Improvement of mechanical behavior of neoprene rubber by means of glass fiber

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Abstract. Materials of the present article are concerned with research related to creation of new composites and studying their properties. In the course of the study, a polymer-based composite was created using neoprene; it was reinforced with multidirectional glass fiber, and polar solvent based on ethyl acetate and carbon tetrachloride was chosen as the most suitable solvent. Moreover, influence of fiber orientation on mechanical behavior of composites depending on the solvent type and amount was studied too.

1. Introduction
Study of mechanical properties of complex structurals is a major topic to be considered, as it defines their behavior when they are subjected to stress and various ambient conditions, such as pressure, temperature, solvent nature and other factors, having a significant impact on them. Mechanical properties are especially important for polymer-based composites, as they affect any of their other properties [1,2].

Composites are a product consisting of two or more materials with different properties that are bonded together in a specific way to give the composite the expected and better overall properties than the materials included in their composition, if used alone [3,4].

Figure 1. Main forms of fibers used in composites.
Composites have a great capability to control the environment, so that we can combine the material in accordance with the intended shape and properties, controlling their quantitative and qualitative composition, and position fibers in the required direction to one another. Figure 1 shows some of the main fiber shapes that can be used in composites. In other cases, fibers can be of many shapes, including short and long, random or planned, and can be arranged in a number of different ways, in two-dimensional or three-dimensional forms [3,5,6].

Fiber-reinforced materials are considered to be one of the most important types of composites used in industry and engineering.

The way the support element is positioned plays a significant role in determining properties of the substance being made, and as is seen, it can take various forms; it can be evenly distributed in the body material or arranged inside on the top of each layer and shaped so that we can control the direction of fibers at our will [7-9].

Therefore, we can control the set of properties of composites as necessary, and thus obtain the required properties.

Polymer-based compounds are the most commonly used materials, since they are less expensive than ceramic or mineral-based ones and can be prepared due to a wide range of their properties [10,11].

Bonding materials can be in the form of particles, fibers, or sheets, which make it possible to utilize good characteristics of various materials involved in forming a composite, to relieve from defects in them and to be more suitable for industrial applications.

That is why we can say that composites consist of two phases:

• first phase includes basic material;
• second phase includes materials reinforcing the whole composite.

These two structures are connected to each other by bonding surface called release surface. Composites can consist of one or more main phases and one or more reinforcing materials to obtain a complex of compounds by binding reinforcing materials with basic materials; obtained composition is called hybrid composite material [12-14].

Due to light weight and good thermal and electrical insulation of composites, there is an increasing need for their application in many different fields, which required some adjustment to their properties, especially mechanical ones, by reinforcing them with other materials to achieve the required goal. From the perspective of the scope of its application, samples were made of composites based on polymer reinforced with glass fiber, and then studies of their mechanical properties were carried out [15-17].

2. Goal of research
Preparation of polymer-based composites using neoprene reinforced with glass fiber in various directions and studying the effect of fiber orientation types on mechanical properties of composites, along with the type and amount of a suitable solvent.

3. Sample preparation
Studies were performed using solvents suitable for neoprene in various quantities, and selection of a suitable solvent for dissolution was made. To prepare experimental samples, the composite material was prepared and fixed with glass fibers cut from E glass, using a hand-molded technology with various induction methods. The prepared samples were left to become hard at room temperature (25 °C). Some of sample properties were studied. Mechanism for all prepared models is as follows:

• 1 - Neoprene polymer.
• 2 - Neoprene polymer and axially-oriented glass fiber.
• 3 - Neoprene polymer and transversal glass fiber.
• 4 - Neoprene polymer and random-oriented glass fiber.

4. Materials being used
1-Neoprene: teoprene rubber is considered to be one of important types of flexible polymers, fabrication of which has started since the thirties of the last century. This polymer offers quite satisfactory
mechanical and physical properties, as it is highly resistant to chemicals, solvents and oxidation; it is obtained by emulsion polymerization of chloroprene (11, 8). The chemical formula of chloroprene \((\text{CH}_2=\text{CH}-\text{CCl} = \text{CH}_2)\) is \(\text{C}_4\text{H}_5\text{Cl}\), the chemical structure of which is shown in figure 2:

![Chemical structure of chloroprene compound](image)

**Figure 2.** The chemical structure of chloroprene compound.

2- Solvents:
- benzyl chloride \(\text{C}_6\text{H}_5\text{CH}_3\);
- carbon tetrachloride \(\text{CCl}_4\);
- methyl propionate. \(\text{C}_2\text{H}_5\text{COOCH}_3\);
- ethyl acetate \(\text{C}_2\text{H}_5\text{COOC}_2\text{H}_5\).

3- Additives: various application of neoprene rubber requires specified polymer specifications, such as strength and characteristics that vary on temperature change. Raw neoprene rubber is usually transformed into these different types by adding some external materials to it and reinforcing it. The most important additives are antioxidants, metal oxides, hardeners and accelerators, fillers or plasticizers.

There are other additives, but they are added to neoprene rubber for special applications. The most important of these materials include: counterweights, some polymer resins or other types of rubber, and some blowing agents.

Major metal oxides that are added to neoprene rubber are magnesium oxides, zinc oxides and some lead oxides that are used for strengthening.

4- Glass fiber: it is considered to be the most commonly used type of fiber and is generally characterized by high tensile force, high abrasion resistance, high flexibility, high dimensional stability and the ability to absorb high stresses without constant stress on the material, high elasticity, light weight and corrosion resistance, relatively low cost, high strength, flame retardant, chemical resistance and sunlight resistance. The most commonly used types of glass fiber - E, S, R types.

5. Devices being used
For the purpose of tensile testing, we cut samples of standard size in accordance with standard specifications. Using special device shown in figure 3, the results were obtained, summarized in table 1.

![Chloroprene glass fiber samples subjected to tensile test](image)
### Table 1. Experimental results.

| No. | Solvent quantity | Time for aging | Solubility rate, % | Comments |
|-----|------------------|----------------|--------------------|----------|
| 1   | 40 ml of methyl propionate | Four days | 25 | The dissolution process proceeds slowly and unsatisfactory, collecting resin as a single unit in the lower part of the solution |
| 2   | 40 ml of methyl propionate | Four days | 50 | The dissolution process proceeds slowly and unsatisfactory; obtained liquid has high viscosity |
| 3   | 50 ml of methyl propionate | Four days | 90 | The dissolution is satisfactory, its leaching is slow; obtained liquid has slightly higher viscosity |
| 4   | 27 ml of methyl propionate, 3 ml of ethyl acetate | Four days | 50 | Solution process is unsatisfactory; obtained liquid has high viscosity |
| 5   | 34 ml of methyl propionate, 10 ml of ethyl acetate | Three days | 75 | Solution process is unsatisfactory; obtained liquid has high viscosity |
| 6   | 40 ml of methyl propionate, 10 ml of ethyl acetate | Two days | 90 | The melting process is satisfactory; obtained liquid has slightly higher viscosity |
| 7   | 27 ml of methyl propionate, 3 ml of benzyl chloride | Three days | 75 | The melting process is satisfactory; obtained liquid has high viscosity |
| 8   | 34 ml of methyl propionate, 6 ml of benzyl chloride | Two days | 90 | The melting process is good; obtained liquid has acceptable viscosity |
| 9   | 40 ml of methyl propionate, 10 ml of benzyl chloride | One day | Full melting of the sample | The melting process is good; obtained liquid has good and acceptable viscosity |
| 10  | 27 ml of methyl propionate, 3 ml of carbon tetrachloride | Three days | 75 | The melting process is satisfactory; obtained liquid has high viscosity |
| 11  | 34 ml of methyl propionate, 3 ml of carbon tetrachloride | Two days | 90 | The melting process is good; obtained liquid has acceptable viscosity |
| 12  | 40 ml of methyl propionate ethyl acetate, 10 ml of carbon tetrachloride | One day | Full melting of the sample | The melting process is satisfactory; obtained liquid has high viscosity |

Following the tests, two samples of adhesive were prepared:
- Sample No.1 contains: 10 g of neoprene, 40 ml of methyl propionate, 10 ml of benzyl chloride.
- Sample No.2 contains: 10 g of neoprene, 40 ml of methyl propionate, 10 ml of carbon tetrachloride.
Each sample was then split into two parts and ZnO was added to one of the two sections to test the effect of zinc oxide on adhesive quality.

To one of the two samples of neoprene, 1% ZnO was added, which amounted to about 0.1 g. To determine the strength of the adhesive and its quality, tests were carried out in pieces of synthetic leather. It turns out that the adhesive in both samples (containing ZnO and not containing ZnO) is able to bond synthetic leather pieces safely, but the adhesive containing ZnO is able to bond them much faster than the other one.

We then tested the strength of the adhesive using synthetic leather pieces that were glued with adhesive containing 0.1 g of ZnO by stretching it at both ends. Where gluing area is 8 cm², the results were obtained, summarized in table 2.

Table 2. Tensile test results after adding zinc acid to two neoprene samples.

| No. | Ingredients of the adhesive being used | Tension force, H | Tension stress, H/cm² | Description of the state of a synthetic leather section |
|-----|----------------------------------------|----------------|-----------------------|--------------------------------------------------------|
| 1   | 10 g of neoprene, 40 ml of methyl propionate, 10 ml of benzyl chloride, ZnO (0.1g) | 1900 | 240 | it was found that a synthetic leather section had cut off the glue area |
| 2   | 10 g of neoprene, 40 ml of methyl propionate, 10 ml of carbon tetrachloride, ZnO (0.1 g) | 2000 | 250 | it was found that the top layer of a piece of synthetic leather was torn off from the bonding area |

The glass fiber reinforced specimens were then prepared for testing with a stretching device by pouring a small amount of polychloroprene resin mixture into wooden molds to prevent heterogeneous agglomeration. Further, after adding fibers separately and saturating fibers with resin in certain proportions, the quality of their impregnation was controlled. About 30% of fibers and 70% of chloroprene were sampled. After polymerization was achieved, the samples were dried. The results are shown in graphs that represent values of tensile force and extension from the perspective of support material and the fiber orientation method.

Figure 4 shows the values of resistance to tensile stress and extension for unprocessed polymer samples without a substrate (a control sample). The results show that the tensile force is relatively low for such materials and the extension is relatively high.

![Figure 4. Results of tensile tests of raw polychloroprene samples.](image-url)
Figure 5 shows the tensile force and extension of polymer samples reinforced with glass fiber in transverse direction. The results showed that the tensile force remained constant and the extension was less by about 29% than the control value.

![Figure 5](image)

**Figure 5.** Results of tensile tests of polychloroprene with transverse fibers.

The values of tensile force and extension of polymer samples reinforced with glass fiber in random direction are shown in figure 6. The results showed that the tensile force value changed because the maximum tensile force value in this case was 85 Nm, and the extension value decreased by 49% from the control value.

![Figure 6](image)

**Figure 6.** Results of tensile tests of polychloroprene with random-oriented glass fibers.
The results showed that the tensile force and extension values changed, but with different values compared to previously obtained, the tensile force values increased by 100 N, and the extension values decreased by about 68% from the reference values. The tensile force and extension values of polymer samples reinforced with longitudinally oriented glass fibers are shown in figure 7.

![Graph showing tensile force and extension](image)

**Figure 7.** Results of tensile tests of polychloroprene with longitudinal fibers.

Table 3 summarizes the results obtained earlier.

| Longitudinal reinforcement | Random reinforcement | Transverse reinforcement | Without reinforcement | Samples          |
|----------------------------|----------------------|--------------------------|-----------------------|------------------|
| 160                        | 85                   | 60                       | 60                    | Tension force, H |
| 32                         | 51                   | 71                       | 100                   | Tensile strain, %|

Polychloroprene is considered to be one of the elastic rubber materials because its tensile force is very low, which we, in general, observed when analyzing the obtained results, but when we added fibers to these materials, its tensile force improved significantly, as most of the applied load caused by the samples, is carried by fibers, which increases the tensile force resistance of the composite material according to the reinforcement method, as the fibers show high strength that is significantly higher than those of the base material.

6. Conclusions
Here are the most important findings made in the course of this study:

- A mixture of methyl propionate and ethyl acetate or methyl propionate and carbon tetrachloride with 80% of methyl propionate, 20% of ethyl acetate or carbon tetrachloride are considered to be the best solvents. Since neoprene is a chlorinated rubber and has a high polarity, a polar solvent is needed to dissolve it, and ethyl acetate and carbon tetrachloride are some of the most important solvents.

- The time required for dissolution decreases with an increase in the amount of solvent.
• The time required for dissolution decreases with an increase in percentage of polar solvent (ethyl acetate or carbon tetrachloride).
• Addition of ZnO reduced the adhesion time and increased the adhesive strength.
• Polychloroprene resins are highly elastic rubber materials and therefore have poor mechanical properties.
• Mechanical properties of polychloroprene resin are improved as a result of its reinforcement with glass fibers, and this improvement depends on the method of longitudinal fibers’ orientation.
• The values of all mechanical properties of polychloroprene resin improve with an increase in fractional weight.

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