BIO Web of Conferences **52**, 00036 (2022) https://doi.org/10.1051/bioconf/20225200036
FIES 2022

Influence of a stopping angle of a spiral coil on the operation of a spiral-screw dispenser

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Abstract. Dosing of dry concentrated feed to dairy cows is one of the most important tasks in the field of livestock mechanization. Devices that carry out volume dosing are more reliable and easier to be manufactured. Volumetric dispensers also include a spiral-screw dispenser – a special case of a screw dispenser. It is proposed to study the working process of the spiral-screw dispenser, namely the influence of a stopping angle of the last turn of the transporting spiral at the end of the discharge hole of the cylindrical casing. The paper indicates the method of determining and the value of the physical and mechanical properties of granulated feed. A laboratory installation on which it is possible to change the angle of installation of the spiral on the drive shaft is described. To study the effect of the stopping angle of the last turn of the transporting spiral on the accuracy of the formation of the feed portion, spirals with a diameter of 49, 73, 97 mm with different steps of 0.75, 1 and 1.25 of the diameter values were used. As a result of the experiments, it was revealed that the lowest coefficient of variation is 0.56 – 17.50%. And, accordingly, the greatest dosing accuracy is obtained when the last turn of the spiral stops at the position of 0°. That is, when the turn stops at the edge of the discharge neck in its lower part and this is typical for all sizes of spirals that were used.

1 Introduction

As noted earlier by many scientists and researchers, spiral-screw feeders – a special case of screw feeders – are promising in the field of volumetric dosing of bulk materials [1 – 3]. With regard to agriculture, specifically in animal husbandry, this is expressed in the dosing of dry concentrated feed to various farm animals [4 – 9].

In this industry, spiral-screw dispensers are increasingly used, since in dairy farming, according to zootechnical requirements, it is necessary to produce highly concentrated feed with high accuracy (at least 95%) [10 – 14].

Especially well proven spiral-screw dispensers are, in which the dosing of a portion of feed occurs according to the number of whole perfect revolutions of the spiral [5, 15]. When testing and studying the workflow of the dispenser, the question arose how and in what way the location of the last turn of the dosing spiral at the edge of the discharge neck would affect the operation of the dispenser.

In this regard, the goal was to investigate the process of dosing a portion of food at different angles of start and stopping the spiral.

2 Materials and methods

The task of the tests was to determine the accuracy of the formation of a portion of feed, depending on the angle of location of the last turn of the spiral at the end of the discharge neck.

The tests were carried out on granulated feed corresponding to GOST 9268-2015 with the following physical and mechanical properties: humidity – 6.1%; angle of natural slope – 42°; collapse angle – 48°; the angle of friction on the steel – 22°; bulk density – 658 kg/m^3. The sum of the Karr score is 81; flowability is good. These properties and criteria were determined according to GOST R 51850-2001, GOST R 57059-2016, GOST 13496.0-2016, GOST 28254-2014 [16].

To study the process of dosing and forming a portion of feed with a spiral-screw dispenser, a dispenser was designed, the scheme of which is presented in Figure 1. The basis of the spiral-screw dispenser includes a replaceable spiral and a casing. The spiral is driven by means of a coupling through a 16.3730 DC gear motor with a capacity of 100 W [5].

This motor gearbox allows stopping the spiral with a step of its rotation angle of 90°.

Figure 2 shows a general view of the laboratory spiral-screw dispenser

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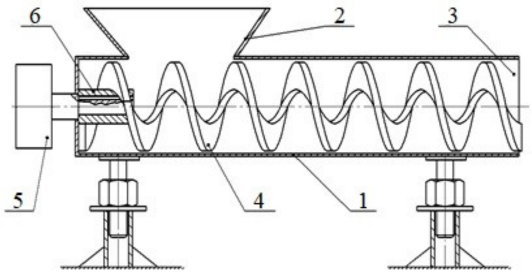


Fig. 1. Schematic diagram of spiral-screw dispenser: 1 – cylindrical casing; 2 – loading neck; 3 – discharge neck; 4 – spiral; 5 – drive (geared motor); 6 – coupling

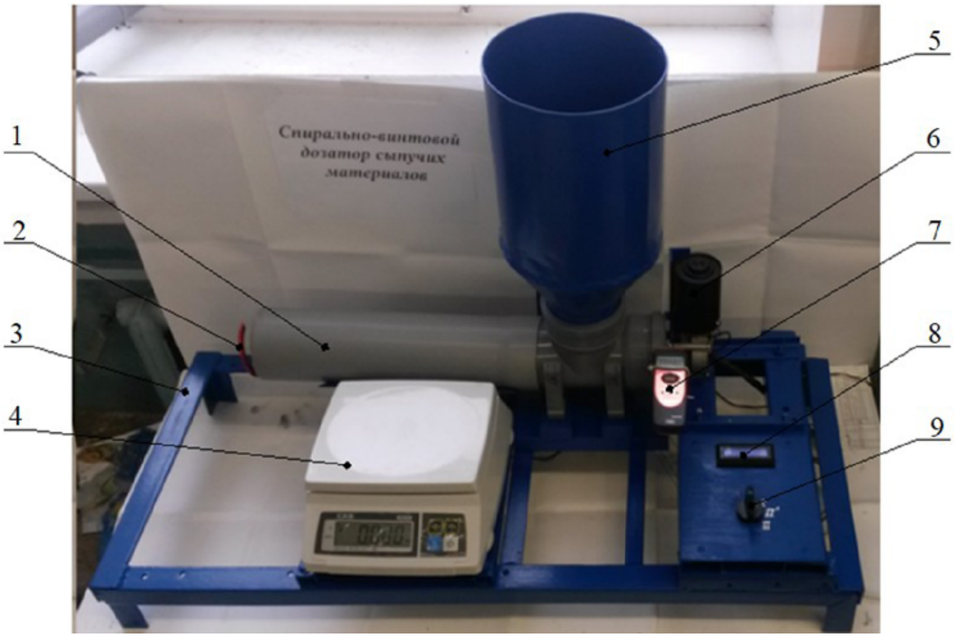
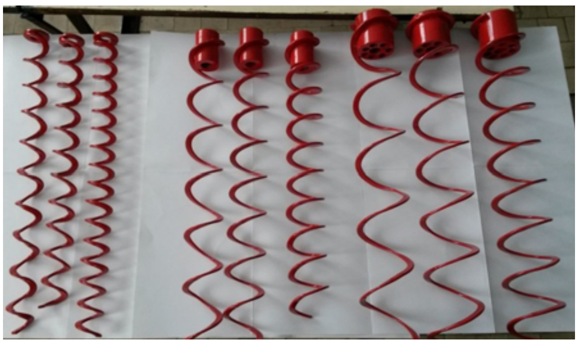


Fig. 2. General view of the experimental laboratory installation: 1 – cylindrical casing, 2 – spiral, 3 – frame, 4 – scales CAS SW-05, 5 – hopper with loading neck, 6 – motor reducer 16.3730, 7 – tachometer SM8238, 8 – measuring complex MYLB-G. T. Power RC 130A, 9 – switch

The estimation of the error in the formation of the feed portion was carried out on spirals of various diameters and pitches (Table 1), (Fig. 3), to ensure a gap of 5 mm between the spiral and the cylindrical casing, 3 round pipes with diameters of 59, 83 and 107 mm were selected.

Table 1. Parameters of the transport spirals used

Spiral diameter d, mm	Strip profile, mm	Spiral pitch, s	Spiral length l, mm
49; 73; 97	4x12	0.75d; 1d; 1.25d	600 ± 50



d = 49 mm d = 73 mm d = 97 mm

Fig. 3. Screw spirals for dispenser

The laboratory dispenser works as follows. When the actuator is switched on, the rotational motion of the drive shaft 8 through the shaft key connection to the rod is transmitted to the transport coil 4, thereby allowing the movement of the bulk material disposed at the bottom of the loading neck 2 in the direction of the discharge neck (window) 3.

The use of a geared motor with an eccentric as a spiral drive allows the spiral to be stopped in a position where the last turn is at the bottom of the discharge neck. The presence of a contact strip on the drive shaft allows you to change the angle of the last turn of the spiral with a step of 90° as shown in Figure. 4. That is, the spiral will constantly stop in one strictly defined position – 0, 90, 180 and 270 degrees, while making the x-number of revolutions.

The experiment was conducted as follows. On the control panel, the number of revolutions of the spiral was set, N = 2 turns. The spiral was installed in one of the 4 positions. After that, the power was supplied to the drive and the feed was issued to the receiving tank and weighed on the SCALES CAS SW-05 with an accuracy of two grams, each experiment was repeated in five time-repetition [16]. At the end of all the series of experiments, the data were structured and summarized in Table 2.

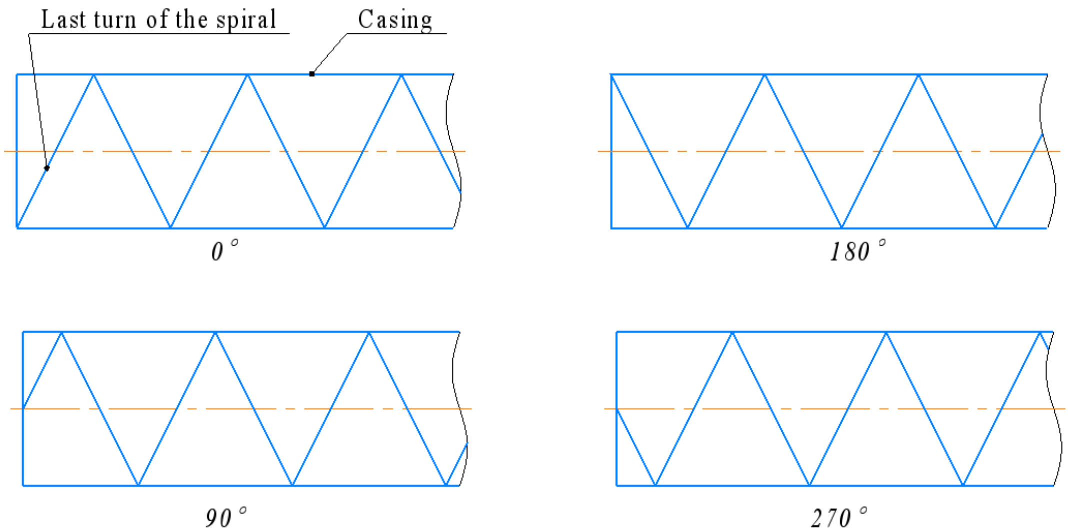


Fig. 4. Options for stopping angles of the last turn of the spiral at the end of the discharge neck

Table 1. Parameters of the transport spirals used

Angle of coil	D_k	d_{sp}	S	Weight of feed issued in experiment i					Σm_i, g	M_{av}, g	v, %
				m_1, g	m_2, g	m_3, g	m_4, g	m_5, g			
0°	109	97	1.25d	1352	1350	1326	1338	1372	6738	1347.6	**17.50**
90°				1356	1326	1334	1338	1382	6736	1347.2	29.64
180°				1322	1310	1374	1306	1364	6676	1335.2	59.87
270°				1324	1342	1328	1364	1358	6716	1343.2	18.65
0°	109	97	1d	1210	1202	1218	1220	1216	6066	1213.2	**3.51**
90°				1190	1222	1198	1230	1212	6052	1210.4	18.03
180°				1208	1198	1210	1216	1232	6064	1212.8	10.37
270°				1226	1190	1240	1222	1218	6096	1219.2	21.99
0°	109	97	0.75d	970	968	970	978	976	4862	972.4	**1.55**
90°				940	978	970	970	968	4826	965.2	17.67
180°				954	950	960	948	980	4792	958.4	13.92
270°				926	956	968	946	962	4758	951.6	22.77
0°	83	73	1.25d	600	598	594	612	607	3011	602.2	**6.93**
90°				614	580	614	618	590	3016	603.2	38.62
180°				600	612	617	602	622	3053	610.6	11.77
270°				590	610	578	594	607	2979	595.8	22.85
0°	83	73	1d	538	536	552	540	544	2710	542	**5.90**
90°				556	518	536	538	536	2684	536.8	27.00
180°				532	542	530	542	548	2694	538.8	8.49
270°				542	540	550	538	532	2702	540.4	6.34
0°	83	73	0.75d	410	404	402	420	402	2038	407.6	**11.54**
90°				392	412	412	412	386	2014	402.8	32.41
180°				402	412	396	422	396	2028	405.6	25.01
270°				398	392	404	402	414	2010	402	13.13
0°	59	49	1.25d	196	194	206	202	198	996	199.2	**9.32**
90°				196	198	194	198	208	994	198.8	11.75
180°				194	192	188	202	208	984	196.8	26.50
270°				198	188	196	204	196	982	196.4	13.36
0°	59	49	1d	170	172	170	170	172	854	170.8	**0.56**
90°				180	170	178	172	176	876	175.2	7.85
180°				170	178	176	178	172	874	174.8	6.04
270°				178	170	174	184	172	878	175.6	14.03
0°	59	49	0.75d	142	136	144	140	142	704	140.8	**5.23**
90°				148	148	142	144	152	734	146.8	8.28
180°				140	144	138	146	138	706	141.2	7.48
270°				136	132	142	138	136	684	136.8	7.72

3 Results and discussion

To assess the quality of the formation of a portion of feed, a coefficient of variation was adopted, which allows characterizing the dosing error with the lowest coefficient of variation, the greatest accuracy of feed coding will be observed.

In Table 2, the following symbols are adopted: D_k - diameter of the cylindrical housing, mm; d_s – spiral diameter, mm; S – pitch of the spiral in fractions of units of diameter; m_i – feed weight issued in experiment i, g; Σm_i – sum of feed masses for 5 experiments, g; m_{av} – average value of the mass of the feed issued, g; v – coefficient of variation, %.

Analysing the data obtained during the experiment, it can be noted that the lowest coefficient of variation is obtained when the last turn of the spiral stops at a position of 0°, that is, when the turn stops at the edge of the discharge neck in its lower part (Fig. 5). This phenomenon is observed on all studied standard sizes of spirals.

Fig. 5. Spiral stopped at 0°

Coefficients of variation at D_k = 83 mm, d_{sp} = 73 mm and S = 0.75...1.25d ranged from 1.55% to 59.87% and the lowest values of the coefficient of variation were 1.55%, 3.51%, 17.50% with the corresponding spiral steps obtained at 0°.

Coefficients of variation at D_k = 109 mm, d_{sp} = 97 mm and S = 0.75... 1.25d ranged from 5.90% to 38.62% and the lowest values of the coefficient of variation were 11.54%, 5.90%, 6.93% with the corresponding spiral steps also obtained at 0°

Coefficients of variation at D_{k} = 59 mm, d_{sp} = 49 mm and S = 0.75...1.25d ranged from 0.56% to 26.50% and the lowest values of the coefficient of variation were 5.23%, 0.56%, 9.32% at the corresponding spiral steps obtained similarly at 0°.

4 Conclusion

Thus, the previously put forward assumption was confirmed and the last turn of the spiral is able to perform the function of a cut-off and provide a more accurately formed portion of the feed by stopping at the bottom of the casing and counteracting the uncontrolled angle of collapse of the feed. And the results obtained are recommended to be taken into account when designing a spiral-screw dispenser and when using it in practice.

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