MICROSTRUCTURE AND MECHANICAL PROPERTIES OF FRICTION WELDED IRON ALUMINIDES

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Abstract: Fe–40Al alloy were welded by the friction welding technique. Samples were welded for different welding time under a constant forging and friction pressure at 1000 rmp. Microstructures of the welds were examined by optical microscopy. The results showed that the welded samples were free of any pore or crack along the weld interface except for 3s. The micro hardness of the welded samples was measured. The strength of the welds was determined by the shear tests. It was observed that the shear strength of the welds depended on the welding time. The maximum shear strength was 466, 8 MPa.

Keywords: Iron aluminides, friction welding, shear strength

Introduction

Iron aluminides based on Fe_3Al and FeAl are excellent candidates to be used as structural materials for high-temperature service conditions. The advantages of these materials include their low cost, low density, and high sulfurizing and oxidizing resistance at high temperatures (Liu 1997, Stoloff 2000, Deevi 1997, Deevi 1998). These advantages have led to the identification of several potential uses, including heating elements, furnace fixtures, heat-exchanger piping, and sintered porous gas-metal filters, automobile and other industrial valve components, catalytic converter substrates and components for molten salt applications (Stoloff, 1998). However, these alloys have poor ductility at the room temperature, relatively poor high- temperature strength and creep resistance (McKamey, 1991). The development of a joining process is very important in the application of iron aluminides, but the study of welding and/or brazing iron aluminides is very limited in literatures. Welding of iron aluminides plays an important role in practical application of such alloys. Welding of iron aluminides is difficult due to its inherent low temperature ductility and poor weldability (Fasching 1995, Lee 2003). Friction welding is one of the available joining techniques, and it has been used successively in metals and alloys (Ozdemir 2005, Ateş 2007, Tao 2015, Della 2013, Winiczenko 2013, Kırık 2013). There has been several published works on the friction welding of Fe_3Al - FeAl type alloys. Sketchley et al. investigated the friction welding of Fe_3Al-based oxide dispersion-strengthened (ODS) alloy and B.J. Inkson et al. studied on friction welding of FeAl40 Grade 3 ODS alloy. They achieved good bonding (Sketchley 2002, Inkson 1998). In addition, author and co-workers reported the successful friction welding of Fe_3Al and dissimilar Fe–28Al alloy and AISI 316 L (Torun 2011, Çelikyürek 2011). In this paper, cast Fe-40Al alloys were welded by friction welding. Effect of welding time on the microstructure and mechanical properties of the cast Fe-40Al alloy were investigated.

Materials and Methods

The alloy Fe-40Al was prepared with vacuum arc melting under an argon atmosphere from iron and aluminum with 99.99 wt. % and 99.7 wt. % purity, respectively. The samples were homogenized at 1100 ◦C for 50 h and cooled in a furnace. Cylindrical cast alloy samples 8 mm in diameter and 50 mm in length were prepared. The friction welding experiments were carried out by a continuous-drive friction welding machine (Fig. 1) for 3, 5 and 7 s friction time under a constant rotational speed, a constant friction and forging pressure (Table 1). After welding, the welded samples were cut perpendicular to the welding interface. The surfaces of the welded samples were ground with 1200 grinding paper and polished with 1 μm diamond paste, then the samples were etched with a mixture of H_2O (30 ml), HNO_3 (30 ml), HCl (20 ml) and HF (20 ml). The microstructures were observed with light microscopy Microhardness values were measured on the welded samples by means of Vickers

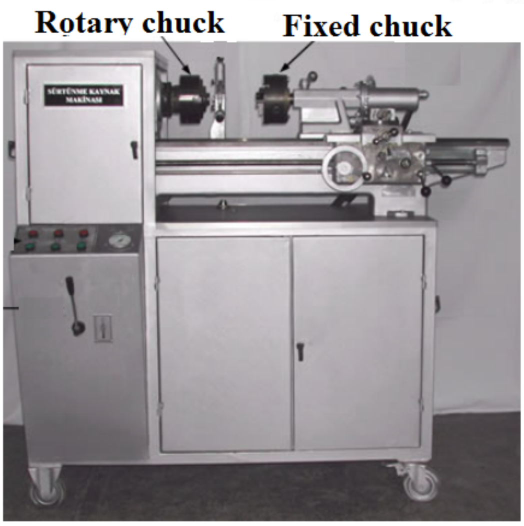

Figure 1.A continuous-drive friction welding machine

indenter with a load of 100 g. Shear tests were performed to determine the strength of the weld interface using an electromechanical universal test machine (Shimadzu AG-IS-250) at room temperature. A specially designed specimen holder was used to measure the shear strength. Three samples were tested for an each welding condition.

Results and Discussion

Flash formation was observed in all welded samples because of plastic deformation during welding. The friction time play an important role in flash formation. The burn-off increased with increase in friction time. More plastic deformation occurs because of the longer friction time, which produces higher heat in the weld interface. Thus, the burn-off (axial shortening) increases with the increase in plastic deformation (Table 1).

Table 1.Parameters of the friction welding.

Friction Speed (rmp)	Forging Pressure(MPa)	Friction Pressure (MPa)	Friction Time (s)	Burn-off (mm)
1000	140	140	3	4.2
1000	140	140	5	10.9
1000	140	140	7	18.5

Microstructural observation was carried out for the weld interface using an optical microscope. Fig. 2 shows the optical micrographs of the weld interface of welded samples for 3, 5 and 7 s.

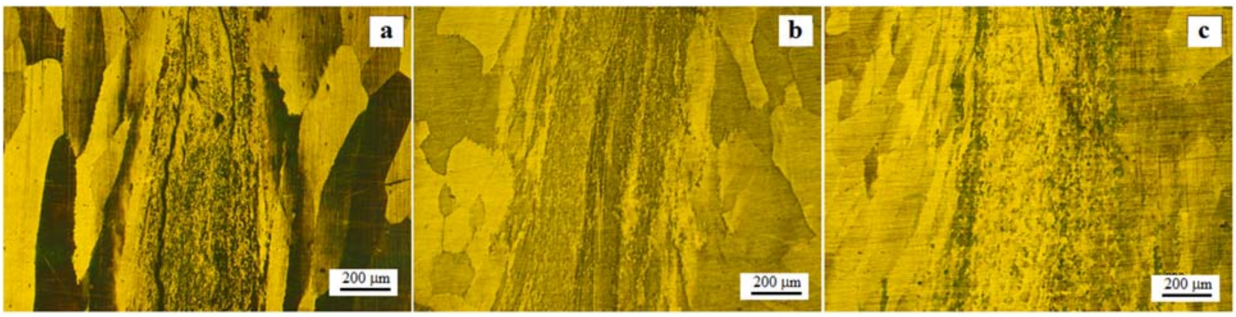

Figure 2. Optical micrographs of the weld interface of welded samples. a)3 s b) 5 s and c) 7 s.

As seen micrographs, the welded samples were of sound quality and they did not exhibit any voids or crack formation along the weld interface except for 3s. Two main regions are observable on the interface of all of the welded samples: a dynamically recrystallized zone with very fine grains and a plastically deformed zone. The width of the recrystallized zone for all of the welded samples was approximately between 400 and 600 µm. Micro hardness welded samples for 3, 5 and 7s is given in Fig. 3. According to the results of measurements, micro hardness profiles for all welding times are found to be similar.

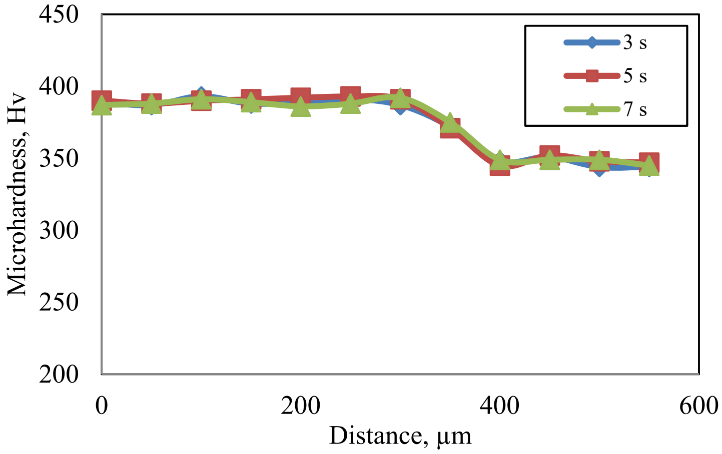

Figure 3. Micro hardness welded samples for 3, 5 and 7s

The shear strengths of welded samples were determined by using a specially designed testing apparatus. The shear of the welds and the base alloy are shown in Fig. 4. Test results demonstrated that the values of the shear strength of the welded samples were increase in increasing of the friction time. It can be said that the shear strength of welds was dependent on the friction time under the experimental conditions. The welded samples for 3s are not high enough to generate the required heat for friction welding. The shear strength of welded samples for 3s has lower due to voids at the weld interface. Test results demonstrate that the shear strength values of the welds are greater than the base metal. This situation shows that the structure with very fine grains formed due to dynamic recrystallization during the friction welding has more strength than the matrix.

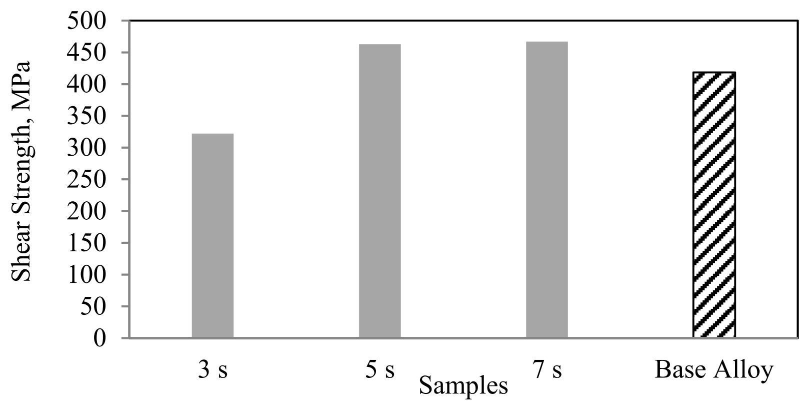

Figure 4. The shear of the welds and the base alloy

Conclusion

In this study, cast Fe–40Al alloy was welded under different conditions by friction welding method. Microstructure studies showed the presence of two different regions at the weld interface: the recrystallized zone and the deformed zone. There was variation in the width of the recrystallized zone and the deformed zone with an increase in the friction time. The micro hardness profiles for all the friction welding times. The shear strengths of the welds increased with increase in the process time. The maximum shear strength was 469,5 MPa.

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