FINITE ELEMENT SIMULATION OF RESISTANCE SPOT WELDING

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Motivation

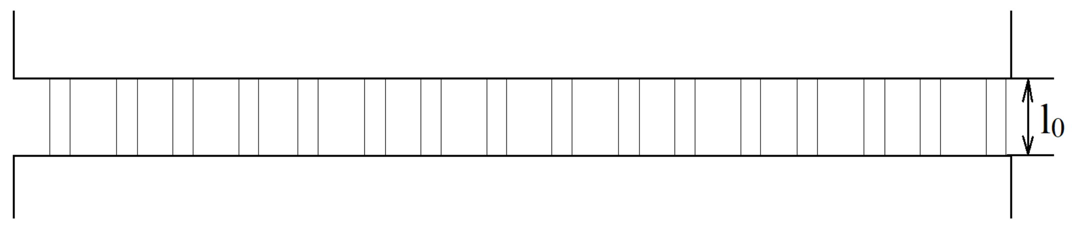
- Great emphasis is being laid on reducing the weight of automobiles in order to reduce their CO_2 emissions.
- Recently developed 3rd generation advanced high strength steels possessing strength >1GPa help accomplish this goal.
- These alloys require dedicated weld schedules to modify weld thermal cycles to prevent brittle failure during loading.
- Accurate but fast finite element simulations are necessary in order to simulate and optimize weld thermal cycles.

Objective

The objective of the project is to study the effect of various welding parameters on accuracy and computational cost of simulating resistance spot welding.

Interface resistance model

Motivation: It is difficult to obtain temperature-dependent sheet-sheet interface resistance using traditional models[1,2]

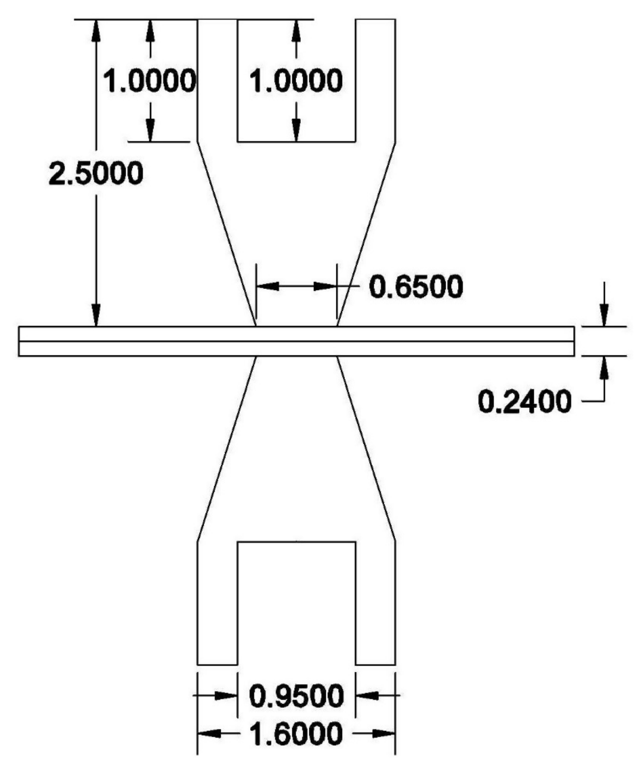


$$R(T) = f_s \times \rho_e(T) \times \frac{\sigma^2(T) \times \rho(T_0)}{\sigma(T_0) \times P \times \rho(T)} \times l_0, \text{ where}$$

R(T) is the sheet-sheet interface resistance,
f_s is film resistance factor,
$\rho_e(T)$ is the electrical resistivity,
$\sigma(T)$ is the yield strength,
$\rho(T)$ is the density,
P is the applied load, and
T_0 is room temperature.

Simulation methodology

COMSOL Multiphysics was used to perform simulations.
Coupled electrical and thermal physics were solved for.
Materials properties were obtained from JMatPro software.
The following geometry was used for the simulations:



All dimensions in cm

Boundary conditions:

1. T=297K at cooling channel surface of both electrodes.
2. Voltage=0 at bottom face of the electrode.
3. Thermal and electrical insulation on remaining surfaces.

The effect of the following model parameters was studied:

1. Geometry
2. Current-time profile
3. Mesh size
4. Interface resistance type (surface resistance/film)

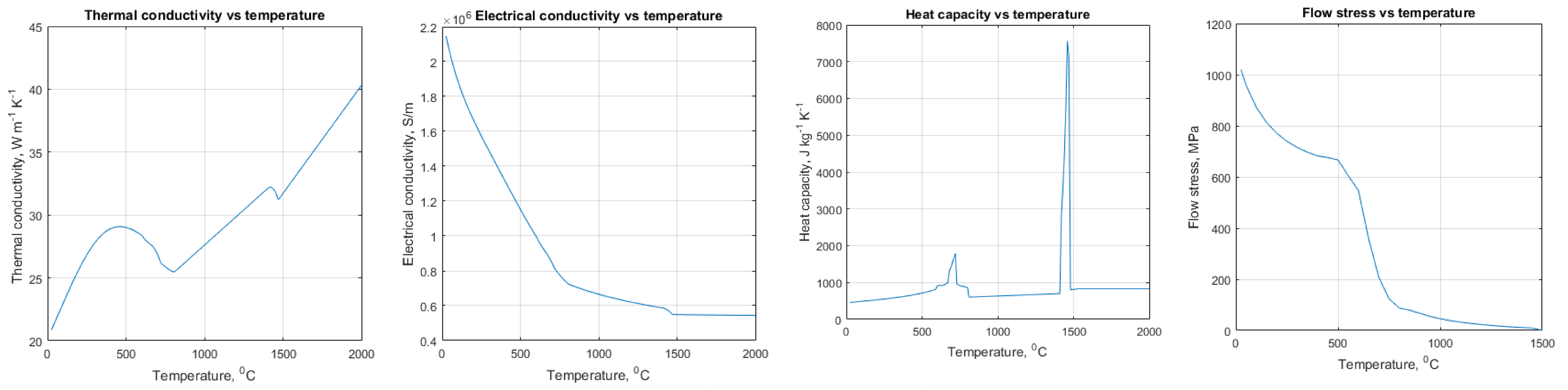
Composition of DP1000 alloy used for simulations is as follows:

Element	Amount, wt%
Carbon	0.22
Manganese	2.90
Silicon	1.90
Phosphorus	0.011
Aluminium	0.05
Chromium + Molybdenum	1.40

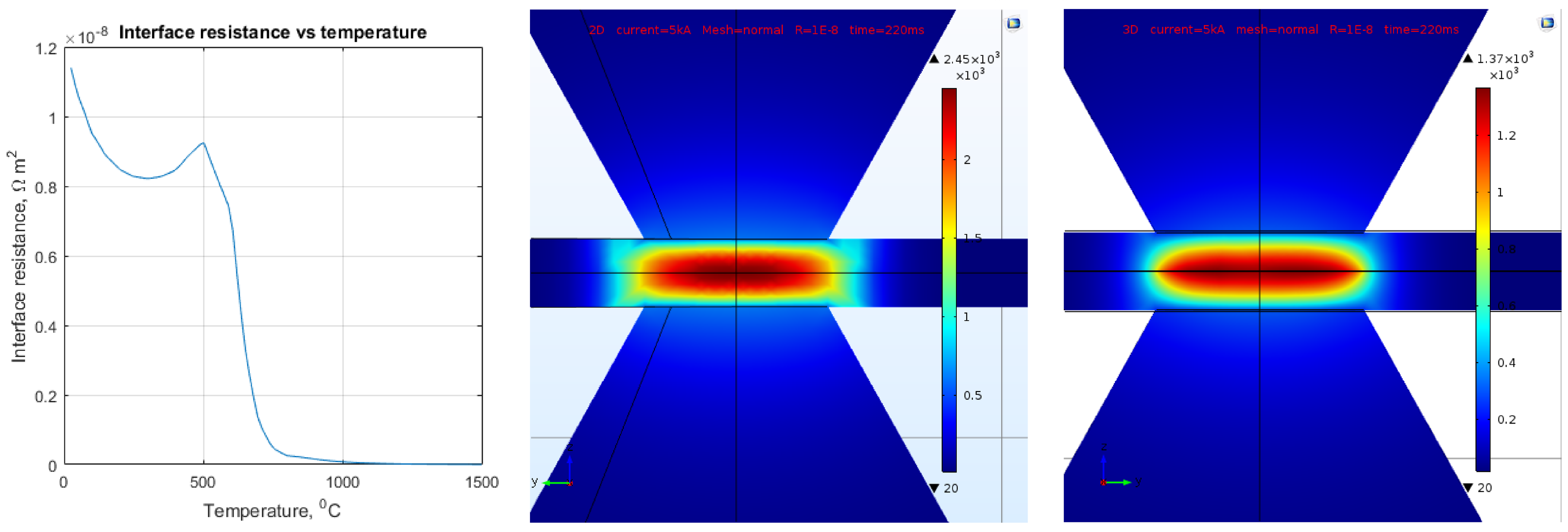
The following welding parameters were used:

Process parameter	Value
Current	4.0-8.0 kA
Electrode force	3.5 kN
Squeeze time	500 ms
Weld time	120 ms
Hold time	380 ms

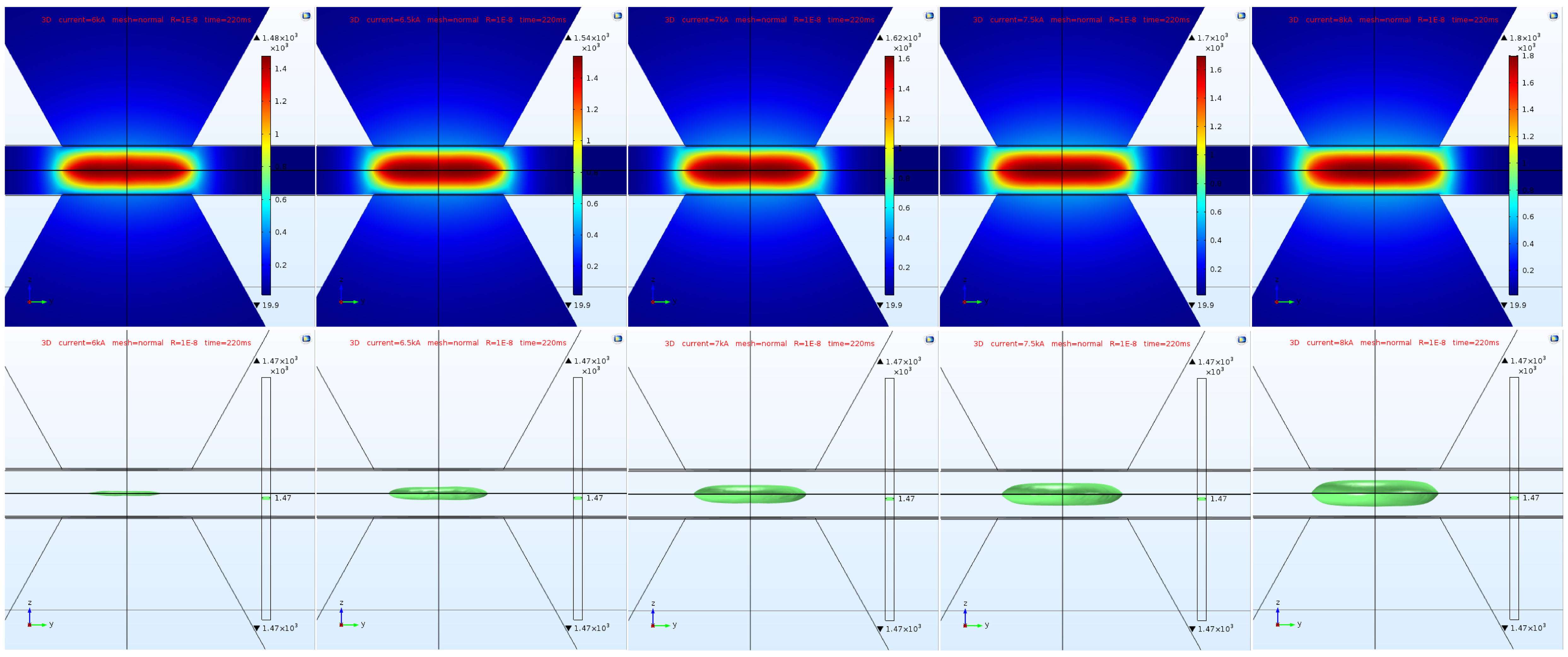
Results & Discussion

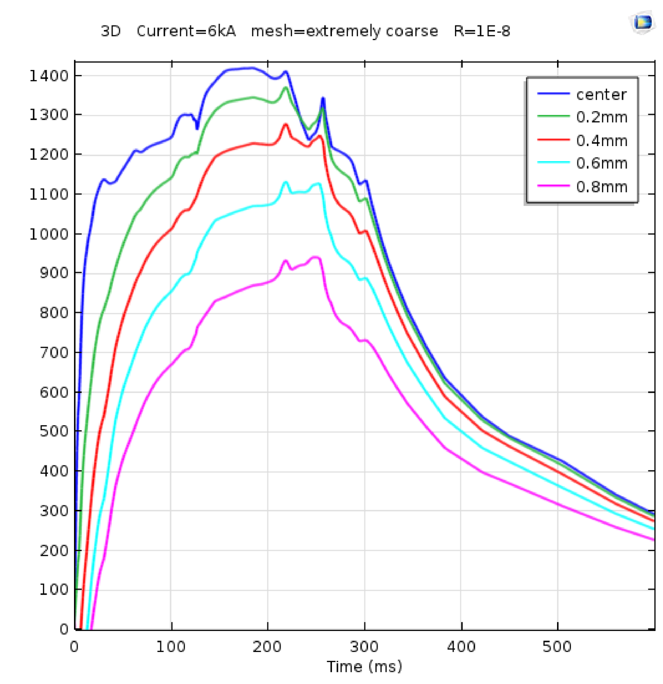


Materials properties plots



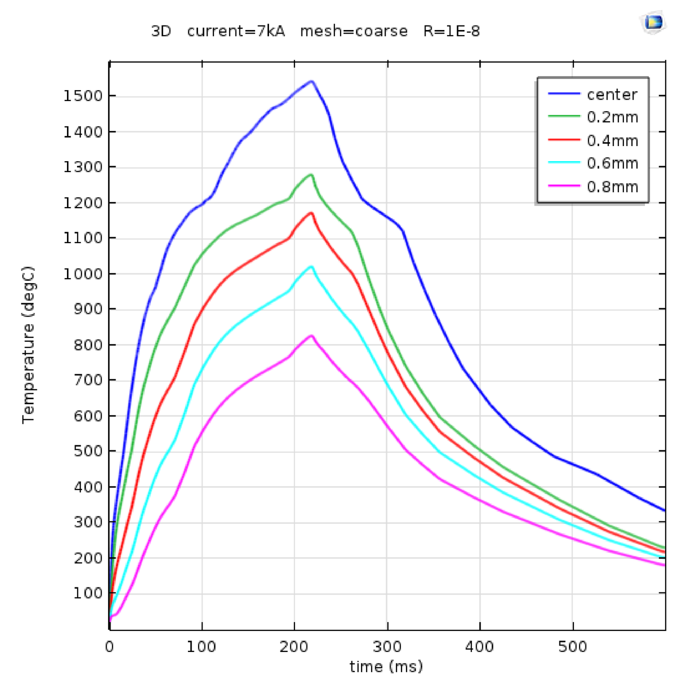
Figures left to right: Interface resistance vs temperature plot (model predicted); temperature profile, 2D axisymmetric model; temperature profile, 3D model.

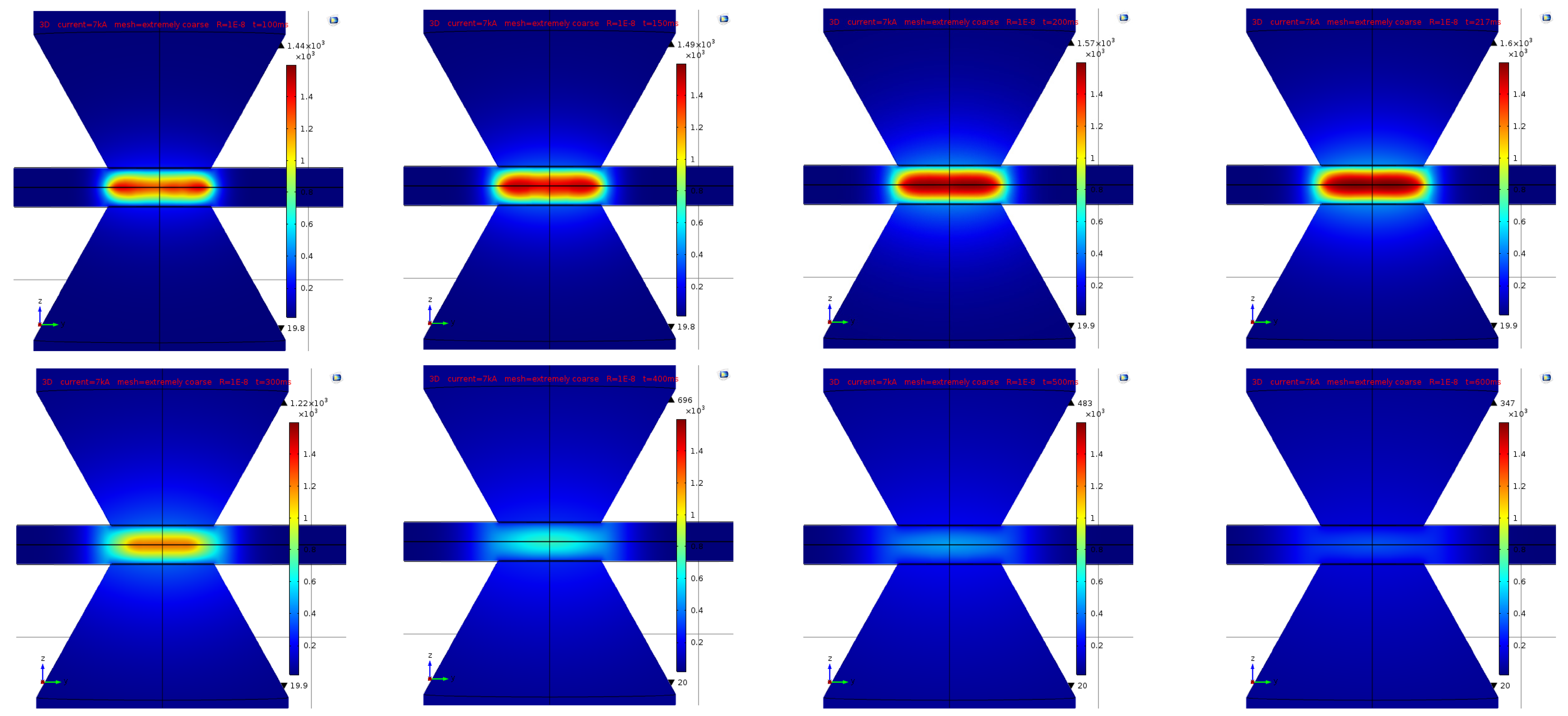




Above: Effect of welding current on temperature profile and weld nugget

Left : Temperature vs time plot, 6kA
Right : Temperature vs time plot, 7kA





Evolution of thermal profile with time

Conclusions

- COMSOL Multiphysics was successfully used to obtain temperature profiles during resistance spot welding.
- Mesh refinement yielded similar peak temperature and temperature profile but at higher computational cost.
- Incorporating interface resistance using equivalent thin layer formulation yielded same results as surface resistance formulation but at lower computational cost.
- Anomalies in thermal profile observed in 2D axisymmetric model. Anomaly also observed in results of De et. al. [3].

Future work

- Experimental validation of weld nugget diameters.
- Phase field simulation of weld microstructure and segregation using temperature profile predicted by finite element simulations.

References

[1] J A Greenwood, British Journal of Applied Physics, 1966, 1621-1632
[2] Greenwood et al, Proceedings to the Royal Society (London) A, 1966, 300-319
[3] De et al, Journal of Manufacturing Science & Engineering, 1998, 246-251