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A Model to Simulate Pulsed Laser Weld Pool Physics Using a Conduction Heat Transfer Code

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Pulsed laser welds are seeing increased use in applications where a precise amount of weld energy is required in a small spot. These welding processes are capable of producing deep weld penetration and high melting efficiency with low power input relative to traditional arc welding processes. However, because of the highly concentrated thermal energy input produced by such welds, large thermal stresses may be generated, resulting in cracking and warpage of the part. Also, it is known that weld pool convective mechanisms can significantly alter weld pool shape and thus the quality of the resulting weld joint. Depending on the surface chemistry of the weld pool, thermocapillary convection may increase or decrease weld pool depth. Additionally, high incident laser intensity may result in rapid vaporization of the melt, driving bulk fluid motion which may induce deep weld penetration. Thus, good control of processing parameters, such as part material, travel speed and incident laser intensity, is necessary to make quality seals. Such process control may be enhanced by use of a predictive welding model.

In this work, a model is developed to simulate thermal response and weld pool shape during pulsed laser welding of a part. Because relatively rapid solution is desired, the full Navier-Stokes equations governing weld pool dynamics are not modeled directly. Instead, weld pool thermocapillary and vaporization driven convective mechanisms are incorporated approximately using an effective thermal conductivity for the melt. Unlike past conduction code treatments of weld pool dynamics, where empirically determined effective thermal conductivities are used, this model calculates effective thermal conductivity based on the expected weld pool physics. Comparison to experiments are provided and results show good agreement between predicted and measured weld pool shape and part temperature distributions for a range of laser travel speeds, spot sizes and average laser powers.

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