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Dissimilar Joining of Metal/Polymer Using Friction Stir Spot Welding Method

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1. Introduction

Although mechanical bonding and adhesives are used to join dissimilar polymer/metal connections, these methods have some weaknesses. Mechanical bonding causes stress concentration in the structure and increases the weight. Adhesives needs long bonding times and proper surface cleaning. Recently, welding methods including friction stir spot welding (FSSW) have been developed for these purposes. In the joining of aluminum and polyethylene sheets with friction stir spot welding method, various factors affect the strength of joints. In this study, the effect of surface conditions and the dwell time of tool have been investigated.

2. Experimental procedures

AA1120 aluminum alloy and high density polyethylene (HDPE) sheets with the thickness of 2 mm were used as the base materials. FSSW was done on specimens using specimens with various surface treatments. The surface treatment was done by three different mandrels. The tool rotational speed and the plunge depth were fixed at 2500 rpm and 3.2 mm. The temperature gradient was measured using type K thermocouples.

The shear tensile strength of samples was measured. The strain rate for the shear-tensile test was 0.5 mm/min. The optical and scanning electron microscopy techniques were applied for more characterization of welds. The Olympus BX60M optical microscope (OM) and a LEO 1450VP scanning electron microscope (SEM) were used for microstructural studies.

3. Results and discussion

The major problem during dissimilar joining of aluminum and HDPE was the large difference between thermal expansion coefficients which could cause the failure of joints. Also, the high thermal conductivity of aluminum led to the surface melting of polymer; however, the aluminum part was the hotter side during welding. According to Fig. 1, the wetting area on the aluminum surface was developed with the increased dwell time. Furthermore, the temperature gradients of different regions during welding are shown in Fig. 2.

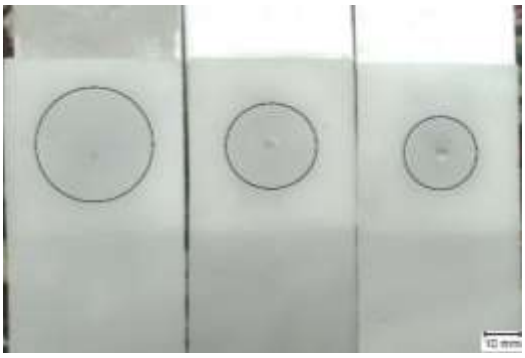

Figure. 1. The increased wetting surface with the dwell time from the right to the left.

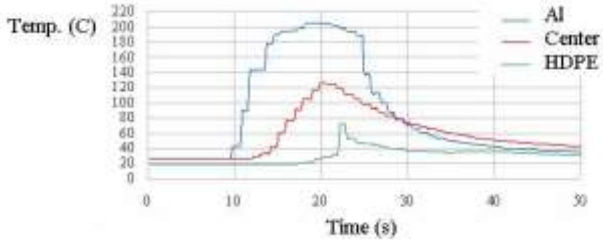

Figure. 2. The temperature gradients.

On melting of polymer, the tool plunging created a knob on the lower surface of the metal sheet. The mechanism of joining was wetting of the metal surface by the molten polymer and mechanical interlocking. The increased dwell time promoted the tensile shear strength of joints. The tensile shear load values are presented in Fig. 3.

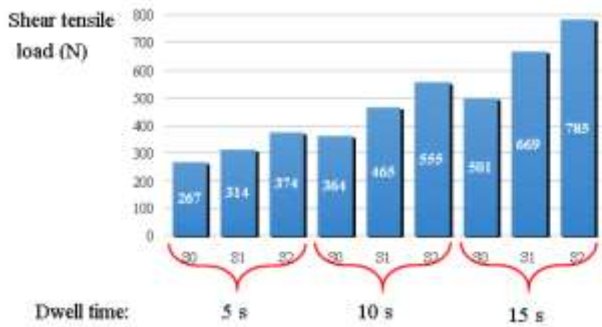

Figure. 3. The tensile shear fracture loads.

The results indicated the increased shear strength with the prolonged dwell time due to the higher frictional heating, more molten polyethylene and adhesion enhancement. The use of mandrill that created more scratches with smaller dimensions was more effective to increase the strength. The highest shear load of joints was 785N.

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4. Conclusions

The high thermal conductivity of aluminum led to the surface melting of polymer; however, the aluminum sheet was the hotter part during welding. The tool plunging created a knob on the lower surface of the Al sheet. The results indicated the increased tensile shear fracture load with the increased dwell time due to the higher frictional heating on FSSW. Macroscopic and microscopic studies revealed that the mechanical interlocking and adhesion of molten polyethylene on the aluminum surface were the main joining mechanisms.