Available online at:
Al-Fiziya: Journal of Materials Science, Geophysics, Instrumentation and Theoretical Physics
Website: http://journal.uinjkt.ac.id/index.php/al-fiziya
Vol. 4 No. 2 Tahun 2021, 124 - 130

Assessment of Number of Layers on Tensile and Bend Strength of HB 500 and ST 42 Dissimilar Weldments

Cut Fitria [1,†], Arif Tjahjono [1], Iwan Setiawan [2]

[1]Department of Physics, Faculty of Science and Technology, Syarif Hidayatullah Islamic State University, Ir. H. Djuanda St, No.95, Cempaka Putih, Ciputat, South Tangerang, Banten 15412, Indonesia
[2]Laboratory of Calibration and Testing, Quality Assurance & K3LH, PT. Pindad (Persero), Gatot Subroto Street No.517, Bandung, West Java 40285, Indonesia
[†]cutfitria1@gmail.com

Submitted : September 2021; Revised : December 2021; Approved : December 2021; Available Online : December 2021

Abstrak. Penggabungan beberapa material dengan karakteristik berbeda sudah banyak dilakukan untuk kemajuan industri, terutama untuk mendapatkan karakteristik material yang lebih unggul dari sebelumnya. Salah satu teknik penggabungan yang paling umum adalah pengelasan. Penelitian ini untuk mengetahui kemampuan las pada baja yang berbeda dengan jumlah lapisan yang divariasikan antara 3 dan 4 lapis. Objek dari penelitian ini adalah sambungan las pelat baja tahan aus HB 500 dengan baja konstruksi ST 42 dimana ketebalan masing-masing material yaitu 10 mm. Pengelasannya dengan metode Gas Metal Arc Welding (GMAW) menggunakan logam pengisi ER 70 S di setiap lapisan dan kuat arus dari 90 A hingga 180 A di setiap sambungan. Pengujian tarik dan tekuk dilakukan sebagai karakterisasi daerah lasan untuk mengetahui sifat mekaniknya. Hasil pengujian memperlihatkan pengaruh yang signifikan dari jumlah lapisan terhadap kualitas sambungan. Nilai optimum terbentuk pada jumlah lapisan pengisi sebanyak 4 lapis dengan kakuatan tarik sebesar 448,37 - 473,292 MPa, tegangan luluh sebesar 305,767 - 317,493 MPa, perpanjangan 33,8 - 34,56%, dan mampu tekuk saat beban 874,498 - 919.544 MPa dengan sudut terbentuk yaitu 85,414° pada bagian dalam dan 86,14° pada bagian muka.
Kata Kunci: *Baja HB 500, Baja ST 42, dan Pengelasan Logam Berbeda*

Abstract. The joining of several materials with different characteristics has been widely carried out for industrial progress, especially to obtain material characteristics that are superior to the previous one. One of the most common joining techniques is welding. This research was conducted to determine the weldability of different steels with the number of layers varying between 3 and 4 layers. The object of this research is the welded connection of HB 500 wear-resistant steel plate with ST 42 construction steel plate where the thickness of each material is 10 mm. Welding with the Gas Metal Arc Welding (GMAW) method employes ER 70 S filler metal in each layer and currents from 90 A to 180 A at each connection. Tensile and bending tests were carried out as a characterization of the weld area to determine its mechanical properties. The results show a significant effect of the number of layers on the quality of the connection. The optimum value is formed in the number of infill layers as much as 4 layers with tensile strength of 448.37 - 473.292 MPa, yield stress of 305.767 - 317.493 MPa, elongation of 33.8 - 34.56%, andable to bend under load 874,498 - 919,544 MPa with angle formed are 85.414° on the root and 86.14° on the face.
Keywords: *HB 500 Steel,ST 42 Steel, and Dissimilar Weldments*

DOI : *10.15408/fiziya.v4i2. 22575*

P-ISSN: 2621-0215, E-ISSN: 2621-489X

INTRODUCTION

High strength low-alloy (HSLA) steel is one of alloy steel's development which designed to provide better mechanical properties required in the industry such as toughness, strength, formability, weldability and atmospheric corrosion resistance than conventional carbon steel [1]. Construction steel is one of HSLA steel which has good tensile strength and toughness with maximum carbon content is 0.2%. The application of this steel is based on consideration of its minimum tensile stress which is high enough, so that its toughness will be maximized. This steel is widely used in the construction of buildings, bridges, engine shafts and gears [2], [3].

Furthurmore, HSLA steel also has special characteristics such as wear resistance. Wear is one of the main demage forms that occurs in the mining, excavation and lifting industries whereas contributes to about 60% of total wear losses [4]. According to the mechanism of damage, wear is classified into corrosion, erosion, adhesion, abrasive, fretting, and fatigue. Another type of HSLA steel is wear-resistant steel. Advance researches and field tests indicate that the degree of wear, abrasion and abrasion-test of a material is linearly correlated with hardness [5]. Therefore, wear-resistant steel has a series name based on the level of hardness.

Dissimilar welds of wear-resistant steel and construction steel are widely employed in the mining of rock and the oil and gas wells in underground workings [6]. Nevertheless, the welding is quite complicated to do because the two materials have different mechanical properties that affect the weldability. The mechanical properties of the material shown in Table 1.

Table 1. Mechanical properties of HB 500 and ST 42 [2], [7]

Material	Hardness	Tensile Strength	Yield Stress	Elongation
	HB	Mpa	Mpa	%
HB 500	477 - 534	11.4090	9.0321	17
ST 42	123	415	290	20

The mechanical properties of dissimilar weld joints regard the critical factors of safety warranty and load ability. The investigation of the dissimilar weldment result by an arc welding method between HSLA and low-carbon steel revealed that the mechanical performance as though maximum load point, bend capability, and tensile strength are considerably improved by the process control (proper heat input and suitable electrode) rather than being dependent mainly on the material alloy element [8]. Besides, numerous studies also have attempted to explain the effect of number of welding layers influences on the performance of mechanical properties. Research has shown that the tensile strength of the joint increases along with the additional number of layers [9].

METHODS

Experimental Materials

The material for the purposes of this work, HB 500 wear resistant plate and ST 42 construction steel with a thickness of 10 mm were used. Both of materials were cut to the obtain equivalent dimensions of 150 x 300 mm. Furthermore, an examination of the chemical composition was carried out using Optical Emission Spectroscopy by placing the lathe material at the mouth of the furnace which was fed with co-axial argon [10]. Optical Emission Spectroscopy reads the material elements by using wavelength and the percentage of content weight by using light intensity, the results given are listed in Table 2. Then, the weld bevel of square groove butt joint are made with a slope of 30° for all the involved materials.

Table 2. Chemical composition of the materials

Material	Chemical Composition wt%						
	Fe	C	Si	Mn	Cr	Ni	Mo
HB 500	97.46	0.147	0.309	0.328	0.982	0.183	0.281
ST 42	98.18	0.177	0.049	0.964	0.0082	0.0015	0.0012

In connection with the weldment using gas metal arc welding method, it requires a gas blanket to protect it from atmospheric contamination [11]. The type of gas used is CO2, accordance with the standards to be applied on carbon steel and low alloy steel materials in the form of sheet metal [12]. The welding wire used for this method is ER70S-6 with a diameter of 1 mm. Table 3 shows the typical chemical compositions and mechanical properties of the filler materials based on AWS A5,18:2005 and A5,20:2005 [13].

Table 3. Mechanical properties and chemical composition of ER70S-6 solid wire

Mechanical Properties			Chemical Composition wt%					
Tensile Strength	Yield Stress	Elongation						
ksi	ksi	%	C	Si	Mn	Cr	Ni	Mo
70	58	22	0.06 - 0.15	0.45 - 0.75	0.9 - 1.4	0.15	0.15	0.15

Welding Procedures

Groove butt joint is the type of weld joint used in this study. The use of sufficient transfer force creates a penetration where the weld material and base metal are fused throughout the entire depth of the joint. Consequently, the small transfer force creates a partial penetration where the edges are not formed optimally and the depth is less than the thickness of the joint [11], [14].

This research used gas metal arc welding technologies, two modes of welding were used, which generated different number of layers. The machine settings are first applied to the current strength from the lowest to the highest, then the welding process uses the down hand position. This method is equipped with a protective gas electrode coating to provide an easy-to-grab and stable arc [13]. This coating material also contains elements that can affect the transport of metal as it crosses the arc. Aswell as providing good mechanical and chemical properties to the alloy formed between the weld metal and the core of the rod at the electrode. When melted, the coating acts as a protection against the atmosphere during welding by forming slag when it cools which further protects the weld during the cooling process [15].

(a) (b)

Figure 1. (a) Welding jigs for each plates, (b) test specimen of mechanical testing

Moreover, for welding quality corresponding to the standards, the welder employed a grinder to rarefaction the weld surface after the layer filled. The plates were fixed by the welding jigs (Figure 1a) and the weld edges were degreased and cleaned before doing the weldment. The weld gap for this method, is 1.5 mm. As for the use of shielding gas, the purity of CO_2 gas is at least 99.8 vol% with flow rates and velocities of 20-25 l/min and 2 m/s, respectively. The distance between the tip of the contact and the base metal (wire extension) is 10-15 mm for the current used of 90 A to 180.

Mechanical Testing

The performance of the tensile and bend test were made by TRUMPF TruLaser 1030 according to the relevant standard ASME QW-463.l for Plates - Longitudinal Procedure Qualification [16]. In order to tensile test, the average values of yield strength, tensile strength, and elongation were obtained. Meanwhile, the bend test is used to obtain an overview of the ductility of the weld. Both tensile and bend test was performed on two samples from each welded joint, where one sample were loaded from the root side and one sample from the face side of the weld. The dimensions of the test specimen are shown in Figure 1b. Measurements were performed on anShimadzu Universal Testing Machine AGX.R testing device.

RESULTS AND DISCUSSIONS

Tensile Test

The average values of the tensile strength (TS), yield strength (YS), and elongation were computed by a static tensile test. According to the mentioned theory, the fracture of dissimilar weldment occurs in the base metal with lower mechanical properties value. The results of this research shown that ST 42 construction steel base metal is fractured, as well as both ER70S-6 and HB 500 wear resistant steel remained intact. Figure 2 shows the fracture specimens that localize the yield point to the sub-critical HAZ (SCHAZ).

(a) (b)

Figure 2. (a) Fracture specimens for three layers weldment, (b) Fracture specimens for four layers weldment

On the one hand, the tensile test has qualified the standard because the results are exceeded the minimum ST 42 steel limit. On the other hand, the specimen with three layers weldment in quantity not as optimal as four layers weldment. Those values both in the root side and face side are shown in Table 4.

Table 4. Mechanical properties of the evaluated dissimilar welded joints of HB 500 and ST42 steel

Specimen	Tensile Strength	Average	YieldStress	Average	Elongation	Average
	Mpa		Mpa		%	
3 Layers	446.927	447.846	316.071	313.076	25.32	26.92
	448.766		310.081		28.52	
4 Layers	448.370	460.831	305.767	311.630	33.80	34.18
	473.292		317.493		34.56	

Maximum tensile strength was possessed by the specimen welded using four layer weldment. The number of layers of this experiment shows that the best tensile strength is reached by the increasing layer treatment.

Bend Test

The value of maximum force and angle formed were computed by guided bend, no die test. Because of the material used has a high hardness (for HB 500 steel), the fluctuation occurs on numerical data for the applied load to bend the specimen. This phenomenon caused the specimens had stroke on the weld metal ER70S-6 and base metal ST 42. The examination carried out on two sides of the part between the root and face of the specimen resulted in bending as shown in Figure 3.

(a) (b)

Figure 3. (a) Specimen with three layers weldment, (b) Specimen with four layers weldment

According to Figure 3, the specimen with three layers weldment in quality not as optimal as four layers weldment because the crack occurred in this specimen. Meanwhile, the four layers weldment had such an optimum results with no cracks occurring in either the weld metal, the heat affected area or the parent metal. The maximum force and angle formed when the deflection reaches its maximum point can be seen in Table 5.

Table 5. Maximum deflexion evaluation dissimilar weldedjoints of HB 500 and ST 42 steel

Specimen		**Maximum Force** Mpa	**Angle Formed** Mpa	**Defect**
3 Layers	Root	1003.41	79.08°	Crack
	Face	873.826	94.78°	Crack
4 Layers	Root	919.544	86.14°	No occur
	Face	874.496	85.41°	No occur

Regarding Table 5, the number of layers have an effect on the bending ability of a welding result. The sample with three layers present high risks of defect in service due to its HAZ. Nevertheless, the sample with four layers had good bending ability both in the root side and face side. Based on the previous research, as the number of layers increased, the tensile strength increased, while ductility and toughness decreases [17]. Hence, the examination diverge from the reviewed literature, this is possibly due to the number of layers in the experiment that leads to good performance of mechanical properties by using such an appropriate electrode for balancing both HB 500 and ST 42 steel.

CONCLUSION

The outcome of the number of layers study can be concluded that there are significant differences in the mechanical properties result. Tensile strength and bend ability of the welded metal show optimal when the layers increased. The results for tensile test shows that the highest point recorded is 460,831 MPa for 4 layers, while bend test without any defects recorded was 919.544 MPa for 4 layers, both using electrode ER70S-6. Based on the response optimizer done by this research, electrode ER70S-6 is the ideal electrode used in this study for tensile and bend.

REFERENCES

[1] ASM International, *Alloying: Understanding the Basics*. New York: ASM International,2001.
[2] DIN Standard, "Steels for General Structure Purposes: Quality Standard," in *Allgemeine Baustähle*, Dessau-Roßlau: Zementanlagenbau GmbH, 1980, pp. 2–15.
[3] A. Tjahjono, *Fisika Logam dan Alloy*. Jakarta: UIN Jakarta Press, 2013.
[4] E. Wen, R. Song, and W. Xiong, "Effect of Tempering Temperature on Microstructures and Wear Behavior of a 500 HB Grade Wear-Resistant Steel," *Metals (Basel).*, vol. 9, no. 1, 2019, doi: 10.3390/met9010045.
[5] A. R. Chintha, "Metallurgical Aspects of Steels Designed to Resist Abrasion, and Impact-Abrasion Wear," *Mater. Sci. Technol. (United Kingdom)*, vol. 35, no. 10, pp. 1133–1148, 2019, doi: 10.1080/02670836.2019.1615669.

[6] A. Czupryński, "Microstructure and Abrasive Wear Resistance of Metal Matrix Composite Coatings Deposited on Steel Grade AISI 4715 by Powder Plasma Transferred Arc WeldingPart 2. Mechanical and Structural Properties of A Nickel-Based Alloy Surface Layer Reinforced with P," *Materials (Basel).*, vol. 14, no. 11, 2021, doi: 10.3390/ma14112805.

[7] Department of Defense Manufacturing Process Standard, *Millitary Specification*, MIL- STD-11. Washington DC: Department of Defense USA, 1979.

[8] B. Mvola, P. Kah, and J. Martikainen, "Dissimilar Ferrous Metal Welding Using Advanced Gas Metal Arc Welding Processes," *Rev. Adv. Mater. Sci.*, vol. 38, no. 2, pp. 125–137, 2014.

[9] M. T. Abdullah, M. L. N. Ajian, and P. E. Sarah, "Studies on The Effects of Multipass Welding on Mechanical Properties of Mild Steel on SMAW Joint," *J. Mech. Eng. Res. Dev.*, vol. 42, no. 5, pp. 202–204, 2019, doi: 10.26480/jmerd.05.2019.202.204.

[10] D. M. Devia, L. V Rodriguez-Restrepo, and E. Restrepo-Parra, "Methods Employed in Optical Emission Spectroscopy Analysis: a Review," *Ing. y Cienc.*, vol. 11, no. 21, pp. 239– 267, 2015.

[11] E. Bonnart, *Welding Principles and Practices*, 5th ed. New York: McGraw-Hill Education, 2018.

[12] J. F. Lancaster, *Metallurgy of Welding*, 3rd ed. London: George Allen & Unwin LTD, 1980.

[13] Kobelco, *Arc Welding of Specific Steels and Cast Irons*. Tokyo: KOBE Steel, Ltd., 2015.

[14] R. L. Brockenbrough and F. S. Merritt, *Structural Steel Designer's Handbook*, 3rd ed. New York: McGraw, Inc., 1999.

[15] J. S. Jensen, *Unitor Maritime Welding Handbook*, 14th ed. Lysaker: Wilhelmsen Ships Service, 2017.

[16] ASME Boiler and Pressure Vessel Code, *Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators.* New York: The American Society of Mechanical Engineers, 2004.

[17] I. Gowrisankar, A. K. Bhaduri, V. Seetharaman, D. D. N. Verma, and D. R. G. Achar, "Effect of the Number of Passes on the Structure and Properties of Submerged Arc Welds ofAISI Type 316L Stainless Steel.," *Weld. J. (Miami, Fla)*, vol. 66, no. 5, 1987.