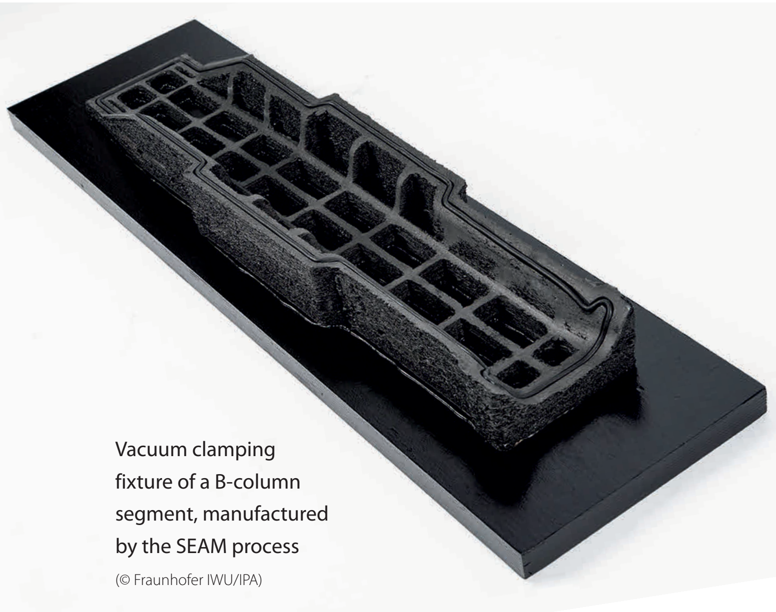
# Ultrafast 3D Printing

## *Additive Manufacturing of Plastic Components in a High-Speed Process Using Standard Pellet Stock*

3D printing is a fast-growing market, opening up completely new product and manufacturing options for customers and industry. The newly developed SEAM process significantly extends the options for the efficient manufacture of printed components. An impression of this is conveyed by the example of a fiber-reinforced clamping fixture.

The SEAM process (screw extrusion additive manufacturing) takes a new approach to high-speed additive manufacturing of plastic components. With printing speeds of up to 1 m/s, it was developed by the Fraunhofer Institute for Machine Tools and Forming Technology (IWU) in cooperation with Metrom GmbH. The 3D printer is based on a combination of an extrusion-based plasticating unit that processes plastic pellets (including fiber-reinforced material), and parallel kinematics for rapid highly dynamic movements with accelerations up to 10 m/s$^2$ and very high positioning accuracy.



Vacuum clamping fixture of a B-column segment, manufactured by the SEAM process (© Fraunhofer IWU/IPA)

Thanks to its mechanical design, it can cross the limits of existing processes and establishes a new generation of 3D printing processes, which is eight times faster than conventional 3D printing. The SEAM process is very material efficient, since it allows components to be manufactured without supporting structures. There are two versions:

- The SEAM-Hex system has a table that moves in three different spatial directions and a fixed printing head (**Fig. 1**).
- The PentaSEAM system is characterized by a movable printing head with fixed build platform or optionally a round table and a linear axis for enlarging the build chamber (**Fig. 2**).

The construction results in parallel kinematics, 6-axis in the first case and 5-axis in the second case.

### *High Process Speed, Low Material Costs*

In the SEAM process, output rates of up to 8 kg/h are generated, for example with a 1 mm nozzle. For comparison, a filament-processing FLM process requires about 20 h for 1 kg of printed component mass, corresponding to a mass output of only 0.1 to 0.2 kg/h. Since standard plastic pellets are processed instead of an expensive FLM filament, there is a huge material cost saving, e.g. a factor of 200, for PA6-CF compared to familiar FLM/FDM (fused layer and fused deposition modeling).

Different plastics, such as thermoplastic elastomers, polypropylene and, as here, a polyamide 6 with 40 % carbon fibers (PA6-CF) have already been tested. These are materials relevant for industry with high stiffness and strength, or high elasticity, which cannot be processed with conventional 3D printers.

Because of the short manufacturing times, a closed material loop and the possibility of being able to subsequently subtractively process the components in one clamping (additive-subtractive hybrid manufacturing), the component costs can be reduced to a fraction, in particular for small series and prototyping, while achieving the same surface quality as for the standard FLM process.

### *Variable Wall Thickness*

Conventional injection molded parts are usually designed as thin-walled structures according to the process and design. The SEAM process permits different wall thicknesses to be generated in one printed track, depending on the table speed and output rate of the extruder. Thus, for example with a 1 mm nozzle and PA6-CF as material, strand widths of between 1.2 and 3.1 mm can be obtained.

Compared to FDM/FLM, where, within narrow limits, the realizable strand width approximately corresponds to the nozzle diameter, the SEAM process is characterized by high variability. This also applies in an unfavorable parameter set – e.g. a low

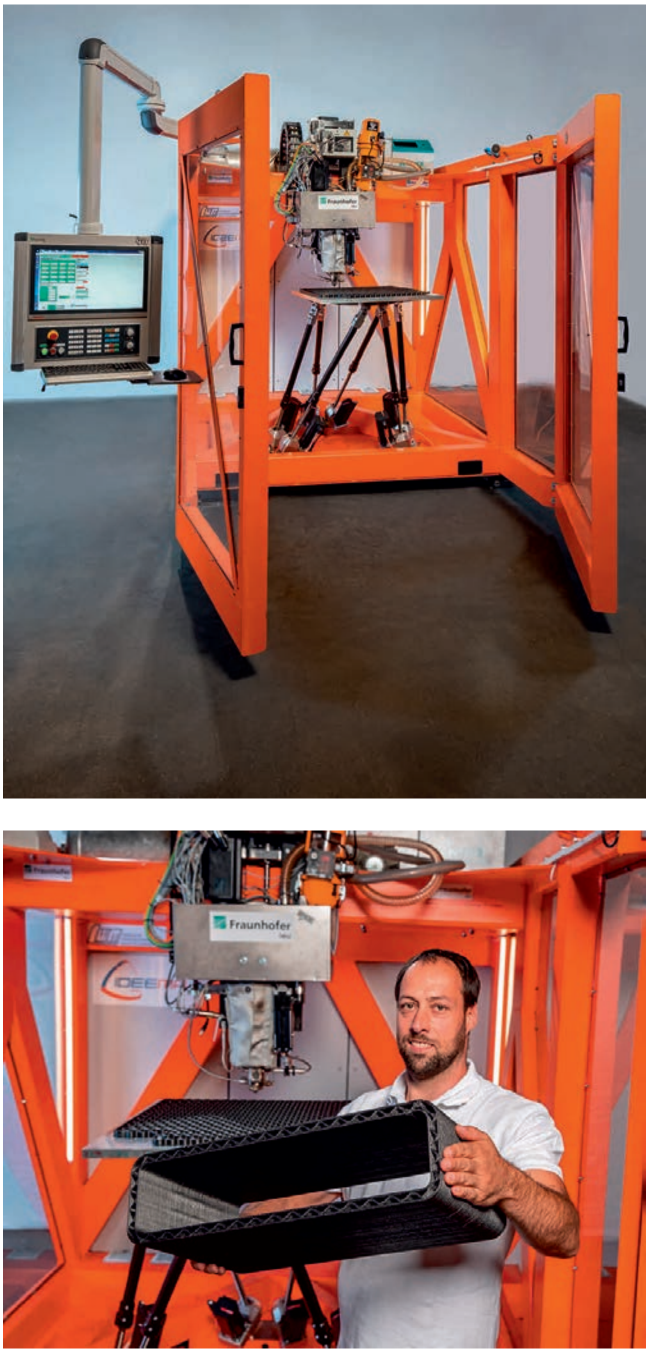



**Fig. 1.** SEAM-Hex machine with extrusion-based plasticating unit and Hexapod 6-axis parallel kinematics (© Fraunhofer IWU, Dirk Hanus)

strand height or a high melt stream – has been adjusted. This can avoid the highly time-consuming infilling of the surfaces, and a significantly higher process speed can be achieved.

For controlled printing in curves and corners, as well as at position jumps without material discharge, the output rate must be controlled depending on the path velocity. Because of the sluggish plastication behavior of an extruder, it is not useful to perform a volume change via the extruder speed. An upstream unit for a velocity-dependent material output of between 0 and 100% has been developed. The patent-pending unit is currently undergoing testing and permits both the familiar path control of classical FLM processes and the manufacture of complex structures as a genuine 5-axis 3D printing process. »

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## Formnext

The two machines – the fastest 3D printers in the world (SEAM-Hex), according to the Fraunhofer IWU, and a Metrom machine for additive-subtractive processing (PentaSEAM) – can be seen live in action at Formnext in Frankfurt/Main, Germany, from November 19 to 22, 2019.

- **Hall 12.0, booth C40**

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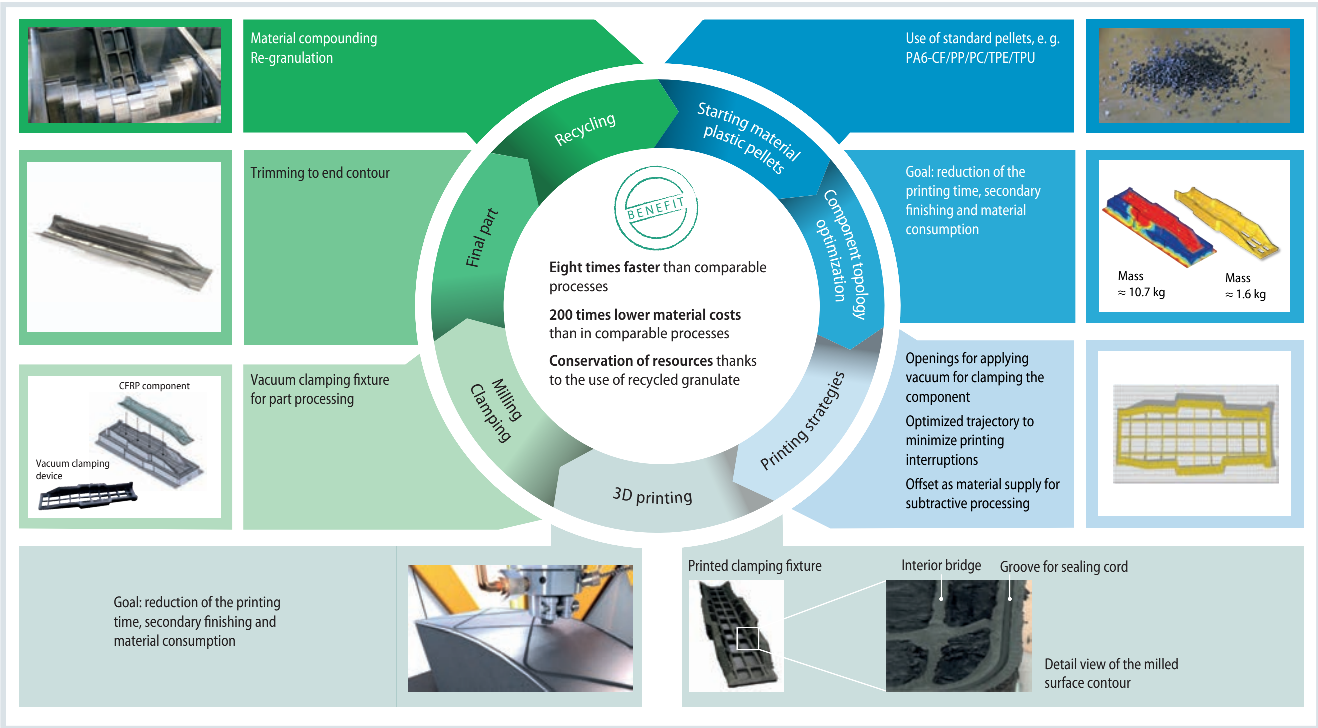


**Fig. 3.** Closed-loop concept with the example of the vacuum clamping fixture (source: Fraunhofer IWU)

## *Typical Application: Fiber-Reinforced Vacuum Clamping Fixtures*

CFRP components are generally manufactured with near-net-shape, so that they only need to be machined at the component edge and for functionalization, for example to introduce bores or recesses. Because of the usually open and large-area part design, they are very unstable and, despite the high stiffness, tend to oscillate, which has a negative effect on the tool life and part quality, for example the dimensional stability and edge quality.

In order to avoid such effects in the end processing, the development partners used the SEAM process to produce a special vacuum clamping device, for processing CFRP components, on which the parts lie in full contact and can be clamped with low vibration by means of vacuum. In the example shown here (**Title figure**), this is a B-column segment with the dimensions 800 x 200 x 3 mm.

In general, the advantages of additive manufacturing lie in the fast and economic manufacture of individual end products, which permit the simple integration of functions such as vacuum fields or milling and suction channels. The targeted introduction of hollow structures additionally permits significant weight savings, which lead to greater material efficiency, shorter printing times, easier handling of the clamping means.

The printed vacuum clamping fixtures can be recycled back to the starting material for reprocessing into plastic pellet stock after their useful life is over, so that the concept of a closed loop system can be applied and, on the other hand, the logistics chain is simplified (**Fig. 3**). If there is subsequently a need for spare parts production, the shape can be rapidly and inexpensively recreated – there is no need to keep molds in storage for many years.

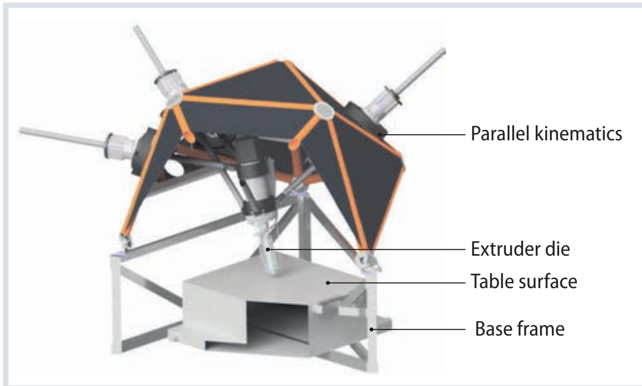


**Fig. 2.** PentaSEAM machine with Metrom 5-axis parallel kinematics and extruder die (© Metrom)

## *Summary*

The SEAM process developed at the Fraunhofer IWU expands the possibilities for the efficient manufacture of plastic components by 3D printing. Thanks to the low material costs and the short manufacturing times, the part costs can be reduced to a fraction. The process also permits the additive processing of materials that could not be processed in this way until now, while achieving the same surface qualities as for the standard FLM process.

In addition, the SEAM process is suitable for manufacturing large structures. For this purpose, early developments have already started, for example for manufacturing large-format laminated molds and processing devices for large-area fiber composites. To this end, an extrusion unit is integrated into a portal movement system and thus achieves a construction volume of several cubic meters. Overall, the new process could represent a crucial step in increasing the efficiency of 3D printing processes. ■