Layer-by-Layer from Granulate to Part

*High-Speed Additive Manufacturing of Fiber-Reinforced Structural Parts*

A new joint venture is getting a hybrid manufacturing cell ready for market. A screw-based plasticizing unit is mounted on a 6-axis robot. The novel processing approach facilitates additive manufacturing of structural parts from granular and fiber-reinforced standard compounds.
over, functional integration increases machine productivity by eliminating downstream processing steps, such as the joining or mounting of components. In an overall concept with greatly reduced tooling invest, rapid manufacturing will enable economical production of such structures for small series.

However, the series production of such a carrier structure cannot be realized using the additive manufacturing methods established in the market today. On the one hand, the available production methods are limited in respect to part size, surface quality, functional integration, and production time. On the other hand, the range of applicable materials for additive manufacturing is severely limited. When filament-based processes are used, processors are dependent on filament manufacturers and their high filament prices. Furthermore, highly reinforced plastics have hardly been utilized, which in turn has impeded the production of parts with targeted anisotropic mechanical properties.

At the Institute of Plastics Processing (IKV) at RWTH Aachen University, Germany, an additive production system is being introduced that exceeds the capabilities of familiar filament-based systems. It includes the capabilities of the constantly growing automation sector and pursues a future-oriented approach that efficiently exploits the technological potential.

**Hybrid Production Concept, New Areas of Application**

The base of the development is a hybrid production cell based on screw-based extrusion. The system enables the automated combination of subtractive and additive production methods. The IKV introduced it at the IKV colloquium 2016, presented it to the public at the K2016, and since then has continuously developed it (Fig. 1).

A 6-axis industrial robot is used as a linear positioning system and overcomes the usual limitations regarding part size and complicated design. To ensure reproducible dimensional stability and high surface quality without simultaneously limiting part complexity, subtractive processes (e.g., milling, drilling) are integrated into the part creation process. Thereby, additive manufacturing and machining are combined in a single production system. This approach makes it possible to integrate inserted parts, such as threaded or bearing bushes, molded parts, electronic or ceramic inserts, and to equip the part with additional functions during construction. To do so, the drive used for extrusion and machining operation is equipped with a standardized tool changing system, thus enabling high automation and flexibility.

The centerpiece of the hybrid system, the screw-based plasticizing unit operates with plastic granules. Compared with filament-based production methods, this enables processing with both unreinforced and highly reinforced plastic compounds at simultaneously high and scalable throughputs. Besides increased throughputs, a great advantage is the significantly lower price for granules (approx. EUR 1 to 8 per kg) compared to filaments (approx. EUR 20 to 500 per kg), depending on the particular material. As with all production processes, the results are dependent upon the processability of the applied material. Essentially, this applies to the aspects of dimensional stability (shrink-related) and mechanical properties (adhesion-related).

The materials developers are now required to investigate which materials previously qualified for other series production processes are suitable for additive production, as well.

**Suitability of Qualified Series Materials**

The processing of highly reinforced plastic compounds in additive manufacturing offers new potential in terms of material selection and resulting part properties. The production of highly reinforced plastic compounds within narrow tolerance ranges is the core competency of Akro-Plastic GmbH of Niederzissen, Germany.

Using the IKV’s system technology, Akromid B3 ICF 30, a polyamide 6 with 30 wt.% short carbon fibers, about 300 µm long, was processed successfully. It is already being used in series injection molding applications. Fiber-reinforced compounds fundamentally tend to shrink less, thereby simplifying their processing by plasticizing additive production methods. Due to optimized plasticizing and flow characteristics of this polyamide compound, a robust process can be realized with high production speeds. In the case at hand, production is 28 times faster than filament-based Fused Layer Modeling.
Fig. 2. Mechanical properties of additively manufactured parts made from Akromid B3 ICF 30 PA6 compound depending on substrate temperature (source: IKV)

The Authors

Prof. Dr.-Ing. Christian Hopmann is the Director of the Institute of Plastics Processing (IKV) in Aachen, Germany.

Celina Hellmich is employed as a scientific associate for additive manufacturing at the IKV.

Nicolai Lammert is the Acting Director of additive manufacturing at Yizumi Germany GmbH; n.lammert@yizumi-germany.de

Dr. Jan Dormanns is employed as an advanced development engineer for interiors at SMP Deutschland GmbH of Bötzingen, Germany.

Jürgen Rinderlin is employed as an advanced development engineer for exteriors at SMP.

Thilo Stier heads the department of sales & innovation at Akro-Plastic GmbH of Niederzissen, Germany.

Josef Zgrzebski is employed as an application engineer at Akro-Plastic GmbH.

New Partnership Paves the Way to Industrialization

The screw-based additive production system is being industrialized in cooperation with the equipment manufacturer Yizumi Germany GmbH, Aachen, Germany. Aiming at an industry-ready solution, the IKV and Yizumi Group will work very

Service

Digital Version

» A PDF file of the article can be found at www.kunststoffe-international.com/7079955

German Version

» Read the German version of the article in our magazine Kunststoffe or at www.kunststoffe.de

Fig. 3. Pilot plant with exchangeable construction bed module for application-oriented use as presented at the Fakuma (© Hanser/F. Gründel)
close together. A pilot machine was successfully presented in live operation at the Fakuma 2018 and can also be seen at the Formnext 2018 (Fig. 3). The system pursues a platform strategy that enables both hybrid additive-subtractive versions, as well as simpler, screw-based extrusion solutions, depending on the application requirements. Flexible machine construction results in variable investment costs.

The system concept integrates methods of additive manufacturing for functionalization in existing production chains of, for example, injection molded or die cast components. In this way, multi-material applications can be created economically by combining an injection molding process with additive manufacturing. Thus, housing parts, for example, can be produced with local sealing or reinforcement elements. Today, this would require a multi-component process with two injection molding machines including two molds. In the future, the combination of an injection molding process with an additive manufacturing line will enable local reinforcements. The high productivity of the system technology presented here makes it possible to apply sealings or reinforcement structures to the part within the cycle time of the injection molding process. This will save a second injection molding machine, while lowering mold investment significantly. Production flexibility will be increased simultaneously, thereby making it possible to economically produce several product versions.

Conclusions

The new process will be developed and marketed via the joint venture with Yizumi and in technological cooperation with companies along the entire value chain. Continuous development of this production technology will expand the limits of additive manufacturing and its transfer to series production. The further development of existing series compounds and new materials will contribute to this expansion, as well. The results relating to the strong anisotropy in mechanical properties will be a special challenge for the software branch. Economical and fast CAM systems are required for load path-oriented part construction. The machine hardware and raw materials are available and can be utilized selectively.