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EXPERIMENTAL STUDIES ON EFFECT OF HYDROLYTIC DEGRADATION ON ADDITIVE MANUFACTURED POLYMERIC PARTS

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1. Introduction

Damage of the polymer chains can be a result of one of three processes: depolymerization, destruction or degradation. For aliphatic biopolymers used in medical applications the main area of research interest is investigation of hydrolytic degradation. Hydrolytic degradation leads to erosion of biomaterials matrix. This process starts, when aliphatic polymers are immersed in water. The effect of immersion in aqueous medium is absorption of degrading agents. Absorbed water penetrate the polymer matrix and changes the water gradient between the surface and the inner part of the material. This process was described in paper [4].

Currently additive manufacturing (AM) is strongly developing method of Rapid Prototyping (RP) and Rapid Tooling (RT). One of widely used Rapid Prototyping method is Fused Deposition Modeling (FDM). FDM is also called 3D printing technology. In this method 3D objects are constructed directly from 3D CAD data and then prepared with thermoplastic materials. These thermoplastic materials are melted in extruder. Then thin fibers are deposited on flat surface to become all layers of the model.

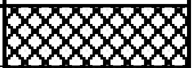
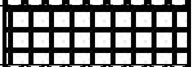
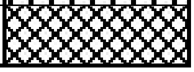
Literature analysis has been shown to increase interest in mechanical properties of 3D printed parts, like porous scaffolds [3] and standardized specimens [1]. However, these results are not sufficient to determine the mechanical behavior of 3D printed biodegradable materials.

The purpose of this paper is to preliminary investigate the use of polylactic acid (PLA) in fused deposition modeling (FDM) to fabricate specimens for determination effects of hydrolytic degradation in new material model. It also aim to examine the effects of different printing raster patterns on mechanical properties of PLA specimens.

2. Methods

2.1 Materials

In these investigation specimens according to the ISO 527-1:2012 standard geometry 1A/1B were used. FDM specimens were prepared in three raster paterns (DaVinci 1.0A). The raster paterns were dependent on percentage infill and print direction. Specimens type are presented in tab. 1.

No.	Infill [%]	Print direction [°]	Pattern
I.	90	0	
II.	90	45	
III.	30	0	

Tab. 1. FDM specimens.

As a reference material model the injection molded specimens were used (Engel e-victory 310/110 injection molding machine). To the injection molding Ingeo™ Biopolymer 3100 HP, Nature Works LLC was used.

2.2 Hydrolytic degradation

All groups of specimens were immersed in Phosphate Buffered Saline. The type of degrading medium and other conditions, like temperature, was chosen based on prior investigations of injection molded specimens [2]. Degradation time for FDM specimens was 12 weeks.

2.3 Medium absorption

The percentage amount of medium absorption was calculated from the relationship Eq. (1), corresponding to the difference between specimen mass before degradation (m_0) and specimen mass measured after a specified period of degradation (m_t). Sample mass after degradation was determined for specimens, which were dried with paper towels in order to remove medium from the specimen surface.

$$\Delta\text{m} = \frac{m_t - m_0}{m_0} \cdot 100\% \qquad (1)$$

2.4 Static mechanical properties

Static mechanical properties and their changes as a function of degradation time were determined based on uniaxial tensile test. The testing machine was electromagnetic actuator Instron E3000 (± 3 kN). Test speed was 1 mm/min.

3. Results and discussion

Results of amount of medium absorption are presented in Tab. 2.

Specimen type	Degradation week		Δm	SD (σ)
	W0	W12		
	m_0, g	m_t, g		
IM	12,4548	12,5820	0,0102	0,0005
90	11,1900	11,6140	0,0379	0,0037
90.45	10,9784	11,3327	0,0323	0,0037
30	7,3917	7,6826	0,0393	0,0157

Tab. 2. Average amount of degrading medium absorption.

The percentage test results were calculated from the Eq. (1). Results after 12 weeks of degradation were similar for each FDM specimens. Amorphous injection molded specimens (IM) was less medium than FDM specimens absorbed, also they were characterized by lower dispersion of results.

Tab. 3. shows results of static mechanial properties.

Specimen type	Degradation week		SD (σ)	
	W0	W12	W0	W12
	σ_M, MPa		-	-
IM	57,5643	55,4794	0,8238	0,3311
90	38,6772	20,2685	1,7813	0,5083
90.45	35,3055	27,3844	0,3790	0,9633
30	25,1771	14,5511	1,0752	0,6534

Tab. 2. Average tensile strength.

It was noted that injection molded specimens have the highest tensile strength, and they were measured only as a reference material model. In the comparision of the test results for FDM materials differences for raster patterns can be observed. Thus, modification of the structure, affects on varied behaviors of specimens with the same percentage infill. Specimens with infill along load axis (90.45) have lower strength, than specimens with angular oriented infill (90). Also, it was noted that specimens with axialy oriented infill can degrade more slowly than specimen with angular oriented infill.

4. Remarks

Based on the investigation, it can be observed that the proposed research methodology can be applied in the study of FDM materials. For all samples received lower dispersion of the test results.

In the further research plans other raster paterns would be included. Likewise increasing the number of short-term degradation measurements (to 12 weeks) is provided. In long-term degradation of injection molded specimens it has been shown that up to 12 weeks in the mechanical strength changes are statistically insignificant. Therefore, in the preliminary studies of FDM specimens, only the strength and medium absorption changes for week 0 and 12 were compiled.

References

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