## E. Modeling Resistnace Spot Welding Electrode Life

*S. S. Babu†, M. L. Santella† and W. A. Peterson††, †Metals and Ceramics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6096, ††Edison Welding Institute, Columbus, OH-43221*

### Introduction

Electrode deterioration during resistance spot welding of coated steels and aluminum alloys is a well-known problem. There have been many attempts to model thermo-electricaldeformation response of electrodes through finite element modeling. However, the application of such models for extended life (> 500 welds) is severely limited by the computational time required to simulate each weld cycle. In addition, the modes of electrode deterioration at different regions of the electrode are still complex. In this research, we have developed a semiempirical model to predict the electrode life as a function of electrode property and peak temperatures achieved at the electrode-steel interface.

### Technical Approach

In this model, we hypothesize that the deformation at copper interface will be limited by its stress-strain constitutive behavior at the peak temperature. With this approach, the radial strain at copper electrode interface for each welding cycle was calculated. Through sequential accumulation, the increase in electrode diameter with number of welds was described. A simple finite difference method coupled with contact resistance model was used to describe the peak temperatures achieved at the copper-steel interface as a function of current density. In addition, to describe the chemical attack, the liquid-solid interface movement was modeled using diffusion controlled transformation models.

### Results/Discussion

The first step in the modeling approach is to describe the effect of temperature on the yield strength of the material. This was modeled using standard power law and by fitting to experimentally determined stress-strain diagrams. In the next step, the model requires the description of an average peak temperature achieved at the copper-steel interface as a function of current density. This relation was described using a sigmoidal curve based on simple finite difference model developed as a part of the current research. Previously published contact resistance model that relates the electrode strength, welding load and temperature was coupled with finite difference model. The model also used experimentally determined electrode strength deterioration with number of weld cycles. With this approach, the increase in electrode face diameter as a function of number of welds was predicted. The above model successfully described experimentally measured electrode face diameter with number. Parametric analysis using the model showed the sensitivity of electrode life to both yield strength at room temperature and the softening rate with temperature. The validity of the model for different conditions is evaluated with experimental measurements from different welding electrodes. Attempts to include the liquid-metal attack due to melting of zinc coating was made by using diffusion controlled transformation models. For this, the liquid-solid interface growth was calculated as a function of temperature and liquid composition in contact with a solid copper electrode.

## Conclusions

A semi empirical approach to model the electrode life as a function of electrode geometry, properties, steels coating, steel type and process parameters was proposed. The model has been constructed to consider the sequential deformation of copper at the steel sheet-electrode interface. The model successfully described the increase in electrode face diameter as a function of number of welds and showed the importance of yield strength of copper as well as softening resistance of copper. Preliminary attempts to describe the chemical attach was made through diffusion controlled growth models.

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