Measures to Ensure Stable Operation of Diesel Engines in Locomotives Used in the Republic of Uzbekistan

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**Abstract.** This article focuses on assessing the technical condition of internal combustion engines in locomotives operating in the Republic of Uzbekistan based on oil analysis results and measures to ensure their stable operation. The analysis process identifies existing technical and organizational issues, provides a comparative assessment with modern technologies, and develops recommendations for improving efficiency. The article emphasizes the importance of the oil system in enhancing locomotive operational efficiency and offers scientific and practical suggestions for improving the existing system.

**Keywords:** locomotive, diesel engine, oil system, wear, abrasive particles, spectral analysis, oil filters, centrifugal cleaning

# Introduction

Today, to increase the operational efficiency of locomotives in the Republic of Uzbekistan, it is considered crucial to analyze the malfunctions occurring in them and, based on the results of this analysis, develop solutions aimed at their prevention.

In all types of transport systems, including railway transportation processes, high accuracy and the shortest possible time are required. Today, due to the increase in transportation volume and the daily running time of locomotives, the demands for their durability are growing, and it is crucial to enhance the durability of their components.

Currently, mainline diesel locomotives such as UzTE16M, TEP70BS, TE10M, and 2TE116 are widely used on non-electrified railway sections of the Republic of Uzbekistan. These locomotives are primarily located in the territories of Navoi, Urgench, and Kungrad locomotive depots, with most of them operating under challenging climatic conditions [1].

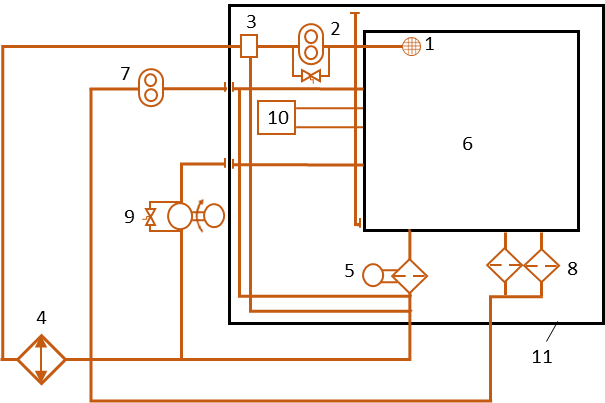
Furthermore, most of these locomotives have been in operation for many years, and their technical condition, especially the reliability of diesel engines, requires constant monitoring. The current maintenance system sometimes fails to fully address existing problems. This leads to an increase in unscheduled repairs of locomotives, higher repair costs, and negatively impacts operational continuity. Considering the above factors, the reliability and efficiency of the diesel engines and oil systems of UzTE16M and TE10M locomotives are crucial, as they serve as the primary rolling stock for freight transportation.

# Materials and Methods

## Parts and Functions of the Oil System in Operational Diesel Locomotives

Diesel locomotive engines are technically complex and high-precision power units, the reliability of which directly affects the efficiency of the entire locomotive. The proper functioning of a diesel engine depends, first and foremost, on the condition of its oil system. The oil system components of a diesel locomotive engine perform fundamental functions such as lubricating the friction parts of hydraulic drives and auxiliary units, reducing friction on their surfaces, cooling moving parts, protecting against wear, filtering oil, and cooling [2, 3]. Inadequate performance of these functions leads to engine failure or a significant reduction in service life.

Figure 1 shows the diagram of the locomotive's oil system and the layout of its main components.



**FIGURE 1.** Oil system diagram of the UzTE16M locomotive  
*1-oil receiver; 2-oil pump; 3-thermoregulator; 4-heat exchanger; 5-fine cleaning filter (self-cleaning); 6-crankcase; 7-pump for supplying oil to centrifugal filters; 8-centrifugal filters; 9-electrically driven oil pump; 10-turbocharger; 11-diesel engine*

To ensure the normal operation of a diesel engine, diesel oils (M14V2 and M14G2 (GOST 12337-84)) with specific viscosity are used. These oils maintain their lubricating properties at both high and low temperatures and require a high degree of resistance to acids [4].

Currently, the "third generation" M14G2 brand oil product, which is widely used in domestic locomotive diesels, shows low dispersive properties, indicating that it does not sufficiently maintain high performance of crankcase oil. As a result, the process of capturing and removing various polluting particles formed during diesel engine operation is not consistently carried out. This, in turn, leads to excessive load on the diesel engine's filter elements, reducing their efficiency and negatively affecting the reliability of the diesel engine, while also resulting in higher requirements for these components [5].

In the cylinders, gases (temperature 1700-2000°C) and heated surfaces of the cylinders and pistons (temperature 300-400°C) affect the oil. Under these conditions, the oil partially burns and forms coke. A portion of the oil solidifies on the cylinder walls and piston bottoms, creating a thin lacquer-like film. During diesel engine operation, contaminant particles such as soot, coke, and carbon deposits enter the diesel crankcase through gaps between the liners, pistons, and piston rings under the pressure of combustion chamber gases, accumulating there. During circulation, oil flowing from the pistons into the crankcase splashes and reacts with the crankcase air, oxidizing. As a result of oxidation, sediment accumulates in oil along with solid particles, causing a narrowing of the cross-section of oil pipelines and making it difficult for oil to move through the system. Additionally, abrasive particles of various sizes, produced by the wear of friction surfaces on diesel engine parts, are introduced into the oil. These particles intensify the wear of friction surfaces as the oil circulates through the system. Additionally, oil quality deterioration occurs due to incomplete fuel combustion, atmospheric dust, cooling water, and other factors [6].

## Defects Caused by Issues in the Oil System

The lubricating properties of the oil deteriorate due to the accumulation of solid particles, combustion products, and oxidation byproducts. The oil in the lubrication system must be checked or replaced at specified intervals. This is because oil that has been used for a long time does not effectively reduce the wear of engine parts. On the contrary, an excessive increase in abrasive particles in the oil accelerates the wear process. These wear issues can be prevented by maintaining proper oil filtration and quality control. For more effective cleaning, the oil filtering system typically consists of several different filters connected in series or in parallel.

In addition, improper operation of the oil system, deterioration of oil quality, use of low-quality oil, excessive particles formed from wear of parts in the oil, insufficient cleaning of oil by filtering elements, incomplete removal of accumulated impurities and abrasive particles in the oil during operation, and partial retention of contaminants in the oil cleaning filters or system lead to a number of serious issues [7].

Malfunctions arising in the friction parts of the diesel engine due to malfunctions in the oil system are shown in Figure 2.



*a) b) c) d)*

**FIGURE 2.** Malfunctions occurring in parts and components of the D49 diesel engine  
*a) occurrence of cracks (fissures) in the main connecting rod; b) loss of geometric dimensions of the auxiliary connecting rod as a result of heating; c) piston breakage; d) cracking of the intervalve section of the diesel cylinder head*

## Research Through Modeling the Oil System

An approach combining theoretical and experimental methodologies was used to assess the oil system of locomotive diesel engines and the processes of malfunction occurrence within it. This approach includes laboratory oil analysis, on-site pressure and flow measurements, and mathematical modeling of key performance indicators.

Samples of oil used at various stages of engine operation were taken from the diesel engine of the UzTE16M locomotive. Laboratory tests were conducted using optical emission spectrometry to determine viscosity, acid number, and concentration of metal particles. Additionally, attention was focused on the quantitative assessment of the number and size of solid contaminants.

The dynamic accumulation of contaminants in the oil was modeled as follows:

(1)

where is the concentration of contaminant, is the rate of formation as a result of wear, and is the cleaning rate through filtration. These values were obtained from laboratory data and operational measurements.

The degradation of the filter over time is characterized by an exponential decrease in permeability model:

(2)

where is the initial permeability, and is the clogging coefficient, estimated based on the data of pressure and flow reduction across the filters.

The filtration efficiency was quantitatively assessed based on the number of particles at the inlet and outlet using the following formula:

(3)

where *d* - for particle sizes, determined by particle analysis before and after filtration.

Pressure loss through oil channels and filters was estimated using an expression based on the Hagen-Poiseuille law:

(4)

where represents the viscosity, and respectively represent the effective length and radius of the filter, and is the flow rate measured by the flow meter.

The following empirical model was used for the approximate calculation of the rate of abrasive wear in friction components due to wear particles accumulated in the oil:

(5)

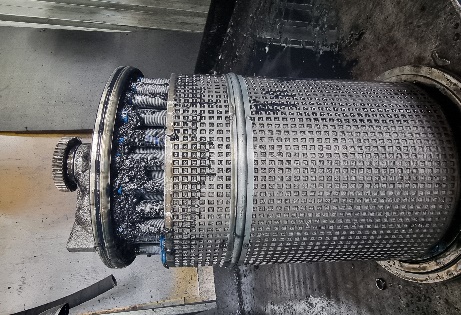
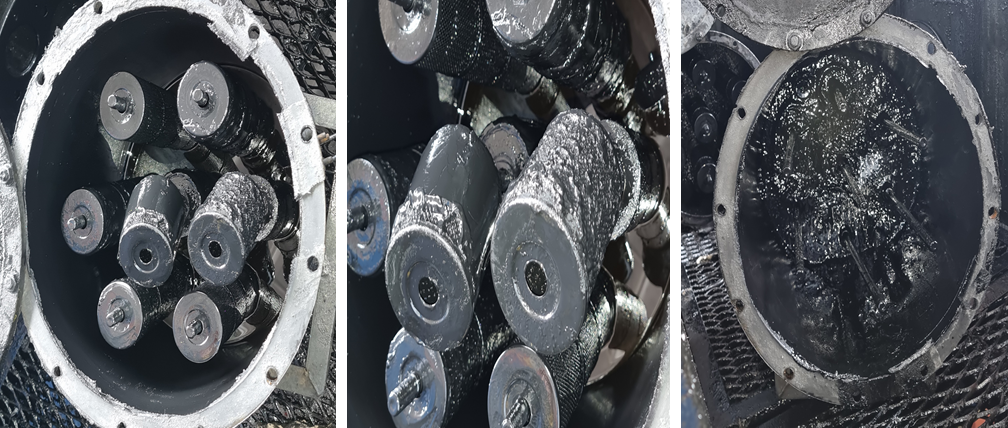
where - particle concentration, - oil velocity, and - constant coefficients determined experimentally.

All models were validated using empirical data collected from controlled bench tests and operational monitoring of selected locomotives. This comprehensive approach ensures the correspondence of theoretical predictions to practical results, enabling reliable diagnostics and system optimization.

# Results and Discussion

## Analysis of Existing Defects and Preventive Measures

To more thoroughly investigate the malfunctions and shortcomings in the oil system cleaning filters of diesel locomotives and diesel engines and their operation, practical research was conducted at the locomotive repair plant of JSC “Uztemiryo'lmashta'mir”. During this study, the pre-repair technical condition of the oil system and cleaning filters of the UzTE16M2-005 series mainline diesel locomotive and D49 diesel engine, belonging to the “Qo'ng'irot” depot and undergoing major repairs at the enterprise, was examined.

*a) b) c) d)*

**FIGURE 3.** Technical condition of oil filters received for repair  
*a) Boll-Kirch self-cleaning filter; b) fine cleaning filter; b) coarse cleaning filter; b) water-oil heat exchanger*

Practical research and studies conducted have revealed an excessive increase in contamination products in the oil composition and excessive pollution of the filters. As shown in Figure 3, the internal and external surfaces of the filter elements are completely covered with sludge and sediments accumulated in them, rendering them entirely unusable.

The filters are structurally clogged, and in some cases, the filter elements are partially or completely filled. This seriously hinders the proper circulation of diesel engine oil throughout the system. Due to these factors, there is a sharp decrease in the separation and cleaning efficiency of filters. As a result of their inability to perform full operation, friction parts are not adequately lubricated, or contaminated oil containing abrasive wear particles directly reaches the surfaces of friction pairs. An increase or decrease in oil pressure in the system and a rise in oil temperature significantly intensify the wear of these parts and considerably increase the occurrence of the aforementioned diesel engine malfunctions.

Such malfunctions, which may arise during the operation of locomotives, pose a serious threat to the reliable and stable operation of the diesel engine, leading to a reduction in service intervals, an increase in maintenance costs, and the premature need for major repairs.

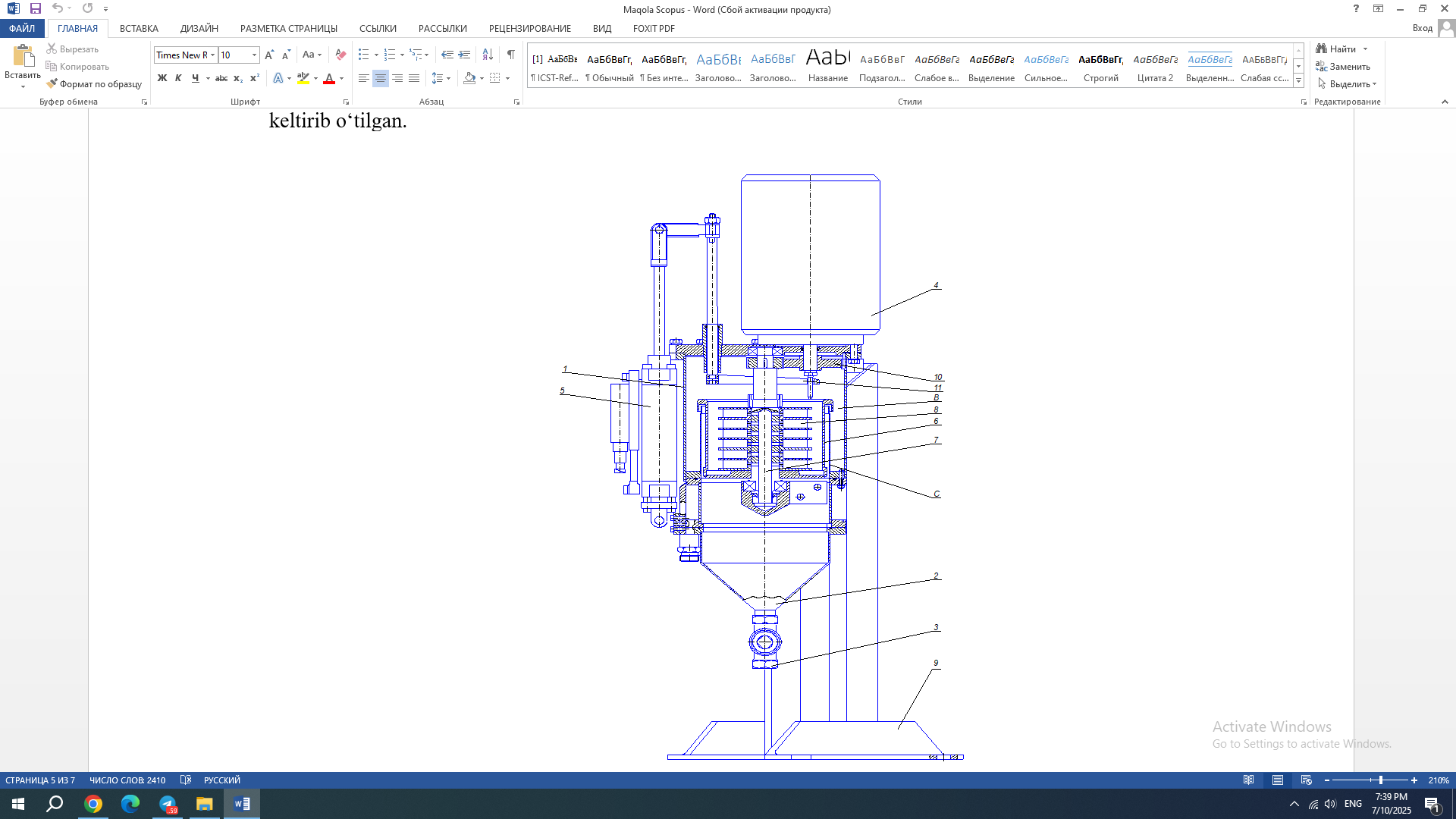
As a result of these observations, it was concluded that the existing oil purification system in the diesel locomotive engines under consideration, specifically the traditional fine-cleaning filters with replaceable filtering elements, does not have sufficient efficiency under operational loads during the use of diesel locomotives. This is because these fine cleaning filters can only eliminate mechanical contaminants of inorganic and organic origin with a size of 16 μm. Therefore, using them to clean fine particles with a size of 5-10 μm quickly contaminates the filters, since the majority of impurities consist of mechanical contamination particles with a size of 1-10 μm. Consequently, their use as filters for mechanical contamination in the oil system is not advisable.

An effective solution to address the aforementioned problems is to implement a modern, automatic, self-cleaning, centrifugal fine-cleaning filter in the oil system. This centrifugal fine-cleaning filter, which incorporates a self-cleaning element, reduces wear by improving the fineness of filtration, lowers the maintenance costs of the lubrication system, eliminates the need to dispose of replaceable filter elements, and as a result, decreases the demand for spare parts.

The automation of the fine cleaning filter rotor's cleaning process under the influence of centrifugal force provides a basis for classifying this device as self-cleaning. This, in turn, significantly reduces operational costs for maintaining the lubrication system. The maintenance practice in such a system is mainly limited to cleaning or replacing the container that collects impurities accumulated in the filter at certain intervals. It operates in harmony with the existing oil flow without obstructing the circulation in the system. Practically, implementing such equipment into the system does not require structural changes. On the contrary, it can be integrated with existing filtering devices in parallel or series. This increases the overall reliability of the system and significantly extends the maintenance interval.

Below, the design structure, operating principle, and possibilities of implementing this device into the system were examined.

Figure 4 illustrates the scheme for using the proposed filter design for efficient oil purification in the regeneration flow, taking into account the operational characteristics of the UzTE16M locomotive's diesel engine.



**FIGURE 4**. Centrifugal Fine Cleaning Filter

The centrifugal fine cleaning filter consists of the following parts: housing 1, sludge chamber 2 with drain valve 3, electric motor 4, pneumatic cylinder 5, self-cleaning mechanism drive of rotor 6, hollow shaft 7 with blades 8, and assembly column 9.

When the electric motor 4 is turned on, the torque is transmitted from the output shaft through gear 10 to the rotor 6 and blades 8.

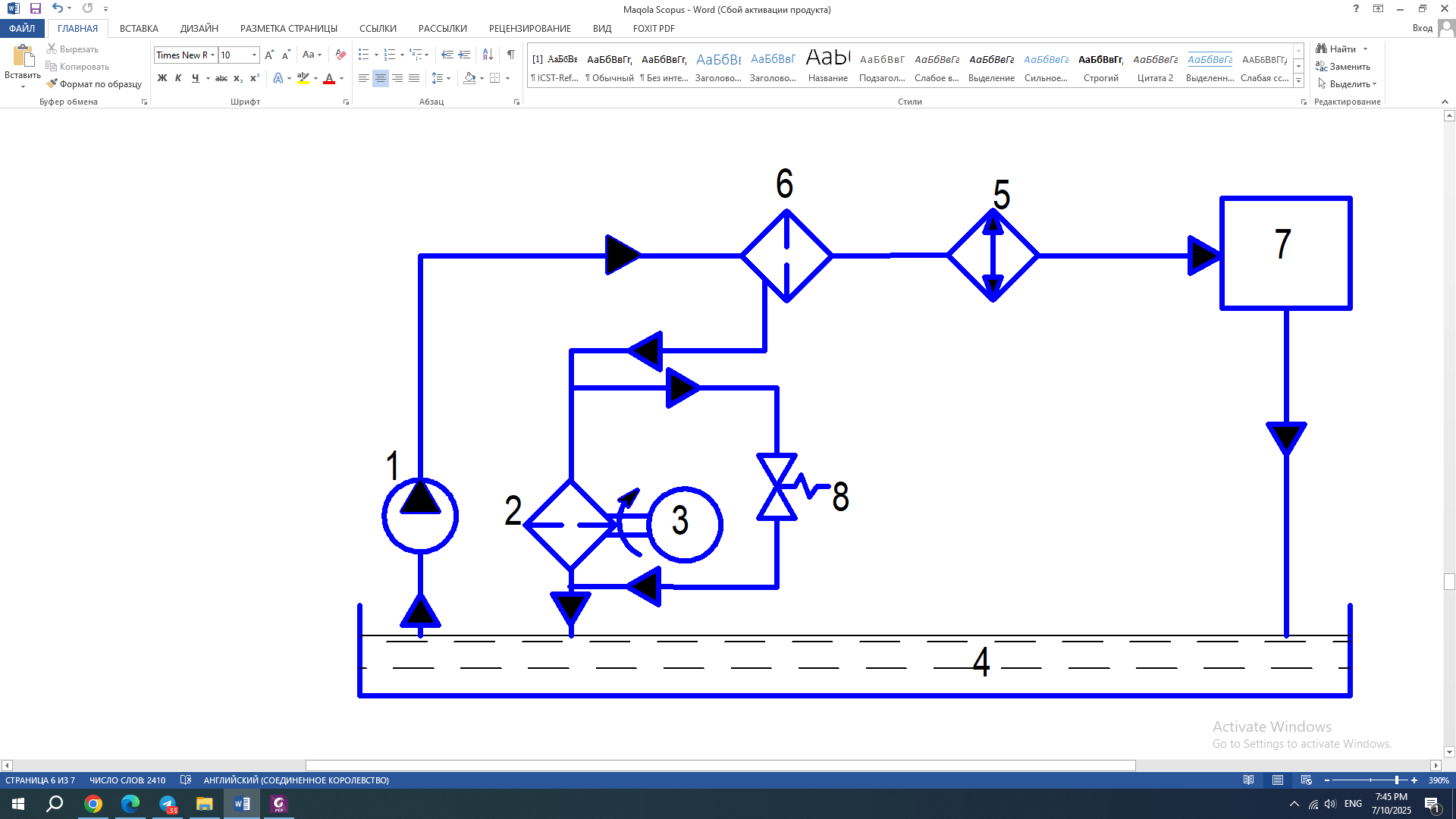
In the Ball-Kirch fine cleaning filter (self-cleaning filter - SCF), the concentrated flow of washed impurities is directed to the inner part of the rotor 6 through the inlet pipe of the centrifugal fine cleaning filter, holes "A" in the hollow shaft 7 and blade 8. This flow, with the help of blades, acquires an angular velocity equal to the rotational angular velocity of rotor 6. Impurities settle on the inner wall of the rotor under the action of centrifugal force. The main flow of the purified working fluid rises and enters the cavity "B" between the housing 1 and the stationary wall "C," from where it naturally flows through a pipe into the engine crankcase.

Periodically, following a command from the control unit, the electric motor is switched off, and the pneumatic unit 5 of the cleaning element 11 drive is activated. The impurities are moved to the sludge chamber 2 using the cleaning element. After this, a command is given from the control unit to lift the cleaning element.

The operation of the centrifugal fine-cleaning filter continues until the rotor begins self-cleaning in the oil purification mode from the Ball-Kirch fine-cleaning filter (FTF).

The duration of the filtration process can be adjusted and determined based on the degree of contamination of the inlet flow.

Thus, taking the above into account, the most optimal hydraulic scheme in terms of optimizing the operating modes of the locomotive diesel engine and the degree of cleaning crankcase oil from mechanical contaminant particles is shown in Figure 5.



**FIGURE 5.** Installation diagram of the centrifugal fine-cleaning filter on a D49 diesel engine  
*1 - oil pump; 2 - centrifugal filter; 3 - electric motor; 4 - diesel crankcase; 5 - oil cooler; 6 - self-cleaning filter; 7 - diesel engine;   
8 - valve*

The results obtained through modeling the experimental locomotive UzTE16M, equipped based on this scheme, are shown in Figure 6. Firstly, it was determined that the rate of mechanical impurity accumulation in the crankcase of the experimental locomotive's diesel engine is 5-6 times lower than in locomotives with a conventional filtration system. Consequently, cleaning the stream of impurities washed from the automated filter using a centrifugal force filter (CFF) ensures minimal load on the filtering elements of the existing self-cleaning filter (SCF). This increases its operational efficiency.

**FIGURE 6.** Dynamics of crankcase oil contamination in the D49 diesel engine

# Conclusions

Positive results are achieved by introducing a centrifugal fine-cleaning filter into the oil system: extending the service life of friction pairs, increasing the interval between oil changes, maintaining the required throughput of the entire oil flow with a cleaning accuracy above 30 microns, dramatically increasing the maintenance-free operating time of the filter (approximately 4 times), reducing operational costs for maintaining oil system filters, decreasing labor costs for filter maintenance, and increasing the level of automation in engine and overall locomotive maintenance.

Furthermore, the adaptability of installing a self-cleaning full-flow filter and a self-cleaning centrifugal filter for cleaning crankcase oil allows for the modernization of the existing locomotive fleet with minimal modifications under locomotive depot conditions. This extends the service life of the locomotive's power unit.

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