INTERNATIONAL MULTI DISCIPLINARY JOURNAL FOR RESEARCH & DEVELOPMENT
eISSN 2394-6334 Impact factor: 8.854 Volume 13, issue 04 (2026)

STUDY OF THE PHYSICAL AND MECHANICAL PROPERTIES OF RIGID POLYURETHANE FOAMS OBTAINED ON THE BASIS OF SYNTHESIZED PRODUCTS

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Abstract

This article presents the physical and mechanical properties of rigid polyurethane foams. Specifically, the properties of five rigid polyurethane foam samples obtained are compared with those of the standard PPU-307 formulation. Impact properties, strength properties, water absorption, and flammability are compared. Based on these data, a sample with acceptable physical and mechanical properties was selected.

Keywords: secondary raw materials, tertiary amines, catalysts, physical and mechanical properties, IR spectrum, density, freon.

Introduction

Currently, the increasing demand for polymers is significantly impacting the rapid development of this industry. This, in turn, ensures the production of high-quality products, the manufacture of finished polyurethane foam products, and their practical application. In recent years, scientists worldwide and in our country have achieved significant results in improving the quality of polyurethane foam products, refining synthesis technologies, and implementing them into industrial production.

At the same time, using local raw materials and recycling, it was possible to synthesize tertiary amines as catalysts for rigid polyurethane foams for industrial use.

Tertiary amines act as chemical reaction accelerators [1]. Without catalysts, the process of producing rigid polyurethane foams (start-up time, gel time, and pour time) will take longer, which can negatively impact their physical and mechanical properties. Therefore, catalysts should be selected based on the conditions of use. Urethane formation is typically catalyzed by tertiary amines.

Methodology. A hydroxylase-containing compound for obtaining rigid polyurethane foam was synthesized according to the method described in [2].

In our experiment, we used furfural as the aldehyde and diethanolamine as the amine-containing secondary product. The figure below shows a laboratory apparatus designed to obtain a hydroxylase - containing oligomer from diethanolamine and furfural.

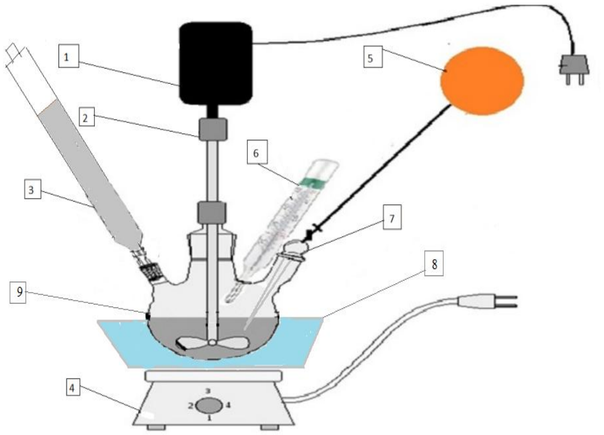

Fig. 1. Laboratory setup for the synthesis of hydroxylase-containing oligomer from diethanolamine and fufural:

1-electric motor; 2-stirrer; 3-separatory funnel with diethanolamine; 4-hot plate; 5-nitrogen ball; 6-thermometer; 7-capillary for introducing nitrogen; 8 - water bath; 9 - 4-neck flask with furfural.

The reaction was carried out in a four-necked flask in bulk at a molar ratio of furfural:diethanolamine = 1:1 mol/mol. Furfural was charged into the flask at room temperature (20 °C), and then, with vigorous stirring, diethanolamine was added dropwise to furfural at such a rate that the temperature of the reaction mixture did not exceed 30 °C. Then, after the diethanolamine was completely added dropwise, the resulting mixture was subjected to heat treatment at 50 °C for 0.5 hour. After heat treatment at 50 °C for 0.5 hour, water was distilled off in a vacuum P res. = 0.8-0.9 kgf/cm^2 at a temperature not exceeding 70 °C. Then the final product was subjected to vacuum distillation at a residual pressure $P_{res.}$ = 1.0-0.9 kgf/ cm^2.

Discussion of results.

In this study, using a synthesized catalyst and varying its ratios, we obtained rigid polyurethane foams with various strength properties. This allowed us to use the synthesized hydroxylase-containing compounds in the production of rigid polyurethane foams, replacing the currently used N,N,N', N'tetraoxypropylethylenediamine (Lapramol-294), with a subsequent reduction in its content in the developed formulation.

During experimental work to produce rigid polyurethane foams, grade PPU-307 polyurethane foam was selected as the standard sample. Five samples of the rigid polyurethane foam we produced were selected, and the molding process parameters and physical and mechanical properties of the rigid polyurethane foams were presented.

Table 1 below presents the technological parameters and physical and mechanical properties of rigid polyurethane foams of five samples.

Table 1.
Comparison of physical and mechanical properties of rigid polyurethane foams

№	Parameters	Compressive strength, MPa	Impact strength, kJ/ m^2	Water absorption, kg/ m^2	Combustibility (fire tube) mass loss, %.
1.	Sample -1	0.35	0.22	0.55	56
2.	Sample 2	0.41	0.23	0.52	55
3.	Sample 3	0.38	0.22	0.52	58

4.	Sample -4	0.41	0.20	0.65	54
5.	Sample -5	0.37	0.25	0.62	57
6.	Standard formulation of grade PPU-307	0.45	0.24	0.42	53.7

In this study, Laprol-373 was left unchanged in the formulation at 70 parts by weight, the amount of Lapramol-294 was varied from 25 to 5 parts by weight, and the amounts of foam regulator (Cap-2a) and water remained unchanged at 1 and 1.5 parts by weight, respectively. The amount of furfurylamine diethanol varied from 5 to 25 parts by weight.

In our previous studies [4-5], we investigated and studied the reaction products of diethanolamine and furfural, and developed optimal formulations for producing rigid polyurethane foams. In this study, we examined the physical and mechanical properties of the resulting rigid polyurethane foams. Four physical properties of rigid polyurethane foam were selected for comparison with certain materials (metals, ceramics, rubber).

Standard scales have been presented for four basic material properties: density, thermal conductivity, Young's modulus (essentially a measure of material rigidity) and compressive strength [6], [7], [8]. The possibility of using solid materials [9] has been demonstrated. Polymer foams, having a low density relative to metals and ceramics, have low thermal conductivity. By varying just one parameter, density, many problematic issues in various industries can be resolved. Low densities have paved the way for the creation of lightweight, rigid components such as sandwich panels [10] and for making large structures portable and accessible for water transport.

Comparing the thermal conductivity of rigid polymers with that of metals reveals that, despite having the same specific gravity, rigid polyurethane foams have lower thermal conductivity than metals. These properties are used in roof insulation, attic insulation, and the production of refrigerated vehicles.

The samples were obtained by replacing part of Lapramol-294 with a synthesized product (Furfuryl minadiethanol) in quantities from 0 to 25 mass parts. The isocyanate index remained unchanged and amounted to 110%.

Comparing the physical and mechanical properties of the obtained samples with the physical and mechanical properties of the materials listed in Table 1 revealed that the density of LPUF is lower than that of metals. This is explained by the presence of pores in the LPUF structure, as well as the lower thermal conductivity of LPUF in relation to metals and other materials. This allows using LPUF as a heat-insulating material. The density of the obtained LPUF varies within the range of 80-88 kg/m^{3,} and the density of metals ranges from 0.47 (lithium) to 22.4 (osmium) kg/m$^{3.}$ Of the above samples, the sample consisting of 10 parts by weight of the synthesized product and 20 parts by weight of Lapramol-294 was selected as acceptable in terms of its physical and mechanical properties.

This choice is explained by the fact that rigid polyurethane foam with the given composition has superior physical and mechanical properties compared to the other four samples, but inferior to metals, hard ceramics, hard polymers, and ceramic foams. However, these disadvantages are minimized during installation and operation of rigid polyurethane foam, and the production process of rigid polyurethane foam does not use expensive freon.

Conclusion.

Based on the conducted research, it can be noted that in obtaining a finished product corresponding in physical and mechanical properties to the standard rigid polyurethane foam grade PPU-307, containing Lapramol-294 in its composition, rigid polyurethane foam was obtained based on the synthesized product by adding 10 parts by weight of the synthesized product and 20 parts by weight of Lapramol-294.

Standard scales for four key material properties —the resulting product—were compared with the standard parameters of PPU-307 polyurethane foam. Furthermore, our formula for producing rigid polyurethane foam eliminates the use of expensive freon, which depletes the ozone layer and leads to environmental disaster.

Based on the data obtained from five samples, sample number 2, in terms of its physical and mechanical properties, corresponds to the physical and mechanical properties of rigid polyurethane foam grade PPU-307, and we selected this sample in accordance with the optimal parameters.

The developed product can replace existing catalysts on an industrial scale and make it possible to obtain products based on local raw materials.

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