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THEORETICAL DETERMINATION OF THE LIFETIME OF FUEL FILTERS FOR FINE CLEANING OF FUEL OF TRACTOR ENGINES.

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Annotation

The processes of fuel contamination in the fuel systems of tractors operated in the natural and climatic conditions of the Central Asian region are quite complex and intense. Contaminants in the fuel tank include: contaminants entering the fuel tank with fuel and contaminants entering the air tank due to the "breathing" of the tank. The article highlights the theoretical issues of determining the resource of fuel fine filters for tractor engines.

Keywords: Fuel contamination, tractor fuel system, contamination in the fuel tank, life of fine fuel filters, engine.

Let us consider the process of accumulation of contaminants in the fuel tank of a tractor included in the most common closed-type diesel fuel system.

The total amount of contaminants present in the tractor's fuel tank at the moment $C_б$ is the sum of the residual and incoming contaminants C_o during refueling, as well as those incoming from the atmosphere during the "breathing" of the tank C_a.

Residual pollution includes products of corrosion $C_к$, oxidation $C_{ок}$, sludge Honeycomb, compaction $C_{уп}$, wear $C_{из}$, i.e.

$$C_o = C_к + C_{ок} + C_{om} + C_{yn} + C_{из}\,.$$

Then $$C_б = C_o + C_a \quad (1)$$

The general equation for the material balance of pollution in differential form can be expressed as follows:

$$\rho_m\,(Q_б - q_t \cdot \tau)\,dC = a_б \cdot d\tau - \rho_m \cdot i \cdot \eta_m \cdot Cd\tau - \rho_m \cdot i \cdot q_m \cdot (1-\eta_r) \cdot \eta_m \cdot Cd\tau \qquad (2)$$

where: $C_б$ is the current concentration of contaminants in the tank;

Q_b - fuel tank volume;

q_t - volumetric fuel consumption of a diesel engine;

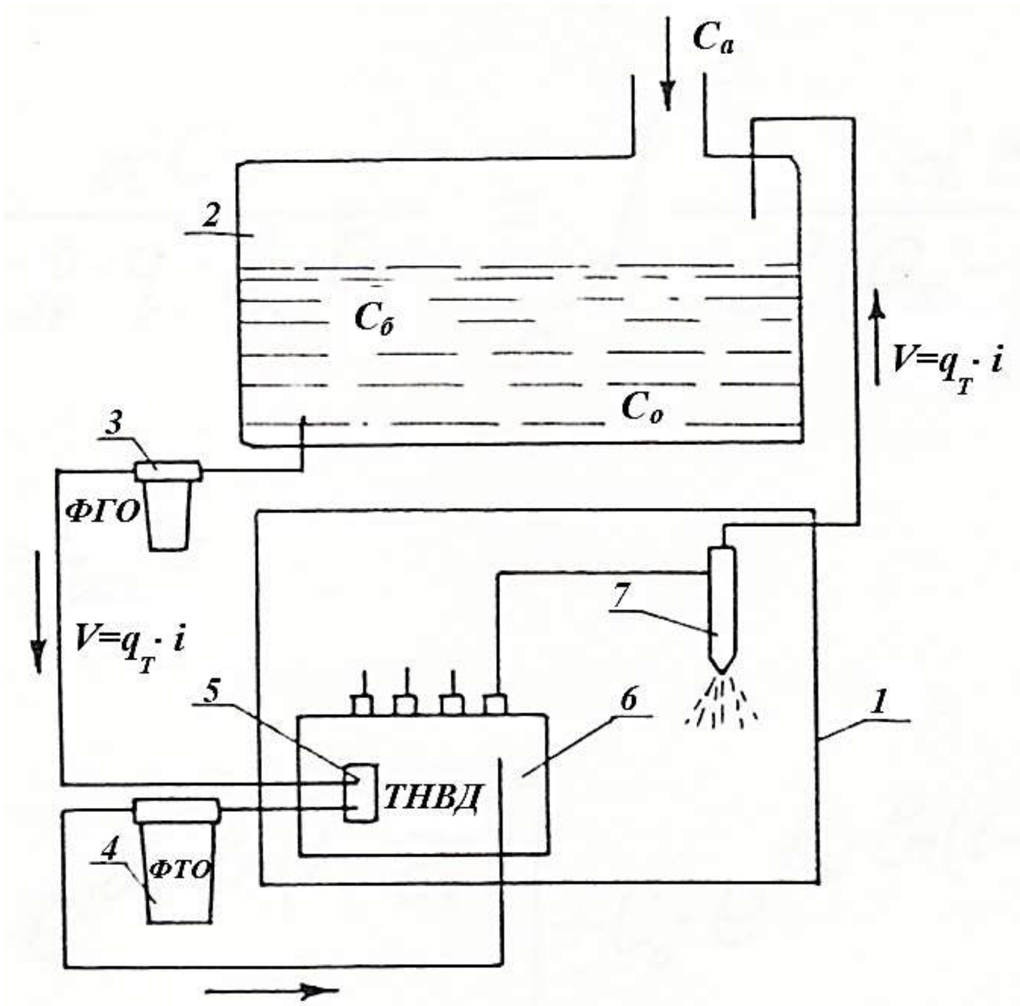
i - circulation rate;

ρ_m -fuel density;

τ - engine operation time;

$\alpha_б$ is the average rate of contaminants entering the tank;

ηr, ηm – efficiency coefficients of coarse and fine fuel filters in the diesel fuel system.



Picture. 1 Scheme of accumulation and purification of fuel of a tractor diesel engine

1-engine; 2-fuel tank; 3-4 filters; 5-fuel priming pump;

6-high pressure fuel pump (ТНВД); 7-nozzle.

The right part of the control (2) expresses an infinitesimal change in the mass of contaminants in the fuel tank. The left side shows the difference between the elementary amount of pollutants coming from the atmosphere at a speed $\alpha_б$ and the amount of pollutants retained by the cleaning equipment.

Separating the variables and integrating equation (2), we obtain:

$$\int_{Co}^{C_\delta^\tau} \frac{\alpha c}{\alpha_\delta - \rho_T \cdot q_T \cdot \text{в}_{\text{ф}} \cdot C} = \int_o^\tau \frac{d\tau}{\rho_T \cdot \left(Q_\delta - q_T \cdot \tau\right)}$$

or when $Q_\tau = q_m \cdot \tau$

$$C_\delta^\tau = \frac{a_\delta}{\rho_T \cdot q_T \cdot \text{в}_{\text{ф}}}\left[1 - e^{\text{в}_{\text{ф}} \cdot \ln\left(1 - \frac{Q_\tau}{Q_Б}\right)}\right] + C_o \cdot e^{\text{в}_{\text{ф}} \cdot \ln\left(1 - \frac{Q_\tau}{Q_б}\right)}$$

where:

$C_б$ – current contamination of the fuel in the tank;

$в_ф = i[\eta_г + (1-\eta_г)\cdot\eta_т]$ - a parameter that takes into account the effect of fuel cleaning on the process of pollution accumulation.

It follows from formula (3) that the contamination of the fuel increases with a constant flow of impurities into the tank and a decreasing amount of fuel in it.

For the average fuel level in the tank $Q_б/Q_τ$=0.5, we obtain the concentration averaged over the time the fuel has been drawn out of the tank:

$$C_б = \frac{q_б}{в_ф}\left(1-e^{-0,7в_ф}\right) + C_o \cdot e^{-0,7в_ф}$$

Where is attracted $q_б = \frac{a_б}{p_T \cdot q_T}$ represents the relative amount of contaminants entering the fuel tank during its operation, and C_o is the concentration of residual and fuel-borne contaminants during refueling.

In the absence of filters ($в_ф$ = 0), formula (4)

takes the form:

$$C_\delta^\tau = C_o + q_б\left[-\ln(1-Q_\tau/Q_б\right]$$

There fore, the average value of fuel contamination in the tank can be represented as follows:

$$C_б = \frac{q_б}{в_ф}\left(1-e^{-0,7в_ф}\right) + C_o^б \qquad (5)$$

At $в_ф = 0$, $C_б = 0,7\, g_б$.

Formula (5) denotes:

$$C_o^б = C_o \cdot e^{-0,7в_ф}$$

In formula (5), the parameter gb significantly depends on the conditional rate of pollution ingress αb . Pollution comes, as a rule, during the "breathing" of the tank, due to a number of factors. Usually a large “breathing” of tanks is due to the gradual filling of the tank with air as fuel is consumed. Small “breaths” are caused by fluctuations in the temperature of air and fuel in tanks, pressure, air flows outside the tank, vibration, the design of the breathing system, etc.

In the absence of air filtration in the breathing system of the fuel tank with a known dust content of the air Sv, the rate of pollution ingress can be summarized as follows:

$$a_б = q_T \cdot K_в \cdot З_в$$

where:

$K_в$ - conditional air exchange rate in the fuel tank or coefficient of intensity of fuel interaction with the atmosphere in the tank-atmosphere system.

Accordingly, the contamination of the fuel in the tank from formula (5) can be represented as;

$$C_б = \frac{K_в \cdot З_в}{p_T \cdot в_ф}\left(1 - e^{-0,7 в_ф}\right) + C_о^б \qquad (6)$$

The Kv coefficient can be given the following physical interpretation. It shows how many times the actual average rate of contaminants entering the tank exceeds the theoretical rate, due only to air exchange during the development of the volume of fuel in the tank. The actual rate of contaminants entering the tank may be higher than the theoretical one due to periodic small “breaths” of the tanks, dust penetration into the tank through leaks. In actual operation, an increased rate of contamination may be due to the action of wind, periodically high local dust concentration in the area of the fuel tank, etc.

Equation (6) in a generalized criterial form describes the average fuel contamination in tractor tanks over the period of one tank volume development depending on all the main factors, excluding the factors that determine the conditional air exchange rate in the tank.

Formula (6) shows that $C_б$ linearly depends on the factors that determine the intensity of pollution from the atmosphere into the tank.

During the operation of the tractor, as the fuel is exhausted from the tank, there is a gradual accumulation of contaminants in the remaining fuel. In general, the contamination of the fuel in the tank during operation can be expressed as follows:

$$C_б^\tau = C_о^б + n_б \cdot C_б = C_о^б + \frac{G \cdot \tau}{V_б} \cdot C_б$$

Где $n_б = \frac{G \cdot \tau}{V_б}$ – the number of fuel fillings in the tank, expressed through the hourly volumetric fuel consumption G , tank volume $V_б$ and operating time τ ;

$C_о^б$ - initial contamination of the fuel in the tank.

Thus, the amount of fuel contamination in the tank from the beginning of operation during the time τ will be

$$C_б^\tau = C_о^б + \frac{G \cdot \tau}{V_б} \cdot \frac{K_в \cdot З_в}{p_T \cdot в_ф}\left(1 - e^{-0,7 в_ф}\right) \qquad (7)$$

In accordance with the theory of similarity and modeling, all dimensionless parameters included in formula (7) are similarity criteria /1,2/ having the following meaning:

$\frac{G \cdot \tau}{V_б}$ - homochronism criterion (number of cycles of fuel production in the volume of the tank);

$в_ф$ - fuel cleaning intensity criterion;

$\frac{З_в}{p_т}$ - the dust content of the air entering the fuel tank, related to the density of the fuel.

The processes of fuel contamination have a significant impact on the clogging of the pores of fine fuel filters operating in the fuel systems of tractor engines. The filter resource, determined by the operating time of replaceable filter elements before replacement in units of filtered fuel volume, can be expressed as a dependence based on the assumption of intermediate-type pore clogging /2/.

$$Q = \frac{\psi \cdot s \cdot \delta \cdot p_з}{K_f \cdot C_б \left[(1-\eta_г)\cdot \eta_T\right] \cdot \rho_T} \cdot \ln\left(\frac{\Delta P}{\Delta P_o}\right) \quad (8)$$

where:

$\eta_г$, $\eta_г$ - coefficients of completeness of filtration or efficiency of purification of contaminants by coarse and fine fuel filters;

Ψ, s, δ - filter curtain characteristics: porosity, surface and thickness;

P_m , $\rho_З$ - density of fuel and pollution;

ΔP_o, ΔP - initial and final pressure difference;

K_f - resource factor that takes into account the physico-chemical factors of the filtration process.

When testing serial fine filters under operating conditions and at the bench, the parameters Ψ, s, δ are the same.

Denoting:

$$\frac{\psi \cdot S \cdot \delta}{(1-\eta_г)\cdot \eta_T} = B$$

The filter element resource equation can be represented as:

$$Q = \frac{B \cdot \rho_з}{K_f \cdot C_б \cdot \rho_T} \cdot \ln\left(\frac{\Delta \rho}{\Delta \rho_o}\right) , \quad (9)$$

With known values of the coefficient K_f , it is possible to determine the resource of fine fuel filters when they work with various filter elements.

Conclusion

1. The processes of contamination and purification of diesel fuel in tractors are quite complex and intensive. Therefore, it is advisable to study them by imitation in the laboratory.

2. Based on the solution of the differential equation of the material balance, an equation was obtained that allows determining the contamination of the fuel in the tank C_σ^τ during the operation.

3. Under the assumption of an intermediate filtration law, the condition of compliance with the simulation of the operation of fine fuel filters was revealed. At the same time, it is proposed to evaluate the degree of compliance with the K_f coefficient, which takes into account the influence of physicochemical factors on the resource of fuel filters.

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