Multiphysics Process Simulation of the Electromagnetic-Supported High Power Laser Beam Welding of Austenitic Stainless Steel

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Introduction & Motivation

- High power laser beam welding is a time and cost efficient joining technology. Advantages compared to conventional arc welding methods are the narrow welds with small heat affected zones and low distortions, high process velocities, small amounts of filler metal and the high flexibility and reproducibility.
- In full-penetration laser beam welding, liquid metal tends to sagging or drop-out when the thickness of the material exceeds a threshold depending on surface tension forces at the root side.
- An electromagnetic weld pool support system was applied to prevent the liquid metal from drop-out.

Figure 1: Macro sections of test welds without magnetic weld pool support for 15 mm AISI 304 stainless steel with 12 kW laser power, 4 mm focus depth and a welding speed of 0.4 m/min.

Weld Pool Support

- An oscillating magnetic field below the welding zone induces eddy currents.
- The interaction of magnetic field and electric currents produces Lorentz forces that are directed against gravity.

Use of COMSOL Multiphysics 4.2 Non-Isothermal Flow and Magnetic and Electric Fields Interface

Figure 3:

Left: coupling between fluid dynamics, heat transport and electromagnetic quantities

Right: schematic electromagnetic weld pool support system.

Figure 2: Macro sections of 20 mm welds consisting of 10 mm stainless steel AISI 304 and 10 mm femtosecond steel S23S, which is outside the penetration depth of the magnetic field. The laser beam power is 18 kW, the focus depth is 6 mm inside the material, the welding velocity is 0.4 m/min.

Numerical Model

B. Wilman et al., Int. J. Thermophys. 29 634-444 (2008)

Figure 4: COMSOL model and meshing.

Figure 5: Material model for stainless steel AISI 304.

Numerical Results

Reference case
- Only minor changes in the temperature and flow field
- Essential differences in the pressure distribution along the vertical direction
- Results point to successful weld pool support for a magnetic flux density of 95 mT at an oscillation frequency of 3 kHz
- Drop-out of weld metal as well as undercuts and sagging of the weld could be avoided experimentally by the applied electromagnetic forces for a magnetic flux density of 234 mT at an oscillation frequency of around 2.6 kHz (Figure 2)

Optimal control case
- Magnetic flux density for optimal compensation was higher than predicted by COMSOL
- Possible influence of weakly ferromagnetic properties of stainless steel AISI 304 in combination with the excess of the Curie temperature around
- Influence of dynamics in the weld pool associated to evaporation at the keyhole wall

Conclusions

References & Acknowledgements

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V. Avilov et al., Proc. EPM 2009, Dresden, Germany


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