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Jolanta DRABIK
Institute for Sustainable Technologies – National Research Institute, Radom
jolanta.drabik@itee.radom.pl
Jolanta IŁOWSKA
The Institute of Heavy Organic Synthesis „Blachownia", Kędzierzyn-Koźle
ilowska.j@icso.com.pl

NON-TOXIC PLASTIC LUBRICANT FOR THE FOOD INDUSTRY

Key words

Base oils, non-toxic plastic lubricants, lubricating properties, oxidising stability.

Abstract

The implementation of mandatory quality management systems in the food industry generates the need to develop lubricating products with appropriate performance properties that are safe for the ecosystem. When designing specialized lubricants, special attention was given to the selection of components, taking into account, in addition to their functional properties, their ecological properties. This article presents a description of a lubricant based on non-toxic ingredients. The main components of the lubricant are synthetic oil and a thickener with certified components. The lubricant performance properties and its oxidising stability were examined.

As a result, a comprehensive lubricant was developed, characterised by performance durability. The designed lubricant has a health clearance certificate of the National Institute of Hygiene and is permitted in the food industry. The

developed product is intended for industrial use as a typical bearing lubricant, wherever it is required to use certified lubricant.

Introduction

The implementation of mandatory quality management systems in the food industry forces the development of the appropriate lubricants with appropriate lubricating properties and non-toxicity [1, 2, 3]. At present, all processing plants producing food, including small and medium-sized enterprises in the food industry adapt their production conditions to the requirements set by the EU directives relating to the safety and hygiene of food production [4] and follow the requirements of machine maintenance in regards to only using certified lubricants [5]. The diversity and specificity of the production in the food industry translates directly into an increased demand for specialized lubricants, which are used wherever there is a risk of food contamination [3].

In addition, the environmental policy pursued by the European Community is committed to the implementation of the certification scheme, which aims to promote those products in the Common Market that have the least adverse impact on the environment [6]. To reduce the harmful effects on the environment of the lubricants, special attention should be paid in their design process to the choice of their components in regards to their non-toxicity and biodegradability, in addition to their performance properties [2, 7].

The increasing demand for specialized lubricating materials for use in machine bearings working in the food industry in a wide range of rotation and loads determined the undertaking of this research in the development of synthetic oil based, non-toxic and biodegradable lubricants [2]. The key issue in the production of non-toxic lubricant is a selection of the main ingredient, which is the oil base. Positive results [2, 9, 10] during the manufacture of plastic lubricants were obtained by using highly refined petroleum oils and synthetic oils from Group IV and V [8] characterised by being less harmful to the ecosystem than other petroleum oils.

The manufacture of lubricants for the food industry included the appropriate requirements for oil bases, thickeners, and additives [9, 10]. The process [11] demonstrated the validity of the application of statistical analysis methods for experimental data in modelling performance properties based on experimental tests results and, in particular, thermal analysis and tribological testing.

In accordance with oil classification of the American Petroleum Institute API [8], which divides oils into five groups depending on their composition, physicochemical properties, and production technology, the selected base oils for the non-toxic plastic lubricants were synthetic oils [2]. In order to produce plastic lubricants with good structural and mechanical stability, and enhanced lubricating properties, a method of in-situ production was developed for manufacturing complex lubricant in a calorimetric reactor [10]. The production of the lubricant using the *in-situ* method consisted in a synthesis of the thickener directly in the base oil and its dispersal in it. Using complex soap as a thickener provides performance enhancement for the lubricant in comparison to the lubricants where simple soap was used as a thickener. Complex thickeners have a very complex structure and usually are in the form of two acids of different chain length and with the type of the introduced action into the soap molecule, which affects the type of the thickener [10, 11].

The aim of the study was to investigate the influence of the composition of the complex thickener on the oxidising stability of lubricants and their lubricating properties determined in boundary and seizure conditions. Achieving this aim required testing for the oxidation of the produced lubricants using thermal analysis methods and friction tests.

1. Materials and test methods

The objects of research were plastic lubricants that were synthesised in a base oil with a complex thickener participation produced by the *in-situ* method with lithium soaps of mono-(MK) and dicarboxylate (DK) acids, with different MK:DK molar ratios [2, 10]. The process consisted in the synthesis of thickener (lithium soaps: 12-hydroxystearic and adipic acids) in oil, which forms the base of the plastic lubricant. Synthetic oil PAO8 – poly-alpha-olefin was used as the base oil. The manufactured lubricants with variable mono-(MK) and dicarboxylate (DK) acids' ratios are indicated as follows: SM A1/0.5 (MK:DK 1:0.5), SM A2/0.6 (MK:DK 1:0.6), SM A3/0.75 (MK DK 1:0.75).

After the plastic lubricant was produced by the in-situ method, based on a complex thickener with varying molar ratios of carboxylic acids, the structures of the produced lubricants were examined using spectral analysis.

Oxidising stability of complex greases was examined using the *Petrooxy* method by determining oxidation induction time. The tests were conducted in isothermal conditions at 140°C and with continuous flow of oxygen.

The parameters used for the basis of the evaluation of lubricating properties were the value of boundary load wear $G_{oz/40}$ and the diameter of the wear trace "d" after an hour test was carried out at a constant load on the node of 3924 N. The obtained value of the wear load (G_{oz}) describes the anti-wear properties of the lubricant in the conditions of boundary lubrication and indicates the stability of the boundary film. The lubricating properties in scuffing was determined by scuffing load P_t and threshold seizing pressure p_{oz} indicating the effectiveness of the lubricant in the conditions of extreme force.

2. Test results

When choosing the oil base made for the complex plastic lubricants, the lubricating properties of the oil were taken into consideration, since they are an essential component of the lubricant (Fig. 1). The lubricating characteristics of the oils from the hydrocarbon group confirmed the highest efficiency in anti-wear performance of the PAO8 oil in boundary lubricating conditions, which was the basis for the selection of this oil as base oil for the production of complex plastic lubricants.

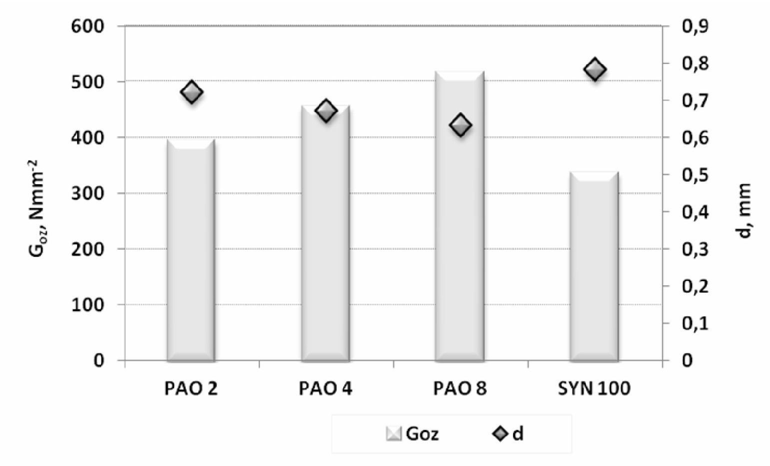


Fig. 1. A comparison of anti-wear properties of synthetic hydrocarbon oil bases – poly-alpha-olefins type (PAO2, PAO4, PAO8, Syn 100)

To monitor the process of in-situ a complex thickener and plastic lubricant production, an infrared spectral analysis method of FT-IR was applied. The FT-IR method is based on the analysis of the characteristic absorption bands of free carboxylic acid (RCOOH) and absorption bands of lithium salts produced in the reaction of the acids with lithium hydroxide (RCOO Li^{+}). The reaction of mono- and dicarboxylate acids with lithium hydroxide results in absorption bands in the 1580 and 1560 cm^{-1} range corresponding to the vibrations of the Group C = O and absorption band ca. 1405 cm^{-1} that come from the C-O group, which was confirmed by the formation of lithium salts (RCOO Li^{+}) by the dicarboxylate acids. The production of complex thickeners was confirmed by the analysis of the change of the intensity of characteristic absorption bands assigned carboxylate ion COO^{-} in the spectral area of 1580–1560 cm^{-1} (Fig. 2).

Based on the analysis, it was found that the structure of the lubricants (SM A1/A2/SM 0.5, 0.6, SM A3/0.75) produced with variable MK:DK ratios show variation in the intensity of absorption bands of carboxylate groups, with a maximum for these bands obtained for the MK:DK molar ratio of 1:0.5. In view of this difference, the impact on the stability of oxidising and tribological characteristics of the manufactured lubricants was assessed.

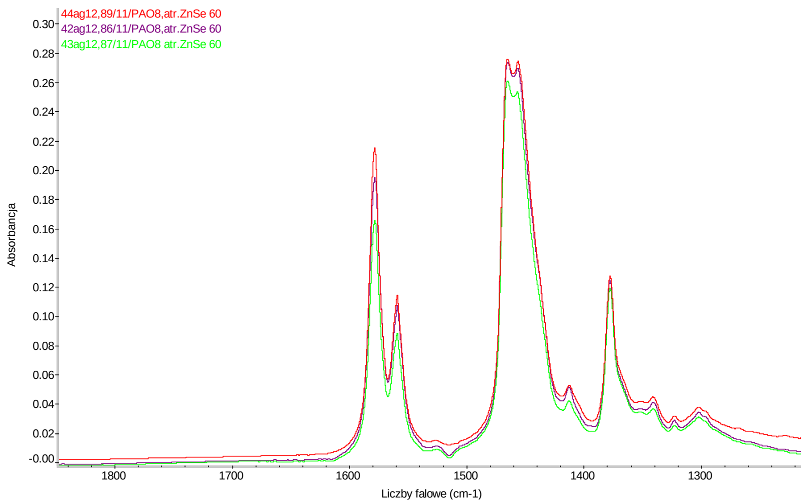


Fig. 2. A fragment of the FT-IR (ATR) spectrum obtained from oil based hydrocarbon lubricant PAO8 with different acid ratios of MK:DK, SM A1/0.5 (1: 0.5), SM A2/0.6 (1-0.6), SM (A3)/0.75 (0.75-1)

The stability of oxidation in the lubricants was assessed on the basis of accelerated oxidation test by the Pertooxy method, by determining, based on the obtained graphs, the pressure drop as a function of oxidation time (Fig. 3a) in the time of oxidation induction (Fig. 3b), which indicates the resistance to the process of oxidation of the tested lubricants.

a) b)

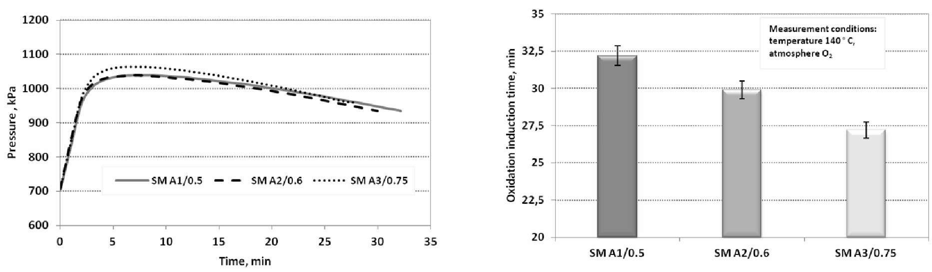


Fig. 3. The influence of thickener component ratios (MK:DK) on the stability of the oxidation of complex plastic lubricants (SM A1/A2/SM 0.5, 0.6, SM A3/0.75) using the Petrooxy method: a) pressure drop graph as a function of time of oxidation, b) oxidation induction time

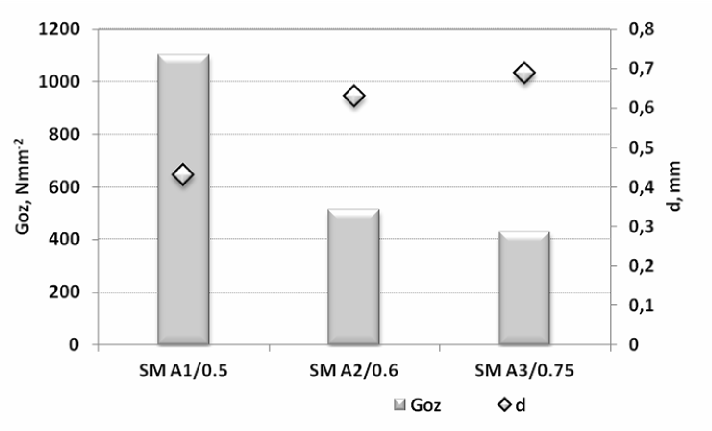
The conducted experiments indicate that the SM A1/5 lubricant with the lowest dicarboxylic acid content in the complex thickener (1–0.5) is characterized by the highest oxidising stability, which indicates its best resistance to oxidation processes compared to other lubricants. The content of the dicarboxylic acid DK in the thickener has a significant impact on the effect of slowing down the oxidation process; in this case, the lower its contents, the longer oxidation induction time was observed.

In tribological experiments, the effectiveness of the anti-wear properties of the manufactured plastic lubricants was tested by specifying the maximum wear load (Fig. 4) and anti-seizing properties in scoring conditions (Fig. 5).

During the wear test, a reduction was observed in the resistance to wear of a steel friction node lubricated with the SM A3/0.75 complex lubricant, manufactured based on the thickener with the maximum content of dicarboxylic acid, which resulted in a significant reduction in the maximum wear load (Figures 4a, 4d).

When the contents of this acid in the thickener were reduced, the obtained lubricant SM A1/0.5 produced a more stable boundary layer. As a result, the resistance to wear doubled in the friction node (Figs. 4a, 4b).

a)



b)

MK:DK 1:0.5

c)

MK:DK 1:0.6

d)

MK:DK 1:0.75

Fig. 4. The influence of molar ratio of carboxyl acids MK:DK in the thickener on the maximum wear load Goz and diameter of a the wear trace in a given complex lubrication composition. Optical microscope image of friction traces on a ball for the lubrication composition: b) SM A1/5, c) SM A2/0.6, d) SM A3/0.75

The test conducted in seizing conditions confirmed the effect of the MK:DK ratio on the course of changes in friction moment as a function of the load increase (Fig. 5). Depending on the content of dicarboxylic acid DK in the thickener, it was observed that each of the tested lubricants shows a different course of the frictional moment, which in turn leads to seizing in different conditions.

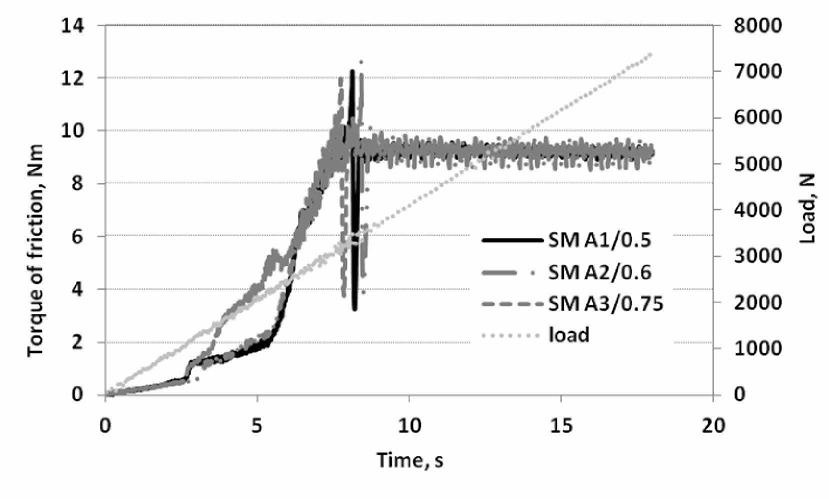


Fig. 5. Changes in the friction moment with a linearly increasing load for plastic lubricants SM A1/A2/SM 0.5, 0.6, SM A3/0.75

Based on the results obtained under the seizing conditions, it can be concluded that the boundary layer created with lubricant SM A1/0.5 and SM A2/0.6 lasts longer than in the case of lubricant SM A3/0.75. In the case of SM A3/0.75 lubricant, a large increase was observed in the frictional moment after crossing the seizing load threshold, while at the same time, the diameter of the scar increased, which indicates the loss of the lubricating properties of the tested lubricant. However, in SM A1/0.5 and SM A2/0.6 lubricants containing less dicarboxylic acid in the complex thickener, the resistance of the node to seizing clearly increases, which indicates an increase load capacity of the lubricating film. After analysing the results, it was concluded that the molar ratio of mono- and dicarboxylic acids, used in the manufacture of a thickener complex significantly affects the evaluated properties.

Conclusions

The production of the lubricant using the *in-situ* method consisted in a synthesis of the thickener directly in the base oil and its dispersion in it. Physicochemical and lubricant properties were modified by the selection of the components that make up the complex thickener.

The research using methods of thermal analysis confirmed the resistance of complex lubricant to the oxidation process. The friction tests have confirmed a significant impact of the molar ratio of mono-and dicarboxylic acids (MK:DK) in the thickener on the anti-wear and antiseizing effectiveness of complex lubricants.

Plastic lubricants for machines and equipment used in the food industry should provide the required level of performance properties, while meeting the requirements of safety and health for food production. The development of a complex lubricant based on non-toxic components guaranteed producing a lubricant that meets the requirements of the food industry, while meeting performance requirements. The designed lubricant has a health clearance certificate of the National Institute of Hygiene HŻ/D/1192/2013 and is permitted for industrial use as a typical bearing lubricant, wherever it is required to use a certified lubricant.

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Nietoksyczny smar plastyczny dla przemysłu spożywczego

Słowa kluczowe

Oleje bazowe, nietoksyczne smary plastyczne, właściwości smarne, stabilność oksydacyjna.

Streszczenie

Wprowadzanie w przemyśle spożywczym obligatoryjnych systemów zarządzania jakością generuje potrzebę opracowania materiałów smarowych o odpowiednich właściwościach eksploatacyjnych oraz bezpiecznych dla ekosystemu. Podczas komponowania specjalistycznych materiałów smarowych zwrócono szczególną uwagę na dobór komponentów, uwzględniając oprócz ich właściwości funkcjonalnych również właściwości ekologiczne. W artykule przedstawiono charakterystykę smaru plastycznego wytworzonego na bazie nietoksycznych składników. Głównymi składnikami smaru są: olej syntetyczny oraz atestowane komponenty zagęszczacza. Zbadano i oceniono właściwości smarne oraz stabilność oksydacyjną wytworzonego smaru.

W efekcie opracowano kompleksowy smar plastyczny charakteryzujący się wysoką trwałością użytkową. Wytworzony smar posiada atest Jakości Zdrowotnej PZH, dopuszczający stosowanie go w przemyśle spożywczym. Opracowany produkt przeznaczony jest do zastosowań przemysłowych jako typowy smar łożyskowy wszędzie tam, gdzie wymagane jest stosowanie certyfikowanych smarów plastycznych.