



CLARIFICATION OF THE METHODS USED FOR CALCULATING POWER OF SIEVE SEPARATORS

Abstract

Calculation of sieve separators power is usually done during their development. The goal of such calculations is to determine the power of driven electric motors.

The imperfection of existing methods for calculating power of some types of sieve separators makes developers to use indicative methods to determine the gear power. For example, it is done using the method of specific energy consumption or the comparison method with parameters of similar equipment. These methods provide only indicative results, that is why the power of the installed electric motors sometimes even exceeds the needed one, so in such way it worsens technical and economic factors of the equipment.

The methods for calculating power of flat-sieve separators moving progressive and invers or circular progressive have clearly determined sense and consider all energy consumptions of separators' engine.

The goal of the calculation of technological equipment and sieve separators in particular is to define the power of the electric motors.

The imperfection of existing methods for calculating power leads to use in some machines of high power engines which selection is based on indicative calculations, for example, using a method of specific energy consumption or comparing with analogues.

As the calculating methods depend on the law of working parts movement and their engine each example considered separately.

In the calculation of the power of separators with flat sieve which are moving oscillatory the effective power required by the engine of sieve bodies equal to the sum of the average power required to drive the oscillatory moving mass; the average power that is needed for product overlocking; the average power required to overcome the friction force of the product in the sieve; the average power used to deform the suspension; the average power need to overcome the drag of the air environment.

The current value of the power which is need to drive the oscillatory construction elements is determined considering the total value of oscillatory bodies mass; the weight and the amount of sieve bodies; the product weight on the bodies sieves; the weight of the oscillator; the frame weight.

During a circular progressive movement of sieve bodies the power which is need to overlock the product mass on the sieve which are moving reciprocally is almost equal to zero, because the product is moving with stops during the all-time being on the sieve. This also refers to the movement of the product on the barrel sieves which are rotating, where parts change the direction of movement while they are slipping down and get accelerated again.

The acceleration power in the separators with circled progressive motion of the sieves is equal to the kinetic energy of its circle oscillations.

To provide the relative motion of the parts on the horizontal sieve surface which is making a circled progressive motion it is necessary that the difference between the centred inertial force and friction force to be more than zero.

Key words: power calculations, determination of power to sieve separators' engine, power for the engine in motion, power for overlocking of the product, power to overcome gravity; power for deformation of suspension brackets; power to overcome the resistance of the environment

Generally, the goal of the calculation of technological equipment and sieve separators in particular is to define the power of the electric motors.

The imperfection of existing methods for calculating power leads to use in some machines of high power engines which selection is based on indicative calculations, for example, using a method of specific energy consumption or comparing with analogues.

As the calculating methods depend on the law of working parts movement and their engine let us consider each example separately.

Calculation of the power of separators with flat sieve which are moving oscillatory

The effective power required by the engine of sieve bodies

$$N_{e\phi} = N_1 + N_2 + N_3 + N_4 + N_5, \quad (1)$$

where N_1 is the average power required to drive the oscillatory moving mass; N_2 - the average power that is needed for product overlocking; N_3 - the average power required to overcome the friction force of the

product in the sieve; N_4 - the average power used to deform the suspension; N_5 - the average power need to overcome the drag of the air environment.

The current value of the power N_{iT} which is need to drive the oscillatory construction elements is determined using the formula

$$N_{iT} = P_i v = M a v, \quad (2)$$

where $M = z_k m_k + m_{np} + m_{\kappa l} + m_p$ - is the total value of oscillatory bodies mass; m_k and z_k are the weight and the amount of sieve bodies; m_{np} - the product weight on the bodies sieves; $m_{\kappa l}$ - the weight of the oscillator; m_p - the frame weight; $v = \omega r \sin \omega t$ - the acceleration of oscillators in case of reciprocating movement of the sieve bodies; the velocity of the oscillation mass oscillating reciprocally.

After transformation we get

$$N_{iT} = M r^2 \omega^3 \sin \alpha \cos \alpha, \quad (3)$$

where $\alpha = \omega t$ - is the instantaneous angle of oscillator's shaft rotation.



The average power value is

$$N_1 = \frac{2}{\pi} \int_0^{\frac{\pi}{2}} Mr^2 \omega^3 \sin \alpha \cos \alpha d\alpha. \quad (4)$$

After integration we get

$$N_1 = \frac{Mr^2 \omega^3}{\pi} \quad (5)$$

During a circular progressive movement of sieve bodies, when $a = \omega^2 r$ і $v = \omega r$, the power is

$$N_1 = M r^2 \omega^3 \quad (6)$$

The power N_2 which is need to overclock the product mass on the sieve which are moving reciprocally is almost equal to zero, because the product is moving with stops during the all-time being on the sieve. This also refers to the movement of the product on the barrel sieves which are rotating, where parts change the direction of movement while they are slipping down and get accelerated again.

The acceleration power in the separators with circled progressive motion of the sieves is equal to the kinetic energy of its circle oscillations, i.e.

$$N_2 = \frac{\Pi \omega^2 r_k^2}{1800}, \quad (7)$$

where Π – is the productivity of the sifter, *kg per hour (kg/h)*;

r_k – is trajectory radius of relative motion of the parts moving on the sieve. To provide the relative motion of the parts on the horizontal sieve surface which is making a circled progressive motion it is necessary that the difference between the centred inertial force $P_i = m \omega^2 r$ and friction force $T = mg f_r$ i.e. to be more than zero

$$m \frac{dV_B}{dt} = m \omega^2 r - mg f_r > 0, \quad (8)$$

where V_B – is the relative velocity of the part;

r – is the radius of the circle oscillation of the sieve;

ω – is the oscillation frequency of the sieve;

f_r – is the coefficient of friction of the product on the sieve.

After transforming the expression (8), we get the condition for the relevant motion of the parts on the sieve

$$\omega > \omega_{kp},$$

where $\omega_{kp} = \sqrt{\frac{g f_r}{r}}$. Taking into account that

$$\frac{dV_B}{dt} = \omega^2 r_k \text{ is the acceleration of the relevant motion of}$$

the parts on the sieve we get

$$\omega^2 r_k = \omega^2 r - g f_r, \quad (9)$$

from which it follows that

$$r_k = r - \frac{g f_r}{\omega^2}. \quad (10)$$

The average power which is need to overcome the friction force of the parts moving on the sieve is determined using the given formula

$$N_3 = T_c v_c, \quad (11)$$

where T_c – is the average friction force of the part's layer motion on the surface of the sieve.

v_c – is the average velocity of the product motion on the sieve.

While sifting using the **reciprocating** motion the current value of the friction force is

$$T = f_r (m_n g \sin \alpha - m_n \omega^2 r \cos \omega t \sin(\alpha + \beta)), \quad (12)$$

where m_n – is the weight of product layer on the sieve, $m_n = F \epsilon_n \rho$; α and β – are the tilt angles of the sieves and the axis of oscillation of the sieve body; r and ω – is the amplitude and the circle frequency of the sieve's oscillation; ρ – is the volume weight of the product; F and ϵ_n – are the sieve area and the average thickness of the product layer on the sieve.

Using (12) and taking into account that $\alpha = \omega t$ in the interval between from 0 to 2π , we get the average value of the friction force.

$$T_c = f_r m_n g \sin \alpha. \quad (13)$$

As the average velocity of the product downward movement on the surface of the flat sloped oscillating sieve is

$$v_{xc} = \frac{g\pi}{4\omega} (\sin x + f_r \cos \alpha) + \frac{2\omega r}{\pi} (\cos(\alpha + \beta) + f_r \sin(\alpha + \beta)) + v_{xo}, \quad (14)$$

where v_{xo} – is the initial velocity of the product, so from the formulas (6) and (11) it is available to get the formula for determination of the average power which is need to overcome the friction force of the product on the sieves

$$N_3 = f_r m_n g \sin \alpha \left[\frac{g\pi}{4\omega} (\sin \alpha - f_r \cos \alpha) + \frac{2\omega r}{\pi} (\cos(\alpha + \beta) + f_r \sin(\alpha + \beta)) + v_{xo} \right]. \quad (15)$$

For the sifters with circled progressive motion of the sieves and angle of inclination to the horizon α

$$T_c = f_r m_n (g \cos \alpha - \omega^2 r \sin \alpha), \quad (16)$$

and velocity

$$v = g(\sin \alpha - f_r \cos \alpha)t + \omega^2 r(\cos \alpha + f_r \sin \alpha)t + v_0 t, \quad (17)$$

where v_0 – is the initial velocity of the product.

The average velocity of the gliding of the product layer with the circled progressive motion on the sieve can be determined by integrating the expression

$$v_{xc} = \frac{1}{t_k} \int_0^{t_0} v_x dt, \quad (18)$$

where $t_k = \frac{\pi}{2\omega}$ – is the integrating constant, which is equal to the time which is need to make the crank's quarter turn. So we get

$$v_c = p \left(\frac{g}{w} (\sin \alpha - f_r \cos \alpha) + wr(\cos \alpha + f_r \sin \alpha) + v_{co} \right), \quad (19)$$

where $v_{co} = v_0 \frac{\omega}{2\pi}$ – is the integrating constant.



Substituting (13) and (19) into (11) we get an expression which determines the power to overcome the friction force of the product on the surface of the sloped sieve with circled progressive motion

$$N_3 = p f_r m_n (g \cos \alpha - w^2 r \sin \alpha) \left(\frac{g}{w} (\sin \alpha - f_r \cos \alpha) + wr(\cos \alpha + f_r \sin \alpha) + v_{co} \right) \quad (20)$$

In case of **horizontal sieves with circled progressive motion**, we get

$$N_3 = \pi f_r m_n g \left(\frac{g f_r}{\omega} + \omega r + v_{co} \right). \quad (21)$$

As the initial velocity v_{co} is mainly low, i.e. $v_{co} \rightarrow 0$, so it can be neglected. The average power which is need to **deform suspension during the circled progressive motion** of the sieves is equal to

$$N_4 = z_n P_c v_{cn}, \quad (22)$$

where z_n – is the number of suspensions; P_c – is the average flex resistance of the suspension; v_{cn} – is the average velocity of the suspensions' deformation. The average value of the flex resistance of the suspension

$$P_c = \frac{2\omega}{\pi} \int_0^{\frac{\pi}{2\omega}} \frac{3J_x E}{l^3} r(1 - \cos \omega t) dt, \quad (23)$$

where l – is the length of the suspension; E – is the elastic modulus of the suspension; J_x – axial moment of inertia of the suspension section relative to its central axis.

After integrating the expression (23) we get

$$P_c = \frac{3J_x E}{l^3} r \left(1 - \frac{2}{\pi} \right). \quad (24)$$

The average velocity of the suspensions' deformation is equal to

$$v_{cn} = \frac{2\omega}{\pi} \int_0^{\frac{\pi}{2\omega}} r \omega \sin \omega t dt. \quad (25)$$

After integrating we get

$$v_{cn} = \frac{2r\omega}{\pi}. \quad (26)$$

After substituting (24) and (26) into (22) we get the formula for determination of the power

$$N_4 = \frac{6Z_n J_x \omega E r^2}{\pi l^3} \left(1 - \frac{2}{\pi} \right), \quad (27)$$

where Z_n – is the number of suspensions.

Power which is need to overcome the drag of the air environment to the motion of sieve body

$$N_5 = P_{nc} v_c, \quad (28)$$

where P_{nc} – is the average drag of the air environment to the motion of the sieve body; v_c – is the average velocity of the sieve body in the air environment.

The average drag of the air

$$P_{nc} = \xi F_{mc} \rho_n \frac{v_c^2}{2}, \quad (29)$$

where ξ – is the coefficient of the aerodynamic drag; F_{mc} – is the midsection of the body; ρ_n – is the air density.

In case when **body is moving reciprocally** (fig.1) **midsection** is defined as so

$$F_{mc} = F_{kr} \sin(\alpha + \beta) + F_{kb} \cos \alpha, \quad (30)$$

where F_{kr} and F_{kb} – is the area of the mutually perpendicular edges of the body.

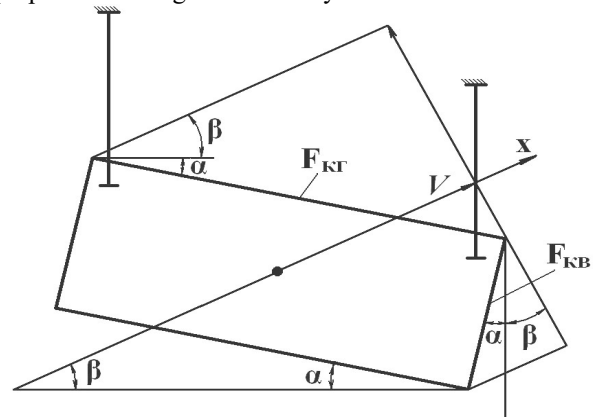


Figure 1 - Scheme of the definition of the midsection of the frame F_{mc} at its progressive-reverse movement

The average velocity of the body which is moving reciprocating

$$v_c = \frac{2\omega}{\pi} \int_0^{\frac{\pi}{2\omega}} r \omega \sin \omega t dt. \quad (31)$$

After integrating (31) we get

$$v_c = \frac{2r\omega}{\pi}. \quad (32)$$

After substituting (30) and (32) into (29), we get

$$P_{nc} = \xi (F_{kr} \sin(\alpha + \beta) + F_{kb} \cos(\alpha + \beta)) \rho_n \frac{2r^2 \omega^2}{\pi^2}. \quad (33)$$

After substituting (33) and (32) into expression (28) we get formula to determine the power which is need to overcome the air drag to the motion of the body when it is moving reciprocating.

$$N_5 = \xi (F_{kr} \sin(\alpha + \beta) + F_{kb} \cos(\alpha + \beta)) \rho_n \frac{4r^3 \omega^3}{\pi^3}. \quad (34)$$

For sieve's bodies which are moving **circled progressive** the current value of the midsection (fig. 2)

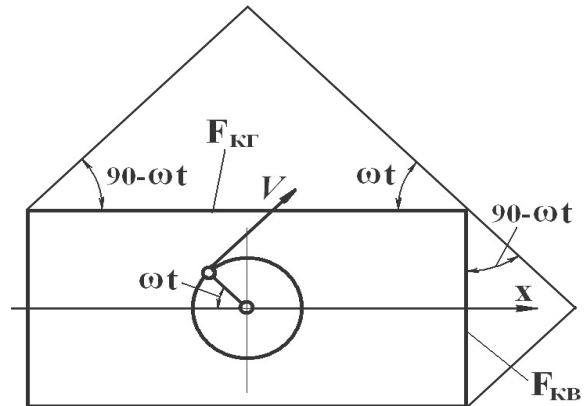


Figure 2 - Scheme of the determining of the midsection of the frame F_{mc} at its circular progressive movement



is equal to

$$F_{mc} = F_{kr} \cos \omega t + F_{kb} \sin \omega t. \quad (35)$$

After integrating this expression in the interval

between 0 and $t = \frac{\pi}{2\omega}$ we get

$$F_{mc} = \frac{2}{\pi} (F_{kr} + F_{kb}). \quad (36)$$

In this case the average velocity of the body is equal to the velocity of circular oscillations, i.e.

$$v_c = \omega r. \quad (37)$$

So after substituting F_{mc} and v_c from the expressions (36) and (37) into expressions (28) and (29) we get that the value of the power used by the sieve's body which is moving circled progressive to overcome the air drag is equal to

$$N_5 = \xi (F_{kr} + F_{kb}) \rho_a \frac{\omega^3 r^3}{\pi}, \quad (38)$$

The methods of calculating the power of the separators with rolling sieves (barrels) are going to be learnt in the next issue of the magazine.

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УТОЧНЕННЯ МЕТОДИК СИЛОВИХ РОЗРАХУНКІВ СИТОВИХ СЕПАРАТОРІВ

Анотація

Розрахунок ситових сепараторів потужності зазвичай робиться при їх розробці. Метою таких розрахунків є визначення потужності керованих електродвигунів. Недосконалість існуючих методів розрахунку потужності деяких типів ситових сепараторів змушує розробників використовувати індикативні методи визначення потужності передачі. Наприклад, це робиться методом питомого споживання енергії або методом порівняння з параметрами аналогічного обладнання. Ці методи дають лише індикативні результати, тому потужність встановлених електродвигунів іноді навіть перевищує необхідну, тому таким чином погіршуються техніко-економічні чинники обладнання. Методи розрахунку потужності плоских ситових сепараторів, що рухаються поступально і інверсійно або кругова прогресивно, мають чітко визначений сенс і враховують всі енерговитрати двигуна сепараторів. Метою розрахунку технологічного обладнання та ситових сепараторів, зокрема, є визначення потужності електродвигунів.

Недосконалість існуючих методів розрахунку потужності призводить до використання в деяких машинах потужних двигунів, вибір яких базується на індикативних розрахунках, наприклад, за допомогою методу питомого споживання енергії або порівняння з аналогами. Оскільки розрахункові методи залежать від закону руху робочих частин і їх двигуна, кожен приклад розглядається окремо.

При розрахунку потужності сепараторів з плоскими ситами, що рухаються коливальними, ефективна потужність, необхідна двигуноу ситових тіл, дорівнює сумі середньої потужності, необхідної для приводу коливальної рухомої маси; середню потужність, необхідну для розгону продукції; середню потужність, необхідну для подолання сили тертя виробу в ситі; середню потужність, що використовується для деформування суспензії; середня потужність необхідна для подолання опору повітряного середовища. Поточна величина потужності, яка необхідна для приводу коливальних елементів конструкції, визначається з урахуванням сумарної величини маси коливальних тіл; вага і кількість ситових тіл; вага продукту на органах сит; вага генератора; вагу рами. Під час кругового прогресивного переміщення ситових тіл потужність, яка необхідна для розгону маси продукту на ситі, що рухається взаємно, майже дорівнює нулю, оскільки виріб рухається з зупинками протягом всього часу перебування на ситі. Це також стосується переміщення виробу на сито, що обертається, де частини змінюють напрямку руху, коли вони ковзають вниз і знову прискорюються.

Потужність прискорення в сепараторах з круговим прогресивним рухом сит дорівнює кінетичній енергії її коливальних кола. Для забезпечення відносного руху частин на горизонтальній поверхні сита, що здійснює круговий прогресивний рух, необхідно, щоб різниця між центрованою інерційною силою і силою тертя була більше нуля.

Ключові слова: силові розрахунки, визначення потужності на привод ситових сепараторів, потужність для привода в рух, потужність для розгону продукту, потужність на подолання сил тертя; потужність на деформацію підвісок; потужність на подолання сил опору середовища.

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