Mechanics Transport Communications

Academic journal http://www.mtc-aj.com

ISSN 1312-3823 (print)
ISSN 2367-6620 (online)
volume 14, issue 3/2, 2016
article № 1407

ANALYSIS OF MARKET DEMANDS FOR ADDITIVE MANUFACTURING IN SERBIA

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Key words: *3D printing, rapid prototyping, rapid tooling, rapid manufacturing*
Abstract:*In the paper are presented analyses of the requests for offer of AM services by SLS technology, which the Laboratory for Advanced Design Technologies "3D Impulse" (Faculty of Mechanical and Construction Engineering in Kraljevo of University of Kragujevac) received in the period September 2013 – September 2016. The analysis considered the number of customers and their size, as well as distribution the number of requests by the size of the customer company. Further were analyzed distributions of requests by the year, economic sectors of the customers, types of application of the requested product and the technology and material requested. For each of the considered distributions are analyzed trends, and explanations of the observed trends are proposed. The analysis lead to measures for expansion of the Serbian market for AM services, but the results may be of interest for application of AM in other underdeveloped countries.*

1. INTRODUCTION

"Additive Manufacturing" (also abbreviated as AM in the text that follows) is a common denominator for several technologies used for manufacturing of products by successive addition of material. The term "additive manufacturing", used here, makes distinction between AM and classic manufacturing technologies of "subtractive manufacturing", achieved by removal of material (by cutting, grinding, drilling or milling) and "formative manufacturing" (by casting or deformation). Modern AM concepts are based on automation of the process of material addition, which is controlled by a computer, according to a digital 3D model of the manufactured object. Usual form of manufacturing of objects by AM is addition of thin horizontal plane layers of a material, where each layer represents a horizontal cross-section of the manufactured object, as it is illustrated in the Fig. 1. The layers may be manufactured by variety of methods and from various materials, which depend on the method that is used [1].

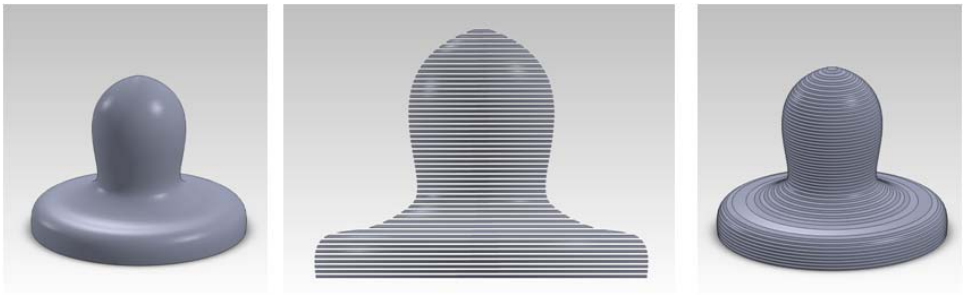

Figure 1. An object, its layered representation and its layered 3D model

AM represents an emerging and promising field of contemporary mechanical engineering because it offers conceptual advantages to both design and manufacturing phases of product lifecycle.

In the phase of design of a product, the advantage of AM technologies lies in their ability to produce complex geometric shapes that cannot be manufactured by other technologies (Fig. 2). Therefore, the AM technologies offer unparalleled freedom to imagination of innovative designers who look for attractive design as a mean to gain competitive advantage for products on market. Complex shapes, however, offer far more substantial advantages than just an attractive look – they are paving the way for innovative products with shape-integrated functionality, i.e. the products in which a part of the product functionality is achieved by its shape.

Figure 2: Complex shapes manufactured by additive manufacturing technologies

In the phase of manufacturing of a product, the advantage of AM technologies is that production process is independent on the manufactured object. Therefore, there is no need for product-specific preparation of production process and the *time-to-manufacturing* of a *new* kind of product in AM technologies is shorter than in other technologies. This crucial advantage of AM technologies is basis for three "rapid" applications for small-volume production:

- rapid prototyping (RP), which refers to manufacturing of prototypes for evaluation purposes during product design phase; AM significantly decreases time for manufacturing of a prototype, and considering that prototypes are frequently changed, even reduces cost of prototype production; RT profoundly simplifies and shortens product design period, boosting innovation potential of industry;
- rapid tooling (RT), which refers to production of tools by AM; the basis for this applications is that tools are usually manufactured in small series, or even as individual products, and large-scale economy is not applicable to tools; besides, since the aspects of weight and cooling are critical for performance of a tool, abilities of AM for lightweight design and manufacturing of conformal cooling channels are frequently making AM the superior solution for manufacturing of tools;
- rapid manufacturing (RM), which refers to production of small series or even individual products; this application is most frequently connected with manufacturing of personalized products, for example adjusted to individual patient in medicine, or customized upon customer request; since AM is its insensitive to variations between the products, the costs of manufacturing of personalized and

serial products are the same, which makes AM a preferable choice for production of small series and individual products;

However, the AM technologies still do not belong to the standard arsenal of of technologies used in industry. The common problems prevent wide application of all AM technologies are [2]: 1) reduced set of materials that may be processed by AM technologies, 2) inverse dependence between surface quality and production speed, 3) high costs of production, 4) long time needed for design of 3D model of complex surfaces and 5) lack of full set of design rules for product design for AM. Therefore, the AM is still not "off-the-shelf" technology, and the industrial and mechanical designers still lack knowledge about the its capacities and limitations. Usually, for successful application of AM are needed teams of that, besides industrial and mechanical designers, include specialist in AM technology. The level and versatility of required expertise make that AM technologies are used either by large and powerful manufacturers or by companies specialized in AM, which are frequently university spin-offs. On the other hand, comparatively high overall costs of AM technologies make that AM technologies are used for hi-tech or high-added-value products, typically in automotive, aerospace or military industry. Since these types of industry are usually bounded for highly developed countries, AM does not seem to have market in underdeveloped countries. Therefore, it is expected that market for AM services in Serbia is not sufficient to enable sustainable operation of even small companies dedicated to AM.

This paper analyzes demands for services of a specialized center for AM research and application that operates mainly on Serbian market. While the center is only partially financed by the incomes from the market services, and the remaining revenue comes from research projects financed by European Commission, Serbian government and local authorities, the obtained data may be useful source of information for those who consider possibility of establishing AM service providers in underdeveloped countries.

2. MARKET OFFER FOR AM SERVICES IN SERBIA

Serbian market offer of AM consists of five SMEs and three research centers that offer various AM technologies.

None of the SMEs has AM as its sole service. Two of the SMEs are representing 3D printer and 3D scanner manufacturers that are trying to develop market for 3D printers. Two of the remaining SMEs offer services of rapid manufacturing of personalized products, while the fifth SME is trying to establish the market for design services.

One of the university research centers offers 3D printing as an advanced service of rapid prototyping in their product development projects. The other research center offers services of rapid prototyping also as a service independent of the project development process.

The technologies that are used arelaser beam 3D printing, inkjet 3D printing and fused deposition modeling (FDM), which enable manufacturing of plastic objects, thus seriously limiting potentials for RT and RM applications in practice.

In June 2012, the Faculty of Mechanical and Civil Engineering at Kraljevo established Laboratory for Advanced Design Technologies "3D Impulse" as a research center that offers services of AM and reverse engineering. The Laboratory provides additive manufacturing of metal and plastic objects using selective laser sintering (SLS). The technology enables processing of polymer materials based on polyamide (pure or with addition of glass, carbon or aluminum powder) and steel (stainless and maraging), as well as aluminum and titanium alloys. The Laboratory thus opens wide possibilities for industrial RP, RT and RM applications. The Laboratory was established during the EU funded project "Innovative management for new products - IMPuls", and until the June of 2013, the Laboratory was

dedicated to the project goals, and did not operate on market principles. After July 2013, the Laboratory is at market that consists of Serbia, Bosnia & Herzegovina and Croatia, and represents by far the largest AM facility in the market. Therefore, the analyses of the requests for the SLS services of the "3D Impulse" Laboratory is an important foundation for estimation of demand for AM in Serbian market.

3. MARKET DEMAND FOR SERVICES OF SLS IN SERBIA

The analysis is based on the structure of requests of AM services of the „3D Impulse" Laboratory. Other approaches, such as analysis of the provided AM services, as well as analysis of revenues from AM services, are possible, but in the authors' opinion, the number of requests for AM services is better indicator of demand of Serbian market, because it also reflects market segments that the Laboratory was not able to satisfy.

The analyzed period lasts for three years, from 1st of September 2013 to 1st of September 2016. In the considered period, the Laboratory received 490 requests from 112 customers.

The number of request received in subsequent periods is shown in the Table 1, and it shows very stable demand. The lack of the expected rise in the initial period is becauseduring the period of work of the Laboratory for needs of the project, it was nevertheless promoted to Serbian industry and in designer community between July 2012 and September 2013, so the Laboratory was well known once it entered the market. The larger number of market requests in period September 2013 – September 2014 is due to the initial interest of the companies, which weresending all kinds of requests before the possibilities of the new technology were clarified to the market.

Period	Number of requests
Sep 2013 – Sep 2014	181
Sep 2014 – Sep 2015	159
Sep 2015 – Sep 2016	160

Table 1: Distribution of the requests in period September 2013 – September 2016

Majority of the customers are companies, 98 (87%) in total, but it should be noted that 14 customers (13%) were individuals, industrial and mechanical designers that wanted functional prototypes of the ideas they wanted to offer to their customers. The structure of the companies is shown in the Fig. 3, and it consists of 71 (63%) small, 15 (13%) medium and 12 (11%) large enterprises.

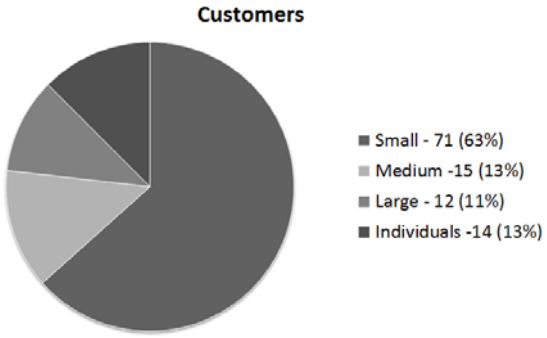

Figure 3: Distribution of customers by size

The distribution of the requests against the size of customers is presented in the Fig. 4, and it shows that the small enterprises made 302 (62%) requests, medium enterprisesmade 59 (12%) requests large enterprises made 88 (18%)requests and individualsmade 41 (8%)requests. It is notablethat large companies have increased participation in requests in comparison to their number, while for the individuals holds the opposite. While such

distribution is expected, it should be noted that some of the individuals are sources of permanent demand of small number of requests.

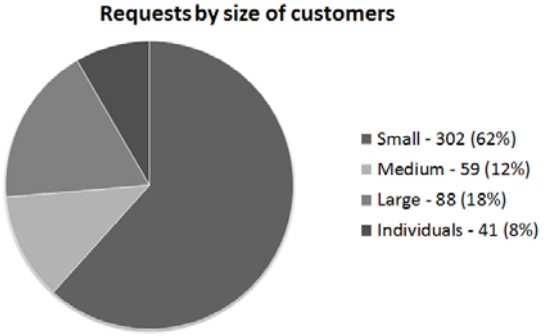

Figure 4: Distribution of requests by size of the customer

The distribution of the requests against economy sector is presented in the Table 2. While the „Industrial & mechanical design"is not an industrial sector, it is notable that a large number of small industrial or mechanical design studios represent an important source of demand for AM services. Those small studios usually develop products for manufacturers of consumer goods, automotive and aeronautics industry, but it is important that customers of AM services suppliers are not the manufacturers, which are quite often large companies themselves,

Sector	Requests	Participation
Industrial&mechanical design	140	29%
Toolmaking	126	26%
Consumer goods	88	18%
Electric appliances	50	10%
Automotive	41	8%
Medical appliances	25	5%
Aeronautics	20	4%

Table 2: Distribution of the requests by industrial sector

The distribution of the requests is given in the Fig. 5, showing that 441 (90%) of requests considered RP, 36 of applications (7%). There two reasons for thedomination of the RP applications.The first reason is that practically all of the products require manufacturing of prototypes, and products that are manufactured in large volumes are not suitable for RM. Therefore, it is expected that the number of RP requests is larger than the number of RP requests. On the other hand, the small number of RT requests is due to the still unknown potentials of AM in the field of toolmaking. Even more, the authors believe that the number of RT applications will rise when the customers of toolmaking companies learn about the advantages of tools manufactured by AM, because only then will the customers start requesting from their suppliers advanced tools.

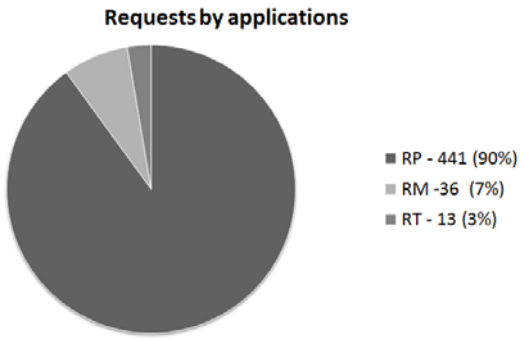

Figure 5: Distribution of requests by application

Finally, the distribution of the requests by technology is presented in the Table 3, illustrating that the requests for AM of polymer materials dominate over the requests of the AM of metals. The main reason is high price of the SLS of metal materials, but also the already mention insufficient knowledge about advanced tools.

Sector	Requests	Participation
SLS of metals	140	29%
SLS of polymers	126	26%

Table 3: Distribution of the requests by technology

4. CONCLUSION

In the paper are analyzed data about the requests for offer that the Laboratory "3D Impulse" received in the period September 2013 – September 2016. The analysis considered the number of customers and their size, as well as distribution the number of requests by the size of the customer company. Further were analyzed distributions of requests by the year, economic sectors of the customers, types of application of the requested product and the technology and material requested.For each of the considered distributions are analyzed trends, and explanations of the observed trends are proposed.

The results of the analysis suggest further marketing actions, which should be oriented towards promotion of advantages of the advanced tools, which will further boost expansion of the RT applications.

5. ACKNOWLEDGMENT

The authors wish to express their gratitude to Serbian Ministry of Education and Science for support through grantsTR35006 and TR37020.

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АНАЛИЗ НА ПАЗАРНОТО ТЪРСЕНЕ НА ПРОДУКТИ ОТ ДОБАВЪЧНОТО ПРОИЗВОДСТВО В СЪРБИЯ

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Ключови думи: триизмерно принтиране, бързо създаване на прототипи, бързо обработване, бързо производство

Резюме: В настоящата статия са анализирани запитванията на клиенти по отношение на услугите, представяни от добавъчното производство с помощта на SLS технология, разработена от Лабораторията за усъвършенствани технологии на дизайна „Триизмерни импулси” (Факултет по Механика и Строително инженерство към Университет Крагуевац, Кралево, Сърбия) в периода септември 2013 – септември 2016. Анализът обхваща броят на потребителите, както и разпределението на заявките на клиентите в зависимост от големината на компаниите, от които са изпратени. По нататък в статията са анализирани заявките по години, сектори на икономиката, начин на подаване и технология. За всяка от изследваните заявки, са проследени тенденциите на тяхното развитие и са обобщени изводи. В резултат на анализа се установява, че услугите на добавъчното производство намират широко приложение в Сърбия, при което те могат да представляват интерес и да бъдат приложени и в други държави с развиващи се икономики.