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Comparison of Sliding Frictions of Different Materials Using a Digital Sliding Friction Tester

*Kamrul Hasan Chowdhury, Md. Nafis Soyaib and Dr. Sobahan Mia**
Department of Mechanical Engineering,
Khulna University of Engineering & Technology, Khulna-9203,BANGLADESH

ABSTRACT: Friction Tester has a greater importance in the field of fundamental friction studies such as friction testing of metal surfaces, soft and hard coatings, plastics, glasses, polymers and different types of fabrics with or without lubricants. So it has been decided to construct a friction tester and measure the coefficient of friction of various materials in different conditions. In order to do that, various types of friction tester has been studied and finally it has been decided to design and construct a Digital Sliding Friction Tester. In this construction a 24 Volt dc motor was used which elevates a sliding plate. A gear mechanism was used to transfer the motion from motor to shaft. After construction performance test has been done with respect to various parameters and conditions. The obtained result from Digital Sliding Friction Tester was compared with manually calculated friction tester and standard ASTM chart. This showed a very good accuracy with a deviation of negligible amount of 1-6%. Results showed that the coefficient of friction is independent of load and is totally dependent on material and surface roughness.

Keywords: Friction, Static Friction, Coefficient of Static Friction, Friction Tester, Lubrication.

1.Introduction

Friction is the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other. As a consequence of friction, the process of motion and the dynamic behavior of the whole system are influenced or disturbed and some part of the energy of motion is dissipated [1].

There are four types of friction namely. Static friction is friction between two or more solid objects that are not moving relative to each other.Static frictional forces from the interlocking of the irregularities of two surfaces will increase to prevent any relative motion up until some limit where motion occurs. It is that threshold of motion which is characterized by the coefficient of static friction. The magnitude of static friction depends upon µs (coefficient of static friction) and N (net normal reaction of the body). Kinetic friction denoted as $\mu_k$comes into play when a body just starts moving along a surface. When external applied force is sufficient to move a body along a surface then the force which opposes this motion is called as kinetic frictional force. µk is coefficient of kinetic frictional force and N is the net normal reaction on the body. The magnitude of kinetic frictional force is always less than magnitude of static frictional force. When value of applied net external force, F is more than f_k then body moves with a net acceleration and when these forces are equal then body moves with a constant velocity. Rolling frictional force is a force that slows down the motion of a rolling object [2]. Basically it is a combination of various types of frictional forces at point of contact of wheel and ground or surface. When a hard object moves along a hard surface then static and molecular friction force retards its motion. When soft object moves over a hard surface then its distortion makes it slow down. When a body moves in a fluid or in air then there exists a resistive force which slows down the motion of the body, known as fluid frictional force. A freely falling skydiver feels a drag force due to air which acts in the upward direction or in a direction opposite to skydiver's motion. The magnitude of this drag force increases with increment in the downward velocity of skydiver. At a particular point of time the value of this drag force becomes equal to the driving force and skydiver falls with a constant velocity.

*Corresponding author. Tel.: +88-01711951400
E-mail address: smia@me.kuet.ac.bd

Coefficient of friction is the ratio of the weight of an object being moved along a surface and the force that maintains contact between the object and the surface[3]. The coefficient of friction is not always the same for objects that are motionless and objects that are in motion; motionless objects often experience more friction than moving ones, requiring more force to put them in motion than to sustain them in motion. The static coefficient of friction is the coefficient of friction that applies to objects that are motionless. The kinetic or sliding coefficient of friction is the coefficient of friction that applies to objects that are in motion.

2. Design and Construction

2.1 General Components

The general components of a Digital Sliding Friction Tester are:

Base Plate: The Base Plate is the part which supports the whole foundation and the other parts of the Friction Tester are mounted on it.

Sliding Plate: Sliding plate is that part on which the test specimen is placed. It is welded with the main shaft.

Main Shaft: The main shaft is welded with the Sliding Plate. The two ends of the shaft are attached to the Base Plate. For smooth rotation of the shaft two bearings are mounted at the two ends of the shaft.

Motor: In this machine the motor is the main mechanical power source to elevate the sliding plate by rotating the main shaft. For smooth elevation of the sliding plate a motor of low rpm and high torque is used.

Gear arrangement: For transmitting the power from motor to main shaft a 2:1 spur gear arrangement is used.

Bearings: A pair of 6202 bearings is used to support the main shaft.

Electronic components: Microcontroller ATmega8, 16x2 LCD Screen, Motor Driver L298N, IR Sensor etc.

2.2 Design Details

Study of mechanics of friction dates back to the sixteenth century, after the invention of Newton's law of motion. The variation of friction depends on interfacial conditions such as geometry, relative surface motion, surface roughness of contact surfaces, type of material, lubrication etc. Among these factors material and surface roughness are two major factors which play significant role for the variation of friction. And in this observation it is high lightened to observe the variation of static friction for different material. In order to determine this observation a Digital Sliding Friction Tester has been designed. This machine is not available in our country. In foreign countries such as China and Canada analog version of this machine is used. Different type of Friction Tester has been studied on internet and learned about the analog version of this machine. Then the machine has been designed in Solid Works 2013.

A schematic diagram of the design has been shown on the Fig.1. Here, the base of the structure is constructed with 0.0625 inch thick galvanized iron sheet. The sliding plate is attached to the rotating shaft. The gear is attached at the middle of the shaft. This whole arrangement is further attached with the base with the bearings. The electric motor is used as a source of mechanical power. A pinion is attached with the motor shaft to transmit power from motor to shaft. The experiment was carried out for different materials.

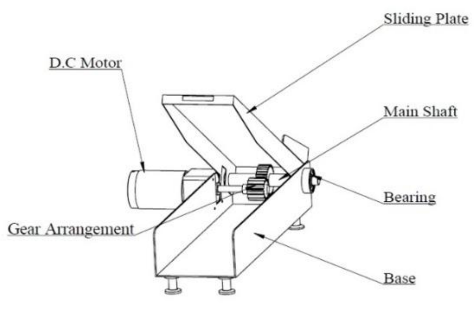

Fig.1 Aschematic diagram of Digital Sliding Friction Tester.

Fig.2 A Digital Sliding Friction Tester after construction.

3. Testing Procedure

To determine the influence of surface roughness of various materials on static coefficient of friction were carried out under both dry and wet condition. At first the testing specimen was placed on sliding plate which was in initial position (0° angle) and another specimen of same material was attached with a sliding block and placed on top of that material. Then the machine was switched on and the sliding plate started to lift at an angle with a constant velocity. For accurate results the angular velocity of the sliding plate should be maintained at a range of 0.3-0.5 rpm. A certain time later for a certain angle the weight block started to move on and the sliding plate stops at that angle immediately. Since the motor speed varies with the load, the load shouldn't exceed 5N. A photo sensor was used to facilitate that immediate action. After that the angle was taken on account and doing the whole calculation with the help of microcontroller the final result was showed on LCD screen. That was the result of static coefficient of friction for that specific material. Finally, another switch was used to bring back the sliding plate in its initial position.

4. Experimental Data

The data collected during the performance test at 70% relative humidity are as follows:

Table1: Coefficient of static friction of various materials without lubrication

M1	M2	Static Coefficient of Friction, μ_s			D (%)
		μ_{s1}	μ_{s2}	μ_{s3}[4]	
Glass	Glass	0.44	0.46	0.45	2.22
Cast Iron	Glass	0.67	0.68	0.70	4.30
Glass	Wood	0.47	0.47	0.45	4.44
GI Sheet	Glass	0.64	0.66	0.50-0.70	1.54
Plywood	Plywood	0.80	0.78	0.70-0.80	1.00
Plywood	GI Sheet	0.59	0.58	0.60	1.67
GI Sheet	Brass	0.36	0.36	0.35	2.78
Cast Iron	GI Sheet	0.63	0.64	0.65	3.08
Wood	Brass	0.65	0.62	0.60	3.33
Wood	Wood	0.48	0.48	0.50	4.00
Cast Iron	Wood	0.60	0.59	0.50-0.60	1.67
Wood	GI Sheet	0.66	0.63	0.65	1.54
Hard board	Hard Board	0.78	0.77	0.75	4.00
Hard board	GI Sheet	0.69	0.68	0.70	1.43
Brass	Glass	0.36	0.36	0.35	2.78
Plywood	Brass	0.53	0.54	0.55-0.60	3.64
Brass	Hard Board	0.58	0.60	0.50-0.60	3.33
Carton	Carton	0.68	0.68	0.70	2.86
Glass	Carton	0.70	0.72	0.75	4.00
Carton	Cast Iron	0.60	0.59	0.60	1.67
Brass	Carton	0.71	0.71	0.70	1.41
Tiles	Tiles	0.56	0.57	0.60	5.00
Brass	Tiles	0.48	0.49	0.50	4.00
Tiles	Cast Iron	0.58	0.59	0.60	3.33

5. Discussion

The main goal in this project was to investigate the influence of surface roughness of various materials on coefficient of friction. The nature of friction is to

Table2: Coefficient of static friction of various materials with lubrication

M1	M2	Static Coefficient of Friction, μ_s			D (%)
		μ_{s1}	μ_{s2}	μ_{s3}[5]	
Glass	Glass	0.21	0.22	0.2	5.00
Cast Iron	Glass	0.28	0.29	0.3	3.33
Glass	Wood	0.32	0.33	0.35	5.71
GI Sheet	Glass	0.34	0.36	0.35-0.40	2.86
GI Sheet	Brass	0.24	0.26	0.25	4.00
Cast Iron	GI Sheet	0.30	0.29	0.30	3.33
Wood	Brass	0.36	0.38	0.40	5.00
Cast Iron	Wood	0.37	0.39	0.35-0.40	2.5
Wood	GI Sheet	0.36	0.34	0.35	2.86
Hard board	GI Sheet	0.38	0.37	0.40	5.00
Brass	Glass	0.24	0.26	0.25	4.00
Brass	Hard board	0.45	0.47	0.45	4.25
Tiles	Tiles	0.33	0.32	0.35	5.71
Brass	Tiles	0.29	0.29	0.30	3.33
Tiles	Cast Iron	0.33	0.33	0.35	5.71

increase with the increase of normal force. Frictional force is independent of apparent area of contact. It has been found that by applying lubricant between the contact surfaces friction can be minimized significantly. For wet condition the friction is also reduced between the contact surfaces. For changing the angular position of the sliding plate smoothly a motor of low speed and high torque was used. The construction was made such a way so that the specimens can be loaded and unloaded easily. Since vibration has a great effect on frictional phenomena, the main basement was welded with legs. During the performance test for keeping one surface fixed clamps were used. The relative humidity of the atmosphere has a great effect on the static friction coefficient. At humid condition, for a pair of metal the water particles of the air act as lubricant at the contact surfaces. But for glass and polymers the coefficient of friction increases with the increase of relative humidity. Lubricants play a great role in reducing the friction. The co-efficient of static friction varies with different lubricants with different additives. The viscous properties of the lubricants vary with the temperature. From tables 1 and 2 it can be seen that for both with and without lubricants the digitally obtained results vary at a range of 1-6% in comparison to the standard values from ASTM chart. The magnitudes of friction coefficient are different for different sliding pairs and lubricants, therefore maintaining appropriate level of relative humidity as well as appropriate choice of sliding pair, friction may be kept to some optimum value to improve mechanical processes.

6.0 Conclusion

From the study and within the experimental setup, the following conclusions may be drawn:

The Coefficient of static friction of various materials at different conditions has been measured. From the test it can be concluded that-

I. The co-efficient of friction depends on contact surface condition of material.

II. The frictional force is independent of apparent area of contact.

III. Test result is satisfactory with 15% variation.

NOMENCLATURE

N: normal reaction force, N

F: force, N

Θ : angle, º

μ_s :coefficient of static friction.

μ_{s1} :coefficient of static friction obtained digitally.

μ_{s2} :coefficient of static friction obtained manually.

μ_{s3} :coefficient of static friction obtained from ASTM chart.

M 1: Material 1

M 2: Material 2

D : Deviation with standard chart, %

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