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Short communication

Effect of rotational speed on the interface properties of friction-welded AISI 304L to 4340 steel

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Abstract

The aim of this study is to investigate experimentally the interface properties in terms of rotational speed in friction-welded AISI 304L to AISI 4340 alloy steel. Friction welding was conducted with five different rotational speeds using a direct-drive type friction welding machine. Friction pressure, forging pressure, friction time and forging time are fixed. The integrity of joints was investigated by scanning electron microscopy, while the mechanical properties assessments included microhardness and tensile tests. The experimental results showed that the thickness of full plastic deformed zone (FPDZ) formed at interface reduce as a result of more mass discarded from the welding interface with increase of the rotational speed. It was also observed that the width of the FPDZ has a important effect on the tensile strength of friction-welded samples and the tensile strength increases with increase of the rotational speed.

Keywords: Friction welding; Interface properties; AISI 304L Stainless steel; AISI 4340 steel

1. Introduction

The austenitic stainless steels are generally considered the easy weldable of stainless steels [1]. Because of their physical properties, their welding behavior may be considerably different than those of the ferritic, martensitic, and duplex stainless steels [2]. It has been generally noted that the austenitic chrome-nickel stainless steels containing 12–25% Cr and 8–25% Ni are the most widely used for corrosion resistant applications and vessels, tubing, wire, medical and dental devices materials [3–5]. The ability to join austenitic steels itself and to other materials with conventional fusion welding process such as gas tungsten, laser, electron beam welding opens up the possibility to product unexpected phase propagation and a series negative metallurgical change such as delta ferrite phase, grain boundary corrosion, strain corrosion and sigma phase occurs at the welding interface. Therefore, extensive care and precautions like pre and post heat treatment or quick welding speeds are required [5–9]. And also the other joining problem on these type steels with fusion welding that long waiting time which lead to grain boundary corrosion between grains and probably to be arisen chrome-carbide precipitate at 450–850 °C of some steels particularly consisting Cr–Ni such as 18/8 [9,10]. As a consequence of this, if the material subjected to corrosive atmosphere it would commence corrosion from grain boundary because of having insufficient chrome of material's some region and finally gradually growing corrosion surrounds material [1,10].

In order to minimize joining problems of dissimilar materials, friction welding has represented the specific joint characteristic [11–15]. The advantages of this

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process are, among others, no melting, high reproducibility, short production time and low energy input [16–19]. Friction welding has advantage in materials that are hard to adopt fusion welding in that, it needs comparatively low thermal energy input in welding and causes minimal thermal degradation as base materials need not be fused for welding. In the practice, it is possible to bond a variety of dissimilar materials by friction welding processes. Friction welding is one of the solid state joining techniques, and in which components are brought into contact and with one of them remaining stationary, the other is rotated while pressure is applied [20]. When the temperature of the interface has reached an appropriate value for plastic deformation, the rotation is halted, while the pressure remains unchanged or increased. The friction welding process also permits the production of high-quality joints with little or no need for post-weld machining [16]. Many factors affect the quality of friction welds, including friction time, forging time, friction pressure, forging pressure, rotational speed and so on.

In the present research, friction welding was applied to join the commercial AISI 304L with commercial AISI 4340 steel. The joining performances of this steel couple were carried out by direct-drive friction welding welder under various friction welding conditions. This paper also aims to demonstrate the influence of increasing in the rotational speed on the interface phenomena, microstructure variation near the weld zone and mechanical properties were evaluated in detail.

2. Materials and method

Materials used in this study were commercial AISI 304L austenitic stainless steel rod (12 mm diameter) and AISI 4340 steel couple. The nominal chemical compositions of the test materials are listed in Table 1. Direct-drive friction welding machine was used in present study. Friction welding conditions are given Table 1. The friction welding assembly is shown in Fig. 1. After welding, the microstructures of friction-welded interfaces were observed by scanning electron microscopy (SEM). For SEM observations, cross-sectional interface of 304L/4340 friction-welded joints was grounded with using a SiC paper, and finally micro-polished using 0.3 μm Al_2O_3 powder. The microhardness values were measured on both sides of welded specimens using a 20 g indentation load. Mechanical properties of friction-welded joints were evaluated by tensile test. Tensile testing was performed at room temperature using an Instron type testing machine with 1.67×10^{-2} mm^{-1} cross head speed. Friction-welded specimens were machined for tensile testing. The dimensions of tensile test specimens are given in Fig. 2 (Table 2).

Fig. 1. The welding assembly of friction-welded AISI 304L/AISI 4340 components.

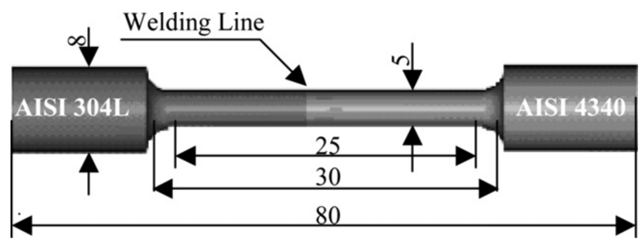

Fig. 2. Dimensions of tensile test specimen.

Table 1
Chemical compositions of test materials

Materials	Alloying elements (weight %)							
	C	Si	Mn	P	S	Cr	Ni	Mo
AISI 4340	0.425	0.343	0.692	0.014	0.007	0.80	1.461	0.220
AISI 304L	0.033	0.480	1.324	0.037	0.005	19.50	7.370	0.313

Table 2
The processes parameters used in the friction welding

Sample no.	Welding parameters					
	Rotating speed (rpm)	Friction pressure (MPa)	Forging pressure (MPa)	Friction time (s)	Forging time (s)	Axial shortening (mm)
S1	1500	40	60	5	10	2.3
S2	1700	40	60	5	10	2.8
S3	2000	40	60	5	10	4.1
S4	2300	40	60	5	10	4.5
S5	2500	40	60	5	10	4.8