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EVALUATION OF THE IMPACT ENERGY OF THE SAMPLES PRODUCED BY THE ADDITIVE MANUFACTURING TECHNOLOGY

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Preliminary Note – Prethodno priopćenje

The article covered the evaluation of the impact energy, notch toughness and morphology of the fracture surfaces of the specimens manufactured by the Direct Metal Laser Sintering Technology. Specimens without heat treatment with no notch were not broken through in course of testing, therefore there was no fracture surface present. The heat treatment resulted in the increase in hardness values. The values of impact energy after the heat treatment was approximately 60 % lower. Ductile intergranular fracture with more or less segmented dimple morphology appeared in every specimen. At places where the internal plastic bond was resisting the test, cracks remaining after particles broke away from the surface can be seen as craters.

*Key words:*metal powder, mechanical properties, impact energy, fracture, surface

INTRODUCTION

Additive Manufacturing refers to a process by which digital 3D design data is used to build up a component in layers by depositing material. The term "3D printing" is increasingly used as a synonym for Additive Manufacturing. [1]

However, the latter is more accurate in that it describes a professional production technique which is clearly distinguished from conventional methods of material removal. Instead of milling a work piece from solid block, for example, Additive Manufacturing builds up components layer by layer using materials which are available in fine powder form. A range of different metals, plastics and composite materials may be used. [2,3]

The technology has especially been applied in conjunction with Rapid Prototyping - the construction of illustrative and functional prototypes. Additive Manufacturing is now being used increasingly in Series Production. It gives Original Equipment Manufacturers (OEMs) in the most varied sectors of industry the opportunity to create a distinctive profile for themselves based on new customer benefits, cost-saving potential and the ability to meet sustainability goals. [4,5]

Figure 1 shows general principle of laser sintering. The system starts by applying a thin layer of the powder material to the building platform. A powerful laser beam then fuses the powder at exactly the points defined by

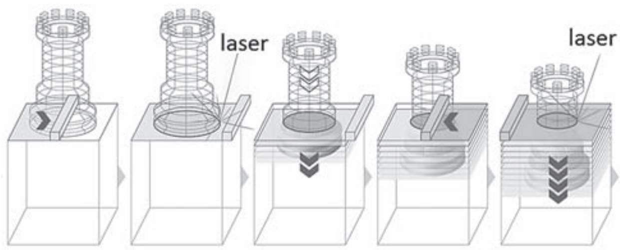

Figure 1 General principle of laser sintering [6]

the computer – generated component design data. The platform is then lowered and another layer of powder is applied. Once again the material is fused so as to bond with the layer below at the predefined points. [6]

EXPERIMENTAL PROCEDURE

The preparation of specimens was performed in compliance with the Slovak Technical Standard EN 10045 - 1 for the bend impact test. The specimens with U – notch, specimens with V – notch and the specimens with no notch l = 55 mm long, b = 10 mm wide, a = 10 mm were prepared. [7]

The specimens were made using the 3D printer implementing the DMLS / Direct Metal Laser Sintering technology in the company 1.PN Ltd. The specimens were printed on the EOSINT M280 3D printer. The data necessary for the manufacturing of the test specimens were provided in form of CAD data. [8]

In order to perform tests, two types of specimens were fabricated. The first specimen group (marked S3D) was printed on the 3D printer and was not heat treated. The specimen's hardness after printing ranked 33 HRC. The second specimen group (marked SPH) received the heat treatment through tempering at 490 °C,

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over 6 hours. The hardness of the heat treated specimen ranked 53 HRC. [11,12]

The measurement tests evaluating the impact energy were performed on the accredited impact testing machine, also called the Charpy test hammer, in the testing and development centre of Labortest, Ltd. at the room temperature of 20 °C. [9, 10]

Subsequently, the impact strength and the morphology of the fracture surface of the specimens were evaluated by the Mira3 scanning electron microscope from Tescan.

RESULTS AND DISCUSSION

Dimensional values of the specimens tested and the final values of the impact energy are listed in Table 1 and Table 2 respectively. Values of the impact energy for the 3D printed specimens with notch are approximately the same, while the values for the specimens with the U - type notch are slightly higher. Specimens with no notch were not broken through in course of testing, therefore there was no fracture surface present. Test specimen was bent and the record shows the impact energy value of 288,3 J.

Even though the heat treatment increased the hardness values from 33 HRC to 53 HRC, the toughness of the material after the heat treatment decreased. The values of impact energy for the V - notch specimens after the heat treatment reached 15,7 J and the values for the specimens with no notch reached 94,1 J, which is approximately 60 % lower.

For a better overview, the values of the impact strength are graphically demonstrated in Figure 2 and Figure 3.

The Figure 2 shows the values of the impact strength of the specimens with no heat treatment at the room temperature of 20 °C (marked S3D). The values of the impact strength of the heat - treated specimens at the

Table 1 **Dimensional and the resulting values of tested samples S3D**

Specimen	b1 / mm	b2 / mm	b3 / mm	b4 / mm	Width b / mm	a1 / mm	a2 / mm	a3 / mm	a4 / mm	Height a / mm
U - notch	10,95	11,02	11,00	10,94	11,0	10,10	10,10	10,06	10,08	10,1
	Height h / mm	Content S_0 / mm^2	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KCU / J/cm^2				
	9,02	99,0	4,0	132	39,2	39,62				
V - notch	10,09	10,04	10,03	10,10	10,1	10,94	11,00	10,95	10,95	11,0
	Height h / mm	Content S_0 / mm^2	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KCV / J/cm^2				
	9,06	91,2	3,6	134	35,3	38,72				
without notch	10,04	10,04	10,11	10,12	10,1	10,88	10,90	10,92	10,92	10,9
	Height h / mm	Content S_0 / mm^2	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KC / J/cm^2				
	10,90	109,8	29,4	15	288,3	262,48				

Table 2 **Dimensional and the resulting values of tested samples SPH**

Specimen	b1 / mm	b2 / mm	b3 / mm	b4 / mm	Width b / mm	a1 / mm	a2 / mm	a3 / mm	a4 / mm	Height a / mm
V - notch	10,03	10,04	10,02	10,03	10,0	10,87	10,86	10,88	10,82	10,9
	Height h / mm	Content S_0 / mm^2	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KCV / J/cm^2				
	8,87	89,0	1,6	146	15,7	17,64				
without notch	10,16	10,08	10,06	10,04	10,1	10,98	11,01	10,91	10,90	11,0
	Height h / mm	Content S_0 / mm^2	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KC / J/cm^2				
	11,00	110,9	9,6	112	94,1	84,86				

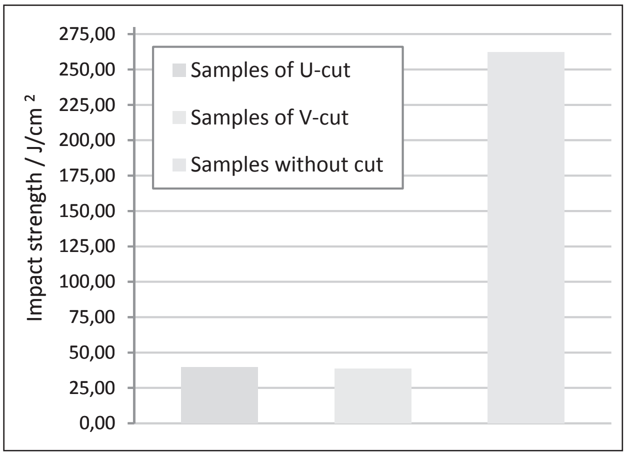

Figure 2 Impact strength of samples S3D

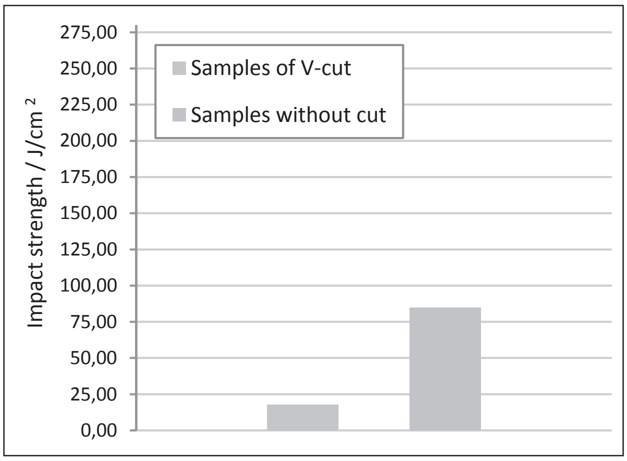

Figure 3 Impact strength of samples SPH

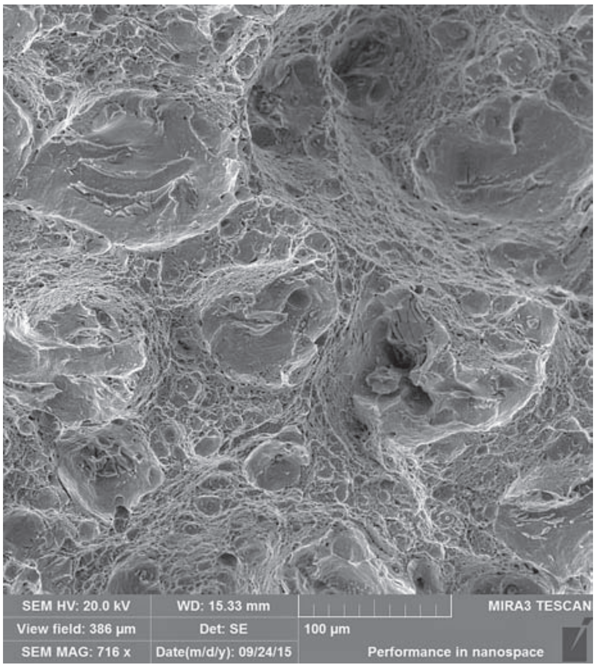

Figure 4 Fracture surface of specimen S3D with U - notch

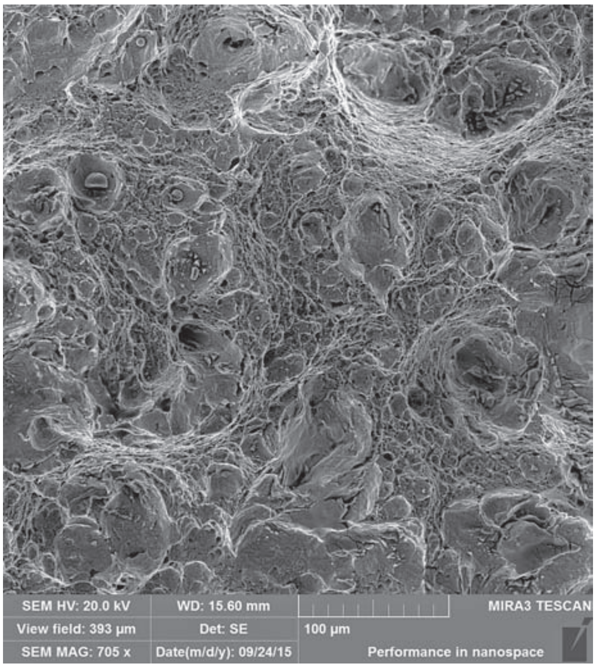

Figure 5 Fracture surface of specimen S3D with V - notch

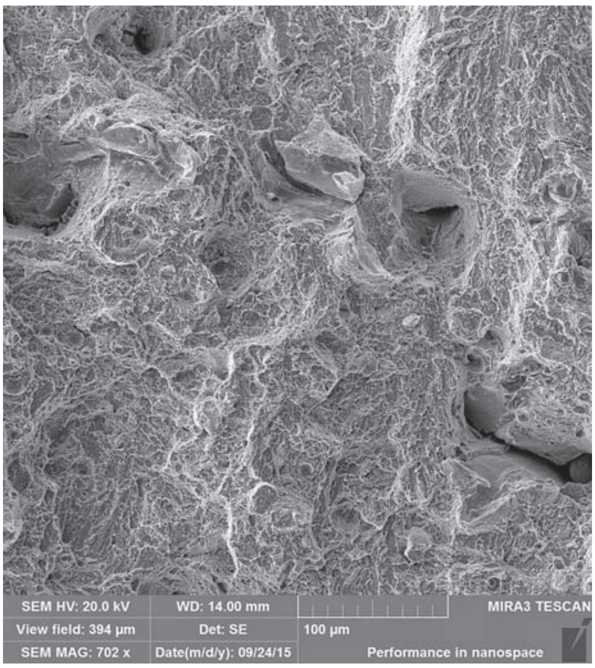

Figure 6 Fracture surface of specimen SPH without notch

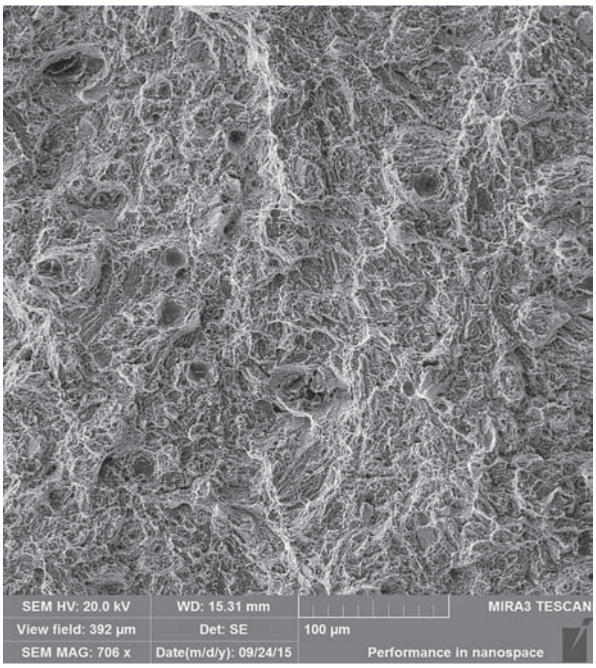

Figure 7 Fracture surface of specimen SPH with V - notch

room temperature of 20 °C (marked SPH) are presented in Figure 3. The evaluation of the fracture surfaces shows the values of the attained impact energy. Figure 4 to 7 present the fracture surfaces magnified 500 times.

Ductile intergranular fracture with dimple morphology was observed in all the specimens. The morphology was more or less segmented, depending on the specimen. In Figure 6 and Figure7 was observed less segmented morphology.

CONCLUSION

The article covered the evaluation of the impact energy, notch toughness and morphology of the fracture surfaces of the specimens manufactured by the DMLS technology. In course of the experiment various values of the impact energy in different specimens were observed. Printed specimens with notch reached somewhat similar values of impact energy. Printed specimens with no notch were not broken during testing, however, they bent in the process. The impact energy reached high value.

After the heat treatment, we subjected the specimens to tests again. It was evaluated the V – notch specimens and the specimens with no notch. The heat treatment resulted in the increase in hardness values from 33 HRC to 53 HRC. The toughness of the material decreased after the heat treatment. Values of the impact energy for the heat-treated specimens were approximately 60 % lower.

Ductile intergranular fracture with more or less segmented dimple morphology appeared in every specimen. At places where the internal plastic bond was resisting the test, cracks remaining after particles broke away from the surface can be seen as craters. The experiment presented us with an opportunity to learn whether reduced temperatures impacted the resistance of the tested material.

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Note: The responsible for English language is Mgr. Lucia Gibľáková from Iluminata Linguistics.