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Metallography of Dissimilar Fe-Ni Joint by Friction Stir Welding

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Friction stir welding (FSW) of commercially pure iron and nickel was carried out using the polycrystalline cubic boron nitride (PCBN) tool. The interface region revealed striations of the phases suggesting a complex flow pattern. TEM and Auger analyses revealed that the width of the interdiffusion zone was about 1.5 μm in single pass and 1.8 μm in double pass joints. The measured concentration profiles could be fitted using calculated profiles generated with static diffusion rates reported for iron and nickel. The diffusion profiles also indicated stabilization of the austenite phase at the interface with a nickel content of about 12 at.% Ni, considerably lower than what is predicted for diffusional or shear transformation to ferrite or martensite, which is proposed to be the result of high levels of plastic strain.

INTRODUCTION

Friction stir welding (FSW) is a solid state materials-joining process invented by TWI in 1991 (Thomas, 1991). In FSW, a hard cylindrical rotating tool is used to soften the materials by frictional heating of the work pieces. Once the rotating tool is fully plunged into the mating interface, it is moved along the joint. As the tool moves, softened material flows from the front of the tool to the rear, leaving behind a solid state joint. FSW is being widely investigated, especially in the aerospace industry, for joining high-strength Al alloys (Lohwasser, 2003).

Recently there has been considerable interest in exploring the use of FSW for joining steels and other higher-melting temperature materials (Ozekcin, 2004; Park, 2003). However, many fundamental aspects of the process still remain unanswered, e.g. the bonding nature of joint and materials flow pattern during welding. Studies regarding interface bonding and diffusion reveal the difficulty of joining similar materials because the identity of the 2 sides is lost during the welding. The overall objective of the present work was to develop a mechanistic understanding of the 3-dimensional flow pattern and interface bonding in FSW by utilizing dissimilar materials joined where flow patterns are easily visualized by differential etching and chemistry. The choice of FSW of dissimilar metals was made based on the following criteria: Similar melting points and comparable flow stresses at the joining temperature, and the same crystal structure at the joining temperature but different crystal structures at room temperature. In this study, Fe-Ni was the system of choice. The focus of this paper is to study the diffusion and microstructure at the interface of the joint. Future work will address the flow patterns observed in the joints.

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KEY WORDS: Friction stir welding (FSW), interface, diffusion, microstructure.

EXPERIMENTAL PROCEDURE

The materials selected for this study were 6.25-mm-thick pure (≥99.9%) nickel and iron plates—approximately 30-cm-long, 15-m-wide, cold rolled plates of commercially pure nickel and iron joined by FSW. Oxidation scale was removed by sand grinding followed by degreasing with methanol. Joining was performed using a polycrystalline cubic boron nitride (PCBN) tool with a head tilt of 3.5°. The tool has a pin with 3 small flats on a concave shoulder; its configuration and geometry are described elsewhere (Packer, 2003). An argon gas atmosphere was used to prevent oxidation during the weld cycle and to prolong tool life.

Both the single pass and double pass joints were produced as illustrated in Fig. 1. The single pass weld was produced by a conventional FSW joint with the tool traversing in one direction. The double pass was over the single pass with the additional FSW with the tool traversing in the opposite direction.

Following joining, samples from the joint regions were cut and prepared for optical, scanning electron microscopy (SEM), transmission electron microscopy (TEM) and field emission Auger electron spectroscopy (FE-AES) studies. Samples for SEM and FE-AES were prepared by conventional metallographic methods. Thin foils for TEM studies were prepared by cutting specimens from the interface, followed by mechanical thinning, dimpling

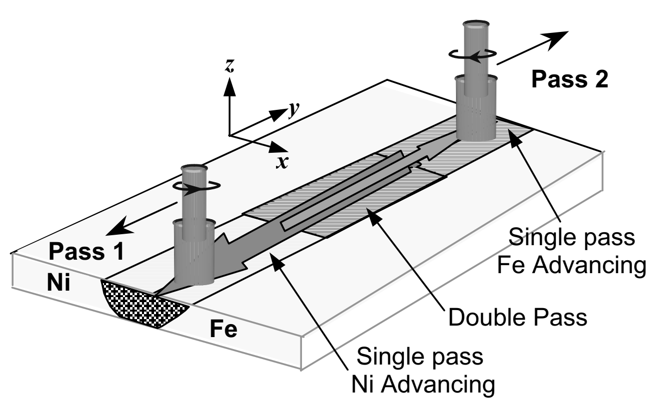

Fig. 1 Schematics of Fe-Ni FSW butt joint