Petroleum and Coal

**Article** **Open Access**

# Recycling of Polymer Waste into Plastic Lubricants

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Received November 8, 2021; Accepted March 21, 2022

**Abstract**

A technology for the production of greases from polymeric household waste has been proposed, including the stage of boiling the polymer in a solvent, which is used as a used motor oil SAE10W-40. In the production of greases using this technology, a significant amount of used polymer products is utilized, while the share of waste from low-pressure polyethylene and polypropylene (PP) is, respectively, 20-50% of the mass and 50-75% of the mass. This approach makes it possible to significantly expand the raw material base of the specified technological process and, due to the involvement of relatively cheap raw materials, significantly reduce the cost of finished products. The results of the study of the adhesive properties of the obtained lubricants allow us to give the following recommendations: for lubricants based on low-pressure polyethylene with a polymer: oil ratio of 1: 1, the rational rotation speed was no more than 2850 rpm, with a ratio of 1: 3 - about 3950 rpm and with a ratio of 1 : 5 - up to 5300 rpm; rational rotation speed for lubricants based on PP at a polymer: oil ratio of 1: 1 does not exceed 3600 rpm, at a ratio of 2: 1- 4900 rpm and at a ratio of 3: 1 - 6000 rpm.

***Keywords**: Grease; Waste oil; Polymer waste; Thermal destruction; Adhesive properties; Solvent; Boiling point.*

## 1. Introduction

Polymer waste, represented mainly by used products made of high and low pressure polyethylene, as well as polypropylene (PP), make up the majority of municipal solid waste. The choice of these polymers as raw materials for the production of various goods (packaging materials, containers, disposable tableware, etc.), their wide household, economic and industrial use is due to their high operational properties (strength, chemical inertness, frost resistance, manufacturability, etc.) and the relatively low cost of polymer products. However, nowadays, not all problems of their disposal have been resolved, as a result of which only a small part of such waste is recycled. As a result, millions of tons of polymer materials have accumulated in various dumps and landfills. Due to the high resistance of polymers to degradation in natural conditions (under the influence of solar radiation, heat and moisture) [1], they have a significant negative impact on the environment.

## 2. Research objective

The main factors hampering the disposal of polymer waste in Ukraine are the weak support of this industry from the state, as well as the lack of sorting points for their distribution according to certain types. Based on the experience of the EU countries in the field of behavior with waste in Ukraine, amendments to the Law of Ukraine " Waste" [2] were adopted in 2018, providing for its sorting, which should contribute to the development of technologies for its disposal.

We can single out two main approaches to the disposal of polymer waste implemented on an industrial scale. The first is the secondary use of polymers in the production of various products (mainly for household and industrial purposes) and building compositions. The second involves the processing of polymers to obtain energy resources and meets the provisions set out in the Energy Strategy of Ukraine [3] to minimize energy imports. Let us consider in more detail the technologies corresponding to the more promising second approach.

It is known that the simplest and most widespread method of processing polymeric waste, which does not require its preliminary sorting and allows to obtain energy in the form of heat, is the combustion of polymers in furnaces, which makes it possible to achieve an average heat of combustion per dry mass in the range from 20 to 45 MJ/kg [4]. However, in the process of incineration of polymer waste, toxic substances (hydrogen chloride, nitrogen oxides, cyanide compounds, dioxin) are emitted. Entering the atmosphere, they cause enormous harm to the environment and human health. In this regard, the further development of this method of recycling polymer waste should be accompanied by an improvement in the technological process of combustion of polymers (taking into account the fact that for the decomposition of the resulting toxic compounds it is necessary to provide a furnace temperature of about 1400°C), and also provide for the use of effective flue gas cleaning systems [5].

The processing of polymer waste is more complicated in terms of equipment (in comparison with combustion) using the method of destruction to obtain fuels of different types and individual components. As an example of using this method, we can cite work [6], which presents the results of a study on the creation of an additive to motor fuels by catalytic destruction of polyethylene at atmospheric pressure in the temperature range of 350–400 ° C. Studies on the processing of polyethylene in the presence of an alum inosilicate catalyst to obtain a fraction similar to gasoline are described in the work [7]. Of interest is the technology for the production of motor fuels with high antiknock properties from waste polymers (polyethylene and polypropylene) using thermocatalytic destruction on bentonite and a spent chromium alumina catalyst at temperatures of 380–430°C and atmospheric pressure [8].

Along with the production of motor fuels, technologies for obtaining lubricants from polymer waste are promising, in particular, demanded greases that satisfy such conditions for their use as resistance to aggressive environmental influences, significant loads and high rotation speeds. The use of polymer waste in the manufacture of greases can significantly reduce the cost of the final product and improve its properties in comparison with industrial analogues. To increase the profitability of the process for the production of greases, it is advisable to use as a thickener used polyethylene products that have lost their operational properties [9], and to intensify this process by preliminary grinding such products to a size of 2 × 2 mm, followed by dispersion at temperatures of 150-200°C in a reactor-type apparatus equipped with a mechanical stirrer.

To simplify the technological scheme for obtaining greases, instead of the stage of dispersing the components using a mechanical stirrer, it is proposed to use the stage of boiling the polymer in a hydrocarbon solvent. In this case, the pieces of polymer waste can be larger, which reduces the time for preliminary preparation of the polymer thickener and energy costs for the technological process. In addition, the absence of high-speed rotating elements with a significant mass increases the safety of the production of greases.

When choosing a solvent for the implementation of the proposed technology, it is necessary to take into account that it must ensure the production of greases on an industrial scale, it should not belong to the class of hazardous substances, it must meet the requirements of fire and explosion safety, and have a low cost.

Considering that polymers (polyethylene and polypropylene) are readily soluble at elevated temperatures in petroleum fractions [10], waste SAE 10W-40 motor oil can be used as a solvent. It begins to boil at a temperature of about 220 ° C and meets the requirements described above, as well as the condition that the boiling point of the solvent must not be lower than the melting point of the polymer.

### 3. Results and discussions

Used products from low pressure polyethylene and polypropylene were selected to implement the proposed technology for processing polymer waste into greases. After preliminary (coarse) grinding, the polymer was loaded into a reactor, where the used engine oil was supplied in the ratio of polymer to solvent 1: 1–1: 5 for low pressure polyethylene and 1: 1–3: 1 for polypropylene. Then, the polymer was boiled for 1800–3600 seconds at 240–270 ° C to ensure condensation of the evolved solvent vapors and their return to the process. After cooling the product, it was homogenized (the lubricant was pushed under pressure through an opening of 100 μm), and then the main indicators of the quality of the samples obtained were determined under laboratory conditions (Table 1).

Table 1. Values of indicators for the obtained samples of greases

| Indicator name | Numerical value of indicators for samples | | | | | |
|---|---|---|---|---|---|---|
| | low pressure polyethylene (HDPE) | | | Polypropylene (PP) | | |
| Polymer: oil ratio | 1:1 | 1:3 | 1:5 | 1:1 | 2:1 | 3:1 |
| Class according to NLGI | 5 | 2 | 00 | 1 | 3 | 5 |
| Penetration, 0.1 mm | 165 | 295 | 438 | 312 | 222 | 149 |
| Dropping point, °C | 112 | 108 | 103 | 82 | 128 | 138 |
| Colloidal stability, wt% | 2.0 | 12.8 | 21.0 | 14.85 | 9.06 | 1.5 |
| Evaporation,% mass | 1.94 | 2.55 | 3.43 | 8.22 | 5.72 | 4.00 |
| Solubility: | | | | | | |
| - in water at 100°C | Insoluble | | | | | |
| - in gasoline at 60°C | Soluble | | | | | |

Conducted studies have shown that samples of greases produced by boiling the polymer in waste oil, despite high polymer concentrations (20-50% for low pressure polyethylene and 50-75% for polypropylene), have a higher volatility value compared to greases obtained as a result of mixing the crushed thickener with used oil at 150–200°C [9]. This can be explained by the fact that at a temperature of 240-270°C, the destruction of the oil occurs, accompanied by the release of light hydrocarbon fractions, which are cooled, condensed and returned to the total reaction volume. Since, when determining the volatility, these fractions are removed from a thin layer of lubricant, this leads to a loss of the mass of the lubricant relative to the mass of the original sample.

With a decrease in polymer concentration, the colloidal stability of lubricants deteriorates. So, for samples obtained from low pressure polyethylene, as the polymer concentration decreases from 50 to 20% of the mass, the consistency of the grease changes from grade 5 to zero, and the colloidal stability decreases by 19% of the mass. For samples obtained from polypropylene, as the polymer concentration decreases from 75 to 50% of the mass, there is a change in the consistency of the grease from the 5th to the 1st class and the deterioration of colloidal stability by 13.35% of the mass.

Along with the indicators given in Table 1, the adhesive properties of greases were also determined (Fig. 1, 2), which characterize the high-speed modes of operation of such greases in bearings. For this, grease was applied to the metal plates (layer thickness - 0.1 mm), the sample masses were determined, and the plates were tested in a centrifuge. The adhesion properties corresponded to the rotational speed of the centrifuge rotor, at which 50% of the original mass of the grease remained on the plate (this indicator was evaluated in accordance with the practical recommendations of the bearing manufacturers).

It has been found that among the samples of greases obtained on the basis of low pressure polyethylene, the best adhesion properties are possessed by a sample in which the polymer: oil ratio is 1: 1, while 50% of the initial grease mass corresponds to a rotor speed of 5300 rpm. For a sample with a polymer: oil ratio of 1: 3, this speed decreases to 3950 rpm, and with a 1: 5 ratio, to 2850 rpm, i.e. with a decrease in the polymer concentration, the adhesive properties of the lubricant deteriorate significantly.

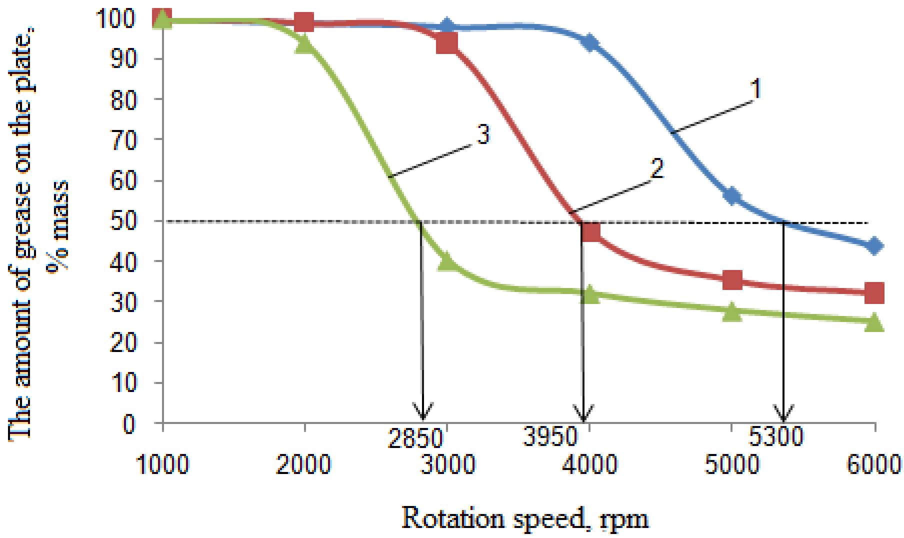


Figure 1.Dependence of the adhesive properties of the low pressure polyethylene grease on rotation speed at polymer: oil ratios 1 : 1 (1), 1 : 3 (2) и 1 : 5 (3)

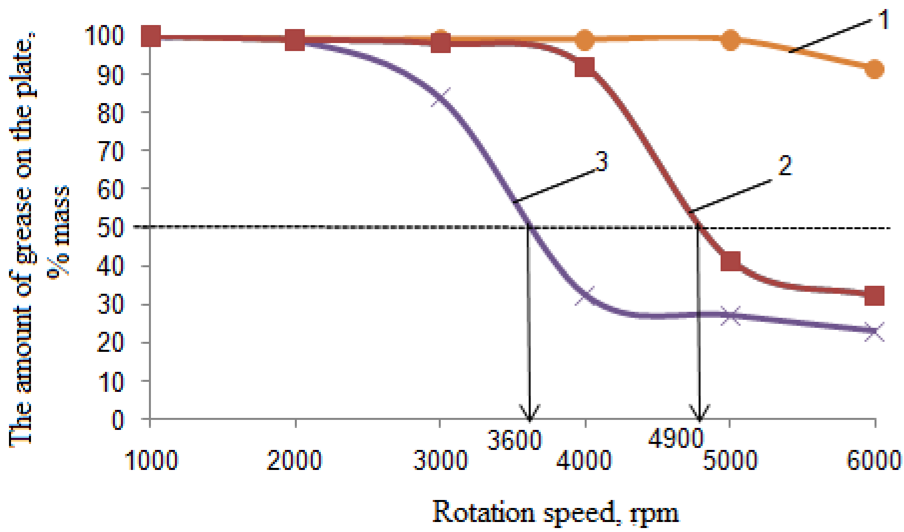


Figure 2.Dependence of the adhesion properties of polypropylene grease on rotation speed at polymer: oil ratios 3 : 1 (1), 2 : 1 (2) и 1 : 1 (3)

A similar picture is observed for samples obtained on the basis of polypropylen. In the investigated range of rotor rotation speeds, only a sample with a polymer to oil ratio of 3: 1 does not reach the limit value of 50% even at 6000 rpm. The lowest rotor speed (3600 rpm) corresponds to a sample with the same polymer to oil ratio. A sample with a ratio of these substances at the level of 2: 1 occupies an intermediate position between samples with a ratio of 3: 1 and 1: 1 in terms of the rotor speed at which 50% of the original mass of the grease is retained.

## 4. Conclusions

Among the existing areas of polymer waste processing, the most promising ones are those that allow the production of relatively cheap fuels and lubricants that can compete in the oil product market with imported foreign counterparts and ensure the energy independence of Ukraine.

The development of the proposed technology, which includes the stage of boiling the polymer in a solvent - used engine oil SAE10W-40, - makes it possible to use a much larger amount of polymers (20-50% polyethylene and 50-75% polypropylene) as raw materials for obtaining greases (20-50% polyethylene and 50-75% polypropylene) than when using traditional technologies for the production of such lubricants (in this case, the proportion of polymers does not exceed 5–7%). This significantly expands the raw material base of the process under study and reduces the cost of finished products (1 kg of polymer costs on average four times less than 1 kg of waste oil).

The greases obtained by the proposed technology in the considered range of concentrations of the polymer thickener have high values of the volatility index. So, for lubricants based on low pressure polyethylene, these values are in the range of 1.94–3.43% of the mass. (depending on the polymer concentration), and for PP-based lubricants - 4–8.22 wt.%, which is explained by the thermal decomposition of solvent hydrocarbons (motor oil) in the temperature range 240–270 ° C. For the same reason, in samples with a minimum content of polymers, a deterioration in the colloidal stability of the lubricant is observed. With a polymer: oil ratio of 1: 5 for low pressure polyethylene, this figure is 21 wt %, and with a polymer: oil ratio of 1: 1 for PP, it is 14.85 wt%.

All the obtained samples of lubricants in the considered range of polymer concentrations have satisfactory adhesion properties, which deteriorate with a decrease in the concentration of polymer in the lubricant, it leads to a change in the consistency of lubricants from hard (NLGI 5) to soft (NLGI 1) or very soft (NLGI 00), which are badly held on a metal surface at high speeds of rotation of the centrifuge rotor.

For lubricants based on low pressure polyethylene with a polymer: oil ratio of 1: 1, the recommended rotation speed does not exceed 2850 rpm; at a ratio of 1: 3, it can reach up to 3950 rpm, and at a ratio of 1: 5 it is up to 5300 rpm. For PP-based greases with a polymer: oil ratio of 1: 1, the recommended rotation speed is no more than 3600 rpm; at a ratio of 2: 1 it can reach 4900 rpm, and at a ratio of 3: 1 it is 6000 rpm or more.

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