more accurately determine the position of the suction and pumping windows.

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Proposals tochnoe decision problem by calculating Square transverse cross-section a working kamerы rotatsyonnoho vacuum pump c naklonnыmy plates in dependence from angle rotation of the rotor. Showing otlychyya new solutions compared with of existing.

Vacuum pump, air apportionment phases, Volume of a working kamerы.

The exact decision of a problem by calculation of the area of cross-section section of the working chamber of the rotary vacuum pump depending on a rotor angle of rotation is offered. Differences of the new decision in comparison with existing are shown.

Vacuum pump, the phase distribution of the air, volume of the working chamber.

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Energetic PARAMETERS plate Vacuum pumps

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The results of theoretical investigations plate rotary vacuum pumps on their basis The necessary guidelines on the design and operation. Unified theoretical position calculation capacity friction vacuum pump with radial and inclined plates.

Vacuum pump friction plate capacity.

Formulation of the problem. The most loaded parts of vacuum pumps is plate plate. Depending on the size of the pump, pressure drop, a material plates, cooling and lubrication method put the 2 to 30 plates.

Lubricants reduce friction plates on the cylinder. Lack of lubrication causes increased wear plate and pump casing. However undulating wear of the cylinder between the discharge and suction window is often visually even in machines with normal lubricants [1].

The presence of wear increases vibration plates in this area and their causes jamming. Identifying the causes of wavy cylinder wear is an important task of designing plate pumps and compressors. The solution to this problem is possible by studying the dynamics of friction plates on the surface of the cylinder. In pumps with radial plates mechanical losses calculation is complicated by the need for separate determination of the force of friction and inertia force of air pressure [2]. The method of calculation of similar indicators inclined plates are complicated. Its main provisions are built through intuitive adjustments dependency dynamics radial friction plates. The generalized mathematical model of the power component friction plates in all their possible range of angles of inclination would help identify patterns of wear inherent to rotary pumps.

The purpose of research. Improved methods of calculating the friction plate to plate cylinder vacuum pumps.

Results. Under the existing method of calculation capacity friction plates [2] first determine the work and power of a friction plate cylinder by excluding the pressure forces the air. The force of inertia of the plate (Fig. 1):

$$Ri = RC + Pn + Pk, \quad (1)$$

where: $P_ц = m\omega^2\left(\rho - \frac{h}{2}\right)$ - Centrifugal component is proportional to the acceleration of the rotation; $P_n = m\frac{d^2\rho}{dt^2}$ - A component proportional to acceleration at reciprocating motion of the plate in the notch of the rotor; $P_k = 2m\omega\frac{d\rho}{dt}$ - Coriolis force; t - weight plates; $\rho - \frac{h}{2}$ - Current radius vector of the center of gravity of the plate; $\frac{d\rho}{dt}$ - The relative speed of the plates in a rotating motion; ω - Angular velocity of the rotor.

Substituting values ρ the equation for the components of inertial forces, we find the following relationship:

$$P_ц = m\omega^2 R\left(1 + \frac{e}{R}\cos\varphi - \frac{h}{2R} - \frac{e^2}{2R^2}\sin^2\varphi\right), \quad (2)$$

$$P_n = m\omega^2 R\left(\frac{e}{R}\cos\varphi + \frac{e^2}{R^2}\right) \text{ And } \quad (3)$$

$$P_к = 2m\omega^2 R\frac{e}{R}\sin\varphi \text{ And } (4)$$

Power Plate weight in the calculations do not include it in the 100 ... 200 times smaller than all the other forces acting on it.

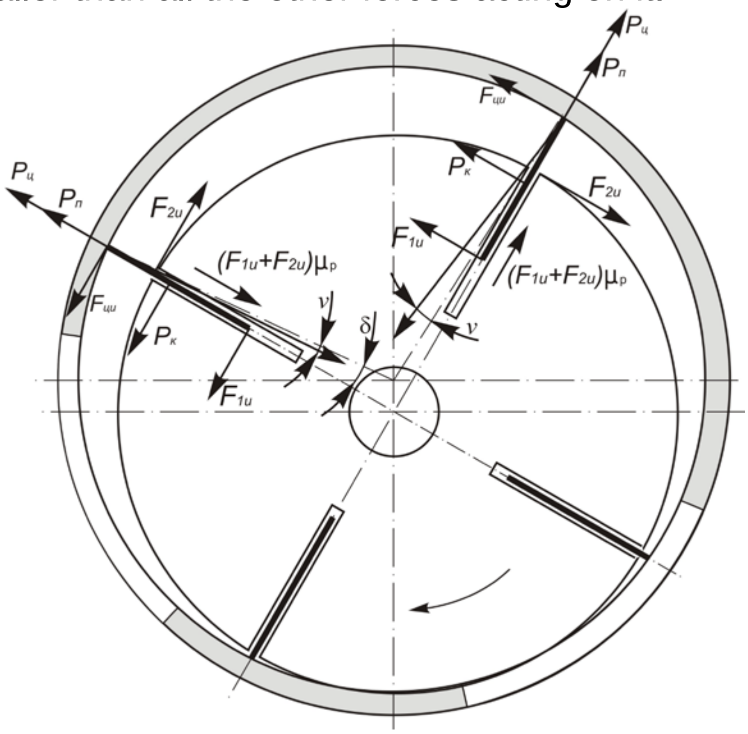

Fig. 1. The scheme of distribution of load inertia forces acting on the radial plate.

With sliding plates on the cylinder by the force of inertia Ftsy there is friction, the motion of the rotor in the groove - friction Fpy. Both forces are directed in the opposite movement of the plate. We form a system of equations for the plate while turning the rotor from 0 to 180°:

$$\begin{cases} F_{1u} + P_к \frac{h}{2} - F_{2u}(\rho - r) = 0 \\ P_к \frac{h}{2} + R_u h \sin(\nu + \delta) - F_{2u}\left[h - (\rho - r)\right] = 0 \\ (F_{1u} + F_{2u})\mu_p + P_ц + P_n - R_u cos(\nu + \delta) = 0 \end{cases} . \quad (5)$$

Where: Ry - a reaction to the plate of the cylinder is directed at an angle to the radius of the cylinder v R; F1y and F2y - normal reactions to the plate of the rotor; Fpy = (+ F1y F2y)μ_p - the friction plate in the notch of the rotor;
r - the radius of the rotor; μ_p - friction plate groove on the surface of the rotor.

From equations (5) we find:

$$R_и = \frac{P_ц + P_п + \mu_p P_к \frac{\rho - r}{h - (\rho - r)}}{\cos(v + \delta) - \mu_p \sin(v + \delta)\frac{h + (\rho - r)}{h - (\rho - r)}} . \quad (6)$$

By turning vid180 360°:

$$\begin{cases} F_{1и} + P_к \frac{h}{2} - F_{2и}(\rho - r) = 0 \\ P_к \frac{h}{2} + R_и h \sin v - F_{2и}[h - (\rho - r)] = 0 \\ (F_{1и} + F_{2и})\mu_p - P_ц - P_п + R_и cos(v + \delta) = 0 \end{cases} . \quad (7)$$

From equations (7):

$$R_и = \frac{P_ц + P_п - \mu_p P_к \frac{\rho - r}{h - (\rho - r)}}{\cos(v + \delta) - \mu_p \sin(v + \delta)\frac{h + (\rho - r)}{h - (\rho - r)}} . \quad (8)$$

Friction plate cylinder on:

$$F_{ци} = \mu_ц cosvR_и = \frac{\mu_ц}{\sqrt{1 + \mu_ц^2}} R_и , \quad (9)$$

But because the friction plate on the cylinder is rarely more than 0.15 [3], we can take Ftsy =$\mu_{ts}Ry$. Then part of Ltsy friction plate cylinder is equal to:

$$L_{ци} = \int_0^{2\pi} F_{ци} \rho d\varphi = \mu_ц \int_0^{2\pi} R_и v d\varphi . \quad (10)$$

Schedule changes $\frac{R_и}{m\omega^2 R}$ without pressure drop represented a smooth curve in Figure 1. 2.

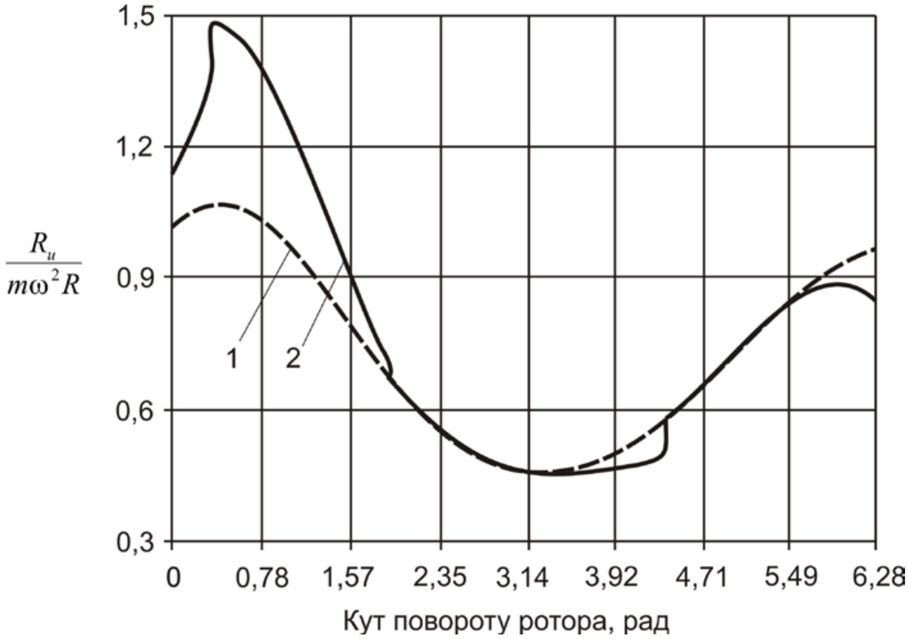

Fig. 2. The curve changes $\frac{R_u}{m\omega^2 R}$ 1 - without pressure drop; 2 - taking into account the pressure drop.

Then determine the work and power the action of friction plates only force of air pressure $P_{\Delta p}$. This division doubles the computing time operations and excludes assessment by the force of friction plate cylinder taking into account all of the forces. When rotating rotor plate in the groove takes by the force of friction inclined position, resting his face in the wall of the groove. This is due to the presence of gaps between the plate and the walls of the groove. The gap plate in the groove of the rotor rotary machines is 0.3 ... 0.8 mm [2]. The mean free path of air molecules at any pressure can be determined by the equation (8):

$$\lambda = \frac{6{,}2 \cdot 10^{-3}}{p}, \quad (11)$$

If the vacuum pump creates suction pressure of 50 kPa, then the pressure will be responsible $\lambda = 0.124 \cdot 10^{-3}$ mm. This mean free path is more than 2400 times smaller gaps modern rotary machines. Thus, when calculating these vehicles should take into account air pressure between the plate and the wall of the groove. If the pump end clearances were missing, after passing the plate suction box pressure notch in the plate can be considered equal pressure absorption until a plate discharge box. In this case it is necessary to consider not only the strength of the pressure differential between the suction and discharge areas, as is done in the above calculation, but the force of the pressure differential between the injection zone and groove. If we take the pressure in the groove equal suction pressure zone, the pressure drop across the force can be applied to the center of the plate, which allows joint friction loss calculation taking into account all of the forces. In this case the reaction is support (upper marks on the side of the equation just absorption, lower - side injection):

$$R_и = \frac{P_ц + P_n \pm \mu_p (P_к + P_{\Delta p}) \dfrac{\rho - r}{h - (\rho - r)}}{\cos(\nu + \delta) \mu\mu_p \sin(\nu + \delta) \dfrac{h + (\rho - r)}{h - (\rho - r)}}. \quad (12)$$

Work friction in the groove is only 0.3 ... 0.5% of the work friction on the cylinder. Taking into account the reduced formulas work rubbing one plate for one turn will be 6.64 J (shell radius R = 0,0725 m eccentricity e = 0.0094 m rotor radius r = 0,063 m; weight plates t = 0.072 kg; height plate h = 0,040 m rotor speed ω= 23.67·2π= 148.723 rad / c; μ_{ts}= 0.1; μ_n= 0.1; number plates n = 4. For 4-plate friction work for one turn will 26.56 J corresponding power 628.67 watts or 0.63 kW. If you increase the radius of the case twice, the capacity will increase to 2,08 kW. The increase in power consumption will also increase the number of blades case. Thus, increasing the number of blades from 4 to 12 increases the power consumption of about 3 times.

Reducing power consumption at selected held constant radius hull possible by reducing eccentricity, length and number plates, as well as by increasing the height of the plate. Power consumption at constant radius hull varies directly proportional to the eccentricity (Fig. 3), in inverse proportion to the height of the plates (Fig. 3). As the length of the plate Power consumption is reduced almost in direct proportion. Thus, while reducing the length of the plate at 16% power consumption is reduced by only 0.71%. Increased pressure absorption capacity reduces friction. As the number of plates power consumption increases almost in direct proportion to the number of plates (Fig. 3).

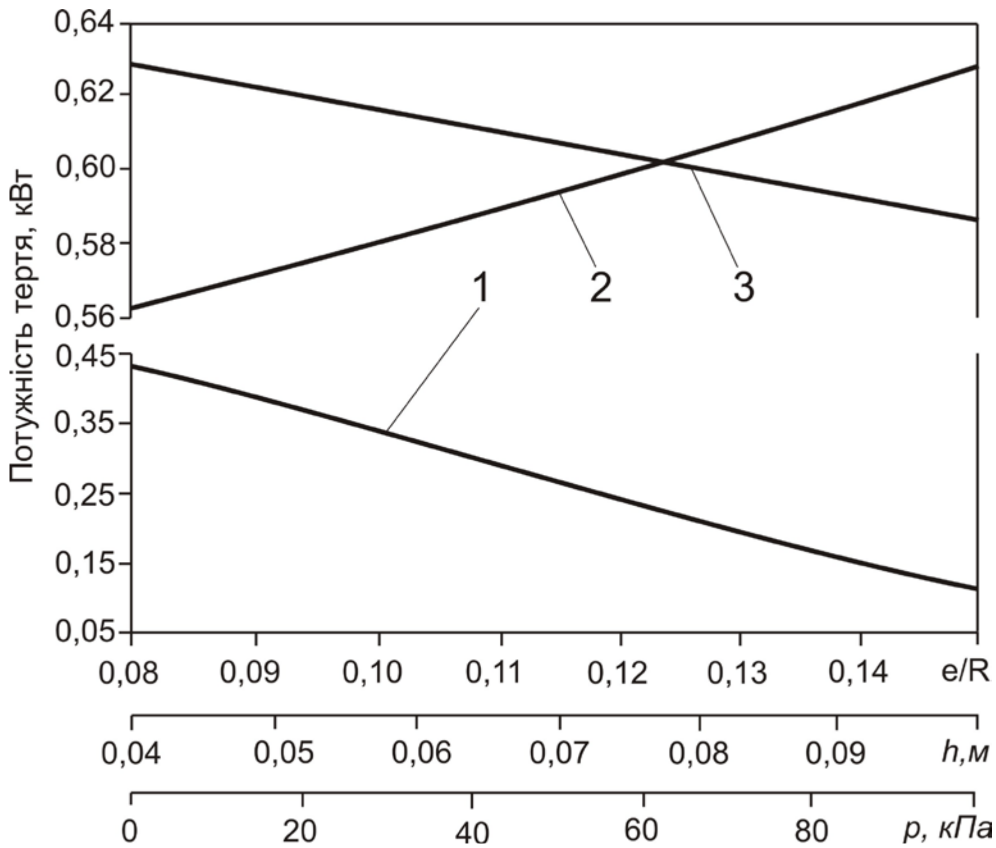

Fig. 3. Dependence of power at the height of the friction plates (1), eccentricity (2) and suction pressure (3).

In determining the eccentricity, the number and length of plates determining factor is the performance of the vacuum pump. For example, to improve the efficiency of the cylinder necessary to increase the eccentricity. However, its value is limited ultimately possible depth of the groove of the rotor. For example, if the maximum radius plate protruding height of the rotor is the second part that is necessary for normal to full height plate h = (3,5 ... 4) is, and the depth of the groove hn = h + (0 5 ... 1 mm), which eliminates the jamming of the plate in the groove of the rotor. In addition, with increasing eccentricity grows moment that bends the plate. Given these conditions, the size of existing machines eccentricity accept e = (0,09 ... 0,15) R [2].

Smaller values are under high pressure and ways in two-stage compressors and more - in blowers and vacuum pumps. Thus, the most effective way to reduce the power of friction plates is to increase the height of the plates. When held constant eccentricity without reducing performance vacuum pump, increasing the height of the plate can significantly reduce the capacity of the friction plates. The main way to increase the depth of the groove - the use of inclined grooves rotors (Fig. 4).

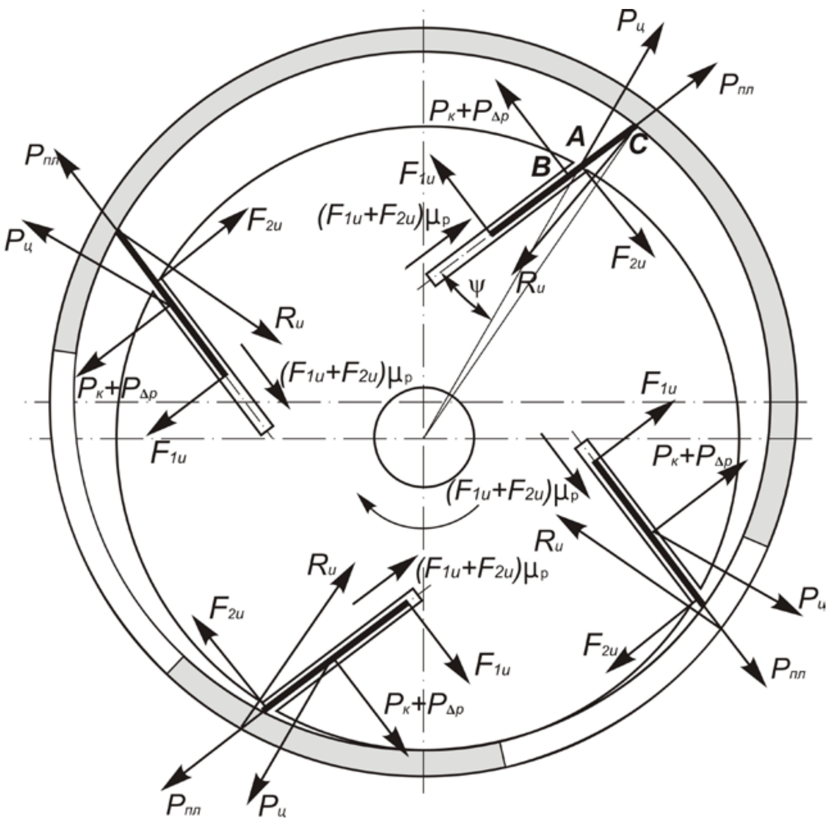

Fig. 4. Scheme workloads inclined plates along the rotor.

The required slope angle plates determined ψ between the plate and the straight line connecting the center to the edge of the rotor groove (segment OA in Fig. 4). Determine the value segment of the AU, which is a projecting from the groove of the plate. For this we consider the triangle ΔCCA. Let AC = s.

$$\rho = \sqrt{r^2 + s^2 - 2rs\cos(\pi - \psi)} = \sqrt{r^2 + s^2 + 2rs\cos\psi}\ . \quad (13)$$

Solving equation (13), we find:

$$s = -r\cos\psi + \sqrt{(r\cos\psi)^2 + \rho^2 - r^2}. \quad (14)$$

Let corner $\angle AED = \alpha$. From the law of sines of ΔSLA find:

$$\sin\alpha = \frac{r\sin\psi}{\rho}, \cos\alpha = \sqrt{1 - \left(\frac{r\sin\psi}{\rho}\right)^2}\ . \quad (15)$$

Let corner $\angle ATS = \beta$. WITH ΔATS find:

$$\sin\beta = \frac{\rho\sin\alpha}{OB} = \frac{r\sin\psi}{OB}\ . \quad (16)$$

To determine $\sin\beta$ necessary to determine the agents. For this look ΔATS.

$$OB = \sqrt{\rho^2 + \left(\frac{h}{2}\right)^2 - 2\rho\frac{h}{2}\cos\alpha} = \sqrt{\rho^2 + \left(\frac{h}{2}\right)^2 - \rho h\cos\alpha} \quad (17)$$

Then,

$$\sin\beta = \frac{r\sin\psi}{\sqrt{\rho^2 + \left(\frac{h}{2}\right)^2 - \rho h\sqrt{1-\left(\frac{r\sin\psi}{\rho}\right)^2}}}. \quad (18)$$

Putting the system of equations. By turning the rotor from 0 to 180°:

$$\begin{cases} F_{1u}h - F_{2u}s + (P_ц \sin(\pi-\beta) + P_к + P_{\Delta p})\frac{h}{2} = 0 \\ (P_к + P_{\Delta p} + P_ц \sin(\pi-\beta))\frac{h}{2} - R_u h\sin(\alpha - v - \delta) - F_{2u}(h-s) = 0 \\ R_u \cos(\alpha - v - \delta) + P_ц \cos(\pi-\beta) + \mu_p(F_{1u} + F_{2u}) + P_{пл} = 0 \end{cases}. \quad (19)$$

Let:

$$\alpha - v - \delta = \lambda \quad (20)$$

Then Ry expression will look like:

$$R_u = \frac{P_ц \cos\beta + P_{пл} \pm (P_к + P_{\Delta p} + P_ц \sin\beta)\frac{\mu_p s}{h-s}}{\cos\lambda + \mu_p \sin\lambda\frac{h+s}{h-s}}. \quad (21)$$

where

$$\alpha - v + \delta = \lambda. \quad (22)$$

The top marks equation (21) holds the suction side, bottom - side injection. Consider the option of slope side plates opposite rotation (Fig. 5).

Putting the system of equations. By turning the rotor from 0 to 180°:

$$\begin{cases} F_{1u}h - F_{2u}s + (-P_ц \sin(\pi-\beta) + P_к + P_{\Delta p})\frac{h}{2} = 0 \\ (P_к + P_{\Delta p} - P_ц \sin(\pi-\beta))\frac{h}{2} + R_u h\sin(\alpha - v - \delta) - F_{2u}(h-s) = 0 \\ -R_u \cos(\alpha - v - \delta) + P_ц \cos(\pi-\beta) + \mu_p(F_{1u} + F_{2u}) + P_{пл} = 0 \end{cases}. \quad (23)$$

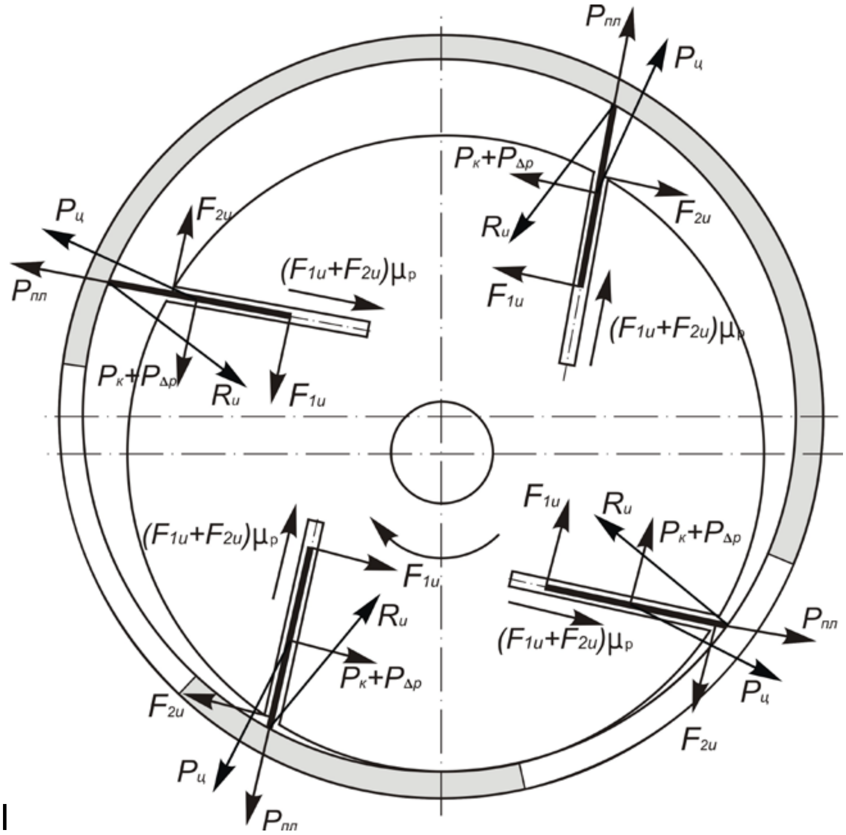

Fig. 5. Scheme workloads inclined plate against the rotor.

In this case, the formula for determining the Ru will be as follows:

$$R_{и} = \frac{P_{ц}\cos\beta + P_{пл} \pm (P_{к} + P_{\Delta p} - P_{ц}\sin\beta)\dfrac{\mu_p s}{h-s}}{\cos\lambda \mu\mu_p \sin\lambda \dfrac{h+s}{h-s}} \quad (24)$$

The upper marks on the side of the equation just absorption, lower - side injection. Analyze the forces of reaction formula in the case of the plate for radial plates (12), inclined to the course of rotation (21) and for slant against rotation (24). Obviously, the slope of the plates in both reduces the reaction force Ru. First, this is achieved by dividing the RC into two components: $P_{ц}\cos(\pi-\beta)$ and $P_{ц}\sin(\pi-\beta)\dfrac{\mu_p s}{h-s}$. As the calculations, the amount of these components exceeds EC only on the angles of rotation close to 0°. Second, in (24) the second component has a negative sign. However, calculations show that the greatest effect is achieved by reduction of Ru in (21), where the denominator all members are positive. As a result of friction when maximum minimum turning plates along the rotor (Fig. 6).

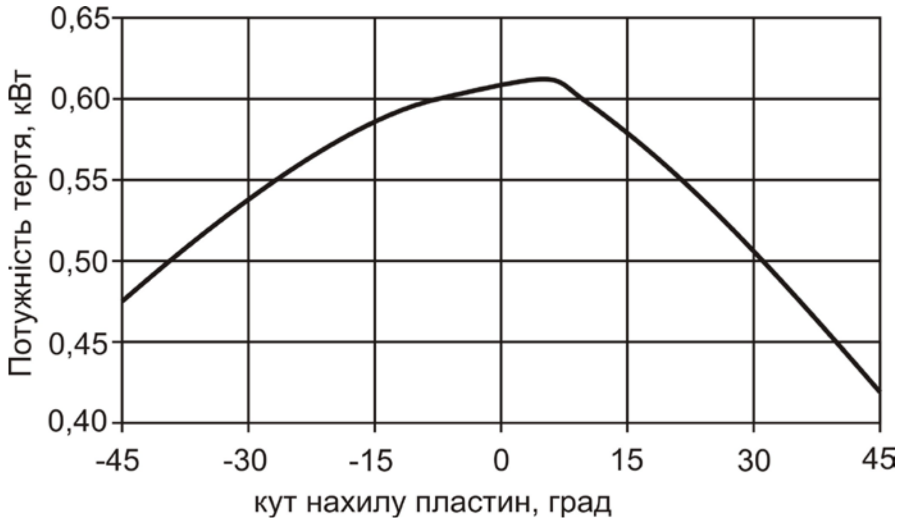

Fig. 6. The dependence of the friction plates of powerangle inclination grooves vacuum pump.

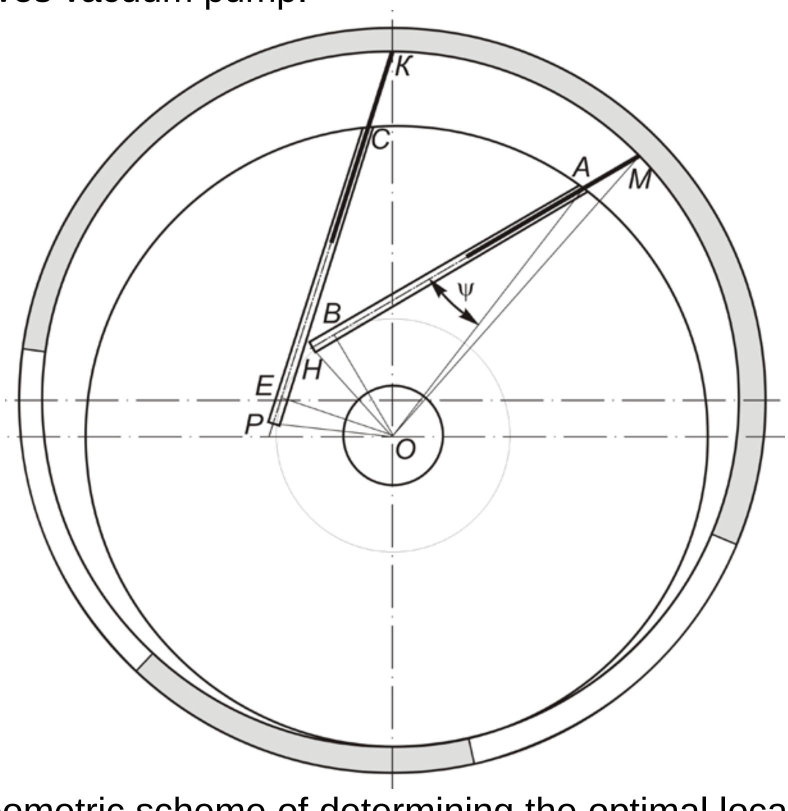

Fig. 7. Geometric scheme of determining the optimal location of the groove.

From Fig. 6 shows that the minimum output friction plates on the cylinder of 0.42 kW ψ= 45 °. If the height of the plates will be maximum for this angle (hm =0.089 m), The friction will power 0.16 kW. Efficient provision defines grooves of equations (25), prepared in accordance with Fig. 7.

$$\begin{cases} AO = r \\ AB = r\cos\psi \\ \angle AOC = \dfrac{2\pi}{z} = \theta \\ \angle COB = \dfrac{\pi}{2} - \psi - \theta \\ EOC = \dfrac{\pi}{2} - \psi \\ \angle BOH = \dfrac{\angle COE - \angle COB}{2} = \dfrac{\frac{\pi}{2} - \psi - (\frac{\pi}{2} - \psi - \theta)}{2} = \dfrac{\theta}{2} \\ BH = OBctg\angle BOH = r\sin\psi tg\dfrac{\theta}{2} \\ AH = r\cos\psi + r\sin\psi tg\dfrac{\theta}{2} \end{cases} \quad (25)$$

Conditions extremum:

$$AH(\psi)' = -r\sin\psi + r\cos\psi tg\frac{\theta}{2} = 0. \quad (26)$$

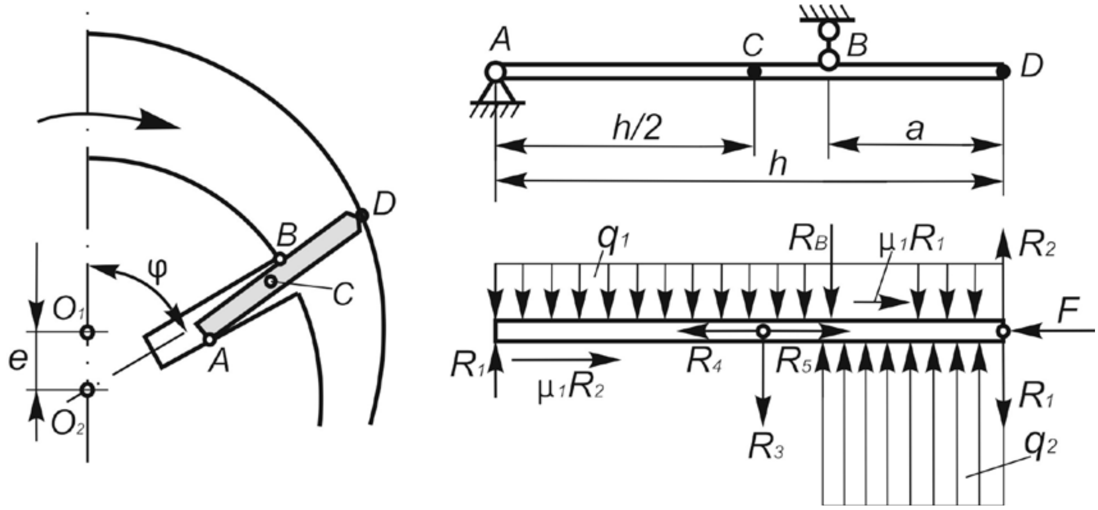

Fig. 8. Diagram effort acting on the plate

Where $\psi = \frac{\theta}{2} = \frac{\pi}{z}$. Thus, the angle of the grooves in the rotor is inversely proportional to the number of plates. For optimal material selection plate of thickness (a known width) must take into account the efforts that are on it, given the pressure drop. Reactions plate in the groove of the rotor define a static equation proposed [5]. Location of force shown in Fig. 8, where the camera is working at the corner gas compression.

Reactions plates at points A and B:

$$R_A = \frac{a}{h-a}\left[(q_1 h + R_3)\left(1 - \frac{h}{2a}\right) + q_2 \frac{a}{2} + (\sin\gamma\cos\gamma + \mu_2 \cos^2\gamma)F\right]. \quad (27)$$

$$R_B = \frac{h}{2(h-a)}\left[q_1 h + R_3 + q_2 a \frac{2h-a}{h} + 2(\sin\gamma\cos\gamma + \mu_2 \cos^2\gamma)F\right]. \quad (28)$$

where: and - speaking from the rotor plate of the city.

Longitudinal force of centripetal acceleration and acceleration plates on the rotor:

$$R_5 = -m_{пл}(j_C + j_{3/2}). \quad (29)$$

Longitudinal component weight plates:

$$R_4 = -m_{пл} g \cos\varphi. \quad (30)$$

where: μ_1 - friction plate in the groove of the rotor.

$$F'_{тр} = \pm\mu_1(|R_A| + |R_B|) \quad (31)$$

Sign "+" refers to the angle of rotation of the plate from 0 to πAnd the sign "-" of π 2π. Sign in (31) applies only factor A = sinφ/ | Sinφ|:

$$F'_{тр} = A\mu_1(|R_A| + |R_B|). \quad (32)$$

This formula is valid for all values of the angle φ rotation of the rotor, except φ = 0 π.However, these angles of rotation friction $F'_{тр}$ = 0, so that the speed of movement of plates in the grooves of the rotor 2 v3 = 0. The total longitudinal force is defined as the sum of forces:

$$F = R_4 + R + F'_{тр}. \quad (33)$$

At φ = 0 and π Longitudinal force:

$$F = R_4 + R_5. \quad (34)$$

Substituting values RA and RB and decided to equation (33) with respect to F, we obtain:

$$F = \frac{R_4 + R_5 + \mu_1[a/(h-a)](q_1 h + R_3) + \mu_1[h/(h-a)]q_2 a}{1 - \mu_1(\sin\gamma\cos\gamma + \mu_2\cos^2\varphi)[(h+a)/(h-a)]}. \quad (35)$$

It should be noted that this calculation because of low values do not include longitudinal forces: $\mu_2 F\cos\gamma\sin\gamma$ i F$\sin 2\gamma$And moments from the forces of friction plates in the groove of the rotor:

MA=$\mu_1 RB\delta$ *and* MB = $\mu_1 Ra\delta$,

where: δ - The thickness of the plate. This error does not exceed 1 ... 1.5%.

Conclusion. A plate of vacuum pumps reduce power consumption at selected constant radius hull possible by reducing eccentricity, length and number plates, as well as by increasing the height of the plate. The most effective way to reduce the power of friction plates is to increase the height of the plates. The main way to increase the depth of the groove - the use of inclined grooves. This rotor grooves must have a maximum depth and the angle of inclination is inversely proportional to their number plates.

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Theoretically Pryvedenы results of research rotatsyonnыh plastynchatыh vacuum pumps, the basis pryvedenы neobhodymыe s recommendations on designing and operation. Theoretical calculations Unyfytsyrovanы POSITION trenyya-power vacuum pump with a radyalnыmy naklonnыmy plates.

Vacuum pump trenye, plate capacity.

Results of theoretical studies of rotary vane vacuum pumps based on them are given the necessary recommendations on the design and operation. A unified theoretical principles of power calculations friction vacuum pump with radial and inclined plates.

Vacuum pump, friction, vane, power.