*J. Agric. Sci. Technol. (2002) Vol. 4: 11-22*

# Effects of Normal Pressure, Sliding Velocity and Moisture Content of Chickpeas on Dynamic Friction Coefficient on Steel Surfaces

T. Tavakoli[1], A. M. Kermani[1] and J. Khazaei[2]

## ABSTRACT

**In this research, an apparatus was made and utilized to determine the friction coefficient of chickpea grains on steel surfaces. Experiments were carried out on two black and galvanized surfaces and at four sliding velocities of 5, 20, 100 and 500 mm/min, at three moisture content of 7.5%, 15% and 21% wet basis (w.b.) and at three vertical pressure values of 14.28, 100 and 150 kPa. The following results were obtained.**

**1) For surface conditioning, the steel plates need to be passed through the grains for at least 7 times. 2) At low sliding velocity, by increasing the velocity from 5 to 20 mm/min, the dynamic friction coefficient of chickpea grains increased, and at a sliding velocity of 500 mm/min it was decreased. 3) For the black steel surface, by increasing the moisture content of chickpea grains from 7.5% to 15% w.b., the value of the friction coefficient increased; but at a moisture content of 21% w.b., it decreased. For galvanized steel surfaces, and sliding velocities of 5 and 20 mm/min, increasing the moisture content, the value of friction coefficient was found to decreased, but for sliding velocities of 100 and 500 mm/min it's behaviour was similar to the black steel surface. 4) Normal pressure has no significant effect on the friction coefficient (at 0.01 level) and the difference between the mean values of the coefficient of friction associated with the normal pressure of 14.28 kPa and 100 kPa, as well as 100 kPa and 150 kPa was not significant at the 0.05 significance level.**

**Keywords:** Apparatus, Chickpea, Friction coefficient.

## INTRODUCTION

In Iran, the annual production of chickpea grains is 80000 tons and it has important role in the population's diet as a source of protein. Much research has already been conducted to mechanize the farm operations, such as the manufacture of chickpea combine machines and sorters.

Static and dynamic coefficients of friction of grains and other food materials on various surfaces are needed by design engineers for the rational design of these machines and handling equipment and storage facilities such as bins and silos (Mohsenin, 1986). Friction created during the moving and displacement of grain over surfaces can effect the performance and output of agricultural machines. Also the friction of grains against machine parts can cause machanical damage. Therefore, knowledge of the magnitude of the friction coefficent is important for the design engineers.

The specific objectives of this study were to:

- Devlop a method to measure the friction coefficient of chickpea grains on steel surfaces.
- Study the effects of normal pressure, moisture content and sliding velocity of sur-

[1]Department of Agricultural Machinery, College of Agriculture, University of Tarbiat Modares, Tehran, Islamic Republic of Iran.
[2] Department of Agricultural Machinery, College of Agriculture, University of Tehran, Karaj, Islamic Republic of Iran.

faces on the friction coefficient using the apparatus and methodology developed.

## Background

The laws of friction, first stated by Amontons and later verified by Coulomb are usually stated as follows: 1) frictional force is proportional to the normal load, 2) frictional force is independent of the area of contact surface, 3) frictional force depends upon the nature of the materials in contact. Recent investigations have shown that some of these time-honored concepts of friction can no longer be explained by Coulomb's law of coefficient of friction. Sherwood, summerized the more commonly accepted concepts of friction writing in 1951. Some of these are as follows: 1) the friction force is directly proportional to the actual contact area, 2) the friction force depends on the sliding velocity of the contacting surfaces, 3) the friction force may be regarded as being composed of two main components a force required to deform and sometimes shear the asperities of contacting surfaces, and a force required to overcome adhesion or cohesion between the surfaces (cited in Mohsenin, 1986).

Very limited published results on the friction coefficient of chickpea grains are available. This paper describes the coefficient of dynamic friction for chickpeas on steel surfaces.

Different methods are employed for the measurement of the friction force. In some of these methods, material is placed in contact with a positively driven surface which is either mounted on a revolving circular disk or on a horizontal table. The horizontal force of friction was measured either with a spring scale or a system of beams and linkage with strain gages or transducers as the force sensing element (Mohsenin, 1986). Many workers have observed an increase in coefficient of static and dynamic friction for various food grains with an increase in moisture content. For sorghum grains (Stewart *et al.*, 1969), barley, oats, shelled corn, soybean and wheat (Brubaker and Pos, 1965), beans and peanut (Chung and Verma, 1989), pigeon pea (Phirke *et al.*, 1996), soybean, red kidney beans and unshelled peanuts (Tsang-Mui-Chung *et al.,* 1984), sunflower grain and kernel (Gupta and Das, 1998) the effect of moisture content was found to be pronounced on the coefficients of static and dynamic friction. Thompson and Ross (1983) determined the coefficient of friction of wheat on steel surfaces and observed an increase with moisture content, but at higher moisture contents it decreased. Tsang-Mui-Chang *et al*. (1984) developed a friction device (later modified by Chung and Verma, 1989) to determine the coefficient of dynamic friction for soybean and corn. They observed that the velocity of the test surface had little effect on the coefficient of dynamic friction. Similar observations have also been reported by Snyder *et al*. (1967) and Gupta and Das (1998). Thompson and Ross (1983) observed that the coefficent of dynamic friction increased significantly by increasing the sliding velocity of the test surface and mentioned that as the sliding velocity was increased, the frictional energy also increases with the increased energy released in the form of heat. The change in surface temperature produces a change in the physical properties of the sliding material and as surface temperature increases a decrease in strength occurs resulting in a decrease in the friction forces which act between the two sliding surfaces. Phirke *et al.* (1996) reported that the dynamic coefficient of friction at higher speed was further decreased with an increase in speed. Buelow (1961) working with maize on steel surfaces reported a slight increase of the coefficient of friction with increase of normal load, but concluded that this is not statistically significant (cited in Lawton, 1980). To obtain reproducible results, several invetigators have found that the surface must be conditioned by making repeated passes before recording friction data (Mohsenin, 1986). Thompson and Ross (1983) reported that pulls were used at least five times for the surface conditioning.

## MATERIALS AND METHODS

For this study, the *Gam* varitey of chickpea grains were provided from Maragheh Dry Farming Researh Site. The grains had a mass of one thousand grains of 352g, sphericity percent of 86% and the initial moisture content was found to be 7.5% w.b.

This work was conducted in two stages. In the first stage, effects of moisture content (at 7.5, 15 and 21% w.b.) and normal pressure (at 14.28, 100 and 150 kPa) on the dynamic friction coefficient with two types of surfaces (black and galvanized steel) was studied. In these tests, the sliding velocity was uniform at 100 mm/min (constant sliding velocity). In the second stage, effects of moisture content (7.5, 15 and 21%, w.b.) and sliding velocity (5, 20, 100 and 500 mm/min) on the dynamic friction coefficient of chickpeas on the same types of steel surfaces were studied. All the tests were conducted at 150 kPa normal pressure (constant pressure). The original sample which had about 7.5% w.b., moisture content, was wetted to the desired value and allowed to equilibrate in a sealed polythene bag before use. A factorial experiment based on complete randomized block design was conducted and results were analyzed and compared using analysis of variance (F-test) and Duncan's multiple range test at each stage. Three replications were used for each treatment. The statistical analysis software MSTAT-C was used to analyzed the data. The apparatus shown schematically in Figure 1 was constructed and utilized to conduct the friction tests (Kermani, 1999). The samples were placed in the flexible cylinder (rubber diaphragm) in contact with the metal plate (test surface) and pressured air was entered in the closed space exert a known normal pressure on the grain mass. The metal plate was attached to a universal test machine (Instron, 1186) which was used to measure the required force to pull it through the grain mass.The metal plate used in all the tests was 3 cm wide, 60 cm long and 0.2 cm thick. The forces exerted on the plate by grain acted over a lengh of approximately 6.66 cm in the middle of the test apparatus.

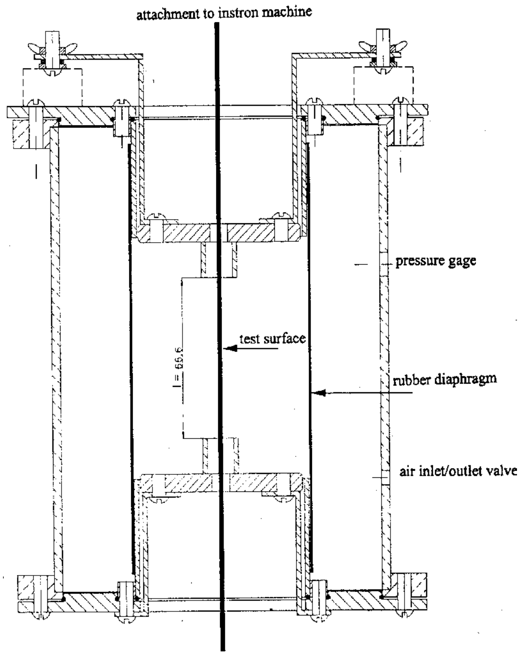


**Figure 1.** Front cross-sectional viwe of the coefficient of friction test apparatus.

In Figure 2 a typical diagram of friction force versus displacement has been illustrated. It is evident that the quantity of friction force is not uniform due to a process called stick and slip. To determine the mean value of friction force, it is necessary to calculate the area under the force-displacment curve and divide it by the displacement.

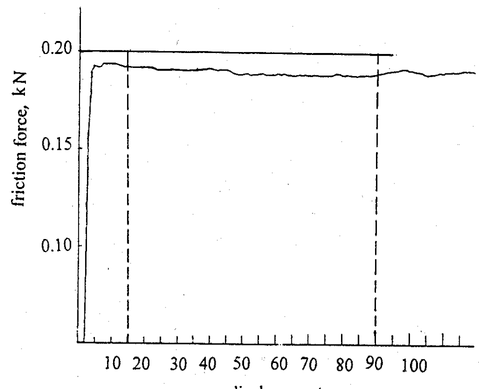


**Figure 2.** A typical friction force-displacement curve.

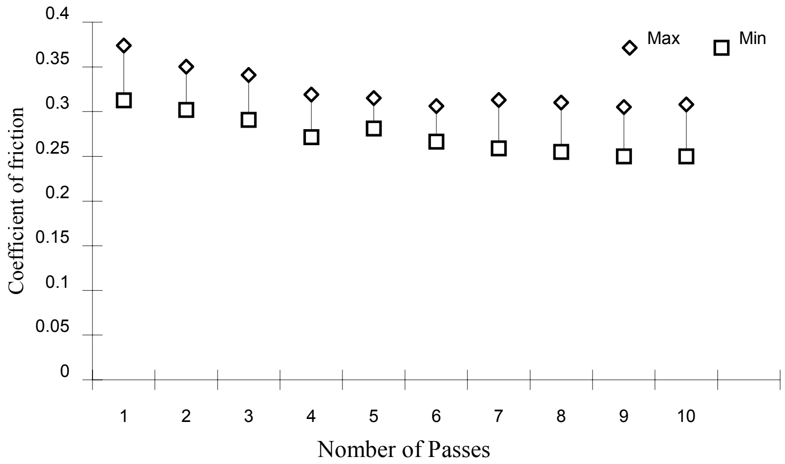


**Figure 3.** The effect of number of passes on the friction coefficient of chickpea grains on galvanized steel surface.

The friction coefficient was calculated using the equation:

$$\mu = \frac{F}{2pl(w+t)} \quad (1)$$

where:

*F*= force required to pull the plate through the grain mass, N;
*p*= pressure exserted on the grain, Pa;
*l*= lengh of the test section, 6.66 cm;
*w*= width of the test plate, 3.00 cm ;
*t* = thickness of the test plate, 0.20 cm; and
μ= dynamic coefficient of friction.

The grains within the apparatus were unloaded by opening the cap below the device. The test chamber was loaded with a new batch of grains to replicate the tests.

## RESULTS AND DISCUSSION

### The Effect of the Number of Passes on the Friction Coefficient

It became evident in the preliminary experiments, that the value of the friction coefficient in the initial passes of the plate within the grains was high. By increasing the number of passes, it decreased and reached at a constant value. However, it was necessary to condition the plate surface in order to obtain a reproducible friction force. The surfaces were conditioned by making repeated passes through chickpea grains.

**Table 1.** Coefficient of friction for chickpea grains on the galvanized and black steel surfaces, at a moisture content of 7.5% w.b., sliding velocity of 100 mm/min and normal pressure of 150 kPa.

| Surface | No. of Passes | Mean | Standard deviation | Coefficient of variation | Min. | Max. |
|---|---|---|---|---|---|---|
| black steel | 1 | 0.335 | 0.159 | 0.474 | 0.240 | 0.519 |
| | 6 | 0.297 | 0.044 | 0.148 | 0.258 | 0.346 |
| | 10 | 0.271 | 0.040 | 0.147 | 0.241 | 0.346 |
| galvanized | 1 | 0.349 | 0.32 | 0.091 | 0.312 | 0.373 |
| steel | 7 | 0.277 | 0.027 | 0.095 | 0.258 | 0.313 |
| | 10 | 0.278 | 0.029 | 0.103 | 0.250 | 0.308 |





[ DOR: 20.1001.1.16807073.2002.4.1.5.5 ]

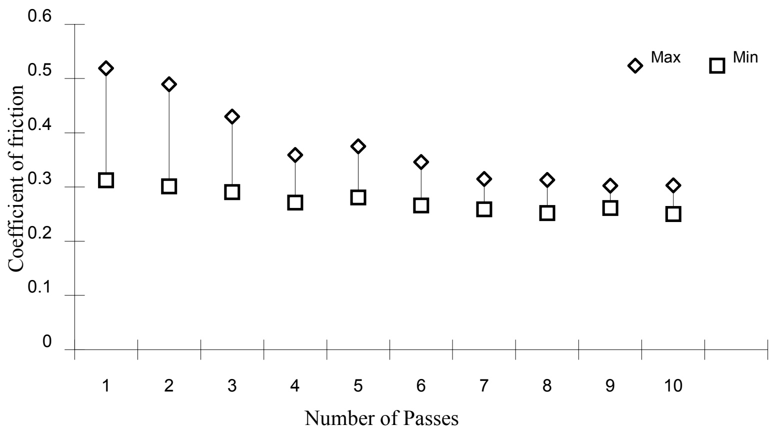


**Figure 4.** The effect of number of passes on the friction coefficient of chickpea grains on black steel surface.

In this research, for surface conditioning of the black and galvanized steel plates, each of them are passed through chickpea grains, at a sliding velocity of 100 mm/min and under a vertical pressure of 150 kPa having three replicates. For each pass, the friction coeffcient was calculated and the results are shown in Table 1 and Figures 3 and 4. As evident for black steel plate, the value of the friction coefficient was higher in initial passes and its range of variation between minimum and maximum values was greater. Comparison of averages at the 0.05 significance level indicated that, after the sixth pass of the black steel plate, the amount of the friction coefficient became uniform. For galvanized steel plates this occurred after the seventh pass. After conditioning of the plate surfaces, values of friction coefficient of chickpea grain on steel plates, were measured.

## The Effect of Normal Pressure on the Dynamic Friction Coefficient

In many previous works, the effect of normal pressure on the friction coefficient has not been significant. The analysis of variance of the data from the first set of the

**Table 2.** Analysis of variance for friction coefficients of chickpea grains on steel surfaces from the first set of the tests.

| Source | df | SS | MS | F value |
|---|---|---|---|---|
| Replication | 2 | 0.002 | 0.001 | $0.092^{ns}$ |
| Moisture(M) | 2 | 1.035 | 0.517 | $42.187^{**}$ |
| Pressure(P) | 2 | 0.89 | 0.045 | $3.637^{*}$ |
| MxP | 4 | 0.008 | 0.002 | $0.167^{ns}$ |
| Surface(S) | 1 | 0.000 | 0.000 | $0.0002^{ns}$ |
| MxS | 2 | 0.144 | 0.072 | $5.870^{*}$ |
| PxS | 2 | 0.017 | 0.008 | $0.683^{ns}$ |
| MxPxS | 4 | 0.011 | 0.003 | 0.217 |
| Error | 34 | 0.417 | 0.012 | |
| Total | 53 | 1.722 | | |

ns,**,* = Non significant, significant at P=0.05 and P=0.01, respectively.

**Table 3.** Duncan's multiple range test for comparison of average friction coefficient for difference normal pressure ($LSD_{0.05}$=0.0742).

| Normal Pressure (kPa) | Mean of friction coefficient |
|---|---|
| 14.28 | 0.294 b[a] |
| 100 | 0.331 ab |
| 150 | 0.392 a |

[a]Means in rows followed by the same letter are not significantly different at the P=0.05 level according to Duncan's multiple range test.

the difference between the coefficient of friction at normal pressure of 14.28 kPa and 100 kPa, also 100 kPa and 150 kPa is not significant at the 0.05 level. Figures 5 and 6 shows that the coefficient of friction increased with increasing normal pressure. Buelow (1961), working with maize on steel surfaces, reported a slight increase in the coefficient of friction with an increase of normal load, but concluded that it was not statistically significant (cited in Lawton, 1980).

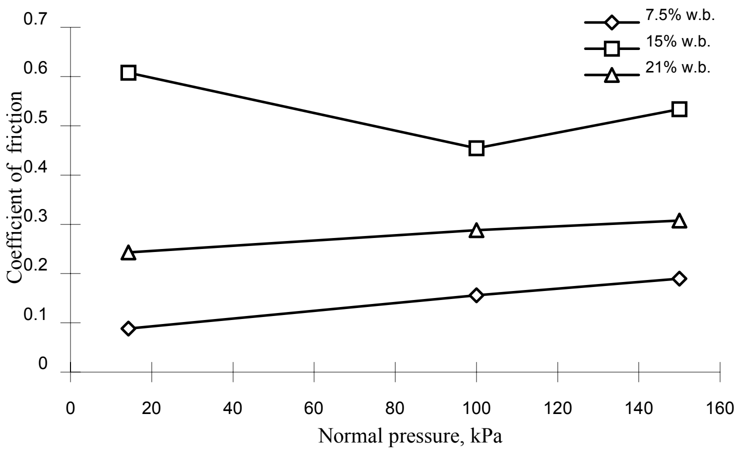


**Figure 5.** Effect of normal pressure on the dynamic coeffcient of friction of chickpea grains on a black steel surface at sliding velocity of 100 mm/min.

tests are shown in Table 2. This shows that the coefficient of friction of chickpea grains is affected by the moisture content and normal pressure, but the type of steel surface has no significant effect. This shows that the effect of normal pressure is significant at the 0.05 level and is not significant at the 0.01 level.

Results of Duncan's multiple range test on values of mean dynamic friction coefficient are shown in Table 3. This Table shows that

### The Effect of Moisture Content and Sliding Velocity

Mean values of friction coefficient of chickpea grains on the black and galvanized steel surfaces from the second set of experiments are shown in Tables 4 and 5.

Results of the analysis of variance of the data show in Table 6. It is evident from this Table that:

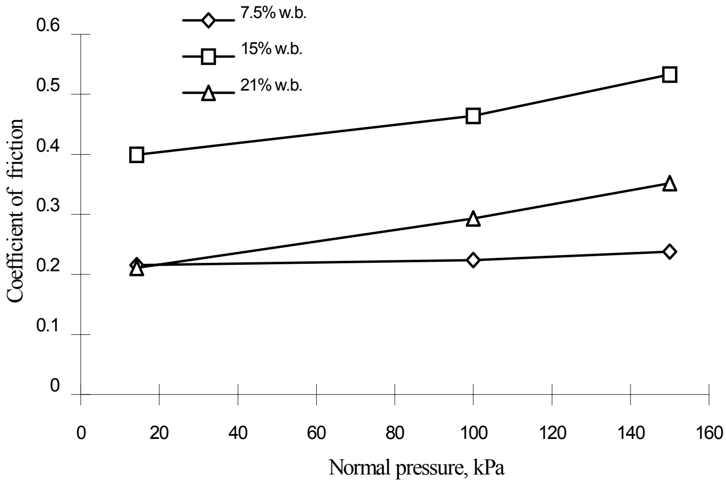


**Figure 6.** Effect of normal pressure on the dynamic coefficient of friction of chickpea grains on a galvanized steel surface at sliding velocity of 100 mm/min.

1) The moisture content of grains has a significant effect on the dynamic friction coefficient.

2) The sliding velocity of surfaces has a significant effect on the dynamic friction coefficient.

3) The dynamic friction coefficient of chickpea grains on the black and galvanized steel surfaces show no significant difference.

## The Effect of Moisture Content

Table 7 contains the results of Duncan's multiple range test at 0.05 significance level for comparison of friction coefficient averages at different moisture contents. It is obvious that moisture content significantly affects the dynamic friction coefficient. The value of the coefficient of friction at the 15% w.b. moisture content is the largest.

**Table 4.** Mean friction coefficient of chickpea grains on a galvanized steel surface in the normal pressure of 150 kPa.

| Moisture content (%w.b.) | Sliding velocity (mm/min) | Mean | Standard deviation | Coefficient of variation | Min. | Max. |
|---|---|---|---|---|---|---|
| 7.5 | 5 | 0.277 | 0.039 | 0.141 | 0.2328 | 0.3050 |
| | 20 | 0.333 | 0.027 | 0.082 | 0.3043 | 0.3578 |
| | 100 | 0.213 | 0.044 | 0.207 | 0.1635 | 0.2478 |
| | 500 | 0.228 | 0.059 | 0.259 | 0.1665 | 0.2842 |
| 15 | 5 | 0.250 | 0.035 | 0.138 | 0.2114 | 0.2745 |
| | 20 | 0.291 | 0.057 | 0.194 | 0.2270 | 0.3321 |
| | 100 | 0.533 | 0.281 | 0.528 | 0.3371 | 0.8590 |
| | 500 | 0.393 | 0.059 | 0.155 | 0.3277 | 0.4435 |
| 21 | 5 | 0.248 | 0.030 | 0.121 | 0.2215 | 0.2438 |
| | 20 | 0.307 | 0.045 | 0.145 | 0.2566 | 0.3410 |
| | 100 | 0.351 | 0.062 | 0.176 | 0.2816 | 0.3963 |
| | 500 | 0.335 | 0.032 | 0.096 | 0.3005 | 0.3636 |

**Table 5.** Mean friction coefficient of chickpea grains on a black steel surface in the normal pressure of 150 kPa.

| Moisture Content (%w.b.) | Sliding velocity (mm/min) | Mean | Standard deviation | Coefficient of variation | Min. | Max. |
|---|---|---|---|---|---|---|
| 7.5 | 5 | 0.193 | 0.012 | 0.064 | 0.1848 | 0.2073 |
| | 20 | 0.167 | 0.036 | 0.215 | 0.1296 | 0.2023 |
| | 100 | 0.189 | 0.034 | 0.179 | 0.1577 | 0.2258 |
| | 500 | 0.206 | 0.035 | 0.169 | 0.1663 | 0.2299 |
| 15 | 5 | 0.245 | 0.023 | 0.093 | 0.2210 | 0.2664 |
| | 20 | 0.335 | 0.044 | 0.131 | 0.2858 | 0.3677 |
| | 100 | 0.611 | 0.095 | 0.155 | 0.4876 | 0.6697 |
| | 500 | 0.329 | 0.068 | 0.207 | 0.2590 | 0.3949 |
| 21 | 5 | 0.327 | 0.024 | 0.073 | 0.3071 | 0.3537 |
| | 20 | 0.312 | 0.012 | 0.039 | 0.2994 | 0.3233 |
| | 100 | 0.308 | 0.021 | 0.069 | 0.2861 | 0.3283 |
| | 500 | 0.344 | 0.012 | 0.034 | 0.3334 | 0.3574 |

Figures 7 and 8 show the effect of the moisture content on the values of dynamic friction coefficient of chickpea grains on the black and galvanized steel surfaces. It was observed that by increasing the moisture content from 7.5%w.b. to 15% w.b., the value of friction coefficient increased and that, at the speed of 100 mm/min, it was the highest. This phenomenon is due to an increase in the elasticity of the grains which increased the actual contact area. Based on these data it can be concluded that from 15% w.b. to 21% w.b. moisture content, the friction coefficient was decreased. Addition of water to the surface of the chickpea grains resulted in lubricant property. For the galvanized steel surfaces, at sliding velocities of 5 and 20 mm/min, the value of friction coefficient was decreased by increasing the moisture content, but for sliding velocities of 100 and 500 mm/min, it was similar to the black steel surface.

## Effect of Sliding Velocity

Table 8 contains the results of Duncan's multiple range test for comparison of the average friction coefficient of chickpea grains at different sliding velocities. It was observed that during the increase of the sliding velocity from 5 mm/min to 100 mm/min,

**Table 6.** Analysis of variance the values of dynamic friction coefficient of chickpea grains on steel surfaces.

| Source | df | SS | MS | F value |
|---|---|---|---|---|
| Replication | 2 | 0.002 | 0.001 | $0.12^{ns}$ |
| Moisture(M) | 2 | 0.169 | 0.085 | $10.625^{**}$ |
| Velocity(V) | 3 | 0.206 | 0.069 | $8.625^{**}$ |
| MxV | 6 | 0.203 | 0.034 | $4.25^{**}$ |
| Surface(S) | 1 | 0.018 | 0.018 | $2.25^{ns}$ |
| MxS | 2 | 0.045 | 0.023 | $2.875^{ns}$ |
| VxS | 3 | 0.003 | 0.001 | $0.125^{ns}$ |
| MxVxS | 6 | 0.061 | 0.010 | $1.25^{ns}$ |
| Error | 46 | 0.353 | 0.008 | --- |
| Total | 71 | 1.060 | | |

ns,**,*= Non significant, significant at P=0.05 and P=0.01, respectively.

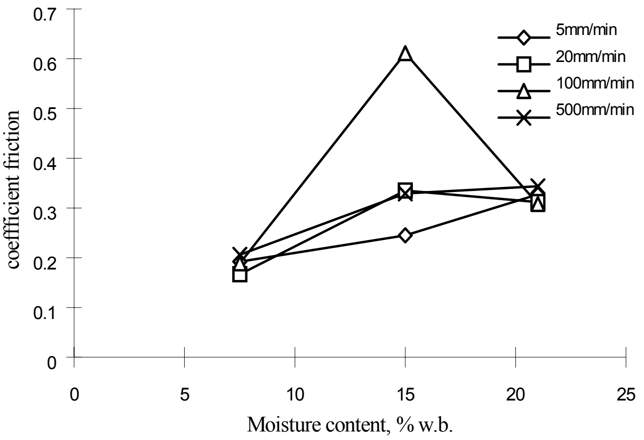


**Figure 7.** The effect of moisture content on the friction coefficient of chickpea grains on a black steel surface at the normal pressure of 150kPa

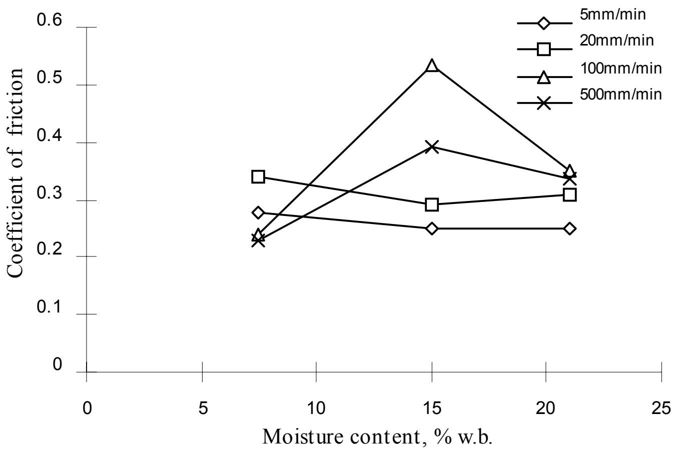


**Figure 8.** The effect of moisture content on friction coefficient of chickpea grains on a galvanized steel surface at the normal pressure of 150kPa.

the value of the friction coefficient increased, but from 100 mm/min to 500 mm/min it decreased significantly. Since the adhesion occurs between the sliding surfaces (plate and chickpea) at the points of contact, at very low sliding, velocities of 5 to 100 mm/min, the materials deformed slightly around the asperites, causing an increase in the coefficient of dynamic friction to occur. As the sliding velocity was increased to 500 mm/min, the frictional energy also increased, with the increased energy being released in the form of heat. The change in surface temperature produces a change in the physical properties of the sliding material and, as surface temperature increased, a decrease in strength occurred, resulting in a decrease in the friction forces which act be-

**Table 7.** Duncan's multiple range test for comparison of average friction coefficient for difference moisture content ($LSD_{0.05}$=0.0519).

| Moisture content (%w.b.) | Mean of friction coefficient |
|---|---|
| 7.5 | 0.2507 c[a] |
| 15 | 0.3694 a |
| 21 | 0.3127 b |

[a]Means in rows followed by the same letter are not significantly different at the P=0.05 level according to Duncan's multiple range test.

**Table 8.** Duncan's multiple range test for comparison of average friction coefficient for difference sliding velocity ($LSD_{0.05}$= 0.060).

| Sliding velocity (mm/min) | Mean of friction coefficient |
|---|---|
| 5 | 0.245 c[a] |
| 20 | 0.292 bc |
| 100 | 0.392 a |
| 500 | 0.313 b |

[a]Means in rows followed by the same letter are not significantly different at the P=0.05 level according to Duncan's multiple range test.

tween the two type sliding surfaces. Figures 9 and 10 show the sliding velocity effect on friction coefficient on both surfaces.

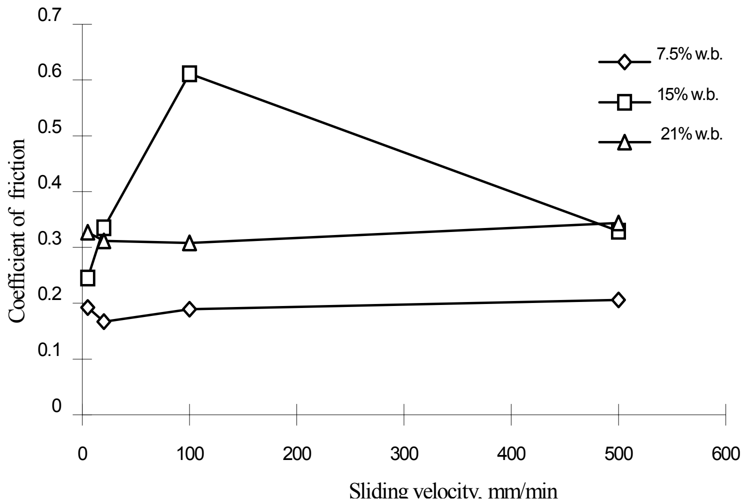


**Figure 9.** The effect of sliding velocity on friction coefficient of chickpea grains on a black steel surface.

## CONCLUSIONS

The conclusions drawn from this study are as follows.

1- Before beginning the experiments and recording data, for conditioning the surfaces they should be passed at least 7 times through the grains.

2- At low sliding velocity, by increasing sliding velocity from 5 to 20 mm/min, the dynamic friction coeffcient of chickpea grains increased and at a sliding velocity of 500 mm/min it decreased.

3- For the black steel surface, by increasing the moisture content of chickpea grains, from 7.5% to 15% w.b., the value of the friction coefficient increased but, at 21% w. b., moisture content, it was decreased. For the galvanized steel surface, at sliding velocity of 5 and 20 mm/min, by increasing moisture content, the values of friction coefficient decreased, but for velocities of 100 and 500 mm/min, the behaviour was similar to that of the black steel surface.

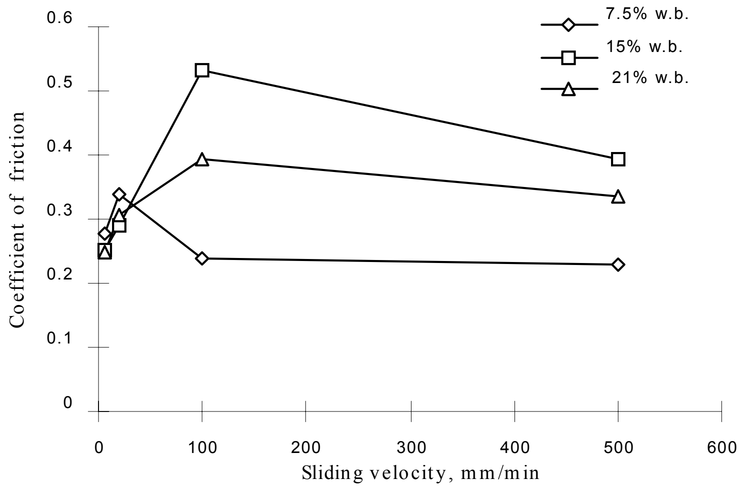


**Figure 10.** The effect of sliding velocity on the friction coefficient of chickpea grains on a galvanized steel surface.

4- The normal pressure has no significant effect on friction coefficient at 0.01 significance level.

## REFERENCES


1. Brubaker, J. E., and Pos, J. 1965. Determining Static Coefficient of Friction of Grains on Structural Surfaces. *Trans. ASAE.,* **8(1)**: 53-55.
2. Chung, J. H., and Verma, L. R. 1989. Determination of Friction Coefficients of Beans and Peanuts. *Trans. ASAE.,* **32(2)**: 745-50.
3. Clark, R. L., Welch, G. B., and Fox, W. R. 1970. Kinetic Friction of Cotton on Steel as Affected by Several Factors. *Trans. ASAE.,* **13(2)**: 708-709, 714.
4. Gupta, R. K., and Das, S. K. 1998. Friction Coefficients of Sunflower Grain and Kernel on Various Structural Surfaces. *J. Agric. Eng. Res.,* **71**: 175-180.
5. Kermani, A. M. 1999. Determining Coefficient of Friction of Chickpea Grains. M. Sc. Thesis. Tarbiat Modares University. Tehran. Iran (in Farsi).
6. Lawton, P. J. 1980. Coefficient of Friction Between Cereal Grain and Various Silo Wall Materials. *J. Agric. Eng. Res.,* **25(1)** : 75-86.
7. Mohsenin, N. N. 1986. Physical Properties of Plant and Animal Materials. Second Edition. NewYork. Gordon and Breach Science Publishers. U. S. A.
8. Phirke, P. S., Bhole, N. G., and Adhaoo, S. H. 1996. Friction Coefficient of Pigeon Pea Grain with Abrasive Surfaces Used for Dehulling. *Agricultural Mechanization in Asia, Africa and Latin America.,* **27(4)**: 27-31.
9. Synder, L. N., Roller, G. E., and Hall, G. E. 1967. Coefficient of Kinetic Friction of Wheat on Various Material Surfaces. *Trans. ASAE.,* **10 (3)**: 411-413,419.
10. Stewart, B. R., Hossain, Q. A., and Kunze, O. R. 1969. Friction Coefficients of Sorghum Grain on Steel, Teflon and Concrete Surfaces. *Trans. ASAE.,* **12(4)**: 415-18.
11. Thompson, S. A., and Ross, I. J. 1983. Compressibility and Frictional Coefficient of Wheat. *Trans. ASAE.,* **26(4)**: 1171-1180.
12. Tsang-Mui-Chung, M., Verma, L. R., and Wright, M. E. 1984. A Device for Friction Measurement of Grains. *Trans. ASAE.,* **27(6)**: 1938-1941.

# تاثیر فشار عمودی، سرعت لغزشی و رطوبت بر ضریب اصطکاک دینامیکی دانه نخود روی سطوح فولادی

ت. توکلی، ع. م. کرمانی و ج. خزایی

## چکیده

در این تحقیق، وسیله‌ای جدید برای تعیین ضریب اصطکاک مواد دانه‌ای روی سطح فولادی ساخته شد و جهت تعیین ضریب اصطکاک دانه‌های نخود بکار رفت. اثر رطوبت دانه و سرعت لغزش آن روی ضریب اصطکاک بررسی شد. سطوح رطوبت دانه‌ها ۷/۵، ۱۵و ۲۱٪ (برپایه وزن‌تر) و سطوح سرعت لغزش ۵، ۲۰، ۱۰۰ و ۵۰۰ میلی‌متر بر دقیقه بود. اندازه‌گیری در سه بار عمودی ۱٤/۲۸، ۱۰۰ و ۱۵۰kPa انجام گرفت و نتایج زیر بدست آمد:

۱- جهت پرداخت سطح لازم است که حداقل هفت بار عبور دانه‌های نخود از روی سطح فولادی انجام شود.

۲- ضریب اصطکاک دینامیکی دانه‌های نخود در سرعت‌های لغزش پایین با افزایش سرعت از ۵ تا ۲۰ میلی‌متر بر دقیقه افزایش و در سرعت لغزش ۵۰۰ میلی‌متر بر دقیقه کاهش می‌یابد.

۳- ضریب اصطکاک دانه‌های نخود روی سطح فولادی سیاه با افزایش رطوبت دانه‌ها از ۷/۵ تا ۱۵٪ افزایش ولی در رطوبت ۲۱٪ کاهش می‌یابد. این ضریب روی سطح فولادی گالوانیزه برای سرعت‌های لغزش از ۵ تا ۲۰ میلی‌متر بر دقیقه با افزایش رطوبت دانه‌ها، کاهش می‌یابد ولی در سرعت‌های بین ۱۰۰ تا ۵۰۰ میلی‌متر بر دقیقه شبیه ضریب اصطکاک بر روی سطح فولادی سیاه است.

٤- فشار عمودی تاثیر معنی‌داری بر ضریب اصطکاک ندارد وسطوح مختلف فشار عمودی در سطح ۰/۰۵ اختلاف معنی‌داری ندارند.





[ DOR: 20.1001.1.16807073.2002.4.1.5.5 ]