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M.S. Isataev , G. Toleuov , Zh.K. Seydulla , B. Rakhataeva , A. Sagtagan
al-Farabi Kazakh National University,
Almaty, Republic of Kazakhstan
**E-mail: Zhanibek.seidulla@kaznu.kz*

HEAT EXCHANGE OF AN ANNULAR JET TRANSMITTED OVER A CYLINDRICAL SURFACE

Abstract. A large number of papers are devoted to theoretical and experimental studies of heat transfer and control of jet mixing processes. In this paper, a thermocouple for measuring the temperature of the cylinder surface, according to the amount of heat transmitted by a unit of the surface of the cylinder heated by an electric current when measuring the local heat exchange coefficient, the distribution of pulsation characteristics is studied using a thermoanemometer. The paper considers the problem of the distribution of laminar flow flowing through Ring nozzles of the last size along the cylinder of a constant radius along its length. When solving the problem, a semi-empirical speed profile is used. As the horizontal curvature increases, it is shown that the speed profile in the boundary layer in the cylinder is more filled in comparison with the speed profile in the plate. Later, a theoretical and experimental study of the longitudinal flow of a long cylinder, which is not smoothed by a uniform turbulent flow, was carried out. The study of the influence of acoustic effects on heat exchange in partially restricted lowland submerged currents and satellite flow is carried out. There is a possibility of resonant amplification of the turbulence development of a partially restricted flow, such as free flows. This reduces the length of the laminar boundary layer of the wall, shortens the laminar flow zone, and establishes the area where the turbulent flow previously developed. Exposure to high-frequency vibrations stretches the laminar-turbulent transition.

Keywords: cylindrical surface, heat exchange, semi-linear flow, pulsation, turbulent jet, turbulent development, heat exchange of an annular jet.

М.С. Исатаев, Г.К. Толеуов, Ж.К. Сейдулла, Рахатаева Б, А. Сақтаган
Казахский национальный университет им. аль-Фараби,
Алматы, Республика Казахстан
e – mail: Zhanibek.seidulla@kaznu.kz

ТЕПЛООБМЕН КОЛЬЦЕВОЙ СТРУИ ПРОХОДЯЩЕЙ ПО ЦИЛИНДРИЧЕСКОЙ ПОВЕРХНОСТИ

Аннотация: Большое количество работ посвящено теоретическим и экспериментальным исследованиям теплообмена и управления процессами струйного перемешивания. В данной работе термопара для измерения температуры поверхности цилиндра, по количеству тепла, передаваемого единицей поверхности цилиндра, нагреваемой электрическим током, при измерении локального коэффициента теплообмена исследуется распределение пульсационных характеристик с помощью термоанемометра. В работе рассматривается задача о распределении ламинарного потока, протекающего через кольцевые сопла последнего размера, вдоль цилиндра постоянного радиуса по его длине. При решении задачи используется полуэмпирический профиль скорости. По мере увеличения горизонтальной кривизны показано, что профиль скорости в пограничном слое цилиндра более заполнен по сравнению с профилем скорости в пластине. Позже было проведено теоретическое и экспериментальное исследование продольного течения длинного цилиндра, не сглаженного равномерным турбулентным потоком. Проведено исследование влияния акустических эффектов на теплообмен в частично ограниченных низинных подводных течениях и спутниковых потоках. Существует возможность резонансного усиления развития турбулентности частично ограниченного потока, такого как свободные потоки. Это уменьшает длину ламинарного пограничного слоя стенки, укорачивает зону ламинарного течения и устанавливает область, где ранее развивалось турбулентное течение.

Ключевые слова: цилиндрическая поверхность, теплообмен, полулинейное течение, пульсация, турбулентная струя, теплообмен кольцевой струи.

М.С. Исатаев, Г.К. Төлеуов, Ж.Қ. Сейдулла, Рахатаева Б, А. Сақтаған
Әл-Фараби атындығы Казақ ұлттық университеті,
Алматы, Казахстан Республикасы

e – mail: Zhanibek.seidulla@kaznu.kz

Аннотация: Көптеген жұмыстар жылу беруді теориялық және эксперименттік зерттеулерге және реактивті араластыру процестерін басқаруға арналған. Бұл жұмыста цилиндр бетінің температурасын өлшеуге арналған термопара, электр тогымен қыздырылған цилиндр бетінің бірлігіне берілетін жылу мөлшеріне сәйкес, жылу алмасудың жергілікті коэффициентін өлшеу кезінде термоанемометр көмегімен пульсациялық сипаттамалардың таралуы зерттеледі. Жұмыста ұзындығы бойынша тұрақты радиусы бар цилиндр бойымен соңғы мөлшердегі сақиналы саңылаулар арқылы өтетін ламинарлық ағынның таралуы қарастырылады. Мәселені шешу кезінде жартылай эмпирикалық жылдамдық профилі қолданылады. Көлденең қисықтық жоғарылаған сайын, цилиндрдің шекаралық қабатындағы жылдамдық профилі пластинадағы жылдамдық профилімен салыстырғанда көбірек толтырылғандығы көрсетілген. Кейінірек біркелкі турбулентті ағынмен тегістелмеген ұзын цилиндрдің бойлық ағынын теориялық және эксперименттік зерттеу жүргізілді. Акустикалық әсерлердің ішінара шектелген ойпатты су асты ағындары мен спутниктік ағындардағы жылу алмасуға әсерін зерттеу жүргізілді. Еркін ағындар сияқты ішінара шектеулі ағынның турбуленттілігінің дамуын резонанстық күшейту мүмкіндігі бар. Бұл қабырғаның ламинарлық шекара қабатының ұзындығын азайтады, ламинарлық ток аймағын қысқартады және турбулентті ток бұрын дамыған аймақты белгілейді.

Түйін сөздер: цилиндрлік бет, жылу алмасу, жартылай сызықты ток, пульсация, турбулентті ағын, айналмалы ағынның жылу алмасуы.

Introduction

The study of heat exchange of semi-limited flow flows is devoted to theoretical and experimental work. Interest in these tasks is due to its wide application in semi-limited flow industries: in Chemical Technology, in the technological processes of drying bonfires, in the cooling of combustion chambers, blades of gas turbines, jet engines, etc.

In most cases, at small values of the horizontal curve parameter, flow patterns were considered in flat and radial semi-bounded flows or flows spreading along the cylindrical surface, which can be ignored under the influence of which.

Of great interest, both from a scientific and practical point of view, is the study of heat exchange of annular flows distributed over a wide range of changes in the curve parameter along a cylindrical surface. Due to the influence of the horizontal curve parameter, the problem of the distribution of ring flow along a cylindrical surface is not an auto model, and it is very difficult to theoretically study it on the basis of boundary layer theory.

There is absolutely no data on the study of the laws of vortex formation and the study of the laws of turbulence development in valal and transition sections of Wall-ring flows. This was the basis for setting the following task in this work.

Partially restricted flow research

An annular ribbed flow occurs when a cylindrical body flows longitudinally [1]. The flow passes through a circumferential hole of width b_0 and propagates along a cylinder of constant radius R_0.

Like the movement of a flat ribbed jet, the entire flow sphere can be divided into three parts: primary, transition, and main [2]. The primary part is characterized by the presence of a constant velocity core, bounded by a free layer of interference from the outside and a boundary layer of the inner wall. In the initial part, at the end, the boundary layers bend at the maximum speed line.

The transition after the initial part, and then after reaching the developed level of speed and intensity of turbulence, begins from the place where the main section of the current extends. In the initial and transition parts of the flow, the length depends on the initial thickness of the boundary layer (internal and external), the level of turbulence and the Reynolds number of the flow, as well as the intensity of various impacts [3].

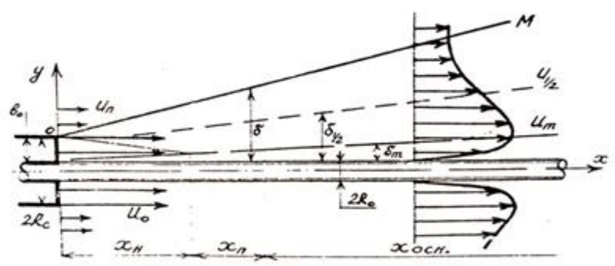

Figure 1– Circular spreading along the surface of the cylinder flow chart of the stream

The distribution of the turbulent flow over the cylinder surface is obvious; the laws in the ribbed boundary layer are close to the laws of the turbulent boundary layer when the cylinder flows longitudinally [4].

In this work, the values of indirect stresses, averaged and pulsation velocities are measured over the cross section of a circulating jet flowing from a nozzle with a diameter of 16.9 *mm* and propagating through a cylinder with a diameter of 12.7 *mm* ($S_{R_0} = \frac{b_0}{R_0} = 0.33$).

Experimental installations and measurement methods

According to the requirements, two units were assembled: for the study of heat exchange, vortex structure of the flow and visualization.

Figure 2 shows the installation scheme that meets the specified requirements:

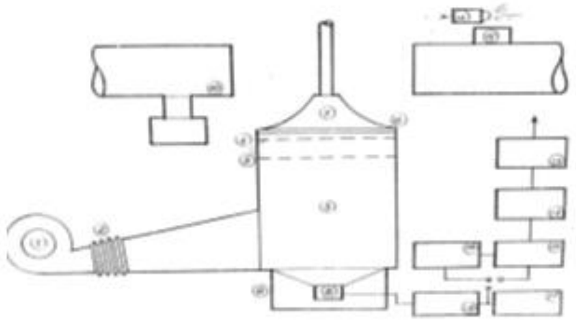

Figure 2– Experimental installation diagram

Before conducting the experiment, the width of the gap between the cylinder surface and the nozzle in the output section is carefully monitored and, if necessary, the speed profile in the initial, transition and main parts of the flow is checked the symmetry was smoothed out. Especially carefully monitored and maintained speed stability in the exit section of the PLO.

Experiments on the study of the pulsation structure and heat exchange were carried out in units that differ from each other in some features arising from the conditions for setting tasks. To monitor the flow pattern, the studied flow area is located in the working part of the shadow instrument IAB-451.

From The Fan 1 through the soft touch of rubber 2, air is fed through the diffuser 4,5 to the calming Chamber of the grid 3 and ends from the soplo along the cylindrical insert. 8 loudspeakers are installed in the lower part of the silencing chamber with a power of 25 w, a protective casing 9. a plastic bar is attached to the side to seal the chamber and improve the transmission of the loudspeaker to the protective casing. In order to reduce the acoustic resonance of the chamber walls, it is made of wood-chip material with a thickness of 25 *mm* and inside it is sound-absorbing material with a thickness of 15 mm. The grid 5 has a cell size of 0.7*0.7 *mm* and serves to heat the flow. Heating is carried out by passing alternating current through it. In experiments, a small heating up to 30-40 flows was used to visualize the flow pattern. In the upper part of the camera 3, the holder 6 is mounted [5].

When studying the heat exchange and vortex structure from the visual drawing, the air is connected to a low-power 300 *W* fan with less air consumption. To obtain high speeds up to 80 *m / s*, the unit is connected by a soft touch of the air duct from the TV-80-1,6 type centrifugal compressor. The flow rate was regulated by changing the voltage applied to the electric motor of the small fan and by flaps in the air duct of the centrifugal compressor.

The study of heat exchange during the flow of a cylinder jet in the same installation (Fig.2) is made of sheet steel heated by electrical conductivity using a working cylinder made of a thin-walled tube. In the practice of heat transfer research (0.84 ohms· mm^2/m) a high resistivity stainless steel cylinder was used.the outer diameter is 14 mm, the wall thickness is 0.22 mm and the length is 850 mm. the cylinder was heated by an electric current that was passed through the copper tips to the edge of the cylinder . The decrease in the electric current voltage in the cylinder varied within 1 *V* and was measured by devices of the electromagnetic system of the e 59 brand with an accuracy class of 0.1.The current value varied within 10 *A* and was measured by an e

59 electromagnetic system device with an accuracy class of 0.1.

The uniformity of the cylinder wall thickness was checked by measuring the voltage drop along the length of the working cylinder [6]. A direct current passed through the cylinder and the voltage drop was measured using a pptn-1 potentiometer. The uniformity of the cylinder wall thickness was checked by measuring the voltage drop along the length of the working cylinder. A direct current passed through the cylinder and the voltage drop was measured using a pptn-1 potentiometer. The stress unevenness did not exceed 10.3% and therefore was considered $q_w = const$ along the length of the cylinder.

Experimental results and discuss

To study the influence of the horizontal curve parameter and the development of turbulence, local heat transfer coefficients of the cylinder $u_0 = 3.32, 9.62, 14.51 m/s$ with a diameter of $2R_0 = 14mm$ were measured for a rotational flow flowing into the cylinder flow, 25.0 *mm* and 40.0 *mm* with knowledge of the initial flow velocity. The curve parameters for the studied flows had the values $S_{R_0} = \frac{b_0}{R_0} = 0.79$ and 1.86, where b_0 is the width of the annular gap at the nozzle outlet.

The value of the local heat transfer coefficient decreases to a distance of $4 \div 5mm$ from the nozzle, after which the local heat transfer coefficient increases to a distance of $\frac{x}{b_0} = 10 \div 15.$

At $x/b_0 > 15,$ a monotonous decrease in the heat transfer coefficient removed from the nozzle is observed in all measurements.

Up to $x/b_0 \ll 5,$ the nozzle section near the cylinder surface has a laminar flow mode, while in zone $5 < x/\mathrm{b}_0 < 15$ there is a transient flow mode, and in zone $x/b_0 > 15$ there is a turbulent flow mode.

The influence of acoustic influence on the development of axial symmetrical free flow was studied in the works. A review of studies and generalized conclusions on the study of the influence of acoustic chokes of different intensities and frequencies on free and Wall flows are presented in the paper. The problem of the impact of acoustic protests on the wall and the flow has now become particularly relevant, since the impact effects can be used to intensify heat mass exchange during turbulent mixing or deceleration, forced and free convection in streams [7].

Thus, using acoustic influence, as well as using other methods (mechanical action using a velocity pulsator, increasing turbulence of the initial level, etc.), it is Possible to control the intensity of heat exchange within the initial and transition sections of the flow during the flow of the body jet.

However, the intensity of heat exchange in the main section of the flow remains unchanged for all values of the frequency of acoustic influence. The change in the local heat transfer coefficient at different frequencies of acoustic influence is shown here [8].

Thus, in an annular flow, as well as in flat partially restricted and free axisymmetric flows, the influence of acoustic influence depends only on heat exchange within the initial and transition sections of the flow and practically does not affect the intensity of heat exchange in the main section of the flow.

In this work, an attempt is made to account for the effect of the turbulence level on the heat transfer intensity at the outer boundary of the wall boundary layer when the plate flows with a flat partially restricted flow [9]. With the introduction of a correction factor, he was able to link the heat exchange of plates when flowing with a heat exchanger when flowing with a uniform flow. In this case, the heat exchange during the flow is characterized.

A correction similar to the effect of turbulence was made for the heat exchange of the surface of a cylinder flowing in a rotating flow. In this case, the velocity in the rotating flow is calculated of the change in the turbulence level along the maximum line. The experimental data processed are shown in Fig.3.

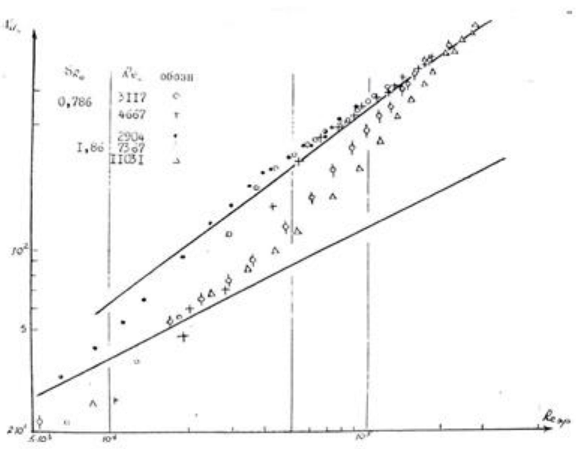

Figure 3– Dependence of the dimensionless coefficient of heat exchange in the rotating flow of the cylinder $\mathrm{Re}_{Eph,}$ taking into account the effect of the horizontal curvature of the filling surface.

With additional consideration of the influence of the level of turbulence, the dependence of the heat exchange of the cylindrical surface during the flow of the plate can be reduced to the dependence of the heat exchange during the flow of the plate with a uniform unlimited flow.

Conclusion

When the cylinder is fed through the size of the local heat transfer coefficient, as well as in cases of plate flow, a laminar boundary layer occurs at the initial section of the rotating jet near the cylinder surface; the heat exchange intensity removed from the nozzle decreases to the end of the initial section. In the area of $5 \ll x/b_0 \ll 10 \div 15,$ there is a transition zone of the flow, the heat transfer coefficient of which is removed from the nozzle. At a large distance from the 15-gauge nozzle, the flows in the turbulent boundary layer and the heat exchange intensity are monotonously eliminated, moving away from the nozzle.

Processing experimental data at coordinates $Nu_x = f(\mathrm{Re}_{mx})$ does not provide a universal dependency as a flat semi-bounded stream. This is due to the fact that at a great distance from the nozzle.

$\mathrm{Re}_{mx} = \frac{u_m x}{\nu}$, the value stops changing under the influence of the horizontal curvature of the flowing surface, but Nu_x continues to grow.

To calculate the heat transfer intensity, the universal dependence can be obtained by introducing the effective Reynolds number, which takes into account the influence of the horizontal curvature parameter of the flowing surface. As a result of the analysis of experimental data, an empirical dependence is obtained for calculating the heat transfer intensity of the cylinder for annular flow and Reynolds flow in a wide range of the horizontal curve parameter.

The effective value of the Reynolds number taking into account the influence of the parameter of horizontal curve, and the intensity of turbulence at the ribbed border of the boundary layer depends on the heat transfer plate in a uniform ow stream by heat exchange flow cylinder flow.

The acoustic effect mainly affects the heat exchange rate at the initial and transition sections of the rotating partially restricted flow and does not affect the heat exchange rate at the main section of the flow. The resonant acoustic effect slightly increases, and the high-frequency effect weakens the intensity of heat exchange in the initial and transition sections.

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