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INVESTIGATION OF PROPERTIES OF LUBRICANTS IN LOCOMOTIVE DIESELS

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Abstract. This paper describes experimental investigation of lubricant properties used in locomotive engines. The workbench for experimental investigation is described, which presented theoretical background and technique of the experiment. The results are analyzed and presented graphically. Their interpretation shows the direction for further investigation. Final conclusions of the results are made.

Keywords: lubrication quality, quality criteria, optical density.

1. Introduction

A big number of diesel locomotives is used in Lithuanian Railroad Company for a long period and their main part is inherited from the former Soviet Union. The park of these ones in Lithuania mainly consists of a single and double unit of linear locomotives M62, the engine lubricant of which was investigated.

The amount of oil in such engine crankcase is big enough (about 800 l) [1] and the possibility to save at least a few percents of such amount of oil seems very attractive. Bad quality of a lubricant causes serious damage of engine and its parts. This can be illustrated as a broken cylinder sleeve [2].

Bad lubrication quality causes few parameters – high consumption of oil during the period between technical maintenance, obtainable blue-smoke output in case of running a hot engine and dark color of used oil even if the first maintaining between oil changes.

Considering from the other point of view such indication can be caused by a bad engine – from design to exploiting quality.

The known investigation [3] of lubricants in railroad transport, covering traffic safety and lifetime of exploiting materials, shows the actuality of the presented paper.

Nevertheless the engine of locomotives M62 was designed in 1950 and it has prototypes of two-stroke diesel engines like “Detroit Diesel”. They are used in our days in the Western countries. It is also known that the age of locomotives reaches 20 and more years with the mileage about few millions of kilometers.

According to [4], the quality of a lubricant is a big complex of properties, having no direct mathematical expression. Indirectly the indication of a bad lubricant quality can be obtained [4] as the increased consumption of a lubricant in comparison with a fresh lubricant, noisier engine performance, a more difficult start and so on.

The amount of a lubricant used in such unit is huge and the cost of technical maintenance of such units is connected with significant expenses. A long period between oil changes which approximately equals to one year, tells about the quality of lubrication inside a diesel engine [5]. Often the addition of oil during a long period between technical maintenance provokes the mentioned investigation.

2. Formulation of investigation

The purpose of such investigation is to define real lifetime of an engine lubricant as a function of real locomotive engine wearing degree and mileage which can not be the same.The quality of such lubricants is not definable directly, so quality criteria were created, including some physical properties of a lubricant. The first indication is the amount of pollution in a lubricant. Direct detecting of the amount of grease in oil is very sophisticated and costly. The amount of grease in a lubricant causes the reduction of optical density, which can be used as a substitution of grease amount in a lubricant. Experimentally this property is determined as optical density in centigrade degrees from initial optical density of a pure (new) lubricant. The second important criteria is coefficient of friction f_s, which represents real set of properties of the investigated lubricant. So, it can be expressed as:

$$Q = f\begin{cases} D = D(ml) \\ F_s = F(ml) \end{cases},$$

where Q – relative estimated quality, D – optical density of lubricant; F_s – coefficient of friction of lubricant film; *ml* – mileage of locomotive, in km.

Quality criteria of a lubricant are non-dimensional and valid only for one kind of an engine lubricant. When one of quality criteria violates a limit, the total value of criteria becomes negative, which means "out-of-range".

The mentioned criteria can be created only on the basis of a huge amount of investigation. This is the first step to create objective indication enabling to detect a limit, from which it is needed to change oil instead of using a mileage limit.

The other desired feature is to define a lack of additives in a lubricant during a mileage between technical maintenances. This can form a special additional oil portion, compensating a lack of additives in oil with the purpose to save oil lifetime.

The results of such investigation will be used for further project as the data of lubricant quality improvement using special additives and extra filtering.

3. Technique of investigation

Experimental investigation was performed in two steps: the first to define the dependency of optical density on mileage and the second – to define the dependency of a coefficient of friction on locomotive age and mileage.

Samples of lubricants were taken from all locomotives M62 during technical maintenance TP-3 with the mileage between them approximately 8000 km. Samples were taken during three months and covered all the park of linear locomotives. Every sample includes 500 g of a lubricant and was taken from a diesel crankcase by soaking through a hose from the middle of oil can. All the samples were numbered and included into the experimental journal in order to purify experimental results. Such order gives the possibility to create experimental series as quasi-experimental data. Afterwards the results of measuring were sorted and mean values of the same argument were taken for further investigation.

Optical density of a lubricant was measured using special equipment in relative units, when 0 represents ideal optical transparency. It must be stated, that the term "optical density" here is used only as the reduction of the amount of light, passing through the tested material, what is different from the term used in physics where it means the influence of refraction angle of a light beam.

In densitometer measuring area one drop of oil was placed and in order to keep equal thickness of a lubricant film two glasses were used with calibrated distance between glasses (Fig 1). In our case we used calibrated distance of 0,15 mm. Optical density was measured twice and the mean of values was taken as a result.

At the beginning two empty glasses with air in place of oil drop were measured. Afterwards a drop of pure

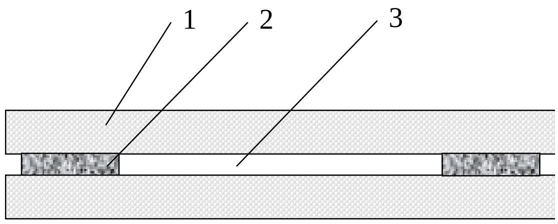

Fig 1. Cell for measuring optical density of a lubricant: 1 – glass, 2 – calibrated distance, 3 – measured lubricant

unused lubricant M14V2 was placed between glasses and measured. Difference between results will give optical density of pure oil.

Afterwards the samples of used oil were measured. All used oil samples were placed quietly to settle some biggest particles of oil pollution.

The difference between the optical density of pure oil and used oil gives the indication of pollution amount in used oil. Then the results got after the processing are presented graphically in result section.

Optical density was measured using a special digital densitometer Mac Bet TR-927.

All measurements were performed with the accuracy of 3 digits, but for the evaluation only two were used.

A coefficient of friction was measured using modified friction-wearing machine SMC-2 (Fig 2). Modification of a machine allows to take friction force value from a sensor on the shaft and then to transmit it via cable to transducer which is mounted in a computer as ISA standard card. This transducer transforms the analog signal into a digital and it can be saved with prescribed time step in a computer file. This information was used for further processing.

Tests to define coefficients of friction were performed on friction pair shaft – pad (Fig 3), which is closest to real situation in crankshaft - bearing friction pair.

One test takes 200 g of oil and is sufficient for two

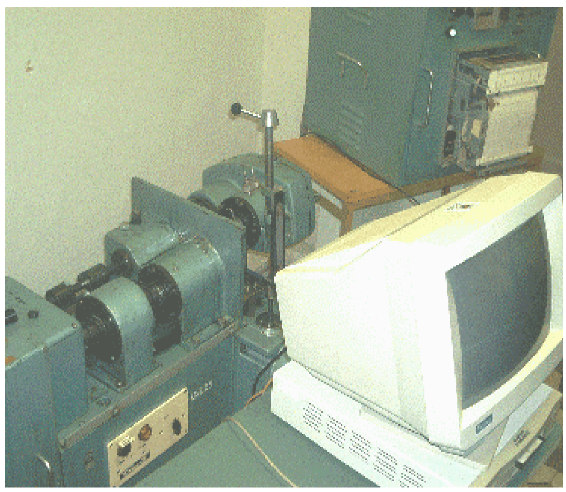

Fig. 2. Friction-wearing machine SMC-2

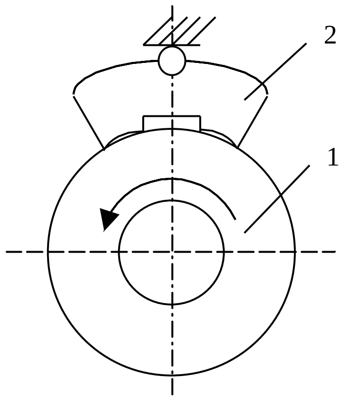

Fig. 3. Friction pair shaft – pad: 1 – rotating shaft, 2 – friction pad.

tests of one portion. Every test is performed on a new portion of oil, because a lubricant became much more polluted after the test.

All the surfaces of friction pair are made of modified cast iron, their roughness R_z = 40, hardness – 40 HRC. Test duration is 180 seconds, pressing force is 400 N.

The results of such measuring are expressed as torque on rotating shaft into a computer file. Torque values at every time moment are accumulated and used afterwards to calculate a coefficient of friction value. In these calculations arithmetical mean of all values is taken as a friction force.

Tests on a friction machine were performed twice.

4. Results

The results of the first test can be seen as the change of optical density of a lubricant from locomotive mileage (Fig 4), measured using proposed technique.

Optical densities are presented as graph (Fig 4), where points show real optical densities of lubricant dependency from locomotive mileage. Experimental results were approximated by 2nd order polynomial as trend line with 95 % probability of distribution.

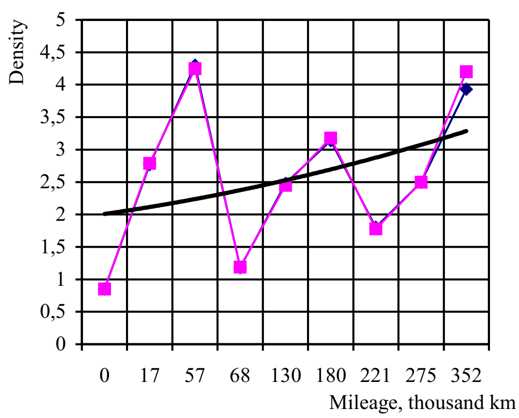

Fig 4. Optical densities of samples: 1st is a fresh lubricant

Regression equation of such dependency can be expressed as $y = 0{,}0075x^2 + 0{,}085x + 1{,}9152$, so it is evident that optical tendency increases when mileage of locomotive increases, it means that the more mileage of a locomotive, the more pollution in a lubricant.

The character of a trend line shows that the increase of mileage of a locomotive makes the quality of a lubricant worse. Experimental data have significant distribution of values around a trend line, therefore to smooth the result output it is needed to perform more tests. Also it can be stated that optical density depends on more factors, that were assumed in the theoretical background of the experiment.

The results of a coefficient of friction dependency on locomotive mileage (Fig 5) and locomotive age (Fig 6) are presented below.

The dependency of a coefficient of friction on locomotive mileage has an increasing character and a regression equation can be expressed as $y = 2\text{E-}05x^2 - 5\text{E-}05x + 0{,}0218$, which evidently shows the increasing character of dependency on mileage. Also it can be stated that a

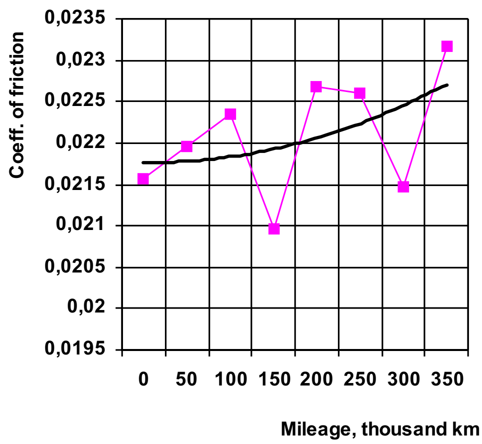

Fig 5. Dependency of coefficient of friction from locomotive mileage

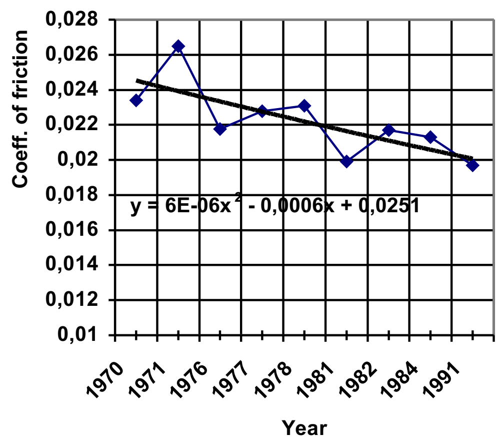

Fig 6. Dependency of a coefficient of friction on locomotive age

coefficient of friction can reach the value which does not allow to use a lubricant longer, but some indirect indications can show the limit of oil use.

In series of experimental investigation using a higher pressing force (up to 800 N) lubricant properties look worse and in some cases friction comes into dry regime a lubricant film became interrupted.

The dependency of a coefficient of friction on locomotive age is a specifying quality of diesel engines. The curve of a coefficient of friction is inclined, so the tendency of a lubricant quality to decrease due to locomotive age is evident. Trend line in Fig 6, described as the equation of regression $y = 6E–06x^2 – 0,0006x + 0,0251$, states about quasi –linear character of property change.

The presented results prove evident quality loss in older locomotive engines and big loss of efficiency of a lubricant during the period between technical maintenances.

5. Conclusions

The results of the performed investigation evidently show a big possibility to improve the existing situation with locomotive engine lubricants. The improvement of lubricant quality at the end of lifetime period of a lubricant and the reduction of use of materials during exploitation can be done.

Shortly some conclusions can be made:

1. The quality of a locomotive lubricant at the end of its use is below a reasonable level.

2. The influence of age of locomotives on lubricant quality is statistically proven and shows the unsufficient level of reparation or exploitation.

3. The amount of pollution particles in a lubricant points to weak efficiency of lubricant filtering.

The research of lubricant properties revealed a lot of problems in locomotive engine lubrication, so further investigation is needed to detect more dependencies in lubricant quality and to create technique to improve them.

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