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PRODUCTION OF POLYMER-BASED RESINS FROM PYROLYSIS PRODUCTS AND THEIR SOLUBILITY IN SOLVENTS

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Abstract

This scientific article investigates the chemical composition and physicochemical properties of pyrolysis fractions obtained from the Ustyurt gas-chemical complex, as well as the possibilities of obtaining high-quality petroleum polymer resins through their modification. Pyrolysis distillate, condensate, and tar products were fractionated according to temperature ranges, and their density, viscosity, thermal stability, and compositional components were analyzed. Additionally, the solubility of the resins in various solvents was evaluated depending on temperature and time.

Keywords: *pyrolysis fraction, petroleum polymer resin, distillate, condensate, tar, solubility, temperature, solvent, viscosity, density, Ustyurt gas-chemical complex*

Introduction

In modern industry, the creation of corrosion-resistant, environmentally friendly, and economically efficient coatings is of great importance. At the Ustyurt gas-chemical complex, various fractions such as pyrolysis distillate, pyrolysis condensate, and tar products are separated. These fractions are rich in benzene, toluene, styrene, aromatic, and aliphatic hydrocarbons, enabling the production of highly reactive petroleum polymer resins. Contemporary research in the petrochemical field primarily focuses on the chemistry of pyrolysis fractions and improving the quality of petroleum polymer resins derived from them. Petrov and Ivanov (2018) thoroughly studied the chemical composition of raw materials in petroleum pyrolysis and their role in polymer resin production, identifying key problems and solutions in the field (Petrov, V.V., & Ivanov, A.N., 2018). Sokolov and Lebedev (2017) analyzed the synthesis of polymer resins from pyrolysis products and the possibilities of their modification using various chemical methods (Sokolov, M.M., & Lebedev, P.I., 2017).

Zhang and Wang (2019) determined the physicochemical properties of pyrolysis fractions obtained from natural gas processing, emphasizing their high chemical activity (Zhang, L., & Wang, H., 2019). Kim and Lee (2020) investigated the tar product formed during pyrolysis, noting its high molecular weight and thermal stability, recommending it as a promising raw material for high-quality polymers (Kim, S.Y., & Lee, J.H., 2020).

Singh and Sharma (2016) proposed phenol-formaldehyde-based polycondensation methods to chemically modify petroleum polymer resins and improve their physicomechanical properties (Singh, R., & Sharma, P., 2016). Zhao and Chen (2021) conducted a deeper analysis of this process, achieving enhanced thermal and mechanical stability of resins derived from pyrolysis fractions (Zhao, Y., & Chen, X., 2021).

In the field of corrosion-resistant coatings, Kumar and Singh (2018) assessed the effectiveness of polymer coatings derived from petroleum on metal surfaces (Kumar, A., & Singh, J., 2018). Chen and Zhang (2019) thoroughly studied the production technology and characteristics of these coatings, recommending them as effective agents for industrial corrosion protection (Chen, L., & Zhang, T., 2019). Furthermore, opportunities and challenges in producing polymer resins from natural gas pyrolysis fractions have been analyzed, highlighting the importance of scientific research in this area (Karimov, B., & Rasulov, D., 2022). Scientific investigations have also been conducted on processing pyrolysis products from the Ustyurt gas-chemical complex and producing high-quality coating materials based on them (Toshpulatov, M., & Abdurahmonov, I., 2021).

Results and Discussion

The chemical composition and physicochemical properties of pyrolysis fractions obtained from the Ustyurt chemical complex were investigated. The pyrolysis distillate, characterized by its light and easily flammable nature, mainly consists of benzene, alcohols, and acidic compounds. The pyrolysis condensate contains a high amount of aromatic and condensed components with a high molecular weight and a distinctive odor, providing significant advantages during modification due to its high thermal stability. The tar product, composed of solid, black-colored resins with a high molecular weight, can be utilized primarily as a solid and highly thermally stable material. The analysis of the fraction compositions confirmed the possibility of chemical modification of these fractions to obtain high-quality petroleum polymer resins. Resins obtained through polycondensation reactions based on phenol, formaldehyde, and maleic anhydride exhibited good physicomechanical properties. Their heat resistance and acid-water resistance were also evaluated through appropriate tests.

The density, boiling point, and viscosity of the pyrolysis distillate, condensate, and tar products obtained from the Ustyurt gas-chemical complex, as well as the presence of alcohols, acids, aromatic hydrocarbons, and resin components in the fractions, differ significantly in composition. Therefore, these substances were studied primarily based on their density, boiling point, and viscosity parameters (Table 1).

Table 1. *General analysis of pyrolysis fractions according to their physicochemical properties*

No.	Fractions	Temperature °C	Viscosity, mPa•s	Density, g/cm³
1	Distillate	60–90	0.8	0.75
2	Distillate	90–120	1.0	0.75
3	Distillate	120–150	1.5	0.75
4	Condensate	150–200	100	1.1
5	Condensate	200–250	150	1.1
6	Condensate	> 250	200	1.1

By fractionating the pyrolysis products based on temperature, three main fractions with distinct differences in density, viscosity, and chemical composition were separated. The pyrolysis distillate obtained in the temperature range of 60–150 °C had a density of 0.75 g/cm³ and a viscosity between 0.8–1.5 mPa·s. Its composition included benzene, alcohols, and acids, making it a reactive and liquid raw material suitable for the production of modified resins. The pyrolysis condensate collected between 150–250 °C had a density of 1.1 g/cm³ and a viscosity ranging from 100 to 200 mPa·s. It consisted mainly of aromatic and high molecular weight hydrocarbons and was effectively used for producing stable and durable polymer-based materials. The tar product, obtained at temperatures above 250 °C, exhibited a density of 1.3 g/cm³ and viscosity equal to or greater than 200 mPa·s. It was composed of solid, polymer-structured resins, distinguishing it as an important raw material for industrial applications such as corrosion-resistant coatings and insulation materials. Overall, as the temperature increased, the density and viscosity of the fractions also increased, which enhanced their polymer properties and expanded their potential industrial applications.

Additionally, the physical and chemical properties of the isolated tar product – such as density, softening point, odor, and viscosity – determine the resin's performance characteristics and its field of application. In this study, the high density, softening point, and viscosity levels of the resins were considered key indicators for evaluating their quality (Table 2).

Table 2. *Physicochemical properties of tar products*

No.	Properties	Value	Description
1	Density, g/cm³	1.3	Hard and dense consistency
2	Melting point, °C	> 250	Low melting point, solid resin
3	Odor	Odorless	Odorless, suitable for industry
4	Viscosity, mPa · s	1000+	Very high viscosity

The density of the studied resins was found to be 1.3 g/cm³, and they exhibited a solid and dense consistency. Their softening point was above 250 °C, indicating their thermal stability at high temperatures. The absence of odor enhances their industrial usability, which is particularly important for applications sensitive to smell.

The viscosity exceeded 1000 mPa · s, demonstrating that the resins have very high adhesiveness and the ability to form a solid structure. Thus, these two-layered pyrolysis products separated from the raw materials serve as high-quality insulating and coating materials in the production of petroleum polymer resins with the participation of solvents. They are effectively used in various industrial sectors as protective coatings and adhesives. Their chemical composition and interaction with solvents play a crucial role in their application. Solubility is significantly dependent on temperature, as an increase in temperature activates molecular motion and accelerates the dissolution process. In this study, the solubility of the isolated resins was investigated in various solvents within the temperature range of 50 °C to 75 °C (Table 3).

Table 3. *Temperature dependence of petroleum polymer resin solubility*

No.	Solvents	50 °C	60 °C	70 °C	75 °C	Average (%)
1	Benzene	32	40	45	58	**43.8**
2	Ethyl acetate	20	27	28	38	**28.2**
3	Chloroform	35	60	–	–	**23.7**
4	n-Heptane	12	17	25	25	**19.8**

The solubility of petroleum polymer resin in various solvents was observed to increase with rising temperature. According to the study results, the solubility of the resin was examined in benzene, ethyl acetate, chloroform, and n-heptane within the temperature range of 50 °C to 75 °C. In benzene, solubility consistently increased with temperature, reaching 58% at 75 °C from 32% at 50 °C, with an average solubility of 43.8%. This indicates that benzene is an effective solvent for the resin. Solubility in ethyl acetate was relatively low, increasing from 20% to 38% with rising temperature, averaging 28.2%. Solubility in n-heptane was very low, rising from 12% at 50 °C to 25% at 75 °C, with an average of 19.8%. Considering the boiling points of solvents, the solubility of the resins was also studied in suitable solvents within the temperature range of 80 °C to 120 °C (Table 4).

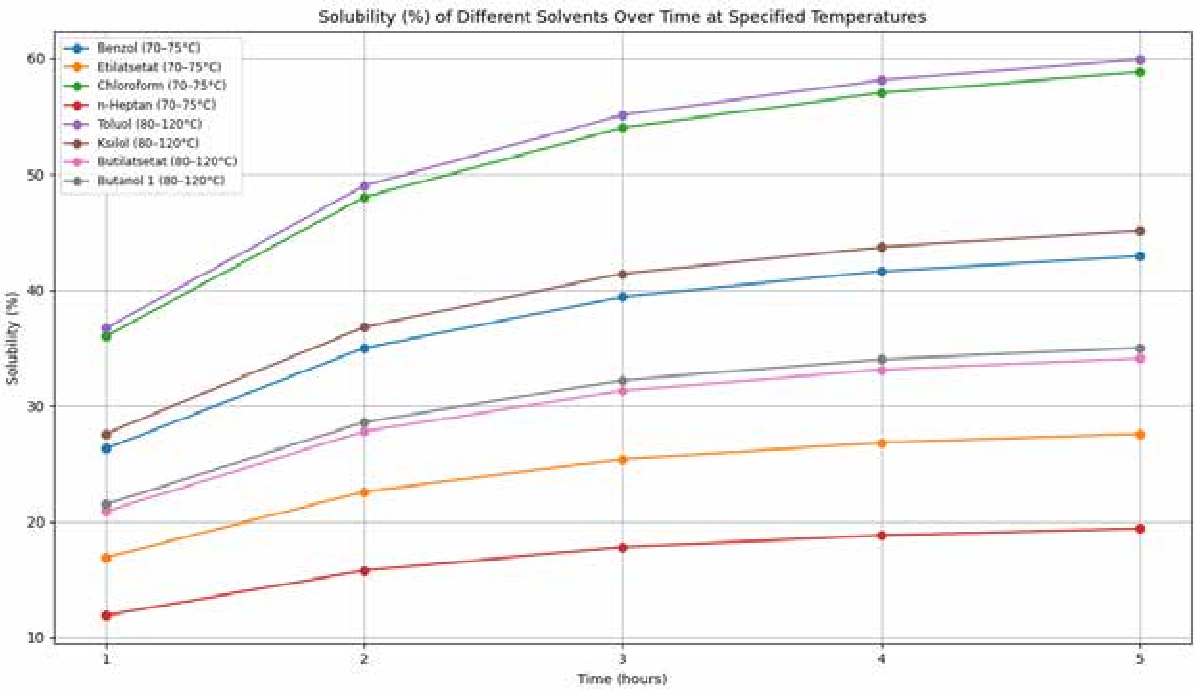
Table 4. *The temperature dependence of the solubility of petroleum polymer resin*

No.	Solvents	80 °C	90 °C	95 °C	100 °C	110 °C
1	Toluene	48	60	70	68	60
2	Xylene	35	45	54	52	46
3	Butyl acetate	24	32	42	41	—
4	Butanol 1	33	40	45	39	30

Among the solvents listed in the second table, toluene shows the highest solubility for the petroleum polymer resin, increasing from 48% to 70% as temperature rises from 90 °C to 95 °C, with an average solubility of about 61.2%. Xylene has an average solubility around 46%, reaching a maximum of 54%, but its solubility decreases with rising temperature. Butyl acetate and butanol-1 exhibit relatively lower solubility levels, averaging around 34.8% and 35.8%, respectively.

Comparing to the solvents in the first table, benzene reaches 58% solubility, while toluene reaches 70% in the second table. Thus, while benzene and toluene offer the highest solubility, solvents like ethyl acetate, butyl acetate, and butanol-1 are safer choices. The resin's solubility depends not only on the solvent type and temperature but also on the duration of the reaction. The study analyzed solubility levels at two temperature ranges (70–75 °C and 80–120 °C), shown in Figure 1.

Figure 1. *Discussion on solubility of petroleum polymer resin in various solvents*



Experimental results show that the solubility of petroleum polymer resin increases depending on temperature and time. Within the temperature range of 70–75 °C, benzene exhibited high solubility, while in the range of 80–120 °C, toluene and xylene stood out as effective solvents. Over time, the solubility in all solvents increased, although some solvents like n-heptane maintained low solubility. Overall, benzene, toluene, and xylenes are considered the best solvents for dissolving petroleum polymer resin, provided that safety precautions are observed. Solvents with lower solubility (ethyl acetate, butyl acetate, butanol-1) have advantages in terms of safety but lower efficiency. Therefore, when selecting a solvent, a balanced decision must be made considering solubility, temperature, time, and safety factors.

Conclusion

The study results demonstrated that the pyrolysis fractions obtained from the Ustyurt gas-chemical complex are promising raw materials for industry. The distillate collected at 60–150 °C consists of liquid components and can be used in the production of modified resins. The condensate at 150–250 °C and tar product obtained above 250 °C have high density and thermal stability, making them important for polymer resin manufacturing. Although high solubility of resins in benzene and toluene was identified, safety measures must be followed when using these solvents. Ethyl acetate, butyl acetate, and butanol-1, despite their lower solubility, are considered environmentally safer. Overall, analyzing pyrolysis fractions and optimizing resin production technology contribute to increasing efficiency in the petrochemical industry. When choosing solvents, efficiency must be balanced with safety and environmental considerations.

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