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DETERMINATION OF THE LAYER CORNSTRAW PARTICLES HYDRAULIC RESISTANCE

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A b s t r a c t. With the purpose of controlling the process of wet cornstraw bales storage, physical and fluidic properities of corn straw have been measured. This paper brings an analysis of the results obtained, aiming at a general mathematical expression of particles resistance dependence on several variables expressing the properties of corn straw.

For the purpose of cornstraw analysis NSKK-606, the most fertile hybrid corn from Novi Sad, was chosen. Samples were selected regarding moisture content compared to the wet base, so as to be near characteristically values: 80, 60, 40 and 20 %, v/v. The cornstraw was chopped to the theoretical particles length of 40 mm, with the 'Lifam' stationary cutter with two L shapped rotating blades. The air flow resistance of particles through the compressed and ancompressed cornstraw were measured with the experimental test set up.

On the basis of regressional analysis of the experimental results concerning physical and fluidic properties of chopped, wet, compressed and uncompressed cornstraw a simplified analytical expression has been established for calculation of aerodynamic material particles at air flow through the cornstraw layer (Eq. (10)).

By means of regressional analysis the values of particle resistance coefficient K of the exponent a over air flow velocity in the layer v, of the exponent b over the layer density ρ and of the exponent c over moisture content w, have been obtained for chopped cornstraw samples.

K e y w o r d s: cornstraw, layer, air flow, resistance

INTRODUCTION

These research are about determination of physical and fluidic properties of cornstraw [1]: structure of chopped particles, layer density, aerodynamic resistance of particles at air flow through the layer of wet, chopped, uncompressed and compressed cornstraw. This work brings the analysis of the results obtained, aiming at a general mathematical expression of particles resistance dependence on several variables expressing the physical properties of cornstraw.

Analysis of the experimental results of aerodynamic resistance of particles at the air flow through the layer of wet, plant material, by a few authors, was published by Turek (after Maltry [4]). On the basis of the analysis he found (in 1969) analytical dependence of material resistance of the air flow through the bales of the grass and alfalfa and dependence on physical properties of material:

$$\Delta p = K h w^{a} \rho^{b} v^{c} \qquad (1)$$

where K=32.9±7.3; a=0.00-0.11; b=0.28-1.04; c=1.36-1.55.

Resistance Δp for fibrous material (hay, straw) could be calculated according to empiric Ljubarski expression [3]:

$$\Delta p = K h \rho^{a} v^{b} \qquad (2)$$

where $K=9.2\cdot10^{-2}$ - parallel air flow, a=1.2-straw; $K=5.4\cdot10^{-2}$ - crossed air flow, b=1.54 - hay with lot leaves; a=2.74 - hay with lot leaves, b=1.60 - hay with few leaves, a=2.40 - hay with few leaves, b=1.60 - straw.

List of symbols used:

a,b,c(-) - exponent in expressions, h(m) -

heigh of the layer, K(-) - layer resistance coefficient, l(mm) - length of particles, Δp (Pa) - layer material resistance, $\Delta p/h$ (Pa/m)- layer specific resistance, R (-) - coefficient of correlation, v (m/s) - air flow velocity in layer, w (-) - relative moisture content in material, ρ_m (kg/m^3) - layer density of the material.

MATERIAL AND METHOD

For the purpose of cornstraw analysis, NSSK - 606, the most fertile hybrid corn from Novi Sad was chosen. Samples were selected regarding moisture content compared to the wet-base, so as to be near four characteristic values: 80, 60, 40 and 20 %, v/v. Reserch has been done in the laboratory of the Institute for Mechanization of the Faculty of Technical Science in Novi Sad [1]. The cornstraw was chopped to the theoretical length of 40 mm with the 'Lifam' stationary cutter with two L shaped rotating blades. Rotation speed was 1 450 °/min. Layer density was measured in cylindric chamber, diameter 410 mm and 1 m height without shaking of material. Whole mass of the samples was weighed on the technic weigher 'Biserba' ±1 g precision variation. Layer porosity of uncompressed corn straw was measured with an air pycnometer by Havelka method [1]. Compression of cornstraw has been done with load carrier and weights. Next pressure values were perfomed; 0, 2, 10 and 15 kPa, in purpose of achieving different values of layer density. Air flow particles resistance through the uncompressed and compressed cornstraw layer has been measured on experimental set constructad particularly in this purpose. Statistical data processing has been done on computer with 'Microstat' programme.

RESULTS AND DISCUSSION

Basic parametr values of chosen samples are shown in Table 1. On the basis of these figures it is obvious that increasing of moisture content caused decrease of the particles leant. For all samples shown in Table 1, aerodynamic resistance was determined in dependence on the velocity of air flow through the layer [1]. According to literature and graphs analysis of the physical expression has been established for calculation of aerodynamic material particles resistance at air flow through the cornstraw layer (Eq.(2)):

$$\Delta p/h = K v^{a} \rho^{b} \tag{3}$$

The values of coefficient and exponent in Eq. (3) were obtained through statistical data processing by 'Power curve fit' computer programme. Table 2 shows values of the coefficient K and exponent a and b for corn stalk chopped with stationary cutter, for three different air flow velocity and layer density of chopped cornstraw. By using computer programme 'Microstat' analytical expression for next samples were obtained.

Sample I:

$$\Delta p/h = 9.10 \cdot 10^{-2} v^{1.623} \rho^{2.545} \tag{4}$$

where $R = 0.978$.

Sample II:

$$\Delta p/h = 1.02 \cdot 10^{-2} v^{1.976} \rho^{2.569} \tag{5}$$

where $R = 0.997$.

Sample III:

$$\Delta p/h = 5.49 \cdot 10^{-3} v^{1.710} \rho^{2.517} \tag{6}$$

where $R = 0.993$.

Sample IV:

$$\Delta p/h = 2.44 \cdot 10^{-4} v^{1.252} \rho^{2.838} \tag{7}$$

where $R = 0.931$.

Comparing coefficient values and exponents from Eqs (4)-(7) with adequate data for samples from Table 1 we can make conclusion that the coefficient value K decreases with moisture content increase and with particle lenght decrease. Value of exponent a decreases too, as for exponent b value is mainly constant (b=2.5). There is a fact that sample I has the lowest level of bulk density 24.3 kg/m^3 and sample IV the highest 228.9 kg/m^3.

If the values of coefficient and exponents from Eqs (4)-(7) are compared with the values of coefficient and exponents for adequate samples shown in Table 2 it is clear that the coefficient value *K* is approximately suitable just for the first sample, while the *K* values for other samples are significantly higher than figures shown in Table 2, according to adequate values given in analytical expression. The same is with exponent value *b*. In Table 2 they are mainly decreasing with layer density increase but in analytical value of coefficient *b* is mainly constant, about 2.5.

Besides, it is to be pointed out that coefficient correlation values of figures shown in Table 2 and in Eqs (4)-(7) are very high. It means that results given in Table 2 and Eqs (4)-(7) could be used in practice. The differences of the coefficient and exponent values are apparent, because they refer to different conditions of data processing in research. Data given in Table 2 consider on single (separate) graph of air flow layer resistance [1] in dependence on the layer density and analytical expressions involve the change

Table 1. Basic parameter values of the chosen samples

No.	Sample	Moisture content (%)	Average length of particles (mm)	Mass ratio of stalk/leaf (%)
1	I	19.6	66.5	61.2
2	II	39.1	49.2	62.8
3	III	62.5	41.0	66.5
4	IV	79.4	25.8	68.7

Table 2. Coefficient values K and exponents a and b for chopped cornstraw with a stationary cutter [2]

Sample	No.	Layer density (kg/m^3)	K for air flow velocity (m/s)			Exponent b
			0.5	1.0	1.5	
	1	24.3	$2.94\cdot10^{-2}$	4.94·10-2	$15.15\cdot10^{-2}$	1.97
	2	42.6	$2.59\cdot10^{-2}$	$4.55\cdot10^{-2}$	$14.18\cdot19^{-2}$	1.75
I	3	60.3	$2.21\cdot10^{-2}$	$4.38\cdot10^{-2}$	$13.31\cdot10^{-2}$	1.56
	4	72.0	$1.96\cdot10^{-2}$	$4.12\cdot10^{-2}$	$12.65\cdot10^{-2}$	1.34
	5	79.3	$1.72\cdot10^{-2}$	$4.01\cdot10^{-2}$	$12.31\cdot10^{-2}$	1.24
	Exp.	a	2.88	2.71	2.44	-
	1	54.0	4.57·10-4	$6.83\cdot10^{-4}$	$9.98\cdot10^{-3}$	2.01
	2	98.1	4.21·10-4	$6.20\cdot10^{-4}$	$9.61\cdot10^{-3}$	1.92
II	3	130.1	3.94·10-4	$5.79\cdot10^{-4}$	$9.35\cdot10^{-3}$	1.86
	4	160.6	3.81·10-4	$5.38\cdot10^{-4}$	$9.20\cdot10^{-3}$	1.81
	5	179.9	3.59·10-4	$5.17\cdot10^{-4}$	$9.02\cdot10^{-3}$	1.76
	Exp.	a	2.56	2.47	2.44	-
	1	114.7	$3.96\cdot10^{-5}$	$7.78\cdot10^{-5}$	$10.81\cdot10^{-5}$	1.62
	2	163.1	$3.52\cdot10^{-5}$	$7.59\cdot10^{-5}$	$10.02\cdot10^{-5}$	1.61
III	3	202.9	$3.12\cdot10^{-5}$	$7.32\cdot10^{-5}$	$9.83\cdot10^{-5}$	1.77
	4	239.0	$3.01\cdot10^{-5}$	$6.01\cdot10^{-5}$	$9.28\cdot10^{-5}$	1.90
	5	269.2	$2.85\cdot10^{-5}$	$6.85\cdot10^{-5}$	$9.19\cdot10^{-5}$	1.73
	Exp.	a	3.14	3.03	2.99	-
	1	228.9	$3.61\cdot10^{-6}$	$10.04\cdot10^{-6}$	$12.41\cdot10^{-6}$	1.85
	2	280.2	$3.12\cdot10^{-6}$	$9.02\cdot10^{-6}$	$11.82\cdot10^{-6}$	1.46
IV	3	338.0	$2.63\cdot10^{-6}$	$7.91\cdot10^{-6}$	$11.28\cdot10^{-6}$	1.16
	4	385.9	$2.16\cdot10^{-6}$	$7.03\cdot10^{-6}$	$10.35\cdot10^{-6}$	1.08
	5	-	-	-	-	-
	Exp.	a	3.50	3.43	3.41	-

of the layer density for the concrete sample. It is to be mentioned that in both cases figures are valuable for certain moisture content and particle length of chopped cornstraw.

In order to determine value of influence of moisture in sample and influence of particle length in analysis, data for all samples from I to IV have been applied according to Eq. (1):

Samples I to IV:

$$\Delta p/h = 4.922 \cdot 10^{-2}\, v^{1.071}\, \rho^{2.439}\, w^{-2.801} \quad (8)$$

where R =0.874.

According to particle length of sample is:

$$\Delta p/h = 6.2 \cdot 10^{-8}\, v^{1.046}\, \rho^{2.148}\, l^{3.649} \quad (9)$$

where R = 0.829.

From Eqs (8) and (9) significant deviation of data are noticeable (13 to 17 %), so this difference could not be taken in consideration.

In the purpose of achieving more precise results, samples with average length of 50 mm has been taken into account.

Samples II to IV:

$$\Delta p/h = 7.41 \cdot 10^{2}\, v^{1.780}\, \rho^{2.605}\, w^{-3.080} \quad (10)$$

where R = 0.986.

According to particle length of samples is:

$$\Delta p/h = 7.58 \cdot 10^{-7}\, v^{1.740}\, \rho^{2.341} l^{2.677} \quad (11)$$

where R = 0.722.

From coefficient correlation value it can be seen that Eq. (11) is useless, because deviation of the data is 28 % (high dissipation of data).

The similar situation is with all variables in samples I to IV:

$$\Delta p/h = 4.945 \cdot 10\, v^{1.075}\, \rho^{2.445} w^{-} 2.571\, l^{0.374} \quad (12)$$

where R=0.874.

On the basis of afore mentioned expression it can concluded that general Eq. (10) is useful, because it refers to approximately same particle length of samples (50 mm). From this expression it can be seen that increase of moisture content in the sample has inverse proportionaly influence on the layer particle resistance because exponent is negative.

CONCLUSIONS

On the basis of regressional analysis of the experimental results of the physical and fluidic properties of wet, chopped, uncompressed and compressed corn straw by using 'Microstat' computer programme, a simplified analytical expression has been established for calculation of aerodynamic material particle resistance at air flow through the cornstraw layer (Eq. (10)).

By maens of regression analysis the values of particle resistance coefficient K=7.41·10^2, air flow velocity exponent in layer a=1.78, layer density exponent b=2.605, moisture content exponent c=3.080, has been obtained. These values refer to the samples chopped on stationary cutter, average length 50 mm. Further research work should be directed towards the determination of influence of the particle length on the corn straw layer resistance.

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REFERENCES

1. **Brkić M.:** Determining legitimacy changes of resistance to air flow through the layer of cornstraw (in dependence of preparation of the material for storage). Ph.D. Thesis, Faculty of Agricultural Science, Zagreb, 1986.
2. **Brkić M., Tesić M.:** Modulation of the experimental results of cornstraw particles aerodynamic resistance. Proc. 4-th ICPPAM. Rostock, Germany, 94-98, 1989.
3. **Ljubarskij M., Pjatrusjavicjos F., Kucinskas I., Parazinskas P.:** Aktivnoe ventilirovanie sielskohozjajstvenijih produktov. Kolos, Moskva, 1972.
4. **Maltry W., Potke E., Schneider B.:** Landwirtschaftichle Trocknungstechnik. VEB Verlag Technik, Berlin, 1975.