MODELLING LASER ABLATION

David Bruneel, process and modelling unit manager for R&D at Lasea, discusses the benefits of simulation in micromachining

Ultrafast lasers have been shown to be excellent tools for micromachining virtually all types of material, provided a good processing parameter window is chosen so that thermal effects are negligible.

However, given the complex nature of the laser-matter interaction for these types of laser, the search for the optimal processing parameters often requires a thorough parametric study. This means testing several parameters by machining different matrices on the material.

This empirical approach needs a laser micromachining system and can be quite a time- and material-consuming process. Research for the optimal parameters is often the bottleneck for improving the yield of a micromachining machine, in terms of money and time.

Why use simulation?

How ultrashort laser pulses interact with matter has been studied for a long time. Being able to simulate ultrashort pulse laser ablation to obtain the optimal processing parameters, instead of doing it empirically, would thus be ideal.

Lasea has developed a tool called LS-Plume, which simulates ablation according to different processes, such as percussion drilling, engraving and milling. The tool is based on the knowledge of ultrafast laser-matter interaction.

The tool was developed to gather all the relevant knowledge that explains the interaction. Instead of starting from the observation and moving to a more detailed understanding of the interaction, we decided to use the existing knowledge to reproduce and predict the results of laser processing.

Laser-material interaction models can be highly complex and extremely consuming in terms of computational power and run time. Such a detailed approach is not practical for industrial processing, where results must be generated in seconds or minutes. To overcome this restriction, the model behind the simulation takes into account simplified laws of ablation, such as depth as a function of fluence.

The simulation is based on an engineered physical model of the interaction. It takes into account two sets of parameters: the optical beam characteristics applied to the part, and the material and the laser-matter interaction properties. The first set of parameters includes the spot size – taking into account the model of the laser machine – the wavelength, the pulse energy, the pulse repetition rate, the scanning velocity, and the angle of incidence in relation to the workpiece surface. For the second set of parameters, the model requires the ablation threshold, the radiation penetration depth, the incubation factor, and the complex refractive index of the material.

Physics behind the model

This tool implements a physical model based on a well-defined absorption law of energy in the material, calculating the ablation depth as a function of the energy, the ablation threshold of the material, and the radiation penetration depth specific to the material. The simulation also considers the depth as a function of the centre of the beam. In order to predict accurately the ablation dimensions, the model takes into account that the threshold decreases with the number of pulses because of material incubation. The reflectivity of the material is also included to calculate the absorption of the energy, depending on the incident angle of the beam in relation to the surface.

Another aspect considered is processing quality, in terms of heat put into the part. A femtosecond laser is often considered to have a non-thermal interaction with matter. This is valid in certain parameter ranges, for example when a low number of pulses is used, or low repetition rates. In the case of machining in a real application in industry, where speed and efficiency are required, a lot of pulses at much higher rates can be used.

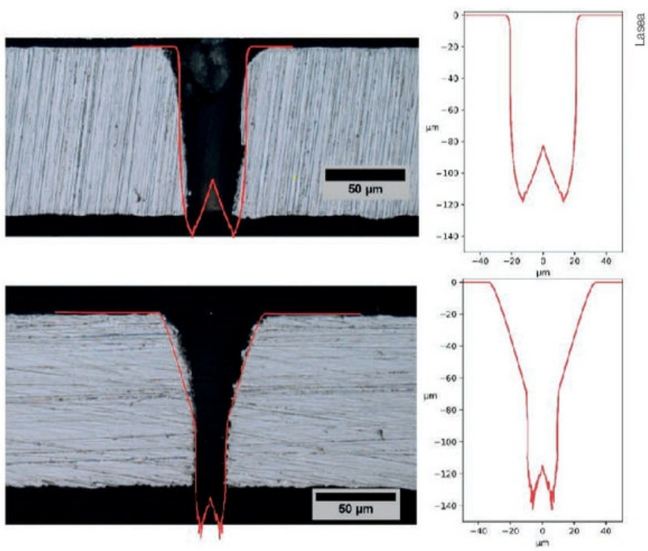
> **"The model takes into account simplified laws of ablation such as depth as a function of fluence"**

In some regimes, femtosecond laser machining can cause heat to accumulate in the material, depending on the parameters applied. If the repetition rate is high enough, the time between two consecutive pulses will be too short to let the material cool down and, depending on the number of pulses, the repetition rate and the velocity, this can melt the material. This effect is calculated by the model and, by knowing the properties of the material, our tool can predict if this decrease in processing quality will occur or not.

The simulation tool offers a database of different generic materials such as 316L stainless steel, copper and titanium. In parallel, customers can add their own specific materials into their own database.

To sum up, the LS-Plume tool speeds up research of optimal parameters for micromachining by simulating the profiles that will be obtained on the workpiece, without using material or needing an ultrafast laser machine. It helps improve the yield of the machine and reduces overhead costs.

Based in Liège, Belgium, Lasea specialises in precision laser machining. Its LS-Plume tool was developed by David Bruneel, Liliana Cangueiro, Chris Reed, Paul-Etienne Martin and Jose-Antonio Ramos de Campos



Example of a comparison between simulated profiles and experimental results showing a good fit