# Abstract

The current environmental and societal challenges require producing highly customised products as fast as possible and using the smallest amount of resources. Facing these challenges requires a total redefinition of the production paradigms. Among the answers to these problems, the additive approach to manufacturing could be the key. In additive manufacturing (AM), unlike traditional production techniques, a component is produced by adding material layer by layer until complete component production. The material adopted could be polymeric or metallic, and the techniques can produce definitive components and prototypes. Additive manufacturing processes are complex due to the different physics phenomena involved. Considering the AM processes based on powder feedstock material, besides the pure melting, another interesting phenomenon may occur: the sintering among the particles. This process could be performed by purpose or can appear as a side effect of the heat transfer between the melt pool and the surrounding material. Despite the crucial role that sintering could play in certain AM processes, the analysis of sintering phenomena had received extremely little attention. In particular, this is true for those processes, such as the electron beam powder bed fusion (PBF-EB), in which the effects of a sintering process are exploited to conduct the process safely and prepare the powder bed properly for the subsequent steps. In this case, the sintering process is used to tune some fundamental properties of the powder bed, such as the thermal conductivity and the apparent density.

Therefore, the current work aims to investigate the dynamic of sintering phenomena that occurs during the PBF-EB process. The final objective is to characterise the powder material's thermal conductivity and its evolution during the process. The aim is achieved by developing a modelling framework for evaluating the sintering degree, considering the characteristic of the whole thermal history of the PBF-EB process. The framework is based on a combined approach between a phase field simulation with a novel thermal load definition and an analytical thermal conductivity description using a novel adaption of the tortuosity factor concept.

The PF model is validated against experimental data obtained by designing an ad-hoc experiment setup when processing Ti6Al4V material powder by PBF-EB. The PF model is then used to investigate the effect of specific processing conditions, such as delay in sintering start, particle diameter's influence and preheating's influence on the neck radius dimension and its time evolution. The neck is generated as a consequence of the sintering and is a material link connecting the particles. Response surface methodology is applied to explore the relationship between several explanatory variables, such as the powder particle diameter and the ratio between their diameters and the neck radius. The evolution of the neck dimension is then used as a critical variable for the definition of thermal conductivity and its variability over the process.

The application of the proposed framework is shown in a representative powder bed portion undergoing sintering.

Overall, the results show that a delay in the start of sintering produces the same neck dimension after preheating and that an increase in particle diameter and temperature variability during preheating produces a larger neck radius. Also, the packing density and the neck geometry strongly influenced the thermal conductivity.