# Algorithm for calculating the criterion for the temperature-dynamic characteristics of the cooling system of tractor and car engines

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**Abstract**. The article provides information on the temperature-dynamic qualities of the cooling system for tractor and car engines. A parameter that determines the efficiency of the cooling system. Definitions of the criterion of temperature-dynamic characteristics. Calculation algorithm for determining the initial temperature difference. The results of the calculated and experimental data of the temperature-dynamic characteristics of the cooling system of the UAZ-469 car and the TTZ-80 tractor. **Keywords:** temperature, air, water, heat dissipation, airflow, tractor, car, radiator, speed.

## 1 Introduction

The use of modern technologies and the constant introduction into production of progressive methods and means of cultivating agricultural crops requires efficient operation of the cooling system of cars and tractors.

During operation, the efficiency of the cooling system is affected by the ingress of air, gases and steam from the water flow moving through the radiator. Therefore, the study of the availability of the flow of the coolant through the channels of the radiator in a single-phase state is relevant.

The de-aeration effect of automotive radiators has not been studied enough, although it is known that de-aeration effects in the collectors of radiator cores in near-critical conditions cause flow disruption, as a result of which the temperature of the coolant rises sharply and a dangerous overheating of the engine occurs and the temperature regime of the engine cooling system unsteady character, which ultimately leads to engine stop [1-5].

## 2 Putting the issue

Due to the constantly increasing energy saturation of tractors and cars, the problems of cooling their various functional systems from year to year are becoming increasingly important. Temperature-dynamic qualities express the dependence of the temperature regime of the functional systems of aggregates, assemblies and even parts of tractors and cars on external factors affecting them: road, atmospheric and climatic, load and driving modes.

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A general assessment of the efficiency of a tractor or automobile cooling system can be made by choosing a parameter that would take into account in a general form the influence of a large number of various factors on this efficiency. Most often, the initial temperature difference is used as the determining parameter, which is calculated by the equation

$$\Delta T_{н} = T_W^{'} - T_L^{'} \quad (1)$$

$T'_W$ - is the temperature of the coolant at the inlet to the radiator;
$T'_L$- air temperature in front of the radiator front.

The initial temperature difference is also called the "radiator constant" [2]. Thus, it is implied that with a change in the ambient air temperature, the value remains unchanged, i.e.

$$\Delta T_{н} = idem \quad (2)$$

According to [2], it can be seen that the effect of temperature $T_L'$ on the $\Delta T_{н}$ value is insignificant only for small changes in $T_L^{'}$.

The criterion of the temperature-dynamic characteristics is determined by the formula (3)

$$\Delta T_H = \frac{Q_{dv}}{\varkappa \cdot Q_{pn}} = \frac{Q_{dv}}{\varkappa} \cdot \frac{1+\frac{W_L\cdot\left(1-e^{-N_{tu}}\right)}{2\cdot W_W}}{W_L\cdot\left(1-e^{-N_{tu}}\right)} \quad (3)$$

$Q_{dv}$ - engine heat transfer to the coolant; $Q_{pn}$- specific potential heat transfer of the radiator; $W_L$- water equivalent of the air flow; $W_w$ - is the water equivalent of the coolant; $N_{tu}$- is the number of heat transfer units; $\varkappa$ - is the implementation coefficient.

The heat transfers of the engine into the coolant or lubricating oil included in the last formula is determined from the heat balance graph of the engine [5-11].

The water equivalent of the air flow is determined based on the average air velocity in front of the radiator front. To correctly determine this average speed, it is necessary to build the aerodynamic characteristic of the engine compartment - this is the most important for determining the temperature-dynamic characteristics of the tractor and the car. Research [2] found that for each specific case of vehicle movement ($V_\alpha$ and $i_k$), the air velocity in front of the radiator front can be determined from the aerodynamic characteristics of the engine compartment of the vehicle or by the formula

$$V_L = \alpha \cdot V_a \quad (4)$$

α- coefficient of the oncoming air flow; $V_a$- vehicle speed.

The value of the water equivalent of the water flow is determined from the flow characteristics of the coolant circuit. The flow rate of the coolant is determined for a given design of the pump and the circulation circuit and changes mainly with a change in the speed of the pump shaft, i.e., depends on the speed of the machine and the gear engaged [3].

$$G_w = A_1 \cdot i_n \cdot n_{dv} = A_1 \cdot A_2 \cdot i_n \cdot i_k \cdot V_a \quad (5)$$

Where $A_1$-is the characteristic coefficient; $A_2$ - a constant value for a given brand of machine; $i_n$-gear ratio of the pump drive; $n_{dv}$- engine speed; $i_k$-is the gear ratio of the gearbox.

The number of heat transfer units Ntu and the heat transfer coefficient can be determined from formulas (6) and (7) respectively.

The dimensionless characteristic of heat exchangers for evaluating the process of heat dissipation is the so-called number of heat transfer units $N_{tu}$:

$$N_{tu} = \frac{K \cdot F_L}{C_{pL} \cdot G_L} \tag{6}$$

As you know, the heat transfer coefficient K of the radiator is determined by characteristic equation

$$K = C \cdot (\gamma \cdot V_L)^n \cdot V_w^q \tag{7}$$

The heat transfer coefficient K depends on the design of the cooling surface, the manufacturing technology of the radiator, and the speed of the heat carriers (liquid and air). The determination of the values of the criteria for the temperature-dynamic characteristics is accompanied by the identification of the degree of realization of the potential properties of radiators.

This approach thus makes it possible to identify the existing shortcomings in the design of the tractor and the vehicle associated with the layout of the cooling system and outline measures for the most effective improvement of this system. These shortcomings are evaluated by the so-called implementation coefficients, the value of which is determined [12-18].

$$\varkappa = \varkappa_1 \cdot \varkappa_2 \cdot \varkappa_3 \cdot \ldots \cdot \varkappa_n \tag{8}$$

Where the individual values included in the product are related to the constraints imposed on the workflow of the heatsink. Such restrictions include aeration of the fluid flow passing through the radiator, uneven air velocity in front of the radiator front, radiator contamination, etc.

## 3 Solution method

At present, the work of mainly domestic scientists and engineers has determined the influence of a significant number of structural and operational factors on the heat transfer of a radiator installed on a machine. In most cases, the operating conditions of the radiator on the machine will reduce the thermal efficiency of the radiator. There are, however, positive factors, such as increased turbulence in the air flow at the radiator inlet or radiator vibrations, which lead to an increase in thermal efficiency. In this regard, there is a reserve that should be used in the design of cooling systems for tractors and cars. On the other hand, revealing the essence of the limitations and taking them into account in the design of tractors and cars makes it possible to increase the reliability and effectiveness of the layout decisions made in terms of ensuring the specified values of temperature-dynamic indicators.

Based on the above theoretical assumptions, an algorithm for calculating the initial temperature difference on a computer was developed, which allows determining the values of the criterion for the temperature-dynamic characteristics of a tractor or car. The initial data for calculating the initial temperature difference are: heat transfer from the engine to the coolant $Q_{dv}$; coolant flow rate $G_w$; open area $F_{js}$; heat capacity of water and air and ; volumetric air mass $\gamma_L$; air velocity $V_L$; radiator front surface area $F_{fr}$; characteristic parameters that evaluate the heat transfer of a given cooling surface $C_1$, n and q; air side radiator cooling surface $F_L$.

After data is entered, a calculation is made.
1.Coolant rate

$$V_w = \frac{C_w}{Fjs}100$$

2. Water Equivalent Coolant Flow

$$W_w = C_{p_w} \cdot G_w$$

3. Bulk air velocity in front of radiator front

$$\gamma_L \cdot V_L$$

4. Weight air flow through radiator

$$G_L = F_{fr}\gamma_L V_L$$

5. Water equivalent air flow through radiator

$$W_L = C_{pL} G_L$$

6. Heat transfer coefficient

$$K = C \cdot (\gamma \cdot V_L)^n \cdot V_w^q$$

7. Number of heat transfer units

$$\mathrm{N_{tu}} = \frac{\mathrm{K \cdot F_L}}{\mathrm{W_L}}$$

8. Potential specific heat transfer of the radiator

$$Q_{pn}^{'} = \frac{W_L(1 - e^{-N_{tu}})}{1 + \left(\frac{W_L}{2W_w}\right) \cdot (1 - e^{-N_{tu}})}$$

9. Initial temperature difference

$$\Delta T_н^{'} = \frac{Q_{dv}}{Q_{pn}^{'}}$$

## 4 Results and Samples

According to the compiled program, the value of the initial temperature difference was calculated. To verify the correctness of the calculation of the value of the initial head, an experimental study was carried out. In order to conduct experimental studies, the tractor and the car were equipped with the necessary instruments and equipment.

The results of the calculation and experimental data are presented graphically in Fig.1.

An analysis of the graphs makes it possible to establish that the calculated and experimental curves do not coincide, and the calculated data are more preferable (by 2.6-6%).

This discrepancy between the calculated and experimental data can be explained by the decrease in the potential properties of the radiator during its operation as part of the engine installation of a tractor and a car. Evaluation of the indicated decrease in potential properties allows us to determine its following values

$$\varkappa = \frac{\Delta T_{Hrasc}}{\Delta T_{H\,eksp}} = 0.94 - 0.974 \quad (9)$$

For all gears in the transmission. Experiments have shown that limitations include aeration of the water flow passing through the radiator, uneven air velocity in front of the radiator front, and other reasons. The relative decrease in the heat-dissipating capacity of the radiator due to the uneven field of air velocities is determined from the formula

$$\frac{Q_o - Q_H}{Q_o} = F\,\frac{\sum_{i=1}^{n} \delta_i^2}{n} \quad (10)$$

Where $Q_o$ and $Q_H$-are the heat transfer of the radiator, respectively, for uniform and non-uniform velocity fields, F-is the heat flux of the radiator (the ratio of water equivalents of heat carriers), $\delta_i$-is the coefficient of non-uniformity of the velocity field along the front of the radiator.

For the UAZ-469 car with values, $N_{tu}$, $W_L$ and $W_w$ corresponding to the mode $n_{dv}$=2000 $min^{-1}$ when driving in gear F=0.13. Then, substituting the corresponding values into formula (10), we will have for the fourth gear with a copper-soldered radiator.

$$\frac{Q_o - Q_H}{Q_o} = 0.13 \cdot 0.076 = 0.00988 \quad (11)$$

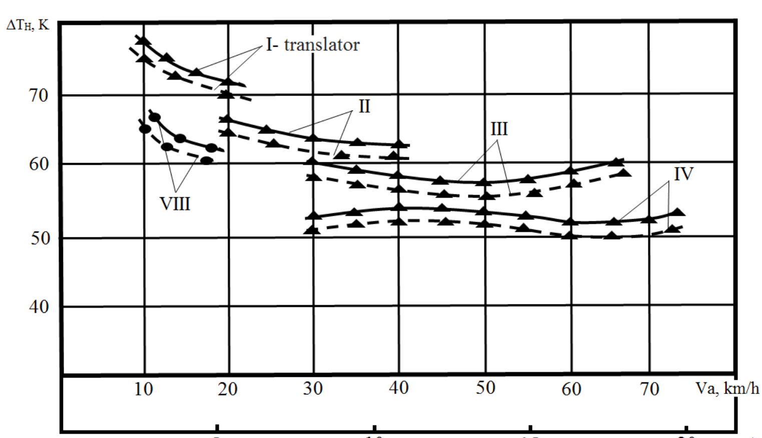


**Fig. 1.** Calculated and experimental temperature-dynamic characteristics of the cooling system of the engine of the UAZ-469 car (▲), and the TTZ-80 tractor (●) according to the initial temperature difference and - - - - - - calculated; ▬▬ - experimental.

It follows that the decrease in the heat transfer of the radiator due to the non-uniformity of the air velocity field ahead of their front is only about 1%, which only partially explains the value of the implementation coefficient obtained above.

Distortions in the temperature fields of the air flow entering the radiator are most often caused by the recirculation of heated air to the front of the radiator due to the pressure difference at the inlet section of the tract and in the engine compartment. This factor is especially noticeable when the design of the radiator enclosures is unsatisfactory and their tightness is insufficient.

## 5 Conclusion

As a criterion for the temperature-dynamic characteristics of the cooling system of a tractor or car, it is necessary to use the initial temperature difference.

The value of the criterion of the temperature-dynamic characteristics of the tractor and the car is affected by the heat transfer of the engine to the coolant, the water equivalent of the air flow, the water equivalent of the water flow, the number of units of heat transfer.

Determining the value of the criterion allows you to identify the degree of implementation of the potential properties of the radiator.

The developed algorithm and calculation program makes it possible to determine by the calculation-experimental method the initial temperature difference and the construction of the temperature-dynamic characteristics of the tractor and vehicle cooling system.

According to the results of the calculation, it is possible to identify discrepancies between the calculated and experimental data, thereby determining the place where the potential properties of the radiator decrease during its operation as part of the engine installation of a tractor and a car.

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