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A Fatigue Prediction Method for Spot Welded Joints

UNIVERSITY OF MICHIGAN-DEARBORN

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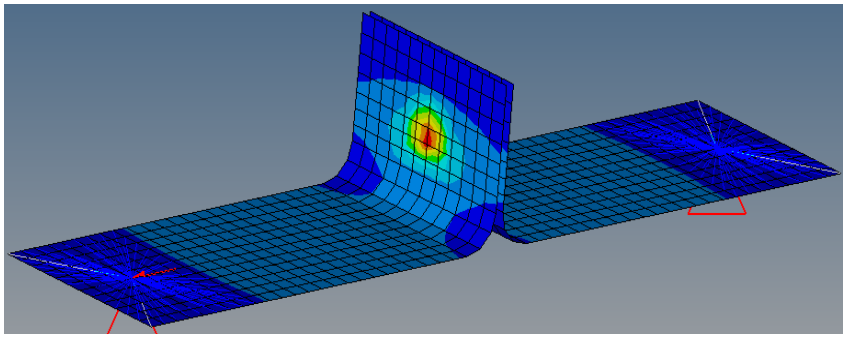

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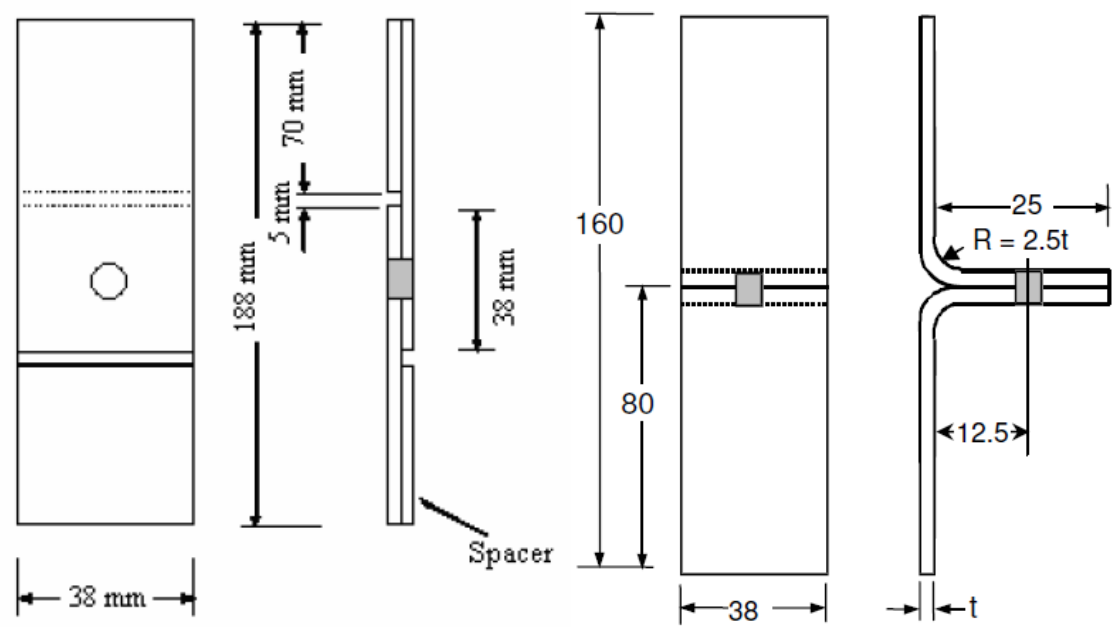
Objective

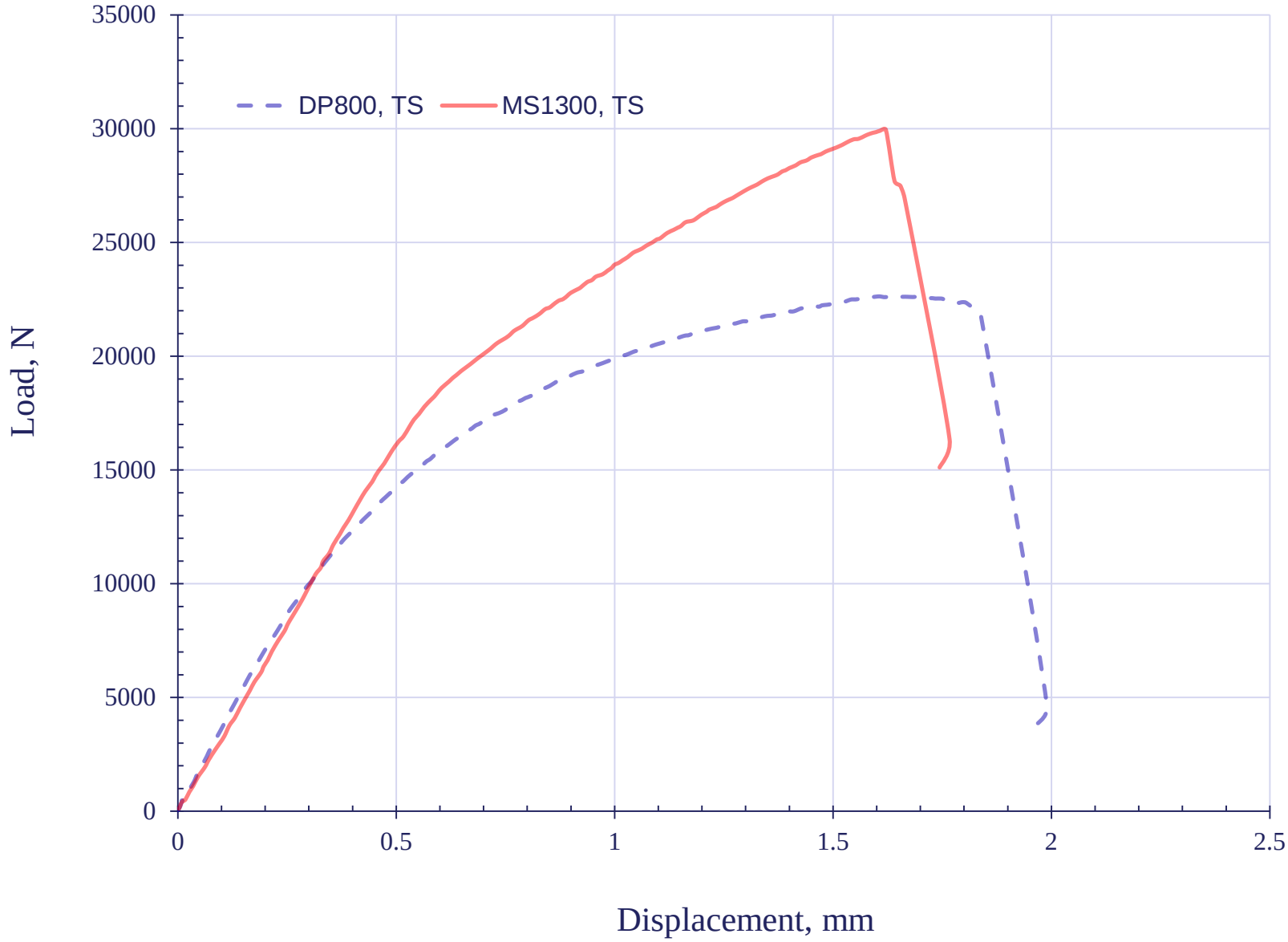
- The structural stresses are calculated using a linear elastic FEA result.
- Thus, it could predict conservative results or a static failure of spot welded joint in worst case even though it carries hundreds of cycles at the applied load range.
- This study attempts to introduce a methodology to correlate the structural stress range with cycle to failure when the applied load range is beyond the yield strength of the joint.

Materials And Specimen Geometries

- Materials: DP800, MS1300, and DQSK
- Thickness: 1.6 mm
- Specimen Types:



Tensile Test Results

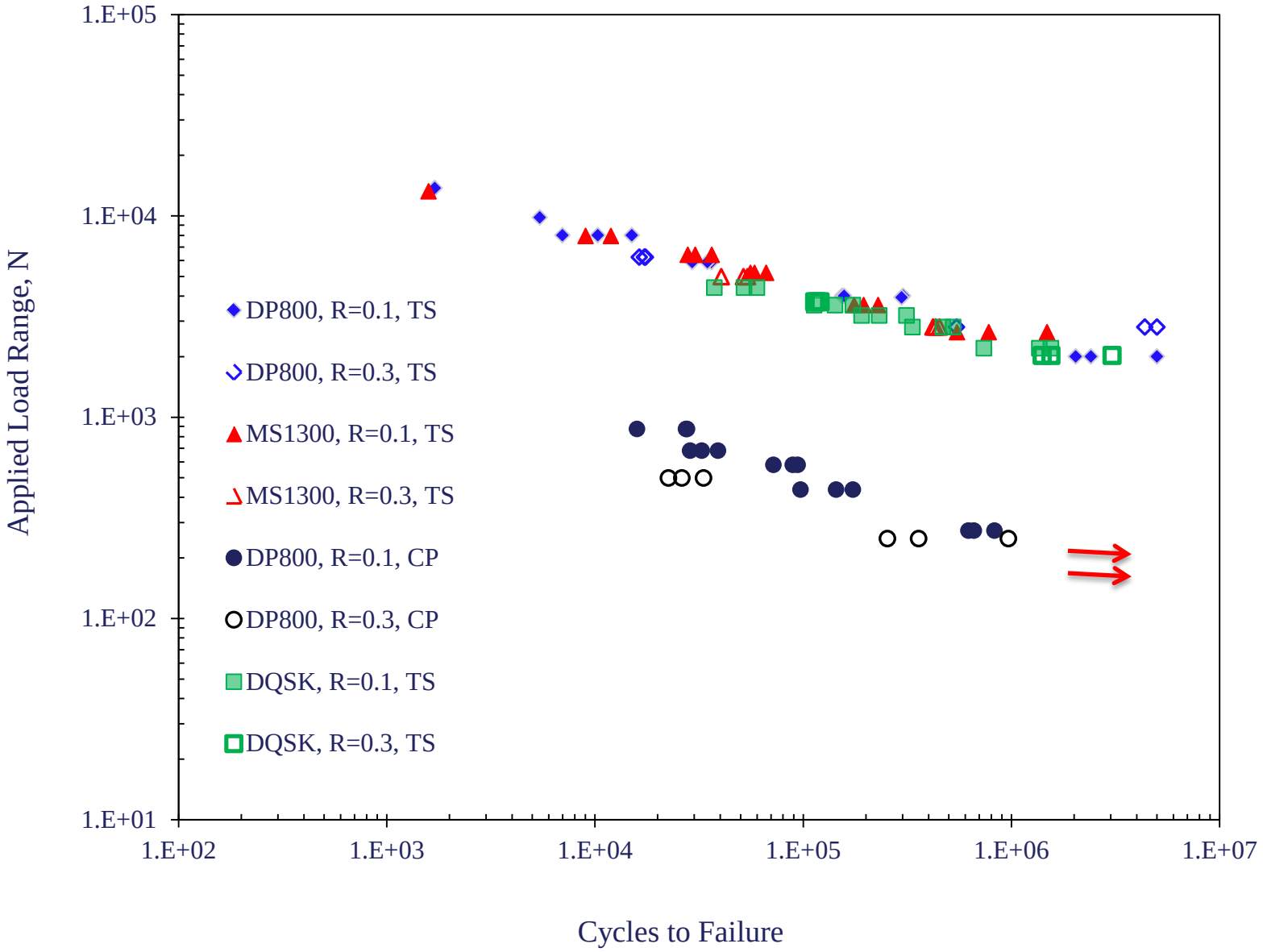


Fatigue Tests[1]

- Loading frequency between 5 Hz and 30 Hz.
- The load ratios (P_{min}/P_{max}) were R = 0.1 and 0.3.
- Definition of fatigue failure: complete separation of the specimen in two pieces, or the preset displacement limit.
- Runout cycle: $5x10^6$ cycles.

[1]Bonnen, J., Agrawal, H., Amaya, M., Mohan Iyengar, R., Kang, H., Khosrovaneh, A., Link, T., Shih, M., Walp, M., and Yan, B., "Fatigue of Advanced High Strength Steel Spot Welds," *SAE 2006 Transactions Journal of Materials & Manufacturing*, pp. 726-744, 2007.

Fatigue Test Results



Rupp et al Method

- Structural Stress Method
- Beam, shell, and plate theory are utilized to obtain the force and moment information at the joint
- In FEA model sheet steels are represented with shell elements, and the spot weld is modeled with a stiff beam element.
- The length of the beam element is set as the average thickness of the sheets joined.

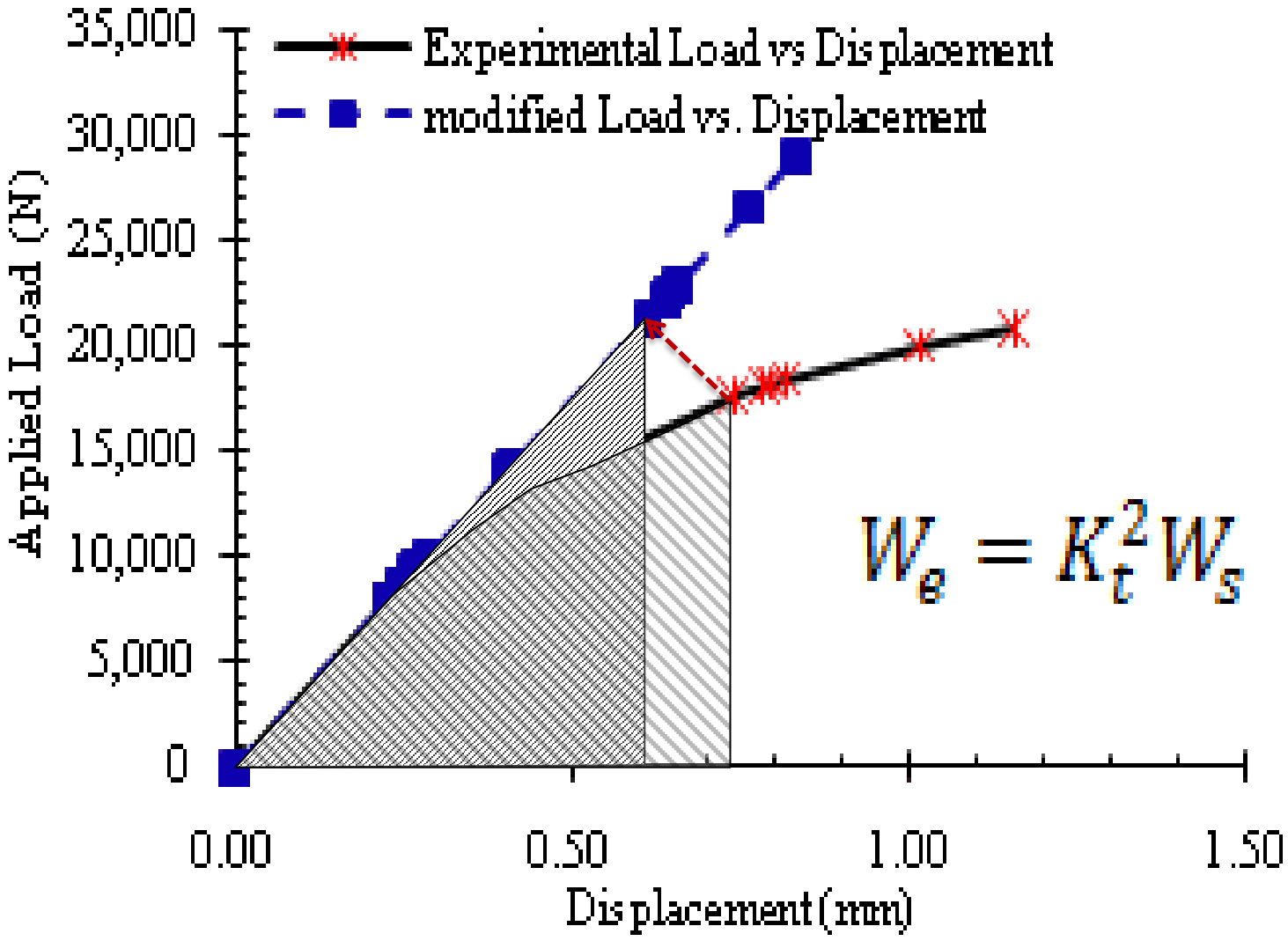
Modification of S-N Curve

- The behavior of the material is no longer linear between the applied load and displacement after the material is yielded.
- However, most of the fatigue database does not include the effect of the non-linearity.
- Without the correction of the non-linearity effect in FEA model, the prediction life of the spot weld becomes conservative.

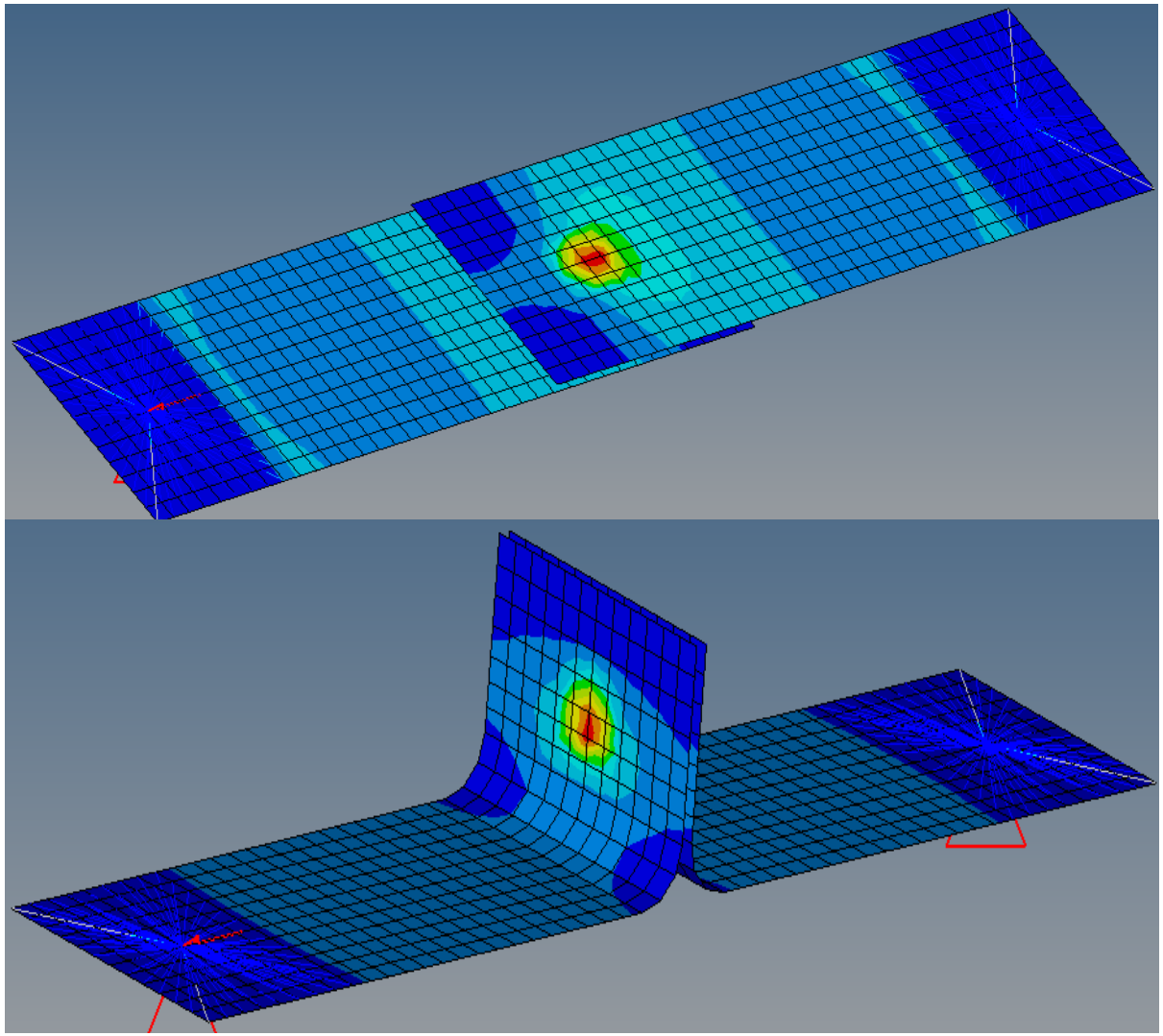
Modification of S-N Curve

- Thus, the load applied for fatigue test of spot welded joints should be modified to include the non-linearity effect on stress calculation using linear elastic FEA techniques.
- The basic idea is to transfer the non-linear relationship in experimental data into a linear one in FEA using an energy method or other methods.
- This study used the strain energy density method to convert the load during tensile testing to the corresponding load in FEA.
- The load applied during experiment is modified to the equivalent load for calculating the maximum equivalent structural stress for the specimen.

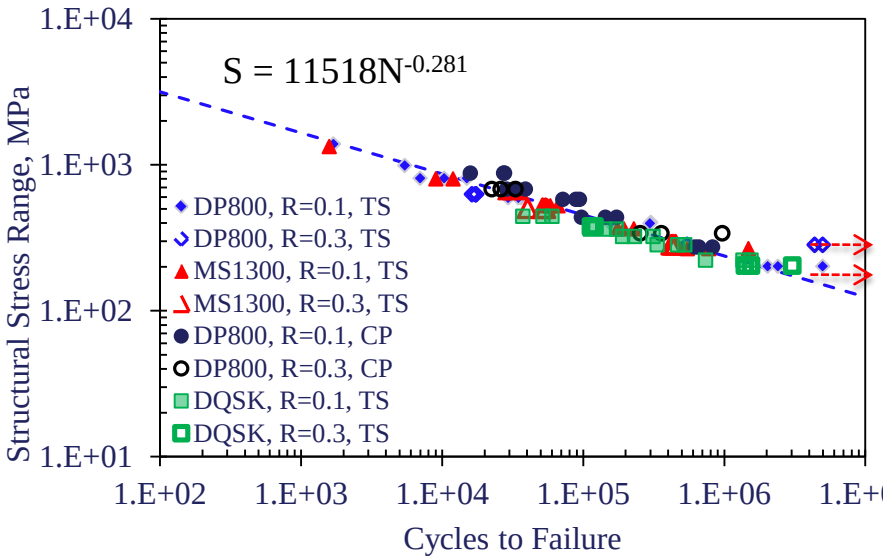
Modification of S-N Curve



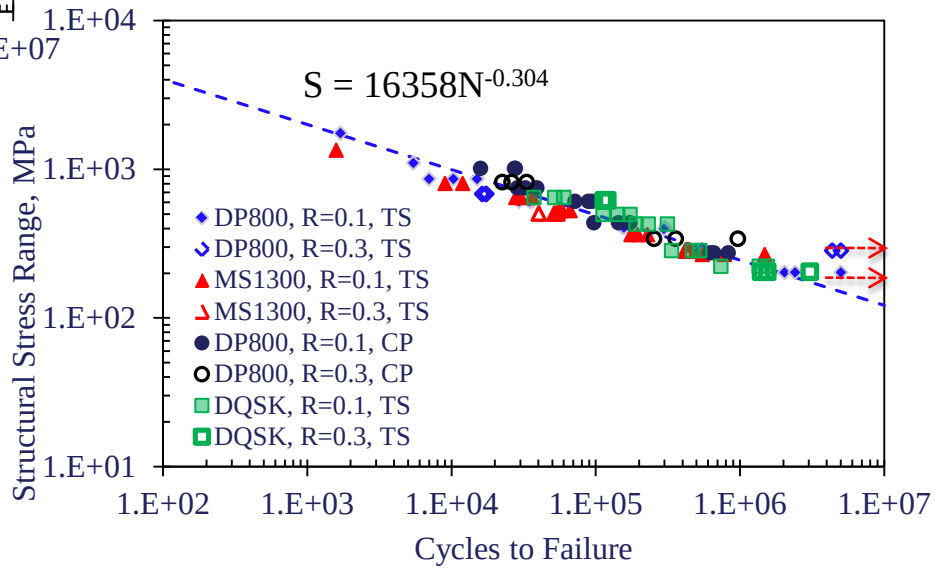
Modification of S-N Curve



Modification of S-N Curve



Before Modification



After Modification

Summary and Conclusions

- The S-N curve has been modified to consider the elastic-plastic behavior of spot welded joint but still using linear elastic FEA.
- Thus, fatigue life of spot welded joints is always under estimated when the applied maximum load is beyond the yielding load of the specimen.
- This study successfully introduced a methodology to modify the experimental applied load range using energy density method.
- The proposed method increased the slope of S-N curve for the structural stress method thus reducing the false static failure.

Thank you!

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