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3D printing and applications: academic research through case studies in Finland

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Abstract

This research presents a comprehensive view of 3D printing technologies and their evolution. Additionally, it provides a Nordic perspective on the topic by summarizing project based research conducted in Finland. Expert interviews and research data extracted from case studies are analysed to cover topical areas on additive manufacturing transferability. The contribution of this research is to combine industry case research with expert interviews, and finally present recommendations to promote technology transfer.

The synthesis of the presented cases allowed us to conclude that additive manufacturing will offer greater possibilities in applications when: (1) innovation and design processes need to be enhanced, (2) customization is an advantage, (3) supply chain needs to be flexible, simplified or compressed, (4) material usage and inventories need to be reduced, (5) energy usage and waste in manufacturing have to be minimized and (6) product performance has to be optimized.

In consequence, to promote technology adoption and competitive advantage in companies - policy actions should be focused on increasing input for innovation and R&D, improving and increasing the supply of skill as well as generating and exploiting the connections and complementarities of country-specific academia, research institutions, industrial clusters and funding bodies.

Keywords: Additive manufacturing; 3D printing; Digital manufacturing; 3D printing applications; Innovation policies

1 Introduction

During recent years, 3D printing (3DP) (also known as additive manufacturing [AM]) technologies have become mainstream. The expiration of essential technology patents, as well as the development of new materials along with innovative additive processes, has attracted the renovated interest of industry, academia and public media. The claim is that AM can replace conventional manufacturing solutions (Campbell, Bourell & Gibson, 2012) and reinvent the way products are designed, manufactured and distributed globally (Khajavi, Partanen & Holmström, 2014). Today the technology has a strategic position in the definition of innovation policies on a global scale. AM is considered an enabler for companies to gain competitive advantage. Thus, giving them a new range of opportunities in terms of quick product and production line reconfiguration, distributed manufacturing, customization and personalized product development. In the future, AM systems will produce the key components of a product, driving the digitalization of design and manufacturing environments to the next industrial revolution (Horizon 2020 FP7, 2014). On the negative side, the hype is much more visible than the reality. Industry and academia have identified intrinsic drawbacks to AM technology. The first issue is linked to the limited characterization of the additive machines and materials. Standardization of the technology, processes and material is at early stages. Tackling this issue is fundamental in order to make AM technology accepted by regulated industries (such as the aeronautic, aerospace, automotive, medical and manufacturing industries). With this in mind, there is a lack of research that would help understand the societal, economic and technical implications of the technology for modern organizations (Flores Ituarte et al., 2015).

The second drawback is related to the reliability and repeatability of AM processes. Improvements in quality, performance validation and expanding materials options as well as the size capabilities of new-generation machines are likely to impact positively as development in this area is in the early stages (Guo & Leu, 2013). Finally, there is a lack of understanding of the technology from the practical application perspective. This is still vague among the industry professionals, partly because the relevant standards only define AM technology as machine process, not depending on the application areas in which the technology is being used. In addition, recent studies show that the AM industry is still optimizing costs structures (i.e. those of machine costs, material costs and labour costs), this being a significant factor affecting whether companies adopt AM technologies or not (Thomas, 2013). Reducing these costs may boost the AM industry and truly drive the use of AM technologies as a production method in the forthcoming digitalized era. However, currently the shift towards AM as a production method is still not fully clear in traditional design and engineering industries as the positioning of AM technology as something that creates value in company operations is still vague.

In this regard, this work will present ongoing industrial, medical and design case study research of early adopters in Finland. Based on this, we will shed light on future policy strategies for Nordic countries. This work intents to synthetize key enablers for the successful technology adoption in industry to connect with policy strategies which need to be articulated in order to benefit from 3DP technology.

2 Materials and methods

The research methodology is grounded on case study research design and action research, and hence involves a mix of quantitative and qualitative research methods. Quantitative data presents AM market evolution, which has been obtained by studying industry-specific market reports. In this case, the data presented in Figure 1 and Figure 2 has been compiled using Wohlers Report (2000–2015). In addition, the empirical case research has been collected in a series of case studies starting in 2010. Qualitative data was included through two non-structured interviews with industry technology users and academics who have worked in AM application research for the past 20 years. The contribution of this research is to link case research with industry data (Eisenhardt, 1989) in order to finally build new theory on strategic implications for policy makers and companies.

3 3D printing: the industry, applications and market evolution

Traditionally, industrial applications of 3DP/AM are linked to the early stages of the design and product development process. The technology helps companies in the iterative design process, early stage product functionality testing and also as a tool for product designers to communicate ideas. ISO/ASTM standard defines this as rapid prototyping (RP). In addition, the tooling industry uses AM to produce parts that serve as the actual tools or tooling components, such as molds or mold inserts (e.g. patterns for casting applications or wax models for investment casting). This process is defined as rapid tooling (RT) (ASTM International, 2013). Finally, the use of AM to produce components to be used directly in end products or to repair or rework high value components is defined in literature as direct component manufacturing or rapid manufacturing (RM) (Hopkinson & Dickens, 2003).

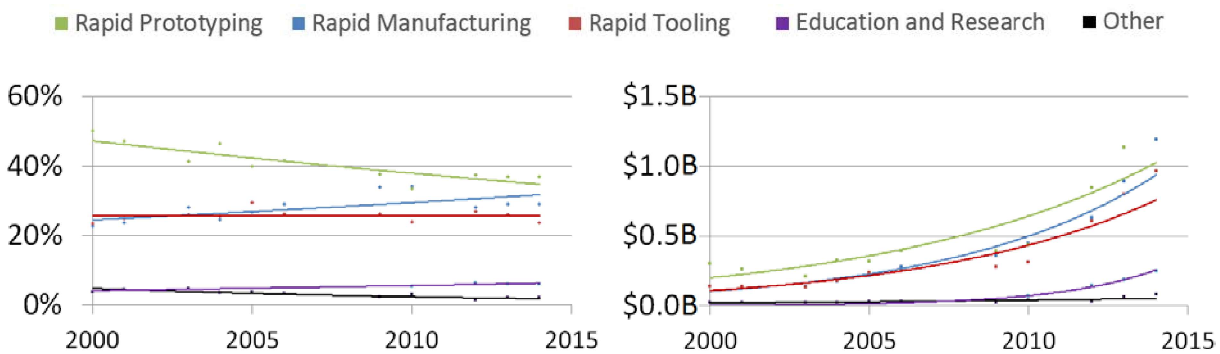

Figure 1 – Leftmost: the percentage of usage. Rightmost: revenue in US$ billion per industrial application. Adapted from Wohlers Report (2000–2015).

By looking at the trend lines presented in Figure 1, the AM market (consisting of all products and services worldwide) grew 35.2% from 2013 to 2014, representing $4.1 billion. The average annual growth during the past 26 years has been 27.3%, of which half of revenue stream have always been linked to RP activities, whereas RT and RM applications cover the other half. Trend lines show that AM technology is evolving towards the production of end-use applications, also known as RM. Comparing this data with Finnish industrial ecosystem, automotive and aerospace industry activities are minor. Whereas, medical and dental industry – and especially consumer products and electronics, and industrial and business machines – are present. According to the data, the mentioned industrial sectors are driving AM revenue growth internationally, covering approximately 80% of AM applications.