Experimental Analysis of Fatigue Life for Spot Welded Joints With Different Arrangement

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ABSTRACT

Spot welded joints are widely used to fasten metal sheets together. In the present study, the effects of spot weld arrangements in multi-spot welded joints on the fatigue behavior of the joints are studied. Three different four-spot welded joints are studied: one-row four-spot parallel to the loading direction, one-row four-spot perpendicular to the loading direction and two-row four-spot weld specimens. The experimental fatigue test results reveal that the differences between the fatigue lives of three spot welded types in the low cycle regime are more considerable than those in the high cycle regime. However, all kinds of spot weld specimens have similar fatigue strength when approaching a million cycles. A non- linear finite element analysis is performed to obtain the relative stress gradients, effective distances and notch strength reduction factors based on the volumetric approach. The work here shows that the volumetric approach does a very well in predicting the fatigue life of the multi-spot welded joints.

Keyword : - Spot welded joints, Fatigue strength, Fracture mechanisms, Nugget Diameter.

1. INTRODUCTION

There are several joining methods such as adhesive bonding and laser beam welding but resistance spot welding remains the primary method for joining bodies and panels in automobile sector. In automobile and other industries to produce complex components multi spot welded joints are often used. But the size and complex nature of this joint often makes the testing of joint difficult and complex, especially when long term testing is to be performed, as in the case of determining the fatigue properties. On the other hand it is easy to produce and test single spot weld on existing equipment without any modification. Of course, it is very useful to be able to predict the fatigue properties of multi-spot welded components based on data obtained from testing single spot welds. There are currently several models proposing methods for predicting the fatigue life of specific joints using simple geometry, most of which are based on fracture mechanics approaches. However, as more spot welds are added and with that joint complexity increases, these models, which are the existing models tend to lose the accuracy that they are having. The primary purpose of this project is to divide complex multi point welded joints into individual welds and determine whether the overall fatigue properties of the joint as a whole can be determined by understanding the fatigue properties of individual welds. If this process is proven, the accuracy of existing fracture mechanics models can be maintained even for complex joints, provided the joint is first divided into welds. The purpose of this project was to divide a complex multi-point weld joint into individual welds and determine if understanding the fatigue properties of individual welds could determine the overall fatigue properties of the joint as a whole. If this process is proven, the accuracy of existing fracture mechanics models can be maintained even for complex joints, provided the joint is first divided into welds.

2. LITERATURE REVIEW

Nejad et al. (2021) numerically investigated the material 2024 aluminum plate riveted joints for fatigue life and the fatigue crack growth path. Importance given to the problem of crack growth in 2024 aluminum plates, having the geometrical and physical parameters of the problem, the goal was to achieve the exact path of crack growth and fatigue life of riveted joints. Fatigue crack growth simulation was performed on the samples using the boundary element method. The results showed that the geometric parameters and the rivet material have a significant effect on fatigue cracking in aluminum plates. Ertas et al. (2021) experimentally investigated fatigue phenomenon of the spot welded sheet metals, by taking electrode force into consideration. For this purpose, spot-welded modified tensile shear (MTS) test specimens were utilized. The data obtained showed that the number of cycles to failure changes depending on the spot generating schemes in terms of electrode force and welding schedules. Through the investigation of an optical micrograph of partially failed spot welded MTS specimens for different groups of spot welds created under different electrode force effects, it is seen that the fatigue failure is dominated by the through thickness cracking. Aleniu et al.(2006) have investigated Spot weldability of dissimilar metal joints between stainless steels and non stainless steels The aim was to determine the spot welding parameters for the dissimilar metal joints and to characterize the mechanical properties of the joints. Bin Zhou et al.(2006) has presented a methodology for determining the cohesive facture parameters associated with pull-out of spot welds. Mixed-mode fracture of the base metal is responsible for failure of a spot weld by pull-out, the cohesive parameters for ductile fracture of an aluminum alloy were determined and then used to predict the failure of two very different spot-welded geometries. Helmut Dannbauer et al.(2005) modeled has given an overview of some common methods and standards for the assessment of welding seams and spot joints including spot welds and self piercing rivets. It has been indicated, how the effect of the mesh quality and the element size can be kept minimum. It has been shown, that usually stress based concepts deliver better results and can be applied for self piercing rivets too, but the effort for the local mesh refinement is very high and error prone. Jeremy et al.(2005) have designed tests with the intention of addressing the highway sign problem and determining a solution as quickly as possible with the limited amount of material available for testing. It must be noted that these results are based on testing sample connections from one new sign panel. Unfortunately, the testing procedures described did not adequately model the loading conditions found in the field because the load ranges that found “infinite fatigue” life cycles are still higher than the fatigue loads due to wind gusts in the field. Palma E.S. et al.(2002) presented a method for design durability qualification of a vehicle body shell. Fatigue analysis methods are used to access and compare the fatigue damage imposed during durability test and laboratory (torsion) experiments. Ertas et al.(1990) found better correlation with experimental data using the strain–life approach compared to the stress–life approach, which was overly conservative. Ertas concluded that the mean stress effects in spot weld fatigue, for example caused by residual stress or external loading, are not important.

3. EXPERIMENTAL SETUP AND RESULTS

Fatigue tests were executed using the Kalpak Computerized Servo Hydraulic MachineTest System, which has a load range up to 100 KN. All tests were performed under load-controlled sinusoidal constant-amplitude loading, with a frequency of 10 Hz, as is commonly used in steel fatigue testing and an R-ratio of 0.1. The specimens were clamped using bolt-tightened grips, as displayed in Figure 1.

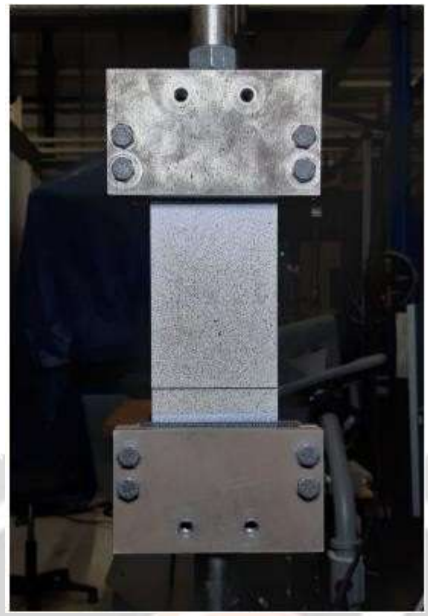
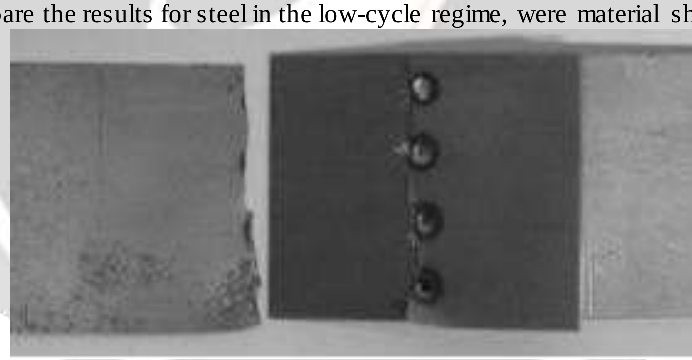
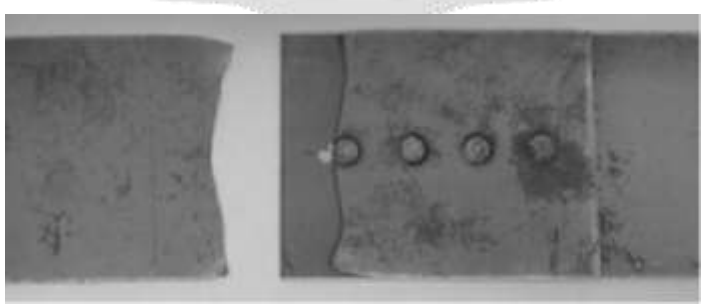


Fig -1: Clamping of Specimen on Machine

Fatigue life testing was done at 70% of the measured static failure load, with the goal of ending up in the low-cycle fatigue regime. Tests performed at these relatively high load levels were expected to allow the most informed comparison with steel joint fatigue behavior. It is found that steel spot welds in the low-cycle regime consistently failed from fracture through the spots. This same failure mode was, however, not observed in the high cycle regime: here, steel sheet fracture transverse to the loading direction was found to be the dominant failure mode. Although it is assumed that spot welded joints in steel fail from spot fracture regardless of applied load level, it was considered most interesting to compare the results for steel in the low-cycle regime, were material show a failure mode.





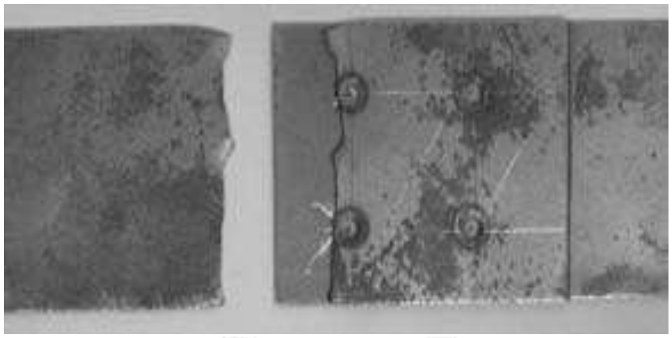
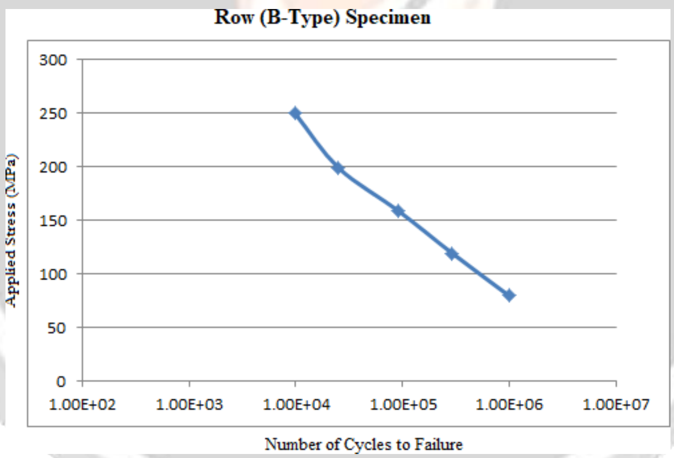


Fig -2: Fatigue fracture of all kinds of the specimens under different loadlevels.

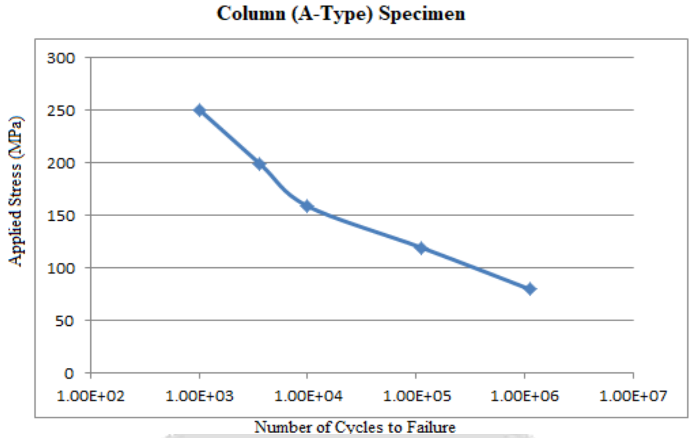
3.1 RESULTS AND DISCUSSION

Figure 1 to 3 shows the stress vs failure cycle at different cyclefor different arrangements of spot weld joint. A type specimen represents Row type spot welded specimen, B type Specimen Represents Row type spot welded samples and C type specimen represents square type spot welded joints.



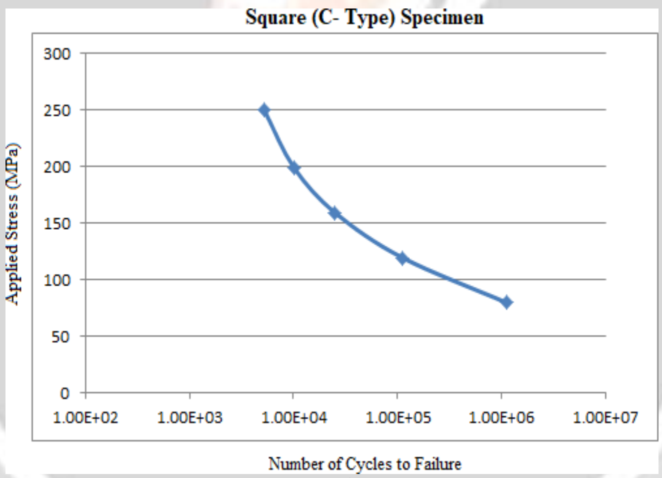
Graph -1: Stress Vs Failure cycle for Row(B-Type) Specimen

As per this graph, at load of 250 MPa it requires 25233 cycle for failure. When applied stress value decreases, sustainability of steel sample increases. At 79 MPa load, it required above 10 lakh cycles for failure.



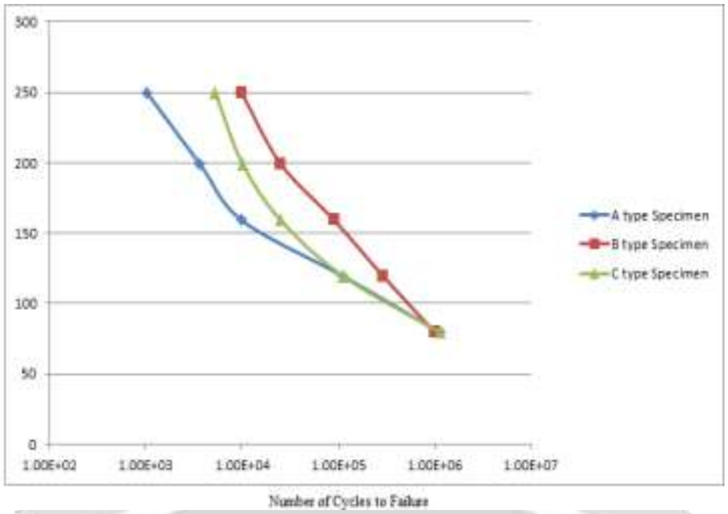
Graph -2: Stress Vs Failure cycle for Column (A -Type) Specimen

As per this graph, Column type specimen failed in just 3652 cycles at 250 MPa stress. This is very lowest value as compared to all other samples failure cycle at similar loading conditions.



Graph -3: Stress Vs Failure cycle for Square (C -Type) Specimen

As per graph, it shows that at 250 MPa applied stress, 10150 cycles required to failure. This values is lower than B type specimen and quite higher than A type specimen. Also, number of failure cycles at 119Mpa is similar to A type section.



Graph -4: Stress Vs Failure cycle

As it can be seen in Fig. 3, the B-type specimens have higher fatigue lives comparing to the two other types of specimens while of A-Type specimen have the lower fatigue lives. Furthermore, as it can be seen in this figure, the difference between the fatigue lives of spot-weld specimens in the low cycle regime is greater than those in the high cycle regime. Correspondingly, it can be detected that, in the low cycle fatigueregime, the fatigue lives of B-Type spot weld specimens were the longest, while those of A-Type specimen were the shortest. With attention to the fatigue fracture of the mentioned spot-welded joints, it can be concluded that the fatigue fracture mechanisms of the specimens be influenced not only by the factors such as sheet thickness and nugget diameter, but also by the other important parameters such as the spot-welds arrangement and applied load levels.

4. CONCLUSIONS

In this study, three types of spot weld joints are used i.e. Row Type, Column Typeand Square Type. The major objective of this research was to analyze the behavior of fatigue properties of spot welded joints with different arrangements. The fracture mechanism of multi-spot welded steel joints in cyclic loading is not only a function of nugget diameter and sheet thickness, but also strongly dependent on the arrangement of spots and applied load levels in the multi- spot welded joints. It is also found that Row type spot welded joint have highest fatigue strength as compared to all other type of joint up to 10000 cycles. At 250 MPa applied stress, column type joint failed at early stage i.e. at 1023 cycles. Also, at 80MPa applied stress, all the specimen shows nearly equal fatigue life i.e. ten lacks cycles. Hence from this study, it is found that the fatigue strength approaching a million cycles of all types of spot weld specimens mentioned were the same but their low cycle fatigue lives were different. Row type spot welding is recommended for the applications where high applied stresses are applied on the joint. For applied stress applications use of any type of joint is recommended due to similar fatigue properties.

5. REFERENCES

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