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EFFECT OF GRAIN DUST ON THE FRICTION FACTOR IN SLIDING KINEMATIC PAIRS OF PLASTIC - STEEL

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Abstract. The studies on the polymer-metal friction nodes operating in the presence of corn dust have been presented.

The results of studies prove the feasibility of plastic application in designing machines for corn and feed processing.

Keywords: grain dust, sliding factor, kinematic pairs

INTRODUCTION

Lately steel-plastic associations in sliding kinematic pairs have been used more often in food machines. Kinematic pairs perform rotation, swinging motion or sliding-reversible motion usually without lubrication, i.e., in conditions of technically dry friction.

In the last years machine and installation parts made of metal have been replaced by parts made of plastic because of simple adaptive methods, shape repeatability, lack of corrosion etc.

A particularly important reason for using plastic in food industry is that most of it is allowed in contact with food products.

FRICTION MECHANISM

Theoretical models of friction process known and used in scientific studies do not describe effects occurring when kinematic pairs of polymer-metal work in dust sufficiently. The friction model which describes these effects in the best way is called "mixed friction" (Fig. 1).

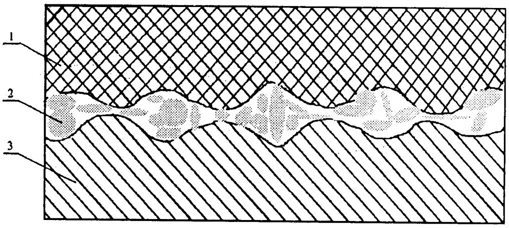

Fig. 1. Mixed friction mechanism: 1 - plastic, 2 - dust, 3 - steel.

Most studies on these effects [1-5] have shown that friction coefficient always increases in the presence of dust.

Specific features of dust originating from grain product processing affects correlation between friction coefficient and the load of kinematic pairs as well as the speed of displacement.

WORK ENVIRONMENT OF KINEMATIC PAIRS

Description of the testing device

Measurement of the friction coefficient was conducted on the testing stand constructed on the basis of Froude's pendulum principle. Its scheme is shown in Fig.2.

The steel control-sample is presented in Fig. 3 and the plastic sample in Fig. 4, respectively.

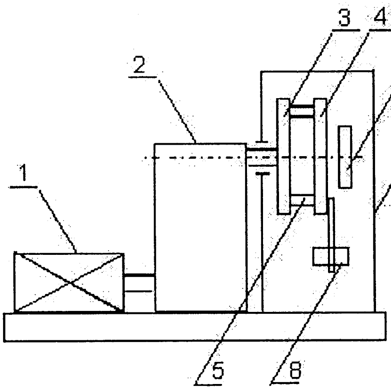

Fig. 2. Testing device: 1-engine, 2-gear, 3-movable disk with contra-sample, 4-immovable disk with samples, 5-samples, 6-converter, 7-tight casing (dusty space), 8-sample load.

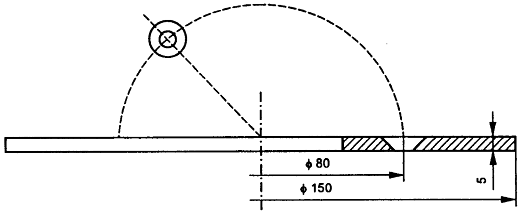

Fig. 3. Dimensions of the control-sample.

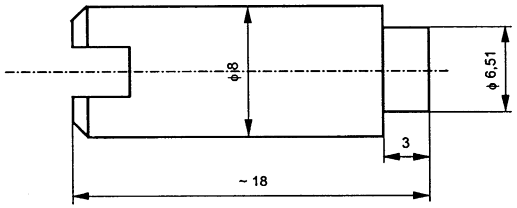

Fig. 4. Shape and dimensions of the sample (3 pieces for measurement).

Characteristics of the testing device

1. Rotational speed of the control-sample: 29.91 - 439.37 rpm.
2. Unit pressure on the samples: 1.962 - 5.885 MPa.
3. Loading system: lever - mass.
4. Characteristics of the load: constant during measurement.
5. Measuring system for the determination of the moment of friction rotational-impulse converter coupled with computer.
6. Cooling: natural heat exchange between rubbing surfaces and environment.
7. Friction medium: dry or dusted with feed grain products.

Method of friction coefficient determination

After determining the measuring parameters of assembling the head with the samples and installing the thight casing with dust, a control-sample drive was put in motion. Dust was in continous circulation under the action of the head. Measurement of pendulum deflection and its recording were performed automatically. One test lasted for 300 s. The range of the obtained speeds rubbing is presented in Table 1 and the load values obtained in Table 2, respectively.

In order to determine the value of friction coefficient, equilibrium of moments was applied i.e., torque caused by weight and the moment of friction caused by pressure on the samples. The diagram presenting equilibrium of moments is shown in Fig. 5.

Basing on this diagram, we can write:

$$M_T = 3\frac{N}{3}\mu r \tag{1}$$

$$M_o = Q R \sin\alpha \tag{2}$$

when

$$M_o = M_T$$

then

$$N \mu r = Q R \sin\alpha$$

and the calculated friction coefficient is described by the relation:

$$\mu = \frac{QR}{Nr}\sin\alpha. \qquad (3)$$

For the testing stand, the values of r, Q, and R are constant and equal to:

$$Q = 29.43 \text{ N},\ R = 400 \text{ mm},\ r = 60 \text{ mm}$$

which allows us to write:

$$\mu = \frac{192.2}{N}\sin\alpha = C\sin\alpha. \qquad (4)$$

Table 1. The rubbing speeds of the control-sample in respect to the number of revolutions

No.	n (rpm)	v ($\mathrm{m\ s^{-1}}$)
1	29.91311	0.1879494
2	49.42166	0.3105251
3	77.93416	0.4896743
4	111.19873	0.6986616
5	134.60899	0.8457725
6	172.97581	1.0868381
7	209.39177	1.3156461
8	222.39747	1.3973633
9	236.21097	1.484156
10	265.37282	1.6673851

Table 2. Value of surface pressure (MPa)

N_1	1.962
N_2	2.946
N_3	3.924
N_4	4.905
N_5	5.885

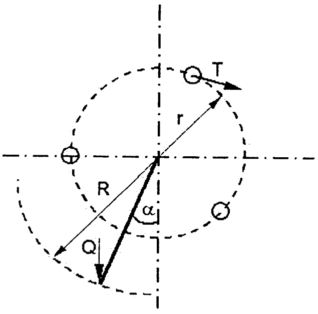

Fig. 5. Diagram of torque and moment of friction equilibrium.

The calculated C constant values are within the range from 1.00 to 0.33 for the loads from 196.2 to 588.6 N.

The measuring accuracy for the friction coefficient value depends on the measuring accuracy of the pendulum deflection angle. This measurement was conducted with a rotational -mass converter CPPB-12 characterised by the accuracy of measurement equal to rad.

As a typical environment dust condition and composition of a grain mill was assumed. The results of measurements of dustiness and distribution of grain composition in dust are shown in Tables 3 and 4.

For the investigation of friction coefficient in the kinematic pair plastic-metal, dust taken near self-acting scales and from under accepting baskets was used.

Grain composition of dust was described using a laser apparatus Analysette 22 of Fritsch. Investigations were carried out in the Department of Apparati for Chemical and Food Industry at the Faculty of Technology and Chemical Engineering of the University of Technology and Agriculture in Bydgoszcz.

Table 3. Dust contents in air

Place of measurement	Dust concentration ($\mathrm{mg\ m^{-3}}$)
Heads of scoop elevators	85
Self-acting/automatic scales	245
Chute tubes for chambers	99
Chute car of belt conveyors above chamber	328
Engine room of store-room	324
Under chambers	135
Under accepting baskets	220
At outlet of chute tube	1755

Table 4. Particle size of investigated dust

Particle size (μm)	Part of fraction (%)
till 5	5
5 - 10	10
10 - 20	50
20 - 40	20
40 - 60	10
above 60	5

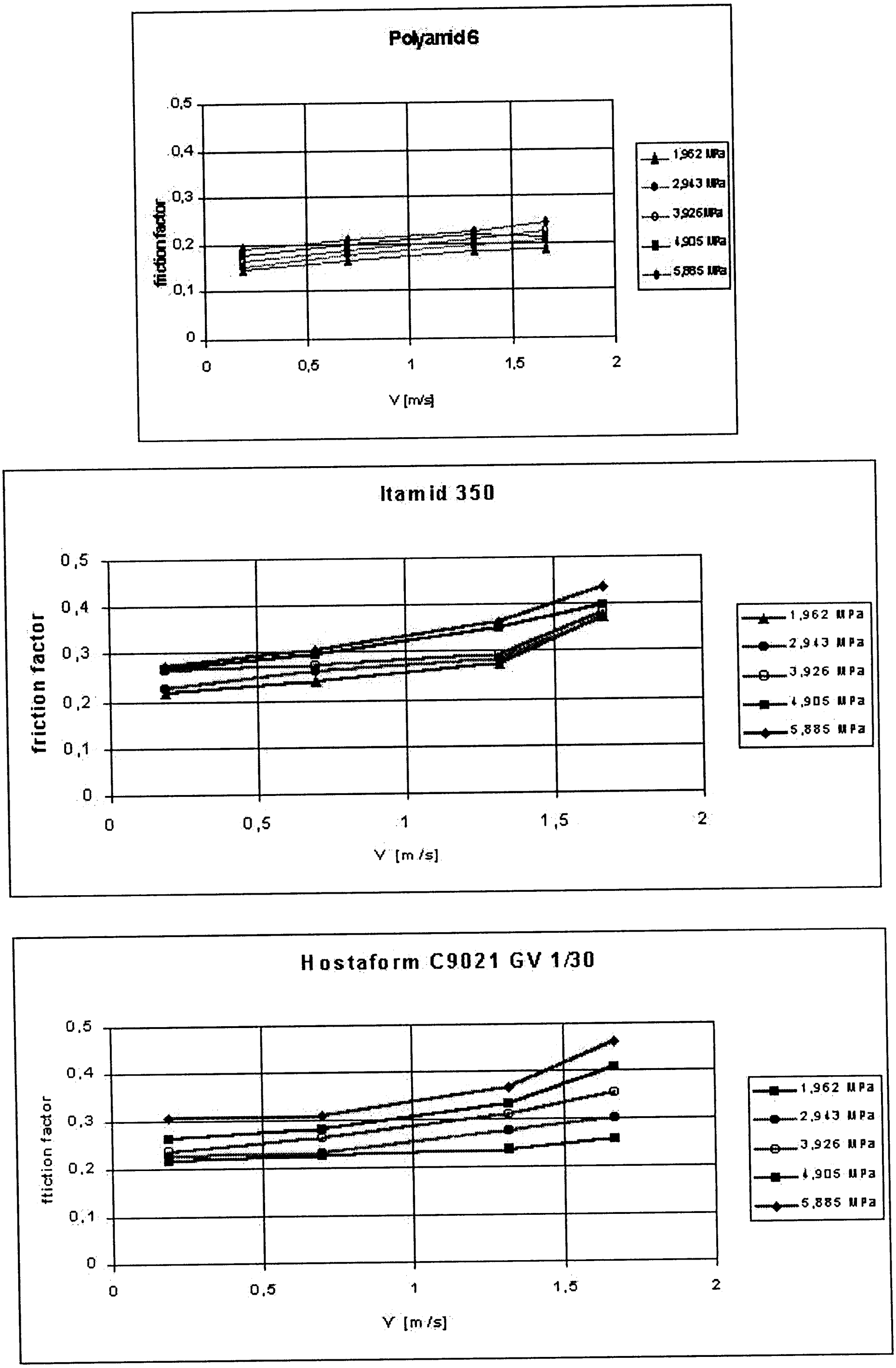

Fig. 6. Friction coefficients in the steel-polymer kinematic pairs: steel with polyamid (Polyamid 6), glass fibre reinforced polyamid (Itamid 350) and reinforced polyacetal (Hostaform C 9021GV 1/30) in the conditions of dry friction.

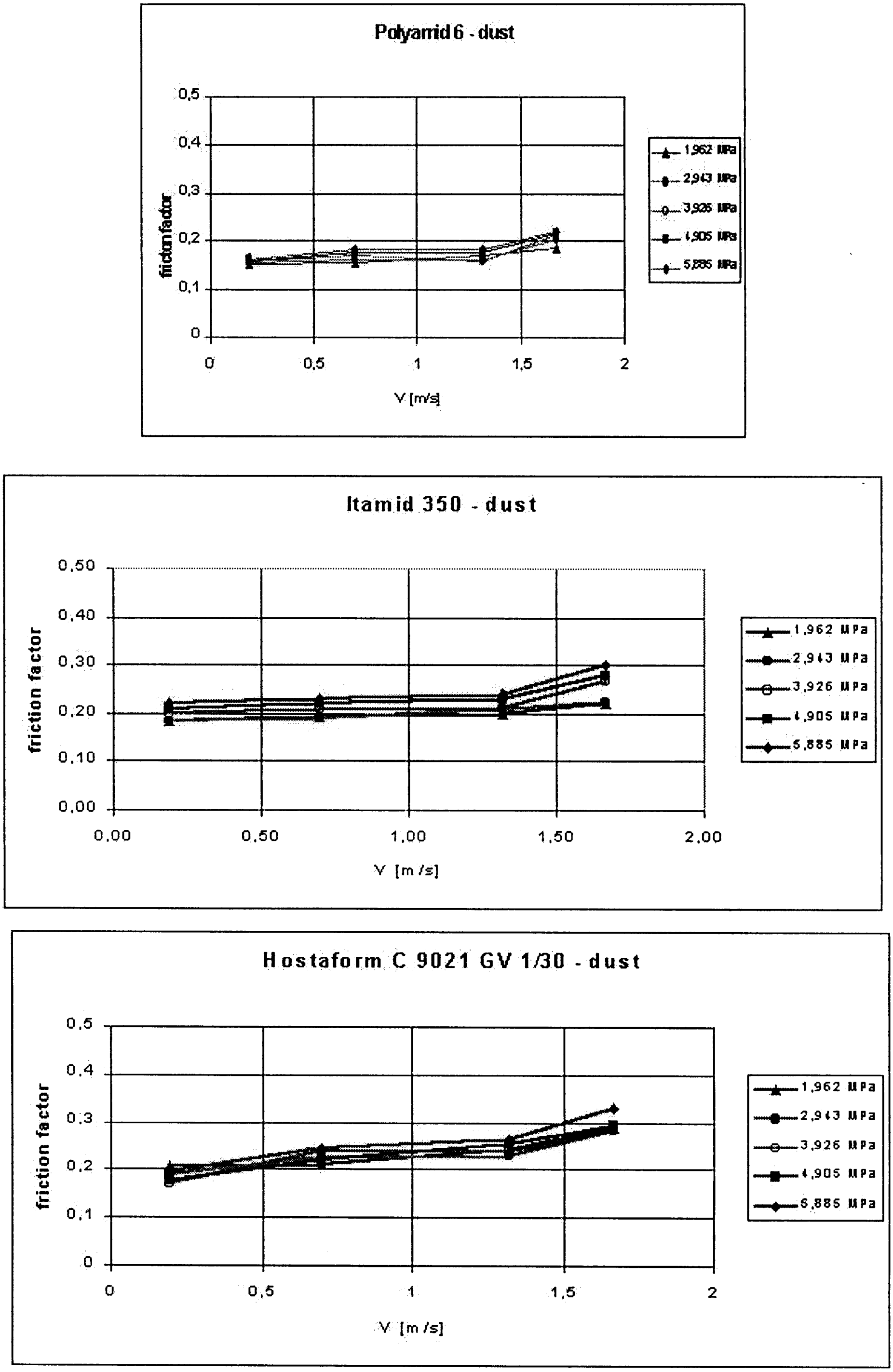

Fig. 7. Friction coefficients in the steel-polymer kinematic pairs: steel with polyamid (Polyamid 6), glass fibre reinforced polyamid (Itamid 350) and reinforced polyacetal (Hostaform C 9021GV 1/30) in the conditions of grain product dusting.

CHOICE OF CONSTRUCTIONAL PLASTIC

Steel 45 and constructional plastic were investigated. Their characteristics are shown in Table 5.

Table 5. Investigated plastics

Type of plastic	Density (kg m^{-3})	Reinforcement contents (%)	Tensile strength (N mm^{-2})	Bending strength (N mm^{-2})	Modul of elasticity (N mm^{-2})	Impact resistance (MJ m^{-2})
Poliamid 6	1120	-	110	150	5500	0.025
Itamid 350	1410	35	165	220	8000	0.040
Hostaform C 9021GV 1/30	1560	30	130	285	10500	0.060

Pure and reinforced polyamides and polyacetales are presently most often associated with steel in the sliding kinematic pairs of friction of the machines applied in grain - feed industry.

PROGRAMME OF INVESTIGATIONS, TEST STAND, SAMPLES

Investigations were carried out on the test stand [6] which allowed to perform tests on:

- friction speed $0.188 \div 2.761$ m s^{-1},
- average pressure $1.960 \div 5.880$ MPa,
- test time max. 300 s.

For every pair of load and speed values three repetitions were made. Within the investigated range five loads and five speed levels were performed.

The measurement of the friction coefficient was recorded continuously by the measuring set consisting of an analog - to digital converter and a self - registering recorder.

Within the investigated range there are replacement speeds and loads of the friction between kinematic pairs often used in the machines and equipment for grain processing.

RESULTS

The study results on the friction coefficient in the steel - polymer kinematic pairs, i.e., association of steel with polyamid, glass fibre reinforced polyamid (Itamid 350) and reinforced polyacetal (Hostaform C 9021GV 1/30) in the conditions of dry friction are shown in Fig. 6, and similar results obtained in the conditions of grain product dusting are shown in Fig. 7.

CONCLUSIONS

On the basis of the present experiments carried out on the friction coefficient in dusty conditions generated by grain dust, we can formulate the following conclusions:

1. Dusting by grain-feed products of kinematic pairs steel: 45-polymer lowers the friction coefficient within the range of the investigated pressures and speeds.
2. Variation course of the friction coefficient in conditions of grain-feed dusting is more flat than in the "dry" conditions; it is especially visible for polyamides.
3. Grain dust in the kinematic pairs: steel -polymer behaves like a lubricant, which can suggest higher durability of these associations.

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