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APPLICATION OF 3D PRINTING IN RAILWAY INDUSTRY

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Abstract *– In this paper, attention is focused on the application of 3D printing in railway industry based on examples that have been developed in last few years. Concrete examples of the application of 3D printing in industrial branches such as medicine, electronics, mechanical engineering, construction and railways are presented. The paper gives examples of the use of 3D printing in railways, which gives an answer especially why and in what way this type of technology is used in the railway itself, then which 3D printing are most used and which materials are currently represented in 3D printing. This paper presents examples that show the successful applications of products made with 3D printing in the railway industry, such as the wheel bearing cover, then the connecting element used in maintenance, the first approved 3D printed safety metal part for connecting the suspended brake and plastic components (cup holders, radio mounts, window frames, wiper covers and door holders).*

Keywords – 3D printing, Replacement parts, Plastic components, FDM, SLM

1. INTRODUCTION

This review aims to show the current comprehensive application of 3D printing in various industry fields as well as the application in the railway industry.

The application of 3D printing is reflected in the production of functional prototypes, spare parts, molds and tools, also Rapid prototypes are based in part on 3D printing. An analysis of the application of 3D printing will be performed through certain examples that can be found in different industry fields.

3D printing was recognized as one of the pillars of the fourth technological revolution. Currently, there are powerful companies in the market that deal with 3D printing, such as Stratasys, 3D Systems, Proto Labs, and which are trying to find a place for 3D printing on the market.

3D printing is a production method that creates three-dimensional objects by depositing material, usually by joining material layer by layer.

Most important 3D printing technologies are given in Table 1.

Tab. 1. List of 3D technologies and used materials

Technology	**Used material**
Stereolithography (SLA) Polyjet	Photopolymers
Fused Deposition Modelling (FDM)	Thermoplastics
Selective laser melting (SLM) Direct Metal Laser Sintering (DMLS) Electron Beam Melting (EBM) Laser Engineering Net Shape (LENS)	Metal materials
Material Jetting (MJ)	Powder materials
Binder Jetting (BJ)	Powder materials
Selective Laser Sintering (SLS)	Powder materials

The most-commonly used 3D printing process (46% as of 2018) is a material extrusion technique called fused deposition modeling or FDM. While FDM technology was invented after the other two

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most-commonly used 3D printing technologies is stereolithography (SLA) and selective laser sintering (SLS), FDM is typically the cheapest technology, which makes this process popular. Every firm that has a need for rapid prototyping acquire a FDM printer first, after which other printing technology like SLA or SLS depending on the needs of the company [1].

All reports that are dealing with 3D printing and manufacturing trends are forecasting significant growth of investment and market share. For example: The Wohlers Report 2019 forecasts for 2020 is $15.8 billion for all 3D printing products and services worldwide. The company expects that revenue forecast to climb to $23.9 billion in 2022, and $35.6 billion in 2024 [2].

2. EXAMPLES OF 3D PRINTING APPLICATIONS

2.1. 3D Printing for Medical Implants

Today, it is possible to achieve with the help of this technology, orthopedic implants (Fig.1) that are used to replace a missing joint or bone part [3].

Fig.1. Implants 3D printing using Arcam's EBM technology [3]

The advantage of this technology for medical implants is the flexibility of design, ie the manufacture of complex designs that are otherwise difficult to achieve with traditional technologies [3]. The market for orthopedic 3D printing was estimated at 691 million dollars in 2018, SmarTech analysis predicts that the value will grow to 3.7 billion dollars by 2027 [4].

2.2. 3D Printing in Electronics

3D printing as a technology is also used in the field of electronics, especially in the development and production of fast prototypes, but there are also indications that it will soon find its application in the production of functional electronic components. It is an interesting prediction that by 2029, the electronics market with 3D printing will reach a value of over two billion dollars. Development of products has been significantly accelerated, with the help of 3D printing in a matter of few hours ready-made prototypes of electronic components can be made, such as printed circuit boards, antennas, capacitors (Fig.2) and sensors [5].

Also a big advantage of 3D printing of electronic components is the possibility of miniaturization of electronic components, with increased demand with advanced functions [5].

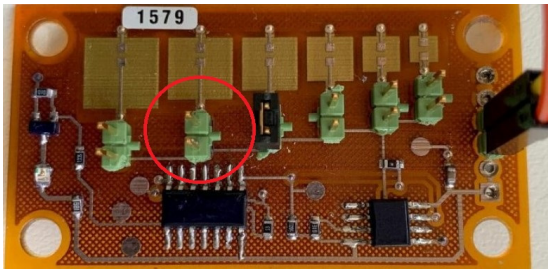

Fig.2. A 3D-printed capacitor [5]

2.3. 3D Printing for Bearings

Bearing manufacturers have also noticed 3D printing as an opportunity to develop and fabricate a better construction of the bearings themselves. By applying 3D printing, the complexity of bearing design has increased, an example being Bowman International, a bearing manufacturer that redesigned the cage to add more rolled bearing elements, resulting in increased bearing life (Fig.3) [6].

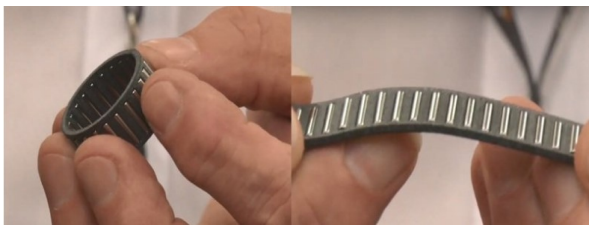

Fig.3. Cage obtained by 3D printing using flexible material [6]

2.4. 3D Printing in the construction industry

The advantage of 3D printing in the construction industry is reflected through innovative design, then in the reduction of material waste and manual labor, as well as in the faster construction of an object. One of the 3D printing technologies which is used in the construction industry is contour crafting which employs the Robotic Hand Extruder (Fig.4). This technology works similarly to FDM desktop 3D printers [7].

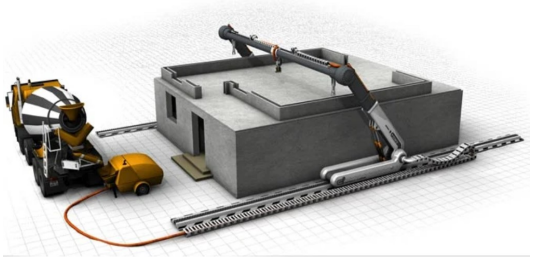

Fig.4. Contour Crafting Technology [8]

Another example is Sand 3D Printing, which is similar to 3D printing technologies such as SLS, this technology works by applying a liquid binder to the layers of powder material. Also Wire Arc Additive Manufacturing (WAAM) technology is used in the construction industry (Fig.5), WAAM works by melting metal wire using an electric arc as a heat source. WAAM equipment can work with a range of metals, such as aluminum, steel and titanium, and the technology can be used to produce large structures such as a steel bridge [9].

Fig.5. A 3D-printed steel bridge [10]

3. 3D PRINTING IN RAILWAY INDUSTRY

Companies such as Deutsche Bahn, Bombardier and Angel Trains have started investing in 3D printing in order to get to know the technology better and take advantage of its possibilities. Railway companies over time start having problems due to a lack of replacement components that were manufactured 20 to 30 years ago and for which production no longer exists. Presently it is not profitable to produce spare parts of obsolete design in small quantaties using traditional manufacturing technologies. Due to high costs, railway companies are looking for new ways to produce obsolete spare parts faster and cheaper. This is one of the main reasons why railway companies are persistently investing in 3D printing technology. 3D printers do not require specialised tools in order to manufacture products of various geometric configurations. Tool-free production can significantly reduce production time for obsolete spare parts, in some cases by as much as 95%. This way, railway companies can speed up the train maintenance process [11].

The 3D printing technologies used for railway components are mainly polymer additive technologies, such Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS). These technologies are optimized to produce parts that can function with high performance, for example by using nylon and ULTEM materials. Materials to be used for rolling stock must be covered by a certain standard EN45545-2 for industrial fire protection. Several companies offer flame-retardant thermoplastics [11].

The standard applies to manufacturers of rail vehicles, including high-speed trains, regional trains and trains in industrial transport. The following tests are used to measure product compliance with product requirements: 1. TO1 Oxygen Index; 2. 03 Flue gas density; 3. T12 Smoke toxicity. Key parameters to be measured include flame spread, flammability, heat release, smoke opacity, and toxicity [12].

Comparative properties of plastic materials used for 3D printing and traditional production methods in railways are shown in Table 2. It can be concluded that the mechanical properties of materials used in 3D printing are similar to those of materials used for traditional production methods in Railways. Which shows the possibility of applying 3D printing materials in railways from the aspect of mechanical properties.

Tab. 2. Mechanical properties [13-14]

	3D Printing materials			**Traditional materials in Railway**	
	PLA	ABS	ULTEM	SUSTAMID 6 FR (PA 6)	Maywoflamm Plus (PC/ABS Blend)
Tensile Modulus [MPa]	3039	2230	2150	3800	4650
Tensile strength, Ultimate [MPa]	48	32	69	66.5	41
Density [g/cm³]	1.24	1.05	1.34	1.17	1.35

3.1. Plastic components

Plastic components for the interior of the train such as armrests, handles, seat trays and connectors (Fig.9) can also be made by 3D printing (FDM technology) thanks to the high-temperature thermoplastic material ULTEM 9085. The production of the armrest with 3D printing took only a week, a reduction of 94% compared to conventional production methods. The Spanish manufacturer of railway vehicles, equipment and buses has produced about 2,400 3D-printed parts for use for its rolling stock, including cup holders, radio mounts, window frames, wiper covers and door holders [11].

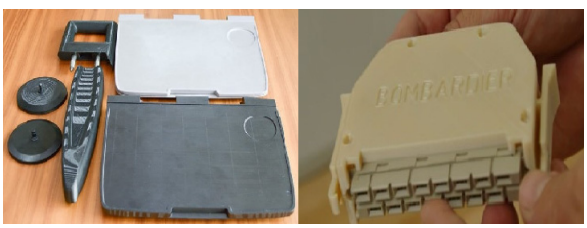

Fig.9. FDM 3D-printed parts [11]

3.2. Metal replacement parts

Deutsche Bahn has recognized the possibility of using 3D printing for more than 100 use cases. One example of such a part is the wheel bearing cover for a Class 294 locomotive. The bearing cover is made using WAAM technology which uses wire as input material. The part weighs 13 kg and was printed for a total of 7 hours (Fig.6) [11].

Fig.6. A 3D-printed near-net-shape wheelset bearing cover (left) and a post-machined part (right) [11]

Siemens Mobility has also made a connecting element used in maintenance using 3D printing. This element is very difficult to make by traditional methods, due to the complex shape (Fig.7) [11].

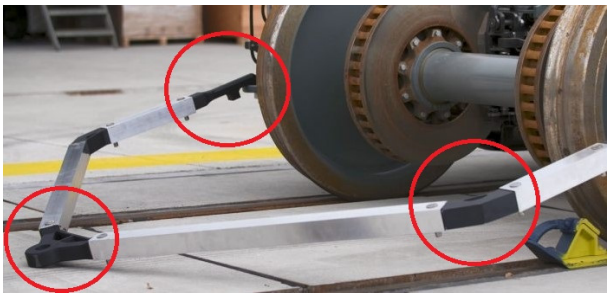

Fig.7. A 3D-printed bogie tooling [11]

3D printing has enabled Siemens Mobility to take advantage of 3D printing and replace traditional production methods for tool application [11]. By purchasing two 3D printers from the American manufacturer Stratasys, Siemens Mobility plans to use 3D printing to produce spare parts for Sapsan high-speed trains running in Russia. They will improve the maintenance operations of these vehicles [15].

Figure 8 shows the first approved 3D printed safety component for the railway sector by the German Mobility Goes Additive (MGA) network. This is a metal connection of the suspended brake, which was successfully installed on the subway of the German company Hamburg Hochbahn AG [16].

Fig.8. The approved 3D printed part [16]

4. CONCLUSION

In general, the examples given in this paper show that companies are currently trying to identify more cases in which the 3D printing can be useful, they also recognized the drastic difference in costs when it comes to making small series of parts using 3D printing compared to traditional technologies. The main reason for the application of 3D printing in the railway is the problem with obsolete spare parts and long delivery times of tools and components for end use. The result of solving this problem with the help of 3D printing is reflected in a significant drop in production costs and delivery time. It is considered that the production of additives is also a green technology, because material is a added instead of being subtracted from stock if compared to other traditional technologies. Currently, 3D printing is mainly used in maintenance, but with the potential for wider application.

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