W H I T E P A P E R

Virtual Thermoplastics Particle Manufacturing

Mainstreaming Additive Manufacturing

New thermoplastics additive manufacturing technology meets the real needs of industry and research

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INTRODUCTION

Industrial 3D printing (also known as Additive Manufacturing, or AM) shows tremendous promise for improvements over traditional manufacturing methods in a number of applications:

- Faster prototyping.
- Reduced waste of materials.
- Lower production costs, particularly on short run or one-off items.
- Development and use of important new materials.
- Creating objects of complex geometry, including those that cannot be produced by traditional manufacturing methods.
- Improved speed of production.
- And a number of other possibilities.

In the field of scientific research, 3D printing technology promises to increase the speed and scale of projects dramatically while reducing costs and material waste.

To date, however, industrial 3D printing has not fully delivered on these promises. In industry and in research there has been limited adoption of AM and it has remained a somewhat niche technology.[1]

The present white paper explains the root causes of the limited adoption of one particular type of potentially very valuable industrial 3D printing – thermoplastics extrusion.

It introduces an emerging, breakthrough technology in this field – Versatile Thermoplastics Particle Manufacturing (VTPM) – and explains it in detail. This new technology overcomes most of the limitations of existing thermoplastics extrusion AM and opens the door for this type of additive manufacturing to become a mainstream player in many industries, as well as in research.

This is not technology of the future. It exists and is available for use right now, tested and proven.

[1] "The mainstreaming of additive manufacturing" by Jörg Bromberger, Julian Lig, and Ana Maria Miranda for McKinsey & Company 2022.

WHY THE SLOW ADOPTION OF ADDITIVE MANUFACTURING TECHNOLOGY?

Despite the fact that 3D printing technology has been available since the mid 1980s, the technology has yet to see widespread use in the production line of manufacturers around the world.

"… a recent study found that 63 percent of enterprise AM users deploy the technology for prototyping, while only 21 percent use AM for items that cannot be made with any other manufacturing technology. That is, of course, if AM is being used at all. In some cases, engineers only use 3D printers to test out idle curiosities; in others, the AM machines are simply left in the corner to collect dust.

"These numbers clearly indicate that there is still something preventing manufacturers from integrating AM technologies more generally into their manufacturing process. It shows that we still have challenges that must be addressed before AM achieves widespread adoption, particularly technical, IT, design, capability and financial challenges."[2]

Meeting the needs of industrial production

For any new technology to be widely and rapidly adopted by industry, it must answer the challenges that industry has set itself. What are those challenges? And what are the objectives of industrial production?

For the purposes of this explanation, the basic types of industrial production have been classified as follows:

1. Making solid objects of a specific shape (the lion's share of industrial production).
2. Liquid and fluid products.
3. Gaseous products.
4. Electronics can be treated as a separate class.

In this white paper, we are interested in the first class above: making solid objects or parts which are then assembled into larger units, which in turn are combined into final products.

Manufacture of solid objects or parts can be classed by the following criteria:

1. Types of materials (metals, plastics, etc.).
2. Method of manufacture (casting, forming, etc.).
3. Ways of changing physical and chemical properties both during and after fabrication. Such changes can be reversible (e.g. heating glass to change its shape) or irreversible (e.g. firing, photo-polymer reactions, etc.).

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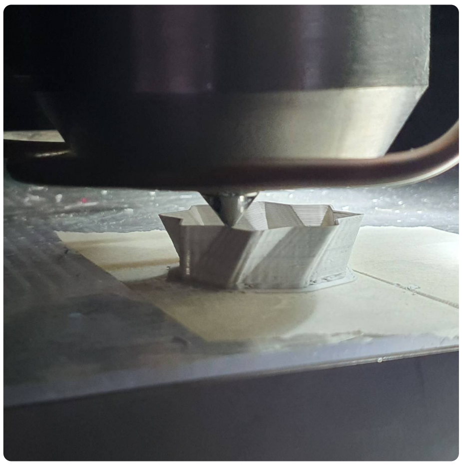
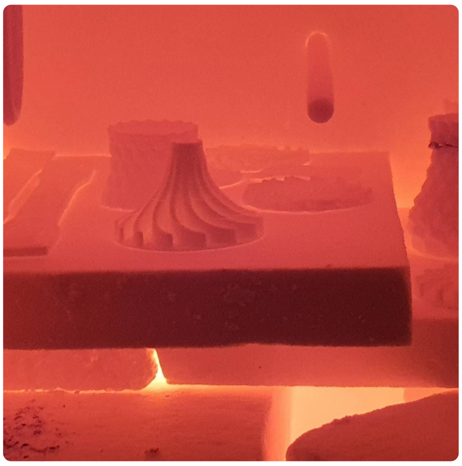
[2] "Challenges of Additive Manufacturing – Why companies don't use Additive Manufacturing in serial production" Deloitte, 2019.

One of the main technical objectives of manufacture is to make objects or parts of the required geometric shape that have the necessary properties. This requires working with a wide selection of materials to obtain the required shape, and also being able to change the properties of materials during and after manufacture, using physical or chemical processes.

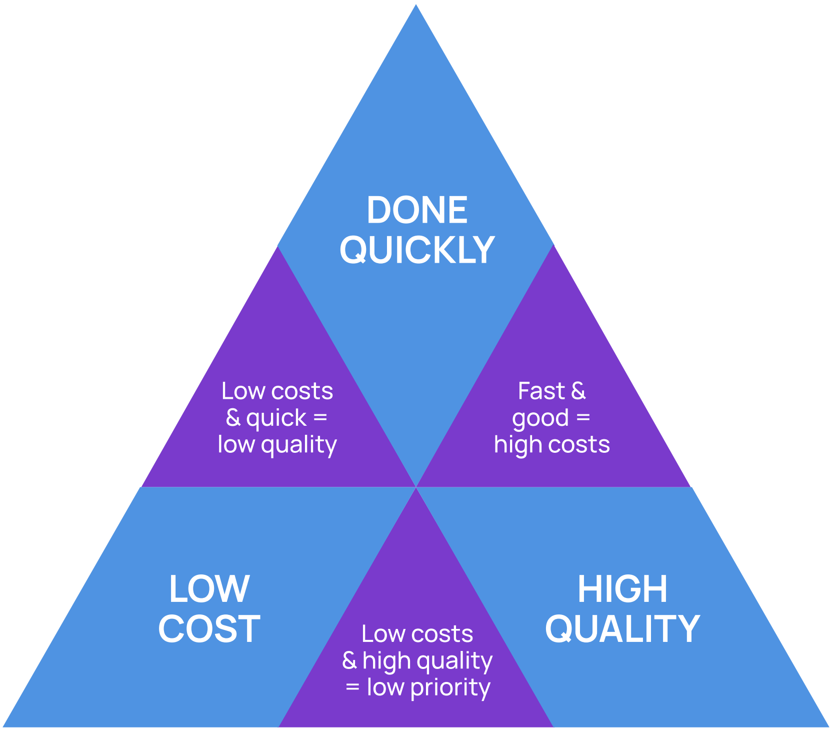
A simple example would be first forming clay into the shape of a cup, and then firing it in a kiln to achieve the final product with the desired shape and properties.

To perform the task well it is necessary to be able to choose from the widest range of materials and to be able to create the desired, geometrically accurate shape.





The economic aspects of production – price, quality and speed – must also be taken into consideration:



THE MAIN METHODS OF MANUFACTURE

In order to produce objects and parts of the required shape, industry uses four main methods.

Casting

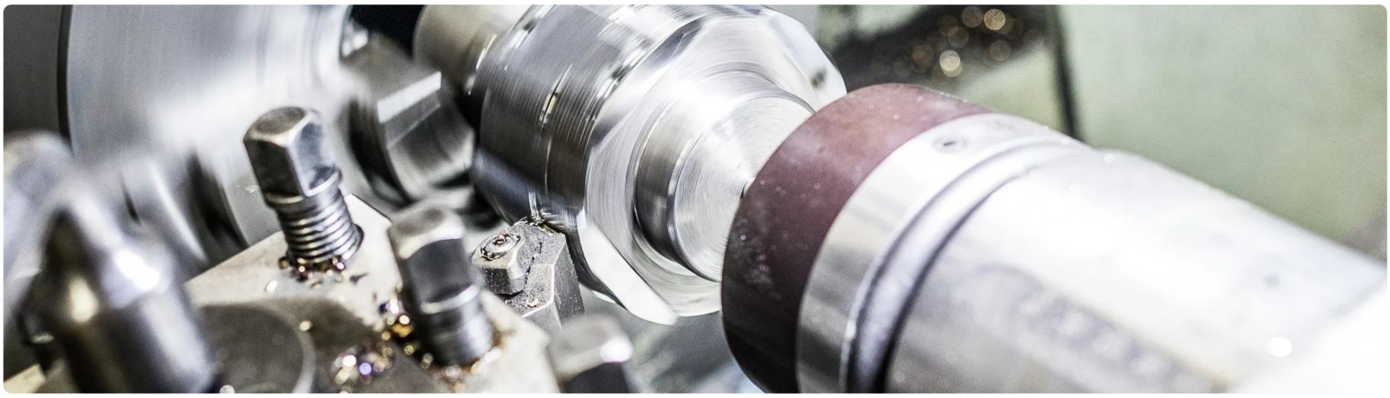
Creating an end-product of predefined shape by pouring liquid or molten material into a mold and allowing it to solidify.

Forming

Creating an end product by subjecting a workpiece to mechanical pressure until the desired shape is achieved.

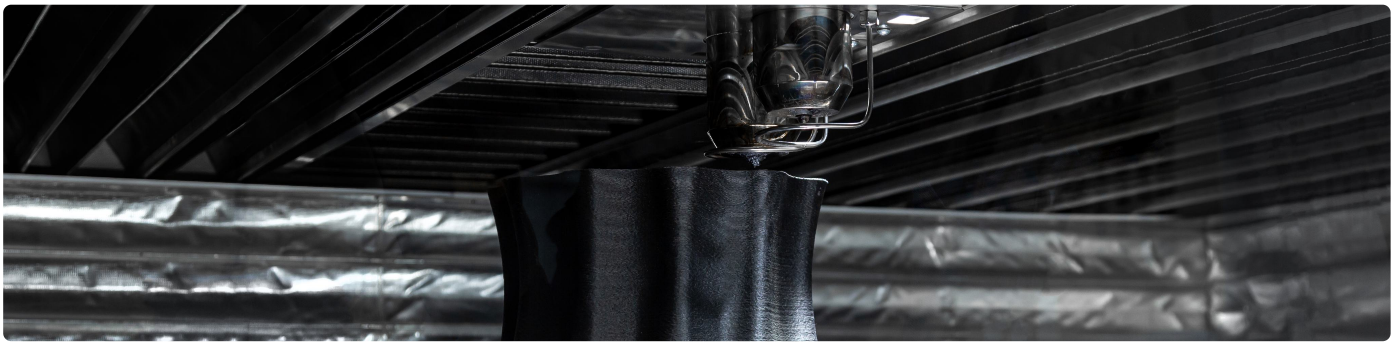
Subtractive machining

Creating an end product by removing materials from a larger block.



ADDITIVE MANUFACTURING (AM)

Automated addition of material layer by layer into a build space until the end product is achieved. A new manufacturing method introduced in 1986 that is actively being developed but still has limitations.



The appropriate method or combination of methods is chosen, depending on the job at hand.

Each method of obtaining the desired shape and properties has its own advantages and disadvantages. Therefore, one has to choose the appropriate method for a particular task.

Manufacturers have some challenges that traditional manufacturing methods do not address well, and which could potentially be solved to their advantage by the right thermoplastics-based AM technology:

- Rapid production of prototypes allowing for numerous, frequent design corrections and changes to perfect a product – trying to do this with traditional methods can be very slow and expensive, delaying time to market and increasing the cost of a new product prohibitively.
- Creating complex objects such as spare parts or customized products in small lots or one-of-a-kind production quickly, on-demand and relatively inexpensively – again, traditional methods can be comparatively slow and expensive.
- Making molds and tooling – this is something that thermoplastics-based AM can do much more cheaply and rapidly than traditional manufacturing methods.
- Researching new materials or the best material for creating certain parts, improving strength, weight, temperature resistance and other properties – thermoplastics-based AM could lend itself perfectly to this, particularly where many tests with a wide range of settings are required.
- The technology extends to other industries than manufacturing, such as the theater or art and design where certain art objects or props can be made more easily and cheaply with better quality by 3D printing than by any other method.

These are just a few examples of real-world tasks that industry needs to accomplish which industrial 3D printing promises to help achieve. But the successful outcome depends on the right thermoplastics-based industrial 3D printing technology, properly aligned to the purposes of industry.

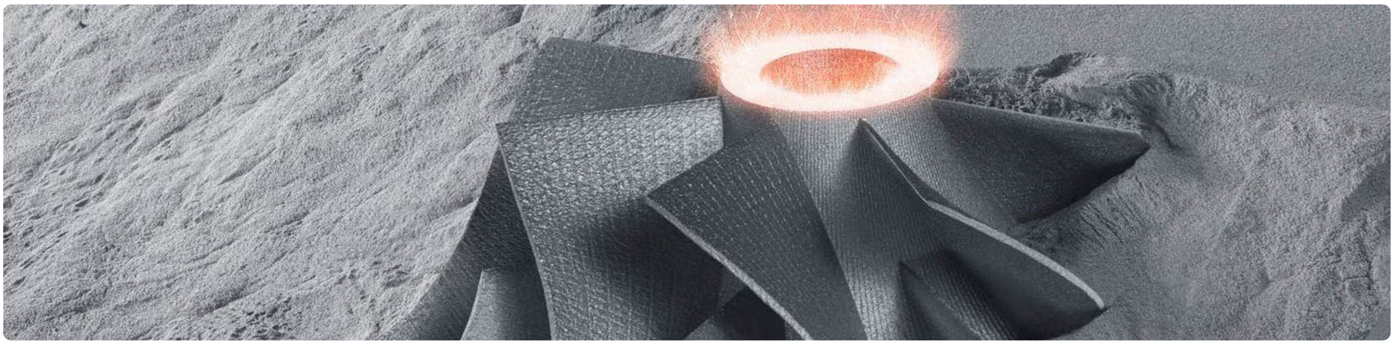
The fact that additive manufacturing is not used more actively in industry suggests that it has not been able to meet the goals of industry, technically and economically. The question of how to use additive technologies to produce objects of the required shape with sufficient precision, with the required properties (which implies working with the widest range of materials), with high quality, fast enough and with reduced costs has not previously been considered in this way.

If it had been examined in this light, the new technology discussed in this white paper would have come into existence long ago.

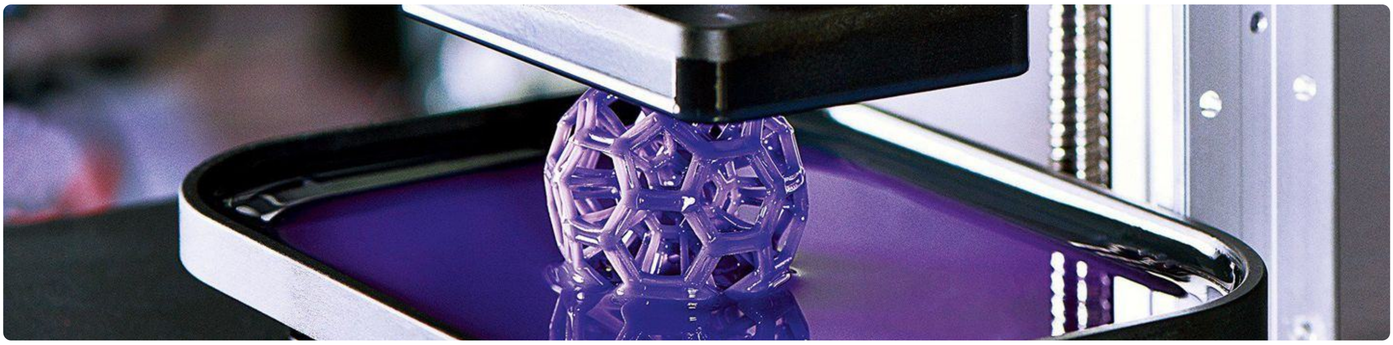
A closer look at additive manufacturing methods

There are many additive manufacturing methods. These are the main ones used in industry:

Powder additive manufacturing – creating an end product by adding material in powder form to the build platform and then bonding, fusing or sealing it.



Photopolymer additive manufacturing – creating an object by exposing layers of light-activated resins to light of a certain spectrum so that they cure from liquid to solid.



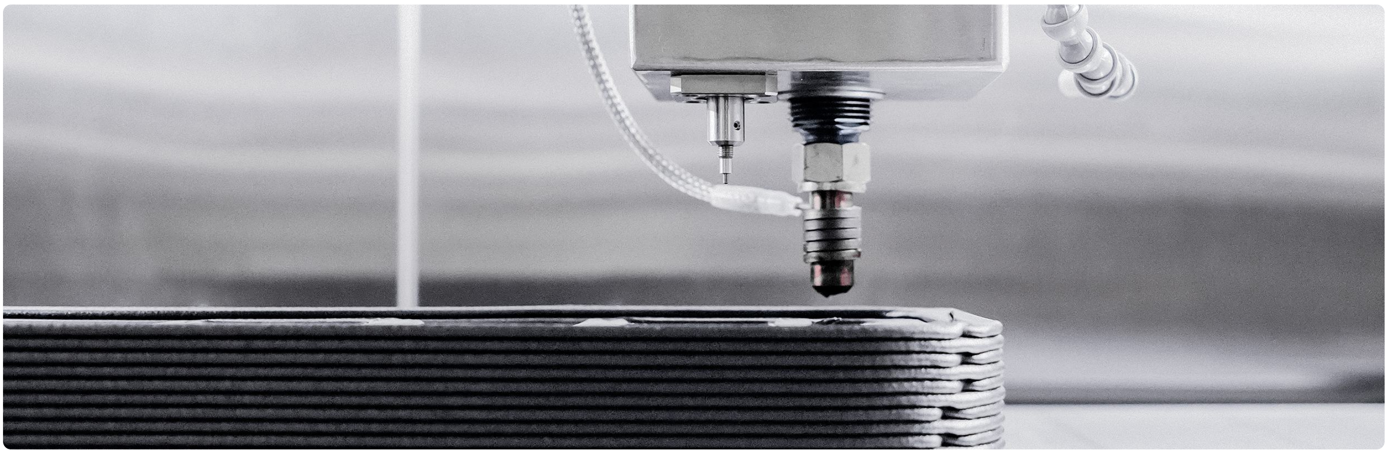
In this white paper we are concentrating on thermoplastic extrusion additive manufacturing rather than the other methods. It shows the most potential for widespread use in industry but has been held back by the limitations of the existing technologies. This is the type of additive manufacturing for which a new technology is being presented in this white paper.

There have been two main methods of polymer extrusion additive manufacturing. We are introducing a third.

EXISTING EXTRUSION ADDITIVE MANUFACTURING METHODS

Fused Deposition Modeling (FDM)

Additive technology that involves extrusion of melted thermoplastic-based materials supplied in the form of a thread or a rod (a filament).



Technical aspects:

- Limited range of feedstock.
- Open-source AM systems in the low-price segment, and proprietary systems in the engineering segment.
- Medium-quality end products (inferior to that of subtractive technologies).
- Post-processing required.
- May need innovations in product development.
- Highly complex geometries possible.

Economic factors:

- Medium-cost feedstocks.
- Average production time compared to other additive technologies.
- Cost-efficient for one-off or medium lot production.

Summary:

- Inefficient for large lots of simple parts.
- Medium surface quality.
- Indispensable for highly complex or medium-size thermoplastic objects.
- May exhibit pronounced anisotropy[3]

Fused Granulate Fabrication (FGF, or pellet-based additive manufacturing)

Additive manufacturing technology that involves extruding melted thermoplastic-based material supplied in the form of granules or pellets which are then deposited or printed layer by layer.

Technical aspects:

- Limited range of feedstocks.
- Open-source AM systems.
- Lower quality end products (inferior to that of FDM).
- Post-processing required.
- May need innovations in product development.
- Medium complex geometries.

[3] Anisotropy refers to the internal structure of a material and characterizes the change in its physical properties depending on the direction. For example, wood is anisotropic - it is easier to split a piece of wood along the fibers than against the fibers. That is, the same force applied in different directions gives a different effect. This also applies to other physical properties such as thermal and electrical conductivity, elasticity, hardness, etc. 3D printed objects typically have anisotropy. Therefore, when planning three-dimensional printing, it is necessary to take into account the direction of loads that the finished product will experience.

Economic factors:

- Low cost of feedstocks.
- High speed of production compared to other additive technologies due to faster throughput.
- Cost-efficient for one-off or medium lot production.

Summary:

- Impractical for large lots of simple parts.
- Surface quality the lowest of AM technologies.
- Cost-efficient for manufacturing billets to be subsequently post-processed.

Why the existing thermoplastics AM technology fails to meet the requirements of industry

The words “limited” and “limitations” are frequently used with regard to the thermoplastic extrusion 3D printing technologies available today. How are FDM and FGF technologies limited? What are the limitations that underlie the lack of widespread adoption?

Their limitations include:

- Limited range of materials that can be printed
- Problems with quality of the finished objects
- Size limitations (most 3D printers have a relatively small print envelope)
- High costs of materials
- Lack of the necessary support, training, advice and technical assistance needed to use the AM system.

Any one of these factors greatly reduces the value of thermoplastic extrusion technology to industry. For example, if a company wants to take advantage of 3D printing for rapid prototyping but needs to make fairly large objects, the restricted print envelope size is a barrier. Or perhaps another company has a need for short run production of a part that requires a specific composite so as to obtain the right properties, but finds that the 3D printer they are using or want to use cannot attain the required temperature to print that material. They have to resort to some other method of manufacturing and the potential benefits that this system could offer are lost.

Sometimes to try to get around these limitations two or three separate 3D printers are needed to complete a particular job. This is not economical or practical. And even then, the battery of printers may not be able to produce the desired result.

In research, it is vital to be able to vary all the printing parameters considerably so as to test different combinations. If the 3D printer in use is not capable of these parameters, the research cannot be done.

Both of the existing AM technologies available, FDM and FGF have their particular strengths but also have their weaknesses as explained above.

The various limitations, individually or in combination, cast doubt in the minds of manufacturers and researchers about the value of thermoplastics additive manufacturing. Is it needed? How much is it needed?

Surmounting the limitations – what are the requirements?

To work at an industrial level and meet the major challenges of manufacturing and materials research that AM is capable of solving, extruded thermoplastics AM technology needs to meet certain requirements listed below.

It was to meet these requirements that the new Versatile Thermoplastics Particle Manufacturing technology was developed.

These requirements can be summarized as follows:

1. The ability to print from a very wide range of materials.

These include conventional polymers, high crystalline and super engineering plastics (super structural and engineering polymers) which have very high tensile strengths, excellent heat and chemical resistance, and processability.

They also include plastic-filled composites with a polymer base and a variety of additives to achieve specific properties in the printed object. The additives include fiberglass, carbon fiber, ceramic and mineral particles, wood and cellulose particles, metal powders and others.

There is another category of materials that use polymer binders as in the case of Metal Extrusion Molding (MEM) and Ceramic Extrusion Molding (CEM)[4]. Here the metal or ceramic in powder form is mixed with a polymer thermoplastic binder and printed with an extrusion thermoplastics-based printer, allowing for very complex, strong shapes.

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[4] Terms introduced by Aleksandr Iugov and Eldar Urmancheev in 2021 (DICTIONARY OF 3D TERMS, www.3DEencyclopedia.com/glossary).

Once printed, the polymer binder is removed and the object is baked in an oven to obtain the finished product.


A truly valuable thermoplastics-based extrusion AM system needs to be able to print all of these materials and more. From a research point of view, the system should be able to be tested with new materials not yet used in 3D printing.

2. **The creation of large or small geometrically complex objects with relatively high speed and precision.**

The technology needs to be capable of creating geometrically complex objects of sufficiently large size with high accuracy.

As we have discussed, many of the traditional methods of manufacturing are unable to create geometrically highly complex objects or, if it is possible, it is prohibitively expensive, labor-intensive and time-consuming. AM shines in this area. But to be of value to many industries, the technology needs to be able to make quite large objects of complex geometry, rapidly and with precision. It is not enough to be able to create small objects. This can lead to the situation where in order to make a complex part of significant size, several smaller objects must be made and then joined together. This is not efficient or practical and can reduce the quality of the finished object.

If the object is not precisely made, it again may be of little value to the industry it is intended to be used by. The aerospace industry, for example, where printing large, complex parts of light, strong material could be of great value, would have no use for such parts if they were not printed with precision.



3. High quality of the final product.

If a manufacturer is going to embrace thermoplastics additive manufacturing as a new technology to add to the production line, the final products achieved must be of sufficiently good quality to meet his requirements. This means that the quality needs to be comparable to what he has been able to achieve with traditional manufacturing methods. Or, if he is introducing AM to create objects that were not previously possible, the products must match or be better than the other objects being created and assembled into final products.

This is not just surface quality. It includes other properties such as isotropy (uniform properties along different axes, such as equal tensile strength in the horizontal axis and the vertical axis). The printed object needs to meet all the requirements of strength, weight, heat, chemical resistance and other properties demanded by the manufacturer.

It is not enough to meet just one or even two of the above requirements. In order to be of real value to industry, the thermoplastics AM technology and system needs to meet all three. And these three major requirements must all fit within the manufacturer's or the researcher's parameters for price, quality and speed.

Neither FDM nor FGF meet the above three requirements. This is why there is frequent reference to the limitations of thermoplastic extrusion AM technology. Each method has limitations which prevent them from being the promised solutions for industry's problems.

Is this technology feasible?

Can a system of thermoplastics-based additive manufacturing be designed, engineered and built that meets all three requirements within acceptable parameters of price, quality and speed?

Yes. In fact, such a system has been developed, designed and built and exists in serial product form today, available to industrialists to incorporate into the production line, and for researchers to greatly expand their research capabilities for 3D printing and new materials.

This new technology is Versatile Thermoplastics Particle Manufacturing™ (VTPM™) described in detail below.

VERSATILE THERMOPLASTICS PARTICLE MANUFACTURING (VTPM)

VTPM as it is now, began in the minds of two highly successful inventors, entrepreneurs and investors around 2017. They formed a company for developing and exporting innovative technologies that would be beneficial to industry and society, Advanced Engineering Intellectual Property® (AEIP®). They saw the potential of thermoplastic extrusion AM technology. They also saw the limitations of existing technology and realized why these limitations existed.

Working with an international team of engineers hired specially for the job, they systematically set about resolving the limitations of existing thermoplastic extrusion AM technology one by one, so that the new technology and business model they developed would overcome all these obstacles and put thermoplastic additive manufacturing firmly in the mainstream of industry and research, a valuable solution to real-world challenges faced by industrialists and researchers.

The development of VTPM has been carried out in stealth mode. This was mainly to protect the intellectual property until the technology and related equipment could be evolved successfully to the stage of serial production, which has now been achieved. This was made possible by the fact that the entire project was funded in advance through the AE Family Office.

Today, VTPM technology meets all the criteria laid out above for a versatile and valuable thermoplastics-based extrusion additive manufacturing system.

How is this accomplished?

1. A requirement of VTPM is to print from the widest range of materials.

This is made possible by:

- The printer's ability to extrude pellets (avoiding the limitations of filament-based extrusion where a narrower range of materials is available).
- Extruder temperature (the wide range of temperatures which can be set, makes it possible to use a broad selection of thermoplastic-based material).
- A universal extruder which can be replaced with a special extruder when needed. An enormous amount of research and development has gone into creating the VTPM extruders so as to be able to print from the widest possible range of materials.
- The active, heated chamber[5] makes it possible to create the necessary conditions in the printing area for printing many different materials.

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[5] Active heated chamber - a thermostated print zone space that utilizes heating elements to provide the required air temperature in the work space. It is used to reduce the rate of cooling of the printed layers, which provides better quality of material penetration of layers into each other and prevents warping of the printed product. Active thermal chambers are typically used in industrial 3D printers where precision is important and where high temperature engineering polymers are involved.

Filament printers (FDM) have the ability to print precisely and produce products of relatively good quality. However, their usefulness is limited in part by the fact that they require material in filament form to extrude and print. The range of materials available in filament form is not very extensive. The cost is higher than for the same material in granular or pellet form simply because the material has to be made into filaments, a costly process. Further limitations surround the fact that proprietary 3D printers may require proprietary filament in order to work. A filament spool is of a set length and when the filament comes to an end, the printing stops even if it's not complete leaving, a defect at the point where it stops.

FGF is capable of relatively high throughput. However, FGF, for a number of reasons, creates lower quality objects - the quality and accuracy of FDM printing is significantly higher than that of FGF printing.

VTPM has incorporated the strengths of both these systems and eliminated the weaknesses of each, and extended the technology further to create an entirely new level of thermoplastics AM. This is achieved by a number of factors including multiple extruders, interchangeable extruder head, wide range of temperature of the extruder, and an active heated chamber. These factors greatly expand the range of settings and parameters possible, which in turn allows for the use of many different thermoplastics and composites while maintaining high speeds of printing, good quality, and low cost of materials.

2. A second requirement of VTPM is to create large or small geometrically complex objects, working with a wide range of speeds and sufficient accuracy.

Large or small object sizes are possible due to the large print area available.

Geometric accuracy is ensured by:

- Accurate positioning of the print head(s).
- Precise dosing of the materials.
- Proper selection of melting and ambient temperatures.
- Multiple print heads to create support elements that can easily be removed after printing, if necessary. This also allows for printing of two different materials at the same time or printing the same material in two resolutions (for example, a small nozzle for precise, detailed parts and a wider one to fill a larger area).
- The combination of a large print area and high precision in the production of the product.

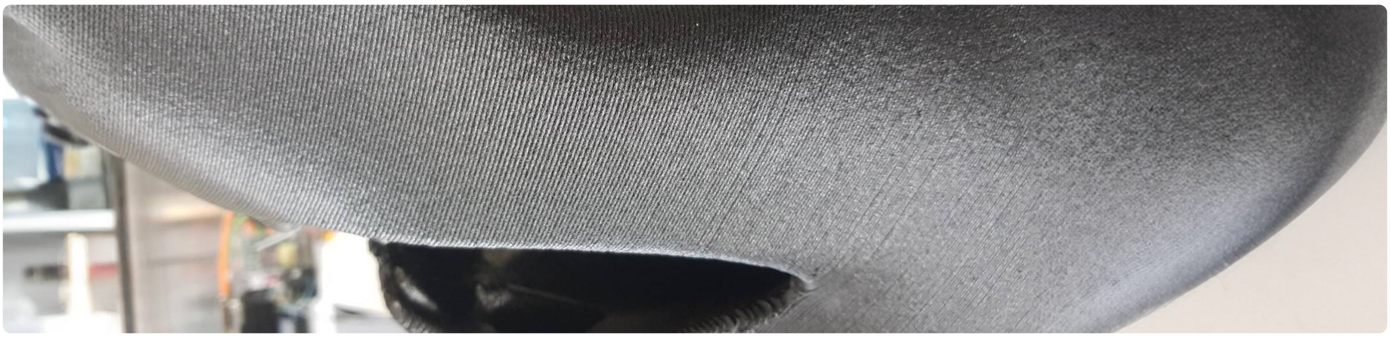
It is important for industrial uses of thermoplastics AM that the system be able to print small or large objects of complex geometry without the loss of quality, precision or speed. VTPM was designed to meet these requirements and delivers all of this.

3. VTPM is capable of high quality of the final product

Quality is ensured by the following features and parameters:

- The wide temperature range of the extruder.
- The necessary conditions required in the thermal chamber and directly around the nozzle(s) for the specific material being used..
- Extruder output rate.
- Potentially high print speeds and acceleration of the print head while maintaining positioning accuracy.
- Wide-range control of finish quality of the printed parts.

As a result, the structure of parts created using VTPM technology comes the closest to those made by conventional methods, while maintaining all the advantages inherent in additive manufacturing methods.



Key features of VTPM

To summarize, the VTPM requirements for additive manufacturing systems (3D printing systems) are as follows:

- Ability to work with pellets (ordinary petrochemical products) and recycled thermoplastic materials.
- Extruder temperature up to 500°C in order to melt all existing thermoplastics.
- A universal extruder which can be exchanged for a special extruder when needed.
- Interchangeable nozzles of different sizes available.
- Precise dosing of materials.
- Controllable thermal chamber with a wide range of parameters, permitting ambient temperatures of over 150°C to be maintained.
- Kinematic capabilities of simultaneously providing high geometric positioning accuracy, high travel speeds and rapid print head acceleration.
- Ability to adjust surface quality widely.
- Multiple extruders capable of printing with different materials and with different sized nozzles on each individual print layer.
- Relatively large build envelope (for example the internal measurements of the existing VTPM AM system's chamber exceed 1750 × 1200 × 950 mm).
- Great flexibility of adjustment of all major printing parameters.

VTPM compared to FDM and FGF

Comparing VTPM to the existing thermoplastics AM technologies – FDM and FGF – we can quickly see that VTPM is the technology required by industry and research to make widespread use and integration into production lines and research facilities a reality.

VTPM TECHNICAL ASPECTS:

- Widest range of feedstocks among extrusion-based additive technologies.
- Open-source AM system (best fit for research in innovative thermoplastic materials).
- Printed products are closest in structure to those made by conventional methods.
- Standard industrial polymer feedstocks.
- Highly complex geometries possible.

VTPM ECONOMIC FACTORS:

- Low-cost feedstocks.
- Used material can be recycled.
- High production speed compared to other additive technologies.
- Cost-efficient for one-off or medium lot production.

VTPM ECONOMIC FACTORS:

- Indispensable for highly complex medium- or large-size objects from thermoplastic-based materials
- Practically the only way in the world to create complex large-sized polymer products and blanks.
- Suitable for the creation of metal and ceramic products with complex shapes.

The narrow range of materials and settings that most 3D printers work with often makes it necessary to change printers for different jobs or research projects.

The motto of VTPM is **“Change the settings, not the printer.”**

The key VTPM breakthroughs

There are several key hardware and software differences between VTPM and other thermoplastic extrusion industrial 3D printing technologies that enable this technology to meet the wider needs of industry and research.

1. UNIVERSAL EXTRUDER

The patented, award winning technology built in to the extruder is a major breakthrough.

This technology is required to make the VTPM extruder truly universal. Being able to achieve a very wide range of temperatures all the way up to 500°C is needed in order to melt and extrude the widest range of plastics and composites.

The VTPM universal extruder is the only extruder we know of that has five heating zones. The size and geometry of the extruder as well as the material it is made of all contribute to making it able to extrude the widest range of polymers and composites, including materials which are so abrasive that they would destroy a lesser extruder after a short period of use.

Seven years of testing and tens of millions of dollars in R&D have resulted in the VTPM-capable universal extruder.

2. LARGE VOLUME ACTIVE CHAMBER

One of the hardest elements of the VTPM printing system to create is the active chamber.

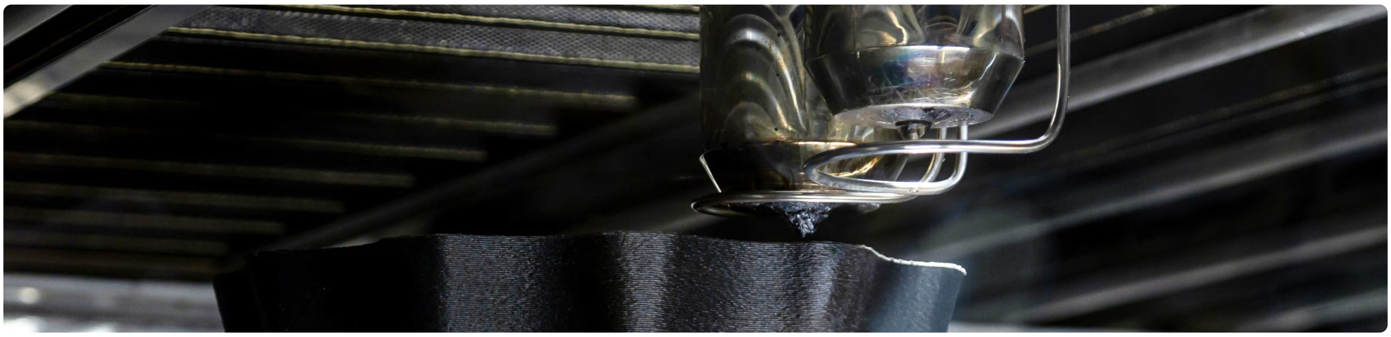
Industrial needs include the ability to print relatively large objects from the widest range of materials, avoiding warping and artifacts so as to also achieve high quality and reduce anisotropy. In order to accomplish this, the chamber needs to be relatively large.

The chamber must be thermo-isolated to help maintain the temperature inside and for the safety of the operators outside. At the same time, there are many delicate electronics inside the chamber in the printing head that cannot be heated above about 40°C.

Therefore we made it using the same materials and with the same approach as is used to thermo-isolate spaceships.

It also needs to be able to be heated to about 150°C evenly throughout. It has to be heated and cooled rapidly so that printing is not seriously delayed while the temperature is raised or lowered for various printing tasks. It is important that the thermal chamber holds the temperature for a long time, as printing can take tens of hours. And all this must be accomplished with a large chamber which has more than six square meters of moving side walls and roof that need to be thermo-isolated. Plus we had to create a proprietary door mechanism.

A large amount of R&D was required to achieve this, but this task has been accomplished. It was overcoming all these difficulties that resulted in the only chamber of its type in the industry. It adds to the cost of the printing system, but the advantages far outweigh the expense.



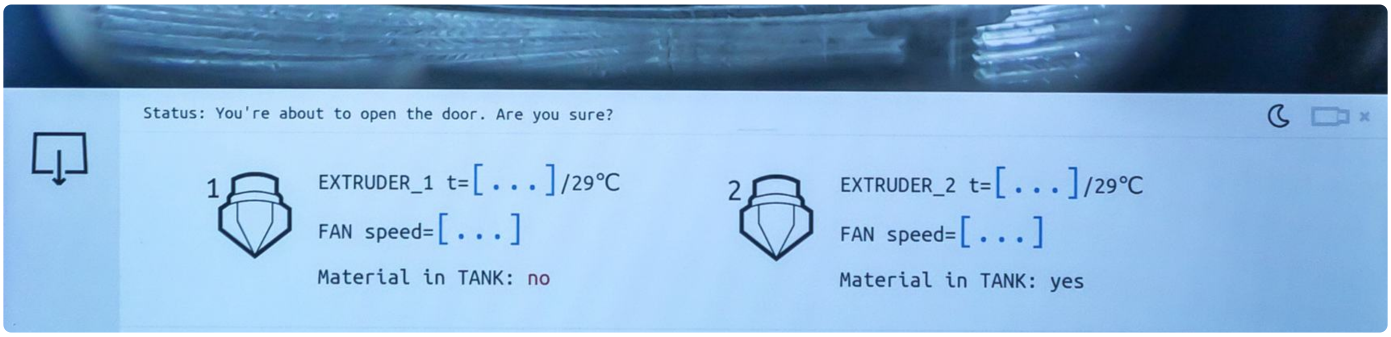
3. KINEMATICS

A third breakthrough which has made VTPM technology possible is in the proprietary kinematics that are employed.

Without going into technical details, the kinematics of the VTPM printing system allow it to print more rapidly and precisely than any other system in its class that we are aware of.

The special engines used allows the print head to achieve printing speeds up to three meters per second (although this is not the speed usually used because each project and every material and each quality requirement has a different optimum printing speed). The precision of the head is 100 μm along the X and Y axes and 50 μm along the Z axis. The speed and precision combined allow for very consistent layers with almost no artifacts.

As far as we know, the speed of printing is two, three and as much as ten times faster than other machines in this class. The many years of research that have gone into finding and using the best motor to achieve ideal kinematics and developing the current system, when taken together with the extruder capabilities and the active chamber have raised VTPM technology to the point where it is truly useful to industry and invaluable in research.



4. SOFTWARE

Because there was no software available to control a VTPM machine, allow for the very large number of settings and parameters needed in order to print with true versatility, we had to develop our own software.

The software in use in the VTPM systems is entirely proprietary and not available elsewhere. (This applies to the machine's internal control system. The other software in use for VTPM printing such as slicers and standard G-codes, is widely-used, open source software.) In fact we had to also create our own computer hardware including the motherboard and electronics that drive a VTPM printing system. These are key factors in making it possible to print so flexibly from such a wide range of materials and achieve the precision and quality that a VTPM machine is capable of. This is a major point in the "V" of "VTPM" – Versatile.

While the above are the main technical advances that make VTPM possible, there are many other features which are a necessary part of the system. For example, safety and security are vital for the protection of the personnel using the equipment and for the security of the proprietary technology. There are dozens if not hundreds of advanced safety and security features built in which make the VTPM system secure, safe and compliant with all requirements.

Each of these technical breakthroughs represents a major step forward in the technology. However, only when all of these factors are taken together in combination, and backed up by a whole ecosystem of support and services, can VTPM become a reality and thermoplastic extrusion industrial 3D printing can match the goals of industry and become a mainstream method of manufacturing.

CONCLUSION

By paying close attention to the real challenges faced by manufacturers and researchers and by deciding to employ thermoplastics-based additive manufacturing to solve these challenges where possible, a new technology has been created: Versatile Thermoplastics Particle Manufacturing.

It combines the most useful features of the existing thermoplastic technologies – Fused Deposition Modeling (FDM) and Fused Granulate Fabrication (FGF) – but greatly extends the scope of thermoplastic extrusion additive manufacturing well beyond the capabilities of either technology through the development of highly innovative features and capabilities all designed with one purpose in mind: to overcome real-world manufacturing challenges and empower manufacturers to accomplish their goals more rapidly, efficiently, at lower costs and more sustainably.

It makes it possible to use industrial 3D printing with the widest range of materials, from simple thermoplastics to superconstructive polymers and composites including printing objects from metal (MEM) and ceramics (CEM).

Because of the very extensive range of settings and materials which can be used, VTPM is invaluable for research into 3D printing methods and materials, including the creation of new materials for 3D printing.

Thanks also to the wide range of settings available, VTPM works better than any other AM technology in combination with other methods of manufacture such as casting or subtractive methods.

VTPM opens the door to a new era in manufacturing – an era in which thermoplastics AM takes on a mainstream role.

ADDITIONAL INFORMATION:

A description of VTPM technology, its applications and uses can be found at this technology website: www.VTPM.Tech

Descriptions of the existing VTPM-compliant additive manufacturing systems can be found at these websites (depending on geographic location):

- for North America www.AnyFormFactory.com
- for Europe, Middle East and Africa www.Gigaprinters.com
- for Southeast Asia www.AdditiveFactory.com

Universities and research institutions wanting to find out more about how VTPM can help with their research projects should visit: www.AEIP.llc/vtpm-collaboration

North American universities and research institutions, please contact South Texas Center of Excellence for Advanced Thermoplastics Additive Manufacturing and Materials Research (STCoE) www.SouthTexasCenterofExcellence.org, www.stcoe.org

For Europe, Middle East, Central Asia and Africa, there is a dedicated center for research, development, training, best practices, quality control and a repository of knowledge on the subject of Versatile Thermoplastics Particle Manufacturing: VTPM Center of Competence for Advanced Thermoplastics Additive Manufacturing and Materials Research www.VTPM.CC