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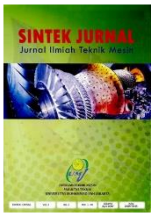

THE EFFECT OF NICKEL ADDITION ON THE MECHANICAL PROPERTIES OF LOW CARBON STEEL WELDED JOINTS

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ABSTRACT

The SMAW process is a commonly used metal joining method because it is very practical in its use, less cost, and easy availability of equipment. The SMAW process is also easy to operate and can be used in all welding positions. The problem that often occurs in steel construction lies in the welded joints. Therefore, it is necessary to increase the mechanical properties by adding nickel (Ni) to the welded joints. In this research, E 6013 electrodes and steel of ASTM A 36 were used. The tensile tests, bending tests, hardness tests, macrostructure, and microstructure will be carried out to see changes in mechanical properties. The addition of Ni contributes well to mechanical properties. The tensile strength, face bending, side bending, and hardness increased by 27.6%, 14.5%, 4.8%, and 20.9%, respectively. In the observation of the macrostructure, the porosity was not visible in all samples, while in the microstructure observation, ferrite and pearlite phases were formed in all samples.

Keywords: A36; E 6013; Ni; Mechanical Properties; Macro-Micro Structure.

1. INTRODUCTION

Welding is a technique of metal joining by melting part of the parent metal with or without filler metal for producing continuous metal. One of the welding processes that is widely used is shielded metal arc welding (SMAW) [1]. The SMAW process is a commonly used metal joining method because it is very practical in its use, less cost, and easy availability of equipment [2,3]. The SMAW process is also easy to operate and can be used in all welding positions [4–6].

Many parameters are used in welding to produce better mechanical properties, such as current, polarity, and bevel shape. The higher the welding current will be resulting in the higher the hardness of the material [7]. The DC+ polarity will produce higher tensile strength than DC- polarity [8]. Moreover, DC+ polarity also produces higher hardness than DC– polarity [9]. Kuncoro was found the X bevel is resulting in the highest tensile strength than K and H bevel. The tensile strength of X, K and H bevel is 29.52 kg/mm^2, 27.18 kg/mm^2, and 28.32 kg/mm^2 respectively [10].

Besides the welding parameter, material selection is equally important. One of the materials usually used for construction today is low carbon steel [11,12]. The ASTM A36 low carbon steel is widely used for construction and various research were study of metal joining this material [8,13].

The frequency of failure in a steel structure lies in its joints. Disruptions and loads received by the construction will cause cracks (the beginning of failure), especially in the connection section [14]. This problem can be solved by the addition of certain elements that have special properties to improve the quality of welding joints. Nickel (Ni) is a metal that is easily combined with various other metals, such as Ferrous and non-Ferrous [15]. The addition of Ni elements can increase the toughness and hardness properties of low carbon steel. The Ni tends to help in the process of reducing distortion and cracking during the cooling time rate when receiving the heat treatment process. This is because Ni can reduce temperature rapidly [16]. Moreover, the Ni significantly increases the hardness of the low carbon steel [17].

Based on the above discussion, we would add Ni to the ASTM A36 steel weld joint to see the mechanical properties that are formed. The tensile tests, bending tests, hardness tests, macrostructure, and microstructure will be carried out to see changes in mechanical properties.

2. METHODS

2.1. Materials preparation

ASTM A36 was used as parent material and cut into sizes 300 mm x 100 mm x 10 mm. Electrode E6013 from Kobe manufacturing with sizes ∅ 2.6 mm and 3.2 mm were used as filler metal. An electrode with electroplated Ni was used for Ni addition about 8 pcs [17]. The X bevel was used for parent material joining. The X bevel was carried out using a hand grinder with a slope angle of 60°.

2.2. Welding Process

The welding process was used DC electric welding machine voltage 400/230V. The procedure is similar to previous work[18]. From Table 1 can be seen specimen welding process with the addition of Ni, has an average speed of 0.196 cm/S. Thus speed is slightly faster compared to specimens without the addition of Ni with an average speed value of 0.162 cm/S. The welding time and speed average are seen in Table 1.

Table 1. Welding time and speed average

Samples	Time (s)	Speed (cm/s)	Speed average (cm/s)
NA	175	0.171	0.196
	133	0.225	
	138	0.217	
	145	0.206	
	162	0.185	
	171	0.175	
NNA [18]	167	0.179	0.162
	178	0.168	
	211	0.142	
	197	0.152	
	202	0.148	
	164	0.182	

2.3. Materials characterization

In this study, there are two types of test specimens that namely Ni addition (NA) and absence of Ni addition (NNA). The tensile strength, hardness, bending test, macro, and microstructure would perform for each sample. For tensile test specimens, preparation is based on the ASTM E8 standards by three specimens for each sample. The sample was tested with UTM Shimadzu EHP-EB20186838. The test was performed with 20 Ton of load and a speed of 30 mm/minute.

For bending test specimens, preparation is based on the ASTM E 290 standards by two specimens for each sample. This test was performed with a side bend and face bend using UTM Shimadzu EHP-EB20186838 with 20 Ton of load.

The hardness tests were performed with Vickers hardness tester FV-300e based on the ASTM E 92 standard. The number of hard-tested points on each specimen was 9 points. Which are 3 points on the metal weld area, 3 points in the heat-affected zone (HAZ) area, and 3 points in the base metal area.

The Macrostructure observation was used with a digital camera. The sample was cut and polishing using sandpaper and etching liquid for 5 minutes until seen difference between. weld metal area, HAZ area, and the base metal. To see microstructure, an Inverted Metallurgical Microscope Olympus BX-41M-LED was used. The specimen was prepared by polishing on the surface and then etched with nital 5%. The observation was taken with 500x of magnification.

3. RESULTS AND DISCUSSION

3.1. Tensile Test Results

The tensile test results are shown in Table 2.

Table 2. Tensile test results

Sample	Speciment	Tensile Strength (MPa)	Average Tensile Strength (MPa)
NA	1	529	522.7
	2	529	
	3	510	
NNA [18]	1	352	378.7
	2	402	
	3	382	

Based on Table 2 is seen the sample with the addition of Ni has an average tensile strength of 522.7 MPa, while the sample without Ni has an average of 378.7 MPa. The average tensile strength value between samples with the addition of Ni and without the addition of Ni has a difference of 144 MPa or 27.6% and can be seen in Figure 1.

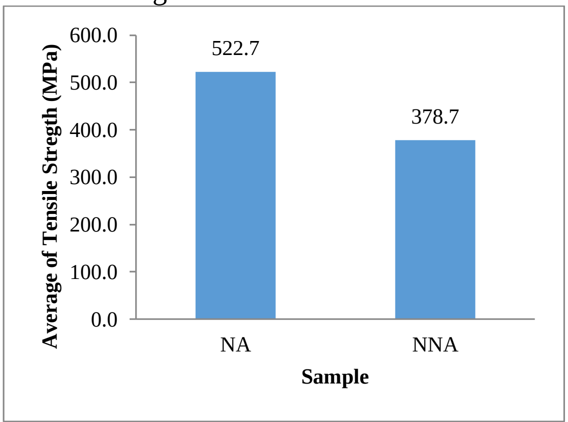

Figure 1. Comparison of the tensile test average results

Based on mild steel certificates, this material has a tensile strength of about 454 MPa. The tensile strength of the AWS E 6013 electrode is about 413.68 MPa. After the A36 material joins with weld, the tensile strength average is about 379 MPa. This is due to the influence of heat during the welding process. Hasan has found tensile strength of A 36 material with various heat treatments is different [12]. Heat input can be caused by the weld current is used, Syaripuddin *et al*. found that variations in the weld current used in the A 36 material joining produce different tensile strengths[19].

3.2. Bending Test Results

The bending test results are shown in Figure 2.

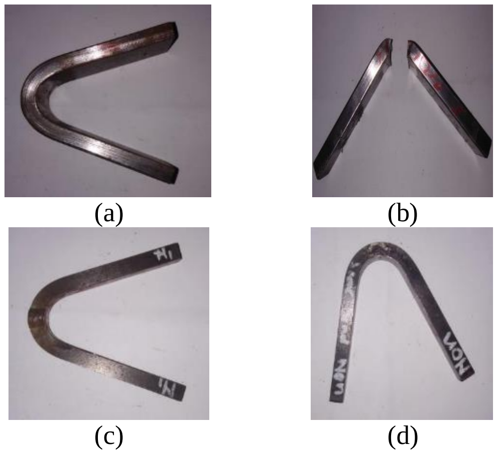

Figure 2. Bending test result (a) Face bend NA (b) Face bend NNA (c) Side bend NA (d) Side bend NNA

Based on Figure 2 we can see the bending test results. In bending test results is found broken in the welding area on face bend sample NNA. While the specimen of Ni addition does not see cracks or broken in the weld results, so this shows the weld results meet the standard.

Table 3. Bending test results

Samples	Maximum Load (Kg)	Description
Face Bend NA	2925	180° without cracking
Face Bend NNA	2500	45° broken in welding
Side Bend NA	820	180° without cracking
Side Bend NNA	700	180° without cracking

Based on Table 3, it can be seen the bending value with face bend and side bend Ni addition is indicated value of 2925 Kg and 820 Kg respectively, while for face bend and side bend without Ni addition is indicated by the value of 2500 Kg and 700 Kg respectively. The bending test obtained that the value of face bend strength is higher compared to side bend. This is easy to understand because the volume of

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welding metal is greater on face bend which causes the normal strain held by the bending moment to be greater. [20]. The addition of Ni to the weld metal affected the bend load value, with a percentage of face and side bend load increase of 14.5% and 4.8% respectively.

3.3. Hardness Test Results

In the hardness test, there are 9 testing points, where 3 points in the weld metal, HAZ, and base metal area respectively. The hardness test points on a sample with the addition of Ni can be seen in Figure 3 and without the addition of Ni can be seen in Figure 4.

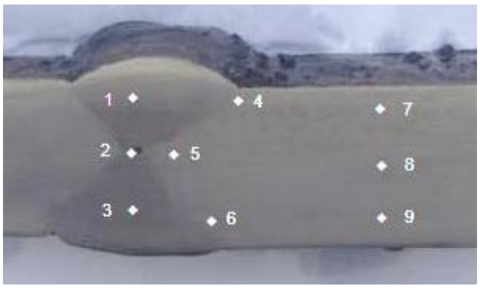

Figure 3. Hardness test points on NA sample

Figure 4. Hardness test points on NNA sample [18]

The hardness test result of the samples is seen in Table 4.

Table 4. Hardness test results

Area	Hardness Test Point	Hardness (VHN)		Hardness Average (VHN)	
		NA	NNA [18]	NA	NNA [18]
Weld Metal	1	186	149	190	150.3
	2	194	149		
	3	190	153		
HAZ	4	125	112	124.7	112.7
	5	121	113		
	6	128	114		
Base Metal	7	130	114	128.7	116.3
	8	127	119		
	9	129	116		

Based on Table 4, we can see hardness value of the NA sample in weld metal areas is higher than the hardness value of the NNA sample. In the HAZ region, the hardness value of the NA sample was higher than the hardness value of the NNA sample. Moreover, in the base metal area, the hardness value of the NA sample is then the hardness value of the NA sample. Generally, the hardness of the base metal and weld metal is higher than the HAZ area. Soleh *et al.* and Sanjaya *et al.* were found the hardness in the weld metal is higher than the hardness in the HAZ area, this is caused by welding metals mixed with the parent metal has a high hardness, while in HAZ the hardness is lower due to structural changes [21,22]. A comparison of the hardness between NA and NNA samples with three areas is seen in Figure 5.

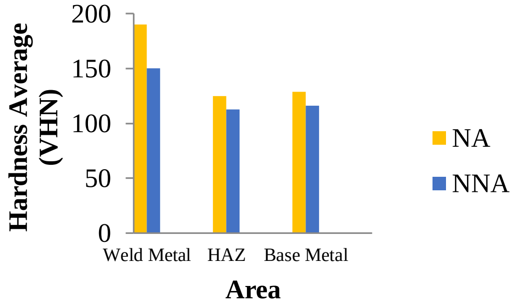

Figure 5. Hardness test result diagram

Based on Figure 5, are seen NA sample is a higher hardness average than the NNA sample. The addition of Ni to the weld metal had an effect on the hardness value with a hardness increase percentage of 20.9%.

3.4. Macrostructure Observation Results

The macrostructure observation results are seen in Figures 6 and 7.

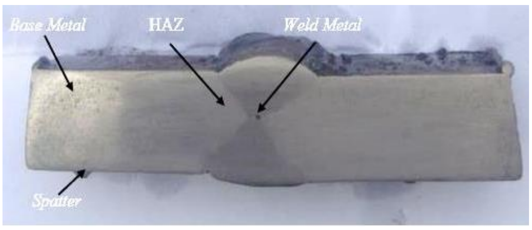

Figure 6. Macrostructure NA sample

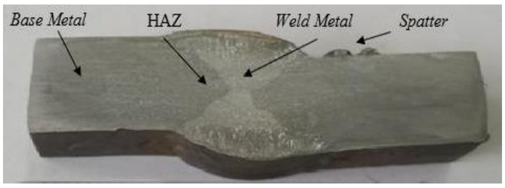

Figure 7. Macrostructure NNA sample [18]

Based on Figures 6 and 7, we can see the macrostructure figure on each sample using a digital camera. The visual observations found no porosity defects in specimens with the addition of Ni and without the addition of Ni.

3.5. Microstructural Observation Results

The microstructure observation results are seen in Figures 8 and 9.

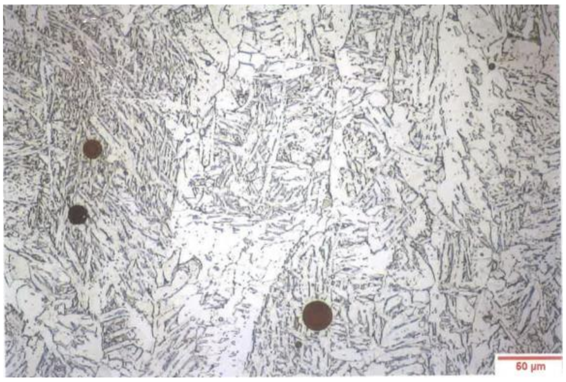

Figure 8. Microstructure NA sample magnification 500x

Figure 9. Microstructure NNA sample magnification 500x

The microstructure formed on the welded joint is generally ferrite and pearlite[23]. The addition of Ni elements can affect the microstructure of a low-carbon steel alloy[15]. Based on Figures 8 and 9, microstructure observation results obtained more pearlite structure in specimens with the addition of Ni compared to without the addition of Ni. This phenomenon leads to an increase in hardness in welding joints because pearlite has higher hardness than ferrite[12].

4. CONCLUSION

The mechanical properties in welding joints with the addition of Ni increased when compared to without the addition of Ni. The tensile strength, face bending, side bending, and hardness value increased by 27.6%, 14.5%, 4.8%, and 20.9%, respectively. So, it can be concluded that the addition of Ni can improve the quality of welding joints. Moreover, based on microstructure observation, ferrite and pearlite are forming in the samples, wherein the sample with Ni addition has more perlite phase compared to without the addition of Ni.

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REFERENCES

[1] Putri, F. Analisa pengaruh variasi kuat arus dan jarak pengelasan terhadap kekuatan tarik, sambungan las baja karbon rendah dengan elektroda 6013: Jurnal austenit. 2010**;** 2: 13–25.

[2] Saxena, A.; Kumaraswamy, A.; Madhusudhan Reddy, G.; Madhu, V. Influence of welding consumables on tensile and impact properties of multi-pass SMAW Armox 500T steel joints vis-a-vis base metal: Defence Technology. 2018**;** 14: 188–195.

[3] Fitri, M.; Sukiyono, B.; Simanjuntak, M.L. Pengaruh Waktu Penahanan pada Perlakuan Panas Paska Pengelasan terhadap Ketangguhan Sambungan Las Baja: SINTEK JURNAL: Jurnal Ilmiah Teknik Mesin. 2019**;** 13: 80.

[4] Suprijanto, D. Pengaruh Bentuk Kampuh Terhadap Kekuatan Bending Las Sudut SMAW Posisi Mendatar Pada Baja Karbon Rendah. In Proceedings of the SEMINAR NASIONAL ke8 - Tahun 2013□: Rekayasa Teknologi Industri dan Informasi; 2013; ; pp. 91–96.

[5] Azwinur; Ismy, A.S.; Nanda, R.; Ferdiyansyah Pengaruh Arus Pengelasan SMAW Terhadap Kekuatan Sambungan Las Double Lap Joint Pada Material AISI 1050: Journal of Welding Technology. 2020**;** 2: 1–7.

[6] Azwinur; Syukran; Hamani Kaji Sifat Mekanik Sambungan Las Butt Weld Dan Double Lap Joint Pada Material Baja Karbon Rendah: Jurnal Sintek. 2018**;** 12: 9–16.
[7] Basori; Syamsuir Pengaruh arus terhadap struktur mikro dan kekerasan lasan JIS Z 3251 DF2a-350-R: Jurnal Kajian Teknik Mesin. 2019**;** 4: 21–25.
[8] Putra, A.R.T.; Wulandari, D. Pengaruh Polaritas Pengelasan Dan Jenis Elektroda Terhadap Kekuatan Tarik Dan Ketangguhan Las SMAW (Shielded Metal Arc Welding): Jurnal Pendidikan Teknik Mesin. 2017**;** 06: 84–93.
[9] Susetyo, F.B.; Kholil, A.; Fatihuddin, M. Efek Polaritas Dan Media Pendingin Terhadap Nilai Kekerasan Permukaan Hardfacing Baja Karbon Rendah: Jurnal Konversi Energi dan Manufaktur. 2019**;** 6: 1–5.
[10] Kuncoro, A.T. Pengaruh Variasi Arus Dan Jenis Kampuh Pengelasan SMAW Terhadap Kekuatan Tarik Sambungan Baja ST 41, 2017.
[11] Santoso, T.B.; Solichin, S.; Tri Hutomo, P. Pengaruh Kuat Arus Listrik Pengelasan Terhadap Kekuatan Tarik Dan Struktur Mikro Las SMAW Dengan Elektroda E7016: Jurnal Teknik Mesin. 2015**;** 23: 56–64.
[12] MF, H. Analysis of Mechanical Behavior and Microstructural Characteristics Change of ASTM A-36 Steel Applying Various Heat Treatment: Journal of Material Science & Engineering. 2016**;** 05: .
[13] Recloux, I.; Gonzalez-Garcia, Y.; Druart, M.E.; Khelifa, F.; Dubois, P.; Mol, J.M.C.; Olivier, M.G. Active and passive protection of AA2024-T3 by a hybrid inhibitor doped mesoporous sol–gel and top coating system: Surface and Coatings Technology. 2016**;** 303: 352–361.
[14] Siregar, H.A.; S, S.W.; Baharudin, B. Analisa Pengaruh Variasi Derajat Kampuh Terhadap Distorsi Yang Dihasilkan Pada Posisi Pengelasan 3G SMAW Sambungan Butt - Joint: Polibatam Repository. 2011**;** 1–5.
[15] Saifullah, A. Pengaruh Penambahan Nikel (Ni) Terhadap Sifat Kekerasan Dan Struktur Mikro Pada Paduan Aluminum–Silikon (Al-Si) Melalui Proses Pengecoran, 2014; .
[16] Binud, R.; Adjiantoro, B. Pengaruh Unsur Ni , Cr Dan Mn Terhadap Sifat Mekanik Baja Kekuatan Tinggi Berbasis Laterit: Majalah Metalurgi. 2014**;** 29: 33–40.
[17] Syaripuddin; Rohma, K.; Susetyo, F.B. Pengaruh Penambahan Unsur Nikel/ Karbon Pada Deposit Las Elektroda E6013 Terhadap Sifat Mekanik: Jurnal Konversi Energi dan Manufaktur. 2019**;** 6: 22–29.
[18] Syaripuddin; Alamsyah, S.F.; Susetyo, F.B. Pengaruh Krom pada Sambungan Las Terhadap Sifat Mekanik Baja Karbon dengan Elektroda E 6013: Assimetrik. 2021**;** 3: 9–16.
[19] Syaripuddin, Imam Basori, Y.M.P. Pengaruh Jenis Kampuh Las Terhadap Kekuatan Tarik Baja Paduan Rendah (ASTM A36) Menggunakan Las SMAW: Jurnal Konversi Energi dan Manufaktur UNJ. 2014**;** 2: 94–97.
[20] Affi, J.; Gunawarman Pengaruh Lapisan Oksida Tambahan Pada Struktur Mikro Lasan Baja Karbon Rendah: TeknikA. 2007**;** 1: 1–20.
[21] Anjis Ahmad Soleh, Helmy Purwanto, I.S. Analisa Pengaruh Kuat Arus Terhadap Struktur Mikro, Kekerasan, Kekuatan Tarik Pada Baja Karbon Rendah Dengan Las SMAW Menggunakan Jenis Elektroda E7016: Jurnal Ilmiah Cendekia Eksakta. 2017**;** 1: 29–35.
[22] Sanjaya, A.; Sutowo, C. Pengaruh Hasil Pengelasan GTAW Dan SMAW Pada Pelat Baja SA 516 Dengan Kampuh V Tunggal Terhadap keekuatan Tarik, Kekerasan Dan Struktur Mikro: Jurnal Sintek. 2013**;** 7: 49–58.
[23] Sopiyan; Basori; Susetyo, F.B. The Effect Of Water Temperature As Quenching Media On The Characteristics Of HV 350 Weld Deposits: SINTEK JURNAL: Jurnal Ilmiah Teknik Mesin. 2020**;** 14: 118–122.