Continuous Feed Mixer Performance

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Abstract--- Existing calculation formulas for determining the mixer performance do not sufficiently take into account peculiarities of design and shape of mixing chamber. The aim of the study is to determine the performance of a continuous mixer with an energy-saving mixing chamber in the form of a trihedral box. The analysis of factors affecting the mixer performance and the existing calculation formulas for its determination is carried out. It is established that the influence of the mixer working chamber shape on quality and productivity is insufficiently studied, and the influence over the screw space on the filling factor is not taken into account when determining the productivity of continuous mixers. Analytical dependence for determining the productivity of a continuous mixer with a mixing chamber in the form of a trihedral box depending on its parameters and mode, as well as design features, is obtained. By results of researches it is established that, at speed of rotation of the screw 36,61 s-1 and a factor of filling of the mixing chamber 0,02-0,09 productivity of the mixer makes: at mixing of green weight and silage with mixed fodder - 19 t/h, the crushed fodder root crops with mixed fodder - 23 t/h.

Keywords--- Mixer, Feed, Mixing Chamber, Rotational Speed, Reflector, Lid.

I. Introduction

In Uzbekistan, research work is being carried out to develop energy and resource-saving technologies and technical means for soil tillage, sowing, harvesting and primary treatment of crops [1-11]. Production and preparation of fodder is one of the central activities in this direction. Fodder entering for tillage undergoes a number of interrelated operations without trans-shipment operations, which require a lot of live labor. The final operations of fodder mixtures preparation are mixing of components in batch or continuous mixers. One of the basic indicators of efficiency of use of a mixer is productivity of machines which is defined by quantity of the work executed for certain time. A.N.Timofeev [12], A.D.Seleznev [13], F.G.Stukalin [14], B.A.Komarov [15], V.A.Chueshkov [16], E.M.Poghosyan [17], A.P.Chabala [19], H.O.Dumikjan [20], Je.U.Jeshdavlatov [21-23] and others have been engaged in research of continuous feed mixers and methods of their productivity calculation. B.A. Komarov [15] obtained a formula for productivity depending on the size of the gap between the casing and the blades, as well as the angular velocity of the blade shaft. This formula for productivity is valid only for a mixer with a cylindrical casing. V.A.Chueshkov [16] has substantiated the dependences of energy consumption and productivity of continuous twin-shaft blade mixers on the parameters of the working elements taking into account the qualitative mixing of mineral fertilizers. At calculation of productivity of a mixer V.A.Cheshkov [16] the form of the top part of a casing having the rectangular form is not considered. G.M.Kukta [17] investigated influence of constructive parameters, form of a mixing chamber and operating modes of the mixer of continuous action on quality of mixing, productivity and power consumption of process. E.M.Poghosyan [18] and H.O.Dumikyan [20] investigated the influence of the design features of the lid, the working body and the height of the free space between the screw and the lid on the performance of a single-shaft continuous screw mixer for mixing rough and juicy forages. The analysis of the conducted researches shows that the existing design formulas for determining the performance of mixers do not sufficiently take into account the design features and shape of the mixing chamber. The purpose of the study is to determine the performance of a continuous mixer with energy-saving mixing chamber in the form of a three-sided box.

II. Materials and Methods

The capacity (t/h) of a continuous mixer can be determined in general [12, 18, 19, 20] by the following formula

$$Q = 3{,}6 A \rho \varphi_H V_n, \quad (1)$$

DOI: 10.5373/JARDCS/V12SP7/20202343
ISSN 1943-023X
Received: 22 May 2020/Accepted: 20 June 2020

Where A – mixing chamber cross-section area, m^2; ρ – feed mixture density, kg/m^3; $\varphi_н$ – filling factor; V_n – mass axial velocity, m/s.

Axial mass velocity for single-entry solid propeller is equal to

$$V_n = \frac{S\omega}{6{,}28}, \tag{2}$$

Where S – is screw step, m; ω – is screw speed, s^{-1}.

This formula is fair if we imagine that the feed mass moves progressively along the axis of the screw like a nut fixed in the guides on the forming hood and moving as the screw rotates. However, the design features of the mixture make some adjustments in the definition of the axial velocity of the mixture and, consequently, the capacity of the mixer [21; 22; 23].

The presence in the mixer design of a multistage screw with alternating interrupted by the value of one step turns and the free space in the upper part of the body of the mixer contributes to the tossing of feed particles and, accordingly, lengthening the trajectory of its movement. A certain amount of time is spent for this, which affects the value of V_n.

The axial velocity V_n can be determined by the formula

$$V_n = \frac{S}{T}, \tag{3}$$

Where T is the total transit time of a feed particle over the length of a single coil step, s.

The value of T according to Fig.1. is equal to

$$T = T_1 + T_2 + T_3 + T_4, \tag{4}$$

Where T_1 – time of motion of particles on the screw winding (way CA), s; T_2 – time of flight of particles at their flip (way AB, BK), s; T_3 – time of motion of particles with a screw after their reflection (way KS), s; T_4 – time of delay of particles due to the presence of displacement between adjacent screw wrenches, s.

To determine T, let us consider the trajectory of feed particles at mixing (Fig.1). The movement of particles occurs in two zones: in the lower part of the mixer hood and in the free space above the screw. Let us consider the movement of the particle in each zone separately and determine the time spent by the particle on its movement.

For definition T_1 we accept, that at flight of particles longitudinal movement will not be, then time of influence of the first (or one) screw winding can be defined by the formula [18].

$$T_1 = \frac{S\sin(\alpha + \beta_o)}{\omega r \sin\alpha \sin\beta_o}, \tag{5}$$

Where ω –is the angular velocity of the screw, c^{-1}; r – is the radius of the screw, m; α – is the angle of the screw line rise; β_0 – is the angle between the vectors of the portable V_{pr} and absolute V_a velocity.

To determine the T_2 flight time of a particle planted from point A (Fig.1), we believe that when the particle approaches point A, the friction between the particle and the screw coils disappears, as does the friction between the particle and the hood. At this time the longitudinal velocity of the V_n particle decreases sharply, so it could be assumed that the particle is thrown perpendicular to the radius of the screw, i.e. it does not perform longitudinal motion when flying. Ignoring the air resistance, we accept that the particle is absolutely elastic, i.e. the K_p recovery factor when the particle strikes the cap is equal to one (K_p=I). Then, using the flight path of the particle shown in Fig.1, we can determine the time of flight T_2.

$$T_2 = t_{21} + t_{22}, \tag{6}$$

Where t_{21} – particle flight time at flip, c; t_{22} – particle flight time after reflection, c.

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ISSN 1943-023X
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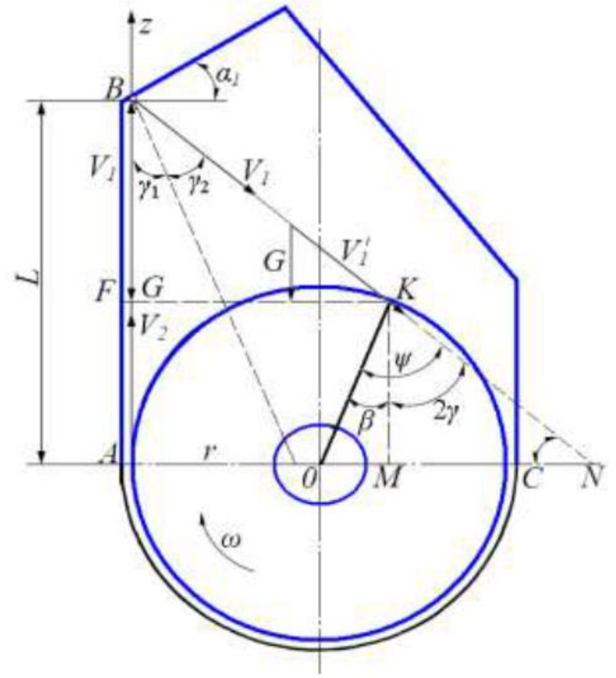

Fig.1: The Scheme of Determining the Coordinates of a Point

The flight time of T_2 is determined as a result of solving the equations of motion for the flip-flops [20].

$$m\frac{d^2X_1}{dt_{21}^2}=0;(7)$$

$$m\frac{d^2Z_1}{dt_{21}^2}=-mg \quad (8)$$

With start conditions

$$t_{21}=0;\quad X_0=0;\quad Z_0=0;\ V_{x_0}=0;\quad V_{z_0}=V_2=\omega_0 r.$$

And the equations of motion for reflected particles:

$$m\frac{d^2X_2}{dt_{22}^2}=0;\ m\frac{d^2Z_2}{dt_{22}^2}=-mg \quad (9)$$

With start conditions

$$V_1^1=-V_{z_1};\quad t_{20}=0;\ X_{20}=0;\quad Z_{20}=H;\quad V_{x_{20}}=V_{z_1}\cdot\sin 2\gamma;\quad V_{z_{20}}=-V_{z_1}\cos 2\gamma.$$

After solving these equations, we get

$$T_2=\left(\omega_0 r-\sqrt{gH/4\cos 2\gamma}\right)/g+\sqrt{4H\cos 2\gamma/g} \quad (10)$$

Where ω_o – is the angular velocity of the propeller, providing the flight of particles to the point K (Fig.1), provided that the particle is absolutely elastic, s^1.

$$\omega_0=\sqrt{\left(2+\frac{1}{4\cos 2\gamma}\right)gH/r^2} \quad (11)$$

The particle, after contact with the screw at point K, rotates with the screw until it meets the casing, i.e. to point C. The particle then moves, as previously stated, along the screw and around the casing. To determine the time of the particle's movement from the point K to the point C, it is necessary to determine the angle $\rho=<KOC$ (Fig.2).

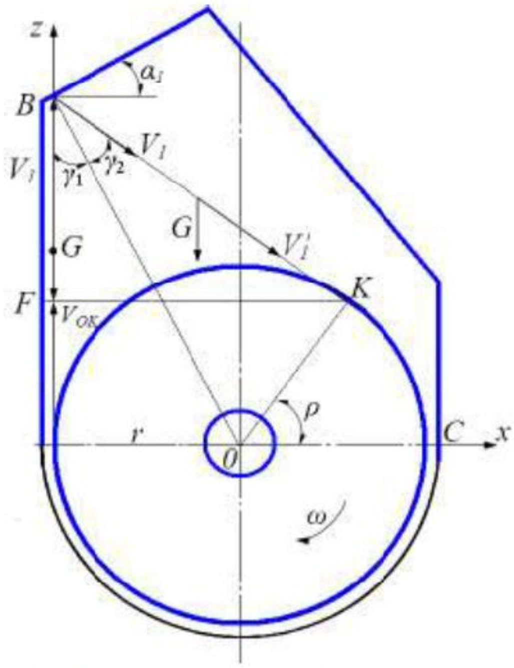

Fig.2: Scheme of Particle Flight Time Determination

You can see from the figure that $\Delta OAB = \Delta OKB$ from where $\gamma_1 = \gamma_2 = \gamma$.

Hence

$$\frac{AB}{AO} = tg\gamma_1 \text{ and } \frac{BK}{OK} = tg\gamma_2$$

Where comes from

$$\frac{AB}{AO} = \frac{BK}{OK} = \frac{H}{r} = tg\gamma.$$

Then

$$\gamma = arctg\frac{H}{r}. \qquad (12)$$

The *AOK* angle is 2γ, then

$$\rho = 180^\circ - 2\gamma = \pi - 2\,arctg\frac{H}{r}. \quad (13)$$

The T_3, time taken to move a particle from *K* to *C* can be determined from the ratio of

$$T_3 = \frac{\rho}{\omega} = \frac{\pi - 2arctgH/r}{\omega}. \qquad (14)$$

After the expiry of the time of being under the influence of the first coil, the particle leaves the zone of action of the first coil and after an optional time T_4 enters the zone of action of the second coil. Since the second coil of the winding is shifted from the first coil to the corner $2\pi/z$, then

$$T_4 = \frac{2\pi}{Z\omega} \qquad (15)$$

Where *Z* – is the number of turns.

To determine the true speed value, we enter a correction factor μ

$$\omega = \mu\omega_o, \qquad (16)$$

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Where the μ – is a factor that takes into account the drop in particle velocity after impact.

$$\mu = \frac{1}{K_n}, \qquad (17)$$

Where K_p – is the material recovery factor.

Then

$$\omega = \frac{1}{K_n}\omega_o; \quad \omega_o = K_n\omega. \qquad (18)$$

By substituting the values of T_1, T_2, T_3, T_4 in formula (4), we determine the total time

$$T = \frac{S \cdot \sin(\alpha + \beta_0)}{\omega \cdot ч \cdot \sin\alpha \cdot \sin\beta_0} + \frac{1}{g}\left(\omega \cdot ч \cdot K_n + \sqrt{\frac{gH}{4\cos 2\gamma}}\right) - \sqrt{\frac{4\cos 2\gamma \cdot H}{g}} + \frac{\pi - 2arctgH/r}{\omega} + \frac{2\pi}{Z \cdot \omega} \qquad (19)$$

By substituting the value of the total time T in formula (3), we determine the axial velocity of the feed mass

$$V_n = S/\left\{\begin{matrix} [S \cdot \sin(\alpha + \beta_0)]/(\omega \cdot r \cdot \sin\alpha \cdot \sin\beta_o) + (\omega \cdot r \cdot K_n - \sqrt{gH/4\cos 2\gamma})/g - \\ \sqrt{4H\cos 2\gamma / g + (\pi - 2arctg\frac{H}{r})} / \omega + 2\pi / Z \cdot \omega \end{matrix}\right\} \qquad (20)$$

III.Results and Discussions

For revealing of influence of speed of rotation of a screw on time of arrival and axial speed of a feed mix in the mixing chamber and arbitrariness we will present expressions (1) and (19) in a graphic view (fig.3). At that H=0,35 m, r=0,2 m, α=31°, S=0,4 m, K_p=0,4, Z=2, $\gamma_{см}$=600 kg/m; A=0,13 m^2 and L=4 m.

From Fig.3 we can see that with increasing speed, the time of stay of feed mixture in the mixing chamber decreases, and the axial speed of feed mixture and productivity of the mixer increases. After the rotational speed reaches 36.61-41.84 s-1. These figures remain unchanged. At further increase of hour of rotation, time of stay of weight in the mixing chamber increases, and axial speed of a feed mixer and productivity decreases. This phenomenon can be explained by the fact that the time of longitudinal movement of particles under the influence of screw winding decreases according to formulas (5), (14) and (15), and the time of stay of feed mass in the screw space, determined by the formula (10), increases.

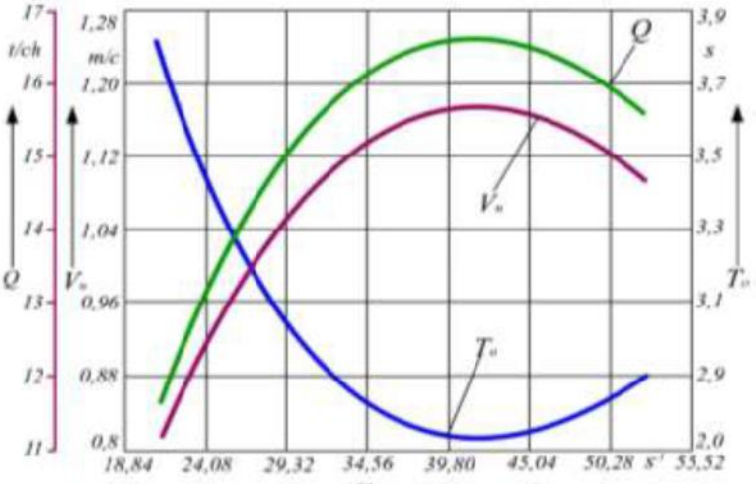

Fig.3: Dependence of Time of Stay, Axial Speed of a Forage Mass in the Mixing Cham Ber and Productivity of a Mixer on Speed of Rotation of the Screw at α=31°, $\varphi_н$=0,05, K_p=0,4.

As the large circumferential speed of the screw causes the effect of centrifugal force, the feed mixer will be located on the periphery of the mixing chamber.

DOI: 10.5373/JARDCS/V12SP7/20202343
ISSN 1943-023X
Received: 22 May 2020/Accepted: 20 June 2020

After substitution of the value of V_n from the formula (20) in (1), we will obtain a refined formula for the theoretical performance of the continuous mixer, taking into account the influence of the shape of the mixing chamber and reflecting the surface of the cover on the movement of feed particles.

IV. Conclusions

1. It is established that the influence of the mixer working chamber shape on quality and productivity is insufficiently studied, and the influence over the screw space on the filling factor is not taken into account when determining the productivity of continuous mixers.
2. Analytical dependence for determining the productivity of a continuous mixer with a mixing chamber in the form of a three-sided box depending on its parameters and mode, as well as design features is obtained. 3.
3. By results of researches it is established that, at speed of rotation of screw 36,61 s^{-1} and a factor of filling of the chamber of mixing 0,02-0,09 productivity of the amalgamator makes: at mixing of green weight and silage with mixed fodder - 19 t/h, the crushed fodder root crops with mixed fodder - 23 t/h.

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ISSN 1943-023X
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