High temperature mechanical behavior of solid state welded pure Ti

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1. Introduction

Solid state welding can be used to obtain welds with excellent mechanical properties through microstructure development, which is attributed to a lower heat input relative to that in fusion welding using arc, laser, and electron beam [1]. In particular, a lower heat input suppresses hot cracking and distortion of materials and production of harmful gas [2]. As a type of solid state welding, friction welding (FW) applies a friction force, rotation speed, and upset force at the material joints, and the microstructures and the mechanical properties of the welds are determined by these parameters. Besides, the friction heat and the metallic plastic flow that occurs during FW are sufficient for dynamic recrystallization of welds which results in grain refinement of the welds. Studies on welding of high temperature materials by several techniques have been reported. However, FW of pure Ti has been rarely reported. Therefore, this study was carried out to evaluate the microstructure development and mechanical properties of friction-welded pure Ti at high temperature.

2. Experimental procedures

The material used in this study were pure Ti (Grade 2), to apply the FW, specimens were prepared with a size of 15 mm diameter and 50 mm length. Subsequently, the specimens were welded using the FW machine of Nitto-Seike TM (FF-30II-C Model) at a rotation speed of 2,000 rpm, friction force of 20 kgf/cm^2, upset force of 30 kgf/cm^2, and upset length of 2-4 mm. Then, the surfaces of the specimens were electro polished at 20 V and –40 ℃ using a solution comprising 100 ml perchloric acid and 900 ml methanol. The sample surfaces were then investigated using an orientation image mapping system incorporated with a scanning electron microscope. For the evaluation of mechanical properties at high temperature, tensile tests by gleeble system were employed. Tensile tests were then conducted to the transverse direction of the friction welds at temperature of 400-600 ℃.

3. Results and Discussion

The FW on pure Ti led to significant grain refinement in the welds without the formation of a HAZ owing to the absence of coarsened grains near the welded zone. In general, frictional heating (approximately 0.5 – 0.6 Tm) and metallic plastic flow that take place during FW are sufficient to produce dynamic recrystallization during welding. Furthermore, severe metallic plastic flow during FW also contributes to simultaneous dynamic recrystallization, consequently leading to the formation of refined grains in the friction-welded zone relative to the base material. In this study, the friction-welded zone (average 0.7 μm) showed significantly refined grains when compared to the base material (average 11 μm). These refined grains at the weld zone lead to an increase in the mechanical properties such as yield and tensile strength at high temperature. Consequently, the yield and tensile strengths of the friction-welded material increased to more than 10% and 15% when compared to the base material zones, respectively.

4. Conclusions

Pure Ti was soundly welded without the formation of any defects, such as voids, cracks, distortion, etc., in the welds. The application of FW led to grain refinement of the welds owing to dynamic recrystallization, which resulted in significantly improved mechanical properties, such as microhardness and yield and tensile strengths when compared to the base material at high temperature. Furthermore, the absence of HAZ and phase transformation in the welds contributed to fracture at the base material zone, and not at the welded zone. Therefore, FW of pure Ti improves the microstructures and the mechanical properties of the welds when compared to fusion welding.

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