



Effects of Superplastic Deformation on the Diffusion Welding of SuperDux 65 Stainless Steel

A two-stage diffusion process resulted in greatly improved weld strength

BY M. S. YEH, Y. H. TSENG AND T. H. CHUANG

ABSTRACT. The SuperDux 65¹ stainless steel diffusion welded in a nonsuperplastic state (880°C, 60 min) required greater pressure, compared to aluminum and titanium alloys, to create a contact area at the weld interface, which will increase the atomic diffusion paths. However, an unsatisfactory weld strength of 45.3 MPa was obtained under the applied pressure of 7 MPa. This alloy deformed easily at its superplastic temperature of 970°C, resulting in a tight contact surface. The higher welding temperature was also beneficial for atomic diffusion. Both effects were advantageous for diffusion welding, while the joined workpieces macroscopically deformed markedly. In this study, a two-stage diffusion welding method was proposed. The specimens were diffusion welded in a nonsuperplastic (or superplastic) state for a short time and then further diffusion welded at superplastic (or nonsuperplastic) temperatures for a longer heating period. It was found that the welding strength could be improved drastically using such a two-stage process. The contributions of superplastic deformation on the diffusion welding of this alloy during the two-stage process were clarified.

M. S. YEH is with Department of Mechanical Engineering, Chung-Hua University, Hsin-Chu, Taiwan, R.O.C. Y. H. TSENG and T. H. CHUANG are with Institute of Materials Science and Engineering, National Taiwan University, Taipei, Taiwan, R.O.C.

1. SuperDux 65 stainless steel is manufactured by Nippon Yakin Kogyo Co. Ltd, Japan.

Introduction

Duplex stainless steels are Fe-Cr-Ni ternary alloys that possess a microstructure consisting of nearly equal amounts of ferrite and austenite. These stainless steels offer several advantages over the austenitic and ferritic stainless steels, namely, higher mechanical properties, good weldability, superior corrosion resistance and a lower price (Refs. 1-3). As a result, the duplex stainless steels have been widely used in the aerospace, chemical, power generation and oil and gas industries (Ref. 4). Good joining techniques are necessary for expanding the applications of duplex stainless steels. Fusion welding has been most commonly used. However, the heat-affected zone (HAZ) generated by fusion welding could reduce the mechanical properties and corrosion resistance of the joined workpieces (Refs. 1, 5). Diffusion welding is another choice. Because diffusion welding requires atomic diffusion at the weld interface for the transportation of el-

ements, material with a finer grain size provides a larger number of grain-boundary diffusion paths and, therefore, would possess better diffusion weldability.

In addition, another necessary condition for satisfactory diffusion welding is intimate contact between the surfaces to be joined. Such intimate surface contact can be obtained in the conventional diffusion welding process by applying sufficient pressure, which causes microscopic plastic deformation at the contact surface between joined parts. It is well known that material with very fine grain size and a duplex structure will possess superplasticity at a certain strain rate (10⁻³~10⁻⁴ s⁻¹) and higher temperature (>½T_m, where T_m is the melting point in degrees Kelvin). A superplastic material can be greatly deformed under very little applied stress. For this reason, intimate surface contact can be obtained easily during diffusion welding of a superplastic alloy. This implies a superplastic alloy can be diffusion welded under a lower applied normal pressure.

Using the advantageous effect of superplasticity on diffusion welding, a two-stage heating process was proposed. During such a process, the specimens were first diffusion welded at a nonsuperplastic (or superplastic) state for a short time and then further diffusion-welded at a superplastic (or nonsuperplastic) temperature for a longer heating period. The welding stage at superplastic temperatures (higher than 900°C) offered a beneficial effect of an intimate contact surface while the other stage at nonsuperplastic tempera-

KEY WORDS

Diffusion Welding
SuperDux 65
Stainless Steel
Superplastic
Shear Strength

