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Tensile Strength Test of SMAW Welded Joints on ASTM A36 Steel with Cooling Media Variations Water, SAE 10W- 40 oil, and Air

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Abstract

Welding is one of the essential processes in the manufacturing industry. One of the factors that affects the quality of welding results is the cooling medium used after the welding process. This study aims to determine the effect of different cooling media on the tensile strength of SMAW (Shielded Metal Arc Welding) welded joints on ASTM A36 steel. Three types of cooling media were used air, water with a pH of 6.5–8.5 and SAE 10W-40 oil. The welding process was carried out using an I-groove with a butt joint in the 1G position, using an E7018 electrode with a diameter of 3.2 mm and a current of 100 A. The tensile tests were conducted according to the ASTM E8 standard.The results showed that the specimens cooled with SAE 10W-40 oil produced the highest average tensile strength of 574.9974 Mega pascal and the highest average elongation of 38.73%. Cooling with water resulted in an average tensile strength of 566.5932 Mega pascal and a maximum elongation of 28.27%. Meanwhile, cooling with air resulted in the lowest average tensile strength of 545.5592 Mega pascal and an elongation of 30%. The highest modulus of elasticity was obtained from water cooling at 2051.55 Mega pascal, followed by air at 2048.60 Mega pascal, and the lowest was from oil at 1493.83 Mega pascal.Based on these results, it can be concluded that the variation of cooling media affects the tensile strength of welded joints. Cooling with SAE 10W-40 oil provided the most optimal results, producing the highest tensile strength and good ductility. Therefore, SAE 10W-40 oil is recommended as the best cooling medium for the SMAW welding process on ASTM A36 steel, especially in ship hull applications.

Keywords: SMAW, ASTM A36 Steel, cooling media, tensile strength, ship hull.

INTRODUCTION

Welding plays an important role in the manufacturing industry as one of the primary techniques for joining metals. Various welding methods are available, each with techniques that can be adjusted to specific needs, one of which is electric arc welding. This method uses electrical energy as a heat source to melt and join metals. One type of welding that utilizes this technique is Shielded Metal Arc Welding (SMAW) [1]. In the SMAW process, an electric arc forms between the electrode tip and the surface of the material, causing the base metal to melt. The electrode used consists of a wire coated with protective flux. As the electrode melts, its material mixes with the base metal and solidifies into a solid weld joint [2]. Welding is crucial in manufacturing engineering and is widely applied across various industrial sectors, including building construction, machinery manufacturing, shipbuilding, bridge construction, railway vehicle frames, and conveyor belts [3].

Due to its broad application, welding has become the primary method for joining metals. In the shipbuilding industry, the process of joining metal plates is a critical stage in ship maintenance, especially concerning the hull. The hull is a vital component that directly contacts seawater and is highly susceptible to external pressures such as waves and cargo loads. Therefore, the quality of weld joints on the hull significantly affects the safety and long-term durability of the ship [4]. Damage or failure in weld joints can have fatal consequences for the ship's structure, as occurred in the sinking of the KMP Darma Rucitra III ferry at Padang Bai Port, Bali, on June 12, 2020. The ferry experienced hull leakage while docked and was carrying an overload that increased pressure on the hull plate joints, causing leakage and further damage [5].

This incident highlights the critical importance of weld quality, especially in a dynamic and high-pressure marine environment.One important factor affecting weld joint quality is the cooling process after welding. The cooling rate, whether too fast or too slow, can influence the mechanical properties of the metal, particularly its tensile strength. This study aims to analyze the tensile strength of weld joints on ASTM A36 steel welded using the SMAW method. The primary focus is to determine the effect of different cooling media on the tensile strength of the welds. The threecooling media used are air, water with a pH of 6.5–8.5, and SAE 10W-40 oil. After welding, the joints will be cooled using each of these media. These three media have different cooling rates, which affect the quality of the weld joints. A study conducted by Gumelang, D., Kurniawati, D., and Supriyanto, H. (2023) on SMAW ST-41 steel with ASTM E8 tensile test standards showed that samples with a V-groove in the 1G position cooled with oil had the highest tensile load of 50.43 MPa, while samples cooled with air had the lowest tensile strength of 42.36 MPa [2].

Based on these results, the researcher is interested in analyzing tensile strength tests on SMAW weld joints cooled with water, oil, and air. This study will conduct tensile testing on ASTM A36 steel welds with an I-groove butt joint in the 1G position, commonly used on ship hulls. The main challenge in this process is the post-weld cooling procedure. Using improper cooling media can reduce joint quality, causing defects such as cracks and decreased tensile strength. Although ASTM A36 steel has advantages in tensile strength and ease of welding, microstructural changes caused by uncontrolled cooling can make the joints more brittle and less resistant to dynamic loads [6]. Therefore, this research is important to determine the most effective cooling medium among water, oil, or air in maintaining the integrity of weld joints. It is expected that the results of this study will improve the welding quality of ASTM A36 steel, especially in ship hull applications, considering the limited research on the effect of cooling media on I-groove butt welds of ASTM A36 steel.

RESEARCH METHODS

2.1 Methodology

This study uses an experimental method to determine the effect of cooling media on the tensile strength of welded joints in ASTM A36 steel. The cooling media used are water with a pH of 6.5–8.5, SAE 10W-40 oil, and air. The research process involves several stages, namely specimen fabrication, preparation of cooling media, welding process, specimen cooling, and tensile testing [7],[8],[9]. In the specimen fabrication stage, ASTM A36 steel plates with a thickness of 8 mm are used as the main material. The welding process is carried out using E7018 electrodes with a diameter of 3.2 mm and a Miller Gold Star 402 SMAW welding machine. After the welding process is completed, the specimens are cooled using three types of cooling media according to the treatment: water with a pH of 6.5–8.5 measured by a water pH meter, SAE 10W-40 oil, and air [8][9]. Other equipment used includes a milling machine for specimen machining, a grinding machine with cutting tools to cut and finish the welds, a chipping hammer to clean welding slag, as well as rulers and vernier calipers for dimensional measurements. Gloves are used as protection during the work process. Tensile testing is performed using a Universal Testing Machine (UTM) to obtain the tensile strength values of each specimen [7][9].

2.2 Time and Place of Research

This research was conducted from March to June 2025. The locations for the completion of this final project consist of two sites:

1. The welding process was carried out in the welding workshop at Politeknik Negeri Bengkalis.
2. The tensile testing was conducted in the laboratory at Politeknik Negeri Bengkalis.

Thus, all research activities were performed in facilities that are supportive and suitable for achieving the objectives of the study

2.3 Fabrication of Tensile Test Specimens

The specimens used for the tensile test have a total length of 300 mm and a thickness of 8 mm. At both ends
of the specimens, there are grip sections, each measuring 100 mm in length and 20 mm in width. Between the grips and the testing area, there is a fillet radius of 12.5 mm, which serves to reduce stress concentration. Meanwhile, the central portion of the specimen that experiences the primary load, referred to as the gauge length, measures 57 mm in length.

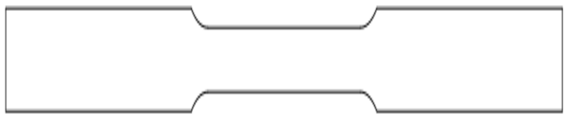

Fig. 1. Standard Tensile Test Specimen According to ASTM E8

2.4 RESULTS OF STRAIN, STRESS, ELASTIC MODULUS, AND TENSILE STRENGTH CALCULATIONS OF COOLING MEDIA

This section presents the results of tensile tests on SMAW weld joints cooled with water, oil, and air. The parameters measured include strain, tensile stress, elastic modulus, and maximum tensile strength. Calculations were performed based on the data obtained from the tests, using standard mechanics of materials formulas considering the initial cross-sectional area, maximum load, and specimen elongation, as follows:

Cross Sectional Area $A_0 = b \times t$ (1)

Stress $\sigma = \frac{F}{A_0}$ (2)

Strain $\varepsilon = \frac{\Delta L}{LO} \times 100\ \% =$ (3)

Elstic Modulus $E = \frac{\sigma}{\varepsilon} =$ (4)

Ultimate Tensile Strength $UTS = \frac{P_{Max}}{A_0} =$ (5)

RESEARCH RESULTS

The tensile test was conducted in accordance with ASTM E8 standards, which are used to determine the mechanical properties of materials, particularly ASTM A36 steel. Through this testing process, data regarding the tensile strength of specimens that have undergone cooling processes with various media were successfully obtained. The results of these tests are presented in the following **Table 1**.

Table 1. Summary of Tensile Test Results for Various Cooling Media Water, SAE 10W-40 Oil, and Air

Cooling Media	Specimen	Cross-sectional area (mm)	Initial length (mm)	Final length (mm)	Tensile stress (MPa)	Strain (%)
Water	1	100 mm^2	50 mm	63,34 mm	601,0223 Mpa	26,8 %
	2	100 mm^2	50 mm	61,8 mm	539,187 Mpa	23,6%
	3	100 mm^2	50 mm	67,2 mm	559,5703 Mpa	34,4 %
			Average		566,5932 Mpa	28,27 %
Air	1	100 mm^2	50 mm	71,75 mm	513.4528 Mpa	43,5 %
	2	100 mm^2	50 mm	63,5 mm	558.2308 Mpa	27 %
	3	100 mm^2	50 mm	59,75 mm	564,994 Mpa	19,5 %
			Average		545.5592 MPa	30%
SAE 10W-40 Oil	1	100 mm^2	50 mm	67,75 mm	596.2827 Mpa	35,5 %
	2	100 mm^2	50 mm	69,75 mm	588.1202 Mpa	39,5 %
	3	100 mm^2	50 mm	70,6 mm	540.5892 Mpa	41,2 %
			Average		574,9974 Mpa	38,73%

After the tensile test is conducted, the obtained data will be analyzed in depth to calculate the average values of each measured parameter. These average values will then serve as a reference for constructing comparison graphs among the various cooling media.

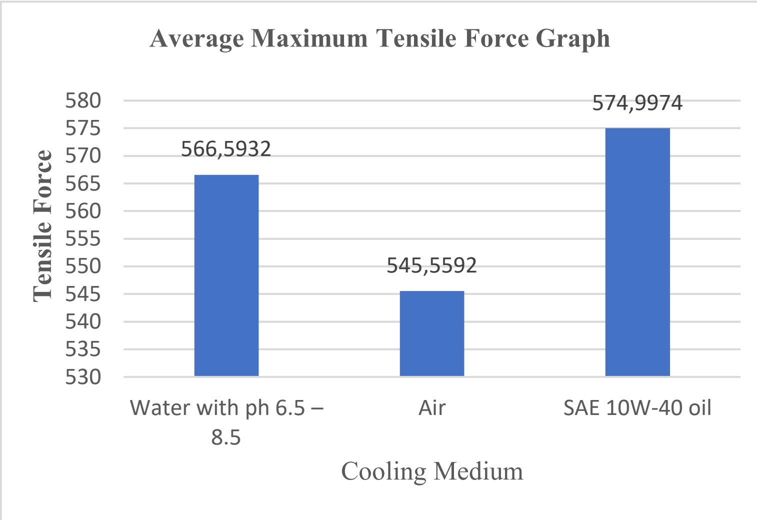

Fig. 2. Average Maximum Tensile force Graph

The presented graph shows that the highest average maximum tensile strength is achieved with SAE 10W-40 oil at 574.9974 megapascal. This is followed by water cooling, which yields an average tensile strength of 566.5932 megapascal, while air cooling results in the lowest value of 545.5592 Megapascal. These results are consistent with previous studies indicating that the type of cooling medium used during the welding process significantly affects the tensile strength of the welded joint. The superior performance of oil-cooled specimens can be attributed to the slower cooling rate of oil compared to water and air, which allows for a more controlled solidification process and the development of a finer microstructure in the heat-affected zone. Water cooling, with its moderate cooling rate, still maintains good mechanical properties, whereas air cooling, having the fastest cooling rate, leads to the lowest tensile strength. These findings suggest that cooling media with slower cooling rates, such as oil, enhance the welded joint's resistance to tensile forces by minimizing thermal stresses and reducing the formation of brittle microstructures, in line with previous research on the effects of cooling media in welding.

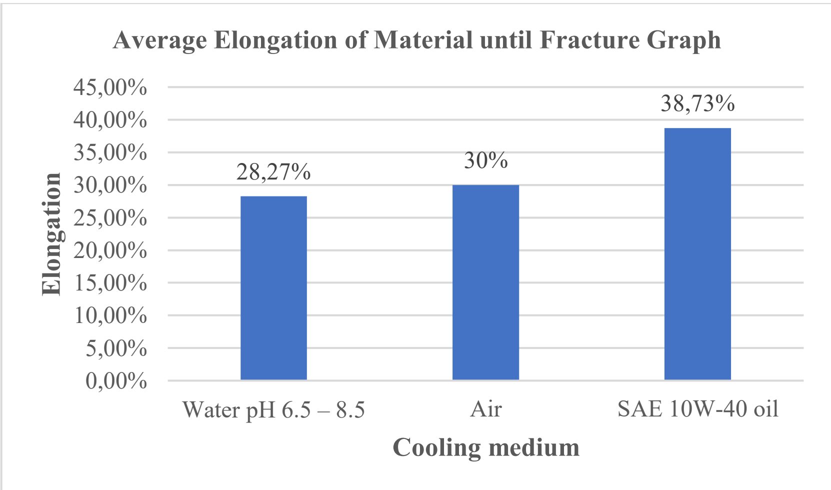

Fig. 3. Average Elongation Of Material Until Fracture Graph

The analysis indicates that specimens cooled with SAE 10W-40 oil exhibited the highest average elongation at 38.73%. Air-cooled specimens ranked second with an elongation of 30%, while those cooled with water showed the lowest elongation at 28.27%. The low strain value in the water-cooled specimens is attributed to the very rapid cooling rate after welding, which causes the material to become more brittle and lose some mechanical properties.These findings are supported by the research conducted by Tarigan et al. (2023), titled *"Analysis of Tensile Strength on ST.37 Material with SMAW Welding Variations of SAE 10 Oil and Water Cooling,"* which found that using oil as a cooling medium resulted in the highest tensile strength of 365.15 N/mm², surpassing air cooling at 347.75 N/mm² and the condition without cooling at 343.35 N/mm². This reinforces the hypothesis that cooling media, particularly oil, play a crucial role in enhancing tensile strength.Moreover, these results align with previous studies demonstrating that cooling media significantly affect the mechanical properties of welded joints, especially tensile strength. For example, Kumar and Gupta (2021) showed that oil cooling produces a finer microstructure and higher tensile strength compared to water and air cooling. Additionally, Singh et al. (2022) found that slower cooling rates reduce thermal stresses and prevent the formation of brittle zones in welds. Therefore, this study supports and strengthens the hypothesis that oil as a cooling medium effectively improves weld quality.

CONCLUSION

Based on the research titled "Tensile strength test of SMAW welded joints on ASTM A36 steel with cooling media variations water, SAE 10W-40 oil, and air" several conclusions can be drawn as follows:

1. The The type of cooling medium significantly affects the tensile strength of welded joints. Cooling with SAE 10W-40 oil resulted in the highest average tensile strength of 574.9974 Megapascal, followed by water at 566.5932 Megapascal , and air at 545.5592 Megapascal. The maximum tensile load (FLAS) was also highest in oil cooled specimens 57,499.74 N, followed by water 56,659.32 N and air 54,555.92 N. Thesedifferences are attributed to the effect of cooling rates on the micro structure formation oil, with a moderate cooling rate, produces a fine ferrite-pearlite structure that is strong and balanced water, with a rapid cooling rate, forms a hard but brittle martensitic structure while air, with a slow cooling rate, results in a coarse ferrite-pearlite structure that is softer and weaker.
2. The cooling medium also influences the ductility of the welded joints. The highest average elongation was observed in specimens cooled with SAE 10W-40 oil, reaching 38.73%, followed by air 30% and water 28.27%. The highest modulus of elasticity was recorded in water-cooled specimens 2051.55 Mega pascal, followed by air 2048.60 Mega pascal and the lowest in oil 1493.83 Mega pascal, indicating that water and air produced stiffer materials, while oil yielded more elastic behavior. This elasticity supports greater plastic deformation before fracture, making SAE 10W-40 oil the most recommended cooling medium for improving both tensile strength and ductility of SMAW welded joints on ASTM A36 steel.

RECOMMENDATIONS

Based on the findings of this study, several recommendations can be made as follows:

1. For future research, it is suggested to include the Post Weld Heat Treatment (PWHT) process. This aims to provide a clearer comparison of the material properties between specimens that undergo post-weld heat treatment and those that do not.
2. It is advisable that tensile testing be conducted following non-destructive testing methods, such as ultrasonic tests and penetrant tests. This step is crucial to ensure that the welding results meet the expected quality standards.

NOMENCLATURE

A0	Plate cross-sectional area (mm²)
I	Plate thickness (mm)
T	Plate thickness (mm)
σ	Maximum Tensile Strength (N/mm² or MPa)
F	Maximum Force (N)
ΔL	Elongation (mm)
Lo	Initial Length (mm)
ε	Strain (%)

E	*Elastic Modulus (MPa)*
UTS	*Tensile Strength (MPa)*
Pmax	Maximum Load (N/mm^2)

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