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RESEARCH OF ENVIRONMENTALLY SAFE MATERIAL BASED ON POLYESLESULPHONE

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Abstract

Among all polymeric materials, a special place is occupied by structural polymers, which are capable of withstanding various operating conditions and exhibit increased thermal resistance. One of these classes of promising polymers are aromatic polyethersulfones characterized by a complex of valuable physical and mechanical properties. Synthesis of polyethersulfones with terephthaloyl-di (p-hydroxybenzoic) acid groups in the main macromolecular chain has been carried out. For the synthesis of these polyethers, the method of acceptor-catalytic polycondensation was employed. For all synthesized polyethersulfones, such mechanical characteristics as tensile strength and breaking strain, which characterize the behavior of polymer under high loads applied, were investigated. The obtained polyethersulfones with p-hydroxybenzoic acid units exhibit high thermal and mechanical characteristics. Polyethersulfones can be used as structural polymers. The synthesized polyethersulfones with p-hydroxybenzoic acid units exhibit high thermal and mechanical characteristics, tensile strength and breaking strain, and high glass transition temperature. This suggests that some of the proposed polyethers may be industrially promising engineering polymeric materials.

Keywords: Catalytic polycondensation, polyethersulfones, polyethers, synthesis, macromolecular, structural polymers

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1. Introduction

Among all polymeric materials, a special place is occupied by structural polymers that can withstand various operating conditions and have increased heat resistance. These materials are widely used in various industries due to their strength, resistance to chemical influences and durability. They are used in the automotive industry, aerospace industry, electronics and many other areas where reliability and stability in extreme conditions are required (Feng et al., 2021; Kumar et al., 2022).

One of these classes of promising polymers are aromatic polyethersulfones. These polymers are characterized by a set of valuable physical and mechanical properties, including high heat resistance, which allows them to maintain their characteristics at temperatures inaccessible to many other materials. Aromatic polyethersulfones also have excellent resistance to oxidation and hydrolysis, making them ideal for use in aggressive chemical environments. In addition, these polymers have low flammability and good electrical insulation, which expands their application in the electrical and electronics industry. Due to their ability to withstand high temperatures and mechanical loads, aromatic polyethersulfones are actively used in the production of parts for engines, pipelines and other structures where a combination of lightness and strength is required (Kraev et al., 2022; Ruiz-Perez et al., 2022).

Research and development in the field of aromatic polyethersulfones is ongoing, aimed at improving their properties and expanding their application areas. This makes them one of the most promising materials for future innovations in the field of high-tech engineering polymers (Shlensky et al., 1999).

2. Problem Statement

Polyethersulfones were obtained by the method of acceptor-catalytic polycondensation (Asueva, 2010) according to the scheme in Figure 1:

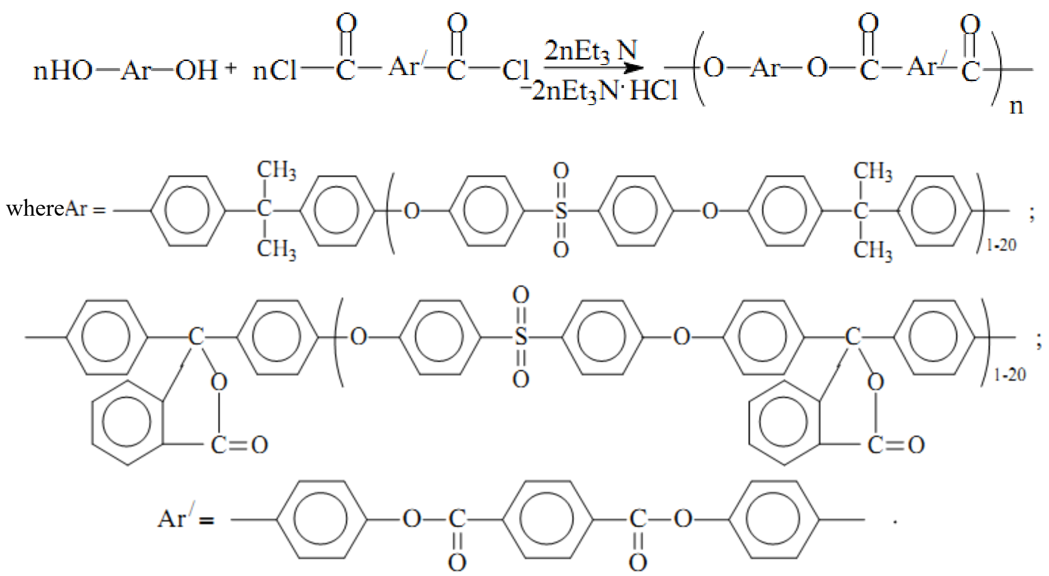

Figure 1. Diargam for acceptor-catalytic polycondensation

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Terephthaloyl-di (p-hydroxybenzoic) acid dichloride was taken as an acid component for the synthesis of polyethers (Bilibin et al., 1982). The presence of p-hydroxybenzoic acid fragments in the polymer macromolecular chain significantly improves its physical and mechanical properties. These fragments contribute to an increase in the rigidity and strength of the polymer due to their ability to form strong intermolecular interactions. This leads to increased resistance to deformation and improved thermal stability of the material. In addition, the introduction of p-hydroxybenzoic acid into the polymer structure helps to improve its chemical resistance. Such polymers become more resistant to aggressive chemical environments, which expands their application in various industries, including the chemical industry and electronics (Eremin et al., 2020; Yao et al., 2021).

It is also worth noting that the presence of these fragments helps to improve the barrier properties of the polymer. This makes it more effective as a packaging material, especially for products that require protection from moisture and oxygen. As a result, polymers with p-hydroxybenzoic acid are widely used in the production of high-strength composites, films and fibers that are used in the automotive, aviation and space industries. Research in this area is ongoing, with the aim of further improving the properties and developing new materials with unique characteristics (Khasbulatova et al., 2008; Khasbulatova, 2010).

3. Research Questions

Figure 2 shows a sharp change in heat capacity (0.057 /gK) of a polyethersulfone sample based on OS-10F in the glass transition region due to defrosting of segmental mobility (Figure 01, curve 1).

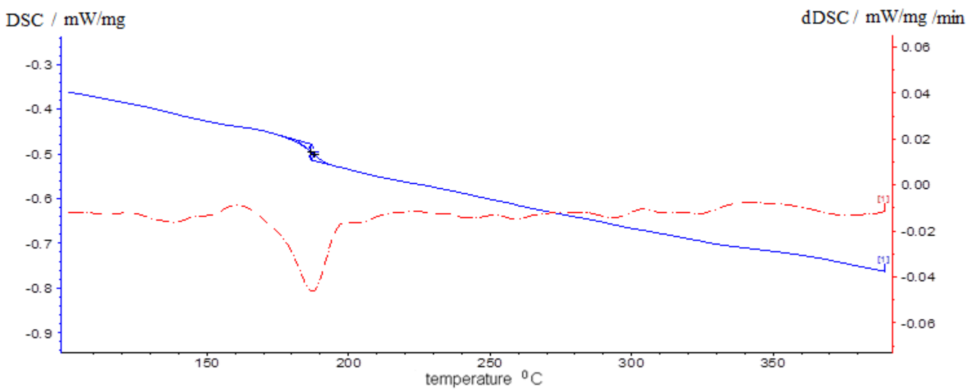

Figure 2. DSC curves for polyethersulfonterephthaloyl-di (p-hydroxybenzoates) based on phenolphthalein oligosulfone (n = 10)

The inflection point and the position of the minimum on the differential scanning calorimetry (DSC) curves (Figure 02, curve 2) indicate the glass transition temperature of polyethersulfone based on phenolphthalein oligomer with a degree of condensation of 10, which is 255 °C. This parameter is an important indicator of the thermal properties of the material, since the glass transition temperature determines the transition of the polymer from a glassy state to a more mobile, rubber-like state. A glass transition temperature of 255 °C indicates high thermal stability of the material, which makes it suitable for use in high-temperature conditions. Polyethersulfones are known for their excellent thermal stability

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and mechanical strength, which makes them in demand in the aviation and automotive industries, where materials are subject to significant thermal and mechanical loads. The phenolphthalein oligomer in the polyethersulfone improves its physical properties, such as resistance to chemical influences and stability at high temperatures. This makes these polymers particularly useful in the production of high-temperature composites and films used in a variety of engineering applications. Research into the modification of polyethersulfones is ongoing, with the aim of further enhancing their performance characteristics, including improved impact strength and resistance to long-term thermal effects. This opens up new possibilities for their use in a wider range of industrial applications (Gladkov et al., 2021; Pletnev & Nepochatov, 2022).

Figure 02 shows the data of thermogravimetric analysis (TGA) (curve 1), thermal effects of differential thermal analysis (DTA) (curve 2) and differential thermogravimetry (DTG) (curve 3) of a polyether sample based on OS-10F. As can be seen from the figure, the thermal decomposition of polymer samples is of a two-stage nature, with the maximum rate of sample weight loss in the temperature range of 520°C and ~ 621°C. The minima at 520°C are likely due to the decomposition of thermally unstable ester bonds.

4. Purpose of the Study

The second stage is probably associated with the destruction of the carbon skeleton to low molecular weight products (Figure 3).

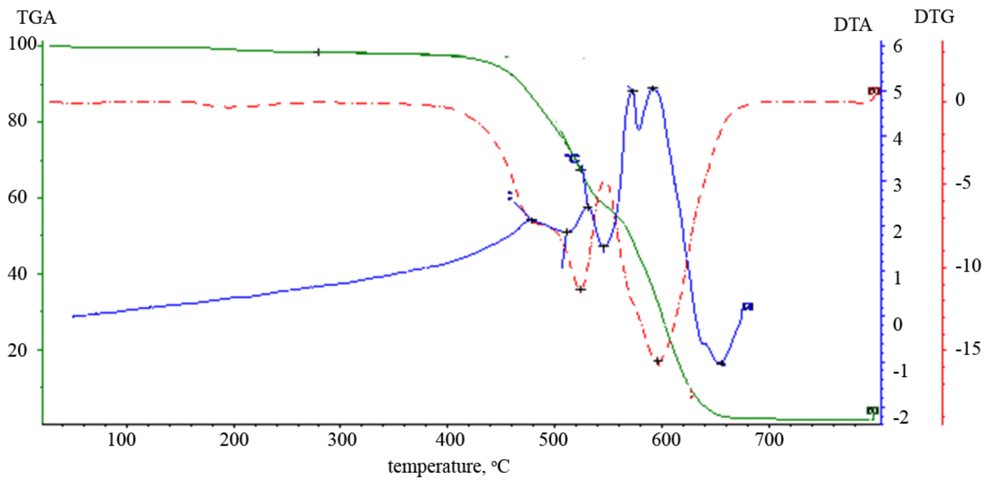

Figure 3. TGA data for polyethersulfonterephthaloyl-di (p-hydroxybenzoate) based on phenolphthalein oligosulfone (n = 10)

Increasing the temperature to 650°C (for the polymer sample based on OS-10F) leads to thermal degradation of the polymers (DTA curve), which is an important factor in assessing their heat resistance and durability. At such a high temperature, molecular bonds are destroyed, which leads to a loss of mechanical and physical properties of the material. This limits the use of polymers in conditions where they can be exposed to extreme temperatures. However, polyesters demonstrate significant thermal stability, which allows them to be processed at temperatures up to 400°C without the risk of degradation.

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This property makes them especially valuable in various industrial processes that require high processing temperatures, such as in the production of high-temperature composites and engineering plastics. In addition, polyesters can withstand short-term heating up to 450°C, which expands their range of application. Such heat resistance allows them to be used in conditions where short-term temperature peaks are possible, for example, in the aviation and automotive industries. This property also makes polyesters suitable for use as protective coatings and insulation materials in electronics and other high-tech applications.

In general, the high thermal stability of polyesters makes them indispensable materials in various engineering applications that require a combination of strength, stability, and durability at elevated temperatures. Research continues to improve their characteristics, including resistance to long-term thermal effects and chemically aggressive environments.

5. Research Methods

For all synthesized polyethersulfones, such mechanical characteristics as tensile strength and breaking strain, which characterize the behavior of polymer under high loads applied, were investigated. Polyethersulfones belonging to the diane and phenolphthalein series demonstrate stable tensile strength values in the range of 54.0–74.0 MPa. These characteristics make them suitable for use in various engineering applications where high mechanical strength and reliability are required. One of the reasons for such high values is the plasticizing effect of flexible diane oligosulfones, which helps improve the mechanical properties of the polymer. The flexibility of oligosulfones allows polyethersulfones to maintain plasticity even under significant loads, which prevents their destruction and ensures the durability of the material. This property is especially important in areas where materials are subject to regular mechanical impacts or vibrations, such as in the aviation and automotive industries (Lavrov et al., 2021; Wu et al., 2021).

In addition, polyethersulfones have high thermal and chemical resistance, which makes them in demand in the production of components operating in aggressive environments. Their resistance to high temperatures and chemicals allows them to be used as structural materials in the chemical industry and electronics. Research into the modification of polyethersulfones continues, with the aim of improving their mechanical and thermal properties and expanding their range of application. This includes the development of new compositions and additives that can further enhance their strength and plastic properties.

6. Findings

It is known that polyethersulfones based on phenolphthalein oligomers demonstrate higher strength properties compared to analogs based on diane oligomers. This is due to the unique structure of phenolphthalein units, which provide a more rigid molecular network and increased intermolecular bonding. Such a structure helps to increase the elastic modulus and improve resistance to deformation under load. Phenolphthalein polyethersulfones have higher heat resistance, which allows them to retain their mechanical properties even at extreme temperatures. This makes them especially useful in areas

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where materials are subject to significant thermal loads, such as in the aviation and space industries. The high glass transition temperature of these materials also contributes to their use in conditions requiring resistance to thermal aging. In addition, phenolphthalein-based polyethersulfones demonstrate excellent chemical resistance, which allows them to be used in aggressive chemical environments. This quality makes them ideal for use in the chemical industry, where materials are exposed to various reagents and solvents.

Research shows that the introduction of phenolphthalein units into the structure of polyethersulfones improves their resistance to ultraviolet radiation and oxidative processes. This opens up opportunities for their use in outdoor applications and in conditions of increased radiation. As a result, such materials become promising for use in construction and electronics, where high durability and reliability are required. Thus, phenolphthalein-based polyethersulfones not only surpass diane-based analogs in strength characteristics, but also have a number of additional advantages that expand their scope of application in various high-tech and industrial sectors.

Among all synthesized polyethers, a sample of polyethersulfone based on phenolphthalein oligomer with n = 20 shows the highest tensile strength. Most of the polyethersulfones synthesized in this study exhibit plastic deformation.

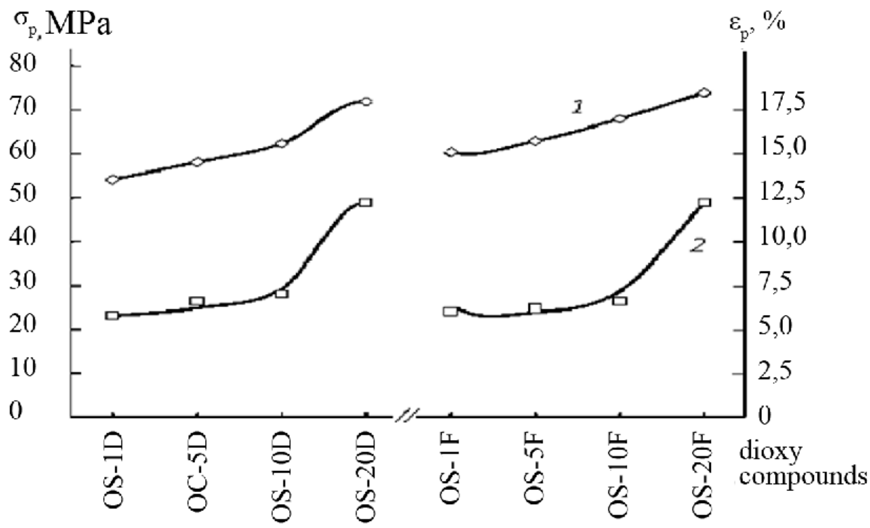

Figure 4. Dependence of ultimate tensile stress σp (1) and strain to fracture ε_p (2) of polyethersulfones on the composition and structure of initial dioxy compounds

7. Conclusion

The synthesized polyethersulfones with the inclusion of p-hydroxybenzoic acid units demonstrate outstanding thermal and mechanical properties. These polymers have high tensile and tear strength, which makes them resistant to mechanical stress and deformation. The high glass transition temperature of these materials indicates their ability to maintain structural stability when exposed to high temperatures, which is especially important in operating conditions where the temperature can vary significantly. Such properties make polyethersulfones ideal candidates for use as structural materials in various industries.

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For example, in the aviation and automotive industries, where materials are subject to intense mechanical stress, polyethersulfones can provide the necessary durability and reliability. Their thermal stability also makes them suitable for use in electronics and electrical engineering, where materials must withstand high temperatures without losing functionality.

In addition, the high chemical resistance of these polyesters allows them to be used in aggressive environments, such as the chemical and oil and gas industries. This expands their potential as industrially promising engineering polymer materials that can replace traditional materials, offering improved performance and durability. Ongoing research and development in this area is aimed at further improving the properties of polyethersulfones, including modifying their structure and introducing new functional additives. This opens up new possibilities for their application in high-tech areas such as the space industry and medicine, where a combination of strength, stability and lightness is required.

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