6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

Simulating the Heat and Fluid Flow during Electron Beam Welding of CrMnNi Steels

S. Borrmann[1]* and R. Schwarze[2]

[1] Institute of Mechanics and Fluid Dynamics, TU Bergakademie Freiberg, Lampadiusstraße 4, 09599 Freiberg, Germany, sebastian.borrmann@imfd.tu-freiberg.de, http://tu-freiberg.de

[2] Institute of Mechanics and Fluid Dynamics, TU Bergakademie Freiberg, Lampadiusstraße 4, 09599 Freiberg,, Germany, ruediger.schwarze@imfd.tu-freiberg.de, http://tu-freiberg.de

Key Words: *Computational Fluid Dynamics, Electron Beam Welding, CrMnNi-steel*

Industrial applications of recently developed materials, such as new high-strength CrMnNi-steels require in-depth knowledge of fabrication processes, including thermal joining. For the latter purpose electron beam welding (EBW) has shown to be a highly reliable tool. It is of particular interest for producing dissimilar weldings, minimized thermal loadings and excellent precision.

Simulating the EBW process constitutes a multiphysical and strongly coupled problem for the modeling methods. The energy input by the electron beam needs to be represented as a heat source, which heats up the solid material. Furthermore, melting, strong convection in the weld pool and solidification needs to be taken into account, together with the release and absorption of latent heat. Due to the partially melting behavior of the steel alloy, a mushy zone evolves during melting and solidification and needs to be considered as well.

Several publications have performed CFD simulations of deep penetration welding processes. While most of them address keyhole mode laser welding, only a few concern EBW (see e.g. Rai et al. [1]). Nevertheless, all of them use constant thermophysical material properties.

The base of our further investigations of EBW processes and associated phenomena is the presented model. It consists of a combined heat source with a double ellipsoid for the upper nail head part of the fusion zone and a conical part for the lower, narrowing region [2]. Heat and fluid flow are solved using the open-source CFD library OpenFOAM. To model melting and solidification of steel, a solver by Miehe [3] was adopted. Since a large influence of thermophysical properties on the shape of the fusion zone was detected in our simulations, temperature sensitivity was found to be very important and is thus taken into account.

Once the material is heated above the melting point, the weld pool begins to form. As the electron beam is moved in welding direction, the melt behind the weld pool solidifies and forms the fusion zone (see Figure 1). Besides the heating through the combined heat source, the heat travels through the solid material due to heat conduction. This causes further melting in immediate vicinity of the heat source.

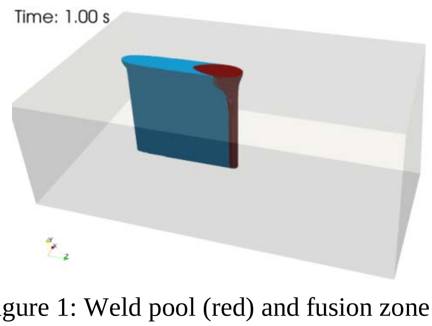

Figure 1: Weld pool (red) and fusion zone (blue)

References

[1] R. Rai, T. A. Palmer, J. W. Elmer and T. DebRoy Heat Transfer and Fluid Flow during Electron Beam Welding of 304L Stainless Steel Alloy. *Welding Research*, Vol. **88**, pp. 54-61, 2009.

[2] A. Lundbäck and H. Runnemalm, Validation of three-dimensional finite element model for electron beam welding of Inconel 718, *Science and Technology of Welding and Joining*, Vol. **10** (6), pp. 716-724, 2005.

[3] A. Miehe, Numerical Investigation of Horizontal Twin-Roll Casting of the Magnesium Alloy AZ31, Ph.D. thesis, TU Bergakademie Freiberg, 2014.