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# Failures in Spot Welding

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**Abstract**—*Resistance spot welding is an extensively used welding process for joining thin metal sheets in automobile, rail and aircraft industries. Research on resistance spot weldability of stainless steel attracts more and more attention with the increasing usage of various types of stainless steel in industries.Resistance spot welding is used to join two or more metal sheets together, and the technique is used widely in theautomotive industry, for example. Furthermore, other metal-to-metal connections, such as wire-to-wire joints inthe electronics industry, are accomplished by resistance spot welding. In this paper, a review of works done on failures arrive in resistance spot welding is presented.The areas chosen for most of the works by researchers in the past have been found as process modelling and finite element analysis, dissimilar metal welding, failure mode analysis, parametric optimization and characterization of resistance spot welds. The information presented in this report may definitely give the fresh researchers, a view of the research work done in the past, in this field, and is expected to provide them the right direction for the future research work, in this area.*

***Keywords***-*Resistance spot welding,stainless steel, failure.*

## I. INTRODUCTION

Resistance spot welding was invented in 1877 by E. Thomson. It is a process of joining two or more metal parts by fusion at discreet spots at the interface of work pieces. Resistance to current flow through the metal work pieces and their interface generates heat and hence temperature rises at the interface of work pieces. When the melting point of the metal is reached, the metal will begin to fuse and a nugget begins to form. The current is then switched off and the nugget is cooled down to solidify underpressure [1, 2].

Resistance spot welding is widely used in sheet metal fabrication as an important metal joining process. It has got lot of applications in the field of automobile industries, rail coach manufacturing, aerospace and nuclear sectors, electric and electronic industries. It can be used on a variety of materials such as low carbon steel, nickel, aluminium, titanium, copper alloy, stainless steel and high strength low alloy steel. It is also plays an important role in Robotics. Chaostated that the modern vehicle contains 2000 to 5000 spot welds. Simplicity, low cost, high speed and automation possibility are among the advantages of this process[ 3 ].

## II. Failure analysis of lap-shear specimens in resistance spot welding

With the rapidly increasing requirements in lightweight, many automotive companies arewidelyusingvarious advancedmaterials,suchasaluminumalloyandadvancedhigh strength steel(AHSS),tostampinto final productssuchas automotivebodypanelsandothermajorstructuralframes.AHSSs, as oneclassofpromisingengineeringmaterialsusedincarbody structures, havedrawnincreasingattentionrecently,these results in reduction of structuralweightbutenhancingtheperformanceunder operational andcrashingconditions[ 4 ].

In general there are two modes through which a spot weld fails: interfacial and pullout (figure 1). In the interfacial mode, failure occurs by crack propagation through fusion zone (weld nugget).In the pullout mode, failure occurs by complete (or partial) nugget withdrawal from one sheet.

Failure mode of RSWs can importantly affect the carrying capacity and energy absorption capability. Spot welds which fail in nugget pullout mode provide higher peak loads and energy absorption levels than spot welds that fail in interfacial fracture mode. To ensure reliability of spot welds during vehicle lifetime, process parameters should be adjusted so that pullout failure mode is guaranteed.

Fusion zone's size is the most important parameter which help in determining its mechanical behavior. There are various standards which recommended a minimum weld size for a given sheet thickness. For example, American

 

Welding Society/American National Standards Institute/Society of Automotive Engineers (AWS/ANSI/SAE) has recommended equation (1)

$d=4t^{1/2}$ …….. (1)

Where, d and t are weld nugget diameter and sheet thickness in mm respectively.

In practical automobile applications, the nugget pullout is a preferable failure test approach because the load-carrying capacity is higher, and the interfacial failure usually carries lower mechanical loading and absorbs less energy than the nugget pullout failure. Since the spot weld may generate an inherent crack along the weld nugget, it is of a critical importance to the study on failure modes.

*(a) (b)*

*Figure 1. Failure modes of spot welds during tensile-shear test a) interfacial and b)pullout failure mode.*

### 2.1 Pullout failure mechanism of tensile-shear test specimen

Figure2 shows a simple model describing stress distribution at the interface and circumference of a weld nugget during the tensile-shear test. Shear stresses are dominant at the interface. At the nugget circumference, stresses are shear tensile at position T and shear compression at position C (Figure 3).

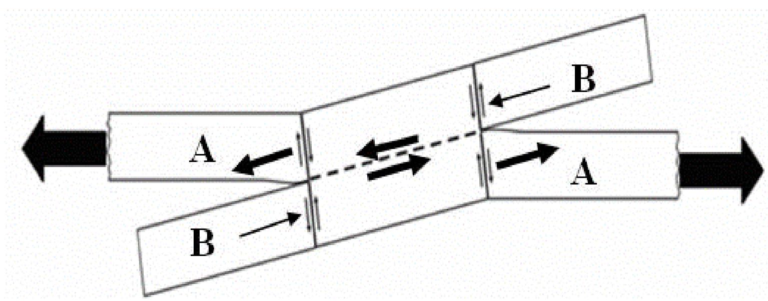


*Figure 2. A simple model describing stress distribution at the interface and circumference of a weld nugget during the tensile-shear test.*

In pullout failure mode, when there is certain amount of rotation, the tensile stresses formed around the nugget cause plastic deformation in sheet thickness direction. Finally, necking occurs at T sites as tensile force increases. These T sites are located in HAZ (Heat affected Zone) or in the BM (Base Metal). In case of B sites necking does not occur because normal stresses are of compression type in these sites. This necking is not equal in both sheets. The stress concentration caused by the uneven necking in the two sheets leads to the failure of spot weld from one sheet. If the necking area is continually stressed, the nugget will eventually shear off from the other sheet.

Figure 3 shows macrograph of fracture surface of a spot weld which failed at pullout mode. The failure of the spot weld appears to be initiated near the middle of the nugget circumference, and then propagated by necking/shear along the nugget circumference until the upper sheet is torn off.

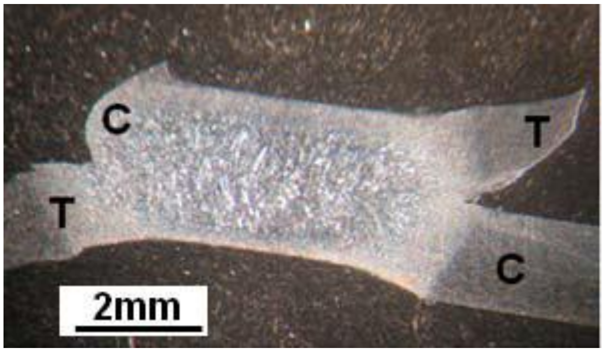


*Figure 3 A typical macrograph of fracture surface cross section of spot welds which failed via pullout failure mode during tensile-shear test. T: Subjected to tensile stress; C: Subjected to compressive stress*

**2.2 Pullout failure mechanism of coach-peel specimens**

*(a) (b)*

*Figure 4. Failure modes of spot welds during coach-peel test a) interfacial and b) pullout failure mode.*

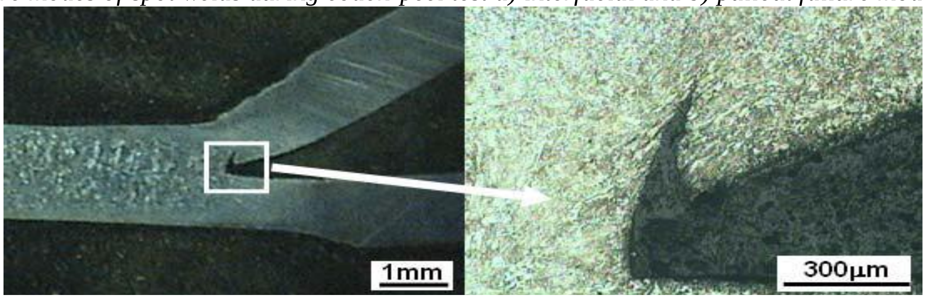


*Figure 5. A typical macrograph of fracture surface cross section of spot welds which failed via pullout failure mode during coach-peel test.*

In order to understand the failure mechanism, micrographs of the cross sections of the spot welded joints after coach-peel are examined by optical microscopy. Macrograph of fracture surface of a spot weld which failed at pullout mode during coach-peel test. As can be seen, failure mechanism of the coach-peel specimens is distinctly different form that of tensile-shear specimens. Pullout failure in coach-peel test is accompanied by crack initiation and propagation. As can be seen form Figure 5 crack initiates adjacent to the notch tip, at or near the faying surface. Crack initiation site is located in the coarse grained HAZ. Final fracture occurs as the crack propagates through the sheet thickness. The observed mechanism is in agreement with mechanism suggested by Zuniga and Sheppard [5]. They divided the failure sequence of the spot welds in the coach-peel specimens into four stages:

I) Propagation of the notch tip toward the fusion zone,
II) Large tensile strains at the faying surface blunt the notch tip.
III) Ductile fracture initiation adjacent to the blunted notch tip. Crack initiation occurs by micro void coalescence.
IV) Final fracture occurs by crack propagation in through thickness direction.

**Conclusions**

1. The coach-peel specimens in pullout failure mode failed by initiation and propagation a crack adjacent to the blunted notch tip. Tensile-shear specimens in pullout failure mode failed by through thickness necking.

 

2. Failure locations of coach-peel and tensile-shear specimens were in the base metal region and coarse grain HAZ, respectively.
3. There is a minimum fusion zone size to ensure pullout failure mode during mechanical testing of resistance spot welds. The critical fusion zone size to ensure pullout failure mode during tensile shear test was larger than that of during coach-peel test.
4. Force is necessary for fusion zone formation in resistance spot welding, overloading will results in excessive reduction of weld nugget size, failure strength and changes failure mode from pullout to interfacial.

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