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Prediction Method of Transient Temperature Distribution in Friction Welding of Two Similar Materials of Steel

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ABSTRACT

A numerical method was proposed to predict transient temperature distribution in friction welding of two similar materials of steel. In this method, heat input was estimated using the data of thrust pressure and rotation speed which could be easily measured under a commercial friction welder. The estimated heat input was given as a boundary condition of heat flux at the weld interface, and a finite element method was used for solving an unsteady heat conduction problem of two-dimensional axis symmetry. Transient temperature distributions during whole friction welding process were calculated using variable thermal properties of the specimen materials of mild steel and stainless steel respectively. Calculated results were compared with experimental results, and the relationship between calculated temperature distribution and measured hardness distribution was investigated in the vicinity of weld interface.

KEY WORDS: Friction welding; friction heat input; cooling cycle; temperature distribution; heat affected zone; finite element analysis.

INTRODUCTION

Friction welding is a solid-state welding process for joining two similar or dissimilar materials. It is used widely throughout many manufacturing processes where high production rates are required. Friction welding conditions for the process are generally selected on the basis of past experience or study report. However, establishment of a method to decide the friction welding conditions in response to the phenomena which occur during friction welding has been needed because optimum welding conditions depend on each welding machine. Accordingly, many researchers have investigated the relationship between mechanical work, namely heat input, during friction welding and joint performance.

Shinoda et al. (1993) revealed that the mechanical properties were correlated with the heat input, and they concluded that the optimum welding condition was obtained with large heat input. Sawai et al. (1999; 2001; 2002) have demonstrated that the mechanical work in the upsetting stage affects tensile strength of the weld joints. On one hand, a lot of studies to analyze temperature distribution in the vicinity of weld interface have been carried out to understand the phenomena during friction welding process in detail. Numerical analysis of transient temperature distribution during friction welding of tubular form was carried out supposing heat flux at weld interface (Cheng 1962; 1963). Wang and Nagappan (1970) studied transient temperature distribution in inertia welding of steels. Suga et al. (1999) estimated heat input from friction torque measured by an experiment, and they calculated temperature distribution in friction welding of carbon steel with this heat input. Furthermore, simulation was carried out using a precise model of friction torque in the first phase of friction welding by Kimura et al. (2002).

Few investigations, however, have been carried out for a method to estimate transient temperature distribution using the data of thrust pressure and rotation speed which are able to measure easily in a commercial friction welder. Therefore the authors proposed a new method which combined a finite element analysis of unsteady heat conduction and a simplified model to estimate friction heat input based on the data of thrust pressure and rotation speed (Isshiki 2005a). By this method, the transient temperature distributions for different materials can be calculated using the different thermal properties such as specific heat and thermal conductivity of each material.

In this study, the method was applied to the friction welding of two similar materials of S25C (JIS) carbon steel and SUS304 (JIS) stainless steel. Experiments were carried out using a commercial friction welder, and calculated results of heat input and temperature distribution were compared with measured results. In addition, temperature distribution in the vicinity of weld interface and heat affected zone were investigated for carbon steel and stainless steel.