	22	22.30	22.34
	2	22	22.33	
	3	22	22.38	
Average (mm)				22.55

TABLE IX

THICKNESS RESULTS OF SA-537 AT 343 °C

Location	Trial	Actual (mm)	Result (mm)	Average (mm)
Point 1	1	13	13.97	13.93
	2	13	13.90	
	3	13	13.93	
Point 2	1	13	13.77	13.71
	2	13	13.69	
	3	13	13.68	
Point 3	1	13	13.86	13.84
	2	13	13.88	
	3	13	13.78	
Average (mm)				13.83

D. Discussion

Figure 3 compares the shell thickness of SA-516 Grade 70 material and SA-537 Class 2 material, both measured at a temperature of 250°C but with different shell thickness standards. For the SA-516 Grade 70 material, with a standard thickness of 13 mm, all measurement results meet or exceed the actual value. Similarly, the SA-537 Class 2 material, with a standard thickness of 25 mm, also shows no measurements below the actual value. Therefore, both materials are considered to comply with ASME standards.

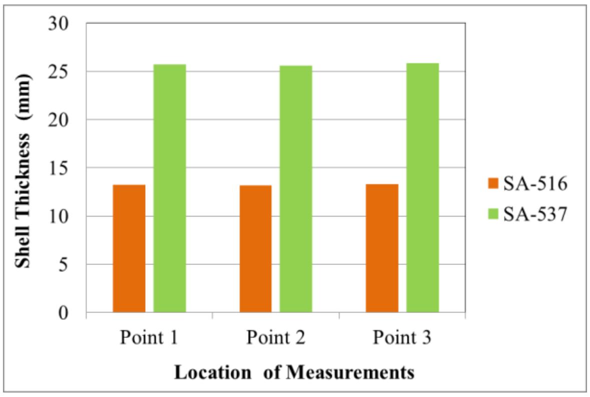

Figure 3: Shell thickness comparison of SA-516 Ge 70 and SA-537 Class 2 at 250°C

Figure 4 compares the shell thickness of SA-516 Grade 70 material and SA-537 Class 2 material, both measured at a temperature of 235°C and with the same shell thickness standard of 18 mm. For the SA-516 Grade 70 material, all measurement results meet or exceed the actual value. Similarly, the SA-537 Class 2 material also shows no measurements below the actual value. Therefore, both materials are deemed to comply with ASME standards. Although both pressure vessels share the same nominal shell thickness, the measurement results differ slightly but are not significantly far apart.

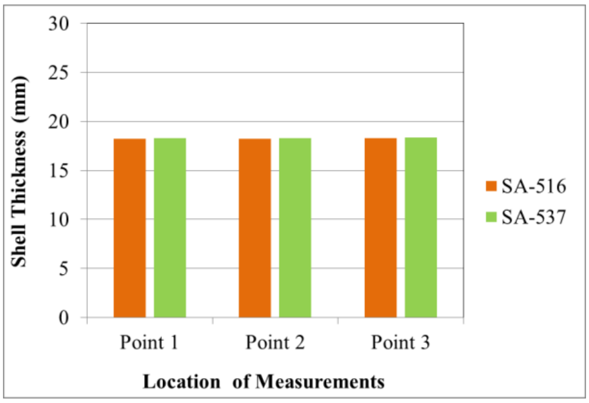

Figure 4: Shell thickness comparison of SA-516 Ge 70 and SA-537 Class 2 at 235°C

Figure 5 compares the shell thickness of SA-516 Grade 70 material and SA-537 Class 2 material, both measured at a temperature of 343°C with different shell thickness standards. For the SA-516 Grade 70 material, with a standard thickness of 22 mm, all measurement results meet or exceed the actual value. Similarly, the SA-537 Class 2 material, with a standard thickness of 13 mm, also shows no measurements below the actual value. Therefore, both materials are declared to meet ASME standards since their measurements are not less than the actual values.

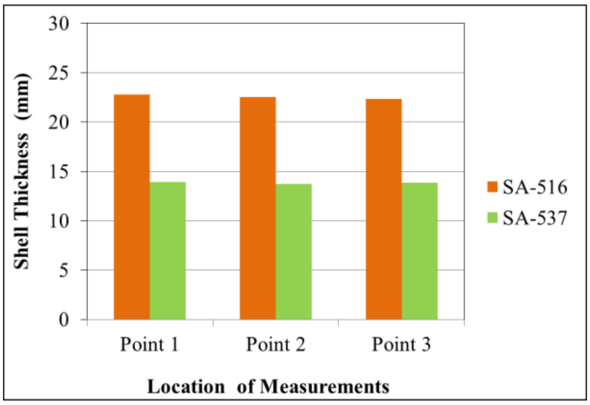

Figure 5: Shell thickness comparison of SA-516 Ge 70 and SA-537 Class 2 at 250°C

The analysis of the two materials indicates that the measurement results align with ASME standards. The nominal thickness specified in the drawings is considered ideal, and the measured thicknesses exceed this ideal value. As long as the measurements are not less than the ideal values, they are deemed compliant with ASME standards. Once the shell measurements are completed, they will be validated by the relevant inspection authority, ensuring adherence to the required standards.

4. Conclusions

Based on the results of the research conducted in this project, both materials meet ASME standards, as the measurements and tests align with the ideal thickness specified in the drawings. None of the measurements fall below the ideal thickness, ensuring that the hydrotest inspection can proceed smoothly and safely. Once all inspections are completed, ASME provides a stamp on the shell, indicating that the pressure vessel is suitable for operation. Both materials are carbon steel, with SA-516 Grade 70 being the most commonly used due to its wide availability in the market.

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