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INFLUENCE OF SLM PROCESSING PARAMETERS OF Co-Cr-W POWDERS ON THE VICKERS HARDNESS

BY

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Abstract. Selective Laser Melting (SLM) represents an Additive Manufacturing method used in dental medicine. The 59% Co, 25% Cr, 2.5% W alloy powder (Starbond CoS Powder 55, S&S Scheftner C, Germany) was processed (SLM) on a Realizer SLM 50 equipment (SLM Solution, Germany). This paper presents the influences of the laser power (P = 60.61W, 80.30 W and 100 W), the scanning speed (v_{scan} = 333.33 mm/s, 500 mm/s and 1000 mm/s) and the exposure time (te = 20 μs, 40 μs and 60 μs) on the Vickers hardness of the samples obtained by SLM processing. Based on the obtained results, we can conclude that the combination of the parameters P = 100 W, v_{scan} = 1000 mm/s and t_e = 20 μs leads to the highest Vickers hardness value.

Keywords: Selective Laser Melting; Co-Cr-W dental alloy; Vickers hardness.

1. Introduction

The American Standard defines additive manufacturing (AM) as the process of computer-assisted construction (CAM) of three-dimensional parts by

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making and overlapping layer by layer the elementary sections of the future part (Zhou *et al*., 2019).

The SLM technology allows the execution of metal parts with complex geometries, due to the CAD/CAM nature of the processing. For the CAD component, it is necessary to make the 3D design and the (.stl) file of the final part, while the CAM component refers to the actual processing of the part on specialized equipment (Koutsoukis *et al*., 2015; Anusavice, 2012).Under these conditions, the 3D Printing or the Rapid Prototyping technology is recommended for the manufacturing of parts for various industrial fields, including metal components for dental prosthetics (Ucar *et al.*, 2009). The role of dental prostheses is to restore the teeth with coronary lesions (lost in inorganic and organic matrix of the dental tissues), and the interrupted dental arches (Vasluianu *et al*., 2016; Vasluianu *et al*., 2018).

The surface quality and the mechanical properties of the processed metal parts will be influenced by the technological parameters specific to the SLM processing: laser beam power, scan speed, exposure time (Baciu *et al*., 2018). The values of these parameters require an optimization process to obtain the best functional and durability characteristics of the products made.

2. Materials and Methods

Vickers hardness measurements were performed on 18 samples obtained by the additive/SLM processing of the Co-Cr-W metal powder, Starbond CoS Powder 55 (S&S Scheftner C, Germany), with different sizes of the powder layers and different processing parameters (Table 1).

Table 1
Sets of Technological Parameters Adopted for the SLM Processing of the Co-Cr-W Metal Powder, Starbond CoS Powder 55 (S&S Scheftner C, Germany)

Set no.	Sample Mark	Powder layer thickness [μm]	Technological parameters		
			P [W]	V_{scan} [mm/s]	t_e [μs]
1		25	100	500	40
2	25-01	25	100	1000	20
3	25-03	25	100	333.33	60
4	25-05	25	80.30	500	40
5	25-07	25	80.30	1000	20
6	25-09	25	80.30	333.33	60
7	25-11	25	60.61	500	40
8	25-13	25	60.61	1000	20
9	25-15	25	60.61	333.33	60
10	25-17	50	100	500	40

Table 1
Continuation

Set no.	Sample Mark	Powder layer thickness [μm]	Technological parameters		
			P [W]	V_{scan} [mm/s]	t_e [μs]
11	50-02	50	100	1000	20
12	50-04	50	100	333.33	60
13	50-06	50	80.30	500	40
14	50-08	50	80.30	1000	20
15	50-10	50	80.30	333.33	60
16	50-12	50	60.61	500	40
17	50-14	50	60.61	1000	20
18	50-16	50	60.61	333.33	60

The CAD/CAM processing of the samples for experimental research required the (.stl) file specific to the mechanical testing, Fig. 1.

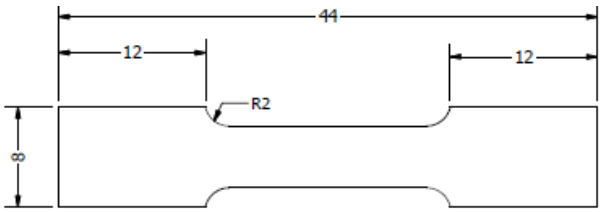


Fig. 1 – The (.stl) file intended for the 3D printing of the study test samples.

The samples were SLM processed on a Realizer SLM 50 equipment, having the following technical features:

– laser power: P_{max} = 100 W;

– laser beam diameter: d = 0.2…0.4 μm;

– recommended size of the metal powder particles: 20…50 μm;

– thickness of the 3D printed metal layer: g_1 = 25 μm; g_2 = 50 μm;

– metal powders used: Ti alloys, Co - Cr alloys, 316 L stainless steel, Ni (Inconel 725) based alloys, Gold based alloys.

The tests were performed on a HVT-1000 Micro Hardness Tester (Shanghai Daheng Optics and Fine Mechanics Co., Ltd.), using a pressing force of 2942 N (300gf), for a pressing time of 15 sec.

3. Results and Discussions

Three determinations were performed on each sample, their mean values being presented in Table 2 and Table 3.

Table 2

Vickers Hardness Values for the Samples Processed by SLM from a Co-Cr-W Metallic Powder Layer, Starbond CoS Powder 55 (S&S Scheftner C, Germany), 25 μm Thick

Set no.	Sample mark	HV	$HV_{max.}$	$HV_{min.}$	ΔHV	Standard deviation, [%]
1.	25-01	445.7	458.6	430.8	27.8	6.2
2.	25-03	492.8	517.0	467.2	49.8	10
3.	25-05	461.3	480.3	446.3	34.0	7.4
4.	25-07	485.8	494.7	472.9	21.8	4.5
5.	25-09	478.8	482.0	477.2	4.8	1.0
6.	25-11	441.5	460.0	428.1	31.9	7.2
7.	25-13	456.2	495.4	385.1	110.4	24.1
8.	25-15	411.3	458.1	275.4	182.7	44.3
9.	25-17	447.5	448.9	446.8	2.2	0.5

Table 3

Vickers Hardness Values for the Samples Processed by SLM from a Co-Cr-W Metallic Powder Layer, Starbond CoS Powder 55 (S&S Scheftner C, Germany), 50 μm Thick

Set no.	Sample mark	HV	$HV_{max.}$	$HV_{min.}$	ΔHV	Standard deviation, [%]
1.	50-02	443.8	459.7	427.6	32.1	7.2
2.	50-04	422.1	431.4	417.4	14.0	3.3
3.	50-06	473.9	497.9	433.5	64.4	13.5
4.	50-08	433.7	451.9	424.6	27.3	6.2
5.	50-10	416.5	433.1	380.8	52.4	12.5
6.	50-12	436.4	451.8	418.6	33.2	7.6
7.	50-14	451.7	459.7	437.9	21.8	4.8
8.	50-16	347.4	466.4	270.6	195.8	56.1
9.	50-18	439.4	446.4	431.6	14.8	3.3

The correlation between the technological parameters of SLM processing and the Vickers hardness obtained on the 3D printed samples is presented in Table 4.

Table 4

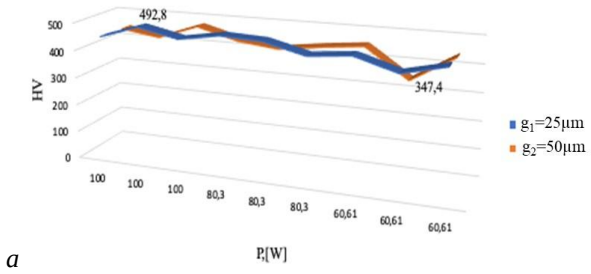
Technological Parameters and Vickers Hardness Values for the Samples Processed by SLM from a Co-Cr-W Metallic Powder Layer, Starbond CoS Powder 55 (S&S Scheftner C, Germany), with a Thickness of g_1 = 25 μm and g_2 = 50 μm

Set no.	Sample mark	Technological parameters			HV
		P [W]	v_{scan} [mm/s]	t_e [μs]	
1.	25-01	100	500	40	445.7
2.	25-03	100	1000	20	492.8
3.	25-05	100	333.33	60	461.3

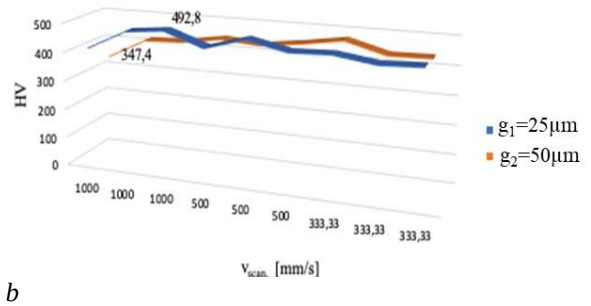
Table 4
Continuation

Set no.	Sample mark	Technological parameters			HV
		P [W]	v_{scan} [mm/s]	t_e [μs]	
4.	25-07	80.30	500	40	485.8
5.	25-09	80.30	1000	20	478.8
6.	25-11	80.30	333.33	60	441.5
7.	25-13	60.61	500	40	456.2
8.	25-15	60.61	1000	20	411.3
9.	25-17	60.61	333.33	60	447.5
10	50-02	100	500	40	443.8
11	50-04	100	1000	20	422.1
12	50-06	100	333.33	60	473.9
13	50-08	80.30	500	40	433.7
14	50-10	80.30	1000	20	416.5
15	50-12	80.30	333.33	60	436.4
16	50-14	60.61	500	40	451.7
17	50-16	60.61	1000	20	347.4
18	50-18	60.61	333.33	60	439.4

Based on the experimental results, the variation curves HV = f(P) and HV = f(v_{scan}) were determined for the 3D samples printed from powder layers with a thickness of g_1 = 25 μm and g_2 = 50 μm (Fig. 2*a*, Fig. 2*b*).



a



b

Fig. 2 – Vickers hardness variation curves: *a* – HV=f(P); *b* – HV=f(v_{scan}).

The analysis of the values obtained for the Vickers hardness indicated that the use of a 25 μm thick powder layer in combination with high laser beam power (P = 100 W), high scanning speed (v_{scan} = 1000 mm/s) and short exposure time (t_e = 20 μs) resulted in high hardness samples, the surfaces of which are more difficult to process mechanically.

4. Conclusions

The following conclusions can be formulated, based on the determinations performed:

1. The SLM processing of the metal powder was performed according to the 9 sets of technological parameters (P, v_{scan}, t_e) values and for two thicknesses of the powder layer (g_1 and g_2).

2. The 3D printing of the powder required the creation of (.stl) files specific to each type of test tube for Vickers hardness testing.

3. Vickers hardness measurements indicated uniform values for all sets of technological parameters.

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INFLUENȚA PARAMETRILOR DE PROCESARE SLM A PULBERILOR DE ALIAJ Co-Cr-W ASUPRA DURITĂȚII VICKERS

(Rezumat)

Topirea Selectivă cu Laser (SLM) reprezintă o metodă de fabricație aditivă utilizată în medicina dentară. Pulberea de aliaj 59% Co, 25% Cr, 2,5% W (Starbond CoS Powder 55, S&S Scheftner C, Germania) a fost procesată (SLM) pe un dispozitiv Realizer SLM 50 (SLM, Germania). Această lucrare prezintă influența puterii laserului (P = 60,61 W, 80,30 W și 100 W), a vitezei de scanare (v_{scan} = 333,33 mm/s; 500 mm/s și 1000 mm/s) și a timpului de expunere (t_e = 20 μs; 40 μs și 60 μs) asupra durității Vickers a epruvetelor obținute prin procesare SLM. Pe baza rezultatelor obținute, putem concluziona că combinația parametrilor P = 100 W, v_{scan} = 1000 mm/s și t_e = 20 μs va determina obținerea celei mai mari valori a durității Vickers.