CONSIDERING THE STRENGTH ASPECTS OF THE MATERIAL SELECTION FOR THE PRODUCTION OF PLASTIC COMPONENTS USING THE FDM METHOD

ANTON PANDA[1], LUDMILA NOVAKOVA-MARCINCINOVA[1], EMA NOVAKOVA-MARCINCINOVA[1], JAN DUPLA[1], TADEUSZ ZABOROWSKI[2]

[1]Technical University of Kosice, Department of Manufacturing Technologies, Faculty of Manufacturing Technologies with a seat in Presov, Slovak Republic

[2]IBEN Gorzow Wlkp.,Poznan, Poland

DOI: 10.17973/MMSJ.2018_12_201866

e-mail: anton.panda@tuke.sk

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

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

1 INTRODUCTION

Sophisticated production technology, which we call Rapid Prototyping, is primarily applied in all manufacturing sectors. This technology is used to hire in piece and small-scale production, especially in the first stage of product development. While modeling or specimens are taken off in classical technology, and in sophisticated RP technology, the shape of the model or samples is formed by the gradual addition of material that is in the form of a powder or gtavenin or a layer of photopolymer that is gradually cured with UV laser to to the final form of the prototype or sample. This sophisticated DP technology, with this modern approach, becomes a powerful tool for the modern development of prototypes or samples. Also, this modern and rapidly evolving sophisticated technology enables radically shorter development and implementation time. With traditional product design, 2D drawings are created from a 3D model or sample. In the initial drawing, 2D designs are transformed during the phase of the specification into 3D concepts[Fig.1]. the proposal is, of course, reviewed several times on the basis of the results of the experiments using the production equipment. In confrontational! processes with conventional production methods takes prototype production by rapid prototyping methods to substantially shorter to several days of months.[Novakova-Marcincinova L. 2014b,Novak-Marcincin J. 2012, Balara 2018, Zaborowski 2007, Michalik 2014, Monkova 2013, Mrkvica 2012, Peterka 2014].

2 PLA- POLYLACTID ACID – BIOPLASTIC

It is a material that is produced from renewable sources and is therefore independent from petroleum and impurities. It is a plastic made from biomass. At first sight it looks and to touch it feels the same as commonly used plastics made from petroleum, reaching even the same qualities as flexibility, hardness, transparency, flexibility and durability. However, it is specific by ist processing and production process. It differs from traditional plastics in that it can be degraded biologically, composted and converted to humus or biomass quality, which does not constitute environmental burden. The products of these bioplastics are tasteless, absolutely free of allergens. Globally recognized and certified for use in food and they guarantee health safety. The basic raw material for production is plant biomass, such as maize, cereals, potatoes, sugar beet, sugar cane, soybean, tobacco, and natural materials such as cellulose and lignite. Bioplastic is made from the starch of these plants. In order to transform the starch material properties corresponding to plastic from petroleum, it must be exposed to high temperatures and by isolation we get glucose from it.[Plancak 2009, Novakova-Marcincinova L. 2013a,Panda 2011a, Balara 2018]

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 L. 2014c]

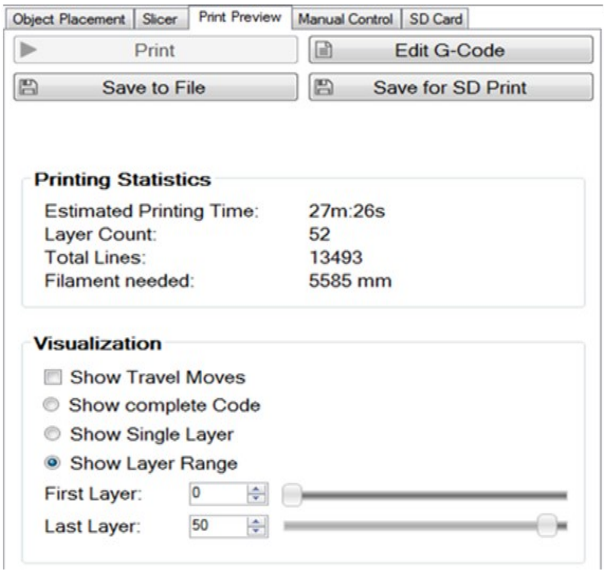

Figure 1. The parameters in the software Repetier-Hostproduced samples horizontally in length.

2.2 Measuring of test samples for determining the tensile properties

So that the prescribed measurement conditions are kept, for measuring linear dimensions a caliper had to be used with an accuracy of 0.02 mm. [Fig.3,Fig.4]. Universal testing machine Tira-test 2300 is PC controlled ripper machine, mainly designed to test the tensile strength of maximum test load of 100 kN, with load range of 1, 10 and 100 kN. In addition of tensile test, it is possible to implement strength tests of welded and bonded joints. The perfect state of machine is confirmed by certificate of verification of the testing machine for strength determination of metals and plastics under no. 0305/323-04/11. EN ISO 527. [Novakova-Marcincinova L. 2014c,Vojtko 2014, Prislupcak 2014, Sebo 2012, Panda 2016, Jurko 2016]

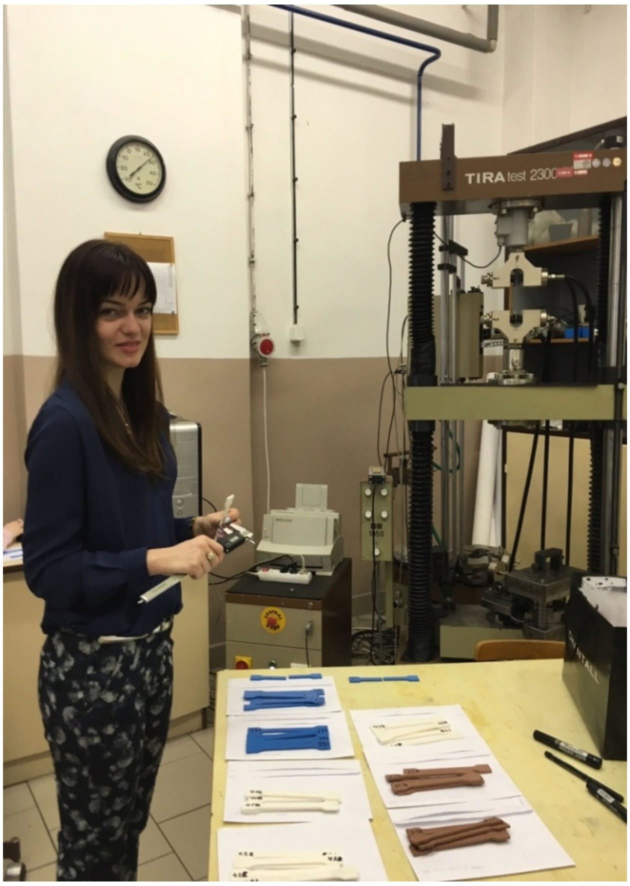

Figure 2. Measurement of test samples

3 IMPLEMENTATION OF EXPERIMENTAL TESTS TO DETERMINE TENSILE PROPERTIES

The course of experimental tests [Fig.2] to determine tensile properties were recorded using a testing machine in which incorporated sensors record the results in computer software and are subsequently evaluated. Measured and calculated values obtained during the execution of experiments on test samples are shown in Table 1 and Table 2. The measured values of force Fm [N] force on strength limit - the highest load are maximum values of measured force detected during the test. These force values may determine ultimate tensile strength σM [MPa], as well as elongation at ultimate tensile strength εM [Panda 2011b, Novakova-Marcincinova L. 2013b, Novakova-Marcincinova L. 2014a, Novakova-Marcincinova E, 2017, Krenický 2012, Krolczyk G 2014,Peterka 2014]

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 width number of melt:
type of test:
MECHANICAL PROPERTIES - PLASTIC PULL

serial number	sample label	a_0 [mm]	b_0 [mm]	A_0 [mm²]	L_0 [mm]	L [mm]	F_y [N]	F_m [N]	σ_y [MPa]	σ_m [MPa]	ε_m [%]
1	1.2 A	3,29	10,34	34,02	50,00	1,28	0,00	1085	0	32	2,55
2	1.2 B	3,14	10,53	33,06	50,00	1,35	0,00	1217	0	37	2,69
3	1.2 C	3,30	10,37	34,22	50,00	1,05	0,00	942	0	28	2,10
4	1.2 D	3,33	10,97	36,53	50,00	1,05	0,00	957	0	26	2,10
5	1.2 E	3,47	10,62	36,85	50,00	0,91	0,00	865	0	23	1,82

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

Table 1. Measured values in the static tensile test of PLA samples - clear horizontally in width

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 width number of melt:
type of test:
MECHANICAL PROPERTIES - PLASTIC PULL

serial number	sample label	a_0 [mm]	b_0 [mm]	A_0 [mm²]	L_0 [mm]	L [mm]	F_y [N]	F_m [N]	σ_y [MPa]	σ_m [MPa]	ε_m [%]
1	2. 2 A	3,42	10,74	36,73	50,00	1,09	0,00	1031	0	28	2,18
2	2. 2 B	3,43	10,65	36,53	50,00	1,34	0,00	1158	0	32	2,67
3	2. 2 C	3,49	10,59	36,96	50,00	1,64	0,00	1340	0	36	3,27
4	2. 2 D	3,50	10,60	37,10	50,00	1,62	0,00	1352	0	36	3,25
5	2. 2 E	3,64	10,55	37,40	50,00	1,50	0,00	1257	0	33	2,99

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

Table 2. Measured values in the static tensile test of PLA samples - blue horizontally in width

Figure 3. Test samples of clear PLA plastic horizontal in width after the test

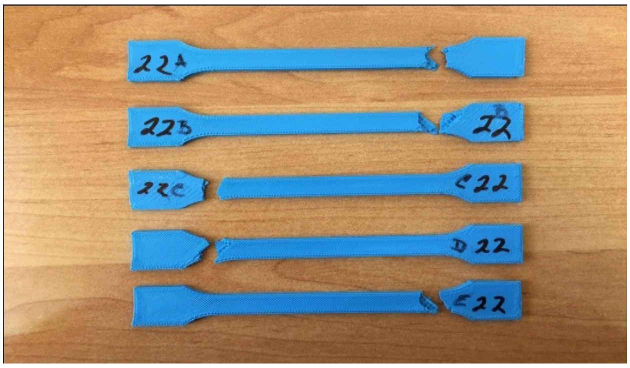

Figure 4. Test samples of blue PLA plastic horizontal in width after the test

4 STATIC TESTS - STATISTICAL EVALUATION

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

$$\overline{\sigma_{M2}} = \frac{1}{n}\sum_{i=1}^{n}\sigma_{Mi} = \frac{1}{5}(32+37+28+26+23)$$

$\overline{\sigma_{M2}} = 29,2$ MPa (1)

s2 = 5,4498 MPa (2)

22,4313 MPa <m< 35,9687 MPa (3)

Calculation of static tensile test on test samples of blue PLA in width:

$$\overline{\sigma_{M5}} = \frac{1}{n}\sum_{i=1}^{n}\sigma_{Mi} = \frac{1}{5}(28+32+36+36+33)$$

$\overline{\sigma_{M5}} = 33$ MPa (4)

s_5 = 3,3166 MPa (5)

28,8808 MPa <*m*< 37,1192 MPa (6)

5 CONCLUSIONS- ANALYSIS OF RESULTS

The most significant increase in ultimate tensile strength test samples printed width, was recorded with the use of PLA material clear where the ultimate load was recorded at the limit of 33 MPa. [Fig.5].

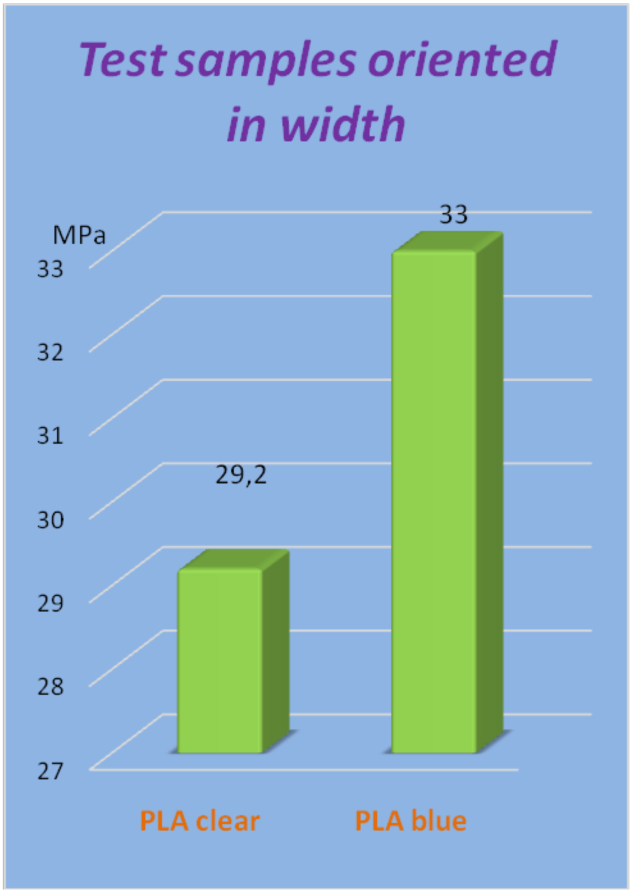

Figure 5. Graphical evaluation of test samples oriented in width

ACKNOWLEDGEMENTS

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

The authors would like to thank the VEGA grant agency for supporting research work and co-financing the project VEGA 1/0045/18.

REFERENCES

[Balara 2018] Balara, M., Duplakova, D., Matiskova, D. Application of a signal averaging device in robotics. In: Measurement. Vol. 115, No. 2, pp. 125-132, Issue 5-8, 2018, ISSN 0263-2241

[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

[Jurko 2016] Jurko, J., Panda, A., 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

[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.

[Michalik 2014] Zajac, J., Hatala, M., Mital, D. and Fecova, V. Monitoring surface roughness of thin-walled components from steel C45 machining down and up milling. In: Measurement, vol. 58, 2014, p. 416-428, ISSN 0263-2241.

[Monkova 2013] Monkova, K., Monka, P. and Jakubeczyova, D. The research of the high speed steels produced by powder and casting metallurgy from the view of tool cutting life. In: Applied Mechanics and Materials, TTP, Switzerland, vol. 302, no. 302, 2013, p. 269-274.

[Mrkvica 2012] Mrkvica, I., Janos, M. and Sysel, P. Contribution to milling of materials on Ni base. Applied Mechanics and Materials, Advanced Materials and Process Technology, vol. 217-219, 2012, p. 2056-2059.

[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. 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

[Novakova-Marcincinova, 2017] Nováková-Marcinčínová.E., Panda, A. Nováková-Marcinčínová, L. - 2017. Sophisticated production from organic PLA materials processed horizontally by fused deposition modeling method In: Key Engineering Materials : Manufacturing Technologies: Materials, Operation and Applications volume 756. - Switzerland : TTP, 2017 P. 88-95. - ISBN 978-3-0357-1196-7 - ISSN 1013-9826

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

[Panda 2011b] 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 2016] 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

[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. DOI:10.17973/MMSJ.2016_11_201648

[Peterka 2014] Peterka, J., Pokorny, P. Influence of the Lead Angle from the Vertical Axis Milling on Effective Radius of the Cutter. In: Key Engineering Materials, Trans Tech Publications Inc. Switzerland, vol. 581, no. 581, 2014, p. 44-49, ISSN 1013-9826.

[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.

[Prislupcak 2014] Prislupcak, M., Panda, A., Jancik, M., Pandova, I., Orendac, P., Krenicky, T. Diagnostic and experimental valuation on progressive machining unit. In: Applied Mechanics and Materials, Trans Tech Publications, Zurich, Switzerland, vol. 616, 2014, p. 191-199, ISSN 1660-9336.

[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

[Sebo 2012] Sebo, J., Svetlik, J., Fedorcakova, M. and Dobransky, J. The comparison of performance and average costs of robotic and human based work station for dismantling processes. In: Acta Technica Corviniensis: Bulletin of engineering, vol. 5, no. 4, 2012, p. 67-70, ISSN 2067-3809.

[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.

[Vojtko 2014] Vojtko, I., Simkulet,V., Baron, P. and Orlovsky, I. Microstructural Characteristics Investigation of the Chip-Making Process after Machining. In: Applied Mechanics and Materials, Trans Tech Publications, Zurich, Switzerland, vol. 616, 2014, p. 344-350, ISSN 1660-9336.

[Zaborowski 2007] Zaborowski, Ekowytwarzanie. Gorzow, pp. 100

[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

CONTACT:

Prof. M. S. E. (Ing.) Anton Panda, PhD.

Technical University Kosice with seat in Presov
FVT, Department of Manufacturing Technologies
Bayerova 1, Presov, 080 01, Slovak Republic
e-mail: anton.panda@tuke.sk