

The Asymptotic Hole Shape in Long Pulse Laser Drilling: The Influence of Multiple Reflections

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Abstract : In long pulse laser drilling of metals, it can be demonstrated that the ablation shape approaches a so-called asymptotic shape such that it changes only slightly or not at all with further irradiation. These findings are already known from ultra short pulse (USP) ablation of dielectric and semiconducting materials. The explanation for the occurrence of an asymptotic shape in long pulse drilling of metals is identified, a model for the description of the asymptotic hole shape numerically implemented, tested and clearly confirmed by comparison with experimental data. The model assumes a robust process in that way that the characteristics of the melt flow inside the arising melt film does not change qualitatively by changing the laser or processing parameters. Only robust processes are technically controllable and thus of industrial interest. The condition for a robust process is identified by a threshold for the mass flow density of the assist gas at the hole entrance which has to be exceeded. Within a robust process regime the melt flow characteristics can be captured by only one model parameter, namely the intensity threshold. In analogy to USP ablation (where it is already known for a long time that the resulting hole shape results from a threshold for the absorbed laser fluency) it is demonstrated that in the case of robust long pulse ablation the asymptotic shape forms in that way that along the whole contour the absorbed heat flux density is equal to the intensity threshold. The intensity threshold depends on the special material and radiation properties and has to be calibrated by one reference experiment. The model is implemented in a numerical simulation which is called AsymptoticDrill and requires such a few amount of resources that it can run on common desktop PCs, laptops or even smart devices. Resulting hole shapes can be calculated within seconds what depicts a clear advantage over other simulations presented in literature in the context of industrial every day usage. Against this background the software additionally is equipped with a user-friendly GUI which allows an intuitive usage. Individual parameters can be adjusted using sliders while the simulation result appears immediately in an adjacent window. A platform independent development allow a flexible usage: the operator can use the tool to adjust the process in a very convenient manner on a tablet during the developer can execute the tool in his office in order to design new processes. Furthermore, at the best knowledge of the authors AsymptoticDrill is the first simulation which allows the import of measured real beam distributions and thus calculates the asymptotic hole shape on the basis of the real state of the specific manufacturing system. In this paper the emphasis is placed on the investigation of the effect of multiple reflections on the asymptotic hole shape which gain in importance when drilling holes with large aspect ratios.

Keywords : asymptotic hole shape, intensity threshold, long pulse laser drilling, robust process

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