FEM 방법을 이용한 저항 점용접 공정의 열분석에 관한 연구

A study on the thermal analysis of resistance sport welding Process using a FEM method

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ABSTRACT In this paper, a 2D axisymmetric model of thermoelectric Finite Element Method (FEM) is developed to analyze the transient thermal behavior of Resistance Spot Welding (RSW) process using commercial software, called ANSYS. The determination of the contact resistance at the faying surface is moderately simplified to reduce the calculating time, while the temperature dependent material properties, phase change and convectional boundary conditions are taken account for the improvement of the calculated accuracy. The thermal history of the whole process (including cooling) and temperature distributions for any position in the weldment is obtained through the analysis.

1. Introduction

RSW process is a complex process in which coupled interactions exist between electrical, thermal, mechanical, metallurgical phenomena, and even surface behaviors [1]. Because of this complexity, it is very difficult to obtain insightful information of welding process through the most ambitious experiments alone. On the other hand, numerical modeling provides a powerful tool in studying these interactions. In the recent years, many related works have been carried out on the numerical modeling of RSW. Especially the FEM, which can deal with nonlinear behaviors and complex boundary conditions, has become the most important method for the analysis of RSW process [2-4].

Even if the iterative method provides the stress field, the electric potential field, the current density distribution and the transient temperature history in one calculation, the modeling of transient processes with such a methodology would probably require a tremendous computing time. Therefore, a relatively simple method should be considered to analyze the large complex structure such as automobile body component with thousands of welding spots and the minimum lost of accuracy.

The objective of this research is to develop a simplified method to predict thermal behavior of RSW process, and to prepare for further stress and strain analysis for large complex structure in RSW process. The developed simplified transient thermal analysis of RSW process has been performed in the commercial FEM program, ANSYS, and only the energy equation is considered due to limitation of thermal analysis. To keep the calculation accuracy, temperature dependent material properties, phase change and coupled electrical-thermal field are taken into account. To reduce the computing time, the relation between temperature field and contact status is also simplified.

2. Computational model

The transient thermal analysis of the RSW process in this research was modeled as an axisymmetric problem. Since the model is also mirror symmetric about the faying surface, only values of upper half of the model is considered and listed. In modeling RSW process with the complicated thermoelectric behavior, several physical phenomena must be considered. It is of great importance to define the parameters correctly to obtain realistic results. In this analysis, all the related values were cited from heat transfer and welding handbooks and other relative literatures [5]. Because the materials are subjected to a wide range of temperatures, these properties, except latent heat and density, were all considered as temperature dependent.

To simplify the problem, many researchers take the contact resistance as a function of temperature [5]. This simplification is reasonable since firstly, the load is constant in a specified RSW process; secondly, the yield strength of the materials, which determines the contact status in the contact area, is essentially influenced by temperature. Therefore, in this research, the temperature dependent contact resistance was imposed at the faying surface contact area (contact line in a 2D axisymmetric model). During the RSW process, the contact status continuously changed because the yield strength of the materials changed with temperature, even if the contact length did not change very much. Therefore, a constant contact length was adopted in this research. Several structural analyses were performed to determine the contact length, using Young's Modulus and yield stress at different temperature

3. Results and discussion

The heat transfer model proposed defines the temperature of any location in the workpiece and electrode as a function of time from the start of the process. Consequently, it can also define the time when the weld nugget begins to form. Fig. 1 represents the temperature versus time predictions at the center of the weld nugget as well as the center of the electrode-sheet interface, from which we can see the changing of temperature during the welding process.

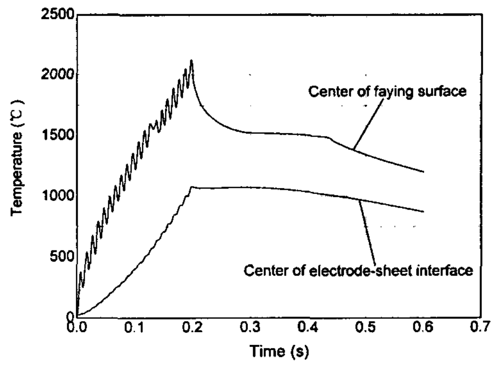

Fig. 1 Temperature distribution of two point

The calculated results also show that the temperature near the edge of the electrode-sheet contact area is very high compared with the center point, which is due to the heat generation at the edge of the contact, since a contact resistance (though a very little value) was specified. Fig. 2 represents the temperature history of the edge of electrode-sheet interface. It can be noted from the figure that the maximum temperature was up to 1346℃, nearly the molten point of mild steel, and verified by the observation of the surface of the weldment after welding. It can be concluded that a maximum stress occurred near the edge of electrode tip throughout the welding process as the similar researcher carried out [2]. The combination of high temperature and large stress could be the vital cause for the wear of electrode tip.

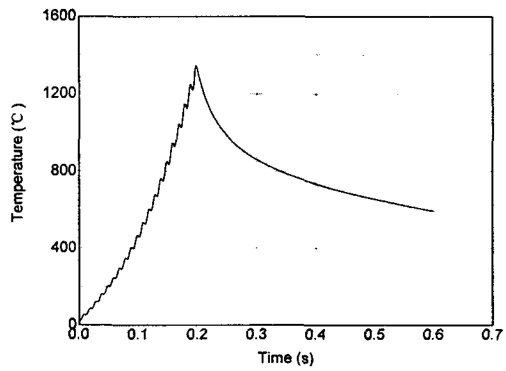

Fig. 2 Temperature history for the edge of electrode tip

4. Conclusions

A thermoelectric 2D FEM model has been developed to analyze the transient thermal behavior of RSW process and to predict the temperature distributions as a function of time and location for any position in the weldment. The developed model takes into account the following considerations: electric and thermal conduction in the solid, convection of cooling water and ambient air, latent heat of fusion due to solid-liquid phase change, and material properties as functions of temperature. The contact problem is moderately simplified to de-couple the interaction between thermoelectric and structural field. The contact resistance is considered as temperature dependent function, and the contact length is assumed to be constant. The thermal history of the whole process (including cooling) and temperature distributions in the weldment has been obtained through the analysis.

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