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Friction welding of ductile cast iron using interlayers

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ABSTRACT

In this paper, ductile cast iron–austenitic stainless steel, ductile cast iron–pure Armco iron and ductile cast iron–low carbon steel interlayers were welded, using the friction welding method. The tensile strength of the joints was determined, using a conventional tensile test machine. Moreover, the hardness across the interface of materials was measured on metallographic specimens. The fracture surface and microstructure of the joints was examined using either light stereoscope microscopy as well as electron microscopy. In this case, scanning electron microscopy (SEM) and transmission electron microscopy (TEM) were applied. The results of the analysis shows that the joint has the tensile strength compared to that of basic material. In case of ductile cast iron, it is possible to reach the tensile strength equals even 700 MPa. It was concluded that the process of friction welding was accompanied with diffusion of Cr, Ni and C atoms across the ductile cast iron–stainless steel interface. This leads to increase in carbon concentration in stainless steel where chromium carbides were formed, the size and distribution of which was dependent on the distance from the interface.

1. Introduction

The joining of dissimilar materials plays a critical role in advanced manufacturing technology, since different properties are required within any particular application, the properties of which cannot be obtained by a single material. Depending on the manufacture and operating function, different materials are used for individual elements of a machinery component or structure to achieve an optimum of economical manufacture and mechanical properties.

Friction welding is one such solid-state welding process widely employed in such situation. Main advantages of friction welding are high material saving, low production time and possibility of welding of dissimilar metals or alloys. For example engine pistons, mainly for truck applications can be friction welded. In general there are two different types of material combinations-the first being a combination of steel and aluminum and the second ductile cast iron with mild steel. For the past 50 years friction welding has been used no only in the automotive industry but also in many other heavy and light engineering applications. Typical examples include electrical, hydraulic, tool and oil industry applications.

Many studies about the friction welding of dissimilar materials have been conducted by various researchers:

Akata and Sahin [1] investigated the effect of dimensional differences in friction welding of AISI 1040 specimens. Next year, Sahin and Akata [2] conducted an experimental study on the friction welding of medium carbon and austenitic stainless steel components. Sahin [3] investigated the tensile strength of austenitic-stainless steels friction welding joints. Sahin also studies [4] friction welding of medium-carbon steel and austenitic-stainlees steel componets. Sahin et al. [5] conducted an experimental study on joining of serve plastic deformed aluminum materials with friction welding method. Sahin [6] joined stainless steel and copper materials with friction welding. Sunay et al. [7] investigated the effects of casting and forging processes on joint properties in friction welded AISI 1050 and AISI 304 steels. Taban et al. [8] joined aluminum and AISI 1018 steel with friction welding. Arivazhagan et al. [9] investigated AISI 304 stainless steel to AISI 4140 low alloy steel dissimilar joints by friction welding. Özdemir et al. [10] investigated effect of rotational speed on the interface properties of friction-welded AISI 304L to steel. He found that tensile strength of joints was markedly affected by joining rotational speed selected. Özdemir [11] have also observed that the width of the full plastic deformed zone (FPDZ) has an important effect on the strength of the friction welded samples. Sathiya et al. [12] joined similar AISI 304/AISI 304 and AISI 430/AISI 430 with friction welding. Their friction processed joints were subjected to mechanical and metallurgical investigations. The mechanical properties and microstructure of friction welded joints between AISI 4140 and AISI 1050 steel was observed by Celik and Ersozlu [13]. The were no cracks or blank spaces in optical and SEM observations. Ahmad Fauzi et al. [14] investigated the microstructure and mechanical

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Table 1
The chemical composition of materials (wt.%).

Material	Alloying elements (wt.%)								
	C	Si	Mn	P	S	Cr	Ni	Mg	Fe
60-45-12	3.50–3.90	2.25–3.0	0.30–0.45	0.012–0.05	0.004–0.022	0.03–0.2	0.02–0.15	0.041–0.105	Balance
AISI 321	0.08 max	0.8 max	2.0 max	0.045 max	0.030 max	17–19	9–12	–	Balance
AISI 1010	0.08–0.13	0.05 max	0.30–0.60	0.04 max	0.050 max	–	–	–	Balance

properties al alumina-6061 aluminum alloy joined by friction welding. They observed that the microstructure of alumina–aluminum alloy friction welded joints revealed three different regions at the weld interface.

According to Crossland [15], friction welding is the ideal method of joining dissimilar metals. In his opinion, this process is also suitable for materials, which can be welded with difficulty. Thus, ductile cast iron can be welded and also joined to other materials such as steels with high alloy-content. Friction welding is applied for welding low ductility materials because it causes crystal refinement, the pattern of heat flow is simple and high compressive residual stresses are involved on the surface of these joints. However, there are also negative opinions, such as e.g. The American Welding Society [16], and Lebedev and Chernenko [17] from Paton Electric Welding Institute who have concluded that the friction welding of ductile cast iron is not possible because graphite acts as a lubricant and prevents the generation of heat sufficient for joining.

The structure of ductile cast iron is changed in the connection region such that the mechanical properties of the parts which have

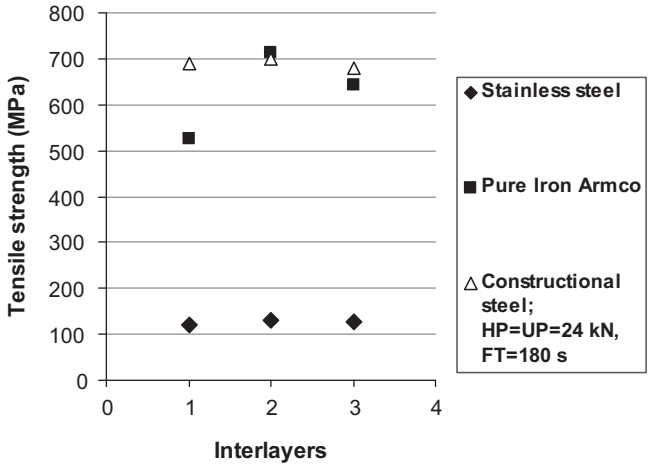

Fig. 2. Relationship between tensile strength and interlayers.

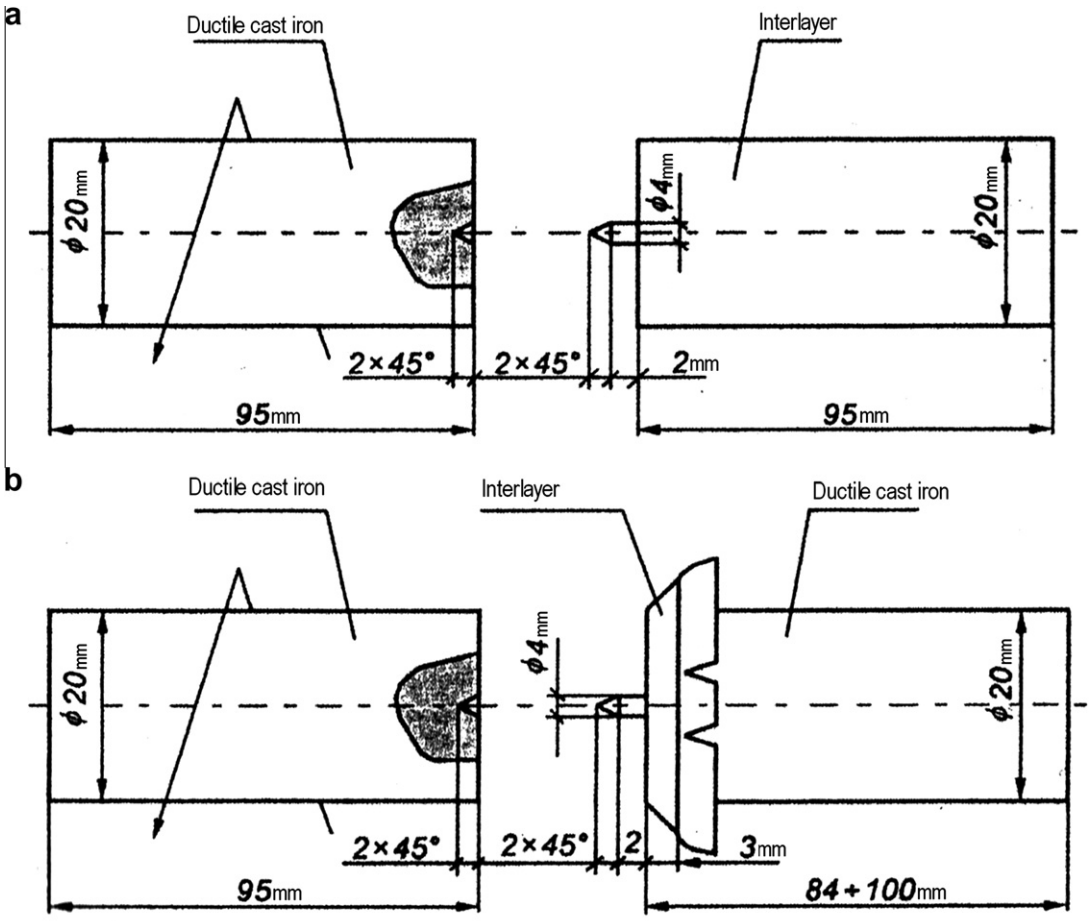

Fig. 1. Shape and size of specimens (unit-mm) before friction welding: (a)-friction welding of ductile cast iron to interlayer, (b)-friction welding of ductile cast iron to ductile cast iron by interlayer.