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COMPLEX MODIFICATION OF POLYPROPYLENE YARN WITH ELASTOMERS AND CALCIUM CARBONATE

This article presents the results of a study aimed at enhancing the overall performance characteristics of polypropylene (PP) yarns through a method of complex modification, with the goal of significantly improving their key functional properties. Thermoplastic elastomers (TPEs) and a mineral filler – calcium carbonate ($CaCO_3$) – were used as modifying agents. The main objective of the work is to improve critically important mechanical properties such as impact strength and elongation at break, as well as to increase the thermal stability of the material, while a key requirement is maintaining control over and optimizing the cost of the final composite.

In the experimental part of the study, various PP composite formulations with varying contents of TPE and $CaCO_3$ were developed and prepared by extrusion. The resulting samples were subjected to comprehensive testing of their physical and mechanical properties in accordance with international standards.

The test results clearly demonstrate that the introduction of thermoplastic elastomers into polypropylene compositions leads to a significant increase in their plasticity and impact strength. The simultaneous addition of calcium carbonate effectively contributes to an increase in the stiffness (modulus of elasticity) of the composite and a noticeable reduction in shrinkage. Particular attention in the study is given to analyzing the synergistic effect that arises from the combined use of elastomers and mineral filler.

Keywords: polypropylene, thermoplastic elastomers, calcium carbonate, mechanical properties, modification, composites.

Introduction

Polypropylene (PP) is widely used in the production of technical yarns and textile materials due to its properties such as low density, thermal resistance, chemical inertness, and ease of processing [1]. However, its brittleness and limited impact strength restrict its application under high loads and low temperatures [2].

Modern methods of PP modification include the use of thermoplastic elastomers (TPEs), such as ethylene-propylene copolymers (EPR, EPDM), as well as styrene block copolymers like SEBS. These materials improve flexibility and impact strength but increase the product cost [3]; [4]; [5].

Another approach involves the addition of mineral fillers, such as calcium carbonate ($CaCO_3$), which reduces cost and increases stiffness, but may decrease impact strength and elongation at break [3]; [6]; [7].

The aim of this study is to assess the synergistic effect of the combined use of elastomers and calcium carbonate to improve the mechanical properties and reduce the production cost of polypropylene yarns [8].

Materials and Methods

The base polymer used was a homopolymer polypropylene grade RPN 030 produced by «Kompaniya Neftekhim LTD» LLP, Republic of Kazakhstan, with a melt flow index (MFI) of 12 g/10 min at 230 °C and a 2.16 kg load, melting point around 165 °C, and density of 0.905 g/cm^3.

As a modifier, the thermoplastic elastomer Engage™ 8180 by Dow was used. It is an ethylene-propylene rubber containing 10 % ethylene and has an MFI of 5 g/10 min [9]. The mineral filler used was precipitated calcium carbonate Kapol $CaCO_3$-25, modified with stearic acid and with a median particle size of 2–3 μm [10].

Compositions with various component contents were obtained via two-stage extrusion: in the first stage, compounding was carried out on a twin-screw extruder with L/D = 40 and a temperature profile of 190–230 °C. In the second stage, a single-screw extruder was used to form a tape yarn 3 mm wide, with a linear density of 850 denier.

Sample testing was conducted as follows: tensile strength and elongation at break were measured on a Zwick/Roell BasicLine Z005 universal tensile machine at a stretching speed of 250 mm/min in accordance with ISO 2062–2014. Shrinkage was measured in a Testrite LTD MK 3 heat shrinkage oven with automatic deformation measurement at 130 °C for 2 minutes.

Results and Discussion

Table 1 presents the main mechanical properties and shrinkage of the polypropylene tape yarns with various contents of Engage™ 8180 elastomer and Kapol $CaCO_3$-25 calcium carbonate.

Table 1 – Effect of composition on properties of PP compositions

№	Composition (wt. %)	Breaking load, MPa	Strength, g/den	Elongation, %	Impact strength, kJ/m²	Shrinkage, %
1	PP 100	360	4,66	15	4,8	2,1
2	PP 90 + EPR 10	320	4,14	45	9,0	1,7
3	PP 80 + EPR 10 + $CaCO_3$ 10	300	3,88	40	9,5	1,5
4	PP 70 + EPR 10 + $CaCO_3$ 20	280	3,62	35	10,0	1,3
5	PP 70 + $CaCO_3$ 30	260	3,36	12	5,2	1,8

Pure homopolymer polypropylene (PP 100 %) shows the highest tensile strength – 360 MPa, but has relatively low elongation (15 %) and impact strength (4.8 kJ/m²), which is typical for PP with its rigid and brittle structure.

The addition of 10 % EPR thermoplastic elastomer decreases tensile strength by approximately 11 % (to 320 MPa), but significantly increases elongation nearly threefold (to 45 %) and nearly doubles the impact strength (to 9.0 kJ/m²). This indicates a substantial improvement in plasticity and impact resistance due to the elastomer acting as a shock-absorbing phase.

With the addition of 10% $CaCO_3$ to the composition containing 10 % elastomer (PP 80 + EPR 10 + $CaCO_3$ 10 %), there is a slight decrease in strength (to 300 MPa) and elongation (to 40 %), but the impact strength increases to 9.5 kJ/m². This is attributed to improved load distribution via the rigid filler and the effect of the surface-modified $CaCO_3$ particles.

Further increasing $CaCO_3$ content to 20 % with a constant 10 % elastomer (PP 70 + EPR 10 + $CaCO_3$ 20 %) reduces strength to 280 MPa and elongation to 35 %. However, the impact strength reaches a maximum of 10.0 kJ/m², indicating a synergistic effect of combining the elastomer and filler in enhancing impact resistance. This may result from restricted polymer chain mobility due to the filler and improved heterogeneous structure of the composition.

The formulation with 30 % $CaCO_3$ and no elastomer (PP 70 + $CaCO_3$ 30 %) shows the greatest reduction in strength (260 MPa) and low elongation (12 %), similar to pure PP. The impact strength increases only to 5.2 kJ/m², indicating a more brittle structure at high filler content without a flexible phase.

The effect of calcium carbonate and elastomer content on tensile strength, impact strength, and shrinkage of polypropylene yarns is shown in Figure 1.

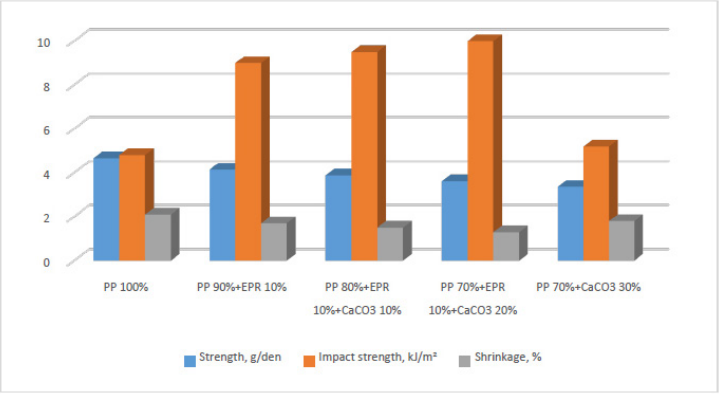

Figure 1 – Effect of composition on the properties of PP yarns

Shrinkage decreased with increasing elastomer and $CaCO_3$ content. Pure PP had a shrinkage of 2.1 %, while compositions with 10 % elastomer and 10–20 % $CaCO_3$ showed shrinkage in the range of 1.3–1.7 %. The reduction in shrinkage is associated with restricted compression and relaxation of polymer molecules due to the presence of the elastomer and rigid filler, as well as more efficient load distribution within the material. This effect contributes to improved dimensional stability of the tape yarn during heat treatment and use.

The study demonstrated that the combined use of thermoplastic elastomer Engage™ 8180 and Kapol calcium carbonate in the production of polypropylene yarns significantly affects the key performance characteristics of the material.

The addition of 10 % EPR elastomer substantially improved yarn plasticity and impact resistance – elongation at break increased more than threefold, and impact strength nearly doubled, indicating improved resistance to dynamic and impact loads. Despite some reduction in tensile strength, the values remained high enough for most technical applications. The addition of 10–20 % $CaCO_3$ further enhanced impact performance.

A reduction in shrinkage to values below 1.5–1.7 % when combining elastomer and filler indicates increased thermal stability and reduced internal stresses in the material, improving the quality and reliability of the final yarns. These indicators are critical for applications requiring high dimensional accuracy and resistance to deformation during heating.

Conclusions

The results indicate that combining elastomers and mineral fillers is an effective approach to improving the performance properties of polypropylene. This opens up possibilities for the development of new compositions with enhanced characteristics tailored to the needs of modern markets and industries such as packaging, textile production, and technical fibers.

Further research is advisable to study the effects of other types of elastomers and filler modifications, as well as the long-term stability and wear resistance of the resulting compositions under real operating conditions.

References

1 **Karger-Kocsis, J., Bárány, T., Czigany, T.** Application of the essential work of fracture (EWF) concept of polymers, related blends and composites: A review // Progress in Polymer Science. – 2010. – № 35(10). – Pp. 1257-1287. – [Electronic resource]. – URL: https://doi.org/10.1016/j.progpolymsci.2010.07.001.

2 **Carraher, C. E.** Introduction to polymer chemistry. Fourth edition / C. E. Carraher Jr. – Boca Raton : CRC Press, 2017. – 536 p. – [Electronic resource]. – URL: https://api.pageplace.de/preview/DT0400.9781498737852_A29110298/preview-9781498737852_A29110298.pdf.

3 **Al-Salem, S. M., Lettieri, P., Baeyens, J.** Recycling and recovery routes of plastic solid waste (PSW): A review // Waste Management. – 2010. – № 29(10). – P. 2625–2643. – [Electronic resource]. – URL: https://doi.org/10.1016/j.wasman.2009.06.004.

4 **Gong, G., Xie, B.-H., Yang, W., Li, Z.-M., Lai, S.-M., Yang, M.-B.** Plastic deformation behavior of polypropylene/calcium carbonate composites with and without maleic anhydride grafted polypropylene incorporated using the essential work of fracture method // Polymer Testing. – 2006. – № 25(5). – P. 791–798. – [Electronic resourse]. – URL: https://doi.org/10.1016/j.polymertesting.2005.09.010.

5 **Wu, C.-L., Zhang, M.-Q., Rong, M.-Z., Friedrich, K**. Tensile performance improvement of low nanoparticles filled-polypropylene composites // Composites Science and Technology. – 2002. – Vol. 62. – № 10–11. – P. 1327–1340. – [Electronic resource]. – URL: https://doi.org/10.1016/S0266-3538(02)00079-9.

6 **Chan, C.-M., Wu, J., Li, J.-X., Cheung, Y.-K.** Polypropylene/calcium carbonate nanocomposites // Polymer. – 2002. –№43(10). – P. 2981–2992. – [Electronic resourse]. – URL: https://doi.org/10.1016/S0032-3861(02)00120-9.

7 **Yang, X., Feng, J.** Improving mechanical performance of immiscible polypropylene/poly(methyl methacrylate) blends by adding calcium carbonate nanoparticles with bifunctions of compatibilization and βnucleation // Composites Part A: Applied Science and Manufacturing. – 2024. – Vol. 158. – Article 108640. – [Electronic resource]. – URL: https://doi.org/10.1016/j.compositesa.2024.108640.

8 **Ma, C.-G., Mai, Y.-L., Rong, M.-Z., Ruan, W.-H., Zhang, M.-Q.** Phase structure and mechanical properties of ternary polypropylene/elastomer/nanoCaCO₃ composites // Composites Science and Technology. – 2007. – Vol. 67, № 14. – C. 2997–3005. – [Electronic resource]. – URL: https://doi.org/10.1016/j.compscitech.2007.05.022.

9 Dow Chemical Company. Engage™ Polyolefin Elastomers Technical Data Sheet, 2023. – [Electronic resource]. – URL: https://www.dow.com/en-us/search.html#t=All&sort=relevancy&f:@dow_market_hierarchy=[Chemical%20Manufacturing%20and%20Industrial,Plastic%20Compounding] (Date of access 18.04.2025).

10 **Cao, Z., Daly, M., Clémence, L., Geever, L. M., Major, I., Higginbotham, C. L., Devine, D. M.** Chemical surface modification of calcium carbonate particles with stearic acid using different treating methods // Applied Surface Science. – 2016. – Vol. 378. – Pp. 320–329. – [Electronic resource]. – URL: https://doi.org/10.1016/j.apsusc.2016.03.205.

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ПОЛИПРОПИЛЕН ЖІБІН ЭЛАСТОМЕР МЕН КАЛЬЦИЙ КАРБОНАТЫМЕН КЕШЕНДІ ТҮРЛЕНДІРУ

Бұл мақалада полипропилен (ПП) жіптерінің негізгі пайдалану сипаттамаларын айтарлықтай жақсартуға бағытталған кешенді модификациялау әдісі арқылы олардың жұмыс сипаттамалары кешенін арттыруға арналған зерттеу нәтижелері келтірілген. Модификациялаушы агенттер ретінде термопластикалық эластомерлер (ТПЭ) және минералды толтырғыш – кальций карбонаты ($CaCO_3$) қолданылды. Жұмыстың негізгі мақсаты – соққыға төзімділік пен үзілу кезіндегі ұзару сияқты маңызды механикалық қасиеттерді жақсарту және материалдың термиялық тұрақтылығын арттыру, сонымен қатар соңғы композицияның өзіндік құнын бақылау мен оңтайландыру негізгі шарт ретінде қарастырылады.

Зерттеудің эксперименттік бөлімінде әртүрлі мөлшердегі ТПЭ мен $CaCO_3$ қосылған ПП-композициялар әзірленіп, экструзия әдісімен дайындалды. Алынған үлгілердің физика-механикалық қасиеттері халықаралық стандарттарға сәйкес жан-жақты сынақтардан өткізілді.

Сынақ нәтижелері термопластикалық эластомерлерді полипропилен құрамына енгізу оның иілгіштігі мен соққыға төзімділігін едәуір арттыратынын нақты көрсетті. Сонымен қатар кальций карбонатын қосу композицияның қаттылығын (серпімділік модулін) арттыруға және шөгуді айтарлықтай азайтуға тиімді әсер ететіні анықталды. Жұмыста эластомерлер мен минералды толтырғышты бір мезгілде қолдану нәтижесінде пайда болатын синергетикалық әсерге ерекше назар аударылды.

Кілтті сөздер: полипропилен, термопластикалық эластомерлер, кальций карбонаты, механикалық қасиеттер, модификация, композициялар.

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КОМПЛЕКСНАЯ МОДИФИКАЦИЯ ПОЛИПРОПИЛЕНОВОЙ НИТИ ЭЛАСТОМЕРАМИ И КАРБОНАТОМ КАЛЬЦИЯ

Данная статья представляет результаты исследования, направленного на повышение комплекса эксплуатационных характеристик полипропиленовых (ПП) нитей методом комплексной модификации с целью существенного улучшения их ключевых эксплуатационных характеристик. В качестве модифицирующих агентов использованы термопластичные эластомеры (ТПЭ) и минеральный наполнитель – карбонат кальция ($CaCO_3$). Основная цель работы – улучшение критически важных механических свойств, таких как ударная вязкость и удлинение при разрыве, а также повышение термостабильности материала, при этом ключевым условием является контроль и оптимизация себестоимости конечного композита.

В экспериментальной части исследования были разработаны и приготовлены методом экструзии различные составы ПП-композитов с варьируемым содержанием ТПЭ и $CaCO_3$. Полученные образцы подверглись всесторонним испытаниям их физико-механических свойств в соответствии с международными стандартами.

Результаты проведенных испытаний четко демонстрируют, что введение термопластичных эластомеров в состав полипропилена приводит к значительному повышению его пластичности и ударной прочности. Одновременное добавление карбоната кальция эффективно способствует увеличению жесткости (модуля упругости) композита и заметному снижению величины усадки. Особое внимание в работе уделено анализу синергетического эффекта, возникающего при совместном использовании эластомеров и минерального наполнителя.

Ключевые слова: полипропилен, термопластичные эластомеры, карбонат кальция, механические свойства, модификация, композиты.

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