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Method of Cleaning Internal Combustion Engine Radiator Tubes with Ultrasound

Sakhapov R. L.*
Kazan (Volga region) Federal University, Kazan, Russia
*corresponding author

Annotation. The article provides an experimental justification for cleaning radiator tubes. The method consists in the destruction of slag on the inner walls of the radiator tubes due to the cavitation of water under the action of ultrasonic waves. The description of the stand, the experimental technique and its results are given. In particular, the dependences of the slag mass on the time of exposure to ultrasound on the tubes, the temperature of the water and its air saturation are given. The obtained dependencies are reflected in the regression equation. The analysis of the regression equation allowed us to determine the optimal time of exposure to ultrasound. The coefficients of the ratio of the increase in the rate of fluid outflow from the radiator tubes, the mass of the slag and the density of the liquid before and after exposure to ultrasound are proposed. The design and equipment for the radiator cleaning station in the conditions of production and their manufacture at machine-building plants are given.

Keywords: radiator, cavitation, ultrasound, mechanical engineering, dispersion, ultrasonic generator, emitter.

Introduction

Vehicles equipped with an internal combustion engine have, with a few exceptions, a liquid engine cooling system. The heat exchanger in this system is the radiator tubes through which the coolant is pumped [1]. Over time, as the radiator is used, it gets dirty from the outside, and slag settles on the walls in its tubes. All this leads to a decrease in the heat exchange of the radiator with air, overheating of the engine, deterioration of the heating system and incomplete combustion of fuel in the engine [2,3]. This, in turn, worsens the environment and causes various diseases. Increased levels of air pollution caused by emissions from cars and other sources can worsen air quality and weaken human respiratory functions. This can increase the risk of COVID-19 infection and worsen the severity of the disease in those who have already been infected. [4,5,6]. To reduce the impact on the environment and improve public health, various measures can be taken, such as improving the efficiency of vehicles by improving the methods of car maintenance and installing additional exhaust gas purification devices for internal combustion engines [7,8].

Currently, radiator tubes are cleaned mechanically and chemically. The mechanical method is to guide the probe into the radiator tubes. This can damage it due to scratches and chips [9]. The chemical method consists in washing copper radiators with alkali, and aluminum radiators with acid. At the same time, parts made of other materials corrode, streaks and microcracks occur [10].

Modern mechanical engineering produces a number of devices for the diagnosis of diseases, geographical research, purification of gases and liquids and laundry. Ultrasonic and electric pulse methods of exhaust gas purification are developing prospectively. This method involves the use of ultrasonic waves to destroy pollution particles in exhaust gases. Both of these methods are aimed at reducing the level of harmful emissions from automobile exhaust, which contributes to improving air quality and reducing the negative impact on the environment and human health. [11,12].

In connection with the above, we have proposed a method for cleaning the walls of the radiator from scale by ultrasonic action on the water poured into the tubes.

This method has no disadvantages of chemical and mechanical methods and is therefore relevant.

We have proposed a method for cleaning radiators by cavitating water in tubes under the action of ultrasound.

The purpose of the experiment was to confirm the hypothesis of the effectiveness of the proposed method.

The practical usefulness of the proposed method is to simplify the washing procedure and make it safer for the structure.

The scientific novelty is in obtaining dependences of the efficiency of radiator cleaning on the mass of washed scale, pulp density and the rate of liquid outflow from the tubes.

During the experimental study, the following tasks were solved: equipment and measuring equipment were selected, a plan and procedure for conducting the experiment were developed, controlled factors and parameters were determined, quantitative and qualitative indicators determining the process under study were proposed, experimental data were obtained and experimental results were processed.

1. Methods and materials

The process of cleaning radiator tubes is carried out by cavitation of water under the influence of ultrasound.

Cavitation is a process of rapid destruction of air bubbles in a liquid having a strong destructive effect on the contact surface [13].

The authors conducted a preliminary experiment on cleaning the radiator tubes of a car. The experiment showed the effectiveness of the cleaning method [14]. However, due to the small size of the radiator, there was doubt about the effectiveness of the process on large radiators. This doubt was due to the fact that the scale coefficients in this case are not linear and it is impossible to determine a multiple of the size to change the result.

Also, a preliminary experiment, during which two main effects were considered: along and across the radiator tubes, showed that the longitudinal effect has a more effective result in the process of cleaning the radiator with ultrasound. This is due to the fact that with a transverse wave, it is necessary to cross the interface of the media several times, in this case, twice the walls of each tube. This leads to a rapid attenuation of the transverse wave [14 p. B290].

To implement a preliminary experiment on ultrasonic cleaning of the radiator, a liquid with the lowest viscosity was selected, while the liquid was saturated with air. This is justified by theoretical assumptions, according to which the use of a low-viscosity liquid contributes to a more efficient generation of cavitation bubbles under the influence of ultrasonic waves [14 p. B293, 15,16]. Air saturation additionally enhanced the cavitation processes, contributing to a more efficient removal of impurities from the internal cavities of the radiator tubes [17, 18].

An experimental study on cleaning the radiator of the cooling system was carried out on the radiator from the UAZ PATRIOT car using an assembled ultrasonic installation for cleaning car radiators based on preliminary results.

The installation for cleaning radiators by ultrasound consists of the following elements, shown in Figure 1.

Fig.1. – Installation for cleaning radiators with ultrasound

To clean the radiator with an ultrasonic wave, three ultrasonic generators and emitters with a frequency of 40 kilohertz and a power of 120 watts were used.

Longitudinal ultrasonic action was performed on the radiator by three emitters simultaneously shown in Figure 2.

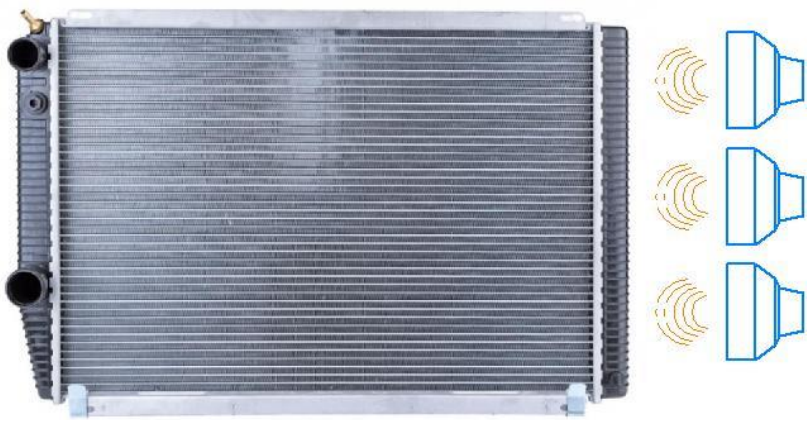

Fig. 2. – The effect of ultrasound on the radiator

During the experiment, liquid parameters such as density, volume and mass were determined. The following equipment was used to determine the parameters: electronic jewelry scales MN-500, measuring cylinder 50ml., measuring jug 1000 ml.

3. Experiment

In the experiment, distilled water with the lowest dynamic viscosity was used as a washing liquid. The water was saturated with air using an air pump and heated to a temperature of 55 degrees Celsius. The selected liquid parameters provide optimal conditions, fast and effective manifestations of cavitation processes and scale dispersion in the radiator [18, 19].

The experimental study was conducted in accordance with the following procedure: pure distilled water was poured into the radiator, the mass, volume, density and rate of water flow through the radiator were determined. Then the water was poured back, the water was saturated with air through the pump, ultrasound was applied for various times and the rate of water flow through the radiator, mass, volume and density were re-determined. The determination of liquid parameters before and after exposure to an ultrasonic wave was carried out by weighing, which made it possible to obtain accurate quantitative data on the mass and density of the liquid. The scale mass was determined by subtracting the mass of pure water from the total mass of the obtained pulp, which allowed to obtain the mass of washed scale. The pulp is a liquid with scale obtained as a result of exposure to ultrasound on the radiator [20]. Scale is solid deposits formed on the surfaces of heat exchange elements, where the liquid is heated or cooled [21]. The efficiency of the purification process was determined by the difference obtained. Figure 3 shows the detached scale from the internal cavities of the radiator.

Fig. 3. – Washed scale after exposure to ultrasound

Scale formation is not only associated with the decomposition of the coolant, but also occurs due to the effects of additional substances such as engine oil, gasoline, solid oil and others [21,22,23]. These components can contribute to the formation of solid deposits and affect the efficiency of heat transfer in the radiator.

3. Results and discussion

The conducted experiment was analyzed, as a result of which patterns were revealed and dependencies between the measured parameters were obtained. Graphs were plotted based on these dependencies, which made it possible to visualize the results and better understand the effect of ultrasonic exposure on the liquid poured into the radiator.

The measured parameters were systematized and presented in table 1, which makes it possible to evaluate changes in various parameters during the exposure to ultrasonic cleaning and to conduct a detailed analysis of the experimental results.

Table 1. Measured parameters when exposed to ultrasound

№	Ultrasound exposure time in seconds	The mass of the liquid in grams	Volume of water in milliliters	The density of the liquid in g/cm^3	Liquid expiration time in seconds	The temperature of the liquid in C^o	Fluid flow rate in ml/s
1	0	49,53	50	0,9906	3,34	55	299,40
2	600	51,39	50	1,0278	3,243	55	308,36
3	1200	53,74	50	1,0748	3,127	55	319,80
4	1800	57,18	50	1,1436	2,98	55	335,57

The analysis of experimental data made it possible to establish a relationship between the density and the rate of fluid flow through the radiator, depending on the time of exposure to ultrasound, which is reflected in Figures 4 and 5. These dependencies allow us to estimate the degree of intensity of cleaning the radiator tubes.

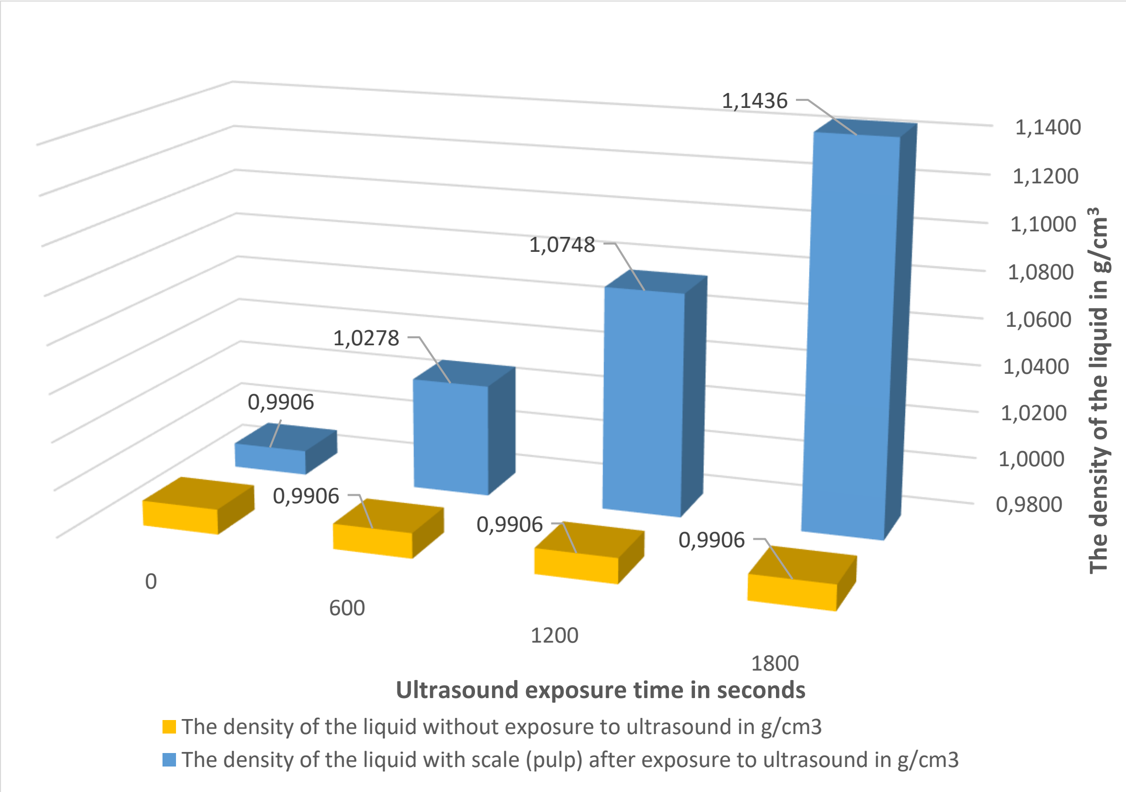

Fig. 4. – Changes in the density of the liquid depending on the time of exposure to ultrasound

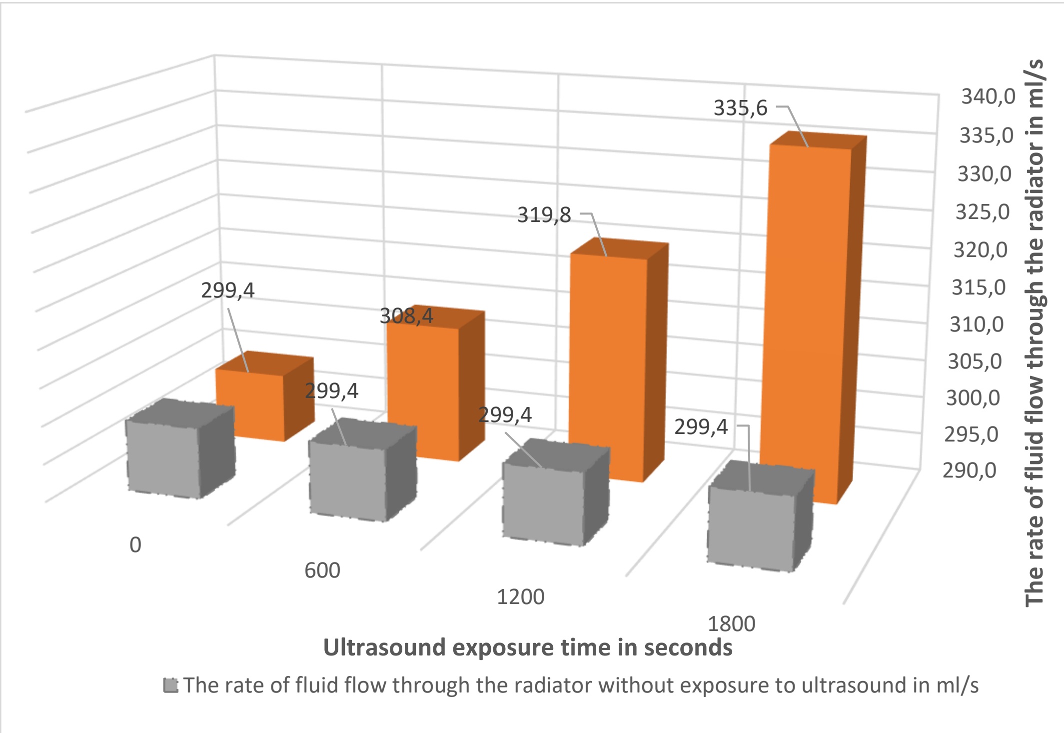

Fig. 5. – Changes in the rate of fluid flow through the radiator of the car depending on the time of exposure to ultrasound

The obtained graphs are a tool for visual examination, deeper data analysis and drawing conclusions about the effectiveness of ultrasonic exposure in the radiator cleaning process. Graph analysis makes it possible to assess the dynamics of the effect of ultrasound on the flow processes and properties of the liquid in the radiator, providing information on the effectiveness of ultrasonic cleaning depending on the exposure time.

With an increase in the time of exposure to ultrasound, an increase in the rate of discharge of liquid with scale is observed. This means that the effect of ultrasound has a more pronounced effect on the expiration of the pulp compared to pure water with an increase in processing time.

Table 2 shows the dynamic changes in pulp mass depending on the time of exposure to ultrasonic treatment and plots shown in Figures 6 and 7. These data reflect the weight of the pulp and the scale content, as the time of exposure to ultrasound. By subtracting the mass of pure water from the total mass of the pulp, the mass of washed scale was obtained. This approach allows us to quantify the effectiveness of the ultrasonic cleaning process and highlight the effect of this effect on descaling from the internal cavities of the radiator.

Table 2. Measured liquid parameters

The time of exposure of the ultrasonic wave to the radiator	seconds	0	600	1200	1800
The mass of the liquid	grams	49,53	51,39	53,74	57,18
Scale mass after exposure to ultrasound	grams	0	1,86	4,21	7,65

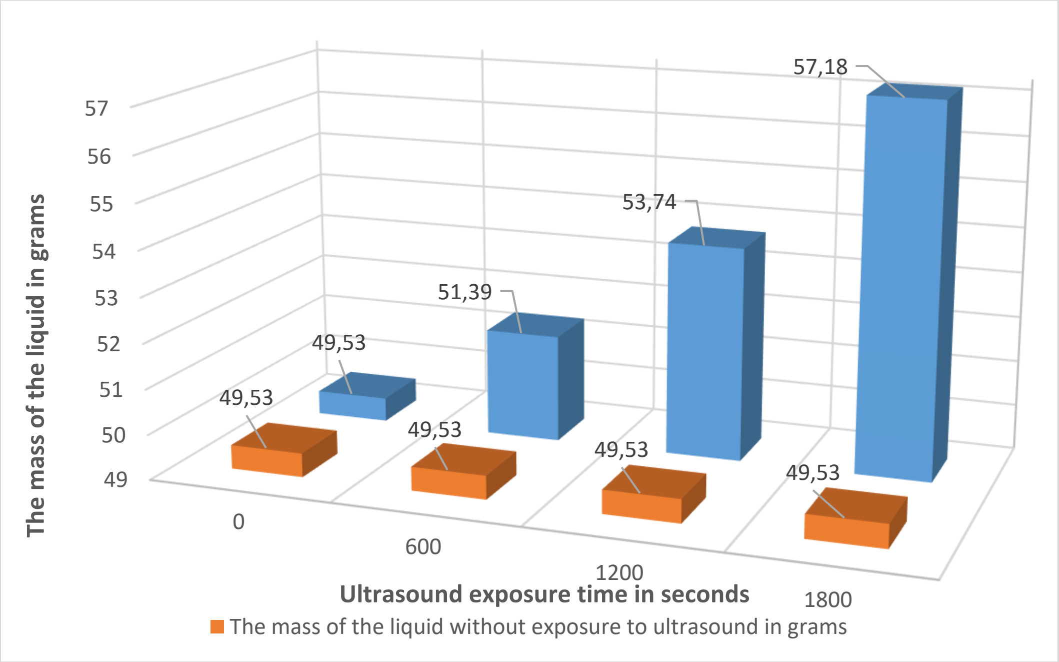

Fig. 6. – The obtained pulp mass depending on the time of exposure to ultrasound

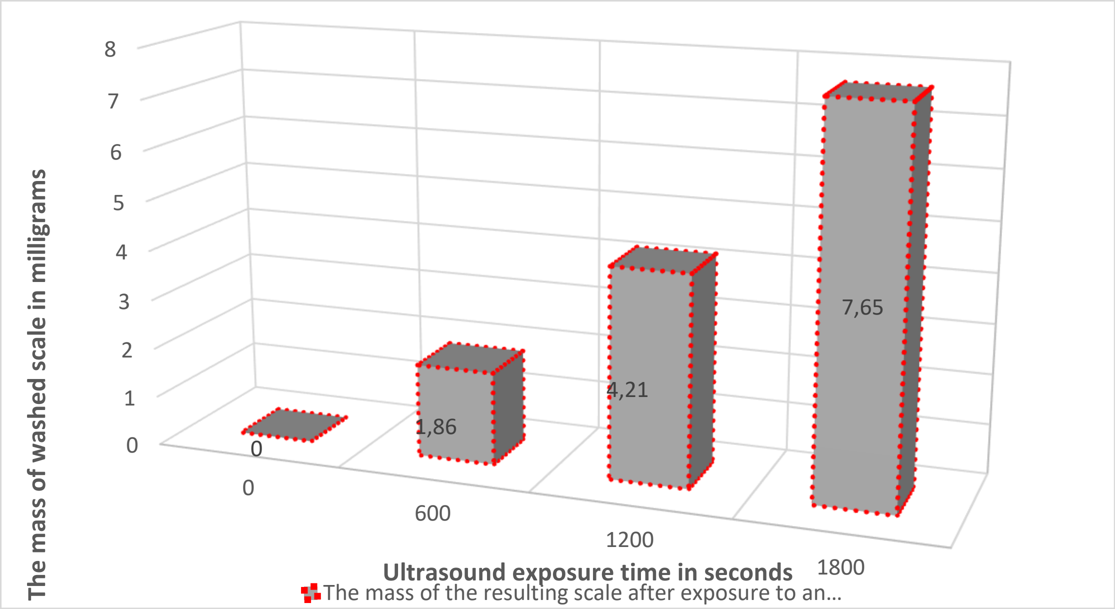

Fig. 7. – The resulting scale mass depending on the time of exposure to ultrasound

The analysis of these changes makes it possible to assess the dynamics of descaling from the radiator. With an increase in the time of exposure to ultrasound on the car radiator, the scale content in the liquid increases. The obtained dependences emphasize the effect of ultrasonic cleaning on the effective removal of scale from the radiator, which supports the initial assumption about the effectiveness of this method in the field of maintenance of the cooling system of transport equipment.

The resulting fluid mass data were interpolated by the Newton polynomial to more accurately determine the regression. From the analysis of the calculations performed for the highest values of the correlation coefficients, determination and the lowest values of the average approximation error, the quadratic regression equation was used for the radiator cleaning process by ultrasound:

$$y=ax^2- bx+c \tag{1}$$

$$y = 0{,}0000010973x^2 - 0{,}0021370795x + 49{,}6540167414$$

Correlation coefficient = 0,9996895857;
Coefficient of determination = 0,9993792678;
Average approximation error = 0,0901504992%.

The purification efficiency coefficients were calculated using the ratios of scale mass, density and fluid flow rate at different exposure times to ultrasound. These coefficients are presented in Table 3 and shown in Figure 8. The obtained coefficient values reflect the degree of effectiveness of ultrasonic cleaning depending on the exposure time, providing a quantitative assessment of the experimental results [14 p. B297].

Table 3. Coefficients justifying the efficiency of radiator cleaning

The effects of the ultrasonic wave on the radiator in seconds	The coefficient of increase in the rate of fluid flow after exposure to ultrasound	The coefficient of increase in the mass of washed scale after exposure to ultrasound	The coefficient of increase in liquid density after exposure to ultrasound
0	1	1	1
600	1,029927	1,037553	1,037553
1200	1,068136	1,084999	1,084999
1800	1,120808	1,154452	1,154452

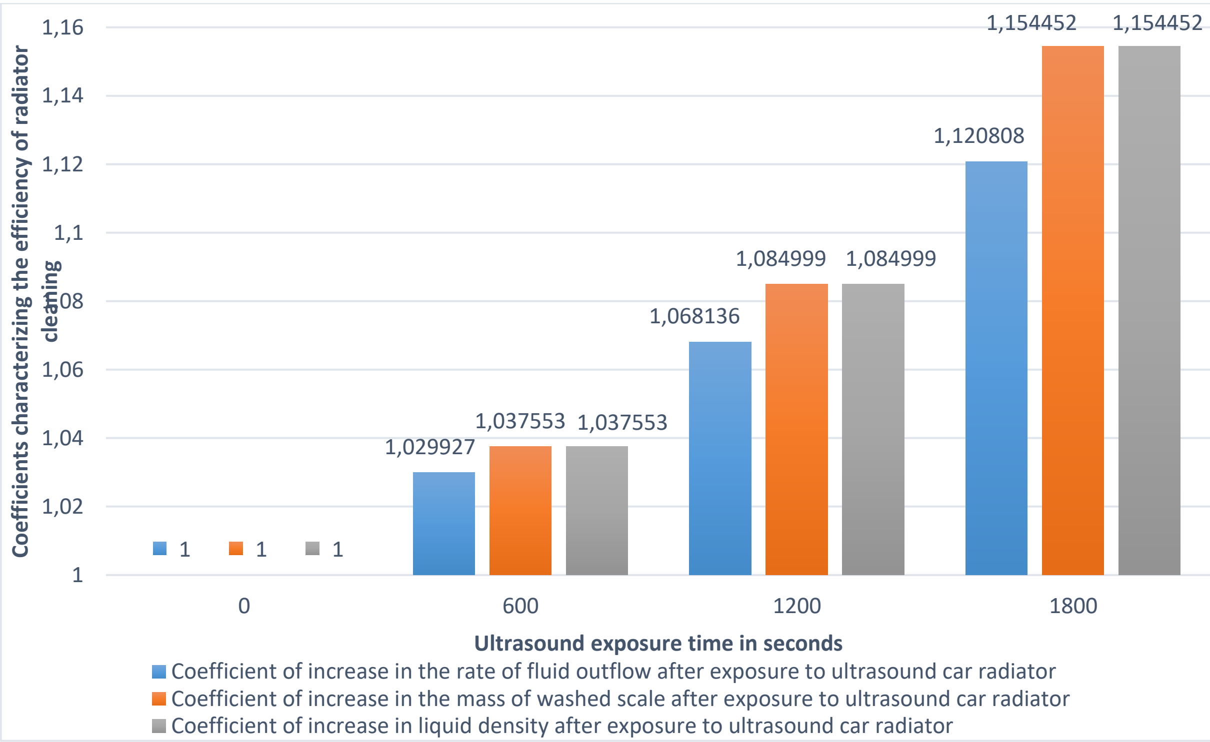

Fig. 8. – Coefficients justifying the efficiency of radiator cleaning

The obtained coefficients shown in Figure 8 reflect the processes that occur during cavitation into a liquid under the influence of ultrasound, and justify the effectiveness of scale destruction in radiator tubes. These coefficients represent a quantitative assessment of the degree of scale destruction and serve as important indicators of the effect of ultrasonic cleaning on the radiator, where higher values indicate a more efficient cleaning process.

Conclusions

The experiment confirms the hypothesis of the effectiveness of the proposed method for cleaning radiators of the cooling system of transport equipment equipped with internal combustion engines.

During the experimental study, the possibility of manufacturing new equipment for safe and innovative descaling of radiators using ultrasonic exposure, during maintenance of the cooling system of transport equipment, was proved.

The results obtained are a key component in understanding the cleaning process and can serve as a basis for further optimization of ultrasonic radiator cleaning conditions.

The results have both scientific and practical significance in the field of developing a methodology for calculating the parameters of the technological process and equipment for radiator maintenance. These findings are important for clarifying and optimizing the maintenance procedures for cooling systems, in particular radiators, which contributes to improving the efficiency and durability of automotive systems.

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Information of the authors

Sakhapov Rustem Lukmanovich, d.t.s., professor, Kazan (Volga region) Federal University
e-mail: coolzero7777@gmail.com