Analysis of SMAW Welding On Three-Layer Polyethylene Carbon Steel for Liquid Petroleum Gas Pipeline

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ABSTRACT

This research presents a comprehensive analysis of Shielded Metal Arc Welding applied to Three-Layer Polyethylene coated carbon steel pipes utilized in Liquefied Petroleum Gas distribution systems. Given the critical role of LPG piping in ensuring safe and efficient energy transport, the research underscores the necessity for stringent adherence to welding standards and practices. The methodology encompasses three key phases: preparation, execution, and testing, which collectively ensure the integrity and safety of welded joints. The preparation phase involved selecting API 5L carbon steel pipes and establishing a controlled welding environment, while the execution phase focused on employing SMAW with precise welding parameters. Following the welding process, a series of non-destructive testing methods, including visual inspections and radiographic testing, were employed to evaluate weld quality. Results indicate that while the welding process generally met established standards, certain defects were identified, emphasizing the importance of meticulous execution and the need for corrective measures. This study highlights the critical interplay between welding techniques, material integrity, and inspection methodologies, advocating for continuous improvement in practices to enhance the safety and reliability of LPG distribution systems. The findings contribute to the broader discourse on pipeline integrity management and the implementation of advanced corrosion protection strategies, ultimately supporting the sustainability of energy infrastructure.

I. INTRODUCTION

Liquefied Petroleum Gas (LPG) piping systems are critical components in the safe and efficient distribution of LPG for various applications, including residential heating, cooking, and industrial processes. These systems are designed to transport LPG in its liquid state under pressure, necessitating the use of materials and construction methods that can withstand the specific physical and chemical properties of the gas. The design considerations for LPG piping systems include factors such as pressure ratings, temperature fluctuations, and the potential for leakage, which necessitates rigorous adherence to safety standards and regulations. Additionally, the selection of appropriate fittings, valves, and connectors is essential to ensure system integrity and prevent catastrophic failures. Regular maintenance and inspection protocols are vital for the longevity and safety of LPG piping systems, as they help identify potential hazards and ensure compliance with industry best practices. Overall, the effective management of LPG piping systems is imperative for promoting safety, reliability, and efficiency in the utilization of this versatile energy source.

The term 3LPE (Three-Layer Polyethylene) refers to a corrosion protection system widely utilized in the pipeline industry, particularly for steel pipes transporting aggressive substances such as LPG. This system comprises three distinct layers: an epoxy primer that adheres to the steel substrate and provides an initial barrier against corrosion, an adhesive layer that ensures a strong bond between the primer and the outer layer, and a high-density polyethylene (HDPE) outer layer that offers mechanical protection and resistance to environmental factors. The implementation of 3LPE coatings significantly enhances the durability and longevity of pipelines, reduces maintenance costs associated with corrosion, and aligns with industry standards aimed at ensuring the safe and efficient transport of fluids. Consequently, the 3LPE coating system represents a sophisticated approach to corrosion protection, contributing to the sustainability and reliability of energy distribution systems.

Welding is a fundamental process in the construction and maintenance of piping systems, particularly in industries such as oil and gas, petrochemical, and power generation. The integrity of welded joints is crucial, as they often serve as the primary means of connecting pipes, fittings, and valves, thereby ensuring the seamless flow of fluids and gases under various pressures and temperatures. The selection of appropriate welding techniques—such as shielded metal arc welding (SMAW), gas tungsten arc welding (GTAW), or submerged arc welding (SAW)—is influenced by factors including the materials being joined, the operating environment, and the specific requirements of the piping system. Furthermore, adherence to established codes and standards, such as those set forth by the American Society of Mechanical Engineers (ASME) and the American Welding Society (AWS), is essential to guarantee the quality and reliability of welds. Comprehensive inspection and testing methods, including non-destructive testing (NDT) techniques, are employed to evaluate the strength and integrity of welded joints, thereby mitigating the risk of failures that could lead to significant safety hazards and economic losses. Ultimately, the application of rigorous welding practices within piping systems is vital for ensuring operational efficiency and safety in industrial applications.

Improper welding in piping systems can lead to a multitude of severe consequences, both immediate and long-term, significantly impacting operational safety and structural integrity. One of the primary risks associated with inadequate welding practices is the potential for leaks, which can result from insufficient penetration, improper joint design, or inadequate filler material. Such leaks not only compromise the efficiency of the piping system but also pose substantial safety hazards, particularly in systems transporting hazardous materials such as gases or corrosive liquids. Additionally, poorly executed welds may lead to mechanical failures, including catastrophic ruptures or fractures, which can cause extensive damage to equipment, infrastructure, and the surrounding environment. The economic implications of such failures are considerable, encompassing repair costs, production downtime, and potential regulatory fines. Furthermore, inadequate welding can undermine the reliability of the piping system, leading to increased maintenance requirements and reduced operational lifespan. From an academic perspective, the critical importance of adhering to established welding standards and practices is underscored by the need to mitigate these risks, thereby ensuring the safe and efficient operation of piping systems across various industrial applications.

II. METHODS

The methodology employed in this study focuses on the analysis of the welding process and the quality assessment of carbon steel pipes used in the Liquid Petroleum Gas (LPG) distribution system at the Integrated Terminal Surabaya. The methodology is divided into several key phases, which include preparation, execution, and testing.

A. Preparation Phase

The initial phase involved thorough planning and preparation for the welding process. This included:

Material Specification: The carbon steel pipes selected for the project were of type API 5L, with specific dimensions and properties as outlined in the project specifications. The pipes had an outer diameter of 273.1 mm, an inner diameter of 254 mm, a wall thickness of 9.3 mm, and were coated with a three-layer polyethylene (3LPE) to prevent corrosion.

- Welding Habitat Setup: A welding habitat was constructed to ensure safety during the welding operations. This involved creating a controlled environment to minimize fire hazards associated with hot work, using wet burlap to suppress flames and prevent the spread of fire.
- Fit-Up Procedures: Prior to welding, the pipes underwent a fit-up process to ensure proper alignment and spacing. This included cleaning the pipe edges, adjusting the bevels, and securing the pipes with flanges to facilitate accurate welding.

B. Execution Phase

The welding process was conducted using the Shielded Metal Arc Welding (SMAW) technique. The parameters for the welding process were meticulously followed as per the specifications:

Welding Parameters: The welding was executed with the following parameters:

Electrode Types: E 6010 was used for the root pass, while E 7010 was utilized for the hot, fill, and capping passes.

Amperage: The current settings varied from 75 to 130 A depending on the specific pass being executed.

Voltage: The voltage was maintained between 22 to 25 V throughout the welding process.

Travel Speed: The travel speed was adjusted according to the specific welding pass, ranging from 75 to 115 mm/min.

The welding was performed by certified welders, ensuring adherence to industry standards and safety protocols.

C. Testing Phase

After the completion of the welding process, a series of non-destructive testing (NDT) methods were employed to evaluate the quality of the welds:

Visual Inspection: Initial assessments were conducted visually to identify any obvious surface defects or irregularities in the welds.

Radiographic Testing: Radiographic tests were performed to detect internal flaws such as porosity and cracks. This involved using radiographic film to capture images of the welds, allowing for detailed analysis of the internal structure.

Documentation and Analysis: All findings from the inspections and tests were meticulously documented. The results were analyzed to ensure compliance with ASME standards, specifically focusing on the integrity and safety of the welded joints.

III. RESULT AND DISCUSSION

Testing on this project is by using non-destructive testing, namely NDT. According to relevant research [XXX], NDT is a test or inspection activity on a material or component which is to obtain a characteristic in terms of micro and mechanical properties to determine the presence of defects, cracks without having to damage the material. The other side of this test is carried out so that it aims to guarantee the material in terms of safety or not passing with a predetermined tolerance. NDT testing has several types of testing stages.

A. Visual Test

Visual testing is one of the most fundamental non-destructive testing methods, primarily relying on the observer's visual acuity to assess the condition of materials and welds. This technique employs visual media, leveraging the five human senses—particularly sight—to evaluate the surface characteristics of the material under examination. The visual test is adept at performing macro or surface inspections, allowing inspectors to identify visible defects such as cracks, porosity, and misalignment in welds. However, it is important to acknowledge the limitations inherent in this method; specifically, visual testing cannot adequately perform micro-level examinations or detect finer details that may compromise the integrity of the material.

The efficacy of visual testing is governed by established standards, which dictate the criteria for acceptable and unacceptable conditions in welded joints. The results of such tests typically yield an outline of the expected quality, providing a preliminary assessment of the welding integrity.

For instance, as illustrated in Figure 1, the results of the visual inspection indicate that the overall welding layout is neat and adheres to predetermined standards, suggesting a competent execution of the welding process.

Several factors significantly influence the quality of welding and, consequently, the outcomes of visual inspections. These factors include the skill level of the welder, the appropriateness of the welding technique employed, and the quality of the materials used. The findings from visual testing serve as a critical foundation for subsequent testing methodologies, as they provide an initial evaluation of the welding results. The example depicted in the aforementioned figure exemplifies welding outcomes that align with industry standards, thereby reinforcing the importance of visual testing as a preliminary step in the comprehensive assessment of weld quality. Ultimately, while visual testing is a valuable tool in the quality assurance process, it should be complemented by more advanced testing methods to ensure a thorough evaluation of material integrity.

B. Radiography Test

Radiography Test testing is a test with a testing accuracy level of 0.02mm of material thickness. This Radiography Test is a test classified as micro testing. This test is by using a Radiography film that is able to detect directly the location of the defect in the material. This is able to show clearly and be able to guarantee the layout of defects from the welding of the material. Radiography rays have a fairly dangerous effect because they can have a negative effect on the surrounding. Therefore, this test is carried out out of reach and prioritizes the safety of workers. The picture above is one of the results of radiography testing. The welding results above can be analyzed that in terms of welding it is quite good and evenly distributed, but the welding still does not have the appropriate thickness where the welding results on the film are less thick or the white color that is printed is less patterned where the thinness of the color on the film can indicate that the welding results lack the appropriate thickness. The thickness that has been determined where the thickness greatly affects the welding and this can require a repair of the welding results or it can be said by rewelding to get good and maximum results. The thinness of the welding can affect the connection which can later appear the problem of a leak in the flowing fluid. The record that occurs is a record caused by a moist electrode or can be said to be less dry as a whole and this can be done with welded drying which is a dryer from the electrode itself which when used will really be ensured to be dry and not damp. The layer tested by radiography is the capping layer which is the outermost layer of the welding layer. The picture above has 3 layers on the right side, left side and center.

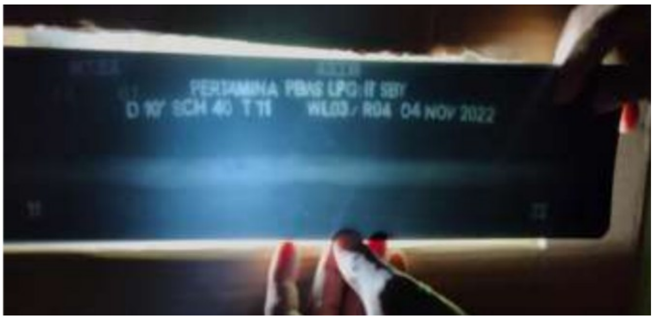

Fig. 1. The result of SMAW on T71 ipie

The welding results on the T71 pipe connection have a defect in the welding results, namely the presence of several colours that do not match or can be said with a black colour that proves the existence according to the record. The defect that occurs is that there are defects in the welding results. The defect is caused by the instability of the current in the welding which will have a significant effect on the welding results and also the influence of dirt on the media to be welded which before welding will be cleaned with a grinder which can be called an abrasive metal grinding disc. This record has several defect tolerances, which range a maximum of 25 mm, if the record is below the predetermined limit, the record does not have a major effect on the welding results.

IV. Conclusion

Comprehensive analysis of Liquefied Petroleum Gas (LPG) piping systems, particularly in the context of welding and inspection methodologies, underscores the critical importance of adhering to rigorous standards and practices to ensure safety and operational efficiency. The integration of advanced corrosion protection techniques, such as the Three-Layer Polyethylene (3LPE) system, significantly enhances the durability and longevity of these pipelines, mitigating the risks associated with corrosion and environmental factors. Furthermore, the welding process, as a fundamental aspect of piping construction, necessitates meticulous execution and adherence to established welding techniques to maintain the integrity of welded joints. The findings from non-destructive testing methods, including visual inspections and radiographic evaluations, reveal the necessity of a multi-faceted approach to quality assurance in welding operations. While visual testing provides an essential preliminary assessment of weld quality, radiographic testing offers a more detailed examination, capable of identifying micro-level defects that could compromise system integrity. The presence of any identified defects, particularly those stemming from improper welding techniques or material preparation, highlights the need for corrective actions, such as rewelding, to uphold the safety and reliability of the LPG distribution system. Ultimately, the synthesis of these methodologies and findings reinforces the imperative for continuous improvement and adherence to best practices within the industry, thereby ensuring the safe and efficient transport of LPG and contributing to the sustainability of energy distribution systems.

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