

Fatigue Assessment of Spot Welds Based on Local Stress Parameters

Critical annotations to formulas proposed by S. Zhang

BY D. RADAJ

Editor's Note: The presentation below is a critical assessment of the research paper "Approximate Stress Intensity Factors and Notch Stresses for Common Spot-Welded Specimens" by S. Zhang, published in the Welding Journal, May 1999, pp. 173-s to 179-s.

The fatigue assessment of spot welds is based on local stress parameters: structural stress, stress intensity factor (SIF) and notch stress (Refs. 1–3). A high degree of expertise is necessary to define these stress parameters in a consistent manner and to apply them appropriately to the fatigue assessment of spot-welded specimens and structural members. The approximated SIF and notch stress formulas proposed by S. Zhang (Refs. 4, 5) have deficiencies, which are summarized below.

Suitability of Local Stress Parameters

The structural stress in the overlapping plates at the periphery of the weld spot is the most important parameter for characterizing the (high-cycle) fatigue resistance of spot-welded joints. It is successfully used directly for this purpose, and is the basis for determining the stress intensity factor at the sharp slit tip or the notch stress concentration at the rounded slit tip. The structural stress is defined as membrane and bending stress linearly distributed over the plate thickness that is

without the stress increase by the slit tip notch. It can be calculated rather accurately by the finite element method with fine meshing or approximated by the joint-face forces and self-equilibrating forces in the overlapping plates based on finite element results with coarse meshing, the weld spots being substituted by rigid bars. The procedures above apply to plate fractures of well-designed weld spots whereas joint-face fractures in weld spots of too small a diameter are described by the structural stresses in the nugget.

The SIF approach is less suited for characterizing the fatigue strength of spot welds because sharp slit tips seldom occur in reality and because the nonsingular stress components are neglected. The notch stress approach is also less suited because the real notch shape at the slit tip scatters with the production conditions (no data available) and because the support effect of sharp notches makes a special hypothesis necessary, which is not verified for spot welds.

A general theory of forces and struc-

tural stresses at weld spots was developed by the author (Ref. 6) together with an efficient method of determining the SIFs at the weld spot periphery on the basis of the structural stresses (Refs. 1, 2).

The design stresses of spot welds in the European automotive industry refer to the structural stress approach. The SIF approach has found some consideration in Japan. The notch stress approach is still a mere research option.

Deficiencies of Zhang's Approach

The main deficiencies of Zhang's approach (Refs. 4, 5) are summarized below without the theoretical details. Accurate data on stress parameters in spot-welded joints are given in Refs. 3, 7 and 8.

The SIF approach in Refs. 4 and 5 neglects the stress effects of the self-equilibrating forces. These are forces (and moments) acting in the overlapping plates without generating a joint-face force. The above means that the weld spot strength is considered as being independent of the support conditions of the plate (e.g., one-sided against two-sided support in shear loading, Fig. 1) and as being independent of certain loading conditions (any self-equilibrating force system may be superimposed, Fig. 2). But the weld spot fatigue resistance depends on the support and loading conditions mentioned above.

The SIF formulas in Refs. 4 and 5 do not capture the plate width as an important geometrical influencing parameter. This has the consequence that the fatigue resistance of spot welds is considered as independent of the plate width, which is not really the case. Narrow flanges espe-

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