FRICTION WELDING OF DISSIMILAR AISI 304 AND AISI 8640 STEELS

Serkan BATI[1,*], Musa KILIÇ[2], İhsan KIRIK[3]

[*1]Batman University, Faculty of Technology, 72060 Batman, Turkey

[2,3]Batman University, Faculty of Engineering and Architecture, 72060 Batman, Turkey

[*]serkan.bati@batman.edu.tr

Received: 1 November 2016; Accepted: 28 December 2016

This study investigates the joinability of AISI 8640 heat treatable steel and AISI 304 austenitic stainless steel combined with friction welding. These steels have completely different properties and widely used in industrial applications. Welding is applied on steels with the parameters of 1800 rev/min turning speed, 50 MPa friction pressure and 2, 4, 6, 8 and 10 sec friction time by using continuously driven friction welding machine. After the welding process, tensile and hardness testing applied to determine tensile and hardness strength of welded samples. Additionally, in order to determine the microstructural features, research using the optical microscope, scanning electron microscope (SEM) with Energy-dispersive X-ray spectroscopy (EDS) analysis tests were done. According to the information derived from the results, AISI 304 and AISI 8640 steels joined with friction welding without any problem.

Key words*: Friction welding, AISI 304 steel, AISI 8640 steel*

INTRODUCTION

1. Introduction

Especially power generation industries need to weld austenitic stainless steels to low alloy steels [1-3]. Corrosion behavior of some advanced materials formed by friction welding still needs to research and development widely [1]. Austenitic chrome-nickel stainless steels including 12-25% Cr and 8-25% Ni, which is the most common corrosion resistant materials, it is applied on CPI HX and vessels, tubing, wire, medical and dental devices [4, 5].

Friction welding heat create by altering mechanical energy to thermal energy on the foreheads of the workpieces during rotation and under pressure. In general, friction welding used to combine circular or non-circular cross sections easily. Material saving, low production time and making possible to weld materials made of different metals and alloys, these are the most important advantages of friction welding. Turning speed, friction pressure, friction time, forging time and forging pressure are the most attractive parameters of friction welding [6]. The superiority of friction welding attracts attention especially in cylindrical piece's forehead part's welding when the other welding processes are insufficient [7].

Numerous ferrous and non-ferrous alloys can be joined by friction welding. Friction welding usable to join metals that have very different thermal and mechanical features. Generally joining parts that cannot be welded by other welding methods because of brittle phase formations which makes the joint poor in mechanical features. Friction welding enable many combinations possible because of short welding time and sub-melting temperatures [8].

Material saving, short manufacturing time and high probability of welding different alloys or metals are the main advantages of friction welding [6, 9]. In these days, gears, bandix gears, gearshaft components, axle shafts, turbocharged fan shafts, fork shafts connections, valves etc. in automotive industry are manufactured by the consolidation of alloy steel and normal carbon steel using friction welding process [9, 10].

There are various situations arise in joining dissimilar materials in industrial applications. Joining dissimilar metals are generally more difficult to weld than similar metals because of difference in the mechanical, metallurgical and physical features of parent metals. In order to benefit from all the advantages of the properties of dissimilar metals, it is necessary to produce high quality joints between them. That is only way to use most suitable materials for designers. Developing opportunity of new materials and higher requirements being placed on materials creates a larger demand for joints of different metals [11].

Friction welding of dissimilar steels were studied before by some researchers. Özdemir (2005) investigated the mechanical features of friction welded AISI 4340 and AISI 304L steels as a function of turning speed.

Arivazhagan et al. (2008) investigated an evaluation of hot corrosion behavior, impact strength and hardness of friction welded different type of weldments between AISI 304 and AISI 4140 steels. Çelik and Ersözlü (2009) investigated the microstructure and mechanical features of friction welding of AISI 1050 and AISI 4140 steels couple.

In the literature, AISI 304 and AISI 8640 steel welding has not been studied previously. The main purpose of the research is to join chemically and mechanically dissimilar AISI 304 and AISI 8640 steel couple by friction welding machine with 2,4,6,8 and 10 sec. friction time, 10 sec. constant forging time, 50 Mpa constant friction pressure, 100 Mpa constant forging pressure and 1800 rpm constant rotational speed have been investigated. Effect of increasing friction time on the strength and quality of welding also studied.

2. Material and Method

AISI 304 and AISI 8640 steel rods, which have 12 mm diameter and 70 mm length were used in experiment. Samples were machined in desired dimensions and then welded without any preheating process. Welding parameters are listed on Table 1. Chemical compositions of samples are listed on Table 2. Welded specimens are represented on Fig. 1.

Table 1. Friction Welding Parameters

Specimen No	Rotation Speed (rpm)	Friction Pressure (Mpa)	Forging Pressure (Mpa)	Friction Time (s)	Forging Time (s)
1	1800	50	100	2	10
2	1800	50	100	4	10
3	1800	50	100	6	10
4	1800	50	100	8	10
5	1800	50	100	10	10

Table 2. Chemical composition of parent materials

	Alloying Elements (wt.%)											
	C	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**Ni**	**Al**	**Cu**	**V**	**W**
AISI 304	0.036	0.334	1.54	0.038	0.030	18.26	0.390	8.41	0.023	0.681	-	0.094
AISI 8640	0.407	0.244	0.721	0.024	0.017	0.52	0.162	0.455	-	0.327	0.004	0.030

Fig. 1. Welded specimens

The specimens were polished then etched with %5 HNO3 solution on the AISI 8640 side and electrolytic etched at ~0.1 A/cm2 for 1-2 min in a 50% solution of nitric acid in water on the AISI 304 side. Microstructure of welded parts were observed by optical microscopy. Mechanical properties of welded specimens were measured with using 100 kN capacity Shimadzu tensile tester. Schematic illustration of tensile test specimen are represented in Fig. 2. The specimens for hardness test were polished with 240,400,600,800,1000 and 1200 grade emery papers and then etched. Polished specimens are represented on Fig 3. Vickers hardness test was done to measure hardness of welded zones. Hardness values were taken as a interval of 1mm on the surfaces.

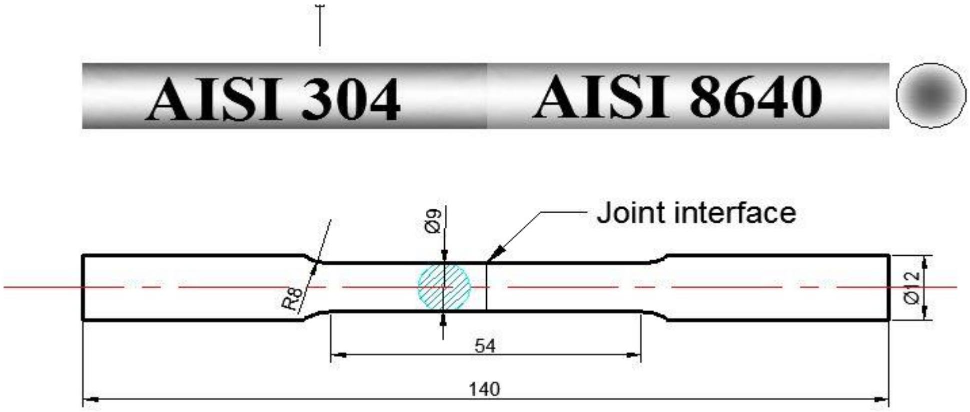

Fig. 2. Schematic illustration of tensile test specimen.

Fig. 3. Macro-photograph of welded and polished samples.

3. Results and Discussion

3.1. Hardness test results

Test results of welded zone of three specimen (S1,S2 and S3) are given in Fig. 4. Hardness values measured on welded zone from both sides. Highest hardness values taken from welding surfaces 421,441, 305 HV respectively. Highest hardness values were measured at welded zones and this values were much higher than parent materials.

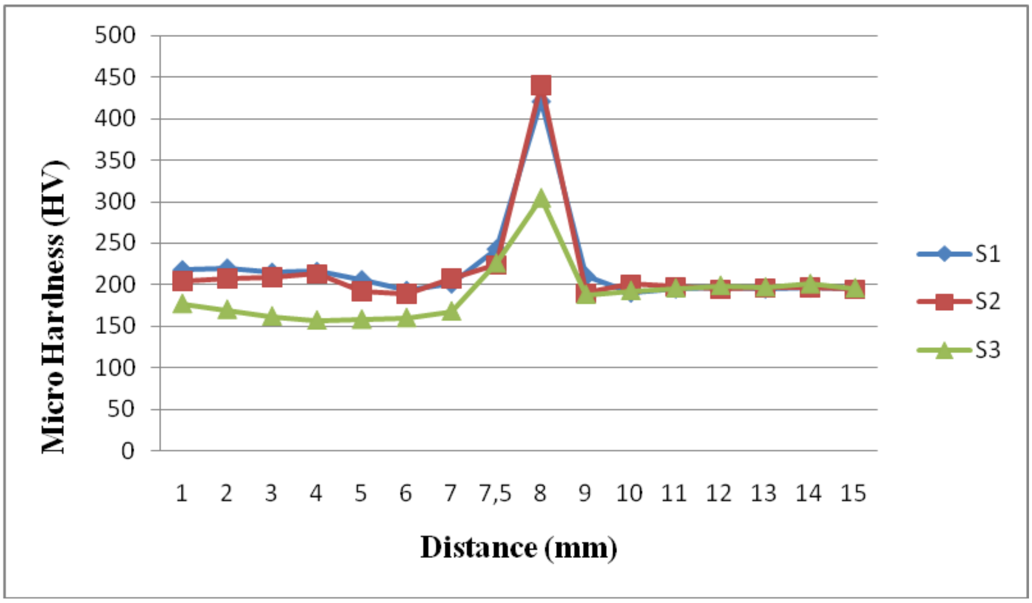

Fig. 4. Hardness values of welded samples

3.2. Tensile properties

Friction welding processes was performed successfully and then tensile test were applied all the specimens. During tensile test, all fractures were ductile and occurred at AISI 8640 steel (Fig. 5.), none of them occurred at weld zone, therefore all the tensile strengths and elongations were given almost the same results (Fig. 6.). That means all the joints were perfectly welded, independent from time and more durable then one of parent material AISI 8640.

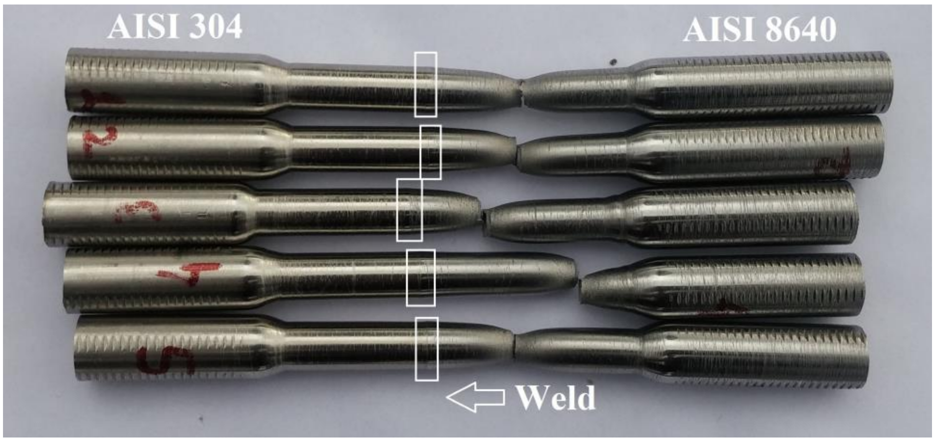

Fig. 5. Fractured tensile specimens

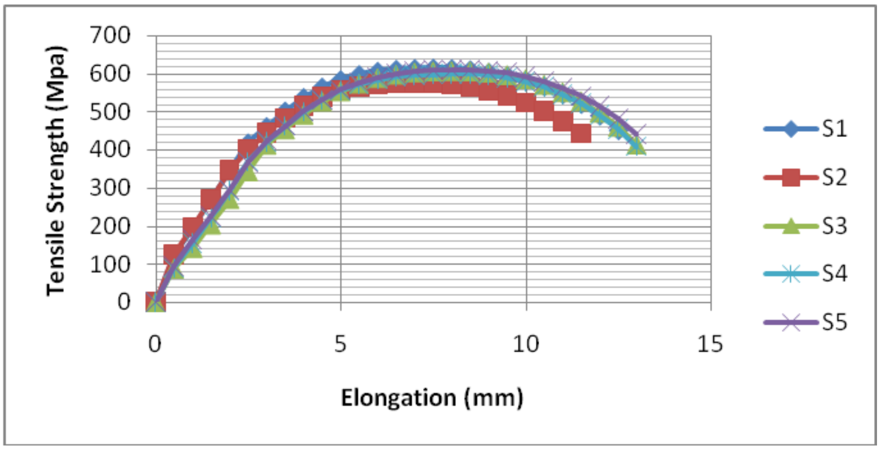

Fig. 6. Graph of tensile test results

3.3. Macro and microstructure

Flash formation was changing with time as seen in Fig. 1, also flash forming on steels were different due to heat capacity of AISI 8640 steel is lower than AISI 304 steel. Flash amount increasing with the friction time. Optical microscopy views are shown in Fig. 7. Deformed zone and deformation directions are clearly visible. Detail views of base metals are shown in Fig. 8. Deformed zone width of AISI 8640 steel was larger than AISI 304, because of the heat capacity of AISI 8640 steel is less than AISI 304 steel.

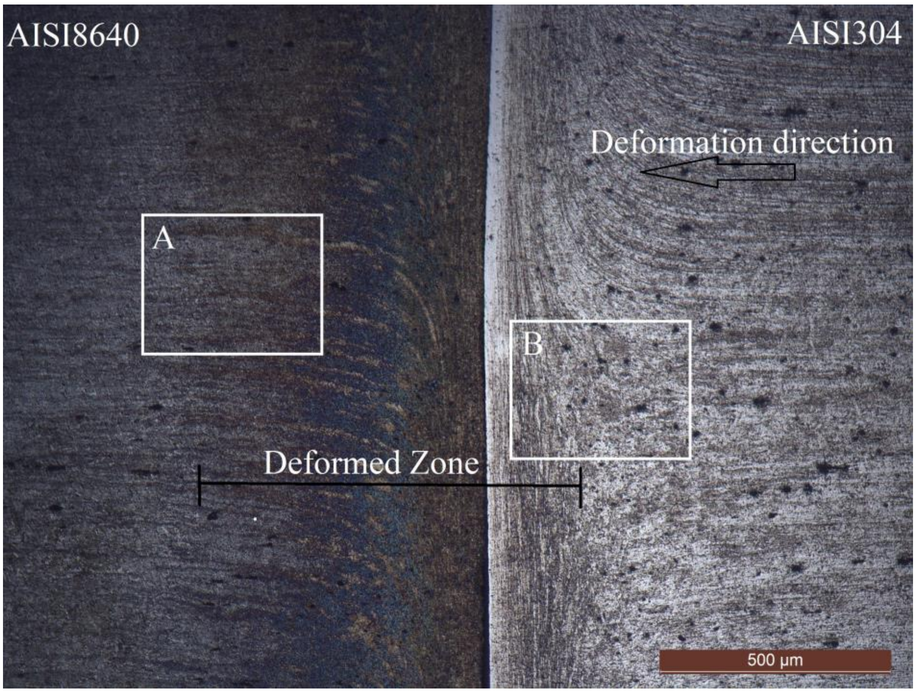

Fig. 7. Optical microscopy view of welded zone

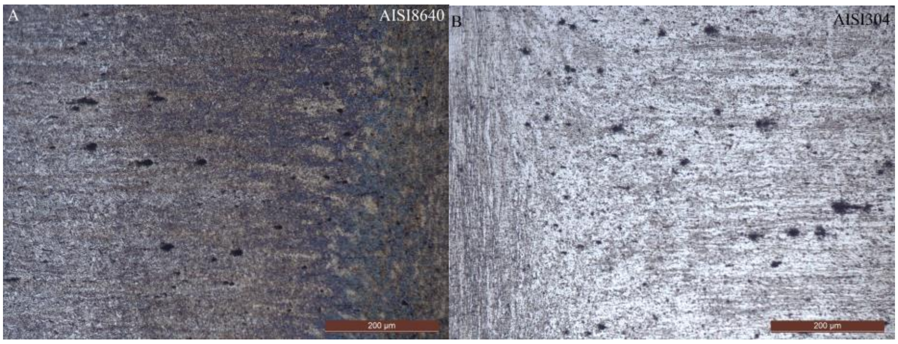

Fig. 8. Detailed views of base materials

3.4. EDS analysis

EDS analyses were carried out at seven points, which are shown in Fig. 9. Chemical analyses results were listed on Table 3.

Material diffusion occurred at weld zone due to mixing and pressing of frictionally heated metals. At the point, 4 which is weld zone, Fe, Cr, Mn and Ni ratios significantly increased. Chromium diffuses at that point and it increases the hardness at that point significantly. Increment of Cr and Ni ratios at point 4, increased tensile strength of the welding zone and the situation explains why fracture not occurred at weld zone.

EDS analyses also showed that, an important diffusion was not observed between base materials except weld zone.

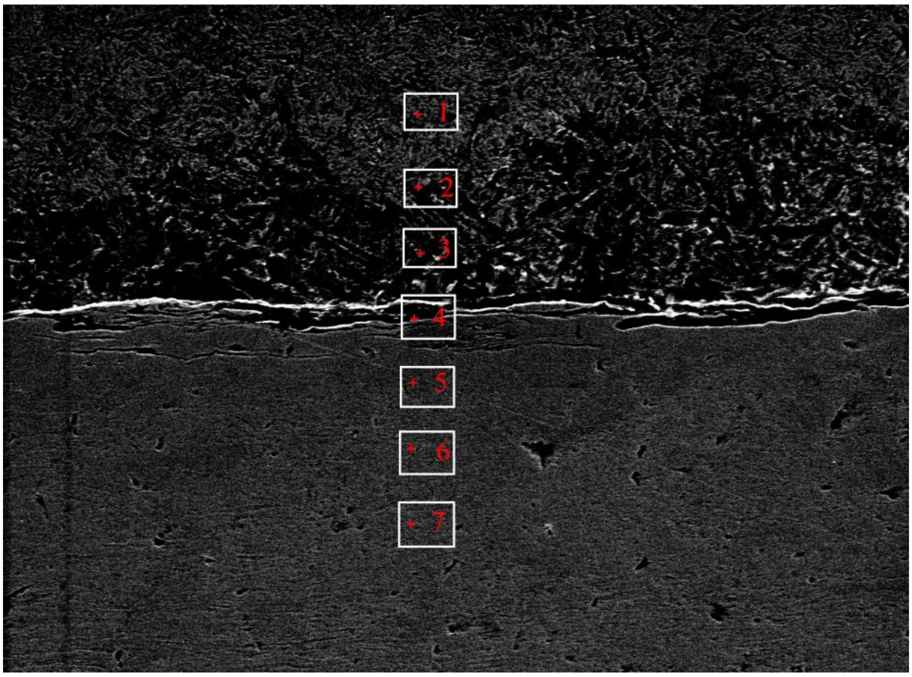

Fig. 9. SEM photo of welded specimens

Table 3. EDS data's of points 1 to 7.

Points		1	2	3	4	5	6	7
Elements % Wt	Ti	0.085	0.181	0.253	0.195	0.270	0.177	0.144
	Cr	0.651	0.590	0.959	8.882	19.945	20.113	20.081
	Mn	0.914	0.746	0.732	1.393	1.431	1.345	1.542
	Fe	97.130	97.297	96.947	85.335	70.560	70.274	70.373
	Ni	0.760	0.854	0.723	3.257	7.257	7.316	6.965
	Cu	0.459	0.332	0.385	0.939	0.536	0.776	0.896

4. Conclusion

The experiment showed that; AISI 304 and AISI 8640 steels joined with friction welding without any problems and also;

- dissimilar metals can be welded easily with friction welding,
- in friction welding, preheating is not necessary for heat treatable steels,
- hardness of the weld zone higher than parent materials,
- there were no cracks occurred at weld zone in SEM and optical microscopy observations,
- diffusion of materials was observed at weld zone,
- the welding has sufficient strength,
- flash formation increased with the time.

Acknowledgment

This study was conducted with the help of Fırat University Faculty of Technology/ Elazığ, Turkey, and Naci Uyar Iron and Steel Company/Esenyurt, Turkey

References

[1] N. Arivazhagan, S. Singh, S. Prakash, G.M. Reddy, The International Journal of Advanced Manufacturing Technology, 39 (2007) 679-689.
[2] A. Farkash, I. Fleischer, M. Schorr, E. Weintraub, R. Cytermann, Corrosion Reviews, 8 (1989) 333-388.
[3] S. Shushan, E. Charles, J. Congleton, Corrosion science, 38 (1996) 673-686.
[4] S. Anık, Elektrik Ark Kaynağı, Gedik Holding Yayınları, İstanbul, 1991.
[5] N. Özdemir, Materials Letters, 59 (2005) 2504-2509.
[6] M. Sahin, Journal of Materials Processing Technology, 153-154 (2004) 1011-1018.
[7] M.T. Erdoğan, Fen Bilimleri Enstitüsü, Celal Bayar Üniversitesi, Manisa, 2004, pp. 114.
[8] A.Z. Sahin, B.S. Yibaş, M. Ahmed, J. Nickel, Journal of Materials Processing Technology, 82 (1998) 127-136.
[9] S. Celik, I. Ersozlu, Materials & Design, 30 (2009) 970-976.
[10] R.E. Chalmers, Manufacturing Engineering, 126 (2001) 64-66.
[11] V.V. Satyanarayana, G. Madhusudhan Reddy, T. Mohandas, Journal of Materials Processing Technology, 160 (2005) 128-137.