Unlock the Full Potential of Additive Manufacturing

Cover image, courtesy Avio Aero, a GE Aviation Business
Avio 3D-printed LPT blades for the LEAP, GEnx, GE90 and GE9X jet engines. Avio Aero thinks additive! Avio Aero has developed metal powders specifically for Selective Laser Melting (SLM) and Electron Beam Melting (EBM). The process of melting powders layer by layer to make objects from 3D models – instead of subtractive manufacturing processes - allows a reduction in costs and increases the range of alloys available. This technology offers elevate mechanical properties, competitive rough parts costs and energy savings with low emissions, while increasing design freedom and manufacturing speed.

materialise
innovators you can count on

In 2000, Phonak officially started their collaboration with Materialise and its team of software developers to create a solution that would forever change how hearing aids are designed and produced: Rapid Shell Modeling. Thanks to RSM, it was possible to put a new digitized and automated process in place, saving time and effort, and resulting in a more comfortable, acoustically optimized hearing aid that can fit so deep in the ear that it is nearly invisible to the outside world.

3D Printing, An Industry in Transition

In its early days, 3D Printing reinvented the prototyping process by allowing a faster and more cost-efficient way to create new products. The effortless experimentation with CAD designs and the production of proof-of-concepts with almost no design limitations or material waste, revolutionized the prototyping world.

More than 25 years later, 3D Printing has become an industry that stands on its own. It is often referred to as the Additive Manufacturing (AM) industry, reflecting its use as a manufacturing technique by industrial companies.
This transition from prototyping labs towards manufacturing lines has the potential to disrupt different industries, especially when AM is used as a complement to other prevalent production methods rather than in an isolated way.

The hearing aid industry is a perfect example of the revolutionizing power of AM when linked to design flow automation. In less than five years, this industry transitioned from a labor-intensive manual process to a fully digitalized process that combines additively manufactured shells with traditional electronic inserts. Phonak, the instigator of this revolution, was a pioneer in adopting AM to produce custom-made hearing aids. Their main goal was offering individualized, perfectly fitting hearing aids to customers in a much faster and easier way. A few years ago, more than 10 million custom-made hearing aids were already produced using AM.

From the very beginning, Materialise has been a strong believer in the power of 3D Printing to create a better and healthier world. Every day, together with our customers, we experience the value that AM brings to the business world and individual lives. During our 25 years of existence, we have grown from a small local service bureau to a global AM technology leader that offers software, engineering and 3D Printing services to a wide range of industries and markets. Throughout our history, we have achieved many successes, but also faced many hurdles. Therefore, we understand very well that adopting AM technology and introducing it into the production lines of any company is a journey started with great expectations, but one that always includes unforeseen challenges. If companies are not well prepared, the success of AM adoption can be undermined. Research by IBM in 2013 supports this apprehension:

"Despite the press coverage that technologies like 3D Printing receive, manufacturing leaders remain ill-prepared for their impact (IBM 2)."

Contrary to other literature that focuses on the potential of AM in general and the importance of investing in it, this paper discusses the key elements that can determine your success once you start your AM journey. Based on our experience and that of the many customers we work with, we look at how AM has an impact on different manufacturing models, we provide three key insights about AM adoption, and explain why proper know-how and the right software are essential to unlocking the full potential of AM.

Pinovo is a company that develops tools for anti-corrosion surface treatments of oil and gas pipelines. The PiConnect is a solid tool conceived for hand-operated blasting of a variety of surfaces in demanding environments. Through the use of AM using Alumide, small series of PiConnect custom click-on adapters can be produced in a durable, fast and flexible manner.

Different Production Applications, Different AM Benefits

3D Printing has experienced a huge growth in popularity over the last few years. Many small and large businesses across a range of industries are considering investing in or have already adopted 3D Printing technology in their production processes. At the same time, the fear of high costs and long production times has prevented some companies from adopting AM. This fear is not justified, however, if you use AM for applications that have the right balance of complexity, part size, and production batch size. Like many other emerging technologies, the costs inherent to 3D Printing technology are decreasing rapidly. If the predictions given in 2013 in the study by IBM are valid, then those costs will soon be irrelevant in the decision process about whether to use AM for your application:

"3D Printing costs should fall by 79 percent over the next five years – and by 92 percent over the next decade, making it more cost-effective than all but the largest production runs (IBM 5)".

The benefits of AM as a manufacturing technique change as production applications differ. Today there are four main areas where AM is making a difference as a cost-effective and fast time-to-market technology.

Prototyping

The most obvious area, and the one where AM originated from, is prototyping. 3D-printed proof-of-concept models are created in R&D labs to help visualize, integrate, feel and test new product ideas. Conventional prototype creation requires substantial craftsmanship and patience, restricts design freedom, and incurs high waste and costs. 3D Printing technology, on the other hand, enables the user to create intricate designs while saving 45–95% in time to market (Stanley Morgan 8) and 90% in material consumption (CSC LEF 9). This is a major reason why this technology is now dominantly used for prototyping in almost every industry. Today, a whole ecosystem of machine manufacturers, material suppliers, and service and software providers is available and the market is growing year after year.

Small Batch Production

3D Printing technology also makes it possible to manufacture final products on demand and where needed, without requiring specialized tools. It thus eliminates the need for stock and allows efficient local production. In addition, the time needed for production changeover can be greatly reduced. These are all reasons why AM, especially for small production batches, proves to be a more cost-efficient manufacturing technology than conventional techniques, which explains its growing popularity. At the moment, it is mostly independent and specialized service bureaus that produce small series using AM, but it is expected that in the future more companies will invest in this technology and offer a wide range of small series applications manufactured with AM.

Mass Customization and Series Production

The ability to produce parts without geometry limitations while also improving process efficiency, is obviously a very attractive proposition if you produce larger series. Aerospace companies, for example, maximally benefit from the performance optimizations AM has to offer through its ability to produce lightweight and assembly-free designs. It is thus unsurprising that manufacturing companies involved with the aerospace industry are heavily investing in 3D Printing technology to manufacture parts for aircraft. The durability and production costs of engine components such as fuel nozzles and engine blades benefit from the transition from a purely conventional process towards one combined with AM. At the same time, the medical industry is using AM to "digitalize manufacturing" and make "mass customization" a reality. The rapid manufacturing of custom parts such as implants and personalized medical devices can significantly improve or even save a person's life. Mass customization can only be implemented in a sustainable manner through an AM process, where design flexibility can be maintained without compromising cost effectiveness.

The successes of manufacturing larger production batches in the aerospace and medical markets are going to be crucial to the wider industrial adoption of AM.

"Traditional markets may not yet recognize or require the benefits of 3D Printing, but that is expected to change as the manufacturing sector feels the impact of this radically different production method (CSC LEF 4)."

Spare Parts

When considering spare parts, AM offers another important benefit: decentralized production. Demands for spare parts are typically intermittent, and it is difficult to forecast when specific parts will be needed and where. Through AM, production of spare parts can be done on demand and locally, avoiding inventories and transforming entire supply chains. As such, "spare parts" are transitioning into "replacement parts". However, the ability to produce parts locally is not always sufficient to ensure that a switch to an AM process is economically viable. The viability increases if there is an opportunity to optimize a feature of the design – its topology, for instance – simultaneously. When you carefully choose your parts, the production cost of replacement parts can be decreased significantly through AM. Therefore, the number of replacement parts produced through AM is expected to significantly grow in the next several years.

Three Insights to Capture the Full Value of AM

#01 The Science of Producing Quantities

The number of parts that you plan to produce will influence your design and process choices whether the method is casting, molding, forming, machining or AM. The impact is even larger than one might expect when using AM, given that the machines, materials and processes were intended, and thus better suited for, the creation of one-off parts. The flexibility of the technology can have drawbacks if it is not handled properly. Every small inconsideration in the design or manufacturing process can introduce additional material, increase machine time, or introduce piles of scrap or supplementary labor-intensive finishing treatments. This greatly impacts the costs and time-to-market of products manufactured with AM, particularly when produced in larger volumes. Setting up a process that is efficiently scalable from the research phase to actual production is – like in any other production flow – crucial. Yet the constraints that need to be taken into account to ensure manufacturability are very specific to 3D Printing technology and require expert knowledge to be applied from the very beginning.

Learn by Doing

Without proper AM know-how, it will be extremely difficult to set up a process that is efficient and scalable. Too often companies dive into AM without realizing that textbook information about the pros and cons of its different aspects covers only the tip of the iceberg. Although this standard information may be sufficient to create a single prototype, far more knowledge is required to successfully implement AM in your business. An increasing number of articles and presentations illustrate how the design, production preparation, building and finishing steps have an impact, not only on each other, but also on the cost drivers of AM. For example, the orientation of your part on the 3D Printing platform determines the amount of support structure required during the build process, which in turn influences material costs, building time, finishing time, and much more. Unfortunately, today there are not yet exact recipes for successfully making a product multiple times using specific AM technologies and materials. You will need to adopt a new engineering culture. When starting your AM journey, you have to undertake fieldwork. Although much process knowledge and software is available, AM is not yet a "push button" solution. A specific AM knowledge base will need to be created for your particular application. Only in this way can you be sure that you have set up a process that is not only capable of delivering one or a few optimal copies, but one that stays economically viable when moving out of research and increasing the production volume to the required amounts.

Use Feedback to Grow & Improve

Without the support of specialized AM software, it is hard for engineers to obtain the proper research data. Engineers need software packages to help convert a CAD design into an optimally buildable part, whether it is a prototype or an end product. AM software is one of the tools that can help introduce buildable, lightweight designs, create randomized structures or easily removable supports, and apply optimal hatching strategies; however, these tools alone are not sufficient to optimally build an efficient AM process.

For proper research, engineers also require a system that can capture valuable information such as process, machine, material, and sample data so that they can efficiently create links between the different test data, gain deeper insight into the consequences of certain choices and help reveal bottlenecks more quickly and thoroughly. This kind of process management system, when adapted to the AM process, will have a significant impact on the ease of process stabilization, overall efficiency, and scalability of your process. As the AM process is a digital one, software tools are the preferred way to automate design and production steps. They decrease human labor and error, which further increases the efficiency of the process, especially for larger production runs.

#02 Repeatable Quality, a Focus from the Start

Although the quality of what you produce is always important, when you start manufacturing series, the repeatability and predictability of this quality is just as important. The larger the production scale, the bigger the difference between the quality of a product and the repeatable quality of the products. AM is a process where materials are not welded, but melted and fused together layer upon layer. As materials undergo a transformation, the microstructure or macroscopic mechanical properties of the materials can change, making it even more challenging to ensure reproducibility at an industrial level. Next to scalability, this needs to be taken into consideration from the start of your AM journey, otherwise it will become almost impossible or extremely expensive to consistently deliver quality products.

Keep Parameters under Control

According to a report by Roland Berger, there are currently over 180 parameters that can influence the surface, quality, accuracy and mechanical properties of AM parts (Berger 18). One wrong setting on one or multiple parameters can cause delamination, deformation, re-melting, porosity, and other negative effects. Because of the current nature of AM machines, it is not possible to completely lock these parameters, so variation in the build process is a reality. While awaiting further stabilization of those parameters, engineers can only suppress these undesirable effects by learning about the effects that fluctuations of various factors have on the AM build process. Consequently, they can understand which parameters are relevant for a particular build and, moreover, what variations are acceptable without compromising the quality of the resulting parts. That said, it is not only the machine in combination with the part geometry that should be taken into account when planning a build. The material choice and its properties have an equal impact on the quality of your final parts. In other words, there are many factors that prevent the adoption of standard procedures when it comes to ensuring that parts have repeatable quality for AM. At the moment, engineers need to take an iterative approach to discover the optimal combination of design, machine, material and process parameters amongst the multitude of possibilities. An important initial step to ensure repeatable quality with AM is to identify and investigate the root causes of current failures and inefficiencies, so that corrective measures can be devised.

There is no doubt that AM processes will gradually standardize. Some initiatives have already been set up to reduce the amount of required trial-and-error experiments and corrective actions during production. Through in-process monitoring and control of the complete AM process, distortion can be detected during the build process instead of after a build failure or through destructive quality checks. In addition, machine settings will eventually become adjustable during the manufacturing process. We believe that, in the longer term, in-process monitoring and control is mandatory to achieve an economically viable AM mass production process. As this is a fairly new and challenging step for AM, it is important to be aware that implementation is still a gradual process.

Process Management

"Without a proper AM process management system, scrap and surplus material can take up a significant proportion of your build. Several iterations will be required during the research, validation and production phases or else parts will be produced with inferior quality, not complying with the required standards. Depending on what you manufacture and at what scale, insufficient process control can increase product remanufactures by an additional 10%"

Bart Van der Schueren, Vice President Industrial Production at Materialise.

Monitor Production and Trace Products

Today, it is a reality that engineers must integrate constant feedback into their process and analyze their findings if they want to ensure repeatable quality. With the support of a software system that acts as a backbone to store all relevant information and ensure that proper actions can be taken, a great deal can already be accomplished in terms of simplifying this kind of research and reducing the number of trial-and-error iterations needed. Particularly when the system supports the automated labeling of parts and test bars, the relationships between different test data such as the interaction between laser and material can be better analyzed. If this system is also directly connected to the machine control software or to hardware and sensors that monitor and control the machine, a true closed feedback loop system can be created. This connection is vital to maximize control over the process and manage the predictability of its quality.

One may wonder whether it is necessary to start storing all process data and, if so, how to process such an information overload. Although you may want to record many different parameters during the research phase such as all temperature variations, melt-pool sizes, and shapes, the list of parameters that need to be traced during production will be significantly shorter. Analysis of research data has become smarter, enabling better simulations, and avoiding many trial-and-error iterations. In the future, systems offering in-process control will further decrease the need to monitor all data during production and will instead allow management by exception. Moreover, the causes of errors will already be corrected during the process instead of having to wait until the print cycle is complete.

Manage Compliance

The complexity of quality assurance increases further when creating parts such as medical implants or aerospace parts that need to comply with the FDA, ISO or other regulations. In addition to quality assurance, you need to ensure that your complete process can be tracked and traced and that a full device history record (DHR) can be consulted during the product service time. Risks such as human error must be minimized. Traditionally, traceability is supported via paperwork and well-defined processes. In the case of mass customization, the complexity of what needs to be tracked increases significantly and the paper trail becomes almost impossible to manage. By instead using a process management system, additional flexibility can be gained since such a system allows for differentiation between the procedures used during research and the ones used during the production of different kinds of parts. Automatic part serialization or labeling software combined with a database that efficiently and reliably supports tracing and report creation facilitates – or in specific cases even enables – the certification of your production quickly and with the necessary flexibility.

#03 AM, a Link in the Chain

To exploit the full potential of AM as a new manufacturing method, you also need to ensure that your AM capabilities are fully aligned with your broader business environment.

Make-To-Order

The complete AM process, from order to finished parts, must be in line with sales, overall resource planning, supply management, stock control and much more. Especially when AM is combined with conventional ways of manufacturing, the process becomes more complicated, leading to an increased need for a smooth and aligned process flow covering all of your various production techniques. Unlike most traditional production technologies, AM goes beyond just make-to-stock to also include make-to-order. In addition to providing input on certain specific standardized options – a common procedure in the automotive industry– customers can actually change and personalize the design. Although this offers new business possibilities, introduces new ways of reducing stock, and optimizes supply chains, it also creates additional challenges for the optimal integration of AM into your business.

Business Integration

To ensure that production preparation, scheduling, post-processing and quality control steps are executed timely, efficiently and to a high standard, a software system that can manage and track the complete AM process is a vital link in the chain. When connecting this database with Enterprise Resource Planning (ERP), Product Lifecycle Management (PLM), or other company systems, a continuous and seamlessly integrated flow is within reach, giving you full control over your business and providing the necessary predictability and traceability any company is looking for.

Searching for New Business Models

To keep the momentum, we not only need to focus on the technical change but also must further exploit new business opportunities. Thanks to scanning devices, design data can be easily recreated and out-of-production parts can be effortlessly reproduced with AM. This obviously raises discussions about digital rights management and intellectual property; however, at the same time, it also forms ideas about new business opportunities for companies to sell their rights and outsource the maintenance of their products. In addition, AM enables local production. This reduces stock and simplifies supply chains. Business schools clearly have an important role in investigating and driving new business opportunities and models with AM.


Discover the
Best of 3D Printing

Ready to Start the Journey?

The way we manufacture products is changing. Conventional technologies are gradually making room for 3D Printing technologies, enabling an additive way of manufacturing.

If you have identified a suitable application and want to unlock the full potential AM has to offer, you need the right focus from the start: your engineers need to adopt an AM mindset and build up application-specific AM know-how, and you will need to invest in specialized AM process management systems and software tools.
If time or resources are limited, do not try to cut corners. Instead, establish a partnership with a company experienced in AM applications, processes and software systems to get a proper head start. Only in this way will you capitalize on your investment and ensure that you manufacture products reliably with an AM technology well suited for your industry.

Whether you choose the path of partnering or you decide to build up AM know-how and experience in-house, we are convinced that with the right focus and a good understanding of the journey ahead, you can pursue your AM ambitions today!

Materialise as Your Partner

Since Materialise's foundation, our focus has been on innovating product development through our software and hardware infrastructure and in-depth knowledge of AM. We have experience in AM software development and process set-up for plastics and metals, prototyping, mass customization, series production, certified medical and aerospace production, and much more. In addition, we have enabled the creation of meaningful subsidiaries such as RSPrint, OBL, Mobelife and RapidFit+. We have established partnerships with numerous institutions such as universities, research centers, and machine suppliers, as well as companies using AM to change their industries such as Phonak, Avio Aero, Zimmer, and Formula 1 companies.

Through its consultancy, engineering, production services, and software solutions, Materialise can help you identify how AM can be beneficial for your specific needs, and equip you with all the software and systems needed to use AM yourself or develop an AM manufacturing plan for you.

Contact Us

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About Materialise

With its headquarters in Leuven, Belgium, and branches worldwide, Materialise is a provider of Additive Manufacturing (AM) software solutions and sophisticated 3D Printing services in a wide variety of industries including healthcare, automotive, aerospace, art and design, and consumer products. Materialise has been playing an active role in the field of AM since 1990 through its involvement in AM for industrial and medical applications, by providing biomedical and clinical solutions such as medical image processing and surgical simulations, and by developing unique solutions for its customers' prototyping, production, and medical needs.

The company began as a specialist in Rapid Prototyping (RP) and AM and has grown into the market leader for Digital CAD and 3D Printing software. With our intimate knowledge of the technologies and the bottlenecks, our software development stays ahead of the trends with revolutionary solutions that drive down costs, increase efficiency and help ensure repeatable quality and traceability of the complete process. We provide software solutions for every step of the AM process, from design to printed part. Together these solutions form a software platform for 3D Printing that links applications to a wide range of 3D printers and AM technologies.

As Europe's largest single-site factory for AM, with more than 120 3D Printing machines and a fully equipped factory for Vacuum Casting, Materialise houses one of the most advanced and mature AM production facilities in the world. We hold an EN9100 certification and our aerospace manufacturing process follows dedicated procedures to meet your requirements in traceability and quality control, every single time. As an EASA Part 21G certified production organization, we can deliver parts with a Form 1.
For additional information, please visit: www.materialise.com.