Effect of Porosity on the Thermal Conductivity of 3D Printed Parts by Fused Filament Fabrication (FFF)

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Fused Filament Fabrication (FFF) is the most widely used process among Additive Manufacturing (AM) techniques.

One of the major issues in FFF printing is the presence of porosity inside the printed parts. In fact, the presence of voids involves a significant decrease in mechanical properties, making FFF components not comparable to the parts obtained by Injection Moulding [1,2].

Several works have focused on the porosity prediction of FFF parts [3-5]. In the field of FFF composite materials, a recent application is the printing of metal and ceramic filled filaments [6,7]. The final metal or ceramic part is first printed (green part) and then subjected to debinding and sintering treatment in order to remove the polymeric binder and to obtain the highly dense final part in metal or ceramic.

To obtain good final sintered parts, it is essential to predict and limit shrinkages. To do this, the porosity of the green part must be very low. In this work, the thermal conductivity of the FFF green parts was related to their porosity. The stainless steel filled filament, Ultrafuse 316L from BASF, was investigated. To introduce a known macroscopic porosity, samples with different infill percentage (0, 50 and 100%), shaped in squares of 12.7 x 12.7x 3 mm^3 of dimensions, were printed by using a Zortrax M200 (Zortrax, Olsztyn, Poland) (Fig. 1).

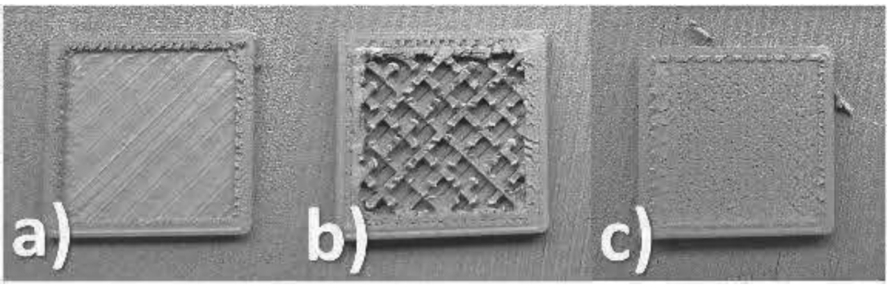

Figure 1. Cross-sections of green parts samples with different infill percentages: a) 0%; b) 50%; c) 100%.

The samples were coated with graphite and introduced into the instrument for thermal conductivity tests, a Laserflash LFA467 Netzsch (Netzsch, Verona, Italy), Fig. 2b.

The thermal conductivity was calculated by applying formula (1).

$$(1)\ \alpha = \frac{k}{\rho \cdot Cp}$$

where α is the thermal diffusivity ($m^2 \cdot s^{-1}$), k is the thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$), ρ is the density ($kg \cdot m^{-3}$) and C_p is the specific heat capacity ($J \cdot kg^{-1} \cdot K^{-1}$).

The C_p of the material was calculated by DSC analysis, using a Mettler DSC1 Star System (Mettler-Toledo, Milan, Italy), shown in Fig.2a.

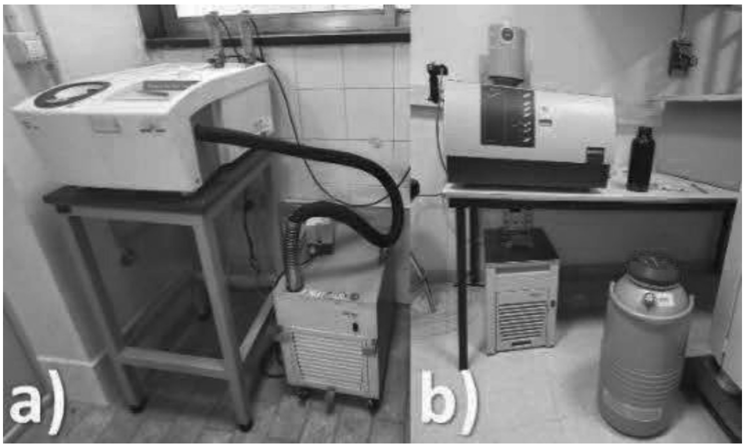

Figure 2. a) DSC and b) Thermal conductivity test apparatus.

In conclusion, the knowledge of thermal conductivity has allowed us to estimate the degree of porosity inside the 3D printed parts as a function of the temperature variations. This characteristic is very important, for example, for the estimation of shrinkages in those processes where porosity and temperature influence the final dimensions of the parts, such as in the sintering process.

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