POLISHING OF SURFACES BY LASER

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Introduction

Recently different *Rapid Manufacturing* (RM) techniques have been developed to repair high added value parts or even build up small functional parts. These techniques such as: LENS [1], Selective Laser Sintering [2] or Selective Laser Melting, build up fully functional metal parts from raw powder material using a laser to melt material and build up the geometry layer by layer. The main advantages are the manufacturing-time reduction and the possibility of building parts with very complex geometry. One of the most extended applications of RM processes is the manufacturing of small inserts for larger moulds or small-medium injection moulds with complex internal cooling conducts, which may lead on a reduction of the cooling time for plastic injected parts in more than 30%.
Among the existing RM methods, Selective Laser Sintering (SLS) is one of the most extended in industry according to the Wholers Associates report [3]. This process allows the fabrication of complex parts in different materials (polymers, ceramic and some metallic alloys). However, the resultant surface quality is very poor. In general, one of the main disadvantages not only for SLS, but also for all the metal additive processes, is the poor quality of the surface [4]. Mean surface roughness values for RM techniques used to be between 5µm and 7µm Ra. However, average values for injection moulds have to be less than 1 µm Ra [4].
The same manual abrasive techniques used for machined moulds are used to achieve the final finishing requirements in parts made by SLS. The finishing operation of large metallic surfaces is one of the most important operations for the die and mould industry. Actually the final polishing operation is carried out manually taking more than 20% of the total manufacturing time of the entire mould or stamping die. Moreover, it must be performed by high qualified workers, so this means high production cost and long lead times. There are new processes that have been developed to improve these drawbacks. Among these new processes, *laser polishing* is one of the most relevant processes. Laser polishing process is based on the melting and later solidifying of a micro layer of material using a laser beam as heating source in order to get a smoothed topography. The laser polishing process has been applied for more than ten years for the polishing of non metallic materials, such as diamond coatings, optical lenses and silicon wafers but there are few studies on the application of laser polishing process on metallic surfaces [5].
Thus, laser polishing process parameter identification and its optimization for SLS material are presented. Starting from simple geometry study to obtain the process optimum parameters and applying to real part geometry polishing.

2. Laser polishing test on SLS surfaces

A series of simple line tests on planar surface and single pass overlap on planar surface polishing were carried out. The test parts of LaserForm ST-100© were fabricated by SLS applying a layer width of 0.15 mm, resulting on an initial mean roughness of 7.5 µm Ra.
In order to evaluate the effect of process parameters on achieved surface quality, a Design of Experiments (DoE) study was performed for simple line polishing tests. In DoE study the output considered was the roughness reduction rate. The tests were carried out using a CO_2 laser up to 2,500W. The tested parameters were the power, the feed rate and focal offset distance, considering for each parameter three different values. The tested parameters are shown on Table 1.
The experimental results are gathered in Fig.1. For all tests, Argon was injected coaxially as shielding gas. The results of the experiments show that the optimum parameters were 600 W and 40mm (distance between the laser head and the surface) for a feed rate of 800 mm/min.

Power [W]	600 – 900 – 1,200
Feed [mm min-1]	800 – 1,400 – 2,000
Focal Offset [mm]	20 - 30 - 40

Table 1 Laser-polishing test parameters

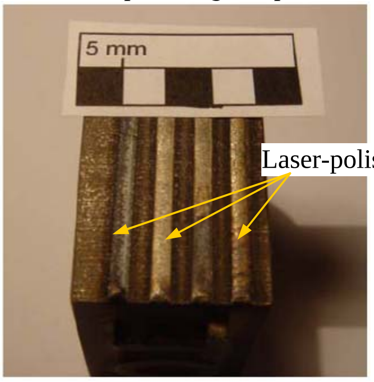

Fig. ***1.*** *Simple line polishing test part*

Fig. 2 shows the roughness reduction reached for each energy density tested. The figure shows 27 different energy densities for each parameter combination (three parameters at three different values) and 5 repetitions (2,647 J/cm2) in order to guarantee the study robustness. An evolution of the roughness reduction rate depending on the energy density can be appraised. For energy density values from 1,800 to

3,000 J/cm^2, a maximum roughness reduction is obtained with roughness reduction rates between 75% and 85%.

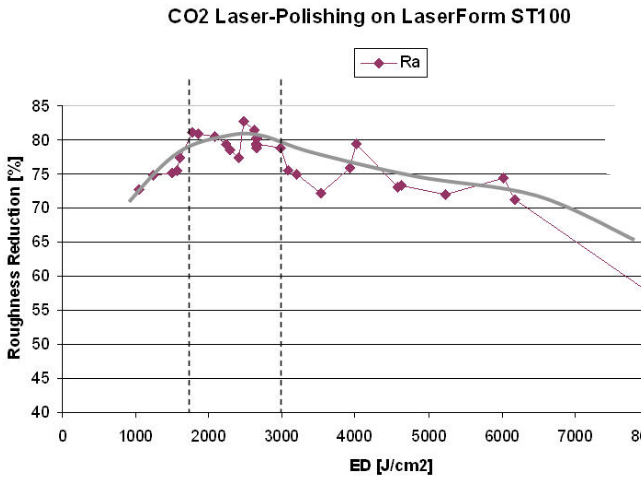

Fig. *2*. Laser-polishing experiments results

Fig. *3* shows topography after laser polishing process. The processed surface is smoother than the original one and keeps the initial profile. So, laser polishing only reduces surface roughness without modifying part shape.

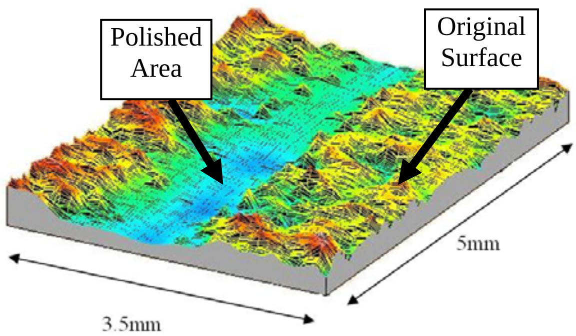

Fig. 3. Topography of laser polishing test

Once the optimum parameters for linear polishing tests were found, horizontal surface polishing tests were performed. These tests were carried out by overlapping line tests on the surface. A new parameter, denominated *overlap index* (O_i), is introduced in this case. The overlap index measure the relative distance that a line overlaps with the last one. Using the optimum process parameters obtained in simple polishing line tests, different O_i values between 25% and 50% were tested. The best results were obtained with 25% overlap reaching a roughness reduction rate of 78.2% as it is shown in Fig. 4.

3. Real part polishing test

Once process parameter study on horizontal surfaces was finished, optimum process parameters were applied on real mould polishing. The tested mould is shown in Fig. *5*. Since the file type used to build up the geometry by SLS is a STL file, the geometry shows the typical faceted shape in triangle. The mould presents a narrow and deep shape with almost vertical faces and sharp edges to study the limitations of laser polishing process. The same 2,500W CO_2 laser equipment was in experimentation with coaxial gas protection nozzle.

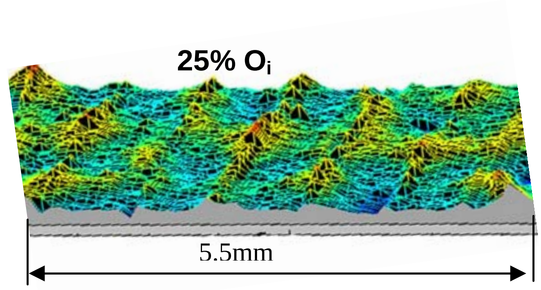

Fig. 4. Overlapping tests on LaserForm ST-100

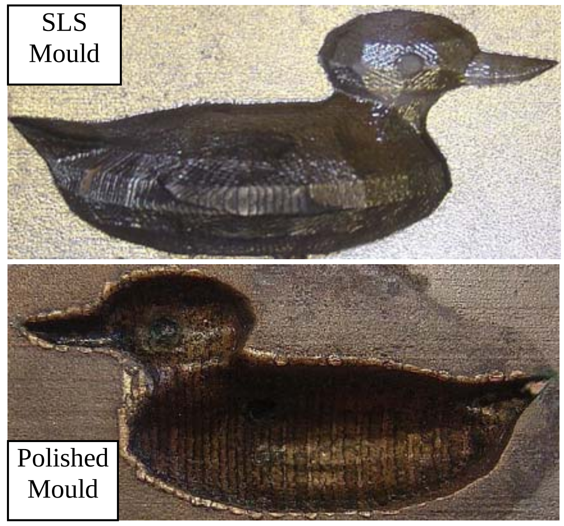

Fig. 5. SLS mould (top) and laser polished (bottom)

The polishing was carried out by a raster strategy along Y axis with an overlap index of 25% on X axis direction. The power control was set at 600W and the feed rate at 1,493mm/min with a focal offset distance of 20mm. This means an energy density of 2,149J/cm^2 which is within the optimum parameter range defined before.

The original surface shows a mean roughness of 8.44µm Ra, which is higher than the typical mean roughness of SLS surfaces because of the faceted shape mentioned. On the polished surface a mean roughness of 1.93µm Ra was obtained.

Acknowledgments

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