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# EFFECT OF HEAT TREATMENT ON SELECTIVE LASER MELTED STEEL PARTS

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***Abstract:*** *Selective Laser Sintering (SLS), has become one of the most popular technique in the layer manufacturing processes because of the ability to build complex geometries models with a wide range of materials.*
*Driven by the need to process nearly full dense objects, with mechanical properties comparable to those of bulk materials and by the desire to avoid long post processing cycles, Selective Laser Melting (SLM) has been developed. In SLM complete melting of powder occurs,unlike SLS which is mainly characterised by liquid phase sintering or partial melting.*
*The aim of this work was to evaluate performances of SLM parts built with powders of* 18 Ni Marage 300 *steel after a tempering treatment.*
*The optimal process parameters (in terms of laser power and scanning strategy) has been determined in order to get parts of almost full density. A full DOE plan was used with a three level of energy density.*
***Key words:*** *Rapid prototyping, Selective Laser Melting, metal powders, Maraging steels*

## 1. INTRODUCTION

Selective Laser Sintering (SLS) is a Rapid Prototyping (RP) and a Free-Form Fabrication (FFF) technology in increasing development, since it allows to produce complex parts, that cannot be manufactured by a traditional process, with a very short lead time (Wang, X. C. et al., 2002) and exhibits a high potential, related to its flexibility, unlike Stereolithography, that is not limited by fundamental properties of specific materials (Glardon, R. et al, 2001)

Selective laser sintering (SLS) produces parts by partial melting or sintering together, with a laser beam, successive layers of powder material. One of the major advantages is that it is able to process a very wide range of materials (thermoplastics (nylon, polycarbonate, etc.), polymer-coated steel powders, nickel-bronze or steel powders, ceramics, metallic alloys, cermets in a direct way while yielding excellent material properties.

Recently, the interest in SLS is mainly focused into metals because of the possibility of producing models not only for the prototyping step but also as functional parts (Khaing, M.W., 2001).

Selective Laser Melting (SLM) is a technique created from the SLS, with the objective of produce functional components with a near full density (Kruth, J.P. et al, 2004), with mechanical properties comparable to those of bulk materials (Campanelli et al., 2010), and to disengage from long and expensive post treatments that characterize the SLS process.

The main objective of the research in this field is, nowadays, to produce parts with mechanical properties comparable with those of components produced with traditional processes. These properties depend, not only on compositionand size of the used powder, but are strongly affected by process parameters and manufacturing strategy.

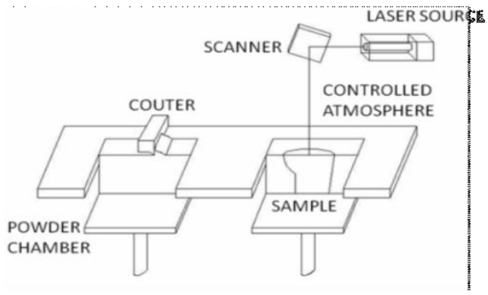


Fig. 1. SLM process

The aim of this work was to evaluate performances of SLM parts built with powders of 18 Ni Marage 300 steel after a tempering treatment.

## 2. THE PROCESS

The Selective Laser Melting Equipment technology provides a laser system, a set of optical laser beam focusing, a powder feeding system (loader and roller or coater) and a control center (Fig. 1).

The piece to be achieved should be drawn using a three dimensional solid or surface modeler, then the mathematical model is developed in STL (Solid To Layer) format compatible with the management software of the RP machine.

The STL file is then processed for the orientation and slicing phases. After introducing the STL file, properly sliced, in the control station, the powder room is raised by an amount such that the deposited powder by roller or coater, on the surface of the building chamber, deposits a layer of a thickness equal to that determined by the slicing operation, while the working chamber decreases the thickness of a layer; the coater deposits the powder on the building chamber and than the laser beam selectively scans the surface of the powder, that is melted.

When the first layer is created, the process is repeated until the intere object is built.

## 3. MATERIAL

A material with the typical composition of maraging steels reinforced with cobalt, was used for this study. Specifically, the composition was very close to the 18 Ni Marage 300 steel.

Maraging steels are a special class of low-carbon ultra-high-strength steels, which derive their strength not from carbon, but from precipitation of inter-metallic compounds; the term maraging is derived from Martensite + Aging (martensite age hardening) and denotes the age hardening of a low-carbon, iron-nickel lath martensite matrix. At room temperature, the mild and tough martensitic phase presents a hardness variable between 28 and 35 HRC. To increase its hardness, it can easily be subjected to a post-curing process (a treatment for increase in hardness by a simple heat treatment at relatively low temperature, which causes precipitation of components or alloy phases from a supersaturated solid solution).

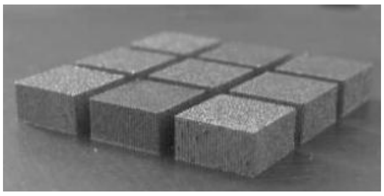

Fig. 2. Built samples

## 4. MACHINE SET UP

The machine used to perform experiments was equipped with a RofinNd:YAG laser source characterized by a wavelength of 1.064 µm, a spot diameter of 200 µm and a maximum output power of 100 W. The laser light was moved over the powder surface by means of scanning mirrors in order to draw selectively every layer of the powder.

In order to produce parts with low residual stresses, it has been shown that appropriate scanning strategy reduces the deformation of the SLM parts, so the scanning strategy was optimized by dividing the part area in small island of 5×5 $mm^2$. Furthermore, a random scanning sequence was chosen to melt each sector. Fig. 2 shows the built samples.

### 4.1 Melting Process Parameters

In SLM, there is a number of input parameters that can be controlled and varied in order to get parts with optimized quality. Some of these parameters depend on the process type, others are dependent from the laser source, others on the material type and on the characteristics of the used powder.

The Energy density ($E_d$) of a single track can be calculated by the relation between laser power (P), scan speed (v) and spot diameter (d):

$$E_d = \frac{P}{v \cdot d}\left[\frac{J}{mm^2}\right] \quad (1)$$

Experimental tests were conducted in order to study the effect of the scanning speed on the quality of manufactured parts in terms of density and hardness before the heat treatments. Table 1 shows the process parameters.

### 4.2 Heat Treatments Parameters

The AISI 18 Marage 300 steel is usually found, on the market state, after a heat treatment of tempering, that is, always, preceded by solubilization.

To compare, therefore, the best performance of the samples produced by Selective Laser Melting with the ones built by conventional processes, in this study was repeated the same pattern of treatment. Fig. 3 shows the heat treatments used in this study.

| $E_d$ [J/mm²] | Power [W] | Scanning Speed [mm/s] |
|---|---|---|
| 2 | 100 | 250 |
| 2,5 | 100 | 200 |
| 3 | 100 | 167 |

Tab. 1. Process parameters

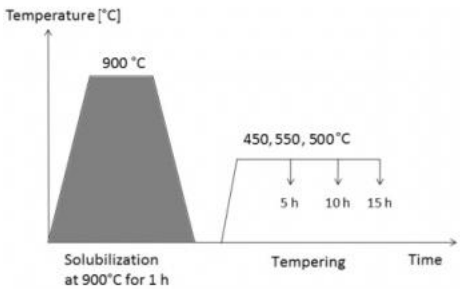


Fig. 3. Heat treatments parameters

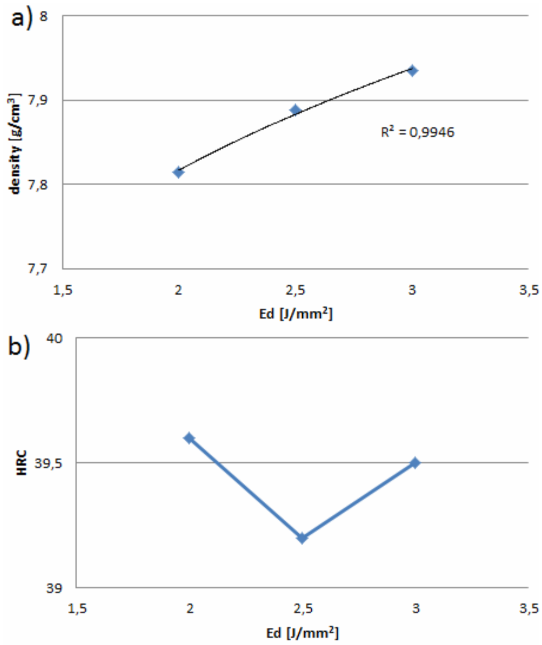


Fig. 4. a) Density test; b) Rockwell C hardness test

Three levels for theenergy density (2, 2.5 and 3 J/$mm^2$), time (5, 10 and 15 h) and temperature (450, 500 and 550 °C) were tested. For each combination of parameters was built a set of three samples.

## 5. RESULTS AND CONCLUSION

Results of experiments before heat treatmentshowed that, the density increases with increasing energy density, reaching a maximum value of 7.9 g/$mm^2$ (Fig. 4a).Moreover a value of about 39 HRC was found for hardness (Fig. 4b).

Results of experiments after heat treatment showed that hardness can be considerably increased.Specifically, the best results were obtained using a temperature of 500 °C and a treatment time in oven of 15 h, leading to a value of harness of 57 HRC.

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