International Journal of Advanced Research in Science, Engineering and Technology

ISSN: 2350-0328

IJARSET IMPACT FACTOR 7.150

Vol. 12, Issue 7, July 2025

"Investigation of the Physical and Mechanical Properties of Composite Materials Modified on the Basis of Polyethylene Terephthalate Waste"

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ABSTRACT: In this article, polyethylene terephthalate (PET) waste was processed using NaOH solutions with concentrations of 25%, 30%, 35%, and 40%, resulting in its transformation into a powder form. Polyethylene terephthalate (PET) and technical starch were mixed in various ratios — 95:5; 90:10; 85:15; 80:20; 75:25 — and stirred at a temperature of 80–90 °C until a homogeneous mass was obtained. Films were then produced from the resulting mixture by pressing. The resulting samples were tested using special equipment, and important parameters such as tensile strength, relative elongation, and elastic modulus were determined.

KEYWORDS: elastic modulus, relative elongation, tensile strength, modification, composite, thermoplastic, thermosetting material, pressing, crystallization, solubility.

I.INTRODUCTION

In recent years, the intensification of global environmental problems—particularly the accumulation of polymer waste and its negative impact on the environment—has significantly increased the urgency of their disposal, recycling, and reuse as raw materials. Especially in the current context of growing demand for primary resources, the production of high value-added products through waste recycling has become a critical issue. Polyethylene terephthalate (PET) and similar thermoplastic polymers are widely used in various industries, ranging from beverage containers to the textile sector. Consequently, the volume of waste generated from these materials is increasing annually. The development of new composite materials from such polymer waste and the study of their physical and mechanical properties present opportunities for improving environmental sustainability and creating import-substituting materials. In this study, the physical and mechanical properties of modified composite material samples based on polymer waste—such as strength, deformation characteristics, tensile strength, and elastic modulus—are investigated. Furthermore, the prospects for obtaining strong and environmentally safe coating materials by pressing PET-based composites blended with natural polymers such as starch are evaluated. This article explores not only an innovative approach to waste recycling but also the scientific foundations for the creation of new composite materials.

The object of the study is composite material samples prepared from polymer waste—specifically, secondary polyethylene terephthalate (PET) and natural starch—in the following ratios: 95:5, 90:10, 85:15, 80:20, and 75:25 (% by weight). These materials were modified and processed into films using a pressing device. The relationship between the physical-mechanical properties of the resulting films and the amount of technical starch incorporated into the composites was investigated.

II.MATERIALS AND METHODS.

The following GOST standards and methods were used in conducting the scientific research: GOST 29240-91 – Molding of thermoplastics and their blends by pressing method; GOST 11262-2017 – Determination of mechanical properties of plastics by tensile testing; GOST 9550-81 – Measurement of the elastic modulus of polymer materials; GOST 15173-70 – Evaluation of resistance to deformation; GOST 27651-88 – General rules for microscopic analysis; GOST ISO 10993-5-2011 – Biological evaluation: in vitro cytotoxicity testing (biocompatibility). The following materials were used in the research: Secondary polyethylene terephthalate (PET) (GOST 20282-86), with a density of 1.41 g/cm³, refractive index of 1.575, and a melting point of 250–260 °C; Starch (GOST 53876-2010), with a density of 1.5 g/cm³, refractive index of 1.53, and a melting point of 200 °C.

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III.EXPERIMENT AND ANALYSIS OF RESULTS

Within the scope of this study, biocomposite materials were prepared using polymer waste—specifically, secondary polyethylene terephthalate (PET) and natural starch. Mechanical Testing Results: According to the analysis conducted on the RM-0.5 device, samples with a higher starch content (2.7 g starch – 0.3 g PET) exhibited greater elasticity but lower tensile strength. As the proportion of PET increased, the mechanical strength of the material improved. Notably, the sample with a 1.5 g:1.5 g ratio demonstrated the highest tensile strength and elastic modulus. An optimal composition was identified as the sample with 2.1 g starch and 0.9 g PET, as it exhibited stable elasticity, good resistance to deformation, and relatively high mechanical performance.

According to the experimental results, the composite materials obtained from PET and starch are environmentally safe and based on recycled raw materials, making them suitable for application as reactive coatings on the inner surfaces of biotechnological bioreactors.

The physical and mechanical properties of the composite materials prepared from PET and starch, along with the measurement methods used, are presented in the table below.

Table 1.
Physical and mechanical properties of samples prepared from PET and technical starch

№	**Samples**	PET (g)	Starch (g)	Tensile Strength at Break (%)	Elongation at Break (MPa)	Elastic Modulus (MPa)	Measurement Method (GOST)
1.	№1	9,5	0,5	5	4.1	110	GOST 11262-2017
2.	№2	9,0	1	10	5,6	130	
3.	№3	8,5	1,5	15	5,1	145	
4.	№4	8,0	2,0	20	4,8	158	
5.	№5	7,5	2,5	25	3,9	170	

Table 1.
The tensile strength at break, elongation at break, and elastic modulus values were analyzed to evaluate the mechanical performance of the composite materials.

Name	Maximum Force	Maximum Stress	Maximum Elongation	Maximum Deformation
30%PVX	104.567	10.4567	0.36667	1.11111
30%PVX	180.084	18.0084	0.71670	2.17182
30%PVX	119.122	11.9122	0.64993	1.96950
30%PVX	134.591	13.4591	0.57777	1.75081
30%PVX	139.483	13.9483	0.64515	1.85185
Maximum Value	180.084	18.0084	0.71670	2.17182
Minimum Value	104.567	10.4567	0.36667	1.11111

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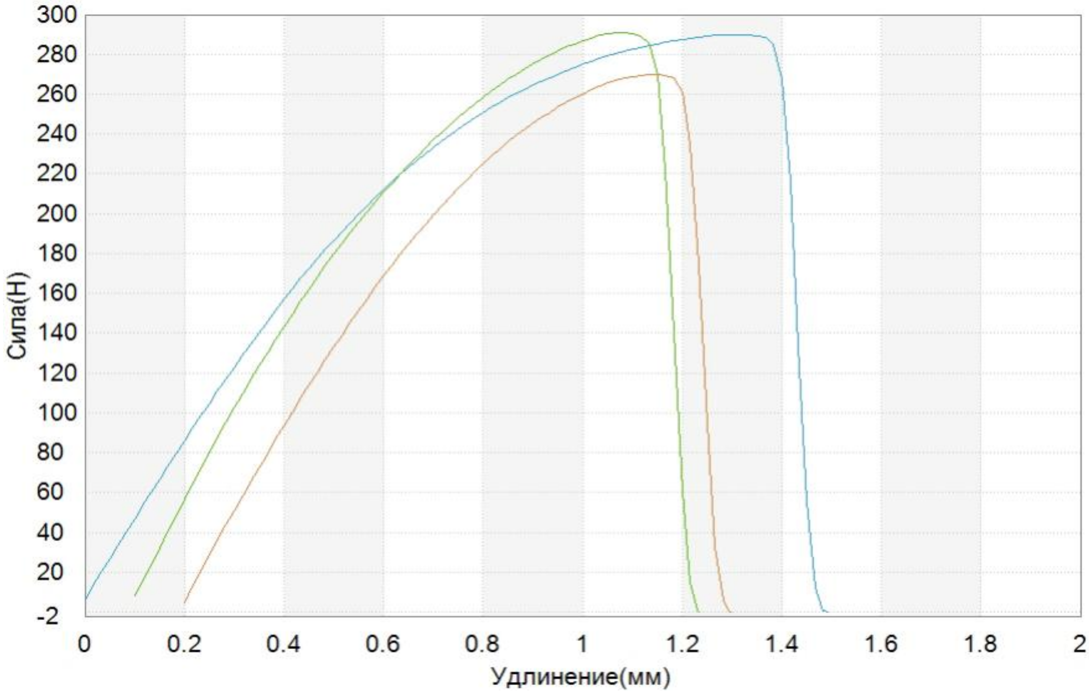

Figure 1. *The tensile strength at break as a function of applied force is shown below.*

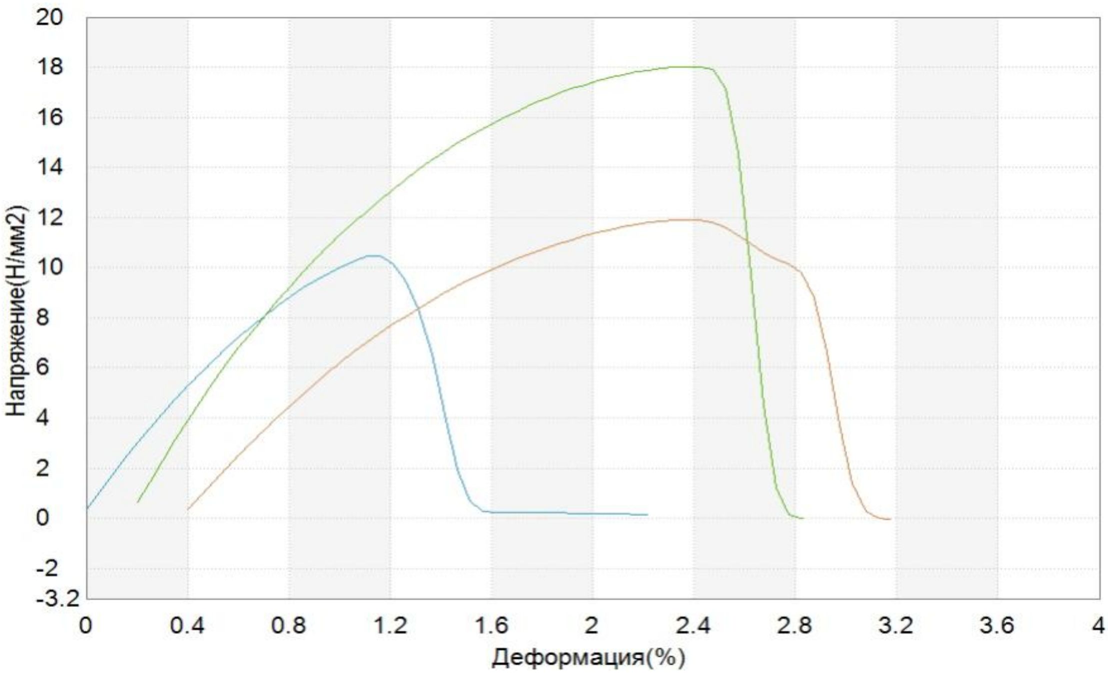

Figure 2. *The following graph illustrates the dependence of deformation on relative elongation.*

IV.CONCLUSION

The analysis showed that as the amount of PET increases, the density and mechanical strength of the composite materials improve; however, this is accompanied by a decrease in elasticity. Conversely, samples with a higher starch content exhibited lighter structure but lower mechanical resistance. Based on the experimental results, the composite with a 90:10 PET to starch ratio (Sample No. 2) demonstrated the most optimal mechanical properties. This sample can be considered suitable for use as an environmentally safe, stable, and bio-coating material in biotechnological systems. Various physical and mechanical characteristics of the prepared composite samples were examined and analyzed using the RM-0.5 device. Sample No. 2 was found to possess optimal parameters, showing the best results in terms of tensile strength at break, deformation limit, and elastic modulus. These findings confirm the existence of a synergistic interaction between PET and starch components. Taking into account the compatibility between surface structure and material density, these composites are recommended for use as bioreactor coatings, eco-friendly containers, or other components in biotechnological systems.

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