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EXPERIMENTAL RESEARCH IN THE FIELD OF SLM IN ORDER TO REFLECT THE MACHINE WORK PARAMETERS FOR DIFFERENT MATERIALS AND COMPONENTS

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Abstract: *This paper describes the process of selective laser melting, the process of obtaining the components of two types of Ti and stainless steel. The ability to select components according to the size that can be placed and processed directly on manufacturing plate or supports . Melting regime applied to each component and their manufacture, varying parameters for finding the correct components in order to manufacturing industrial and medical implants.*

Key words: *Selective Laser Melting, Supports, Specimens, Scanning speed, Stainless Steel, Parameters.*

1. INTRODUCTION

Selective laser melting (SLM) is an additive manufacturing technology that uses a high powered ytterbium fiber laser to fuse fine metallic powders together to form functional 3-dimensional parts.

The process is digitally driven, direct from sliced 3D CAD data, in layer thicknesses ranging from 20 to 100 microns that form a 2D cross section. The process then builds the part by distributing an even layer of metallic powder using a recoater, then fusing each layer in turn under a tightly controlled inert atmosphere. Once complete, the part is removed from the powder bed and undergoes heat treatment and finishing depending on the application.[6]

Selective laser melting has appliance in medical and industrial fields and lot of areas are opened for this technologies.

Early adopters of SLM in the medical orthopedics and dental sectors saw benefits from the technology's ability to manufacture complex geometries and structures in high grade materials such as titanium and cobalt chrome dental alloys. From patient specific hip implants to series volume production of dental crowns and orthopedic implants featuring hybrid structures, SLM has an established following in these sectors.[7]

In industrial field, from tooling inserts featuring conformal cooling channels through to lightweight structures for aerospace and high technology applications, SLM significantly reduces the constraints on designers. This design freedom results in optimized structures and shapes that would otherwise be constrained by conventional processes or the tooling requirements of large volume production. SLM helps to reduce lead times, reduce tooling costs and permits the creation of designs not previously possible.

For the manufacturing of components, machine parameters were varied, and were build components with different dimensions.

2. STEPS TO OPTAIN COMPONENTS BY SLM

For the construction of a component should be taken into consideration its size and mechanical characteristics. Are two ways to build a component, these variants were shown experimentally. If the component has small dimensions and the height is not big one, this could be manufactured on supports the other way, if the component has large dimensions this must to be made directly on to manufactured plate and be welded on this.

The reason why part is welded directly to the board is due to the contractions that occur during processing and part has tendency to detach himself from the plate.

Are few types of supports who are used in this technologies, like block, line, contour and combi supports.

Like any type of supports they being combined with laser power and scanning speed give a very good resistance of the work piece helded on the plate.

These types of supports, can be used to further stiffen the edges or a component if is a complex component in certain sections of it to avoid dislodging it from the plate or from another form in the final component.

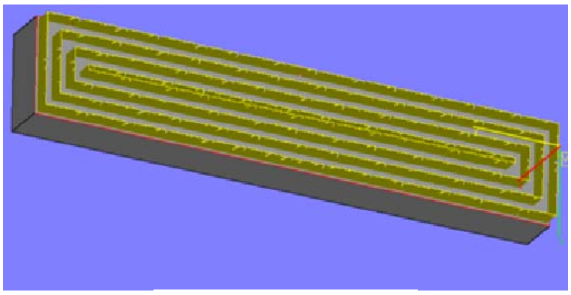


Fig.2.1. Contour support

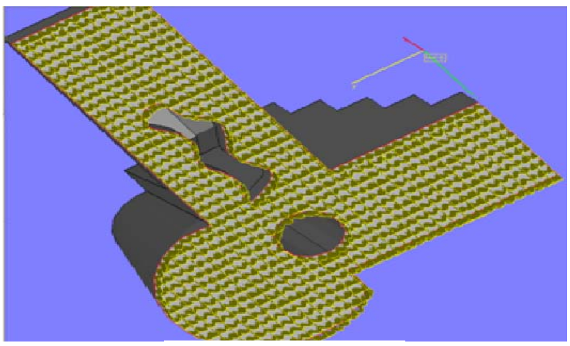


Fig.2.2. Block support

After the supports were chosen is move to the track location on the virtual worktable, the choice of working parameters adapted to the type of the component, depending on material and size of component. If all parameters are choose the manufacturing process starts .

2. SAMPLES OF Ti MADE ON SLM

Were fabricated Ti6Al7Nb specimens for testing of their tensile, roughness, adhesion and cell culture to see if they behave like bone structure and from tests varying the working parameters of the machine to succeed bringing metal components in an area close to the biocompatibility and bone strength.[3]

SLM is a complex thermo-physical process which depends on a lot of material, laser, scan and environmental parameters. For both selected materials, a parameter study has been performed to optimize the process regarding part density, since porosity has a harmful effect on the mechanical properties of the part. Four main process parameters are selected for experimentation: laser power, layer thickness, scan speed and hatching space. These factors determine the energy supplied by the laser beam to a volumetric unit of powder material, defined as energy density, an experimental quantity which has large influence on part density

For the manufacture of specimens for implants requires an porous surface more to adhere to the surface tissue and for this laser power range so that we are on the border between porosity and mechanical strength of the implant.[5]

Have used laser powers ranging between 50 and 200 W, in some cases as in figure 4.1. below specimens were bent and broke away from the surface due to internal tensions that appear in them.

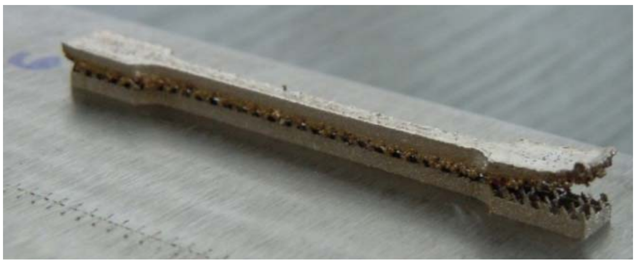
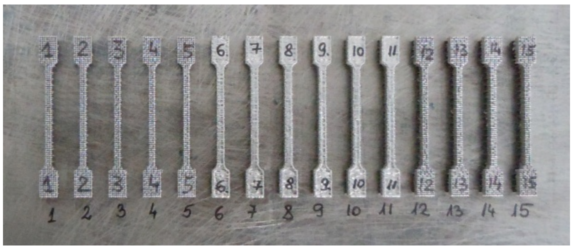


Fig 3.1. Exfoliation of sample[1] [4]

However, during processing and after internal tensions appear to prevent this flaking, was resorted to use two different laser powers, one for support and the other for body specimen.[5]

Increasing laser power and changing the type of supports to sustain any deformation, was one of the solutions.

To reduce tensions in the plate and samples has been made a stress relieving of their, that is placed in an oven and maintained at a temperature of 400 and 500Celsius degrees.



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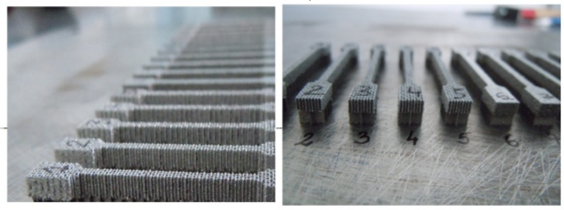

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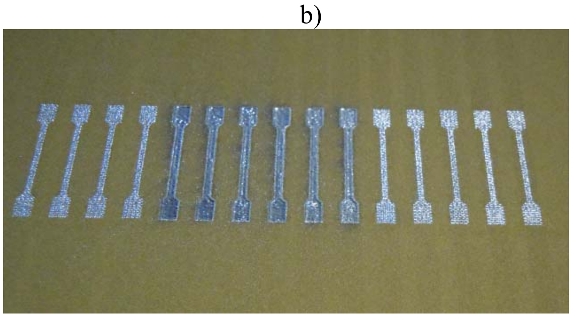
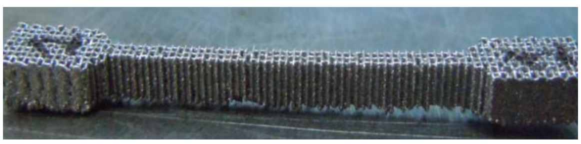


c)

Fig 3.2. Samples a) Top view on plate b) front view c) on powder bad [1] [4]

For the specimens construction has selected a scan with a hatching surface with gaps between 0.4 0.5 0.6 mm and a porous structure in order to join cellular cultures easily as the depth of specimen material, to show more better biocompatibility.



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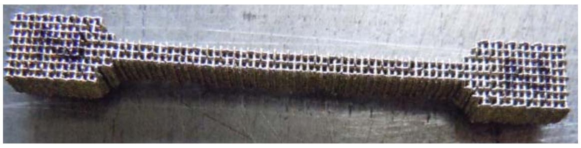

b)

Fig 3.3 Cellular samples with 0.4mm gap a) A side view b) top view [1] [4]

For cell culture to adhere as well to cell structure in Ti powder mixture has added a 2% hydroxyapatite concentration.

In the figure above are shown the specimens with porous and cellular structure, for adhesion and cell culture tests.

3. TESTS ON SPECIMENS

To see the future implant characteristics and behavior tests were made on specimens for compression roughness adhesion traction, cell culture.

Tab 4.1 Roughness [1] [4]

Samples nr.	11	12	13	14	15
Power	185	145	130	160	200
Ra	6.49 3.83 4.09	7.22 5.96 4.76	7.08 9.48 5.51	6.54 6.38 4.73	4.6 4.23 3.32
Average	4.80	5.98	7.36	5.88	4.05
Rz	33.13 32.26 21.29	31.06 26.97 21.69	32.25 41.19 30.93	34.18 35.44 21.75	20.68 24.4 18.08
Average	28.89	26.57	34.79	30.46	21.05
Rq	8.16 5.1 4.97	8.51 7.16 5.57	8.25 10.72 6.78	7.95 8.06 5.77	5.35 5.29 4.12
Average	6.08	7.08	8.58	7.26	4.92

From these tests have varied characteristics of the machine work to bring the implant to the desired standards. Roughness is desirable to be a low as in depth of material because adhesion of cells to be as good.

Tab.4.2 Tensile strength and elongation obtained [1]

	180W specimen		200W specimen	
No.	R_m (N)	A_t (%)	R_m (N)	A_t (%)
1	829	12.6	950	15
2	935	12.1	703	14.9
3	511	10.7	659	11.6
4	681	12	939	16.1
5	624	9.8	670	8.9.

*R_m tensile strength; **A_t elongation

A total of 10 test specimen, 5 made with power of 180 W and 5 specimen with power of 200 W, with gaps of 0.6 mm which are obtained from the overlapping scan lines has been made (fig.5). Then, these test specimen were tested on the machine Zwick Roell z005.Test results are summarized in the table below:

Titanium alloys quenched and resistance characteristics high mechanical (Rm= 900...1300 N/mm^2, $Rp_{0,2}$= 820...970 N/mm^2) and at the same time has good plasticity and toughness characteristics (A= 10... 15%, Z =20 ...25%... 35 KV = 30J).

5. SAMPLES OF STAINLESS STEEL MADE ON SLM

Tab. 5.1. Stainless steel powder comosition 316L[4]

ITEM	Material	Min Value	Max Value
	C	-	0,03
	Mn	-	2,0
	Si	-	0,75
316L	P	-	0,045
	S	-	0,03
	Cr	16,0	18,0
	Mo	2,00	3,00
	Ni	10,0	14,0
	N -		0,10

Tab.5.2. Mecanical properties [4]

316L	Value
Tensile strength MPa	485
0,2% Mesured tensile (MPa) min	170
Elongation (% in 50mm) min	40
Rockwell B hardness (HRB) max	95
Brinell (HB) max	217

Grade 316 is the standard molybdenum-bearing grade, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments.

Grade 316L, the low carbon version of 316 and is immune from sensitization (grain boundary carbide precipitation). Thus it is extensively used in heavy gauge welded components (over about 6mm). There is commonly no appreciable price difference between 316 and 316L stainless steel. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

Compared to chromium-nickel austenitic stainless steels, 316L stainless steel offers higher creep, stress to rupture and tensile strength at elevated temperatures.

For 316 L stainless steel specimens were varied powers from 50 to 200W. Was found that high deformations of specimens appear to 160 laser power.

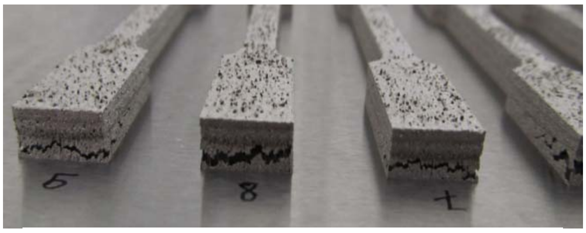

Fig.4.1. Detachment of the heads of the specimens

Was found that the ideal power for manufacturing stainless steel powder is 160 to 200W. Less power what is applying on the powder surface lead to incomplete melting of these or occur to deformation of the samples.

After the laser power was set, the next step is variation and calculation of speed scanning.

Scanning speed was calculated with the following parameters:

$$v = \frac{pdist[\mu m]}{expo[\mu s]} \qquad (1);[2]$$

pdist - is distance between two points of scanning measured in micrometers;

expo – is time between laser stays on layer in microseconds.

These parameters are taken from materials files, what represent the process parameters of melting procedure, and these parameters could be modifying with a wish value.

expo Hatch solid [µs]	P dist Hatch solid [µm]	Scanning speed V [mm/s]
100	100	1000
200	100	500
250	100	400
300	100	333
400	100	250
500	100	200
550	100	181
600	100	166
700	100	142

Scanning speed of 400mm/s is standard speed in material file witch components are made. For all specimens tested before it is used by default scanning speed. The 1000 mm/s speed is a big one and the components made on these speed are not fully melted.

Tab. 5.3.Scanning speed calculation

Tab.5.4. Variation of scanning speed

Nr. of samples	Power in W	Scanning speed in mm/s
7	160	1000
8	160	500
9	160	333
10	160	250
11	160	200
12	160	166
13	160	320
14	160	600

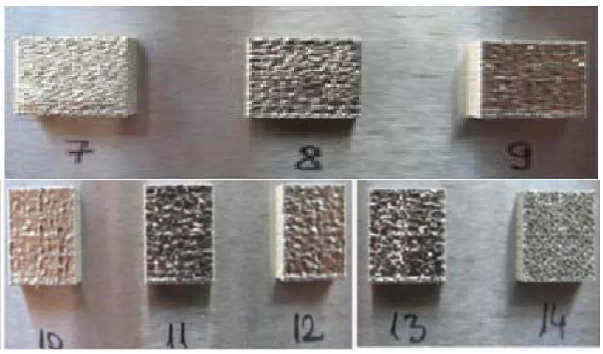

Fig.4.2. Specimens with scanning speed from 166 to 1000mm/s

From the above tests, samples 10 and 12 with speeds of 250mm/s and 166mm/s have the best quality surface. If the scanning speed is to height, powder is not completed melted and if the power is big and scanning speed is low powder can be melted too much and lead to a burning surface.

4. TEST COMPONENTS WITH DIFFERENT DIMENSIONS MADE ON SLM

After the laser power was established, it could be passing at manufacturing of component of different dimensions and geometries to see the behavior of melting procedure on this components.

a)

b)

Fig.5.1. Component in steps and angle

For this component was applied a power of 160W and a scanning speed of 400mm/s. the goal of this component is to observe differences between angles and layers.

It could be observe circle manufacturing and tapering witch are made in increments not in a continuous line the roughness is less in different angles but the best in vertical line.

This manufacturing component was not made on supports because the dimensions not allow this, was welded on plate.

Dimensions length and width of this component is 70/70mm and a height of 50mm. For this technologies this component is a big one because the dimensions of working table is 250/250mm

6.CONCLUSIONS

In this paper has shown selective laser melting process, how this process works and details of this newest structure. Have described the types of materials used for laser melting machine and details of these used for tests as Ti6Al7Nb and stainless steel 316L being described all the technical data of this type of material.

Different laser powers were tested for these two materials and was varied scanning speed, to find the best power with the best scanning speed .

Supports were tested for what types of components and sizes are fitted or if are necessaries for bigger dimensions of component.

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CERCETĂRI EXPERIMENTALE ÎN DOMENIUL SLM ÎN VEDEREA EVIDENȚIERII PARAMETRILOR DE LUCRU AI MAŞINII PENTRU DIFERITE MATERIALE ŞI COMPONENTE

Rezumat: În această lucrare se descrie procedeul de topire selectivă cu laser, procedeul de obținere a componentelor din două tipuri de materiale Ti şi oțel inoxidabil. Capacitatea de selectare a componentelor în funcție de dimensiuni care pot fi aşeyate şi prelucrate pe suporți sau direct pe placa de fabricație.

Regimul de topire aplicat pentru fiecare componentă în parte şi fabricarea acestora, variind parametrii pentru aflarea celor corecți în vederea fabricării de componente industriale şi de implanturi medicale.

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