SAE FD&E

Simufact and MSC Software
Total Life T-Joint
Welding Simulation
Residual Stress Results Update

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Presented by: Jeff Robertson
May 16th, 2018

Background

SAE FD&E
- Ongoing effort by members of SAE FD&E committee to understand weld induced residual stress (RS) and effects on fatigue
- Multiple physical tests and simulations in conducted attempt to quantify RS

Simufact
- Welding, Metal Forming, Additive Manufacturing simulation software
- Ability to chain multiple processes (e.g. forming -> welding)
- Complete multi-physics, non-linear, elastic-plastic modeling capability
- Fully coupled thermal, mechanical, metallurgical solution

Current Involvement
- Initial simulation results presented in May 2016
- Rerun with updated solver for May 2018

Objective

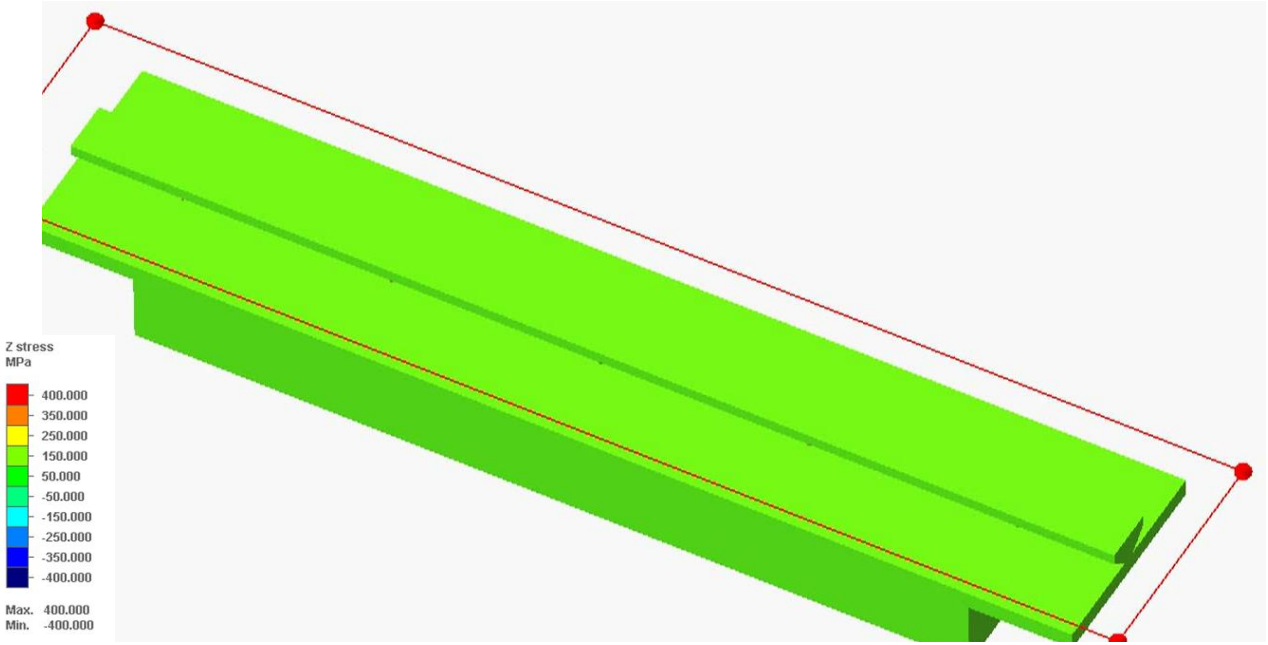
Primary Objectives:

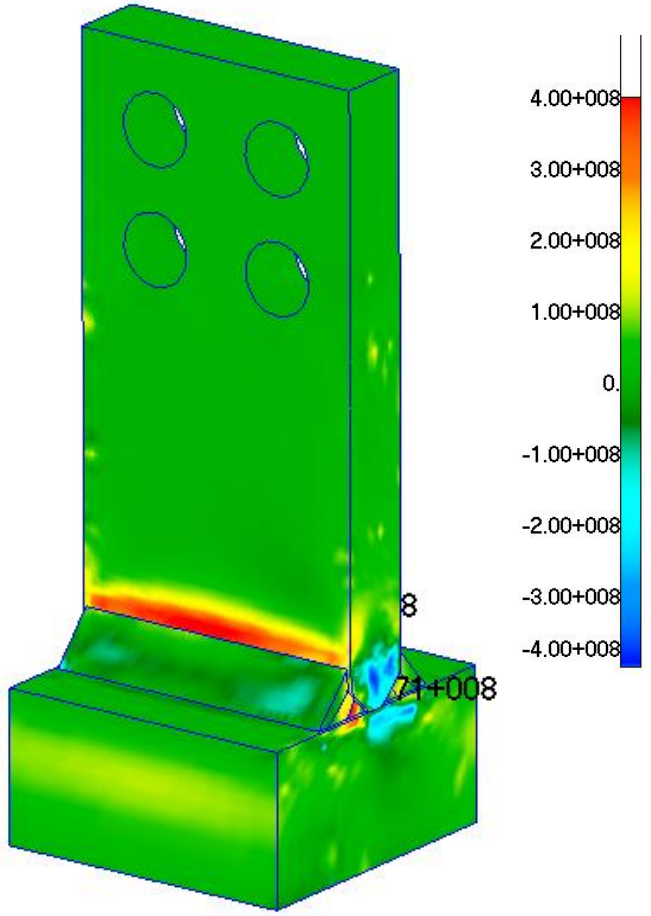
1. Simulate residual stress and distortion within the welded T-Joint assembly
2. Simulate cyclical load case on welded assembly
3. Simulate fatigue life based on load case and weld induced residual stress

Welding Simulation Results

Sectioning the Assembly

- Residual stress profile predicted for entire T-joint assembly
- Assembly must be virtually “cut”
- Stress profile changes slightly during sectioning
- Many ways to do this sectioning virtually





Welding RS Exported from Simufact Welding

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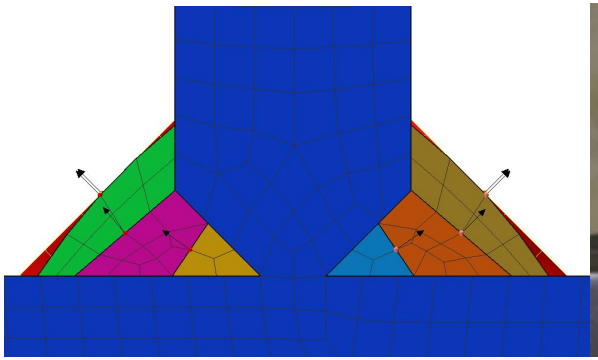
Welding Simulation Setup and Assumptions

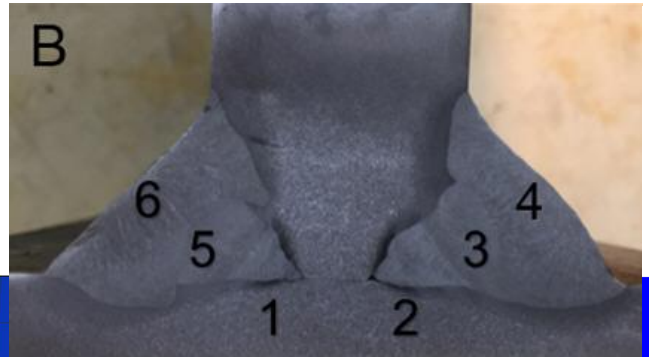
Simulation Setup and Assumptions

- Four blocks w/ run-offs
- Full transient moving heat source
- Simulated tack welds by “gluing” elements
- Weld sequence and parameters as provided
- Heat source calibrated with macro-graphs
- Multi-phase material model for A36 created with flow curves above melting temp

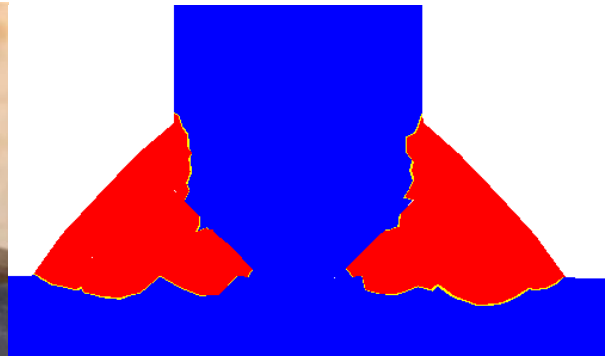
Weld	Side	Starting End	Voltage	Current	Wire Speed	Travel Speed	Work Angle	Cooling Time
1	1	A	38.5 V	235 A	7 m/min	40 cm/min	45	NA
2	2	B	38.5 V	235 A	7 m/min	40 cm/min	45	45 s
3	2	B	39.0 V	300 A	8 m/min	35 cm/min	45	3 s
4*	2	B	39.5 V	225 A	8.5 m/min	60 cm/min	45	3 s
5	1	A	39.0 V	300 A	8 m/min	35 cm/min	45	1 m 30 s
6*	1	A	39.5 V	225 A	8.5 m/min	60 cm/min	45	2 m 30 s



Weld bead geometry model



Weld bead macro-graph

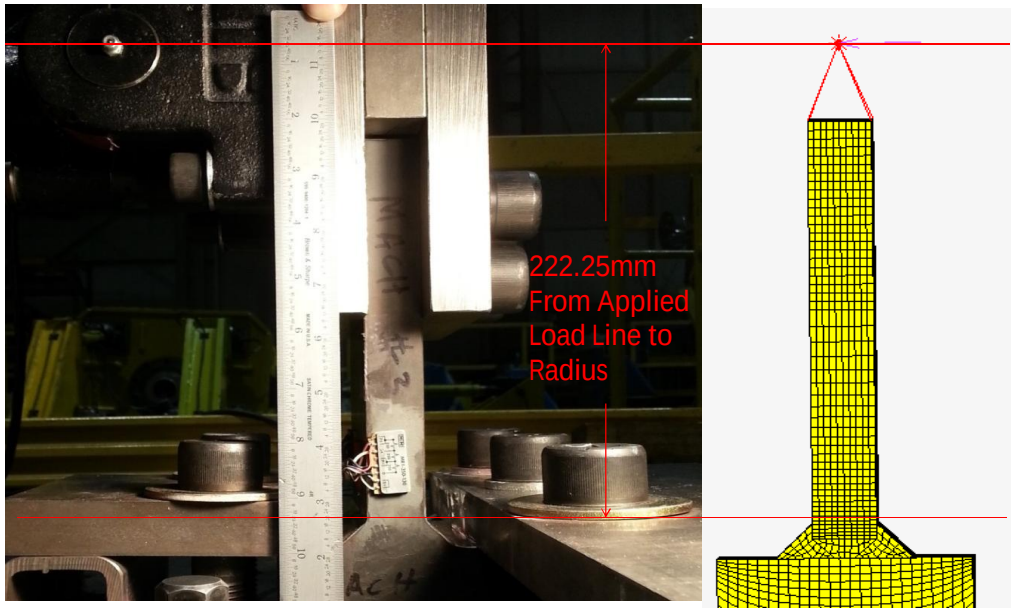


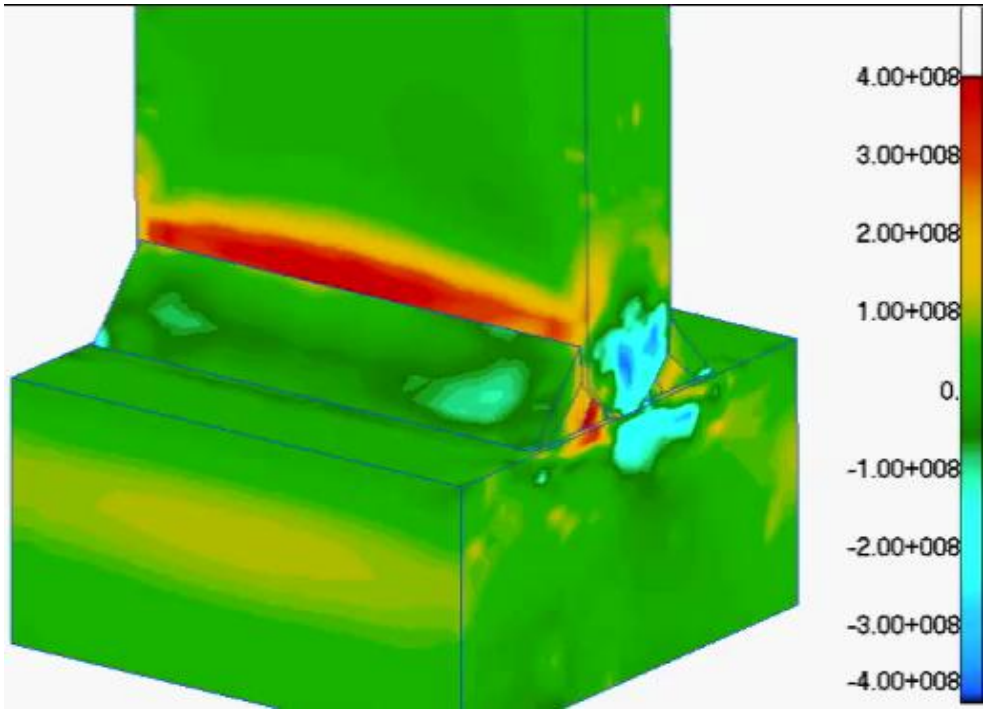
Simufact weld bead calibration

Loading Simulation

Applying the load

- Load can be applied man different environments
- Calculates stress levels through load cycle
- Complete stress history transferred to MSC Fatigue





Cyclical Load Cycle with Residual Stress
Max Load: 24kN, Load Ratio: 0.1

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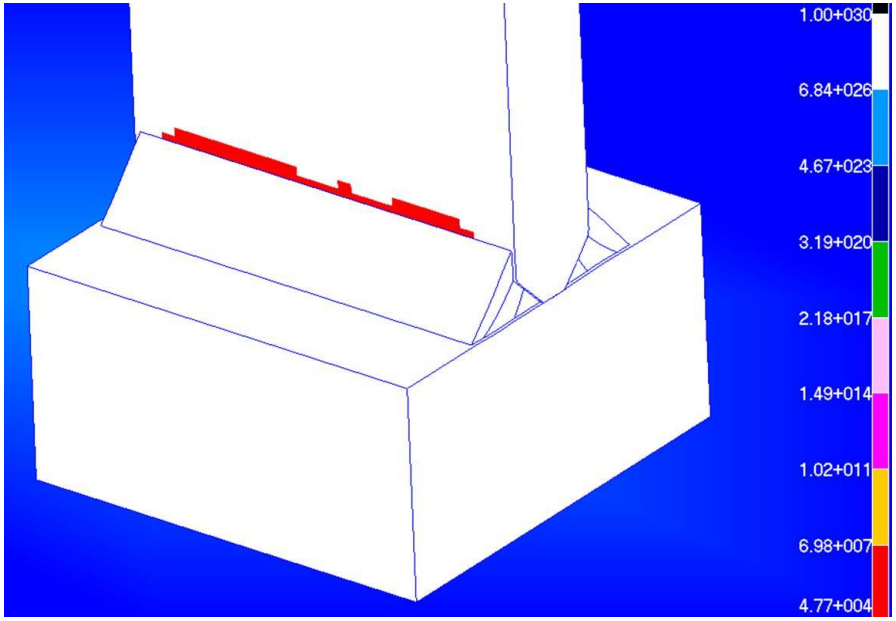
Fatigue Simulation

MSC Fatigue
- S-N Method
- nCode based solution
- Fatigue life of complete failure

Combines the effects of three discrete simulations :
- Welding
- Loading
- Fatigue

Enables prediction of:
- Weld induced residual stress
- Combined weld and load stress
- Fatigue life based on combined weld and load stress

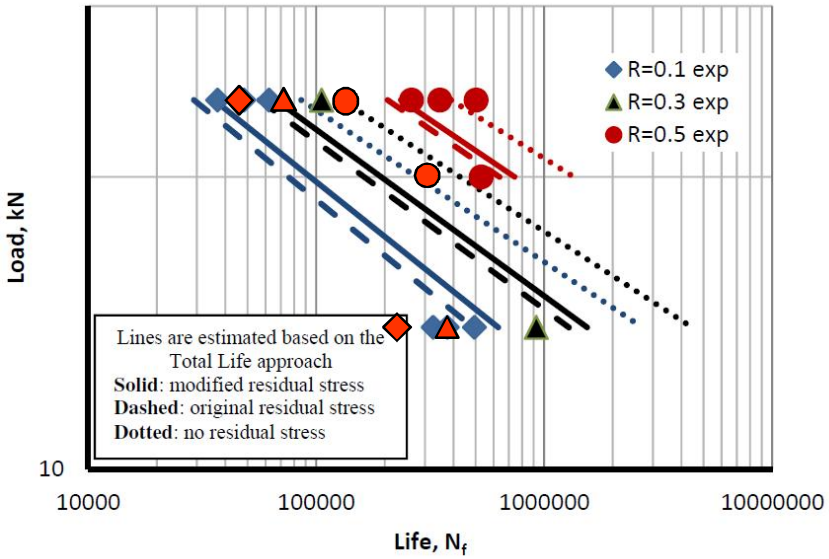


Fatigue Life Failure Prediction:
Max Load: 24kN, Load Ratio: 0.1
Simulated life: 47,700

Fatigue Simulation Results

Fatigue Life Comparison

- Experimental test data has a range of observed values
- Conservative fatigue analysis results generally agree with experimental test data
- Continued work underway to understand and validate model

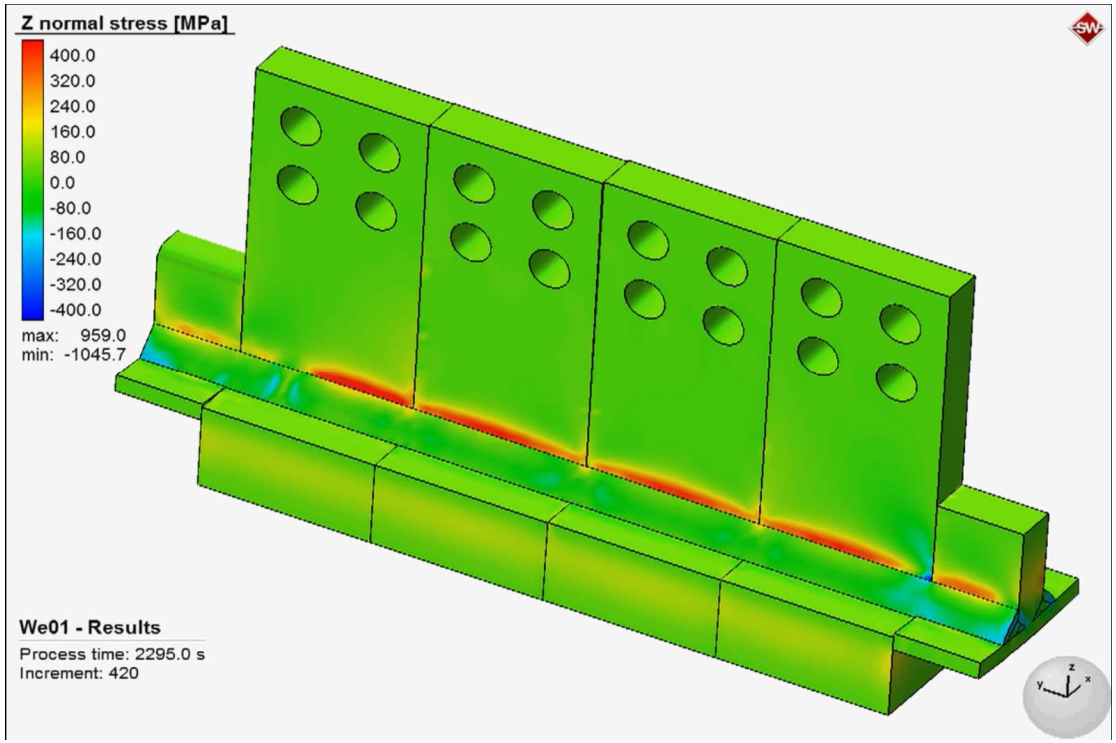


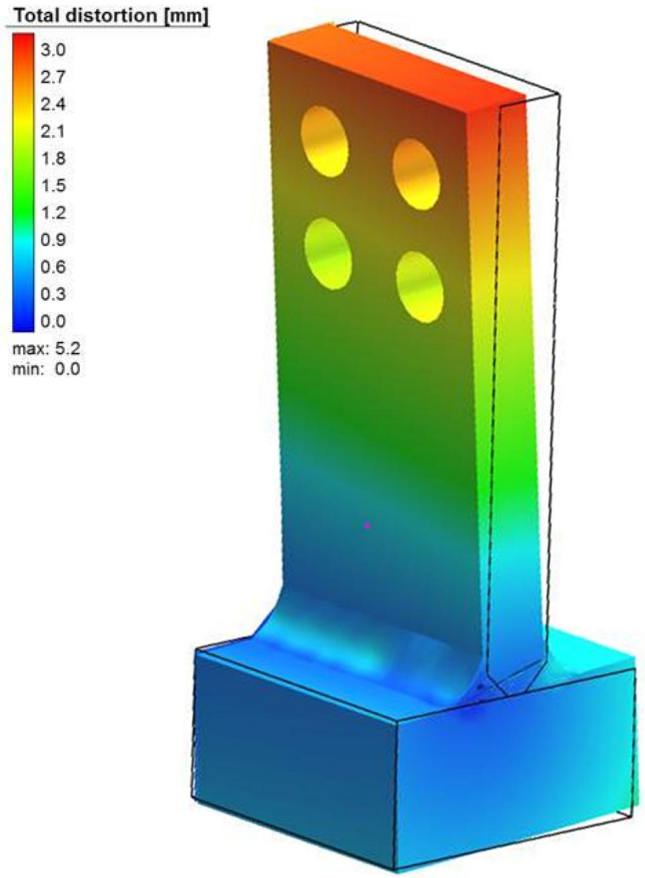
Experimental Fatigue Test Results

Max Load	R	Min of Test Data	Max of Test Data	Mean of Test Data	Simulated Fatigue Life
24kN	0.1	36,700	61,500	50,000	47,700
	0.3			105,000	70,100
	0.5	270,000	500,000	365,000	129,000
20kN	0.5			540,000	306,000
14kN	0.1	367,000	493,000	390,000	225,000
	0.3			900,000	386,000

Fatigue Life Failure Prediction

Welding Simulation Results





Max Distortion: 2.7mm

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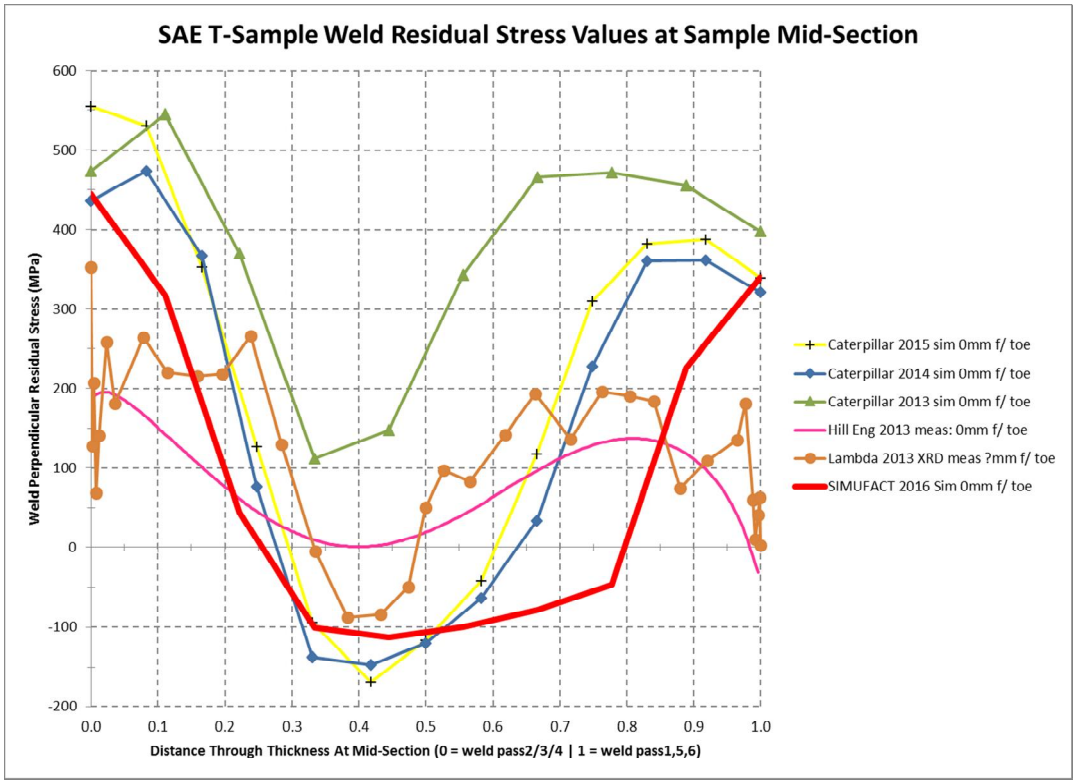
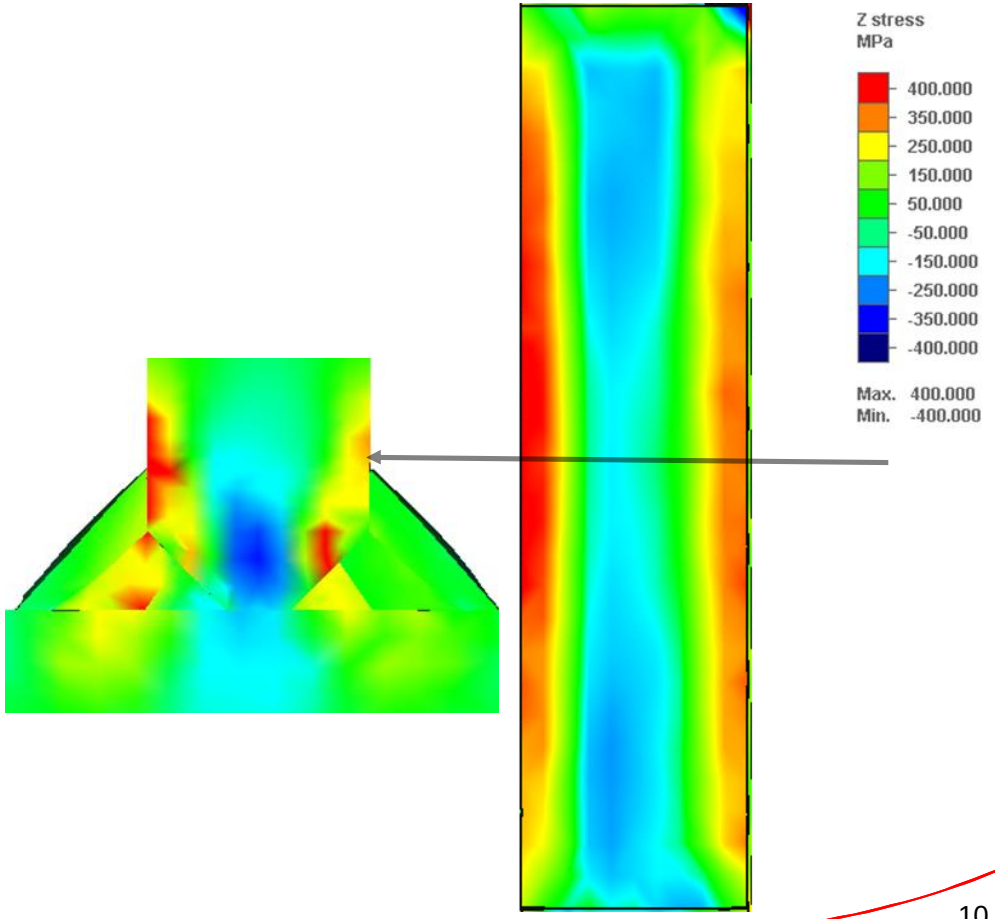
Welding Simulation Results – May 2016

Mid-section Residual Stress Profile Comparison
Spring 2016





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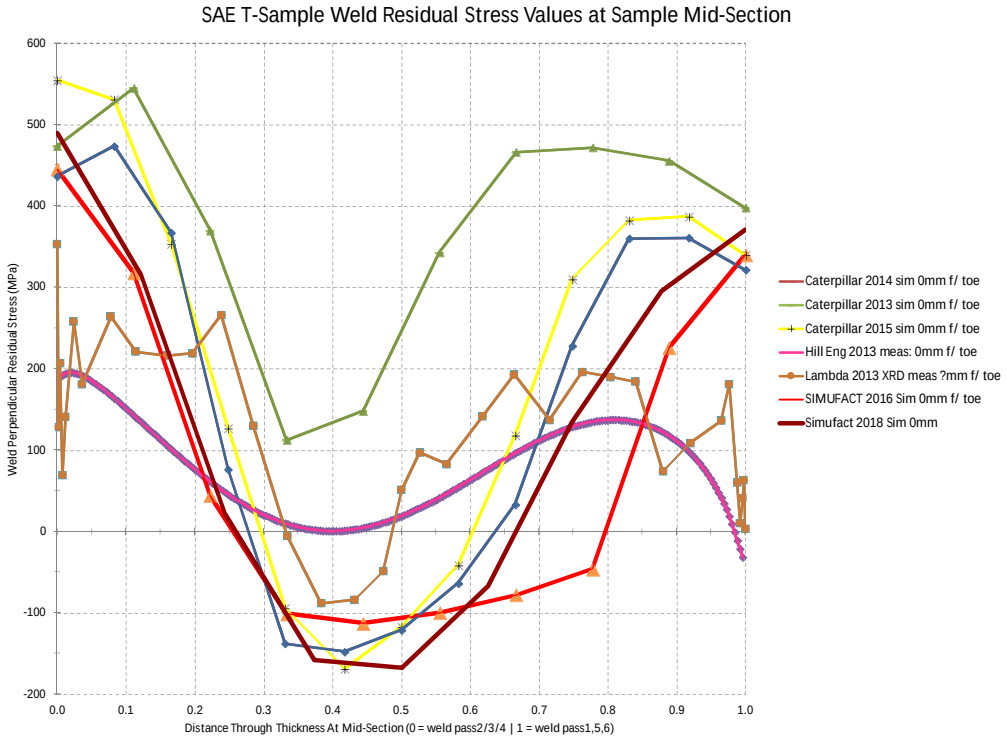
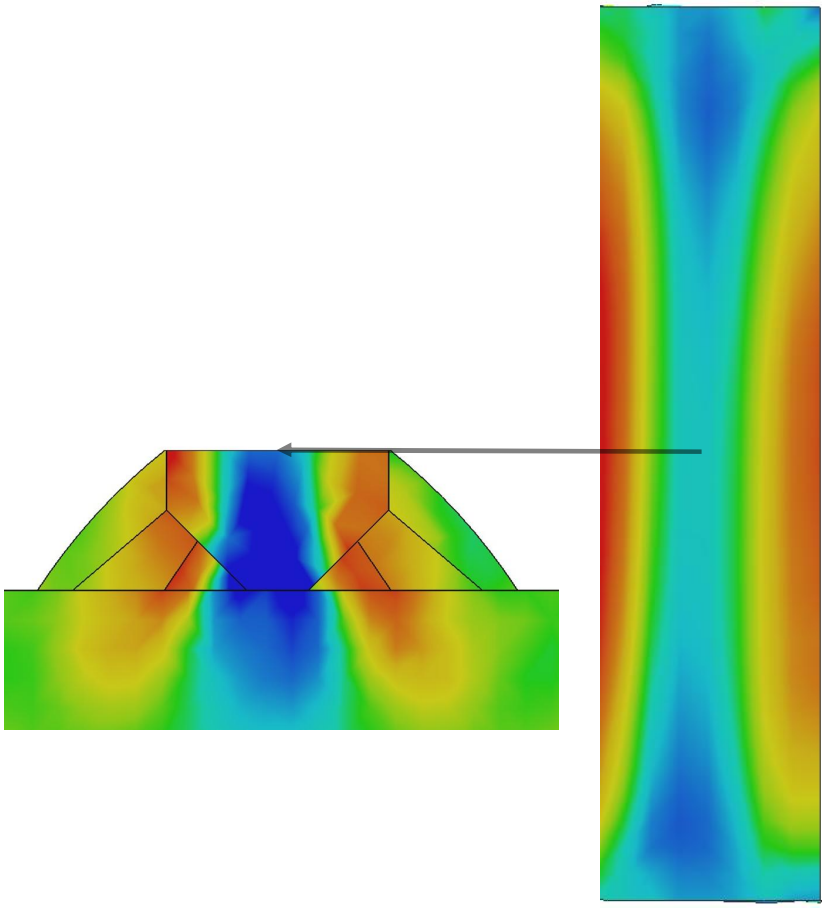
Welding Simulation Results – May 2018

Mid-section Residual Stress Profile Comparison Spring 2018





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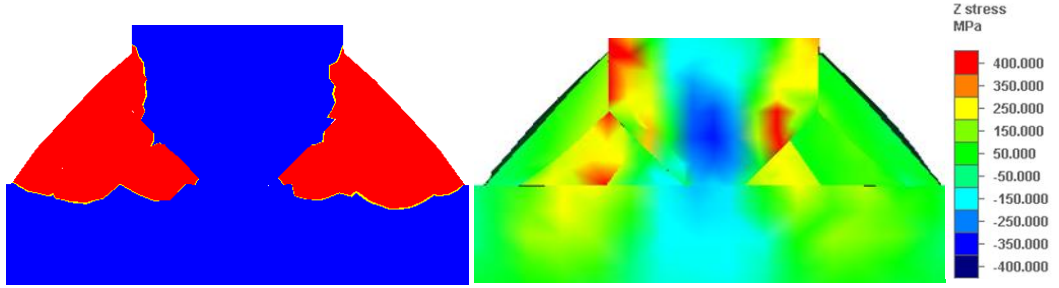
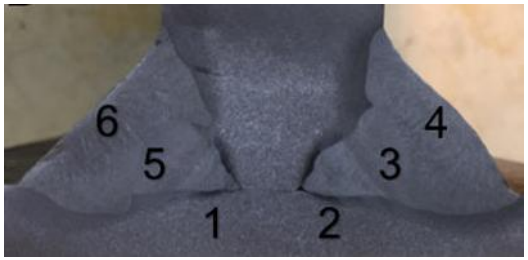
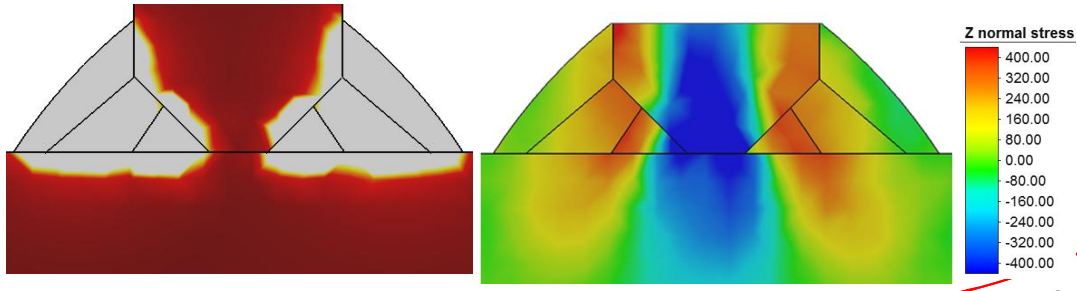
Results Comparison

Simufact May 2016 Results
- Initial model run with older version of solver
- Challenges with contact calculation in multi-layer welds
- Thermal “peak temp” profile not very smooth
- Residual stress profile shows discontinuities



Simufact May 2018 Results
- Run with updated Marc solver
- Contact calculation improved
- Conduction/convection/radiation of lower weld layers realistically applied
- Thermal profile improved (excess penetration)
- Residual stress profile is smoother
- Residual stress plot (data points) is more in line with CAT results





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Conclusion

Key Takeaways

- Predicting weld induced residual stress with simulation becoming more accessible
- Chaining welding simulation results with fatigue analysis is helpful in life prediction
- More valuable when analyzing complex assemblies/geometry

Potential Implementation

- Understand what parameters drive desirable fatigue behavior in real world assemblies
- Sensitivity analysis to evaluate design and manufacturing process
- Life prediction of welded components under in-service loading conditions

Bottom line

- Out of the box software solution
- Enables seamless chaining of multiple analysis
- Metal forming -> Welding -> Loading -> Fatigue
- Additional analysis is in-progress to validate correlation

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Thank you for your attention !

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