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ON FRICTION PROPERTIES OF WHEAT GRAIN

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S y n o p s i s. In the study the authors compared two methods for determination of the internal coefficient of a grainy medium: that of the direct shearing and the triaxial compression, obtaining identical values of the parameter studied Moreover, the authors tried to determine whether the spatial orientation of grains distinguished affects the friction of grain against a smooth glass plate. The study shows that such an effect results from grains immobilization, while spatial orientation brings no further change in the friction properties.

INTRODUCTION

For many years the friction properties of granular materials have been studied by numerous authors. Despite this fact so far no general theory of such media has been formulated that would cover all the relationships observed experimentally. The reason for this is the extraordinary complexity of effects taking place in such a medium, as well as the dependence of the characteristics determined on numerous factors, not always under control in the experiments. Consequently, the mechanical parameters, frequently measured under highly similar conditions, differ considerably from one experiment to another [3, 5], and therefore there still exists a demand for simple, but credible parameters that would grasp the essence of the process of friction [2].

The topic of the study presented herein was to compare two methods for determination of the internal friction coefficient of granular medium: the method of direct shearing, and the triaxial compression. Moreover, the authors tried to establish whether the effect of spatial orientation of grains on the internal friction coefficient, experimentally observed [4], will also appear in the case of external friction of grain against a smooth glass surface.

MATERIAL AND METHODS

The measurements were carried out on the grain of MV-4 (Martonvasar) wheat variety, of a moisture content of 10%. The friction properties of the grain were determined using a modified apparatus for direct shearing, 200 mm by 200 mm (Fig. 1), designed and built at the Department of Mechanics, Agricultural University, Gödöllő, and a modified triaxial compression apparatus, for samples 150 mm in diameter and 300 mm high, designed and built at the Institute of Agrophysics, Polish Academy of Sciences, Lublin.

FRICTION OF WHEAT ON A GLASS PLATE

The friction of wheat grain on a glass plate was determined by means of the direct shearing apparatus (Fig. 1). Glass was chosen as a reference material due to its low chemical activity, as this permitted considerable stability of friction properties during the experiment. Three series of wheat grain friction tests on a glass plate were carried out, according to the diagram of the experiment as presented in Fig. 1.

In the first series (Fig. 1 - Test A) the grain was loosely poured into the measurement box, the cover was put in place, the grain was loaded with normal force F_3, and then the glass plate was pulled out at the rate of 0.75 mm/s.

During the glass plate travel over a distance of 40 mm, friction force F_1 was measured every 5 mm of the plate shift. The experiment was repeated 3 times for each of 8 values of normal loading F_3 ranging from 500 N to 3500 N.

The second series of measurements (Fig. 1 - Test B) was carried out for grains glued at random onto a rigid flat surface. Wheat grains were placed at random on a plate, 200 by 200 mm, coated with epoxy putty. When the putty was dry and the grains fixed, the friction between the fixed grains and a glass plate was measured. The remaining conditions of the experiment were the same as in Test A.

The third series of mesurements (Fig. 1 - Test C) was carried out in a manner analogous to Test B, but here the grains were bonded to the plate so that the long axes of the grains were parallel to one another as exactly as it was only possible.

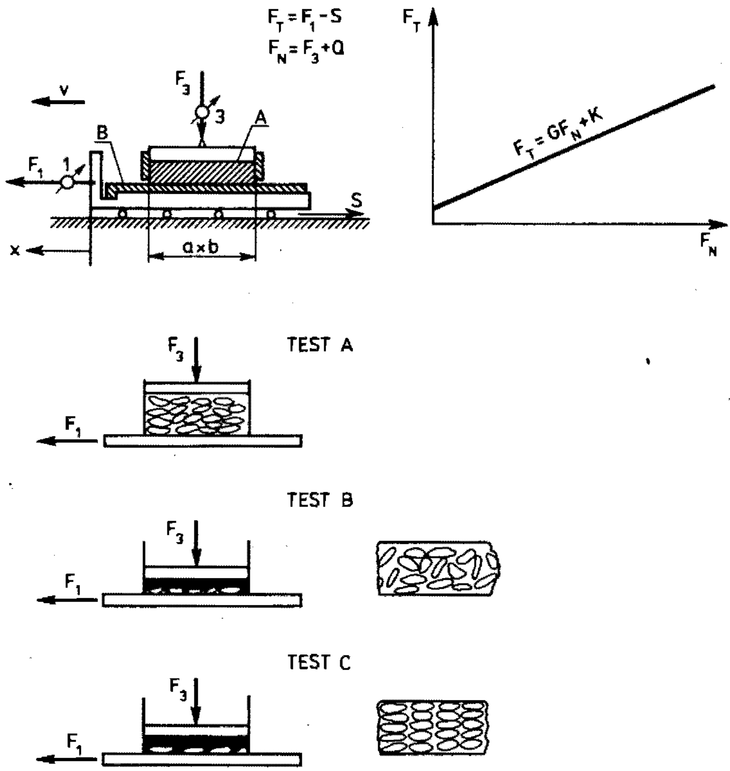

Fig. 1. Test of grain friction on a glass plate

The total value of normal force F_N was determined by adding the weight of the grain and equipment Q to the value of active force F_3: $F_N = F_3 + Q$, and the tangential force F_T was determined by detracting the inherent friction of equipment S, determined in additional test, from the force measured F_1: $F_T = F_1 - S$, according to the method elaborated earlier and discussed in detail in [1].

INTERNAL FRICTION

The internal friction of wheat grain was determined using two methods:

1. direct shearing test,
2. triaxial compression test.

The procedure of the direct shearing test was analogous to that used to determine grain friction on glass, the only difference being that the glass plate was replaced with the second element of the direct shearing apparatus (Fig. 2). The experiment was repeated 3 times for each of 8 values of normal force varying in the range from 700 N to 4400 N. Maximum displacement was 30 mm.

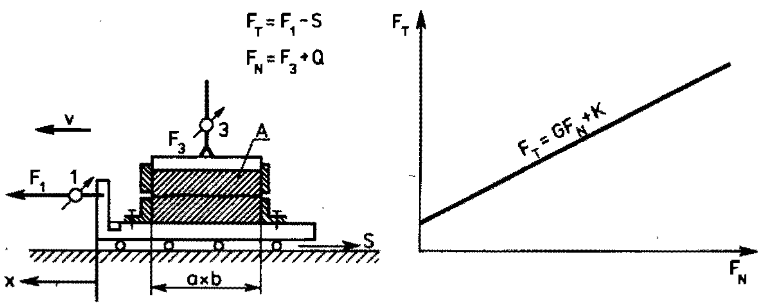

Fig. 2. Direct shearing test

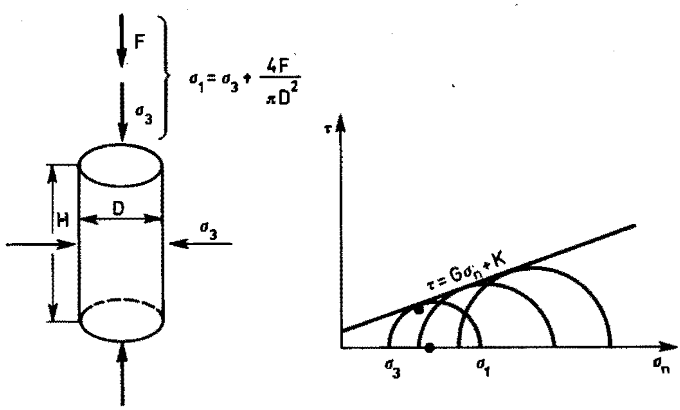

Fig. 3. Triaxial compression test

The procedure of sample preparation and of the triaxial compression test was the standard procedure for tests of this type, the only difference being that the source of hydrostatic pressure σ_3 was not the pressure of a liquid in a chamber surrounding the sample, but vacuum generated inside the sample by means of a vacuum pump [4]. Such a method allows for triaxial compression tests to be performed quickly on a dry granular medium, within a range of stress values σ_3 from 0.03 MPa to 0.09 MPa. The experiment was repeated 3 times for each of 7 values of stress σ_3 within the range specified, at equal grading every 0.01 MPa.

A source of an additional force F acting in the direction of the axis of symmetry of the sample, that generates, together with stress σ_3, the greater main stress σ_1, was the loading system of the Instron strength-testing apparatus that enforced a displacement at a rate of 50 mm per minute. Sample deformation was continued till the moment of its destruction, i.e. till the moment when force F, recorded as a function of displacement, began to decrease, which occured at displacement of the order of 60 to 85 mm.

RESULTS AND DISCUSSION

The relations between forces F_T and F_N, both in the test of friction on a glass plate and in the direct shearing test, were expressed in the form of a linear relationship:

$$F_T = GF_N + K$$

(G - direction coefficient of regression line, K(N) - "cohesion") on the basis of the method of the least squares. In the case of the triaxial compression test, the value of the internal friction coefficient G, and that of cohesion K [MPa], were determined on the basis of the maximum value of the main stress ratio $\sigma_1:\sigma_3$, according to the linear plasticity condition of Coulomb-Mohr

$$\tau = G\sigma_n + K$$

where: σ_n and τ - stress normal and stress tangent to the sliding plane, respectively.

The numerical values of coefficients G and K obtained, as well as the standard deviation and correlation coefficient R for the succesive tests are presented in Tables, 1, 2, 3, 4, and 5.

Table 1

Friction parameters of freely heaped grain - Test A

Displacement X [mm]	G	K [N]	Standard dev. ± [N]	Coeff. of correl R
5	0.0934	-1.61	2.70	0.997
10	0.0912	-1.90	2.61	0.998
15	0.0933	-11.55	2.82	0.997
20	0.0915	-6.88	2.99	0.997
25	0.0876	0.22	2.70	0.997
30	0.0875	3.60	2.90	0.997
35	0.0880	9.83	3.38	0.997
40	0.0937	1.57	3.49	0.997
Mean	0.0908	-0.84	2.95	0.997

In the test of grain friction on a smooth glass plate an evident increase was observed in the value of coefficient G in the case of grains glued onto a rigid

Table 2

Friction parameters of grain glued at random - Test B

Displacement X [mm]	G	K [N]	Standard dev. ± [N]	Coeff. of correl. R
5	0.0976	14.64	3.92	0.992
10	0.0997	13.68	4.06	0.992
15	0.1004	6.39	4.24	0.991
20	0.0996	9.35	4.27	0.991
25	0.0945	15.36	3.85	0.993
30	0.0969	13.87	3.74	0.993
35	0.0941	9.47	4.56	0.992
40	0.0987	12.86	6.57	0.978
Mean	0.0977	11.95	4.40	0.990

Table 3

Friction parameters of grain glued with the long axis of grain oriented in the direction of movement - Test C

Displacement X [mm]	G	K [N]	Standard dev. ± [N]	Coeff. of correl. R
5	0.1037	-3.69	3.83	0.994
10	0.1061	-5.82	3.97	0.994
15	0.1063	-12.06	3.83	0.994
20	0.1032	-4.35	4.20	0.992
25	0.1016	-0.23	3.88	0.993
30	0.1070	-3.65	3.90	0.994
35	0.1049	+1.06	4.83	0.994
40	0.1099	-5.06	4.77	0.993
Mean	0.1053	-4.22	4.15	0.994

Table 4

Internal friction parameters of wheat grain, obtained in the direct shearing test

Displacement X [mm]	G	K [N]	Standard dev. ± [N]	Coeff. of correl. R
5	0.4086	13.06	14.32	0.992
10	0.4966	-4.14	6.36	0.999
15	0.5161	-17.35	5.06	0.999
20	0.5158	-17.02	5.26	0.999
25	0.5115	-16.98	5.81	0.999
30	0.5063	-29.49	6.59	0.999
Mean	0.4925	-11.99	7.23	0.999

Table 5

Internal friction parameters of wheat grain, obtained in the triaxial compression test

G	K [MPa]	Coeff. of correl. R
0.4855 ± 0.0140	0.002 ± 0.002	0.997

plate (G ~ 0.1, Table 2 and 3), with respect to the experiment with grain loosely heaped (G = 0.0908, Table 1). The increase in the value of coefficient G was nearly identical for the grains glued onto the plate at random, and for the grains glued onto the plate in such a manner that the long axis of the grains was oriented in the direction of plate motion (Test C). On the basis of the results obtained it may be stated that the spatial orientation of grains did not have any effect on the value of the coefficient of friction on a glass plate obtained, while the fixation of the grains in itself, achieved through their gluing onto a rigid surface, increased the friction coefficient considerably. The fixation of grains made it impossible for them to assume a position optimum from the viewpoint of energy requirements under the conditions of the experiment, which was reflected in the increase of the value of coefficient G. Moreover, even the greatest care exercised during the glueing of the grains did not ensure identical depth of grains embedding in the glue. Therefore, it is to be expected that in the case of grains glued onto a rigid surface the number of friction contacts of the grains with the glass plate was smaller than in the case of loosely heaped grain. Hence, it should follow that the contact strain in the case of grains glued onto a plate should be considerably higher than that of grains loosely heaped.

On the other hand the authors did not observe any significant effect of the friction distance X on the values of the coefficients obtained. This effect would probably become manifested at many times greater friction distances, due to the change in the surface properties of grains in the state of friction [5].

What deserves particular emphasis is the fact of obtaining identical values of the internal friction coefficient in both the direct shearing test and the triaxial compression test. In the case of the direct shearing test the value of the internal friction coefficient stabilised already at a displacement level of approximately 15 mm. In the triaxial compression test, on the other hand, the maximum stress value σ_1 (on the basis of which the friction coefficient was calculated) stabilised at a deformation, with respect to sample ε_1, of the order of 0.20 to 0.28, and the lower the value of stress σ_3 was, the greater was the deformation ε_1 necessary to obtain the maximum σ_1. The identical values of the friction coefficients obtained indicate that in the direct shearing apparatus, i.e. at a very low level of displacement that the state of plasticity is enforced on the sample examined, the state of plasticity is being identical to that which occurs in the triaxial compression apparatus in a more natural manner, but at a considerably greater sample deformation.

CONCLUSIONS

1. The obtaining of identical values of internal friction coefficient in the triaxial compression test and the direct shearing test, as well as the high order of simplicity of making the direct shearing test, indicate the high applicability of the test for making rapid and convenient measurements of friction properties of granular media.

2. The fixation of grains by means of gluing them onto a rigid plate increases by approximately 10% the value of the friction coefficient obtained.

3. The enforced orientation of grains and friction way within the range of 5 : 40 mm have no significant effect on the value of the coefficient of friction on a smooth glass surface.

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O WŁASNOŚCIACH CIERNYCH ZIARNA PSZENICY

S t r e s z c z e n i e

W pracy porównano dwie metody wyznaczania współczynnika tarcia wewnętrznego ośrodka ziarnistego - bezpośredniego ścinania i trójosiowego ściskania, uzyskując identyczne wartości badanego parametru. Ponadto starano się ustalić, czy wyróżnio-

na orientacja przestrzenna ziaren ma wpływ na tarcie ziarna o gładką płytę szklaną. Przeprowadzone badania wykazały, że wpływ taki posiada samo unieruchomienie ziaren, zaś orientacja nie powoduje dodatkowej zmiany własności ciernych.

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О СВОЙСТВАХ ТРЕНИЯ ЗЕРНА ПШЕНИЦЫ

Р е з ю м е

В работе сравнены два метода определения коэффициента внутреннего трения зернистого центра и непосредственного среза и трехосного сжима, получив идентичные величины исследуемого параметра. Сверх того старались установить, влияет ли выделенная пространственная ориентация зерен на трение зерна на гладкой стеклянной пластинке. Проведенные исследования показали, что такое влияние показывает сама иммобилизация зерен, ориентация же не вызывает дополнительного изменения свойств трения.