Г. В. Алексеев [G. V. Alekseyev]
И. И. Бриденко [I. I. Bridenko]
А. А. Суомалайнен [A. A. Suomalainen]

УДК 642.5:001.895

ЭКСЕРГЕТИЧЕСКИЙ АНАЛИЗ ХАРАКТЕРИСТИК КОМПРЕССОРА С ИСПОЛЬЗОВАНИЕМ ЕГО КОМПЬЮТЕРНОЙ МОДЕЛИ

EXERGETIC ANALYSIS OF COMPRESSOR CHARACTERISTICS USING ITS COMPUTER MODEL

Санкт-Петербургский национальный исследовательский университет информационных технологий, механики и оптики. Санкт-Петербург, Россия, e-mail: gva2003@mail.ru

Аннотация. *Современные требования по ресурсосбережению все более серьезно ставят вопросы вторичного использования основного сырья и вспомогательных материалов в производственном цикле. Пищевые производства, кроме рецептурного использования воды, используют ее в значительных количествах и как вспомогательный материал. Безусловное первенство в таких процессах занимают разные этапы мойки перерабатываемого сырья и транспортировка отходов.*

Метериалы и методы, результаты и обсуждения. *В статье рассматриваются вопросы оценки эффективности работы одного из главных составляющих практически всех систем подготовки использованной воды к возвращению в производственный цикл. Пройдя первичную очистку в физических фильтрах, усредненные сточные воды, свободные от жировых включений, попадают в аэротенк, где доочищаются под воздействием микроорганизмов. На данном этапе очистки вода насыщается кислородом, являющимся источником энергии для микроорганизмов. В кислородной среде при достаточном объеме питательных веществ и соответствующей температуре, аэробные организмы начинают активно размножаться, формируя макроколонии. Именно эти колонии являются активным илом, выпадающим в виде осадка и циркулирующим в толще воды при аэрации. В аэротенке очистка воды происходит путем окисления органики с последующим её поглощением. Прошедшие аэрацию стоки отводятся вуспокоитель, где активный ил оседает и перенаправляется по водообменной системе на участок анаэробной очистки или на повторную аэрацию. Вместе с тем, существуют издержки, которые следует учитывать при выборе системы очистки. Аэротенки являются энергозависимыми устройствами и их функционирование невозможно при отсутствии электропитания. Микроорганизмы, осуществляющие очистку стоков, погибают менее чем через 12 часов простоя. Поэтому, при повышенном энергопотреблении возникает необходимость подключения очистной установки к резервной сети или генератору, способному обеспечить бесперебойную работу компрессора. В зависимости от производителя и модели очистной установки аэротенки могут отличаться по технологическим и конструкционным принципам. Большинство отечественных компаний, выпускающих бытовые и промышленные установки, используют пневматические компрессоры для аэрации стоков, поступающих в аэротенк. Аэраторы изготавливаются из керамики, металла или полимерных материалов. Существует комбинированная система аэрации, где нагнетаемый компрессором воздух выходит через форсунку и направляется в фильтр-пластину, повышающую площадь распределения воздуха и уменьшающую размеры пузырьков. Такая технология нашла широкое применение в импортных бытовых установках и некоторых отечественных моделях. Работа таких систем невозможна без участия различного рода воздухонагнетателей, в частности вентиляторов. Конструкция этих устройств существенно зависит от геометрии отдельных рабочих органов, например, лопастей.*

Заключение. *Авторами предлагается подход отработки таких деталей с использованием компьютерного моделирования осуществляемых процессов.*

Ключевые слова: ресурсосбережение, вторичное использование вспомогательных материалов, пищевые производства, мойка перерабатываемого сырья, транспортировка отходов, оценка эффективности работы, аэротенк.

Abstract. *Modern requirements for resource saving are increasingly serious questions of the secondary use of primary raw materials and auxiliary materials in the production cycle. Food production, in addition to the prescription use of water, use it in large quantities and as an auxiliary material. Unconditional superiority in such processes is occupied by different stages of washing of processed raw materials and transportation of waste.*

Materials and methods, results and discussions. *The article deals with the evaluation of the effectiveness of one of the main components of almost all systems of preparation of used water for return to the production cycle. After primary cleaning in physical filters, the average waste water free from fat inclusions enters the aeration tank, where they are cleaned under the influence of microorganisms. At this stage of purification, the water is saturated with oxygen, which is a source of energy for microorganisms. In the oxygen environment,* *with a sufficient amount of nutrients and the appropriate temperature, aerobic organisms begin to actively multiply, forming macrocolonies. These colonies are the active silt, falling in the form of sediment and circulating in the water column during aeration. In the aeration tank, water purification occurs by oxidation of organic matter with its subsequent absorption. The last aeration of the effluent discharged uspokoitel, where the activated sludge settles and is vodoobmena system to the site anaerobic treatment or for re-aeration. However, there are costs to consider when choosing a cleaning system. Aeration tanks are energy-dependent devices and their operation is impossible in the absence of power supply. Microorganisms that clean wastewater die in less than 12 hours of downtime. Therefore, with increased power consumption, it is necessary to connect the treatment plant to a backup network or generator that can ensure the smooth operation of the compressor. Depending on the manufacturer and model of the treatment plant aeration tanks may differ in technological and structural principles. The majority of domestic companies producing household and industrial installations, use of pneumatic compressors for the aeration of the wastewater entering the aeration tank. Aerators are made of ceramic, metal or polymeric materials. There is a combined aeration system, where the air injected by the compressor goes out through the nozzle and is directed to the filter plate, which increases the air distribution area and reduces the size of the bubbles. This technology is widely used in imported domestic installations and some domestic models. The operation of such systems is impossible without the participation of various types of air blowers, in particular fans. The design of these devices depends significantly on the geometry of the individual working bodies, for example, blades.*

Conclusion. *The authors propose an approach of working out such details using computer simulation of the processes.*

Key words: resource saving, reuse of subsidiary materials, food production, washing of processed raw material, transportation of waste, the assessment of the effectiveness of an aeration tank.

Introduction. After primary purification in physical filters, the averaged wastewater, free of fatty inclusions, enter the aerotank, where it's cleaned up under the influence of microorganisms. At this stage of purification, water is saturated with oxygen, which is a source of energy for microorganisms. In an oxygen medium with a sufficient volume of nutrients and a corresponding temperature, aerobic organisms begin to multiply actively, forming macrocolonies. It's these colonies that are active silt, precipitating as a sediment and circulating in the water column during aeration. In the aeration tank, the water is purified by oxidizing the organic matter and then absorbing it. Passed aeration sinks are diverted to the soot, where the active sludge settles and is redirected through the water exchange system to the anaerobic treatment site or to repeated aeration.

However, there are costs that should be considered when choosing a cleaning system. Aerotanks are volatile devices and their operation is impossible when there is no power supply. Microorganisms that purify sewage are killed in less than 12 hours of downtime. Therefore, with increased power consumption, it becomes necessary to connect a cleaning plant to a backup network or a generator capable of ensuring uninterrupted operation of the compressor. Depending on the manufacturer and model of the treatment plant, aerotanks may differ in terms of technological and design principles. Most domestic companies that produce domestic and industrial installations use pneumatic compressors for aeration of effluents entering the tenk. Aerators are made of ceramics, metal or polymeric materials. There is a combined aeration system where the air injected by the compressor exits through the nozzle and is directed to the filter plate, which increases the air distribution area and reduces the bubble size. Such technology has found wide application in imported domestic installations and some domestic models. The operation of such systems is impossible without the participation of various kinds of air blowers, in particular fans. The design of these devices is highly dependent on the geometry of the individual working elements, for example, blades. The authors propose an approach for working out such details with the use of computer modeling of the implemented processes.

Compressor technology nowadays used not only for equipment used for environmental protection, but also in a wide range of areas of the economy. With its help, air masses are injected into various mines during the extraction of minerals, oil wells, as well as powerful ventilation of production premises or the movement of special products in food or biotechnological industries. It's known that the force interaction of a gas or liquid flow with a streamlined body is carried out through two types of force reactions: through the action of distributed forces of excess pressure and through the action on the body of tangential friction forces. In some cases, the design of compressors, which are the main component of injection systems for the purpose of energy-saving for their experimental development, are using the models of these devices.

Calculation practice shows that for practically used compressors in the range of large Reynolds numbers, the total force of the aerodynamic action of the blades of the rotating rotor is determined mainly by the force from the distributed pressure. Only with zero lift for very thin wing profiles does the component from frictional forces begin to be significant in the overall strength of the resistance. Proceeding from this, it's advisable for the non-fine profile of the injection blade to determine the force action created exclusively by the distributed pressure forces [5-6].

Materials and methods. Experimental definition of distribution of pressure on such structure can be made at a purge in a subsonic wind tunnel rectangular, by way of the blade, a constant structure in all cross-section sections. On the average section the blade drained. Each aperture of a drainage on the blade is hermetically connected with the top end of a tube battery manometer. At blow covered with airflow on a wing some distribution of pressure is established. To some the accuracy depending on number of points of a drainage, cleanliness of processing of reception apertures, etc., it is possible to define this distribution by gauging of pressure in all points of a drainage [7].

If, at the same time, a positive excess pressure is set in the hole on the wing, the liquid level in the manometer tube drops below the zero mark; If the excess pressure is negative (rarefaction in this part of the wing), then the liquid level rises. Denoting the height of the change in the liquid level in the tube of the manometer and considering it to be an algebraic value (h> 0, if the liquid in the tube drops, and h <0, if the liquid rises), it is possible for each measured value to find an overpressure:

$$\Delta p_i = p_i - p_\infty = \gamma_\delta \Delta h_i \quad (1)$$

where γ_δ – specific gravity of liquid in manometer (if manometer is filled with colored water, $\gamma_\delta = 10^{-3}$ кгс/см^3).

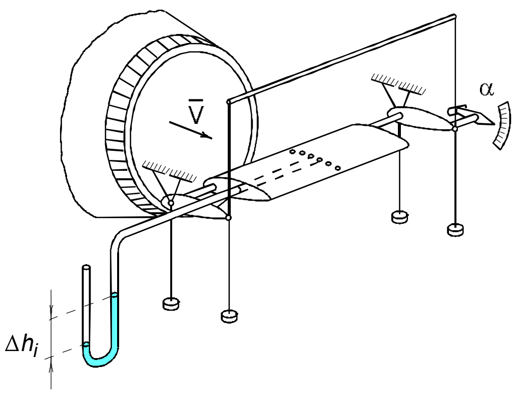


Fig. 1. Overpressure measuring circuit

Simultaneously with the fixation of pressure at various points in the profile, the velocity head must be measured, using the Pitot tube. Then the pressure coefficient in the i-th hole on the profile is:

$$c_{pi} = \frac{p_i - p_\infty}{\rho_\infty \frac{v_\infty^2}{2}} = \frac{\gamma_\delta \Delta h_i}{\gamma_p \Delta h_{pito}} \quad (2)$$

Using the obtained data on the pressure distribution, it is possible to construct the so-called vector diagram, Fig. 2. On the vector diagram, the blade is plotted accurately and the drainage points are drawn; at each point, a vector equal to the magnitude of the pressure coefficientat c_{p_i} a given point is attached to the wing surface. If the coefficient c_{p_i} is positive, then the vector is directed to the wing, if negative, then the vector is directed to the outside. The ends (or beginnings) of a vector are connected by an envelope line. Such a vector diagram gives a graphically clear picture of the distribution of the rarefaction and compression zones along the profile of the blade profile [8-10].

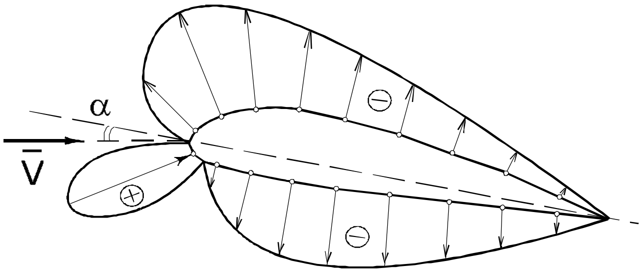


Fig. 2. The vector diagram of the blade

The axis $0x_1$ is directed in parallel to a vector of not indignant speed of an accumulating stream. The angle between axes $0x$ and $0x_1$ is angle of attack α . On a contour of a considered structure we shall note the bottom surface covered OBA and top surface OCA. On these surfaces of a point B and C is special. These points at the most are removed from a chord of the blade accordingly on the bottom and top surfaces of the blade and allocate a frontal surface covered BOC and a fodder surface BAC .

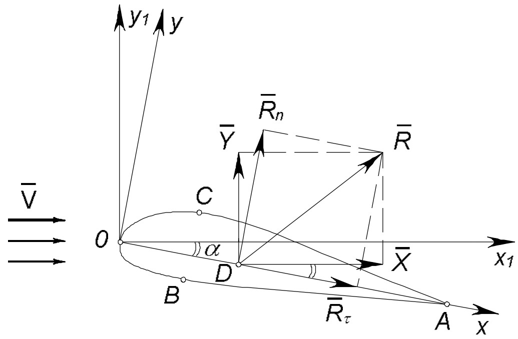


Fig. 3. The diagram of the appendix to a structure of the blade of various forces

On fig. 3 point D notes the center of pressure in which equally effective aerodynamic force $\vec{R}$ is enclosed. Aerodynamic force $\vec{R}$ can be spread out on two mutually perpendicular components. If these components are parallel to axes of high-speed coordinate system component X refers to as force of frontal resistance, and Y - elevating force. If these components are parallel to axes of the associated coordinate system component R_τ refers to as longitudinal force, $R_п$ - cross-section. Let's consider a surface of the blade of individual scope. On this blade it is possible to allocate an elementary rectangular platform dS , formed with an element of a contour dS so $dS = ds \cdot 1$. The Elementary piece of a contour dS is inclined to axis $0x$ under angle θ (fig. 4).

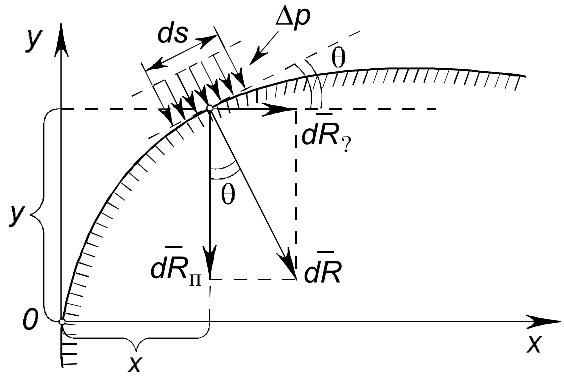


Fig. 4. Occurrence of horizontal and vertical components

If on a surface of a streamline structure in this seat superfluous pressure Δp force is enclosed to the given site dR where $dR = \Delta p ds$ on a normal to a surface operates. This force can be spread out on two mutually perpendicular components dR_τ and $dR_п$, parallel to axes $0x$ and $0y$:

$$dR_\tau = dR\sin\theta = \Delta p\sin\theta ds\, ;\; dR_п = -dR\cos\theta = -\Delta p\cos\theta ds \qquad (3)$$

From fig.4 is visible that $ds\cos\theta = dx; ds\sin\theta = dy$. Than:

$$dR_\tau = \Delta p dy; dR_п = -\Delta\ p dx$$

Being based on dependences (3), we shall find total forces: longitudinal R_τ , parallel to chord OA, and cross-section $R_п$, perpendicular to a chord.

For reception of force $R_п$ it is necessary to integrate dependence for $dR_п$ on top and the bottom surface of a structure:

$$R_{п} = -\int_{y_O}^{x_A} \Delta p_{в} dx + \int_{y_O}^{x_A} \Delta p_{н} dx,$$

where $\Delta p_{в}$ and $\Delta p_{н}$ - superfluous pressure accordingly on the top and bottom surface of a structure. Considering, that $x_o = 0; x_{А} = b$; we have:

$$R_{п} = \int_{0}^{b} (\Delta p_{н} - \Delta p_{в}) dx \tag{4}$$

In a similar way for reception of force R_{τ} , it is necessary to integrate dependence for from (3) on frontal (site BOC) and fodder (site BAC) to parts of a structure:

$$R_{\tau} = \int_{y_B}^{y_C} \Delta p_{л} dy_1 - \int_{y_B}^{y_C} \Delta p_{к} dy,$$

Notice that:

$$y_B = y_{\min}\ ;\ y_C = y_{\max} \tag{5}$$

Then:

$$R_{\tau} = \int_{y_{\min}}^{y_{\max}} (\Delta p_{л} - \Delta p_{к}) dy \tag{6}$$

Let's pass from longitudinal and cross-section forces R_{τ} and $R_{п}$ to forces in high-speed system of coordinates: to force of frontal resistance X and elevating force Y . This transition is carried out under formulas:

$$X = R_{\tau} \cos\alpha + R_{п} \sin\alpha;$$
$$Y = -R_{\tau} \sin\alpha + R_{п} \cos\alpha \tag{7}$$

Forcos X и Y in aerodynamics are represented through factors of frontal resistance c_x and elevating force c_y under formulas:

$$X = c_x \frac{1}{2} \rho_{\infty} v_{\infty}^2 S\ ;\ Y = c_y \frac{1}{2} \rho_{\infty} v_{\infty}^2 S \tag{8}$$

Here the characteristic area S is maybe presented as $S = 1 \cdot b$ (the blade of individual scope).

In a similar way longitudinal and cross-section forces can be presented:

$$R_{\tau} = c_{\tau} \frac{\rho_{\infty} v_{\infty}^2}{2} S\ ;\ R_{п} = c_{п} \frac{\rho_{\infty} v_{\infty}^2}{2} S \tag{9}$$

Substituting (8) and (9) in (7), it is possible to receive:

$$c_x = c_{\tau} \cos\alpha + c_{п} \sin\alpha;$$
$$c_y = -c_{\tau} \sin\alpha + c_{п} \cos\alpha \tag{10}$$

Dimensionless factors c_{τ} and c_n also are defined, if (9) to substitute in parities (4) and (6) and to consider definition of factor of pressure under the formula (2):

$$c_{п} = \frac{1}{b} \int_{0}^{b} (c_{p_H} - c_{p_B}) dx;$$
$$c_{\tau} = \frac{1}{b} \int_{y_{\min}}^{y_{\max}} (c_{p_{л}} - c_{p_{к}}) dy \tag{11}$$

It is meaningful to enter dimensionless coordinates:

$$\bar{x} = \frac{x}{b};\ \bar{y} = \frac{y}{b} \tag{12}$$

Enter also new designations:

$$\Delta c_{p_п} = c_{p_н} - c_{p_В};$$

$$\Delta c_{p_\tau} = c_{p_л} - c_{p_к} \qquad (13)$$

come to following rated formulas:

$$c_п = \int_0^1 \Delta c_{p_п} d\bar{x};$$

$$c_\tau = \int_{\bar{y}_{min}}^{\bar{y}_{max}} \Delta c_{p_\tau} dy. \qquad (14)$$

Integrating this dependence on a wing contour, we come to dependence

$$M_z = \frac{1}{2}\left[\oint \Delta p \cdot d(x^2) + \oint \Delta p d(y^2)\right] \qquad (15)$$

Contour integrals in (15) are calculated at a contour round clockwise.

In an aerodynamics the moment of pitch of M_z is bound to coefficient of the tangazhny moment c_{mz} with formula:

$$M_z = c_{mz}\frac{\rho_\infty v_\infty^2}{2}Sb, \qquad (16)$$

where $S = b \cdot 1$

Comparing records (15) and (16) and considering designation of a coefficient of pressure (2), receive:

$$c_{m_z} = \frac{1}{2}\cdot\frac{1}{b^2}\left[\oint c_p d(x^2) + \oint c_p d(y^2)\right] \qquad (17)$$

Transform one of contour integrals:

$$J_x = \oint c_p d(x^2) = \int_0^b c_{p_B} dx^2 + \int_b^0 c_{p_H} dx^2 = \int_0^b (c_{p_B} - c_{p_H}) dx^2$$

Similary:

$$J_y = \oint c_p dy^2 = \int_{y_{min}}^{y_{max}} c_{p_л} dy^2 - \int_{y_{max}}^{y_{min}} c_{p_к} dy^2 = \int_{y_{min}}^{y_{max}} (c_{p_л} - c_{p_к}) dy^2$$

Considering received and also designations (12) and (13), instead of (17) write:

$$c_{m_z} = 0{,}5(J_x + J_y), \qquad (18)$$

where:

$$J_{\bar{x}} = -\int_0^1 \Delta c_{p_п} d((\bar{x})^2) \quad J_{\bar{y}} = \int_{\bar{y}_{min}}^{\bar{y}_{max}} \Delta c_{p_\tau} d(\bar{y}^2) \qquad (19)$$

Tangage moment can be show with forses $\vec{X}$ и $\vec{Y}$, attached to a center of pressure in a point D with coordibates $x_D = x_д$; $y_D = 0$:

$$M_z = -Xx_д \sin\alpha - Yx_д \cos\alpha$$

transform:

$$\bar{x}_д = \frac{x_д}{b} = -\frac{M_z}{Y\cos\alpha + X\sin\alpha}$$

or $\bar{x}_д = -\dfrac{c_{m_z}}{c_y\cos\alpha + c_x\sin\alpha}$ (20)

This formula defines the provision of a center of pressure.

An inspection of the explained reasons was carried out by means of the virtual model operation of a wind tunnel of subsonic speeds. The blade model in model is suspended on extensions in a working part of a pipe with realization of the following conditions:

1.to install the blade on the given angle of attack α.

2.to place the receiver of a tube of Pitot-Prandtl in a zone of a nonperturbed stream before model, to measure size $\Delta h_{п}$ and to put a pipe into operation

3.to measure change from position of equilibrium of fluid levels in pipes of the battery manometer and to enter measured sizes Δh_i with their signs in the table.

4.to provide accuracy of measurements to the tenth shares of centimeter.

After carrying out measurements on a formula (2) values of a coefficient of pressure c_{p_i} are calculated and results are entered in the table.

Then built a coordinate charts of $c_p = f(\bar{x})$ and $c_p = f_1(\bar{y})$. For this purpose, using these tables, the experimental points are $(c_{p_i}, \bar{x}_i)$ and $(c_{p_i}, \bar{y}_i)$. These points connect the smooth curves. With inscriptions $c_{p_н}$ and $c_{p_в}$ put pressure distribution curve on the top and bottom surface of a wing (see fig. 5); on other chart curve pressure profiles on front and fodder parts of a profile are noted by inscriptions $c_{p_л}$ and $c_{p_к}$.

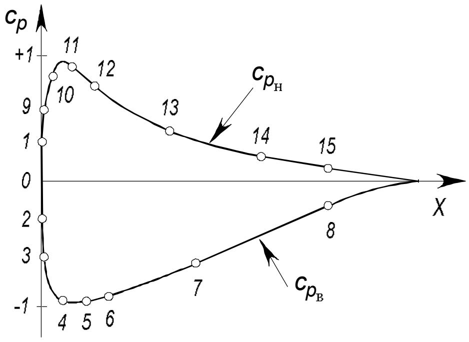


Fig. 5. Coordinate charts

Further it is necessary to calculate value of coefficient $c_{п}$ on the first formula from (14) For this purpose use Simpson's formula for a numerical integration:

$$c_{п} = \frac{1}{3(N-1)} \left\{ \Delta c^{(1)}_{p_п} + 4\left[\Delta c^{(2)}_{p_п} + \Delta c^{(4)}_{p_п} + \ldots + \Delta c^{(N-1)}_{p_п}\right] + \right.$$
$$\left. + 2\left[\Delta c^{(3)}_{p_п} + \Delta c^{(5)}_{p_п} + \ldots + \Delta c^{(N-2)}_{p_п}\right] + \Delta c^{(N)}_{p_п} \right\}$$

For use of this formula all interval of change $\bar{x}(0 \le x \le 1)$ drop to $N-1$ equal parts, where N – odd number. Any $\Delta c^{(i)}_{p_п}$ is $\Delta c_{p_п} = c_{p_н} - c_{p_в}$ in a point with coordinates $\bar{x} = \bar{x}_i = \frac{i-1}{N-1}$. At practical calculation of value $\Delta c^{(i)}_{p_п}$ act from the schedule measurement of distance between curves $c_{p_н}$ and $c_{p_в}$ with the corresponding coordinate $\bar{x}$ which taking algebraic sign $\Delta c^{(i)}_{p_п}$. Value $\Delta c_{p_п}$ in extreme points, apparently from fig. 5, are always equal to zero: $\Delta c^{(1)}_{p_п} = \Delta c^{(N)}_{p_п} = 0$.

The similar pattern of calculation of integral can be offered also for the second dependence (14). The calculated formula takes a form:

$$c_{\tau} = \frac{\bar{y}_{max} - \bar{y}_{min}}{3(N_1-1)} \left\{ \Delta c^{(1)}_{p_\tau} + 4\left[\Delta c^{(2)}_{p_\tau} + \Delta c^{(4)}_{p_\tau} + \ldots + \Delta c^{(N_1-1)}_{p_\tau}\right] + \right.$$
$$\left. + 2\left[\Delta c^{(3)}_{p_\tau} + \Delta c^{(5)}_{p_\tau} + \ldots + \Delta c^{(N_1-2)}_{p_\tau}\right] + \Delta c^{(N_1)}_{p_\tau} \right\}$$

где Δc_{p_τ} – value of $\Delta c_{p_\tau} = c_{p_л} - c_{p_к}$ in a point with coordinate:

$$\bar{y} = \bar{y}_{\max} - \frac{\bar{y}_{\max} - \bar{y}_{\min}}{N_1 - 1}(i-1)$$

These value can be defined by immediate measurement of distance between curves $c_{p_л}$ and $c_{p_к}$ at the corresponding coordinate $\bar{y}$. Also the sign of size has to be considered Δc_{p_τ}. Here, as well as at calculation of value c_n, r N_1 – odd number, also $\Delta c_{p_\tau}^{(1)} = \Delta c_{p_\tau}^{(N_1)} = 0$.

The calculated values c_n and also allow to find aerodynamic coefficients c_x and c_y according to formulas (10).

For calculation of coefficient of the tangage moment c_{m_z} on a formula (18) calculate integrals $J_{\bar{x}}$ and $J_{\bar{y}}$, set by formulas (19). For this purpose use the same technique of a numerical integration, as at calculation of coefficients $c_п$ and c_τ. Dependences have to be for this purpose graphically constructed c_p by $\bar{x}2$ and c_p by $\bar{y}2$. Having broken an integration interval $0 \le x^2 \le 1$ on an even number of pieces, with use of a formula of Simpson calculate integral $J_{\bar{x}}$, and then similarly $J_{\bar{y}}$. On a formula (20) it is possible to find the provision of a center of pressure $\bar{x}_д$.

The results of the experiment

The virtual experiment for definition of aerodynamic characteristics of a profile of the blade was made on the model containing the wind tunnel of subsonic speeds forming an airflow and a receiver pipe for utilization of an airflow.

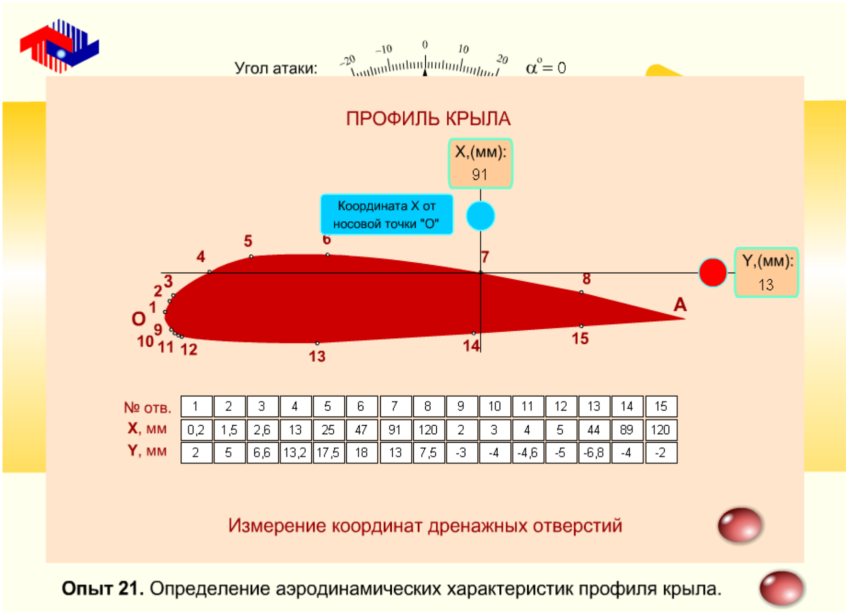
In a working gap of a pipe the blade with a number of drainage openings on a profile is installed. Each opening is connected to the measuring manometer (a piezometer with water). All manometers are united in the battery. Besides, Pitot-Prandtl's tube is connected to the battery manometer. The tube is established just before the blade in a nonperturbed part of a stream.

The angle of attack of a wing was changed ranging from -14° to +14° with a step of 1 lake. At the same time indications of all 15 piezometers connected to the corresponding drainage openings of the blade changed.

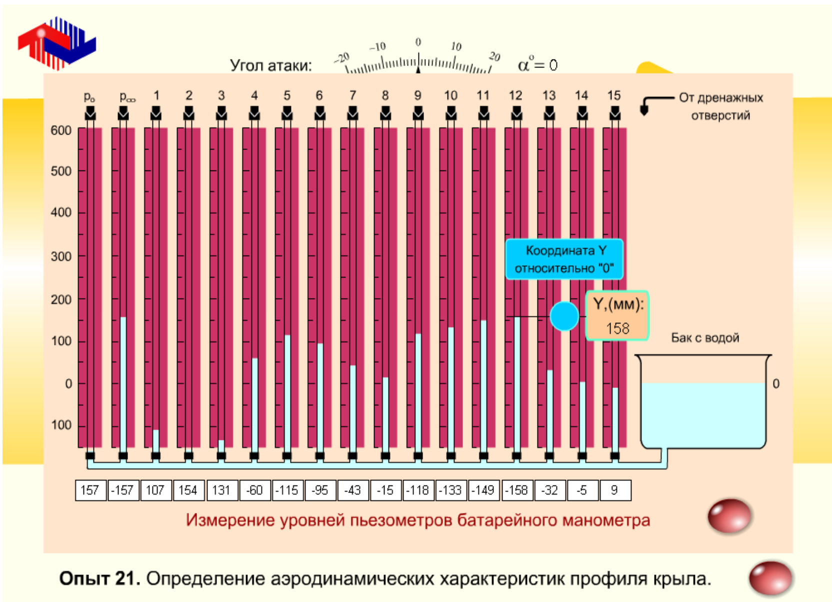
Geometrical measurements were taken by express measuring rulers on an axis "X" and "Y". Rulers moved by means of a mouse.

The click in the field of the battery manometer called the panel for measurement of fluid levels in the corresponding piezometers. Measurements were taken a measuring ruler on an axis of "Y", in beforehand the Zoom In mode chosen and providing necessary accuracy.

a)



b)



c)

Fig. 6. The virtual model of laboratory installation

Conclusions The conducted pilot studies showed good convergence with the results received on natural laboratory installations at economy of the electric power by 6-8 times. It allows to investigate more carefully characteristics of compressors for the choice of option more preferable in the eksergetic relation. Data interpretation was carried out by means of a software package of Mathcad according to the known aerodynamic model of a wing not of a thin profile which is written down in a look:

$$J_x = \oint c_p d(x^2) = \int_0^b c_{p_B} dx^2 + \int_b^0 c_{p_H} dx^2 = \int_0^b (c_{p_B} - c_{p_H}) dx^2 .$$

$$J_y = \oint c_p dy^2 = \int_{y_{\min}}^{y_{\max}} c_{p_л} dy^2 - \int_{y_{\max}}^{y_{\min}} c_{p_к} dy^2 = \int_{y_{\min}}^{y_{\max}} (c_{p_л} - c_{p_к}) dy^2 .$$

The error of the obtained data made 15–17%, in comparison with calculated results on analytical model that testifies to a possibility of preliminary estimate of new designs of compressors by the used technique.

ЛИТЕРАТУРА

1. Правила охраны поверхностных вод (типовое положение). М.: Гос. комитет по охране природы, 1991.
2. Рябчиков Б. Е. Современная водоподготовка. М.: ДеЛи плюс, 2013. 680 с.
3. Спеллман Ф. Р. Справочник по очистке природных и сточных вод. Водоснабжение и канализация / пер. с англ.; под ред. М. И. Алексеева. СПб.: ЦОП «Профессия», 2014. 1312 с.
4. Солодянников В. В. Расчет и математическое моделирование процессов водоподготовки. М.: Энергоатомиздат, 2003.
5. Голубев В. В. Труды по аэродинамике. М.- Л.: ГИТТЛ, 1957. 979 с.
6. Петров Г. И. Аэромеханика больших скоростей и космические исследования. Избранные труды. М.: Наука, 1992. 306 с.
7. Осипцов А. Н. Тонкий профиль в потоке дисперсной смеси. Изв. АН СССР, МЖГ, 1981. N 5. С.147-154.
8. Холявин И. И., Кравцова Е. В., Леу А. Г. Математическое моделирование возможностей ресурсосбережения // Интеграция науки, общества, производства и промышленности. Сборник статей Международной научно-практической конференции. 2016. С. 52-54.
9. Алексеев Г. В., Бриденко И. И. Виртуальный лабораторный практикум по курсу "Механика жидкости и газа". СПб., 2007. 198 с.
10. Баранов В. Б. Гидроаэромеханика и газовая динамика. М.: Изд-во МГУ, 1987. 184 с.
11. Лабораторный практикум. Задачи общего практикума по аэромеханике и газовой динамике. М.: Изд-во МГУ, 1972. 115 с.
12. Попов С. Г. Некоторые задачи и методы экспериментальной аэромеханики. М.: ГИТТЛ, 1952. 96 с.
13. Холявин И. И., Новиков И. В., Леу А. Г. Оценка эффективности предварительной подготовки при выработке крахмала // Инновационно-технологическое развитие науки. Сборник статей международной научно-практической конференции: в 3 частях. 2017. С. 162-166.
14. Алексеев Г. В., Мосина Н. А. Абразивная обработка картофеля и овощей с дискретным энергоподводом: монография. Саратов, 2013. 215 с.

REFERENCES

1. Pravila okhrany poverkhnostnykh vod (tipovoe polozhenie). M.: Gos. komitet po okhrane prirody, 1991.
2. Ryabchikov B. E. Sovremennaya vodopodgotovka. M.: DeLi plyus, 2013. 680 s.
3. Spellman F. R. Spravochnik po ochistke prirodnykh i stochnykh vod. Vodosnabzhenie i kanalizatsiya / per. s angl.; pod red. M. I. Alekseeva. SPb.: TSOP «Professiya», 2014. 1312 s.
4. Solodyannikov V. V. Raschet i matematicheskoe modelirovanie protsessov vodopodgotovki. M.: Ehnergoatomizdat, 2003.
5. Golubev V. V. Trudy po aehrodinamike. M.- L.: GITTL, 1957. 979 s.
6. Petrov G. I. Aehromekhanika bol'shikh skorostey i kosmicheskie issledovaniya. Izbrannye trudy. M.: Nauka, 1992. 306 s.
7. Osiptsov A. N. Tonkiy profil' v potoke dispersnoy smesi. Izv. AN SSSR, MZHG, 1981. N 5. S.147-154.
8. Kholyavin I. I., Kravtsova E. V., Leu A. G. Matematicheskoe modelirovanie vozmozhnostey resursosberezheniya // Integratsiya nauki, obshchestva, proizvodstva i promyshlennosti. Sbornik statey Mezhdunarodnoy nauchno-prakticheskoy konferentsii. 2016. S. 52-54.
9. Alekseev G. V., Bridenko I. I. Virtual'nyy laboratornyy praktikum po kursu "Mekhanika zhidkosti i gaza". SPb., 2007. 198 s.
10. Baranov V. B. Gidroaehromekhanika i gazovaya dinamika. M.: Izd-vo MGU, 1987. 184 s.
11. Laboratornyy praktikum. Zadachi obshchego praktikuma po aehromekhanike i gazovoy dinamike. M.: Izd-vo MGU, 1972. 115 s.
12. Popov S. G. Nekotorye zadachi i metody ehksperimental'noy aehromekhaniki. M.: GITTL, 1952. 96 s.
13. Kholyavin I. I., Novikov I. V., Leu A. G. Otsenka ehffektivnosti predvaritel'noy podgotovki pri vyrabotke krakhmala // Innovatsionno-tekhnologicheskoe razvitie nauki. Sbornik statey mezhdunarodnoy nauchno-prakticheskoy konferentsii: v 3 chastyakh. 2017. S. 162-166.
14. Alekseev G. V., Mosina N. A. Abrazivnaya obrabotka kartofelya i ovoshchey s diskretnym ehnergopodvodom: monografiya. Saratov, 2013. 215 s.

ОБ АВТОРАХ

Алексеев Геннадий Валентинович, Доктор технических наук, профессор кафедры процессов и аппаратов пищевых производств, Санкт-Петербургский национальный исследовательский университет информационных технологий, механики и оптики. Санкт-Петербург, Россия, gva2003@mail.ru

Alekseyev Gennady Valentinovich, Doctor of Technical Sciences, Professor of the Department of processes and apparatus of food production, St. Petersburg national research University of information technologies, mechanics and optics. Saint Petersburg, Russia, gva2003@mail.ru

Бриденко Игорь Иосифович, кандидат технических наук, доцент кафедры процессов и аппаратов пищевых производств, Санкт-Петербургский национальный исследовательский университет информационных технологий, механики и оптики. Санкт-Петербург, Россия

Bridenko Igor Iosifovich, Candidate of Technical Sciences, associate Professor of the Department of processes and apparatus of food production, St. Petersburg national research University of information technologies, mechanics and optics. Saint Petersburg, Russia

Суомалайнен Анна Алексеевна, магистр, Санкт-Петербургский национальный исследовательский университет информационных технологий, механики и оптики. Санкт-Петербург, Россия

Suomalainen Anna Alekseevna, master, St. Petersburg national research University of information technologies, mechanics and optics. Saint Petersburg, Russia

Дата поступления в редакцию: 01.01.2019 г.
После доработки: 08.02.2019 г.
Дата принятия к публикации: 23.05.2019 г.