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COMPARISON BETWEEN SLM AND SLS IN PRODUCING COMPLEX METAL PARTS

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Abstract: *The paper presents experimental case studies of manufacturing complex metal parts by selective laser melting (SLM) and selective laser sintering (SLS). The objective is to evaluate the benefits, using different criteria, such as the dimensional accuracy, surface roughness and manufacturing time and costs. The capabilities of these rapid manufacturing technologies are also discussed as compare to the well known CNC manufacturing. This research was supported with funds within the PCCE-BIOMAPIM project 5/2010.*
Key words: *rapid manufacturing, CNC machining, SLS/SLM*

1. INTRODUCTION

Selective Laser Sintering (SLS) and Selective Laser Melting (SLM) are layer material addition techniques that allow generating complex 3D parts by selectively consolidating successive layers of powder material on top of each other, using thermal energy supplied by a focused and computer controlled laser beam (Berce 2008). Due to technical improvements, better process control and the possibility to process all kind of metals, a shift from RT to firstly Rapid Tooling (RT) and secondly to Rapid Manufacturing (RM) came up in recent years (Kruth 2005).

To turn the SLS/SLM processes into production techniques for real components, some improvements need to be made. Sometimes, a combination between innovative CNC manufacturing and RM is a good solution, Carean (2009). The presented work investigates how SLS/SLM processes fulfill some requirements, especially the accuracy and surface roughness requirements.

2. SLM IN PRODUCING COMPLEX PARTS

Figure 1 illustrates a case study of producing two main components of a product, designed by a company from Timisoara (RO). The Realizer II SLM 250 (Selective Laser Melting) machine was used, at the TUCN. For example, the “blade rotor”, illustrated in figure 2 (left), has the overall size of: height = 80 mm, interior diameter = 70 mm and exterior diameter = 150 mm.

Fig. 1. Selective Laser Melting, TUCN, DME

Main technological parameters that were used for manufacturing the “blade rotor” part by using the Realizer II SLM 250 equipment are presented in table 1.

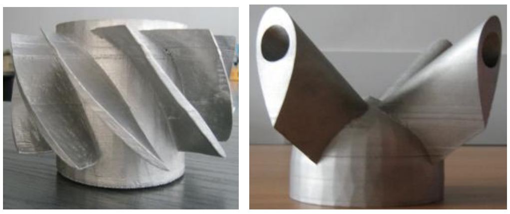

Fig. 2. Complex steel parts, made by SLM at TUCN

Laser power	180 W
Laser thickness	0,05 mm
Build chamber temperature	80 ˚C
Oxygen level	0,1 %

Tab. 1. SLM technological parameters

Besides the specified parameters in the SLM manufacturing software package, an important step consists in correct part orientation. This step is very important because it will determine how the building supports will be generated. This step will not only influence the total time of the part to be manufactured on the machine, but also it will influence its accuracy. The metallic supports needs to be removed as easily as possible afterwards, without influencing the accuracy of the real part. The total time estimated for the “blade rotor” part was 20 hours for 1700 layers to be added on.

The SLM process control is not so simple. The temperature control during the process could be problematic. The manufactured part accumulates heat in time and shrinkage occurs during the SLM manufacturing process. Future research needs to be done in order to better control the temperature during the manufacturing process. Figure 3 presents an intermediary layer of the “rotor blade”.

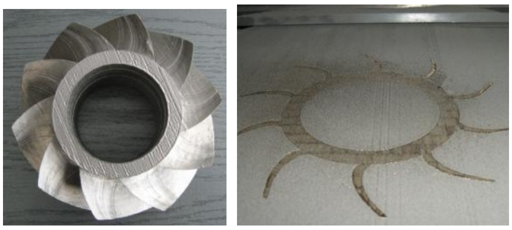

Fig. 3. SLM process, stainless steel

The part was measured by using an electronic caliper. The exterior diameter, the interior diameter and the height of the part were measured 5 times, an average being considered for each measurement that was taken (see Table 2).

Item	CAD dimension	Measured dimension	Deviation (mm)
Exterior diameter	80	80,19	+0,19
Interior diameter	70	70,12	+0,12
Height	150	150,22	+0,22

Tab. 2. SLM measurements

3. SLS EXPERIMENTAL RESEARCH

The part selected for the second case study undertaken within the research presented, is a lid component of a grass cutting machine, made within the Plastor SA, in co-operation with the Brill company from Germany. The CAD model of the lid and the punch were designed at Plastor SA using the SolidWorks 2009 software.

Fig. 4. Injection molded parts, using the SLS tools

The punch (illustrated in Fig. 4) was made by SLS metallic powder (Laserform St-100), using the Sinterstation 2000 equipment, at TUCN. The important technological parameters used for manufacturing the part prototype and the tools on the SLS equipment are presented in Table 3.

Parameter	Punch and die (Laserform St-100)
Scale factors	X=1.02054 Y=1.02144 Z=1.00950
Fill laser power	28W
Sliced fill scan spacing	0.08 mm
Powder layer thickness	0.08 mm
Manufacturing temperature	98˚C

Tab. 3. SLS technological parameters

Scale factors were applied on x,y,z axis in order to compensate not only the errors that occurs in the sintering process on the machine, but mainly the shrinkages that occurs in the post-processing stage in the oven.

The punch was measured at TUCN, using the Werth Video Check Ip 250 equipment. Both, exterior and interior dimensions were measured 5 times. Table 4 presents a comparison between the CAD dimensions of the punch and the measured dimensions of the manufactured punch. The differences between these items are around 0.1-0.2 mm.

CAD model	**Manufactured punch**
D_{e1} = 66.5 mm	D_{em1} = 66.72 mm
D_{e2} = 65 mm	D_{em2}= 65.18 mm
D_{e3} = 62 mm	D_{em3}= 62.15 mm
d_i = 22 mm	d_{im} = 22.14 mm

Tab. 4. SLS measurements

The roughness of the active elements made by SLS is extremely important, as during the injection molding process, the molten plastic penetrate within the micro-cavities of the molds and the plastic part gets stucked into the mold and requires special ejection devices. We analysed the roghness onto three different surfaces, before and after the infiltration. The roughness values are presented in table 5.

Surface 1 / Measurements	**Roughness**, [μm]		
	Punch – in green stage	Punch – infiltrated with bronze	Punch – infiltrated with resin
Average	**4.6**	**6.4**	**3.98**

Tab. 5. Roughness measurements

4. CNC MANUFACTURING OF COMPLEX PRODUCTS

The third case study undertaken within this research was focused on CNC milling of the very complex surfaces in stainless steel, in order to compare the capability of this well known technology to the capabilities of the rapid manufacturing technologies. The purpose was to manufacture the complex turbine (illustrated in figure 5 - left), in one piece. For this particular part, the SLS technology was not suitable because it requires high dimensional accuracy and a good surface roughness. The SLM process is not adequate because it would be impossible to remove the welded supports, from inside the cavities of the part. We decided that the most suitable technology for this turbine is the CNC milling. That is why, we separated the complex turbine into two main parts, the actual turbine and the cover, which will be welded on top of the turbine, after its welding.

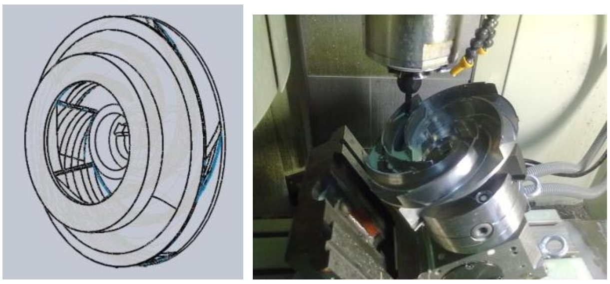

Fig. 5. Complex product - stainless steel, CNC milling

We used the DMG 63 V machining centre from TUCN to carry on the CNC milling with 4 axes simultaneously controlled, as illustrated in figure 5 – right. The cover was manufactured separately at TUCN, being involved both CNC milling and CNC turning operations.

5. CONCLUSIONS

SLM technology is suitable to obtain fully dense metal parts, if the required accuracy is not high. The manufacturing costs are higher, as compare to similar CNC manufacturing.

The SLS parts made on Sinterstation 2000 machines are very fragile in the “green stage” stage and shrinkage could appear during post-processing in the oven. Within the SLM process, the part is manufactured only in one stage, so the technological route is shorter. Future research needs to be done, in order to improve the accuracy on the SLS/SLM systems, as the opportunities of these two technologies are so large, starting with complex steel parts and moving to complex injection molding tools. This research was supported with funds within the PCCE-BIOMAPIM project 5/2010.

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