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APPLICATION OF ADDITIVE MANUFACTURING IN AUTOMOTIVE INDUSTRY

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Key words: *additive manufacturing, rapid prototyping, advanced tooling*
Abstract: *The paper presents an overview and classification of various applications of additive manufacturing in automotive industry. The classification is made from the point of view of advantages in design of the manufactured components and not from the point of view of advantages of manufacturing processes, as it is usually the case.*

1. Introduction

Additive Manufacturing (AM) represents an exciting field of contemporary mechanical engineering that offers unparalleled freedom to imagination of product designers. The advantage of AM technologies lies in their ability to produce complex geometric shapes that cannot be manufactured by other technologies. For that reason, the AM technologies are attractive to innovative designers who look for attractive design as a mean to gain competitive advantage for products on market.

Complex shapes, however, offer more advantages than just an attractive look. For example, structures with large internal spaces enable design of lightweight products and offer advantageous elastic properties, paving way to biomimetic applications. On the other hand, the ability to create complex shapes may also lead to indirect advantages, as it is the case with tools for manufacturing of plastic products with internal cooling channels. The internal channels with complex shapes, which can be manufactured only by AM technologies, are significantly increasing productivity of the tools.

Figure 1: Some examples of natural structures made by addition of layers: pearl, wood and sediment rocks

The Laboratory for is a unit of Faculty of Mechanical and Civil Engineering in Kraljevo, established during the EU funded project "Innovative management for new products" with support EU funded "Regional Socio Economic Development Programme" as a research and development facility that should provide technical basis for enhancing innovation capacity and competitiveness of SMEs in the region. Although recently established, the Laboratory swiftly gained attention in its surroundings, and now has 336 SME companies in its network, financial support from all levels of local and regional governments, and collaboration with chambers of commerce and industrial associations.

The Laboratory has last generation of machines for manufacturing components by selective laser sintering technologies: one machine for manufacturing of objects from plastics (EOS FORMIGA P100) and one machine for manufacturing of metal objects (EOSINT M280), as well as workshop for final surface processing.

2. The Concept of Additive Manufacturing

The "additive manufacturing" is a common denominator for several technologies used for manufacturing of products by successive addition of material. The concept of building objects by addition of successive layers is actually the basic building process in nature, starting from the nano-scale where molecules are made by addition of atoms, over micro-scale examples of organic structures like pearls and wood, up to macro-scale like rocks and mountains (Figure 1). Modern AM concepts are based on automation of the process of material addition, 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 plane layers of a material, where each layer represents a cross-section of the manufactured object, as it is illustrated in the Figure 2.

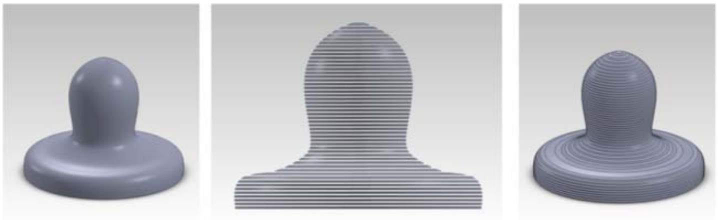

Figure 2: Basic principle of additive manufacturing

For its unique properties, AM may be used in all phases of product lifecycle. In the Figure 3 are represented three main areas of AM technologies applications, classified from the point of view of advantages of manufacturing processes, and shortly explained further.

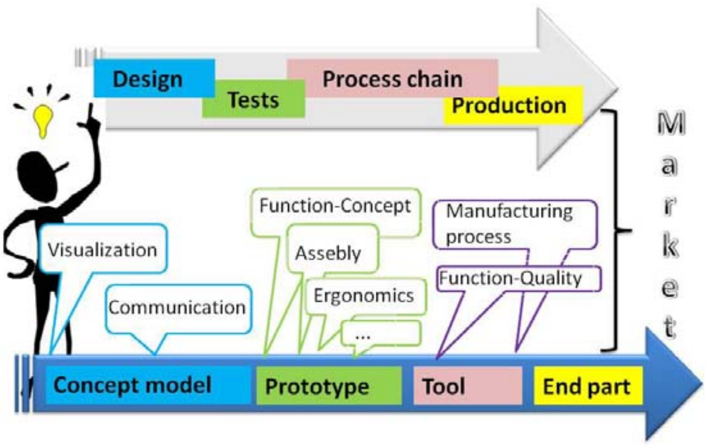

Figure 3: Areas of additive manufacturing applications in the product design cycle

In the phase of product development AM is used for rapid prototyping (abbreviated as “RP”), because it does not need any additional tool for production of a prototype, which substantially reduces time and costs of prototype production (Figure 4).

Figure 4: Examples of application of additive manufacturing in rapid prototyping

In the phase of production, it may be used as a tool for production of molds and complex tools (known also as rapid casting–"RC" and rapid tooling–"RT"). Besides the ability to manufacture the tools for products of complex shape, RT introduces the possibility of producing advanced tools for products of comparatively simple shapes. For example, tools with conformal cooling channels have considerably shorter cooling times and, consequently, improved productivity in comparison with conventionally manufactured tools (Figure 5).

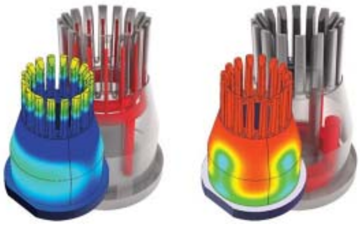

Fig. 5: Temperature distribution on surfaces of conformal (left) and conventional (right) tool [1]

Maybe the most intriguing opportunity for application of AM lies in possibility of direct production of products by AM, so called rapid manufacturing (abbreviated as "RM"). RM is attractive because it offers unlimited freedom in design of product shape (Figure 6), and the usage of the same equipment for large number of different products, which may be even manufactured simultaneously on the same machine.

Figure 6: Products with complex shapes

Therefore, RM is an ideal choice for manufacturing of small series of products, as well as for manufacturing of highly customized products, thus representing a powerful tool for innovative companies.

The Figure 7 presents the distribution of additive manufacturing usage over different applications [2]. The pie chart shows that the main three areas have approximately equal shares and there are no reasons to expect that the distribution is going to be changed in future.

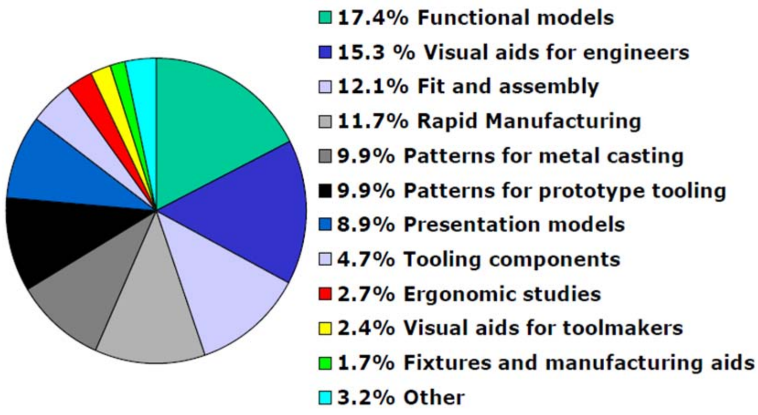

Figure 7: Shares of various applications of additive manufacturing

3. Additive manufacturing in automotive industry

The application of AM in automotive industry passes through evolution since the appearance of AM at the scene of manufacturing technologies. Figure 8 presents a long list of car parts and components that are manufactured by AM technologies. However, it has been already established that the driving mechanisms of the application of AM in automotive industry evolved [3]. In the initial phase of application of AM technologies, the main driver for its application were advantages that AM offers in the phase of production. On the other hand, the advantages of product design that can be achieved by AM technologies gain increased attention in the recent years.

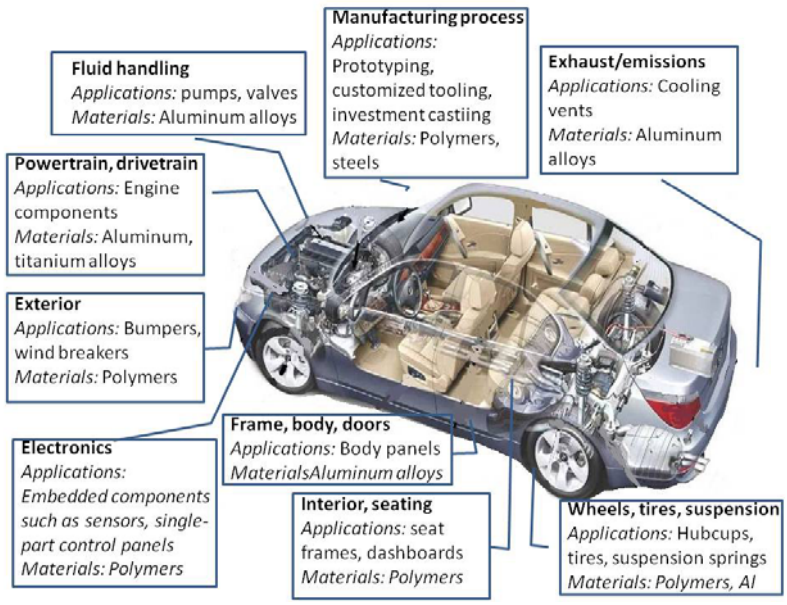

Fig. 8: Car parts manufactured by additive manufacturing technologies

In this paper, the author wish to present several key areas of improvement of automotive components design that may be achieved by application of AM technologies.

3.1. Improved performances

The basic property of AM to produce objects with almost arbitrary shapes enables creation of machine parts with small channels, thin walls and internal cavities. Such mechanical structures have superior fluid flow properties because they offer possibility for control of fluid direction that may not be achieved by other technologies, which is of paramount importance for fuel, air or coolant flow in vehicles.

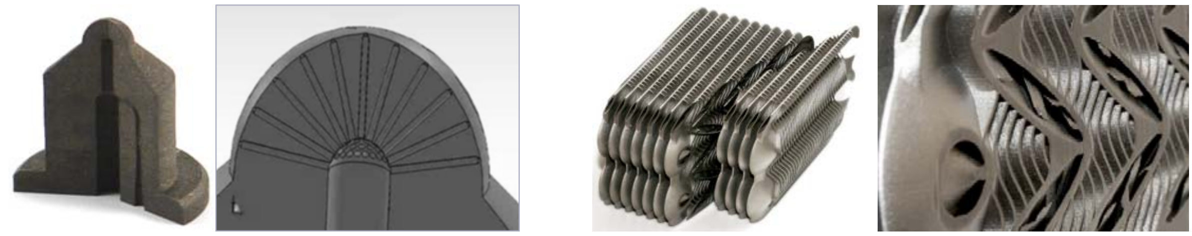

Fig. 9: Nozzle (left) and conceptual heat exchanger (right) with increased performance [4]

Figure 9 illustrates two examples of standard car components with considerably improved key performances by design that is enabled by AM technologies. On the left side is presented fuels nozzle that has tip with 76 channels with diameter that changes from 100 µm at inlet to 20 µm at outlet. The channels cover angle of 150^0, so that the nozzle has superior fuel spray characteristics in comparison to the nozzles manufactured by conventional technologies. At the right side is presented a conceptual heat exchanger that has internal turbulators inside the cooling tubes that disrupt the flow of the cooled fluid, which facilitates heat flow from cooled liquid to the coolant.

3.2. Lightweight design

The above-mentioned ability to manufacture internal channels and cavities is especially used for the sole purpose of mass reduction, which represents a basic vehicle design request since the very beginning of the vehicle production. To these purpose, full material is replaced by hollow (Figure 10 left) or lattice (Figure 10 right) structures.

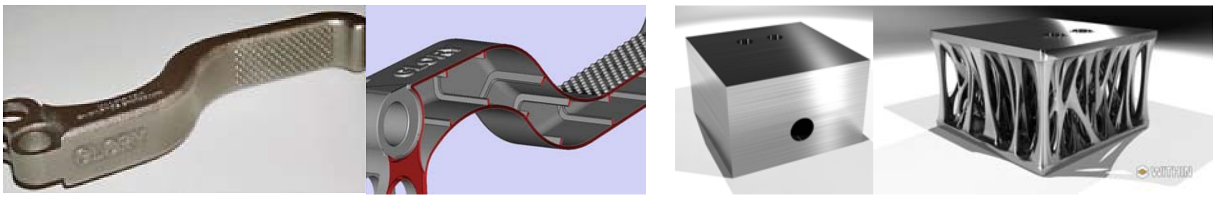

Figure 10: Brake lever (left) and pipe (right) with conventional and lightweight design [4]

For example, the weight of the brake lever shown in the Figure 10 left is reduced from 40 g to 12 g by the changed design enabled by AM technology.

3.3. Shape optimization

Another area of performance enhancement is increasing of stiffness of mechanical structures by designing complex geometric shapes that have maximal stiffness for the selected mass.

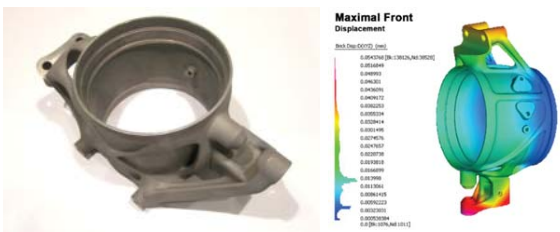

Figure 11: Wheel suspension element with increased stiffness and FEM calculated displacement field [4]

An example for such design in shown in the Figure 11, that presents and element of wheel suspension that has stiffness increased 22%, while the mass is reduced from 435 g to 390 g.

3.4. Shape-integrated functionality

Freedom of shape left to the designers enables design of components that integrate functionalities of several components or even sub-assemblies. It opens completely new horizons to innovative designers and represents new challenge to human imagination and creativity.

Figure 12: Brake disk with integrated cooling channels

One relatively simple, but clear example is shown in the Figure 12. Brake disk of Formula Student race car is designed with internal cooling channels, so that the disk combined functions of braking and cooling. The performance of the brake disk is considerably improved by the enhanced cooling, and the additional reduction of mass by 25% arised as an additional benefit.

A much more stunning example is shown in the Figure 13, which presents a passenger seat with complex shape that integrates several functionalities, which are obtained exclusively by advanced geometric shape of the seat.

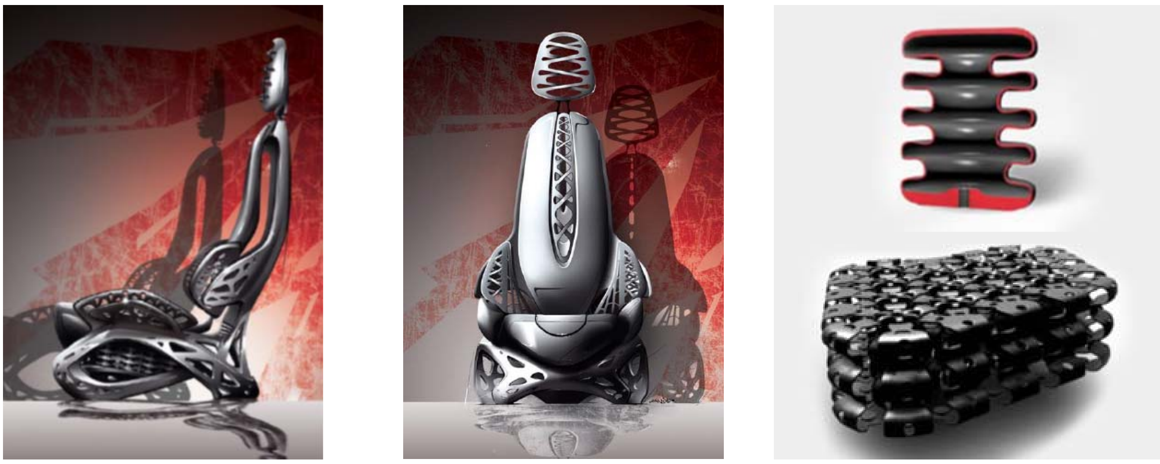

Figure 13: Shape-integrated passenger seat (left and centre), pneumatic actuator (top right) and seat ventilation (bottom right) [4]

Besides the improvement of the basic function of the seat, achieved by free ergonomic design, the seat also features pneumatic actuators and seat ventilation that contribute to the comfort of the passengers. Pneumatic actuators are designed as bellow-like pipe structure placed at joint between the seat and back, and the seat ventilation is realized as cellular structure placed below the seat.

4. Conclusion

In the paper are presented possibilities of application of AM in automotive industry with focus at the possibilities for improvement of design of automotive components. The possibilities may be classified to the following areas:

- design for improved performances
- lightweight design
- shape optimization
- shape-integrated optimization

Of course, the application of AM in automotive design includes also all aspects of improvement of manufacturing processes from rapid prototyping to advanced tooling applications.

For the automotive industry, all these advance possibilities opened doors for the innovative designs and lighter, safer, economic, customized products with better performances.

Acknowledgement

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References

[1] "Selective Laser Melting", Texer Design Srl, Tezze di Vazzola (Italia), 2014
[2] "Wohlers Report 2007", Wohlers Associates, Denver (USA) 2007, ISBN 0-9754429-3-7
[3] C.A. Giffi, B. Gangula and P. Illinda, "3D opportunity in the automotive industry", Deloitte University Press, Westlake (USA) 2014
[4] www.eos.info

ПРИЛАГАНЕ НА ДОБАВЪЧНИ МАТЕРИАЛИ ПРИ ПРОИЗВОДСТВОТО В АВТОМОБИЛНАТА ИНДУСТРИЯ

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***Ключови думи**: добавъчни материали в производство, бързо създаване на прототипи, модерна инструментална екипировка*

***Резюме:** Статията представя обзор и класификация на различни приложения на добавъчни материали в автомобилната индустрия. Класирането е извършено от гледна точка на предимствата за дизайна на произвежданите компоненти, а не от гледна точка на производствените процеси, както обикновено се прави.*