Article

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# Study of the Properties of Ethylene-Propylene Copolymers and Polymers with Functional Groups of a Mixture

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*Article*

# Study of Binary Systems Based on Butadiene-Terephthalate Rubber and Astragalus and İts Rheological Properties

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**Abstract:** In this work, the influence of astragalus as a nano-sized reinforcing material on the kinetics of vulcanization, crosslinking density, and mechanical properties of Butadiene terephthalate rubber (BTFR) was investigated. With this purpose, compositions were prepared for the properties of Butadiene terephthalate rubber (BTFR) with different content of Astragalus at 1, 3, and 5 mass fractions. Their results were compared with the reference compound without nanoparticles. The presence of Astragalus and its distribution in the BTFR matrix was confirmed by determining the melt flow indicators of the binary system. I have studied the effect of Astragalus modification on the main properties of Polybutylene terephthalate. This work has been carried out on purchasing BTFR-based rubber for cables, which is chemically resistant to aggressive environments, more perfect, and can fully satisfy the operational properties, can be applied in our saline areas, suitable for use as a coating. To choose the vulcanization mode for the rubber mixture, the optimum and plateau vulcanization of the process was determined, and it was determined that the beginning of vulcanization starts at 117 $^{o}$C oC and completes at 150-155 $^{o}$C. The main indicators of the received regime were determined by physical-mechanical methods and compared with standard rubbers

**Keywords:** Astragalus; Butadiene terephthalate rubber; modification; vulcanization; rheology

## Introduction

Preparation of BTFR-based nanocomposites

Several authors [1–4] used laboratory rubber mixers as the research methodology [5–8] to prepare nanocomposites. First, BTFR BSK was plasticized in Banbury for 2 minutes to obtain rubber nanocomposites. In this work, a mill was used, which is used to obtain nanoparticles Then, the nanofiller selected in 1, 3, or 5 parts per hour was added to the plasticized BTFR and mixed in the same mixer for 1 minute. This compound was mixed with ZnO as an activator and SC as a lubricant for 0.5 minutes. Then, the stabilizers (TMQ, IPPD, and ozone wax) were combined for another 0.5 minutes [9–14] The rubber nanocomposites were kept in an oven with air circulation for 70 hours at a temperature of 70 ° C to study the effect of thermal aging [14–18].

Modification of Butadiene terephthalate rubber with functional groups [19–25].

Manufacturers of general-purpose synthetic rubbers have devoted considerable effort to equipping such rubbers with chemically functional groups along the polymer backbone. The goals have ranged from improving green strength and tack to creating sites for new forms of crosslinking, grafting, antioxidant activity, and even pharmacological properties. The usual route to such functionalisms is to incorporate small amounts of the monomer carrying the desired group during polymerization. However, polymerization with different functional groups would be expensive, so only a cheap reagent must be used to macro modify elastomers with entirely new physical properties. If we use these polymers outdoors, then the rubber needs to be protected from sunlight, and most types of these polymers have flammable properties [5], although additives can reduce both the modification and the flammability properties [26–30]. used for casings in construction, as connectors

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in automotive manufacturing, and household applications, such as shower heads or irons. It is also found incorporated into toothbrush fibers and false eyelashes and is used in the keycaps of some high-end computer keyboards [31–36].

Yarn can also be made from PBT. It has a similar natural elongation and can be incorporated into sportswear, meaning that PBT is at the forefront of materials used in the production of swimwear in chlorinated waters. In addition, recent studies have shown that BTFR [37–42] is more durable than PET-based fabrics. had superior characteristics [42–48].

**Method**

For the modification of the Butadiene terephthalate rubber, we used astragalus for the first time. It looks like this:

The astragalus grown in the Nakhchivan region of the Republic of Azerbaijan was collected from the seeds collected from the upper and middle mountainous areas, mainly around the villages of Kalaki and Dirnis.

Astragalus (in Azerbaijan it is called Gavan) is a perennial herb 15-35 cm high, stem 4-20 cm long, elongated and erect or erect, reddish. Except for the inner side of the crown, all parts of the plant are covered with whitish or yellowish hairs. The color of the stems is brown-gray, the leaves are gray-green, and the flowers are yellow. It is a deciduous shrub, 20 cm high, with dense branches forming a cushion, prickly leaves, all parts covered with thin, weak hairs. The leaves are 8–12 mm long, feather-shaped, contiguous to half of the stem, linear-lanceolate. The leaves are 6-9 pairs, elliptic or oblong-ovate, 10 mm long, with sharp tips. It is bare above, sparsely or densely hairy below. The flowers form 2-3 short clusters in the axils of the leaves. Inflorescences are flat sepal-shaped and up to 13 mm long. The calyx is 10–16 mm long, tubular, thick, short, white hairy. The teeth are serrated and greenish. Its crown is up to 13 mm long. The sail is 7-8 mm wide and oblong-elliptical. The boat is shorter than the wing. Females are elongated, downy hairy, up to 16 mm long, and the stem is bare columnar. Beans are sessile, oblong, sharp, silky white hairy, single-celled, manyseeded. It blooms in June-**July.**

When the composition of Astragalus used in the research is analyzed, its chemical composition is Selenium 1.5mg%. There are macro and microelements (calcium, silicon, aluminum, iron, magnesium, cobalt, zinc, copper, manganese, molybdenum, chromium).

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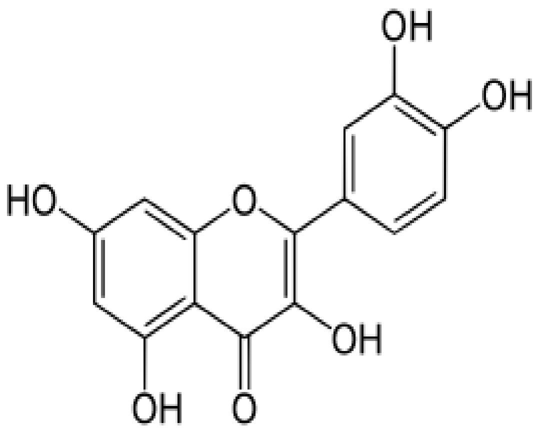


**Results and Discussions Results of Experımental Research**

*Study of Rheological Properties*

: The volume consumption of the mixture and the dependences of the displacement rates of the binary mixtures on the stress (logo) was carried out in the ITER-4 device at temperatures of 100ºC, 130ºC, 150ºC, and 170ºC

: 100°C, 130°C, 150°C and 170°C studies were conducted to determine the flow index of the alloy of the obtained composition, and the results were calculated as follows

1 Cargo

$P1=\frac{11.75}{0.7144}=16.44$ kg sec$^2$

$P2=\frac{20.85}{0.7144}=29.18$

$P3=\frac{27.75}{0.7144}38.84$

$P4=\frac{35.75}{0,7144}=49.34$

$\tau = \frac{P\ \delta}{\pi}=\frac{P\ 0.05}{2.08}=\frac{P\ 0.05}{1.6}$

$\tau 1= \frac{16.44\ 0.05}{1.6}=0.5137*9.80610^4=5.037342\ 10^4 \log 4.70Pa$

$\tau 2=\frac{29.18\ 0.05}{1.6}=0.9118*9.806*10^4=8.9411108\ 10^4 \log 4.95Pa$

$\tau 3=\frac{38.84\ 0.005}{1.6}=1.2137*9.806*10^4=11.901542*10^4 \log 5.08Pa$

$\tau 4=\frac{49.34\ 0.05}{1.6}=1.5418*9.806*10^4=15.11889*10^4 \log 5.18Pa$

$Q=\frac{s}{t}\ \frac{\pi p3}{4}=\frac{0.02}{t}\ \frac{3.14(0.954)2}{4}=\frac{0.014288}{t}$

100°

1 Cargo

$Q1=\frac{0.014288}{118.67}=0.000120\ 0.1210$

$Q2=\frac{0.014288}{71.55}=0.000019969\ 0.19$

2 Cargo

$Q1=\frac{0.014288}{36.85}=0.00038773\ 0.387$

$Q2=\frac{0.014288}{19.67}=0.00072638\ 0.7263$

3 Cargo

$Q1=\frac{0.014288}{18.26}=0.00078247\ 0.7824$

$Q2=\frac{0.014288}{11.34}=0.0001259964\ 1.259$

4 Cargo

$Q1=\frac{0.014288}{12.45}0.00114763\ 1.1476$

$Q2=\frac{0.014288}{8.04}=0.00177711\ 1.772$

130°C

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1 Cargo

Q1=$\frac{0.014288}{60.27}$=0.0000237066 0.237

Q2=$\frac{0.014288}{26.2}$=0.000545345 0.545

2 Cargo

Q1=$\frac{0.014288}{18.34}$=0.000077906 0.779

Q2=$\frac{0.014288}{8.19}$=0.00174456 1.744

3 Cargo

Q1=$\frac{0.014288}{10.29}$=0.00138853 1.3885

Q2=$\frac{0.14288}{4.73}$=0.003020718 3.0207

4 Cargo Q1=$\frac{0.014288}{6.31}$=0.00226434 2.264

Q2=$\frac{0.014288}{3.15}$=0.00453587 4.5358

150°C

1 Cargo

Q1=$\frac{0.014288}{26.48}$ =0.00053957 0.5395

Q2=$\frac{0.014288}{14.83}$=0.00096345 0.9634

2 Cargo

Q1=$\frac{0.14288}{7.27}$=0.00196534 1.965

Q2=$\frac{0.014288}{4.89}$=0.00292188 2.9218

3 Cargo

Q1=$\frac{0.014288}{3.99}$=0.00358095 3.5809

Q2=$\frac{0.014288}{2.43}$=0.00587983 5.8798

4 Cargo

Q1=$\frac{0.014288}{2.92}$=0.00509589 5.095

Q2=$\frac{0.014288}{156}$=0.00915897 9.158

170°C

1 Cargo

Q1=$\frac{0.014288}{15.46}$=0.00092419 0.924

Q2=$\frac{0.014288}{8.48}$=0.000168491 1.6849

2 Cargo

Q1=$\frac{0.014288}{4.71}$0.00303354 3.0335

Q2$\frac{0.014288}{2.33}$=0.00613218 6.1321

3 Cargo

Q1=$\frac{0.014288}{2.79}$=0.00512115 5.12115

Q2=$\frac{0.014288}{1.42}$=0.0100619 10.0619

4 Cargo

Q1=$\frac{0.014288}{2.0}$=0.007144 7.114

Q22=$\frac{0.014288}{0.79}$=0.0180861 18.0861

The dependences of displacement rates of binary mixtures on stress (logo) were performed at temperatures of 100ºC, 130ºC, 150ºC and 170ºC:

100º C

$\gamma = \frac{Q}{\pi\delta 3} = \frac{Q}{0.0003925}$

1

$\gamma = \frac{0.000120}{0.0003925}$=0.30573248$^{\log\text{-}0.5146}$

$\gamma 2$=$\frac{0.00019969}{0.0003925}$=0.5087643$^{-0.2935}$

2

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$\gamma 1=\frac{0.00038773}{0.0003925}=0.98784713^{-0.00531}$
$\gamma 2=\frac{0.00072638}{0.0003925}=1.85064968^{0.2673}$
3
$\gamma 1=\frac{0.00078247}{0.0003925}=1.9935541^{0.2996}$
$\gamma 2=\frac{0.001259964}{0.0003925}=.3.21009936^{0.5065}$
4
$\gamma 1=\frac{0.00114763}{0.0003925}=2.9238981^{0.4659}$
$\gamma 2=\frac{0.00177711}{0.0003925}=4.52766^{0.6559}$
130°C
1
$\gamma 1= \frac{0.000237066}{0.0003925}=0.6039898^{0.2189}$
$\gamma 2=\frac{0.000545345}{0.0003925}=1.389414^{0.1428}$
2
$\gamma 1=\frac{0.00077906}{0.0003925}=1.9848662^{0.2977}$
$\gamma 2=\frac{0.00174456}{0.0003925}=4.444738^{0.6478}$
3
$\gamma 1=\frac{0.00138853}{0.0003925}=3.537656^{0.54878}$
$\gamma 2=\frac{0.003020718}{0.0003925}7.690968^{0.8863}$
4
$\gamma 1=\frac{0.00226434}{0.0003925}=5.7690191^{0.7611}$
$\gamma 2=\frac{0.00453587}{0.0003925}=11.55356^{1.0628}$
150°C
1
$\gamma 1=\frac{0.00053957}{0.000325}=1.3747006^{0.1382}$
$\gamma 2=\frac{0.00096345}{0.0003925}=2.454649^{0.3899}$
2
$\gamma 1=\frac{0.00196534}{0.0003925}=5.007236^{0.6996}$
$\gamma 2=\frac{0.00292188}{0.0003925}=7.4364^{0.8714}$
3
$\gamma 1=\frac{0.000358095}{0.0003925}=9.123439^{0.9602}$
$\gamma 2=\frac{0.000587983}{0.0003925}=14.980458^{1.1755}$
4
$\gamma 1=\frac{0.00509589}{0.0003925}=12.983159^{1.1134}$
$\gamma 2=\frac{0.009155897}{0.0003925}=23.334955^{1.3680}$
170°C
1 Cargo
$\gamma 1=\frac{0.00092419}{0.0003925}=2.3546242^{0.3719}$
$\gamma 2=\frac{0.00168491}{00003925}=4.29276433^{0.6327}$
Cargo 2
$\gamma 1=\frac{0.00303354}{0.0003925}=7.72876433^{0.8881}$
$\gamma 2=\frac{0.00613218}{0.0003925}=15.623388^{1.1938}$
Cargo 3
$\gamma 1=\frac{0.00512115}{0.0003925}=13.047515^{1.1155}$
$\gamma 2=\frac{0.0100619}{0.0003925}=25.635414^{1.4088}$
Cargo 4

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$\gamma 1 = \frac{0.007144}{0.0003925} = 18.201273^{12601}$
$\gamma 2 = \frac{0.0180861}{0.0003925} = 46.079235^{1.6635}$

As a result of the analysis, it was determined that astragalus is compatible with butadiene terephthalate and can form a composition with it in different proportions. However, it was determined that the best result is obtained when the astragalus component in the composition is 10 parts by mass. Considering all this, we aim to improve the physical and mechanical properties of polybutadiene terephthalate. We took the amount of astragalus as 10 parts by mass. The indicators obtained as a result of the report are shown in Figures 1–7

2. content compatibility

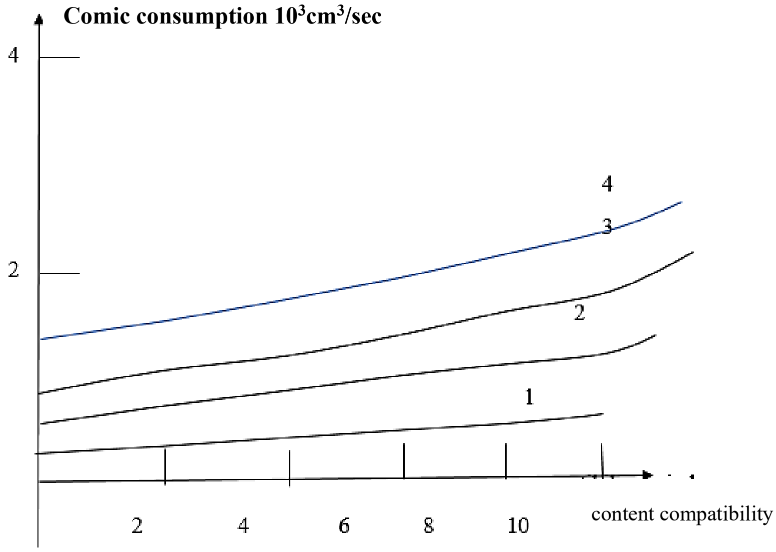


**Figure 1.** Dependence of volume consumption of BTFR and BTFR + astragalus binary mixtures at 100º C on the amount of astragalus in the mixture.

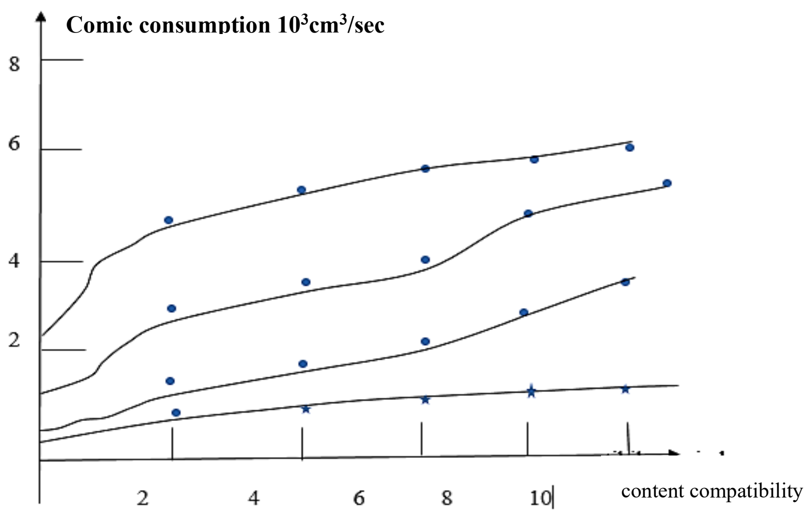


**Figure 2.** Dependence of the volume consumption of BTFR and BTFR + astragalus binary mixtures at a temperature of 130º C on the amount of astragalus in the mixture.

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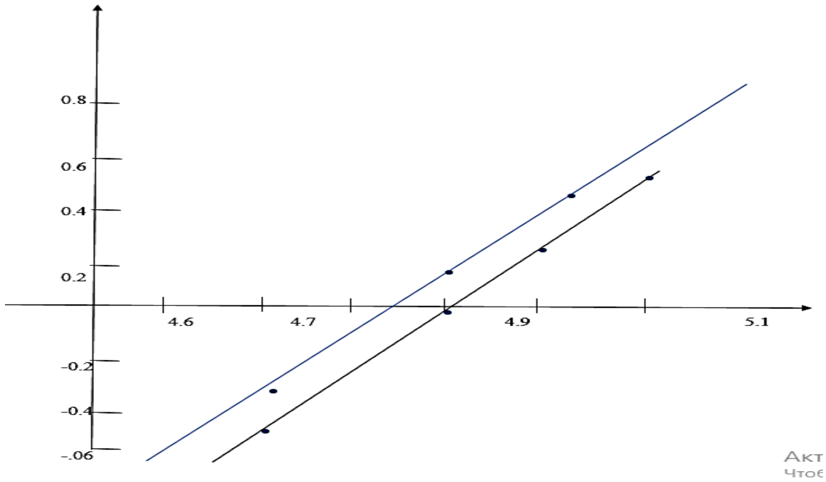


**Figure 3.** Stress (logo) dependences of displacement rates of BTFR and BTFR +astragals binary mixtures at 100º C temperature.

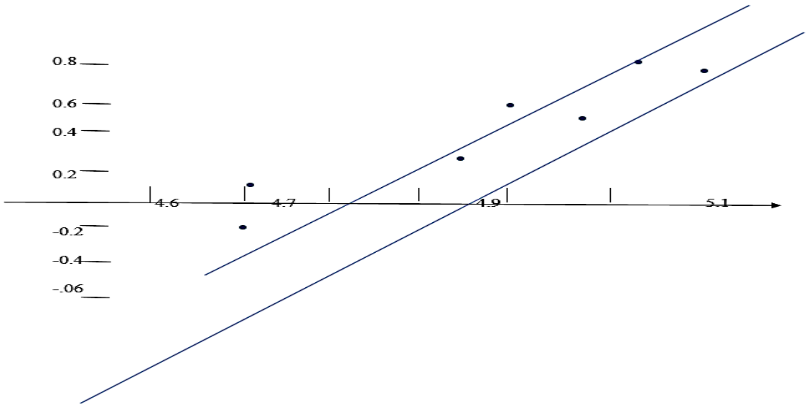


**Figure 4.** Stress (logo) dependences of displacement rates of BTFR and BTFR +astragals binary mixtures at 130º C temperature.

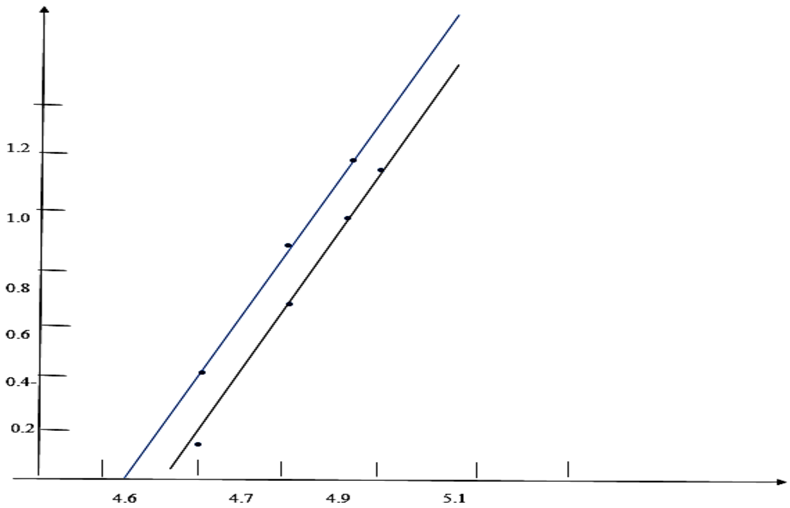


**Figure 5.** Dependences of strain (logo) displacement rates of binary mixtures of BTFR and BTFR + astragalus at a temperature of 150º C.

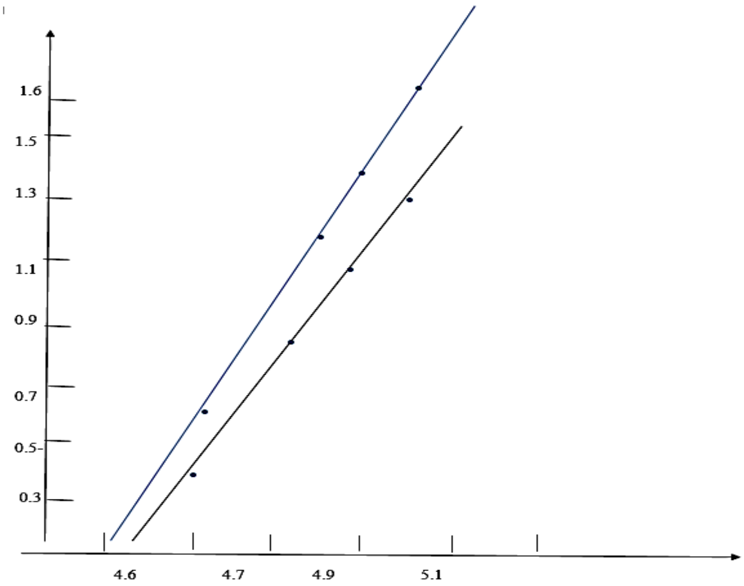


**Figure 6.** 170º Dependences of strain (logo) displacement rates of binary mixtures of BTFR and BTFR + astragalus at a temperature of 150º C.

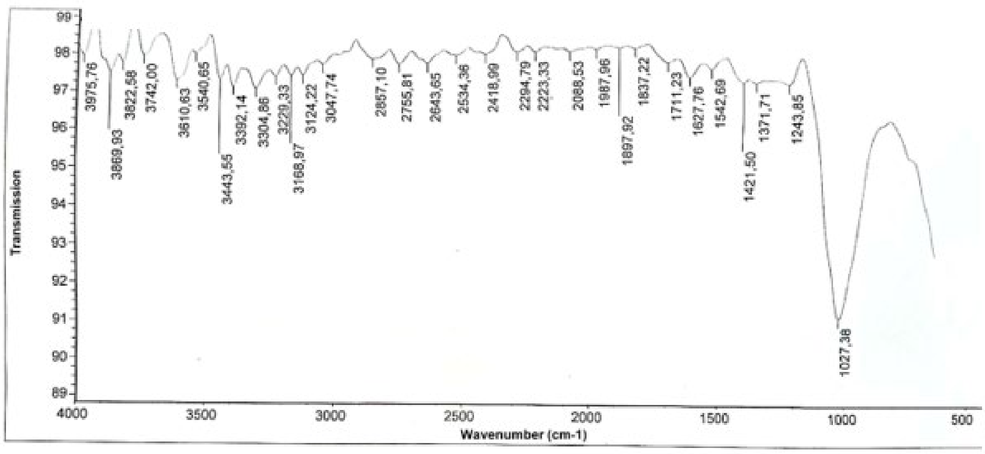


**Figure 7.** The result of x-ray analysis of polymer with astragaus.

*Rubber Mixture Based on BTFR and Astragalus*

Based on BTFR and astragalus, using the flow index of mixtures, we adopt the optimal recipe shown in Table 1

**Table 1.** A rubber mixture made based on polybutylene terephthalate.

| | RECIPE | |
|---|---|---|
| Main components | Standard resin mixture prepared based on polybutylene terephthalate (100 parts by mass, part by mass according to rubber) | The rubber mixture prepared based on polybutylene terephthalate modified with nanomaterials (100 parts by mass, part by mass by rubber) |

| | | |
|---|---|---|
| Polietilen tereftalat | 100 | 90 |
| tree resin | - | 2.5 |
| Astragalus | - | 10 |
| Petroleum bitumen | 5.0 | 5.0 |
| Zinc oxide | 3.0 | 3.0 |
| Stearic acid | 2.0 | 2.0 |
| Sulphur | 2.0 | 2.0 |
| Tiuram | 1.5 | 1.5 |
| Sulfenamide | 1.0 | 1.0 |
| Neazon-D | 3.0 | 3.0 |
| Technical carbon H330 | 30 | 30 |

Based on this recipe, after preparing a rubber mixture for 12 minutes in a laboratory roller at a temperature of 90 $^{o}$C and vulcanizing it in a vulcanization press at a temperature of 155$^{o}$C for 25 minutes, the physical and mechanical properties of the vulcanizate obtained were determined and the results are given in Table 2

**Table 2.** Physico-mechanical parameters of vulcanizate based on PBT.

| The main indicators of vulcanization | Death limit | Requirements of the standard | The result obtained in practice |
|---|---|---|---|
| Relative elongation | % | 300 | 500 |
| Relative residual deformation | % | 3,9 | 2,9 |
| Elasticity (Bending Modulus) | GPa | 3 | 4 |
| Hardness Rockwell M | GPa | 70 | 90 |
| Hardness Area D | GPa | 90 | 95 |
| Stiffness (bending modulus) | GPa | 3 | 4 |
| Ultimate breaking strength | MPa | 40 | 50 |
| Durability (At Room Temp Notched Izod Effect) | J/m | 29 | 45 |
| Low Temperature Hardness | J/m | 45 | 87 |
| Yung's Modulus | GPa | 2 | 3 |
| Electrical property | Electrical property of vulcanizate | Electrical property of vulcanizate | Electrical property of vulcanizate |
| Arc Resistance | sec | 123 | 180 |

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| | | | |
|---|---|---|---|
| Dielectric constant | | 2.9 | 4 |
| Dielectric Strength | kV/mm | 23 | 31 |
| Dissipation factor | 10-200 x $10^{-4}$ | 10-200 x $10^{-4}$ | 10-200 x $10^{-4}$ |
| Volume resistance | Ohm.sm | 15 x $10^{15}$ | 18 x $10^{15}$ |
| Shrinkage | % | 0,6 | 2,1 |
| Water absorption 24 hours | % | 0,11 | 0,24 |
| Density | q/sm $^{3}$ | 1,3 | 1,39 |
| Glass transition temperature | °C | 55 | 64 |
| Coefficient of linear thermal expansion | °C | 6 x $10^{-5}$ | 10 x $10^{-5}$ |
| Thermal conductivity | Vt/mK | 0,21 | 0,27 |
| Resistance to fire (LOI) | % | 20 | 23 |
| Learning class | | HB | |
| Brittle transition temperature | °C | -32 | -39 |
| HDT @0.46 MPa (67 psi) | °C | 123 | 148 |
| HDT @1.8 MPa (264 psi) | °C | 50 | 85 |
| Maximum Continuous Service | °C | 90 | 141 |
| Minimum Operating Temperature | °C | -34 | -40 |

The presence of functional groups formed by using astragals in the polymer can be clearly seen in Figure 9, which is confirmed by IKS-analysis. so it can be safely said that some of the properties of this polymer can be eliminated by modifying it with astragals.

In order to satisfy the chemical stability of the obtained polymer astragalus composition vulcanizate in aggressive environments, we determined the physical and mechanical properties of the vulcanizates by vulcanizing the rubber mixture we prepared in the laboratory at a temperature of 155°C for 15 minutes in accordance with the recipes we accepted (Table3).

**Table3.** Physico-mechanical indicators of vulcanizates of rubber mixtures.

| No | Name of key indicators | Key indicators | | | | | |
|---|---|---|---|---|---|---|---|
| | | Requirements of the standard | | | Results from the experiment | | |
| 1 | | 1 | 2 | 3 | 4 | 5 | 6 |
| | Dartilmada şərti möhkəmlik, MPa | 17 | 16,7 | 16,6 | 18.1 | 18,9 | 17,9 |
| 2 | Relative elongation, % | 320 | 330 | 300 | 360 | 380 | 395 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | Relative residual deformation,% | 12 | 14 | 12 | 12 | 12,2 | 12,5 |
| 4 | Tensile strength, kN/m | 65 | 64 | 68 | 68,3 | 69,6 | 69,2 |
| 5 | Friction, cm3/Wh | 59 | 60 | 56 | 60 | 59 | 58,5 |
| 6 | Metal bond strength, MPa:<br>steel-3<br>brass | 5,8<br>- | 5,4<br>- | 5,5<br>3,6 | 8<br>5,1 | 9,2<br>6,2 | 9,8<br>6,9 |
| 7 | Brittleness temperature, °C | -11 | - | 28 | 26 | 25 | 24 |
| 8 | TM-2 üzrə möhkəmlik, şərti vahid | 82 | 80 | 78 | 82 | 81,6 | 82,1 |
| 9 | 2525°C for 24 hours<br>degree of swelling at temperature, %:<br>in an isooctane-toluene mixture (70:30)<br>in gasoline-benzene mixture (3:1) | 12<br>- | 14<br>- | 14,5<br>23,5 | 10,1<br>14,7 | 10,2<br>13,9 | 10,9<br>14,1 |
| 10 | 25°C for 48 hours<br>heat aging at temp<br>coefficients | 0,85<br>0,64 | 0,87<br>0,62 | 1,03<br>0,88 | 0,92<br>0,83 | 0,94<br>0,86 | 0.95<br>0.90 |
| 11 | Elasticity on jump, % | 10 | 11 | 14 | 13,7 | 14 | 13.8 |
| 12 | 25°C for 27 hours<br>ozone resistance at temp<br>(deformation 20%, ozone hardness 0.015 %) | is falling apart | is falling apart | is falling apart | is falling apart | is falling apart | is falling apart |

**Results**

1. By modifying polybutadiene terephthalate with astragalus, it was determined how the modification process affects its mechanical properties.

3. The ozone resistance of the received resins showed that they are chemically very stable. Taking this into account, the offered rubbers can be used in the preparation of products that are resistant to ozone, oil, and gasoline and can work in aggressive environments.

4. As a result of scientific research, it has been proven that resins based on polybutadiene terephthalate and astragalus nanomaterial can be a special-purpose product. These rubbers can work in a wide range of temperatures and different climates. Ours is a Polybutylene Terephthalate (PBT) based rubber that can be used for general-purpose optical cable.

5. The proposed composition allows to significantly increase the strength of the connection of rubber with metals (steel-3, brass), to increase the resistance to gasoline and to improve the tensile strength index.

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