Simulation of Temperature Profile During Welding with COMSOL Multiphysics® Using Rosenthal’s Approach
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Introduction
The goal is to find a quick and efficient way to simulate the thermal profile during welding. An approach close to Rosenthal’s one [1] is utilized. After validation of the first results the possibility to go beyond the scope of Rosenthal’s results is investigated.

Equation 1 is used, but ρC and k are considered as functions of temperature. Variations in k and C have a significant effect on the thermal profile. As a first approximation to take into account the variation of k and C, p is tuned:

\[ p \frac{\partial T}{\partial t} = \rho C \frac{\partial^2 T}{\partial x^2} \]

\[ p \frac{\partial T}{\partial t} = \rho C \frac{\partial^2 T}{\partial x^2} (\frac{\partial T}{\partial x})^2 \]

A convective heat flux is applied on all boundaries except where the source is applied. The source is applied as an entering flux. The geometry used is shown in Figure 1.

RESULTS

Figure 2a: Thermal profile. Point source. Figure 2b: Absolute relative difference with Rosenthal with a reduced color scale. The features occurring because of point source:
- Results close to Rosenthal’s results for most of the domain
- Large discrepancies with Rosenthal close to the source (Figure 2b)

Figure 3a: Thermal profile. Source applied on a hemisphere. Figure 3b: Absolute relative difference with Rosenthal. Source applied on a hemisphere. Improvements due to the hemispherical source:
- The results are closer to Rosenthal (Figure 3a)
- No temperature below the initial one (Figure 3b)
- Easier post processing

As a first approximation to take into account the variation of k and C, p with temperature, Equation 4 is used, but k and C are considered as functions of temperature. Large discrepancies are observed compared with Rosenthal, which means that the variations in k and C with temperature have a significant effect on the thermal profile. The data used came from the work of Nart and Celik [2].

Highlights of Rosenthal’s one [1]
- It is possible to reproduce Rosenthal’s results accurately with COMSOL
- Applying the source on the surface of a hemisphere is the best way to do so
- Variations of k and C with temperature have a significant effect on the thermal profile
- A numerical and analytical way to simulate two sources welding have been proposed
- Results close to Rosenthal’s results for most of the domain
- Large discrepancies with Rosenthal close to the source (Figure 2b)

Variations of k and Cp with temperature

Figure 4a: Thermal profile. Source applied on a hemisphere. k and C are functions of temperature.

Figure 4b: Absolute relative difference with Rosenthal for k and C functions of the temperature. Same color scale as Figure 3b.

Two sources

Figure 5a: Thermal profile. Two sources applied on a hemisphere. k and C kept constant.

Figure 5b: Absolute relative difference with the analytical model. Two sources applied on a hemisphere. k and C are kept constant.

The difference between the numerical model and the superposition of two Rosenthal’s solutions is bounded by 18%. Therefore the idea of superposing two Rosenthal’s solutions is investigated.

Table 1: Maximum absolute relative error observed for several hemisphere radii.

<table>
<thead>
<tr>
<th>Hemisphere radius (m)</th>
<th>Maximum observed absolute relative error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x10^-2</td>
<td>78.86%</td>
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<tr>
<td>1x10^-3</td>
<td>14.5%</td>
</tr>
<tr>
<td>1x10^-4</td>
<td>11.17% (Figure 3a)</td>
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<tr>
<td>1x10^-5</td>
<td>25.86%</td>
</tr>
</tbody>
</table>

Conclusions
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References:

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