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A Study on Mechanical Properties of Dissimilar Steels Welded with Electric Arc Welding

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Abstract: Different materials may be used together in order to obtain materials having desired properties. The main objective of this study is to investigate weldability and the mechanical properties of welded AISI 316 and AISI 4140 obtained by the electric arc technique. Mechanical properties were determined by tensile and impact tests. The critical points and Charpy energy value have been determined by means of load-elongation curves and impact test, respectively. The information about mechanical properties has been obtained by determining the hardness values at welding points and points which are closest to them. Microstructure investigations have been carried out using optical microscopy. The obtained results indicate that AISI 316 and AISI 4140 steels will be successfully combined with electric arc welding and used safely in engineering processes.

Key words: Electric arc welding, Tensile properties, Steel, Weldability

Elektrik Ark Kaynağı ile Birleştirilmiş Farklı Çeliklerin Mekanik Özellikleri Üzerine Bir Çalışma

Özet: İstenen özelliğe sahip malzemeler üretebilmek için farklı malzemeler bir arada kullanılabilir. Bu araştırmanın temel amacı elektrik ark tekniği ile birleştirilen AISI 316 ve AISI 4140 kaynaklarının kaynaklanabilirliğini ve mekanik özelliklerini incelemektir. Mekanik özellikler, çekme ve darbe çentik testleri ile belirlenmiştir. Kritik noktalar ve Charpy enerjisi değerleri sırasıyla yük uzama eğrileri ve darbe testi yardımıyla belirlenmiştir. Mekanik özelliklere ait bilgiler, kaynak noktaları ve kaynak noktalarına yakın noktalardaki sertlik değerleri belirlenmek suretiyle elde edilmiştir. Mikroyapı incelemeleri, optik mikroskop kullanılarak gerçekleştirilmiştir. Elde edilen sonuçlar, AISI 316 ve AISI 4140 çeliklerinin elektrik ark kaynağı ile başarılı bir şekilde birleştirilebileceğini ve mühendislik işlemlerinde güvenle kullanılabileceğini göstermektedir.

***Anahtar kelimeler*:** Elektrik ark kaynağı, Çekme özellikleri, Çelik, Kaynaklanabilirlik

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1. Introduction

Welding is one of the important process in manufacturing processes. Numerous published articles are available in the technical literature regarding welding [1-7]. Most of these publication, however, have been devoted to either to the technique or comparative merits of the method, manipulations, equipment, etc., rather than to the study of the characteristics of the welding metal itself. Considering the mechanical properties of the welding, it has been shown that heat input and friction welding parameters affect mechanical properties of AA6056 joints [2]. In addition, Jodia showed that welding current increases the tensile strength from 349.07 to 369.44 MPa while it decreases the impact strength and hardness [3]. Also, the effects of different electrode types on the mechanical properties of welded materials have been reported by Okediran et al. [4] These studies indicated that a proper selection of welding parameters for a given task in obtaining good weld quality is need.

In manufacturing, there are many popular types of welding such as metal inert gas welding (MIG welding), tungsten inert gas welding (TIG welding), arc welding, etc. [5,6]. Depending on the welding type, the ratio of the phase components forming in the welding zones as well as their parameters and volume fraction changes [7]. In addition, it has been shown that strength, ductility and crack resistance of welded joints of low-alloyed high-strength steel depend on the microstructure factors such as dislocation densities and grain formations [8]. These results show that various defects that occur in the welding region during welding need to be considered to improve welding quality. In this study, the microstructural and mechanical properties of dissimilar joint between AISI 316 and AISI 4140 steels produced by electric arc welding process have been studied retail.

2. Material and Method

AISI 316 and AISI 4140 steels had plate shape, and test samples having desired dimensions for testing were prepared from these plates. Chemical composition and mechanical properties of base materials and electrodes have been given in Table 1 and 2, respectively. Dissimilar steels were joined by an electric arc welding method using e AS P-316 L as electrode. Four samples were prepared individually combined with the electric arc method for each test. More information about welding method and parameters can be seen in Reference 9.

Table 1. The chemical composition of steels and welding electrode (wt. %).

	C	Si	Mn	Cr	Ni	Mo	Fe
AISI 316	0.06	0.9	1.8	18	10.5	2.4	Bal.
AISI 4140	0.42	0.26	0.90	0.92	-	0.23	Bal.
Electrode (AS P-316 L)	0.03	0.7	0.8	18	12	2.5	Bal.

Table 2. The mechanical properties of steels and welding electrode

	Yield stress (MPa)	Ultimate tensile stress (MPa)	Elongation (%)	Vickers hardnes ($HV_{0.1}$)	Charpy energy (J)
AISI 316	335	542	45	624	155
AISI 4140	417	650	25	568	77
Electrode (AS P-316 L)	298	600	35	424	103

Tensile tests were performed by using a tension-compression testing machine at room temperature. Ultimate tensile strength, yield strength and ductility values of welded samples were determined from load-elongation curves. The images of welded samples before and after tensile test have been given in Figure 1 (a) and (b), respectively.

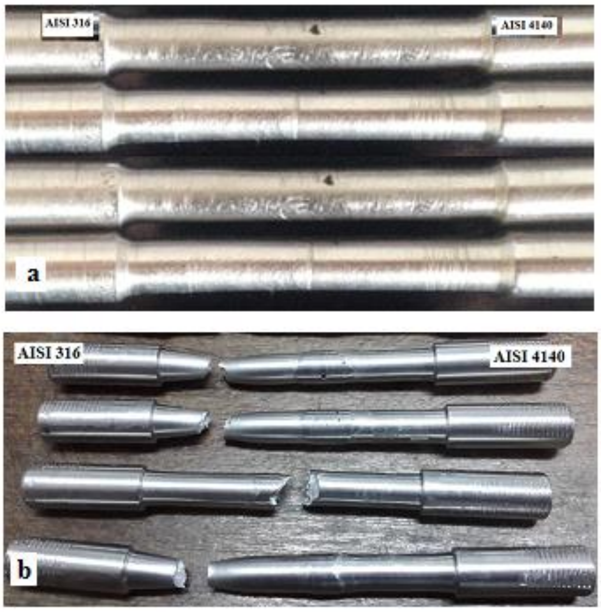

Figure 1. Welded samples: (a) Before tensile test, (b) After tensile test

The impact test is generally used for evaluating the toughness and notch sensitivity of samples. . For that reason, Charpy impact tests were conducted on standard-size Charpy V notch bars (longitudinal-transverse orientation) at room temperature by using an impact tester. The images of welded samples after impact test have been given in Figure 2.

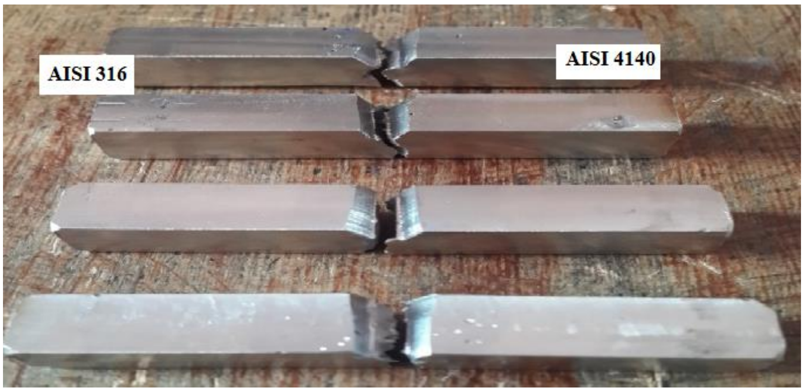

Figure 2. Welded samples after impact test

A Vickers microhardness tester was used to measure the hardness of the welded samples and hardness measurements were made from many points considering hardness marks. Figure 3 shows the image of welded samples before microstructure and microhardness analyses.

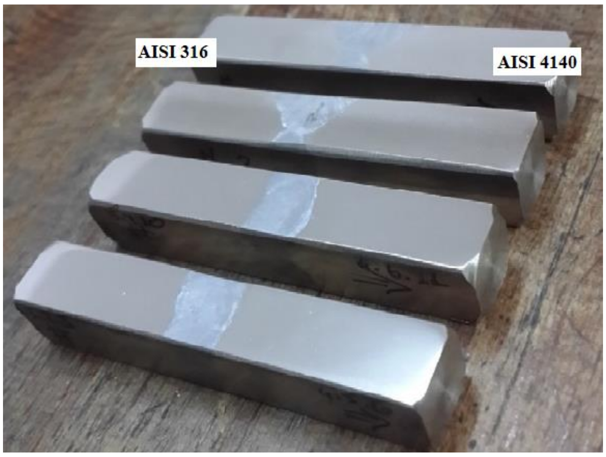

Figure 3. Welded samples before microstructure and microhardness analysis

3. Results

Tensile test measurements showed that necking process firstly appears on the AISI 316 region of all welded materials, and then necked region behaves as a brittle structures and finally, breakes. On the other hand, values of the strength properties of the AISI 316-AISI 4140 dissimilar steel pairs were obtained similar to the those obtained from the base materials. The average yield stress and ultimate tensile stress values have been obtained to be 408 MPa and 639 MPa, respectively.

The hardness values of the welded samples on the AISI 4140 and AISI 316 sides were measured as 901 and 850 $HV_{0.1}$, respectively and given in Figure 4. This value was measured as 619 $HV_{0.1}$ in the welding zone. From these results, it has been observed that while the hardness values of the welded samples increased according to the hardness values of the base metal, the hardness value of the welding region was approximately to that of the base metal (Table 2). The increase in hardness is probably due to structural transformations caused by heat input during welding process.

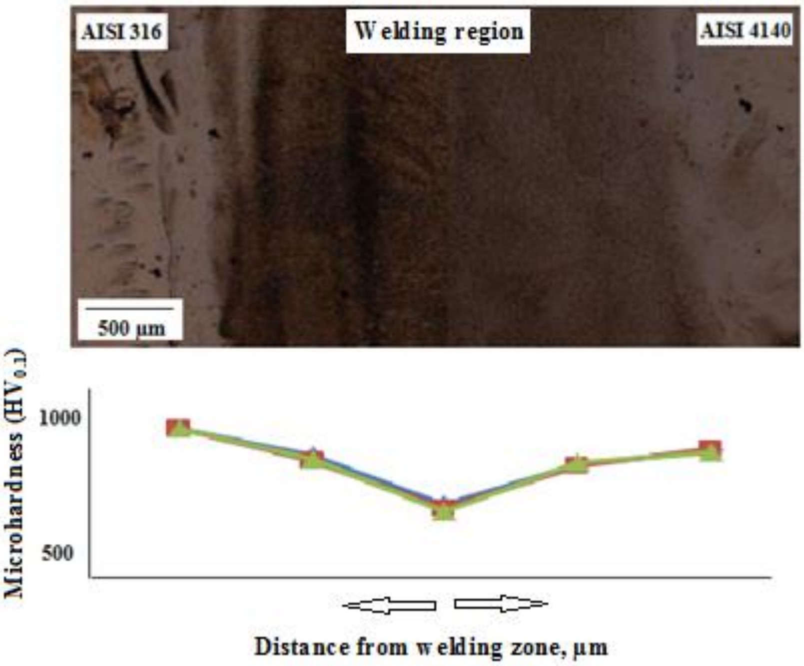

Figure 4. Vickers hardness distribution and optical micrograph of AISI 316-AISI 4140 welds

The results obtained in the welding center showed that fracture of weld zone is a mixture of ductile and brittle structures. The impact strength (Joule) of the dissimilar joints between AISI 316 and AISI 4140 is average 24 J. This value is considerably lower than the impact energies of base metals as can be seen from Table 2. The most possible reason for this can be the cracks. . As can be seen in Figure 5, the cracks have been occurred both in the welding zone and the heat affected zone (HAZ) due to heat transfer during solidification. This result confirms that the fracture is brittle.

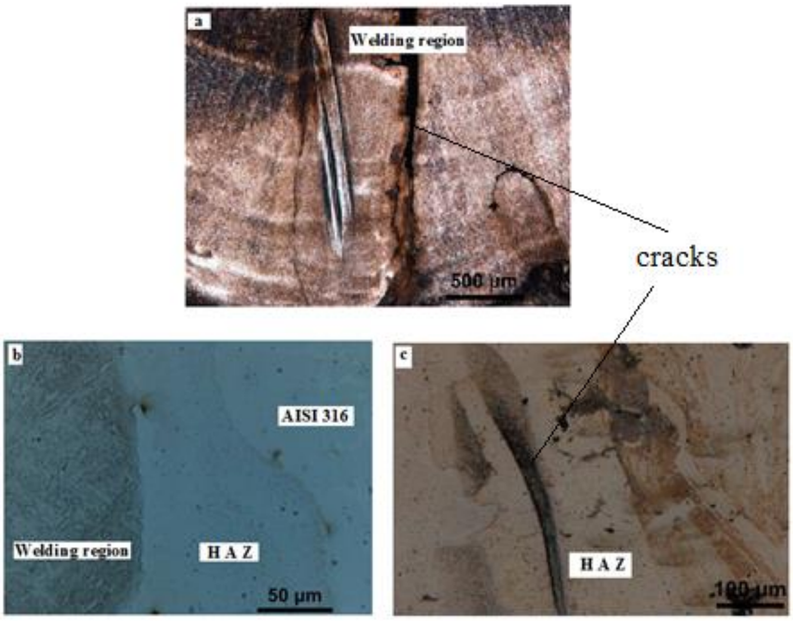

Figure 5. Optical micrograph of AISI 316-AISI 4140 welds. Cracks in the weld region (a) and HAZ of AISI 316, the microstructure of AISI 316 steel after welding (b).

4. Conclusions and Comment

In this study, AISI 316 and AISI 4140 steel were welded with the electric arc method. The microstructural and mechanical properties of the welded samples were investigated. The following conclusions have been obtained:

- The average tensile strength of welded joints was 408MPa, yield strength was 639 MPa and elongation was 34%.
- When the fracture zones of the welded samples were examined after tensile test, fractures have been seen at AISI 316 base material side. This result indicates that AISI 316 and AISI 4140 steels can be successfully combined with electric arc welding.
- Tensile strength of joints combined with electric arc welding increased. In addition, the hardness of the welding point was close to the hardness of the base metal. It shows that these joints can be used safely for many purposes.

Author Statement

Cüneyt Aytekin: Resource/Material/Instrument Supply, Software and Formal Analysis.
Adnan Çalık: Conceptualization, Methodology, Data Curation, Supervision, Observation, Advice and Project Administration.
Nazım Uçar: Investigation, Original Draft Writing, Validation, Visualization, Review and Editing

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Conflict of Interest

As the authors of this study, we declare that we do not have any conflict of interest statement

Ethics Committee Approval and Informed Consent

As the authors of this study, we declare that we do not have any ethics committee approval and/or informed consent statement.

References

[1] J. Yashar and A. Masoud, "Sub-surface stress measurement of cross welds in a dissimilar welded pressure vessel,'' *Mater. Design*, 85, 82–90. 2015.

[2] A. Squillace, G. Campanile, P. Cavaliere, and F. Panella, "Effect of the welding parameters on mechanical and microstructural properties of AA6056 joints produced by friction stir welding,'' *J. Mater Process Tech.*, 180, 263-270, 2006.

[3] W. M. Jodia, "Study the change of current weld on mechanical properties and microstructure of low carbon steel welded by electric arc welding,'' *J. Univ. Babylon Eng. Sci*., 4, 1470-1477, 2017.

[4] B. Okediran, D. S. Yawas, I. A. Samotu, I. M. Dagwa, and D. O. Obada, "Effects of electrode type on the mechanical properties of weldments of some steel samples produced in Nigeria,'' *World J. Eng*., 11, 95-106, 2014.

[5] J. Tusek and M. Suban, "Experimental Research of The Effect of Hydrogen in Argon as a shielding Gas in Arc Welding of High-Alloy Stainless Steel'', *Int. J Hydrogen Energy*., 25, 369-376, 2000.

[6] M. Ural and E. Kaluç, ''Paslanmaz çeliklerin TIG yöntemi ile kaynağı'', *Metal Makina*, 12-20, 1996.

[7] O. Berdnikova, V. Pozniakov, A. Bernatskyi, T. Alekseienko, and V. Sydorets, "Effect of the structure on the mechanical properties and cracking resistance of welded joints of low-alloyed high-strength steels,'' *Procedia Structural Integrity* 16, 89–96, 2019.

[8] L. Markashovaa, O. Berdnikovab, A. Bernatskyic, V. Sydoretsd, and O. Bushmae, "Crack Resistance of 14KhGN2MDAFB high-strength steel joints manufactured by laser welding,'' *IOP Conf. Ser., Earth Environ. Sci*., 224, 1-9, 2019.

[9] C. Aytekin, ''Elektrik Ark kaynağı ile Birlşetirilmiş İki Farklı Çelik Malzeme (AISI 316-AISI 4140) nin Kaynak Bölgesinin İncelenmesi'', Bitirme Tezi, Süleyman Demirel Üniversitesi, Isparta, Turkey, 2017.