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Thermal-Mechanical Numerical Modeling of Friction Element Welding

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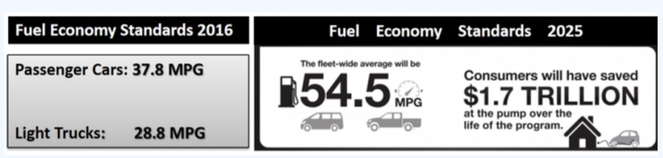
ABSTRACT

A coupled thermal-mechanical finite element model (FEM) is developed using ABAQUS software to simulate friction element welding (FEW) process. The FEM will be used for investigating underlying mechanisms of FEW in joining aluminum alloys to steel alloys.

MOTIVATION

Higher fuel economy → Use lightweight dissimilar materials → Issues! → Solution (FEW)



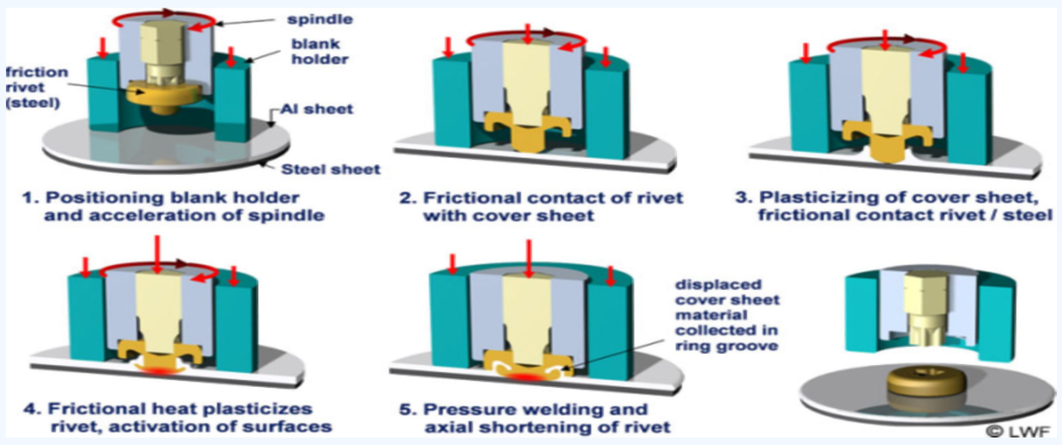
[1]

[2]

1. Inter-metallic compounds (IMC) formation
2. Highly dissimilar properties. For example: melting point, thermal conductivity, etc.

1. Low process time (1 to 1.5 sec).
2. Can join dissimilar materials.
3. High weld strength.

FRICTION ELEMENT WELDING PROCESS



[3]

INTELLECTUAL MERIT

1. Real-time analysis of underlying mechanisms using FEM.
2. Novel implementation of coupled Eulerian-Lagrangian scheme in ABAQUS.
3. Ability to capture extreme deformation of friction element without facing mesh distortion issues.
4. Prediction of temperature, deformation, and final weld quality for given set of process parameters.
5. Optimization of parameters for a given set of materials.

PROGRESS MADE

1. Entire FEW process simulated using coupled Eulerian Lagrangian scheme in ABAQUS.
2. Friction element (tool) defined as Eulerian part having fixed mesh allowing to capture extreme deformation.
3. Using time scaling and efficient mesh design, total computation time was reduced from months to about 40 hours.
4. The developed FEM was validated against experimental results for deformation of parts and temperature measurements.

REFERENCES

1. https://doi.org/10.1557/mrs.2015.268
2. http://www.dierk-raabe.com/dual-phase-steels/
3. DOI 10.1007/s40194-013-0098-3

NUMERICAL MODELING

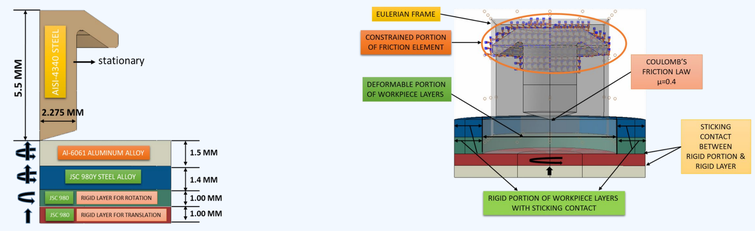


Figure 1: Cross-section of FEM set-up

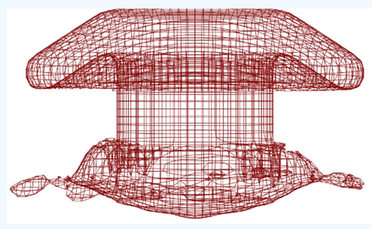


Figure 2: Deformed eulerian friction element

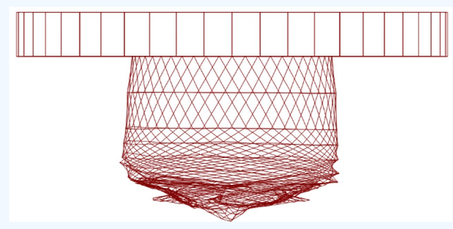
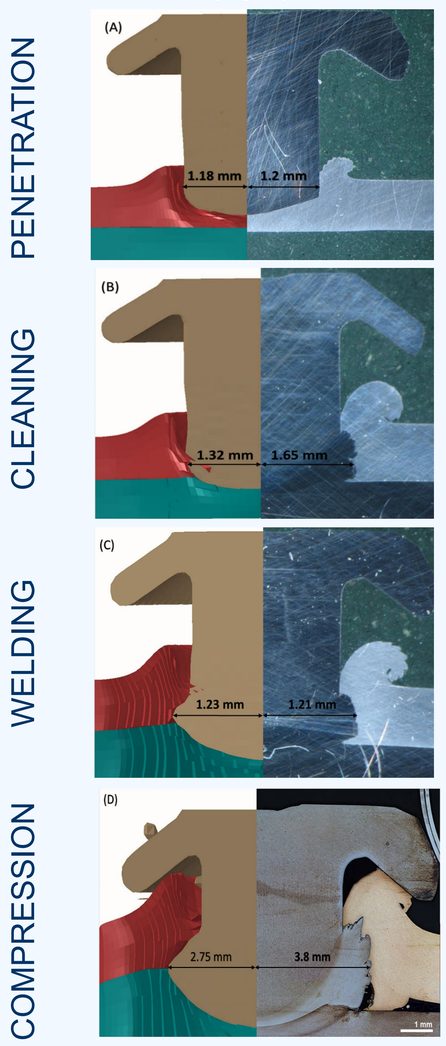


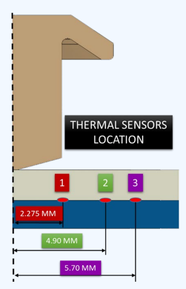
Figure 3: Distorted eulerian friction element

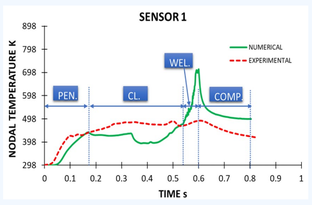
VALIDATION OF NUMERICAL MODEL

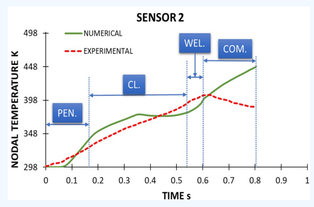
Numerical result (left) Vs Experimental result (right)

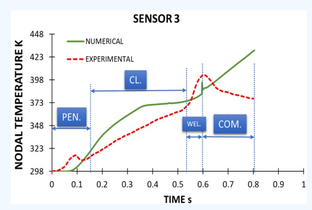
Comparison of temperature history for numerical model and thermal sensors measurements











FUTURE WORK

1. Study the effect of variation of process parameters on temperature evolution, plastic deformation, and stress-strain evolution.
2. Use FEM to identify regions of interest experiencing high temperatures for microstructure analysis.
3. Examining microstructure to determine any inter-metallic compound formation.

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