10th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

FATIGUE BEHAVIOR OF SPOT WELDS IN MODIFIED TENSILE SHEAR SPECIMENS USING NUMERICAL DATA

Ahmet Hanifi ERTAŞ
Boğaziçi University
Mechanical Engineering Department, İstanbul
Turkey

ABSTRACT

The resistance spot wells are used especially in automotive and airplane industry -for example, a car body contains approximately 5000 spot weld and this spot weld numbers reach to 15000 in a bus or coach body according to contraction engineers- because of its simplicity, low cost and of course reliability (which are significant aspects of manufacturing processes) to the other type of joining techniques like rivet joint, bolted joint and bonded joint. In this point, it can be said that the integrity of the resistance spot welds determines the overall structural rigidity and integrity of the vehicle. Thus, it is important to understand the mechanical behavior of spot welds under representative types of loading conditions and the life predictions of spot welded specimens.

Keywords: fatigue, spot weld, life prediction, finite element modeling

1. INTRODUCTION

Resistance Spot Welding (RSW) is a much more convenient joining technique than the other type of joining techniques (e.g. bolted joint, riveted joint, adhesive bonded joint etc.) especially in terms of mass production in industry. In addition to adaptability of RSW to the mass production, it is also an inexpensive and effective way to join especially thin sheet components of metals. Although RSW has been used for many years, predicting exactly what occurs in and around the welds is very difficult and has not been understood exactly by previous researchers. Complex geometries, a non-homogeneous metallurgical structure, and residual stresses make analysis extremely difficult [1, 3].

Fatigue is a frequent cause of failure in sheet steel and aluminum joined by spot welds. The majority of spot welds fail in fatigue due to through-thickness cracks. These cracks initiate from the notch root at the faying surface (shown as point A in the figure) and propagate in the thickness direction (like thumbnail), as shown in Figure 1. Fatigue life is defined as the number of loading cycles it takes for the first crack in the joint to initiate and propagate through thickness of the sheet and becomes visible from the outer side of the sheet [1, 2, 3].

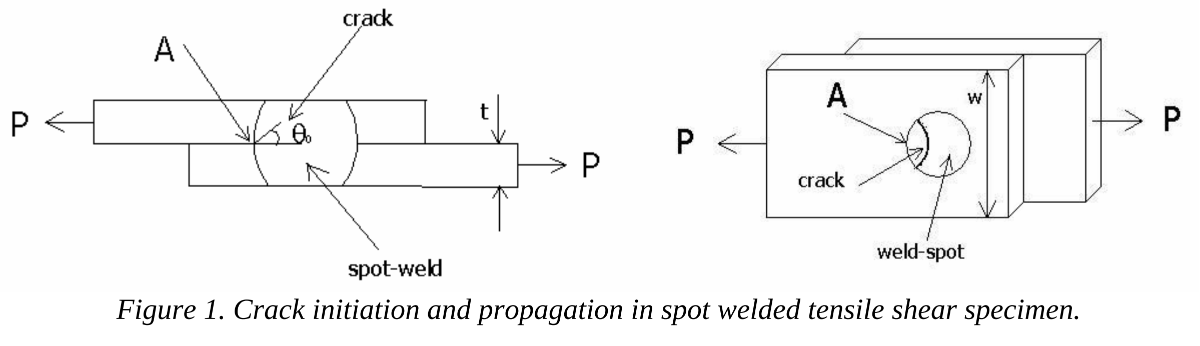

Figure 1. Crack initiation and propagation in spot welded tensile shear specimen.

2. FATIGUE

A fatigue failure begins with a small crack. The initial crack is so minute that it cannot be detected by the naked eye and is even quite difficult to locate in X-ray inspection. The crack will develop at a point of discontinuity in the material, such as a change in cross section, a keyway, or a hole. Less obvious points at which fatigue failures are likely to begin are inspection or stamp marks, internal cracks, or even irregularities caused by machining. Once a crack has developed, the stress-concentration effect becomes greater and the crack progresses more rapidly. As the stress area decrease in size, the stress increases in magnitude until the remaining area fails suddenly [1, 3].

3. FATIGUE LIFE PREDICTION METHODS FOR SPOT WELDS

There are of course different types of fatigue life prediction methods, which are “Local Strain-Based Method”, “Linear Fracture Mechanics Method”, “Nugget Deformation Method”, “Combined Initiation and Propagation Method”, “Structural Stress Method”, to predict the so called fatigue life of the components in a construction and make convenient and reliable designs. For example, using “Combined Initiation and Propogation Method“, the fatigue life of modified tensile shear specimen is represented by the following formula [1, 3];

$$N_f = \frac{1}{2}\sqrt[b]{\frac{\Delta S.K_f}{2\left(\sigma'_f - \sigma_m\right)}} + \frac{1}{C}\int_{a_i}^{a_f} \Delta K^{-m}\, da \qquad (1)$$

where;

N_f = Cyclic life of specimen to some degree of failure,
C, m = Material constants used in Paris-Erdogan power law,
σ'_f , b = Material constants used in Basquin relation,
a_i = Initial crack length,
a_f = Final crack length,
ΔK = Range of stress intensity factors,
σ_m = Mean stress,
ΔS = Remote applied stress,
K_f = Fatigue notch factor appropriate for the notch geometry.

4. FATIGUE LIFE CALCULATION USING NUMERICAL METHOD

Studies on MTS specimens have mainly focused on experimental work. It is important to note that while experimental studies provide the necessary physical insight about the behavior of spot-welded joints, predictive tasks such as design, analysis and evaluation of spot-welded structures are often carried out by computational methods. But because of geometrical complexity of spot welded joints, effective correlation between the mechanical performance of the joints and the stress and deformation fields around the joints is difficult from experimental results. Hence numerical methods have advantages over experimental methods in terms of especially stress distribution and fracture mechanism of specimen [1].

In numerical analysis, the geometric dimensions of the MTS specimen are; the two end pieces of MTS specimen are 70 mm in length, 40 mm in width and 1 mm in thickness, the center piece of MTS specimen 90 mm in length, again 40 mm in width and 1 mm in thickness but at the same time has two flanges which are 9 mm in height and 1 mm in thickness, the diameter of the two nuggets is 8 mm, the overlap length of center and end pieces is 35 mm, and the space between the overlap portions of pieces was assumed as 0.02 mm because in previous studies generally this value has been choosed as 0.02 mm. The material properties are; the Young's values are 1.9E+5 Mpa for base material and 2E+5 Mpa for spots, the Poisson's ratios are 0.25 for base material and 0.20 for spots Using these geometric and material properties, the so called model for MTS obtained with the aid of ANSYS as shown in Figure 2.

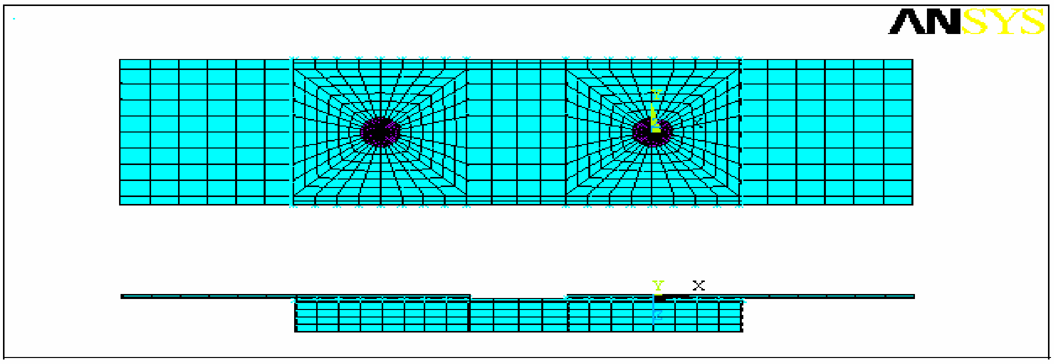

Figure 2. Front and top views of "Modified Tensile Shear Specimen" obtained by using ANSYS .

In order to obtain fatigue life of the so called specimen, some loading cases, which are 3700-200, 3500-150, 2700-150, 2400-150, 2250-150 and 1500-150, were examined, then using these maximum and minimum stress values of the critical nodes, that is the nodes which situated at the peripheries of the spots, with the"Morrow's mean stress method" fatigue life of the specimen under different loading conditions were calculated.

5. NUMERICAL ANALYSIS RESULTS

After conductions numerical analysis via the ANSYS, the stress values for critical nodes, which situated on the peripheries of the spot welds, are obtained and using this values with "Morrow's mean stress method", fatigue life of the so called modified tensile shear specimen were calculated. Figure 6 shows the numerical results of the fatigue life of the MTS in terms of Applied Force versus Number of Cycle. In order to see the stress distribution values on specimen, Figures 3 through 5 were added which show the stress distribution values (in terms of Von-Mises values) on the surfaces of the center and the end pieces (for the loading case of 2400 N).

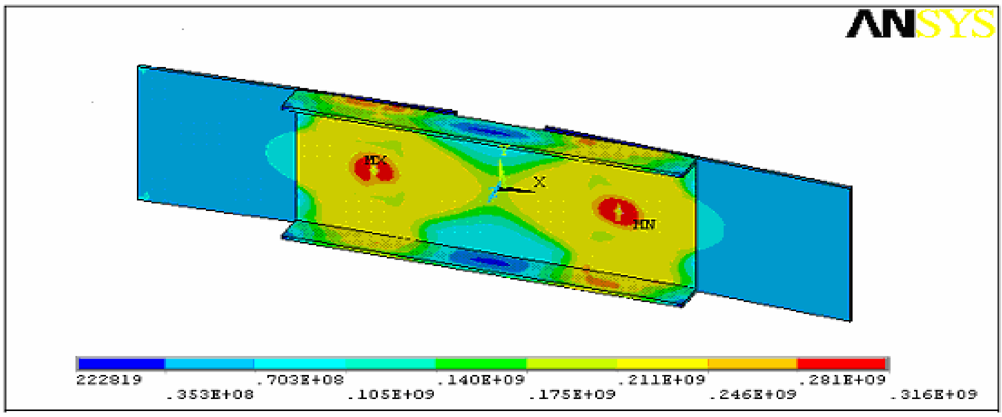

Figure 3. Distribution of Von-Misses stress value on full shape of MTS geometry.

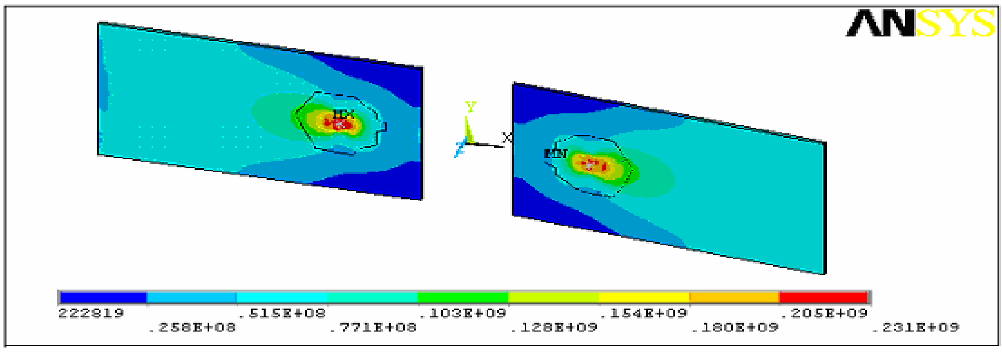

Figure 4. Distribution of Von-Misses stress value on end pieces of MTS geometry.

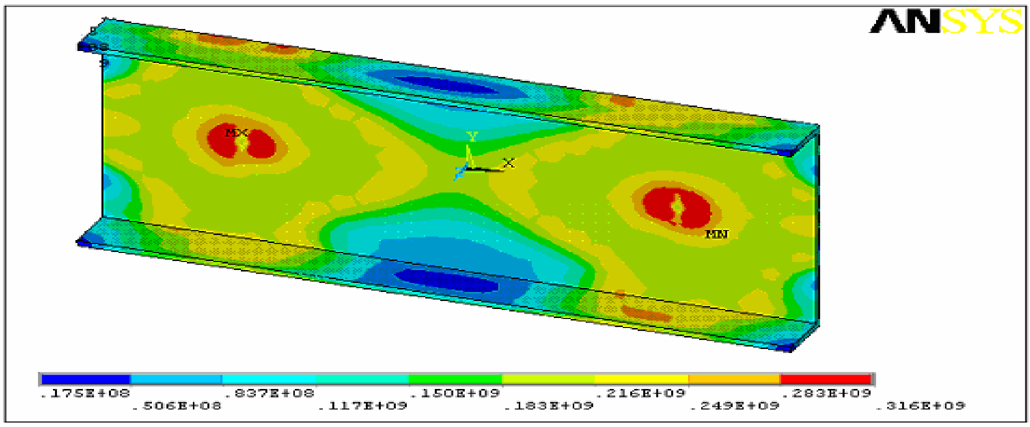

Figure 5. Distribution of Von-Misses stress value on center piece of MTS geometry.

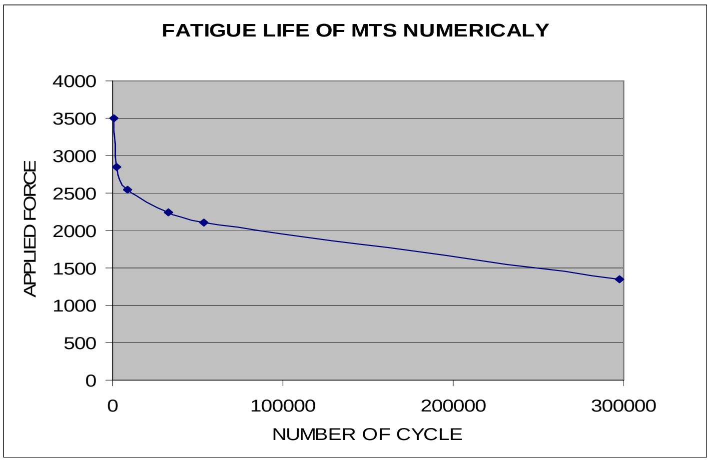

Figure 6. Fatigue Life Values for MTS obtained by using ANSYS .

6. CONCLUSIONS AND RECOMMENDATIONS

Examining the stress distributions of MTS specimen, it can be said that the deformation of lap zones of the spot-welded joint in the middle part is more serious than the other zones of the specimen. The reason for the phenomena may be as follows. The loads which are applied to the spot-welded specimens are borne completely by the spot welds in spot-welded joints. Hence the stresses flow with concentrating to the spot welds in the middle parts of the lap zones, so that high stresses arise there.

From the finite element analysis, it is clear that a stress concentration or singularity exists at the interception of the nugget boundary with the interface of joined sheets because all Von Mises stresses, tensile stresses, bending stresses etc. have their maximum magnitudes near the nugget boundary. These stress distributions explain successfully the phenomenon that why the fractures are generally first created around the nugget for the spot-welded joints.

Finally, as can be seen in Figure 6, with dicreasing load amplitude the life of the specimen increased which support our expectations and the results of experimental studies.

7. REFERENCES

[1] Ertaş A. H., Fatigue Behavior of Spot Welds, M. S. Thesis, Bogaziçi University, 2004.
[2] Ertaş A. H., Vardar Ö., Punta Kaynaklarının Yorulma Davranışı, Havacılıkta İleri Teknolojiler Sempozyumu (HITEK), İstanbul, 2004.
[3] Ertaş A. H., Vardar Ö., Fatigue Behavior of Spot Welds in Modified Tensile Shear Specimens using Experimental Data, 9th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology", Antalya, 2005.