UDC 541; 678; 046.3
DOI 10.52171/herald.298

Comparative Analysis of Composites Based on Corresponding Natural Minerals and their Strength

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Abstract

The article provides a comparative analysis of the degree of strength (tensile strength) of composites based on fillers of various compositions. In this direction, research was conducted and results were obtained taking into account a number of filler characteristics. The corresponding fillers were brought from different places and made suitable for laboratory testing. As a result of comparing the ultimate tensile strength values, it was determined which filler is more suitable and superior to others. The fillers are based on natural mineral rocks, clays, etc., brought from several regions of Azerbaijan. The value of the results directly depends on the dispersion of the filler, the relief structure of the area, the mineralogical wealth of the extracted sources and a number of factors.

Keywords: natural mineral rock, clay, filler, tensile strength (σ), elongation at break (ε), melt field strength (MFS).

Submitted *31 October 2024*
Published *22 September 2025*

For citation:
V.J. Jafarov, M.A. Manafov, N.R. Bektashi, N.A. Alimirzaeva,
S.M. Khalilova, S.A. Salahova, G.H. Musaeva
[Comparative Analysis of Composites Based on Corresponding Natural Minerals and their Strength]
Herald of the Azerbaijan Engineering Academy, 2025, vol. 17 (3), pp. 75-81

Müvafiq təbii minerallar əsasında kompozitlər və onların möhkəmlik dərəcəsinin müqayisəli təhlili

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Xülasə

Məqalədə müxtəlif tərkibli doldurucular əsasında alınan kompozitlərin möhkəmlik dərəcəsinin (dartma qüvvəsi) müqayisəli təhlili verilmişdir. Bu yönümdə tədqiqat aparılaraq doldurucunun bir sıra xüsusiyyətləri nəzərə alınaraq nəticələr əldə edilmişdir. Ayrı-ayrı ərazilərdən gətirilərək laboratoriya şəraitində tədqiqata yararlı hala salınaraq müvafiq doldurucular istifadə edilmişdir. Dartılmada möhkəmlik həddinin qiymətlərinin müqayisəsi nəticəsində hansı doldurucunun daha münasib və üstün olduğu müəyyən edilmişdir. Doldurucuların əsasını Azərbaycanın bir sıra regionlarından gətirilmiş təbii mineral süxurlar, gillər və s. təşkil edir. Nəticələrin yüksəkliyi doldurucunun dispersliyi, gətrildiyi ərazinin relyef strukturu, çıxarıldığı mənbələrin mineraloji zənginliyi və bir sıra amillərdən bilavasitə asılıdır.

Açar sözlər: təbii mineral süxur, gil, doldurucu, dartılmada möhkəmlik həddi (σ), qırılma zamanı nisbi uzanma (ε), ərintinin axıcılıq göstəricisi (ƏAG).

Сравнительный анализ композитов на основе соответствующих природных минералов и степени их прочности

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Аннотация

В статье приведен сравнительный анализ степени прочности (предела прочности) композитов на основе наполнителей различного состава. В этом направлении были проведены исследования и получены результаты с учетом ряда характеристик наполнителя. Соответствующие наполнители были привезены из разных мест для исследования в лабораторных условиях. В результате сравнения предельных значений предела прочности на разрыв было определено, какой наполнитель более подходит и превосходит другие. В основе наполнителей лежат природные минеральные породы, глины и т.п., привезенные из нескольких регионов Азербайджана. Показатели напрямую зависят от дисперсности заполнителя, рельефного строения местности, минералогического богатства добываемых источников и ряда факторов.

Ключевые слова: природная минеральная порода, глина, наполнитель, предел прочности при растяжении (σ), относительное удлинение при разрыве (ε), предел текучести расплава (ПТР).

Introduction

One of the priority directions of modern chemical science is the production of new materials with different compositions and properties based on polymers and their additives. In the production of any polymer composite and in the creation of a new material with higher properties, the influence of the nature, structure and properties of the binder added to the initial polymer is considered to be one of the important factors. Thus, the binder taken must have a number of properties, for example; adhesion, adsorption for aqueous solutions, dispersibility, compatibility enhancing, etc.

It is known from a number of literatures that fillers have different sizes, changes due to the influence of the stabilizing medium, surface activity, and hardness in nature. Such additives are diverse and rich in variety in terms of structure and size, distribution on the polymer surface and impact strength.

A number of American scientists have worked on polymers using small-sized clays as fillers as linking agents. Immediately after the adoption of nanotechnology programs in the USA (2000) and other developed countries, scientists moved from studying polymer composites and heterogeneous mixtures to creating various types of devices based on them. Currently, light-emitting diodes, solar cells, memory devices, gas sensors, catalysts and other devices have been developed based on polymer composites and nanoheterogeneous mixtures [1].

Currently, interest in composite materials based on polymer matrices and nanosized metal particles has increased significantly. This is due to the fact that their application spectrum is quite wide - they can be used in various fields, from catalysis to modern information technology, as well as in various fields of chemistry, physics, and materials science.

The development of scientific research on the study of nanoscale metal particles stabilized in polymer matrices has led to the development of metal-polymer composite materials with many specific physical, mechanical and operational properties. Such materials have properties such as high thermal and electrical conductivity, magnetization ability, and shielding of ionizing radiation.

The use of solid particles of various shapes and chemical nature as fillers in polymeric materials opens up new possibilities for the modification of these materials, since small-sized substances are distinguished by their unusual adsorption activity due to their large surface area and high surface energy. Therefore, in composite materials containing small-sized particles, there is a high adhesion strength between the polymer matrix and these particles [2].

There is extensive information from many sources that the introduction of additives into polymer-elastomer systems has a positive effect on the formation of such a structure and the properties. One of the main factors affecting the impact strength and brittleness temperature of a heterophase polymer-elastomer system is its phase structure - the volume fraction of components, the average size of the dispersed phase particles, the size distribution of particles, the nature of their distribution in the mixture and the characteristics of the rubber (molecular mass, strength, elastic modulus, glass transition temperature, etc.). It is shown that the main condition for achieving high viscosity of the dispersion is the homogeneous distribution of the elastomer phase in the form of small dispersed particles in a continuous matrix phase [3, 4].

Metal-containing polymer-sorbents were synthesized as a result of modification of phosphochlorinated polybutadiene with dithizone. The sorption properties of the obtained polymer-sorbents were studied with respect to gold (III) ion in solution. It was found that the degree of sorption of gold in an acidic medium is 85-95% [5].

By functionalizing multi-walled carbon nanotubes (MWNTs) with various functional polymers (copolymers of maleic anhydride with octene-1 and nonene-1 monomers), CdS, CuS and SnS nanostructures were synthesized and studied using modern analysis methods. Different time intervals of ultrasonic treatment were used to obtain samples [6].

A polymer hydrogel with a memory effect was synthesized based on polyacrylic acid and poly-N-vinylpyrrolidone. Silver nanoparticles were synthesized in a poly-N-pyrrolidone medium, and nanocomposites were obtained from its complex with doxorubicin, and their sorption capacity was studied. It was found that the obtained hydrogels have a high sorption capacity. It is shown that using polymers of this type, the therapeutic dose of doxorubicin for experimental treatment of oncological diseases can be significantly reduced [7].

Nanocomposites of nickel, cobalt and misulfide based on polymers were synthesized by ion layering and sonochemistry methods. The optimal conditions for the synthesis of nanocomposites (equilibrium concentration of reagents, temperature, reaction time, pH, etc.) were determined by sorption processes. It was found that the distribution of ions on the surface is a heterogeneous process and both physical and chemical adsorptions occur simultaneously [8].

Considering the effect of small-sized fillers on polymers and the positive properties of the new material obtained, research was conducted using various natural mineral rocks ground to a micron-sized dispersion level as fillers and positive results were obtained.

Selection and use of fillers to obtain a material with strength properties and low cost; Selection and use of plasticizers, dressings and other purposeful components to simplify technological processes and improve operational properties; Adjustment of friction and antifriction properties; Introduction of additional components to adjust thermal and electrical conductivity; Addition of appropriate flame retardants to increase resistance to combustion; Presence of fungicidal, bactericidal and other properties to increase resistance to microorganisms; Possession of antistatic properties, etc. [9].

Problem statement

Scientific research conducted on the development of composites and filling them with additives to improve a number of their properties is sufficient in number, and the successes achieved in this way are undeniable. For many years, the issue of introducing additives into composites and obtaining positive results has been solved in various scientific research laboratories. Fillers are diverse both in terms of structure and properties. There is a sufficient amount of work with existing fillers in solid and liquid form, and the results are many [10]. Polymers processed with fillers, which are modifying agents that play a coordinating role in obtaining composites with complex operational properties of a new generation, are considered suitable materials [11].

Taking all this into account, a comparative analysis of the physical and mechanical properties of composite samples obtained from different areas with different fillers in terms of their dispersion degree and structural characteristics was carried out. At the same time, the issue of the presence of a finish in the system was also taken into account. The comparative analysis helped us to obtain positive results by taking into account the ratio and the unit of measure of the dispersion of the filler taken.

Solution

Laboratory staff crushed various fillers using appropriate methods, sieved and ground them, achieved micron-sized dispersion, and used them to obtain samples for research. The fillers are natural mineral rocks and clays with sizes of 53 and 106 μm, respectively. In order to improve the compatibility between the polymer matrix and the filler and to achieve higher properties of the obtained sample, sizing agents synthesized in laboratory conditions were included in the polymer-filler type system [12].

Results and their discussion

As a result of the research conducted over several years, the values of the tensile strength of composite samples obtained based on fillers of various compositions are reflected in the table 1. We present a list of fillers taken for the study.

Table 1 – Strength index of composite samples with different fillers

Row	Filler, in %	Matrix, in %	Apprete, in %	Tensile strength, %, σ, MP
1.	Vezuviane-80	PE-20	-	37.4
2.	Bokside-60	PE-40	-	12.8
3.	Kaoline-60	PE-40	(MA+ED-20)-5	15.3
4.	Goydash-60	PE-40	(MA+Hep.1+Acr.ac.)-1/2/1	14.1
5.	Seolite-60	PE-40	(MA+Hep.1+Acr.ac.)-1/1/1	17.8
6.	Alunite-60	PE-40	-	15.3
7.	Silisium gelium-70	PE-30	K salt -3	19
8.	Perlite-70	PE-30	-	15.1
9.	Gadabay dep. clay-70	PE-30	(Hep.1+Acr.ac.)-2/1	16.9
10.	Zakhmatkand-70	PE-30	(Hep.1+Acr.ac.)-1/2	15.4
11.	Keramsite-70	PE-30	-	14.9
12.	Artesian clay-70	PE-30	(MA+Hex.1)-3	15.9
13.	Volcanic mud -70	PE-30	(Hep.1+Acr.ac.)-2/1	13.7
14.	Tursh Su-60	PE-40	(Hek.1+Acr.ac.)-2/1	17.2

Table 2 – Results of research conducted with polyethylene processing

Row	Filler, in %	Matrix, in %	Apprete, in %	Tensile strength, %, σ, MP
1.	Dashkesan ore -70	PPE-30	(Hex.1+Acr.ac.)-2/1	16.7
2.	Bentonite-60	PPE-40	(MA+Hep.1)-1/1	15.8
3.	α-kvars-70	PPE-30	-	31
4.	Tovus clay -60	PPE-40	Polimetakrylate-3	18.8

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Table 3 – Results of research conducted with polypropylene (without apprete)

Row	Filler, in %	Matrix, in %	Tensile strength, %, σ, MP
1.	Mining waste -40	PP-60	33.6
2.	Gisil Zod-30	PP-70	30.6
3.	Damirchi Dam-50	PP-50	32.3
4.	Vulcanic ash -30	PP-70	38

A ranking is presented according to the variety of fillers taken depending on the type of each polymer matrix. Thus, separate presentations are given for polyethylene, processed polyethylene and polypropylene. The aim is to determine which is the most complete result.

The tables 1-3 show the strength of polymer composite samples treated with various fillers corresponding to 53 and 106 μm. The higher tensile strength of the sample treated with each filler was taken. An analysis is presented in accordance with the principle of obtaining a higher result in samples corresponding to which mass ratio in polymer/filler and polymer/filler/size systems corresponding to different mass ratios.

High-pressure polyethylene (HPPE) or low-density polyethylene (ASPE), its derivatives and polypropylene (PP) were taken as the matrix. Separate copolymers synthesized in laboratory conditions were taken as the size. Obtaining samples with higher tensile strength depends on the dispersity, environment, nature, and degree of compatibility with the polymer of each filler taken.

When looking at the tables 1-3, it is determined that the maximum strength is σ=38 MPa in the sample without filler, corresponding to the ratio of volcanic ash-30 and matrix-70 mass%. In this case, polypropylene is present in the system as a matrix. This result is explained not only by the properties of the filler but also by the high degree of crystallinity of polypropylene. Polypropylene differs from other polyolefins due to its high degree of crystallinity and its more appropriate stereoregular structure. Of the composites obtained using processed polyethylene as a matrix, the one with the most superior physical and mechanical properties is the composite obtained based on Tovuz clay as a filler and polymethacrylate as a filler. In this case, the tensile strength is 18.8 MPa.

When looking at other indicators, it is observed that the tensile strength limit of the composite sample based on 80 mass % vesuvian and 20 mass % polyethylene taken as filler has a higher σ=37.4 MPa. Based on this result, it can be said that the nature and compatibility of the filler is superior to other binders.

In addition, with a number of fillers, for example: “Mining Waste”, “Gyzil Zod”, “Demirchi Dam”, “Tovuz Gili”, “Tursh Su” the result (strength limit) gets higher values.

Thus, when giving a final opinion on the results, it is observed that the polymer matrix in composites with high tensile strength limit is polypropylene.

Conclusion

As a result of the analytical study, a comparative presentation of the strength of composites created over the years based on various fillers and finishes is given. The highest result obtained with each filler is taken. It was determined that the value of the tensile strength limit is the highest in the composite sample corresponding to the PP/Volcanic ash-70/30 mass % ratio (σ=38 MPa). It was determined that the maximum value of the tensile strength limit corresponds to the case where polypropylene is used as the polymer matrix, directly depends on various properties of polypropylene, such as its stereoregular structure, crystallinity, melting and solidification temperature. In a number of studies, although the physical and mechanical properties increase with the introduction of a finish into the system, the regularity is relatively violated when polypropylene plays the role of a matrix.

When composites are obtained using polyethylene as a matrix, the maximum physical and mechanical performance corresponds to the sample in which the filler is taken in the amount of 60% by mass. In this case, when IPE/Filler-40/60%, the tensile strength reaches a maximum value of 18.8 MPa. The desired results were obtained in the research-based scientific research work and the work was fully evaluated.

Conflict of Interests

The authors declare there is no conflicts of interests related to the publication of this article.

REFERENCES

1. **Michaylin Y.A.** Polymernıe nanokompositionnıe materialı, Polymernıe materialı, Moskva, 2009, №7, s.10-13.
2. **Əlimirzəyeva N.Ə.** İzotaktik polipropilen və metaltərkibli nanodoldurucular əsasında termoplastik elastomer kompozitlərin alınması və tədqiqi, Kimya üzrə fəlsəfə doktorluğu dissertasiyası, 2021, Sumqayıt, s. 24-24.
3. **Jayraman K., Kolli V.G., Kang S.Y. [et al.]** Shear flow behavior and oil distribution between phases in TPV, J. Appl. Polym. Sci., New York, 2004. Vol. 93, pp.113-121.
4. **Karger-Kocsis J., Shonaiko G.O., Simon G.P.** Polymer Blends and Alloys, Ed. by New York, Marcel Dekker, 1999, pp.125-140.
5. **Yaqubova Ü.İ.** Divinil sintetik kauçuku əsasında sorbentlərin alınması və onların Au^3 sorbsiya xassələrinin tədqiqi, kimya üzrə fəlsəfə doktoru diss. avtoreferatı, Sumqayıt, 2016, s. 20.
6. **Məlikov E.Y.** Malein anhidridi birgə polimerləri və polivinil spirti ilə karbon nanoboruların funksionallaşdırılması və alınan nanoquruluşların tədqiqi, kimya üzrə fəlsəfə doktoru dis. avtoreferatı, Sumqayıt, 2016, s. 25.
7. **Məmmədova S.M.** Doksorubisinin immobilizə olunması üçün polimer gellərin sintezi və tədqiqi, kimya üzrə fəlsəfə doktoru dis. avtoreferatı, Sumqayıt, 2017, s. 25.
8. **Balayeva O.O.** Polimer matrisdə nikel, kobalt, mis sulfidləri əsasında nanokompozitlərin sintezi və onların modifikasiyası. Kimya üzrə fəlsəfə doktoru diss. avtoreferatı, Bakı, 2017, 25s.
9. **Alxanov P.Ş., Bektaşi S.A., Musayeva G.H., Mənəfov M.Ə., Rəcəbova M.C., Xəlilova S.M., Cəfərov V.C.** Poliakrilatın polietilen kompozisiyalarının xassələrinə təsiri, Azərbaycan Mühəndislik Akademiyasının Xəbərləri, Bakı, 2021, cild 13, №4, s. 86-99.
10. **Cəfərov V.C., Alxanov P.Ş., Mənəfov M.Ə., Bektaşi S.A., Xəlilova S.M., Musayeva G.H.** İonomer quruluşlu appretin polimer kompozisiyalarda rolu. Azərbaycan Mühəndislik Akademiyasının Xəbərləri, Bakı, 2024, cild 16, №1, s. 95-100.
11. **Alimirzayeva N.A.** The effect of metal-containing nanoparticles on the thermo-oxidative properties of thermoplastics elastomers based on isotactic polypropylene and ethylene propylene diene rubber, New Materials, Compounds and Applications, 2022, Vol.6, No.3, pp. 220-229.
12. **Jafarov V.J., Alimirzayeva N.A., Musaeva G.H., Manafov M.A., Khalilova S.M., Rajabova M.J.** Production og new generation composite materials based on high-density polyethylene and “Artesian Clay” and the effect of appret, Sumqayıt Dövlət Universiteti: “Elmi Xəbərlər”. Təbiət və texniki elmlər bölməsi, 2024, cild 24, №3, s. 31-36.