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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 Münich, 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 proizvodenih dijelova u značajnoj mjeri ograničava širu primjenu SLS procesa u proizvodnim sustavima. Jedan od zanačajnijih nedostataka ovoga procesa je nemogućnost vršenja potpunog - realnog opterećenja proizvedenih dijelova - prototipova. U radu je izvršena analiziran 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 Münich, Njemačka.

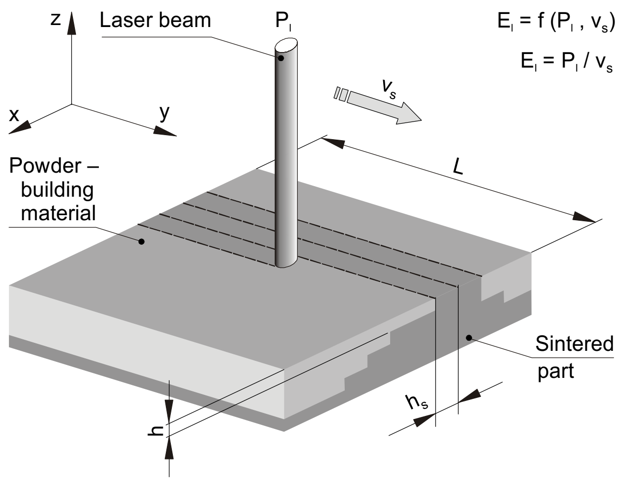
Ključne riječi: *selektivno lasersko sinteriranje, procesni parametri, aksijalna sila kidanja*

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



P_l – Laser power / W
h – Layer thickness / mm
h_s – Step / mm
v_s – Scan velocity / $mm \cdot s^{-1}$
L – Length of sintered lines / mm

P_l = (0 - 200) / W
E_l = (0,4 - 1,72)
v_s = (0 - 500) / $mm \cdot s^{-1}$

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 / mm·s^{-1}	Laser power P_l / 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

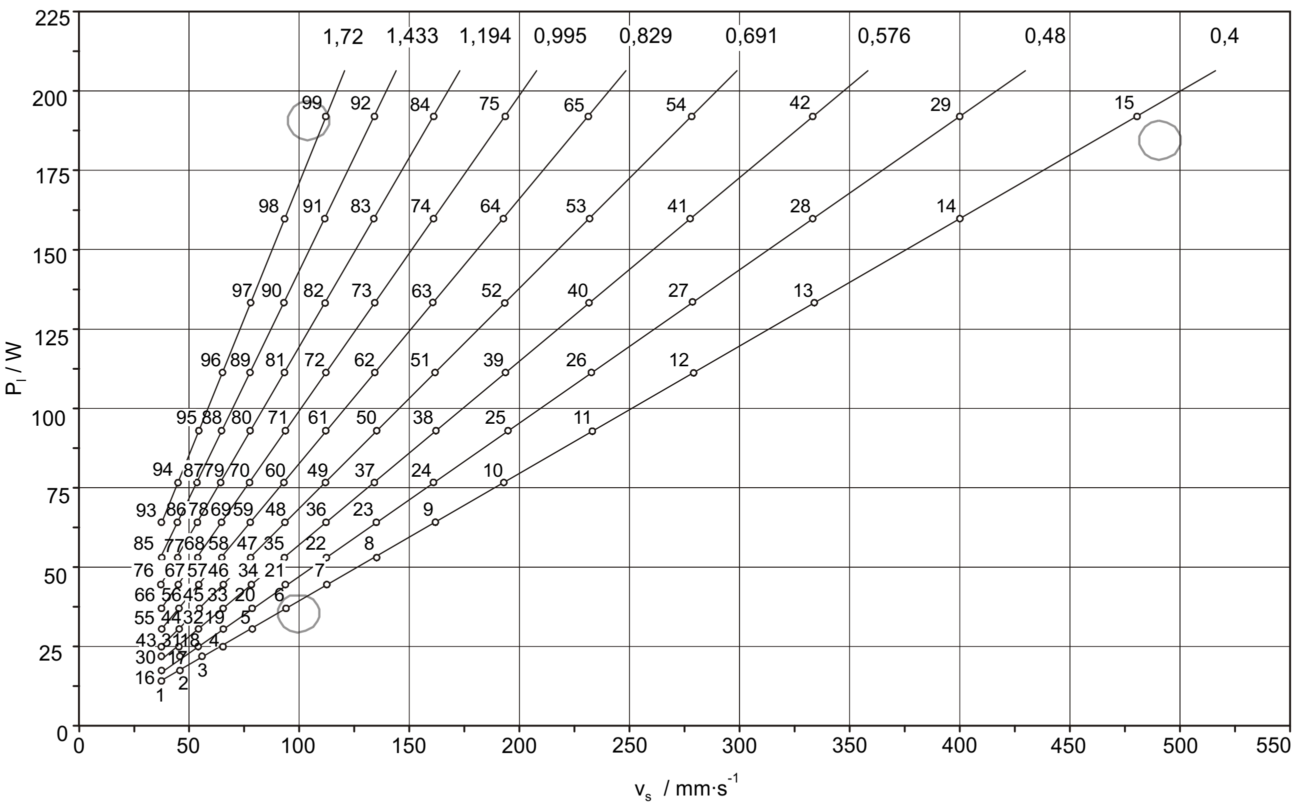

Figure 2. **Working area EOS M250 machine and selected working points used for axial tensile force tests of parts produced by SLS processes**
Slika 2. **Radno područje stroja EOS M250 i izabrane radne točke rabljene za ispitivanja aksijane sile kidanja dijelova proizvedenih SLS procesom**

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 Münich, Germany, parameters of SLS process on the basis of which is defined working area are: scan velocity of laser

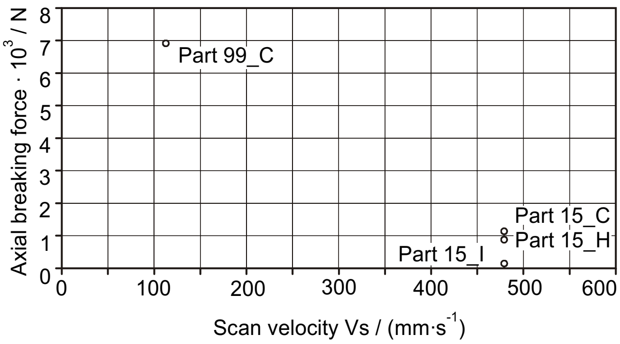

Figure 3. **Functional dependency of axial tensile force and SLS processes parameters per line P_l = const. = 192 / W**

Slika 3. **Funkcionalna ovisnost aksijalne slie kidanja i SLS procesnih parametara po crti P_l = const. = 192 / W**

beam v_s (mm·s^{-1}) and laser power P_l (W, %). In function of those parameters energy lines E_l (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.).

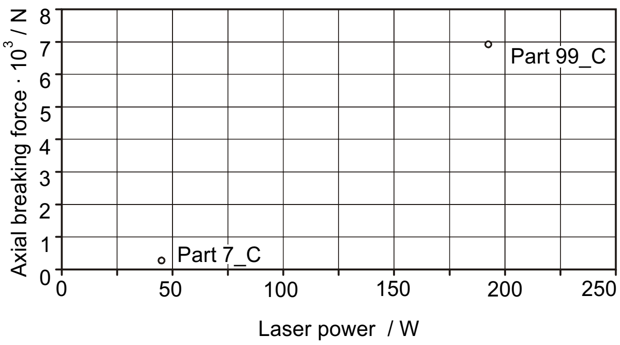

Figure 4. **Functional dependency of axial tensile force and SLS processes parameters per line v_s = const. = 111,63 / mm·s^{-1}**

Slika 4. **Funkcionalna ovisnost aksijalne slie kidanja i SLS procesnih parametara po crti v_s = const. = 111,63 / mm·s^{-1}**

Although it is theoretically possible to provide value of energy line E_l < 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_l = 0,4. Since laser power is restricted within interval P_l = 0 to 200 W, and scan velocity of laser beam within interval v_s = 0 to 500 (mm·s^{-1})

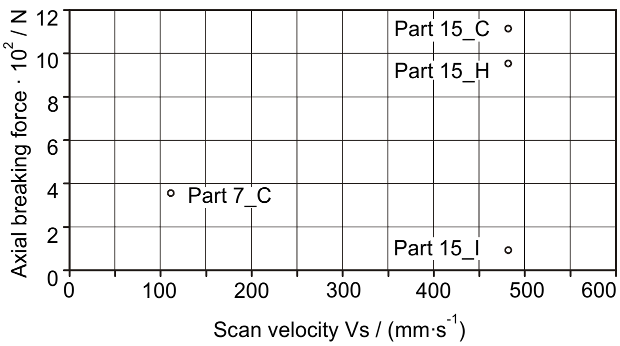

Figure 5. **Functional dependency of axial tensile force and SLS processes parameters per line E_l = const. = 0,4**

Slika 5. **Funkcionalna ovisnost aksijalne slie kidanja i SLS procesnih parametara po crti E_l = 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 Systeme.

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

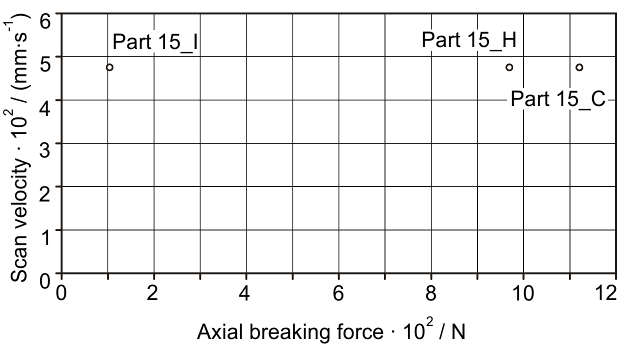

Figure 6. **Functional dependency of axial tensile force and SLS processes parameters for part 15 per line P_l = const. = 192 / W**

Slika 6. **Funkcionalna ovisnost aksijalne slie kidanja i SLS procesnih parametara za dio 15 po crti P_l = const. = 192 / 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 = const. and E_l = *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_l = const. with increase of laser beam scan velocity is decrease of axial breaking force value characteristic occurred (Figure 3.).

P_l = const	v_s = const	E_l = const
v_s↑ ABF↓	P_l↑ ABF↑	P_l↑ ABF↑
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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