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# ORGANIZATION OF PULSATING AIR FLOW THROUGH A HEAT EXCHANGER

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# ОРГАНИЗАЦИЯ ПУЛЬСАЦИИ ПОТОКА ВОЗДУХА ЧЕРЕЗ ТЕПЛООБМЕННИК

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*Abstract.* In recent years, the enhancement of heat transfer by pulsating flow has become a research hotspot. A great deal of work has been done in the past, with remarkable results, to achieve better heat transfer rates. How to improve the efficiency of heat exchanger is always a research topic. In this paper, pulsating air flow is formed by standard ventilation grille and electric actuator, and the pulsating air flow is guided through two-stage heat exchanger to study the influence of pulsating air flow on heat transfer efficiency. The experimental results show that the heat transfer efficiency can be improved by pulsating flow and the heat recovery efficiency can be reduced by increasing the flow rate of the heating medium.

*Аннотация.* В последние годы интенсивная пульсирующая передача стала горячей точкой исследований. В прошлом люди делали много работы, достигали значимых результатов, чтобы достичь лучшей теплопередачи. Вопрос о том, как повысить эффективность теплообменников всегда был предметом исследований. В этой статье используется стандартная вентиляционная решетка и электрические проводящие устройства, которые образуют пульсирующие потоки, которые направляются через двухступенчатые тепловые нагреватели для изучения воздействия на тепловую эффективность пульсации. Результаты экспериментов показывают, что эффективность теплопередачи может быть улучшена за счет пульсирующего потока, а эффективность рекуперации тепла может быть снижена за счет увеличения скорости потока теплоносителя. В связи с ужесточением требований к расходу топлива дизельными двигателями и выбросам загрязняющих веществ повышаются требования к характеристикам систем впрыска топлива дизельных двигателей.

Кавитационный поток в форсунках дизельного топлива является чрезвычайно важным фактором, влияющим на характеристики распыления.

*Keywords: pulsating flow, steady flow, heat exchanger, heat transfer efficiency.*

*Ключевые слова:* пульсирующий поток, постоянный поток, теплообменник, тепловая эффективность.

*Introduction*

In 1929, E.G. Richardson [1] used hot-wire anemometer to measure the velocity of steady-state flow and pulsating flow in the tube, compared the theoretical value and measured value of the average velocity gradient on the cross section of the tube, and found the "ring effect" of pulsating flow velocity, which marked the beginning of the study of pulsating heat transfer. Subsequently, B. West Frank and Allan Taylor [2] studied the convective heat transfer characteristics in the pulsating flow tube generated by the reciprocating pump and obtained the heat transfer enhancement effect of 60–70%. A. K. Openheim [3] and T. J. Williams, Swansea Wales [4] put forward some conclusions on the measurement of pulsating flow, which have important guiding significance for the measurement and calculation of pulsating pressure and velocity. A. Carleton Jealous [5] studied the pulsating flow enhancement separation problem with pulsating cylinder as the generator and proposed the energy equation needed to introduce pulsating action in liquid-liquid separation. In 1954, H. A. Havemann and N. N. Narayan Rao [6] published an article entitled "pulsating flow heat transfer" in the famous Nature academic journal, marking the official rise of the research on pulsating heat transfer. Shortly thereafter, Robert Lemlich [7] not only proposed the equation of the enhanced heat transfer ratio of pulsating heat transfer, but also summarized the research situation of pulsating heat transfer at that time. He systematically summarized the results of 39 groups of experiments, among which most experiments proved that pulsating heat transfer could achieve enhanced heat transfer, and the highest enhancement ratio was 23 times.

In 1971, M. F. Edwards and W. L. Wilkinson [8] summarized the potential application of pulsating flow in pipe, gave the momentum equation and energy equation corresponding to pulsating flow in laminar flow state, and put forward a criterion equation idea. In 1973, A. Evans Norman [9–10] discussed the problem of heat transfer in the unsteady boundary layer on a semi-infinite plate. He believed that in the next 50 years, unsteady fluid mechanics would be the focus of attention. He also listed examples of pulsating heat transfer engineering applications, such as the unsteady combustion of rockets and the heat transfer efficiency of heat exchangers enhanced by unsteady air. In 1975, P. Merkli and H. Thomann [11] studied the transition problem of the flow direction of the pulsating turbulent layer in a tube and believed that the traditional steady-state flow Reynolds number was not accurate in distinguishing the laminar flow from the turbulent flow and proposed a new method to define it. In 1977, W. G. Hill and P. R. Greene [12] applied self-excited acoustic oscillation to enhance the mixing rate of turbulent jet and studied the phenomenon of sentry nozzle, which provided an important reference for the study of self-excited pulsation. These contents can be called the milestones in the development of pulsating heat transfer research and the signs of the gradual progress of pulsating heat transfer research.

In recent years, with the increasingly powerful computer operation function and the progress of modern high-precision measurement and data acquisition technologies, as well as the emergence of CFD numerical simulation and PIV high-precision velocity measurement technologies, pulsating heat transfer research has been provided with a material basis for further development. At present, a number of outstanding researchers have emerged, such as Hwang K. S., Sung Y. J., Hyun J. M. of Korea advanced institute of science and technology [13]; Cho H. M., Hyun J. M. [14]; M. R. Mackley, P. Stonestreet of Cambridge university, England [15–16]; and Ulrich H. Kurzweg of university of Florida, USA. These scholars have made considerable achievements in pulsating heat and mass transfer research. Heat and Mass Transfer areas in the famous International Journal, "International Journal of Heat and Mass Transfer", invited the United States each year at the university of Minnesota you Heat Transfer accomplishment, such as R. J. Goldstein, E. R. G. Eckert for Heat and Mass Transfer in the world to learn calendar year carries on the summary and the summary, the significance of the research content of pulsating Heat Transfer related research has become a fixed content, every year are written to the Heat and Mass Transfer in the academic year review.

*Experimental Research*

Using standard grillage and electric drive production organization pulsating flow, the frequency of pulsating flow is set by the time relay to guide the pulsating flow through the water-air heat exchanger of heat recovery unit 1 and 2, and the heat recovery efficiency under continuous and pulsating air supply mode is obtained from the medium temperature and air temperature at the inlet and outlet of heat exchanger. The experimental schematic diagram is shown in Figure 1.

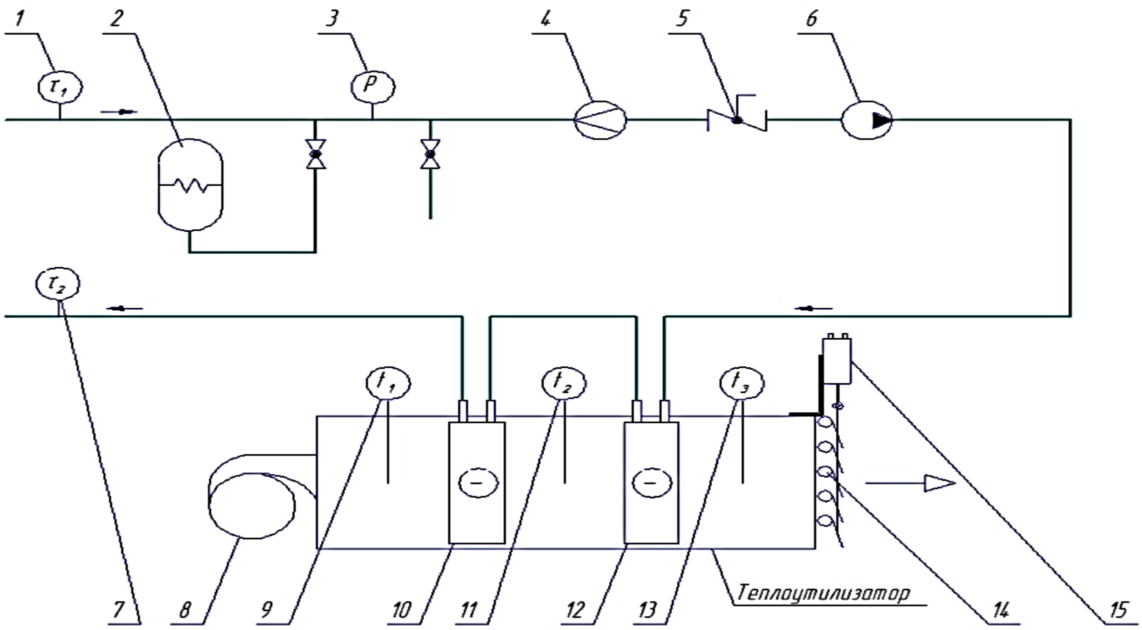


Figure 1. Scheme of the experimental setup: 1 and 7 — resistance thermal converters designed to measure the temperature of the heated medium before and after the heat exchanger, 2 — pressure accumulator, 3 — pressure gauge,4 — electromagnetic flow converter, 5 — manual balancing valve, 6 — circulation pump, 8 — heat recovery unit fan, 9, 11and 13 — resistance thermal converters designed to measure the temperature of the air flow at different points of the heat recovery unit, 10 and 12 — water-air heat exchangers of the heat recovery unit of the 1st and 2nd stages, 14 — air damper,15 — electric air damper.

The experimental apparatus consists of a block and so on heat utilizator well and measuring the complex (Figure 2). Heat exchanger presented is an apparatus including a fan, creating a second flow of air in the range 50–350 m$^3$/h and two water-air heat exchanger arranged in series within the housing panel-frame structure.

 

Figure 2. Photo of the exterior of the heat exchanger housing and the complex, including a circulation pump, a hydraulic accumulator, a balancing valve and an electromagnetic fluid flow converter.

The measuring complex includes a Masterflow 4 electromagnetic fluid flow converter, resistance thermocouples 1 and 7 for measuring the temperature of the heated medium before and after the heat exchanger, and 9,11 and 13 for measuring the air flow temperature at different points of the heat exchanger block (Figure 3).

Figure 3. A fragment of the appearance of the experimental setup.

To ensure circulation and a heated medium, a Wilo 6 pump is included in the circuit. Changing the flow of the medium as grevaemoy medium is possible using manually the balancing valve 5. Smoothing possible water hammer in the system is perceived by the membrane accumulator 2 is also included in the circuit (Figure 4).

Figure 4. A fragment of the appearance of the experimental setup.

We organized the creation of a pulsating flow using a standard ventilation grill and an electric drive, the frequency of which is set by a time relay. The electric power supply circuit of the electric drive is shown in Figure 5.

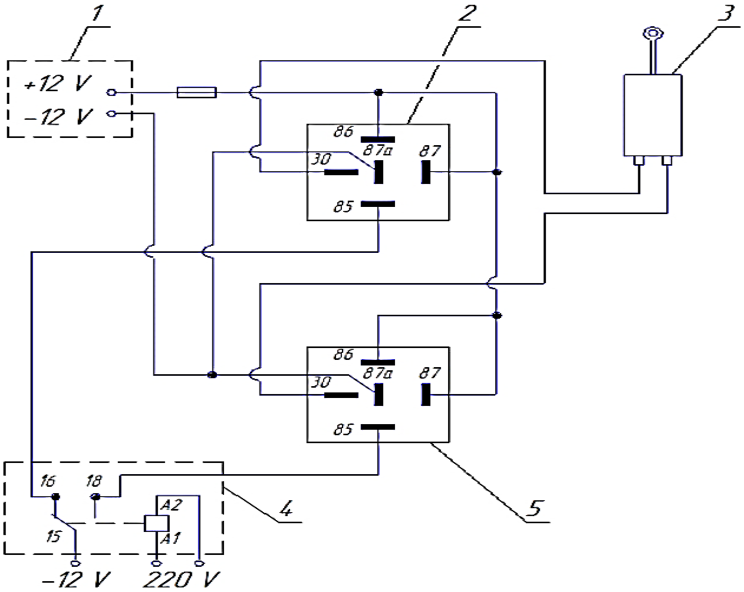


Figure 5. Electrical power supply circuit of the electric ventilation grille: 1 — 12 V DC power supply, 2 and 5 — voltage relay, 3 — electric drive, 4 — RVC-1M time relay.

*Experiment results*

The experiment measured the parameters of the air and the heated liquid in the pulsating and continuous air flow during the flow velocity from 50 kg/h to 400 kg/h in both 226 $m^3$/h and 278 $m^3$/h airflow velocity modes.

The efficiency of the heat exchanger in a pulsating and continuous air flow was determined by the formula:

$$E = \frac{\tau_2 - \tau_1}{t_1 - \tau_1} \cdot 100\% \quad (1)$$

$\tau_1$ — temperature of the heated medium in front of the heat exchanger, °C; $\tau_2$ — temperature of the heated medium after the heat exchanger, °C; $t_1$ — exhaust air temperature at the inlet to the heat exchanger, °C.

For illustrative example, the results obtained are presented in graphical form in Figures 5 and 6.

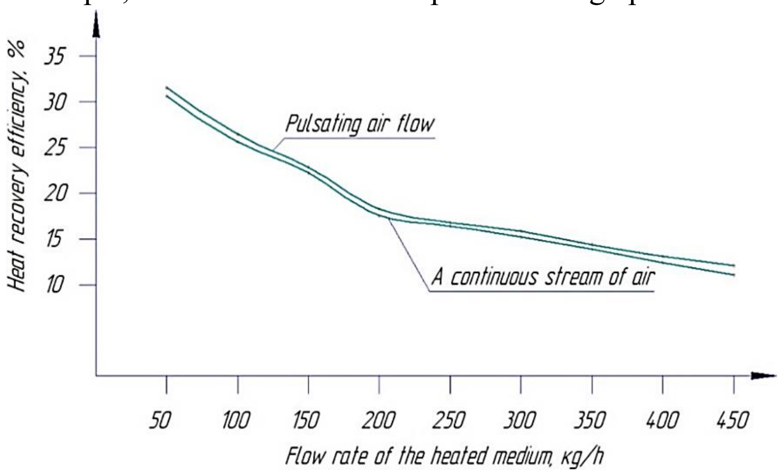


Figure 6. Comparative graph of the efficiency of heat recovery in continuous and pulsating air flows at

a fan capacity of 226 m³/h

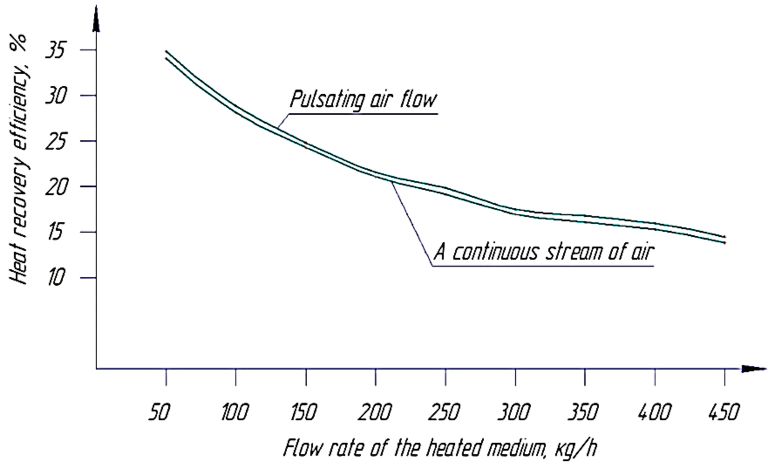


Figure 7. Comparative graph of the efficiency of heat recovery in continuous and pulsating air flows with a fan capacity of 278 m³/h

As can be seen from the results of processing the experiment, the heat recovery efficiency in a pulsating mode slightly increases from 2.2 to 4.8%. The experiment also showed that with an increase in the flow rate of the heated medium from 50 to 450 kg / h, the efficiency of heat recovery decreases.

*Conclusion*

The pulsation is introduced into the heat exchanger. The results show that the heat transfer efficiency of the pulsating flow is slightly higher than that of the steady flow, which indicates that the pulsating flow can improve the heat transfer efficiency of the heat exchanger. In my opinion, the reason why the pulsation enhances heat transfer is that the pulsation flow increases the turbulence of the flow, thus increasing the heat transfer coefficient, and thus improving the heat transfer efficiency of the heat exchanger to some extent. It is also found that the heat transfer efficiency decreases with the increase of liquid flow. In addition, through the comparison of experimental data, it is found that under the same liquid flow rate, the greater the airflow velocity is, the higher the heat transfer efficiency is. We have also designed a new type of pulsating generator, which USES louver-type ventilation grille, which is driven by motor, and the airflow is changed into pulsating airflow through the opening and closing of fan blades. Due to the limitation of experimental conditions, we have only made two groups of different airflow velocity. I think future researchers can try to make several groups of different airflow velocity to give more comprehensive results.

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