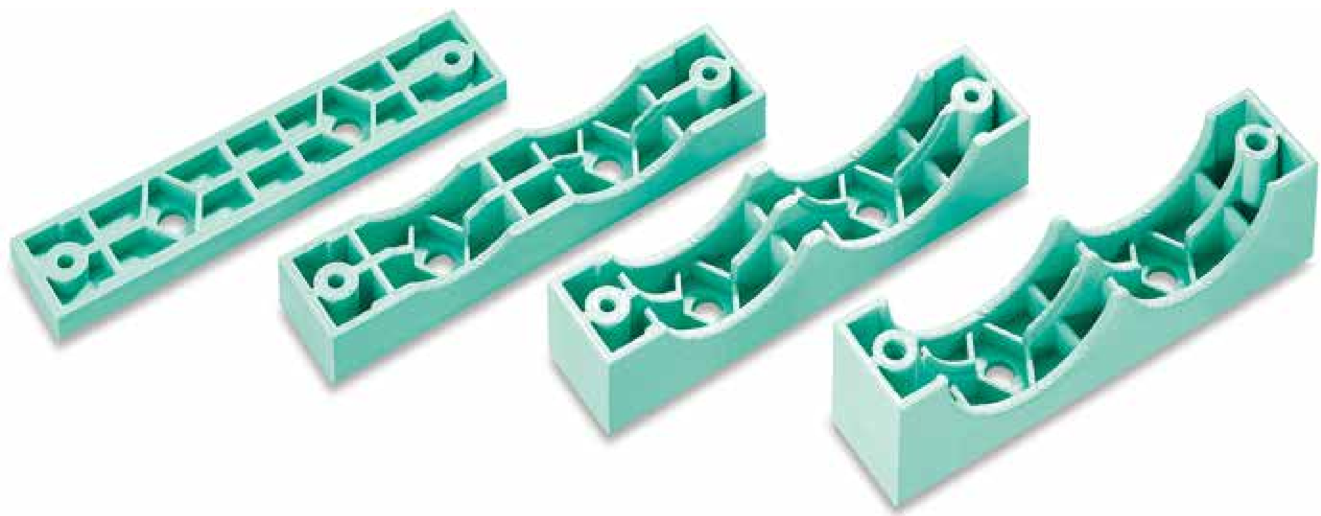
Layered Functional Parts on an Industrial Scale

Arburg Plastic Freeforming Permits Additive Manufacturing from Standard Granulate

Market demands are changing at the same pace as the market for plastics processing. The reasons for this are rapid technical developments, short product lifecycles, increasing variant diversity and the desire for customized products. A new process has what it takes to fill the gap between rapid prototyping and serial injection molding and lead to industrial success.



The component, in this case a hose holder, is built up additively, layer-by-layer from tiny droplets (figures: Arburg)

The wide variety of materials, applications and processes in plastics processing is increasing continuously. Arburg GmbH + Co KG, Lossburg, Germany, already recognized the potential of additive manufacturing many years ago and has, from the perspective of a machine manufacturer, developed and implemented a further industrial process in addition to injection molding, in order to cater to this growing market. Arburg Plastic Freeforming (AKF) and the associated machine base, the Freeformer, celebrated their world premiere at last year's K 2013. A new system is therefore now available with which not only samples and prototypes, but also fully functional one-off parts or small-volume batches can be produced from standard granulates based on 3-D CAD data.

Much More than just 3-D Printing

Whereas injection molding is the process of choice when it comes to producing large unit volumes at a high level of quality, for example in the packaging industry and the medical technology sector, additive manufacturing is ideally suited to the efficient production of one-off parts and small-volume batches across all sectors. The term "additive manufacturing" refers to all processes in which components are produced by building up layers of a material on the basis of 3-D CAD data. There is no need for molds for shaping the parts, familiar from injection molding, for example.

The terms "3-D printing", "rapid prototyping" and "rapid manufacturing" are generally used as synonyms for "additive manufacturing". However, they differ considerably in terms of their areas of application and the quality of the parts produced:

- 3-D printing is only suitable for producing studies or geometric models, for example in the design of cosmetics containers. 3-D printers, which are available from DIY stores for a few hundred or thousand euros, produce low-quality parts and are also mainly aimed at home use.
- With rapid prototyping, samples and components can be made for the

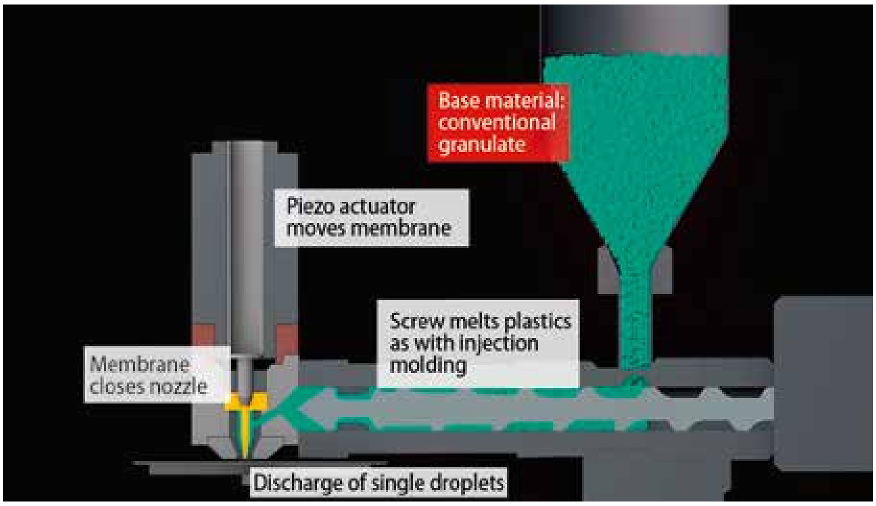


Fig. 1. Arburg Plastic Freeforming (AKF) is based on liquid plastic droplets, which are generated from standard pellets and applied with a piezo-controlled nozzle

Fig. 2. At the Arburg Technology Days 2014, a Freeformer produced twelve connector housings made from ABS as spare parts for Allrounder injection molding machines

purpose of testing a new product. An automotive manufacturer, for example, tested and optimized prototype washer fluid reservoirs under desert and arctic conditions, saving several months of development time.

- Finally, rapid manufacturing, involves industrial additive manufacturing to a high level of quality. This process is ideal if a plastic part has to be produced quickly and does not require the same properties as an injection molded part.

This is the category to which the Freeformer belongs. This machine melts standard granulates, as in injection molding, and produces fully functional one-off components and small-volume batches from tiny plastic droplets.

Industrial Processes

Additive manufacturing processes can be differentiated according to the base materials used and whether the components are built up in chemical or physical processes. Three processes are primarily used in industrial applications.

Stereolithography (STL): The components are created in a material bath filled with epoxy or other synthetic resin. A laser beam controlled via movable mirrors then hardens the resin in thin layers. The finished and drained components are subsequently separated from any supporting structures, washed with solvent and fully hardened under UV light.

Selective Laser Sintering (SLS): This process also employs a laser. Here, the component is melted, or sintered, layer-by-layer in a bed of a powder material. The unmelted powder acts as a supporting structure for projecting parts. SLS requires additional infrastructure for subsequent steps. The plastic part is removed from the powder bed and cleaned, and the unmelted powder is removed and reprocessed.

Fused Deposition Modeling (FDM): The base material here is provided in the form of a plastic filament on a reel. The material is extruded, heated in a freely moveable hot nozzle and applied in liquid form. During subsequent cooling, the individual layers fuse together to form the three-dimensional component. If necessary, supporting structures can be implemented by using a second hot nozzle.

Additive Manufacturing Based on Standard Granulates

In contrast, at the newly developed Arburg Plastic Freeforming (AKF), inexpensive, conventional plastic granulates are the base materials. These are first melted in a plasticizing cylinder as with injection molding. A stationary discharge unit with a special nozzle then applies the plastic droplets layer-by-layer onto a component carrier using high-frequency piezo technology at a specified cycle of 60 to 200 Hz (**Fig. 1**).

The component carrier, which can move on three or five axes, is positioned so that each drop falls onto the precise point calculated in advance. No special processes are required for hardening as the tiny droplets fuse together automatically during cooling. The desired component is thus created layer by layer (**Title figure**).

The construction chamber of the Freeformer is designed so that parts with maximum dimensions of 230 x 130 x 250 mm can be produced. At the Technology Days 2014, Arburg demonstrated, for example, how a connector housing made from ABS can be efficiently manufactured in small unit volumes using the Freeformer. Twelve of these spare parts for Allrounder injection molding machines »

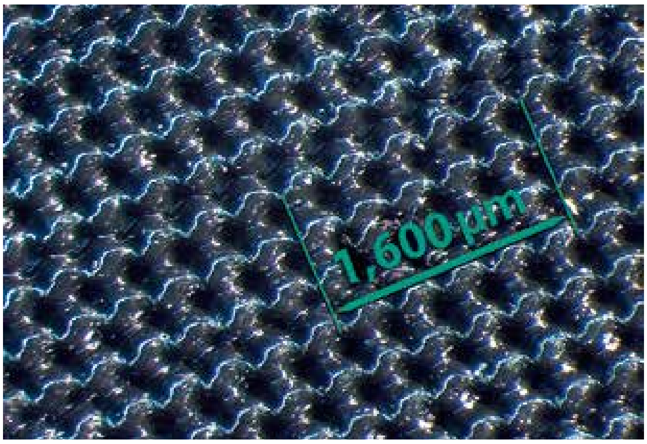


Fig. 3. The macro image (48 x magnification) of a surface created using the Freeformer shows the homogeneous, dense, layered structure

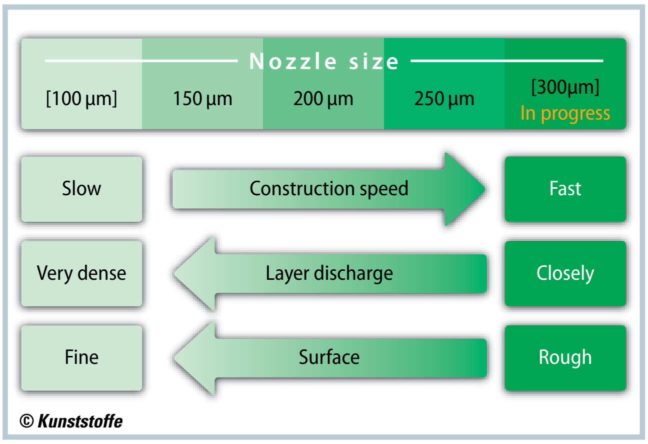


Fig. 4. The Freeformer can be operated with various nozzle sizes. The nozzle size influences the processing parameters

were manufactured in a production time of around 18 hours (**Fig. 2**).

Homogeneous Build-Up of Layers and Excellent Mechanical Properties

Once the melt has been prepared in the plasticizing cylinder, the discharge unit begins with the central additive manufacturing process by means of clocked nozzle closure. With diameters between 0.18 and 0.3 mm (depending on the nozzle), the plastic droplets generated under pressure are consecutively deposited and fuse together to build up the three-dimensional plastic part layer-by-layer.

The surface thus created corresponds to that of a rough-textured molded part. Although it is formed by droplets, it is extremely even in all directions, as the macro images reveal (**Fig. 3**). A good illustration of this, for example, is the production of a drinking cup, which is completely leakproof when filled with water. The same applies to the suction pad components of robot grippers. When produced with the Freeformer, they are fully functional and do not let in any air.

Furthermore, different nozzle sizes are available, which also influence the processing parameters (**Fig. 4**). The smaller the nozzle, the tinier the droplets and the finer the surface texture. However, with a large nozzle, layers are built up faster.

Fig. 5. The control system for the Freeformer builds on the proven Selogica system for Arburg injection molding machines. The multi-touch screen is gesture-controlled

Tensile strength measurements show that the quality of components produced using the AKF process is perfectly adequate for most functional parts and small-volume batches. One difference compared to injection molding is the crack behavior, because virtually no expansion phase occurs. The challenges lie less in achieving good tensile strength and more in implementing thin wall thicknesses of less than 0.6 mm and delicate structures.

The major advantage of the AKF process is that inexpensive standard granulates can be processed. The already specified materials, which can be dyed, currently include ABS, PC, PA and soft TPE. The qualification of further plastics is one of the main tasks during the further development of this new technology. In contrast, glassfiber-reinforced plastics are fundamentally unsuitable for AKF, as these would block the nozzle.

Inexpensive Standard Granulate, Environmentally-Friendly Operation

In order to check whether and how a new material can be processed, numerous tests and testing methods are necessary. The most important parameters include the processing temperature and temperature resistance as well as the geometric slicing into layers.

No dust or emissions are produced when working with the Freeformer, so that no additional infrastructure is therefore necessary. The user needs no extraction units or cooling water. The system is therefore also perfectly suitable for use in an office environment. All that is required are a socket, 3-D CAD data and conventional plastic granulate. Operation is extremely simple. Around one or two days of training are generally sufficient to train someone in the use of the Freeformer.

The control system and software for processing the 3-D CAD data (slicing) has also been developed in-house by Arburg (**Fig. 5**). The operating panel comprises a high-performance industrial PC with a multi-touch screen, which can be intuitively operated by gestures. As with the Allrounder injection molding machines, access authorizations can be issued via transponder cards and data can be stored on compact flash cards.

The operator simply needs to read in the STL data and define the material. Based on this, the control system automatically generates the processing data. Individual parameter entry is however also possible, e.g. if a company that is already familiar with the Selogica control system for injection molding machines wants to specify its own material for a particular product.

Process Variants with Two Components and a Five-Axis Component Carrier

With a Freeformer equipped with two discharge units, multi-component parts can also be produced, for example in different colors, with special tactile qualities, or as hard-soft combinations. The two materials are applied consecutively in each layer. Alternatively, the second component can also be used to construct supporting structures (**Fig. 6**).

The discharge unit and nozzle remain in a fixed position. The movement is performed in the machine by the so-called component carrier, on which the desired product is created. The component carrier moves along three axes as standard. An optional version with five axes is also available for producing projecting parts and undercuts. This is ideal for rotationally symmetrical parts. Supporting structures can also be dispensed with, if not absolutely necessary. Benefits include low material consumption and time-saving production with no need for finishing work.

Summary

The plastics processing market is changing. The variety of materials, applications and processes is increasing. The Freeformer – available in Germany in time for the Fakuma 2014 – is designed for the industrial manufacture of fully functional plastic parts either on a one-off basis or in small-volume batches. The alternative to conventional additive processes will make it easier for users from the injection molding industry in particular to enter into the world of parts production without requiring a mold. This is because, unlike conventional additive manufacturing techniques, AKF is based on low-cost standard granulates, so that there is no need for pre-prepared special materials.

As with injection molding, granulate is first melted in a plasticizing cylinder. The building up of the component geometry from tiny droplets of plastic is a patented process and uses a discharge unit with a nozzle that is controlled using piezo technology. When two nozzles are used, hard/soft combinations and other material combinations are possible. ■

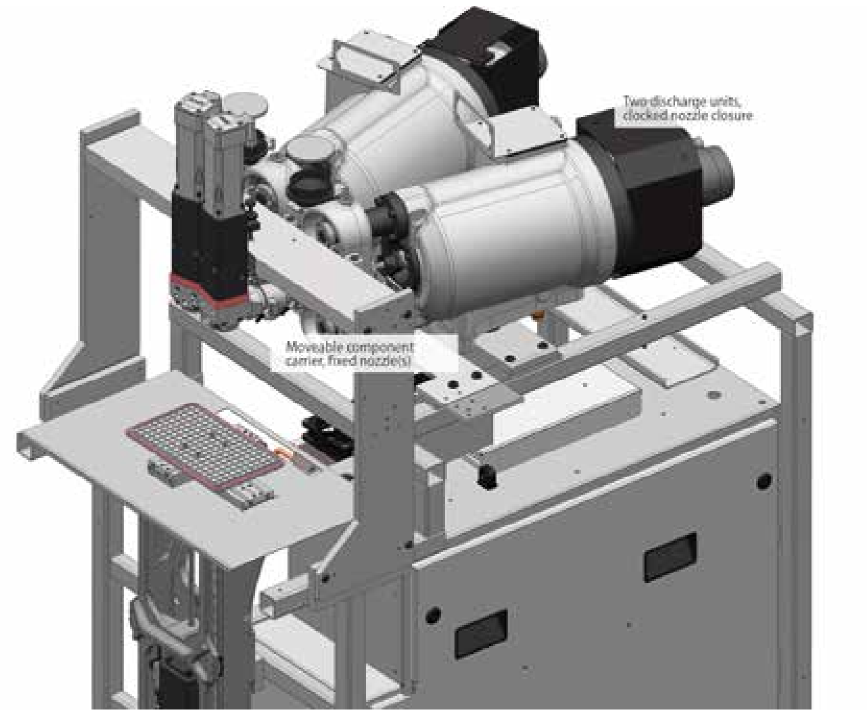


Fig. 6. Equipped with two discharge units, the machine can process different materials, to produce components with hard-soft combinations, for example

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Practical Benefit

Additive industrial manufacture with the Freeformer is not a substitute for, but a useful complement to injection molding. The central question is and will remain how many parts can be produced how quickly and how often. The new machine will primarily be used where a spare part or sample needs to be available quickly. Production can be started within a few minutes. Fully functional one-off parts or small-volume batches can thus be produced in line with requirements. Here, Arburg Plastic Freeforming offers a high level of design freedom and material diversity. Moreover, part geometries can be achieved which could not be demolded using the injection molding process. However, for high-volume production and large unit volumes, injection molding will remain the more efficient solution.

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