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DETERMINATION OF THE EOS MARAGINGSTEEL MS1 MATERIAL RESISTANCE AT LOW TEMPERATURES

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Preliminary Note – Prethodno priopćenje

This article deals with determination of the EOS MaragingSteel MS1 material resistance at different low temperatures. Material resistance was evaluated in two types of standardized specimens. The impact energy at the specimens tested at 10 °C, values for the specimens with no notch were compared to the V - notch specimens, higher by approximately one - third. When the temperature dropped to 0 °C, the values of the impact energy slightly decreased as well. It therefore follows that lower temperatures result in decrease in the values of the impact strength. This experiment provided us with the opportunity to find out whether the decrease in temperature impacts the resistance of the tested material.

Key words: alloy steel, mechanical properties, impact energy, fracture, surface

INTRODUCTION

Additive Manufacturing permits cost-effective production for individual items as well as batch items. The complexity of a part has almost no bearing on manufacturing time and costs. [1,2]

When conventional manufacturing processes such as milling, turning or casting, are used, the production costs are closely linked to the complexity of a part. The reason: It is generally necessary to produce complicated tools or complex specialised solutions. Such specially produced parts are used in many industries. They always represent a risk factor for suppliers because of the constant time pressure associated with prompt manufacturing. [3]

Additive Manufacturing (AM) is the comprehensive solution to these problems: The laser sintering process, because it requires no tools, permits the fast, precise and cost-effective production of complex parts – even in smaller series or even batches as small as one unit. In AM almost the only relevant factor in terms of costs is the external geometry. On the other hand, the complexity of a part has almost no bearing on manufacturing time and costs. Complex lightweight structures can often actually reduce weight and save material costs. [4,5]

The EOS process has proven itself in practice and can benefit from faster and much more cost – efficient production: 43 % shorter cooling time, 31 % shorter cycle time, 43 % shorter production time for the injection mould, consistently high functionality. [6,7]

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EXPERIMENTAL PROCEDURE

The specimens used for the experiment were printed on the EOSINT M280 3D printer in the company 1. PN, Ltd. The printing process was carried out in compliance with the Slovak Technical Standard EN 10045-1 for the bend impact test. It was chosen the EOS MaragingSteel MS1 high strength steel powder to produce the specimens. This metal material is optimised to be used in the EOSINT M systems type of 3D printers. To test the notch toughness, the specimens with no notch and the specimens with a V – notch were printed. Printed specimens were subsequently heat treated in order to evaluate the increase in hardness and its impact on the changed material toughness. The Nabertherm N 41/H chamber furnace with radiant heat transfer was used to heat treat the specimens. The specimens were tempered to the hardness value of 53 HRC at 490 °C over 6 hours. The specimens were cooled in the open air. [8,9]

Prepared specimens were subsequently chilled to 10 °C or 0 °C in laboratory refrigerator. Once the specimens were conditioned, the tests of impact strength and notch toughness were performed in the testing and development centre of Labortest, Ltd., using the Charpy test method. Afterwards, the fracture surface morphology of the specimens was evaluated through the Mira3 scanning electron microscope from Tescan. [10,11]

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. In specimens tested at the temperature of 10 °C, the values of the impact energy for the specimens with no notch were higher by approximately one – third compared to the specimens with the V – notch. The value of the impact energy increased from the V – notch specimen value of 34,3 J to the 98,1 J value of the specimen with no notch. When the temperature dropped to 0 °C, the values of the impact energy slightly decreased as well. The impact energy of the V – notch specimen decreased to 14,7 J and the impact energy of the specimen with no notch also decreased to 74,5 J. It follows that lower temperatures result in reduced values of the impact strength.

For better understanding, the values of the impact strength are graphically demonstrated. The values of the impact strength at the temperature of 10 °C are presented in Figure 1. The values of the impact strength at the temperature of 0 °C are presented in Figure 2.

The evaluation of the fracture surfaces shows the values of the attained impact energy. Figure 3 to 8 pre-

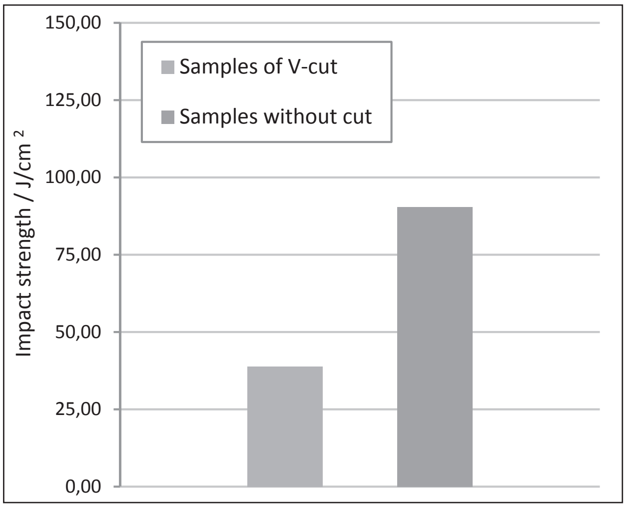

Figure 1 Impact strength at the temperature of 10 °C

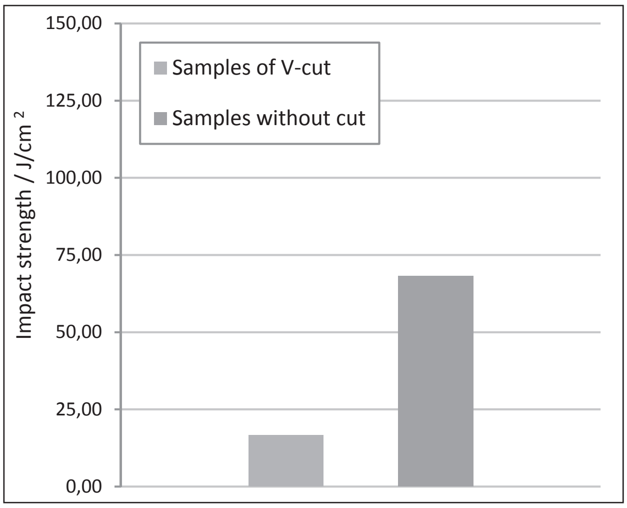

Figure 2 Impact strength at the temperature of 0°C

Table 1 **Dimensional values of the specimens tested and the final values of the impact energy at the temperature of 10 °C**

Speci-men V - notch					Width b / mm					Height a / mm
	b1 / mm	b2 / mm	b3 / mm	b4 / mm		a1 / mm	a2 / mm	a3 / mm	a4 / mm	
	10,03	10,03	10,05	10,04	10,0	10,81	10,89	10,85	10,85	10,9
	Height h / mm	Content S_0 / mm²	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KCV / J/cm²				
	8,81	88,4	3,5	135	34,3	38,81				
Speci-men without notch					Width b / mm					Height a / mm
	b1 / mm	b2 / mm	b3 / mm	b4 / mm		a1 / mm	a2 / mm	a3 / mm	a4 / mm	
	10,02	10,05	10,05	10,03	10,0	10,81	10,84	10,84	10,86	10,8
	Height h / mm	Content S_0 / mm²	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KC / J/cm²				
	10,80	108,4	10,0	106	98,1	90,46				

Table 2 **Dimensional values of the specimens tested and the final values of the impact energy at the temperature of 10 °C**

Speci-men V - notch					Width b / mm					Height a / mm
	b1 / mm	b2 / mm	b3 / mm	b4 / mm		a1 / mm	a2 / mm	a3 / mm	a4 / mm	
	10,05	10,03	10,03	10,03	10,0	10,93	10,92	10,92	10,88	10,9
	Height h / mm	Content S_0 / mm²	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KCV / J/cm²				
	8,80	88,3	1,5	147	14,7	16,66				
Speci-men without notch					Width b / mm					Height a / mm
	b1 / mm	b2 / mm	b3 / mm	b4 / mm		a1 / mm	a2 / mm	a3 / mm	a4 / mm	
	10,04	10,05	10,02	10,02	10,0	10,92	10,90	10,88	10,85	10,9
	Height h / mm	Content S_0 / mm²	Work K / kpm	Angle α / °	Impact energy K / J	Impact strength KC / J/cm²				
	10,90	109,4	7,6	116	74,5	68,16				

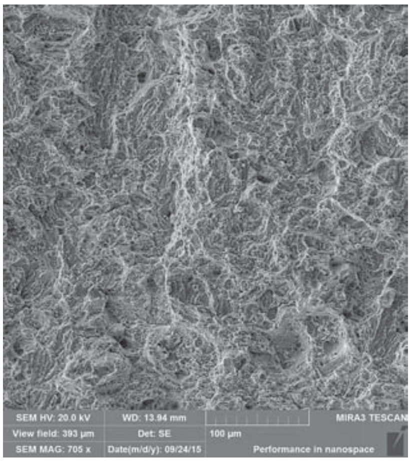

Figure 3 Fracture surface of specimen with V - notch at 10 °C, 500x

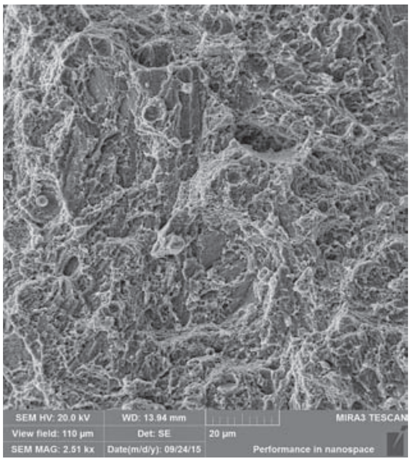

Figure 4 Fracture surface of specimen with V - notch at 10 °C, 1 500x

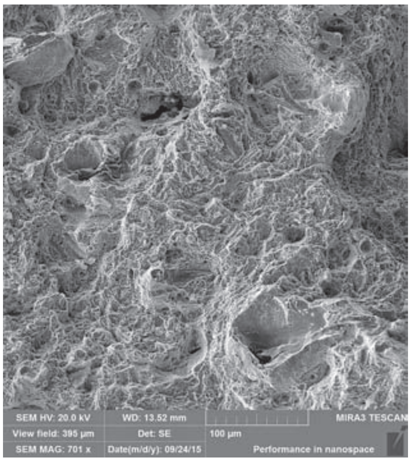

Figure 5 Fracture surface of specimen with V - notch at 0 °C, 500x

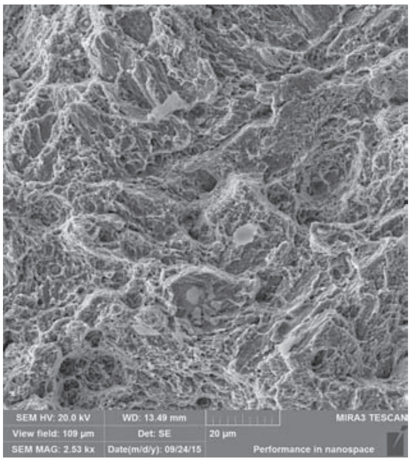

Figure 6 Fracture surface of specimen with V - notch at 0 °C, 1 500x

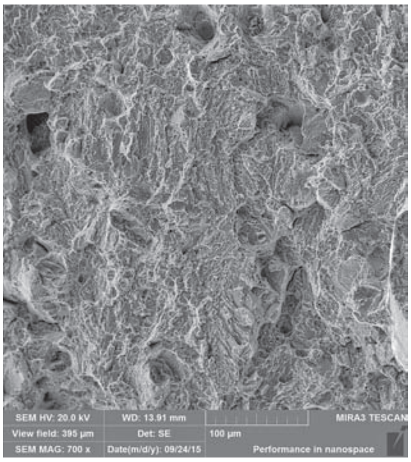

Figure 7 Fracture surface of specimen without notch at 0 °C, 1 500x

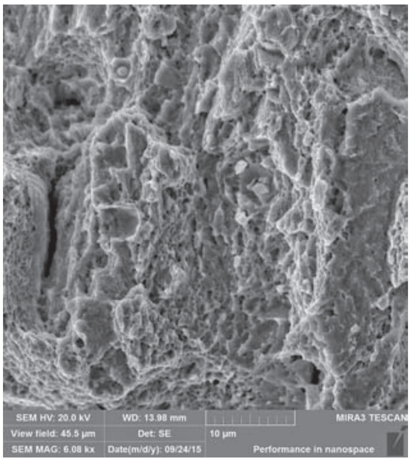

Figure 8 Fracture surface of specimen without notch at 0 °C, 6000x

sent the fracture surfaces magnified 500 and 1 500 times. Ductile intergranular fracture with dimple morphology was observed in all the specimens. Dimple morphology is typical for a ductile fracture with finer segmentation at higher temperatures. It can sporadically see the fragments of the individual particles, like the crater where the inner plastic bond remained during the breakage (Figure 5). Brittle fracture with transgranular fission is expected to be present in the specimens at lower temperatures. In our case, the material is made up of small particles situated on the connection points of the fracture, intergranularly.

CONCLUSION

This article dealt with the topic of determination of the EOS MaragingSteel MS1 material resistance at low temperatures. Material resistance was evaluated in two types of standardised specimens. While evaluating the specimens tested at 10 °C, the impact energy values for the specimens with no notch were, compared to the V-notch specimens, higher by approximately one-third.

When the temperature decreases to 0 °C, these impact energy values decrease slightly. It therefore follows that lower temperatures result in decrease in the values of the impact strength. Ductile intergranular fracture with dimple morphology is typical for a ductile fracture with finer segmentation at higher temperatures.

We can sporadically see the fragments of the individual particles like the crater where the inner plastic bond remained. This experiment provided us with the opportunity to find out whether the decrease in temperature impacts the resistance of the tested material.

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