

## INFLUENCE OF PROCESSES PARAMETERS ON AXIAL BREAKING FORCE OF PARTS PRODUCED BY SELECTIVE LASER SINTERING PROCESS

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Preliminary Note - Prethodno priopćenje

Insufficient knowledge about essence of the Selective Laser Sintering - SLS process and influence of process parameters on properties of produced parts constraints widely usage of SLS process in production systems. One of the most significant process failures is impossibility of full-real load of the produced parts-prototypes. Influence on process parameters is analysed in this paper (laser power and scan velocity), as well as post processing influence on value of axial breaking force of the parts produced by SLS process using material DM50-V2, on machine EOSIMT M250, producer EOS München, Germany.

**Key words:** selective laser sintering, process parameters, axial breaking force

**Utjecaj procesnih parametara na silu kidanja dijelova proizvedenih procesom selektivnog laserskog sinteriranja.** Nedovoljno poznavanje suštine procesa selektivnog laserskog sinteriranja - SLS, te utjecaja procesnih parametara na osobine proizvedenih dijelova u značajnoj mjeri ograničava širu primjenu SLS procesa u proizvodnim sustavima. Jedan od značajnijih nedostataka ovoga procesa je nemogućnost vršenja potpunog - realnog opterećenja proizvedenih dijelova - prototipova. U radu je izvršena analiza utjecaja procesnih parametara (snage lasera i brzine skeniranja), te procesa postprocesuiranja na vrijednost aksijalne sile kidanja dijelova proizvedenih SLS procesom od materijala DM50-V2, na stroju EOSIMT M250, proizvođača EOS München, Njemačka.

**Ključne riječi:** selektivno lasersko sinteriranje, procesni parametri, aksijalna sila kidanja

### INTRODUCTION

Selective Laser Sintering - SLS is one of Rapid Prototyping - RP technologies and this technology is applied in indirect production of parts - especially in manufacturing of molten molds [1]. However, characteristics of process (used materials ready-made parts which represents significant progress in this segment of manufacturing and make basis for future development of) allows direct production of usable direct manufacturing RP systems, Figure 1.[2].

All RP technologies and processes are relatively new, only fifteen years in use. That is the reason why many areas of those technologies and influence of process parameters on quality of produced parts are relative unexplored.

Basic obstacles to broad usage of parts produced by SLS process are inadequate mechanical properties of produced parts and quality of machined surface, which often presents limitation factor for their usage [3]. Impossibility of direct

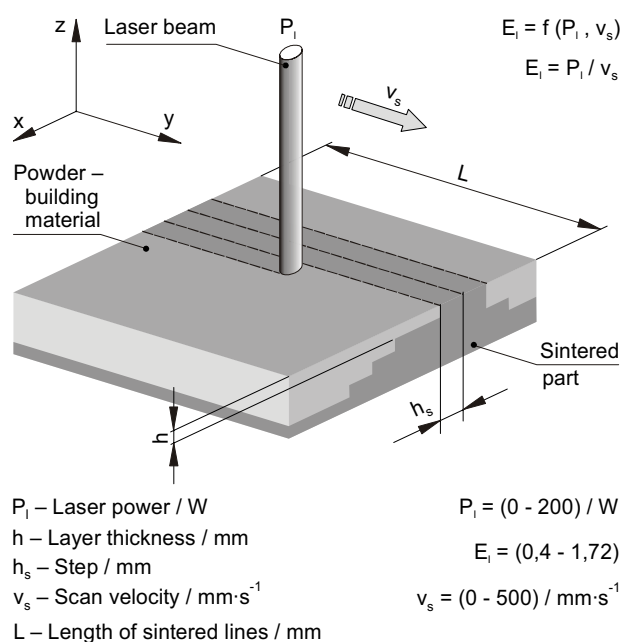


Figure 1. Review of basic proportions for SLS process  
Slika 1. Prikaz osnovnih veličina procesa SLS

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production of ready-made parts in significant quantity constrains unsuspected possibilities, which were indicated by initial results of layer manufacturing processes.

Axial breaking force represents one of mechanical properties that have significant influence on possibility of produced part usage. In real conditions, often impossibility of full-real loading of produced parts disallows right measurements and getting of satisfactory results. Due to that determination of functional dependency of axial breaking force like one of mechanical characteristics of produced parts from processes parameters represents logical activities flow and at the end it will result in improvement of mechanical characteristics of produced SLS parts.

In this field many research activities were, or are begin, carried out. Conditionally all researches are possible to be arrange in two groups often with interlaced borders. The first group includes researches on materials i.e. finding of new adequate or improving of existing materials on the way which enable direct manufacturing of ready-made parts. The second group includes researches that have the goal of determination of process parameter and post-processing influence on mechanical properties of parts, and in accordance with that to make influence on machine and material producers to adjust their products with optimal working parameters.

Table 1. Values of SLS process parameters used for production of parts for axial tensile force analysis

Tablica 1. Vrijednost parametara SLS procesa rabljenih pri proizvodnji dijelova za ispitivanja naprezanja na istezanje

Part	Scan velocity $v_s / \text{mm}\cdot\text{s}^{-1}$	Laser power $P_l / \text{W}$	Laser power $P_l / \%$	Energy line $E_l = P_l / v_s$	Annotation
7.	111,63	44,65	16,37	0,4	3 pieces (cutting)
15.	480,00	192,00	101,30	0,4	9 pieces*
99.	111,63	192,00	101,30	1,72	3 pieces (cutting)

\*Part 15 produced 9 pieces (3+3+3):  
 - 3 Cutting  
 - 3 Cutting + Heating 450 °C, 8 min.  
 - 3 Cutting + Heating 450 °C, 5 min. + Infiltration Sn60AlPb, 8 min.

Produced SLS parts are often submitted to post-processing with the aim of satisfying certain characteristics [4]. Most used post-processes with SLS parts are thermal processing and infiltration processing. Thermal processing represents warming up of produced SLS parts to certain temperature (function of used material) with the aim of part consolidation - finishing of sintering process for remained incomplete sintering partials and for relaxation of internal strains. Infiltration of produced parts is post-processing operation in which the parts are immersed in appropriate solution with aim to eliminate porosity of produced parts. Presumably is

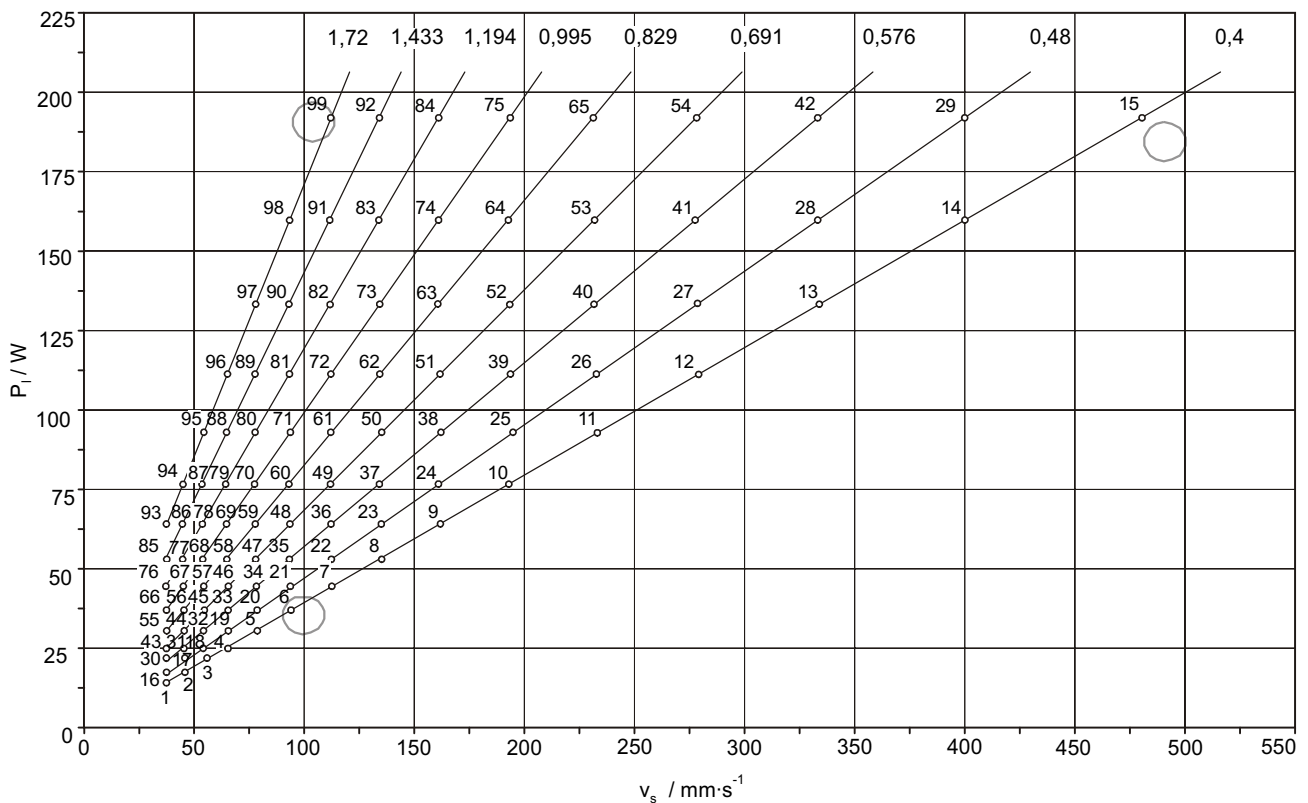


Figure 2. Working area EOS M250 machine and selected working points used for axial tensile force tests of parts produced by SLS processes  
 Slika 2. Radno područje stroja EOS M250 i izabrane radne točke rabljene za ispitivanja aksijane sile kidanja dijelova proizvedenih SLS procesom

that all of those post processing operation on produced parts have some influence on mechanical characteristics and on axial breaking force of produced parts.

**WORKING AREA, MEASUREMENTS AND RESULTS**

With respect to technology characteristics of used machine EOS M250 and material DM50-V2, producer EOS München, Germany, parameters of SLS process on the basis of which is defined working area are: scan velocity of laser

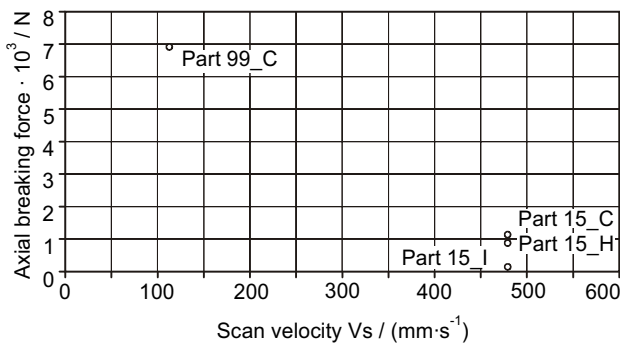


Figure 3. Functional dependency of axial tensile force and SLS processes parameters per line  $P_1 = \text{const.} = 192 / \text{W}$

Slika 3. Funkcionalna ovisnost aksijalne sile kidanja i SLS procesnih parametara po crti  $P_1 = \text{const.} = 192 / \text{W}$

beam  $v_s$  (mm·s<sup>-1</sup>) and laser power  $P_1$  (W, %). In function of those parameters energy lines  $E_1$  (Figure 2.) are defined and research polygon is set. Respecting the fact that SLS is relatively expensive process and used material is very expensive too, for research needs a few parts are produced, which however give opportunity to get access on influence of process parameters on observed characteristic (Table 1.).

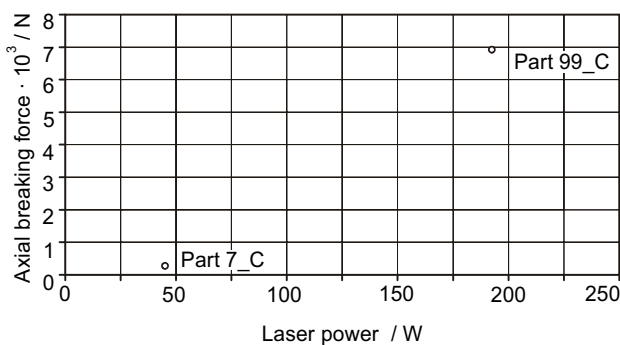


Figure 4. Functional dependency of axial tensile force and SLS processes parameters per line  $v_s = \text{const.} = 111,63 / \text{mm} \cdot \text{s}^{-1}$

Slika 4. Funkcionalna ovisnost aksijalne sile kidanja i SLS procesnih parametara po crti  $v_s = \text{const.} = 111,63 / \text{mm} \cdot \text{s}^{-1}$

Although it is theoretically possible to provide value of energy line  $E_1 < 0,4$  due to properties of used materials which disable adequate sticking among layers, difficulties may occur during manufacturing process with possible

destroying of the part at its end. Because of that adopted minimal value of energy line is  $E_1 = 0,4$ . Since laser power is restricted within interval  $P_1 = 0$  to 200 W, and scan velocity of laser beam within interval  $v_s = 0$  to 500 (mm·s<sup>-1</sup>)

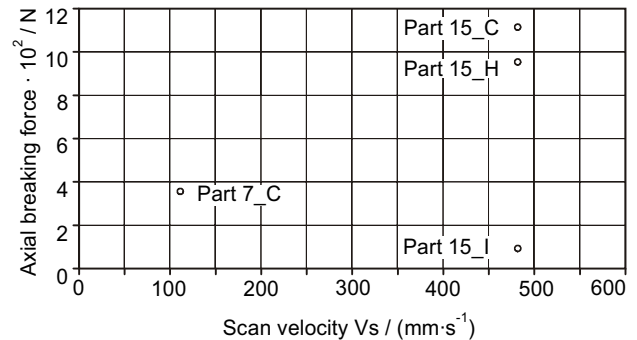


Figure 5. Functional dependency of axial tensile force and SLS processes parameters per line  $E_1 = \text{const.} = 0,4$

Slika 5. Funkcionalna ovisnost aksijalne sile kidanja i SLS procesnih parametara po crti  $E_1 = \text{const.} = 0,4$

on the basis of available domain machine working area is divided by a rule: every following value of energy line is higher then previous value for 20 % (Figure 2.). For analysis of mentioned dependencies parts were produced with geometry characteristics according to DIN 50114 standard.

After production and post-processing of the parts were carried out measurements of axial breaking force on machine for measurement of mechanical characteristics PHOENIX UTS Test System.

Functional dependency of axial breaking force and SLS process parameters are displayed on Figures 3., 4., 5. and 6.

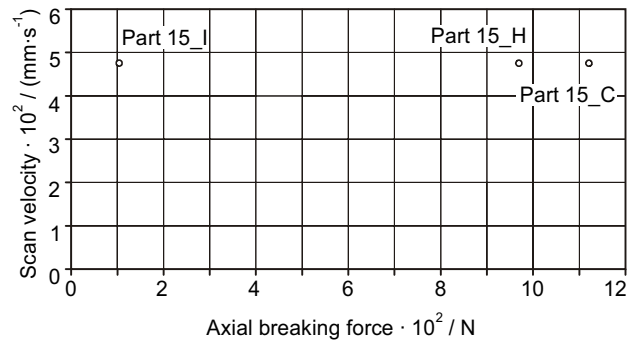


Figure 6. Functional dependency of axial tensile force and SLS processes parameters for part 15 per line  $P_1 = \text{const.} = 192 / \text{W}$

Slika 6. Funkcionalna ovisnost aksijalne sile kidanja i SLS procesnih parametara za dio 15 po crti  $P_1 = \text{const.} = 192 / \text{W}$

**CONCLUSION**

On the basis of presented diagrams it is possible to make certain conclusions. It is obvious that in cases of parts, which are produced, and only cut off - separated from its support, the following dependencies were noted with respect to axial breaking force and SLS process parameters:

1. On the directions  $v_s = \text{const.}$  and  $E_1 = \text{const.}$  with higher power imported in process by laser beam significant increase of axial breaking force value characteristic occurred (Figure 4. and Figure 5.).
2. On the direction  $P_1 = \text{const.}$  with increase of laser beam scan velocity is decrease of axial breaking force value characteristic occurred (Figure 3.).

$P_1 = \text{const}$	$v_s = \text{const}$	$E_1 = \text{const}$
$v_s \uparrow$ ABF $\downarrow$	$P_1 \uparrow$ ABF $\uparrow$	$P_1 \uparrow$ ABF $\uparrow$
ABF - Axial Breaking Force		

According to influence of post-processing parameters, thermal processing and infiltration processing, on breaking characteristic of produced parts, according to Figure 6., it is obvious that post-processing has adverse influence on observe characteristic. This specially refers to infiltration post-processing, which results in tremendous decrease

of axial breaking force characteristics of parts. This post-processing operation strongly decreases observed parts characteristic and it is even less then in case of parts produced with most unfavourable combination of processes parameters - Part 7 (Figure 5.).

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