Powder consolidation mechanism and micro-mechanical properties in Selective Laser Sintering (SLS)

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1 Goal

The goal of this project is to investigate the powder consolidation mechanism, 3D printed parts mechanical and micro-mechanical properties in selective laser sintering (SLS). Experimental data will be collected to calibrate and verify predictions based on analytical results and numerical simulations. The results of this project should be a MSc thesis in form of a paper, with details in the appendix.

2 Background

Additive manufacturing (AM), commonly known as 3D printing, is a manufacturing technology; in contrast to subtractive or formative methods, objects are produced from a three dimensional digital models in a layer-by-layer fashion. AM offers design flexibility and easy customisation that contributed to its rapid growth and wide utilisation in different industrial sectors [1]. Selective laser sintering is a key AM technology, consisting of different stages (pre-heating, spreading, laser-sintering, etc). Objects are produced by spreading successive layers of powder material and solidifying selected parts by sintering them with a laser, see Fig. 1. In SLS, we have two main processes: powder spreading and powder sintering/melting. The main process parameters of powder sintering/melting are laser powder, laser scan speed, hatch spacing and layer thickness.

Laser-based powder consolidation mechanisms are classified into four types: solid state sintering (SSS), liquid phase sintering (LPS)/partial melting, full melting and chemical induced binding. SSS is rarely applied in layer manufacturing (LM) as diffusion of atoms in solid state is slow and not very compatible with the desired high laser scan speed that should yield process productivity and economic feasibility. Liquid Phase sintering (LPS) and partial melting include a number of binding mechanisms in which part of the powder material is melted while other parts remain solid. The liquefied material will spread between the solid particles almost instantaneously as it is driven by intense capillary forces. This allows much higher laser scan velocities than for SSS. When the heat supplied to a powder particle is insufficient to melt the whole particle, only a shell at the grain border is melted. The core of the grain remains solid. This way the molten material will form necks between the particles and act as a binder between the nonmolten particle cores. This binding mechanism can arise as well with metals as with polymers, although the consolidation of polymer powders may also result from other mechanisms (consolidation at the glass transition temperature, which is lower than the melting temperature, polymer chain rearrangement and cross-linking) [2].

The consolidation phenomena invoked for polymers are probably still amongst the least understood. This project will focus on experimental investigations of the powder consolidation in SLS, and using the experimental results to validate simulation ones. In this project, we will investigate powder consolidation in SLS, printed parts porosity and micro-mechanical properties. The study will be conducted for one type and composite powders.

- For porosity investigation, we will print density cubes at different process parameters. Then we calculate the density experimentally (validate DPM simulations by using coarse-graining [3]).
- Parts microstructure investigations to identify phases, particles adhesion and pores.
- We will perform micro-tensile testing to study the material behaviour and calibrate/validate simulation results.
- Thermal transition investigations by differential scanning calorimetry (DSC) and thermal properties measurements (e.g. thermal conductivity, etc)
- In-situ visualization of powder consolidation in SLS.

Two SLS printers are available in the TFE lab to perform the spreading experiments; additional experiments could be performed using a professional SLS printer at the Rapid Prototyping Lab. In addition, the powder properties should be characterised. The experimental data will be used to calibrate and validate a numerical model of powder sintering/melting, which is being developed and has already been implemented in the open-source software MercuryDPM [4]. Using the numerical model, and analytical results obtained by literature review, we aim to explain our observations and get a better understanding of the powder consolidation in SLS.

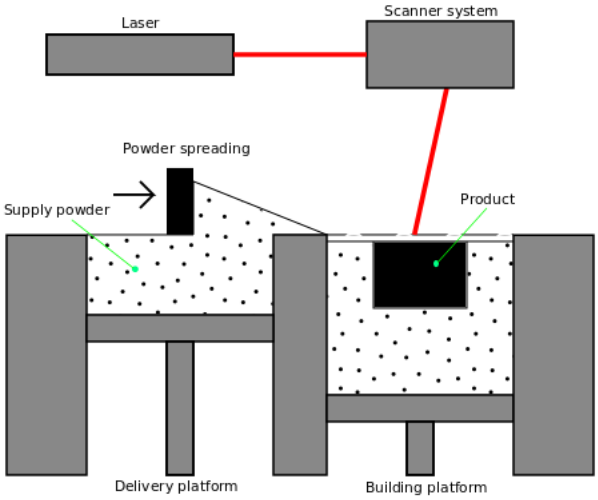

Figure 1: Schematic of the selective laser sintering process

References

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