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Analyzing the Effects of Water, Air, and Saltwater Coolants on the Tensile Strength & Hardness of AISI 1045 Steel Welded with Metal Inert Gas

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ABSTRACT

This study aims to analyze the effect of cooling media variations (air, water, and salt water) on the mechanical properties of AISI 1045 medium carbon steel welded using the Metal Inert Gas (MIG) method. The experimental method was used with steel specimens in the form of plates which were then tested for tensile strength in accordance with the ASTM E8 standard and tested for hardness. The results of the study show that cooling with air produces the highest tensile strength (35.59 Kgf/mm²) due to the formation of ductile pearlite and ferrite microstructures. Cooling with water produced moderate tensile strength (34.42 Kgf/mm²), while cooling with salt water produced the lowest tensile strength (22.34 Kgf/mm²) due to the formation of hard but brittle martensite. Conversely, the highest hardness value was obtained with saltwater cooling (386.20 HV in the HAZ), followed by water, and the lowest with air. In general, slow cooling increases ductility and tensile strength, while rapid cooling increases hardness but decreases ductility. These findings emphasize the importance of selecting the appropriate cooling medium according to application requirements, whether the emphasis is on tensile strength or material hardness.

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INTRODUCTION

Welding is one of the most widely used manufacturing processes in industry to permanently join two or more metal materials (Disya Haeriati Ariwiana Putri et al., 2023). Among various welding methods, Metal Inert Gas (MIG) welding**,** also known as Gas Metal Arc Welding (GMAW), is commonly used because of its high welding speed, good joint quality, and ease of operation (Haris & Widodo, 2021) (Rosidah & Setyowati, 2021). This welding method is frequently applied to various types of carbon steel, including AISI 1045 steel**,** which is widely utilized in engineering applications such as shafts, gears, machine components, and structural parts due to its good mechanical strength and moderate hardness (Wibawa et al., 2023) (Ramadhani et al., 2022).

AISI 1045 steel is classified as a medium carbon steel containing approximately 0.45% carbon, which provides a balance between strength, hardness, and toughness (Budiarto et al., 2020) (Mulyadi et al., 2022). During the welding process, this material experiences thermal cycles caused by the heat generated from the welding arc. These thermal effects can alter the microstructure of the base metal, weld metal, and the Heat Affected Zone (HAZ) (Sihite, 2019). Such microstructural changes may significantly influence the mechanical properties of the welded joint, particularly its tensile strength, which is an important parameter in evaluating the performance and reliability of welded structures (Nugraha et al., 2020) (Haryadi et al., 2021).

One of the factors that can influence the mechanical properties of welded joints is the cooling medium applied after the welding process (Susetyo et al., 2021) (Darmo et al., 2021). Different cooling media such as water, air, and salt water have different cooling rates, which can affect the formation of microstructures in the weld metal and surrounding areas (Lhoksuemawe et al., 2022). Faster cooling rates generally increase hardness but may reduce toughness, while slower cooling rates tend to produce more ductile structures (A et al., 2021) (Wiratmaja et al., 2025). Therefore, the selection of cooling media becomes an important aspect in controlling the final properties of welded materials (Husaini et al., 2020) (Ayoola et al., 2022).

Several studies have investigated the influence of cooling conditions on the mechanical properties of welded steel. However, a detailed comparison of the effects of water, air, and salt water cooling on the tensile strength of AISI 1045 steel welded using the MIG process still requires further investigation (Wisnujati & Andryansyah, 2021) (Haris & Widodo, 2021). Differences in thermal conductivity and heat transfer characteristics of each cooling medium may lead to variations in the resulting microstructure and mechanical performance of the welded joints (Alfryyan, 2022) (Teknik et al., 2020).

Based on this background, this study aims to analyze the effects of different cooling media—water, air, and salt water—on the tensile strength of AISI 1045 steel welded using the MIG welding method. The results of this research are expected to provide scientific insights into the most effective cooling medium for improving the quality and mechanical performance of welded joints, as well as to contribute to the development of welding applications in industrial manufacturing.

METHOD

This study employs an experimental approach as its research method. The experimental approach is a research method used to identify the effect of cooling medium treatment on the tensile strength of AISI 1045 steel. The material used in this study is a square AISI 1045 steel plate measuring 100 mm x 100 mm x 8 mm. The welding method used is MIG (GMAW) with ER70S-6 filler wire having a diameter of 0.8 mm and shielding gas in the form of CO_2 or an Ar+CO_2 mixture with a gas flow rate of 10–15 L/min

The welding process was performed with constant parameters, namely a welding current ranging from 120–180 A, a voltage of 20–24 V, and a welding speed adjusted to produce a uniform joint, using DCEP (Direct Current Electrode Positive) polarity. After the welding process is complete, the specimens are subjected to cooling treatment using three variations of media: air cooling (left at room temperature), freshwater cooling, and saltwater cooling with a solution concentration of ±5% NaCl. The temperature of the cooling medium and the immersion time are kept constant for each specimen to ensure consistency in the treatment.

In this study, each cooling medium variation used 3 specimens for tensile testing and 1 specimen for hardness testing. Tensile testing was conducted in accordance with ASTM E8 to determine the ultimate tensile strength, while hardness testing was performed using the Rockwell method on the weld zone or heat-affected zone (HAZ). The test data was then analyzed to determine the effect of cooling medium variations on the mechanical properties of AISI 1045 steel resulting from MIG welding.

RESULTS AND DISCUSSION

Tensile Strength Test

Based on graph 1, the relationship between variation and three different cooling media shows that cooling using air has the highest tensile strength, which is 35.59 Kgf/mm². Next, cooling with water as the medium obtained a result of 34.42 Kgf/mm². Compared to air as a cooling medium, salt water as a cooling medium had the lowest value, with a tensile strength of 22.34 Kgf/mm².

Figure 1. Tensile test specimens before and after

Table 1. Tensile test results

Cooling Media	Specimen	Area (mm^2)	Pmax (Kgf)	Tensile Strength (Kgf/mm^2)
Water	I	103.28	3137.20	30.38
	II	101.52	3186.80	31.39
	III	99.84	4141.60	41.48
Average			**3488.53**	**34.42**
Air	I	94.88	3980.20	41.95
	II	120.08	1318.00	10.98
	III	99.52	5358.20	53.84
Average			**3552.13**	**35.59**
Saltwater	I	102.08	1715.20	16.80
	II	122.16	3758.80	30.77
	II	97.92	1905.60	19.46
Average			**2459.87**	**22.34**

This is because in the cooling media variation using air media, the slow cooling rate produces a microstructure of pearlite and ferrite, which have soft and ductile properties. And for the hardness test results, the values are low so that the toughness value decreases, but the more ductile and the lower the hardness, the higher the tensile test value. Furthermore, water and saltwater media have low tensile test values due to the fast-cooling rate, which produces a microstructure of martensite and bainite phases with very hard and brittle properties. The hardness test results also have the highest values. The harder and more brittle the material, the lower the tensile test results of the test specimen.

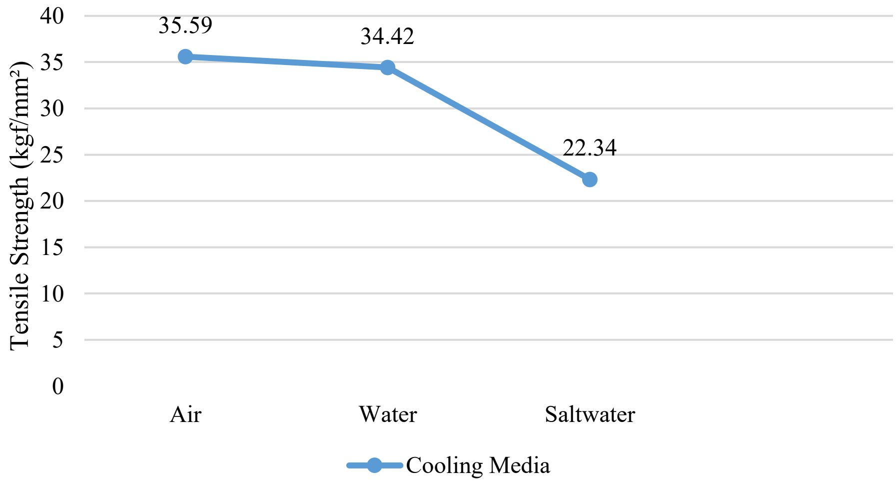

Figure 2. Tensile Test Result

The tensile strength of medium carbon steel decreases after undergoing a heating and quenching process. The higher the temperature variation, the lower the tensile strength. Therefore, high temperatures cause a lower cooling rate, which results in a decrease in tensile strength.

Yunaidi. The Effect of Salt Solution Concentration on the Quenching Process of Medium Carbon Steel S45C. The results of the study indicate that the higher the salt content in the quenching medium, the lower the tensile strength and ductility, and the higher the salt content in the quenching medium, the faster the cooling process. This is evidenced by the appearance of a larger number of finer martensite structures at higher salt contents.

Hardness Test

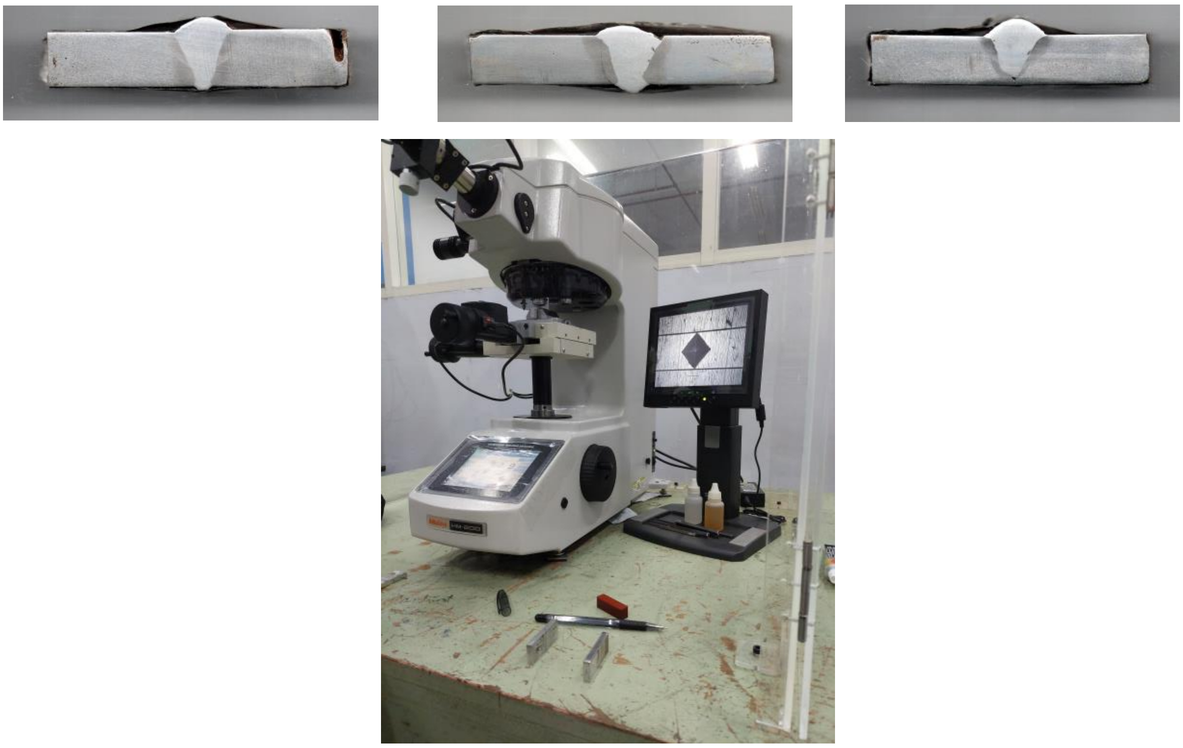

Figure 3. Hardness test

Table 2. Hardness test results

Cooling Media	Area	Indentation I	Indentation II	Indentation III	Average
Water	Weld	226,30	185,5	221.03	211,03
	Haz	243,10	259,7	242,30	248,37
	Base	259,80	182,9	230,20	224,30
Air	Weld	201,90	178,2	188,30	189,47
	Haz	286,60	253,4	251,70	263,90
	Base	317,30	214,2	186,20	239.23
Saltwater	Weld	253,00	205	202,00	220,00
	Haz	459.80	343,5	355,30	386,20
	Base	340,20	291,9	288,40	306,83

In graph analysis 2. The relationship between cooling media variations in welding and hardness values (HV). For water cooling media, the highest graph is in the heat-affected zone (HAZ) with a value of 248.37 HV, followed by the weld metal with a value of 211.03 HV and the base metal with a value of 224.3 HV.

For saltwater cooling media, the highest value is found in heat effect (HAZ) at 386.20 HV, while weld metal has a value of 220.00 HV and base metal has a value of 306.83 HV. For air cooling media, the highest value is found in the heat effect (HAZ) with a value of 263.90 HV, while the weld metal (Weld) has a value of 189.47 HV and the base metal (Base) is found in steel with a value of 239.23 HV.

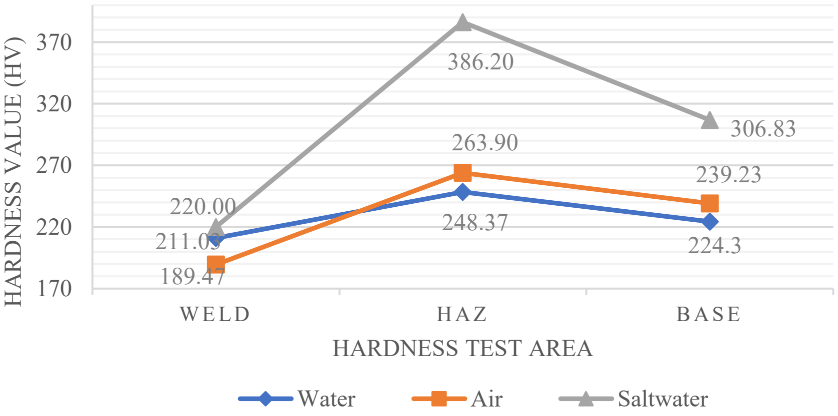

Figure 4. Diagram showing the relationship between hardness and variations in cooling media

The highest hardness value in the welded area was obtained using salt water as the cooling medium. This result is associated with the higher cooling rate of salt water, which accelerates the transformation of austenite into martensite. Compared to freshwater cooling, the hardness values show only a slight difference, indicating that both media provide sufficiently rapid cooling to promote martensitic formation, although saltwater remains more effective.

In contrast, air cooling results in the lowest hardness values due to the formation of ferrite and pearlite phases. These phases are typically formed under slow cooling conditions and are known to be softer and more ductile than martensite and bainite. This observation is consistent with the microstructural analysis.

The cooling rate also influences grain size and mechanical properties. Rapid cooling tends to produce finer microstructures, which increase hardness based on the Hall–Petch relationship. On the other hand, slower cooling allows grain growth, facilitating dislocation movement and reducing strength and hardness.

Furthermore, variations in hardness may also be affected by welding parameters such as current and welding speed, which determine the heat input and cooling rate during the welding process.

CONCLUSION

The results show that the cooling medium significantly affects the mechanical properties of AISI 1045 steel welded using the MIG method. Air cooling produced the highest tensile strength (35.59 kgf/mm²) due to the formation of ductile ferrite–pearlite microstructures from slow cooling. In contrast, water (34.42 kgf/mm²) and especially salt water (22.34 kgf/mm²) resulted in lower tensile strength, as faster cooling promotes the formation of martensite and bainite, which increase brittleness.

Conversely, hardness results show the opposite trend. Saltwater cooling produced the highest hardness (386.20 HV), followed by water (248.37 HV), while air cooling resulted in the lowest hardness (263.90 HV). This confirms that higher cooling rates increase hardness but reduce ductility and tensile strength.

Overall, there is a clear trade-off between hardness and tensile strength. Therefore, the selection of cooling media should be adjusted to application needs: air cooling is suitable for components requiring higher strength and ductility, while salt water is more suitable for applications requiring high hardness and wear resistance. However, further studies are needed to analyze the influence of welding parameters and quantitatively relate microstructure to mechanical properties.

REFERENCES

A, R., Irzal, I., Waskito, W., & Mulyadi, R. (2021). Pengaruh Jenis Media Pendingin Air Garam, Air Sumur, Oli Terhadap Hardness Pada Hasil Pengelasan Baja S45C Mengunakan Las Smaw. *Jurnal Vokasi Mekanika (VoMek)*, *3*(2), 34–40. https://doi.org/10.24036/vomek.v3i2.201

Alfryyan, N. (2022). *Improving Mechanical Properties , Microstructure And Wear Resistance Of Dual-Phase Medium Carbon Steel*. *7*(1), 2379–2387.

Ayoola, W., Durowaye, S., Andem, K., & Oyerinde, O. (2022). *T ikrit J ournal o f E ngineering S ciences Effects of Surface Preparation on the Corrosion Behavior of Mild Steel*. *November 2021*. https://doi.org/10.25130/tjes.29.1.2

Budiarto, DIkki, A. H., Adiman, & Fajar, O. D. (2020). The heat treatment of austenisation analysis of medium carbon steel to the hardness, microstructure, and tensile strength. *IOP Conference Series: Materials Science and Engineering*, *725*(1). https://doi.org/10.1088/1757-899X/725/1/012036

Darmo, S., Sinarep, S., & Soenoko, R. (2021). A study of the pack carburizing quenching treatment with cane molasses cooling medium effect on the wear resistance of low carbon steel. *Eastern-European Journal of Enterprise Technologies*, *2*(12–110), 32–37. https://doi.org/10.15587/1729-4061.2021.228627

Disya Haeriati Ariwiana Putri, Ratna Dewi Anjani, & Iwan Nugraha Gusniar. (2023). Analisis Pengaruh Media Pendingin Terhadap Sifat Mekanik Sambungan Las TIG (Tungsten Inert Gas) Pada Baja St 42. *Jurnal Pendidikan Teknik Mesin Undiksha*, *11*(2), 184–195. https://doi.org/10.23887/jptm.v11i2.65816

Haris, R., & Widodo, I. B. (2021). Analisa Pengaruh Media Pendingin Menggunakan Oli SAE 10 , SAE 40 , dan SAE 90 dari Hasil Pengelasan Metal Inert Gas (MIG) pada Material Baja AISI 1045. *Jurnal Mesin Material Manufaktur Dan Energi*, *2*(1), 26–30.

Haryadi, G. D., Utomo, A. F., & Ekaputra, I. M. W. (2021). Pengaruh Variasi Temperatur Quenching Dan Media Pendingin Terhadap Tingkat Kekerasan Baja AISI 1045. *Jurnal Rekayasa Mesin*, *16*(2), 255. https://doi.org/10.32497/jrm.v16i2.2633

Husaini, M., Yunusa, U., Ibrahim, H. A., Usman, B., & Ibrahim, B. (2020). *Corrosion inhibition of aluminium in phosphoric acid solution using glutaraldehyde as inhibitor*. *01*, 12–21.

Lhoksuemawe, P. N., Negeri, P., & Surabaya, P. (2022). *Hardness Analysis of Weld Metal Electrode Low Hydrogen Potassium E7016 and E7018*. *4*(2), 44–47.

Mulyadi, M., Tafrant, D., Hendradinata, H., & Zainuddin, Z. (2022). The Effect of Quenching Media on the Hardness of AISI 1045 Steel. *Proceedings of the 5th FIRST T1 T2 2021 International Conference (FIRST-T1-T2 2021)*, *9*, 66–71. https://doi.org/10.2991/ahe.k.220205.012

Nugraha, A. P., Fadelan, F., & Winardi, Y. (2020). Pengaruh Media Pendingin Pada Pengelasan Dissimilar Baja Aisi 1045 Dengan Ss 202 Menggunakan Pengelasan Smaw. *Komputek*, *4*(1), 27. https://doi.org/10.24269/jkt.v4i1.348

Ramadhani, S., Basyirun, Rusiyanto, & Sunyoto. (2022). *Pengaruh Variasi Temperatur Preheat Pada Pengelasan Smaw Terhadap Struktur Mikro Dan Kekerasan Baja Karbon Ss400*. *7*(April), 12–20. https://journal.uny.ac.id/index.php/dynamika/issue/view/2267

Rosidah, A. A., & Setyowati, V. A. (2021). *The effect of time variation on the steels corrosion rate in 0 . 5 M*. 0–6. https://doi.org/10.31284/j.jmesi.2021.v1i2.2183

Sihite, E. (2019). Analisis Pengaruh Penuaan Dan Media Pendingin Terhadap Kekerasan Dan Strukturmikro Paduan Cuhfco. *Jurnal Kajian Ilmiah Universitas Bhayangkara Jakarta Raya*, *19*(3), 231–238.

Susetyo, F. B., Basori, I., & Simanjuntak, J. T. (2021). Pengaruh Polaritas Dan Temperatur Media Quenching Air Terhadap Kekerasan dan Korosi Deposit Lasan Baja Karbon Rendah Yang Dihasilkan Dari Proses SMAW Menggunakan Elektroda JIS Z 3251 DF2A-450-R. *Jurnal Kajian Teknik Mesin*, *6*(1), 39–43. https://doi.org/10.52447/jktm.v6i1.4395

Teknik, I., Wibowo, T. N., & Hidayati, N. (2020). *Pengaruh Variasi Temperatur Media Pendingin Pengelasan GMAW Terhadap Sifat Mekanis Baja ST 40*. *12*(1), 103–111.

Wibawa, A., Santosa, B., Fahrudin, I., Mursid, O., Mulyatno, I. P., & Subekti, J. (2023). *Analysis the Effect of Size Variation and Spraying Pressure of Steel Grit on Corrosion Rate of Astm A36 Steel Materials*. *8*(1), 88–96.

Wiratmaja, I. G., Nugraha, I. N. P., & Mahayoga, I. K. A. (2025). Analisis Pengaruh Variasi Pendinginan Terhadap Nilai Kekerasan dan Struktur Mikro Baja ST 42 Hasil Pengelasan SMAW. *Nusantara of Engineering (NOE)*, *8*(01), 250–257. https://doi.org/10.29407/noe.v8i01.23190

Wisnujati, A., & Andryansyah, J. (2021). Analysis Of Mechanical Properties SMAW (Shielded Metal Arc Welding) Welding Joints Of Portable Electric Hydraulic Jack Frame. *INTEK: Jurnal Penelitian*, *7*(2), 155. https://doi.org/10.31963/intek.v7i2.2134