



THE MATERIALS JOINING EXPERTS

Including Weld Process Modeling in Structural and Durability Modeling

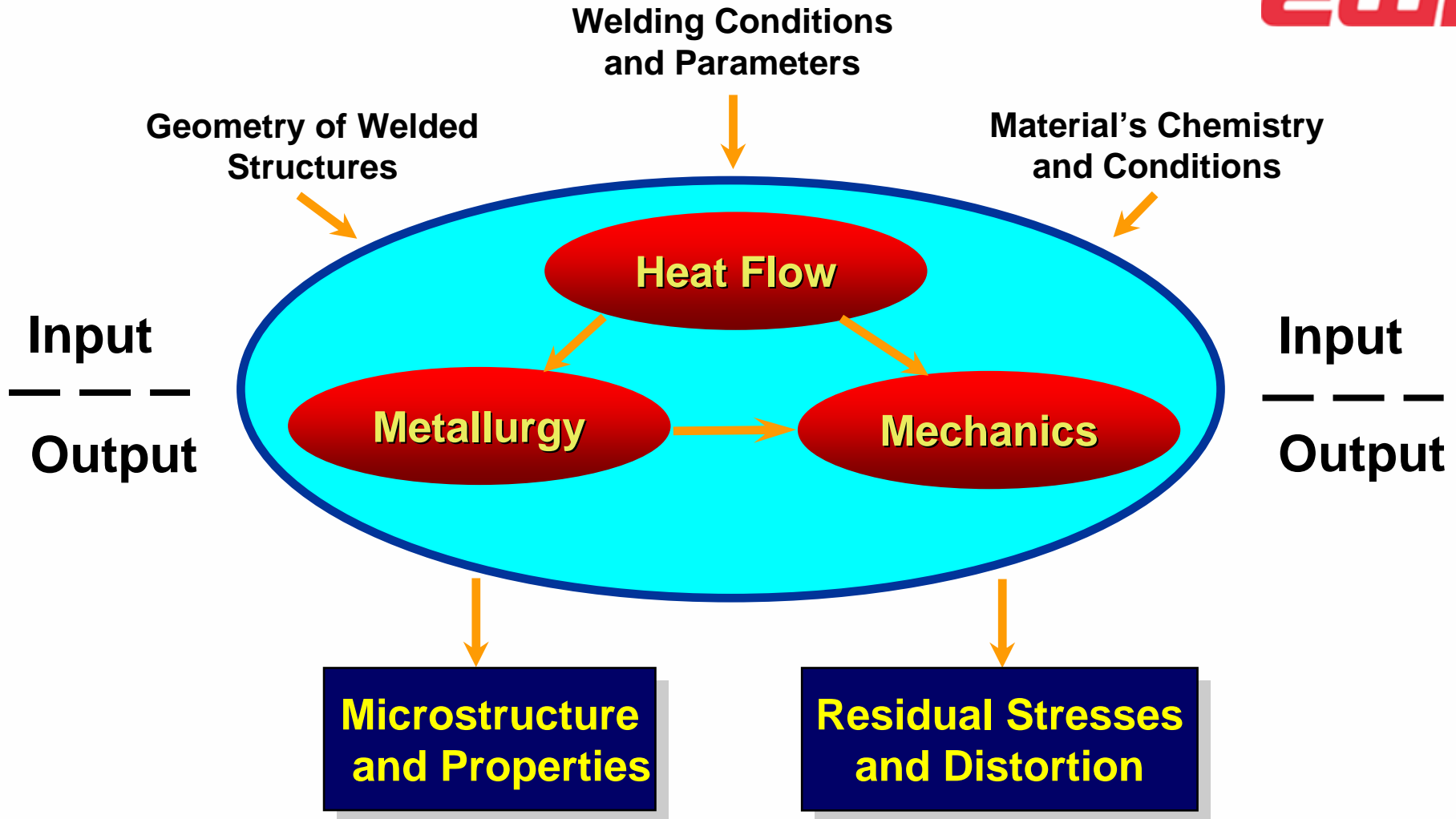
By

Robert N. Yancey, Ph.D.
Shuchi Khurana



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Integrated Modeling Approach



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Development of new welding processes

“What if” scenarios

Failure analysis – “what went wrong”

Validation of existing welding processes

Evaluate results difficult to measure in the lab (i.e. internal temperatures, stresses)

Optimize welding process

Provide welding-induced material properties to the structural analysis



Thermo-mechanical Modeling

- Arc Welding
- Laser Welding
- Friction Stir Welding

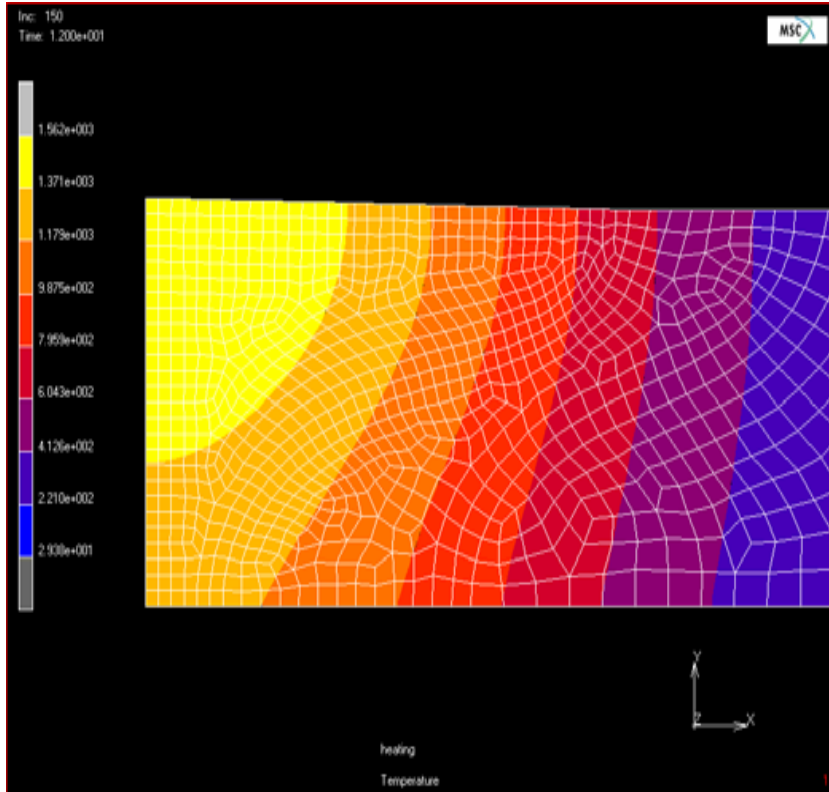
Electromagnetic thermo-mechanical Modeling

- Resistance Spot Welding
- Magnetic Pulse Welding

Fluid-thermo-mechanical Modeling

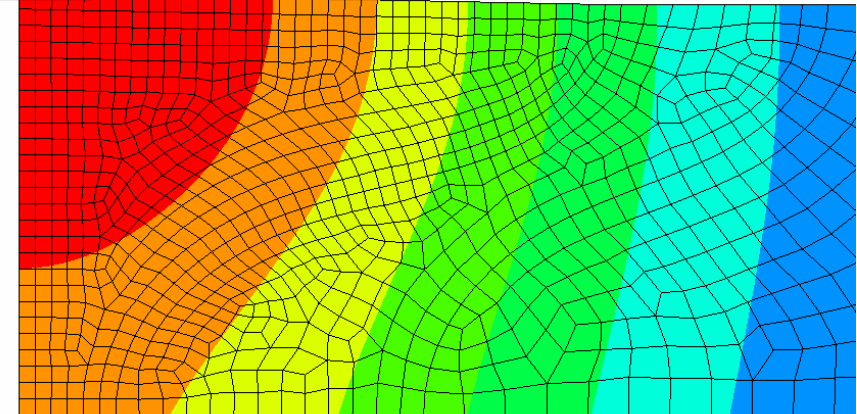
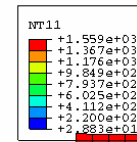
- Weld Pool Modeling

2-D Temperature Model



Marc

Goldak Heat Model

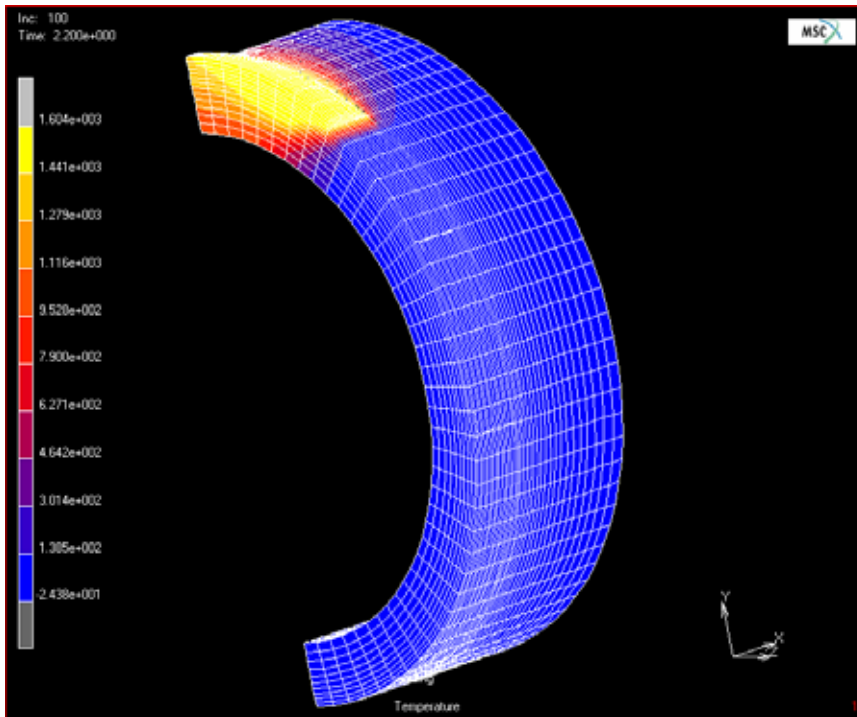


Step: Step-1, thermal step 1- heating
Increment: 153; Step Time = 12.02
Primary Var: NT11
Deformed Var: not set Deformation Scale Factor: not set

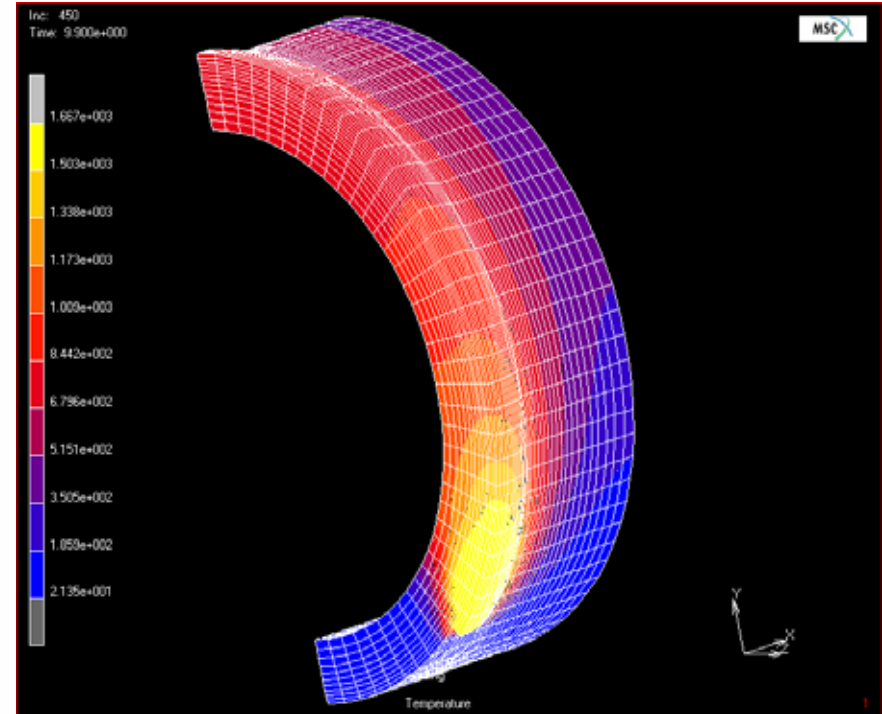
Abaqus



3D Model



Time 2.2 s



Time 9.9 s



Distortion – Affects loading paths and stresses from force fitting structure

Residual Stress – Affects peak stresses in the structure

Microstructure – Affects material response to load

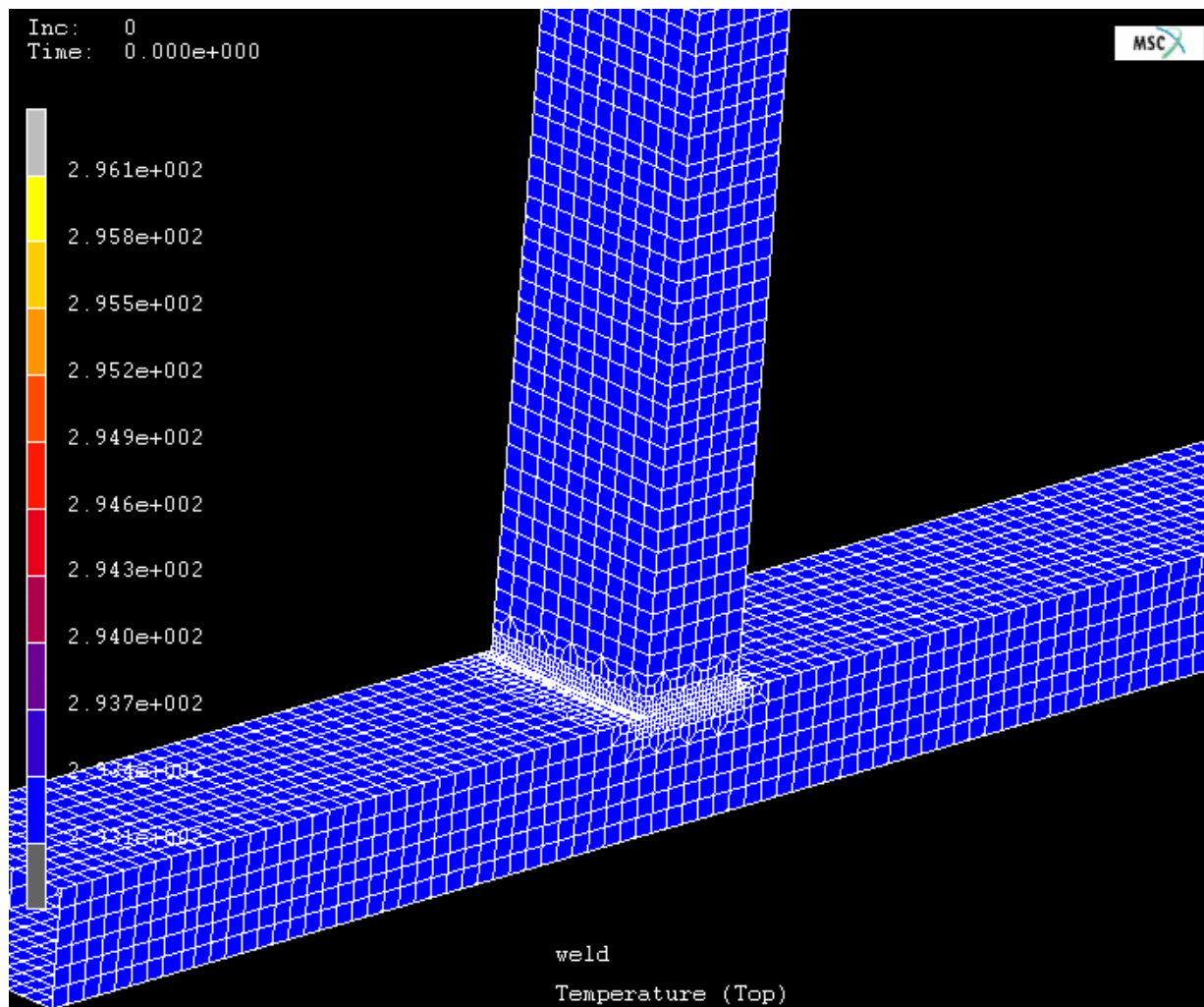
Bead Shape – Influences fatigue initiation

Material Addition – Adds stiffness to the weld joint

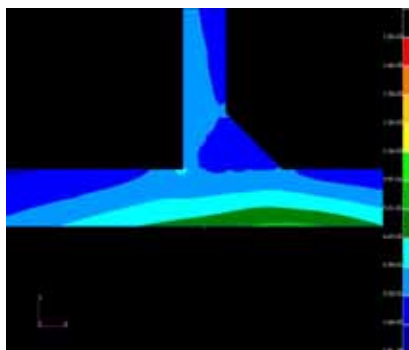
Weld Distortion



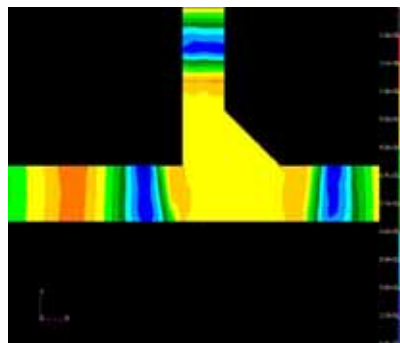
EWi



Stress Evolution in the Weld

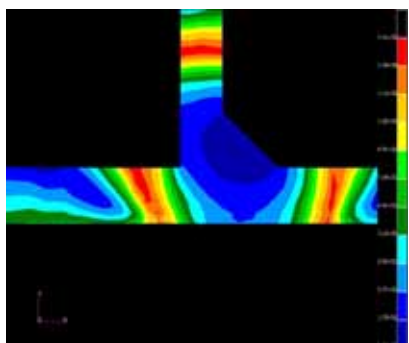


Cross-section B
Arc Location A

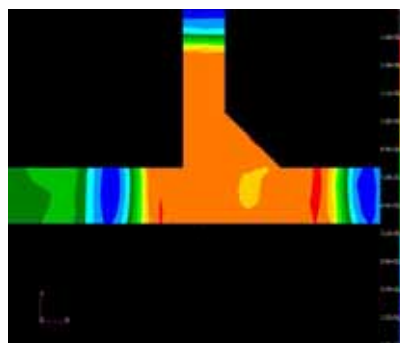


Cross-section B
Arc Location D

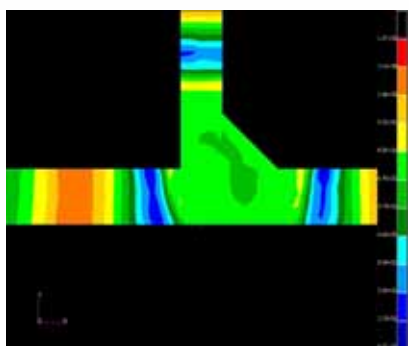
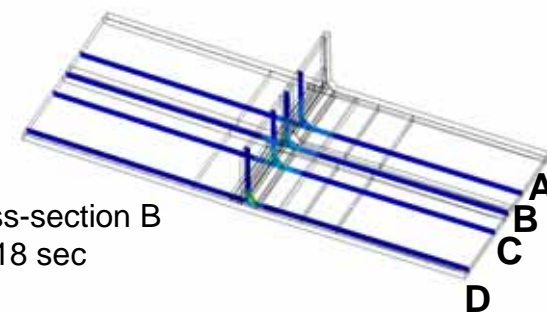
Von Mises Stress
T = Time after weld finish
Yield = 145 MPa



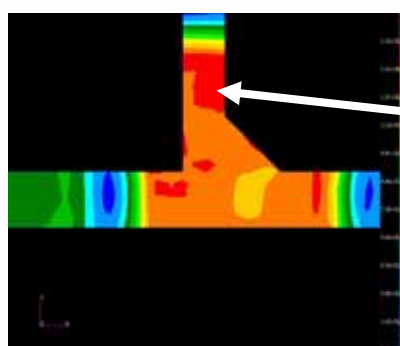
Cross-section B
Arc Location B



Cross-section B
T = 18 sec



Cross-section B
Arc Location C

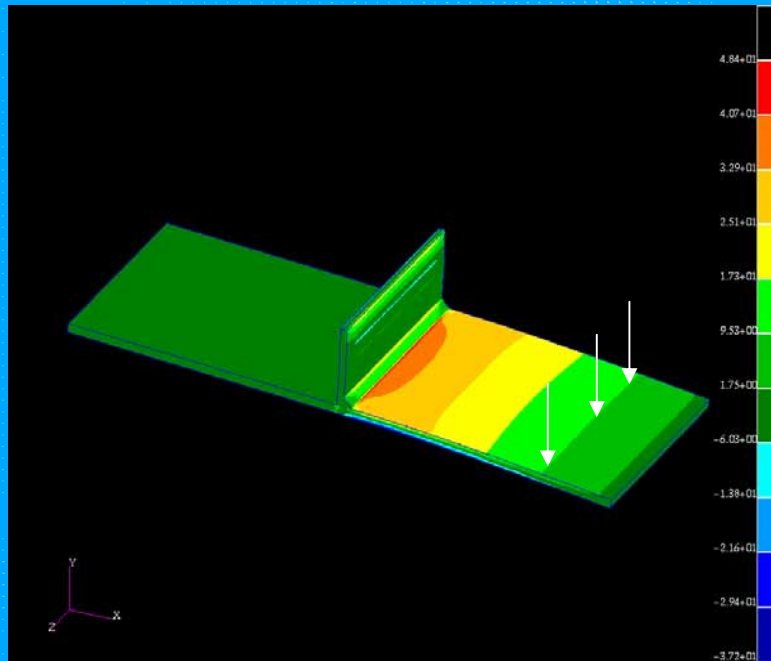


Exceeds Yield

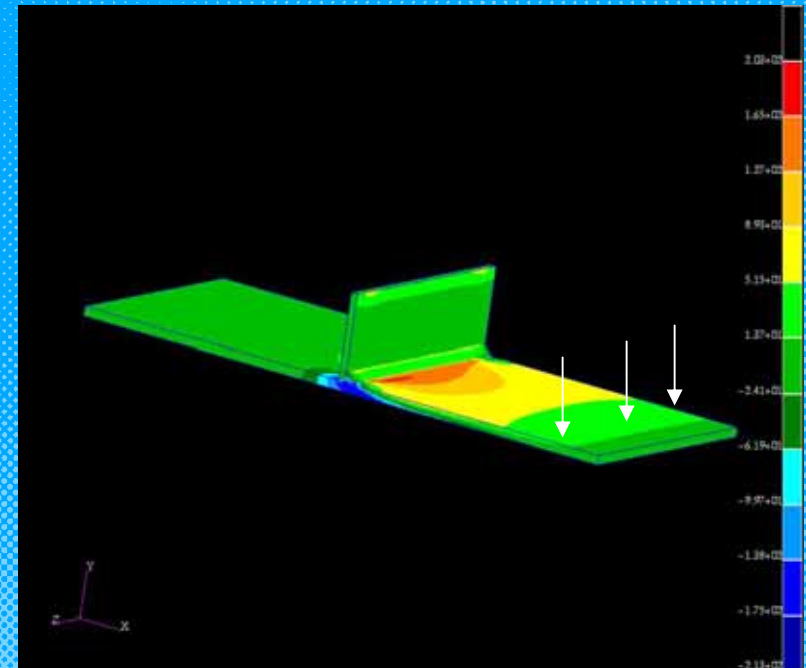
Cross-section B
T = 1 Hour

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Effect of Residual Stress on Performance

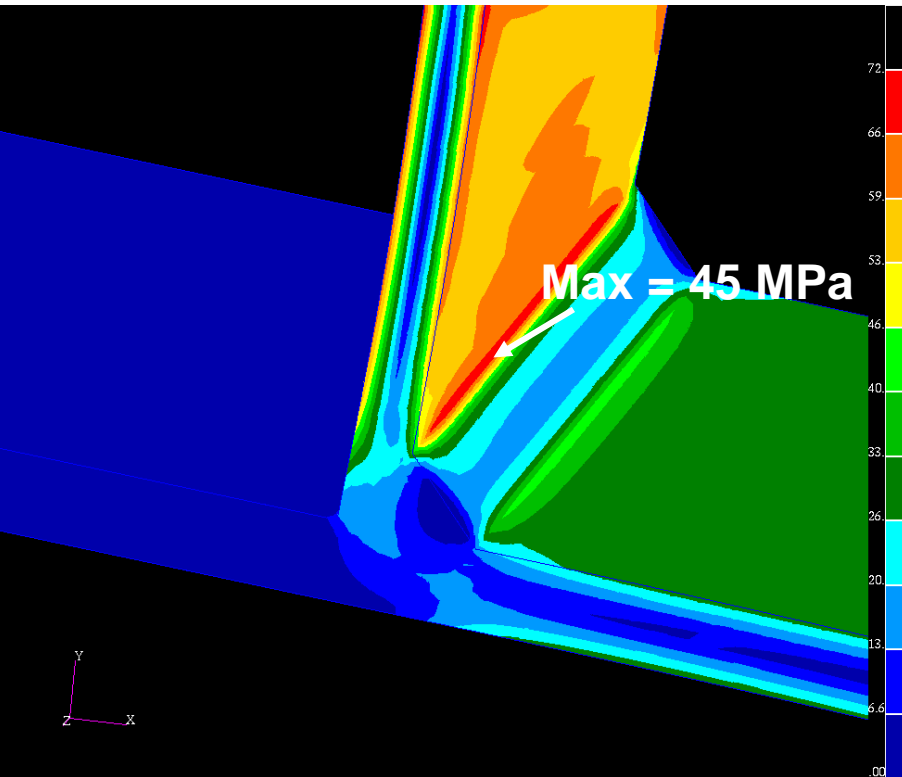


Bending Moment

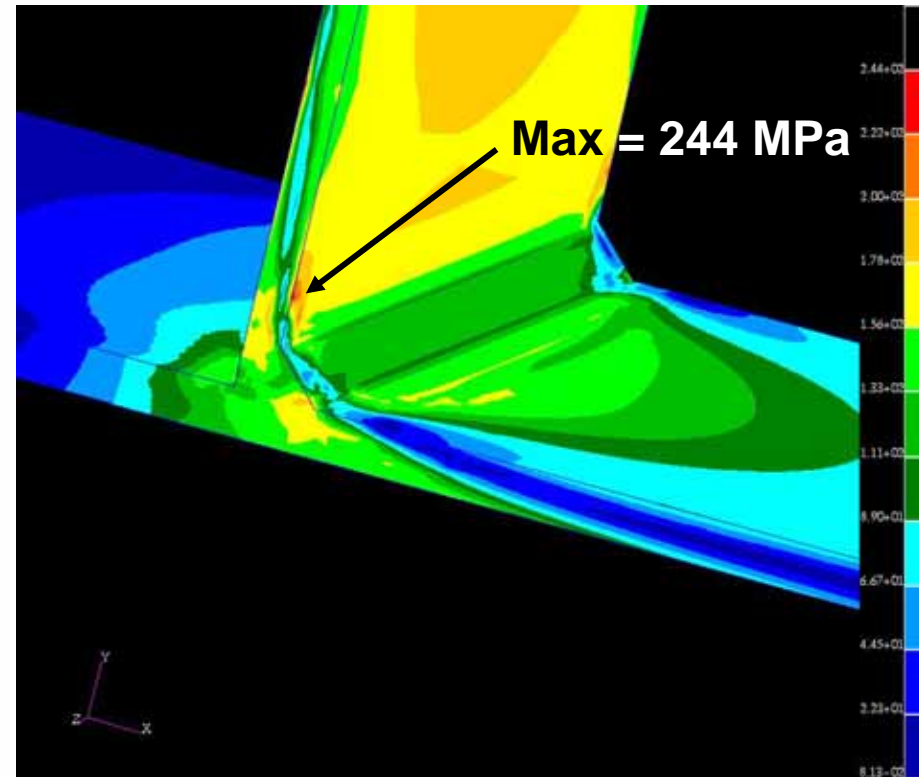


Residual Stress + Bending Moment

Effect of Residual Stress on Max Stress

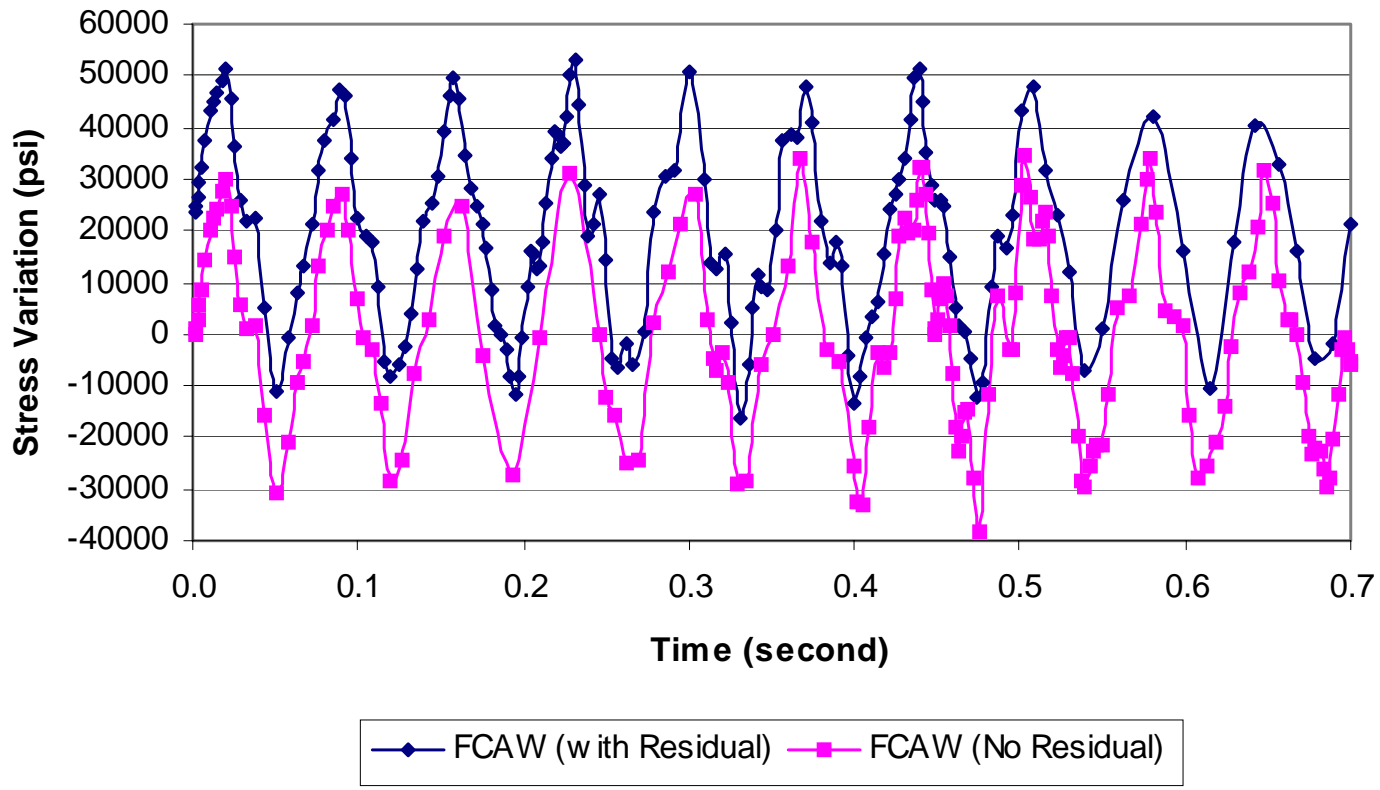


Bending Moment Only

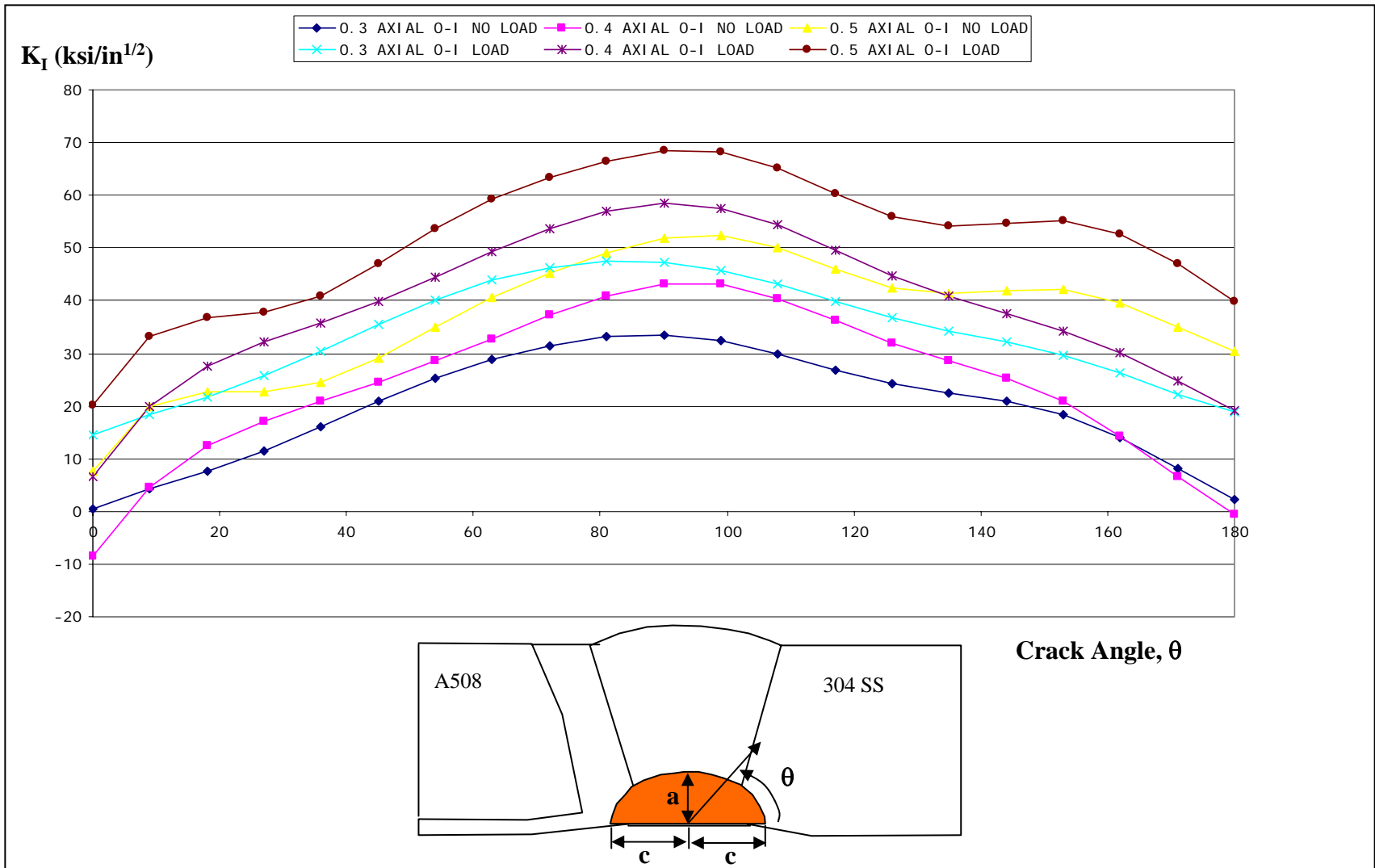


Residual Stress + Bending Moment

Effect of Residual Stress



Effect of Welding on Stress Intensity Factor

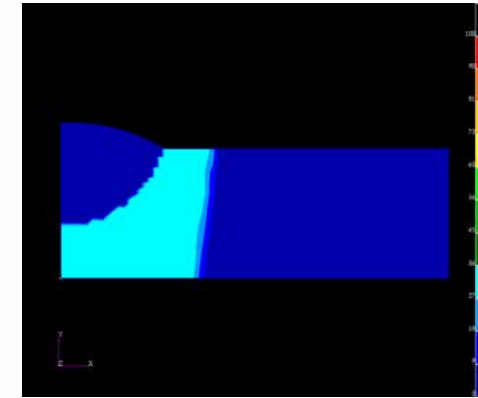
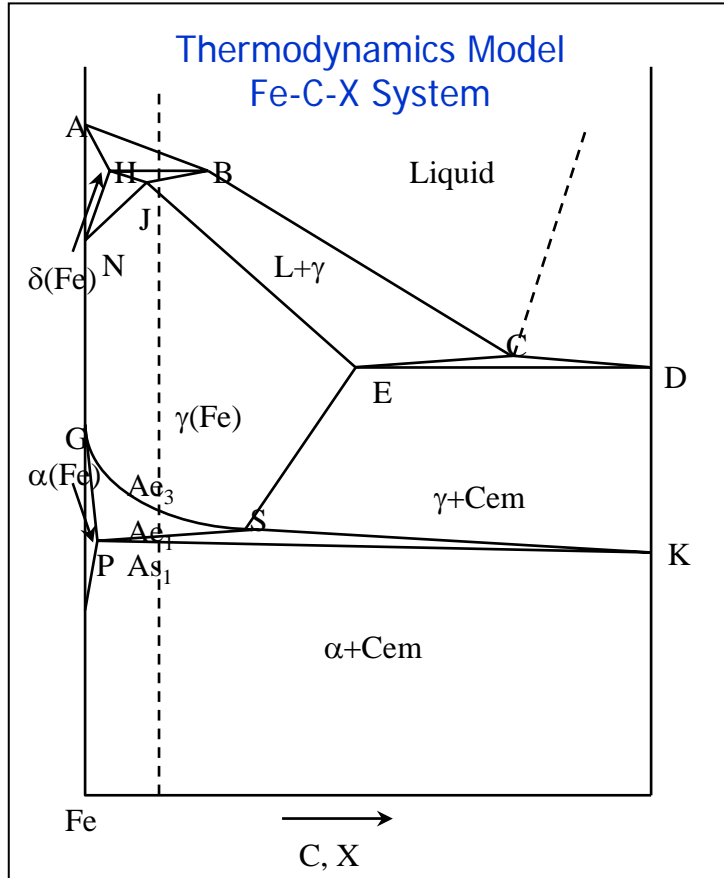


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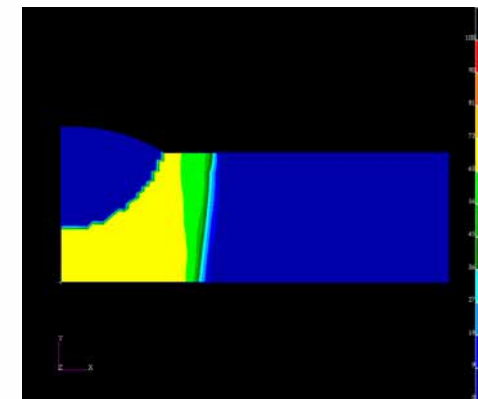
Microstructure Predictions



EWi



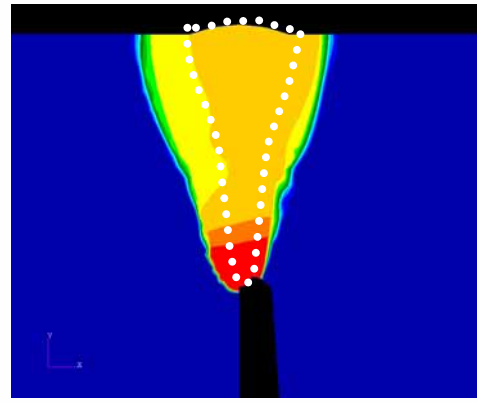
Ferrite



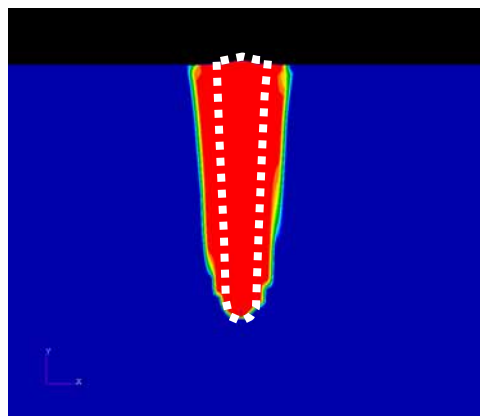
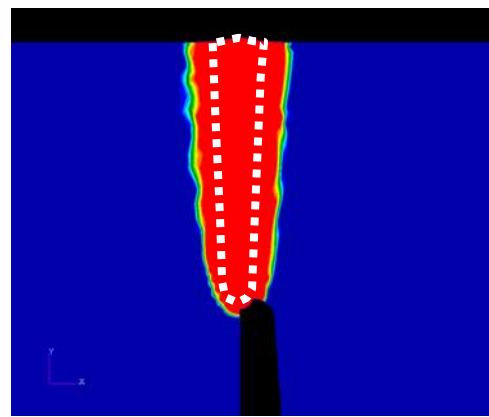
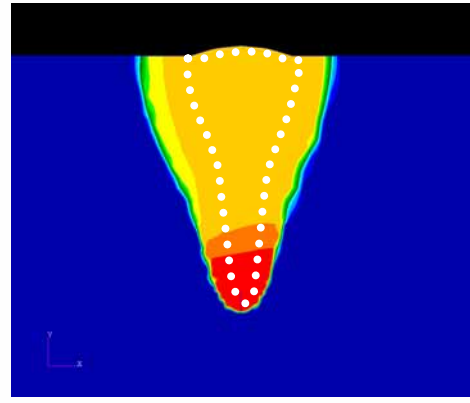
Bainite

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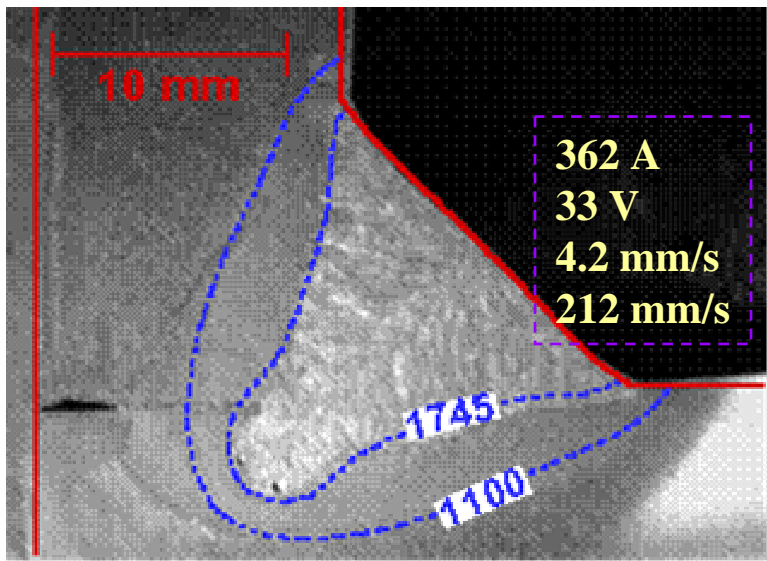
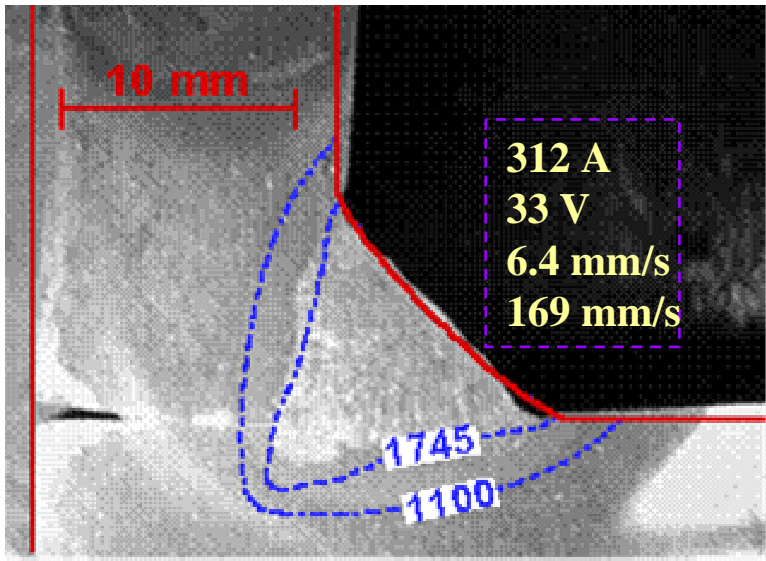
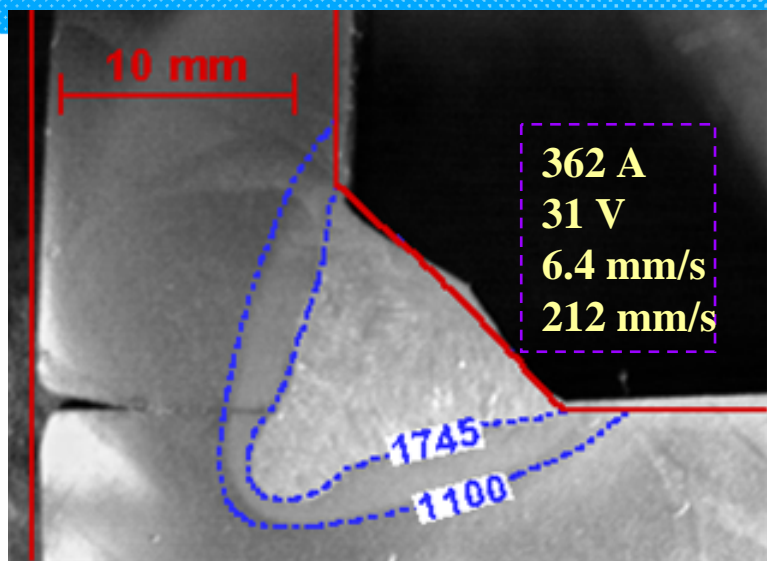
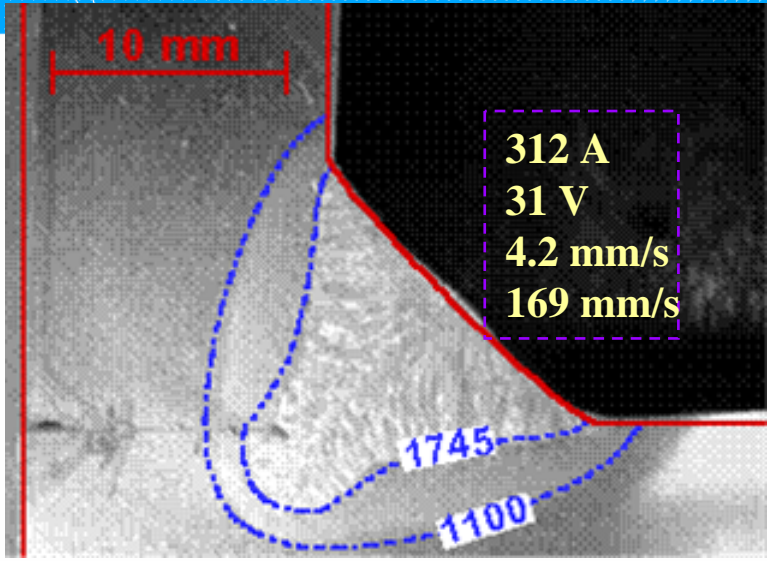
Volume Fraction of Martensite



Unit: %



Weld Bead Profile Prediction

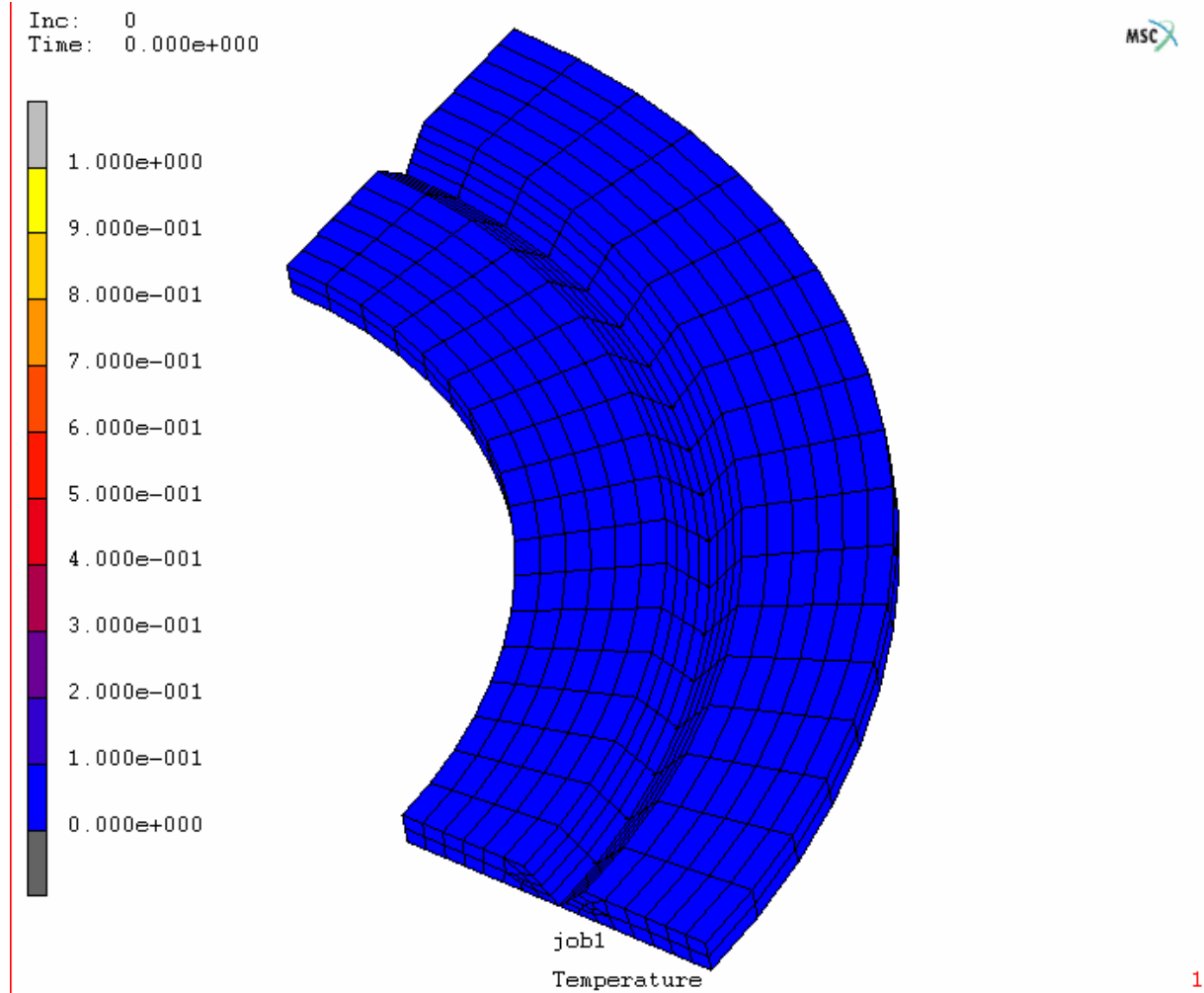


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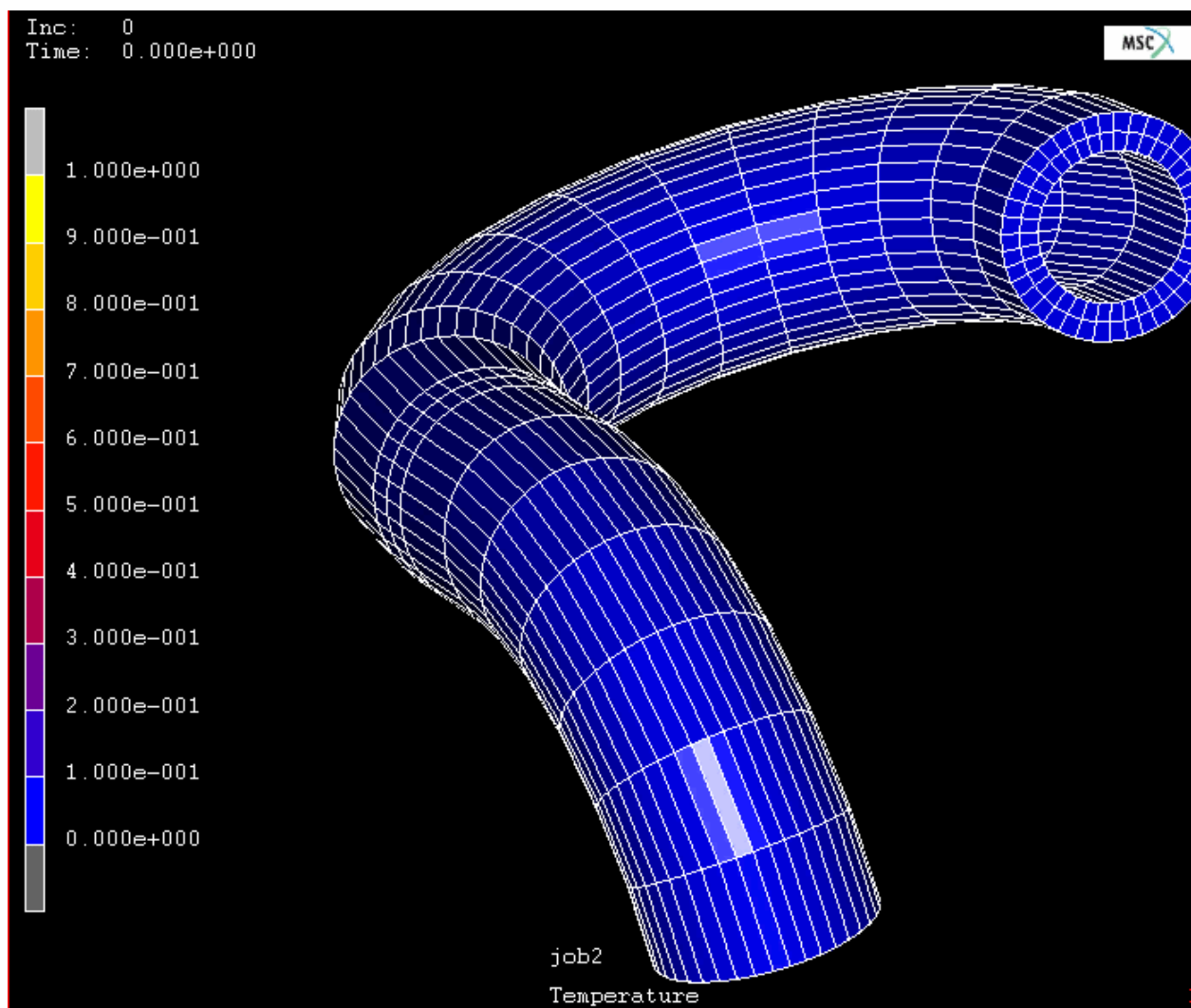
Arc Welding – Adding Filter



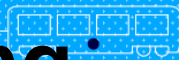
EWi



Arc Welding – Adding Material



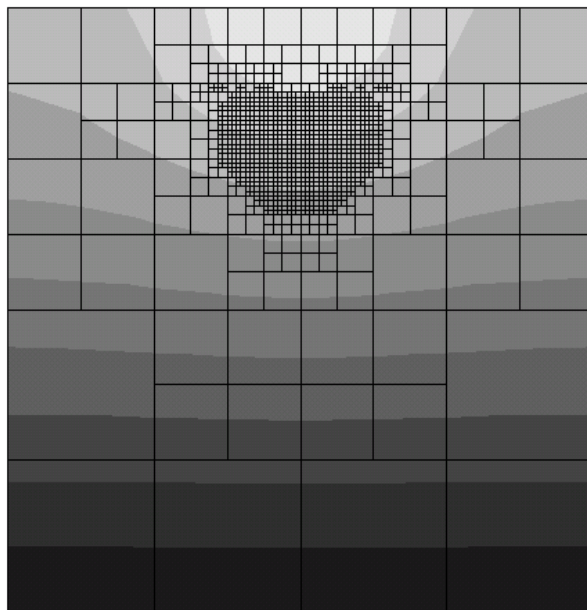
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Local Mesh Refinement can be based on

- Temperature Gradients
- Moving box

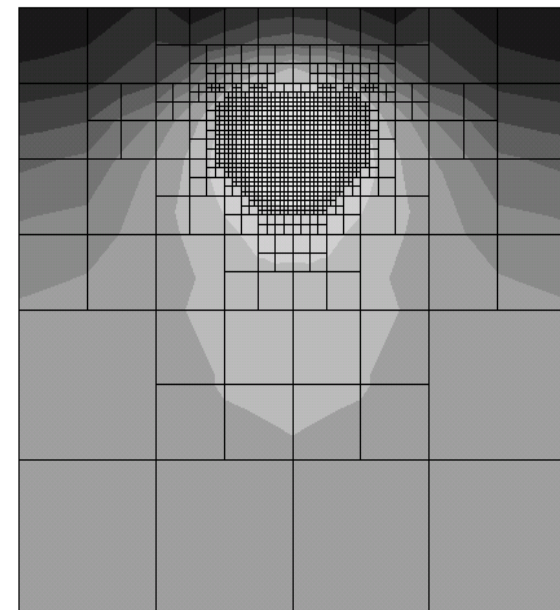
Temperature Contours



MSC

1

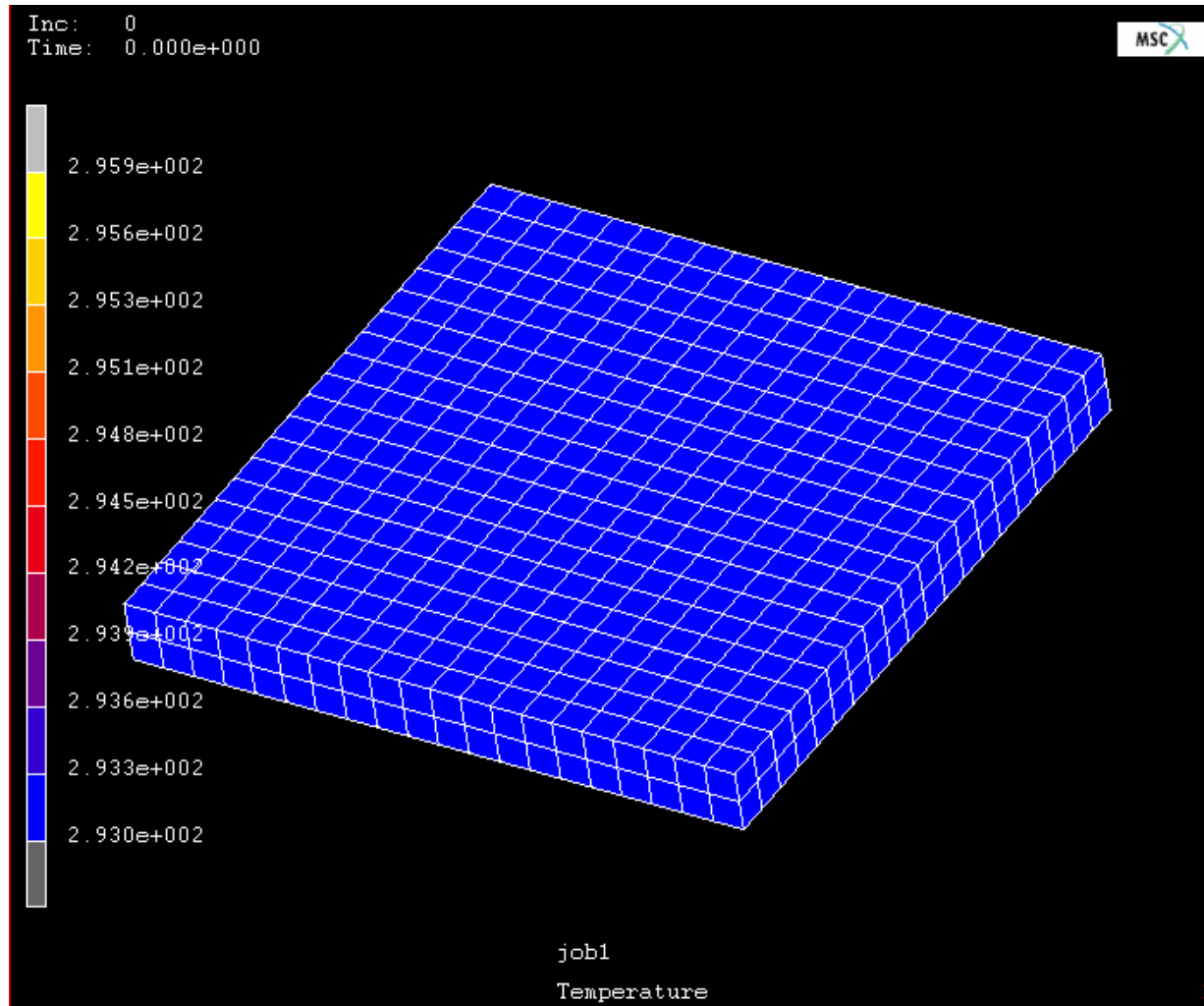
Gradient Contours



MSC

1

Adaptive Mesh Refinement



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Adaptive Meshing can significantly reduce run times

Parallel Processing can significantly reduce run times

Coupling of Weld Model results to Structural and Durability Analysis

- MSC.Nastran
- MSC.ADAMS
- MSC.Fatigue

Conclusions



Weld Zone material properties and stress state will affect the response of the structure to load and vibration

Weld Modeling Tools are Emerging

Coupled, non-linear analysis is required

Mapping Results to other Analyses will be increasingly important