CHEMISTRY THAT MATTERS™

SPECIALTIES

PELLET-FED ADDITIVE MANUFACTURING

ENABLING GROWTH FOR PELLET-FED ADDITIVE MANUFACTURING

Supporting the maturation of additive manufacturing from a prototyping technology to an end use part production process is a strategic focus for SABIC.

You may already know us as a global supplier of ULTEM™ resins for additively manufactured FST compliant aerospace applications and for our collaboration with Local Motors in the large format printing of the Olli and the world's first 3D-printed car, the Strati.

We've expanded our focus to include the development of differentiated materials formulated for use in a variety of additive manufacturing processes that may help designers meet specific functional requirements of production applications and solve processing challenges across a wide range of industries.

Building on SABIC's decades of experience in developing innovative material solutions in support of new processes, we are helping to advance the industry's adoption of pellet-fed additive manufacturing (PFAM), also referred to as Fused Granular Fabrication (FGF) At our Center of Excellence for Additive Manufacturing, SABIC has assembled a unique collection of capabilities to help accelerate the expansion of the use of thermoplastic pellets for additive manufacturing.

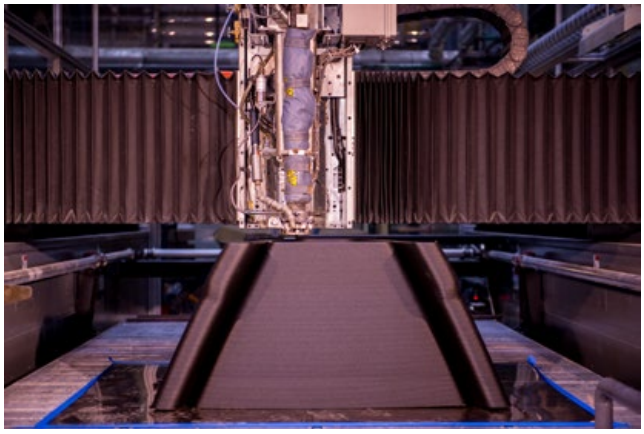
With a broad portfolio of high-performance materials, along with processing expertise and state-of-the-art equipment, SABIC provides a highly supportive research environment for the optimization of design, material, and testing for additive manufacturing processes.

Processing and design expertise using SABIC's Big Area Additive Manufacturing Machine (BAAM®), located at its Center of Excellence for Additive Manufacturing enables rapid development of new materials specifically designed for pellet-fed additive manufacturing processes.

MATERIAL INNOVATIONS FOR PELLET-FED ADDITIVE MANUFACTURING

SABIC's capabilities, from the reactor to the compounded pellet, enable us to bring new materials to market which can not only offer the strength and dimensional stability required for pellet-fed additive manufacturing, but can also offer chemical resistance, thermal conductivity, heat resistance and improved processability tailored to customer and application needs.

Our new family of high performance THERMOCOMP™ AM compounds addresses the unique requirements of 3D printers that use pellet-fed systems to print parts. This includes robotic printers, medium format additive machines and large format additive machines (LFAM). Print parameters and mechanical properties are developed internally using test specimens printed on SABIC's in-house BAAM® machine, and can significantly aid customers in expediting their material selection and processing optimization. Reinforced with carbon or glass fibers for strength, the compounds can be used for applications in tooling, aerospace, automotive and defense industries.



THERMOCOMP AM compounds based on amorphous resins such as ABS, PPE, PC, and PEI exhibit good creep behavior versus semi-crystalline resins, and reduced deformation under constant pressure. Further, lower shrinkage during cooling means these materials demonstrate greater dimensional stability and less thermal expansion during part use.

- ABS-based compounds provide easy processing, low warpage and good print surface quality, making them good candidate materials for a broad range of applications and tooling.
- PPE-based compounds offer lower thermal expansion, outstanding hydrolytic stability, higher strength-to-weight ratio, and higher temperature performance compared to ABS.
- PC-based compounds deliver higher strength, higher temperature performance and higher throughput compared to ABS and PPE, as well as excellent ductility and a smooth surface finish.
- PEI-based compounds, developed from SABIC's inherently flame-retardant ULTEM™ resins, provide low thermal expansion, high temperature performance, excellent strength-to-weight ratio, high modulus, and low creep.

Each of the THERMOCOMP AM materials is reinforced with carbon or glass fiber, depending on the degree of stiffness and dimensional stability required. They are potential candidates for elevated-temperature applications such as thermoforming and composite layup tooling.

SABIC has also recently developed additional PFAM compounds including:

- PC/PBT compound reinforced with carbon fiber to provide amorphous resin processability, low warp and improved chemical resistance vs PC.
- High heat PC compound reinforced with carbon fiber to provide low warp and good processability. This material fills the temperature performance gap between PC and higher heat amorphous polymers like PEI and PESU.
- PESU compound reinforced with carbon fiber to provide additional high heat options where PESU may already be specified.
- A PC copolymer compound reinforced with carbon fiber that is an ideal candidate for train interior components (EN45545 R1 and R27) and also meets requirements of NFPA-130.

MATERIAL INNOVATIONS FOR PELLET-FED ADDITIVE MANUFACTURING

Mechanical properties and processing information for THERMOCOMP™ AM compounds, including tensile and flexural properties, are developed internally using test specimens printed on our large format equipment (see Figure 1). This insight into process conditions and material performance gives customers confidence in the use of our materials and enables faster machine set up as well as higher print productivity.

SABIC's access to a wide range of thermoplastics resins and a number of fillers and reinforcements enables development of new compounds to meet customer and application needs for pellet-fed additive manufacturing (see Figure 2).

FIGURE 1

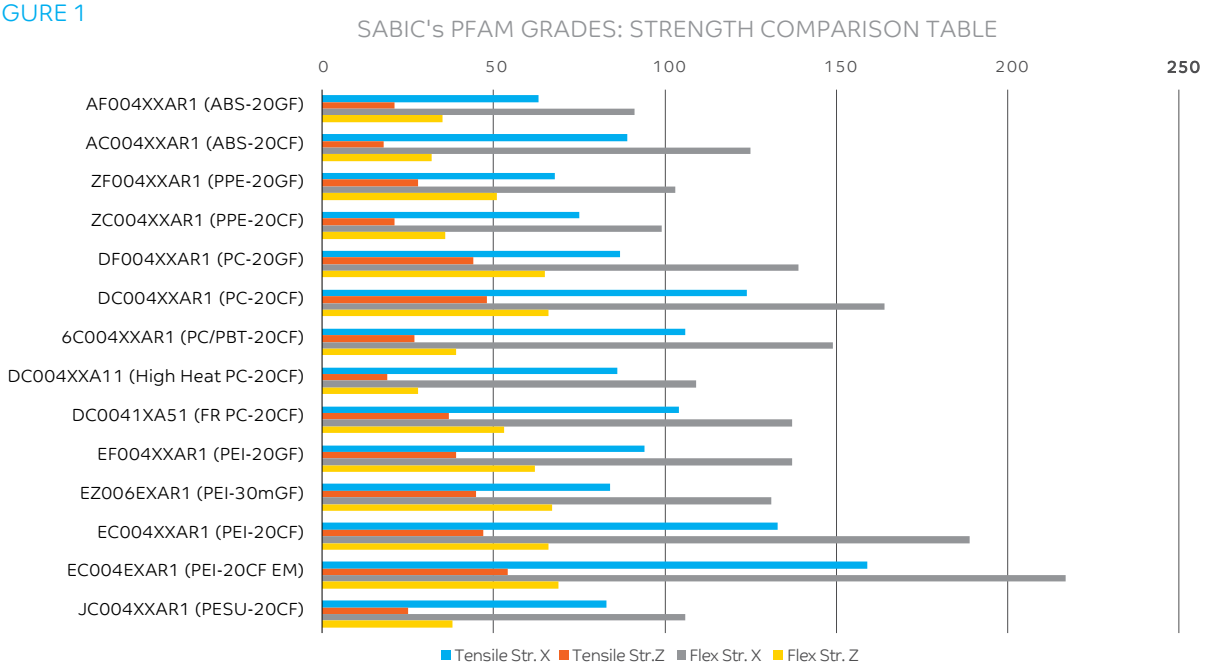


FIGURE 2

THERMOPLASTIC RESINS

- ABS
- PC, PC/ABS, PC/PBT
- PEI
- PSU
- PA11
- PESU/PES
- PPSU
- PEEK
- PPS
- PA6
- PA66
- PPA
- PPE, PPE/Nylon
- OTHERS

REINFORCEMENTS - FILLERS

- CARBON FIBER
- GLASS FIBER
- MINERALS
- FLAME RETARDANTS
- HEAT STABILIZERS
- UV AGENTS
- THERMALLY CONDUCTIVE FILLERS
- OTHERS

APPLICATION DEVELOPMENT CAPABILITIES AND EXPERTISE

In addition to material development, SABIC offers expertise and resources for testing, design and application development for additive manufacturing.

From material chemistry, to material formulation, to print expertise, SABIC integrates design, processing and materials, much like we have done with traditional polymer processes over the past decades, to help solve problems for our customers.

Our application development expertise has now expanded to include capabilities specific to pellet-fed additive manufacturing technology (see Figure 3). This unique position enables us to produce innovative offerings for this space to help drive greater adoption of additive manufacturing for end use production.

FIGURE 3

	TRADITIONAL APPLICATION DEVELOPMENT	CAPABILITIES ADDED FOR PELLET-FED ADDITIVE MANUFACTURING
INDUSTRIAL DESIGN	Application teardowns Concept designs Prototype development	Access to industrial engineers and designers to create parts Reverse engineering to recreate tools and redesign parts specific to additive manufacturing
PREDICTIVE ENGINEERING	Computer aided engineering Computer aided design Process simulation Life cycle analysis	Processing simulation to screen ideas for efficient test runs Fracture analysis to understand failure mode to improve process and materials feed simulation Warp analysis FEA to study printed parts to solve performance issues
PROCESS DEVELOPMENT	Conversion processes Material development Technical scoping and validation Training and consultation	Expertise on a variety of 3D printing equipment to optimize processing parameters enabling faster setup and transition for customers Access to the broad portfolio of LNP™ specialty compounds 3D laser scanner to perform quality checks on printed parts Thermal imaging to monitor processing consistency
APPLICATION PERFORMANCE	Secondary operations Painting and decoration Part testing and end use simulation Regulatory standards	Microscopy for fiber orientation CTE analysis for thermally cycled parts Mechanical properties testing of printed parts to aid customers in material selection Water jet for consistent cutting of printed parts for testing Autoclave, thermoform, vac-form and environmental chamber for tooling validation Non-destructive testing to check for voids or layer adhesion issues Composite testing equipment Post processing

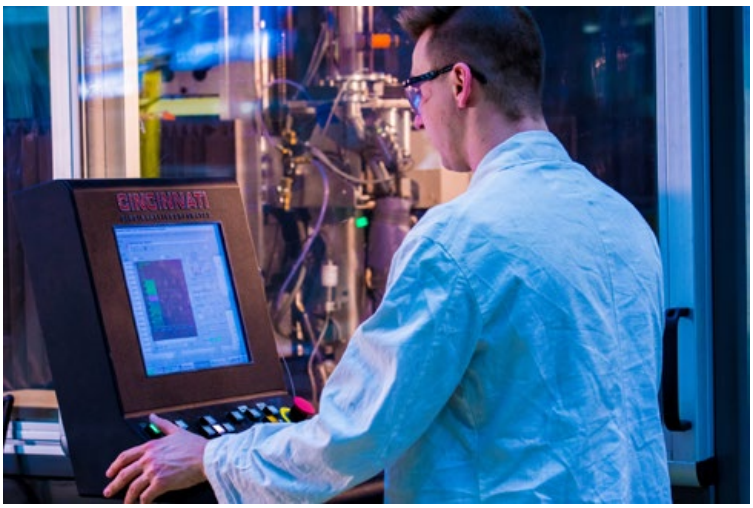
APPLICATION DEVELOPMENT CAPABILITIES AND EXPERTISE

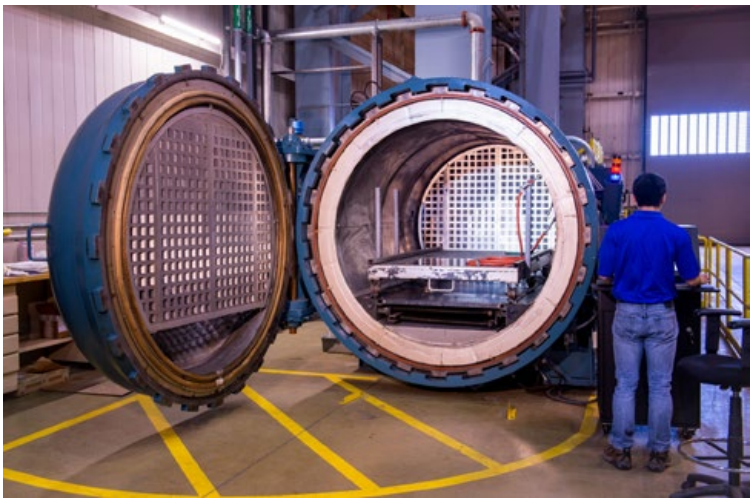
DESIGN AND ENGINEERING

By applying our knowledge of traditional application development methodologies such as simulation, FEA, and fracture analysis we continue to expand our expertise and support our customers as they tap into the full design potential of pellet-fed additive manufacturing.

PROCESS DEVELOPMENT

Unlike other additive manufacturing processes, pellet-fed additive manufacturing is an open process that allows for adjustment in temperature, speed of laydown, layer height and many more parameters. Proper processing is critical to ensure a quality printed part and can help to avoid issues such as polymer degradation which could lead to loss of some physical properties. SABIC develops process parameters for our pellet-fed dditive manufacturing compounds, to be used as starting guidelines which can save customers time and resources. Following proper printing practices with careful consideration of drying time, extrusion residence times, temperatures and pressure will help create a robust part.





Capabilities at SABIC's Center of Excellence for Additive Manufacturing include an autoclave and thermoformer to support application development of printed tooling.

APPLICATION PERFORMANCE

It is important to define the application requirements and the end use environment in order to properly select and evaluate material candidates. Lacking commonly accepted standards to test parts produced by pellet-fed additive manufacturing, scientists at SABIC have developed a robust test regimen to evaluate material properties and processing parameters to assist in material selection and process optimization for pellet-fed additive manufacturing processes.

State of the art testing equipment provides immediate feedback on printed samples, including tensile, flexural and compressive properties. This in-house capability provides the opportunity to validate our optimized print parameters and add speed to our customers' application development process.

At SABIC, supporting the growth of the additive manufacturing industry is an important strategic focus. Our unique experience with a variety of pellet-fed additive manufacturing processes coupled with decades of material and application development expertise provide an exceptional platform for us to bring innovative solutions to the industry. We are committed to helping our customers achieve success through ongoing collaborations with industry leaders at strategic OEMs, research institutes, and equipment manufacturers.

We look forward to collaborating with you.

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