Effect of Electrode Degradation on Nugget Microstructures in Resistance Spot Welding of Aluminum Alloys

S. Fukumoto, E. Biro, I. Lum and Y. Zhou, Department of Mechanical Engineering, University of Waterloo
D. Boomer, Banbury Laboratory, Alcan International Limited

Introduction

Aluminum alloys are attractive materials for the automotive industry because of their high specific strength, superior corrosion resistance and recyclability. However, resistance spot welding of aluminum alloys requires high current density to obtain sound welds, due to the high electrical conductivity of these materials. Therefore, interactions occur between the electrodes and the workpieces, resulting in electrode tip degradation. The degradation mechanism has to be clarified to improve the electrode tip life. This study examines the microstructure of resistance spot welding nuggets and discusses the relation between nugget microstructure and electrode degradation.

Experimental Procedures

Resistance spot welding was carried out on aluminum alloy AA5182 sheets of 1.5 mm thickness. Cu-0.2%Zr electrodes were used. Welding was performed at 6 kN electrode force and a current of 29 kA. 2000 welds were made during the life test. The electrode tip life was estimated by the shear strength and button size after the peel test. Cross sections of the weld nuggets were observed by optical microscope and scanning electron microscope with energy dispersive X-ray analysis.

Results

Electrode performance displayed two stages in the tip life test. In the first stage, the shear strength and button size were adequate and remained constantly high. However, button size suddenly dropped to a small fraction of the initial value at about 400 to 900 welds. After the catastrophic drop, in the second stage of life, the shear strength and button size were not constant and variation became very large. Moreover, the probability of weld failures increased with increasing weld number. There were basically four types of weld failures; undersized oval and/or irregular button, partial button, through-nugget and interfacial failures. These unpredictable phenomena were found to be due to the weld nugget microstructures, which in turn was controlled by the electrode degradation.

The reduction in button size and shear strength was caused by two factors, i.e., insufficient heat input and defects (such as cracks, porosity, and wormholes). First, the contact area between electrodes and sheets increased with increasing weld number, resulting in the reduction of current density and hence undersized buttons. Second, interfacial and partial button failures (i.e., reduction in button size) were caused by edge pores, formed probably because of inhomogeneous pressure and current distribution. This inhomogeneous distribution is believed to be caused by electrode pits and cavities as a result of diffusion reaction between aluminum and copper and subsequent transfer of particles of alloyed material to workpiece surfaces. These two factors make tip life very difficult to predict.

Conclusion

The unpredictable phenomena of tip life in resistance spot welding of aluminum were due to multiple factors. Two interfaces, that is between electrode and aluminum sheet, and between the aluminum sheets, should be considered. Undersized nuggets were caused by the lack of heat input due to increase the contact area between the electrodes and sheets. The interfacial and partial failures were due to pores formed at the edge of the nugget. The reason for pore formation at the edge is probably inhomogeneous pressure and current distribution due to the pitting and cavities on the electrode.