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A Reduced Ablation Model for Laser Cutting and Laser Drilling

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Abstract : In laser cutting as well as in long pulsed laser drilling of metals, it can be demonstrated that the ablation shape (the shape of cut faces respectively the hole shape) that is formed 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 the ultrashort pulse (USP) ablation of dielectric and semiconducting materials. The explanation for the occurrence of an asymptotic shape in laser cutting and long pulse drilling of metals is identified, its underlying mechanism numerically implemented, tested and clearly confirmed by comparison with experimental data. In detail, there now is a model that allows the simulation of the temporal (pulse-resolved) evolution of the hole shape in laser drilling as well as the final (asymptotic) shape of the cut faces in laser cutting. This simulation especially requires much less in the way of resources, such that it can even run on common desktop PCs or laptops. Individual parameters can be adjusted using sliders – the simulation result appears in an adjacent window and changes in real time. This is made possible by an application-specific reduction of the underlying ablation model. Because this reduction dramatically decreases the complexity of calculation, it produces a result much more quickly. This means that the simulation can be carried out directly at the laser machine. Time-intensive experiments can be reduced and set-up processes can be completed much faster. The high speed of simulation also opens up a range of entirely different options, such as metamodeling. Suitable for complex applications with many parameters, metamodeling involves generating high-dimensional data sets with the parameters and several evaluation criteria for process and product quality. These sets can then be used to create individual process maps that show the dependency of individual parameter pairs. This advanced simulation makes it possible to find global and local extreme values through mathematical manipulation. Such simultaneous optimization of multiple parameters is scarcely possible by experimental means. This means that new methods in manufacturing such as self-optimization can be executed much faster. However, the software's potential does not stop there; time-intensive calculations exist in many areas of industry. In laser welding or laser additive manufacturing, for example, the simulation of thermal induced residual stresses still uses up considerable computing capacity or is even not possible. Transferring the principle of reduced models promises substantial savings there, too.

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