ADDITIVE MANUFACTURING – A NEW FAMILY OF TECHNOLOGIES

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Abstract. Additive Manufacturing technologies represent not only a novelty in the field of manufacturing, but a turning point judging from the new manufacturing principle point of view and by the enlarged possibilities of new technologies for manufacturing structures and geometrical shapes that are impossible to be realized using conventional technologies. Diversification of manufacturing systems and raw materials used by AM technologies makes possible the use of these technologies with significant results in various domains, starting from industry and ending with medicine.

Key words: Additive Manufacturing, AM technologies, medical and industrial applications, development perspectives.

1. GENERAL ASPECTS

Manufacturing was, is and will remain a strategic priority of any kind of company. It has been standing for thousands of years and, during the last couple of centuries, has passed through multiple industrial revolutions.

The occurrence at the beginning of 1990's of a new category of manufacturing technologies that allows the materialization of a 3D virtual model into a physical product by adding material only where it is necessary and as much it is necessary, technologies that are nowadays known as Additive Manufacturing (AM) has represented a revolution in the technological research and development. The new technologies are the results of an intense inter and trans-disciplinary research, as well as the result of the progress achieved in various domains, from fine mechanics to numerical control, from the laser technology to CAD software and from IT to materials science.

Additive Manufacturing (AM) can look back to a history of more than 30 years. Started mainly as a technology for physical materialization of a virtual 3D model with reduced usage (checking of right design solutions, promoting of new products and eventually for experimental tests) from a single type of material (photosensitive polymers), the new type of technologies have gradually gained more importance. Nowadays their field of application is very large, from industry to medicine, due to the evolution and performance of AM technologies and due to

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the fact that, today it does not exist any material that cannot be processed using this kind of technologies. It can be stated that this new category of technologies has reached a high level of matureness and that their future is promissive, representing a more and more important pylon for re-considering the manufacturing processes.

Now, there are a growing numbers of case studies and demonstrable business benefits proving that additive manufacturing can be used as mainstream manufacturing technologies. What can be done with AM technologies is not theoretical anymore; it is a fact.

Each type of technology has its specific advantages and limitations regarding the designing process of parts, the raw material used, as well as the properties and manufacturing costs, and use of the manufactured product in the end. The diversification of raw materials used by AM technologies, especially of the metallic and non-metallic powders makes possible the materialization of complex geometrical shapes, which are impossible to be obtained using conventional technologies.

The Additive Manufacturing offers the unique possibility to build complex devices in a resource-efficient way with, for example, filigree structures and integrated functionalities. It is not only an indispensable tool for the direct digital production of models and prototypes but also a manufacturing process for the production of end products of plastic, ceramics, and metal as well as for the production of tools, gauges, and molds. [1]. Additive Manufacturing also enables to produce finished products directly and independently of the batch size. Thus, it marks a revolution in the production technology: The conversion from production technology to the production of large series of equal parts to serial production of different components is made of individual parts, batches of all sizes or even mixtures thereof. [1].

According to Wohlers Report 2019, the Additive Manufacturing industry has continued to grow over the past nine years (after a decline in 2009). Over the past 30 years the Compound Annual Growth Rate (CAGR) of worldwide takings produced by all products and services is a forcefully 26.9%. From 2015 – 2018 the CAGR is 24.4%. Unit sales of industrial systems grew by 17.8% in 2018. However, it must be emphasized that for 22 years (of 31) the Additive Manufacturing revenues have grown in the double digits. It still offers a tremendous unused potential, especially in the customer-specific, individual and short-term partial production. For AM products and services worldwide, the industry has experienced a significant growth during the past nine years – the market has grown by nearly 7.4 times over this period. [2,3].

Fig. 1 shows the Global size of the AM market ($/billion). In the coming years the market is set to grow with a Compounded Annual Growth Rate of 25%, jumping the industry´s income to $17.2 billion. Everyone involved in design and production, as well as in the strategic planning should know that much that a qualified assessment and selection can be made regarding AM. The application fields of the AM technologies are broad: aerospace, automotive, tool building, medical and electronic engineering, furniture industry, architecture, and design, [4].

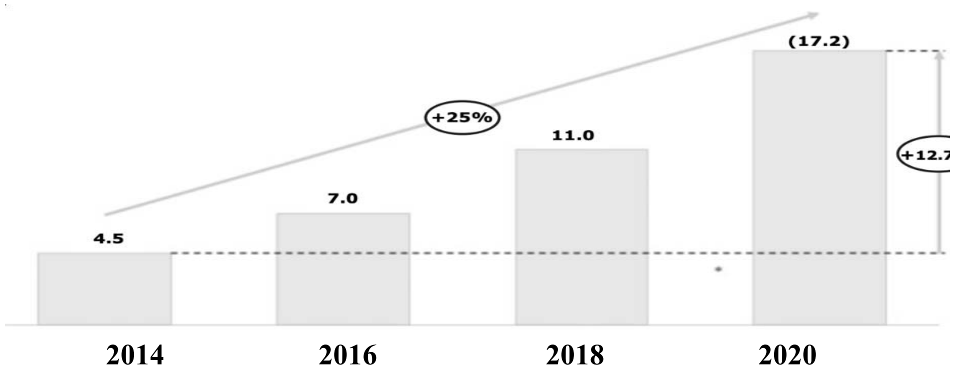

Fig. 1 – Global size of AM market ($/billion), [3].

Each year, the Gartner Institute [5] publishes forecasts for development of new technologies. The so-called "Gartner´s Hype Cycle for emerging Technologies" shows trends for the manufacturing processes and products. The first phase of the Hype Cycle is characterized by growing enthusiasm and expectations, in which users of the technology see new possibilities and potential. After reaching the peak, users recognize the difficulties occurred during the implementation, so that their enthusiasm diminishes at first. The expectations of users rise again, the second growth wave is reached, with increasing investments and developments, until the plateau is reached. Fig. 2 shows Gartner's Hype Cycle for 3D Printing, released at the mid of December 2018.

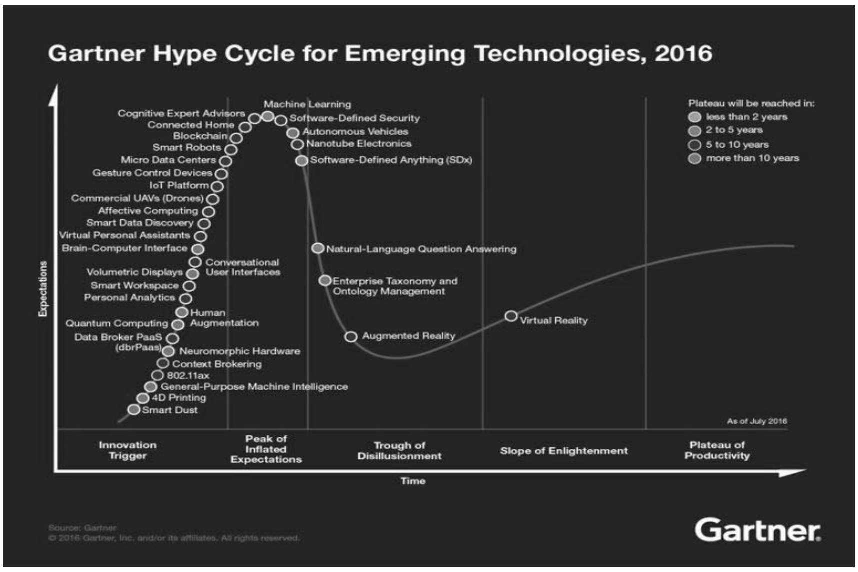

Fig. 2 – Gartner´s Hype Cycle for 3D Printing 2018, [5].

The advantages of AM technologies are given by:

a) The higher freedom of shape design. Designers can be more creative, taking into account that by using AM technologies it is possible to materialize complex geometrical shapes, without any technological constrains and from new types of materials that are difficult to be machined using any other type of technologies;

b) Conceiving and designing new mechanical structures, where a sub-assembly made from different components can be re-designed as a single component, with significant consequences in terms of costs, durability and weight decrease of the overall product;

c) Reducing the manufacturing costs by eliminating the Tools-Device-Checking instruments that are costly, the parts being manufactured and finished using this type of technologies and a virtual model of the product;

d) Decreasing the manufacturing time, by eliminating the cast and stamped semi-finished products, which require long manufacturing time and by using raw materials that are more accessible and much cheaper (wires, plates, powders of different qualities, etc.);

e) Decreasing the waste amount by manufacturing parts with shape and dimensions close to the ones of the final product. This is a significant advantage in manufacturing of parts made of expensive materials and the environment protection;

f) Customization of products. We are living in a society in which the customer wants a customized product, quickly manufactured and cheap. The AM technologies offer this opportunity;

g) Digitized manufacturing. Many AM advantages will be fully capitalized only in correlation with digitized manufacturing. Digitized manufacturing is considered as a physical representation of AM technologies. This means that AM manufacturing allows the flexibility of production, allows manufacturers to design and realize more performing products, allows manufacturing or modifying parts which are no longer in use, increasing in this way the performance of products, allows a quick reaction to the requests and challenges that occur on the market and the capitalization of digitized manufacturing, [6].

2. AM TECHNOLOGIES AT THE TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

Year 1995 marked in Romania the moment of the first contact with this new category of technologies. In that year, the Technical University of Cluj-Napoca has established the first Manufacturing Centre of Additive Manufacturing in Romania, by adopting two of the most familiar systems at that time: LOM 1015 and FDM 1650.

The future development of the Centre, under the aspect of existing infrastructure and human resources in particular allows nowadays the Technical University of Cluj-Napoca to have one of the most important Research Centre for the implementation of the new type of technologies, a Centre that is compatible with any other similar Centre of this type in Europe.

The research performed within the Centre targeted a large number of industrial and medical applications of AM technologies, under the name of so-called "Rapid Tooling" technology. From the research with applicability in the industrial domain one could mentioned: the use of LOM models as master models for sand casting [7], manufacturing and use of silicone rubber molds [8], optimization of the manufacturing process for metal spraying tooling technology [9], manufacturing of structures of tools for injection molding by SLS using coated metallic powder [10], development of different mathematical models for optimizing the manufacturing of parts made by material addition, [11].

From the research with applicability in the medical domain, the most important research refers to: manufacturing of implants made from non-metallic biocompatible materials using the indirect method [12], manufacturing of implants made from non-metallic materials using the direct method [13], manufacturing of customized orthopedic implants made from metallic materials by Selective Laser Melting (SLM) [14], studies on the improvement of bioactivity level of new type of implants made with controlled porous structures and testing their biocompatibility level [15], comparative studies regarding the properties and physical – mechanical characteristics of maxilla-facial implants personalized and made from different types of materials, [16].

3. CHALLENGES AND PERSPECTIVES OF AM TECHNOLOGIES

University institutions, industrial companies and governments have made during the last 30 years decisive steps toward the capitalization of the potential related to new developed technologies. There have been developed national or sectorial strategies regarding the development and implementation of AM technologies in new fields of application, [17].

The main challenges on medium and long term are related to:

a. *Technical, and technological challenges*

These challenges foresee the increased dimensions of the manufactured parts, the improvement of quality and dimensional accuracy, the stability of manufacturing processes, the post-processing stages of the products realized using this type of technologies and decreasing the cost of the equipment items.

b. *Design for AM manufacturing*

There will be necessary guides and specific CAD programs for designing and re-designing products by taking into consideration the principles and possibilities of new types of manufacturing technologies, as compared to the conventional technologies.

c. *New AM processes and new types of materials that can be processed using this type of technologies*

The new processes to be implemented in different applications will be more and more performing from the quality, accuracy and productivity points of view. In the meantime there will be realized a diversification of raw materials (biomaterials,

composites, intelligent materials, etc.) with a high level of recycling. Some studies [19] estimate that the future and the importance of AM technologies will strongly depend on the materials – specifically engineered and application specific materials. The different needs of diverse industries require custom solutions to their problems. Integrating new engineered materials will transform a new generation of applications, including heavily regulated industries.
There will be implemented on a high level hybrid manufacturing systems, which combine the advantages of AM technologies with the ones of CNC machining.

d. *Improving the level of knowledge regarding AM technologies*

The lack of knowledge and abilities required for designing oriented to the new type of technologies, the lack of knowledge on manufacturing processes and the materials used, as well as their performances make the efficiency of this type of technologies to be significantly reduced in this case. As a consequence, it will be necessary retraining the labor force and preparing the next generation, starting with the youngest people from schools and universities by using specific and dedicated programs [18] in close connection with the customer education.

e. *Standardization, and certification*

Standardization and certification will target processes, materials, software applications and products in such a way that it will create a common language between the manufacturers of equipment items, the producers of materials, designers, technologists and consumers.

f. *Digitization, automation, and flexibility of the production*

There will be created the possibility of manufacturing new types of products (Agile product creation), new possibility which rapidly include customers that can change the functionalities of the products, the volumes of the production and circular production flows that are already in the designing stage. Data flows will be integrated without any difficulty in the manufacturing chain that will be digitized with interfaces that will be well defined, having a total inter-operability. Additive manufacturing is leading the way in the digital transformation of Industry 4.0. With AM technologies, manufacturers can better connect the physical supply chain with a digital thread and manage products more efficiently from the concept to the end-of-life. Manufacturing can be distributed to any location that has digital manufacturing systems in place simply by sending a file, [19].

4. CONCLUSIONS

The occurrence, development and implementation of AM technologies represent an essential moment for the manufacturing industry. New type of technologies has demonstrated their changing role in the manufacturing domain and has started to model and change businesses. According to some studies [19], in the next 2–5 years, 86% of the companies expect to use AM technologies in a double ratio as they are using them nowadays and about 40% of the companies are expecting that the use of the new technologies in the world to increase five times more compared to their use at present. As the AM technologies will be implemented, the companies will be able to realize products in small batch production or even customized products, to reduce the costs and finally to set up the basis of a new type of production that will be much distributive, flexible and efficient. There is no need of a crystal ball to see that the future of 3D printing is bright.

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