Heat transfer in selective laser sintering of polyamide powders

Selective Laser Sintering (SLS) is a type of Laser Powder bed fusion (LPBF) and is a layer-wise Additive Manufacturing (AM) process, with which a complex geometry can be manufactured using granular materials. The complex laser-material interaction and the knowledge of associated process parameters is a challenge in the modelling of the SLS process which in turn helps in the standardization of the process. The knowledge of the temperature field in the powder bed is vital in understanding the powder binding mechanism. One of the major defects of the SLS produced parts is the delamination between the layers which is due to lack of fusion. In this study, a stationary laser sintering experimental set-up equipped with two infrared cameras is built to measure the temperature distribution along the depth and the top surface. A thin layer of polymeric powder is spread on infrared-transparent Zinc Selenide (ZnSe) glass so one of the thermal cameras can see the heat transfer along the depth from the bottom. A carbon black treated polyamide 12 (PA12 CB) powder of average particle size distribution of 60µm and PA6 CB of average particle size distribution of 80µm are used in this study. The experiments were conducted by heating the sample for 10 s and allowing it to cool down. A three-dimensional finite element model considering conductive, convective, radiative heat transfer and phase change is developed to accompany the experimental data. As a first, a temperature-dependent emissivity is considered in the model. A statistical examination using the Design of Experiments (DoE) method was performed to evaluate the uncertain material properties such as thermal conductivity and laser absorptivity and their effect on the time-dependent temperature evolution in the powder bed. The accuracy of the model is validated by comparing the temperature data along xyz directions with the experimental values. The PA6 CB powder exhibits higher laser absorption and higher thermal conductivity than PA12 CB. This is evident from the rapid heating of PA6 CB due to higher laser absorption and faster cooling rate due to higher thermal conductivity. The emissivity of the powder bed is nearly uniform with temperature for both powders and drastically increases at melt pool. This change in emissivity is captured in the model. As an add on to the project, heat transfer in electrostatic powder coating is studied. A Finite elements based model is developed with infrared heat input model. The model helps in understanding the temperature reached during infrared heating and subsequently, to know the ideal power required for the heater.

Keywords: Infrared thermography, finite element methods, heat transfer, temperature history.