FRICTION WELDING OF AL 7075 ALLOY AND 316 L STAINLESS STEEL

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Abstract: Friction welding of Al 7075-T6 alloy and 316 L stainless steel carried out for different times under a constant friction and forging pressure, a forging time, rotational speeds. Microstructures of the welds were examined by scanning electron microscopy and optical microscopy. The results showed that all of the welded samples were free of any or crack along the weld interface. The chemical compositions of the interface of the welded joints were determined by using energy dispersive spectroscopy. 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 210, 7 MPa.

Keywords: Al7075, 316 L Stainless steel, Friction welding

Introduction

Cr–Ni austenitic stainless steels, especially, AISI 316 exhibit considerably better corrosion resistance than martensitic or ferritic steels and also have excellent strength and oxidation resistance at elevated temperatures (Kumar 2014, Kumar 2015, Marshal 1984, Oshima 2007). The fusion weld of these steels is usually the part of a system with reduced corrosion resistance and low-temperature toughness, and therefore in many cases it is the limiting factor for material application. The heat of fusion welding also leads to grain coarsening in the heat-affected zone and solidification cracking in the weld metal of stainless steels (ASM Handbook 1999). Aluminum is currently the most widely used metallic material besides steel. The mechanical characteristics of aluminum offer an increasing application field, especially where lightweight constructions are required (Kurt 2007, Lugscheider 1995) Al 7075-T6 alloy which is used in this study has low specific weight, high strength-to-weight ratio, as well as high electrical and thermal conductivity.

Friction welding is well known among solid-state welding methods and used for welding similar and dissimilar materials (Satyanarayana 2005, Torun 2011, Çelikyürek 201, Ates 2007). This method is very useful for the welding of dissimilar combination, and the welding process is easily automated. Also, this welding method has several advantages over fusion welding methods such as high energy efficiency, narrower heat affected zone (HAZ), and low welding cost. In particular, the friction welding is able to easily produce joints with high reliability; it is widely used in the automobile industry and applied to fabricate important parts such as drive shafts and engine valves. Moreover, this welding method can also provide the joint of dissimilar combination as well as the circular pipe. Some researchers have reported that the mechanical and metallurgical properties of the friction-welded joints of circular pipes of dissimilar combination show desirable characteristic (Wang 1975, Maalekian 2007, Kimura 2016)

Materials and Methods

Al 7075-T6 alloy and AISI 316 L stainless steel were received from a private company. The cylindrical samples 50 mm in length and 8 mm in diameter were machined from 316 L stainless steel and Al 7075-T6 alloy. The friction welding experiments were carried out by a continuous-drive friction welding machine for different times under a constant friction and forging pressure, a forging time and a rotational speed (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 316 L sides of welded samples were etched with a mixture of H_2O (30 ml), HNO_3 (30 ml), HCl (20 ml) and HF (20 ml) and The Al 7075-T6 sides were etched with Keller. The microstructures were observed with light microscopy and scanning electron microscopy (SEM). The chemical compositions of the weld zone and the base alloys were determined using energy dispersive spectroscopy (EDS). Microhardness values were measured to both sides from center of the

Table 1. Parameters of the friction welding.

Friction Speed, rmp	Friction Pressure, (MPa)	Forging Pressure (MPa)	Friction Time (s)	Forging Time (s)	Burn-off (mm)
1000	50	100	6	10	0,4
1000	50	100	8	10	0,9
1000	50	100	10	10	1,5
1000	50	100	12	10	2,2

welded samples by means of Vickers 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 each welding condition.

Results and Discussion

Optical micrograph of the sample welded for 10 s is presented in Fig. 1. All of the welded samples were of sound quality, and they did not exhibit any pores or crack formation along the weld interface. Three main regions are observable on the Al 7075 side of the interface of all of the welded samples: a dynamically recrystallized zone with very fine grains (DRX), thermo-mechanically affected zone (TMAZ) and heat affected zone (HAZ) (Fig. 1a) (Khalid 2010). The width of the DRX for all of the welded samples was approximately 250-330µm. The micrographs demonstrated a slight variation in the width of DRX independent on the friction time. There was not any change on the 316 L stainless steel side (Fig. 1b).

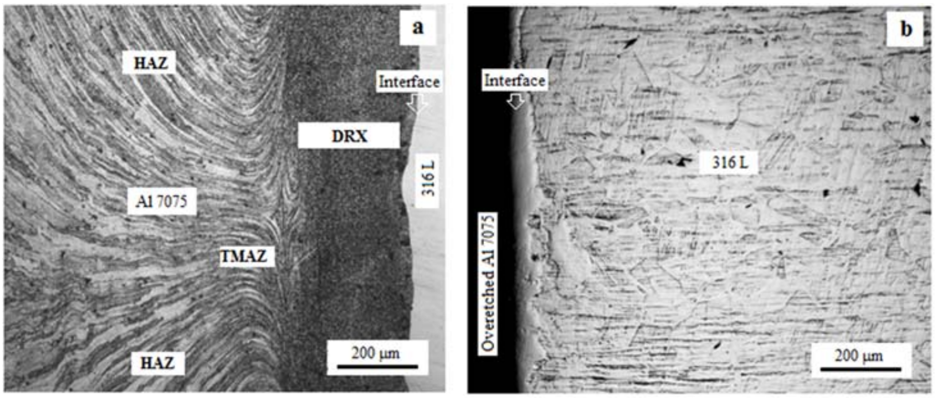

Figure 1.Optical micrograph of the sample welded for 10 s.

SEM micrograph and EDS analysis for welded samples for 10 s are shown in Fig. 2. It cannot be clearly observed that a diffusion zone at the weld interface for all of the welded samples (Fig 2a). However, EDS analysis results showed that there was a diffusion zone at the weld interface all the welded samples (Fig. 2b).

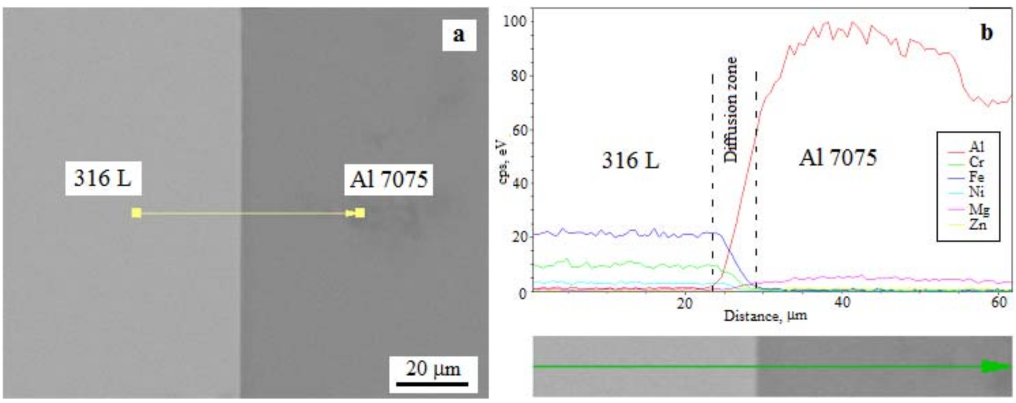

Figure 2.SEM micrograph and EDS analysis of welded samples for 10 s.

The diffusion zone present at the weld interface consists of Fe, Al, Cr, Ni, Mg atoms. The diffusion zone is rich in Fe and Al atoms and has lower amounts of Cr, Ni and Mg atoms.

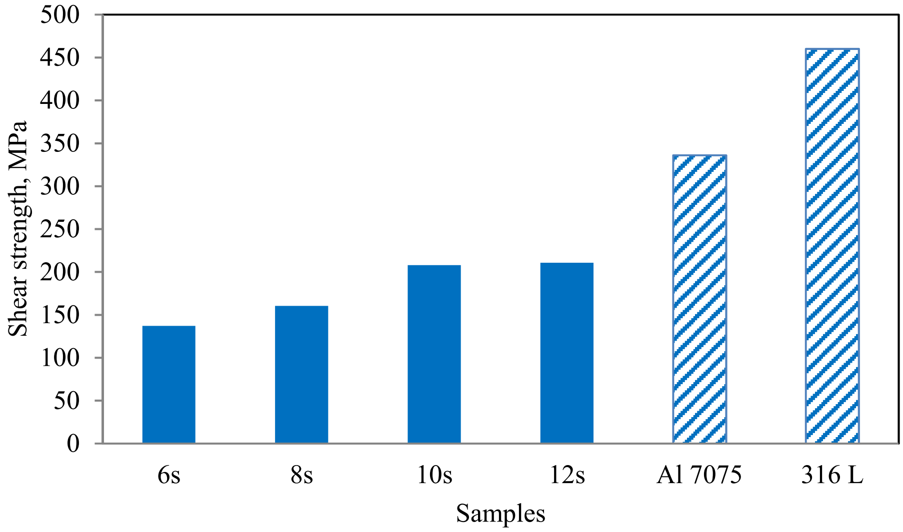

Figure 3.The shear strengths of the welds and the base alloys.

The shear strengths of the welds and the base alloys are shown in Fig. 3. The results showed that the values of the shear strength of the welded samples increase with increase in friction time. Under these experimental conditions, it can be said that the shear strength of welds was dependent on the friction time. This observation indicates that the increase in the shear strength is related to the magnitude of the accumulated heat input, which depends on the friction time. Especially, 6 s and 8 s friction times were not high enough to produce the required heat for the friction welding, compared with the 10 and 12 s treatments. Microhardness values were measured in the direction from the center of the weld to both sides of the welded samples. The micro hardness profiles for all of the friction welding times were found to be similar. Fig. 4 shows the hardness values obtained from all welded samples.

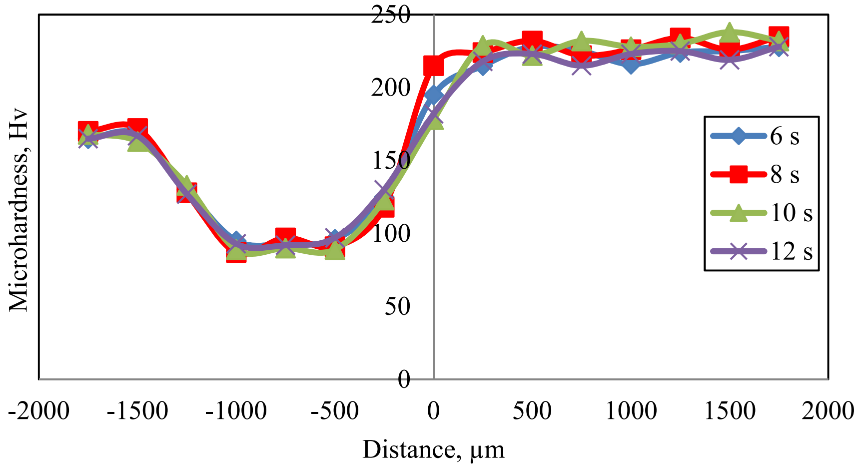

Figure 4. The hardness values obtained from all welded samples.

The hardness of the DRX, HAZ and TMAZ is lower than that of the base alloy on the Al7075-T6 side. The DRX hardness is not as low as the HAZ/TMAZ because of its extremely fine grained microstructure. The drop in HAZ and TMAZ can be explained based on strengthening precipitation. Al 7075 base metal in T6 condition contains a large number of submicroscopic Mg_2Zn and AlCuMg precipitate particles, which confer high strength and hardness to the alloy. During friction welding, The HAZ/ TMAZ experiences high enough temperatures for causing dissolution or coarsening of these strengthening precipitates. During cooling, the cooling rates are high enough to allow any reprecipitation of these strengthening phases. Therefore, the HAZ/ TMAZ hardness is lower than the base alloy harness (Khalid 2010). There was not any change on hardness of 316 L stainless steel side.

Conclusion

Al 7075-T6 alloy and 316 L stainless steel were welded by friction welding methods. All of the welded samples were of sound quality, and they did not exhibit any pores or crack formation along the weld interface. The friction time play an important role in flash formation and welds shear strength. The welds shear strength samples and burn-off increase with increase in the friction time. After welding, while three different zone observed in the Al 7075-T6 side, there was not any difference on the 316 L stainless steel side. The hardness profiles for all friction time are similar. It was observed that Al 7075-T6 side has different hardness values.

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