Providing normal conditions of lubricating of diesel engine during its operation

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Abstract. This paper analyzes the experience of operating an internal combustion engine crankshafts and bearings. The influences on failure depressurization in the lubrication system are evaluated. Means of maintaining pressure in operation are proposed and estimated.

1. Introduction
When operating engines of KAMAZ there is a change that occurs lubrication conditions of crankshaft bearings, significantly reducing the reliability and limiting technical resource [1]. One of the major factors causing engine failures is to reduce the oil pressure in the lubrication system [2, 3, 4].

2. Basic part
Statistical data on engines KAMAZ-740 show (Table 1, Figure 1) that during the operation in the lubrication system there is a decrease of pressure on operating time, which can be represented as an exponential probability model [5]:

\[ P = P_0 \cdot e^{-bl}, \]

where \( P_0 \) - pressure in the lubrication system at the beginning of operation; \( b \) - coefficient characterizing the slope of the curve reducing the pressure in the lubrication system; \( l \) - working hours

Table 1 - Dependence of pressure in the lubrication system of the engine KAMAZ-740 on the mileage at nominal and minimum frequency.

| Frequency, min-1 | Operating the vehicle mileage, thousand km |
|------------------|------------------------------------------|
|                  | 20 | 40 | 60 | 80 | 100 | 120 | 140 |
| 2600             | 0,39 | 0,34 | 0,35 | 0,29 | 0,24 | 0,23 | 0,23 |
| 600              | 0,21 | 0,17 | 0,16 | 0,12 | 0,07 | 0,09 | 0,07 |
Figure 1 - Dependence of pressure in the lubrication system of the engine KAMAZ-740 on operational vehicle mileage: 1 - at n = 2600 min⁻¹, 2 - for n = 600 min⁻¹.

Effectiveness of the lubrication system depends largely on the oil pump performance and reliability of its work [6]. The required pump capacity is determined by the amount of oil needed for distribution to consumers. The reason for reducing the pressure in the engine lubrication system at nominal mode to \( P = 0.2 \div 0.3 \) MPa at 100 \( \div \) 140 thousand km may be the lack of performance of the oil pump. In normal operating conditions may occur in critical modes of the connecting rod bearing lubrication, caused by reduced oil pressure in the lubrication system [7, 8].

The productive capacity of the oil pump engine KAMAZ-740 is 85 l/min in the main section, and 8 l/ min in the radiator section at nominal conditions [9]. The sufficiency of such magnitude performance was determined in the study of connecting rod bearing lubrication conditions under test bench manufacturer [10, 11].

For this pressure measurement was carried out in the lubrication system at different temperatures and oil engine operating modes (no load, with load) with locked valves (differential and the safety did not work for oil drain) [12].
1 - compressor, 2 - high pressure fuel pump 3 - switch of fluid coupling, 4 - sifter, 5, 12 - safety valves, 6 - valve of lubrication system 7 - oil pump, 8, 9 - centrifugal filter valves, 10 - valve of switching of oil radiator, 11 - centrifugal filter, 13 - alarm lamp of clogging of filter 14 - full-flow filter bypass valve, 15 - the full-flow oil purification filter, 16 - oil receiver, 17 - Carter, 18 - the main oil gallery

Figure 2 - The engine's oiling system KAMAZ-740

Figure 3 shows the obtained maximum performance pressure in the lubrication system of the engine depending on the temperature without load. It is seen that by increasing the temperature, the pressure in the lubrication system is reduced significantly, which indicates an insufficient capacity of the oil pump. When the oil temperature is 90 ÷ 100 °C appears performance margin (at P = 0.45 MPa) at a frequency of n > 1700 min\(^{-1}\) with no load. Oil at temperatures over 100 °C margin performance is virtually absent (Figure 3).

![Graph showing pressure vs. temperature](image)

Figure 3 - Characterization of pressure in the lubrication system according to the no-load temperature differential locked and the safety valves.

With the engine running at 90 °C margin performance at idle appears when the engine speed is more than 1,650 m \(\text{min}^{-1}\), and at full load at 2250 min \(\text{min}^{-1}\) and is less than 15 L/min at a frequency of 2930 min \(\text{min}^{-1}\).
1 - Reproducible characteristic of pressure with operating (unlocked) valves (a - at $T_m = 90 \, ^\circ C$ without load, b - at $T_m = 90 \, ^\circ C$ with a load), 2 - stock performance at idle 3 - stock performance with load

Figure 4 - Determination of reserve oil flow

When acceptance tests in factory conditions there are engines with pressure below $P = 0.1 \, \text{MPa}$ at the speed of 600 min$^{-1}$ and below $P = 0.45 \, \text{MPa}$ at 2600 min$^{-1}$. Engines with a flatter characteristic 6, 7 (Figure 5) are removed from the test, as they have no stock performance. However, sometimes there is release of the motor without performance reserves.

![Graph showing pressure vs. speed with characteristic curves for different conditions.](image)

Fig. 5. Characteristics of pressure in the main oil channel of serial engines KAMAZ-740 without load ($T_m = 80 \ldots 90 \, ^\circ C$)

Operating the engine without the stock performance of the oil pump reduces the pressure in the lubrication system in operation long before the establishment of a resource [13].

Carry out the calculation of the resource pressure in the engine lubrication system.
Reducing the pressure in the lubrication system of the engine during operation due to the increase in the bearing gaps and occurs according to an exponential (1).

According to data obtained from the operation (Figure 1), we define the coefficient "b".

Initial data: \( l = 140 \) thousand km \( P = 0.23 \) MPa; \( P_0 = 0.45 \) MPa.

We find that \( b = 0.0049 \).

Critical lubrication regime of connecting rod bearing at \( n = 2600 \) min\(^{-1}\) without load is \( P_{\text{ct.}} = 0.29 \) MPa (rupture of the oil flow). Given this resource engine to achieve the critical pressure of the formula (1) we obtain for the initial characterization with headroom (see Figure 4)

\[
l = \frac{1}{b} \cdot \ln \frac{P_0}{P_{\text{kr}}},
\]

(2)

where \( P_0 = 0.75 \) MPa; \( P_{\text{kr}} = 0.29 \) MPa, and therefore following is calculated:

\[
l = \frac{1}{0.0049} \cdot \ln \frac{7.5}{2.9} = 193 \text{ thousand km.}
\]

If the engine comes in operation without reserve capacity (\( P_0 = 0.45 \) MPa at rated power) its resource is reduced and the life of the engine is:

\[
l = \frac{1}{0.0049} \cdot \ln \frac{4.5}{2.9} = 87 \text{ thousand km.}
\]

Determine the need pressure at nominal conditions to achieve resource engine 300 thousand km. From (1) we get:

\[P_0 = P_{\text{kr}} \cdot e^{bl} = 2.9 \cdot e^{0.0049 \times 300} = 1.3 \text{ MPa}
\]

This pressure corresponds to the characteristic shown in Figure 6.

Setting pressure reducing valve should be raised to 0,6 ÷ 0,7 MPa in order to shift the characteristics on the critical pressures.
Fig. 6 Required characteristic pressure in the lubrication system of the engine to achieve resource 300 thousand km

In modern engines, starting with the KAMAZ-740-11-240 lubrication system has been changed. The oil pump with enhanced performance of up to 150 l/ min (Fig. 7) is used [14].

1 - oil casing; 2 - valve of lubrication system; 3 - the oil pump; 4 - full-flow filter element; 5 - The oil filter; 6 - relief valve; 7 - oil-water heat exchanger; 8 - oil pressure gauge; 9 – indicator of oil pressure; 10 - oil temperature alarm; 11 - piston cooling nozzles; 12 - thermostatic valve; 13 - part-way filter element; 14 - safety valve; 15 - oil drain plug; I - coolant return; II - a cooling fluid inlet; III- plums in a oil casing.

Figure 7 - The engine lubricating oil system KAMAZ-Euro 1
Using high-efficiency pump allowed slowing down the rate of reduction in operating pressure (Fig. 8).

Figure 8 - Dependence of pressure in the lubrication system of the engine KamAZ use: unprimed - KamAZ-Euro; primed - KamAZ-740 (1 - for \( n = 2200 \) min\(^{-1} \), 2 - for \( n = 600 \) min\(^{-1} \))

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