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Thermal equilibrium of the tractor and vehicle engines' cooling systems in agriculture technological processes

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Abstract. The article shows how the heat introduced into the engine is consumed into the coolant. Factors influencing the temperature regime of the tractor and vehicle cooling systems during operation. Necessary dependencies for constructing the heat balance of the cooling system of an automobile and autotractor engine. The use of heat balance makes it possible to determine a criterion for assessing the efficiency of the engine cooling system. Experimental analysis of the thermal balance of the cooling system is based on original equations characterizing the heat transfer of the engine into the coolant, water equivalents of air and water flows through the radiator, and can be used as the basis for a calculation method for determining the characteristics of a cooling system with various radiators.

1 Introduction

Tractors are the main power tool of agriculture and they are designed to aggregate various agricultural machines and perform technological processes in agriculture. Currently, there are many types of tractors used in agriculture, and they are classified according to their purpose, tread, base and other aspects.

According to the use of tractors, tractors intended for general work are used in plowing, planting crops, inter-row cultivation and care, as well as mowing and harvesting, row crops (cotton, corn, beets and others) to universal hay tractors designed for inter-row cultivation and harvesting, to special tractors specialized for use in cotton growing, vegetable-polishing, horticulture, viticulture, tea plantations, forestry, wetlands and mountain farming divided.

VT-150, MX-255, ARION-630C tractors for general purpose tractors, MTZ-80, MTZ-82, T-28X4, TTZ-80 tractors for general-purpose tractors, TTZ-LS 100X, AXOC-340C tractors for special tractors, MTZ-80X cotton, T-16MMCH tea, DT-50, CLAAS NEXOS 230 VE horticulture, DT-75B swamp tractors are examples.

Cars are also used in agriculture. A self-propelled vehicle that moves with its own engine is called a car. The car will be designed to transport passengers, cargo or special equipment and to tow trailers. Cars are divided into transport and special cars according to their use.

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Transport vehicles are divided into several types:

a. light passenger cars - designed to transport several passengers;
b. buses - vehicles designed to carry more, that is, more than eight passengers;
c. trucks - serve for the transportation of various goods.

One of the main parts of tractors and cars is their engine. Engines, in turn, are divided into fuel-powered engines and electric engines. Fuel-powered engines are divided into the following types of fuel:

a. engines running on liquid fuel:
b. engines running on gaseous fuel.

Internal combustion engines used in tractors and cars are classified according to the following characteristics: according to the principle of operation - they are divided into carburetor engines and diesel engines.

Depending on the method of ignition of the combustible mixture (mixture of a certain ratio of fuel and air), piston internal combustion engines are classified into compression ignition (diesel) and electric spark ignition engines (carburetor and gas).

Depending on the method of creating a mixture - engines with external mixture formation are divided into carburetor and gas-powered (diesel) types.

Depending on the method of operation, there are four-stroke and two-stroke types of engines.

Depending on the number of cylinders, there are single-cylinder and multi-cylinder (two, four, six, etc.) engines.

Depending on the location of the cylinders, they are divided into single-row (or linear), that is, the cylinders are located in one row, and two-row (V-shaped), that is, two rows of cylinders are located at an angle relative to each other.

Depending on the type of fuel used, there are engines that run on liquid (gasoline, diesel fuel) and gaseous (liquefied gas) fuel.

Four-stroke multi-cylinder diesel engines are mainly used in modern high-powered tractors and heavy-duty trucks. Four-stroke multi-cylinder carburetor engines are installed on light cars, small (1.0-2.0 t) and medium (2.0-5.0 t) heavy-duty vehicles.

To forcefully remove heat from hot engine parts and transfer it to the surrounding air, a cooling system is required. The operation of the cooling system at changing ambient temperatures depends mainly on the influence of this temperature on the following parameters: the power developed by the engine and the amount of heat it releases into the coolant; radiator heat transfer; mass air flow created by a fan; the performance of the circular pump, therefore, consideration of the characteristics of the thermal balance of the cooling system, which allows for analysis of the operation and determination of the design modes of the auto-tractor radiator, is very important.

2 Problem statement

From an analysis of the engine cycle it follows that only part of the heat generated during fuel combustion is consumed to perform effective work. To determine the nature of heat utilization and ways to improve it, as well as the data required when calculating the cooling system, it is necessary to establish how the heat introduced into the engine is consumed. For this purpose, when studying an engine, the individual components of the thermal balance are determined depending on various parameters characterizing operating conditions (load, rotation speed, mixture composition, end etc.). When the load changes from full to 50%, the effective efficiency, determined by the value of qe, changes by only 2% of its maximum value, achieved at $N_e = 0,88\ N_{e\ max}$. Heat is transferred to the cooling medium from 17% at full load to 23% at $N_e=0,5\ N_{e\ max}$.

A continuous increase in engine power is accompanied by an increase in the amount of heat entering the cooling system and an inevitable increase in the overall dimensions and weight of the system.

The efficiency of a liquid cooling system rises as the liquid circulation, the maximum temperature of the coolant and the amount of heat dissipated by the radiator and is assessed by the power consumption to drive the fan and pump, as well as by overall and mass indicators.

With the help of a cooling system for the entire range of load and speed conditions of the engine, its stable thermal state is maintained and the optimal temperature is provided at which optimal economic and energy performance is achieved.

The equation that establishes the cooling system's temperature regime a autotractor or automobile during operation can be written from the standpoint of a systems approach as follows [1,2,3]:

$$T_w^{/} = \left[K_n; B_x; K_y; B_{dor}; G_a; P_v; B_{atm}; 0(B; A); C_t\right], \quad (1)$$

In this equation, on its right side, the first three terms represent, respectively: K_n - design parameters of the radiator, B_x - output parameters of the radiator operating process: K_n design parameters characterizing the operating conditions of the radiator on a given tractor and vehicle. The remaining factors in brackets are operational and their values are accordingly: B_{dor} - properties of the road or soil, G_a- vehicle weight, P_v - driving mode, B_{atm} - weather and climatic conditions, regulation of the working process in the radiator-0 (B - driver or A – automatically) and other operational factors: C_t – degree of contamination of the radiator, properties of the coolant used, etc.

During operation of the tractor and vehicle with a steady load in the engine cooling system (with factors 0 disabled), the coolant's temperature at the radiator inlet T'_w is stabilized.

$$T_w^{/} = T_L^{/} + \frac{Q_{dv}}{H_\Sigma^e Q_{pn}} \quad , \quad (2)$$

Where: $T_L^{/}$ - temperature of the surrounding air in front of the radiator; Q_{dv} - engine heat transfer into coolant; Q_{pn} - potential heat transfer of the radiator; H_Σ^e– coefficient of realization of the thermal properties of the radiator when operating on a given tractor or car.

The coefficient of realization of thermal properties during operation (H_Σ^e) included in equation (2) takes into account in general terms the integral effect of all restrictions imposed on the potential radiator's heat transfer to the surrounding air.

$$H_\Sigma^e = H_1^e \cdot H_2^e \ldots H_{n-1}^e \cdot H_n^e \quad (3)$$

where each of the product's distinct values corresponds to a certain kind of restriction, such as aeration of the fluid flow, unequal air velocity fields, radiator contamination, etc [4,5,6,8].

A radiator fitted on an autotractor or car must fulfill the requirements for heat transfer

$$Q_{dv} = H_\Sigma^e Q_{pn} \quad (4)$$

We will agree to call the potential radiator heat transfer Q_{pn} the heat transfer of a clean radiator under idealized test conditions in a thermal wind tunnel; this is necessary in order to be able to assess the degree to which the radiator's possible characteristics are realized under operating conditions directly as part of the cooling system in the presence of various types of restrictions.

3 Solution method

The heat balance determines the balance of the amount of heat released in various modes by the functional system of a autotractor or automobile under consideration, and the amount of heat released into the surrounding air by the radiator. This balance should be drawn up on the basis of a systematic approach, thereby achieving a more complete account of all factors acting on a moving tractor or car and on its cooling system.

To build a thermal balance of the cooling system of an automobile and autotractor engine, it is necessary to have the following dependencies.

1. Engine heat transfer into the coolant under various loads and engine shaft speeds.
2. Specific radiator heat transfer at various values of air speed in front of the front and the speed of the coolant in the channels.

To obtain the parameters of the thermal balance on the UAZ-469 automobile and the TTZ-80 tractor (Figure 1), experiments were carried out with the engine operating according to the external characteristic, partial load modes corresponding to the movement of the car on roads with a resistance coefficient Ψ= 0,08 and with a resistance coefficient Ψ = 0,02.

UAZ-469 automobile TTZ-80 tractor

Fig. 1. View of the automobile UAZ-469 and tractor TTZ-80.

The tractor engine operates with a full fuel supply, so the experiments were carried out with the tractor engine operating according to its external characteristics. For this purpose, the required tools and equipment were installed in the tractor and vehicle. The experimental results are presented in Figure 2 and Figure 3 [9,10,11,12].

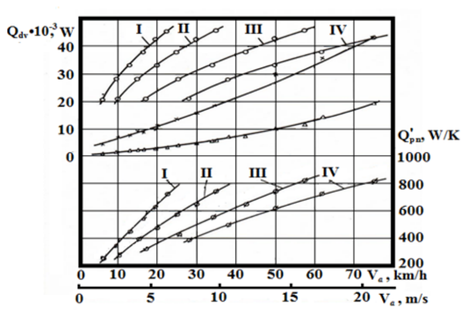

Fig. 2. Thermal balance of the UAZ-469 engine cooling system during steady motion in different gears (I-IV); engine heat transfer into the coolant at full load (oo), at partial loads: Ψ =0,02 (ΔΔ) and Ψ =0,08 (xx); particular radiator heat transfer.

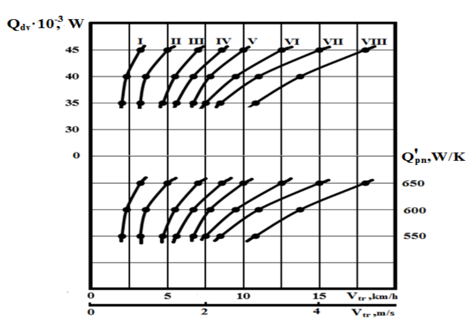

Fig. 3. Thermal balance of the engine cooling system of the TTZ-80 tractor in different gears (I-VIII); heat transfer during full load from the engine to the coolant (••).

4 Results and discussion

Using dependence (2) allows us to determine the engine's heat transfer into water in each mode by calculation. So, in Figure 2. The functions and constructed from recalculation of experimental data are given $N_l = f(V_a, \psi)$ end $Q_{dv} = f(N_{dv}, V_a)$. In Figure 2 the heat balance of the car engine cooling system is demonstrated using the results of experimental studies of its individual elements of engine heat release, cooling water, water equivalents of air and cooling water flows and the specific heat transfer of a water radiator ($Q^{/}_{pn}$) to the surrounding air.

Thus, tests of radiators on a tractor and a car can be accompanied by theoretical and theoretical analyzes of the experimental data of the obtained elements of the radiator system of the hydraulic and air paths of engine heat release into the coolant. Such an analysis reveals the reliability of the obtained temperature-dynamic characteristics under different road loads and the extent to which the projected temperature-dynamic features are implemented created radiators and, consequently, those shortcomings of their design that must be eliminated.

Considering the characteristics of engine heat transfer into the coolant when the tractor and car are moving in different gears. Next, the values of the specific potential heat transfer of the radiator should be plotted on it and we will obtain a graph of the thermal balance of the engine cooling system when the tractor and car are moving at full load.

Experimental analysis of the thermal balance of the cooling system is based on original equations characterizing the heat transfer of the engine into the coolant, water equivalents of air and water flows through the radiator, and can be used as the basis for a calculation method for determining the characteristics of a cooling system with various radiators.

5 Conclusion

Considering the characteristics of engine heat transfer into the coolant when the tractor and car are moving in different gears. The quantity of heat that enters the coolant increases as engine power increases. The radiator's operating circumstances, design characteristics, and other operational elements determine the temperature range of the cooling system in an engine, tractor, and car. A computational and graphical approach for establishing the parameters for the temperature-dynamic characteristics of the engine cooling system can be based on the heat balance of the cooling system that results, which describes the heat transfer of the engine into the coolant.

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