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Analytical Stress Intensity Factor Solutions for Spot Welds Joining Sheets of Different Materials and Thicknesses

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ABSTRACT

In this paper, analytical stress intensity factor solutions for spot welds with ideal geometry in lap-shear specimens of different materials and thicknesses are presented as functions of the applied load, the elastic material property parameters, and the geometric parameters of the weld and specimen. The analytical stress intensity factor solutions are selectively validated by the results of a three-dimensional finite element analysis for a dissimilar spot weld with ideal geometry in a lap-shear specimen. Finally, selected stress intensity factor solutions at the critical locations of spot welds in lap-shear specimens of dissimilar magnesium, aluminum and steel sheets with equal and different thicknesses are presented in the normalized forms as functions of the ratio of the specimen width to weld diameter.

INTRODUCTION

Resistance spot welding is widely used to join sheet metals in the automotive industry. These resistance spot welds are subjected to complex multiaxial loads under service conditions. The fatigue lives of resistance spot welds in various types of specimens have been investigated by many researchers, for example, see Zhang [1]. Since resistance spot welds provide natural cracks or notches along the nugget circumferences, the stress intensity factor solutions at the critical locations of the main and kinked crack fronts for the welds have been developed and adopted in order to investigate the fatigue behaviors of spot welds in various types of specimens [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25].

It should be noted that the analytical stress intensity factor solutions developed in Lin et al. [23] and Lin and Pan [25] are for spot welds joining sheets of identical material and equal thickness. Zhang [16] developed a general procedure to obtain the stress intensity factor and J integral solutions for spot welds joining sheets of different materials and thicknesses. In Zhang [16], the stress intensity factor and J integral solutions are expressed as functions of the structural stresses. In this paper, the analytical stress intensity factor solutions for spot welds are presented as functions of the applied load, the elastic material property parameters, and the geometric parameters of the weld and specimen based on the available structural stress solutions developed by Lin and Pan [24]. The analytical stress intensity factor solutions are selectively validated by the results of a three-dimensional finite element analysis for a dissimilar spot weld with ideal geometry in a lap-shear specimen. Finally, selected stress intensity factor solutions at the critical locations of spot welds in lap-shear specimens of dissimilar magnesium, aluminum and steel sheets with equal and different thicknesses are presented in the normalized forms as functions of the ratio of the specimen width to weld diameter.

ANALYTICAL STRESS INTENSITY FACTOR SOLUTIONS

Fig. 1(a) shows a schematic plot of a lap-shear specimen with a spot weld idealized as a circular cylinder. The upper and lower sheets used to make the specimen have the nominal thicknesses t_u and t_l, respectively. In this paper, a subscript or superscript u represents the upper sheet and a subscript or superscript l represents the lower sheet. As shown in Fig. 1(a), the lap-shear specimen has the width $2b$ and the nugget diameter $2a$. Here, L represents the length of the upper and lower sheets of the specimen, and V represents the overlap