INFLUENCE OF LASER SINTERING PARAMETERS ON MECHANICAL PROPERTIES OF POLYMER PRODUCTS

Ana Pilipović, Bogdan Valentan, Tomaž Brajlih, Tatjana Haramina, Jože Balič, Janoš Kodvanj, Mladen Šercer, Igor Drstvenšek

Abstract: *With Additive Manufacturing - AM it is possible to create physical models, prototypes, components, tools and functional parts from 3D data constructed using the computer (CAD), with complicated geometry, which is very difficult or even impossible to do with other manufacturing technologies. AM processes for the manufacturing of prototypes use metals, ceramics and polymers in the form of liquids, powders, wire, foil, etc. However, there are many limitations, primarily in the selection of materials. Therefore, it is necessary to know the material properties, and how the various parameters of the machine influence on them, especially if it is manufacturing functional parts. The paper provides a brief overview of Selective Laser Sintering – SLS, and how the machine parameters (layer thickness, speed and power of laser) influence the mechanical properties of materials (tensile properties and hardness).*

Key words: *Selective laser sintering, speed, laser power, properties of polymer product*

1. INTRODUCTION

The rapid prototyping (RP) procedures may drastically reduce the time and costs necessary to make a new product from the original concept to the production. RP can help in identifying the basic faults that are expensive to be corrected later, if they are identified when the product is ready for mass production. There are also many restrictions, primarily in the number of available materials and their properties which may differ quite considerably from the properties of the end-user products' materials.

2. SELECTIVE LASER SINTERING - SLS

SLS is one of the most important prototyping procedures. In polymer processing the entire procedure is carried out in a heated chamber filled with inert gas, in order to avoid potential combustion of the powder material particles. (Godec, 2005) The layer of powder is scanned and heated with thermal energy of the laser beam, resulting in mutual sintering of the material particles. The platform is lowered for the thickness of one layer which permits laying of a new powder layer. The new layer is scanned, adapted to the next upper cross-section and adheres to the previous layer. (Gibson et al., 2010) Prototypes made by SLS technology are increasingly used as functional parts that require good mechanical properties. This requirement depends on many factors: accuracy of the CAD model, method of layer slicing, machine resolution, beam offset, layer thickness, material shrinkage, laser speed, laser power, energy density, working base temperature, and hatching distance. The energy density that affects the visual appearance of the product and the very mechanical properties is calculated according to the equation: (Raghunath & Pandey, 2007; Senthilkumaran et al., 2009; Berce et al., 2008; Caulfield et al., 2007)

$$ED = \frac{P}{v \cdot h} \cdot x \qquad (1)$$

where is: ED [J/mm^2] – energy density, P [W] – laser power, v [mm/s] – laser speed, h [mm] – hatch distance, x [mm] – beam overlay ratio:

$$x = \frac{d}{h} \qquad (2)$$

where is: d [mm] – diameter of the focussed beam.

3. EXPERIMENTAL RESULTS

In the experimental part the attempt was made to determine the influence of laser speed and power, i.e. energy density on the tensile and flexural properties of test parts. The tensile properties are determined on the tester according to the ISO 527:1993 standard, and the flexural properties according to the ISO 178:2001 standard. The test specimens are made of PA2200 material using the Formiga P100 SLS machine of the EOS Company. Hatching distance was set at h = 0.25 mm and d = 0,42 mm.

When the energy density is the same, and the parameters of power and speed are changed, the mechanical properties remain the same, which leads to the conclusion that the material properties are only affected by the changes in energy input (Tab. 1, Fig. 1 and 2).

Run	power, W	speed, mm/s	energy density, J/mm^2
1	15	2000	0.05
2	25	3333	0.05
3	7.5	1000	0.05
4	22.5	3000	0.05

Tab. 1. Build parameters

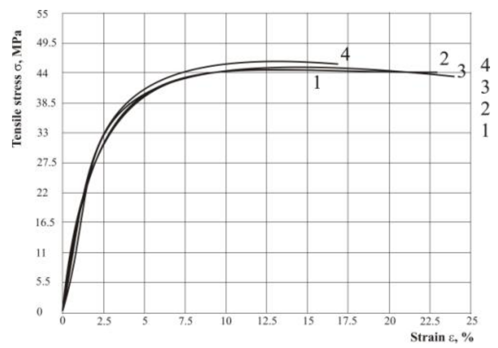


Fig. 1. Diagram tensile stress – strain with the same energy density

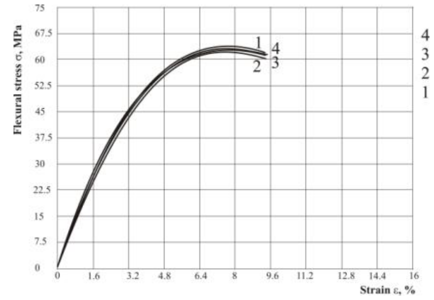


Fig. 2. Diagram flexural stress – strain with the same energy density

Table 2 provides the manufacturing parameters with different energy input. Fig. 3 presents the tensile, and Fig. 4 flexural properties of the material.

Run	power,W	speed, mm/s	energy density, J/mm^2
1	7	3000	0.016
2	10,5	3000	0.024
3	14	3000	0.031
4	18	3000	0.040
5	21	3000	0.047
6	22	1000	**0.148**
7	22	3000	0.049
8	22,5	3000	0.050
9	25	3000	0.056

Tab. 2. Build parameters

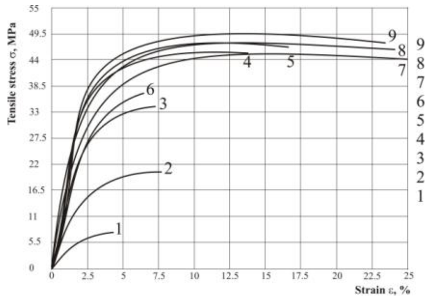


Fig. 3. Diagram tensile stress – strain

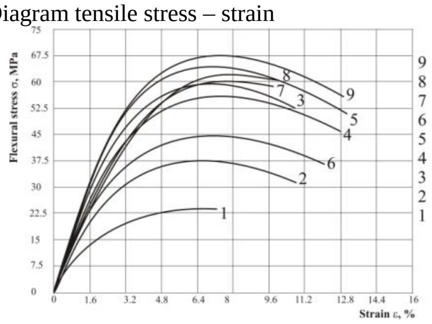


Fig. 4. Diagram flexural stress - strain

From the diagram it can be noticed that the greater the energy input is, the greater are the mechanical properties of test parts. However, it may be noticed also that in case of excessive energy input 0.148 J/mm^2 (test sample no. 6) the properties are reduced, which is a consequence of material overheating.

4. INFLUENCE OF THE LAYER THICKNESS

Since the manufacturing speed depends also on the layer thickness, due to faster production the layer thickness was increased from 0.1 mm to 0.2 mm and the analysis has shown that all the properties (hardness H, tensile stress R_m, tensile stress at break R_p and tensile strain at break ε_p) are reduced by about a half (Fig. 5). Such material behaviour is caused by too little input energy for good joining of thicker layers (Fig. 6.a and 6.b).

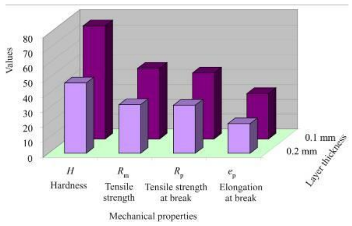
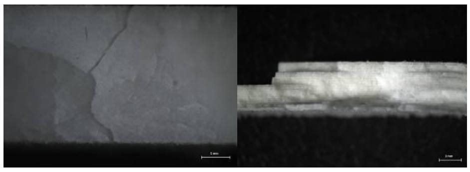


Fig. 5. Comparison of properties with different layer thicknesses



a.) b.)

Fig. 6. Brittle fracture of material: a) test specimens of 0.1 mm thickness, b) test specimens of 0.2 mm thickness

4. CONCLUSION

By setting different laser speeds and powers the properties remain unchanged, provided the energy density remains the same. However, by increasing the energy input the mechanical properties increase. It is also noticed that the energy input must not be too high, since then the properties decrease, and it may be concluded that the optimal energy for the production of products on EOS Formiga P100 machine would be around 0.05 J/mm^2. However, if all this were compared to the change in the layer thickness, one can notice that the layer thickness must be as thin as possible, because with thicker layers higher energy input is required, otherwise the properties decrease.

5. ACKNOWLEDGEMENT

These materials are based on work financed by the National Foundation for Science, Higher Education and Technological Development of the Republic of Croatia and is part of the research included in the projects Increasing Efficiency in Polymeric Products and Processing Development supported by the Ministry of Science, Education and Sports of the Republic of Croatia and FP7 project Knowledge Based Process Planning and Design for Additive Layer Manufacturing (KARMA), founded by the European Commission.

6. REFERENCES

Berce, P., Păcurar, R., Bậlc, N. & Păclişan, D. (2008): SLS parameters optimization using the Taguchi method, *The 2nd International Conference on Additive Technologies*; *DAAAM Specialized Conference*, Ptuj, Slovenia, September, 17th – 18th, ISBN: 390150961-5.

Caulfield, B., McHugh, P.E. & Lohfeld, S. (2007): Dependence of mechanical properties of polyamide components on build parameters in the SLS process, *Journal of Materials Processing Technology* 182 (2007) 477–488, ISSN: 0924-0136.

Gibson, I., Rosen, D.W. & Stucker, B. (2010): *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing*, Springer, ISBN: 978-1-4419-1119-3, USA

Godec, D. (2005). *The influence of hybrid mould on thermoplastic moulded part properties*, D. Sc. Thesis, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, *UDK:* 621.7, 678.027.7.

Raghunath, N. & Pandey, P.M.: Improving accuracy through shrinkage modelling by using Taguchi method in selective laser sintering, *International Journal of Machine Tools & Manufacture* 47 (2007) 985–995, ISSN: 0890-6955.

Senthilkumaran, K., Pandey, P.M. & Rao, P.V.M.: Influence of building strategies on the accuracy of parts in selective laser sintering, *Materials and Design* 30 (2009) 2946–2954, ISSN: 0261-3069.