https://www.imo.org/en/OurWork /Environment/Pages/IMO-Strategy-on-reduction-of-GHG-emissions-from-ships.aspx . – 04.07.2023.

2. ANNEX 11. Resolution MEPC.304(72) Initial IMO strategy on reduction of GHG emissions from ships, International Maritime Organization, URL: https://wwwcdn.imo.org/ localresources/en/KnowledgeCentre/IndexofIMOResolutions/MEPCDocuments/MEPC.304(72).pdf (date of access: 04.07.2023).

3. Minchev D. Marine Diesel Engines Operating Cycle Simulation for Diagnostics Issues / D. Minchev, R. Varbanets, N. Aleksandrovskaya, L. Pisintsaly // Acta Polytechnica.-2021.-vol. 3, №61.- P. 428–440. doi:10.14311/AP.2021.61.0435.

4. Minchev, D. Blitz-PRO User's manual [Electronic resource] / D. Minchev. – Access mode: http://blitzpro.zeddmalam.com/application/index/signin – 04.07.2023.

5. Yeryganov O. Features of the fastest pressure growth point during compression stroke/ O.Yeryganov, R. Varbanets // Diagnostyka.- 2018.-vol. 19, №2.- P. 71-76. doi:10.29354/diag/89729.

6. Neumann S. Vibrodiagnostics of marine diesel engines in IMES GmbH systems/ S. Neumann, R. Varbanets, D. Minchev, V. Malchevsky, V. Zalozh // Ships and Offshore Structures.-2022.-P.1-12. doi: 10.1080/17445302.2022.2128558.

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CORRELATION ANALYSIS OF PHYSICOCHEMICAL, RHEOLOGICAL AND TRIBOLOGICAL PROPERTIES OF USED LUBRICANTS

Literature introduction

Nowadays, with the development of technology, the importance of protecting machines from undesired effects is increasing. One such factor is friction, which results in tribological wear. Particularly exposed to this effect are kinematic pairs, between which there is a precise fit. It goes without saying, therefore, that a car engine, for example, must be provided with adequate lubrication to prevent it from wearing out too quickly. Various types of engine oils are used to protect the engine unit. Each is characterised by slightly different properties, so that the user can match the lubricant to the engine requirements as closely as possible.

The basic parameter determining the properties of lubricants is viscosity. The value of this parameter varies during the service process. Factors such as oxidation, which increases viscosity, or dilution of the lubricant with fuel or refrigerant, which results in a decrease in viscosity, contribute to this [1]. Manufacturers of engine oils have adapted the classification of lubricants according to SAE, however, as research has shown, despite the same designation, they show different viscosity characteristics in a range not covered by catalogue data [2].

Another parameter that varies during the life of the engine oil is the amount of water it contains. It depends on the driving style - whether it is urban, mixed or the vehicle is used on long-distance journeys. Starting the engine at low temperatures and driving short distances contributes to an increase in water content, as the drive unit is not warmed up sufficiently to evaporate this water [3]. Due to the different nature of the molecular structure of water and lubricant, this results in an emulsion that exhibits poorer protective properties. The presence of water in the powertrain carries additional risks, i.e. the formation of corrosion [4].

Another parameter describing the properties of lubricants is density. It is sensitive to the content of wear products in the lubricant, which gives a basis for drawing conclusions about the effect of the condition of the engine unit on the lubricant. An approach to considering engine oils with respect to viscosity, water content and density was demonstrated in their work by Landowski and Baran [5].

In terms of analysing the properties of lubricants, researchers are also interested in referring to laboratory tests using a four-ball apparatus. As the literature review shows, despite the same viscosity class designation, lubricants distributed by different manufacturers show different lubricating properties [6]. Therefore, supplementing physicochemical and rheological tests performed on a group of collected engine oils with tribological tests is justified.

Comprehensive tests with engine oils are conducted to obtain data for developing an assessment of the condition of the lubricant that has been subjected to the operating process. The paper consists of several sections including a literature review, a description of the research methods used together with the results obtained and the conclusions drawn from the research.

Research methodology

The test subjects were samples of engine oils in service. Each sample was described by its viscosity class and the name of the manufacturer by which it was produced. Additional information assigned to the individual samples was: oil mileage [km], type of fuel used to power the engine, engine displacement [dm3], engine nominal power [kW], car mileage at oil drain [km]. Based on the collected data, each sample was assigned a dependent sample belonging to the control group containing fresh oils.

Laboratory tests were carried out using common test methods described in the standards. Viscosity was determined using a Mini AV-X apparatus. The measurement temperature was 40°C (EN ISO 3104:1996) and 75°C (reference temperature for tribological tests). For the measurement of water content, samples with a volume of $1cm^3$ were fed into the Cou-Lo Aquamax KF apparatus (EN ISO 12937:2000). The density of the samples was determined at 15°C (EN ISO 3675:1998) and 75°C (reference temperature relative to tribological tests) using an areometer with a range of 0.8-1.0 g-ml-1.

The tests using the four-ball apparatus were based on EN ISO 20623:2018. A single test run was 3600s at a rotational spindle speed of 1200rpm, and a force of 392N was applied to the kinematic node. The initial temperature of the lubricant was 75°C. After three test runs for each sample, microscopic inspection of the balls comprising the kinematic node was carried out.

Results

The data obtained as a result of the research was placed in a table, which was implemented in Statistica™. Then, using the correlation matrix, correlation graphs were plotted for each variable.

The result of the analysis found a correlation of r=0.7898 and r=0.7964 for the density determination at 15°C and 75°C and the fresh/used oil determination, respectively. The correlation plot showed a decreasing characteristic, indicating that fresh oils have a lower density compared to the density of used oils.

Another correlation with a value of r=0.8306 indicates a relationship between the fresh/used oil designation and the wear diameter measured on the balls comprising the kinematic node. The characteristics of the correlation plot are also decreasing, indicating that the wear marks of fresh oil are smaller than those of used oil.

As the analysis shows, the size of the wear marks was also influenced by the density values read for the individual samples at 15°C and 75°C. The correlation values r were r=0.83914 and r=84598, respectively. Both correlation plots have an increasing characteristic, which indicates that as the density of the lubricant tested increases, the diameter of the wear marks measured on the balls of the kinematic joint also increases.

For the other parameter combinations of the lubricants tested, no significant correlation was found between them.

Conclusions

The tests and analyses carried out made it possible to determine the correlation between the properties of the lubricants tested. Despite the expected correlation between viscosity values and tribological tests, it was not observed in the selected test group. A similar result was obtained for water content. The only correlation between physico-chemical and tribological tests was observed in the density - wear diameter comparison.

Another conclusion of the study is that fresh oils protect the kinematic node better than oils already in service. This underlines the importance of timely lubricant replacement in power units.

Literature

1. Landowski B, Baran M. Analysis of changes in the value of selected lubricant characteristics during use. 18th Int Conf Diagnostics of Machines and Vehicles, Bydgoszcz, Poland. 2019.
2. Ryniewicz A, Bojko Ł, Madej T. Estimation of viscosity engine oils using rotational rheometer. SJSUTST. 2014;83:225-234.
3. Jakóbiec J, Budzik G. Agents influencing degree of engine oil during exploitation. Arch Automot Eng. 2007. 3:209-216.
4. Fatima N, Minami I, Holmgren A, Marklun P, Berglund K, Larsson R. Influence of water on the tribological properties of zinc dialkyl-dithiophosphate and over-based calcium sulphonate additives in wet clutch contacts. Tribol Int. 2015;87:113-120.
5. Landowski B, Baran M. Analysys of selected results of engine oil tests. 18th Int Conf Diagnostics of Machines and Vehicles, Bydgoszcz, Poland. 2019.
6. Farhanah AN, Bahak MZ. Engine oil wear resistance. J Tribol. 2014; https://jurnaltribologi.mytribos.org/v4/JT-V4-10-20.pdf - available online 15.05.2023. https://doi.org/10.1016/j.rser.2016.08.041

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ПИТАННЯ ЧИСЕЛЬНОГО МОДЕЛЮВАННЯ ПОШИРЕННЯ ЗАБРУДНЕНЬ З ТОЧКИ ЗОРУ ВИКОРИСТАННЯ ГІС ТЕХНОЛОГІЙ

Забруднення повітря у міському середовищі на сьогоднішній день становить головну загрозу для мешканців великих міст. Одним із основних джерел цього забруднення є автотранспорт. Повітря над великими мегаполісами містить у декілька разів більше аерозолів і в кілька разів більше шкідливих газів порівняно з регіонами без інтенсивного автотранспорту. До 70% усіх шкідливих викидів, які спричиняють це забруднення, припадає на автомобільний транспорт.

Особливо небезпечною є та обставина, що джерела викидів знаходяться на рівні очей людей, оскільки автомобілі їздять по дорогах, розташованих на рівні мешканців міста. Велика концентрація автотранспорту в 3беспосередній близькості від житлових будинків, освітніх закладів та лікарень створює основну проблему для поширення забруднень від автотранспорту.

Ця проблема вимагає негайного уваги та прийняття дієвих заходів для зменшення викидів та поліпшення якості повітря в містах, що є ключовим завданням для покращення якості життя мешканців та збереження навколишнього середовища.

Побудова області за допомогою ГІС

На першому етапі підготовки тривимірної моделі місцевості з урахуванням рельєфу та споруд були використані данні з відкритих джерел