PRODUCTION BY FDM METHOD RP TECHNOLOGY FROM PLA ECO-MATERIALS EXTRUDED HORIZONTALLY IN LENGTH

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DOI: 10.17973/MMSJ.2018_03_201747

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The authors in their article are devoted to describe the samples production of sophisticated eco-material PLA -PolyLacticAcid extruded horizontally in length, produced by FDM method, Rapid Prototyping. Carried out experimental tests of mechanical properties are presented by the authors in this article. Also in this article eco-materials outputs tested are presented in patterns, measurement protocols recorded in software, the measured values in a static tensile test, recorded in tables and shown in work graphs. Based on obtained results the authors compared produced samples from two PLA eco-materials and determined which PLA – ecoplastic is stronger.

KEYWORDS

rapid prototyping, PLA eco-materials, fused deposition modelling,PLA –PolyLacticAcid,3D model

1 INTRODUCTION

Methods for rapid prototyping commercialized in the late 80's, allow rapid production model, sample or prototype based on the 3D model created in a CAD system or 3D scanning data obtained by spatial digitization. Compared to conventional manufacturing methods, the production of prototype with RP methods takes significantly shorter (a number of days instead of months). To take full advantage of RP it is important to administratethe integration of entire course of product development and appropriate integration of rapid prototyping technology into the development cycle. Prototyping is an important phase of product development, which is essential for the assessment of form, fit and functional design rather than implementing significant investment in tooling required for mass production. Rapid Prototyping mainly used in automated manufacturing of physical models using so-called adding production technologies. Today they are used for a wide range of applications, and also used for the production of high quality end parts in small quantities or samples.[Novakova-Marcincinova 2014b, Novak-Marcincin 2012]

2 THE USE AND RECYCLING OF PLA MATERIAL

PLA materials are often used where it is necessary to use plastic with short lifespan, or where are higher requirements for quality and wholesomeness of what are mainly hospitals, as well as products for home and kitchen, where plastic comes into contact with food.Currently it is possible to produce from these materials almost anything, for example, plates, cutlery, cups, bags, containers for food, cutting boards, dishes, trays etc. Findend-use in fast food restaurants, and festivals or at picnic at home and garden barbecue. Mass spread of bioplastics for now is on the low because of their high price. Currently, still more expensive than synthetic materials made from petroleum. Stricter regulation of individual states and the EU to support the use of environmentally friendly plastics and technological developments, however, may soon reverse this situation. Linked with that is also excessive consumption of oil which leads to price increases and a gradual global decline, contributing the rapid development of bio-plastics, increased production and a gradual reduction of bioplastics price.[Plancak 2009, Novakova-Marcincinova 2013a]

2.1 Production of test samples

In the production of test samples a 3D device and Repetier-Host software was used, the where the working temperature of the nozzle was set to a value of 200°C and work surface to 70°C. Then followed the production of test samples, whereas the nozzle carries out movement in axes X, Y and the table in Z axis. [Novakova-Marcincinova 2014c]

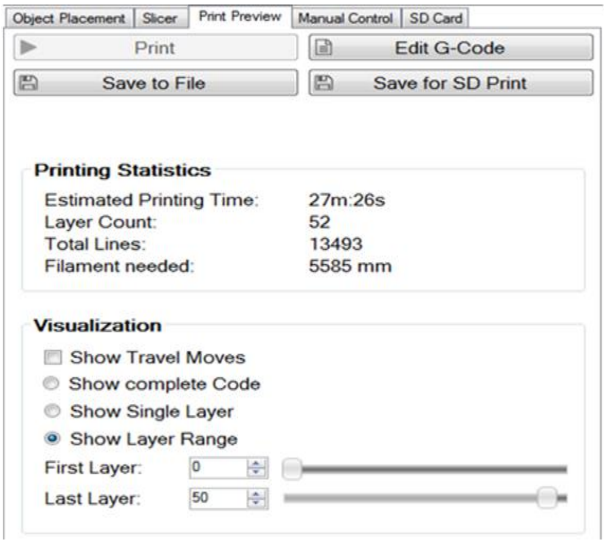

Figure 1. The parameters in the software Repetier-Hostproduced samples horizontally in length

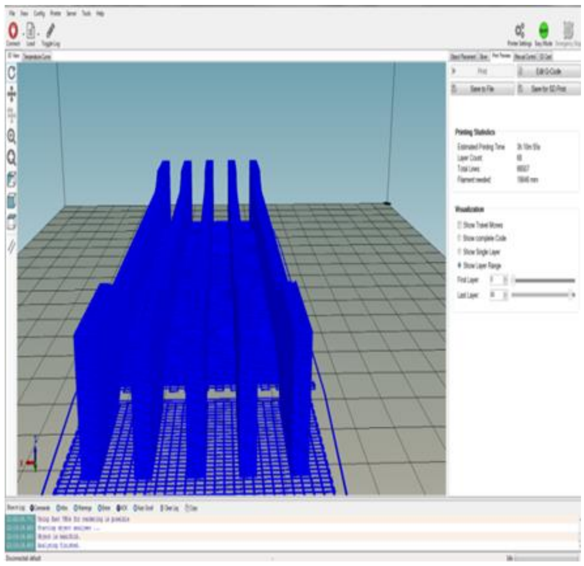

Figure 2. Production of samples horizontallyin length in the Repetier-Host software

Figure 3. Test samples made of clear PLA oriented horizontally in length

Figure 4. Test specimens made of blue PLA oriented horizontally in length

2.2 Measurement of test samples

When performing tests to determine the break point strength of test samples it is necessary to measure the thickness and width of each test sample, and the data was entered in the measurement protocols listed in the software of the certified universal testing machine TIRA-test 2300.The problem of determining the tensile properties of plastics is defined in EN ISO 527. [Novakova-Marcincinova 2014c]

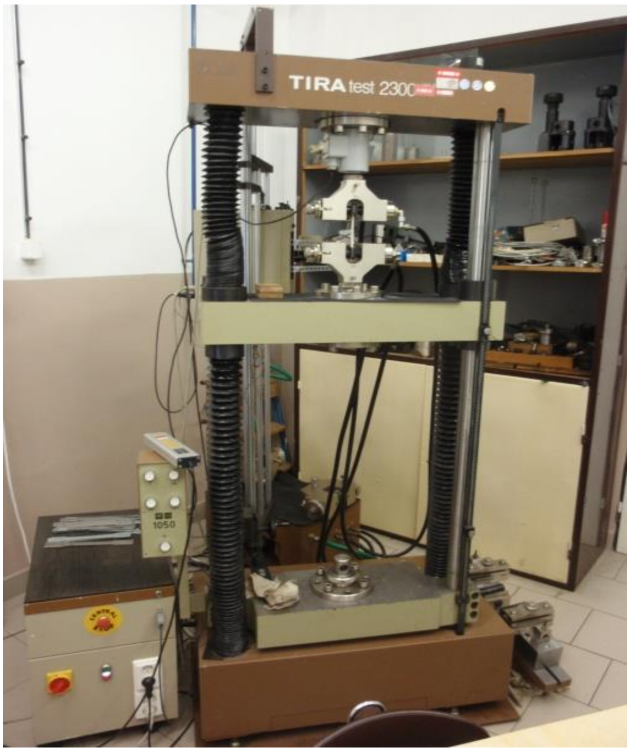

Figure 5.Clamping test sample in the machine

Thickness and width was measured gradually of each test sample, and these values were recorded in the software program on the computer and then the sample was clamped by pneumatic jaws in the Tira-test 2300 machine. Then, the test samples loaded with tensile force up to its breach point upon tearing. [Novakova-Marcincinova 2014a]

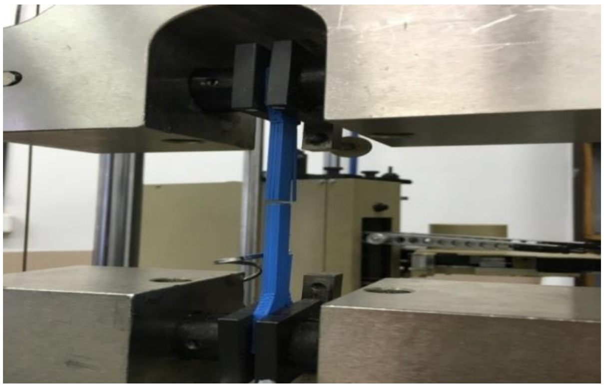

Figure 6. Detail of clamped and by force cracked sample

3 REALIZATION OF EXPERIMENTAL TESTS

The course of experimental tests were recorded using a testing machine incorporating a sensor where results are recorded in computer software and subsequently evaluated. Measured and calculated values obtained during performing of experiments on test samples are shown in tables (Tab.1.,Tab.2.). The measured values of force Fm [N]force on edge of strength - the highest load are maximum values of measured force detected during the test. These force values may be determined by an ultimate tensile strength σM [MPa], as well as relative elongation of tensile strength εM [%].[Novakova-Marcincinova 2013b, Novakova-Marcincinova 2014a]

Department of Technology and Materials
Faculty of Mechanical Engineering
Technical university of Košice

test report number: E. NOVAKOVA-MARCINCINOVA
number of order:

laboratory of mechanical and technological tests
manufacturer: material: transparent PLA in length number of melt:
type of test:

MECHANICAL PROPERTIES - PLASTIC PULL

serial number	sample label	a_0 [mm]	b_0 [mm]	A_0 [mm^2]	L_0 [mm]	L [mm]	F_Y [N]	F_m [N]	σ_y [MPa]	σ_m [MPa]	ε_m [%]
1	11 1.	3,89	10,39	40,42	50,00	2,20	0,00	2081	0	51	4,39
2	11 2.	3,87	10,35	40,05	50,00	2,18	0,00	2065	0	52	4,36
3	11 3.	3,90	10,43	40,68	50,00	2,17	0,00	2060	0	51	4,34
4	11 4.	3,87	10,44	40,40	50,00	2,18	0,00	2066	0	51	4,37
5	11 5.	3,88	10,35	40,16	50,00	2,17	0,00	2055	0	51	4,34

notes: measured: Ema Marcinčinová day: 1.4.2016 made by: Ema Marcinčinová day: 1.4.2016 approved: prof. Spišák day: 1.4.2016

Table 1. Measured values in static tensile test of clear PLA samples horizontal in length

Department of Technology and Materials
Faculty of Mechanical Engineering
Technical university of Košice

test report number: E. NOVAKOVA-MARCINCINOVA
number of order:

laboratory of mechanical and technological tests
manufacturer: material: blue PLA in length number of melt:
type of test:

MECHANICAL PROPERTIES - PLASTIC PULL

serial number	sample label	a_0 [mm]	b_0 [mm]	A_0 [mm^2]	L_0 [mm]	L [mm]	F_Y [N]	F_m [N]	σ_y [MPa]	σ_m [MPa]	ε_m [%]
1	2 .1 A	3,88	10,46	40,58	50,00	1,89	0,00	1946	0	48	3,78
2	2 .1 B	3,96	10,47	41,46	50,00	1,96	0,00	1996	0	48	3,92
3	2 .1 C	3,93	10,61	41,70	50,00	1,94	0,00	1970	0	47	3,87
4	2 .1 D	3,88	10,52	40,82	50,00	1,56	0,00	1709	0	42	3,12
5	2 .1 E	3,83	10,47	40,10	50,00	1,99	0,00	1979	0	49	3,98

notes: measured: Ema Marcinčinová day: 1.4.2016 made by: Ema Marcinčinová day: 1.4.2016 approved: prof. Spišák day: 1.4.2016

Table 2. Measured values in static tensile test of blue PLA samples horizontal in length

During the static test of strength the machines software records the plot of elongation ε [%] from burdensome force F [N]. The following figure include samples after the strength test. The number of samples as well as the course of the test were performed in accordance with the EN ISO 527 standard. [Novakova-Marcincinova 2014a, Novakova-Marcincinova 2013d]

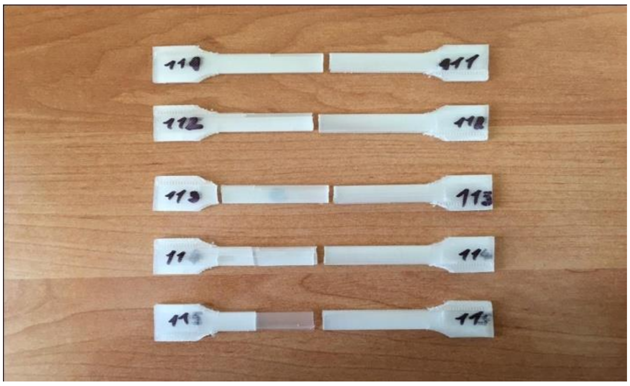

Figure 7. Test samples of clear PLA plastic in length after test

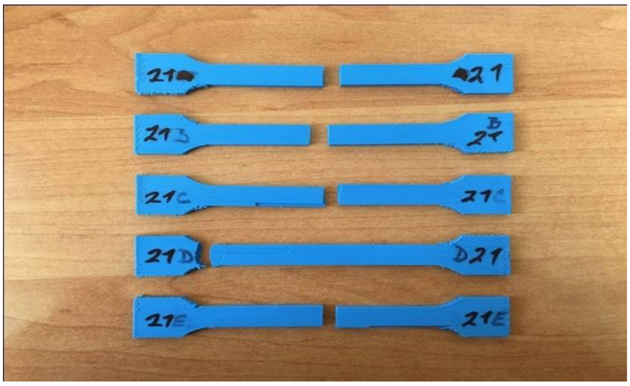

Figure 8. Test samples of blue PLA plastic in length after test

4 STATISTICAL EVALUATION OF STATIC TESTS

Diameter m considered normal distribution is estimated using the arithmetic mean $\overline{\sigma_M}$ z $n = 5$ measured results of test samples made of clear PLA plastic produced horizontally in length:

$$s_1 = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\sigma_{M1i} - \overline{\sigma_{M1}}\right)^2} \quad (1)$$

$$\overline{s_{M1}} = 51{,}2 \text{ MPa} \quad (2)$$

Calculation of static tensile test on test samples of blue PLA horizontally in length:

$$s_1 = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\sigma_{M1i} - \overline{\sigma_{M1}}\right)^2} \quad (3)$$

$$\overline{s_{M4}} = 46{,}8 \text{ MPa} \quad (4)$$

5 CONCLUSIONS

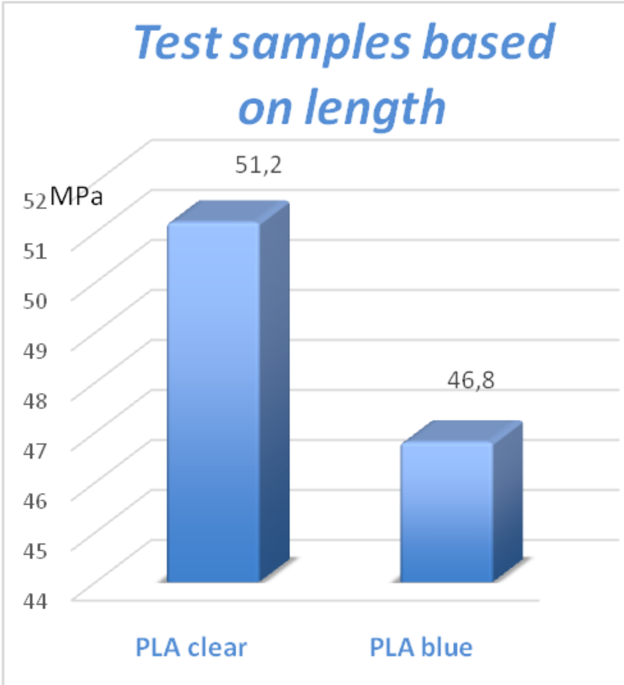

Figure 9. Graphical evaluation of test samples based on length

As shown in the graph which shows a comparison of samples printed horizontally in length, the samples printed from clear PLA material have an ultimate tensile strength of 51,2MPa therefore we conclude that they are the strongest. Tensile strength of blue PLA materials is lower.

ACKNOWLEDGMENTS

The authors would like to thank the KEGA grant agency for supporting research work and co-financing the project KEGA: 004TUKE-4/2017.

REFERENCES

[Duplak 2013] Duplak, J. et al. Comprehensive expression of durability for the selected cutting tools in comparison with standard ISO 3685. Advanced Science Letters 2013, Vol. 19, No. 2, pp 460-463

[Jurko 2012] Jurko, J., Panda, A., Behun, M. Prediction of a new form of the cutting tool according to achieve the desired surface quality. In: Applied Mechanics and Materials. ICAMMM 2012, 2nd International Conference on Applied Mechanics, Materials and Manufacturing, 7-18 November 2012, Changsha, China. Vol. 268, no. 1 (2013), p. 473-476. ISBN 978-303785579-9, ISSN 1660-9336

[Krenicky 2012] Krenicky, T., Rimar, M. Monitoring of vibrations in the technology of AWJ. In: Key Engineering Materials. Vol. 496 (2012), p. 229-234

[Krolczyk 2014] Krolczyk, G., Raos, P., Legutko, S. Experimental analysis of surface roughness and surface texture of machined and fused deposition modelled parts, Tehnicki Vjesnik - Technical Gazette, 21, 1 (2014), 217 – 221.

[Novak-Marcincin 2012] Novak-Marcincin, J., Janak, M., Novakova-Marcincinova, L. Increasing of Product Quality Produced by Rapid Prototyping Technology, Manufacturing Technology, vol. 12, no. 12, 2012, p. 71-75, ISSN 1213-2489.

[Novakova-Marcincinova 2013a] Novakova-Marcincinova, L., Novak-Marcincin, J. Rapid prototyping in developing process with CA systems application In: Applied Mechanics and Materials : IMM 2013 : International Conference on Intelligent Materials and Mechatronics : 1-2 November 2013, Hong Kong. Vol. 464 (2014), p. 399-405. - ISBN 978-303785935-3 - ISSN 1660-9336

[Novakova-Marcincinova 2013b] Novakova-Marcincinova, L., Novak-Marcincin, J. Verification of mechanical properties of ABS materials used in FDM rapid prototyping In: Proceedings in Manufacturing Systems. Vol. 8, no. 2 (2013), p. 87-92. - ISSN 2067-9238

[Novakova-Marcincinova 2013c] Novakova-Marcincinova, L. Increasing of the Reinforced Materials Properties of Parts Produced by Rapid Prototyping / Ludmila Novakova-Marcincinova - 2013. In: Journal CA Systems in Production Planning. Roc. 14, č. 1 (2013), s. 27-30. - ISSN 1335-3799

[Novakova-Marcincinova 2013d] Novakova-Marcincinova, L., Novak-Marcincin, J . Selected Testing for Rapid Prototyping Technology Operation - 2013. In: Applied Mechanics and Materials. Vol. 308 (2013), p. 25-31. - ISSN 1662-7482

[Novakova-Marcincinova 2014a] Novakova-Marcincinova, L., Novak-Marcincin, J. Production of composite material by FDM rapid prototyping technology In: Applied Mechanics and Materials : Novel Trends in Production Devices and Systems. Vol. 474 (2014), p. 186-191. - ISSN 1662-7482.

[Novakova-Marcincinova 2014b] Novakova-Marcincinova, L., Novak-Marcincin, J. Production of ABS-Aramid Composite Material by Fused Deposition Modeling Rapid Prototyping System. In: Manufacturing Technology. Vol. 14, no. 1 (2014), p. 85-91. - ISSN 1213-2489

[Novakova-Marcincinova 2014c] Novakova-Marcincinova, L., Novak-Marcincin, J. Testing of ABS Material Tensile Strength for Fused Deposition Modeling Rapid Prototyping Method. In: Advanced Materials Research : FAMET 2014 : International Conference on Frontiers of Advanced Materials and Engineering Technology : 28-29 March 2014, Hong Kong. Vol. 912-914 (2014), p. 370-373. - ISBN 978-303835077-4 - ISSN 1022-6680

[Olejarova 2016] Olejarova, S., Krehel, R., Pollak, M., Kocisko, M. Research on impacts of mechanical vibrations on the production machine to its rate of change of technical state. In: Advances in mechanical engineering. Vol. 8, no. 7, 2016, p. 1-10. - ISSN 1687-8140.

[Panda 2011] Panda, A., Jurko, J., Dzupon, M., Pandova, I. Optimalization of heat treatment bearings rings with goal to eliminate deformation of material. In: Chemicke listy, 2011, vol. 105, issue 16, ISSN 0009-2770, p. 459-461.

[Panda 2011] Panda, A. et al. Analytical expression of T-vc dependence in standard ISO 3685 for cutting ceramic. In: Key Engineering Materials. 2011, Vol. 480-481 (2011), p. 317-322. ISSN 1013-9826

[Panda 2013] Panda, A. et al. Roller bearings and analytical expression of selected cutting tools durability in machining process of steel 80MoCrV4016. In: Applied Mechanics and Materials, ICACME 2013, 2nd International Conference on Automatic Control and Mechatronic Engineering, Bangkok, Thailand, 21-22 June 2013. Vol. 415 (2013), p. 610-613. ISBN 978-303785865-3, ISSN 1660-9336

[Panda 2016a] Panda, A., Jurko, J., Pandova, I. Monitoring and Evaluation of Production Processes. An Analysis of the Automotive Industry. Monograph, Springer International Publishing, Switzerland, 2016, (8.4.2016), 117 pages, ISBN 978-3-319-29441-4

[Panda 2016b] Panda, A., Jurko, J., Valicek, J., Harnicarova, M., Pandova, I. Study on cone roller bearing surface roughness improvement and the effect of surface roughness on tapered roller bearing service life. In: The International Journal of Advanced Manufacturing Technology. Springer London Ltd, pp. 1099-1106, Volume 82, Issue 5-8, 2016, ISSN 0268-3768

[Pandova 2014] Pandova, I. Nitrogen oxides reduction by zeolite sorbents in manufacturing use. In: Advanced Materials Research, Trans Tech Publications Inc., Switzerland, vol. 937, no. 937, 2014, p. 487-490, ISSN 1022-6680.

[Pandova 2016] Pandova, I. Manufacturing technologies in automotive production and waste water cleaning on zeolite in view of copper. In: MM Science Journal, november, 2016, vol. 2016, Praha, Czech republic, Publisher: MM publishing Ltd., ISSN1803-1269,1218-1221p. DOI:10.17973/MMSJ.2016_11_201648

[Plancak 2009] Plancak, M. Rapid Prototyping and Rapid Tooling, FTN University of Novi Sad, Novi Sad, 2009, 164 p., ISBN 978-86-7892-232-9.

[Rimar 2016] Rimar, M., Smeringai, P., Fedak, M., Kuna, S. Technical and software equipment for the real time positioning control system in mechatronic systems with pneumatic artificial muscles. In: Key Engineering Materials, Operation and Diagnostics of Machines and Production Systems Operational States 3. Vol. 669 (2016), p. 361-369. ISSN 1662-9795

[Straka 2013] Straka, L., Corny, I., Krehel, R. Evaluation of Capability of Measuring Device on the Basis of Diagnostics. In: Applied Mechanics and Materials, Trans Tech Publications, Zurich, Switzerland, vol. 308, 2013, p. 69-74.

[Zelenak 2012] Zelenak, M. et al. Comparison of mechanical properties of surface layers with use of nanoindentation and microindentation tests. Metalurgija, 2012, Vol. 51, pp 309-312, ISSN 0543-5846

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