Çukurova Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 31(ÖS 1), ss. ÖS 143-ÖS 146, Ağustos 2016
Çukurova University Journal of the Faculty of Engineering and Architecture, 31(ÖS 1), pp. SI 143-SI 146, August 2016

Effect of Heat Input on Weld Microstructure in TIG Welding of Duplex Stainless Steels

Alptekin KISASÖZ[*1], Ahmet KARAASLAN[1]

[1]*Yıldız Teknik Üniversitesi, Kimya Metalurji Fakültesi, Metalurji ve Malzeme Mühendisliği Bölümü, İstanbul*

Geliş tarihi: 12.01.2016 Kabul tarihi:30.04.2016

Abstract

Duplex stainless steels are used in many applications as in oil, chemical, petrochemical, nuclear and marine industries. Welding of duplex stainless steels requires higher attention due to changes in ferrite and austenite phase ratio in weld metal. Higher ferrite or austenite phase ratio induces decreases in mechanical properties and corrosion resistance. In this study, effect of heat input on weld microstructure of duplex stainless steels in TIG welding were investigated. Higher heat input induce austenite structure and grain size changes in weld metal.

Keywords: Duplex stainless steels, TIG welding, Mechanical properties

Çift Fazlı Paslanmaz Çeliklerin TIG Kaynağında Isı Girdisinin Kaynak Mikroyapısı Üzerindeki Etkisi

Özet

Çift fazlı paslanmaz çelikler kimya, petrokimya ve nükleer sanayii ile açık deniz uygulamalarında yaygın bir kullanıma sahiptir. Çift fazlı paslanmaz çeliklerin kaynağı, kaynak metalinde ferrit ve östenit faz oranlarının değişimi nedeniyle yüksek özen gerektirmektedir. Ferrit veya östenit oranı mekanik özelliklerin ve korozyon dayanımının olumsuz yönde değişmesine neden olmaktadır. Bu çalışmada, çift fazlı paslanmaz çeliklerin TIG kaynağında ısı girdisinin kaynak mikroyapısı üzerindeki etkisi araştırılmıştır. Yapılan çalışmalar sonucunda yüksek ısı girdisinin östenit yapısında ve tane boyutunda değişimlere yol açtığı belirlenmiştir.

Anahtar Kelimeler: Çift fazlı paslanmaz çelikler, TIG kaynağı, Mekanik özellikler

[*] Sorumlu yazar (Corresponding author) : Alptekin KISASÖZ., *Yıldız Teknik Ünivesitesi, Kimya Meralurji Fakültesi, Metalurji ve Malzeme Mühendisliği Bölümü, İstanbul. akisasoz@gmail.com*

1. INTRODUCTION

Duplex stainless steels (DSS) have ferrite and austenite phases in approximately equal amounts. DSS have been used in many application areas such as in oil, chemical, petrochemical, nuclear and marine industries due to their higher mechanical properties and corrosion resistance [1-4].

Welding of DSS requires higher attention because of the changes in ferrite-austenite phase ratio and the formation of intermetallic phases in weld metal. Especially, phase ratio and microstructure of the weld bead is strongly dependent on the heat input and the thermal cycle. Higher heat input will be reveal the higher ferrite phase ratio and contrary, lower heat input will be lead limited austenite phase ratio. Higher ferrite or austenite phase ratio induces decreases in mechanical properties and corrosion resistance [5].

In this study, effect of heat input on weld microstructure of duplex stainless steels were investigated. Specimens were joined by TIG welding method with two different filler metal diameter. Moreover, microstructure and mechanical properties were investigated with optical microscope analysis and charpy impact test, respectively.

2. EXPERIMENTAL

EN 1.4462 duplex stainless steel plates with 400x150x10 mm dimension were joined with ER2209 filler metal. Filler metals were used with two different diameters as 2.00 mm and 2.40 mm. The chemical compositions of base material and filler metal are given in Table 1.

Specimens were joined with V welding groove joining design by TIG welding. Welding parameters and V welding groove joining design are shown in Table 2 and Figure 1.

The microstructure of the weldments were characterized by optical microscopy. Metallographic preparation was performed by grinding, polishing and etching. Water cooled silicon carbide papers of 180, 240, 320, 400, 600, 800, 1000, 1200 and 2000 grit size in grinding. Latter, the samples were polished using 1 µm diamond paste. Electro-chemical etching was performed using KOH solution.

Table 1. Chemical compositions of base material and filler metal (wt. %)

	C	**Cr**	**Ni**	**Mo**	**Mn**
EN 1.4462	0.02	22.56	5.42	2.95	1.29
ER 2209	0.03	22.00	10.00	2.70	0.90
	Si	**P**	**S**	**N**	**Fe**
EN 1.4462	0.457	0.031	0.014	0.17	Bal.
ER 2209	0.50	-	-	0.12	Bal.

Table 2. Welding parameters

	Specimen 1	Specimen 2
Filler Metal Diameter (mm)	2.40	2.00
Current (A)	190	160
Voltage (V)	15	15
Welding Speed (mm/s)	1.60	2.70
Shielding Gas	Ar	Ar

Effects of the welding process on the mechanical properties of the specimens were investigated with charpy impact tests. Charpy impact tests were carried out according to TS EN ISO 9016:2012 charpy impact test standard.

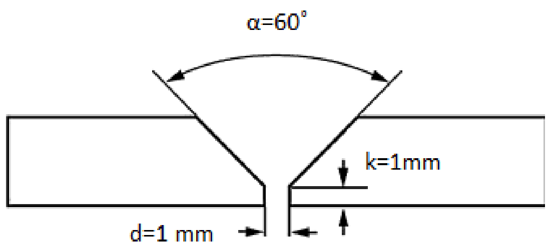

Figure 1. V groove joining design

3. RESULTS AND DISCUSSION

Microstructure properties of welded specimens were characterized by optical microscopy and image analyses, and mechanical properties determined with help charpy impact test. Figure 2 shows the weld seam and HAZ microstructures of welded specimens. In weld seam, different type of austenite phases occur depending on heat input, base material properties (austenite/ferrite ratio), filler metal properties and welding parameters. These structures are Widmanstatten austenite, grain boundary austenite, intergranular austenite and secondary austenite. During the cooling of weld metal, grain boundary austenite comprises from δ ferrite. Also, other austenite structures comprise due to thermal cycles [6, 7].

Moreover heat input (Hnet) during the welding can be calculated from Equation 1.

$$H_{net} = EI / V \quad (1)$$

In Equation 1, E is welding voltage, I is welding current and V is welding speed. Calculated heat inputs for specimen 1 and specimen 2 are calculated as 1781 Ws/mm and 888 Ws/mm, respectively.

Specimen 1 were joined with higher welding current and heat input than Specimen 2. Thus, weld bead of specimen 1 has larger austenite grain size and greater secondary austenite ratio. Also, intergranular austenite phase occurs in specimen 2 due to lower thermal cycle characteristics.

HAZ microstructures of specimen 1 and specimen 2 are shown in Figure 2b and Figure 2d, respectively. According to HAZ microstructures, grain coarsening is more decent in specimen 1 owing to higher amount of welding heat input.

Table 3. Impact test results of welded specimens

	Specimen 1		Specimen 2	
Test Temperature (˚C)	24	-40	24	-40
Weld Bead Impact Strength (J/cm²)	122.30	102.20	131.10	87.95
HAZ Impact Strength (J/cm²)	224.10	111.32	232.12	156.30

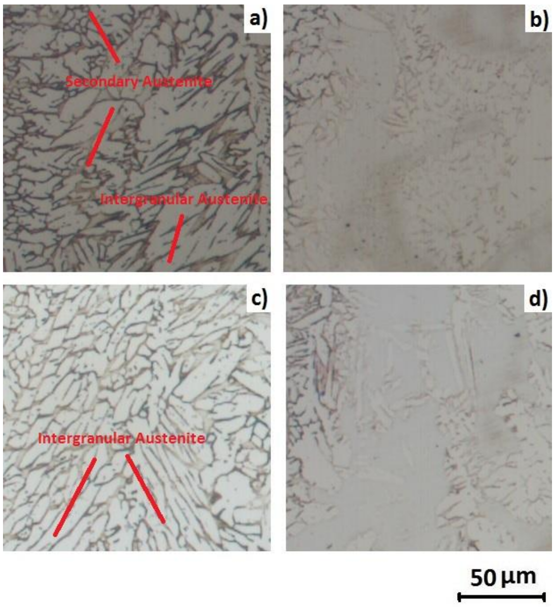

Figure 2. Weld metal structures a) Weld bead microstructure of specimen 1 b) HAZ microstructure of specimen 1 c) Weld bead microstructure of specimen 2 d) HAZ microstructure of specimen 2

Charpy impact test results are given in Table 3. Impact strength values of specimen 1 and specimen 2 is decreasing with decreasing test temperature. Impact strength values of HAZ for both specimens are higher than weld bead impact strength values. Also, impact strength of specimen 2 is higher than specimen 1. Higher heat input values in specimen 1 enhance the grain coarsening and thus, specimen 2 has greater impact strength values.

4. CONCLUSION

In this investigation, heat input values for specimen 1 and specimen 2 were calculated as 1781 Ws/mm and 888 Ws/mm, respectively.

Grain coarsening occurred in weld bead and HAZ of specimen 1. Secondary austenite occurs in specimen 1. Also, intergranular austenite occurs in specimen 2 due to lower thermal cycle characteristics.

Higher heat input values during welding enhanced the grain coarsening and decreased the impact strength values.

In TIG welding of duplex stainless steels, weld seam and HAZ microstructures are strongly dependent on heat input during the joining. Austenite/Ferrite phase ratio and types of austenite structures have great importance for mechanical properties of weld structure.

5. REFERENCES

1. Kısasöz, A., Karaaslan A., 2014. Finite Element Analysis of 2205 Duplex Stainless Steel Welds, Materials Testing, 56, 795-799.
2. Kısasöz, A., Gurel, S., Karaaslan A., 2016. Effect of Annealing Time and Cooling Rate on Precipitation Processes in a Duplex Corrosion-Resistant Steel, Metal Science and Heat Treatment, 57, 544-547.
3. Neessen, F., Bandsma, P., Smitweld, L., 2001. Tankers – A Composition in Duplex Stainless Steels, Welding Innovation, 18, 2-8.
4. Horvarth, W., Prantl, W., Stuwe, H.P., Werner, E., 1995. Influence of Thermal Cycling on the Microstructure of a Ferritic–Austenitic Duplex Stainless Steel, Materials Characterization, 34, 277-285.
5. Hertzman, S., Ferreira, P.J., Brolund, B., 1997. An Experimental and Theoretical Study of Heat-Affected Zone Austenite Reformation in Three Duplex Stainless Steels, Metallurgical and Materials Transactions, 28 A, 277-285.
6. Geng, S., Sun, J., Gou, L., Wang, H., 2015. Evolution of Microstructure and Corrosion Behavior in 2205 Duplex Stainless Steel GTA Welding Joint, Journal of Manufacturing Processes, 19, 32-37.
7. Ramirez, A.J., 2003. The Relationship Between Chromium Nitride and Secondary Austenite Precipitation in Duplex Stainless Steels, Metallurgical and Materials Transactions A, 34A, 1575-1597.