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MANUFACTURE THE PARTS BY SELECTIVE LASER MELTING AND THEIR DIMENSIONAL ACCURACY

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Abstract: *Selective laser melting (SLM) is a Rapid Manufacturing technique in which parts of complex shape are produced by selectively melting layers of powder. During SLM, a high intensity laser beam selectively scans a powder bed according to the CAD data of the part to be produced and powder particles are completely melted. SLM is capable of producing near full density parts with an almost infinite geometric freedom. In this study, dimensional accuracy of the parts obtained by SLM is analyzed. All the experimental investigations were done on the MCP Realizer SLM 250 and it is equipment at the Technical University of Cluj-Napoca (Romania).*

Key words: *rapid prototyping, selective laser melting, dimensional accuracy.*

1. INTRODUCTION

Selective laser melting (SLM) is a powder-based additive manufacturing technology that makes it possible to manufacture complex high geometrical accuracy parts directly from its CAD data. This is a layered fabrication process that can create functional parts with different porous or approximately 100 percent dense internal structure by melting powder particles using a laser [1]. These functional parts are difficult to create using conventional manufacturing methods. The fields of application are varied and include the fabrication of internal cooling channels, complex weight-light structure, functional-graded materials, functional-graded coatings, etc. for aerospace, nuclear, chemical and petrochemical uses, among other applications ([2];[3];[4];[5]). Other applications can be found in the medical field (implants, tissue engineering scaffolds), porous structure, dental restoration – creation of dental crowns, etc. ([6]).

The SLM process is defined by a large number of parameters including the processing parameters such as laser power, scanning speed, scan line spacing (hatch distance), thickness of layer, scanning strategy, working atmosphere, temperature of powder bed, and material-based input parameters. In this study, dimensional accuracy of the parts obtained by SLM is analyzed.

2. MATERIALS AND EXPERIMENTAL STUDY

2.1 SLM technology

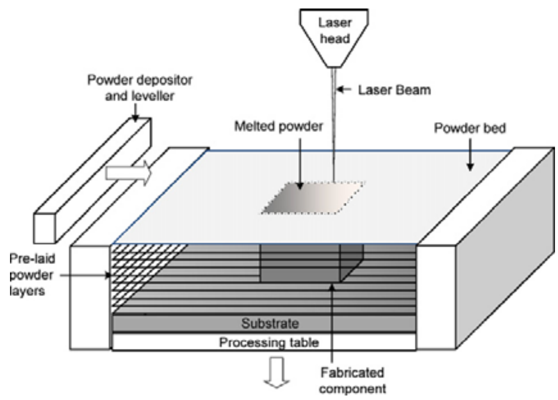

Fig.1 A typical SLM machine

During the SLM process, a powder layer is deposited onto a base plate attached to the building platform of the machine. The laser beam scans the powder bed according to the slice data of the CAD model, and the powder being fully molten forms the first layer on the base plate. Then, the building platform is lowered with an amount equal to the layer thickness and a fresh layer of powder is deposited on the already solidified layer.

Successive scanning and lowering the building platform continues until the part is completely made. A typical SLM machine is shown schematically in Figure 1 with its main components.

2.2 Materials

This study has been done using an austenitic stainless steel in the form of metallic powder (diameter of particles between 10 and 45 μm). The alloy studied is the AISI 316 L, whose composition is shown in Table 1 (1.4404 or X2CrNiMo17-12- 2 after European standard "EN 10083").

Table 1. Composition of studied alloy: austenitic stainless steel AISI 316 L (percentage in weight)

C	≤0.03
Si	≤1.00
Mn	≤2.00
P	≤0.045
S	≤0.015
Cr	2.00–2.50
Mo	2.00–2.50
N	≤0.110
Ni	10.00-13.00

These steels achieve their anti-corrosion properties through the formation of an invisible and adherent chromium-rich oxide surface film. This oxide forms and heals itself in the presence of oxygen. This oxide layer gives to these steels their corrosion resistance properties.

2.3 Experiments

The experiments were carried out on SLM machine SLM Realizer 250, a commercial SLM workstation with a 200W continuous wave Ytterbium Fiber Laser (IPG, Germany) operating at a wavelength of 1071nm (manufactures specification 1065-1105 nm), at the Technical University of Cluj-Napoca. The scanning system used is a dual axis mirror positioning system (Cambridge Technology, UK), which directs the laser beam in the x-and y axis. A flat field is generated using a 300 mm focal length f-Theta lens (Sill, Germany) to produce a focused beam spot size, with a minimum calculated Gaussian spot diameter of 54 μm. Since the powder is fully melted during the process, is essential protection of the SLM parts from oxidation, therefore all metal powder processing occurs in an inert Argon atmosphere of 0.2% Oxygen or less.

In the experimental tests included in this study were varied only two parameters: the laser power and scan speed, while the others were keeping constantly. Sample tests was cubic form 10x10x10 mm and was fabricated with 160W and 180W laser power and 200, 250, 300, 400, 500, 600, and 1000 mm/s scan speed in different combination, and the platform has been pre-heated on 180 °C for 2 hours for all manufactured samples.

In figure 2 is shown the samples fabricated with 160W laser power and v=250mm/s, 200 mm/s.

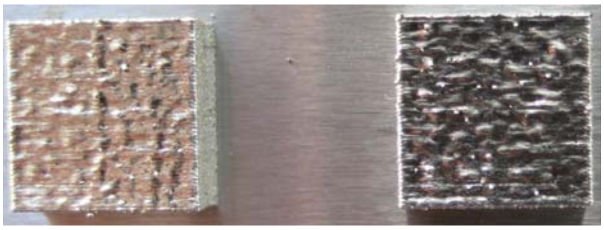

Fig.2 Samples fabricated with 160W laser power and v=250mm/s, 200 mm/s

Figure 3 represented the samples fabricated with 160W laser power v=300mm/s, 600 mm/s.

Fig.3 Samples fabricated with 160W laser power v=300mm/s, 600 mm/s

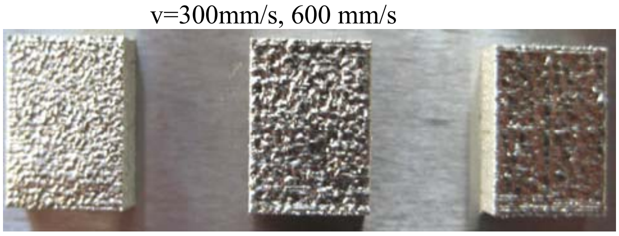

Fig.4 Samples fabricated with 160W laser power and v=1000mm/s, 500mm/s, 400 mm/s

In figure 4 is shown the samples fabricated with 160W laser power and v=1000mm/s, 500mm/s, 400 mm/s. For all samples the X/Y scanning strategy was applied.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Samples were measured on the two directions of manufacturing, respectively on the X-axis and Y-axis.

For the samples manufactured with 160W and different scanning speed, the experimental dimension is shown in figure 5.

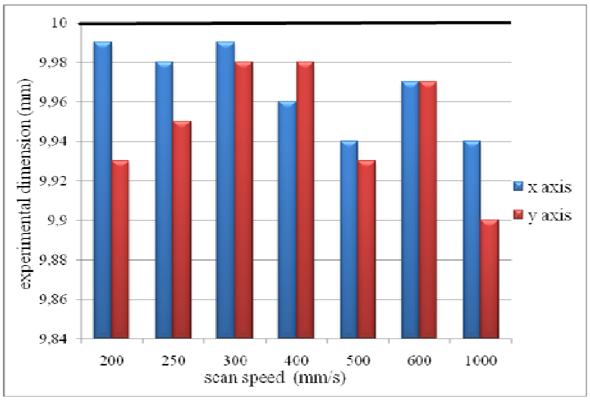

Fig.5 Experimental dimension of the samples fabricated with 160W laser power and different scan speed

Like we see in the figure above, all the samples suffer constraints. For this laser power the optimal scanning speed is between 300-400 mm/s for obtain minimal dimensional errors. There are no significant differences between values obtained on X-axis and Y-axis.

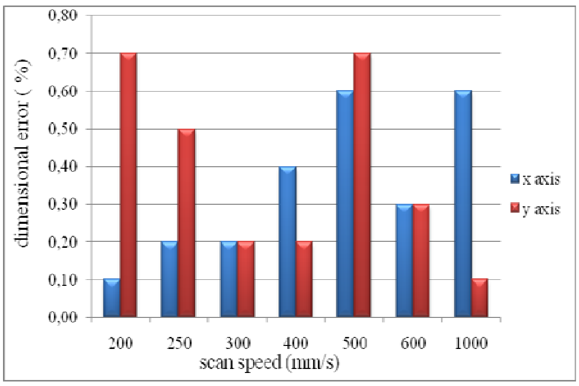

Fig.6 Dimensional errors of the parts manufactured with 160W laser power and different scan speed

The scanning speed has also a significant influence on the accuracy of the SLM manufactured parts, even if the influence it is not important as the influence of the laser power.

For the samples manufactured with 180W and different scanning speed, the experimental dimension is shown in figure 7.

At these samples, one of them suffers constraints, other suffers expansion, but optimal combination between laser power and scanning speed for obtain dimensional accuracy are between 400-600mm/s scanning speed and 180W laser power.

On X-axis a very good results was obtain the 300 mm/s scanning speed , but for Y-axis 600 mm/s was a good scanning speed for minimum dimensional error.

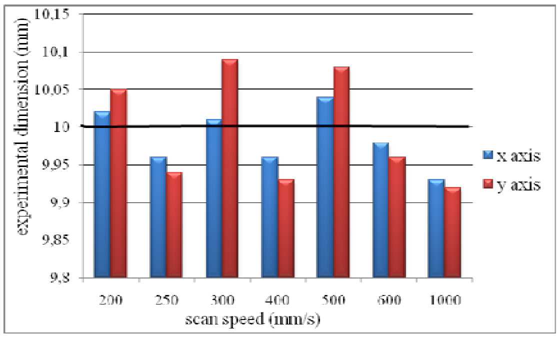

Fig.7 Experimental dimension of the samples fabricated with 180W laser power and different scan speed

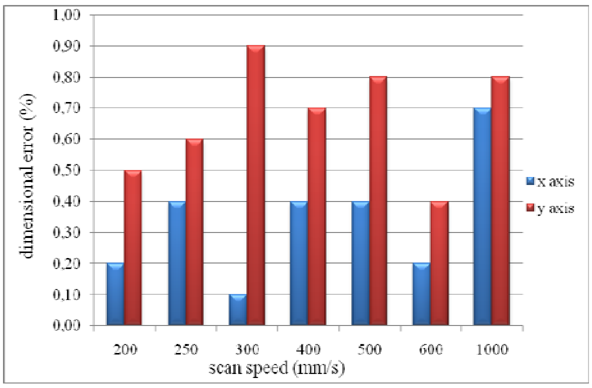

Fig.8 Dimensional errors of the parts manufactured with 160W laser power and different scan speed

4. CONCLUSION

The parts as the one presented in this study were manufactured on the SLM 250 equipment from the Rapid Prototyping Laboratory of the Technical University of Cluj-Napoca (TUC-N) by using the different parameters of laser power and scanning speed. Only these two parameters were modified, while the others were keeping constantly.

The dimensional analysis has been done along X-axis and Y-axis directions and an optimal parameters was been found in order to obtain a dimensional accuracy.

Future research needs to be done related to the optimum laser power and scanning speed in closed connection to the part's geometry and type of metallic powder materials we are working with.

5. ACKNOWLEDGEMENT

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Topirea selectivă cu laser

Topirea Selectivă cu laser (SLM) este o tehnică de fabricare rapidă în care piese de formă complexă sunt produse prin topirea selectivă straturilor de pulbere. În timpul topirii selective cu laser , un fascicul laser de mare intensitate scanează selectiv un pat pulbere conform datelor CAD a piesei care urmează să fie produsă şi particulele de pulbere sunt complet topite. SLM este capabilă să producă piese de mare densitate, cu o forma geometrică liberă. În acest studiu, este analizată precizia dimensională a pieselor obținute prin SLM. Toate cercetările experimentale s-au făcut pe echipamentul Realizer MCP SLM 250 de la Universitatea Tehnică din Cluj-Napoca (România).

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