FDM/FFF Printing of Ceramic Structures

The shaping of ceramics by thermoplastic processing is more and more accepted by the industry. In contrast to commercial casting and pressing processing the storage of the feedstock (ceramic polymer mixture), precise green density and shaping of complex and thin-wall structures are advantages against other ceramic shaping techniques.

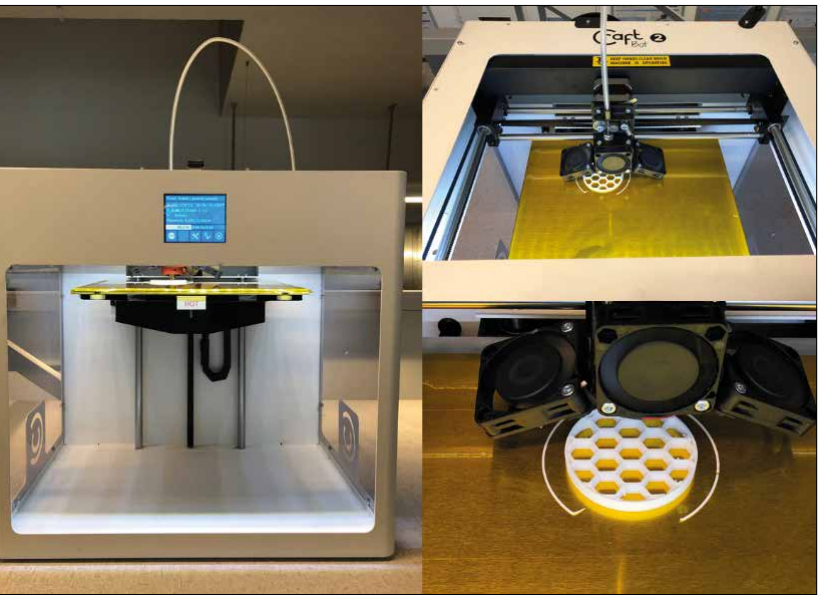

Fig. 1
Commercial FDM/FFF printer which can be used for ceramic printing

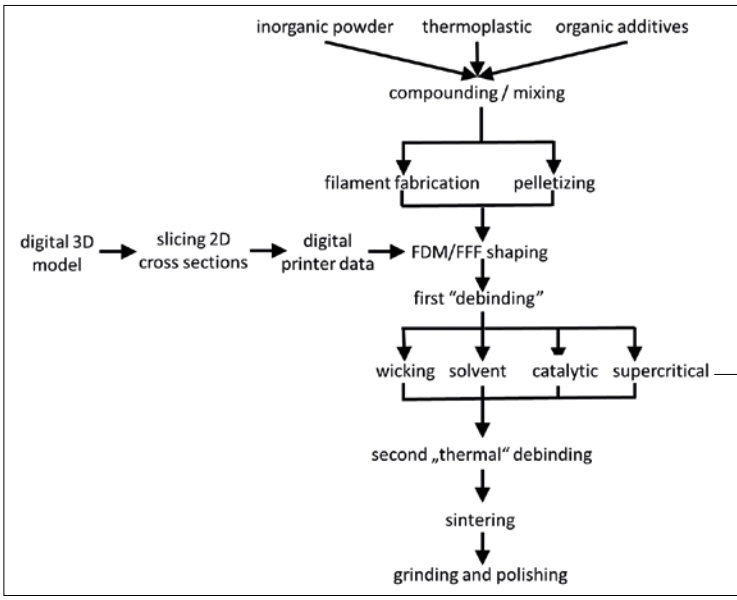

Fig. 2
Schematic process of FDM/FFF printing process: a thermoplastic filament is fed into the extrusion head by feed-ing rollers (a); the polymer is melted and extruded through a nozzle (b); the extruded filament is deposited on the substrate and filament of the subsequent layer is fused with the previous (c) (Source: M. Sami, Empa, 2019)

Introduction

In comparison to industrial thermoplastic shaping methods, like injection molding and extrusion, 3D-printing has the advantage to produce individual structures by slicing and manufacturing in layers (additive manufacturing). Typically the thermoplastic filaments are fed through gear-wheel to a heated nozzle. Instead of a gear-wheel, screw extruder for granulate materials can be used. The polymeric binder of the feedstock will be melted and a filament or a drop will be deposited at a defined position. A typical layer thickness, which can be achieved by this method is between 0,08–1,2 mm.

Keywords
additive manufacturing,
FDM/FFF printing

FDM printing method

The thermoplastic 3D-printing of ceramics can be divided into 4 steps:

1. compounding of the feedstock (homogenization of the ceramic powder and thermoplastic binder mixture);
2. filament or granulate production for the 3D-printing step;
3. FDM/FFF 3D-printing by melting the filament and layer upon layer fabrication.;
4. thermal treatment to decompose the polymeric binder and densification of the ceramic structure.

The surface of the ceramic part can be post-treated after printing, partial debinding step, or after sintering.

In Fig. 1, the 3D-printing of ceramic-based FDM filament on a commercial printer is shown. Empa has a long-time experience in the thermoplastic shaping of ceramic materials (electroceramics, oxides, carbides, nitrates, etc.). Different kinds of thermoplastic binders have been developed for pressing, extrusion, injection molding, dip coating, and 3D-printing. Based on the long-time experience, Empa can develop and optimize the binder system according to the individual requirements of the customer.

Fig. 2 schematically shows the process of an FDM/FFF printer: a thermoplastic fila-

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ment with constant diameter is feed into a heated extrusion head by motor-driven feeding rollers (a). The polymer melts inside the heated 3D-printing head and is extruded through a thin nozzle (b). The extrusion head moves according to the programmed path (x- and y-axis) and is de-positing thin filaments quickly on a substrate. During the deposition process, the material cools and solidifies. In this way, the head makes one layer with the desired shape and pattern of the deposited material. After the completion of the first layer, the head is lifted in the z-direction, and a new layer is deposited fused with the pre-vious (c). Finally, a complete part is constructed layer by layer. In comparison to polymeric materials, the shaping of ceramic is more challenging because of the high solids loading of solid ceramic particles inside the thermoplastic. FDM/FFF printers based on screw extruders, have been developed since a view

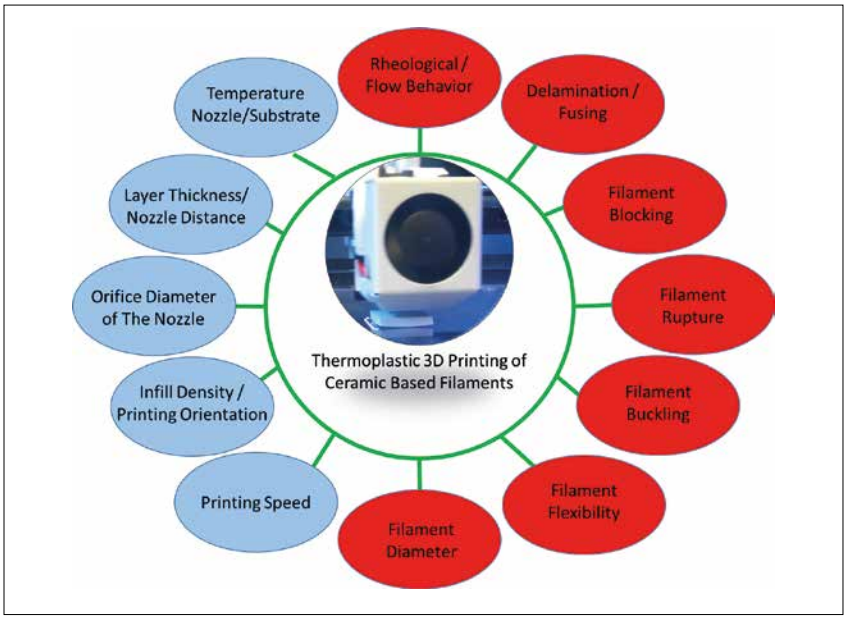

Fig. 3
Effects that will influence the 3D-printing of ceramic-based filaments (blue = machine related effects, red = material related effects)

years. Therefore, thermoplastic-based ceramic pellets for injection molding can be used directly. It is essential to control the rheological properties of polymer-ceramic powder compounds and the effect of organic additives on the printing and debinding processing step [1–12]. There are many challenges during production, which depend on filament properties and processing parameters (Fig. 3). For literature on FDM printing of ceramic structures see the References.

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