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FILAMENT-EXTRUSION 3D PRINTING OF HARDMETAL AND CERMET PARTS

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ABSTRACT

Additive manufacturing is fast-growing and a most interesting fabrication technology also for parts prepared out of composite materials. We recently reported on the first ever conducted extrusion-printing techniques on WC-Co-based hardmetals and Ti(C,N)-based cermets [1,2]. While both materials were prepared with multiphase starting mixtures blended in an in-house drum milling procedure, the present work reports a study using two commercially available starting powders (RTP powders) used for fused-filament fabrication (FFF) of composite parts. In addition, the parts of the present study have a more complicated geometry, not accessible to pressing and MIM techniques.

The hardmetal and cermet powders contained paraffin wax, since they are normally used for press-and-sinter applications, their weight was 7 and 3 kg, respectively. As the specific density of the cermet is approx. half of that of the hardmetal both batches were similar in volume. The multicomponent binder system for FFF was developed at the Chair of Polymer Processing of Montanuniversität Leoben. Feedstocks of various powder contents between 42 and 52 vol% were established.

Filaments were prepared using a single screw extruder. An extrusion die with a diameter of 1.75 mm and a length on 20 mm was used. After exiting the die, the extrudate was transported in a Teflon conveyor belt. Finally, the filament was spooled using a self-developed haul-off and winding unit. The filaments' diameter and ovality was monitored by a laser-based measuring device. A constant geometry of the filament is important for its continuous transportation in an FFF machine. For this reason, the diameter and the ovality of the produced filament were monitored during production. The ovality is the difference between the diameter measure in the horizontal direction minus the diameter measured in the vertical direction; thus, if the filament has a perfectly round cross-section, the ovality is zero. Table 1 gives the diameter and ovality of both types of filaments. Both types of filaments were within the recommended tolerances of 1.75 ± 0.15 mm.

Tab. 1: Diameter and ovality of the two types of filaments

Material	Average Diameter (mm)	Ovality (mm)
Hardmetal filament	1.759 ± 0.0234	0.014 ± 0.0026
Cermet filament	1.724 ± 0.0314	0.010 ± 0.0023

Printing trials were performed on a Wanhao Duplicator i3V2. The nozzle diameter was 0.4 and 0.6 mm and a layer height between 0.1 and 0.38 mm, depending on the part size. The slicer software Slic3r Prusa edition used was. The extrusion temperature was 250 °C and the bed temperature 80 °C. The printing surface was the standard printing surface of the Wanhao FFF machine.

In all printed parts the first layer had a good adhesion to the printing bed (Figure 1). The layer in contact with the printing bed had a smoother and continuous surface, compared to the next layers. The printed layers were bonded correctly.

Fig. 1: FFF printed part on the printing bed, left: hard metal, right: cermet

Solvent debinding was performed on a plastic grid in cyclohexane at 60°C using a magnetic stirrer. The parts were typically submerged for 48-72h, depending on the maximum wall thickness of the parts. After drying and weighing the parts were subjected to a tube furnace for debinding the backbone and pre-sintering. Flowing H_2 and N_2 atmospheres of ambient pressure and various vertex temperatures up to 800°C were applied.

After thermal debinding and weighing the parts were transferred to a vacuum sintering furnace and sintered in a graphite crucible to final density. The sintering programs for hardmetals and cermets were different with vertex temperatures of 1400°C and 1480°C, respectively. Figure 2 shows examples of two sintered hardmetal parts.

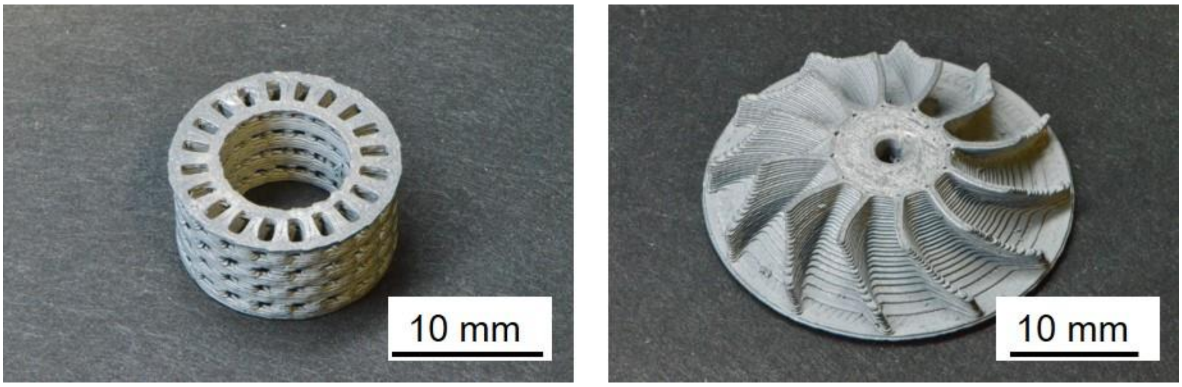

Fig. 2: Sintered hardmetal parts, left: catalyst body, right: turbocharger impeller.

Examples for weight change and shrinkage data are given in Table 2, the reference being the printed body. These figures depend on the amount of filling degree of the printing feedstock.

Tab. 2: Weight change and shrinkage of bodies of the two materials (average of 3 bodies each)

Material	Total Weight change (%)	Total Shrinkage x-y (%)	Total Shrinkage z (%)
Hardmetal	-6.83	-19.72	-22.04
Cermet	-15.03	-23.80	-26.70

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