Andreas Gebhardt
Jan-Steffen Hötter

Additive Manufacturing

3D Printing for Prototyping and Manufacturing

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Foreword

Since the late 1980s, in fact, for more than 25 years, Additive Manufacturing (AM) has been penetrating the world of manufacturing. When the layer-based technology emerged, it was called Rapid Prototyping (RP). This was the best name for a technology that could not fabricate anything but sticky and brittle parts, which could only be used as prototypes. The process was not even "rapid," although it allowed the making of time- and money-consuming tools to be avoided. With the creation of the first prototype by RP, a significant amount of time and money could be saved.

The initial process was called *stereolithography* and it was based on photo-polymerization, which first processed acrylates and then epoxies later on. In the following years, new layer-based processes were developed and an extended range of materials became qualified for AM applications, and all of them were plastics.

Around the turn of the millennium, processes for making metal parts were introduced to the market. With this development, the focus of manufacturers as well as of the users changed from just prototyping to manufacturing because of improved processes, materials, software, and control. The challenge was then to make final parts.

Today all classes of engineering materials, such as plastics, metals, ceramics, and even nontraditional materials, such as food, drugs, human tissue, and bones, can be processed using 3D printers.

There is still a long way to go, but due to vibrant activities concerning all aspects of 3D printing worldwide, this high-speed development is incomparable to the expansion of any fabrication technology in the past.

There are two main reasons for intense interesting in this technology for somebody active in the field of product development and production:

First, to stay competitive, one should be able to judge the capabilities of existing, new, and emerging AM processes in comparison to traditional manufacturing processes and process chains. The task is not just a matter of speeding up the process but to improve the way we do engineering design towards "designing for AM." This makes completely new products possible and shifts the competition of traditional manufacturing towards a new level of lightweight design, as well as resource-saving and environmentally friendly mass production of individual parts.

Second, people begin to understand that AM is not just capable of revolutionizing our way of designing and producing parts, but able to affect many aspects of our daily lives.

AM touches upon legal aspects, such as product reliability and intellectual property rights, as compared to the digital entertainment market. AM also brings even more challenges as parts can cause significant problems like physical injuries or even death, which music and videos do not do.

Digital data, including not only technical data such as a blue print, but the exact information for creating the product, can easily be sent all over the world and encounter every imaginable hurdle, such as frontiers, embargos, custom fees, export regulations, and many more. This requires us to rethink the well-functioning world of today.

Many of the questions raised, if not the majority, need to be decided by people who are not technicians. The better that those involved understand the technical part and the more thorough their information, the better decisions they will be qualified to make.

Consequently, this book was written to support the product developers and people who are responsible for the production, as well as others who are involved in the process of realizing the enormous challenges of this technology.

Aachen in March 2016 *Andreas Gebhardt*

About the Authors

Andreas Gebhardt, born in 1953, studied mechanical engineering at the Technical University Aachen, Germany (RWTH), where he received his Engineering Diploma (Dipl-Ing). In 1986 he passed his doctoral exam (Dr-Ing) at the same university with a thesis on the "Simulation of the transient behavior of conventional power plants."

In 1986, Mr. Gebhardt was appointed general manager of a company that specialized in engine refurbishment. In 1991, he moved to general manager at the LBBZ GmbH, a service bureau on laser material processing, where in 1992, he started working on rapid prototyping. When in 1997, the CP Center of Prototyping GmbH, an Additive Manufacturing Service Bureau was founded, he transferred there as a general manager.

With the beginning of the spring term in 2002, Mr. Gebhardt was appointed Professor for Advanced Fabrication Technology and Rapid Prototyping at the Aachen University of Applied Sciences (FH Aachen) where he established an AM Team and Lab called the GoetheLab for Additive Manufacturing. Since 2002, Mr. Gebhardt has also been a guest professor at the City College of the City University of New York (CCNY).

In 2012, Mr. Gebhardt was elected Dean of the Department of Mechanical Engineering and Mechatronics, FH Aachen. In November 2014, he was appointed extraordinary Professor at the Tshwane University of Technology (TUT), Pretoria, RSA.

Mr. Gebhardt is Chairman of the AM Research Committee (FA13) of the German Welding Association (DVS) and he heads the team of the "Aachen Center of 3D Printing," a joint research group of FH Aachen and Fraunhofer ILT AM specialists.

Since 2004 Mr. Gebhardt has been the editor of the peer-reviewed, open access online journal on AM called the RTeJournal.

Jan-Steffen Hötter, born in 1987, received his Bachelor's Degree (B.Eng.) and Master's Degree in Mechanical Engineering (M.Eng.) from the Aachen University of Applied Sciences, Aachen, Germany. He established the Metal Laser Sintering Lab and Team under the umbrella of the GoetheLab, which he now is heading. He is engaged in the Aachen Center of 3D Printing and coordinates the AM work of the Institute for Tool-less Production (IWF GmbH). Mr. Hötter is a member of the VDI Committee "Additive Manufacturing," and gives guest lectures at several German universities.

Acknowledgements

The interdisciplinary character and the enormous developmental speed of AM in general, and of the layer-based fabrication processes and machines in particular, make it almost impossible for an individual to display this discipline correctly, completely, and entirely up-to-date.

We are therefore very thankful for the enormous assistance from many people.

The practical orientation of this book mainly is backed up by the contribution of the management and the staff of the AM Service-Bureau CP-GmbH, mainly from Besima Sümer, Christoph Schwarz, and Michael Wolf.

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Andreas Gebhardt

Jan-Steffen Hötter

Contents