Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 63 (2022) 149–153

Transportation Research Procedia

www.elsevier.com/locate/procedia

X International Scientific Siberian Transport Forum

On the de-aeration properties of radiators of the cooling system of engines of cars and tractors

Nashir Umirov[a], Shavkatjon Abdurokhmonov[a,*]

[a]*Tashkent Institute of irrigation and agriculture mechanization engineers, Republic of Uzbekistan*

Abstract

The article describes the reasons for the aeration of the fluid flow. Possible modes of vertical and horizontal flows of two-phase liquids. Influence of the structure of a two-phase flow and modes of its movement in radiator channels on thermal efficiency. Results of comparative tests of the efficiency of de-aeration properties of copper-brazed and aluminum radiators. Indicator of the temperature zone of instability of the water flow to assess the degree of perfection of de-aeration devices.

Keywords: engine; coolant; steam; air; temperature; heat transfer; pressure; hydraulic path; boiling point; rotational speed; aeration; radiator; channel; water.

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.

* Corresponding author. Tel.: +7-495-120-3035; fax: +7-495-120-3035.
E-mail address: abduroxmonov.shavkatjon@bk.ru

10.1016/j.trpro.2022.05.017

2. Putting the issue

Aeration of the coolant is understood as the ingress of the gaseous phase into it - air, exhaust gases and steam. Aeration of the liquid is a consequence of a number of reasons, which include:

a) entrapment of air and vapor by liquid in the radiator manifold or expansion tank when it moves at high speeds, during impacts and crushing it, with funnel formations, etc.

b) overheating of the liquid in the water jacket of the engine, especially when it is overloaded;

c) the formation of steam due to cavitation of the circulation pump;

d) insufficient cooling of the liquid and incomplete condensation of steam in the radiator due to a decrease in its thermal efficiency;

e) air leaks into the cooling system through various non-densities and its ingress through the air valve when the load decreases and the engine stops;

f) the presence of stagnant bags in the cooling system, from where the liquid constantly gets air or steam;

g) the ingress of exhaust gases through non-density in the gaskets, especially characteristic of diesel engines, etc.

Thus, aeration of the coolant depends on the design features of the cooling system, design, engine load and operating conditions, and the technical condition of the engine and its systems.

Aeration of the coolant leads to a deterioration in engine cooling due to deterioration of heat transfer in the radiator, a decrease in the performance of the circulation pump due to the appearance of cavitation, a large loss of coolant from the system through the steam valve during starts and changes in engine load, etc.

Aerated liquid flow is always unstable, prone to pulsations, phase separation and other violations of hydrodynamic stability. It is known from hydrodynamics that, in contrast to single-phase flows in two-phase flows, the velocity field does not completely determine the form and character of motion. Here you also need to know the structure of the stream, i.e. distribution of mixture phases over the channel cross section.

In fig. 1. Possible modes of vertical and horizontal flows of two-phase liquids are shown. It can be seen from it that the horizontal channels are likely to have a wide variety of structures, depending on the gas distribution of the mixture, the speed of its movement, the viscosity of the liquid and the diameter of the channel.

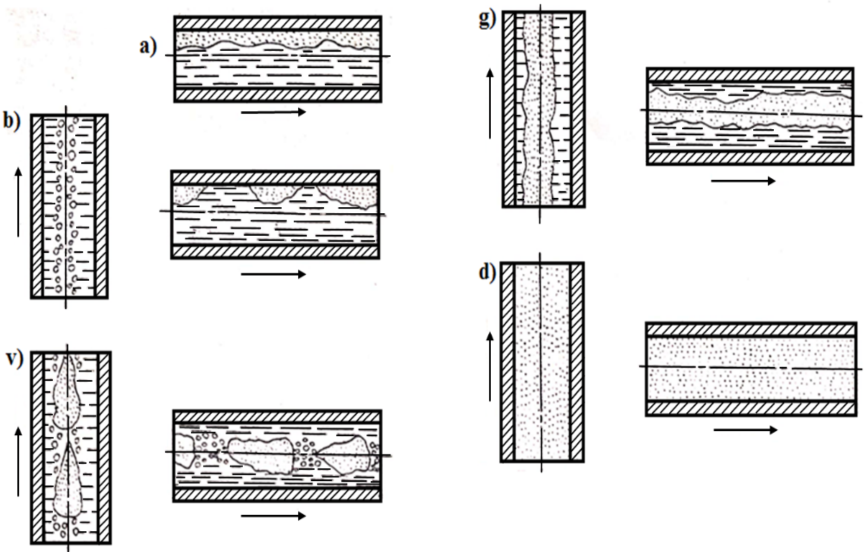

Fig. 1. Possible modes of two-phase flow in vertical and horizontal channels: a - stratified mode, b - bubble mode, c - slug mode, d - rod mode, d - emulsion mode.

The structure of the two-phase flow and the mode of its movement in the radiator channels have a direct impact on their thermal efficiency. This is manifested, in particular, in the fact that it is practically impossible to uniformly distribute a two-phase flow through parallel channels. Therefore, large hydraulic and thermal imbalances occur in the core. The content of the air-vapor phase in the coolant itself directly leads to a decrease in heat transfer in the radiator. This is explained by the fact that the heat transfer coefficient of the two-phase mixture to the walls of the radiator channels may turn out to be less than in the case of the movement of a single-phase dropping liquid, since the thermophysical properties of steam and gases are worse than those of water.

3. Solution method

To ensure reliable operation of the cooling system, the pressure at any point must be higher than the saturation pressure. As a rule, in a working system, the lowest pressure occurs at the suction to the circulation pump. Here, the pressure drop to the saturation pressure level is most likely, which is accompanied by vaporization of the liquid and the occurrence of pump cavitation. Losses of liquid from the cooling system lead to a decrease in the performance of the circulation pump, as a result of which the engine overheats and the efficiency of the radiator decreases.

The task of experimental determination of the effect of water loss from the cooling system on the pump performance at various engine crankshaft speeds under conditions close to operational, and the identification of the degree of influence on this flow rate of aeration of the flow and the accompanying cavitation.

De-aeration systems for copper-brazed and aluminum radiators have fundamentally similar designs, their hydraulic resistances, as can be seen in Fig. 2. almost the same. Therefore, it can be assumed that the de-aeration properties of these two radiators are similar.

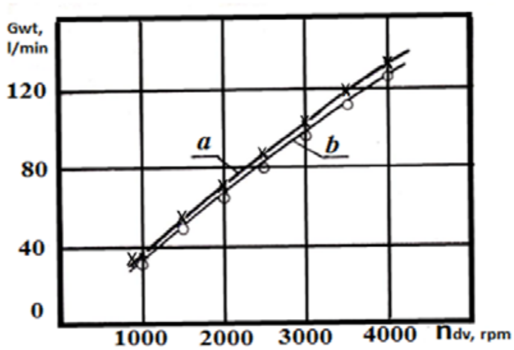

Fig. 2. Dependence of the coolant (water) consumption in the cooling system on the engine shaft speed when installing copper-brazed (x-x) and aluminum prefabricated (o-o) radiators at T_w = 353 K.

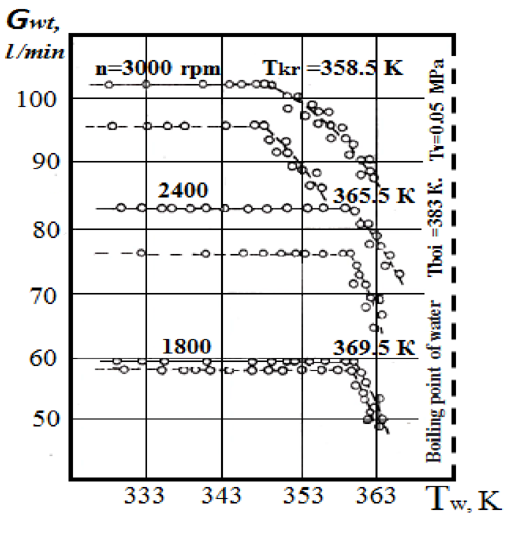

Fig. 3. Deaeration characteristics of an aluminum radiator (O–O) and a copper-brazed radiator (O — O) of a UAZ vehicle.

4. Results and Samples

Figure 3. to confirm these facts, the results of comparative tests of the effectiveness of the de-aeration properties of copper-brazed and aluminum prefabricated radiators are presented. In the graph, the flow rate through the radiators is presented for different engine speeds as a function of the average flow temperature. It can be seen that the flow rate through both radiators is practically the same at low rotational speed (1800 rpm), but as it increases to 2400 rpm, and even more so to 3000 rpm, the costs differ more and more. This is due to the fact that the dependence of the hydraulic resistance on the water flow rate for an aluminum radiator is steeper (exponent 2.0) than for a copper-brazed one (exponent 1.82).

It also follows from the graph that the dependences Gwt = f (Tw) of both radiators have a straight line parallel to the abscissa axis, which at temperatures Tkr = 358.5 - 369.5 K gets a sharp inflection, which indicates the occurrence of crisis phenomena in the flow circulation circuit through radiator. The general nature of these crises is to disrupt the hydraulic stability of the fluid flow going through the radiator to the water pump. For clarity, the graph also shows the boiling point of water equal to 383 K, which indicates the opening pressure of the steam valve equal to 0.05 MPa.

Further analysis of Fig. 3. shows that the value of the temperature difference is equal for

$$T_b = T_{boi} - T_{kr} \tag{1}$$

of the studied systems 13 - 24 K is, along with ΔTн and $\mathscr{H}$, an important operational parameter characterizing the liquid cooling system of an automobile engine. The value of this correction (difference) is essential for determining the value of the next important criterion of temperature-dynamic characteristics - the critical ambient temperature, up to which the trouble-free operation of the cooling system must be ensured, which can be seen from the equation.

$$T_{kr} = (T_{boi} - T_b) - (T'_w - T'_L + \varepsilon) \tag{2}$$

where, ε is the correction for the ambient temperature conditions at which the cooling system tests were carried out (at $T'_L = T_{kr},\ \varepsilon = 0$).

The higher the value of Tb, the lower the efficiency of de-aeration of the liquid flow passing through the radiator and the lower its de-aeration properties, determined by the design and dimensions of the de-aeration device. Taking into account the independent value of the Tb indicator for a possible assessment of the degree of perfection of de-aeration devices, let us call it the temperature zone of instability of the water flow.

Thus, the performed experimental analysis shows that the existing design differences in the hydraulic paths of the studied types of radiators are not so significant as to have a noticeable effect on the flow characteristics of the cooling system when they are installed in this system. Therefore, for all options for completing the cooling system with radiators, you can get by with a single dependence of the form

$$G_w = f(V_{a,}\ i_{tr,}\ T_{w,}\ n_{dv}) \tag{3}$$

where, Gw - coolant flow rate; Va is the speed of the vehicle or tractor; itr - gear ratio; Tw is the coolant temperature; ndv is the number of revolutions of the engine crankshaft.

To determine this dependence in an explicit form, in accordance with the empirical regression line, a power-law dependence of the form was selected.

$$G_w = b_0 (V_a i_{tr})^{b_1} \tag{4}$$

Coefficients b0 and b1 equal to b0 = 0.35 10-4; b1 = 0.969 were obtained by the least squares method, for which dependence (4) was reduced to a linear form by replacing ln Gw = Y, In ndv = X. Correlation coefficient values K = 1.00 indicate a close relationship between the variable.

5. Conclusion

Aeration of the coolant depends on the design features of the engine cooling system, load, design and operating conditions of the engine, and the technical condition of the systems.

The structure of the two-phase flow and the mode of its movement in the radiator channels have a direct impact on their thermal efficiency.

The conditions that cause hydraulic crises in the coolant flow and associated with the unsatisfactory operation of the de-aeration systems of copper-brazed and aluminum radiators are determined.

References

Akhmetov, A., Botirov, R., Abdurokhmonov, Sh., Materials Science and Engineering 883(1).

Akhmetov, A., Botirov, R., Amonov, M., 2020. Sustainable Agriculture Development in Central Asia and South Caucasus CASCADE-2020.

Apsin, V.P., Bondarenko, E.V., Manuylov, V.S., 2008. Bulletin of Moscow Automobile and Road Institute (State Technical University) 2072, 5841.

Averkiev, L.A., Poslavsky, A.P., Khludenev, A.V., 2009. Bulletin of Rostov State University of Railway Engineering 0201, 727.

Burkov, V.V., Redkov, L.I., 1989. On the issue of the hydrodynamics of two-phase flows circulating through autotractor radiators. Scientific works of the Leningrad Agricultural Institute 381, 51-55.

Chernyaev, L.A., Gavrilov, T.A., Collection of scientific papers of the All-Russian Research Institute of Sheep and Goat Breeding 037, 3054.

Khudayarov, B., Mambetsheripova, A., Kuziyev, U., Sarimsakov, B., Materials Science and Engineering 1030(1).

Podgursky, V., 2019. National Scientific and Practical Conference.

Poslavsky, A.P., Fadeev, A.A., 2017. Progressive technologies in transport systems collection of articles of the XIII international scientific and practical conference.

Poslavsky, A.P., Sorokin, V.V., Fadeev, A.A., 2017. Progressive technologies in transport systems collection of articles of the XIII International Scientific and practical conference.

Tarasenko, V.E., Yakubovich, A.I., Bobrovnik, A.I., 2010. Efficiency of the diesel engine cooling system of an agricultural tractor. Vestnik Gomel State Technical University named after P.O. Sukhoi 4, 19-28.

Umarov, G., Buronov, S., Amonov, M., 2020. Earth and Environmental Science 614(1).

Umarov, G., Buronov, S., Amonov, M., Mirzalieva, E., Tulaganov, B., 2020. Materials Science and Engineering 883(1).

Umirov, N., Abdurokhmonov, Sh., 2021. IOP Conference Series: Earth and Environmental Science. International Conference on Agricultural Engineering and Green Infrastructure Solutions (AEGIS 2021) 868.

Umirov, N.T., 2019. On the parameter of diognosity, the operation of the cooling system of engines of tractors and automobiles. Bulletin of the Turin Polytechnic University in the city of Tashkent 3, 58-59.

Umirov, N.T., Abdurokhmonov, Sh.X., Ganiboeva, E.M., 2021. Scientific-Technical Journal of FerPI.

Umirov, N.T., Khudaikulov, F.R., 2016. 1-international scientific and practical Internet conference "Modern ecological state of the natural environment and scientific and practical aspects of rational nature management". "Caspian Research Institute of Arid Agriculture".