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# CONTROL OF VIBRATION PARAMETERS ON THE TANK WALL OF OIL POWER TRANSFORMERS IN OPERATION

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**Abstract:**

**Objective.** evaluation of dynamic viscosity of transformer oil according to vibration parameters under operational conditions.

**Methods.** vibration control, thermal image control, analytical analysis, correlation analysis methods were used.

**Results.** The dynamic viscosity of the transformer oil and the change value of the dynamic viscosity during the current repair interval were determined with the vibration parameter in the frequency range of 1 kHz to 10 kHz.

**Conclusion.** The experimental results of determining the oil viscosity by controlling the vibration parameters in the operational state of the oil power transformer were presented. According to the vibration parameters, the indicators of reduction of the dynamic viscosity from the nominal value are determined. During the current technical inspection of transformers, it was possible to determine the condition parameters in a short period of time and at low costs.

**Keywords:** Oil power transformer, drain, technical condition, diagnostics, method, faults,damage, vibrodiagnostics.

**Introduction.** To evaluate the technical condition of transformers, it is necessary to analyze the parameters of its elements: temperature, pressure, currents, noise level, vibration frequency, vibration speed, vibration acceleration [2]. Early detection of faults and their causes using diagnostic methods of transformers allows to reduce the cost of electrical equipment by 75%, losses caused by lack of power by 63% and save annual costs by 2% [3]. Today, in connection with the growing attention to saving energy and resources at the level of demand, the scientific researches being carried out to ensure the long-term operation of technological devices are aimed at identifying faults that have started in the transformer, extending its service life, and reducing repair costs. is being studied.

Evaluation of the technical condition of oil power transformers is divided into two groups[2]:

1. Assessment of the technical condition in the case of being disconnected from the network;

2. Evaluation of the technical condition in the state connected to the network (operation).

Technical diagnostics of individual elements of the transformer can be carried out without disassembling the transformer, or with partial or complete disassembly. Diagnostics with dissection includes the use of non-destructive and dimensional control methods and tools for the parameters of individual components and parts. To assess the technical condition without disassembling them, diagnostic indicators are used: temperature, pressure, leakage currents, noise level, vibration amplitude, vibration speed, vibration acceleration, etc. [1]. Shows the classification of the main damage of the power transformer.

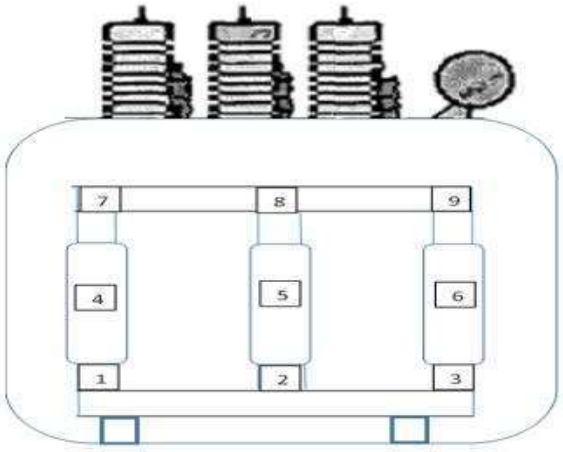
In recent years, the method of vibration diagnostics has been developing in the assessment of the technical condition of oil power transformers. The existing sections of the method of vibration diagnostics allow to assess the technical condition of the mechanical part of oil power transformers. This vibration diagnosis method uses vibration

parameters with a frequency of up to 1 kHz. The results of the high-frequency vibration parameters at 1 KHz do not reflect the results of the mechanical part. Because at a frequency higher than 1 kHz, the effect of mechanical parts in the oscillating motion fades in the oil [3]. In order to increase the accuracy of assessing the technical condition of oil power transformers and to better study the factors that have a negative effect on the operational condition, it is desirable to control them at frequencies of 1 kHz and higher. Research shows that high-frequency vibration parameter values at 1 kHz reflect values arising from small damages. An increase in the particles in the transformer oil indicates that the quality index of the oil is decreasing.

**Methods.** Diagnostic methods, vibration control, thermal image control, analytical analysis, and correlation analysis methods were used in the research process.

**Research results and their discussion.** When assessing the technical condition of an oil power transformer, it is appropriate to control its main structural elements and auxiliary elements. In order for the main components of oil-based power transformers to work in long-term operating conditions, it is necessary to have good quality indicators of oil. The use of the vibration control method in determining the technical condition of the oil in operational conditions allows for quick analysis.

In order to carry out vibration diagnostics of an oil transformer under operating conditions, we divide its tank surface into vertical and horizontal parts.




**Picture 1. Installation points of sensors for monitoring vibration parameters on the surface of the transformer tank**

When carrying out the research results, the vibration results are analyzed according to the frequency. We get the results of the vibration parameter up to 1kHz as values that are resolved in the active part of the transformer. In this case, it is appropriate to accept the values in the lower part. Because the vibration in the mechanical parts, that is, in the ferromagnetic core and coils, spreads to the transformer tank through the base. It is desirable to take into account the value of the vibration parameters at values higher than 1 kHz at the surface of the tank. At high frequency, the vibration parameters of mechanical parts fade and reflect the vibration parameters of small particles. Small particles move along the entire tank along with the oil and create a vibration effect in the transformer tank. The moving

particles in the oil consist mainly of oil droplets and water droplets, and as its value increases, the values of the vibration parameters also increase.

**Picture 2. Oil in operation has high frequency oscillations compared to power transformer oil**

The impurities in the oil are considered as mechanical impurities. An increase in mechanical impurities means that the quality indicator of transformer oil is deteriorating. Monitoring the technical condition of the transformer elements in accordance with the frequency range, while recording the vibration parameters of oil power transformers and studying the reasons for the formation of these parameter values.

According to the vibration parameters in the frequency range from 1 kHz to 10 kHz, the dynamic viscosity is studied in laboratory conditions by taking samples from the oil of each measuring transformer. The dynamic viscosity of the transformer oil was determined using the "Viscosometer" device.

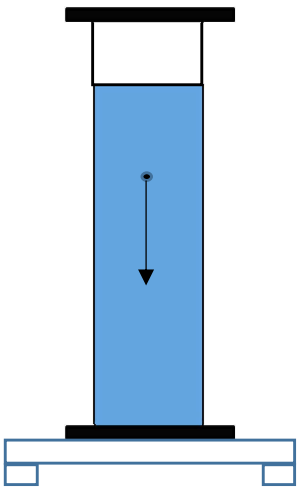


**Figure 3. Capillary viscometer**

The oil of each transformer whose vibration parameters were controlled was checked for its dynamic viscosity using a viscometer laboratory stand. As a result of these tests, the values of dynamic viscosity were studied according to the change of the temperature of the transformer oil in accordance with the results of the vibration speed of the oil power transformer. Viscosity indicators of liquids change depending on its temperature. But the quality indicators of the liquid accelerate these value changes.

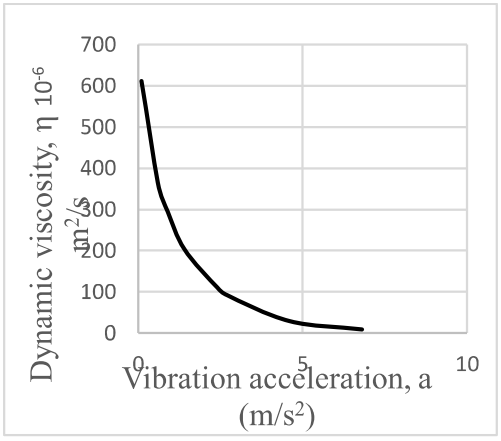
The results of determining the dynamic viscosity of the liquid in Figure 3 can be expressed by the following formula:

$$\eta = \frac{2(\rho_j + \rho_s)gr^2}{9v} \quad (1)$$

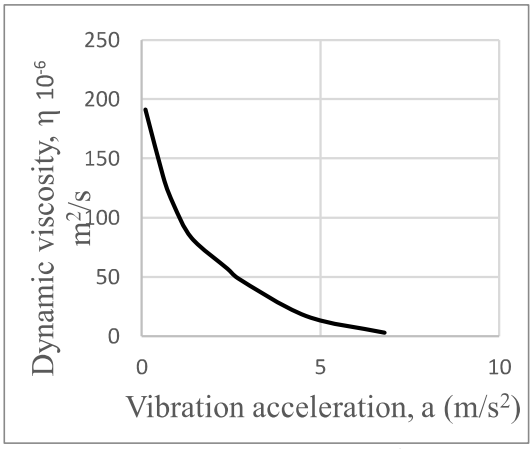
Here:

$\rho_j$ – ball density, $\rho_s$ – liquid density, $r$ – the radius of the sphere, $v$ – the ball's falling speed, $g$ – acceleration of a body in free fall.

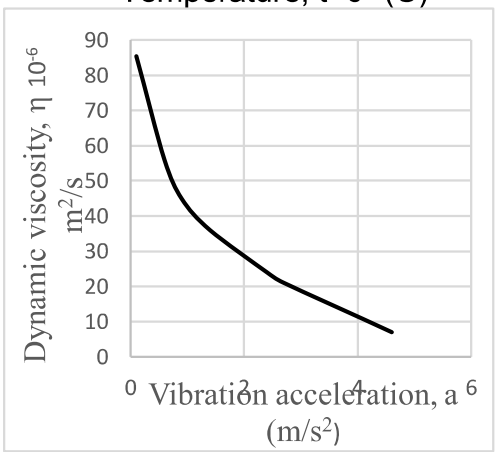
We can see the process of change of dynamic viscosity according to the vibration acceleration for the same temperature on the viscometer laboratory stand through the following characteristics.



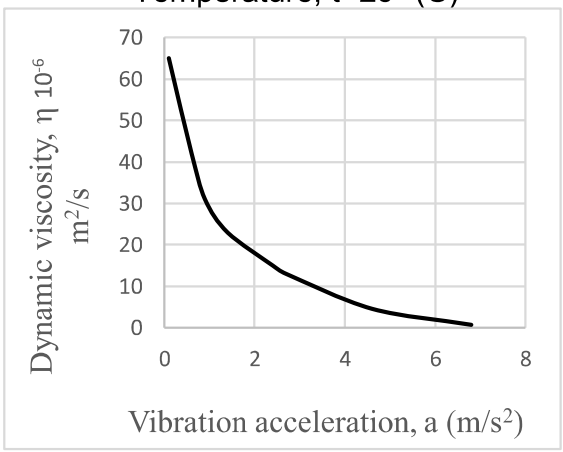

Temperature, t=0$^0$ (C)




Temperature, t=20$^0$ (C)




Temperature, t=40$^0$ (C)




Temperature, t=50$^0$ (C)

**Figure 4. Characteristics of the results of the vibration acceleration of the transformer oil depending on the dynamic viscosity at different temperatures**

According to the results of the research, table 1 was formed on the expression of the dynamic viscosity of the oil at different temperatures by the vibration parameters affecting the wall of the transformer tank according to the quality indicators.

Table 1

| Temperature, t (c) | Vibration acceleration, a (m/s$^2$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0,1 | 0,6 | 0,9 | 1,4 | 2,4 | 2,7 | 4,6 | 6,8 |
| 0 | 611.4 | 365.1 | 302.7 | 203.4 | 111,2 | 91.3 | 29.1 | 9.1 |
| 10 | 325.5 | 235.2 | 186.4 | 121.2 | 82.2 | 64.3 | 22.2 | 7.8 |
| 20 | 191.4 | 135.2 | 111,2 | 83.1 | 57.6 | 49.7 | 17.1 | 2.97 |
| 30 | 121.3 | 95,1 | 74,2 | 61.6 | 45.4 | 42.5 | 12.3 | 2.57 |
| 40 | 85.4 | 67.2 | 51.3 | 36.1 | 28.5 | 25.3 | 7.2 | 2.11 |
| 50 | 65.7 | 42,1 | 31.6 | 27.5 | 21.8 | 17.7 | 3.3 | 0.65 |
| 60 | 46.2 | 34.3 | 26.4 | 19.6 | 10.4 | 8.1 | 1,34 | 0.55 |

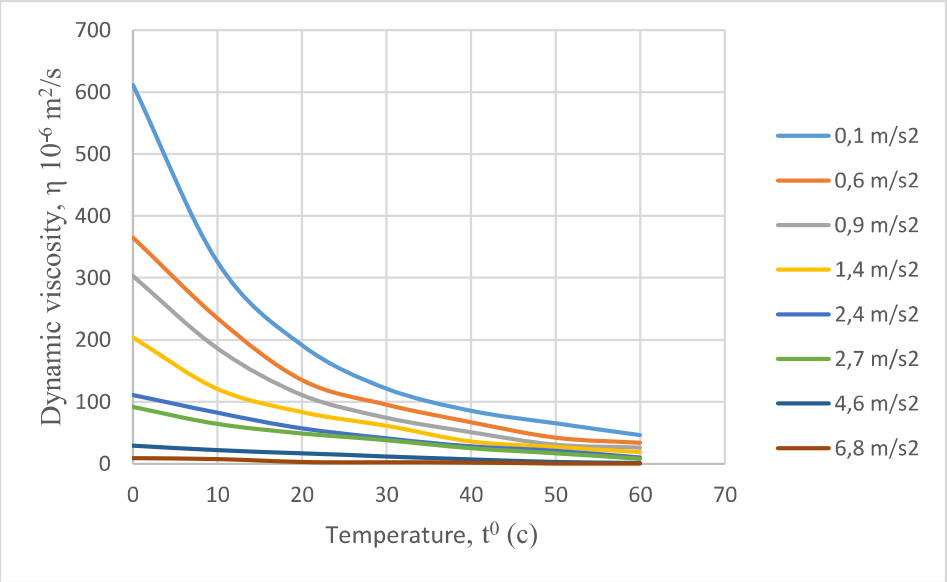



**Figure 5. Characteristic of dependence of dynamic viscosity of transformer oil on vibration parametric and temperature**

Based on the characteristics in Figure 5, we can clearly see the dynamic viscosity of the transformer oil at different temperatures and the vibration indicators affecting the tank wall.

Monitoring the dynamic viscosity values of oil power transformer oil under operational conditions allows them to accurately plan the maintenance costs and service plan of the maintenance personnel. It is possible to reduce the effect of factors such as load and external temperature changes affecting the operation of oil power transformers.

By comparing the quality indicators of transformer oils with controlled vibration parameters, we can see the excess demand placed on the transformer during scheduled maintenance intervals. As an example, we can consider the graph of changes in the quality indicators of transformer oil during the current maintenance period of transformers, that is, six months of control.

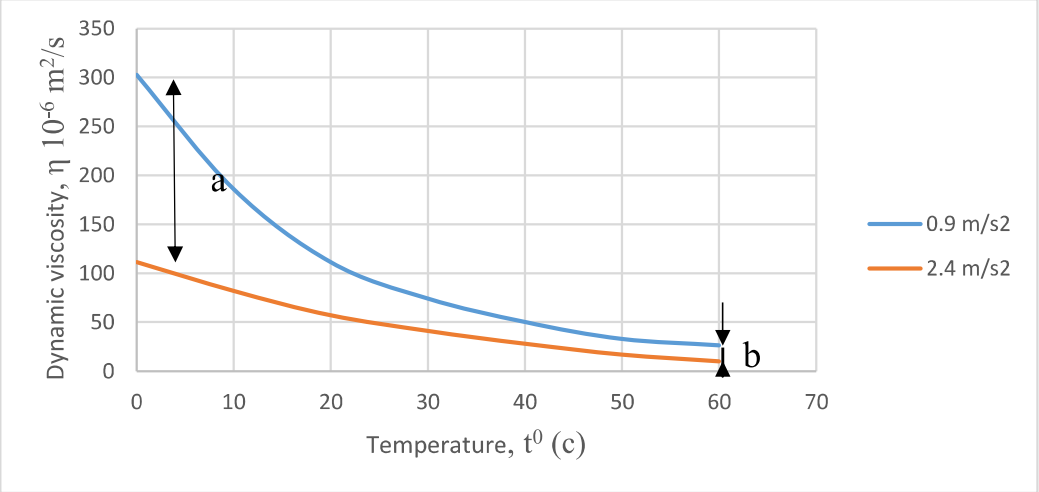



**Figure 6. The difference in the change of the dynamic viscosity of the oil during the current maintenance interval**

The quality indicator of the oil during the current repair period of the oil power transformer allows to determine whether the value of the change exceeds the demand for it. The b value in Fig. 6 is the Δη value of the quality indicator of the transformer oil in the operational state over time between the first control and the second control.

$$\Delta\eta = \eta_2 - \eta_2 \quad (2)$$

Here:

$\eta_1$ – dynamic viscosity of the oil at the initial time;

$\eta_2$ – dynamic viscosity of oil over time.

It is recommended to control the load of the transformer taking into account the temperature of the external environment in accordance with the value of Δη of the oil. The dynamic viscosity of the oil represents the ability to transfer the temperature of the transformer core to the external environment.

**Summary.** The experimental results of determining the oil viscosity by controlling the vibration parameters in the operational state of the oil power transformer were presented. According to the vibration parameters, the indicators of reduction of the dynamic viscosity from the nominal value are determined. During the current technical inspection of transformers, it was possible to determine the condition parameters in a short period of time and at low costs.

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# METHODOLOGY FOR ASSESSING THE LEVEL OF TRAIN SAFETY

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**Abstract.** The results of the analysis of the existing methods of train safety management show that these methods are not enough to solve the issues of economic traffic safety management. This means that there is a need to develop a methodology to improve the efficiency of traffic safety management. This article presents a newly developed new methodology for assessing the level of safety of train traffic, in which the formula for determining the level of safety of cargo transportation is developed taking into account the

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