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Microscale modelling for powderbed based laser melting: A testbed for new system technology

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Due to the high dynamics and small scales of the selective laser melting (SLM) process, experimental observations of the process itself are difficult to obtain. Therefore Gürtler et al. [1], King et al. [4] and Megahed et al. [5] each developed a simulation model of the SLM process at the microscale level to enable process analysis. Khairallah et al. [3] illustrate with the model of [4] different formation mechanisms for pores and spatter.

Spatter is often correlated to pore formation, since the size of spatter can exceed particle size and thus the chosen process parameters will fail to fully remelt the spatter depositions [6]. Kaplan deduces from observations that for the welding case spatter production can be divided into three primary mechanisms: melt flow-driven, vapour jet-driven and low boiling element-driven [2]. Due to the similarity of the processes, these mechanisms can be applied to selective laser melting as well.

We show an extension of the model of [1] and demonstrate how the modelling approach can be used to influence the development of new system technology and enhance the process quality. We improved the spatial discretization of the model to $\sim 1\ \mu\mathrm{m}$. In addition to the already established physical phenomena such as heat transfer, temperature and pressure driven melt flow, surface tension and phase changes and the inclusion of the according latent heat and energy transfer between the phases we also take into account temperature dependent material properties and the cover gas flow.

We propose to use spatial and temporal beam shaping to reduce the three spatter production mechanisms. The melt flow in conventional process strategies is induced by scanning of the laser beam, the thermal gradient and evaporation. Instead of scanning the build sample we employ spatial beam shaping techniques to irridiate large areas, thus eliminating the melt flow induced by the laser scanning. The thermal gradient is consequently reduced as well within the melt pool, lowering the whole melt pool dynamics substantially. Additionally we utilize temporal beam shaping to control temperature and prevent evaporation, eliminating the second and third spatter formation mechanisms.

Figure 1 shows the difference between the two process strategies. The left figure shows a conventional scanning strategy. Spatter is clearly visible. While the spatter particles are of small size and presumably do not influence the process, they are a sign of a high dynamic within the melt pool and a possible warning sign of pore trapping. The right figure shows a beam profile for a large area irridiation strategy.

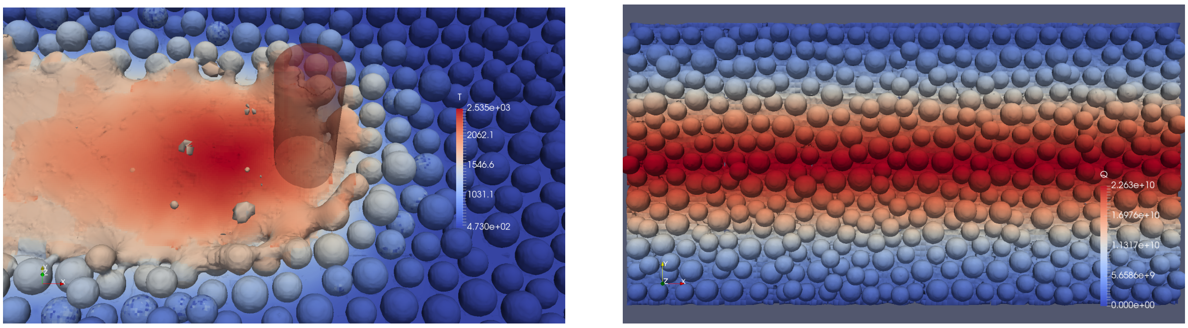

Figure 1: The left figure shows the conventional process with spatter production. The right figure shows a possible beam profile for a large area irridiation strategy.

An experimental investigation of this approach is currently limited due to missing high power spatial beam shaping devices. While there is no general physical restriction on employing optical devices (e. g. diffractive optical elements, electro-optical or acousto-optical deflectors) for high(er) power beam shaping, manufacturers have not yet seen an economical reason to develop them. We hope that showing the advantages of large area irridiation strategies will help to accelerate the academic and commercial development of such devices.

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