FUSED DEPOSITION MODELING WITH METAL POWDER FILLED FILAMENTS (Metal-FDM)

Metallic additive manufactured components can be produced with the Fused Deposition Modeling (FDM) process using polymer filaments that are filled with metal particles. In accordance to the conventional MIM (Metal Injection Molding) process, the FDM process is used to manufacture green parts. The polymer is then removed from these green parts in post-treatment steps to create brown parts. Finally, the brown parts with the metal particles are sintered to create the final components. This project deals with this topic and investigates necessary processing parameters along the process chain and demonstrates achievable component properties.

PROJECT OVERVIEW

DURATION

10/2019 – 12/2019
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PARTNER

Industrial Consortium of DMRC

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Introduction

According to the current state of the art, additive manufactured metallic end-use-parts can be produced with Selective Laser Melting (SLM) or Electron Beam Melting (EBM). Due to the high design freedom in the field of additive manufacturing (AM), these processes are increasingly used for complex parts, small series or individualized products. Disadvantages of the SLM process are the high investment costs for the machines that are equipped with one or more high-power lasers (> 300.000 €). In addition, high costs are incurred for peripheral equipment that is necessary for production: sieving station, vacuum cleaner, blasting station and other post-processing machines. A further disadvantage is the handling of metal powder, which places high demands on work safety.

The process chain

Another possibility for the production of metallic AM parts is the use of the Fused Deposition Modeling (FDM) process based on polymer filaments filled with metal powder (Metal-FDM). In accordance to the conventional Metal Injection Molding (MIM) process, the finished FDM parts (green parts) are cleared from polymer in post-treatment steps (brown part). Afterwards the metal particles are sintered to generate the metallic part (white part).
A major challenge in this Metal-FDM process is the large shrinkage of 15 to 20 % in every direction in space due to debinding and sintering. This shrinkage must be considered when designing parts for this process. Since the filament contains a polymer and metal particles, it can be processed with conventional FDM machines that are available on the market.

Applications and advantages

Possible fields of application could be the manufacturing of parts with internal structures that do not require external accessibility. Furthermore, the Metal-FDM process might be used to produce multi-material parts or parts with otherwise incompatible materials in the future, which is not possible in the SLM- or EBM-process. Another major advantage of the FDM process is that material is only used for the actual part and there is no need to fill the entire build chamber with the material to be processed.
In addition, the process is expected to allow utilizing material systems that are developed and used in today's MIM industry. Therefore, the production of raw material is already established at an industrial scale which shows the potential to reduce material costs for these AM process chains due to the large production amounts coming from MIM.

FIGURE 1 Specimens manufactured in the Metal-FDM process

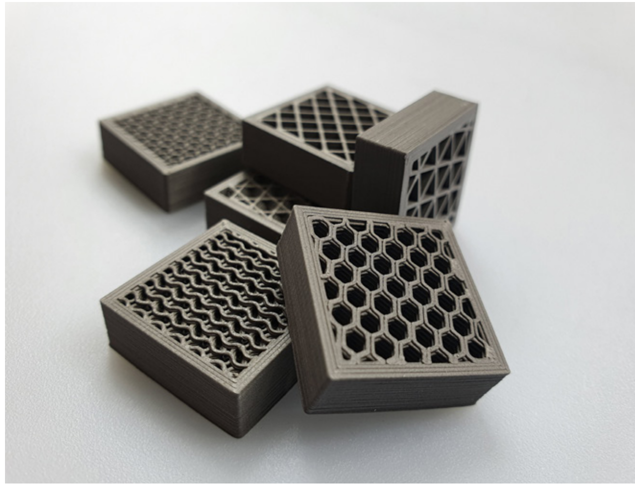

FIGURE 2 Components manufactured with different infill strategies

Approach

In order to build up basic knowledge in this area, a small three-month preliminary project was carried out at the DMRC in 2019. Figure 1 shows some specimens that were produced during the project. On basis of the experience gained, a one year project for 2020 was then conceived and is currently being carried out.

Objectives and Aim

The aim of this project is to generate know-how for FDM with metal filled filaments to introduce it as a further AM process in the DMRC and thus also for the industrial partners. The mechanical characterization and basic design guidelines along the whole process chain should allow a comparison with the established SLM process.

Of course, the process specific challenges must also be considered. One thing to mention here is that the design freedom of Metal-FDM components is not only subject to certain limits in the FDM process but is further limited by the debinding and sintering process. For example, only a certain weight can be supported by a parts structure. If an upper structure of a part is too heavy the component might collapse during the debinding and sintering process.

Furthermore important material-dependent processing parameters are being investigated in this project. The effects on the green parts but also on the white parts are considered. In addition to general process parameters such as the strand deposition strategy and the strand-geometry. Different filling strategies are considered with which, for example, partially filled part areas can be created (cf. Figure 2).

Finally, the investigation of some exemplary use cases that might be provided by the dmrc partners should show the possibilities of the Metal-FDM process. In particular, the aim is to show which component geometries can be realized with the process and what needs to be taken into account during the design phase and for the selection of the FDM process parameters.