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Research paper

Study on the Prospects of Use the Group D Engine Oil in Locomotive Diesel Engines

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Abstract

It was suggested to use group D engine oil with advanced properties instead of group V and G engine oils, which are used in locomotive diesel engines today, to improve the performance of the Ukrainian locomotive fleet of railways.
A series of comparative laboratory studies of these oil groups was conducted to substantiate this suggestion which proved better lubrication and tribological performance of group D engine oil and allowed its performance tests.
Tests conducted on diesel 5D49 for mileage of more then 100,000 km have demonstrated the advantages of group D oils, such as more stable viscosity, neutralizing ,washing and other properties. Studies on the four-ball wear test machine proved better anti-wear, anti-scoring and anti-friction properties of group D engine oil, which appear even after the continuous use of oils in locomotive diesels. Decrease in burning loss of engine oil was recorded, resulting in the decrease of oil fuel consumption for group D by 30-60% vs. the group G oil.
According to the results of performance tests, group D engine oil has been recommended for the use in 5D49 locomotive diesels and some advice on its future implementation have been provided.

Keywords: *engine oil; locomotive diesel; performance tests.*

1. Introduction

Engine oil is an operating material with the functions of friction and wear protection of the engine parts, heat elimination, clearance sealing, corrosion protection, deposit prevention, etc. for internal combustion engines. Such functions are also quite important for locomotive engines, especially considering their specificity of operation, such as a long idle working in heating mode and supporting an operating temperature of heat carriers, significant relative operating time of diesel in transition modes, relatively low capacity utilization rate, operation in a wide range of changes of the environmental conditions, primarily, ambient temperature [1].Besides, the deterioration of the Ukrainian railway rolling stock and not always adequate lubrication performance of diesel fuel and engine oil, especially after the long-term storage in stock, should be taken into account.

1.1. Analysis of the Current Status of the Issue

Nowadays, M-14-G2TS and M-14-V2 engine oils are mainly used at the Ukrainian Railway. Taking into account the wear degree of the Ukrainian railway rolling stock [2], these oils, which were developed back in 1970s - 1990s, just fail to function effectively enough [3].Therefore the issue of using the engine oil with better lubrication and tribological characteristics in locomotive engines is becoming relevant. One of the steps in this respect may be using M-14-D2 instead of M-14-G2TsS engine oil in D49 locomotive diesels. This oil is produced in Ukraine, in particular, by Agrinol company (Berdyansk).

1.2. Objective and Tasks of the Study

A series of studies should be conducted to determine the advantages of this engine oil vs. those being used now in terms of its physicochemical and tribilogical properties, and performance characteristics of locomotive engines to substantiate the feasibility of use of Agrinol M-14-D2 engine oil. For this purpose, the oil was studied in the laboratory and under the actual operating conditions of diesel locomotives under the supervision of specialists of the locomotive departments of the Ukrainian Railways and the Branch Lubrication Research Laboratory (BLRL) of the Ukrainian State University of Railway Transport.

2. Main Body

Comparative studies of M-14-V2, M-14-G2TsS and Agrinol M-14-D2 engine oils in the laboratory conditions have revealed the following:

- all studied engine oils have lubrication characteristics which comply with their applicable norms and specifications;
- some lubrication characteristics of group D engine oils actually exceed those of groups V and G, such as viscosity index by 8-15%, alkali number by 1.5-2.8 times, flash point by 6-11%, and content of active elements by 1.6-3.1 times;
- anti-wear characteristics determined using the SMTS-2 friction machine according to the classic “roller-roller” and “roller-shoe” procedures [4], are better in group D engine oil vs. group V engine oil by average 2.5-2.8%, and vs. group G engine oil by 1.7-2%;

- lubrication properties of Agrinol M-14-D2 oil on the four-ball friction machine (FBM) [4] are better than those of M-14-V2 engine oil, on average, by 12.6% and of M-14-G2TsS by 5.7%.

Positive results of the laboratory studies allowed passing to the next phase of implementation of Agrinol M-14-D2 engine oil – operational tests. They were carried out in Osnova locomotive depot of the Southern Railway on 2TE116 locomotives in the actual conditions of operation of locomotives in freight traffic according to the test programme and methodology developed by the specialists of the BLRL.

During the routine third-order repair of locomotives in the depot (PR-3), the diesel engine of section A of the locomotive was filled with the researched engine oil Agrinol M-14-D2, while the diesel engines of section B were filled up with conventional M-14-G2TsS oil. After performing all PR-3 procedures and preparing the locomotives for operation, they were tested until at least one of the quality indicators of D2 engine oil reached the "rejection" value, for which purpose the properties of the engine oil were monitored from time to time. Lubrication characteristics of the engine oil, which are "rejection" criteria according to the current instruction [5], such as flash point, viscosity, contamination of oil with water, alkaline number were studies. In addition, the oil density, its viscosity index, sulphated ash content, its trace elements content, as well as the tribological properties of the engine oil were studied on the four-ball friction machine.

Samples of engine oils were taken for testing their properties from the diesel engines of both sections at each third-order maintenance (TO-3) and first-order routine repair (PR-1), that is approximately every 10 thousand km of locomotive run [6], which for modes of locomotives operation in Osnova depot is one to one and a half months.

During the operational tests, the locomotives were operated in the regular mode with maintenance and routine repairs in accordance with the Regulation [6]. Studies began on three 2TE116 locomotives (No.1195, No. 1476 and No.1488), but they have been fully completed only on two of them. In one locomotive (No.1488), group D engine oil reached the "rejection" value of "water content" after about 60 thousand km, due to a crack in a cylinder head through which water leaked into the engine lubrication system from the cooling system. Before the "rejection" value was reached, all the properties of group D engine oil were at a high level, and the actual cause of water intrusion into the oil is not related to its performance characteristics. Therefore, the results of tests on this locomotive were recognized as positive by the commission. Two other locomotives, when the engine oil reached the "rejection" values, had run 121,000 km (No. 1195, hereinafter diesel locomotive No. 1) and 102,000 km (No. 1476, hereinafter locomotive No.2) from the beginning of the tests, which quite complies with the test programme and methodology, and therefore only the results of studies on these two locomotives are considered.

During the tests, 12 engine oil samples were taken in accordance to the mileage of locomotive No. 1, and 10 engine oil samples were taken from locomotive No. 2 without taking into account so-called zero "fresh" oil samples, which were taken before filing the locomotive. Meanwhile, D2 engine oil was changed to the fresh engine oil at the mileage of about 65 thousand km in section A of locomotive No. 2, due to water leakage through a crack in a cylinders head.

The study of the kinematic viscosity of engine oil samples from both sections of both locomotives according to ISO 3104: 1994 [7] showed that during the tests it never exceeded the limits of 11.5-16.5 mm2/s established by the instruction [5]. Although viscosity varied constantly to certain extent, the nature of its change in group D and group G engine oils was identical, while the difference between their values within the entire test period was approximately 3 to 8% (more in group D engine oil). The viscosity values of both oils have been constantly adjusted by adding oil because of its burning loss.

Such parameter as viscosity index is important from the point of view of the stability of the viscosity characteristics of the engine oil under different temperature conditions of operation. Its studies according to ISO 2909: 2002 [8] showed (Figure 1 (hereinafter Agrinol M-14-D2 engine oil is referred to as D2 and M-14-G2TsS engine oil as G2)) that during the tests, even though it varies within quite a wide range, it is almost always higher in Agrinol M-14-D2 than in M-14-G2TsS engine oil, which suggests better viscous and temperature characteristics of group D engine oil. On average, during the test, the viscosity index of group D engine oil exceeded the similar value of group G engine oil by about 10 units. Sharp changes in the value of the viscosity index of oils between the samples are again associated with constant refilling of the engine oil.

The density of engine oils of both brands determined using ASTM D1298-2017 method [9] varied very slightly during the tests – no more than 0.5% of its initial value, i.e. it remained approximately at the same level.

Fluctuations in the flash point of the tested engine oils during the test period, determined according to ISO 2592: 2017 [10], vs. the initial value, were: 5.1 to 13.1% in section A and 3.8 to 8.1% in section B for locomotive No. 1; 0.9 to 9.1% in section A and 4.7 to 14.2 % in section B for locomotive No. 2. The absolute values of this temperature for all the samples were much higher than the minimum permissible ones according to the Instruction [5] - 170°C.

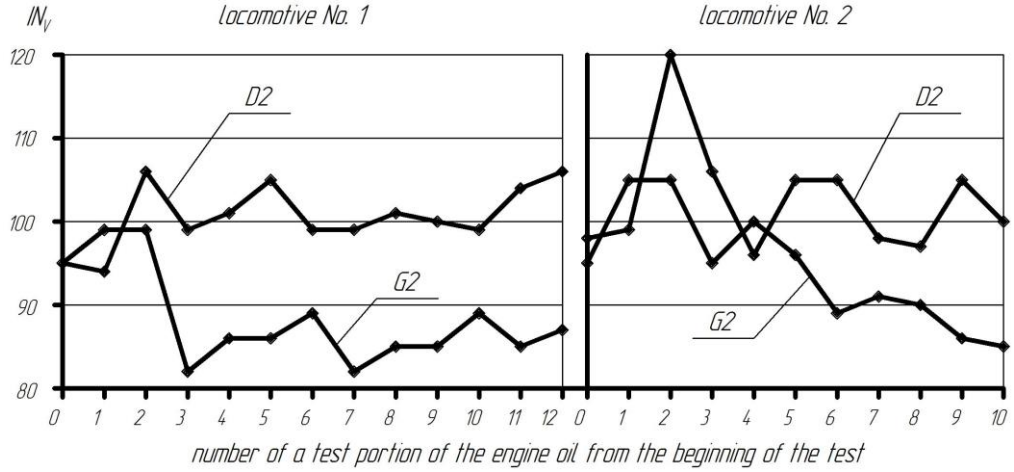

Fig. 1: Viscosity index of the studied engine oils.

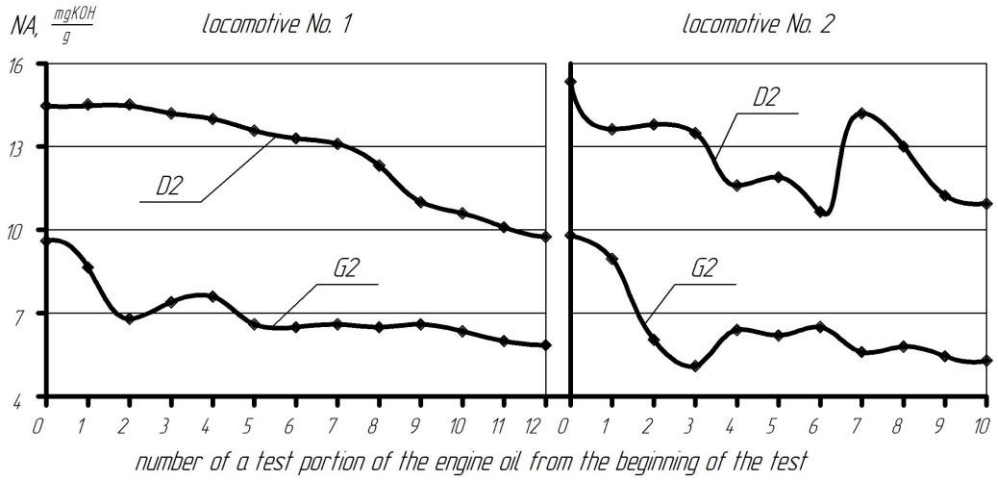

Fig. 2: Alkaline number of the tested engine oils.

The change in the alkali number, which characterizes the ability of the engine oil to neutralize aggressive corrosive products and is directly related to its detergent properties, was determined in accordance with GOST 5094: 2008 [11] and varied during the tests (Figure 2), which is also associated with constant refilling of engine oil. Compared with the value for the initial sample, the alkaline number during the test for both sections of both locomotives changed (decreased) very significantly – from 29% to 46%. But it was constantly at a level much higher than the minimum allowable of 1.2 mg KON / g [5].

Sulphated ash content of oils, which is determined according to ISO 3987:2010 [12] and characterizes the content of additives containing organic compounds of metals (primarily metal containing detergent additives), increases immediately after the beginning of the test (Figure 3), which is probably caused by ingression of wear products of engine parts and metal contaminants that remained in the engine cavities after the repair into oil during the run-in. Further changes in this indicator can be explained by refilling the engine oils and by effect of the additives, as well as by the detergent properties of the oils, due to which they remove contaminants, which may include metal-containing components.

The water content of the oils, which was determined using the method ASTM D95-13e1 [13], is at a safe level – "traces" or no water at all during the entire observation period, except for the cases of failure of the cylinder heads described above. The appearance and disappearance of water in the oil is explained by seasonal and diurnal temperature fluctuations and depends on the sampling time, the engine temperature, and the sample retention before testing.

The quick accumulation of mechanical impurities in both engine oils of both locomotives, which was observed at the beginning of the test, can be explained by the running-in of friction pairs of the diesel engines and the formation of wear products. Further, the quantity of impurities in group D engine oil is higher than in G engine oil, since the first one has better detergent properties and thus more products get into the engine oil, which could have been deposited on the surfaces of engine parts. In general, mechanical impurities get into the engine oil constantly, but due to the operation of the cleaning devices their content is stable and is far from the maximum permissible for diesel oil of 3%.

One of the studied indicators was the content of trace elements, such as calcium, zinc (according to ASTM D4628-16 [14]) and phosphorus (according to ASTM D1091-11 (2016) [15]). These elements are part of the additives added to engine oils to improve their performance properties. Calcium is one of the main components of detergent and dispersant additives that prevent or reduce formation of deposits of oxidation products on the working surfaces of the engine, as well as to keep the products of pollution suspended. Phosphorus and zinc are part of the anti-oxidant and anti-wear additives, which prevent oxidation of the engine oil and reduce the wear of parts. The change in the concentration of active elements in the engine oils of groups G and D is almost the same for both locomotives (Figure 4). Varying concentrations of elements are associated with their wearing out in the performance of their functions and constant adding of large volumes of fresh oil with high concentration. In general, the content of active components in group D oil during the entire test time is higher than that in group G, which is explained primarily by its high initial content.

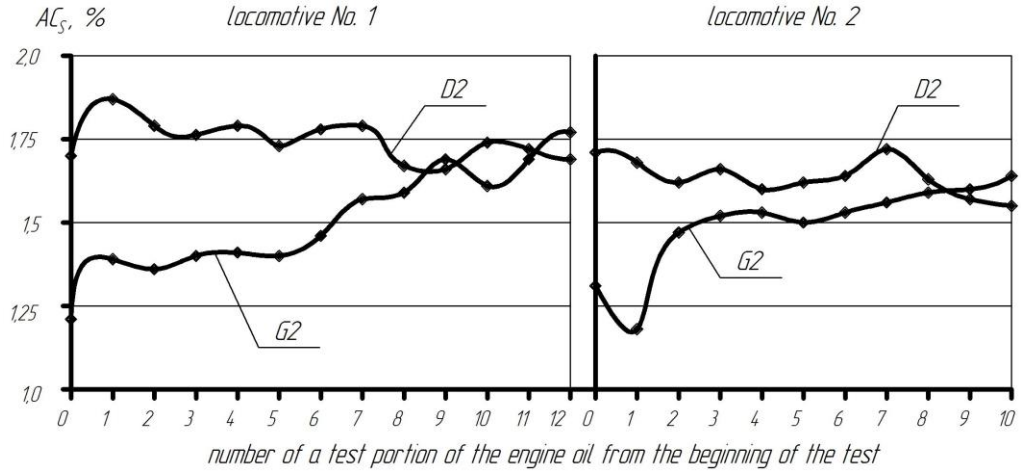

Fig. 3: Change of sulphated ash content of the engine oils during the tests.

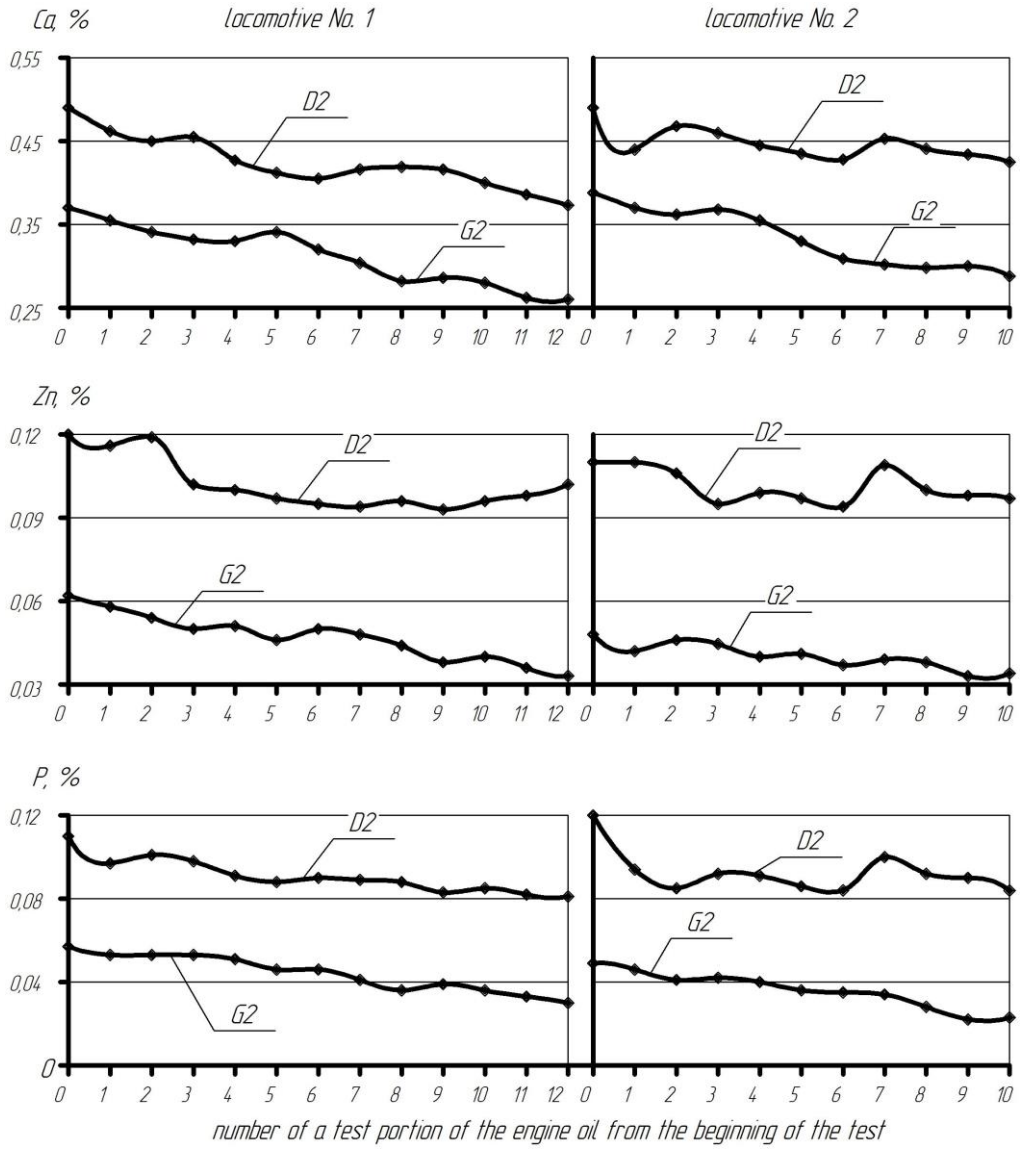

Fig. 4: Change in calcium, zinc and phosphorus content in the engine oils during the tests.

The change in the tribological characteristics of the engine oils determined using the FBM machine [4], according to ASTM D2783-03 (2014) [16] and ASTM D4172-94 (2016) [17] standard methods, also fluctuates in most cases. The diagrams in Figure 5 show that the tribological characteristics of both engine oils are improved in the initial test period, this may be the result of the appearance of oxidation and combustion products in them, which can act as a separation environment for friction pairs, including balls in the FBM friction unit. Over time, the tribological characteristics of both engine oils deteriorate, but they also have a high level in the final samples, which indicates the ability of the engine oils to continue fulfilling their function in locomotive engines. In general, it can be stated, that during tests in engine oils from diesel locomotive No. 1, the critical load is higher for group D engine oil than for group G engine oil by on average 9%, the load wear index – by 12.3%, the welding load – by 10.2%, and the wear factor – by 11.4% lower. In the oils from crankcases of diesels of locomotive No. 2, the parameters of group D engine oils are better than those of group G oil on average by 20% for critical load, by 39.4% for load wear index, by 11.5% for wear scar diameter and by 11.6% for welding load.

In general, tribological studies have shown that during the tests, Agrinol M-14-D2 engine oil has the best anti-wear, anti-friction and anti-scoring properties than M-14-G2TsS engine oil.

In addition to the physicochemical parameters of the engine oils, the burning loss of oil (adding) was used as an indicator characterizing their performance properties during the test. For this purpose, the volume of each portion of the engine oil added to locomotive diesels during the regular maintenances and repairs was carefully monitored. At the same time, statistics on fuel consumption were collected and the oil consumption in relation to the fuel consumption of locomotive diesel was calculated (at the time of testing, this parameter for locomotives 2TE116 should not be more than 2.9%, according to the current regulatory documentation).

According to the statistics collected during the test (Figure 6), the burning loss of engine oil in both locomotives is less in diesel engines filled with Agrinol M-14-D2. engine oil. Thus, in locomotive No. 1, this indicator for the section filled with group D engine oil is lower than for the section filled with group G engine oil by 27.4%, and in locomotive No. 2 - by 56%.

The burning loss of engine oil relative to the fuel consumption was also almost always lower on the sections filled with the group D engine oil. Thus, it varied in locomotive No. 1 within 0.51-1.74% for section A and within 1.75-2.91 % for section B, before the second first-order routine repair (PR-1) (at the mileage of 107,520 km). After the routine repair of the locomotive No. 1, the loss in A section increased significantly, which was the reason for the termination of the operational tests. In locomotive No. 2, the oil loss relative to the fuel consumption in section A averaged 0.74% and 1.73% in section B for the entire test period.

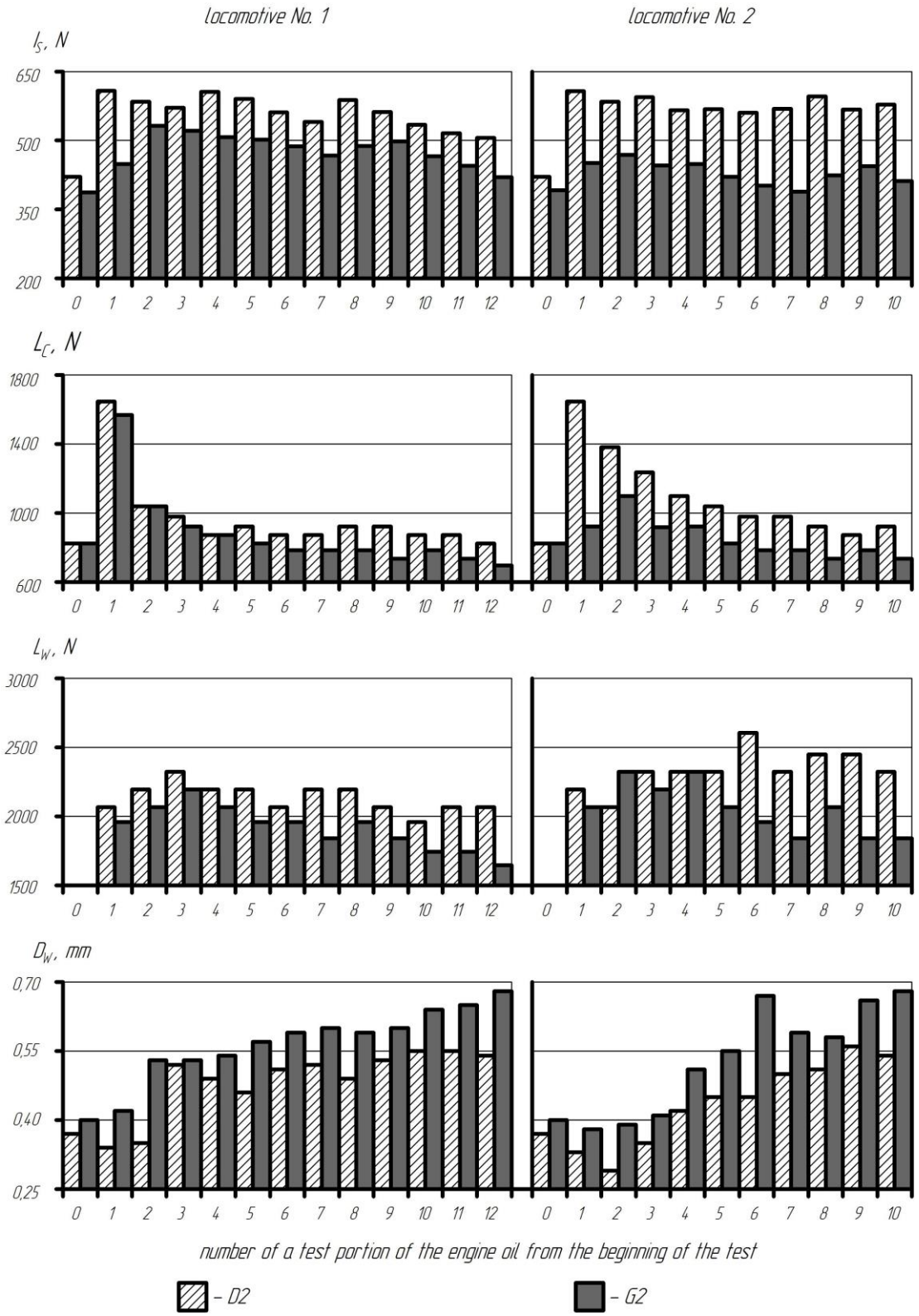

Fig. 5: Tribological characteristics of the tested engine oils: load wear index (Is), maximum load (Lc), welding load (Lw), wear scar diameter (Dw).

3. Conclusions

In general, the results of the studies suggest the expediency of transferring 5D49 locomotives from using M-14-G2TsS engine oil in the lubrication system to Agrinol M-14-D2 engine oil. The issue of the expediency of using the group D engine oils in diesel locomotives, in which now group V engine oil is used, should be further considered and can be finally decided upon after carrying out operational tests on diesel locomotives with these diesel engines according to the programme and methodology similar to those considered in this article.

The analysis of trends in the change in the physicochemical characteristics of engine oils during the operational tests suggests the possibility of a longer service life of Agrinol M-14-D2 engine oil than of M-14-G2TsS in 5D49 diesel engines. However, this issue requires further studies which can be carried out during the operation of these diesel engines with this oil in the regular mode in any locomotive depot of the Ukrainian railways.

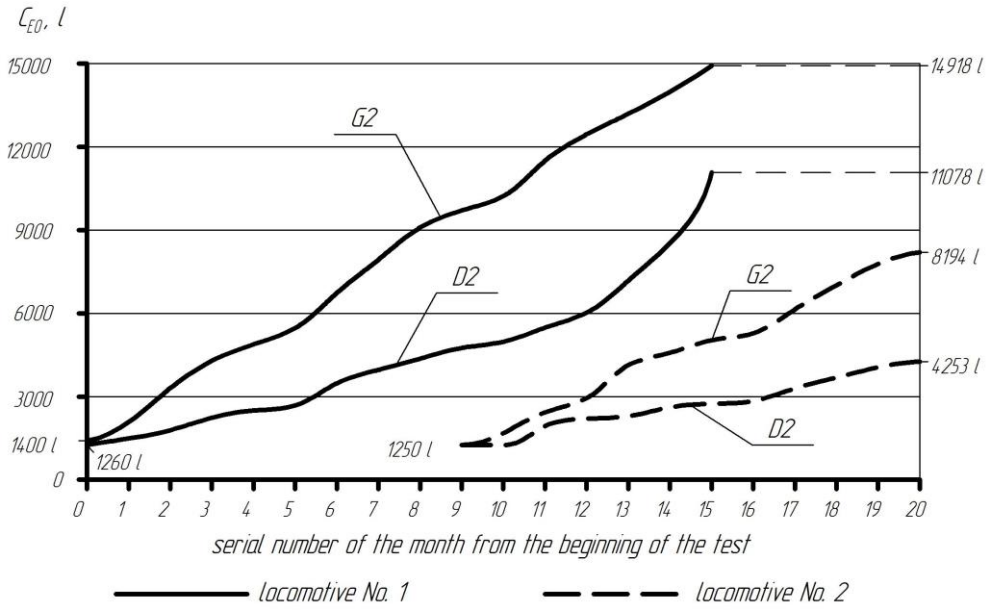

Fig. 6: Burning loss of engine oil.

References

[1] Usloviya rabotyi na teplovoze [Conditions of work on the locomotive], available online: http://dieselloc.ru/books/d49/d49_59.html, last visit: 04.05.2018 [in Russian].

[2] «UZ» - na mezhi krytychnoho znosu infrastruktury ta rukhomoho skladu ["UZ" - on the inter-critical level of the infrastructure and the warehouse], *information from 05.09.2017. Electronic Journal Propozytsiia [Offer]*, available online: http://propozitsiya.com/ua/, last visit: 04.05.2018 [in Ukrainian].

[3] Ryizhov V., Tkachev V. (2008) Motornyie masla dlya forsirovannyih teplovoznyih dizeley [Engine oils for forced diesel locomotives]. *Lokomotiv – Locomotive*, 11, pp. 33-35. [in Russian].

[4] Kombalov, V.S. *Metody i sredstva ispytaniya na treniye i iznos [Methods and means of testing for friction and fretting]*. K. V. Frolova, E. A. Marchenko (Ed.). Moscow: Mashinostroyeniye, (2008), 384 p. [in Russian].

[5] Instruktsiia z vykorystannia mastylnykh materialiv na tiahovomu rukhomomu skladi zaliznyts Ukrainy [Instruction on the use of lubricants on the traction rolling stock of Ukrainian railways]. TsT-0060 (2003), *approved by the order of the Ukrainian Railways since 21.04.2003 No. 110-Ts*. Kyiv, 54 p. [in Ukrainian].

[6] Polozhennia pro planovo-poperedzhuvalnu systemu remontu i tekhnichnoho obsluhovuvannia tiahovoho rukhomoho skladu (elektrovoziv, teplovoziv, elektro- ta dyzel-poizdiv) [Regulations on the planning and warning system of repair and maintenance of the traction rolling stock (electric locomotives, diesel locomotives, electric and diesel trains)]. (20110 *Approved by the order of the Ukrainian Railways since 30.06.2010 No. 093-TsZ*. Kyiv, 28 p. [in Ukrainian].

[7] Petroleum products. Transparent and opaque liquids. Determination of kinematic viscosity and calculation of dynamic viscosity. (1994). *ISO 3104:1994, publication date October 1994 (confirmed in 2007)*. Edition 2, 13 p. [in English].

[8] Petroleum products. Calculation of viscosity index from kinematic viscosity. (2002). *ISO 2909:2002, publication date December 2002 (confirmed in 2014)*. Edition 3, 9 p. [in English].

[9] Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method. (2017). *ASTM D1298-12b, publication date July 2017*, 8 p. [in English].

[10] Petroleum and related products. Determination of flash and fire points. Cleveland open cup method. (2017). *ISO 2592:2017, publication date August 2017*. Edition 3, 18 p. [in English].

[11] Naftoprodukty. Olyvy mastylni, prysadky i pakety prysadok. Vyznachannia zahalnoho luzhnoho chysla metodom potentsiometrysnoho tytruvannia [Petroleum products Lubricating oils, additives and additive packages. Determination of the total a potentsiometrysnoho tytruvannialkaline number by the potentiometric titration method]. (2009). *DSTU 5094:2008, from 1st March 2009*. Kiev: Derzhspozhyvstandart Ukrainy, 10 p. [in Ukrainian].

[12] Petroleum products - Determination of sulfated ash in lubricating oils and additives. (2010). *ISO 3987:2010, publication date November 2010 (confirmed in 2016)*. Edition 3, 7 p. [in English].

[13] Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation. (2013). *ASTM D95-13e1, publication date May 2013*, 6 p. [in English].

[14] Standard Test Method for Analysis of Barium, Calcium, Magnesium, and Zinc in Unused Lubricating Oils by Atomic Absorption Spectrometry. (2016). *ASTM D4628-16, publication date December 2016*, 7 p. [in English].

[15] Standard Test Methods for Phosphorus in Lubricating Oils and Additives. (2016). *ASTM D1091-11, publication date April 2016*, 9 p. [in English].

[16] Standard Test Method for Measurement of Extreme-Pressure Properties of Lubricating Fluids (Four-Ball Method). (2014). *ASTM D2783-03, publication date December 2014*, 9 p. [in English].

[17] Standard Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method). (2016). *ASTM D4172-94, publication date Januare 2016*, 5 p. [in English].