Public summary of PhD-thesis of Fabio Paolucci
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Characterisation of crystallisation kinetics and mechanical properties of Polyamide 12

Polyamide 12 (PA12) is a semi-crystalline polymer that finds wide spread use in many different fields of applications. During the last two decades, PA12 has attracted a lot of interest as material for the Selective Laser Sintering (SLS) process. Laser sintering is an Additive Manufacturing (AM) process that enables the production of three-dimensional objects, built layer by layer, starting from powdered material.

The principal advantage of additive processes is the ability to manufacture parts with significantly greater complexity of geometry than traditional processes, without the need for molds and tools. Moreover, as tooling is no longer required, the economics of production are changed dramatically, enabling low volume production and even customized products for all kind of applications. Nevertheless, there are still steps that have to be improved. The cooling process of the molten pattern is considered as a crucial step of SLS because semi-crystalline polymers show volume shrinkage during cooling due to the crystallization process and this effect leads to reduction of the dimensional accuracy of the sintered part.

Powder degradation, i.e. solid-state post condensation, occurs during the printing process due to the long exposure time at high temperature in a nitrogen atmosphere. Depending on product dimensions, the powder can experience severe thermal conditions for up to 24 hours. Moreover, the powder that is un-sintered is usually mixed and reused together with fresh powder. The level of powder aging is generally unknown leading to poor reproducibility and surface quality. Finally, the relation between final mechanical problems and process conditions is poorly understood.

This project contributes to the understanding and, therefore, the solution of the problems mentioned. The aim of the project is two-fold. First, the effect of process conditions, i.e. crystallization temperature and annealing time and temperature, on the crystallization kinetics of PA12 is investigated. Next, the mechanical response under different loads is investigated for both laser sintered and compression molded PA12. Using a recently developed experimental/numerical protocol, the time-to-failure under constant load (creep) is predicted as function of temperature and relative humidity starting from short-term test. We demonstrate that the model is a valid and reliable tool to predict long-term failure under constant load. In conclusion, this work provides the basic knowledge for a full (numerical) description of the SLS process using PA12, including the effect of re-using PA12 powder, and the tools and procedures for a full mechanical characterization and description of PA12, including the effect of environmental conditions such temperature and humidity.

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