# Comparison and Analysis of Prediction of Residual Stress in a Constrained Weld with Experimental Data

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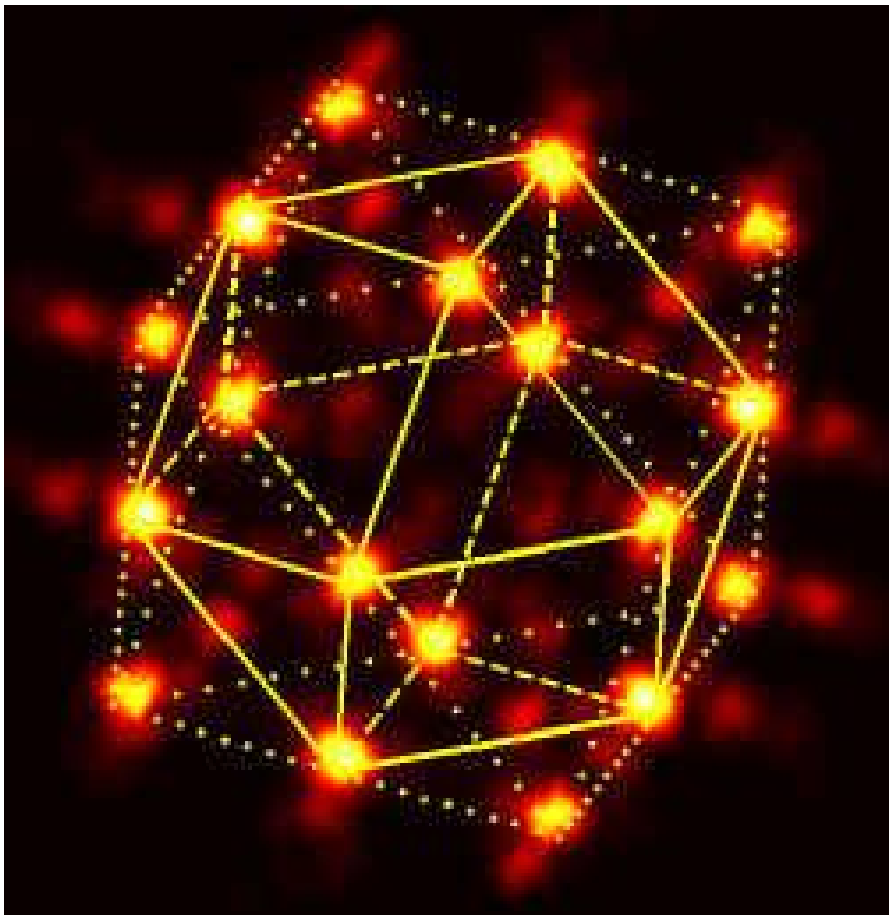

## Abstract:

A software program for analyzing welds, VrWeld, is employed to compute the residual stress in a welded plate restrained to a thick plate by eight tack welds during welding. The tack welds were severed after cool down to release the restraints and then the residual stresses were measured.

The software analyses this problem by solving the 3D transient temperature field using a double ellipsoid heat source model for the welding arc, the evolution of micro-structure and the evolution of the thermo-visco-elasto-plastic stress-strain fields.

Three papers published recently by John W. H. Price and Anna Paradowska present data for experimental measurements of residual stress. In two papers the residual stress was measured by neutron diffraction and in the third paper it was measured by synchrotron x-ray diffraction.

Their data indicate that there is likely a non-ignorable level of measurement error. Unfortunately there is not enough information in the data to estimate the magnitude of this error.

The computed residual stress is compared to the published experimental data to make the point that although the computed residual stress deviates from the experimental results, this deviation may lie within the level of uncertainty in the experiment. Therefore validation by comparison is only possible if a measure of this uncertainty is estimable.

## References;


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# Experimental Setup;

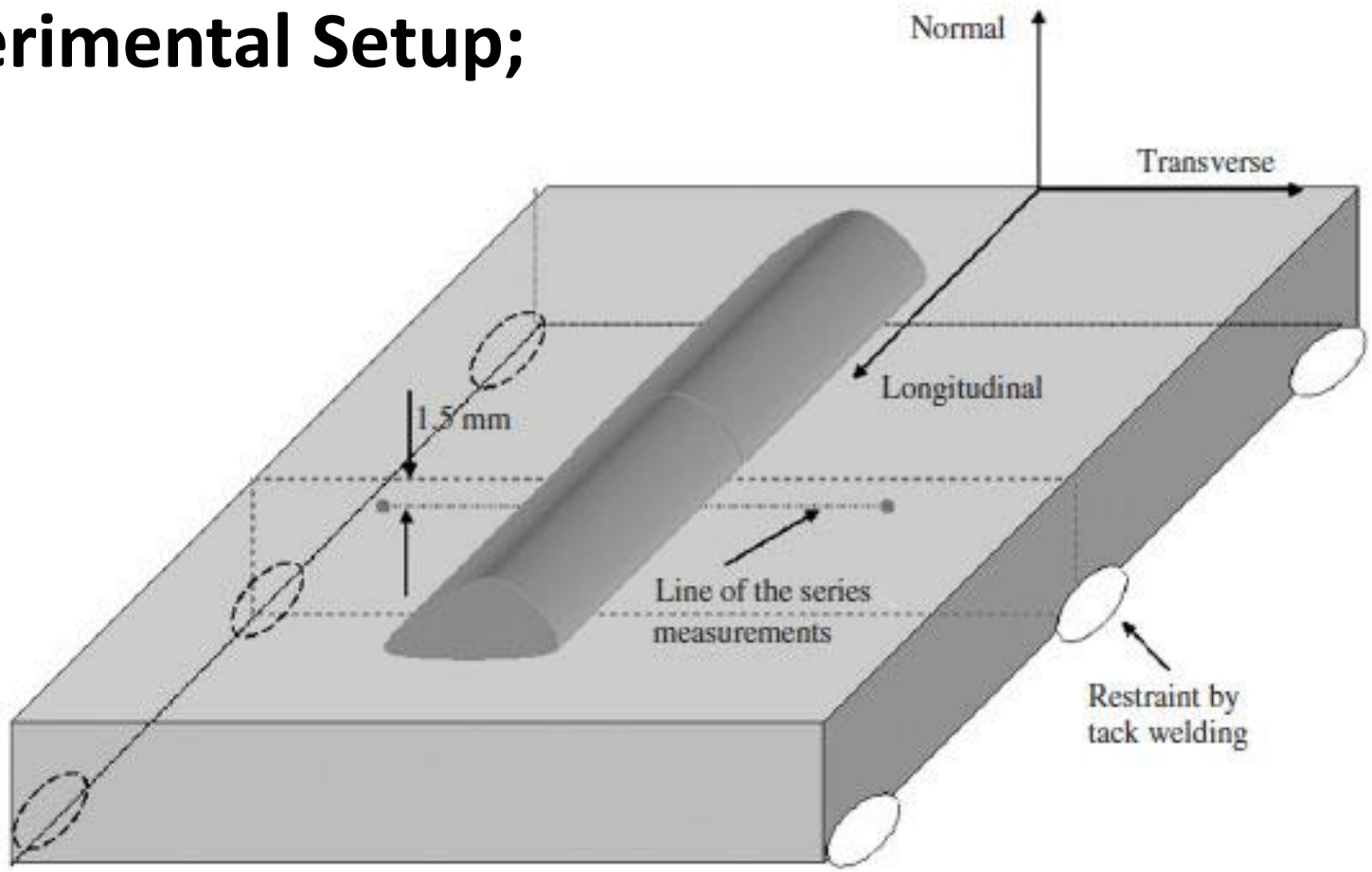
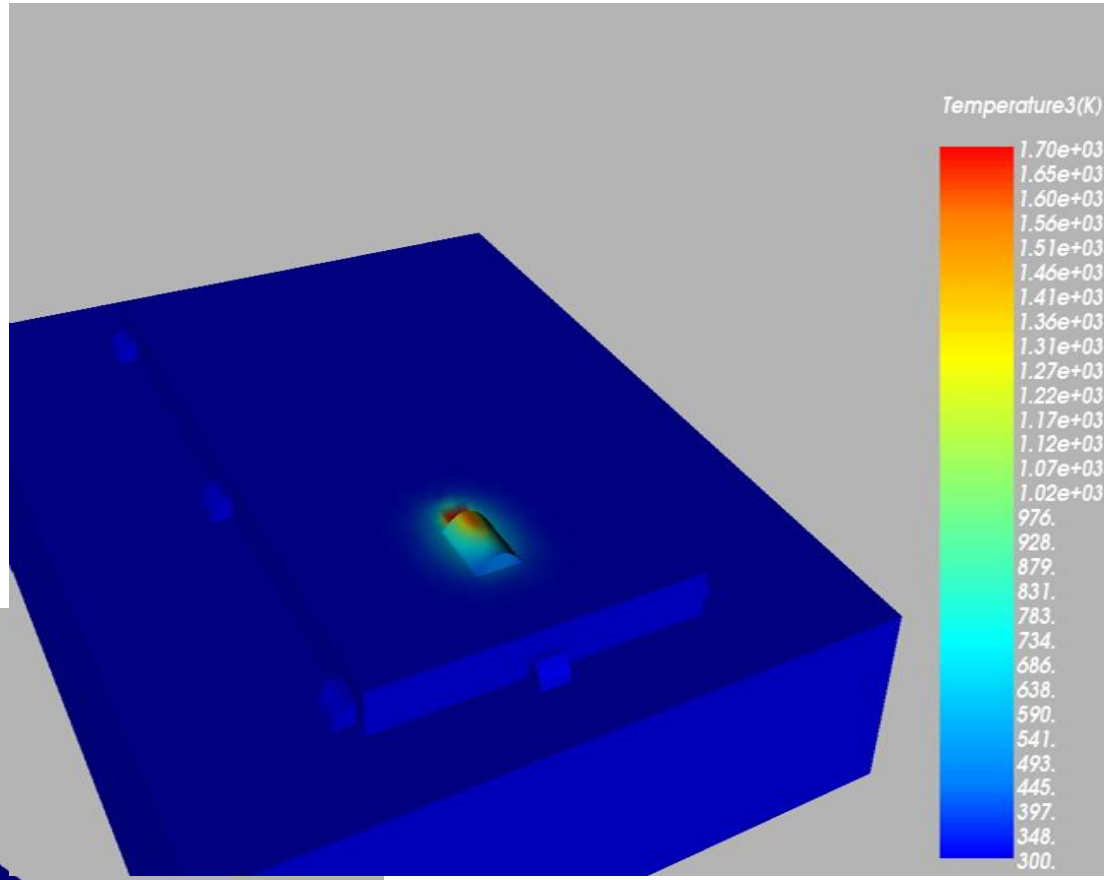
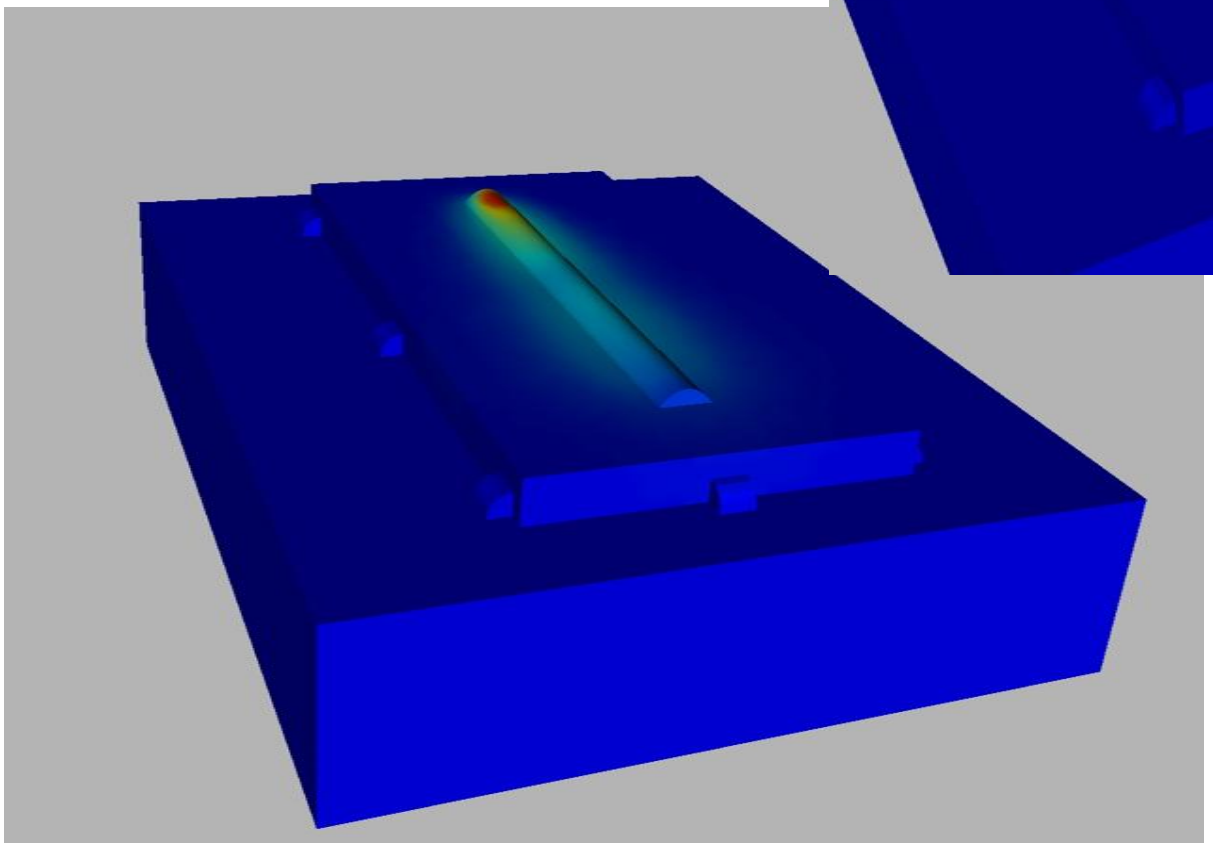


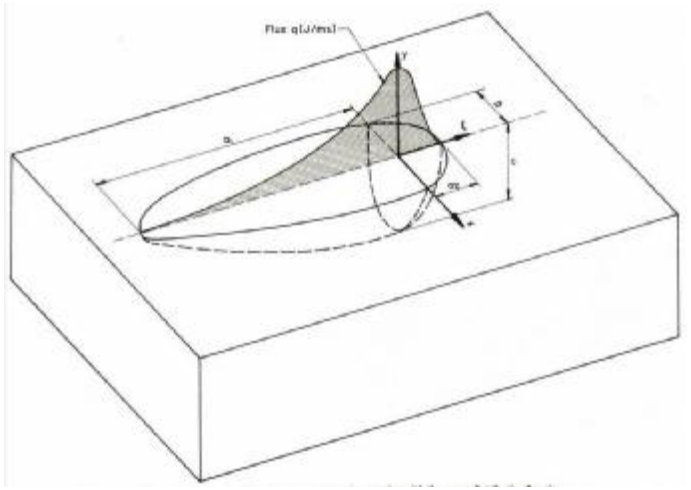

Table 1: Chemical composition of consumable materials (in wt%)

| Composition | C | Mn | Si | S | P | Ni | Cr | Mo | Cu | V | Ti | Co | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parent metal | 0.12 | 0.63 | 0.13 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | <0.01 | <0.01 | <0.01 | 0.03 |
| Weld metal | 0.10 | 1.76 | 0.68 | 0.02 | 0.02 | 0.05 | 0.03 | 0.04 | - | 0.04 | - | - | - |

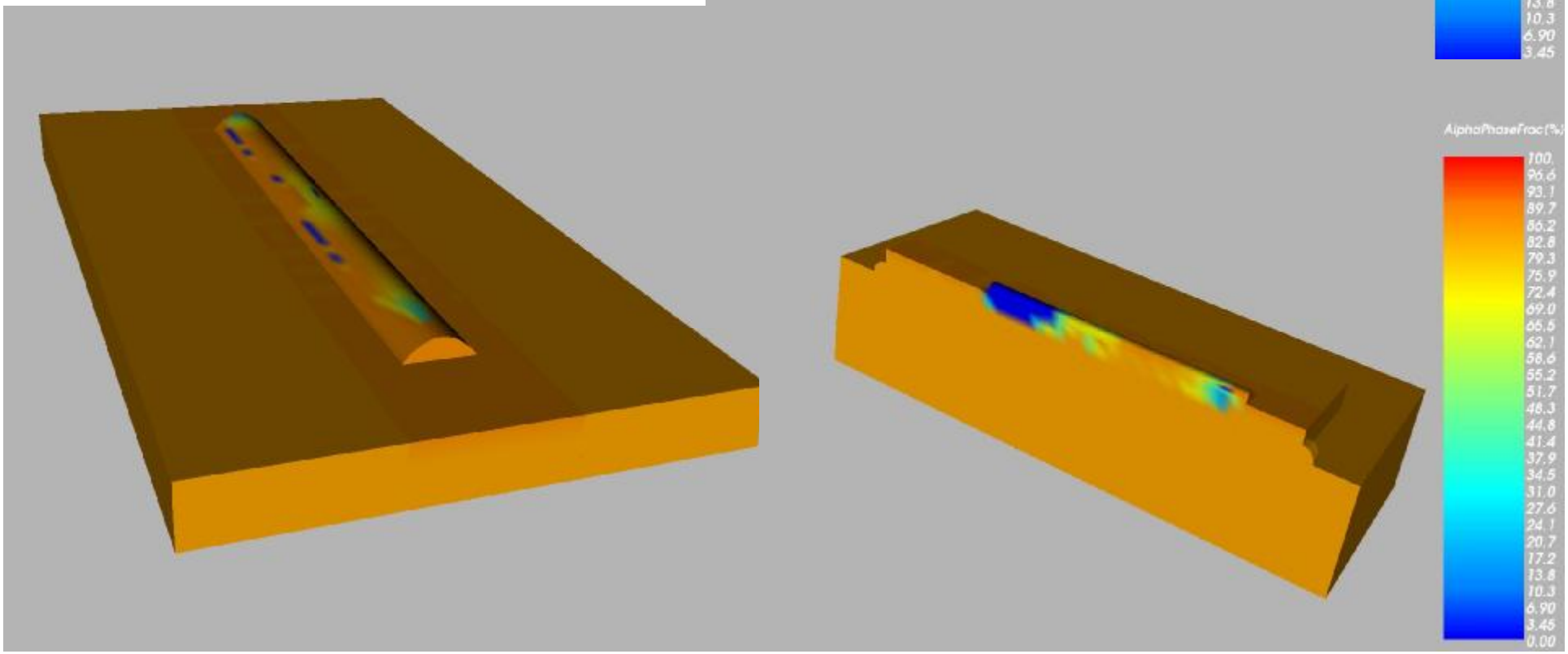
# Numerical Algorithm Thermal;



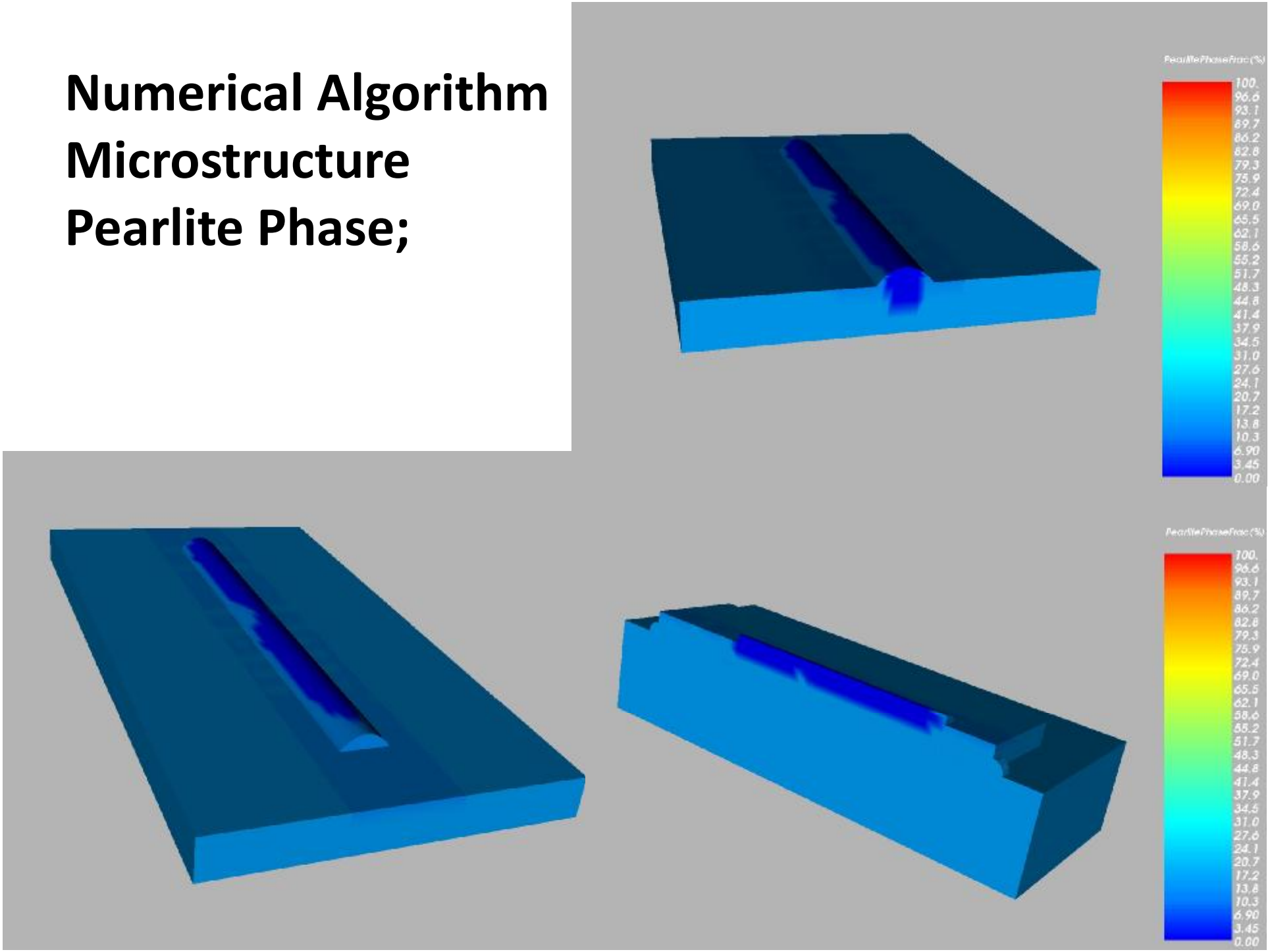





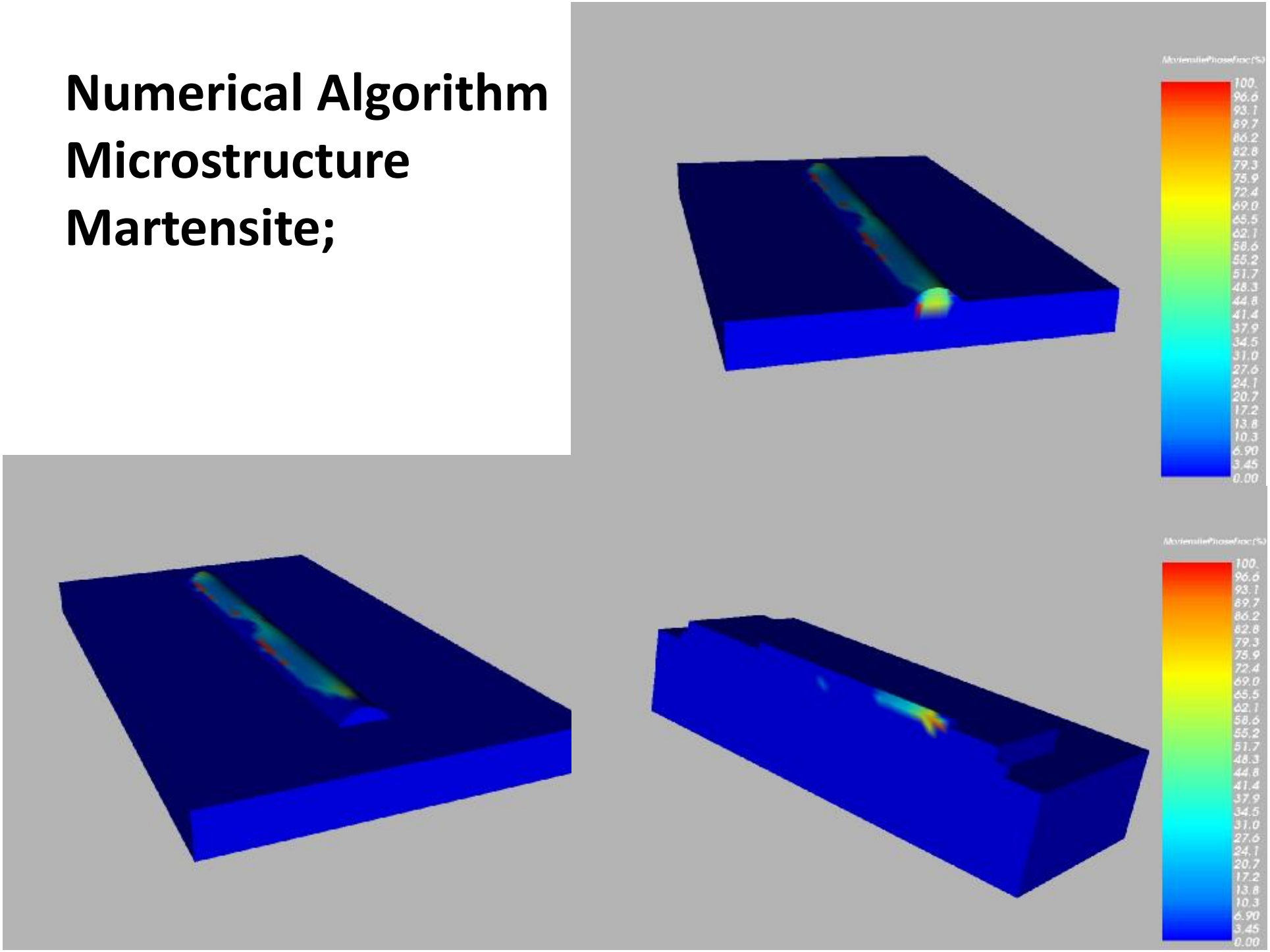
# Numerical Algorithm Microstructure Alpha Phase;



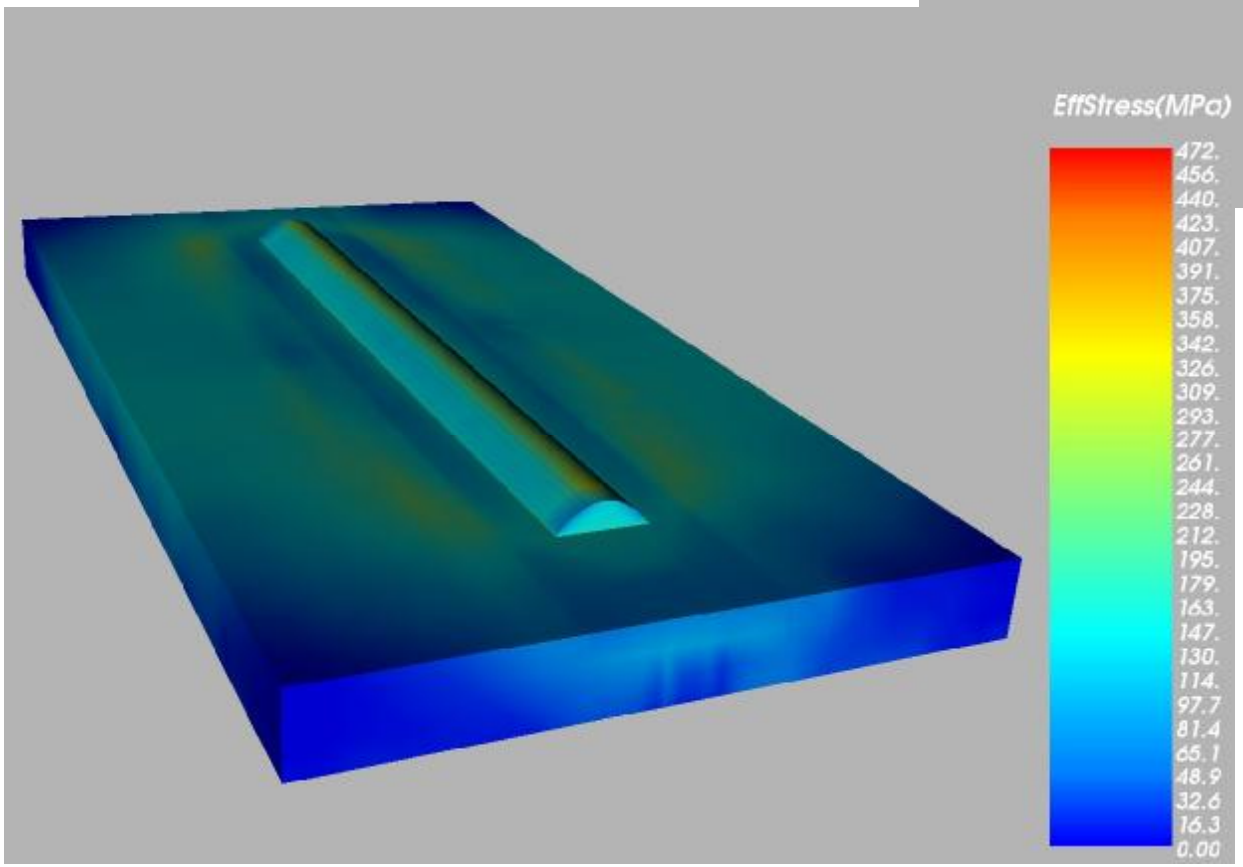
# Numerical Algorithm Microstructure Pearlite Phase;

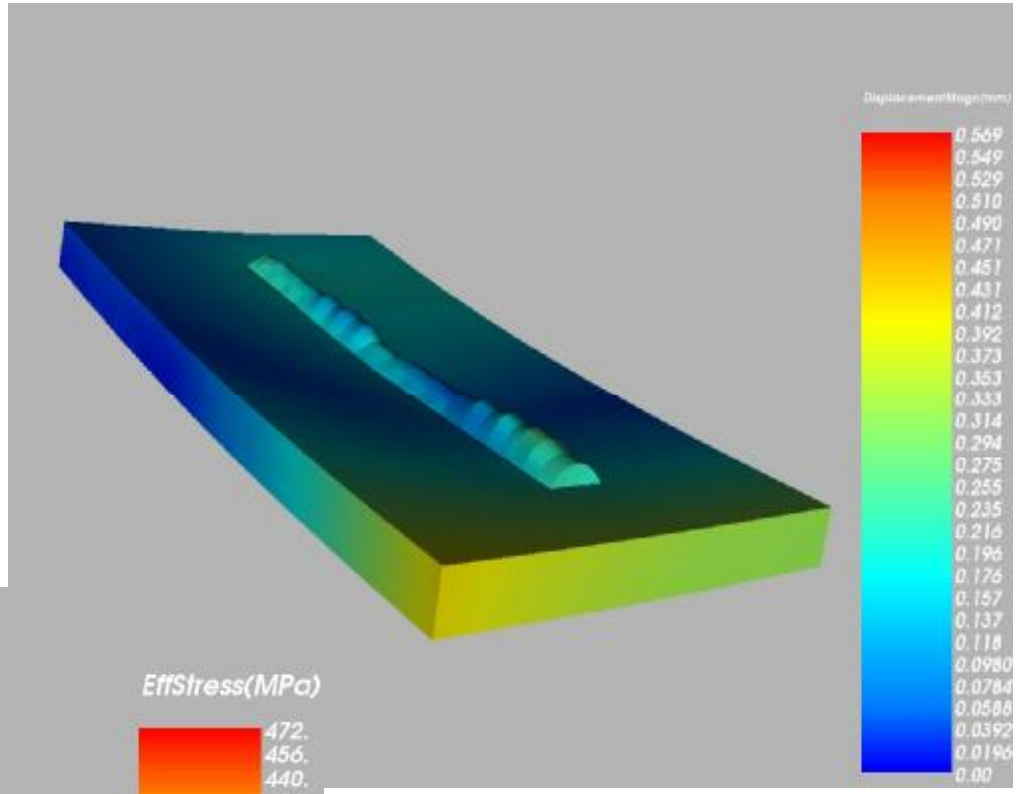


# Numerical Algorithm Microstructure Martensite;

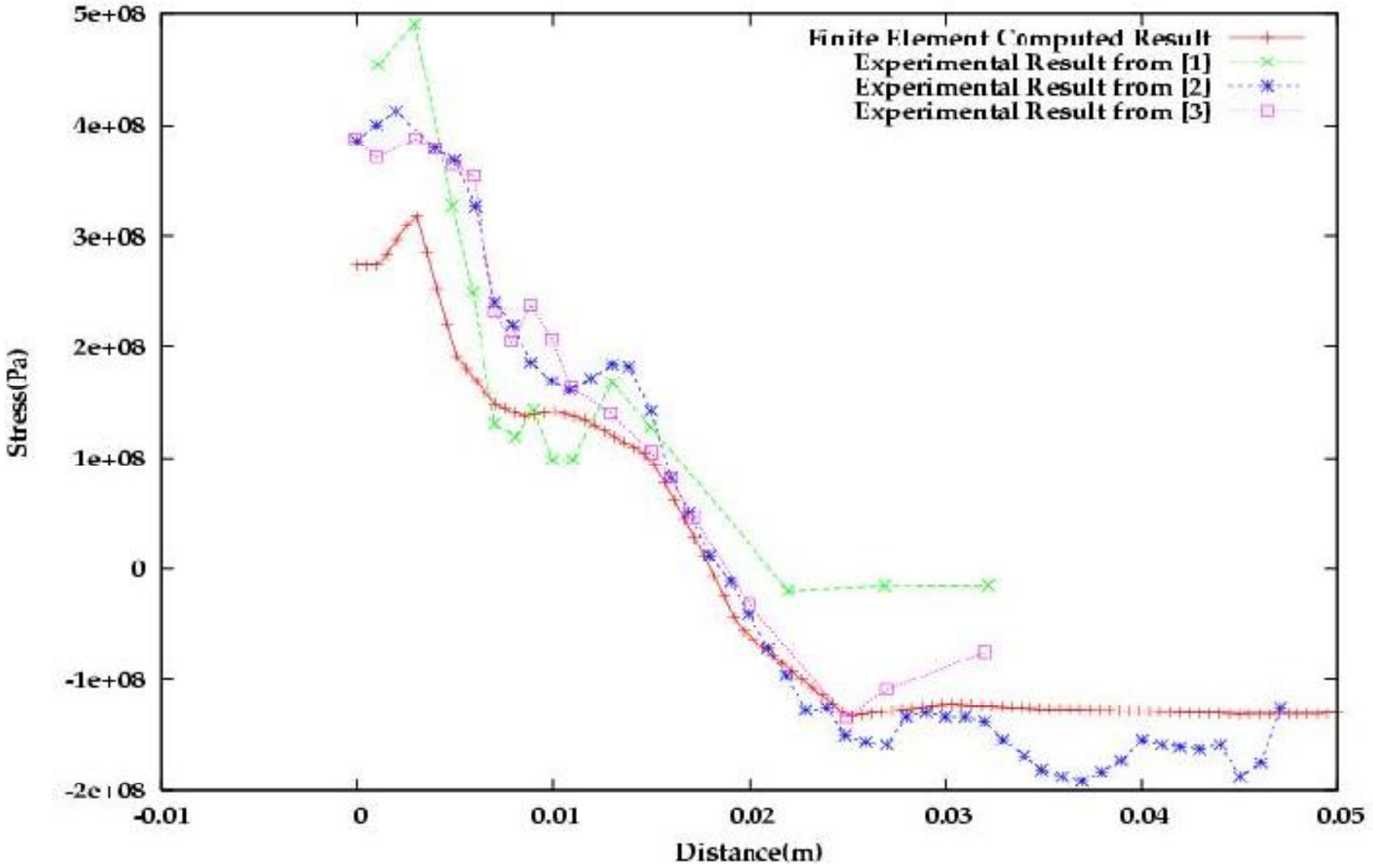


# Numerical Algorithm
# Stress & Displacement;

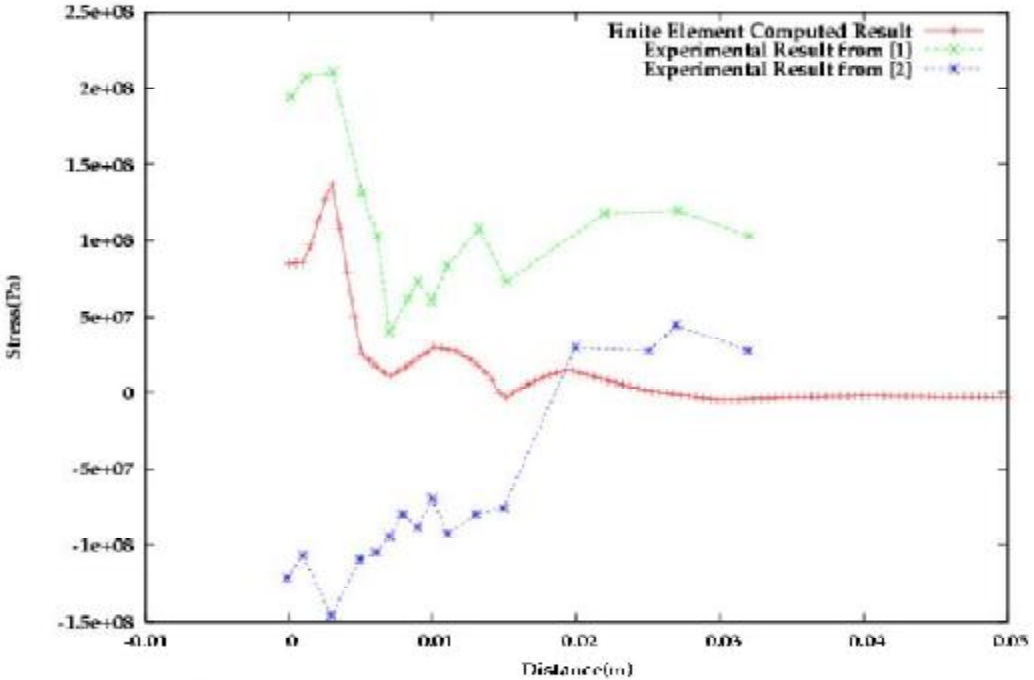


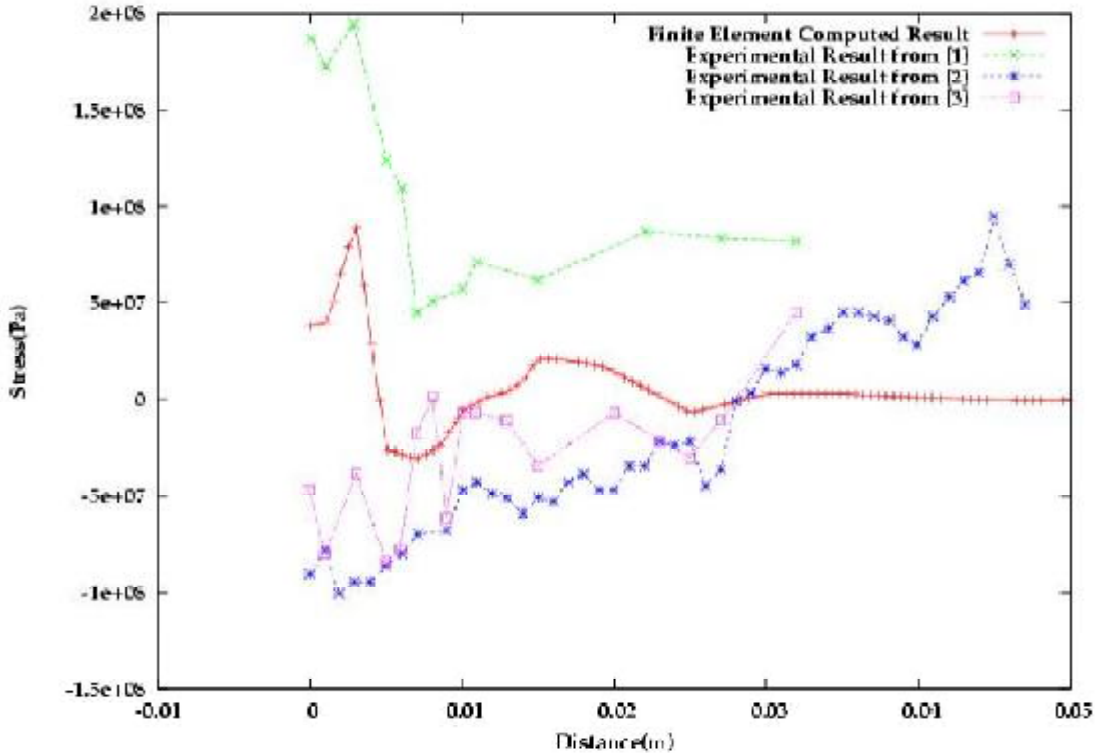



# Comparison to Experimental Data
# Longitudinal Residual Stress;



# Comparison to Experimental Data Transverse & Normal Residual Stress;



## Conclusion;

Transient numerical models are well advanced and often can provide predictions that are close to he observed reality. They have the potential to capture most of the macroscopic behaviour of systems and their algorithms apply most of the known relevant macroscopic physics of the problem. Often they can predict the behaviour of interest. Although they are powerful, they do approximate and their solutions are not exact. It is very common to judge a model by comparing model predictions to experimental data. Often models are criticized if model predictions disagree with experimental measurements.

This argument is only valid if a measure of uncertainty is provided and one can show that model predictions lie outside of a range of acceptable deviation. Similarly, one cannot conclude that ones model has good predictive ability simply because the deviation between the predicted and experimental data is ``small'' since the severity of discrepancy cannot be quantified without some
notion of variability.

It was argued, for instance, that seeking accuracy of stress values with errors less than +/- 2 % is not realistic even if it is suggested by an analysis. Even in engineering practice an accuracy of +/- 10 % for stress would be considered more realistic.

It Comparing different sets of measurement data done on a similar sample for longitudinal, transverse and normal component of residual stress shows a discrepancy between numerical and measured plots. However, without any measure of variability conclusions as to the severity of this
deviation cannot be made. In other words, this experimental data provides no evidence to reject, criticize or embrace the model.

The number of experiments was not sufficient to provide the data needed to use statistical theory to infer a confidence measure for or against the model.

(The author's confidence in the model is not based on comparison with experiment. It is based on the fact that the model uses the best available known relevant physics. This known physics is based on experiments other than welding. However the model does seem to capture the overall trend observed in the experiment suggesting that the model would be useful for a sensitivity analysis. To rigorously compare the model to experimental data, one would need replicate sets of experimental datato establish an estimate of the variability required for statistical inference.