3D PRINTING MATERIALS
Experience the 3Difference

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3D Printing in the Plastics Industry

What is industrial 3D printing? And can a 3D printing technology ever establish itself as a standard procedure for polymer processing in the traditional plastic industry?

LEHVOSS Group

Abstract

Industrial 3D printing with plastics differs quite fundamentally from the currently dominant prototyping business: different objectives, different technologies, different materials, different processing companies. Industrial 3D printing addresses the classic plastics industry, and special 3D printing technologies are actually evolving, with the potential to become established as standard procedures in the near future. In contrast, other 3D printing technologies are distancing themselves from this goal. The same applies to 3D printing materials. For the LEHVOSS Group, industrial 3D printing is in the focus of its activities. We are therefore venturing to provide a prognosis and some recommended actions.

Contents

Cover picture was made by the AI Bing Creator.
The image represents the combination of old and new.

What is the issue?

Industrial 3D printing or what LEHVOSS understands by this term is not currently taking place! Of course, 3D printing is already a widespread procedure for the manufacture of products such as spectacles and hearing aids. From the viewpoint of the plastics industry, though, such individually adapted products are speciality components in small quantities. And they are unable to disguise the fact that 3D printing currently has little to no significance for the production of components in the classic plastics industry.

After all, 3D printing is a forming process for plastics that functions without tooling – which therefore saves on precisely those tools that have to be produced at great expense for injection molding, deep drawing, etc. Hence 3D printing **supplements** classic molding procedures for the manufacturing of plastic components. To be able to do this effectively or merely to be perceived as such by the plastics industry, there are only two essential factors: price and quality.

In the following, we as developers and suppliers of thermoplastic 3D printing materials, explain our definition of industrial 3D printing, the current positioning of the "3D printing sector" in this respect and the contribution that LEHVOSS is offering in order to establish 3D printing in the industrial setting.

Why industrial 3D printing?

Prototyping is still by far the largest application for 3D printing. Speed of production is the main aim in the printing of prototypes, with components usually being ordered overnight. The files are barely inspected by the printing service company and automatically positioned and printed in the build space (in the case of laser sintering) together with other parts. The process requires a certain "robustness" as parts with a completely different geometry and alignment are printed with identical parameters. Just imagine injection molding always being used with the same injection pressure and temperatures regardless of tool geometry and size – difficult, and it is quite certain that the maximum quality that the process would in theory enable cannot be achieved for all parts.

There are materials that function very well for these requirements, such as PLA in filament printing or polyamide 12 for laser sintering. Users definitely expect good component qualities and surfaces, and ultimately they pay a high price for the short delivery time of the part. In most cases, tolerances and other requirements in the status of prototyping have yet to be formulated. Similarly, the price of the part also has no great significance. Instead, the aim is to enable a visual inspection of engineering design or conduct installation tests so that the design can be revised if necessary before investments in expensive tooling are made. The situation in industrial 3D printing is quite different: in this case it is exclusively quality and costs that count.

This is because the aim of industrial 3D printing is to produce parts that are usually injection molded using plastic granules or machined from semi-finished goods. The use of 3D printing for such parts makes economic sense if they differ from a standard geometry and are required in smaller quantities. The aim is to avoid the costs for mold construction. In industry, 3D printing is therefore a tool-less forming technique to supplement injection molding. Under no circumstances is it concerned with replacing injection molding as a procedure, which does not, however, mean that 3D printing is not in competition with injection molding.

Ultimately, the aim is to print components in such a way that they achieve a quality level as close as possible to that of injection molding. This generally results in a comprehensive list of specifications. It contains requirements for surface quality, geometric tolerances to be observed, mechanical performance, fogging, fire characteristics and much more besides. With such requirements, there would barely be any applications for the above-mentioned standard prototyping materials of PLA and PA12. One simple reason is that practically no plastic is used in industrial applications without reinforcing materials such as glass fibers, carbon fibers or fillers such as talc.

There are standard materials for injection molding, which in statistical terms cover most applications. Among these materials are polypropylene with 10% w/w glass fiber reinforcement (PPG GF10) or polyamide 6 with 30% w/w glass fiber reinforcement (PA6 GF30) – referred to as standard polymers or commodities in the specialist jargon. It is not technically possible to use these materials simultaneously for injection molding and 3D printing with identical formulations. The procedures are too different. However, this is also not required. Instead, it is a matter of achieving the same performance on the component. Consequently, there is a need for industrial 3D printing materials with requirements that can be derived from standard injection molding materials. Yet these materials then also require special hardware (e.g. wear-resistant nozzles for carbon fiber-reinforced materials in filament printing) and processing parameters (e.g. temperature, mass flow, energy input) for use in 3D printers. Unlike prototyping, almost every part requires an individual 3D printing profile! This is expensive but the only way to guarantee that components are printed in large quantities with constantly high quality and a high level of productivity.

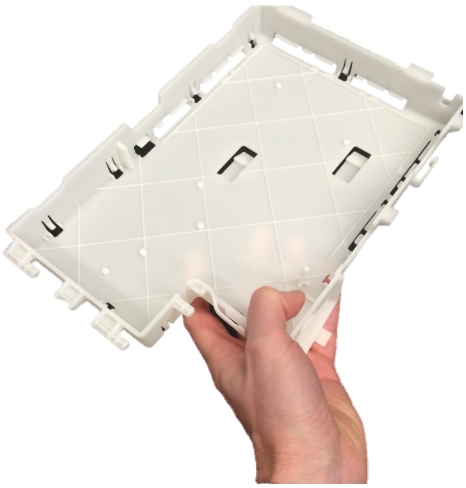
However, it is not only the materials for use in industrial 3D printing that differ from those in prototyping. Machines for 3D printing also have to function in a different way to those for rapid prototyping. In prototyping closed machine and material systems are sold practically as an all-round solution, which definitely makes sense here. The 3D print service demands fast and ideally guaranteed printing results for all types of component to an equal extent. This is why machines and materials are generally supplied from a single source. The user has very limited options for the settings, which means that the machine producer can guarantee the results of printing. Can you imagine an injection molding machine with its settings blocked by the software and only capable of processing one or two materials?

This makes sense for prototyping with 3D printing but is inconceivable for industrial production. The construction of industrial printers has to exhibit maximum individuality and have a full range of optional settings. It is not only a matter of every material and every component requiring individual processing parameters, the users also have to be able to extend their own processing know-how so that for example parts for the spares market do not have to compete with simple counterfeit products.

Industrial 3D printing is price sensitive because – on the basis of a certain quantity – it has to be more economically priced than for example injection-molded or machined parts. The component price is determined by factors such as the machine costs, the media to be used (e.g. nitrogen in laser sintering), the productivity and the material costs. And it is quite conceivable that the material costs will increasingly become the focus for the user as productivity rises. And a dilemma arises at this point: 3D printing needs special materials adapted to the printing procedure, which then compete with low-cost standard materials for injection molding in terms of price. This conflict is very difficult to resolve, thus limiting the quantity that can be printed cost-effectively and cements the status of injection molding for series production.

Furthermore, injection molding with tools has the major advantage that tool surface and textures are perfectly formed. Similar surface qualities can be achieved on 3D printed parts, but this involves the investment of great effort in post-processing. Along with the material costs, this is the second major cost factor, which will also limit the quantity of parts that can be produced cost-effectively in the future.

However, there is also one requirement that applies equally to prototyping and industrial production: geometry. It is the key factor, practically the *raison d'être* for 3D printing. Geometry and changes in geometry are practically free of charge as no adaptation of tools is involved. Admittedly, very innovative free forms or complex lattice structures are shown in connection with 3D printing, but in industrial reality such complex parts are of no significance. The principal concern is to cost-effectively print small quantities of parts that have been designed for injection molding or that require a slightly different version (e.g. mirrored part geometries for right-hand drive motor vehicles). The geometries must be reproduced precisely without having to adapt the design of the original injection molded part specifically to the 3D printing process.



Printed to match injection molded - printed spare part for a dishwasher does not allow 3D printing-specific adaptation of the geometry, here LUVOSINT PP 8824 WT.

Consequently, 3D printing processes that offer maximum geometric freedom are relevant for prototype construction and industrial production. This is the reason why powder bed processes (primarily selective laser sintering) are predominantly used in prototype construction and, for the same reason, are also regarded as the future of industrial 3D printing. However, it is easy to overlook the fact that plastics in powder form can only be modified to a very limited extent. This is one of the reasons why unreinforced, white polyamides have predominated in these applications for decades. There is a clear conflict of objectives here: unrestricted geometric freedom and a broad material portfolio of injection molding-like (reinforced and filled) materials are clearly ruled out for laser sintering at present. For this reason, it is currently necessary to make a decision at the outset for each component in industrial 3D printing as to which printing process can be used. And this is severely limiting the use of 3D printing. Not every part can be achieved in 3D printing without restrictions. At the very least, geometric adjustments are required. As a result, the focus today is (still) on components with simple geometries. And compared to the total number of all plastics, these are one thing above all others: rare.

The key facts at a glance:

- Industrial 3D printing augments conventional procedures of plastics technology and is unable to replace them.
- Industrial 3D printing materials have to make it possible to achieve the performance of injection-molded components.
- High requirements placed on components demand individual solutions and precisely adjustable industrial 3D printers. Quality-assured production is the goal.
- Industrial 3D printers must have a high productivity in order to minimize component costs. To this end, every additional input in the printing process and for post-processing must be avoided (“easy-to-print”).
- Industrial 3D printing materials must be tuned to the respective application and the processing technique in order to guarantee constantly high component quality.
- Despite all the optimization measures, the manufacturing costs in 3D printing are rising increasingly compared with those of injection molding. Consequently, industrial 3D printing will always be limited to individual components with low quantities.
- Industrial 3D printing requires unrestricted geometric freedom of the printing procedure, combined with high productivity. However, the range of materials on offer is currently very limited, specifically for procedures such as these.

Industrial 3D printing processes

As described above, the performance of industrial 3D printing materials must match that of injection molding materials as closely as possible. Thermoplastic polymers such as PP, PA, POM, PC/ABS, PPS and PEEK are predominantly used in injection molding. It would therefore appear wise to use thermoplastics as the basis for materials in industrial 3D printing. Thermosets, i.e. cross-linking systems that are used in 3D printing, are certainly also capable of achieving a level of properties relevant to injection molding. However, the industry insists on the use of identical polymer classes, as this facilitates internal qualification and there are other requirements, such as recyclability, which cannot be met with thermosetting plastics.

For these reasons, thermoplastic polymers are dominant in industrial 3D printing, which then means that 3D printing processes that work with thermoplastics are important for industrial 3D printing. These are:

- Powder-based printing processes or Powder Bed Fusion (PBF)
- Filament printing or Fused Filament Fabrication (FFF)
- Direct extrusion printing or Fused Granulate Fabrication (FGF)

Powder Bed Fusion (PBF)

Powder-based processes such as laser sintering are considered THE industrial processes for 3D printing. And indeed, the layer-by-layer application of a fine powder and its precise selective melting by a laser offers advantages that other 3D printing technologies are not yet able to match: The powder bed process does not require any support materials, as the printed components are enclosed and supported by the powder bed and can therefore be positioned anywhere within the build space. The process therefore offers geometric freedom, which enables almost any component geometry to be created. This is an important prerequisite for industrial 3D printing (see above). The process also enables the production of larger quantities, i.e. relatively high productivity, as the entire build space can be closely packed with components. However, powder bed processes come with constraints and restrictions that clearly disqualify them as the ultimate industrial 3D printing process of the future, as which they are being marketed today.

The major limiting factor is the use of ultra-fine polymer powders. These are not only expensive to produce. They also prevent the modification and finishing required to be able to reproduce industry-relevant plastic properties. It should also be borne in mind that no other process in the plastics industry – apart from electrostatic powder coating – deals with such fine powders. This is because handling ultra-fine powders below 100 micrometers is challenging and requires special safety measures. When handling the powders, for instance, only explosion-proof machines can be used, machines which are not available in the plastics processing industry. Expensive solutions from the food industry are often used for silo technology, powder transport, sieving and mixing. The aim is to prevent the formation of dust, but this is extremely difficult to achieve entirely.

Furthermore, the seemingly high productivity of the process is deceptive. A batch process is involved. Large print jobs take many hours or even days to complete, while heating and cooling times also extend the net printing time. As a result, many components simultaneously pass to what is known as the unpacking process, which involves separating the printed components from the surrounding powder cake, followed by depowdering and cleaning of component surfaces. No recycling service provider accepts the powder residues that accumulate in this process, which means that they have to be disposed of at great expense practically as hazardous waste from plastics production. It is highly unlikely that traditional manufacturers in the plastics industry will be able to manage this additional input.

It is therefore not foreseeable that powder-based processes will find widespread use in the traditional plastics industry in addition to prototype construction, for which they are the optimum process due to the geometric freedom they offer. And in order to be used reliably and on a large scale in specific industries, such as orthopedics, the printers currently used in batch mode must be designed to run **continuously**. Only then will it be possible to automate the complex post-processing steps, allowing complete solutions to be offered to the industry. Only then will it be possible to reliably calculate component costs and throughput – the basic prerequisite for their industrial application.

Yet even under these conditions, the process can only serve very isolated applications. As described above, hardly any engineering plastics are used without reinforcement or modification, i.e. without being adapted to the respective application. Precipitated white polyamide powders have predominated in powder bed processes for decades. Additives and fibers are incorporated as a blended fiber-powder mixture and can separate again as such. These special powder mixtures require the operator to wear uncomfortable personal protective equipment, from masks to respiratory equipment. In most industrial production processes, the safety department simply forbids solutions involving such materials. Without the automation and complete encapsulation of the entire powder cycle described above, widespread use in the plastics industry will certainly be ruled out.

Fused Filament Fabrication (FFF)

In FFF, a previously precisely manufactured filament is extruded, with components being printed layer by layer, working up from a build platform. Printing on a platform means that support materials have to be co-extruded for complex geometries with openings or undercuts. These then have to be removed as part of the post-processing phase. The extrusion process means that the resolution of the print and hence the precision of the component is limited and rather coarse. Layer structures are visible on the surface. Consequently, the process is particularly suitable for the production of components with simple geometries and individual customized components at high printing speeds, while at the same time meeting low surface quality requirements.

The filament is used to ensure a uniform mass flow at the print head and thus produce a homogeneous print image. On the one hand, filament production is an additional processing step that increases material costs, while, on the other hand, the filament simplifies the process on the printer side, as it eliminates the need for very precise extruder technology. This simplifies the machine technology and makes FFF printers cost-effective and easy to service.

However, a distinction has to be made in the FFF process between printers for use in prototype construction and for industrial 3D printing. Industrially designed FFF printers have heatable build spaces and enable higher printing speeds with the highest possible printing precision. This is used to produce print results with engineering polymers or high-performance plastics that are as reproducible as possible in terms of geometry and effect. Such printers are also equipped with additional sensors for quality assurance and software interfaces for linking upstream and downstream processes in order to connect and control them as part of a process chain.

Photo: High-performance fiber-reinforced materials run on technically simple, cost-effective filament printers

For industrial FFF printing, there is a risk that the advantages of the process – simple and cost-effective process technology – will be lost in the attempt to process high-performance plastics with precision. On the materials side, there is therefore a need to adapt materials for use in FFF in such a way that they can be easily printed without a heated build space and are practically reproducible in a robust process. The use of support materials, which have to be laboriously removed afterwards, should be minimized. This is in fact possible!

The reason for this is that the initial form of the materials is a granulate which is molded into a filament. It is therefore possible to mix in additives and reinforcing materials to produce a compound with properties that can be adjusted over a wide range – whether in terms of rheological, thermal or mechanical properties. It also makes it possible to reproduce the performance of the standard materials described above. This means that the FFF process can be used to print components that have the same mechanical performance as industrial injection molding materials.

The filament brings precision and easy handling to the FFF process. At the same time, however, it limits the possibilities for modifying materials in order to match as many injection molding materials and their properties as possible. Consequently, excessively high concentrations of reinforcing materials (e.g. carbon fibers) or functional additives (e.g. flame-retardant additives) lead to problems during the production of the filament, or the filament becomes brittle and breaks easily during handling inside the printer. In addition, many technical plastics and all high-performance plastics must be dry when processed. Filament spools must be dried and remain dry during the printing process. The filament dryers used are further 3D printing-specific devices that increase the process engineering expenditure. It would therefore be very convenient if it were possible to dispense with a filament and print directly with a granulate. This is precisely why direct extrusion printing or Fused Granulate Fabrication is highly relevant to industry!

Fused Granulate Fabrication (FGF)

In this process, granulates are processed directly via an extruder and components are also printed starting from a build platform. This means that standard peripherals from plastics technology, e.g. pellet dryers, can be used. The effort and costs for filament production are eliminated, but at the same time the precision that the filament enables in FFF is lost.

Today, FGF is therefore predominantly used for the production of large components and therefore rarely complements injection molding as a series process, but instead offers an alternative to deep drawing of components or compression molding and other processes that are used today for the production of large parts. The extruder, which cannot be controlled very precisely, and high throughputs of more than 100 kg per hour mean that FGF is used for generating geometries roughly and further processing steps are required for final shaping and precise contouring, usually milling and possibly polishing.

FGF-compliant design and creation of the final contour by milling (courtesy of Nedcam Solutions B.V.)

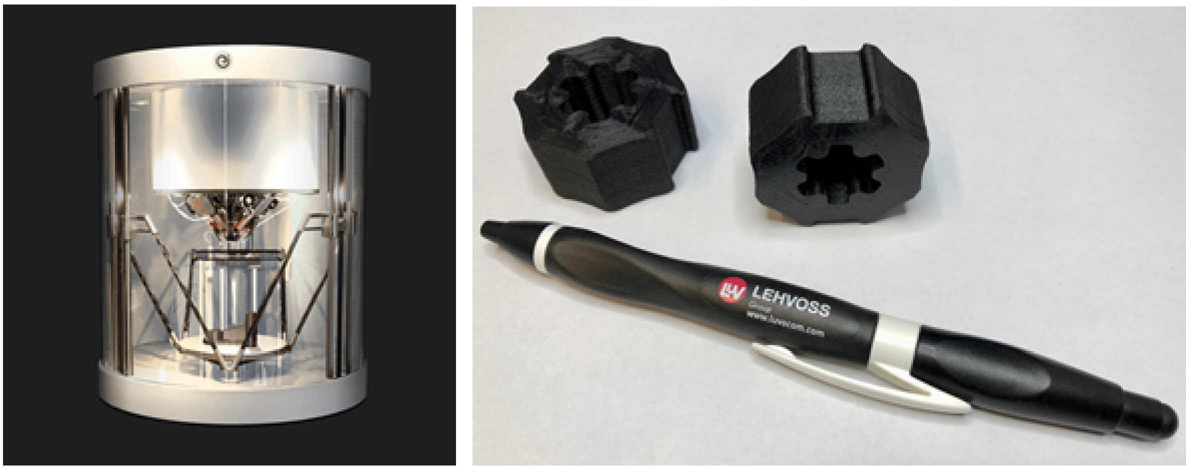
However, direct dosing with an extruder does not just mean extra work on the surface. It is also accompanied by a loss of geometric freedom. With the exception of simple geometries, such as rings for seals, more complex shapes must be designed specifically for FGF. This is because when using large extruders and throughput rates, it is not possible to stop the melt flow for a short time. As a result, more complex molds must be designed in such a way that an uninterrupted pressure can be maintained without interrupting the material flow.

Openings that would be easy to achieve in FFF can only be milled retroactively in FGF. However, large structures are rarely molded in small parts, as standard processes such as deep drawing have similar restrictions, making FGF suitable for a large number of industrial components despite these limitations – often more cost-effectively than the standard process, as the number of parts is seldom large. As the extruder is guided by traverses or robots, it is often possible to change over to milling attachments without having to reclamp the component. This minimizes the additional effort in processing. The loss of material is also low because printing follows the contours closely.

Controlling and guiding the extruder in several axes can be used to improve and constructively utilize the isotropy of mechanical properties when using fiber-reinforced materials. At the same time, limitations imposed by the filament in FFF are eliminated. FGF materials can be highly filled and thus enable components to be produced with very high performance and functionality as required by industrial 3D printing. The process may seem rough and less complex, but the demands on the printing materials are nevertheless high. Printing is often carried out on a piece of wood or similar substrates; the build platform is rarely heated. A build space heater would be almost inconceivable for this size of printer. It is therefore necessary to avoid thermal stresses during the printing process, because they result in distortion. The thermal properties of the plastics have to be adapted accordingly.

Think Big! FGF-printed bridge component in China.

However, machine manufacturers have long been working on FGF printers that have the same dimensions as FFF printers yet achieve the precision and surface quality of today's FFF printers thanks to precisely controlled small extruders that render post-processing of the contour obsolete.

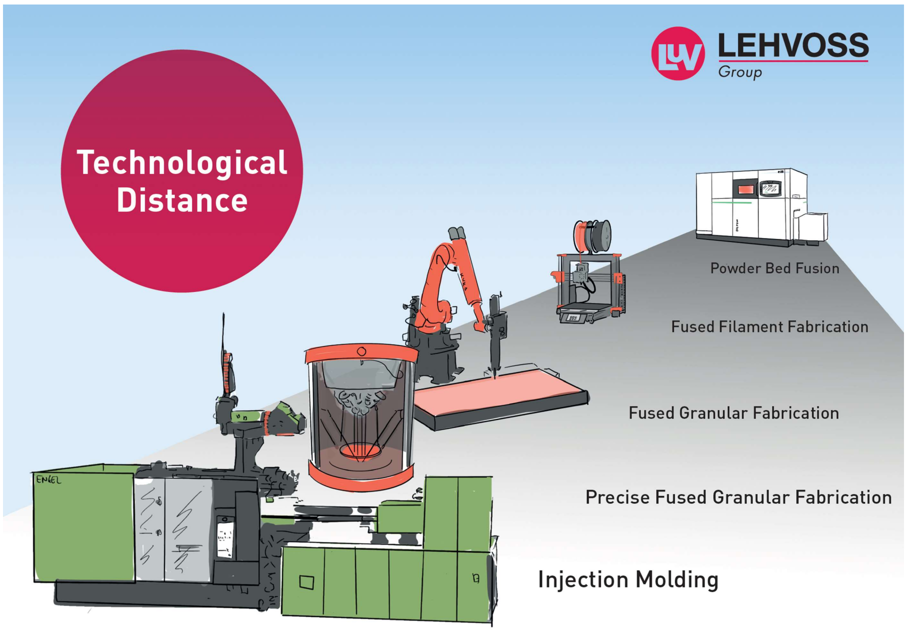


Precise FGF printing: LUVOCOM 3F^{PAHT} 9742 CF printed on Pollin AM Series P-HT (courtesy of Pollen AM Inc.)

This 3D printing technology could therefore be integrated quite easily into the production system of a plastics processor, and the peripheral equipment (e.g. pellet dryer) can also be used. The granulate as a starting material offers the possibility for comprehensive adjustment of the properties and printing performance by compounding, with the aim of achieving injection molding properties for the printed component. Only the geometric freedom of the process needs to be extended. It is therefore easy to predict that multi-axis controlled FGF printers could be the industrial printers of the future and that traditional plastics processors will be able to operate these printers rather than just prototyping service providers or today's 3D printing manufacturers. However, the printing speed of these printers is still slow today in order to guarantee the required precision and surface quality. It raises the question of whether this disadvantage in productivity can be overcome by intelligent control technology. It is currently the filament that combines precision and productivity/speed in FFF printers.

The key facts at a glance:

- Powder bed processes are overrated as the process for the industrial application of the future. They are too complex and have too many restrictions for them to gain industrial significance beyond a few specialist applications.
- FFF technologies are simple and cost-effective. However, they achieve this by using filaments, a form that is still unfamiliar to the plastics processing industry and increases the price of the material.



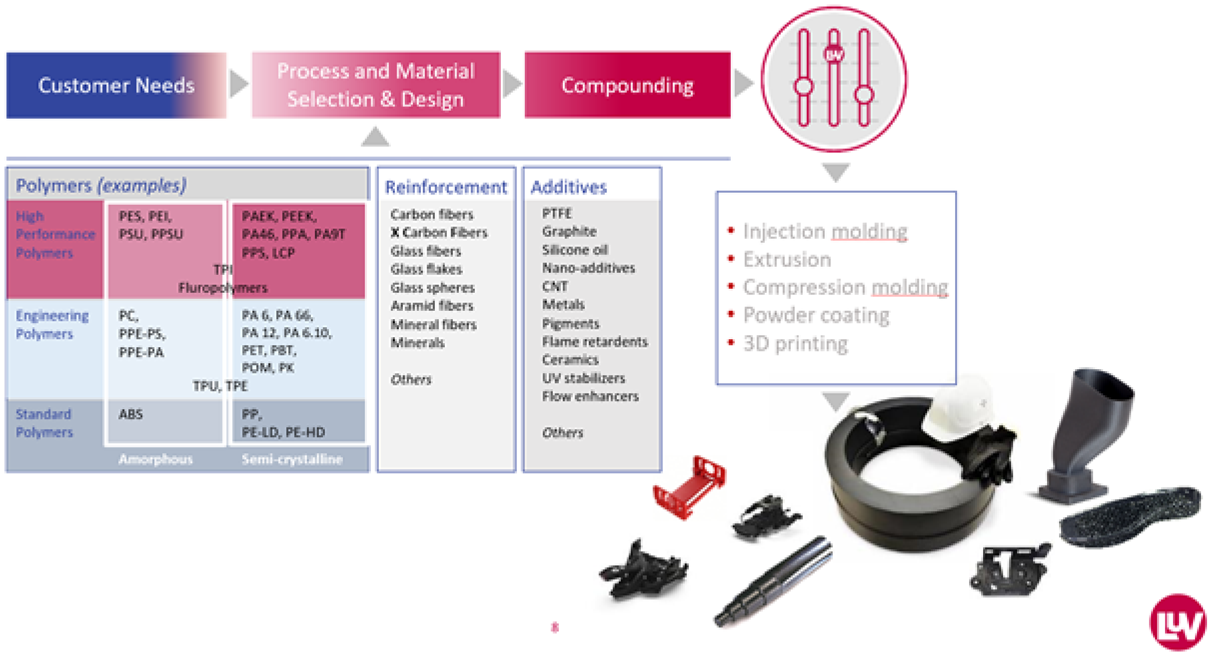
Technological distance, 3D printing is moving closer to the classic plastics industry in terms of technology.

- It is therefore likely that FGF printing could become the industry's preferred technology, as it can be easily integrated into existing peripherals. However, this requires a solution for the current limitation on printing speed.

- Generally speaking, though, it is not individual printers that are of industrial relevance, but rather complete solutions for the production of printed components with the highest possible degree of automation.
- The greater the degree to which 3D printing is able to approach injection molding in technical terms, the more likely it is to be used by the established plastics industry.

Material solutions for industrial 3D printing

LEHVOSS is much more than a normal compounder of plastics. We have been focusing on the development, manufacture and sale of speciality plastics for more than 50 years. This includes all polymers and functionalities beyond the so-called commodities. Our product range includes virtually all engineering and high-performance polymers. They are selected and modified, reinforced or functionalized according to the requirements of the application, the component and the manufacturing process. Whether for injection molding, extrusion, 3D printing or other technologies - we are “open to technology” when it comes to speciality plastics.



Tailor-made speciality plastics for various processing methods

This technological openness requires a high level of complexity in production, but also in laboratory equipment, for product development and for quality assurance. And this is precisely where the difference to other compounders lies. Our products, especially those that combine various functions, have many constituents in the formulation. Many dosing devices are required. This has an influence on the design of the extruder, the respective screw design, the cooling and cutting units, upstream and downstream mixers and dryers and much more besides. We therefore have a large machine park, full of individual special solutions. Our production lines in Germany, the USA and China are equipped according to the task involved. LEHVOSS markets plastics solutions around the world.

Insights into production: Complex technologies for compounding specialities at LEHVOSS

Our material portfolio for 3D printing includes

LUVOCOM® 3F: Pellets for filament and direct extrusion
LUVOCOM® 3F filaments: quality-assured filaments for industrial production
LUVOSINT®: Plastic powders for laser sintering

The common feature uniting all products is that they have been specially developed for 3D printing and the respective process. This begins with the selection of suitable base polymers and other raw materials. Examples include special polymer types with low moisture absorption that also have suitable thermal properties. Reinforcing materials are selected according to the requirements such as strength and surface characteristics of the printed components. These include, for example, special carbon fibers that can follow the movement of the print head in a less rigid manner. They extend to nanoscale additives, some of which have a positive influence on the nucleation behavior and thus inhibit the tendency to warp. Not least among these materials are special pigments that can withstand the short-term high flash temperatures in laser sintering without a color shift. All cases call for the choreography of a complex interplay of different effects, and we can draw on our 50 years of experience in the production of speciality compounds to achieve this in the still young 3D printing business.

Component made from LUVOCOM 3F PET CF

These material solutions are diverse and will not be presented individually here. They include FFF materials with integrated thermal management, which obviate the need for heated build spaces. Other examples are high-temperature materials such as PPS, which can be processed on inexpensive standard printers, colored components as assembly aids, even though they are carbon fiber-reinforced, through to laser sintering powders, which can be completely reused as non-printed build space powders and thus drastically reduce material consumption. Simply contact us if you would like to find out more about our materials portfolio!

What is the next step in industrial 3D printing?

As described above, two distinct factors will determine whether 3D printing establishes itself as a standard process in the plastics industry. They are:

- Price
- Quality

Today, both factors are fulfilled individually – but unfortunately not both together! And this is precisely the premise on which the further development of printing with plastics has to be based.

Quality and price are influenced by a large number of parameters. Nevertheless, the levers for optimizing them are easy to identify. Below are a number of recommended actions for stakeholders in the 3D printing industry and a description of the extent to which LEHVOSS can and will contribute as a material supplier for 3D printing materials.

Industrial 3D printing must become cheaper!

It is laser sintering machines, in particular, with their high investment costs which prevent them from being used more widely in industry. The established manufacturers rarely offer machines for less than €200,000. Added to this are the high costs for servicing and spare parts. At the same time, typical prototype manufacturers do not amortize these machines over 10 years, but instead aim to achieve this within one year. Nevertheless, profit contributions of around 50% are still the rule today. The calculated part costs are correspondingly high, which means that large quantities are not economically feasible for series production.

There is currently a recognizable trend towards larger SLS printers. This was probably triggered by the preceding trend towards metal powder printing (SLM). Dual-laser systems with build spaces having sides of more than 1000 mm in length will be followed by even larger machines with four lasers. Increased productivity then entails even higher investment costs. This seems to be the wrong way!

What is needed are small, inexpensive machines priced between €20,000 and €30,000. At the same time, they must have a sufficiently large build platform to enable them to produce the majority of industrially relevant parts. Very large part dimensions are the exception. A build platform size of approx. 250 x 250 mm is able to cover 95% of the geometries. Despite the favorable price, the core components must be of a high quality. This applies to the laser and the scanner. The entire system must have a simple design so that users can themselves maintain and repair the printer independently, thus eliminating expensive servicing charges.

The requirement for the future of SLS can be summarized under the keyword "affordable SLS".

FFF technologies have shown the way: very low-cost printers with acceptable quality have led to mass distribution down to the consumer level. The high number of users has enabled knowledge of the processing of various materials, as well as the repair and modification of the printers to become widespread. However, an open-source approach to hardware and software has been particularly responsible for this. This market pressure is currently also leading to the more technically complex industrial FFF printers, which were only available as closed systems in the past, becoming cheaper and offering the user more freedom in the choice of materials and the setting of important parameters. This is important so that users can develop their own print quality and set themselves apart from the average market level. It is to be hoped that affordable but powerful FGF printers will soon come onto the market. However, it can be assumed that these machines – whether SLS or FGF – will be supplied by Chinese players. This is because only Chinese companies have mastered the interplay between price and performance, as can currently be seen with FFF printers.

LEHVOSS offers the industry a further option to reduce machine costs: the use of materials perfectly developed for the FFF and FGF processes obviates the need for very complex machine technology. Favorably priced, high-speed printers without a heated build space produce consistently high component quality with LUVOCOM 3F materials. Currently, this means investment costs of less than €2,000.00 per printer and the use of high-performance materials such as PPS CF.

Automated all-in-one solutions for a “cents-per-component” business

Yet, here too, even the most productive printer is unable to exploit its benefits to the full if manual operation is necessary for changing spools, feeding filaments, removing components or even for sorting out small components from a huge powder bed. A high level of automation is necessary to move from a “craft workshop” to a large-volume “cents-per-part” business approach, as is customary in the plastics industry.

And once again it is FFF technology that provides the basis for interesting automation solutions. Fully automated farms form very productive and at the same time flexible, digital production sites. The key is the simplicity and compactness of individual printers (see above) along with the uniformity that this allows and the opportunity to interconnect with larger units. Only in this way will 3D printing fully exploit its benefits as a digital procedure and present a manageable supplement to the injection molding process in terms of productivity and price.

It is to be hoped that the development of precise FGF printers will follow that of FFF printers because the use of plastic pellets would make their automation even easier to achieve. And once again, it is powder bed procedures such as laser sintering that bring up the rear in terms of automation. Only simplification of the technology involving small compact, uniform equipment would offer the opportunity to implement a farm approach for powder bed procedures too. And the combination of powder-based and FFF/FGF printers in one farm would increase the flexibility by a further level; with hybrid farms it would then be possible to achieve optimal control of the printing processes according to the geometry of the part.

The uniformity of printers also plays an important role in the qualification of processes. Powder bed printers, in particular (even those from the same producer), differ so greatly from one another that every printer requires time-consuming and cost-intensive individual qualification testing. Having farm-capable printers eliminates this input. Using an example of a high-temperature polyamide in combination with a technically simple printer manufactured by the company Ultimaker, LEHVOSS achieved certification from TÜV-Süd with narrow guaranteed tolerances in component performance. This was the proof that farm-capable printers with specifically developed 3D printer materials are able to produce parts with guaranteed high qualities. One certificate replaces the individual qualification.


200-printer farm, China, managed by two operators only (courtesy of Raise3D)

The qualification of 3D printed parts must become more straightforward.

Injection molding will remain the procedure for mass production. 3D printing supports this form of production at various points in a product cycle; at the beginning during the prototype phase, in the fabrication of special parts (e.g. for adaptation to country-specific legal requirements) and in the after-sales market for the production of spare parts. However, the elaborate post-qualification and geometric adaptation of a spare part in the after-sales phase is time-consuming and simply too late. Both materials, for 3D printing and injection molding, require joint qualification at the start of product life, and of course in combination with the respective 3D printing process. And in this process, too, technologically simple, uniform printers have advantages. After all, it is necessary to guarantee that the respective process will still exist in more than ten years' time (the beginning of after-sales). Very individual and complex processes would not have the confidence of industry to do this. Experience shows that the usually incomplete documentation will present the most problems in the qualification of Asian printer technology. This will be a phase in which European or US machine producers could make the most of their advantages.

Another important prerequisite for this would be the existence of industrially relevant materials. Materials for 3D printing and injection molding requiring qualification differ in their formulation but have to exhibit a very similar performance so that the geometry designed for injection molding can be printed without alteration. The very similar data sheets are the key to changing flexibly between injection molding and 3D printing – depending on which process is the most cost-effective for the number of parts ordered. This brings us to the final point.

Only reinforced polymers are relevant for industrial printing.

Industrially relevant materials are needed for 3D printing. Printed components must achieve a property profile that corresponds to that of the injection molding materials known as commodity plastics. These include glass-filled polypropylenes, polyamides reinforced with glass and carbon fiber such as PA6, PA66 or PPS.

The respective 3D printing processes impose different restrictions on the formulation of their specific materials. And here too, the closer the respective printing process is to injection molding in terms of technology, the fewer restrictions there will be, and the greater will be the similarity in the materials that can be constructed. For this reason, (precise) direct extrusion, as described above, offers the best conditions to enable future twin materials similar to those used in injection molding without a great deal of investment. Today, FFF processes also make it possible to match the property profile of standard fiber-reinforced injection molding materials by selecting a high-performance polymer as the basis. One example of this is LUVOCOM 3F PPS CF 9938 BK, which is currently establishing itself as a standard material for demanding automotive applications and as such is qualified as an equivalent for PA6 GF30 and similar injection molding grades.

Powder bed processes, such as SLS, are technologically far removed from injection molding. Reinforcing a powder is technologically demanding. The simple mixing of longer fibers into the fine powder is the standard today but is not accepted in industrial supply companies due to high safety standards. The fibers must be incorporated into the compound. But of course, it is not expedient to then grind fiber-reinforced granules into a fine powder - and process the fibers at the same time. Instead, new particle-generating processes are required if powder bed processes are to keep pace with the industrial future of 3D printing.

Our expertise in materials

Further information available at **www.luvocom.com**

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