ON THE HORIZON

Major Advancements in Additive Manufacturing

AUTODESK.

INTRODUCTION

MANUFACTURING TODAY: THE FUTURE OF MAKING THINGS IS NOW

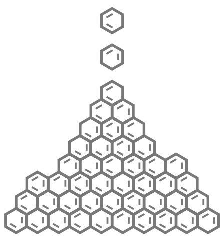
Additive manufacturing (AM) is already helping manufacturers create products with improved performance, respond more rapidly to customer needs, and accelerate time to market. However, many industries are still weighing when and how to integrate AM into product development and production in an efficient and cost-effective manner.

In the recent past, most companies would choose traditional methods that offer far fewer barriers to adoption and more-consistent results. But today, new developments in additive manufacturing tools and processes are helping manufacturers overcome some of the barriers to adoption initially posed by AM—and also take advantage of economies of scale. The barriers to adoption can include:

- Build failures
- Modeling of complex designs that are optimized for additive manufacturing
- Manual post-processing work
- Machine and material expense
- Available expertise

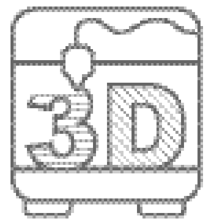
In this guide, you'll learn how advancements in software, process, and materials are helping manufacturers successfully utilize AM to move from prototyping to production—and reap the true benefits of the technology.

TABLE OF CONTENTS



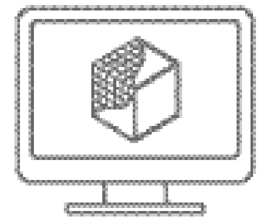
ADVANCEMENTS IN MATERIALS

Recent advancements in materials have made printing more reliable and cost effective, and have also improved part performance.



ADVANCEMENTS IN PROCESS

Tapping simultaneously into the advantages of additive and subtractive manufacturing dramatically improves the design and production processes by facilitating complex geometries with enhanced precision.



ADVANCEMENTS IN SOFTWARE

By using software that can predict thermal stress and deformation caused during the printing process, manufacturers can reduce the number of failed builds, reduce the time it takes to print a part, and reduce waste in materials.

ADVANCEMENTS IN MATERIALS: GREATER CHOICE AND REDUCED WASTE

In additive manufacturing, advanced materials are helping manufacturers realize improved part performance and weight reduction. Several key advancements in materials are making higher-quality 3D-printed parts possible.

MORE CHOICES AND TECHNIQUES IN ADDITIVE MANUFACTURING MATERIALS

Today there are far greater choices in materials for additive manufacturing, which means that more industries can benefit from the design and iterative choices that 3D printing facilitates. For example, metal alloys, traditionally used in medical applications, are making inroads in AM for aerospace and automotive applications.

Here are some of the key advancements in AM materials—both in terms of material types and trends affecting how they are used.

01.

HIGHER POWDER QUALITY:

The powder used for metals and polymers has been improved to present more of the desirable characteristics needed for 3D printing—for example, they flow and pack better and can be sintered more effectively. These powders will create parts that have fewer defects and increased isotropic performance (that is, equal strength in all directions).

02.

GREATER RANGE OF MATERIALS:

Leading metal and plastic suppliers that traditional manufacturers use are offering more products for AM. Their decades of experience in developing and refining plastics for traditional manufacturing will help raise the quality of materials available for AM—and will also increase competition and decrease prices over the long term.

MORE CHOICES AND TECHNIQUES IN ADDITIVE MANUFACTURING MATERIALS CONTINUED

03.

LESS WASTE THROUGH POWDER RECYCLING:

For most applications, reusing powder from previous builds has shown to not have any adverse affects in terms of build quality, especially when topping off the recycled material with fresh powder.

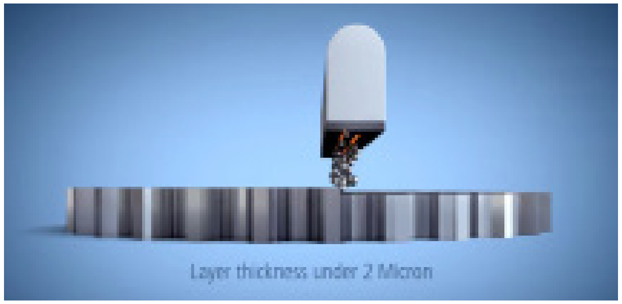
04.

IMPROVED ISOTROPIC MATERIAL PROPERTIES:

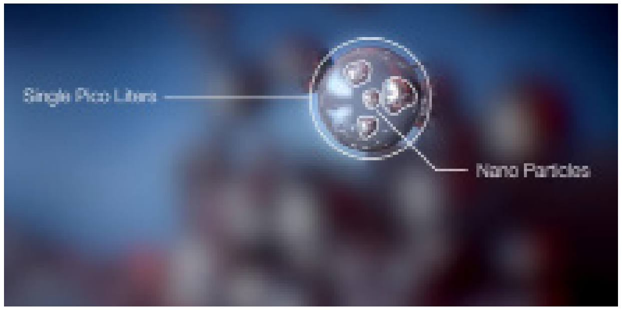
Mechanical properties of AM parts are often anisotropic due to both the layer-based printing of materials and the direction of the printer head. New material and machine combinations—such as the Continuous Liquid Interface Process (CLIP) by Carbon3D—use post-printing thermal curing that results in isotropic performance characteristics.

CASE STUDY:
MORE PRECISE PRINTING WITH NANOPARTICLE JETTING™

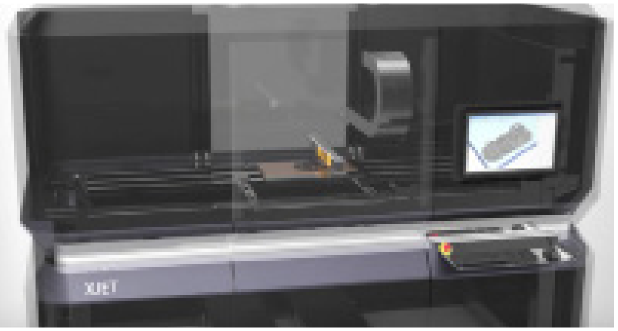
Traditionally, 3D printing with metal has involved compromises in terms of both surface finish and accuracy of parts' details—as well as increased time and cost. A newer generation of printers using nano particles within a carrier instead of powders shows promise for solving some of the challenges of building metal parts using AM. For example, printers from Xjet use liquid droplets carrying metal nano particles distributed through standard inkjet heads. The process is up to 5 times faster than laser 3D printing, and it doesn't require that supports be removed by hand or machine, which can also save time and money. In addition, this technique may be safer, since airborne powders may cause health problems after long-term exposure.[1]



The Print head dropping the metal nano particles



A close up of the nano particle



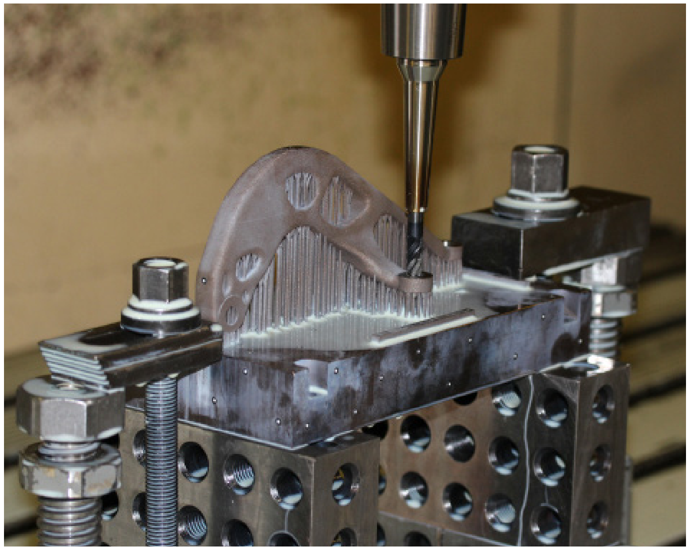
A look inside the XJET Printer

ADVANCEMENTS IN PROCESS

By looking at both additive and subtractive manufacturing with fresh eyes, engineers and designers are making it possible for wider use of AM in more industries and applications. Improvements in process are eliminating some of the challenges that previously prevented AM's adoption in many use cases. Here are some of the process improvements that are supporting a broader adoption of AM.

COMBINING ADDITIVE AND SUBTRACTIVE MANUFACTURING

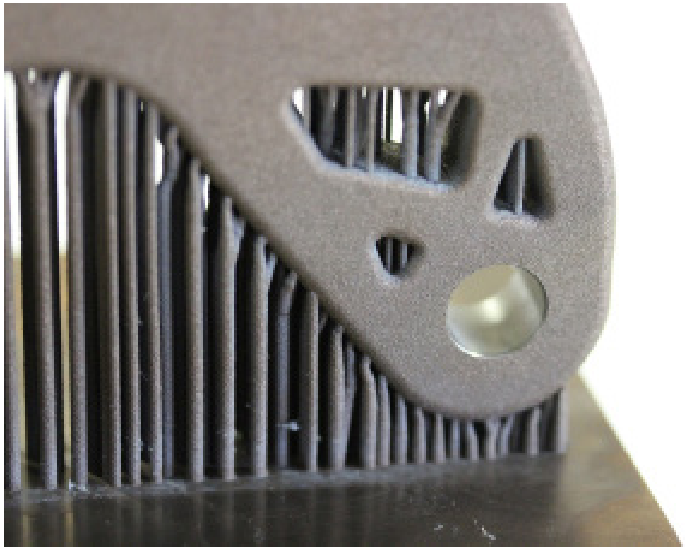
Additive versus subtractive manufacturing is not an either/or question. But, frequently, organizations that are just beginning to explore the benefits of AM see it as a vehicle for completely replacing traditional manufacturing methods. "Additive is only one way of making things," explains Kelvin Hamilton, project engineer at Autodesk. "Completely replacing subtractive with additive is not really viable. You don't want to take a part you can already make through machining and decide to make it through additive—even though those parts have already been optimized for subtractive manufacturing."



A better solution: combining the benefits of additive and the benefits of subtractive, particularly for metal AM. Figuring out when and where to combine the 2 processes requires going back to the core function of the product being manufactured, since that's what drives the decision.

For example, are designers or engineers seeking performance increase? Lighter weight? Customization? Or all of these qualities? If all are needed, then a combination of AM and subtractive processes makes more sense. One option for designers is creating additive parts and then adding material to produce a near net shape that can be finished through machining.

REDUCING THE NEED FOR SUPPORT STRUCTURES



Parts produced through metal additive manufacturing typically need support structures. Manufacturers and designers who are considering a shift to AM must therefore account for the subtractive manufacturing processes needed to remove the support structures after the part is printed—and they must also consider how to smooth surfaces like drill or screw holes that require precision finishes. It may make more sense, Hamilton says, to redesign a part from start to finish for AM so that it needs fewer supports, instead of attempting to simply substitute AM for subtractive manufacturing.

Improved training for designers can help directly address the support-structures challenge. For example, designers should take steps to consider AM-related features during their initial designs—such as where support structures will go, and how easy it will be to remove them post build. In addition, designers should consider the orientation of the build, as it may affect which geometries can be used; and they should take into account the required tolerance level of certain features, such as the sizes of screw threads and the diameters of screw holes.

IMPROVING WORKFLOWS THROUGH SOFTWARE AND TRAINING

To successfully combine additive and subtractive processes, manufacturers need consistent, well-organized workflows—but, to date, meshing the 2 processes has been challenging. Advanced software can span all phases of the product development cycle from concept and testing to build simulation, file preparation, and process control.

What's needed is a broad toolbox that will cover every part of the workflow, as well as technical and process expertise. Software solutions for additive and subtractive manufacturing can anticipate or predict what's needed for successful designs in ways that humans cannot.

WHY USE BOTH AM AND SM?

- Better finishing: Combining the 2 processes can help smooth part surfaces, which is particularly helpful when smoother surfaces improve heat shielding and strength.
- More functional components: Subtractive manufacturing can add holes, screw threads, or part interfaces (i.e., where one part connects to another), when dimensional tolerance requirements are tighter than can be printed via AM.

ADDITIONAL ADVANCEMENTS IN PROCESS

01.

BROADER MANUFACTURING PARAMETERS:

Many AM machines oblige users to adhere to strictly defined requirements and settings, limiting the results that manufacturers could obtained. Some 3D-printing machine manufacturers, such as Arcam AB, Farsoon, and SLM, are supporting open platforms that users can customize to suit unique printing and manufacturing challenges.

02.

NON-DESTRUCTIVE TESTING:

Parts that look successful may have defects and distortion invisible to the naked eye. Tools such as computer tomography can detect such defects, but scanning every component isn't feasible and discarding faulty parts is costly. But newer systems, such as thermal cameras, can monitor a part as it's being printed to identify deviations from designs or discern temperature swings that could cause defects. These new systems offer manufacturers greater confidence in parts' integrity, and also help save time and money.

03.

MECHANICAL TESTING:

While simulation can help design better products, mechanical testing can truly highlight if the part can withstand the stresses it will endure. By testing 3D-printed parts for such qualities as tensile strength, designers can gather data to feed back into the simulation model. Over time, data gleaned from mechanical testing help manufacturers create high-quality parts and fewer failures in service.

ADDITIONAL ADVANCEMENTS IN PROCESS CONTINUED

04.

IMPROVED SURFACE FINISHING:

The surface of a 3D-printed part is generally not as refined as a machined surface, and this has limited the use of AM—where performance is a must. For example, parts with less-refined surface finishes may have shorter lifespans, only lasting 10 years instead of 30 years. Techniques such as electropolishing—which can smooth extremely small sections that larger machines can't reach—are helping raise the surface-finishing standards of AM components.

05.

CONSISTENT STANDARDS:

The standards bodies that are involved in manufacturing and materials, such as ASTM International and the National Institute of Standards and Technology, are creating best-practices manufacturing standards for AM (see list of ASTM standards here). The growth of standards will help improve component quality and encourage greater use of AM in manufacturing.

06.

ENSURING AEROSPACE-QUALITY PARTS:

More 3D-printed parts are being certified for use in aerospace manufacturing. Initially such parts were limited to less-mission-critical applications, such as ductwork or bracketry, given AM's limitations and the strict certifications required. With reliable and high-quality parts available, manufacturers can build for mission-critical systems such as engines, opening new markets.

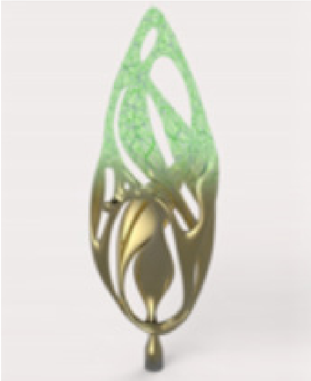
CASE STUDY:

INNOVATIONS IN ADDITIVE MANUFACTURING FOR JEWELRY

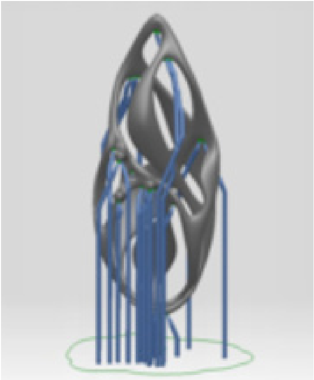
When working with metals, additive manufacturing is best suited for projects that require designers and engineers to overcome the geometric limitations of traditional casting methods. Jewelry makers are using AM to expand their creativity in designs, while still relying on some subtractive methods to finish the pieces. The Precious Project—an initiative of Innovate UK aimed at boosting the United Kingdom's jewelry manufacturing sector—promotes the value of AM for jewelry creation, while also noting the importance of planning for the use of subtractive processes.

For example, the removal of supports leaves small imperfections that must be polished and finished. "If you plan for additive from the beginning, however, you might not need so many supports," says Delcam's Hamilton. He and other AM experts encourage designers and manufacturers working with metal to experiment with parts designs that need fewer support structures—and, therefore, less time spent on finishing or other subtractive processes.[2]

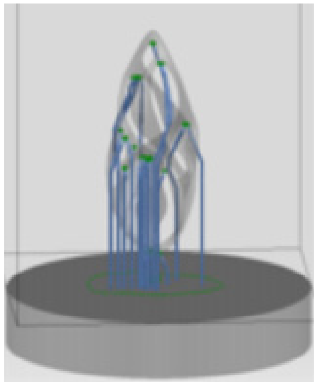
Original piece as-designed



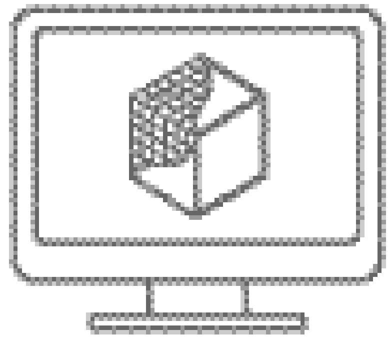
Build orientation decided and additional geometry added



Contract points generated and fixture added



Part as-prepared on the platform and ready for building



ADVANCEMENTS IN SOFTWARE: REDUCING COST AND UNCERTAINTY

The causal effects of failed AM builds are difficult to identify due to the complexity of the process itself. Using software for additive process simulation predicts errors in printing and lets engineers compensate for them with design modifications before moving into production.

HOW SIMULATION CAN SOLVE AM CHALLENGES

As with any manufacturing method, product development is an iterative process. However, the impact of printing failures is magnified when the materials used are far more expensive than traditional plastics. A failed plastic part may cost $50 for each build, while a failed titanium part may cost $10,000. Obviously, repeated iterations of metal parts can quickly eat into budgets.

Metal parts can suffer from warping or cracking due to temperature variations during printing. This can also be a problem if a part distorts and interferes with parts of the machine like the recoater blade, it can destroy portions of a very expensive 3D printer.

Uncertainties about the outcome of builds can hinder an organization's plans to adopt AM. According to a PricewaterhouseCoopers study, 47% of firms surveyed said that uncertain quality of 3D printing was a top barrier to AM adoption for their businesses.[3]

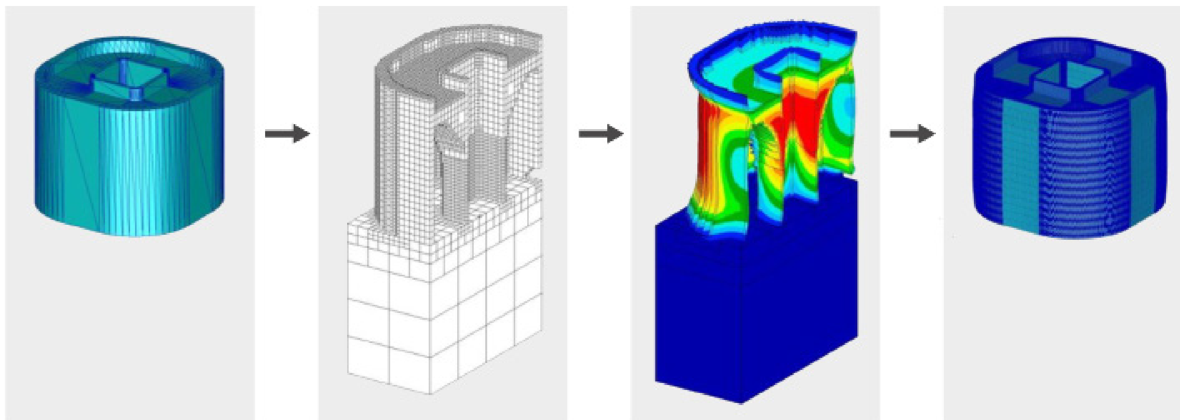
SIMULATION: COMPENSATING FOR WARPING AND DISTORTION

To avoid printing failed parts, designers and manufacturers are beginning to rely on simulation tools, which can virtually test the impact of certain factors on a build. Simulation tools, which rely on physics-based modeling, can help designers experiment with different methods for solving known challenges such as warping and distortion.

For example, if designers know that a cylinder tends to distort in a certain direction due to thermal stresses caused in the printing process, they can quickly identify the problem and retool the design to cause a minimal amount of distortion in the opposite direction to correct the issue. Or, if cracking is a known problem, engineers can test the impact of changing geometries or softening an angle.

According to Wayne King, leader of the Accelerated Certification of Additively Manufactured Metals Project at Lawrence Livermore National Laboratory, models will help organizations better understand the science behind their designs. In fact, simulation can help designers and engineers reach a point where they can print projects without delays.[4]

HOW SIMULATION IS COMPENSATING FOR 3D PRINTING CHALLENGES



.stl file | Auto generated mesh | Distortion results | Compensated.stl file

The powder-bed AM simulation process is a way to predict design changes that may be needed to avoid failed builds, such as temperate changes and stress:

- The process starts with a .stl file, a widely used 3D printing file format.
- Automatic mesh generation then prepares the file for simulation and reduces the required preprocessing time by converting the .stl file into a polygonal mesh.
- The simulation software predicts temperature, residual stress, and distortion. Compensations for the predictive results are applied to the file, reducing the costly trial-and-error iteration process.
- The software creates the compensated .stl file, incorporating the corrections for the predictive distortions.

ADDITIONAL ADVANCEMENTS IN SOFTWARE

01.

GREATER COHESION IN TOOLS FOR DESIGNING PARTS:

In the past, design tools for AM were fragmented. Designers often had to rely on one tool to perform a specific function, then switch to another tool to perform another design task, and so on. Newer software tools offer all of these tools in a single package, and they cover a greater range of design tasks, including simulation as well as creation of designs that combine additive and subtractive manufacturing.

02.

GENERATIVE DESIGN TECHNOLOGY:

Designing products that truly capitalize on the freedom provided by additive manufacturing is practically impossible to do using traditional 3D CAD software. These applications have been built over decades specifically to help engineers design products that will be manufactured via common machining, molding, casting, or forming processes. In order to create the complex, organic structures that can only now be made via AM, generative design tools have been developed that can optimize topologies, create internal lattice structures, or even synthesize forms based on inputs from the user that define any number of performance, aesthetic, or manufacturing considerations.

CONCLUSION

APPLYING ADVANCEMENTS IN AM TO YOUR BUSINESS

By bringing together advancements in software, process, and materials, manufacturers can use AM for more than prototyping, bringing it into full production. For example, new processes and materials help manufacturers reduce cost and waste, consolidate parts and compress supply chains, and increase the reliability of 3D printing.

As new advancements improve the application of AM to your business needs, Autodesk can guide you in choosing the best solutions for your project—improving the chances of successful outcomes.

Visit autodesk.com/solutions/additive-manufacturing to learn more about the newest strategies and tools for your additive manufacturing project.

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[1] "AMUG: XJet Presenting NanoParticle Jetting Metal 3D Printing Process to Large Crowd," 3DPrint.com, April 6, 2016

[2] Precious Project/Innovate UK

[3] "3D printing and the new shape of industrial manufacturing," PricewaterhouseCoopers, June 2014

[4] "Researchers outline physics of metal 3D printing," Lawrence Livermore National Laboratory, January 14, 2016