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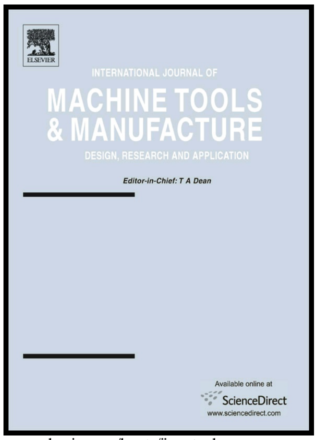

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PII: S0890-6955(16)30294-2
DOI: http://dx.doi.org/10.1016/j.ijmachtools.2017.01.002
Reference: MTM3224

To appear in: *International Journal of Machine Tools and Manufacture*

Received date: 19 September 2016
Revised date: 29 December 2016
Accepted date: 2 January 2017

Heat transfer and material ablation in hybrid laser-waterjet microgrooving of single crystalline germanium

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Abstract

A numerical model describing the heat transfer and material ablation in a hybrid laser-waterjet microgrooving process for a single crystalline germanium (Ge) is developed, considering the relevant physical phenomena involved, such as laser-induced plasma (or optical breakdown) in water, laser beam attenuation in the plasma zone, heat transfer in Ge substrates, and waterjet cooling and impinging effects. The model is then verified, which shows that the respective calculated and measured quantities are in reasonably good agreement. A numerical simulation study is then carried out using the developed model and demonstrates that the shielding effect of the laser-induced plasma increases with the laser pulse energy. In addition, the irradiated material can be expelled by a waterjet at its soft-solid status, and heat accumulation in the workpiece is effectively removed by the waterjet cooling effect during the off-pulse period, so that laser heating induced thermal damage is minimized. The effect of processing parameters on the ablation process is also analysed. It has been noticed that an increase in laser pulse energy leads to a deeper groove, and an increase in the applied water pressure decreases the threshold workpiece temperature for material removal.

Keywords: Laser ablation; Micromachining; Hybrid laser-waterjet; Germanium; Heat transfer; Plasma.