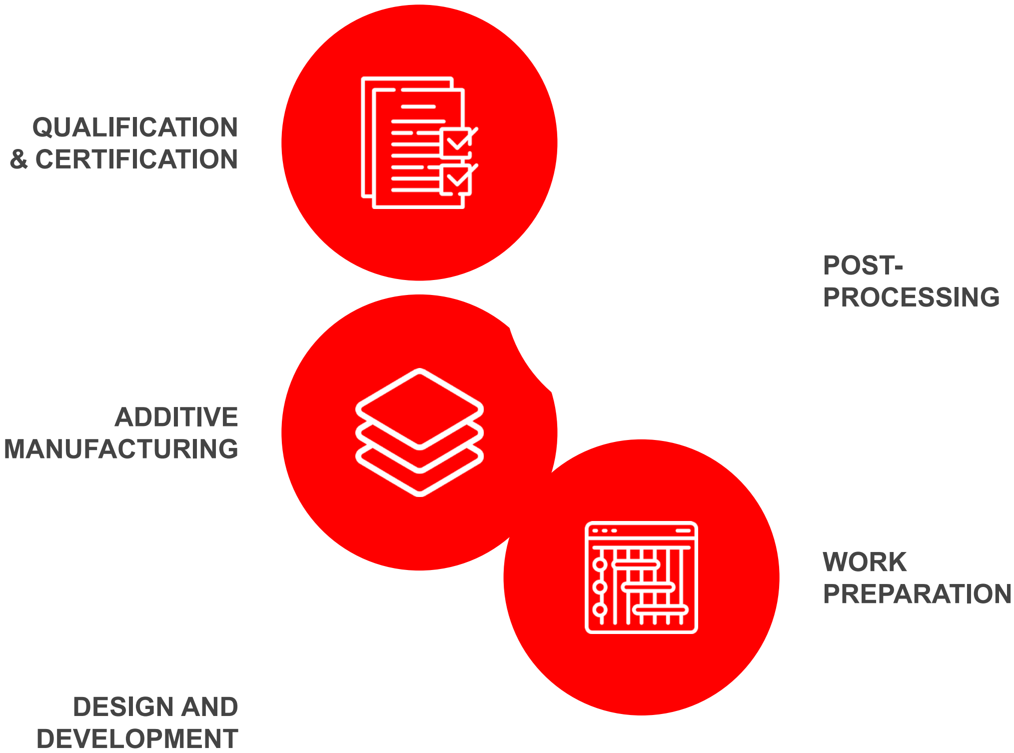
UNIVERSITY OF TWENTE.

FRAUNHOFER INNOVATION PLATFORM
FOR ADVANCED MANUFACTURING

INTEGRATED MANUFACTURING SOLUTIONS


QUALIFICATION & CERTIFICATION
POST-PROCESSING
ADDITIVE MANUFACTURING
WORK PREPARATION
DESIGN AND DEVELOPMENT

CONTENT

THE TECHNOLOGICAL PERSPECTIVE
CLASSIFICATION BY APPLICATION

APPLICATION	CONCEPT MODEL	FUNCTIONAL MODEL	PROTOTYPING TOOL	DIRECT TOOLING	DIRECT MANUFACTURING
QUALITY OF WORKPIECE PROPERTIES					
MATERIALS	**Polymer**	**Polymer** **Metal**	**Polymer** **Metal** **Sand**	**Polymer** **Metal**	**Polymer** **Metal** **Ceramic**
ADDITIVE MANUFACTURING TECHNOLOGIES	**Material Jetting** **Material Extrusion** **Photopolymerization** **Power Bed Fusion** Binder Jetting Direct Energy Deposition ...	**Material Jetting** **Material Extrusion** **Photopolymerization** **Power Bed Fusion** Binder Jetting Direct Energy Deposition ...	**Material Jetting** **Material Extrusion** Photopolymerization **Power Bed Fusion** **Binder Jetting** Direct Energy Deposition ...	**Material Jetting** **Material Extrusion** Photopolymerization **Power Bed Fusion** Binder Jetting **Direct Energy Deposition** ...	**Material Jetting** **Material Extrusion** **Photopolymerization** **Power Bed Fusion** **Binder Jetting** **Direct Energy Deposition** **...**
EXAMPLE PARTS	 Prototype Cellphone Cover	 Prototype Gearbox	 Model for Casting Die	 Injection Molding Tool	 Orthosis, Hearing Aids

ADDITIVE MANUFACTURING

INTRODUCTION

It may be amazing for some of us to know that layer-based Additive Manufacturing (AM, popularly referred to as 3D Printing) technology has been commercially available for more than a quarter of a century. Starting in some research labs, today AM as an in important group of manufacturing technologies enriches industrial production. Additive Manufacturing had a growth rate of nearly 30 % (CAGR) in the past 5 years.

It's a compelling notion to think that we can transfer the 3D designs we create on our computers into a machine that can replicate the geometry into a physical object. This can all be done without the need to concern ourselves with how each geometric feature is going to be made and in what order.

Having said that, many industries have been using AM profitably for many years. High-tech industries, like aerospace, enjoy the geometric freedom that allows them to make lightweight, high performance components, many of which are already incorporated into advanced aerospace engines and vehicles. Volume production industries, like the automotive sector, benefit from being able to prototype their models earlier and bring their products to market as fast as possible. Medical companies value the ability of AM to convert patient-specific data for customized products and medical interventions.

The most well-known AM technologies are the entry-level 3D polymer printers that can now be had for a few hundred euros, which drives a new generation of innovators, working on solutions to real-world problems. However, there are other AM technologies that we see less often that are more expensive, but faster, more accurate, with better and more varied materials, including metals and ceramics. These technologies can be really utilized as new industrial manufacturing equipment and have to be integrated in efficient process chains with further pre- and post-processing steps.

Amazing, yes, but what does that mean to you?

KEY DIFFERENTIATION CRITERIA FOR AM TECHNOLOGY

FREEDOM OF DESIGN

Lightweight

- Static: weight of parts
- Dynamic: moving accelerated parts

Complex components:

- E.g. alternative structures of heat exchangers

COST ADVANTAGE

Integrated functionality

- Embedded functionality without assembly

CUSTOMIZATION

Individualized parts

- Customer specific adaptations
- Cost efficient small series up to ‘lot size one’

TIME TO MARKET

Rapid prototyping

- Fast feasibility feedback of virtual models
- Haptic feedback

ADDITIVE MANUFACTURING

OPPORTUNITIES

Additive manufacturing offers potential solutions when conventional manufacturing reaches technological limits. These include a high degree of design freedom, lightweight design, functional integration and rapid prototyping. It is therefore not surprising that AM is increasingly used in industrial production. Technologies such as powder bed fusion are particularly popular.

New technologies like AM also pose new challenges for research. For the future, it will be essential to define criteria and describe steps that will increase scope as well as reduce costs and time for this technology. The range and complexity of different technologies is vast. Thus, companies regardless of their size cannot not simply keep track and catch up on the latest inventions.

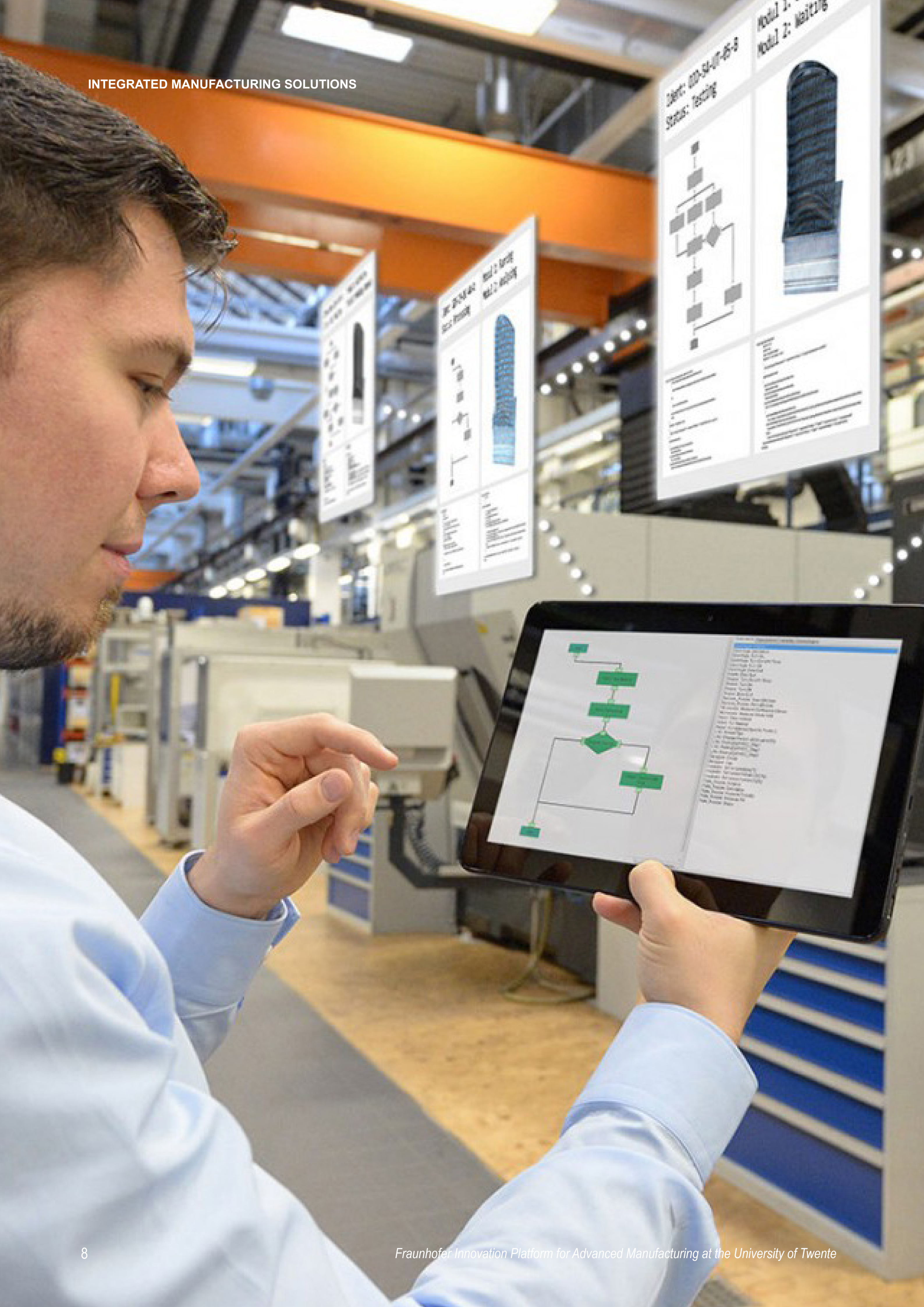
At that point, the Fraunhofer Innovation Platform provides expert support based on wide and long lasting experience and research. The center develops system solutions for adaptive production and offers integrated solutions for companies, suppliers and customers. The aim is to make AM technologies more understandable and accessible for all industries.

There are numerous ways in which competitive businesses can make a case or cases for implementing additive manufacturing, particularly when it:

- adds sufficient extra value to a product to justify additional production costs,
- reduces product development costs,
- reduces production costs,
- reduces costs over the entire value chain,
- reduces lead time or
- reduces the life cycle costs of the product.

AM can be used to increase the economic, ecological, and experiential values of products. Other values such as the freedom to produce parts in-house (eliminating the risks due to dependence on external suppliers and reducing supply chain vulnerability), protecting business secrets, and preventing piracy are difficult to quantify but certainly contribute to profitability. The “tool-less” nature of AM allows it to reduce direct productions costs when complexity and/or customization are high and when volumes are low. It can also shorten lead times compared to conventional methods. As a result, AM can lead to an overall reduction in time to market and time to profit.

Additive manufacturing found its added value initially in prototyping. However, the future and growth potential of the technology at a high level lies in direct manufacturing. This includes the production of consumer products, components and parts for industry, such as tools, machine components and other manufacturing aids.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PROCESS CHAIN

PROCESS CHAIN

It is important to realize that the AM process chain does not start with the AM machine. No AM machine would exist if it were not for 3D data models. 3D data can come from a variety of sources and it may even be that the process chain involves 3D scanning ("reverse engineering") in addition to the CAD modelling. If a 3D model is to be printed, the only major concern is whether the part will fit within the build envelope. If not, then parts may need to be broken into segments that can be assembled later. Choice of process and material may come next as well as some build parameters associated with how accurate the final part should be and how long the machine should take. In general, the more accurate you want the part, the longer it will take to build.

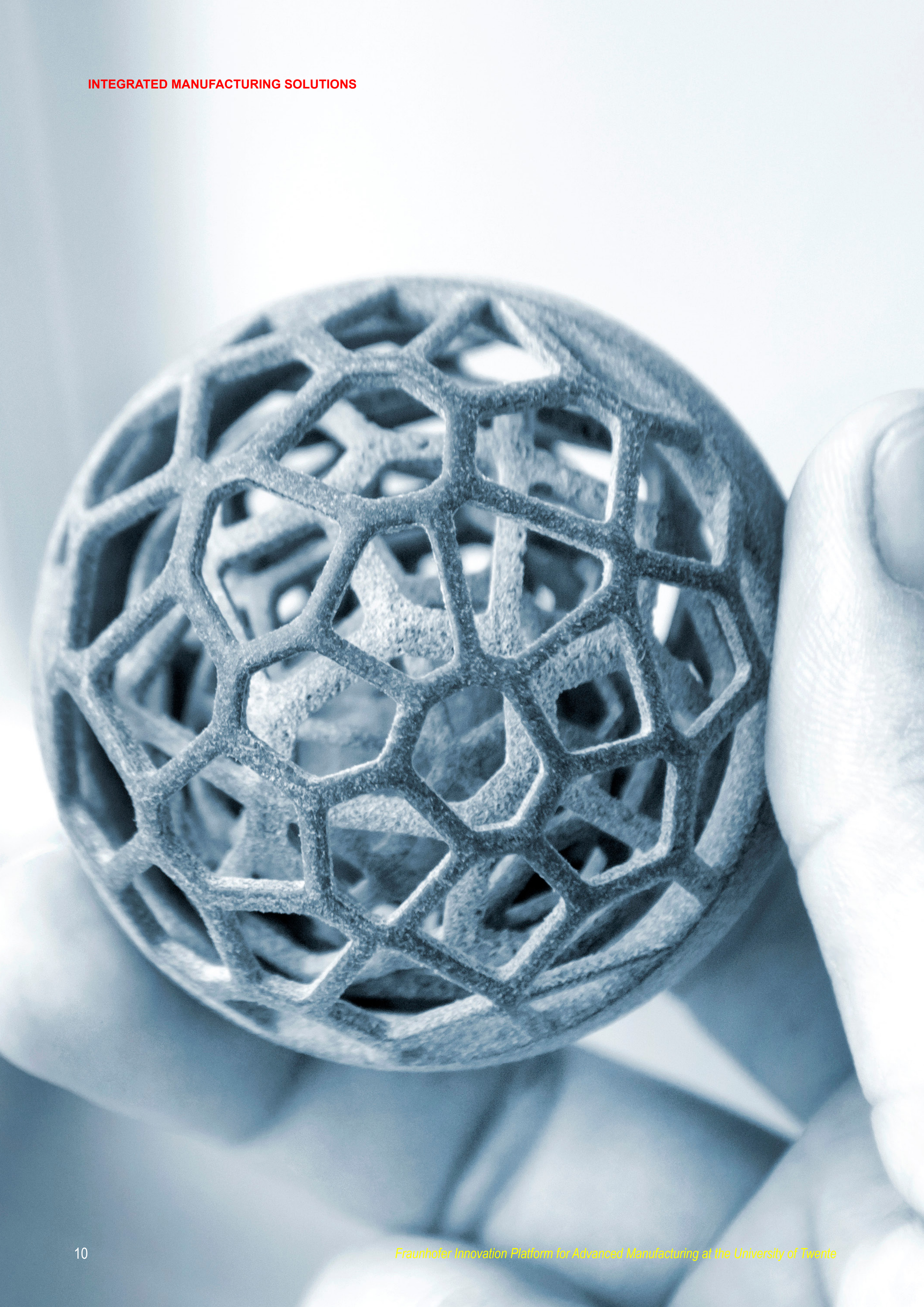
One thing that is often overlooked is the amount of post-processing that is required. This is very product specific. Some applications may be satisfied with the part as it comes off the machine. Other applications may require the parts to be cleaned, machined to precision and surface treated or polished. A major part of our work is identifying the right technologies to achieve workpiece requirements - whether created directly by AM or within balanced process chain containing further manufacturing technologies.

Industry cannot only rely on the pure application of new technologies. It is the combination with existing technologies that enable new product functionalities and keeps costs on a realistic horizon. Optimizing your process chains will thus create new possibilities and reduce the risk of waste. We offer consultancy services for all phases of a product's life cycle from development up till production and process qualification.

Conventional production is predominantly based on established process chains that have been refined over the course of several decades. In this context, design is adapted to the manufacturing technology. This means that the shape and functionality of the components are substantially influences by the manufacturing technology itself. By contrast, additive manufacturing makes it possible to replace the classic case of "design for manufacturing" with "manufacturing for design".

The following aspects should be considered in process planning:

- » What characteristics must the CAD data have?
- » Which simulation results are valuable?
- » What tolerance limits are feasible?
- » Which specific pre- and post-production processes are required?
- » Which process parameters are crucial and thus need to be monitored?
- » Which lot size has to be produced?
- » How can reproducibility and high quality be ensured?



PROCESS CHAIN

DESIGN AND DEVELOPMENT

Implementing additive manufacturing starts with the design phase. Only by considering products in a functional way, the full potential of AM technologies can be converted into successful business cases. Many products can be developed further with AM in intelligent combination with conventional manufacturing technology. The three fundamentals of material properties, product design and manufacturing technology interact in a much more seamless manner in AM. Each of these three components has several design or process factors impacting the performance of the end product. Knowledge of these mutual relationships are the key to successful development of a product using additive technologies.

In the last few years, new polymer materials specifically engineered for additive processes have been developed. Different polymers suit different AM processes and different applications. However, many popular polymers for AM have been adapted to provide good engineering properties. For example ABS is an amorphous polymer that is commonly used and suits the FDM process. Nylon is a semi-crystalline polyamide that is commonly used in SLS. There are numerous commonly used polymers in AM, some of which are certified for aerospace (e.g. flame-retardant) or medical applications (biocompatibility). Recently, many new polymer compositions with reinforcing fibers have been developed with increasing strength and endurance to suit more rigorous application in direct manufacture for professional applications.

Metal powders in AM have always suited direct applications, but are typically not developed for the AM process, yet. The most commonly used AM metal materials are steel, titanium, cobalt/chromium, or aluminum alloys. These are all widely used in almost all manufacturing industries. Work has mainly focused on tuning the minor compositions of these alloys to suit laser processing, developing spherical particle morphology and reducing the cost of production. As metal AM becomes more popular, one can expect a broadening in the range of alloys developed just for AM to include high-strength steels, magnesium, tungsten and other exotic alloys and metal-matrix composites.

AM provides great freedom for designers, with much fewer manufacturing constraints to consider. Topology optimization is the process of minimizing part geometry to suit only the function it is intended for. This approach normally results in highly complex structures with features that cannot be conventionally manufactured without breaking it up into sub-components. Such geometries are automatically generated by complex software systems that use analytical tools to determine whether material is needed within the boundaries of the application. The “geometric freedom” that is normally associated with AM is much better suited to creating topologically optimized structures.

Furthermore, the ability to create encapsulated, undercutting, honeycomb-core, deep-draw and other difficult to produce features enables the creation of “single-piece” parts that drastically reduce the number of components, thus increasing their potential reliability. Other design bonuses from AM include the ability to create living hinges, mesh structures, overlapping features and incorporate mechanistic properties with localized mechanical responses. As a result, parts can behave in very predefined ways over time according to the ingenuity of the designer, which is giving rise to the term “4D Printing”.

PROCESS CHAIN

ADDITIVE MANUFACTURING PROCESS

Additive Manufacturing is represented by a variety of different technologies that has resulted in a very large number of different machines that can be used to create mostly polymer or metal parts. These technologies can be further broken down into the generic terminology for the approach used (as defined by ISO/ASTM), how the physical layers are created for each of these approaches, and then by example commercial terminologies that use these approaches.

The most common metal printing method is powder bed fusion and there are around 20

different companies providing solutions using this approach. The most common polymer printing method is material extrusion, which is used by many hobbyists due to the low entry cost. Commercial users are likely to prefer other approaches that provide better speed, accuracy or material properties.

PROCESS CHAIN

POST-PROCESSING

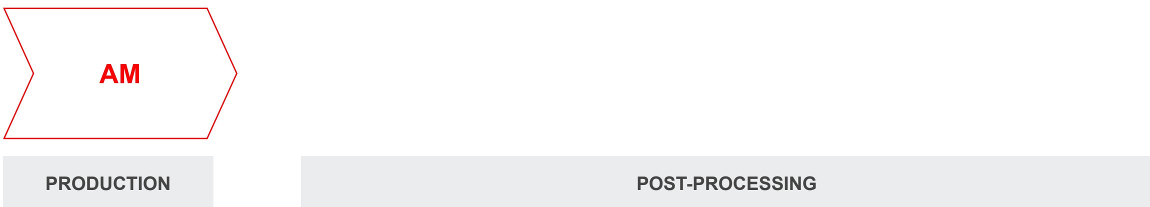
Post-processing of AM parts is a topic that is not discussed anywhere near as much as it should be. Many industrial components made by AM are not directly ready for operation. The type and amount of post-processing customizes the part to suit the final application. Although there are not many automated finishing technologies available, yet. It can require significant amounts of manual time, effort and skill to achieve a desirable high quality result. Almost every company's requirements and resources for post-processing will be unique and it is important to invest significant time to establish what would be the best approaches to integrate AM in a proper process chain - including post-processing.

One major issue with AM is that resulting parts normally have an undesirable surface texture that results from the layer-wise build-up and is particularly obvious on curved and sloped surfaces. Furthermore, the heterogeneous nature of AM can make this texture variable across the surface of complex geometry parts.

Parts may have fine features that require careful attention as well as more robust features that can withstand more rigorous finishing. Hence, a balanced selection of post-processing technologies dependent from geometry features, AM process and its parameters really lifts the potential of an excellent component based on AM.

Polymer parts can be quite soft and may have fragile features that require careful handling. Finishing can often include chemical treatments and surface coatings. Maintaining part accuracy and mechanical integrity can be an important requirement that may also be dependent on individual technical skills. This is true with metal parts too, but with greater emphasis on ensuring the mechanical properties meet the application. This may result in the need to invest in i.e. heat treatment technology or barrel finishing for post-processing besides the actual AM machine.

Overlooking the requirements for post-processing could result in a failed investment into AM!



PROCESS CHAIN

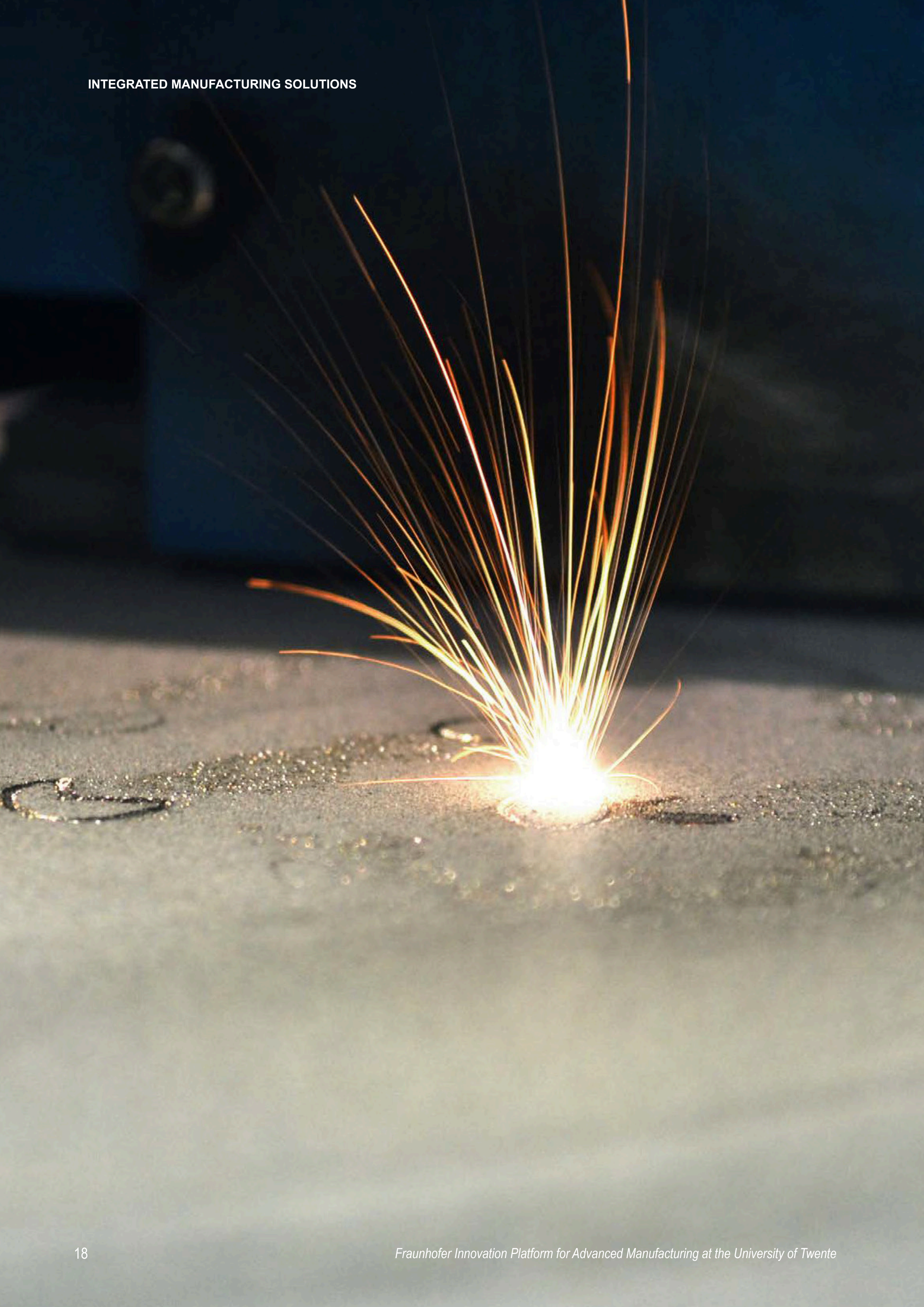
QUALIFICATION AND CERTIFICATION

AM is widely used in many industries, including aerospace, medical and automotive. Such industries are highly regulated, making extensive demands on safety, standards quality and certification. If problems occur with parts, it is vital that the manufacturer can trace back through all the processes and supply chains in order to identify the root causes and ensure that such problems do not continue. Like all technologies, AM is also subject to these regulations and it is important to ensure that machines, materials and processes are appropriate for the planned purpose. Furthermore, these technologies need to be embedded within the company's standard procedures and that associated staff are properly trained to carry these out.

Nowadays, most manufacturers are required to closely track and record batches and even individual products through their shop floors so that they know what materials, machinery, parameters and personnel were involved. AM presents its own problems in this context since they are often involved in customized products and so an individual component may be affected but the remaining batch may not. Furthermore, one aspect of AM is that it is possible to allow the product design to change without affecting the shop floor. This means that we must ensure not to step outside of acceptable standards when we take advantage of this.

Understanding the nature of these constraints maps very well into other key areas like computational analysis and Industry 4.0. Knowledge shared throughout the enterprise can help us to enhance our products whilst keeping them inside certified standard limits. We can then make us of AM to gain competitive advantages without potentially damaging our reputation.

Our experienced team of technical and organizational specialists at the Fraunhofer Innovation Platform can help you understand much more clearly how the adoption of additive manufacturing can affect, and be affected by, the qualification and certification of your products.



OUR AM TECHNOLOGIES

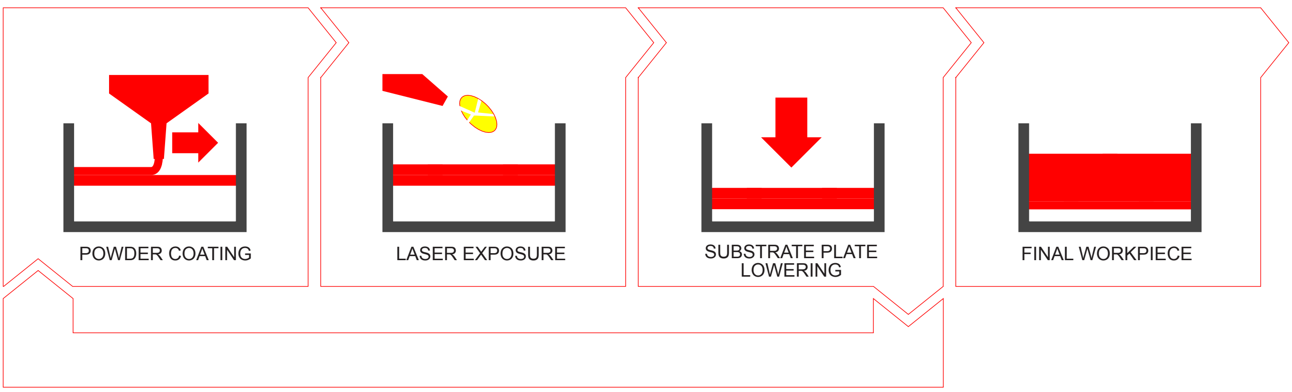
OVERVIEW

Basically, two kinds of additive manufacturing processes are available: One group of processes works in a material powder bed (e.g. L-PBF, SLM, SLS), the other group works with the deposition of material a given surface (e.g. LMD, DED, FDM).

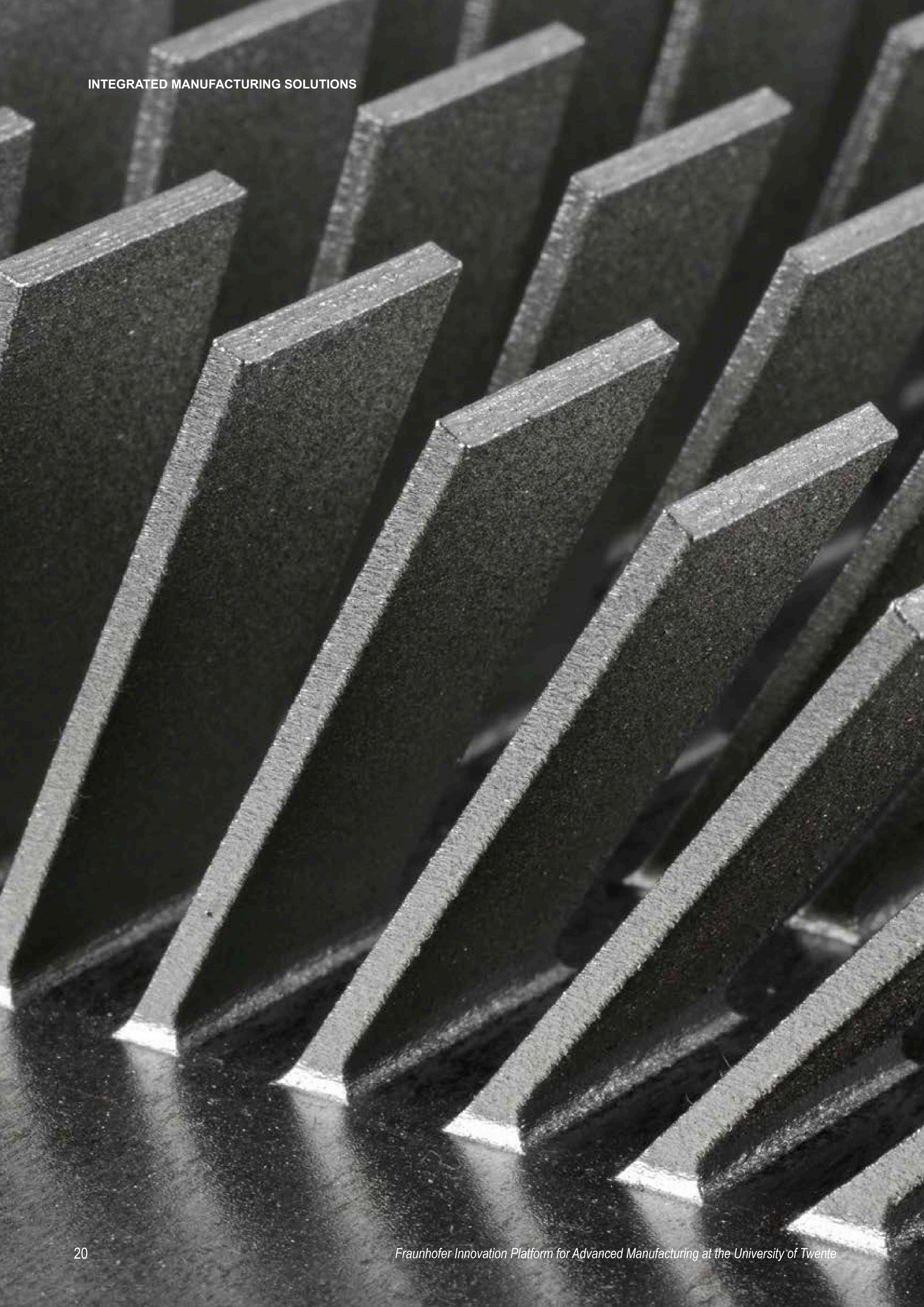
The basic principle of all powder bed-based AM machines is the same. You take the 3D geometry defined by the CAD model and break that up into a sequence of plane 2D cross-sections of a uniform and finite thickness. On each of these layers powder material is fused together. Repeat this layer by layer, the complete 3D object is built up.

In contrast to powder bed-based AM processes, deposition-based processes add material to a substrate. This substrate can be a plain plate or even a complex 3D object. In addition, here the layer thickness is finite. The added material comes from wire or also powder.

Obviously, it's more complicated than that because all manufacturing processes are constrained by size, speed, accuracy, material properties and, of course, cost. Needless to say there are a number of different machines that can achieve this basic processes, which in their own way are constrained. For example most machines require that the model being built is surrounded by some kind of support material that must be removed to reveal the final part.



Function Principle of Laser Powder-bed Fusion (L-BPF)



OUR AM TECHNOLOGIES

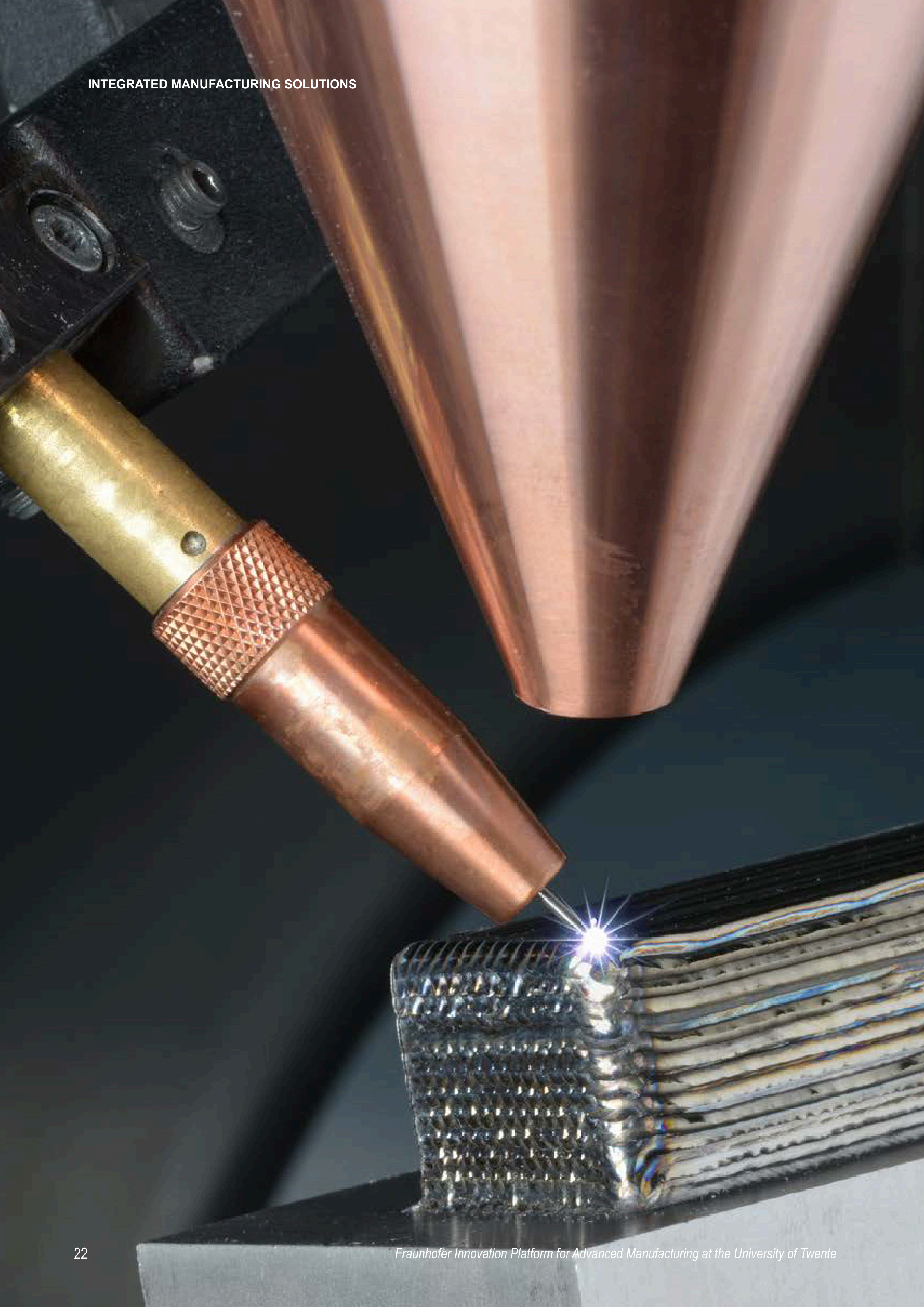
POWER BED FUSION

Powder bed fusion (PBF) relates to a range of technologies that use powder as the initial feedstock, which is spread in layers like in all current AM machines. Although other energy systems can be used (like electron beams), most PBF systems use a high power laser to melt or fuse the powder particles together. Materials can be anything that melts and then reforms in the same state and many machines are used to create polymer parts. In the last decade however, one of the largest growth sectors has been in the use of this technology to create metal parts. Such machines can create parts in steel, titanium, cobalt chromium, aluminium and other types of engineering spec alloys. Parts made from these materials have properties similar to if they were cast and can be used in medical, aerospace, automotive and other similar industries.

Sometimes, parts coming from these technologies can be used directly out of the machines. However, it is more likely that they will require a mixture of manual and machine post-processing. It is common that metal parts are built using supporting structures that connect then to a substrate platform. Wire electrical discharge machining (W-EDM) is commonly used to separate the parts from this platform. Furthermore, parts coming from PBF have a characteristically granular surface finish that may require machining, grinding, polishing, etc. to meet the final part specifications. Although they could be included in the AM build, it may also be more effective to tap screw threads and similar features into the final parts post-build.

Applications for PBF can vary from simple visual prototypes through to direct use in high performance vehicles and other high-stress purposes. The mechanical properties of the parts may suit the application but heat treatments for residual stress relief and improvement of ductility may be applicable in some cases. Surface treatments to increase hardness, chemical or corrosion resistance and for general appearance may also be required.

An effective process chain for industrial production of technical parts using PBF is essential.



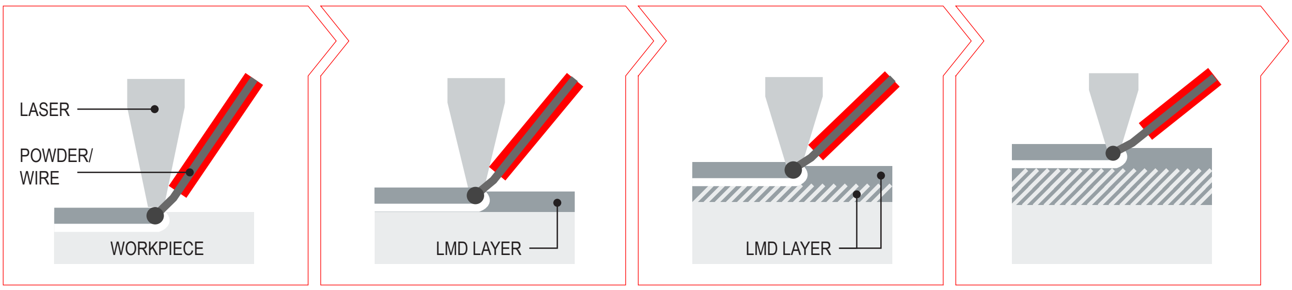
OUR AM TECHNOLOGIES

LASER METAL DEPOSITION

AM is often used synonymously with powder bed-based processes. Powder-based processes are well known for fabricating metallic components, despite disadvantages such as the difficult handling of hazardous particles, insufficient material efficiency and high machine costs. For those reasons, we also focus on the development of wire-based laser metal deposition (LMD-W). Initially designed for wear protection, LMD-W is nowadays an efficient alternative to powder-based additive manufacturing technologies. With their performance, LMD technologies are able to create real 3D parts. They do not need a plane surface to build on. Also freeform shapes can be used as a basis.

For wire-based laser metal deposition, a wire is first melted by a laser beam and then applied in layers onto the component surface - with a material efficiency of 100 percent. A special CAD/CAM software assists the gradual manufacturing process of the part. There is a wide variety of wire materials available for this kind of process: standardized filler wires, solid wires and special laser wires that allow a cost-effective application and near-net-shape manufacturing of high quality parts without porosities.

LMD-W allows a contamination-free handling. Further advantages are shorter machine setup times and quick changes of deposition material. A wide range of materials is available in different diameter sizes, alloy compositions and qualities. A precise wire feed and the adaptation of the laser spot to the respective wire diameter guarantee a highly efficient exploitation of material input and laser energy. The use of shielding gas and modern diode lasers with optical fibers also enables a flexible application of the LMD-W process on larger parts - not only on machine tools but also on robots. Thus, LMD-W is one of the cleanest and most effective alternatives to powder-based additive manufacturing processes.



Function Principle of Laser Metal Deposition (LMD)

CONSULTING, RESEARCH & DEVELOPMENT

DESIGN AND DEVELOPMENT | WORK PREPARATION | ADDITIVE MANUFACTURING | POST-PROCESSING | QUALIFICATION & CERTIFICATION

AUDIT: Ready for Additive Manufacturing

PROCESS CHAIN DEVELOPMENT

FUNCTION INTEGRATION | AM PROCESS INTEGRATION

WORKPIECE PORTFOLIO ANALYSIS | MANUFACTURING STRATEGY

PRE-PROCESSING TECHNOLOGIES | PROCESS DEVELOPMENT | POST-PROCESSING TECHNOLOGIES

FURTHER EDUCATION

DESIGN | ADDITIVE PRODUCTION | MACHINING PROCESS | PROCESS CHAIN

NETWORK

UNIVERSITIES | INSTITUTES | COMPANIES | USERS

OUR APPROACH

Additive manufacturing stands for an innovative technology that shapes the future. With AM integration in process chains, multiple advantages and opportunities such as functional integration for process chain optimization are implemented at the same time. In this way, weak points, some of which result from conventional production, are enhanced. In addition, AM offers completely new possibilities such as increasing flexibility in production, a stockless spare part production and simple integration of functional features at the place of use.

With the “Ready for Additive Manufacturing” audit, the Fraunhofer Innovation Platform supports companies with the implementation of additive manufacturing in the early stages, enabling a cost-efficient start in industrial additive production. Purchasing an AM machine is just the starting point. How to cut off a workpiece from the base plate? What are the workpiece requirements and which kind of post-processing has to be derived? We can help to answer these and further questions.

By working with us and our research partners, your company will become part of an open and successful network. Intensive consulting by the Fraunhofer Innovation Platform with the support of targeted methods for technology development and integration ensures a sustain- able manufacturing strategy.

We offers solutions:

- Analysis and design of the AM process chain with a focus on the degree of added value and standardization
- Analysis of the workpiece portfolio with regard to geometry features and tolerances along the process chain
- Development and integration of powder bed fusion and laser metal deposition processes
- Identification and development of suitable technologies for pre- and post-processing
- Development of CAM modules for AM technology integration into process chains
- Support in the implementation of process chains, e.g. in the form of technology roadmapping

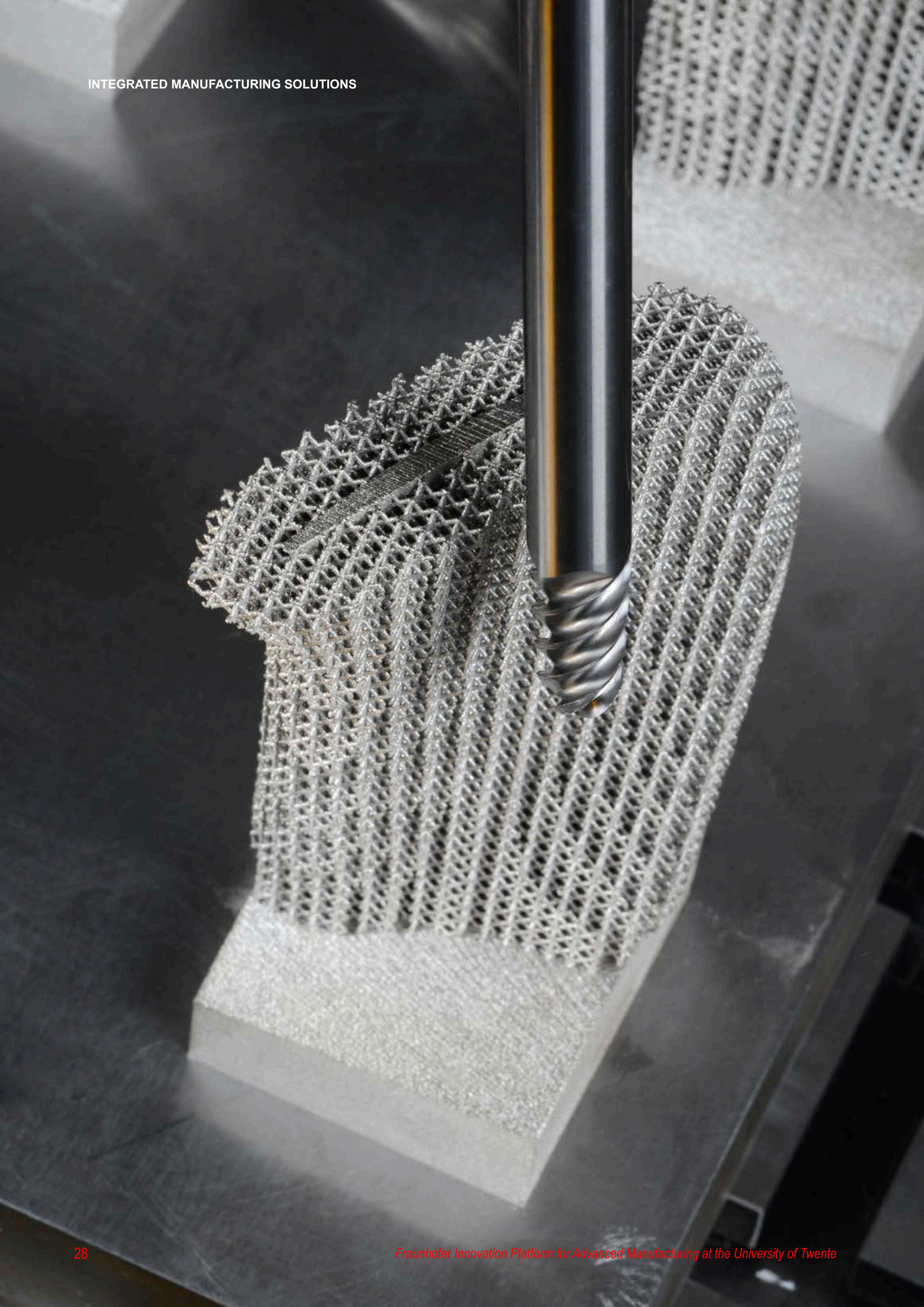
CASE STUDIES

3DS2SKY

The aerospace industry was an early adopter of additive manufacturing (AM) and began to explore applications soon after the technology was commercialized. Large Aerospace companies like GE, Boeing and Airbus are conducting intensive research programs and are increasingly taking benefit of the opportunities the AM technology provides. One of Aeronamic's major Aerospace customers is making leaps forward in developing processes and products for AM. The technology is at the verge of a breakthrough and their client is considering their supply chain strategy: will the go away from the existing supply chain, make use of (internal) 3D printing service providers, and additionally manage all suppliers providing post-processing processes or will they make us of existing, qualified aerospace suppliers with AM capabilities integrated?

Clearly, the latter option is the preferred option for companies like Aeronamic and provides them with new business opportunities, but is only viable if they develop and demonstrate AM capabilities integrated with currently existing manufacturing processes. Rigorous and consistent production quality control are big challenges to the introduction of AM in aerospace applications and must be addressed. Metal additive manufacturing is not a "push button" technology, but rather a collection of techniques, steps and specialized skills required to produce a finished part. At this point, many of the processes required to create finished parts involve a high amount of manual labor. Development of existing machining techniques is therefore required, but also new post-processing techniques will need to be developed.

The goal of the 3D2SKY project is to bring the AM technology up to a readiness level that certifies aerospace parts of material Inconel 718 can be manufactured within the environment of a Tier 2/3 supplier. The core of 3D2SKY is to understand and control the AM process parameters that lead to certified aerospace parts with predictable and consistent quality at reasonable cost. As many requirements are still unknown, material, product and process requirements will be co-developed with the current Tier 1 customer base. Participation of the Fraunhofer Innovation Platform with the Fraunhofer knowledge network is essential for this. Existing and novel post-processing techniques will be developed to enable production of finished parts in series conditions.



CASE STUDIES

SUPPORT STRUCTURES INCREASING POST-PROCESSING PERFORMANCE

One of the main features of additive manufacturing processes is that the complexity of the component shapes it produces, is virtually unlimited. However, high surface quality of metallic components can frequently be achieved only via milling or grinding finishing operations. Milling operations conducted on thin-walled parts in particular often cause vibrations which impact negatively on part accuracy and on machining time.

As a rule, metallic components manufactured additively in a selective laser melting (SLM) process, are designed to have larger-than-usual oversize to allow the functional surfaces to be finished with milling since this is the only way of ensuring that all of the surface tolerances and quality requirements can be met. Thin-walled parts are particularly prone to vibrations in the course of the machining and material removal operation either resulting in poor surface quality or even rendering the components unusable.

An innovative way to overcome these problems is to expand the design of components manufactured in additive processes by including support structures. These structures increase the stiffness of the susceptible areas and consequently reduce vibrations. The supporting elements can be removed with relatively little effort in the course of the subsequent surface finishing operation. Parts stabilized in this way can thus be manufactured in higher quality in less time and with lower level of tool wear.

This approach is facing the whole process chain: What can be adjusted in the AM process to decrease post-processing efforts? – One central question for successful AM applications.

CASE STUDIES

OPEN HYBRID

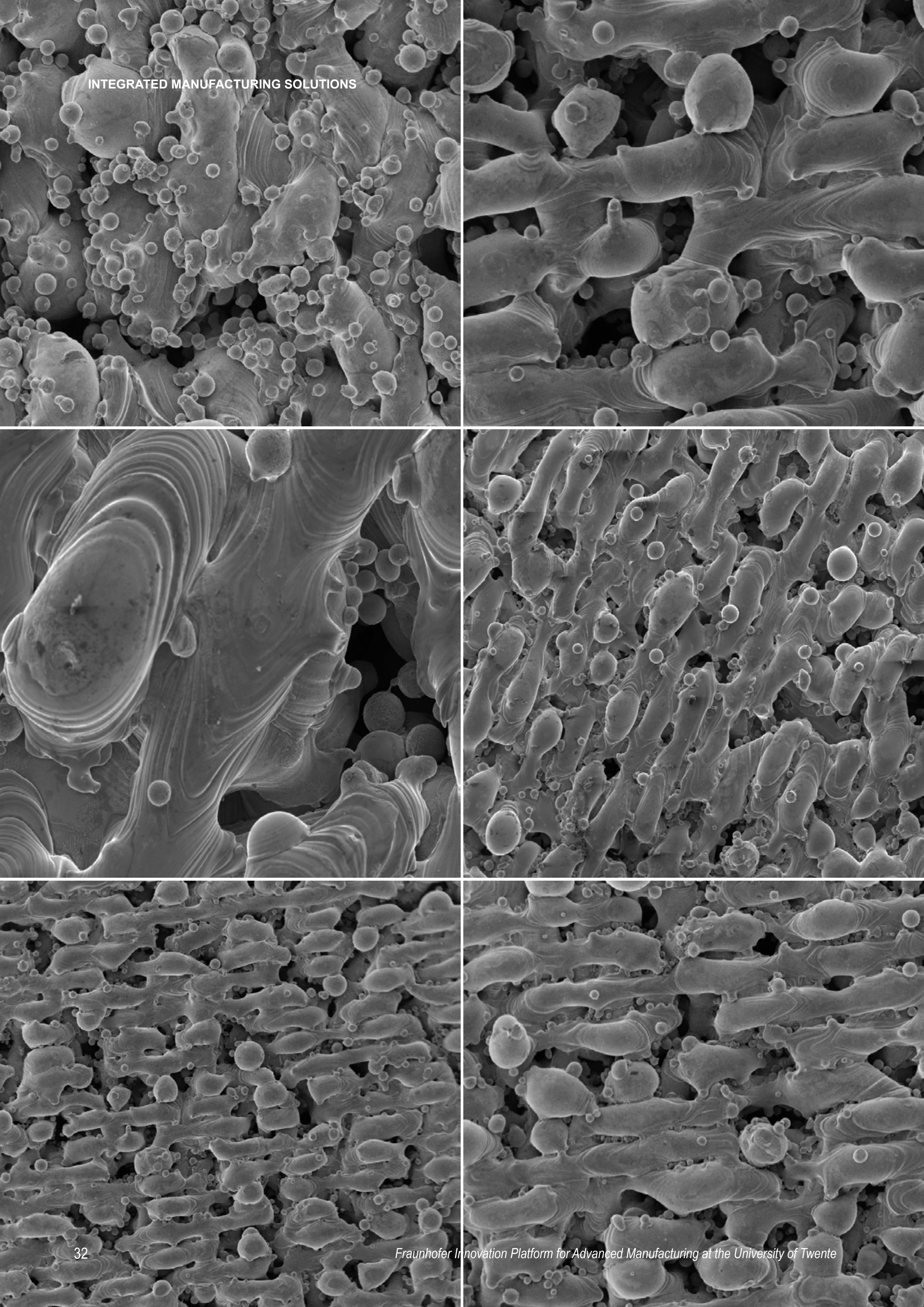
The current trend to realize hybrid machining solutions for additive manufacturing (AM), including pre- and post-processing, is driven by the potential of combining single processes in one machining system. Depending on the part characteristics, a significant reduction of manufacturing time and costs can be achieved. At the same time, the productivity of the AM process increases, especially in the case of high-volume part production. These benefits are interesting especially for industrial companies, which have to face permanently cost pressure, for instance in the field of turbomachinery or in the tool and mold making sector. However, nowadays such hybrid machining solutions still ask for intelligent and economical machine concepts, which can cover the complete process chain for hybrid AM part manufacturing.

To close this gap, EU research project OpenHybrid has been designed to address the current technical and commercial limitations and to transfer such machining solutions into industrial application. Creating the groundwork for a more widespread adoption of AM by developing innovative hybrid machine concepts equipped with subtractive and additive manufacturing technologies, OpenHybrid offers new opportunities and applications. To demonstrate this, two hybrid machining solutions – a hybrid 5-axis machine tool and a gantry system – is being setup within the project.

Therefore, one focus of the project is the development and integration of modular, changeable and compact processing heads, which will be integrated into these machining platforms. For the addressed AM processes, powder-based and wire-based laser metal deposition (LMD-P and LMD-W), the use of modular, changeable LMD processing heads, will enable to switch easily between powder and wire feed-stock within the AM process, providing unmatched flexibility in terms of material selection and combination. Furthermore, additional specific hardware and software modules for pre- and post-machining as well as quality inspection of the parts can ensure consistent part manufacturing in the same setting. These modules are:

- » Smart laser cladding head, incorporating temperature sensors and material feed sensing,
- » Laser scanning head for heat treatment, polishing and texturing,
- » Ultrasonic needle peening head for mechanical stress relieving,
- » Cleaning head for contamination control,
- » Non-destructive inspection modules and
- » CAD/CAM software modules for tool path planning.

Beside the hardware design and development,different process chains related to LMD in combination with pre- and post-processing are currently investigated.



CASE STUDIES

ADVANCED POROUS STRUCTURES

For space (and terrestrial) applications, there is a great interest for developing and designing passive two-phase thermal management solutions. For passive systems, in which the driving force typically comes from a capillary structure, the design of this capillary structure is a key aspect for achieving the optimum performance. Traditionally sintering is used for the fabrication of the capillary structures; however, with the ongoing advancements in the field of additive manufacturing (AM), it seems very promising to take advantage of the new capabilities for the fabrication of freeform-optimized capillary structures. Depending of the thermal-physical design specification of the two-phase technology under design (e.g. loop heat pipe), manufacturing capability that includes 3D gradients in porosity and freeform features would offer great advantages.

The freeform capabilities that AM offers are especially interesting for the fabrication of parts with internal channels for fluid flow, and lattices and porous structures. Currently, the limiting factor in terms of feature sizes is determined by the minimum track width (i.e. a single laser scan vector) that is solidified within the powder bed. From current industry practice it is clear that a minimum feature size of about 100 μm is common. With these feature sizes it is impossible to fabricate small pore size porous structures that resemble the pore sizes that can be achieved using traditional sintering approaches. By stepping out of the current CAM tooling and manipulating the SLM process conditions directly, achieving pore sizes beyond current capabilities and in the order of microns (5-15 μm) is desperately required.

With this research project, we aim to significantly reduce the pore size of additively manufactured porous structures. Rather than following conventional hardware and CAM tooling for selective laser melting, the laser scan parameters and powder bed conditions will be optimized specifically for fabricating small pore size porous structures. Through an extensive experimental investigation, pore sizes in the order of microns (5-15 μm) are sought. This capability would enable the generation of new innovative components featuring multiscale properties and integrated functionality, intrinsically interesting for thermal management, fuel cells, etc.

ABOUT US

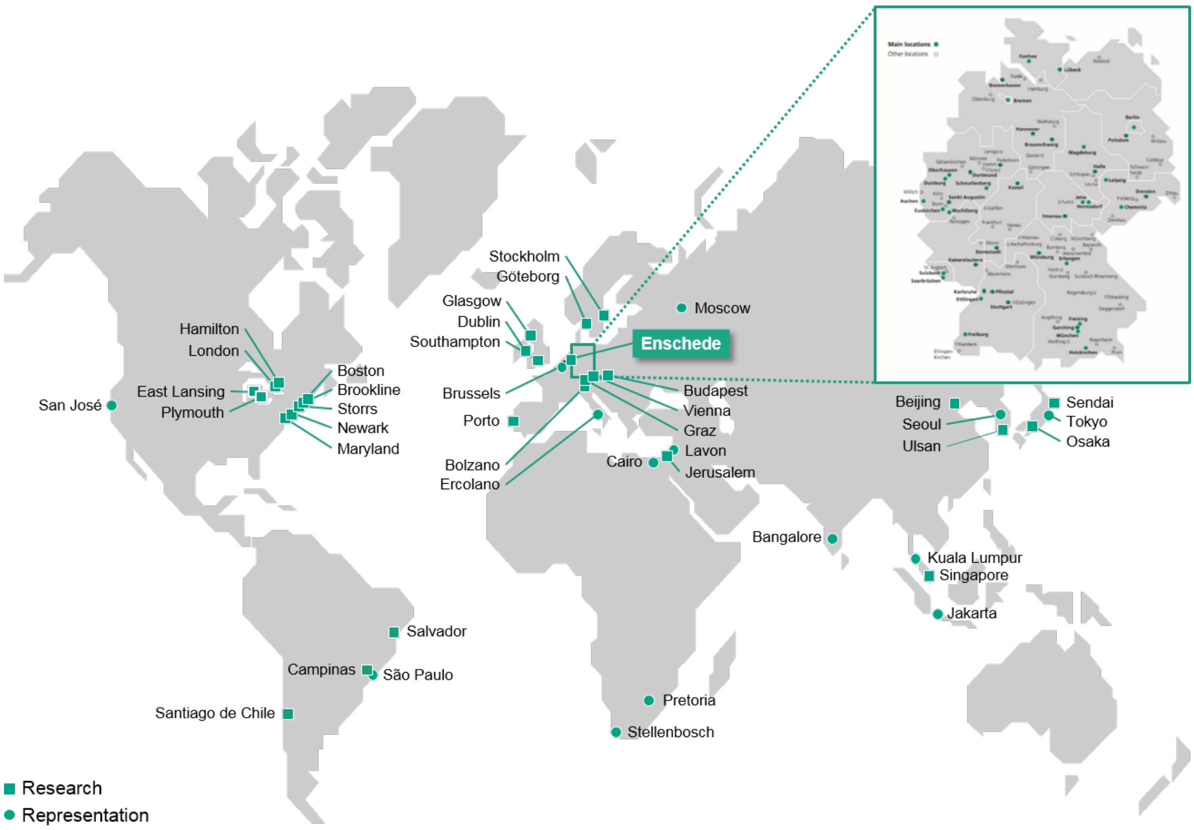
Originally known as the Fraunhofer Project Center at the University of Twente, the Fraunhofer Innovation Platform for Advanced Manufacturing emerged in 2022, continuing the strong collaboration between the Fraunhofer Institute for Production Technology IPT in Aachen and the University of Twente in the Netherlands.

The Fraunhofer Innovation Platform for Advanced Manufacturing at the University of Twente (FIP-AM@UT) is a research centre that collaborates with manufacturers to develop innovative and integrated solutions to serve and strengthen the industrial manufacturing community and benefit society as a whole.

FIP-AM@UT's primary goal is to strengthen and diversify the manufacturing sector in the Netherlands to ensure ongoing adaptability, competitiveness and efficiency. This can be accomplished by bringing highly skilled researchers and supporting staff to the region.

Their secondary goal is to source and develop innovative thinkers by engaging them in cutting-edge applied research for both industrial and public clients, and by promoting technology transfer through the joint exploitation of results.

FIP-AM@UT is part of the University of Twente (UT), the only campus university in the Netherlands. Divided over five faculties, it provides more than fifty educational programmes. In addition, UT has a strong focus on personal development, aiding and encouraging talented researchers to conduct groundbreaking research.



PARTNERS

UNIVERSITY OF TWENTE

The University of Twente is a modern, entrepreneurial university, with 3,000 researchers and professionals and over 10,000 students, leading in the area of new technologies and a catalyst for change, innovation and progress in society. The university's strength lies in its capacity to combine and work on future technologies. The University of Twente is home to powerful research institutes at the forefront of nanotechnology (MESA+), ICT (CTIT), biomedical technology and technical medicine (MIRA), governance and behavioral sciences (IGS), geo-information sciences and earth observation (ITC), and science based engineering.

FRAUNHOFER NETWORK

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 72 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of more than 25,000, who work with an annual research budget totaling 2.3 billion euros. Of this sum, almost 2 billion euros is generated through contract research. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

FRAUNHOFER IPT: INSTITUTE FOR PRODUCTION TECHNOLOGY

The Fraunhofer Institute for Production Technology IPT in Aachen has decades of experience in the production technologies it utilizes to provide companies with a strong basis for the digitization of production processes, machine tools and equipment. Technological expertise is complemented by new production organization methods and by the design of industrial software systems. The institute currently employs around 460 people who are dedicated to applying their creativity to methods, technologies and processes for a connected, adaptive production.

UNIVERSITY OF TWENTE.

FRAUNHOFER INNOVATION PLATFORM

FOR ADVANCED MANUFACTURING

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