Eujin Pei · Mario Monzón
Alain Bernard *Editors*

Additive Manufacturing—Developments in Training and Education

Springer

Additive Manufacturing—Developments in Training and Education

Eujin Pei · Mario Monzón
Alain Bernard
Editors

Additive Manufacturing—Developments in Training and Education

Springer

Editors
Eujin Pei
College of Engineering, Design
and Physical Sciences, Institute
of Materials and Manufacturing
Brunel University London
London
UK

Alain Bernard
ILS2N UMR CNRS 6004
Ecole centrale de Nantes
Nantes CX 03
France

Mario Monzón
Edificio de Fabricación Integrada
Universidad de Las Palmas de Gran Canaria
Las Palmas de Gran Canaria, Las Palmas
Spain

ISBN 978-3-319-76083-4 ISBN 978-3-319-76084-1 (eBook)
https://doi.org/10.1007/978-3-319-76084-1

Library of Congress Control Number: 2018942921

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Putting together this book has been more rewarding than I could have ever imagined. It would not have been possible without the love and encouragement of my parents, Daniel and Lilian, without whom I would never have enjoyed so many opportunities. A big Thank You to my wife, Ying for her enduring support and bearing with me for all the late nights. This book is dedicated to my Grandmother who has always been there for me.

Eujin Pei

Foreword I

Technology is changing the way people live, work and do business. Digitalisation and automation are framing our future. This creates new and exciting opportunities, but at the same time challenges. Many of today's jobs did not exist a decade ago. New jobs in the future will require new skills. We need to ensure our workforce is ready to reap the benefits of change. Because our capacity to continue driving innovation in Europe will to a great extent be determined by how much we invest in people and their skills.

Today, more than 30 million workers form the backbone of the manufacturing industry in Europe. They make the world-class products that keep us ahead of other global competitors.

Manufacturing, together with other key sectors like renewables and green technology, has the potential to drive innovation. But in a fast-changing world, the question of which skills are relevant, and how to anticipate these skills needs is crucial. Without the people with right skills, they cannot reach their potential.

That's why, in 2016, I launched a 'Blueprint for Sectoral Cooperation on Skills' under the new Skills Agenda for Europe. This initiative focuses on closing the skills gaps in key economic sectors. Industry-led partnerships will map skills needs and trends in their sector which are holding back growth. The idea is to develop new curricula that address gaps and ways to boost development of the skills needed.

Additive manufacturing and 3-D printing is one of the 11 sectors that we have identified to implement the Blueprint. This sector requires multidisciplinary teams formed by people with highly diverse backgrounds and skills sets that are at the heart of the race for global competitiveness and leadership. Additive Manufacturing and 3D-Printing sector, one of the most disruptive advanced manufacturing technologies is expected to have an economic impact up to EUR 200–500 billion annually in 2025.

Setting up a sustainable Erasmus + Alliance on skills development between key industry stakeholders in the sector and education and training will be an important step. We know from the past what difference European cooperation can make. European cooperation brings new ideas and approaches to national reform processes, not only at political but also at the grass-roots level. Business and industry anyway think in terms of transnational supply chains and not in national ones. European sectoral cooperation on skills can adjust education and training to this reality. Growing automation of manufacturing processes will require all industry workers to have increased technical skills. Workers will need to acquire skills in digital techniques, computing, analytical thinking, machine ergonomics and manufacturing methodologies. By educating and training our students and labour force, we will ensure that Europe stays at the forefront of disruptive technologies.

I am pleased that CECIMO, the European Association for the additive manufacturing industry, is a strong ally in defending the added-value of EU-funded initiatives on education and training issues by being actively involved in European funded projects on entrepreneurial skills in the machine tool industry and developing vocational training and apprenticeships in 3D-Printing.

This book has built on these projects and will ensure that industrialists, professionals, educators, trainers and researchers become aware of much needed modern educational content and training practices to make our workforce ready for the future.

Brussels, Belgium

Marianne Thyssen
European Commissioner for Employment
Social Affairs, Skills and Labour Mobility

Foreword II

Additive Manufacturing (AM) is a technological marvel that has been attracting the attention of many over these last few years. Often referred to in the mass media as 3D Printing, AM has in fact been around for a lot longer than most people are aware, with the first systems becoming commercially available in the early 1990s. Most of the general public became aware of this technology only recently as machines became more widely available due to dramatic reductions in machine costs combined with easy access to related technologies like 3D Computer-Aided Design, mobile computation, 3D image capture, the Internet, etc. Because of this, there has been huge growth in the industry and there are now hundreds of thousands if not millions of machines in use today.

This, however, causes problems as well as solutions. The main problem associated with this book is that many people now think they know all about AM because they have seen machines in school classrooms or the local hardware store. They are not aware that there are many types of machines and applications from the very simple to the extremely complex. Furthermore, these machines can be used in a bewildering number of areas from conventional model-making through to replacement body parts. AM is used in $300 machines that allow you to design and replace a broken cupboard door handle in your home through to multi-million dollar aerospace manufacturing facilities building the jet engines of the future. When you look at AM this way, it is quite clear that there is more to it than just melting some plastic and creating a 3D model. People need to be made aware of this and so it is vital to have high-quality education in this sector.

I am really pleased that this book has come out. It provides insight into how AM can be applied to teaching and training in a number of contexts. It describes how AM has been a part of the latest stages of the manufacturing industrial revolution and how it has helped to form new thinking in product design and development. It also covers a number of issues surrounding AM like research, technology transfer, intellectual property and AM's relationship with other technologies. It discusses how AM technology is developing as well as how it is a tool to assist learning other areas like design, manufacture, etc. I know nearly all the editors and authors of this book either personally or by reputation. I believe that this book is written by the right people who have the right knowledge and experience to explain how AM can, is and should be implemented in the classrooms, teaching laboratories, training facilities and general maker spaces to ensure we get the fullest potential from it. It comes out at the right time and I trust it will influence many on how to proceed from here with AM.

Geelong, Australia

Ian Gibson
Professor of Additive Manufacturing
School of Engineering, Deakin University

Preface

Additive Manufacturing (AM) is a rapidly developing technology and having well-trained specialists are essential. A future-ready workforce requires the development of new AM training programmes and teaching curricula that not only addresses the employer's needs and includes both technical and business aspects. As a result, educational content and training guidelines need to be updated, so as to ensure that industrialists, educators, researchers and professionals are kept relevant and aware of current practices related to AM. As more and newer jobs around AM will be created, there is a need to develop specific teaching and training strategies that can develop the employability or re-skilling of professionals and workers. This book brings together the contributions of leading experts to discuss aspects of new means of teaching, providing training programmes to gain alternative employment pathways, the need for certification by professional bodies and using community-oriented maker spaces to promote awareness of AM among the society. We hope you will enjoy reading this book.

London, UK — Eujin Pei
Las Palmas de Gran Canaria, Spain — Mario Monzón
Nantes CX 03, France — Alain Bernard

Review I

David Bourell
Professor of Mechanical Engineering and Materials Science and Engineering
The University of Texas at Austin, USA

This book serves a critical need for a more advanced text that takes the reader to the next level once the basics of additive manufacturing (AM) are understood. In this regard, the topics covered are spot on. Overall, the text will be of great use to academics and industrialists who desire to take second and third steps towards fully implementing a culture of AM into manufacturing. The book is much more than just training and education in AM. It moves well beyond this to the integration of AM into industrial practice with practical advice on how to accomplish this. The chapters are written by world experts in their respective areas of AM. Coverage includes when to use AM, when to displace conventionally manufactured parts with AM parts, and more importantly defines the criteria for making such alterations. Standards development in AM is continuously evolving, and the opening chapter provides a clear snapshot of the current state. Chapters "Additive Manufacturing: Instrumental Systems Used in Research, Education, and Service" and "Introducing the State-of-the-Art Additive Manufacturing Research in Education" will be of great use to new academics who find themselves in an AM research environment. Chapter "Developing an Understanding of the Cost of Additive Manufacturing" deals with cost of AM parts. Baumers and Tuck, world experts in this area, have done an excellent job of outlining the cost factors for AM. Chapters "Additive Manufacturing Validation Methods, Technology Transfer Based on Case Studies" and "Teaching Design for Additive Manufacturing Through Problem-Based Learning" extend the value proposition of AM by considering improvements in performance enabled by AM. Intellectual property issues are of great importance generally, and a chapter is devoted to this topic as it applies to AM. Chapter "FoFAM and AM-Motion Initiatives: A Strategic Framework for Additive Manufacturing Deployment in Europe" gives an excellent overview of some of the socio-political impacts of AM as applied to developments in the European forefront. Chapter "The Machine Tool Industry's Changing Skills Needs: What is the Impact of Additive Manufacturing Technologies?" is a refreshing look at an often forgotten application area of AM: tooling. With so much emphasis on aerospace and biomedical applications, the longstanding use of AM in tool generation is overlooked, and most of the issues and recommendations of this chapter are broadly applicable to the general integration of AM into existing manufacturing. Chapter "Teaching Design for Additive Manufacturing Through Problem-Based Learning" provides an excellent closure to the textbook by focusing on the use of AM in design starting at the earliest stages of the design process, rather than taking an existing part made using conventional manufacturing and porting it over to AM. In this way, AM stands on its own merit during the part configuration stage of design, and the impact of design freedom enabled by AM can be fully implemented.

Review II

Ian Campbell
Professor of Computer Aided Product Design and Editor-in-Chief of the Rapid Prototyping Journal
Loughborough Design School, Loughborough University, UK

Additive manufacturing (AM) is indeed a rapidly growing discipline and there is a current shortage of qualified personnel at every level. New courses and programmes need to be developed to meet the needs of every level, from technician to Masters student. The proposed book will provide valuable material for curriculum development in that it covers a series of examples explaining how AM training and education has been or should be implemented. Of particular value is the collaborative nature of the work presented, involving education providers, industry and government. It is essential that this 'triple-helix' approach is followed if AM training and education (and therefore AM implementation) is to reach its full potential. Also of great interest to readers will be the multi-national background of the chapter authors. It is valuable to see the different approaches used in different countries, as well as the different topics that need to be considered. The range of topics covered is impressive, covering the entire value chain. Thus, the book could be used to inform a wide-ranging Masters-level programme or very focused industrial training courses on costing, intellectual property, or standards, for example. Therefore, the potential market for the book is extensive, covering academic institutions, training organisations, internal training departments in companies and even government departments. It could also be a useful textbook for students of AM at all levels.

Contents

About the Editors

Dr. Eujin Pei is the Director for the Product Design and Product Design Engineering programmes at Brunel University London. His research focuses on Design for Additive Manufacturing and Applications for Functionally Graded Additive Manufacturing. He is the Convenor for the International Standards Organisation Technical Committee ISO/TC261/WG4 and Chairs' meetings related to Data Transfer and Design for Additive Manufacture. He is Chair for the British Standards Institute BSI/AMT/8 for Additive Manufacturing. Eujin is also a Chartered Engineer (CEng) and a Chartered Technological Product Designer (CTPD). He is active in various industry and knowledge transfer projects in the UK and across EU. Eujin is also the Managing Editor for the *Progress in Additive Manufacturing Journal* published by SpringerNature.

Mario Monzón Professor of manufacturing processes at University of Las Palmas de Gran Canaria. Coordinator of a research group of integrated and advanced manufacturing. Coordinator of a Ph.D. programme in Chemical, Mechanical and Manufacturing Engineering. Member of ISO TC261 and CEN TC438. Founding member of the Spanish Association of Rapid Manufacturing (ASERM). Member of the editorial board of the *Journal Bio-Design and Manufacturing* (Elsevier).

Prof. Alain Bernard 58, graduated in 82, Ph.D. in 89, was Associate Professor, from 90 to 96 in Centrale Paris. From September 96 to October 01, he was Professor in CRAN, Nancy I, in the 'Integrated Design and Manufacturing' team. Since October 01, he has been Professor at Centrale Nantes and Dean for Research from 07 to 12. He is researcher in LS2N laboratory (UMR CNRS 6004) leading the 'Systems Engineering—Products-Processes-Performances' team. His research topics are KM, PLM, information system modelling, interoperability, enterprise modelling, systems performance assessment, virtual engineering and additive manufacturing. He supervised more than 30 Ph.D. students. He published more than 150 papers in refereed international journals and books. He is Vice-President of AFPR (French Association on Rapid Prototyping and Additive Manufacturing), Vice-Chairman of WG5.1 of IFIP (Global Product Development for the whole product lifecycle) and member of CIRP Council. He coordinated and coauthored two books in French in the field of Additive manufacturing: Le prototypage rapide (Hermès, 1998); Fabrication additive (Dunod, 2015). Actually, he is leading an Industry 4.0 project at Centrale Nantes and is developing a learning factory with its digital twin.

Knowledge Transfer and Standards Needs in Additive Manufacturing

Mario Monzón, Rubén Paz, Zaida Ortega and Noelia Diaz

1 Introduction

Although Additive Manufacturing (AM) technologies have high potential in terms of productivity and competitiveness for companies, their diffusion is still relatively limited among manufacturers and end users. The high cost of this equipment could be a key reason, but there is a general agreement that there is a lack of deep knowledge of these technologies as well as skills for implementing them in companies. Several publications, books and journals specialized in AM (Gibson et al. 2010; Chua et al. 2010) are currently available. In addition, AM has been being recently introduced in many university programmes by the adoption of low-cost equipment for teaching laboratories. Some examples of this equipment are RepRap and RapMan. Both of them use the extrusion-based method (Fused Deposition Modelling) and can build a replicated machine following the instructions supplied and printing the parts needed for the assembly. However, these resources are mainly addressed to scientists and students rather than to companies that need to implement these new technologies in reasonable time to decide if and how to adopt them. This chapter presents an alternative view on how, starting from the development of knowledge in the context of standards in AM, the new standards can provide a real training process taking into account the valuable inputs from industry, academy and final users (Sect. 4). First, Sect. 2 shows a previous view about the current progress on AM standardization in the committees of ISO, ASTM and CEN as well as recommendations in relevant projects carried out such as SASAM (Feenstra et al. 2014). In Sect. 3, some initiatives and projects about learning in AM are presented, in particular, the experience of the authors in the European project KTRM.

M. Monzón (✉) · R. Paz
Department of Mechanical Engineering, University of Las Palmas de Gran Canaria, Las Palma, Spain
e-mail: mario.monzon@ulpgc.es

Z. Ortega · N. Diaz
Department of Processes Engineering, University of Las Palmas de Gran Canaria, Las Palma, Spain

E. Pei et al. (eds.), *Additive Manufacturing—Developments in Training and Education*, https://doi.org/10.1007/978-3-319-76084-1_1

2 Standardization Needs in Additive Manufacturing

Standards are technical documents that define requirements, specifications or guidelines to specify test procedures or quality and safety attributes of materials, products, processes and services. The AM community and industry have been aware that the lack of standards is an important barrier to the more general adoption of AM, mainly in those sectors under strict rules of regulation (medical, aerospace, automotive, etc.). Several factors strongly influence the limited applicability of conventional standards to AM, being the anisotropy and the modification of mechanical properties, depending on the process parameters, the key issue to deal with (Puebla et al. 2012). Nevertheless, for the last years, several international organizations have been working on the development of new standards for AM (ASTM F42 since 2009, ISO TC261 since 2011 and CEN/TC 438 since 2015), with significant number of standards approved so far. Table 1 shows a summary of standards approved by these international organizations until 2017.

It is important to note the following appointments: in a meeting held in Nottingham, UK, in July 2013, ISO TC261 and ASTM F42 agreed jointly to develop AM standards. This was, without any doubt, a relevant landmark for further development of AM standards under a common interest. In 2015, CEN created a new Technical Committee CEN/TC 438, adopting, if possible, those standards agreed by ISO and ASTM. The collaboration between ISO and ASTM takes place by periodic face to face or online meetings, where groups of experts for each side discuss and develop the new proposed standards. In Table 1 is observed those common standards in ISO, ASTM and CEN. Another relevant highlight agreed between ISO TC261 and ASTM F42 was the general structure of how the developed standards should be fitted. In this structure, there are three levels and different target areas in each level (Monzon et al. 2014). From the top to the bottom, the levels are General AM standards; Category AM standards; Specialized AM standards. The target areas are Raw materials; Process equipment; and Finished parts.

Several initiatives have been carried out in different countries to support the development of standards for AM (Monzon et al. 2014), but it should be highlighted the support action funded by the European Commission in 2014, the project SASAM (Support Action for Standardization in Additive Manufacturing) (Feenstra et al. 2014). Among other actions in SASAM, a survey studying the standards needs of the AM community was carried out. In this survey, a group of 122 industrially-driven stakeholders indicated the need and type of standards to be developed. A number of standards categories were distinguished such as design, specific industrial needs, quality of manufactured parts, safety (regulations) and education. These needs were summarized in the roadmap of SASAM (Feenstra et al. 2014). The roadmap is based upon priorities (on a scale from 0 to 5) and it adopted the above-mentioned structure agreed by ISO and ASTM. Since many of the partners of the SASAM project are experts in either ASTM F42, ISO TC261, or CEN/TC 438, some of these recommendations have been implemented in the developed standards, contributing to the successful result of the SASAM project.

Table 1 List of approved standards until 2017

Topic	ISO	ASTM	CEN
Additive manufacturing—General principles—Part 2: Overview of process categories and feedstock	ISO 17296-2:2015		EN ISO 17296-2:2016
Additive manufacturing—General principles—Part 3: Main characteristics and corresponding test methods	ISO 17296-3:2014		EN ISO 17296-3:2016
Additive manufacturing—General principles—Part 4: Overview of data processing	ISO 17296-4:2014		EN ISO 17296-4:2016
Additive manufacturing—General principles—Terminology	ISO/ASTM 52900:2015	ISO/ASTM 52900:2015	EN ISO/ASTM 52900:2017
Additive manufacturing—General principles—Requirements for purchased AM parts	ISO/ASTM 52901:2017	ISO/ASTM 52901:2017	
Specification for additive manufacturing file format (AMF) Version 1.2	ISO/ASTM 52915:2016	ISO/ASTM 52915:2016	EN ISO/ASTM 52915:2017
Standard terminology for additive manufacturing—Coordinate systems and test methodologies	ISO/ASTM 52921:2013	ISO/ASTM 52921:2013	EN ISO/ASTM 52921:2016
Standard Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing		F2971-13	
Standard Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes		F3122-14	
Standard Guidelines for Design for Additive Manufacturing	ISO/ASTM52910-17	ISO/ASTM52910-17	
Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion		F2924-14	

(continued)

Table 1 (continued)

Topic	ISO	ASTM	CEN
Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion		F3001-14	
Standard Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes		F3049-14	
Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion		F3055-14a	
Standard Specification for Additive Manufacturing Nickel Alloy (UNS N06625) with Powder Bed Fusion		F3056-14e1	
Standard Specification for Powder Bed Fusion of Plastic Materials		F3091/F3091 M-14	
Standard Specification for Additive Manufacturing Stainless Steel Alloy (UNS S31603) with Powder Bed Fusion		F3184-16	
Standard Guide for Directed Energy Deposition of Metals		F3187-16	

3 Training Needs and Knowledge Transfer in Additive Manufacturing

In the context of education, in the field of manufacturing processes, the topic of Additive Manufacturing is still going slowly in terms of its inclusion as part of the content of the different curricula at all academic levels, as well as at industrial training. Other methods such as subtractive processes (milling, turning, etc.), welding, casting, forming, etc. are very well represented in the support material for training. Many reasons could explain this but some of them are summarized as follows: conventional procedures have been used for decades, even centuries. The latest advance of these traditional procedures has introduced technological innovations but always keeping the same basic process. For instance, conventional milling machines became into CNC milling machines, but the concept itself is the same. This allows developing books or training content suitable to be up to date for several years, with just a few modifications when necessary. Since the concept of Rapid Prototyping turned up in the 90s (first just as a method for making formal or functional prototypes), many different patents and methods reached the market, but many others could not be successful. This impressive number of new technologies for plastics, metals and ceramics has had a huge capacity of evolution, being quite difficult to arrange them under closed categories. This characteristic, together with the specific materials for AM and the lack of methods for predicting the mechanical behaviour of AM parts, have hindered the process of training. We are facing, without any doubt, a new concept of manufacturing and the traditional rules for teaching manufacturing processes or design require new methods and procedures. One important issue to take into account is that AM for metals requires a different expertise than for example AM for plastics. Although all AM technologies start from a similar base (3D digital data and layering software) the process is different and the behaviour of the material is not the same. This means that an expert in metals for AM is not necessarily an expert for plastics and AM. Although many people think that the training process for metals and plastics could be done on the same basis, the real need of the industry probably requires a more specific training. Even at the same level of plastics or metals, the technologies available in the market start with clear differences and the specialization on each one for increasing the productivity and quality is other relevant issue to take into consideration. Although several books have been edited (Gibson et al. 2010; Chua et al. 2010; KTRM 2012) all of them require more updates at short term than any other handbooks of technology. In any case, the mentioned books are focused on the general technology, but not on specific technologies. Some road maps of AM have highlighted the need of education in AM. For instance, the first relevant roadmap was the one published by the University of Texas at Austin (Bourell et al. 2009), where two recommendations were give as follows:

- To develop university courses, education materials, and curricula at both the undergraduate and graduate levels, as well as at the technical college level.
- To develop training programmes for industry practitioners with certifications given by professional societies or organizations.

Similar conclusions were given in the strategic research agenda of the European sub-Platform of AM (Platform 2014), with the following main recommendations:

- Development of a series of training modules for specific AM processes.
- University and technical college courses, education materials, and curricula at basic undergraduate and post-graduate levels.
- Training programmes for industry practitioners.
- Outreach programmes for the non-technical population.
- AM “design for manufacture” seminars.
- More education books dedicated to increase the knowledge of AM technologies.

Some projects have faced the problem of training in AM, making some surveys about the needs of the industry and providing some recommendations. One example is the project 3DPRISM, funded by Erasmus+ program (European Union) and led by the University of Sheffield Advanced Manufacturing Research Centre (Project 3D

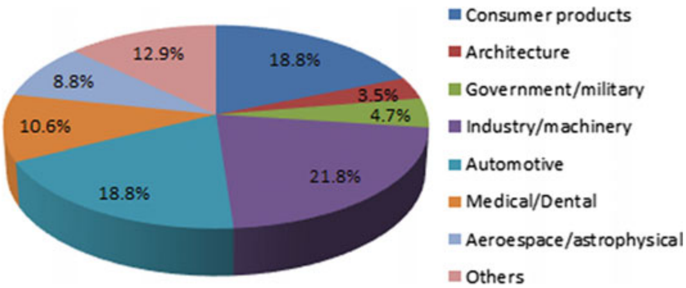

Fig. 1 Distribution of received filled questionnaires by sector

2017). This project facilitates, accelerates and supports the acquisition of leading-edge manufacturing skills by the workforce. It should be also highlighted the European project Knowledge Transfer on Rapid Manufacturing (KTRM), in which the authors of this work actively participated (KTRM 2012). The main objectives of the KTRM project were give as follows:

- To make a survey about training needs in the AM community and industry (about 150 questionnaires responded by 15 countries, mainly from Europe).
- To edit a handbook about additive manufacturing.
- To develop an E-learning platform for training in AM.

The questionnaire had a number of questions regarding training needs: interest in training in this field and aspects of interest in training. The teaching method was also asked so that it could be determined if conventional or online training were preferred and if practical lessons would be useful. Finally, companies were asked about the benefits expected in using these technologies. Figure 1 shows the distribution of sectors in the survey. The most relevant global results of this survey, for companies, are presented in the following figures. In Fig. 2, it is shown the level of knowledge on the main AM technologies, on the basis of the maximum possible knowledge. Also, the difference between large companies and small and medium companies (SMEs) were analysed. It can be observed that any technology has a level of knowledge reaching 50.0%; in general terms and that knowledge on SMEs is over than twice higher than knowledge in large companies.

The highest knowledge was observed for stereolithography, plastic SLS, 3D printers, FDM and metallic SLS. As explained above, it seems that plastic technologies are more known than metallic ones.

To take into account whether or not the availability of any technology could influence the level of knowledge, the survey studied the availability or outsourcing of them (Fig. 3).

The most usual technologies on companies are plastic SLS and 3D printers, followed by stereolithography, FDM and metallic SLS. Outsourcing is over three times higher than availability, being the most important stereolithography and plastic SLS. It is also confirmed that plastic AM technologies are more used than metallic ones.

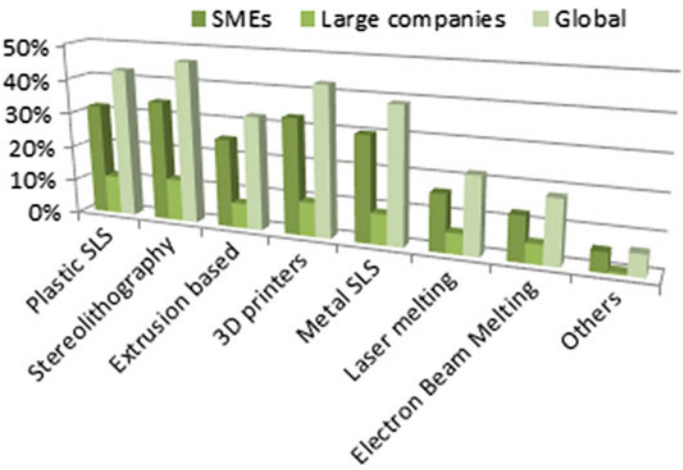

Fig. 2 Knowledge of main AM technologies by size of company

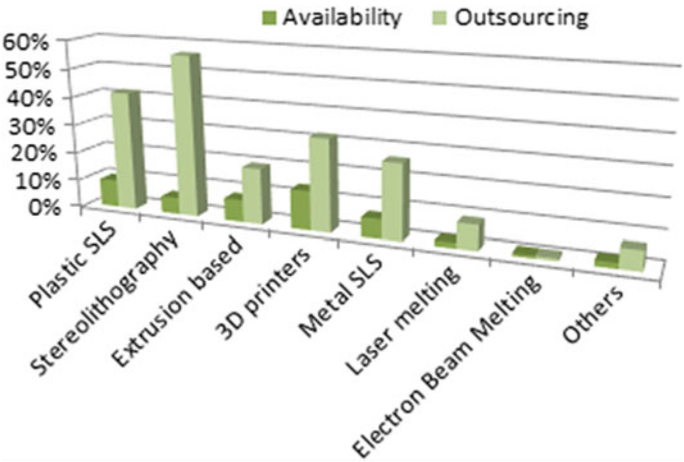

Fig. 3 Availability and outsourcing of AM technologies

As most works in this field are subcontracted, the low level of knowledge on these technologies is thus not surprising. Figure 4 shows the profiles of worker with more needs of training in AM. Designers are the group with more needs in terms of learning about AM.

But if the question is about the aspect to be improved by training of AM, the answer places "design" in the third position (Fig. 5). The general conclusions of this survey, considering also other questions not presented in this summary, are as follows: In general, knowledge on AM is quite low in companies; in large companies is lower than in SMEs. Outsourcing is most usual in companies than owning these systems. SMEs are more involved with AM technologies than large companies, as they are owner