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INFLUENCE OF SCANNING SPEED ON THE MECHANICAL AND STRUCTURAL PROPERTIES OF LASER SINTERED PROTOTYPES

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Abstract

This paper presents the elaboration of the method, the laboratory equipment and the technology (developed in the department) of Selective Laser Sintering for preparation specimens from a Fe-Ni-Cu (-P) powder mixture. During the investigation we focused on the influence of the scanning speed upon the mechanical and structural properties of specimens.

The laser-sintered probes were investigated by light microscopy, compression test and laser topography. The optimum scanning speed was established for 150 W laser power, 0.1 mm scanning distance and 0.1 mm layer thickness.

Keywords: metal selective laser sintering, rapid prototyping, porosity, roughness, compression tests.

1. Introduction

The Selective Laser Sintering (SLS) is one of the important Rapid Prototyping (RP) technologies for productions prototypes. The investigation method and the laser sintering (SLS) equipment were developed, and the technology of sintering was elaborated in our department [1], [2]. The properties of specimen obtained by laser sintering depend on many parameters. One of the most important parameters is the scanning speed.

The aim of investigation is the determination of effect of scanning speed on the mechanical and structural properties of SLS parts.

2. Method, Experimental Setup and Productions Technology

The RP technique consists of three main units: Informatics unit, Mechanics unit and Technology unit [3].

In the *informatics unit* the input is a 3D CAD model. The data arising from CAD model should be sent to the CAM programme through an interface. The CAM programme does transform the 3D movement, and this will be converted to the control programme of the mechanical part by a post processor unit.

The CAD programme has to be easy to handle, and flexible enough, in order to be easily convertable into the CAM programme. The CAM programme should be capable of the slicing the CAD model, the CAD output data should be easy to load and change the parameters.

In the informatics unit we had to check the compatibility of the CAD and the CAM programmes, and we had to enable it to control the mechanics unit.

We use I-DEAS CAD programme and SurfCAM CAM programme in our RP system. As the post processor programme was not available, we had to create it. It was made in 'Borland Delphi' so that it will be a graphic format and easy to handle (*Fig.1*).

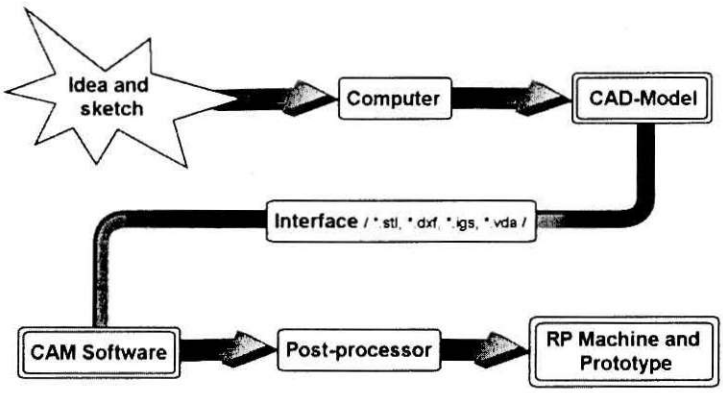


Fig. 1. Process flow of the prototype production

The *mechanics unit* has to control the laser power, to move the laser beam, to switch on and off the laser beam at the border of sliced layer, to move the worktable vertically in order to create the new layer. We prevented the oxidation of the metallic powders using argon protective gas.

The experimental setup of laser beam moving and the laser-material interaction is shown in *Fig. 2*.

A CO_2 continuous wave mode laser (max power: 1800 W) was used. The wavelength of laser beam is 10.6 μm, the non focused beam diameter is $\phi = 14$ mm, and the beam can be focused till $\phi = 200$ μm. The laser beam (going trough the f-Θ optic) was moved in the 'xy' plane with a special ('x' and 'y') mirror system activated by galvanic motors. All these were integrated into the scanning head. The position of sintering plane in the vertical ('z') axes direction was actuated by a stepping motor [4]. The laser beam started at the beginning and switched out at the end of the contour of the specimen. The scanning head and laser process was computer controlled with 25 μm accuracy. The possible maximum scanning speed was 6000 mm/s.

The *technology unit* is containing the main process data of sintering. The

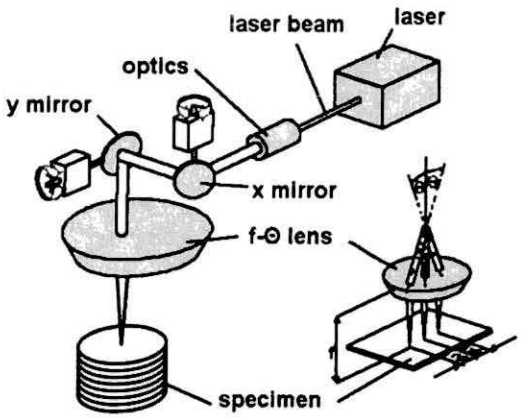


Fig. 2. The scheme of set-up of the experimental mechanics unit

properties of laser sintered specimen depend on the interactions of many parameters, see *Fig. 3.*

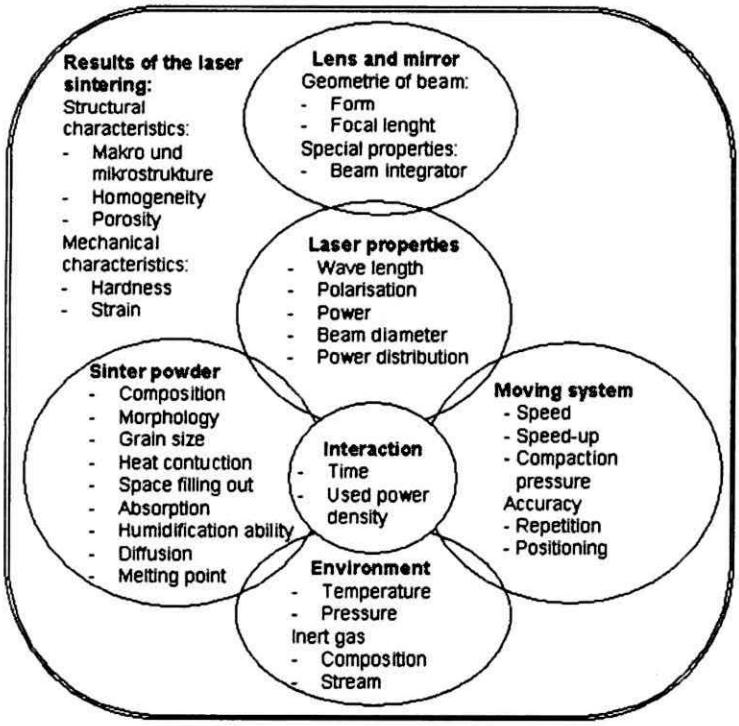


Fig. 3. Interaction of the process parameters in the laser sintering

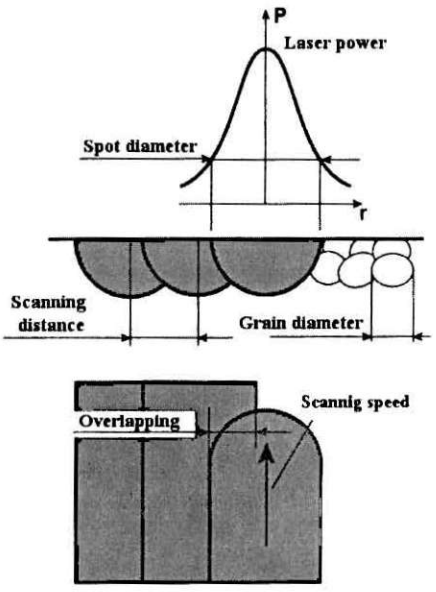


Fig. 4. Main process parameters of laser sintering

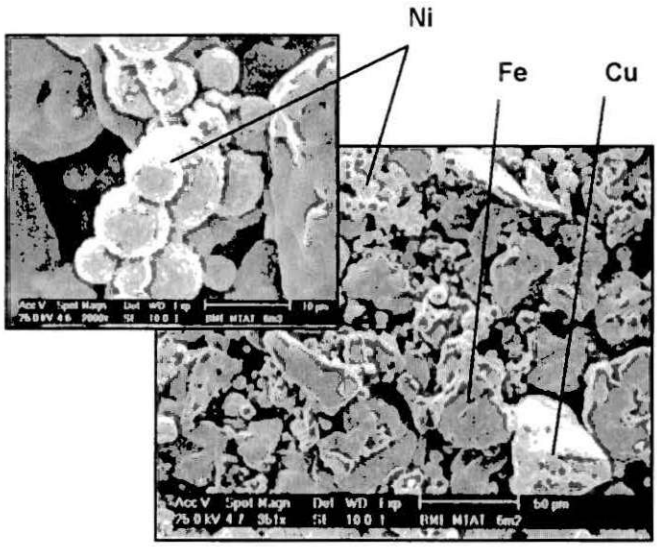
Furthermore, scanning distance, laser spot diameter, grain diameter of powder, inert gas and overlapping have to be taken into consideration (it would be calculated from spot diameter and scanning distance) [5] (*Fig. 4*).

3. Experiments

The SLS is taking place in a special closed chamber. The metal powder mixture is spread in thin layer (0.1 mm) on the bottom of the chamber by means of deposition elements. The scanning laser beam sinters the powders resulting $\sim$ 0.1 mm thick solid layer. At the repetition of the powder spreading and sintering the newly sintered layer will be melt together with the underlying layer. To reach needed height of the specimen we had to repeat this process many times.

The composition of the sintered powder is 72 Wt% iron, 20 Wt% nickel, 8 Wt% phosphorous-bronze (3% P). The scanning electron microscope photo is shown in *Fig. 5*. The used powder average diameter was $\emptyset < 50\ \mu$m.

The sintered specimen consisting of many layers is shown in *Fig. 6*. The size of the cylindrical specimen is $\emptyset$ 10 mm $\times$15 mm. The optimal slice thickness is $\sim$ 0.1 mm, the CO_2 laser optimal power is $\sim$ 150 W (these data were determined by previous experiments). The scanning speed were 200, 300, 400, 500 and 600 mm/s.



Material: 72 Wt% iron, 20 Wt% nickel, 8 Wt% Phosphorous-bronze

Fig. 5. Scanning electron microscope photo of Fe – Ni – Phosphorous-bronze based powder

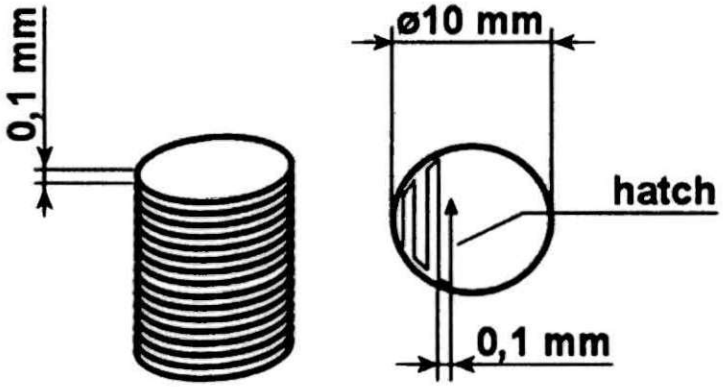


Fig. 6. Dimensions of specimen

4. Experiment Results

The properties of the specimen – beside others technology data – depend on the modification of the scanning speed. We investigated this changes by compression test, determination of porosity and measuring of surface-roughness.

4.1. Compression Test

The compression ultimate strength and the relative shortening belonging to the break down was measured on INSTRON 1195 (maximum load: 100 kN). The scanning speed was 100, 200, 300, 400 and 500 mm/s. Every value was measured three times. The result of the measuring with the average value and with the range of scattering is shown in *Fig. 7.*

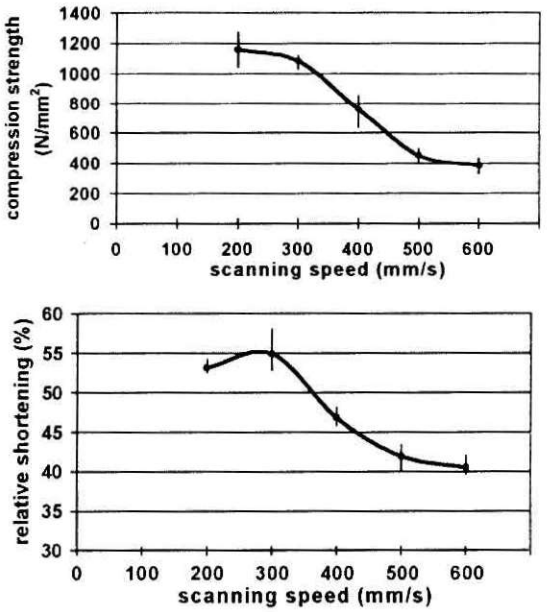


Fig. 7. The compression ultimate strength and the relative shortening

In *Fig. 7* it is shown that with decrease of scanning speed, the compression strength is increasing. The absorbed energy will be greater at lower scanning speed, increasing the interaction time: the particles will be melted together even more.

If we inncrease the scanning speed, the binding force between the grains decreases, and decreases also the compression ultimate strength and the relative shortening. The optimal scanning speed is about 200 and 300 mm/s, the compression ultimate strength is over 1000 N/mm^2. The relative shortening is more than 50%.

4.2. Surface-Roughness Test

After the sintering process the roughness (R_a and R_z) was measured on the face plane (x, y) on the sample with a RODENSTOCK RM600 laser topographer. The

result of the measuring data (average value and the range of scatter) is shown in *Fig. 8.*

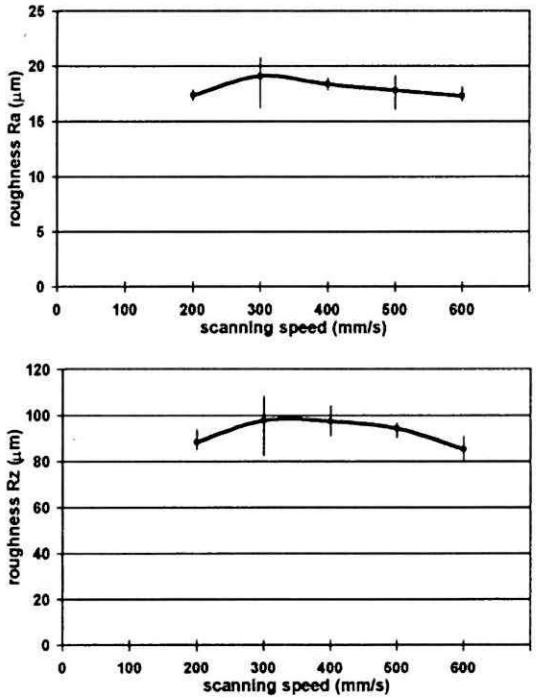


Fig. 8. Value of the surface-roughness R_a and R_z

4.3. Porosity Test

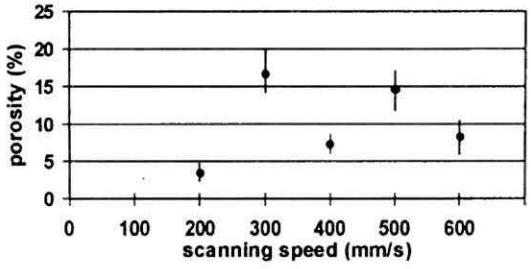


Fig. 9. Porosity of the sintered samples

The porosity of the sintered probes was tested with a light microscope using a picture analyser system. We have to remark in this case that the optical porosity measurement accuracy is scattering to a great extent, and we intend to measure the porosity with another methods in the future. The result is presented in *Fig. 9.* If the scanning speed decreases the absorbed energy will increase, the melted grains fill out even more the free rooms, and the porosity will decrease.

5. Discussion

The optimal scanning speed interval was determined during selective laser sintering for iron-nickel-bronze powder mixture as follows: 50 μm grain size, sintered 150 W CO_2 laser power, 0.1 mm layer thickness, 0.1 scanning distance. Upon the executed investigations we can drew the following conclusions:

1. The developed method, equipment and SLS production technology is a reliable technique for production specimen and parts from metallic powders;
2. During the investigation the effect of the scanning speed upon the mechanical and other structural properties of sintered parts was determined;
3. The optimal scanning speed, taking into count productivity for this powder mixture is, 200 . . . 300 mm/s;

Acknowledgements

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