Analysis of 3D Biocompatible Additive Structure Using COMSOL Multiphysics® Software

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Abstract

Introduction:

Equally answering material strengths and biological compatibility requirements additive structures manufactured from powder grains are more likely to become the next patient specific implant material. Although using different additive manufacturing techniques bone substitutes and 3D scaffolds for the growth of advanced biostructures could be the structural applications towards properly personalized medical parts and devices.
Additive manufacturing techniques become more attractive as the technological path downsizes to micro- and even nanosize interface phenomena. Inside the micro sized powder layer complex packaging pressure and heat transfer phenomena are occurring.
However, during the layer-wise shaping and material consolidation processes a series of quality drawbacks can occur. The melted, respectively dried powder layer may contain post-processing adherent grains. Gas porosity appears as gas is trapped within powder particles from the shielding gas during processing. Process parameters must be adjusted in order to obtain adequate densifications of 3D manufactured parts. Layer additive processes are under stair-stepping effect, thus non-horizontal part surfaces become rough as a consequence of the slice/slide process occurring during the layer by layer growth. The stair-stepping effect decreases as the slice thickness is reduced but two limits are to be considered: grain size distribution and process efficiency.

Use of COMSOL Multiphysics®:

Based on Marangoni effect the Lattice Boltzmann Method (LBM) was used for modelling the interface dynamics during the interaction of droplets. Different process parameters and material properties were considered for this analyses and simulations.
The 2D SolidWorks® model of the grain powder bed (Figure 1) was imported through LiveLink™ in COMSOL Multiphysics®. The vector structure of the melting powder grains (Figure 2) was imported as well through LiveLink™ for SolidWorks®, considering on the model description the influence of powder grains sizes and their density of distribution on air.
The SolidWorks® model was exported through the LiveLink™ for SolidWorks® add-on in COMSOL Multiphysics® where heat transfer and phase transformation analyses were performed.

Results:

For the powder bed formed with particles with different sizes a rain model packing algorithm was used to describe the generation of successive layers. Thus it was assumed that a falling particle reaching a stationary one was following a rolling round trajectory around the stationary particle aiming to minimize its vertical coordinate.

Each phase of the process was properly described and designed with the use of 3D/2D plot groups and line graph tools in COMSOL Multiphysics®. The step by step analyses were considered using process related increments.
During the validation phase the 2D model accurately predicted the main characteristics of the experiments for each of the 3D additive layer wise shaping method analyzed.

Conclusion:

Using the COMSOL Multiphysics® analysis and simulations a new path of energy distribution and soldering geometry was designed and modelled for3D additive growth of biocompatible substances with impact on personalized medicine.

Figures used in the abstract

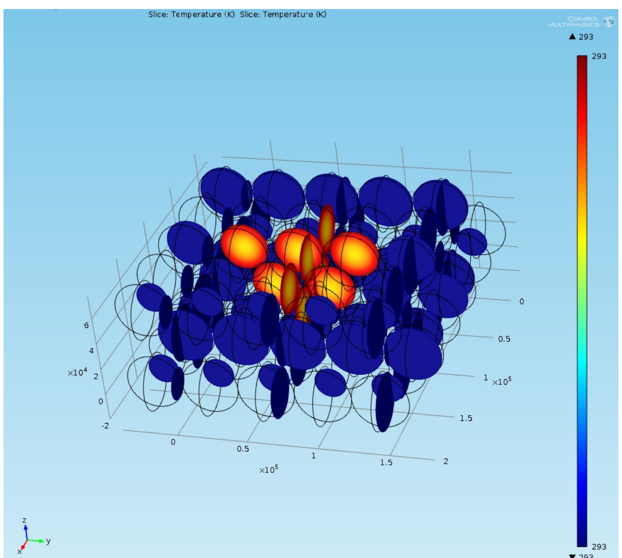

Figure 1: Temperature distribution inside powder bed layer during Selective Laser Melting (SLM) process.

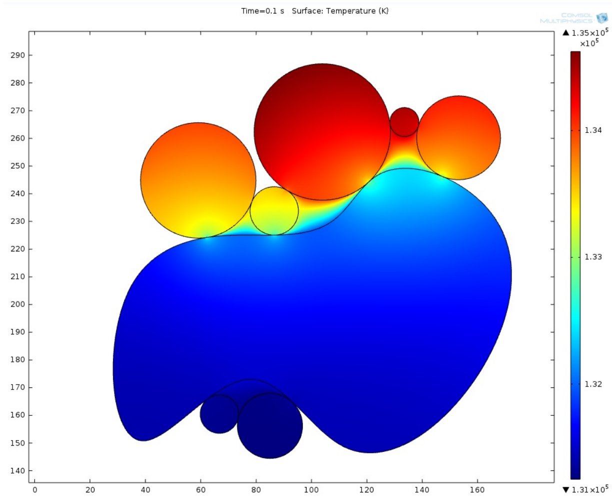

Figure 2: Interface thermal distribution during SLM layer-by-layer additive growth.