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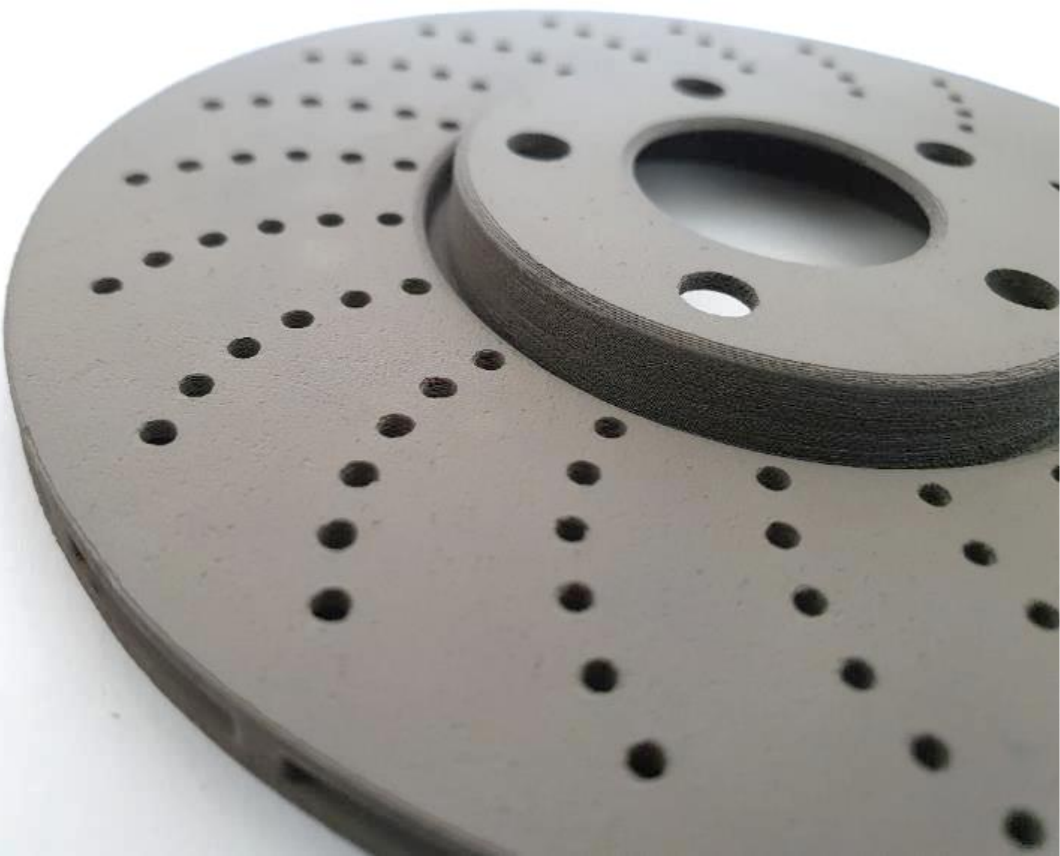
White Paper

The New Innovative MoldJet® Technology

Overview on the process and the machine configuration at Fraunhofer IFAM in Dresden

March 2021

With the MoldJet® process of the Israeli company Tritone Technologies Ltd., the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden is expanding its expertise in the field of sinter-based additive manufacturing processes. The MoldJet® process opens new possibilities in the design freedom of metal components and impresses with its enormous productivity. This paper will give you a deeper insight into the process and the machine configuration at Fraunhofer IFAM in Dresden.



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Introduction

The new MoldJet® machine was installed at ICAM®, the Innovation Center Additive Manufacturing. Here, Fraunhofer IFAM Dresden brings together its wide range of additive manufacturing processes and develops new solutions for materials and component geometries. Beside the new MoldJet® process, customers can profit from the possibilities of **Selective Electron Beam Melting, 3D Screen Printing, metal-based Fused Filament Fabrication, metal-based Gel Casting and Lithography-based Metal Manufacturing**.

Fig. 1 *MoldJet® machine at ICAM®*

Printing Process

The MoldJet® process is a layer wised Additive Manufacturing process. The two essential process steps are the production of a mold as a negative of the desired part geometry and the filling of this with a metal paste. These two process steps alternate with each other.

At the beginning, the first layer of the component mold is produced from a wax-like polymer by an **inkjet printing process.** In this process, the polymer is heated in a reservoir and applied droplet by droplet to the substrate by the print heads. These droplets overlap and form a uniformly molded layer. In the next step, a roller can be used to smooth the mold layer and ensure an even layer height over the entire print area.

Fig. 2 *Scheme mold printing [1]*

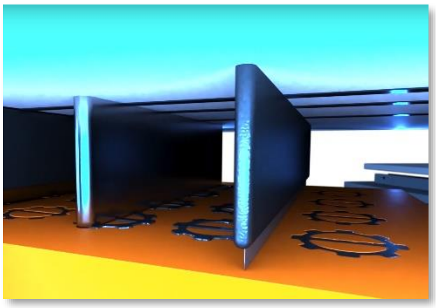


Fig. 3 *Scheme mold filling [1]*

The mold is then filled with the metal paste. This consists of a metal powder of the desired alloy and an organic binder system. For mold filling, a **slot-die coating** and a **blade process step** are used. The paste is evenly fed from a cartridge into the slot-die head to ensure a homogeneous transfer to the mold material. The slot-die head then moves uniformly over the substrate, and continuously filling the cavities of the mold with paste. Since material is applied over the entire substrate width, a blade is integrated into the mold filling process step. This additionally presses the material into the cavities to overcome the capillary forces and avoid material-free areas. At the same time, it ensures that excess material can be removed and collected behind the mold area.

After filling the mold of each layer, a **drying and hardening step** takes place. These three process steps -mold printing, mold filling and drying- are repeated layer by layer until the desired parts are produced. The layout of each individual mold layer can be flexibly and independently adjusted. This allows the production of internal structures and channels as well as parts with free-standing overhangs of even 90°. Completely closed internal channels must be avoided, otherwise the mold material cannot be removed later. If this is taken in account, there are no more design restrictions to the parts printed by the MoldJet® process. (Fig. 10).

Fig. 4 *Scheme drying printed layer [1]*

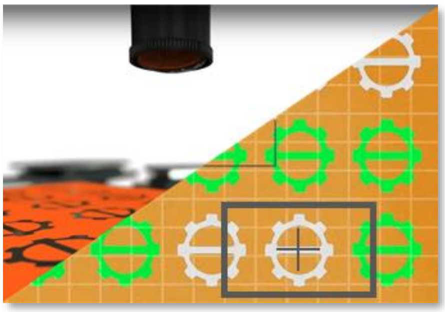


Fig. 5 *Scheme detect and control [1]*

In particular, the MoldJet® process is equipped with a **detect and control (DAC)** process step. Each printed layer can be scanned by a high-resolution camera. The image data of each layer can be stored. In addition, the machine operator can decide on a **mechanical post-processing step** after each printed layer. In the case of printing errors, the last printed layer can be removed and printed again.

At the end of the process chain, a batch consisting of mold material and enclosed printed green parts[1] is available. Finally, the green parts must be removed from the mold material. That is the **demolding process step**. This is done outside the machine without an operator. The wax-like mold material is simply melted off and the demolded green parts remain. These green parts with a high strength are then also **thermally debinded** outside the machine in a heat treatment furnace and **sintered** to dense metal components.

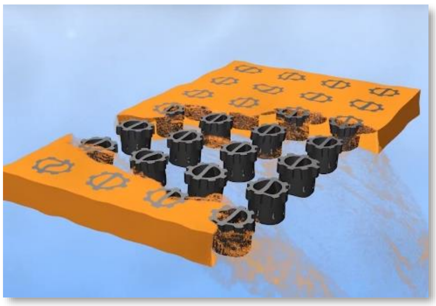


Fig. 6 *Scheme demolding [1]*

[1]*Green parts are components that consist of metal powder and binder. The binder is later extracted by thermal debinding.*

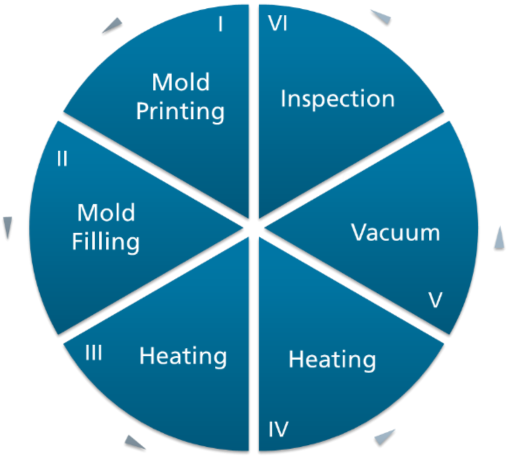
Machine Configuration at Fraunhofer IFAM

The machine concept provides for the use of six independent workstations and six independent workplaces, the so-called trays. Both the workstations and the trays are arranged in a circle (Fig. 8, 9). The workstations are fixed whereas the trays are arranged on a rotating revolver to be moved from one workstation to the next.

Fig. 7 *MoldJet® machine at FrH IFAM*

Workstations

The six workstations of the MoldJet® machine at Fraunhofer IFAM are shown in Fig. 8.



I	Mold Printing	Inkjet Process
II	Mold Smoothing, Filling, Post-processing	Roller, Slot-die Head, Blade, Cutter
III IV	Drying	Hot Air
V	Hardening	Vacuum
VI	Inspection	Detect and Control Camera

Fig. 8 *MoldJet® workstations*

In the machine at Fraunhofer IFAM, four inkjet print heads can be used simultaneously in the first workstation. With a resolution of 2400 x 1800 DPI per print head, a resolution of 11 µm in X-direction, a resolution of 14 µm in Y-direction and a resolution of 100 µm in Z-direction can be achieved during mold production. The part quality is directly determined by the mold (Fig. 11). Currently, the manufacturable layer height is 100 µm. In the future, this will be flexibly adjustable in order to produce even more filigree parts (Fig. 11) or to achieve even higher productivity.

Within the mold filling station, a slot-die head with a width of 235 mm and an effective filling width of 180 mm is used to fill the mold layer with paste. The application speed is 30-40 mm/sec. However, this depends on the material system and is to be increased even further.

In the present configuration, the MoldJet® machine has two drying and one hardening stations. Depending on the paste, drying can sometimes take the longest time compared to the first two stations. The station with the longest working time determines the cycle time and, thus the output of the entire machine. That is the reason why the machine has several drying stations.

This means that the drying process can be split up and printing can continue on the other ones during the drying time of the one tray for example.

The inspection and storage of the data for each layer offers the possibility to process these data in the future. It is conceivable that later, via an intelligent algorithm and machine learning processes, the decision on the necessity of reworking will have to be made by the machine and not by an operator.

Trays

Fig. 9 shows a schematic of the tray arrangement in the machine. The size of a tray is 400 x 240 x 120 mm (L x W x H).

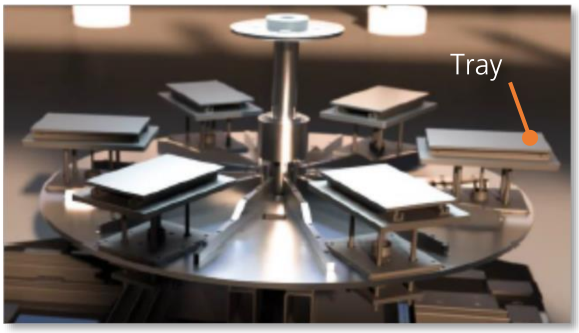


Fig. 9 *Scheme Tray arrangement [1]*

The entire volume per tray can be used. This opens the possibility of arranging several components on top of each other, depending on the component volume. The parts can be stacked and easily separated from each other by a layer of mold material. Different component geometries can be arranged on each tray. It is not necessary to use only one part geometry per tray. Either the entire tray can be used or only a specific area. The entire width, but not the entire length of the tray must always be used. Also, not all trays have to be used at all times.

This means that the number of components to be produced can be flexibly scaled from one part to a medium series. Only as much material is used as it is actually needed. No minimum quantity of holding material is required, which must always be consumed regardless of the number of pieces.

By using the six independent trays, a **productivity** of up to **1,600 cm³/h** can be achieved with the MoldJet® process.

Demonstrators and Material Systems

Fraunhofer IFAM benefits from its many years of expertise in the field of feedstock development for the paste development of the MoldJet® process. At Fraunhofer IFAM, we can look back on many years of paste developments in 3D Screen Printing, paste development for metal-based Gel Casting and feedstock development for metal-based Fused Filament Fabrication. Only water-based pastes are developed and printed in the MoldJet® process. The total binder content is nearly 1.4% [w./w] and the rest is powder. The range of the printable parts is very wide, from small filigree components to large-volume parts as shown in Fig. 10 and 11.

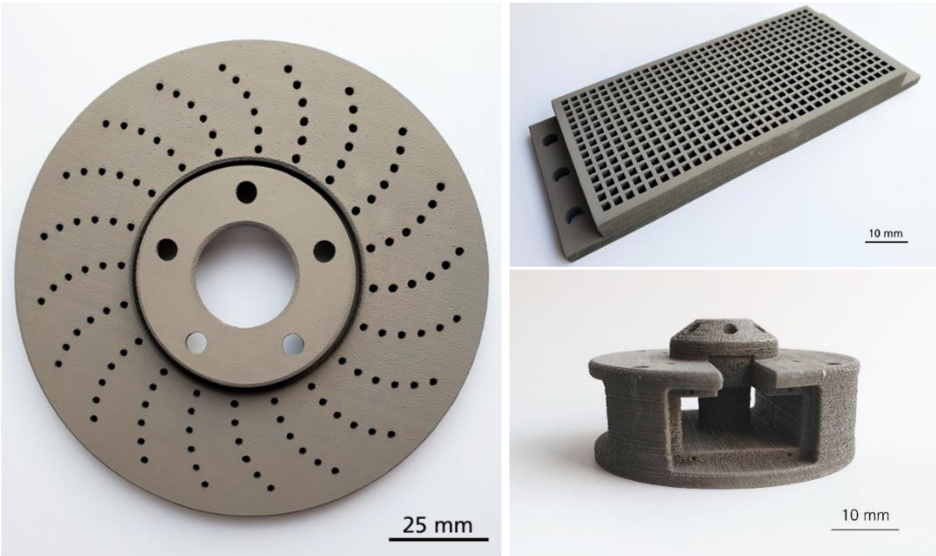


Fig. 10 *Demonstrator green parts 316L (left, top right), Inconel 718 (bottom right)*

The surface quality is mainly determined by the printed form. For this purpose, a printed component was measured with a Keyence VR-5000 profilometer.

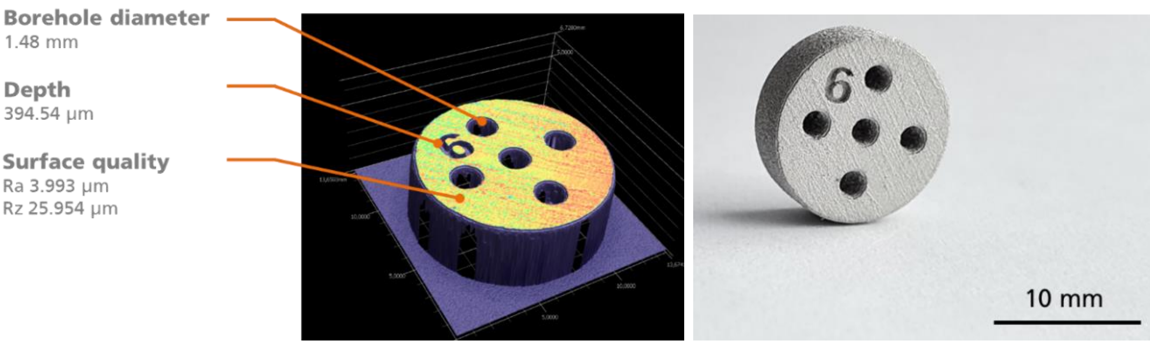


Fig. 11 *Profile measurement with the Keyence VR-5000 (left), sintered part 316L (right)*

Shrinkage of the components during the furnace process is similar to other sinter-based additive manufacturing processes at around 11-15 %. Relative component densities of > 99 % can be achieved. A distinctive feature of the MoldJet® process is the high green part strength. This makes it possible to transport the components without damage until heat treatment (thermal debinding, sintering). With regard to the powders that can be used, there are hardly any limits to the MoldJet® process. Here, it is advisable to use cost-effective MIM powders.

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Conclusion

The MoldJet® process is a manufacturing process created for industrial applications in the field of sinter-based additive manufacturing. The process is characterized by the following features:

- High productivity up to **1,600 cm³/h**
- **Large volume components** can be produced
- Easy **scalability of part quantities** (from one piece to mass production)
- Nearly **no design restrictions** (internal channels, overhangs of even 90° etc.)
- **No** need for **support structures** from the part material
- **High green part strengh**
- **No cost-intensive operator time** for demolding or removal of support structures
- **Low-cost standard powders** (e.g. MIM powders) can be used
- Safe process as the **powder is bonded in the paste**
- **Wide range of material systems** (all sinterable materials)

The MoldJet® process, which was released for the first time in 2019, is a new process that already achieves a high component quality and still leaves plenty of room for Fraunhofer IFAM for further developments. The current focus relates both to the further development of the process together with the company **Tritone Technologies Ltd**. and to the development of new material systems. Fraunhofer IFAM therefore offers:

- Optimization of existing material systems (stainless steel, tool steel, high temperature alloys, titanium, copper-based materials)
- Continuous development of new water-based pastes
- Part geometry development and testing
- Permanent optimization of the printing process

The advantage at Fraunhofer IFAM is that the entire process chain from paste development, printing tests, geometry optimization and heat treatment (thermal debinding, sintering) can be mapped to achieve dense sintered functional parts.

References

[1] Tritone® Technologies Ltd., March 2021