Simulation of the Temperature Profile During Welding with COMSOL Multiphysics® Software Using Rosenthal's Approach

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Abstract

Welding is a multiphysics process in which the number of parameters involved is such that it is impossible to investigate them all experimentally. That is why modeling is important in this field. Modeling the temperature profile is of interest because it is not easy to measure. The temperature profile can be simulated using Rosenthal's model [1], which is based on an analytical solution. Therefore, having the capability to reproduce and then go beyond the Rosenthal's approach with finite element analysis software will help in studying specific welding parameters and their effect on the thermal profile.

To reproduce Rosenthal's analytical results using COMSOL Multiphysics® software, a 3D square block of mild steel is considered [2]. The dimensions of this block are large enough to comply with the semi-infinite assumption, but small enough to get a result in a reasonable amount of time. In Rosenthal's approach, the coordinate system used follows the source. In this coordinate system steady-state conditions are assumed. Therefore, as the coordinate system moves a new term has to be implemented in the weak form of the heat transfer equation utilized in COMSOL. The energy transferred by the arc during welding is taken into account as an incoming flux. Two approaches are then taken. The first one is to apply the input heat flux as a point source; the second one is to apply the heat flux as a hemisphere into the surface of the block. The results obtained are compared to analytical ones. The geometry is then changed to see its effect on the agreement between COMSOL results and analytical ones. This is followed by welding with two sources with comparison to a superposition of two analytical solutions.

For the initial geometry and the selected parameters with one hemispherical source, 1.10 -4 m in diameter, the absolute relative error between the COMSOL and Rosenthal results ranged from 0% to 11.17% (Figures 1 & 2). With two sources of the same size, the error ranged from 0% to 17.74%. When the dimensions of the block were reduced in the two directions perpendicular to the welding direction the error increased. Along the welding direction the error increased as the length increased.

During this study a way to deal with a quasi-steady state problem has been successfully found. The numerical results are close to the analytical ones. This gives a basis for a first estimate on

the effect of various parameters on the thermal profile.

Reference

1. Rosenthal D., The theory of moving sources of heat and its application to metal treatments, Trans A.S.M.E., 68, 849-866 (1946).

2. Nart, E. and Celik, Y., A practical approach for simulating submerged arc welding process using FE method, Journal Of Constructional Steel Research, 84, 62-71(2013).

Figures used in the abstract

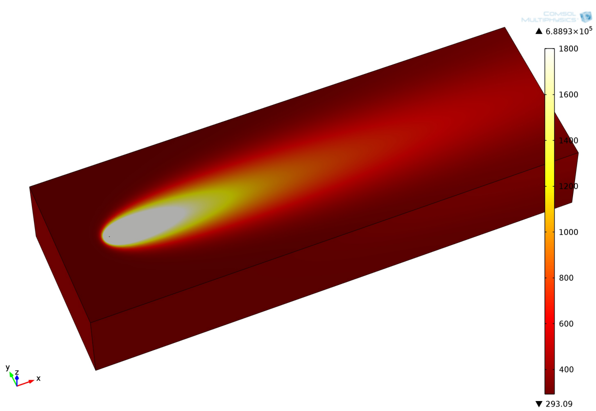

Figure 1: Thermal profile obtained by simulation within the scope of Rosenthal's assumptions with an incoming flux applied as a sphere. The part in white represents temperatures of 1800 K and above.

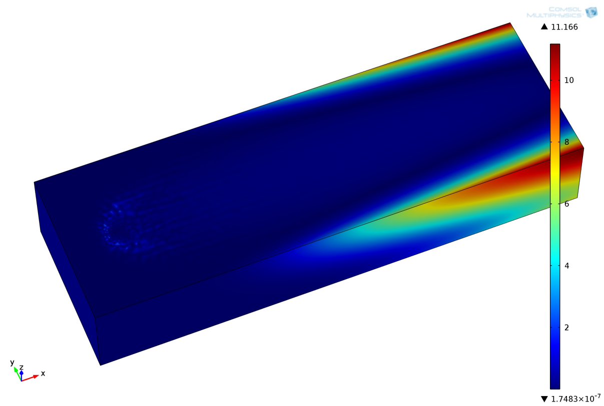

Figure 2: Absolute relative differences between Rosenthal's model and the simulation results, which are represented in Figure 1.