

EFFECTIVENESS INCREASE THE LASER SINTERING OF POWDER MATERIAL

Saprykin Alexandr, Saprykina Nataly, Kuzmin Sergey

Yurga technological institute (branch) of Tomsk polytechnic university

652050, Kemerovskaya oblast, Yurga, Leningradskaya st., 26, Russia.

alex_sapr@rambler.ru

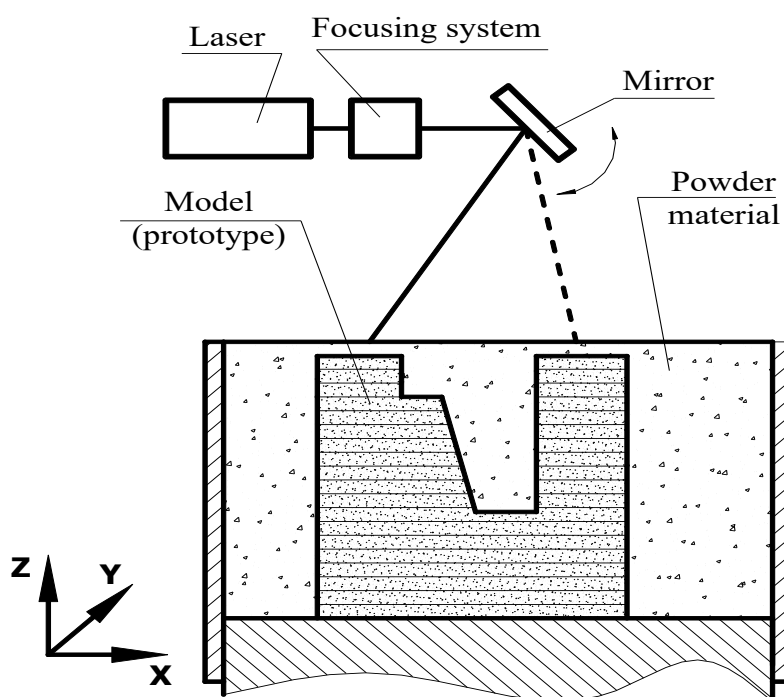
Abstract

During the research the following problem was raised: to define the pulse laser radiation influence value on different powder materials, as well as to define experimentally the thickness and width relations of a sintered powder layer from technological laser radiation parameters.

Keywords: *Rapid prototyping. The process of selective laser sintering. The powder materials.*

At present there are various methods of rapid prototyping. Different physical processes and materials for making prototypes are employed: stereo-lithography – layered hardening of liquid monomers with UV-laser beam trough light influence: LOM method employs sheet materials cut with laser beams; FDM-method – layered covering of melted polymer fibers; selective laser sintering – SLS. At the last process prototypes are made from sintered powder materials under thermal effect of laser beam [1,2,10].

Fig. 1 – General scheme of SLS – process



The given research was made for technological ensuring of the process of selective laser sintering of powder materials.

Analysis of information sources has shown that SLS is one of the prospective processes of layered synthesis; as there is a vast choice of materials such as metals and non-metals, also there is an opportunity of obtaining functional products.

As quality of the surface of the sintered product directly depends on thickness of sintered layer (fig.2), estimation of quantity of laser effect rate at layer's size was needed.

Laser thermal sintering is conditional upon effect of intensive laser radiation stream on a local area of powder surface and absorbing of laser radiation by surface layer of the material; and in consequence of that, almost immediate high-temperature heating of this area occurs [3,4,5,6,8]. After laser radiation stops, fast cooling of this area takes place due to heat conductivity of inner layers of the material and also heat conduction from the surface. For development of the theory of powder sintering by laser beam the certain information on laser surface hardening and laser welding of thin sheets may be used with some changes, as these processes are almost identical [5,6,7]. For theoretical estimation the formula for impulse laser effect on the surface of material was used, that presented in works of academician Ricalin N.N. (USSR) [6].

At short-term influence of beam impulse on the surface a heated area appears which has an axial symmetry (fig.3). When impulses are short the general heat stream in the material expands along the normal-line to the surface.

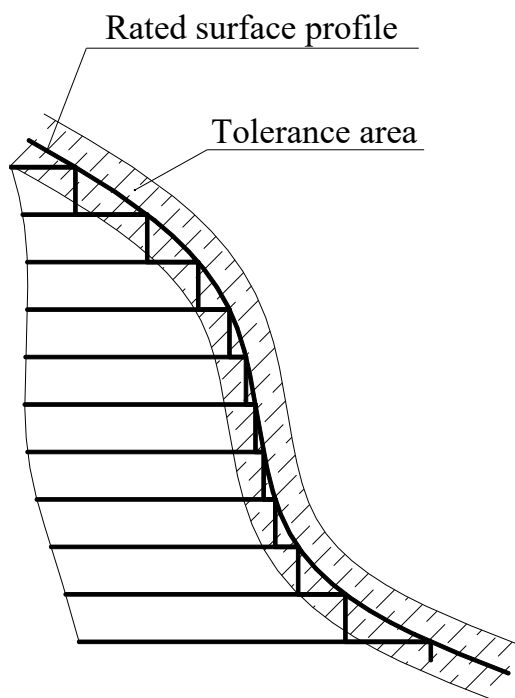


Fig. 2

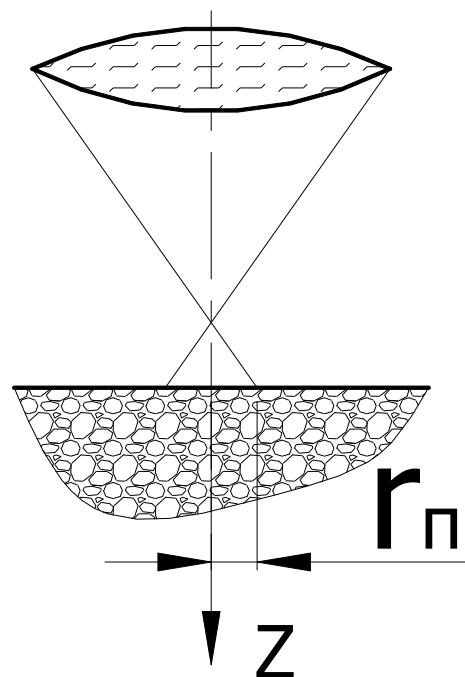


Fig. 3

Therefore, the task on thermo-conductivity may be considered as single-dimensional one along the axis Oz (to depth) [5,6,7]. Single-dimensional heated area made in semi-infinite body with homogeneous beam of round cross section with radius r_n , at $t > \tau_u$ is:

$$T(z, t) = \frac{2q_n \sqrt{a}}{\lambda_T} \left[\sqrt{t} i\Phi \left(\frac{z}{2\sqrt{at}} \right) - \sqrt{t - \tau_u} i\Phi \left(\frac{\sqrt{z^2 + r_n^2}}{2\sqrt{a(t - \tau_u)}} \right) \right],$$

where t – time counted after laser impulse stops;

z – interval counted along axis Oz (fig. 3);

$i\Phi$ – relativity integral function [9];

$a = \lambda_T / (c\gamma)$ – material's heat conductivity factor;

$c\gamma$ – volume thermo-capacity factor.

If to simplify $r_n \gg \sqrt{at}$ [5,7], the formula for relative calculation of thermo laser effect depth is obtained:

$$T(z, t) \approx \frac{q_n}{\lambda_T} \left(2\sqrt{\frac{at}{\pi}} - z \right),$$

where z – heat depth till $T(z, t)$.

Finally it was accepted that the volume of the sintered layer is defined by the area where the temperature of initial material sintering was achieved.

Figures 4-6 present graphs of dependence of copper powder [11] sintered layer depth from various rate laser processing parameters. One can see that control of the sintered layer thickness may be obtained by changing of volume of power density in a laser impulse (fig.6). The given parameter, as accepted in laser technology [4, 5], limits maximum and minimum thickness of the sintered layer.

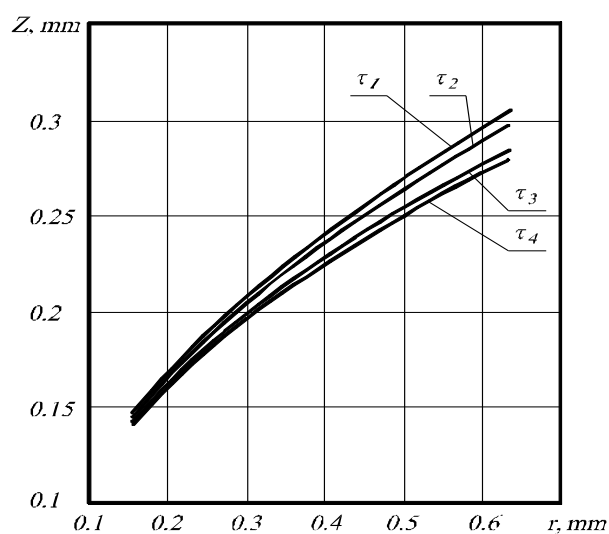


Fig. 4 – Graph of dependence of sintered layer depth from radius of laser spot
($\tau_1=2\text{mc}$, $\tau_2=2,5\text{mc}$, $\tau_3=4\text{mc}$, $\tau_4=5\text{mc}$)

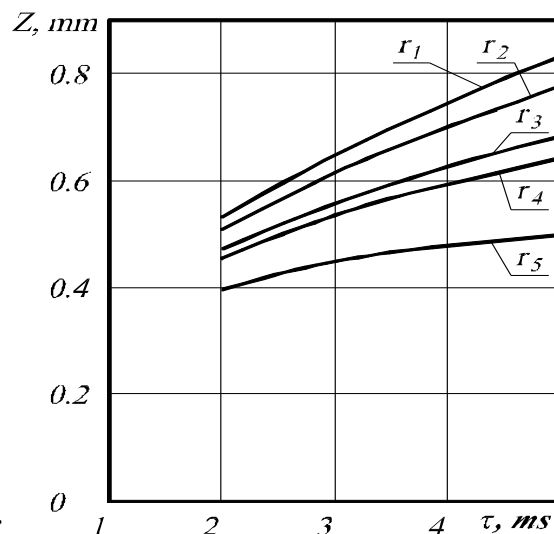


Fig. 5 – Graph of dependence of sintered layer depth from impulse duration
($r_1=0,15\text{mm}$, $r_2=0,3\text{mm}$, $r_3=0,45\text{mm}$, $r_4=0,5\text{mm}$, $r_5=0,65\text{mm}$)

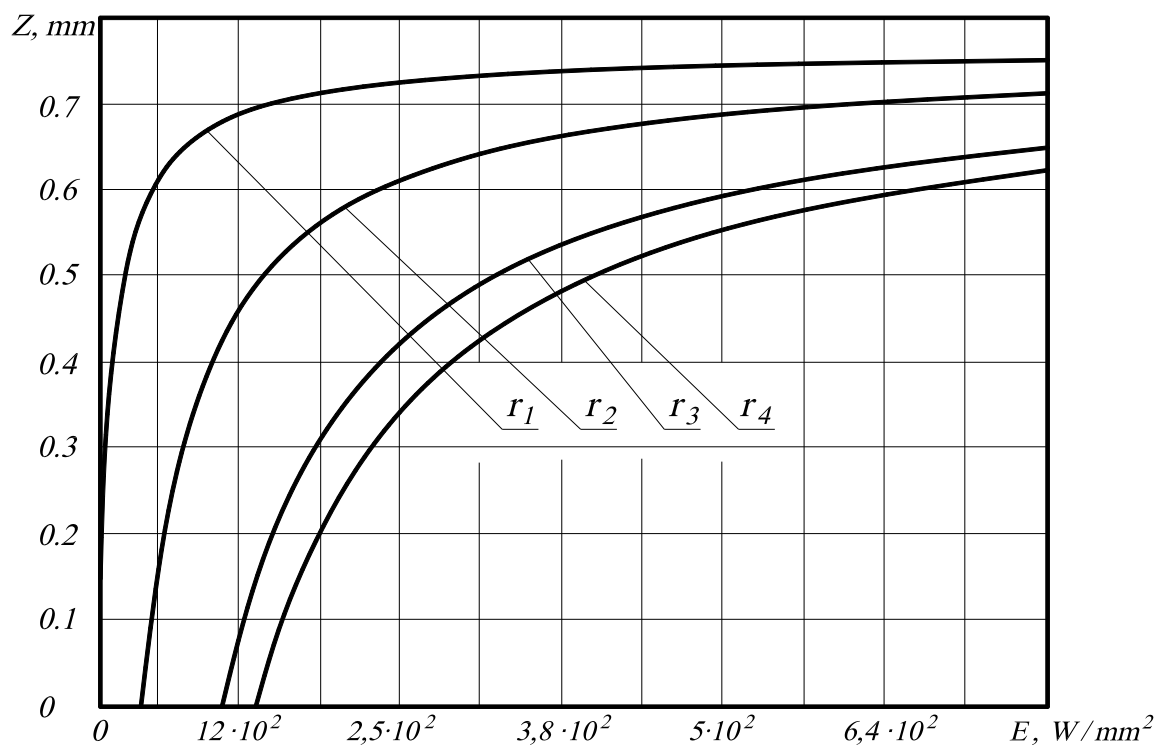


Fig. 6 – Graph of dependence of sintered layer depth on impulse power density
($r_1=0,15\text{mm}$, $r_2=0,3\text{mm}$, $r_3=0,45\text{mm}$, $r_4=0,5\text{mm}$, $r_5=0,65\text{mm}$)

As powder is not a homogeneous body, defining of its thermo-conductivity analytically is rather complicated, that's why equivalent thermo-conductivity is used for preliminary computing [12].

For more accurate computing of the sintered layer size, thermo-physical characteristics of powder materials were determined experimentally. The pulse method was employed [13]. Experimental equipment included laser, millivoltmeter, thermocouple (Chromel-alumel) and digital video cam. Experiments resulted graphs of temperature changes in the set area, and thermo-physical characteristics of powders were determined for computing.

During the research the following problem was raised: to define the pulse laser radiation effect value on different powder materials, as well as to define experimentally the thickness and width dependence of a sintered powder layer on technological parameters of the laser beam. As a result, sintered prototypes were obtained, estimated and measured.

For research realization the following powders were selected as materials for sintering: copper powder, constructional steel powder, polymer powder and their mixtures (fig.7).

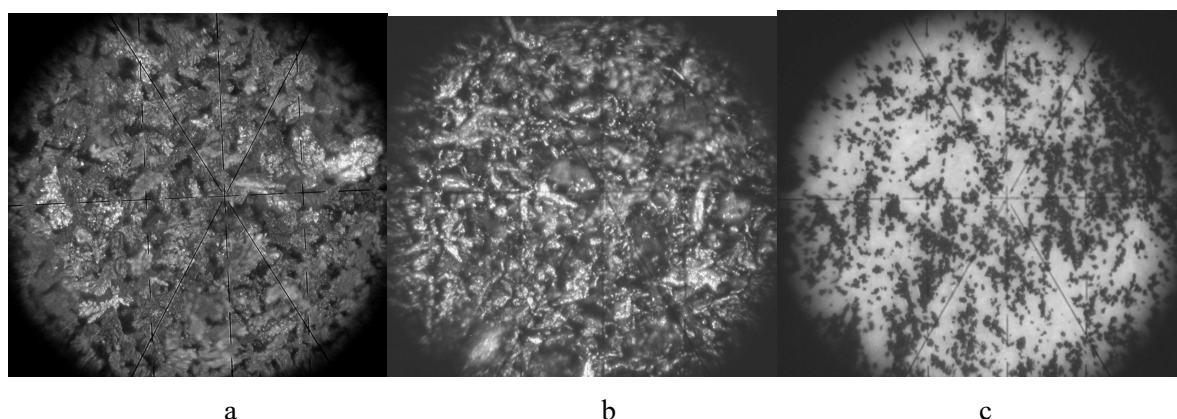


Fig. 7 The initial powders ($\times 150$)

a) copper powder ПМС-1; b) constructional steel powder; c) laser printer toner

On carrying out the experiments the pulse repetition rate and laser radiation power were being changed, and the radiation energy was being fixed. Diameter of the laser spot and its moving speed remained constant. The experiments were being conducted till the appearance of obvious sintered layer defects, such as shrinkage and conches (fig.8).

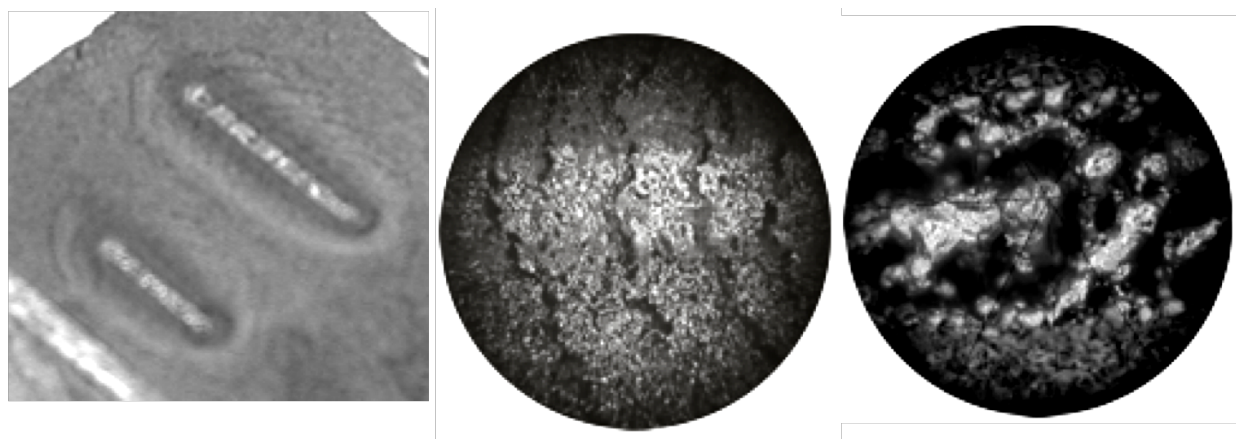


Fig. 8 – Sintered layer defects

During the experiments the great variety of patterns were obtained which the depth and width sintered layer measurements were taken from. According to the results, graphs of width and depth sintered powder layer dependence on laser beam power density were made (fig. 9).

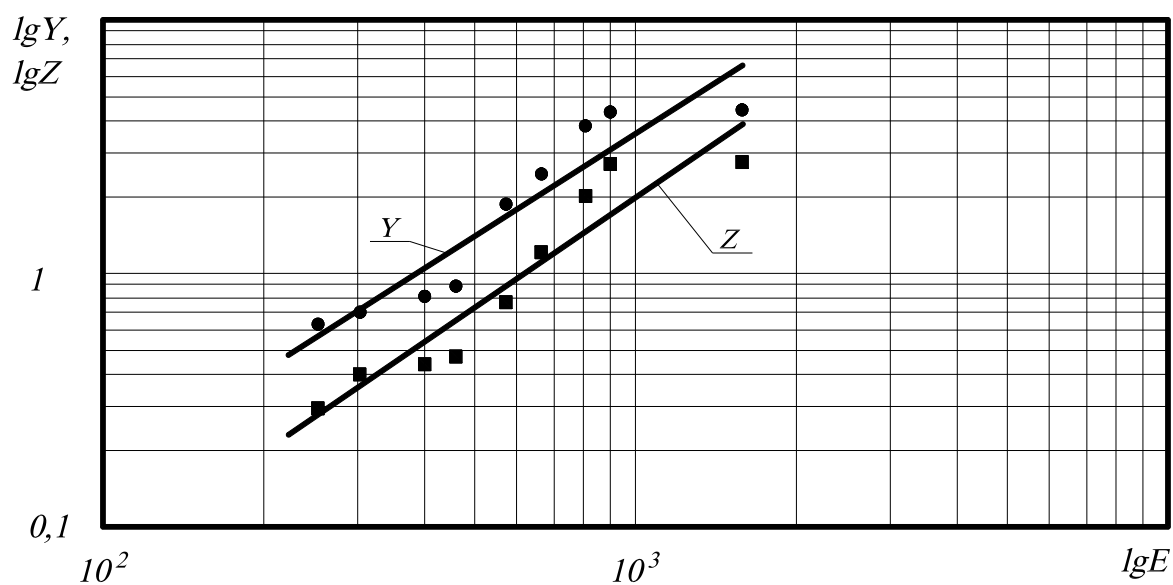


Fig. 9

Analytical processing of experimental results allowed receiving empirical-formula depth and width dependences on a sintered layer on laser radiation power density [14,15]:

- for sintered layer depth
$$Z = C_z \cdot E^{X_z} ;$$

- for sintered layer width $Y = C_y \cdot E^{X_y}$;

where: C_y , C_z , X_y , X_z - coefficients, values are set in the chart:

Coefficients	Laser impulse repetition		
	1 Hz	2 Hz	5 Hz
C_y	4×10^{-4}	3×10^{-6}	9×10^{-5}
C_z	10^{-4}	2×10^{-8}	8×10^{-5}
X_y	1,3324	1,1526	0,9605
X_z	1,4342	1,4923	0,9063

As a result of the conducted experiments, it was established, that there is an opportunity to change the sintered layer thickness in considerable limits due to the change of laser processing modes of operation. So it was found out that applying of metal powders in the pure state without shielding medium is limited because of their intensive oxidation. It is necessary to apply the polymer component in order to reduce a reflection coefficient of an initial model material, decrease the oxidation and increase the strength of sintered prototype. The feasibility of the pulse laser beam for layered laser synthesizing of complicated work pieces from powder materials is demonstrated. Also the guidelines in rational modes selection of laser effect are given.

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