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Modelling laser percussion drilling

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Lasers

Since the first demonstrations of the ruby laser in 1960, the LASER (Light Amplification by Stimulated Emission of Radiation) found its use in a variety of applications. The reason is that lasers typically produce energy in a highly concentrated way being transferred without direct contact.

Laser Percussion Drilling

The laser is used to drill holes in parts of gasturbines. Here this is done using multiple laser pulses; *laser percussion drilling*; see the illustration.

Figure 1 : A photo of a laser percussion drilling process in action. (By permission of ELDIM B.V.)

Objectives

The ultimate goal of this project is to get a full understanding of the laser drilling process and to provide a simulation model in which all physical phenomena that play a role in the drilling process are included.

Physical Phenomena

We summarize the phenomena playing a role.

Heating without phase-change At relative low intensities: the surface material starts to heat up.

Melting At moderate intensities the surface reaches, at a certain time, the melting temperature and starts to melt.

Vaporization At even higher intensities the melt reaches the vaporization temperature and starts to vaporize.

Splashing When the vapour reaches a certain pressure the melted material is pushed out.

Solidification during Splashing The melt flows along the relative cold sides, and may on its way even resolidify partially.

Energy Absorption by the Vapour The vapour has also an effect on the effectivity of the beam; indeed, it may eventually absorb the radiated energy to such an extent that the material gets shielded by it.

Multiple Reflections Reflection of incoming radiation acts as a secundary source.

Periodic Behaviour All phenomena mentioned above may interact and happen more than once during one pulse.

Approach

The melting is modelled through the energy equation in enthalpy form

$$\frac{\partial H}{\partial t} = \operatorname{div}(k \operatorname{grad} T).$$

Here, the enthalpy H is a known function of the temperature T

$$H(T) = \int_{T_{ref}}^{T} \rho c(\tilde{T})\, d\tilde{T} + \rho L_f \mathcal{H}(T - T_m),$$

where $\mathcal{H}$ is the Heaviside function and L_f is the latent heat of fusion. The thickness of the meltpool when vaporisation starts, follows from this model. This is used as input for the splashing model. The recoil pressure, an other input for the splashing, follows from the vaporization model as sketched below.

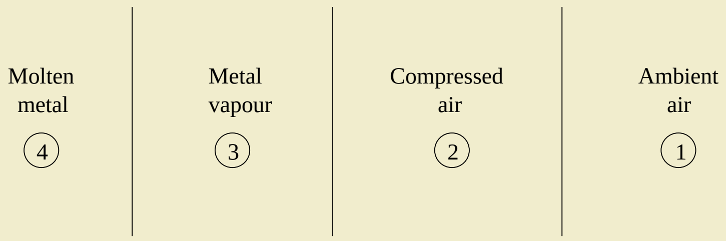

Figure 2 : The geometry of the gas dynamics.

Here, the lines between ④ and ③, ③ and ②, and between ② and ① are the liquid-vapour interface, the contact discontinuity and the shockwave, respectively.

Numerical Results

We show some numerical results of the solidification model made using NumLab. The picture below shows a blob of melt flowing along the sides of the hole due to recoil pressure.

Figure 3 : Melt blob flowing along sides of the laser drilled hole.

Cooperation

The Scientific Computing Group cooperates in this project with ELDIM B.V. and Rolls-Royce plc.