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# Tensile strength of welded joints in low carbon steel using metal inert gas (MIG) welding

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## Abstract

The development of technology that has penetrated the industrial sector is very rapid. Many industrial fields apply the use of MIG (Metal Inert Gas) welding for various jobs in steel construction, especially mild carbon steel. MIG welding has good welding results and fast welding time efficiency. The purpose of this study is to analyze the tensile strength of welded joints on low carbon steel using MIG welding. The experimental method used in this study is to perform MIG welding on low-carbon steel plate profiles. The welded carbon steel is used as a test specimen and is formed according to the ASTM E8-M standard. Tensile testing is performed using a Shimadzu UH-300 kN type tensile testing machine. From this study, the tensile strength value of the test specimen welded by MIG (Metal Inert Gas) welding is higher than the tensile strength of the parent metal (low carbon steel), so this shows the strength of the weld joint. The average value of tensile strength on the test specimen is (σ) 507.40 N/mm$^2$ and average strain (ε) 3.63%. The MIG welding process, between the base metal and filler metal with different chemical compositions, can cause mixing and a dilution effect of two compositions.

**Keywords:** MIG Welding, Welded Joint, Low Carbon Steel, Tensile Strength

## 1. Introduction

The development of technological processes in Industry has been increasingly rapid and advanced. This requires balancing with quality human resources to adopt these developments so that they can be utilized optimally. In the development of technological processes, especially welding in metal construction. According to DIN (Deutsche Industrie Norman), welding is a metallurgical bond in the joining of metal alloys through a local melting process, using coil electrodes or filler metal, with or without pressure and added materials [1]. In the welding process, the strength and ability of the weld joint are required, so that failure of the welding results can be avoided. The strength of the welding result is of course influenced by the amount of current, arc voltage, welding speed, electric polarity, or the skill of the welder [2]. The quality and strength of the welded joint is strongly influenced by the position of the welding being carried out and refers to the WPS (Welding Procedure Specification) [3]. The welding process can cause physical changes to the weld metal so that it can affect quality welding caused by welding procedures that are not carried out [4]. Welding speed has a large effect on the tensile strength of the weld joint [5]. The MIG welding it is noticeable that welding voltage and the voltage-speed interaction significantly affect both tensile and penetration depth [6]. The welding process must be carried out with correct welding procedures according to standards, but standard welding procedures do not always guarantee the quality of the welding results obtained [7]. In addition, the failure of the welding results can also be caused by the inappropriate use of the type of welding. The welding process cannot be separated from the use of groove weld. The use and selection of groove weld are very important in welding, because this will affect the final result and the quality of the welding that has been



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carried out. Arc and groove welds during MIG welding and there may be errors if operators are not very skilled [8].

Several types of welding are applied in industry, including SMAW welding (Shielded Metal Arc Welding), TIG welding (Tungsten Inert Gas), MIG welding (Metal Inert Gas) and many more [1]. MIG welding (Metal Inert Gas) including the type of welding GMAW (Gas Metal Arc Welding) which is widely used in the welding industry of ships, bridges and objects that require joint strength and the ability to support objects firmly. Metals like steel, aluminium and copper a joined with MIG and industries like ship building, automobile and aircrafts apply it [9]. Welding of high quality steel such as stainless steel, carbon steel and non-steel cannot be welded in any other way. Based on the carbon composition of steel, it is categorized into low carbon steel, medium carbon steel, high carbon steel and alloy steel [10]. There are many forms of steel, including plate profiles, bars, pipes, elbows and so on.

In MIG welding, the heat generated by a current moving through the gap between the electrode and the metal object is carried out automatically or semi-automatically with a direct current of reverse polarity. The electrode velocity is fixed by means of pull or push-pull feeding. This heat causes the parent metal and the electrodes to melt, which then freezes together to form bonds. The resulting arc is always sharp, this is what causes the molten metal grains to become fine and the transfer takes place very quickly. MIG welding is the process of joining two or more metal materials into one through a local liquefaction process, using a coil electrode which is the same as the base metal and using a protective gas or inert gas.

MIG welding process, the heat from this welding process is generated by a welding arc that is shaped between the wire electrode and the workpiece. During the MIG welding process, the electrodes will melt and then become a weld metal deposits and form weld beads. Shielding gas is used to prevent oxidation and protect the weld during solidification. MIG welding process [11], using argon gas, helium or a mixture of the two. But sometimes $O_2$ gas is added between 2% to 5% or $CO_2$ between 5% to 20% in order to stabilizer the welding arc. Argon is also commonly used without gases, such as oxygen, helium, hydrogen, and nitrogen [12]. MIG welding usually uses electrode wires of 1.2 to 2.4 mm in diameter. In addition, electrodes with a diameter of between 3.2 and 4 mm are used with high currents which are usually used for welding thick plates.

The quality of the MIG welding joint, which in this case is expressed as a parameter of the strength of the welded joint, still needs to be analyzed. The objective of this research is the tensile strength of welded joints on low carbon steel using MIG welding. The strength of MIG welded joints applied to low carbon steel is a testament to the quality with which steel construction welding can be used. Analysis of proving the strength of MIG welded joints on steel is carried out by tensile testing. The results of the analysis in this experiment can later become information for users in applying the MIG welding process.

## 2. Method

Experimental was research conducted by testing the strength of the connection results with MIG welding. As the object used in this study, a low-carbon steel plate profile with a thickness of 10 mm according to the ASTM E8-M standard was used. Tensile specimens were prepared as per ASTM-E8/E8M-08 standard [13]. The shape and dimensions of the test specimens are shown in Figure 1. The welded specimens were subjected to tensile testing using a Shimadzu UH-300 kN type universal testing machine with a capacity of 300 kN (Figure 2).

The method of conducting research is carried out according to the procedures that have been designed. The preparation of the materials used, namely low-carbon steel plate profiles, is measured and cut according to the dimensions needed, where the length is 300 mm and the width is 300 mm. On the plate that will be joined by welding, first in the form of a welding groove, which is the type of groove V with a grinding machine. Then the welding process is carried out by a certified welder with standard WPS procedures. However, beforehand conditioning or preparation was carried out including the speed of motion of the electrode wire by making adjustments, adjusting the voltage-current 120 Ampere. Determination of the position of the weld used where the position of 1G.

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After completing the arrangement, the welding can be carried out as needed and cooling with air. The type of electrode wire used is ER70S-6 with a diameter of 1.2 mm. This type of electrode uses a protective gas mixture of Argon-Oxygen plus $CO_2$ with the type of DCRP Current. The addition of $CO_2$ gas to Argon gas will increase the amount of electric current. MIG welding on a low carbon steel plate is shown in Figure 3.

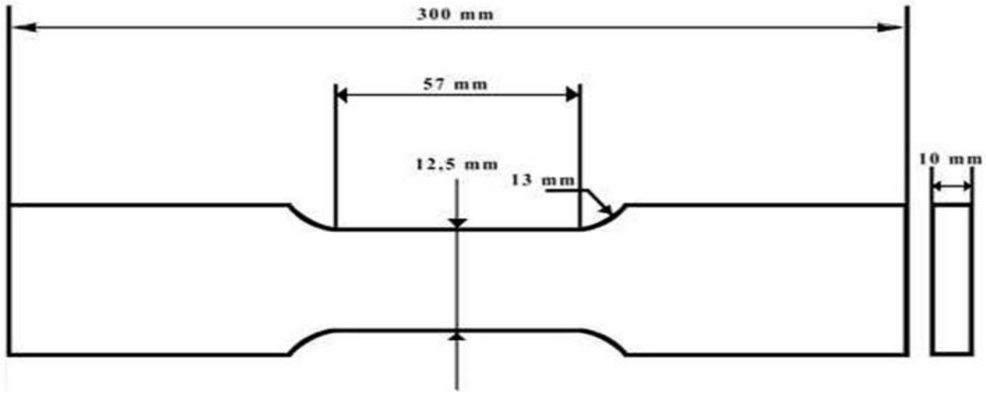


Figure 1. Shape and Dimensions of Test Specimens According to ASTM E8-M

Figure 2. Shimadzu UH-300 kN type tensile testing machine

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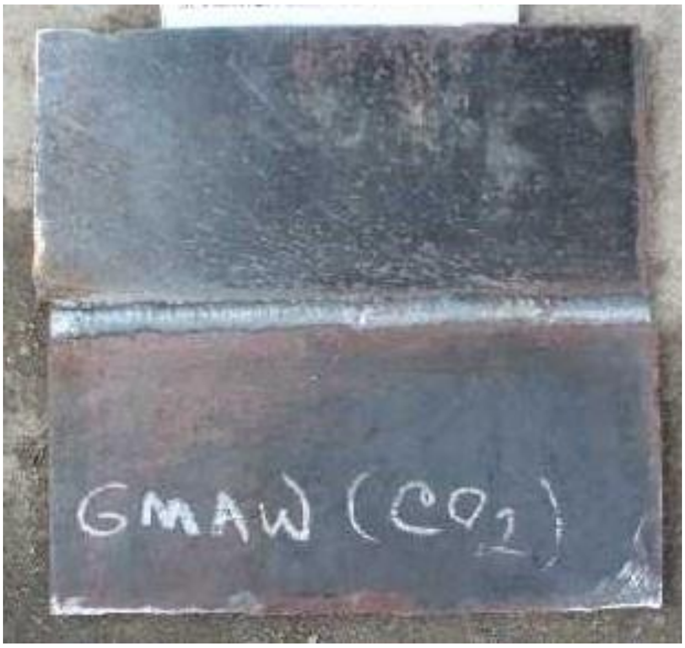


Figure 3. Low Carbon Steel Plate after welding

After the joint welding process is completed the next step is to make the test specimen according to ASTM E8-M standards. The process of making the shape of the test specimen according to the standard is carried out using a scrap machine, a milling machine and a grinding machine. The low carbon steel plate test specimen according to the ASTM E8-M standard is shown in Figure 4. The next step is to perform a tensile test on the prepared test specimen. This test, it is carried out by applying a tensile load slowly until the specimen breaks or breaks. From this tensile test, a graph of the test data of each specimen was obtained and then the analysis was carried out using several equations in obtaining the final result.

Figure 4. Low carbon steel test specimens according to ASTM E8-M standard

## 3. Results and Discussion

In this research, several low carbon steel test specimens were tested using a Shimadzu UH-300 kN type universal testing machine. The material used in this research is low carbon steel which is widely used in construction with the minimal workloads. Test object Carbon steel plate in the shape of groove V and then connected with MIG welding. The test data obtained in this study are as shown in Table 1.

Table 1. Tensile Test Result Data

| Test Specimens | Force (N) | Breaking Point (N) | Stress σ (N/mm$^2$) | Strain ε (%) |
|---|---|---|---|---|
| I | 67424 | 60760 | 539.40 | 2.457 |
| II | 65464 | 44394 | 523.71 | 4.509 |
| III | 68796 | 46060 | 550.37 | 4.561 |
| IV | 60368 | 53116 | 482.94 | 3.246 |
| V | 55076 | 42532 | 440.61 | 3.404 |
| Average | 63425.6 | 49372.4 | 507.40 | 3.636 |

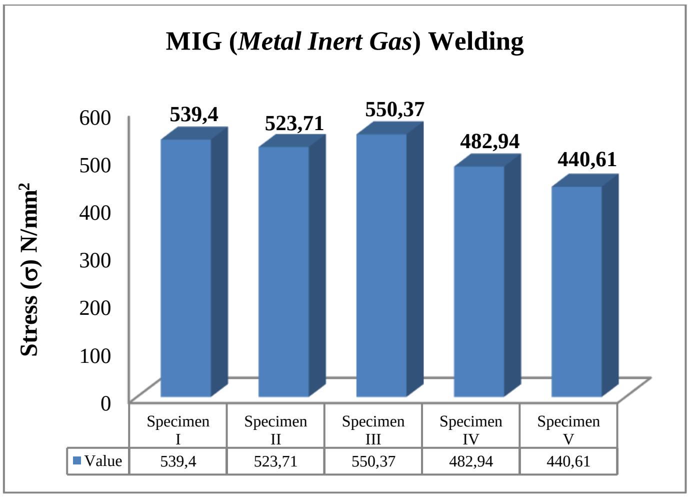


Figure 5. Comparison of Tested Specimen Stresses

Figure 5 shows the value of tensile stress resulting from testing the specimens using Metal Inert Gas (MIG) welding. Specimen I has a value of (σ) 539.40 N/mm², specimen II has a value of (σ) 523.71 N/mm², specimen III has a value of (σ) 550.37 N/mm², specimen IV has a value of (σ) 482.94 N / mm², and specimen V has a value of (σ) 440.61 N/mm². Of all the specimens that were carried out the tensile test, the average stress value was (σ) 507.40 N/mm². While the value of the tensile strength of low carbon steel without welding treatment is 439.04 N/mm$^2$. From these data, it shows that there is an increase in the tensile strength of low carbon steel with MIG welding compared to low carbon steel without welding.

From the tensile test carried out on each test specimen, the break area was obtained around the base metal (Figure 6). This indicates that the strength of the welded joint exceeds the strength of the low carbon steel being welded. The area of the weld metal, base metal and the area of the Heat Affected Zone (HAZ), where during the welding process undergo a thermal cycle of rapid heating and cooling, causing changes in structure and properties. MIG welding can affect the behavior of the heat affected zone (HAZ) so that it has an impact on the mechanical properties steel [14].

Figure 6. The Break Area in The Test Specimen

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In addition, when welding the base metal and filler metal with a different chemical composition, the two compositions will mix and experience a dilution effect. This alloy between the base metal and filler metal is called diluted metal. Welding dilution is defined as the comparison between the melting parent metal part and all the molten metal parts resulting in changes in the chemical composition of the metal that occur at the time of welding. The composition and properties of clad metals are strongly influenced by dilution so that reduces the alloying elements and increases the carbon content in the clad layer. Dilution is affected significantly by wire feed rate because of the reason that due to high welding current, heat input per unit length of the weld bead increases, which increases the depth of penetration [15]. The weld dilution dictates the degree of base metal fusion, which must be adequate to maintain weld quality [16]. Due to the mixing process, the dilution effect that occurs will cause the welds formed to have a different composition from the base metal and filler metal. The impact will cause the value of stress and strain to increase which indicates the tensile strength of the weld joint.

## 4. Conclusion

Based on the research conducted, it can be concluded that the tensile strength value of the test specimens welded by MIG welding is higher than the tensile strength of the base metal in low carbon steel, so this shows the strength of the weld joint. The average value of tensile strength on the test specimen is (σ) 507.40 $N/mm^2$ and and average strain (ε) 3.63%. The MIG welding process, between the base metal and filler metal with different chemical compositions can cause the two compositions to mix and experience a dilution effect. MIG welding has an impact on the behavior of the heat affected area (HAZ) so that the tensile strength of the weld joint will increase from the base metal

## References

[1] K. Weman, *Welding processes handbook*. Elsevier, 2011.
[2] P. Kah, R. Suoranta, and J. Martikainen, "Advanced gas metal arc welding processes," *Int. J. Adv. Manuf. Technol.*, vol. 67, no. 1, pp. 655–674, 2013.
[3] T. Lienert, T. Siewert, S. Babu, V. Acoff, and S. W. P. Specifications, *ASM handbook, volume 6A: welding fundamentals and processes*. ASM International Materials Park, OH, 2011.
[4] A. Wari, H. Nurdin, and K. Z. Ya, "Porosity Defect Analysis in ST 37 Steel Welding Joints Using the Dye Penetrant Method," *Teknomekanik*, vol. 3, no. 1, pp. 1–8, 2020.
[5] S. R. Patil and C. A. Waghmare, "Optimization of MIG welding parameters for improving strength of welded joints," *Int J Adv Engg Res Stud.-Sept*, vol. 14, p. 16, 2013.
[6] E. I. Fauzi, Z. Samad, M. C. Jamil, N. M. Nor, and G. P. Boon, "Parametric modeling of metal inert gas (MIG) welding process using second-order regression model analysis," *J. Adv. Manuf. Technol. JAMT*, vol. 12, no. 1 (2), pp. 367–382, 2018.
[7] H. N. Irzal, "Analisis Kekuatan Tarik Sambungan Las Pada Pipa Baja Karbon Menggunakan Elektroda E 7018 Dengan Posisi Pengelasan 5G," *proceedingfptk*, vol. 437, 2015.
[8] A. Anders, "Tracking down the origin of arc plasma Science-II. Early continuous discharges," *IEEE Trans. Plasma Sci.*, vol. 31, no. 5, pp. 1060–1069, 2003.
[9] H. B. Cary and S. C. Helzer, *Modern Welding Technology, 2005*. NJ: Pearson Education.
[10] D. R. Jones and M. F. Ashby, *Engineering materials 2: an introduction to microstructures and processing*. Butterworth-Heinemann, 2012.
[11] K. Weman and G. Lindén, *MIG welding guide*. Woodhead Publishing, 2006.
[12] H. Latifi Jr, "Advanced orbital pipe welding," 2012.
[13] A. Standard, "E8/E8M-08,"," *Stand. Test Methods Tens. Test. Met. Mater. ASTM Int. West Conshohocken PA*, 2008.
[14] P. K. Yadav, M. Abbas, and S. Patel, "Analysis of heat affected zone of mild steel specimen developed due to MIG welding," *Int. J. Mech. Eng. Robot. Res.*, vol. 3, no. 3, p. 399, 2014.
[15] A. S. Shahi and S. Pandey, "Modelling of the effects of welding conditions on dilution of stainless steel claddings produced by gas metal arc welding procedures," *J. Mater. Process. Technol.*, vol. 196, no. 1–3, pp. 339–344, 2008.
[16] K. Pal and S. K. Pal, "Effect of pulse parameters on weld quality in pulsed gas metal arc welding: a review," *J. Mater. Eng. Perform*, vol. 20, no. 6, pp. 918–931, 2011.