Modelling of pulsed laser interaction with stainless steel for laser ablation.

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Abstract

The decommissioning and disposal of structural materials exposed to radiation is especially difficult for very large components. Removing the highly active outer surface, so that the remainder can be treated as low-level waste, is desirable and several methods are being investigated. One option is laser ablation, where laser pulses cause melting and local damage causing material to spall off. However, the interaction of high-power pulsed lasers with steel surfaces is a complex phenomenon, involving an interplay of optical, thermal, fluid, and material processes. These interactions are inherently non-linear, making the precise control and prediction of outcomes challenging. To address these complexities, computational modelling emerges as a cost-effective and powerful tool for enhancing laser treatment procedures.
As part of this work, the Finite Volume Method (FVM) has been employed to simulate the dynamic behaviour of the laser-induced molten pool, as well as the resulting crater formation, material ejection and plasma generation. The FVM allowed for the detailed capture of the transient and spatially varying phenomena associated with pulsed laser heating. By varying the material composition and laser parameters, particularly laser power and pulse duration, their effects on the time-temperature profiles and the resulting crater dimensions were investigated. This is in addition to model specific criteria such as the heat source type and viscosity model used.

The thermal model has been calibrated against thermal camera measurements during laser pulse testing. The resulting material response - such as molten zone shape, transformation boundaries and phase fractions at locations during the pulse - have been validated with microscopy and synchrotron X-ray data. Allowing for direct comparison with model outputs.
Much of the work is performed using the open-source software package OpenFOAM, it is hoped that producing an accessible model for such work will allow facilitate future research with other data sets.

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