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Factors affecting the thermal efficiency of the engine cooling system of cars and tractors

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ABSTRACT

The article shows the output parameters of the radiator workflow. Conditions corresponding to the operation of the radiator of the installed radiator on tractors and cars. On the potential heat transfer of the radiator. Implementation coefficient, which generally takes into account the integral effect of all restrictions imposed on the potential heat transfer of the radiator in the ambient air. Characteristic features of the air flow at the inlet to the core of the radiator installed on the tractor and the car. The parameters that determine the thermal efficiency of the radiator of the cooling system of tractors and cars, for this, a quantitative assessment of the unevenness of the velocity field in front of the radiator front, the coefficient of the amount of air movement, the field coefficient, the coefficient of unevenness of the velocity field along the radiator front were used. The results of the obtained values of the coefficient of non-uniformity of the velocity field along the radiator front.

Keywords: Radiator, tractor, car. core, cooling surface, heat dissipation, heat transfer, potential, air flow, engine, radiator front, fan, speed, turbulence.

1. INTRODUCTION

During the operation of tractors and cars, various factors affect its mechanisms and systems, therefore, determining the factors affecting the efficiency of the radiator cooling system is very relevant.

During the operation of tractors and cars, various factors affect its mechanisms and systems, therefore, determining the factors affecting the efficiency of the radiator cooling system is very relevant [1, 2].

2. PUTTING THE ISSUE

The output parameters of the working process of the radiator as a separate heat exchanger include internal factors that determine its potential. This usually includes heat transfer and heat transfer coefficients, aerodynamic and hydraulic resistance.

The design parameters of the radiator include, in particular, the dimensions of the core, the dimensions and shape of the elements of the cooling surface and radiator collectors, the scheme of fluid circulation in the radiator. Design parameters characterize the operating conditions of the radiator on the tractor, i.e. complex relationships with the design of this machine design features of the air path. Therefore, the heat transfers of the radiator installed on the tractor must meet the condition [1-3].

$$Q_{gb} = \varkappa_{\Sigma} \cdot Q_p^1 \tag{1}$$

where, Q_p^1- is the potential heat transfer of the radiator; $\varkappa_{\Sigma}$ -is the coefficient of realization of the potential properties of the radiator during its operation on a given tractor or car.

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Let us agree to call the potential heat transfer of the radiator Q_p^1 the heat transfer of a pure radiator under idealized conditions in a thermal wind tunnel. This is necessary in order to be able to assess the degree of implementation of potential conditions directly in the composition of the cooling system in the presence of various kinds of restrictions.

The implementation coefficient takes into account in general terms the integral effect of all restrictions imposed on the potential heat transfer of the radiator to the surrounding air, these restrictions refer to any one type of restriction, for example, aeration of the fluid flow, uneven velocity air fields, radiator pollution, etc.

Therefore, usually $\varkappa_\Sigma$<1, although cases are theoretically possible when $\varkappa_\Sigma$>1.

The structure of the air flow at the inlet to the core of a radiator mounted on a tractor is usually very complex. The characteristic features of this structure are distortions of velocity and temperature fields and increased turbulence, which is inevitable at the inlet to the radiator in the same way as it occurs in all cases of air being sucked from the atmosphere into the pipeline without special directing devices. The perturbing effect on the flow is exerted by elements located in the air path in front of the radiator, i.e. cladding, shutters, oil coolers, etc. Therefore, the design of the air path is essential, which is mainly determined by the mutual position of the radiator and engine on the machine.

Air supply through the air path can be carried out in the following ways:

1. Fan - in the cooling systems of tractors, combines, stationary engines, as well as in the interior and cabin heating systems;

2. Due to the action of the oncoming air flow - in the cooling systems of racing cars and in heating systems;

3. Simultaneously with a fan and due to the action of incoming air - in the cooling systems of most cars.

3. SOLUTION METHOD

The elements of the cooling surface, evenly distributed along the front of the radiator, are flowed around by an air flow that usually does not fill the entire section of the radiator to the same extent, while one part of the front is blown at speeds that are much higher than the calculated one, the other part is blown at speeds that are less than the calculated one, or is not blown at all or even has reverse flow direction. Under these conditions, the efficiency of the radiator is lower than that which could be achieved with a uniform flow distribution. The limiting factors most often associated with tightness in the engine compartment include: various obstacles to the air path before and after the radiator; lack of smooth transitions from one section of the air path to another; low sweeping coefficient of the radiator, i.e. the ratio of the area swept by the fan to the area of the front; the distance between the lining and the radiator, as well as between the radiator and the fan; the presence of a fan casing and its design; clearance between casing and fan, etc.

The following parameters are used to quantify the non-uniformity of the velocity field ahead of the radiator front [4-9]:

- Air momentum coefficient

$$M_L = \frac{1}{F_{fr}\int_{F_{fr}}}\left(\frac{V_{Li}}{V_{Lcp}}\right)^2 dF_{fr} \tag{2}$$

where: F_{fr} - front cooling surface; V_{Li} is the air velocity in front of the radiator front; V_{Lcp} - is the average air speed in front of the radiator front, which is always equal to or greater than one, and the larger its value, the higher the degree of unevenness of the velocity field along the radiator front;

- Fields coefficient:

$$\varphi = \frac{V_{Lcp}}{V_{L\,max}} \tag{3}$$

where, V_{Lmax} - is the maximum air velocity in front of the radiator front.

- The coefficient of non-uniformity of the velocity field along the front of the radiator, determined by the dependence:

$$\delta^2 = \frac{1}{n}\sum_{i=1}^{i=n}\frac{(V_{Li}-V_{Lcp})^2}{V_{hcp}^2} \tag{4}$$

The value δ is a criterion for the average deviation of the local velocity V_{Li} at point *i* from the average velocity ahead of the front. With a uniform distribution of speeds δ=0.

The influence of the non-uniformity of the velocity field can be taken into account using the potential heat transfer coefficient, which is the ratio of heat transfer Q_H, for a given non-uniformity of the field to the heat transfer Q_0, determined on the assumption that the air flow velocity is constant along the entire front and is equal to the average velocity:

$$\varkappa_{\mathrm{H}} = \frac{Q_H}{Q_0} \tag{5}$$

4. RESULTS AND SAMPLES

An analysis of the last formula (4) shows that the decrease in the efficiency of the radiator depends not only on the installation conditions of the radiator, but also on the thermal properties of the cooling surface of the radiator, estimated by the characteristic coefficient n. In this case, the closer the value of n is to unity, the smaller the decrease in the efficiency of the cooling surface due to the non-uniformity of the velocity field [9-10].

The turbulence parameters, which determine the nature of the air flow in front of the radiator, have a significant effect on its thermal efficiency. This effect of heat transfer intensification in the radiators of modern tractors is used completely insufficiently due, firstly, to the lack of reliable data on the intensity of the flow turbulence behind the various elements that make up the inlet section of the air path of the cooling system. Secondly, there are no data on the dependence of heat transfer of various types of radiators on the parameters of air flow turbulence.

To carry out the test, the car and tractor were equipped with the necessary instruments. When measuring air flow rates, the sensors were installed in front of the radiator front. Measurements of the air flow speeds in front of the front of the car radiator were made at different speeds, and on the tractor at different engine crankshaft speeds.

Lower speeds correspond to the areas of the radiator front shaded by the lining. Attention is also drawn to the fact that the formation of stagnant zones is determined both by the operation of the fan and by the speed of the incoming air flow. The predominance of any of these factors deforms the velocity field ahead of the radiator front accordingly. One of the reasons for the unevenness is also the fact that the fan sweeps far from completely. The ratio of the area swept by the fan to the radiator front area is 0.63 for the UAZ 469 car, and 0.7 for the TTZ-80 tractor. For domestic cars and tractors, this coefficient is in the range from 0.40 to 0.70, and, therefore, for a car and a tractor, it has a high value.

The values of the non-uniformity parameters for different engine crankshaft speeds and vehicle and tractor speeds are determined mainly by the flow velocity in front of the radiator front. The values of this field coefficient are observed from 0.44 to 0.78, which indicates a significant ratio of local air velocities in front of the radiator. The maximum field coefficient is observed at high vehicle speeds, and the minimum one corresponds to low speeds, which indicates a decrease in the values of the maximum deviations of the local speed with an increase in the flow velocity. The standard deviation S and coefficient of variation v, usually used in statistics, here characterize the averaged and relative averaged difference in local velocities along the radiator front. The nature of the change in S indicates an increase in the absolute value of the unevenness with increasing flow velocity, S since the value increases from 1.0 m/s at V_L= 2.0 m/s to 2.5 m/s at V_L= 8.0 m/s, the however, the quality of the flow is improved, since the relative value of non-uniformity at these flow rates is reduced from 55 to 30%. At the same time, it should be noted that in the prevailing modes of the vehicle during operation, when the average air speed is less than 6 m/s, there is a high unevenness. Therefore, it is necessary to further improve the aerodynamic path of the cooling system.

For the subsequent assessment of the decrease in the efficiency of the radiator due to the unevenness of the air flow according to the formula (3), the unevenness index was calculated and the results of the calculation are shown in figure 1. As can be seen, the nature of the change in δ^2 corresponds to the indicated change in the previous parameters. At the same time δ^2, the indicator characterizing the degree of implementation of the potential properties of the radiator for low air velocities is four times higher than at maximum ones [11-12].

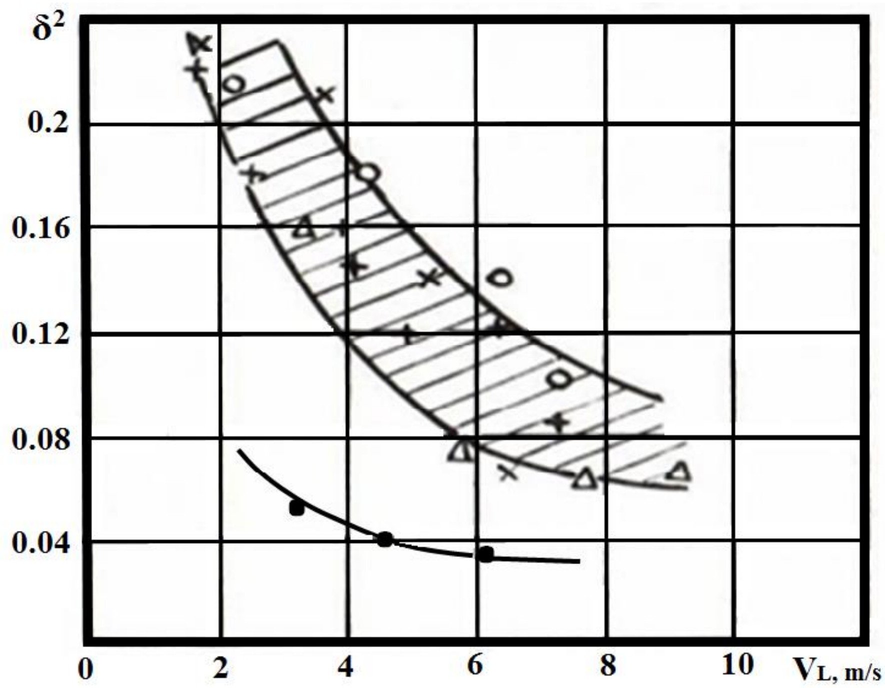

Figure 1. The dependence of the flow deterioration index depending on the average air speed in front of the radiator front when the UAZ-469 vehicle is moving in the second (x), third and fourth (Δ) gears, with the fan (+) and (·) of the TTZ-80 tractor turned off.

In the same figure 1, the values of the non-uniformity indicators are plotted when driving with the fan turned off. A comparison of the curves shows that the leveling effect of the fan affects only certain modes. This also indicates an insufficiently satisfactory layout in terms of the internal aerodynamics of the engine compartment of the car. The same figure shows the results of testing the cooling system of the TTZ-80 tractor. It can be seen from the graph that the values of the unevenness indicators are much lower than those of the car. This indicates a satisfactory layout of the internal aerodynamics of the engine compartment of the tractor engine.

An analysis of the designs of the air paths of the engine cooling system of tractors and automobiles shows that in the overwhelming majority of cases, in order to increase the heat transfer of radiators, there is no need to install any additional elements in the air path.

The goal can be achieved by a rational layout of the inlet section and by improving the quality of the radiator airflow.

5. CONCLUSION

The factors affecting the thermal efficiency of a radiator installed on a tractor and a car are determined. The implementation coefficient takes into account in general terms the effect of all restrictions imposed on the potential heat transfer of the radiator to the surrounding air. The structure of the air flow at the inlet to the core of the radiator installed on the tractor and the car is different, this structure is the distortion of the speed and temperature fields, the uneven distribution of the air flow along the front of the radiator.

For a quantitative assessment of the non-uniformity of the velocity field in front of the radiator front, the air momentum coefficient, the field coefficient, and the velocity field non-uniformity coefficient were used.

The equalizing effect of the fan of the car engine cooling system can only be in certain modes. This indicates an unsatisfactory layout of internal aerodynamics.

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