Effect of Humidity and Vibration on the Friction and Wear Properties of Mild Steel

A thesis submitted to the Department of Mechanical Engineering, BUET, Dhaka,
in Partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE IN MECHANICAL ENGINEERING

by
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CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Azad

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DEDICATION

In The Name of Allah
The Most Beneficent
The Most Merciful

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ABSTRACT

Friction and wear properties of mild steel are tested in a pin-on-disc type apparatus. The effects of vibration on friction and wear of mild steel are taken into consideration. An experimental setup is designed and fabricated by which the friction co-efficient of mild steel plate is measured. During the experiment, normal load, speed, vibration, relative humidity and surface-finish of disc are varied. Effects of the above parameters on friction and wear properties of mild steel are measured. Two types of surface-finish ('as-turned' and 'as-ground') are considered for disc sample. Friction co-efficient is measured as the ratio between horizontal and normal forces. Wear rate is measured by taking weights before and after abrasion loss of mass. It is observed that the friction co-efficient increases linearly with duration of rubbing upto a certain time and becomes constant afterwards. Both the friction co-efficient and the wear rate increase with the decrease of relative humidity. Friction co-efficient remains almost constant with normal load. But wear rate increases with increasing normal load and increasing linear velocity. Rate of increase of frictional co-efficient is more at lower linear velocity than that at higher linear velocity. Values of friction co-efficient and wear rate also depend on the type of surface-finish. In these experiments, for 'as-ground' surface, wear rate was found to be 44% and friction co-efficient was found to be 40% to 45% less than that for 'as-turned' surface. The difference of frictional co-efficient and wear rate of vibrating and non-vibrating plates increase with the increase of frequency of vibration.

CONTENTS

NOTATIONS

Fc = Friction co-efficient without vibration

Fć = Friction co-efficient with vibration

Wr = Wear rate without vibration

Wr' = Wear rate with vibration

C-1 = Curve – 1

C-2 = Curve – 2

C-3 = Curve – 3

C-4 = Curve – 4

C-5 = Curve – 5

C-6 = Curve – 6

μ_k = Kinetic friction co-efficient

μ_s = Static friction co-efficient

A_t = True area of contact

A = Apparent area of contact

N = Normal load

σ = Flow pressure of the soft metal

τ_t = Tangential shear stress

τ_m = Critical shear stress

F = Frictional force

T = Recorded temperature

T_0 = Ambient temperature

CHAPTER – I

❖ Introduction

INTRODUCTION

Study of the Mechanics of friction and the relationship between friction and wear date back to the sixteenth century, almost immediately after the invention of Newton law of motion. Newton had conquered the simple laws of forces, reactions, accelerations, and the momenta. The great era of classical mechanics had begun. Despite extensive research on these fields, no simple model have so far been developed to predict or calculate friction co-efficient. Even now a days, the effect of various parameters such as, humidity, vibration, speed, load and others on friction are less understood. That is, not all of these variables have been fully studied. But tribology and its area of research are important to understand the behaviour of material surfaces undergoing friction. Therefore, for better understanding of the mechanism of friction and wear, more research are necessary.

Considering relative velocity between surfaces, friction co-efficients are either static or kinetic. But the main interest of the researchers is on kinetic friction co-efficient because of its extensiveness in the modern era of friction research.

Two bodies pressed into each other with a normal force N is constrained from moving in any direction perpendicular to N. The constraining force Fr, usually called friction force, is found to be proportional to N. This proportionality constant is called the co-efficient of friction. We are familiar with two kinds of friction co-efficient. One is referred to as static friction co-efficient (μ_s) and the other is kinetic co-efficient of friction (μ_k). Static friction co-efficient is measured when the surfaces in contact are static and at the point of impending motion. Kinetic friction co-efficient is measured when two bodies in contact are in relative motion. Friction co-efficient of both kinds varies with the type of material of the mating surfaces, the quality of the surface, type of lubrication, and some other minor factors. Kragelskii and Ishlinsky (1) suggested that static friction force depends on the duration of static contact and kinetic friction remains unchanged or slightly varies with speed. These variations are observed at lower sliding speeds and become constant at a certain higher sliding speed. They proposed that the static co-efficient of friction is a function of time but the kinetic co-efficient of friction is almost constant. When there is vibration, the contacting surfaces do not remain in contact all the time. There is always separation between these two surfaces. So, this condition is completely different from the above mentioned well recognised conditions. Therefore, an attempt is made to investigate the mechanics of the friction co-efficient when the contacting surfaces are subjected to different types of vibration.

The analysis and study of vibrations has become increasingly important in recent years owing to the current trend towards higher speed machines and lighter structure. Depending on the direction of oscillation, vibration can be classified as (i) longitudinal, (ii) transverse and (iii) torsional. In the present study, the effect of longitudinal vibration on friction and wear properties of mild steel are investigated.

It is known that the oxides formed during friction process usually influence the friction and wear properties of metal. Wear may be defined as unitentional deterioration of surface (2). It may be considered essentially as a surface phenomenon. The formation of oxides on the worn surface is obviously one of the important factors causing mild wear (3). The displacement and detachment of metallic particles from a metallic surface may be caused by the contact with (i) another metal (adhesive or metallic wear), (ii) a metallic or a non-metallic abrasive (abrasion), or (iii) moving liquids or gases (erosion). Erosion is usually accompanied by some form of corrosion (4). The three types of wear mentioned earlier may be subdivided into wear under rolling friction or sliding friction and, further, according to whether lubrication is used or not used. Depending on sliding speed, applied load, surface-finish, kinds of atmospheric gases and friction force, the rate of wear evidently changes (5). Load on the sliding pair tangibly affects its wear life.

Stresses at the spots of real contact increase with the load, which may result in the plastic deformation of asperities and even in seizure and micro cutting. Increased loading also results in sharply elevated temperatures at the sliding interface. To avoid such effects, minimum possible loads and hard materials should be used in tribological joints (6). Increased sliding speed results in greater wear rate due to rising temperature at the friction zone, a longer path of friction and a longer time of exposure of the materials to the aggressive medium. On the other hand, under atmospheric conditions, wear becomes milder, friction is also lower and wear debris contain a considerable amount of metal oxides (7). Water and water vapour clearly play an important role in wear behaviour. Lancaster (8) reviewed the influence of humidity and water vapour on friction and wear properties of various materials, and emphasised the role of humidity on the formation of extra surface layers. Different authors (9,10,11) showed the effects of humidity on the friction and wear properties of tin, mild steel and ceramic materials. These studies suggest that the friction co-efficient increases with the decrease of relative humidity.

Objectives of This Study

The following are the objectives of the present study:

1. Design and fabrication of a setup for measuring the sliding kinetic friction co-efficient and wear rate with and without vibration.

2. Determination of the effect of vibration and humidity on the friction and wear properties of mild steel at different speeds, normal loads and surface finish of the mating surfaces.

3. Comparison of the results with those available in the literature.

4. Investigation of the effect of duration of rubbing on friction co-efficient and wear rate.

CHAPTER – II

❖ Literature Survey

LITERATURE SURVEY

2.1 Friction and Mechanism of Friction

2.1.1 Friction

It is known that the surfaces of the bodies are never perfectly smooth. When, even a very smooth surface is viewed under a microscope, it is found to have roughness and irregularities, which may not be detected by human senses. If a block of one substance is placed over the plain surface of another block of the same or of different material, a certain degree of interlocking of the minutely projecting particles of the surfaces takes place. This does not involve any force so long as the block does not move or tend to move. But, whenever one block moves or tends to move tangentially with respect to the surface, on which it rests, the interlocking property of the projecting particles opposes the motion. This opposing force, which acts in the opposite direction of the movement of the upper block, is called the force of friction or simply friction. It thus follows that, at every joint in a machine, friction force arises due to the relative motion between two parts and hence some energy is lost to overcome the friction. Though the friction is considered undesirable, yet it plays an important role both in nature and in engineering, like walking on a road, motion of locomotive on rails, transmission of power by belts, gears, and others.

❖ Types of Friction

In general, there are two types of friction:

1. Static friction: It is the friction, experienced by a body at rest while in contact with another.
2. Dynamic friction: It is the friction, experienced by a body, in contact with another when in motion. Dynamic friction is also called kinetic friction and is less than the static friction. Dynamic friction is again classified into:
   (a) Sliding friction: It is the friction, experienced by a body, when it slides over another body.

(b) Rolling friction: It is the friction, experienced between the surface which have balls or rollers interposed between them.

(c) Pivot friction: It is the friction, experienced by a body, due to rotational motion as in the case of foot step bearings.

❖ Laws of Kinetic or Dynamic Friction

- ✧ Friction force always acts in a direction, opposite to that in which the body is moving.
- ✧ The magnitude of the kinetic friction bears a constant ratio to the normal reaction between the two surfaces. But this ratio is slightly less than that in case of limiting friction.
- ✧ For moderate speeds, the force of friction remains constant. But it decreases slightly with the increase of speed.

❖ Area of contact

Consider a surface loaded against another (Fig. 2.1), both having protuberances as is the case with all engineering surfaces. Contact cannot occur over the whole apparent area of the interface and the two solids can only meet at those aspirates which approach one another favourably. That is, this way areas of contact a_1, a_2,--- will form giving the true area of contact A_t such that

$$A_t = a_1 + a_2 + a_3 + \text{-------} + a_n. \quad (2.1)$$

Measurement of electrical conductivity of stationary surfaces shows (12) that the true contact area is a mere fraction of the apparent area of contact. For example, for steel surfaces, $A_t = (A/10{,}000)$, where A is the apparent area of contact which is the measured surface area of the interface. A small area of contact means that the load is supported at a few isolated points. This results in an intensified normal stress at the interface and it is well established that the material at a_1, a_2, a_3 - - - - - - a_n flows plastically and forms strong junctions between surfaces 1 and 2. Obviously, the sum of the interfacial areas of all the junctions is the true area of contact and these must be broken in order that one surface can slide relative to the other.

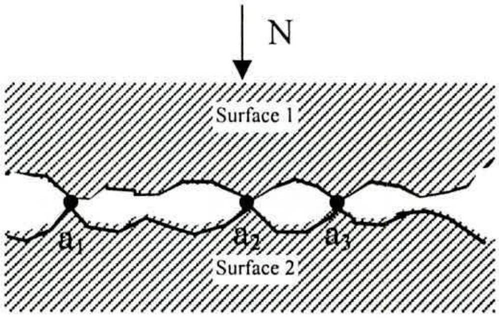


Fig. 2.1 Surface 1 is resting on surface 2 under a normal load N. Contact occurs only at a few asperities, a_1, a_2 and a_3.

❖ Adhesion of Junctions

Development of a finite strength at the interface by plastic interaction depends largely on the mechanical properties of the material. Thus if the applied normal load on surface 1 (Fig. 2.1) is N and σ_y is the flow pressure of the softer element of the two, for an established true contact area A_t, $N = A_t\sigma_y$

$$A_t = \frac{W}{\sigma_y} \qquad (2.2)$$

If the load is removed, the surfaces may separate if the junctions are ruptured by the process of elastic recovery of the underlying material (13). The harder the indented metal the greater is its elastic recovery.

❖ Mechanism of Friction

The pioneering work providing evidence of the true contact area being a mere fraction of the apparent area should be attributed to Holm (14) but it would appear that the mechanism of friction embodying adhesion gained acceptance subsequent to the work of Hardy and Hardy (15), reported in 1919 and again a decade later by Tomlinson(16).

Bowden and Tabor (17) consider the frictional resistance between two surfaces as the sum of a shearing and a ploughing component. For hard metals loaded against similar surfaces or, possibly, for most combinations at light loads, the ploughing term becomes insignificant. The co-efficient of friction μ becomes the frictional resistance per unit load.

2.1.2 Effect of sliding

Since a metal couple under load will form junctions by plastic flow of favourably disposed surface peaks, the first effect of sliding is to rupture these peaks and effect a change in surface topography. Sliding inevitably generates frictional heat, which is responsible for two important metallurgical effects. Firstly, there is thermal softening of the interface with a concomitant lowering of yield stress of the metals. Secondly, unless the operation is carried out in vacuum, oxidation of the interface is facilitated. A low yield stress means that asperity yielding becomes easier but the presence of a partitioning film of oxides dilutes the metal interaction and hence lowers the frictional resistance.

❖ Junction Growth

Bowden and Tabor (18) point out that for most dry sliding situations in room condition, $\mu = 1$. One could argue that the observed values of μ are high because work hardening is ignored here which would cause an increase in the shear strength of the interface. However, it should be remembered that the effect of work hardening is to cause an increase in the value of the flow pressure also.

The discrepancy between the observed and calculated values of co-efficient of friction has been explained in terms of junction growth, that is, a lateral growth of the true contact area upon the application of a tangential pull. Work of McFarlane and Tabor who slid steel and indium, a material with a low work hardening characteristic, and that of Parker and Hatch (19) who used lead, show that the initial effect of a tangential pull is to cause micro-displacement of the contact spots, generally in the horizontal direction. The micro-displacement of junctions under the combined action of normal and tangential loading has been shown to occur even before macroscopic sliding on a large scale takes place.

❖ Equation for Junction Growth

The basic equation for junction growth is given as

$$\sigma^2 + \alpha_0\tau_t^2 = \alpha_0\tau_m^2 \tag{2.3}$$

where α_0 is a constant with a value of about 9. τ_t is the shear stress at the interface or, more specifically, the applied tangential stress to cause rupture of the junctions and τ_m is the critical shear stress of the soft metal. The above equation suggests that as the tangential force is increased monotonically from zero up to a value when sliding is just about to commence, σ tends to 0 because of micro-displacement of the contact area and consequently τ_t tends to τ_m.

❖ Work of Adhesion

The foregoing discussion suggests that the interfacial shear stress of two interacting bodies can never be greater than the critical shear stress of the junctions. Machlin and Yankee (20) postulate that the magnitude of the frictional force is probably decided in accordance with the ability for junction growth by the solid phase weldebility of a couple, which may be defined as the ratio of the work of adhesion of the surfaces to the strength of the weaker component. Rabinowizc (21, 22) uses the work of adhesion E between two interacting surfaces to explain friction and shows that this gives a better agreement between the theoretical and experimental values for the co-efficient of friction.

❖ Kinetic Friction

The frictional force shows a dependence on the shear strength of the adhered surfaces. A junction forms and grows radially so that the true contacting area assumes a large enough size to support the normal load. The area spreads out further in the direction of motion as sliding commences. The normal stress should decrease with a concomitant rise in the shear stress of the interface.

That is, with the onset of a tangential pull, a maximum static frictional resistance will develop until, with increasing external force, the interface will separate. At this instant, frictional resistance is zero but fresh junctions form elsewhere and the process is continued this way. Rabinowicz (23) shows that, depending on the nature of the surfaces, the static co-efficient of friction persists for a distance of the order of 10^{-6} m as sliding commences and its magnitude then falls up to a distance of 10^{-5} m when the kinetic component of frictional resistance is reached. This is shown schematically in Fig. 2.2.

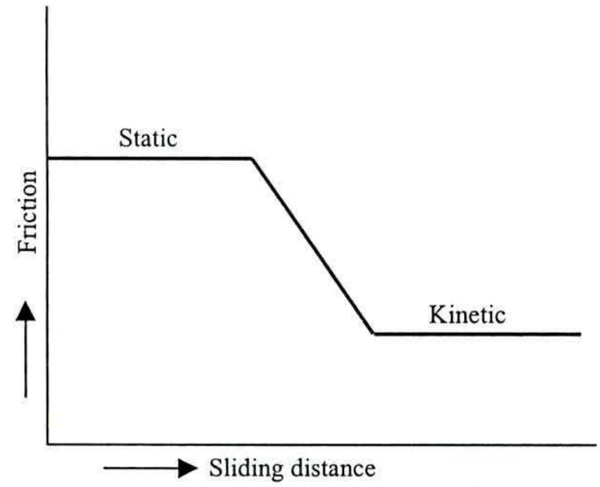


Fig. 2.2 Schematic representation of static and kinetic friction between two surfaces with the onset of sliding. Static friction persists at the beginning of motion but soon falls to the value of the kinetic friction.

Consolidation of the junctions and hence the magnitude of the resistance to sliding depends on the life of the stationary contact, being small when the contact time is measurable in milliseconds and large when this is a few seconds. In a typical tribological situation, the contact time between two sets of interacting asperities is small and, hence, the kinetic fiction should always be lower than the static component which is the force necessary to initiate sliding between two initially stationary surfaces. An increased strength of a static interface under load with time is attributed to a process analogous to creep when the junctions grow in all directions.

❖ Stick-Slip

It follows that, in a sliding situation, a smooth motion giving a steady friction should not be expected. As the asperities adhere during an encounter, the moving parts of a machine should stick followed by a high value of friction. If the external force is maintained and the junctions rupture, the system will slip and the friction will tend to zero. Adhesion of asperities follows the rupture of the interface; that is, the process of stick-slip, inevitably occurs as dissimilar metals slide under load. Similar metal couples also show large fluctuations in friction but these are comparatively slow and very irregular (24).

Frictional effects extend beyond the surface to a depth below, into the bulk material, so that the mechanical properties of an interacting couple would also contribute to the nature of the interfacial forces. Experiments with various metals sliding on steel have shown a dependence of slip on the melting points of the materials.

The nature of the friction traces obtained by Bowden et al (25) is shown schematically in Fig. 2.3.

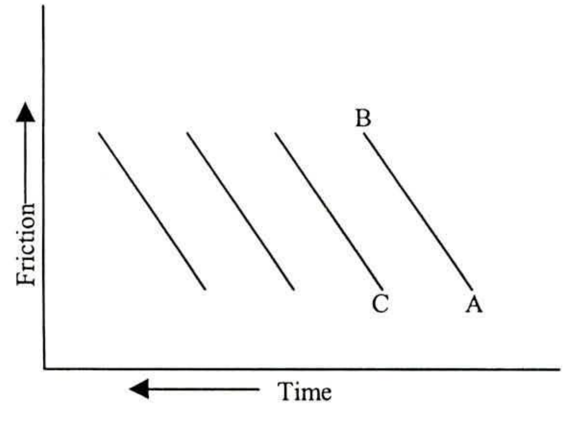


Fig. 2.3 Stick-slip phenomena (25).

With the onset of motion the magnitude of friction increased as shown by AB. It is observed that, during this period, the rider moves forward with the same velocity as the slider. That is, in the time interval A to B the surfaces are sticking. At B, there is a rapid slip between the surfaces and the frictional force diminishes to C. Simultaneous measurement of surface temperature shows that every time a slip movement occurs. There is a sudden rise and fall in temperature, the whole thermal flash lasting for less than a thousandth of a second. This temperature flash and the stick-slip movement continues throughout the experiment.

The high melting point metals, such as molybdenum, cut a grooved track in steel, the width of which is larger and the melting point of the rider is higher. Low melting point metals such as zinc forms a smeared layer on steel surface. Aluminum shows a transitional behaviour in that it both scratches the surface and deposits a layer of metal.

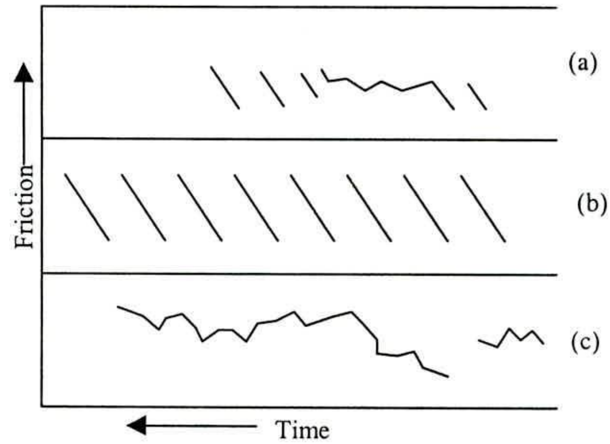


Fig. 2.4 Stick-slip of three different metal combinations. (25) (a) Hard pin on soft surfaces; (b) Soft pin on hard surface; (c) Similar metals.

From detailed experiments, the authors conclude that there are three types of sliding.

(1) When a hard high melting point rider slides on a soft lower melting point metal, the motion is jerky but sudden slip is not so obvious (Fig. 2.4a).

The rider remains unaffected, but a track is torn in the softer metal. It suggests that frictional resistance is due mainly to the ploughing of the softer metal.

(2) When a low melting point metal slides on a hard surface, the motion is jerky and the extent of the rapid slip is much greater (Fig. 2.4b) than that in the first type (Fig. 2.4a). The hard surface is not scratched and the soft metal is smeared over it. It suggests that high contact pressure and frictional heat liberated during rapid slip solders the low melting point metal on to the hard slider. As the surfaces begin to stick, the solders are drawn out thinly until during the next slip when soldering occurs again.

(3) For similar metals, frictional forces are very much higher than those for the last two combinations and large fluctuations are observed (Fig. 2.4c) without any rapid slip. A large groove forms in the flat surface and welding and incipient fusion again occurs causing damage to both surfaces.

❖ Thermal Effect

In 1903, Beilby (26) reported his observation that polishing of metals produced enough frictional heat to result in a surface layer, which was physically different from the bulk of the material. Presence of this Beilby layer, as it was named, was confirmed by Cochrane (27) in 1938 from an analysis of the electron diffraction patterns of polished surfaces. Such surfaces are now known to posses a high dislocation density, giving a disordered structure and are technologically important, as an engine is being run-in because this layer is harder and tougher than the underlying metal (28). Formation of such a surface layer due to polishing has also been confirmed by Bowden and Hughes (29).

Bowden and Ridler (30) show a linear increase in temperature of sliding surfaces with speed or load until the melting temperature of one of the elements forming the couple is reached when the temperature remains at a constant value. Their experimental set up comprised a rotating annular ring upon which a pin was loaded and both the ring and the pin were connected to form a thermocouple. Some typical results obtained by sliding gallium on mild steel is shown in Fig. 2.5 where, on the ordinate, T is the recorded temperature and T_0 is the ambient temperature. That is, $T - T_0$ is the rise in the bulk temperature of the interface as a result of frictional heat generated during sliding.

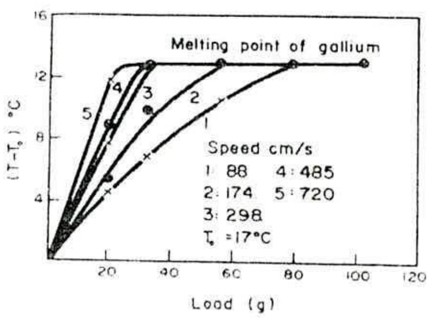


Fig. 2.5 Variation of temperature with load for gallium sliding on mild steel (30).

It is known that there is usually deterioration in mechanical properties of metals as the temperature of the surrounding environment is raised. In consequence, an increase in surface temperature should facilitate plastic flow of the asperities under normal and tangential stresses. Since the metal is weak at high temperature, the critical shear strength of the junctions should fall and a low value of the co-efficient of friction is expected in spite of an increase in the contact area. This is true for most metal combinations with some exceptions. For example, Bowden and Hughes (31) found that, upon sliding gold on gold, the co-efficient of friction rose to a value of the order of 30 at an experimental temperature of about 600^0C. The authors suggest that, since gold is a soft metal, the contact area increases readily resulting in a high frictional resistance. This, unfortunately, poses the embarrassing anomaly that the shear strength of the junctions decreases with a rise in surface temperature.

These experiments bring out an interesting point which is that calculations show that for a 1 mm diameter constantan cylinder sliding at 1m/s on mild steel at a normal load of 100 g, the rise in interface temperature is 75^0C assuming that the whole surface is in contact. However, if the true contact area is $\frac{1}{10}$th of the apparent area, the temperature of the junctions is 414^0C and it is 2372^0C when the fraction is taken as $\frac{1}{100}$. It is permissible to speculate if the rise in friction between metals at high temperature is a result of the highly viscous molten metal or, conversely, a fall in friction is due to the lubricating effect of a fluid film of metal at the interface.

❖ Oxide Film

Theories of friction so far discussed assume that metal junctions are chemically clean before and during interaction, that is, they are free from contaminants. It is possible to clean metals free of grease, but it is a ubiquitous feature that most metals are covered with a layer or more of an oxide in room condition. The effect is that, metal to metal interaction is diluted by a non-plastic medium at the sliding interfaces. Heavy loads may be capable of breaking up the coherency of oxides but, at light loads (32), with metals which can form strong oxides, the frictional resistance is low.

The efficiency of the role of oxidation is controlled by surface preparation, an abraded surface giving lower friction than the one prepared electrolytically. Experiments (33) with a number of metals within a load range of 0.0039 to 10 kg show that presence of oxides does not necessarily mean that frictional forces are low but there is less surface damage. This contradicts the postulate that for the frictional resistance to be high, strong metallic junctions must form giving rough surfaces as they rupture. However, hard metals tend to assume a polished appearance as they slide. They give low values of friction generally (34) and it is known (35) that they undergo considerable plastic interaction.

Experiments (36) in a vacuum of 10^{-6} torr shows that couples give a high value of friction but this falls quickly in about 2 seconds if an amount of oxygen is introduced into the system. As the couples are given prolonged exposure in the oxygen atmosphere, it would appear that an oxide film forms and thickens to a constant value when the co-efficient of friction also settles down at a constant figure. Tingle (37) suggests that it is the oxide films immediately adjacent to the metal surface that decides the magnitude of the frictional resistance and not its thickness, which increases with time.

❖ Sliding between Brittle Surfaces

An oxide is largely brittle and interaction of surface asperities of brittle materials should not give rise to plastic flow, although it has been observed to happen with certain non-metals. In the absence of plastic flow, adhesion of surfaces and the subsequent shearing of junctions would seem unlikely. Byerlee (38) proposes a model where, at an encounter, the asperities fail by brittle tensile fracture rather than by plastic shear. Measured values of the co-efficient of friction with materials such as quartz agree well with calculated values and the co-efficient of friction is found to increase as the surface becomes rougher.

❖ Effect of contaminants on Friction

Real surfaces are contaminated either or both with oxides and atmospheric gases. Contaminants, if non-corrosive, are beneficial from the view point of friction and wear.

An interesting phenomenon is that, at any load, the true area of contact is the same for both lubricated and unlubricated conditions. Growth of the junctions occurs in both cases as a tangential pull is applied although the lubricated junctions cease to grow sooner than the clean areas of contact.

Tabor (39) suggests that a contaminant forms an interfacial layer between the two surfaces whose critical shear stress τ_i is less than τ_m, the critical shear stress of the metal junctions. As long as the applied tangential stress τ_t does not exceed τ_i, the normal and tangential stresses can be transmitted through this interfacial layer to the metal substrate for it to flow plastically. Growth of the points of contact occurs and, when $\tau_t = \tau_i$, sliding commences as the interfacial layer shears.

2.1.3 Temperature and speed

Friction and wear of metals are shown to be governed largely by the interaction of asperities of two sliding surfaces. Energy dissipated due to mechanical work inevitably causes a rise in temperature but it happens intermittently in so far as the points of actual contact are concerned due to sticking and then slipping of the junctions. These temperature flashes are short lived in the order of 10^{-4} second. The heat evolved in friction is dissipated to the surrounding with the result that the asperity tips are at a high temperature but the bulk of the component remains relatively cool. An increase in load or speed raises the temperature of the junctions and, in extreme cases, may cause incipient fusion. There is no simple way of measuring the temperatures of the actual contact areas but the bulk temperature of an interacting couple can be obtained. Since both adhesive and abrasive wear laws incorporate the mechanical properties such as yield stress and hardness of the metal and since both these are affected by the thermal environment, a study of friction and wear at high temperatures is of value. It is also important because rotating parts are required to operate at elevated temperatures.

❖ Temperature

A very useful experiment has been carried out by Lancaster (40) who slid 60/40 brass pins on hard steel rings at room temperature while the couple has been heated by a surrounding furnace. As the temperature was raised, the effect was to increase the rate of wear of the pin, which reached a peak at a characteristic temperature depending upon the normal load (Fig. 2.6). Beyond this peak, there was a fall in the wear rate of the brass. Figure 2.6 shows the rate of wear at a constant load of 2 kg, the ring rotating at a surface speed of 13 mm/s. A low surface speed was employed to keep the frictional heating to a minimum.

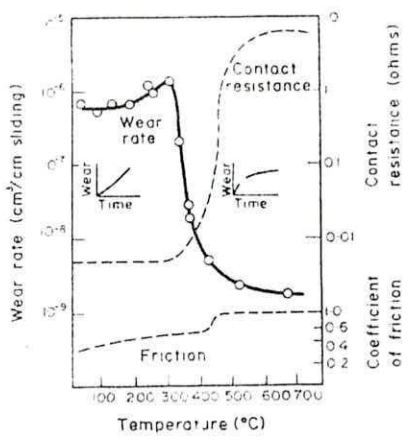


Fig. 2.6 Variation of wear rate with temperature for 60/40 brass on tool steel (40).

The first regime of wear (Fig. 2.6) shows that the contact resistance is nearly constant but there is a small progressive increase in friction. It is shown that, since the hardness of the brass pin decreases with temperature, the rate of wear, being inversely proportional to this mechanical property, increases. An increase in the contact resistance means a decrease in electrical conductivity. This can happen if the metal junctions are diluted by an insulating material such as oxide, the formation of which is facilitated because of the high temperature of the environment. The reason for a sudden rise in the co-efficient of friction is not given.

At any temperature, there is a transition load below which the surface oxides are not completely destroyed and the wear rate is low. Above the transition load, metal to metal contact is extensive and wear is high. The magnitude of the transition load increases with temperature, being 0.2 kg under ambient condition and 6 kg at 350^{0}C. The authors show that the mechanism of wear at any load or temperature is by transfer of brass onto the steel ring and the subsequent detachment of this deposited layer.

Hughes and Spurr (41) have slid wax pins on cast iron discs over a speed range of 1–5 m/s at varying loads from 0.8 – 3 kg. An increase in load and speed caused the temperature to rise and hence the hardness of the pin to fall. The authors measured the hardness of the wax at the resultant temperature given by a particular combination of load and speed. If the rate of wear is now plotted against the reciprocal of this measured hardness, a linear relationship is obtained as shown in Fig. 2.7.

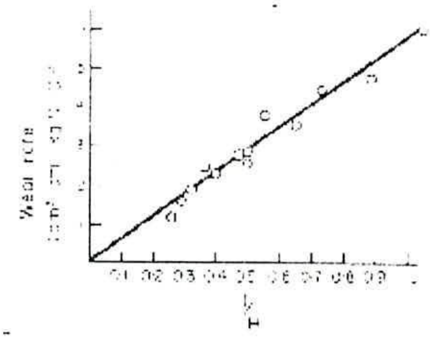


Fig. 2.7 A plot of wear rate against the reciprocal of hardness (41).

❖ Speed

Since the effect of speed causes an increase in temperature of the sliding interface, oxide formation should be facilitated. An increase in temperature also means that the hardness of the metal will decrease so that an increase in the rate of wear should be expected. This is so, if the interface temperature is high enough. Indeed, at very high speeds, melting of the rubbing surfaces is known to occur, the effect being accentuated if the melting point and the thermal conductivity of the material is low (42).

However, the general effect of increasing surface velocity is to cause a reduction in the rate of wear (43) and this is shown in a detailed study of wear of 60/40 brass on steel over a speed range of 0.0001 to 5 m/s using a pin-ring machine (44). The variation of wear rate at a load of 22.5 kg with speed is shown in Fig. 2.7 which shows a fall followed by a rise in the rate of metal loss beyond a speed of about 1 m/s. The authors observed the rate of metal transfer by using radioactive tracer technique and Fig. 2.8 shows that this is the same as the rate of wear.

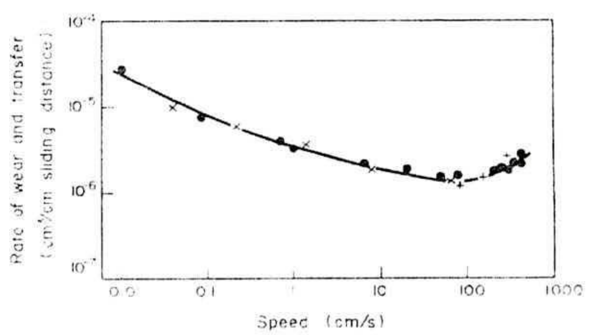


Fig. 2.8 Variation of wear rates and metal transfer with speed. Load 22.5 kg. ●, Rate of wear; x, rate of transfer below 0.65 m/s; + rate of transfer above 0.65 m/s (44).

In other words, the basic mechanism of wear remains unaltered irrespective of the surface speed, that is metal is first transferred to the bush from the pin and wear debris is produced from this deposited layer. To see if it was the effect of a rise in temperature, a set of experiments were conducted where the pin was water cooled. Figure 2.9 shows that in that case the rate of wear continues to fall. Conversely, if the brass was thermally insulated from the pin holder, the increase in wear at the high speed range was greater than that obtained when the pin was not insulated or was water cooled.

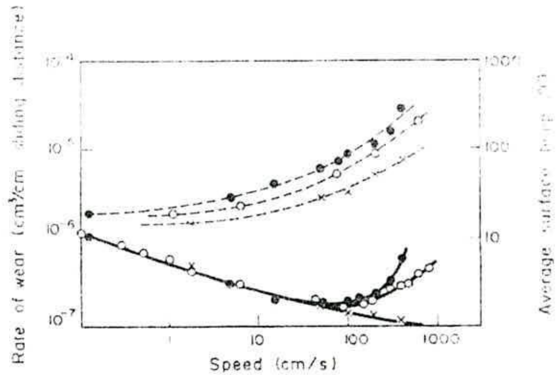


Fig. 2.9 Variation of wear rate and surface temperature with speed for thermally insulated and cooled pins. Load, 3 kg. – wear rate; ----surface temperature; 0, metal pin-holder; x, water-cooled pin holder; ●, thermally insulated pin-holder (44).

Figure 2.9 shows that the temperature, as recorded by a thermocouple 2 mm behind the interface, increases progressively with speed and there is no abrupt rise in temperature at the speed where the rate of wear begins to increase. Calculations suggest that for the water-cooled pins, the flash temperature at the contact points can be as high as 260^0C when the temperature recorded by the thermocouple is 70^0C. These flash temperatures are quite high and there is no sudden rise in temperature at the point of deviation of the rate of wear (Fig. 2.9). The authors therefore discount any direct effect of surface temperature on the mode of wear but suggest that wear rates of brass are governed by two sets of factors:

(1) Those which influence the size of the individual transferred fragment,

(2) Those which determine how frequently they are formed.

Observations in these experiments show that the size of the transferred fragment decreases as the speed is increased as it should be since time is not available for junction growth. Transfer of brass on steel occurs only when the surface of the former has been deformed a critical number of times. This critical number is dependent on speed, being high when the velocity of sliding is increased. This means that the frequency of metal transfer will decrease with increasing surface speed resulting in a progressive fall in the rate of wear. The second effect of speed is to cause a progressive rise in temperature with a concomitant fall in shear strength of the brass, resulting in an increased junction size. A progressive rise in temperature with increased speed, therefore, causes the amount of brass, which is deposited to get larger and, when this overcomes the effect of the frequency of transfer, wear rate increases. Figure 2.9 shows that the rate of wear of the thermally insulated pin rises at a lower surface speed and is also greater than the pins which are cooler.

Cocks (45) attributes the reduced wear rate of metals to the protective effect of oxide films when surfaces interact at high speeds. Several metal combinations were studied at varying loads up to 3 kg on an apparent contact area of 36 mm^2. The surface speed in these experiments was 65 m/s and several couples of like metals such as copper and nickel were used. The other combinations were copper-steel and tungsten carbide sliding on itself. Low rates of wear observed for all couples except nickel on nickel.

Diminished wear rates of copper-tin alloys have been found to be dependent on the amount of tin and this would appear to be due to an alloying effect but oxidation is observed as well, specially at high sliding velocities. Experiments of DeGee et al (46) showed that at a load of 10 kg and a surface speed of 1m/s, for test runs each lasting 2 hours, the weight loss of a 12% tin-copper alloy was about one half of the alloy containing 5% tin.

It was observed (47) that the general effect of sliding steel on bronze was the pick-up of the latter by the former, particularly at high loads. Frictional heating occurred at high sliding velocities and oxides, probably of copper, were apparent particularly at high loads. Electron micro-probe analysis of the transferred layer on the steel after it had slid for 100m showed the composition to be 62 – 74% copper, 10 – 25% iron, 5 – 6% tin and about 10% oxygen. The bronze itself had 10.6% tin and 0.6% phosphorus. The total wear at a velocity of 1 m/s was about ¼ of that at 70 cm/s and the amount of bronze transferred to the steel increased with sliding velocity. As in the case of brass on steel, the transferred material was harder than the original metal. Films of oxide formed at the sliding interface and a reduction in the rate of wear was noted.

2.1.4 Friction and Oscillations

Friction and oscillations are closely related. Friction is capable of generating oscillation, and oscillation has influence on friction (48). The analysis of the phenomena taking place in the friction contact that the friction force is mainly formed by a load normal to the rubbing surface and by the corresponding normal contact deformation (Amonton's law) (49). Oscillation in a complex elastic system is interdependent, that is, oscillation of slider will create oscillation to the rubbing surface (50). Again when one kind (longitudinal) of oscillation occurs then other types (both longitudinal and transverse) usually take place too (51). This interdependence is determined by how close the natural frequencies of the respective oscillations are and by the character of their relation. If a sliding body (usually referred to as a slider) has a height that is not much greater than its transverse dimensions, the elastic compliance of the slider in the normal direction is lower than the compliance of the contact layer, the latter being a layer formed by the peaks and valleys of micro irregularities of the rubbing surfaces (52). In this case, the slider is roughly similar to an absolutely rigid body that rests on a number of minute springs, which simulate the peaks of surface irregularities. Some of these are in contact and carry the normal load, while others, the smaller ones, are out of contact. Any casual normally directed pulse acting on the slider will cause its free oscillations in the normal direction. These oscillations are non-linear and asymmetrical, because more and more new smaller peaks come into contact as the slider moves downwards. An increase in the amplitude of these oscillations causes the mean level of the slider over the counterface to rise and thereby the total real contact area to decrease. As the slider moves along the counterface, its surface asperities receive micro pulses from the asperities of the counterface. The normal components of these micro pulses continuously generate the oscillations of the slider as a whole in the normal direction. Because the amplitude of these oscillations is small (micrometers or their fractions), the fundamental oscillation frequency is very near the natural frequency of linear oscillations. The oscillations considered, being asymmetrical, lift the slider and reduce the friction force (53). The higher the speed of sliding, the more intensive are the normal components of the micro pulses between the surface asperities, and hence the greater is the amplitude of the oscillations, the higher is the mean level of the slider movement, the smaller the real contact area, and the weaker the friction force. That may explain the drooping of the friction force-speed characteristic, that is, reduction in the friction force with increase in the speed of sliding in the absence of lubrication. To sum up, the force of dynamic sliding friction is always the same, it is weakened by the contact oscillations generated by micro asperities whose amplitudes are one tenths to hundredths of micro-metres (54, 55). To reduce friction, use is made of normally-directed forced oscillations whose frequencies are usually very different from the contact resonant frequency. For this reason a tangible reduction of friction force requires the application of powerful vibrators. It must be borne in mind that in actual tribological joints the character of the normal oscillations is determined, strictly speaking, not only by the contact rigidity of the rubbing interface ("friction rigidity"), but also by the rigidity of the joints components, their arrangement, etc (56). Therefore resonance effects sometimes can be observed at various frequencies.

2.2 Wear and wear mechanism

2.2.1 Wear

Wear processes in metals have been classified into many types depending on the mechanism responsible for removal of material from surfaces. Thus corrosive wear implies the formation of loosely held fragments and their subsequent detachment when two bodies are in relative motion. Whatever the nature of the geometry of movement or the environment, it would appear that most wear processes involve adhesion of asperities and the subsequent shearing of the junctions or a direct process of abrasion of a soft surface by a hard material.

❖ Types of Wear

A potential wear situation exists whenever there is relative motion between two solids under load. Broadly speaking, the motion can be unidirectional or reciprocating - either sliding or rolling. It would be a combination of rolling and sliding or wear may occur due to oscillatory movement at small amplitudes. A metal can interact with a non-metal or liquids such as lubricating oil or marine water. Depending on the nature of movement or of the media involved in an interaction under load, the following types of wear have been classified.

✧ Adhesive wear

In this, the relative movement can be unidirectional or reciprocating, sliding or interaction occurs under small amplitude oscillatory contact under load. The mating surface peaks are known to flow plastically and to form strong work hardened junctions. As these break under an imposed tangential traction, material loss from the solids may occur.

✧ Abrasive Wear

Abrasive particles in the form of wear debris or adventitious particles of grit and dust from the surroundings remain trapped at the sliding interface and remove material largely by ploughing.

✧ Other Forms of Wear

Fretting is a form of wear which occurs as a result of oscillatory movement between two surfaces as in machine parts undergoing vibration. Fatigue wear arises as a result of cyclic loading, for example, in rolling element bearings and loss of materials occurs by spelling of surface layers. Erosive wear results when grits impinge on solids while cavitation erosion may arise when a component rotates in a fluid medium.

❖ Wear Curve

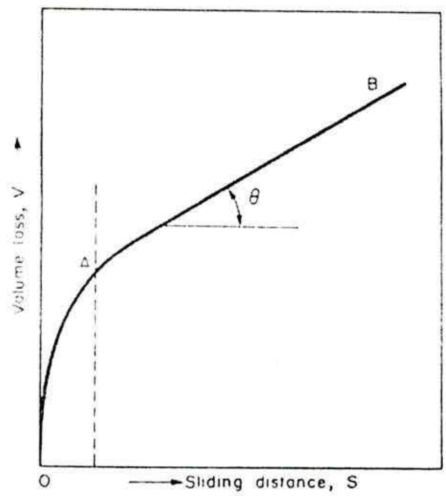


Fig. 2.10 The pattern of a typical wear curve 0A is curvilinear and is the running-in wear. AB is linear and is the steady state wear. Tan θ measures the rate of wear in loss of volume per unit sliding distance.

If volume or weight loss is plotted continuously with sliding distance a characteristic curve is obtained as shown in Fig. 2.10. The point 0 is when a machine starts, that is when the sliding distance is zero. The weight loss is initially curvilinear and the rate of weight or volume loss per unit sliding distance decreases until at A where it joins smoothly with the straight line AB. The amount of volume loss in the regime given by 0A is the running-in wear and AB is the steady state. The slope of the linear steady state regime is used to express the wear rate of a material per unit sliding distance and, at a given load and speed, it is constant for a material depending on the nature of the other surface. The pattern of the curve as in Fig. 2.10 has been shown to be the same in actual machine parts and there is due emphasis on the importance of running-in before a sliding component takes up its full load during its life of operation.

❖ Wear Mechanism

Surfaces under counter formal contact, for example a hemispherical pin on a bush, create a situation where the load is concentrated on a parallel narrow band of highly stressed metal (57). The soft member of the couple will flow plastically and the area of contact will grow into an equilibrium size commensurate with the applied load. If both the metals are hard, the high spots will also be removed by some mechanism and again the surface undulations will take up a flat appearance as the area of true contact increases. That is, the surfaces have reached an equilibrium state and they have run-in (58). It is not certain if a run-in condition can be completely achieved once an equilibrium area of contact has been established. It is known (59) that gross surface flow occurs when sliding commences even at a moderate load causing an increase in the hardness of the interface. A work hardened zone also forms below the surface and there is evidence of formation of strongly adherent oxides, which protect machine parts from gross distress in service. For example, electron diffraction shows that the run-in surfaces of cast iron piston rings and cylinders possess an oxide layer and there is the presence of graphite flakes, which are oriented with their cleavage, planes parallel to the surface (60). The mechanisms of running-in wear are probably governed by a large number of interrelated factors and should be a field for further research.

2.3 Surface topography

Prior knowledge on the nature of surfaces is very important to understand the mode of interfacial interaction between moving parts of machinery. An important aspect of surfaces is whether they are free from atmospheric contaminants or oxides. On the other hand, it may be necessary to know whether a surface is soft or hard. Above all, the lack of flatness of a surface on a microscopic scale has been shown to be the basic parameter to understand the mechanism of friction and wear.

❖ Asperities

A perfectly flat surface as shown in Fig. 2.11a is never achieved by the usual methods of surface preparation such as machining, grinding, lapping, and the like. Instead, surfaces have asperities, that is undulations in the form of hills and valleys. Fig. 2.11 shows that the surfaces b – e have protuberances that are all of the same depth but the wave length is macro-geometrical as in b or micro-geometrical (fig. 2.11e). Figure 2.11b shows that the asperities have a large wave length and such a surface is described as smooth but not flat. Figure 2.11e has many protuberances of short wave length and a surface like this is deemed to be flat but rough. The nature of surfaces with roughness in between Fig. 2.11b and e are shown in Fig. 2.11 c and d. The actual engineering surfaces, depends on the method of production, the height of the peaks may vary between 0.05 μm to 50 μm while the spacing between them range form 0.5 μm to 5 mm.

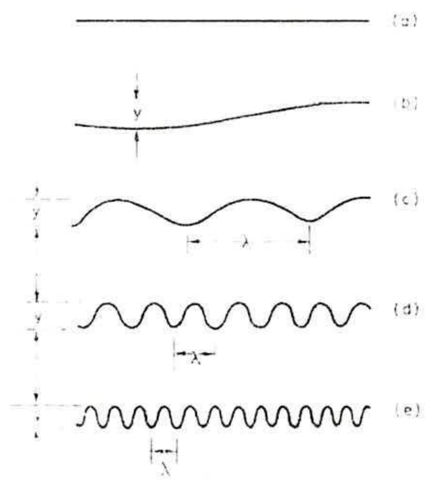


Fig. 2.11 Idealised traces of surface asperities showing the same peak to valley height but differing wavelengths.

❖ Asperity Angle

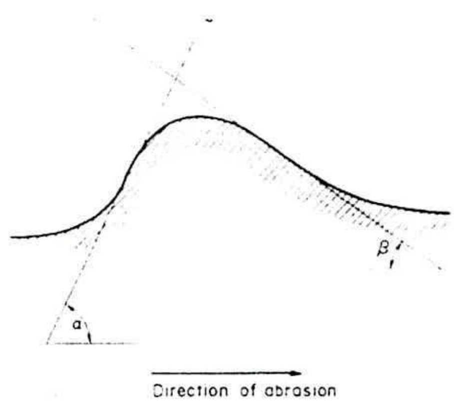


Fig. 2.12 Asperity slopes of an abraded surface (61).

Halliday (61) has measured the angles of surface asperities with the aid of reflection electron microscopy by viewing the surface as obliquely as possible so that the asperities are seen in profile. Abraded surfaces often show an asperity to slope at different angles to the surface from two directions. Figure 2.12 shows the nature of the asperity slopes where the angle α falling ahead of the abrading particle is always greater than β. For copper, α and β were found to be 2.5 and 1^0 respectively, being much smaller than this, about 0.1^0, for tool steel. Abraded mild steel showed α and β to be the same at 2^0. Asperity angles play a positive role in the mode of deformation of metals when relative movement of surfaces under load ensues and often an average value of 5^0 is taken, assuming $\alpha = \beta$.

❖ Contact of Solids

If a surface is pressed upon another, the load is supported on the tips of a few peaks of the bottom surface, assuming that the top member of the couple is perfectly flat. There is thus an apparent area of the interface between two surfaces but the true area of contact is only at a few points at the tips of the asperities. If the load is low and the material has a high yield strength, contact will be elastic. On the other hand, for the opposite case, the interface will flow plastically. Both modes of behaviour appear to occur in the kinematic interface of most tribological situations and both friction and wear processes in metals and materials have a dependence on the nature of the true area of contact of the mating surfaces.

CHAPTER – III

❖ Experimental Setup

EXPERIMENTAL SETUP

3.1 Introduction:

The setup is essentially a modified version of the pin disc machine (fig. 3.1), where the pin is loaded normally. In this setup, a circular mild steel test sample (disc) is fixed on a rotating table. Weights are placed on the load arm in such a way that it can directly act at the tip of the pin. The major feature in the present machine is the vibration generating system. Relative linear velocity of the pin can also be varied by changing the location of the pin on the disc.

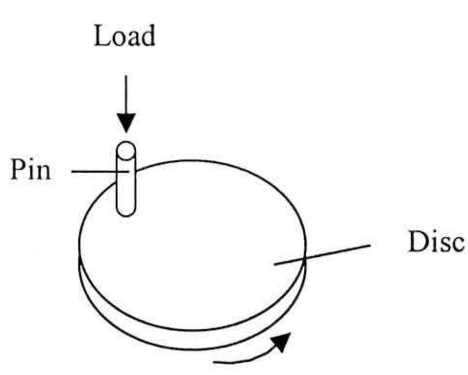


Figure 3.1 : A pin-disc machine

To rotate the table with test sample on it, a set of pulleys, V-belt and electric motor are used. When the motor starts, rotation of the motor is transmitted to the table through V-belts and shafts. In this setup a mechanism is incorporated to generate vibration.

3.2 Components of the set up:

A schematic diagram of the experimental setup is shown in figure 3.2 and a photograph of the setup is shown in figure 3.3.

This setup comprises of,

(a) Basic structure

(b) Rotation and vibration generating mechanism of the table

(c) Loading and load measuring mechanism

3.2.1 Basic structure

The components of the basic structure are shown in figure 3.3. These are:

(1) Main Base

(2) Stands

(3) Middle rectangular plate

(4) Upper rectangular plate

(5) Motor Base

The basic structure is used to support the rotating table, test sample, motor, pulley, shafts and the vibrating mechanism.

3.2.2 Rotation and vibration mechanism

Components of the rotating and vibration generating mechanism are shown in figure 3.3. These are:

(6) Main shaft

(7) Compression spring

(8) Spring holder

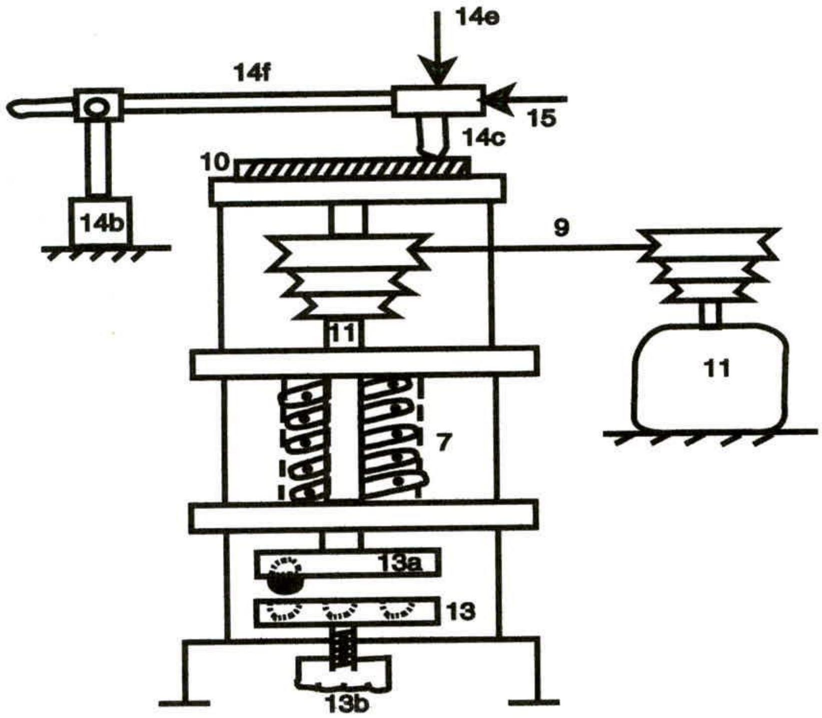
(9) V-belt with pulleys

(10) Rotating table with the facility of clamping the test plate on the table

(11) Motor

(12) Motor adjusting screw

(13) Adjustable vibration generating system



Normal load (14e)
Spring balance (15)
Pin sample (14c)
Test disc (10)
Load arm (14f)
Load arm holder (14b)
V-belt & Pulleys (9)
Motor (11)
Compression spring (7)
Main shaft (6)
Upper circular plate (13a)
Lower circular plate (13)
Height adjustable screw (13b)

Figure 3.2 : Schematic diagram of the experimental setup.

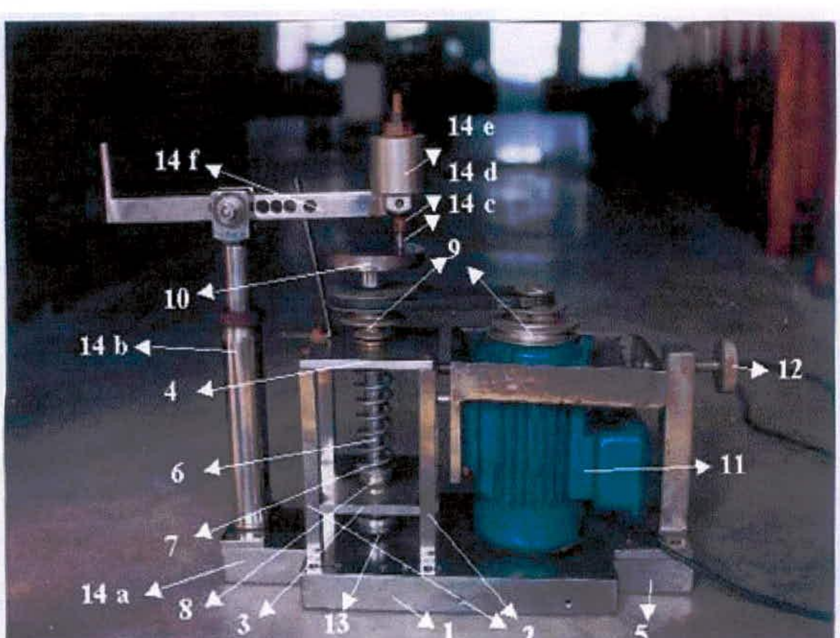


Figure 3.3 : Experimental setup

Figure 3.4 : Construction of load arm.

Rotation of motor is directly transmitted to the rotating table through pulley and V-belt. Two sets of compound pulleys are arranged– one with motor shaft and another with the shaft of the rotating table. For different speed, different combinations of pulleys are connected by V-belt. To change speeds different sets of pulleys on the motor shaft and the rotating table are engaged. During this changed position, the motor needs some adjustment which is done by the motor adjusting screw. Three rotational speeds of the table can be achieved– these are 642, 1000 and 1500 rpm.

Linear velocity of the pin can be varied:

1. By changing rotational speed, which can be done by using different combinations of pulleys and V-belt.

2. By changing the location of the pin on the disc.

   For generating vibration of the rotating table, a plate with a ball at its lower surface (upper plate) and compression spring are fixed with the main shaft. A second plate (lower circular plate, part no. 13, figure-3.2) is fixed with the base with the help of a height adjusting screw. This plate has some slots. When the motor is not rotating, the compression spring pushes the shaft downward and the upper plate goes down. Therefore, the ball exerts pressure on the lower plate. During rotation of the shaft this ball also rotates on the slotted lower plate. Due to the combined effect of compression spring and the movement of the ball on the slotted plate, a vibration of the shaft as well as the table is generated. By adjusting the height of the lower plate (slotted plate), the amplitude of vibration can be varied. By varying the rpm of the rotating shaft (rotating table) the frequency of vibration can also be varied.

3.2.3 Loading and load measuring mechanism

Loading and load measuring mechanism (shown in figures 3.3 and 3.4) consists of:

(14). Load and pin holding arm

- (14a). Load arm base
- (14b). Load arm holder
- (14c). Pin
- (14d). Pin holder
- (14e). Load
- (14f). Load holder

The load arm holder (14b) is placed on two bearings so that it can be rotated almost without friction, that is, the load arm can rotate about the pivoted point without friction. To avoid error due to friction, load applied on the pin is directly measured at the tip of the pin. Dead weights to create normal loads of 9.81, 12.75 and 17.66 N are used for the tests. A calibrated spring is connected to the load arm to measure the frictional force.

3.3 Adjustment of Relative Humidity

The whole experimental setup was covered by a box made of perspex (Fig. 3.5). The relative humidity of the environment inside the box was measured by a digital hygrometer. Water vapour produced from water in a closed and insulated vessel by heating with Bunsen burner was used to control the humidity inside the perspex box. A pipe was connected through a small opening of the closed vessel and the perspex box of the experimental setup. Vapour of varying amount from this heating chamber was introduced into the perspex box of the experimental setup. Therefore, the relative humidity around the experimental setup was changed to a different level.

3.4 Measuring equipment

Measuring equipment used are:

(a) Tachometer,

(b) Hygrometer,

(c) Digital vibration meter,

(d) Electronic balance,

(e) Digital stop watch,

(f) Spring balance

3.5 Test sample preparation

Mild steel was used as a test material for pin and disc sample (figure 3.6). Two types of surface-finish were considered for the test-disc sample, such as, 'as-ground' and 'as-turned'. Twenty pieces of test-disc were used for turning condition and another twenty pieces of 'as-ground' test-disc were used for ground condition. During the test, similar roughness was maintained for 'as-turned' and 'as-ground' plates.

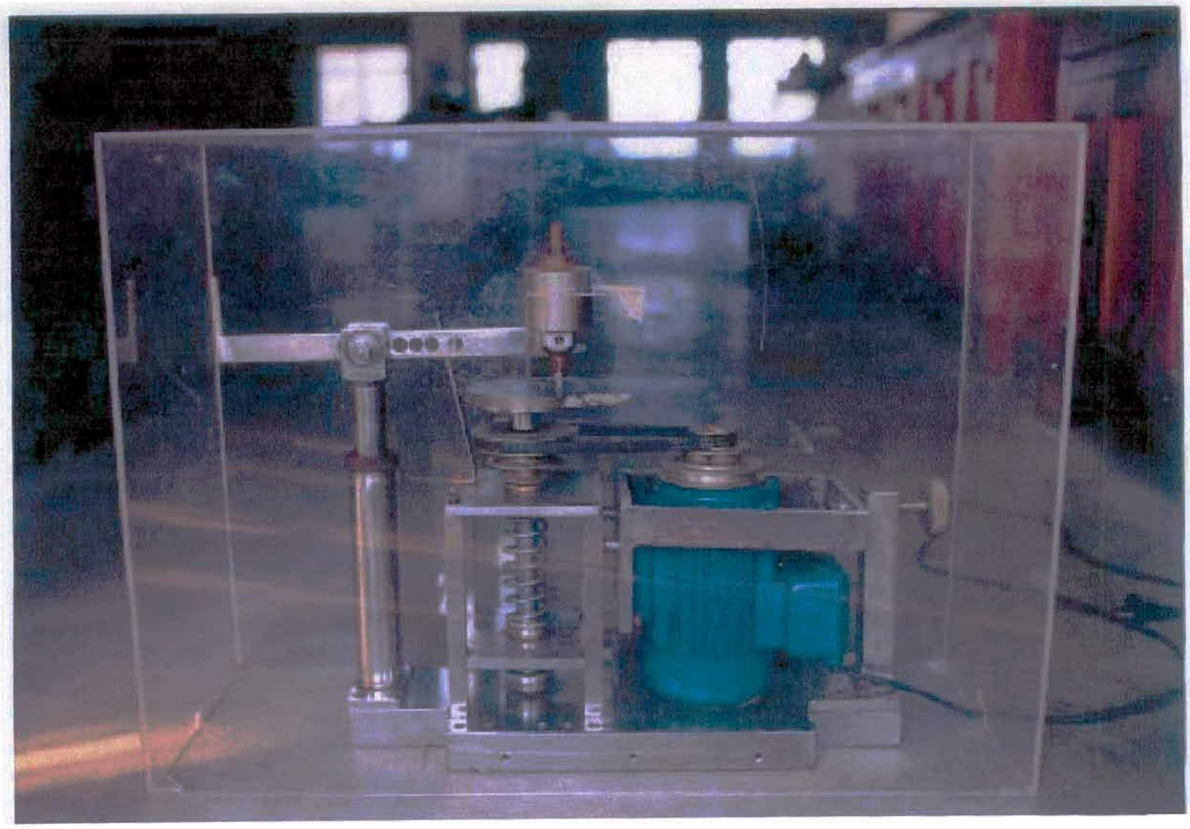


Figure 3.5 : Pin on disc wear-testing machine within perspex-box cover

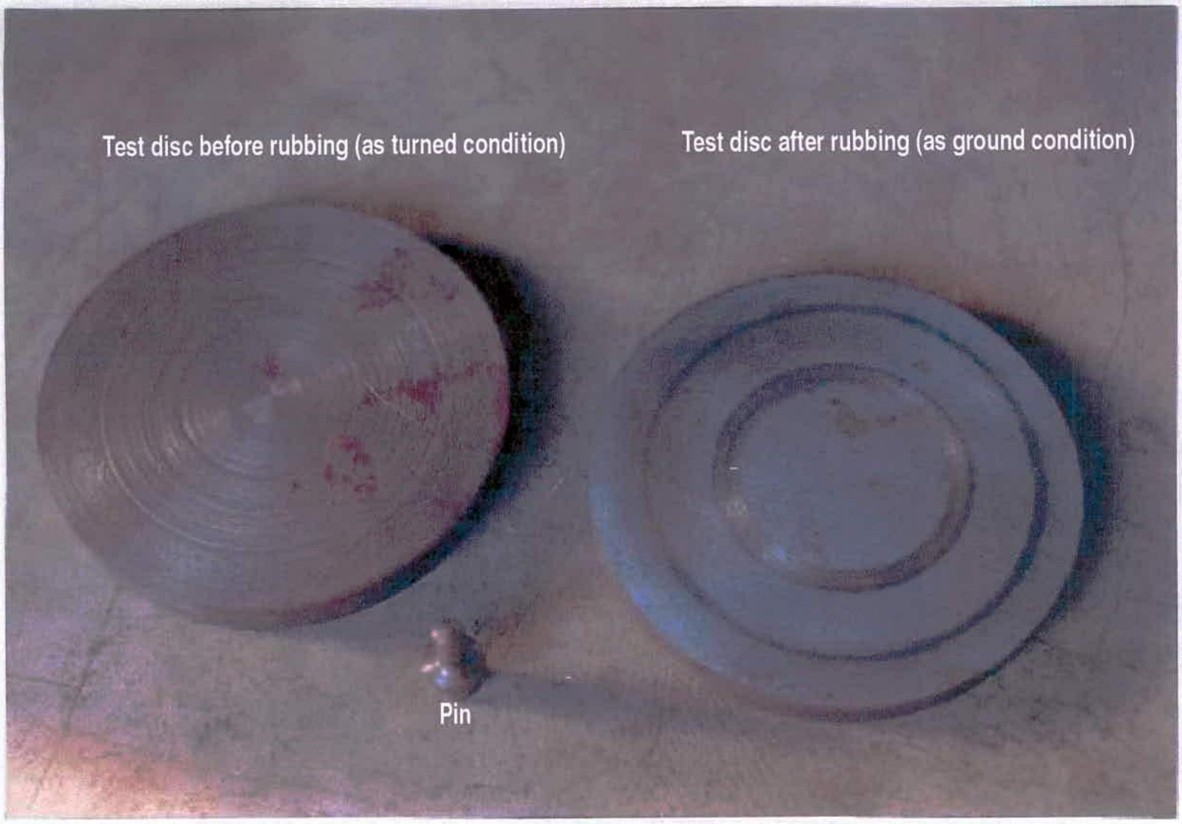


Figure 3.6 : Test disc and pin sample (mild steel)

CHAPTER – IV

❖ Experimental Procedure

EXPERIMENTAL PROCEDURE

4.1 The test procedure for measuring frictional force (without vibration)

a) For conducting test for friction co-efficient without vibration, the experimental setup was first placed on a table.

b) Two types of test-disc of different surface-finish were used for test. The surface-finishes were 'as-turned' and 'as-ground'.

c) The test-disc was clamped with the rotating table by two screws.

d) Cylindrical pin was clamped with the pin holder by a screw and the pin holder was attached to the load arm. Cylindrical pins were used because, during rubbing, due to wear, the area of contact could change if the pin was not cylindrical.

e) Dead weights of 9.81, 12.75 and 17.66 N were used to apply normal load for test. These dead weights were placed on the load arm in such a way that the load acts directly on the pin. To find out the probable frictional loss at the fulcrum, the load arm with the normal load was calibrated. These calibrations were done by putting the pin on a electronic balance, directly, keeping the load arm horizontal. The reading in the electronic balance provided the actual normal load applied on the discs.

f) Linear velocity of the pin was varied by two methods:

   (i) Two vertical stepped pulleys were arranged, one with the motor shaft and the other with the shaft of rotating table. For different rpm, different steps of the two pulleys were connected by a V-belt. Three rotational speeds of 642, 1000 and 1500 rpm were used in the test.

(ii) Linear velocity was also varied by changing the location of the pin on the disc. This could be done by adjusting the length of the load arm.

The rpm was measured with a digital tachometer.

g) When the motor started, due to friction between the plate and the pin, the load on the pin became inclined with the vertical along the direction of rotation. A stopper was fixed to stop the inclination of the load arm. A spring was used to resist the frictional force acting on the pin under the load. Due to this frictional force, the spring was compressed. From the change of length of the spring, the resisting force was calculated. The load deflection relation of the spring was measured during its calibration.

h) The reading for frictional force was taken at an interval of one minute up to 5 minutes for each plate. Duration of rubbing was measured by digital stopwatch.

i) For every set of reading of frictional force, a new pin was used.

j) Friction co-efficient was measured from the ratio of frictional force to normal force.

4.2 Measurement of wear rate (Without vibration):

a) The initial weight of pin sample was taken by digital electronic balance.

b) Duration of rubbing was considered 5 minutes for each pin.

c) After rubbing, the final weight of pin sample was measured by digital electronic balance.

d) Wear rate was measured by taking weight of pin sample before and after rubbing.

e) For every set of readings for measuring wear rate, a new pin was used.

4.3 Measurement of frictional force and wear (with vibration):

When vibration was taken in consideration, the following extra arrangement, in addition to the above, was made:

In this experimental setup, two circular plates (upper and lower, Article- 3.2.2) are used to generate vibration. When the lower plate is turned down so that the upper and lower plates are not in contact, there was no vibration. When lower plate is raised upward by rotating a screw, the slots engraved in the lower plate create disturbance to the rotation of the ball, fixed at the bottom surface of the upper plate, and hence vibration is generated. The amplitude of vibration of the plate depends on the amount of upward movement of the lower plate. The values of displacement, velocity and acceleration were directly measured by digital vibration meter.

CHAPTER – V

❖ Results and Discussions

RESULTS AND DISCUSSION

5.1 Analysis of friction co-efficient:

Figure 5.1 shows the effects of the duration of rubbing on the value of friction co-efficient. The surfaces of the samples were made by turning and the linear velocity was 1.51 m/s. This figure was drawn using the data shown in table 1, 19, 109, 123, 137 and 151. Curves were drawn for different relative humidity with frequency of vibration 0 and 128.4 Hz (Acceleration = 1.08g, Displacement = 0.322 mm, and Velocity = 1.58 cm/s).

Curve 1 of this figure shows the variation of friction co-efficient at 0 Hz and 60% relative humidity. The value of friction co-efficient varies between 0.30 and 0.60 with duration of rubbing. From curve 1, it is also observed that, under the test condition, friction co-efficient increases linearly up to 0.50 over a duration of 3 minutes of rubbing and after that it remains constant. Curve 2 shows the variation of friction co-efficient at a vibration of 0 Hz and 70% relative humidity. The value of friction co-efficient varies here from 0.27 to 0.54. In curve 2, under test condition, friction co-efficient increases linearly upto 0.45 in a duration of 3 minutes of rubbing and, after that, it remains constant. Curve 3 shows the variation of friction co-efficient at 80% relative humidity. This curve also shows the same trend as that of the above two curves. All other parameters for these three curves were identical. The initial increase of friction co-efficient might be due to increase of roughness during rubbing which might be the effect of the removal of material from the surfaces. Increase of surface temperature might have some role on this removal of material as well. After a certain duration of rubbing, the increase of roughness may become steady, and hence the values of friction co-efficient remain unchanged. In these three curves it is also seen that the values of friction co-efficient decreases with the increase of relative humidity. The increase of relative humidity might moisten the test disc surface which might have some lubricating effect and hence, the resistivity was reduced. Therefore, it can be concluded that, with the increase of relative humidity, the value of friction co-efficient decreases. This finding may be considered similar to the findings of Yasuo Imada (10). He also showed similar relation between friction co-efficient and relative humidity for mild steel. In case of Sn (9) and Ceramic materials (11), friction co-efficient decreases with the increase of relative humidity.

Curve 1 of figure 5.1 was drawn at a vibration of 0 Hz and 60% relative humidity. Curve 4 was drawn at a vibration of 128.4 Hz and 60% relative humidity. The value of friction co-efficient varies from 0.27 to 0.55 in curve 4. From this curve it is observed that under this test condition friction co-efficient increases linearly up to 0.46 in a duration of 3 minutes of rubbing and after that it remains constant. These two curves show the variation of friction co-efficient at vibration of 0 and 128.4 Hz over a certain duration of rubbing. From these two curves, it can be concluded that friction co-efficient is more at a vibration of 0 Hz (0.30 to 0.60) than that at a vibration of 128.4 Hz(0.27 to 0.55) . This might be due to the reduction of rubbing surface, because there is always more separation between these two surfaces due to vibration of higher frequency (53).

Curves 2 and 5 of fig. 5.1 correspond to 70% relative humidity and vibrations of 0 and 128.4 Hz. The value of friction co-efficient in curve 5 varies from 0.24 to 0.48. It is observed that friction co-efficient is more at a vibration of 0 Hz (0.27 to 0.54) than that at 128.4 Hz (0.24 to 0.48). Similarly curve 3 and 6 show the variation of the value of friction co-efficient at 0 and 128.4 Hz and 80% relative humidity. The value of friction co-efficient in curve 6 varies from 0.21 to 0.42. It is also seen that friction co-efficient is more at 0 Hz (0.23 to 0.48) than that at 128.4 Hz (0.21 to 0.42). Thus, it can be concluded that friction co-efficient is more at 0 Hz than that at 128.4 Hz. From these two curves it is also observed that the values of friction co-efficient decreases with increasing of relative humidity.

Figs. 5.2 and 5.3 correspond to similar data as of fig. 5.1; only the rubbing speed is different. The variations of friction co-efficient with linear velocities are shown in figures 5.4 to 5.6. These figures were drawn using the data shown in tables 3, 21, 125, 139 and 153. Friction co-efficient varies from 0.30 to 0.60 for linear velocity 1.51 m/s, 0.25 to 0.64 for 0.874 m/s and from 0.22 to 0.67 for 0.336m/s. These values are obtained under at 0 Hz and 60% relative humidity. At linear velocity 1.51 m/s, friction co-efficient varies from 0.27 to 0.55, at 0.874 m/s, it is 0.23 to 0.59 and at 0.336 m/s, it is 0.20 to 0.62 (for vibration). Therefore, it can be concluded that the rate of increase of friction co-efficient is more at lower linear velocity than that at higher velocity. During the tests it was observed that friction co-efficient was high at static condition. With the increase of speed the values of friction co-efficient reduce gradually. Therefore, at lower speed fictional co-efficient is higher than that at higher speed. In both the cases, the times to reach maximum value were the same. So, the rate of increase is higher at lower speed, as observed during the above tests. All the results mentioned above were obtained for mild steel plate of 'as-turned' surface. Similar experiments were done on mild steel specimens of ground-surface. The variation of friction co-efficient with vibration of different Hz, relative humidity, speed (as before) are shown in figs. 5.7 to 5.12. These figures are drawn using data shown in tables 4 to 6, 22 to 24, 112 to114, 126 to128, 140 to142 and 154 to 156. Curves drawn for 'as-turned' surface and 'as-ground' surface show similar trend. But the values of friction co-efficient are less in case of 'as-ground' surface, compared to 'as-turned' surface. It is also observed that the values of friction co-efficient of ground-surface is 40 to 45% of that of turned-surface of mild steel. This might be due to less number of asperities in 'as-ground' surface compared to that in 'as-turned' surface.

Different experiments were carried out to investigate the effect of normal load on the friction co-efficient. Results of these experiments are presented in tables 7, 10, 13, 16, 25, 28, 31, 34, 115 to118, 129 to 132, 143 to 146 and 157 to 160. Using these tables, figures 5.13 to 5.16 were drawn. From curve 1 of figures 5.1, 5.7 and 5.9, it is seen that the values of friction co-efficient at 9.81, 12.75 and 17.66 N of normal load and at 0 Hz varies from 0.30 to 0.60 for 'as-turned' surface and 0.13 to 0.17 for 'as-ground' surface. Similarly, the co-efficient at higher Hz varies from 0.27 to 0.55 under 'as-turned' condition and 9.81,12.75 and 17.66 N and 0.15 to 0.31 for ground-surface. Therefore, friction co-efficient is not effected by the normal load, as already established by different authors and by Amonton's second law.

To observe the effect of frequency of vibration on the friction co-efficient, different experiments were carried out. For this purpose, three values of frequency (128.4, 200 and 300 Hz) were selected. The results are presented in tables 37, 40, 55, 58, 73, 76, 91, 94, 119 to122, 133 to 136, 147 to 150 and161 to 164. Using these tables, figs. 5.17 – 5.32 were drawn. From the tables and figures, it was observed that when the frequency of vibration is 128.4 Hz, the difference of friction co-efficient between vibration of 0 and 128.4 Hz is 7-10%, for 0 and 200 Hz 11-15% and for 0 and 300 Hz 20 - 25%. That means, the more the frequency of vibration, the more the difference of friction co-efficient between vibration of 0 and higher Hz. This might be due to the more the frequency, more the time during which two rubbing surfaces do not remain in contact.

5.2 Analysis of wear rate:

Wear rates are observed in relation to relative humidity, with and without vibration and rubbing speed. Figure 5.33 has been drawn using data shown in tables 1 to 3, 19 to 21, 109 to 111, 123 to 125, 137 to 139 and 151 to 153. Curve 1 of this figure shows that at 0 Hz, wear rate varies from 0.0096 to 0.012 g/m for 80 to 60% relative humidity and with vibration of 128.4 Hz, 0.00852 to 0.01065 g/m (curve 4). That means that wear rate increases with decreasing relative humidity. From these two curves it can be also concluded that wear rate is more for a vibration of 0 Hz condition (0.0096 to 0.012 g/m) than that of a vibration of 128.4 Hz (0.00852 to 0.01065 g/m). For 0.874 m/s, the value of wear rate with vibration 0 Hz varies from 0.007 to 0.0056 g/m and with vibration of 128.4 Hz, 0.00625 to 0.0050 g/m. Similarly, for a linear velocity of 0.336 m/s the value of wear rate with a vibration of 0 Hz varies from 0.0025 to 0.0020 g/m and with a vibration of 128.4 Hz, 0.00225 to 0.0018 g/m. This result shows that the values of wear rate increase with the increasing linear velocity. This is due to the fact that duration of rubbing is the same for all linear velocities, while the length of rubbing is more in case of higher speed.

The above mentioned results are considered for mild steel plate with 'as-turned' surface. The same experiments have been carried out for 'as-ground' surface and are presented in tables 4 to 6, 22 to 24, 112 to 114, 126 to 128, 140 to142 and 154 to 156. Figure 5.34 is an outcome of these tables. Curves drawn for 'as-turned' and 'as-ground' surface conditions show a similar behaviour. The values are relatively lower for 'as-ground' surfaces than that of 'as-turned' surfaces. It is seen that the values of wear rate are 44% less for ground-surface compared to that of the turned-surface.

To investigate the effect of frequency of vibration on wear rate different experiments have been carried out. They are presented in figures 5.35 to 5.38.

These figures are drawn using the data shown in tables 37 to 42, 55 to 60, 73 to 78, 91 to 96, 109 to 114, 119 to 128, 133 to 142, 147 to 156 and 161 to 164. One can readily see from the above mentioned tables and figures that the difference of wear rate with vibration of 0 and higher Hz increases with increasing the frequency of vibration. The variation of average wear rate with frequency of vibration of 0 to 128.4 Hz is 13% , for 0 and 200 Hz 20% and for 0 and 300 Hz 23%. This result is supported by the M.D. Bryant, A. Tewari and D. York (62). They showed in their investigation that micro-vibrations could reduce sliding wear by 50%.

The effects of normal loads on wear rate are investigated by using fig. 5.39 and 5.40. These figures are drawn using data shown in table 1 to 36. Curve 1 of figure 5.39 shows that the values of wear rate (for 'as-turned' surface) with vibration of 0 Hz varies from 0.0074 to 0.0133 g/m for 9.81 to 17.66 N normal load. For the same loading, values of wear rate varies from 0.0066 to 0.01178 g/m with a vibration frequency of 128.4 Hz (curve 4). The above values for 9.81 to 17.66 N normal load with a vibration of 0 Hz and 'as-ground' surface varies from 0.00404 to 0.00742 g/m and with a vibration of 128.4 Hz from 0.00368 to 0.00658 g/m. From these curves it can be concluded that the values of wear rate increases with increasing normal loads under identical conditions and that the volume of material removed due to sliding is directly proportional to the applied normal load.

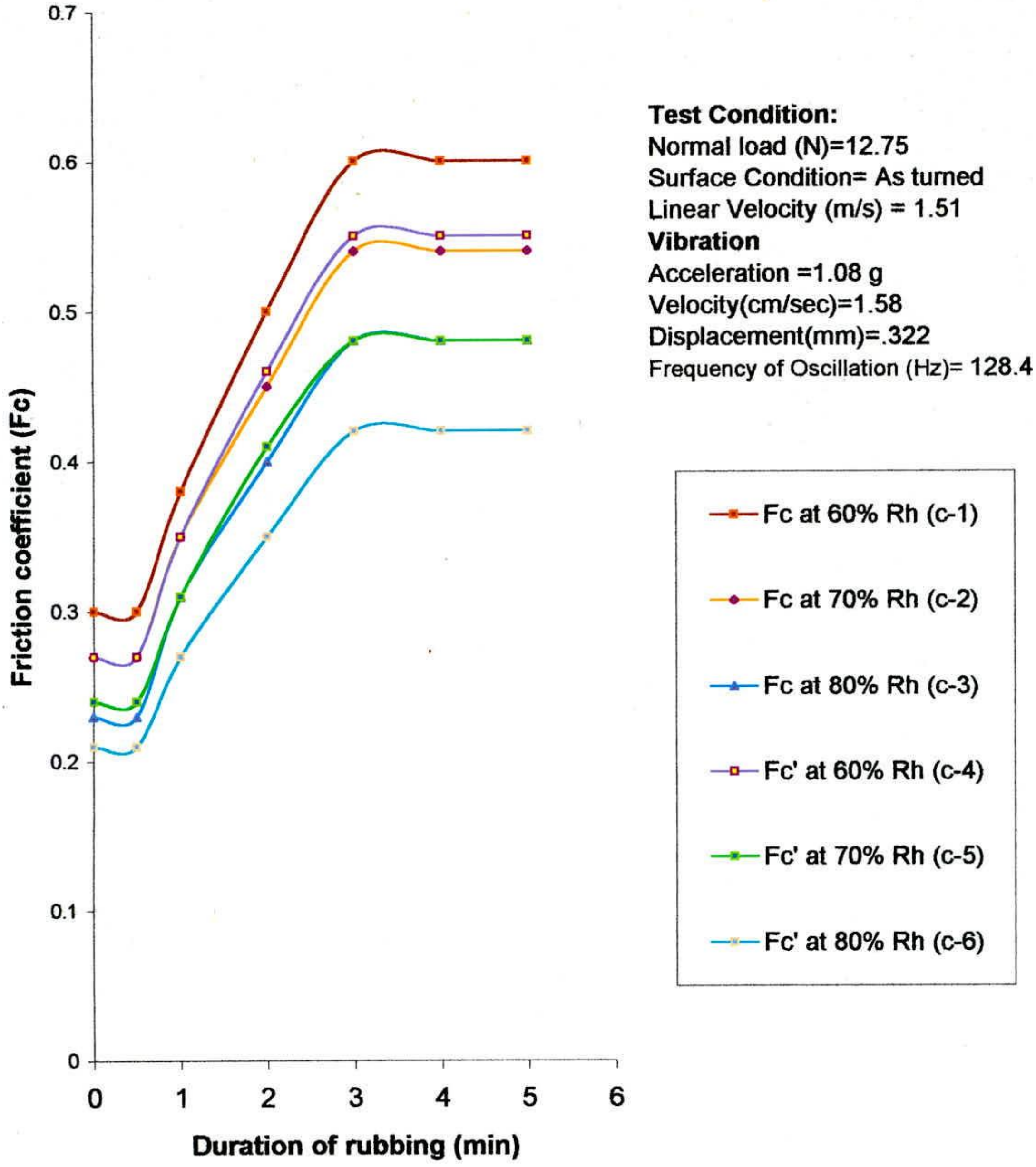


Fig.5.1: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 1.51 m/s, Normal load = 12.75 N, as turned)

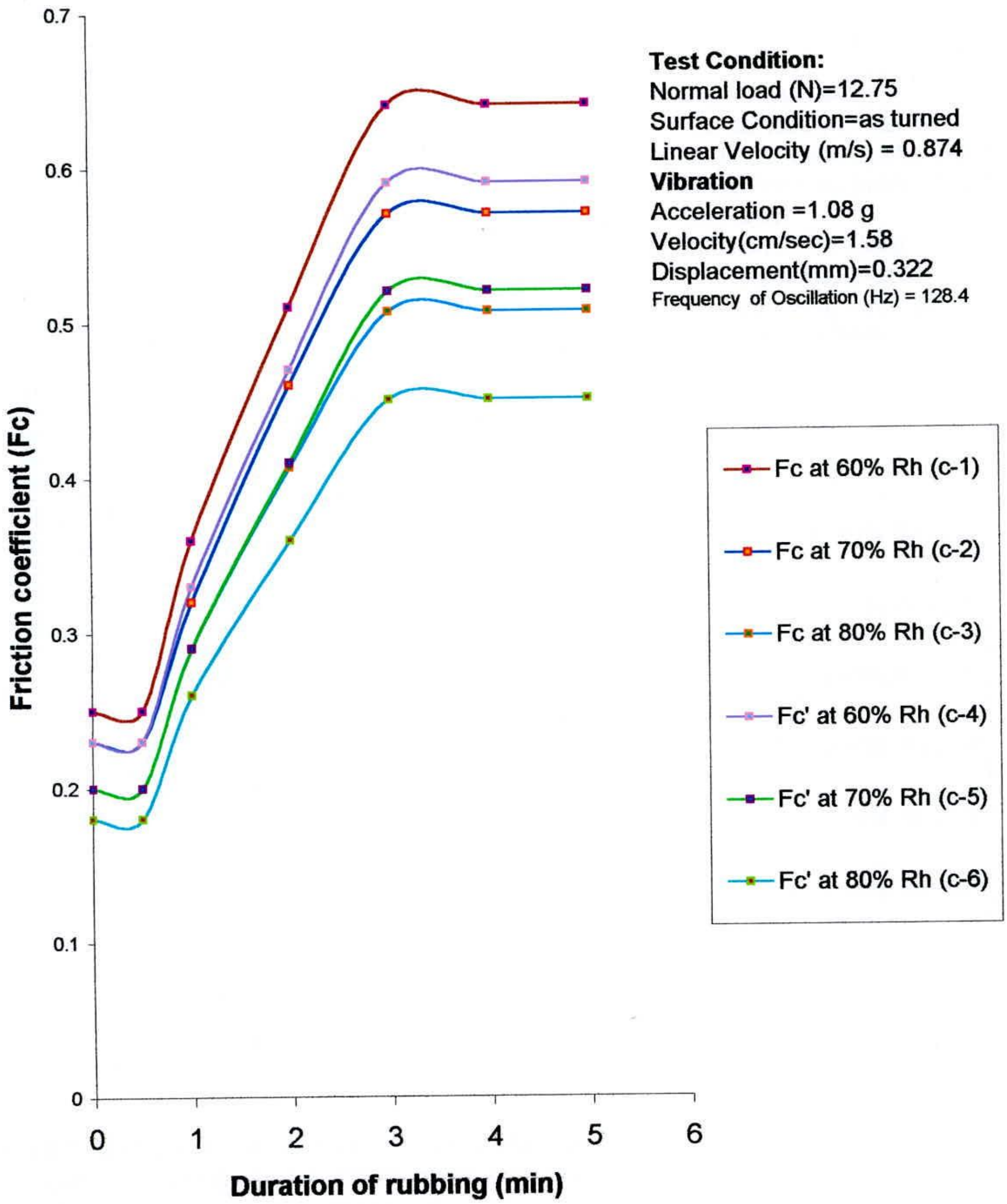


Fig.5.2: Duraion of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity 0.874 m/s, Normal load = 12.75 N, as turned)

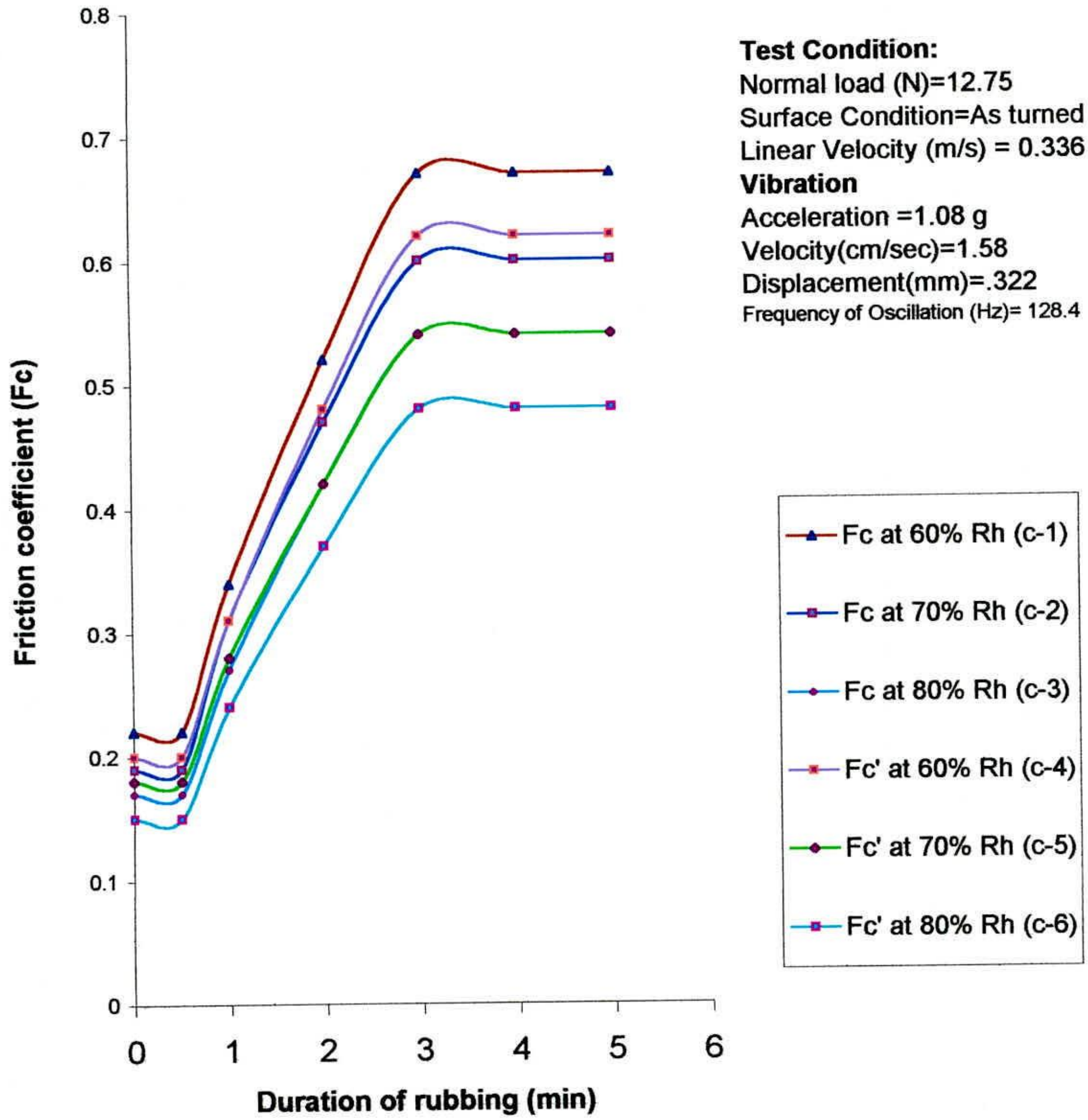


Fig.5.3: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 0.336 m/s, Normal load = 12.75 N, as turned)

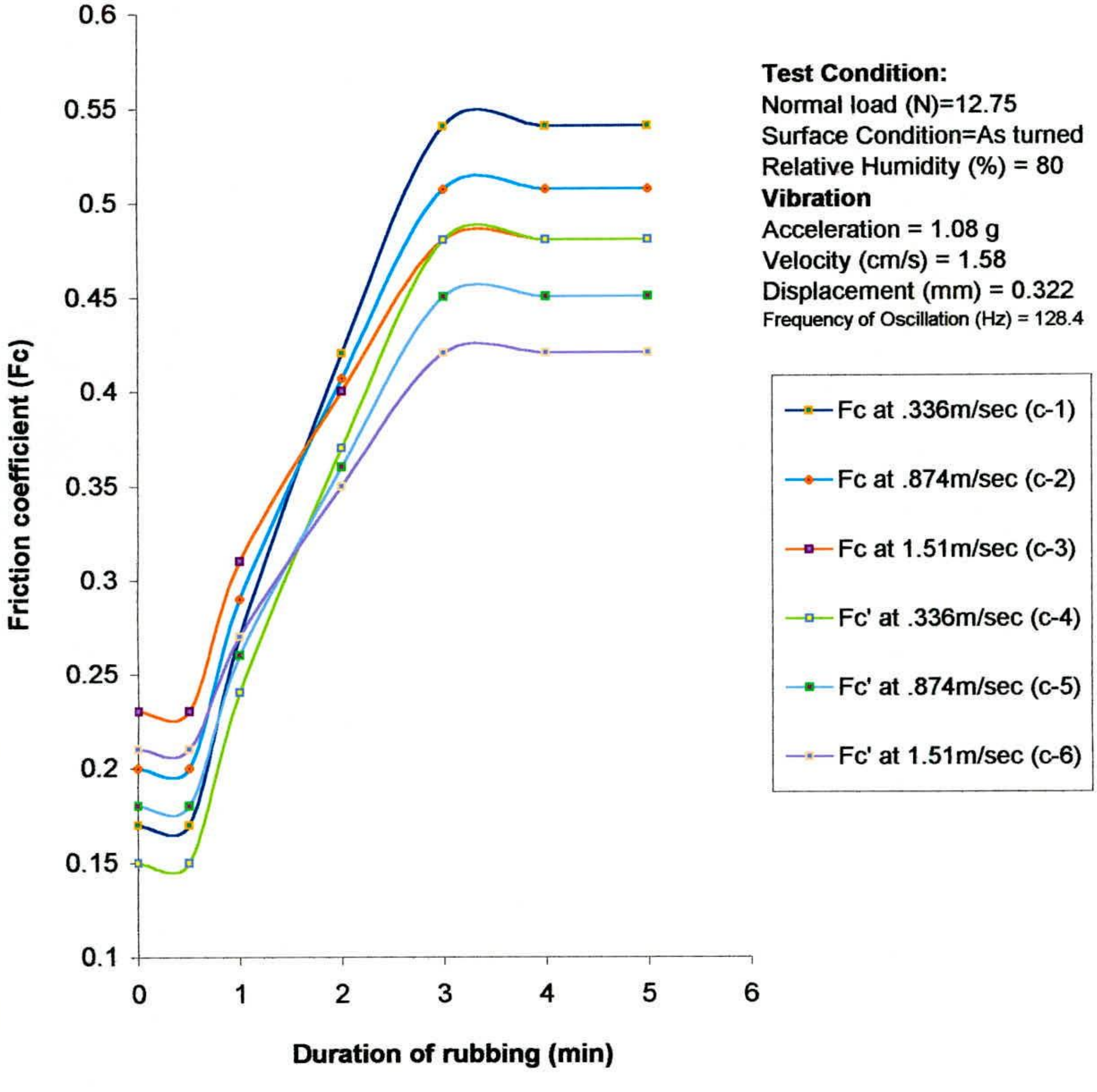


Fig.5.4: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 80%, Normal load = 12.75 N, as turned)

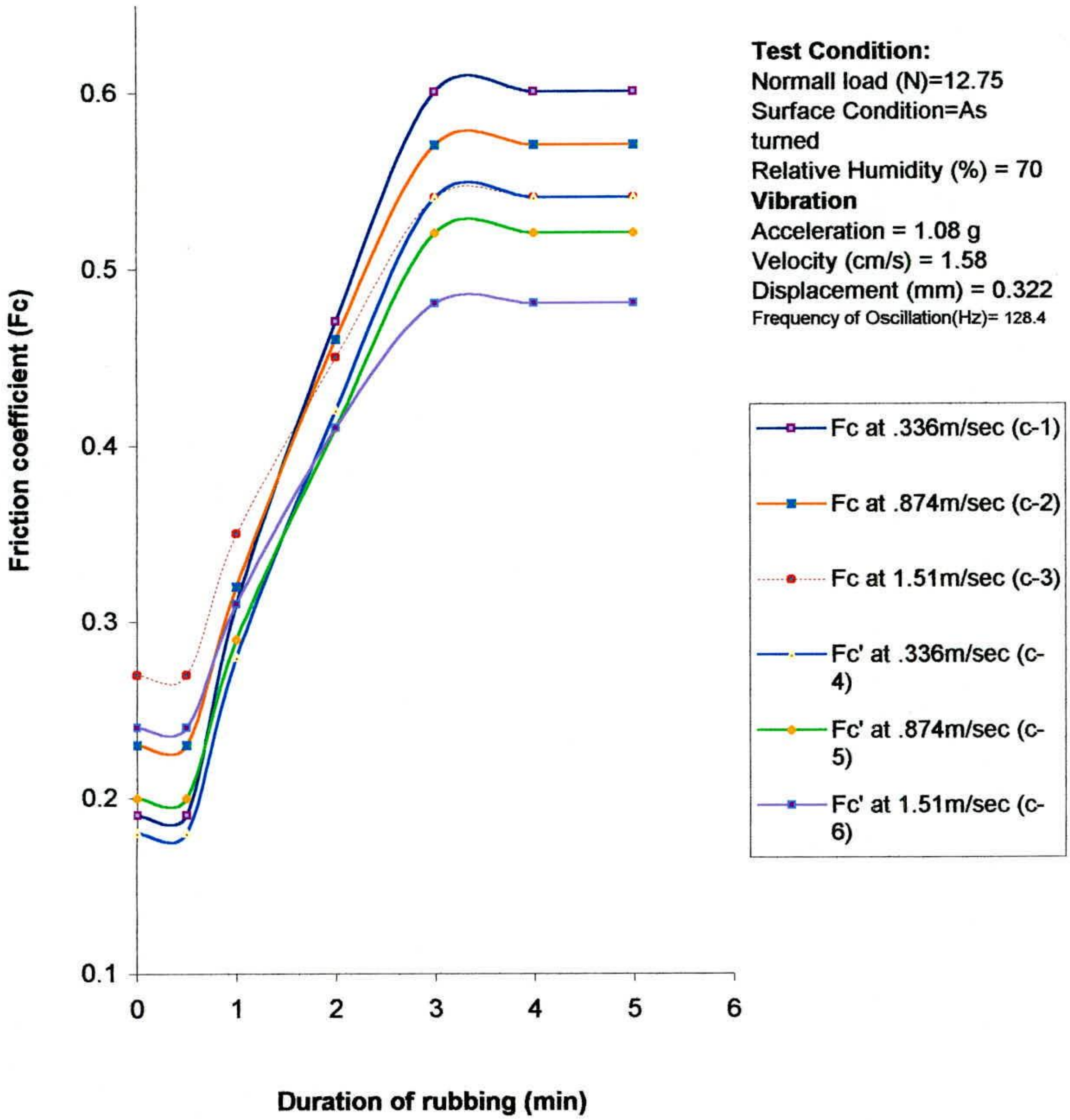


Fig.5.5: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 70%, Normal load = 12.75 N, as turned)

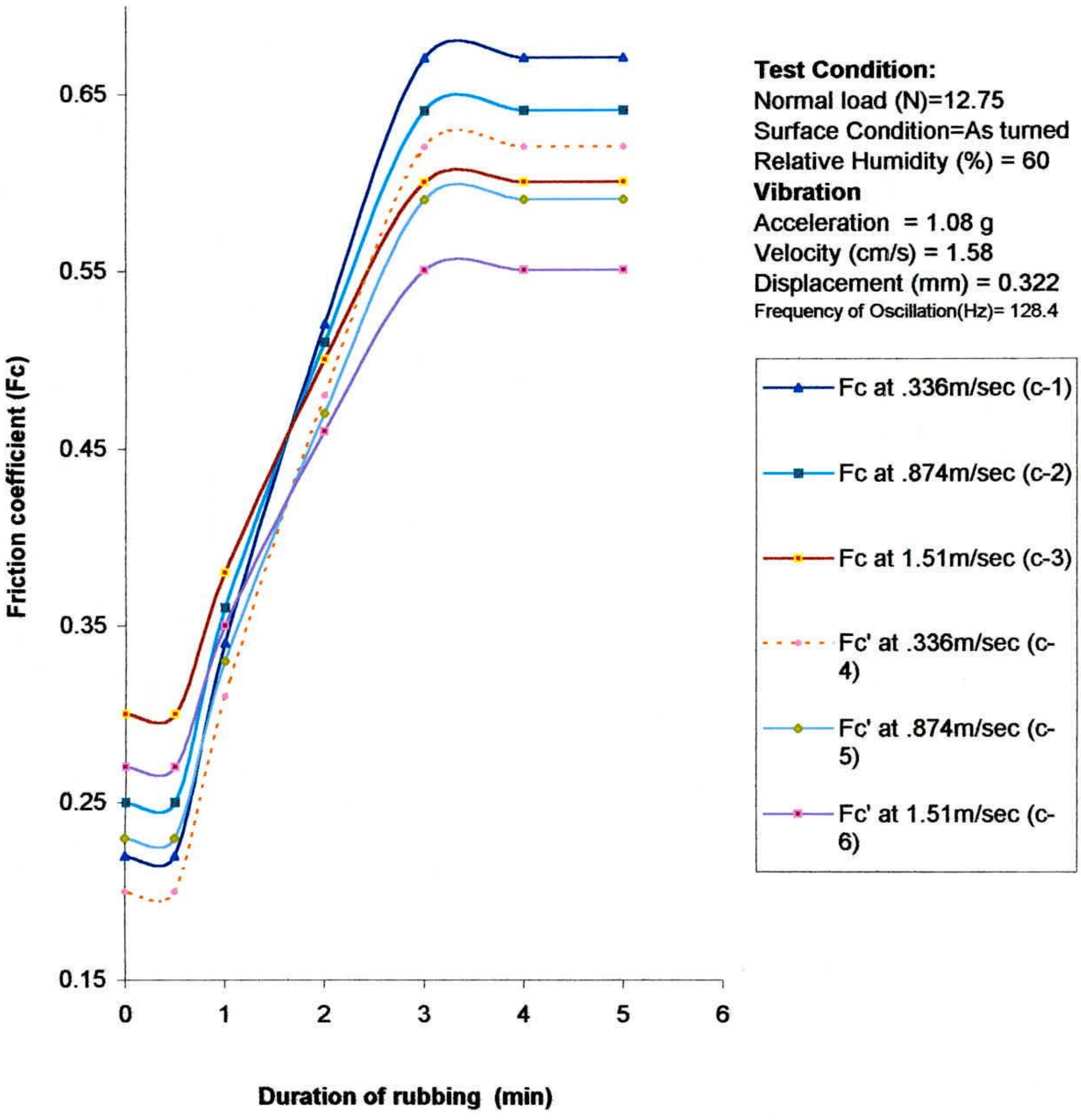


Fig.5.6: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 60%, Normal load = 12.75 N, as turned)

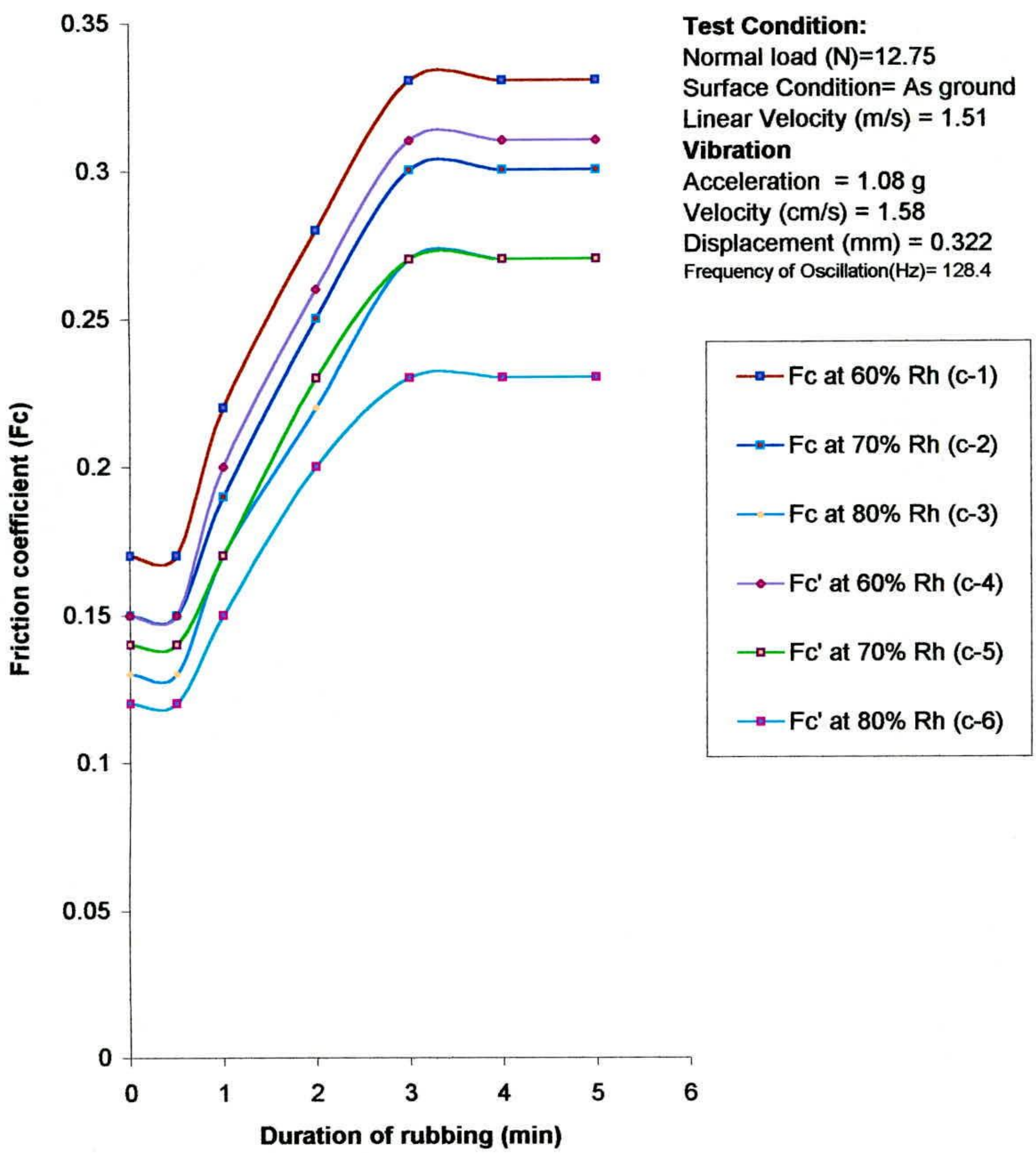


Fig.5.7: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 1.51 m/s, Normal load = 12.75 N, as ground)

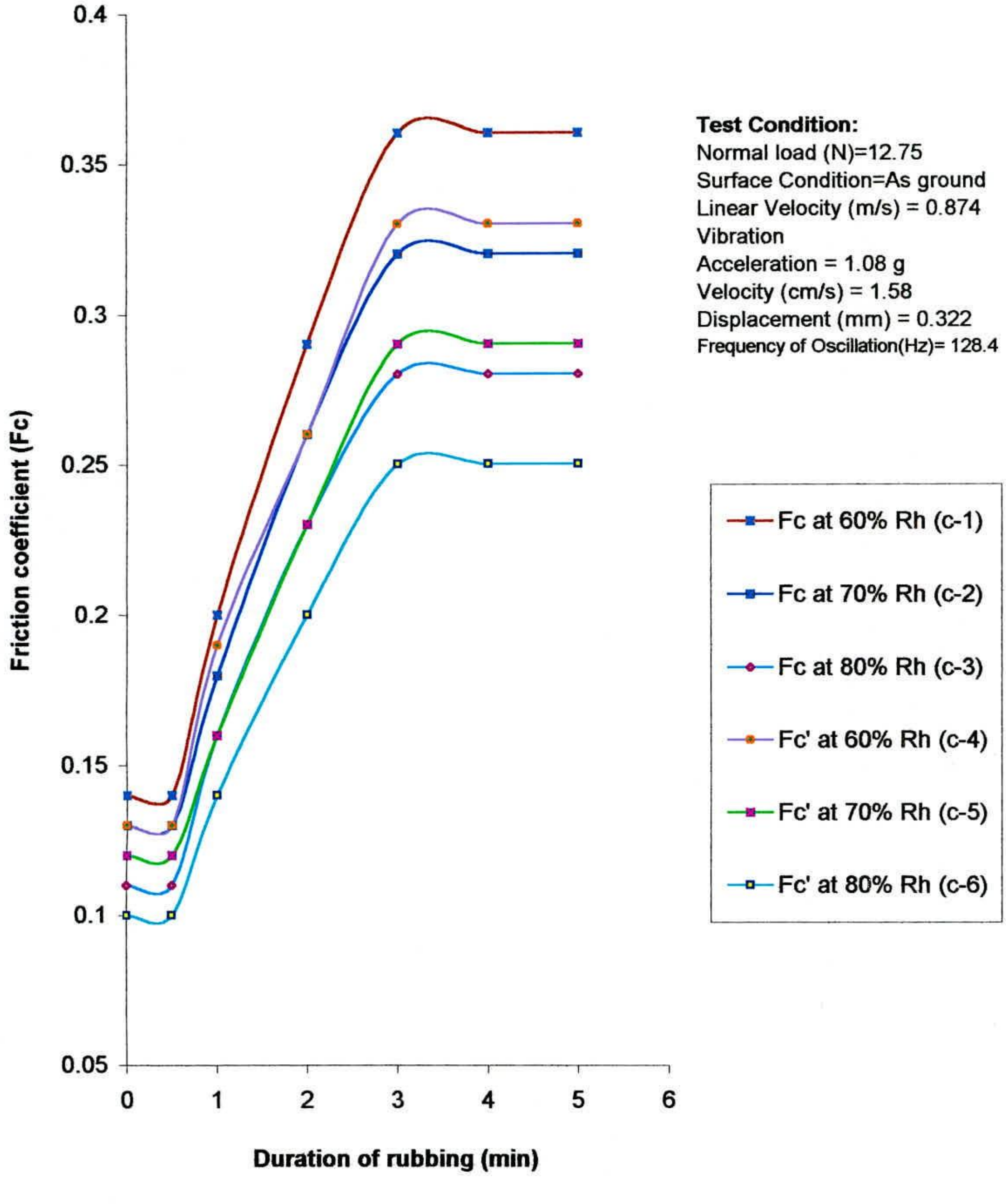


Fig.5.8: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 0.874 m/s, Normal load = 12.75 N, as ground)

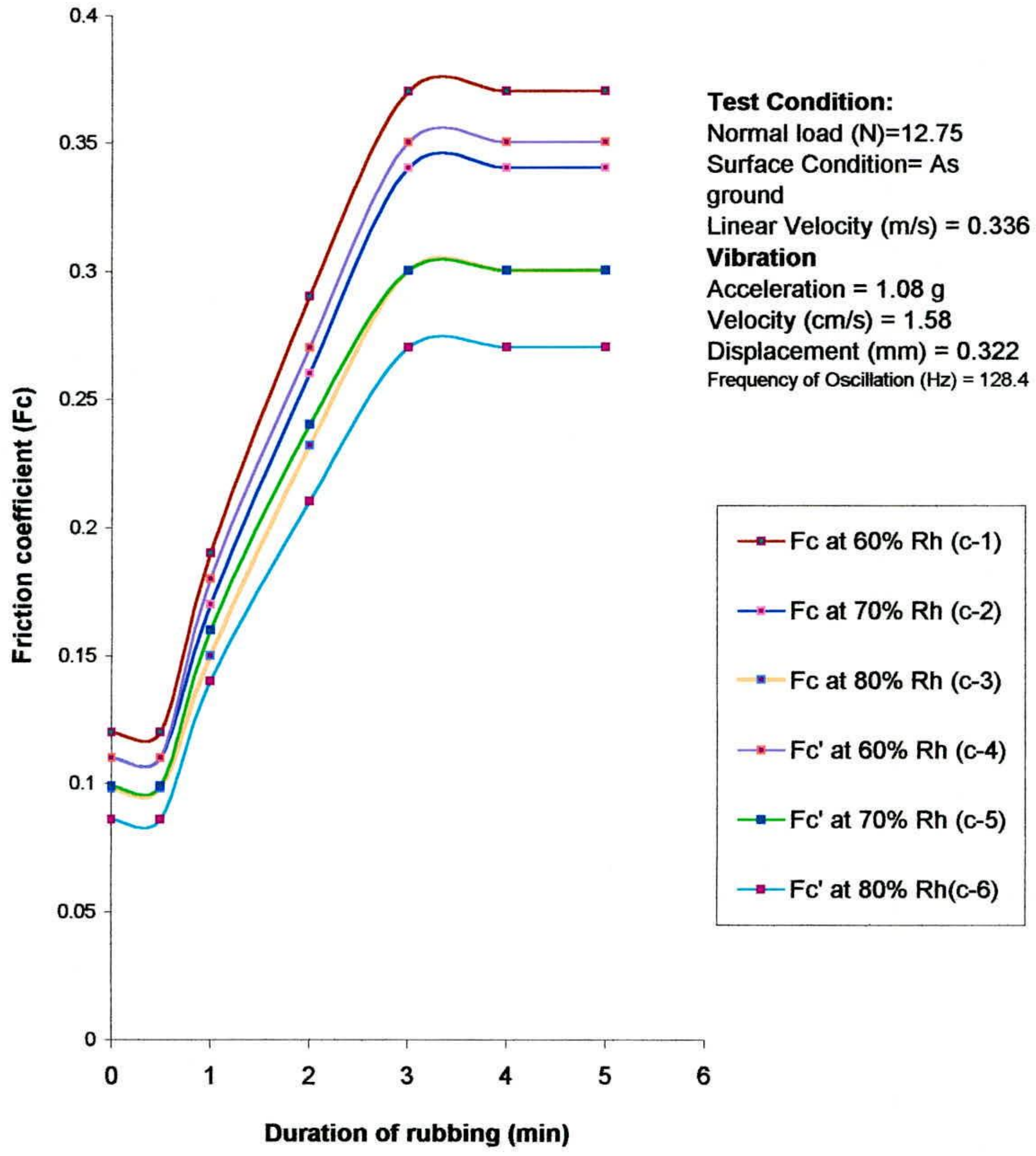


Fig.5.9: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 0.336 m/s, Normal load = 12.75 N, as ground)

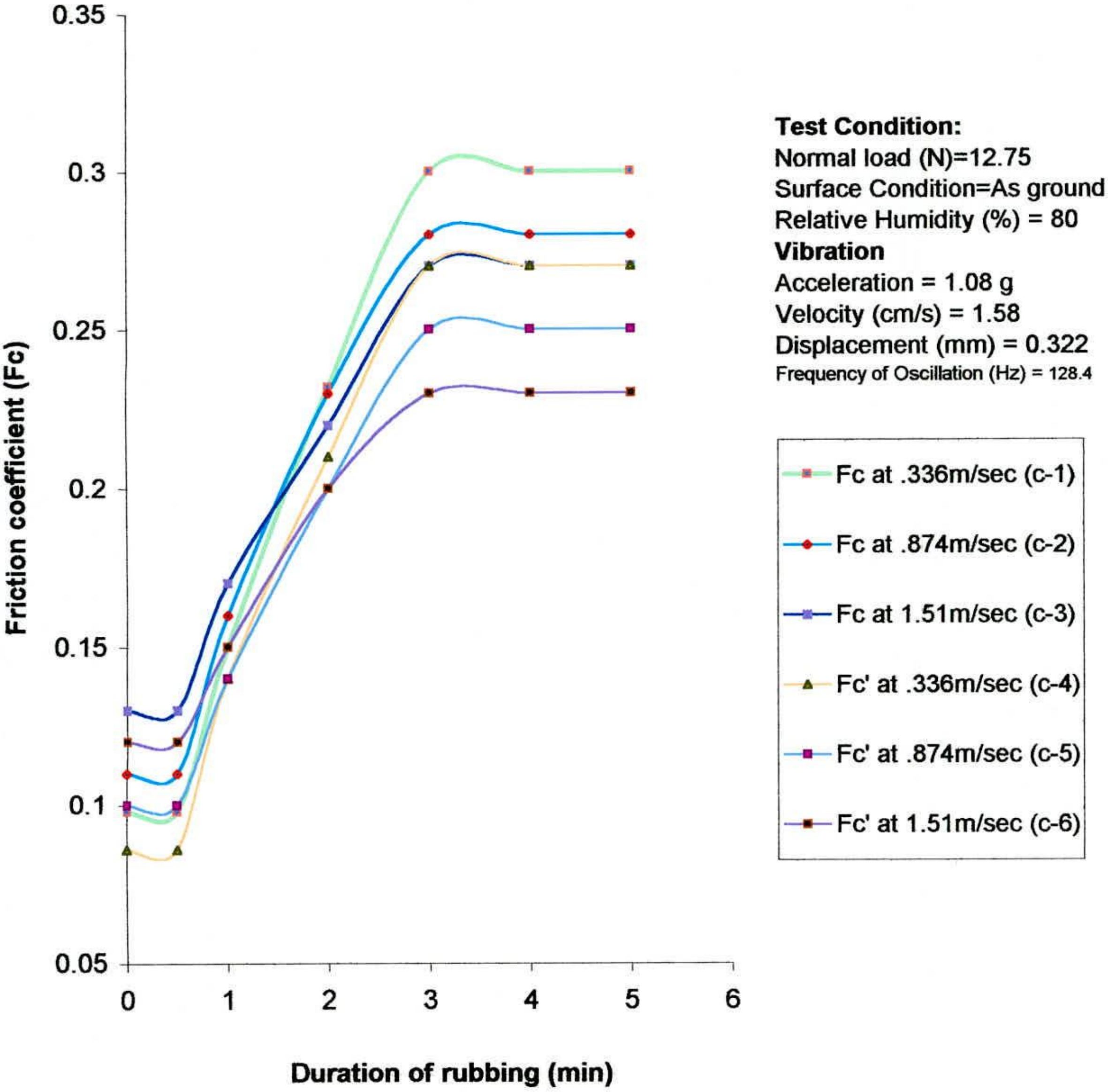


Fig.5.10: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 80%, Normal load = 12.75 N, as ground)

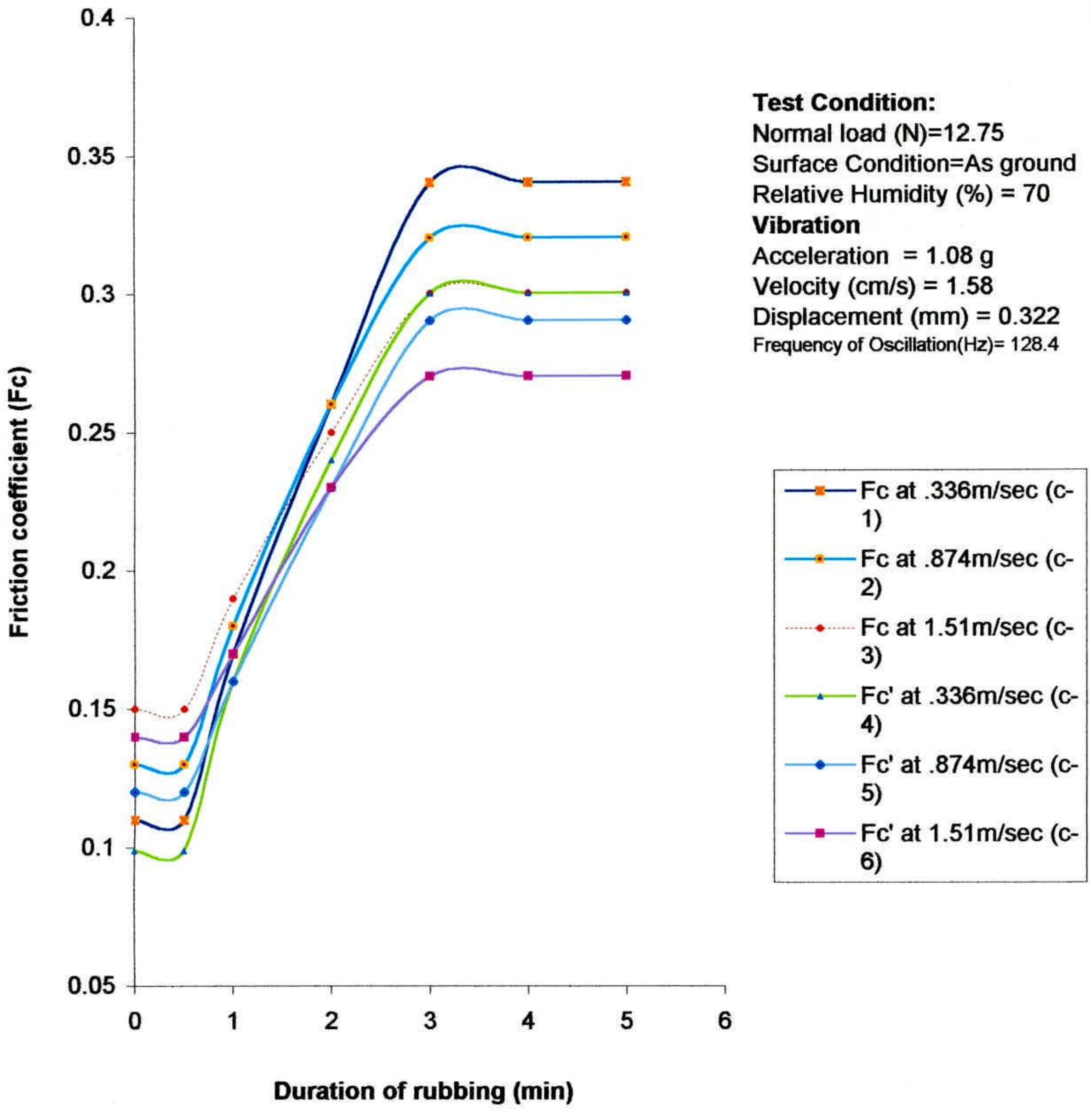


Fig.5.11: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 70%, Normal load = 12.75 N, as ground)

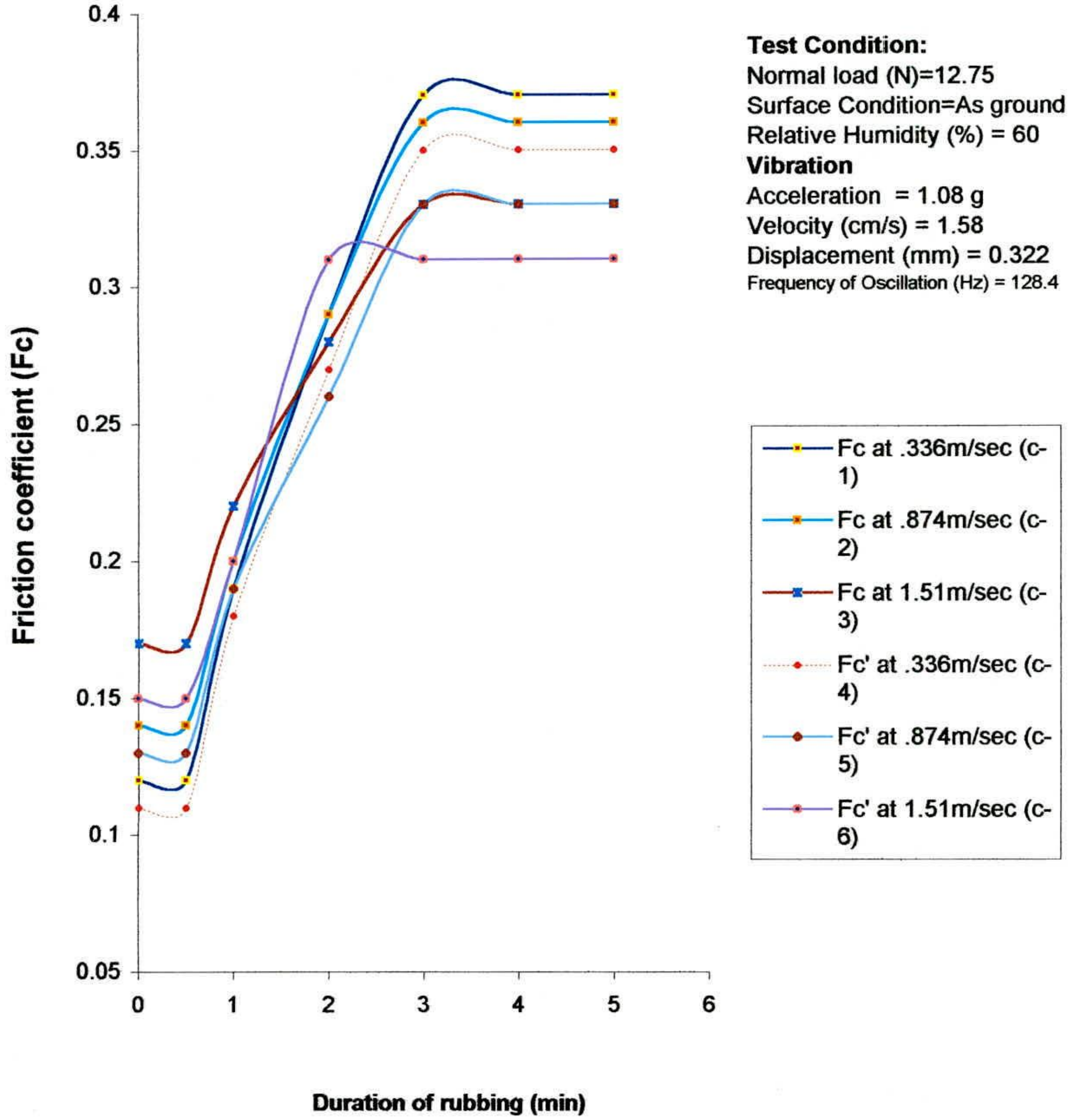


Fig.5.12: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 60%, Normal load = 12.75 N, as ground)

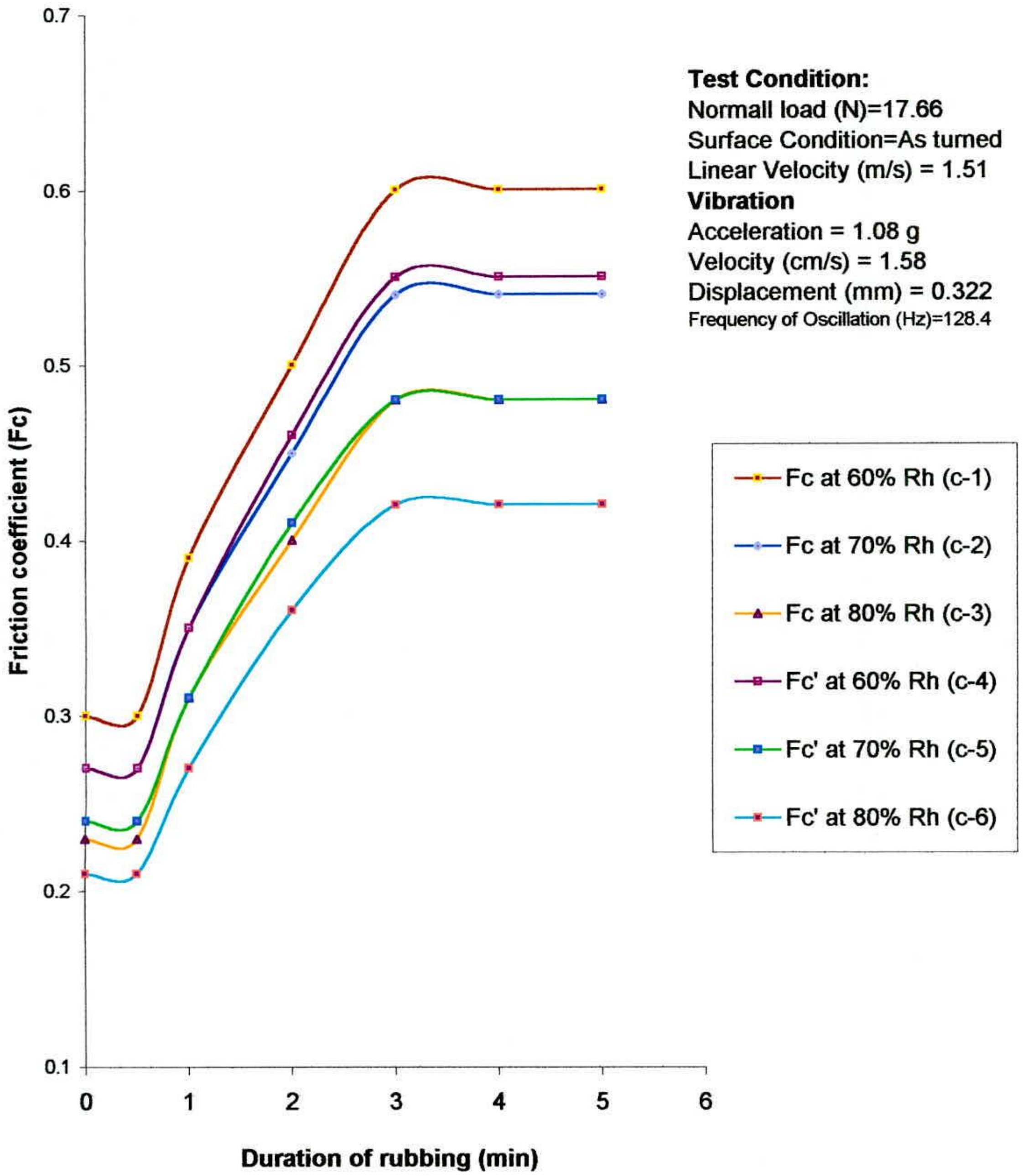


Fig.5.13: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 1.51 m/s, Normal load = 17.66 N, as turned)

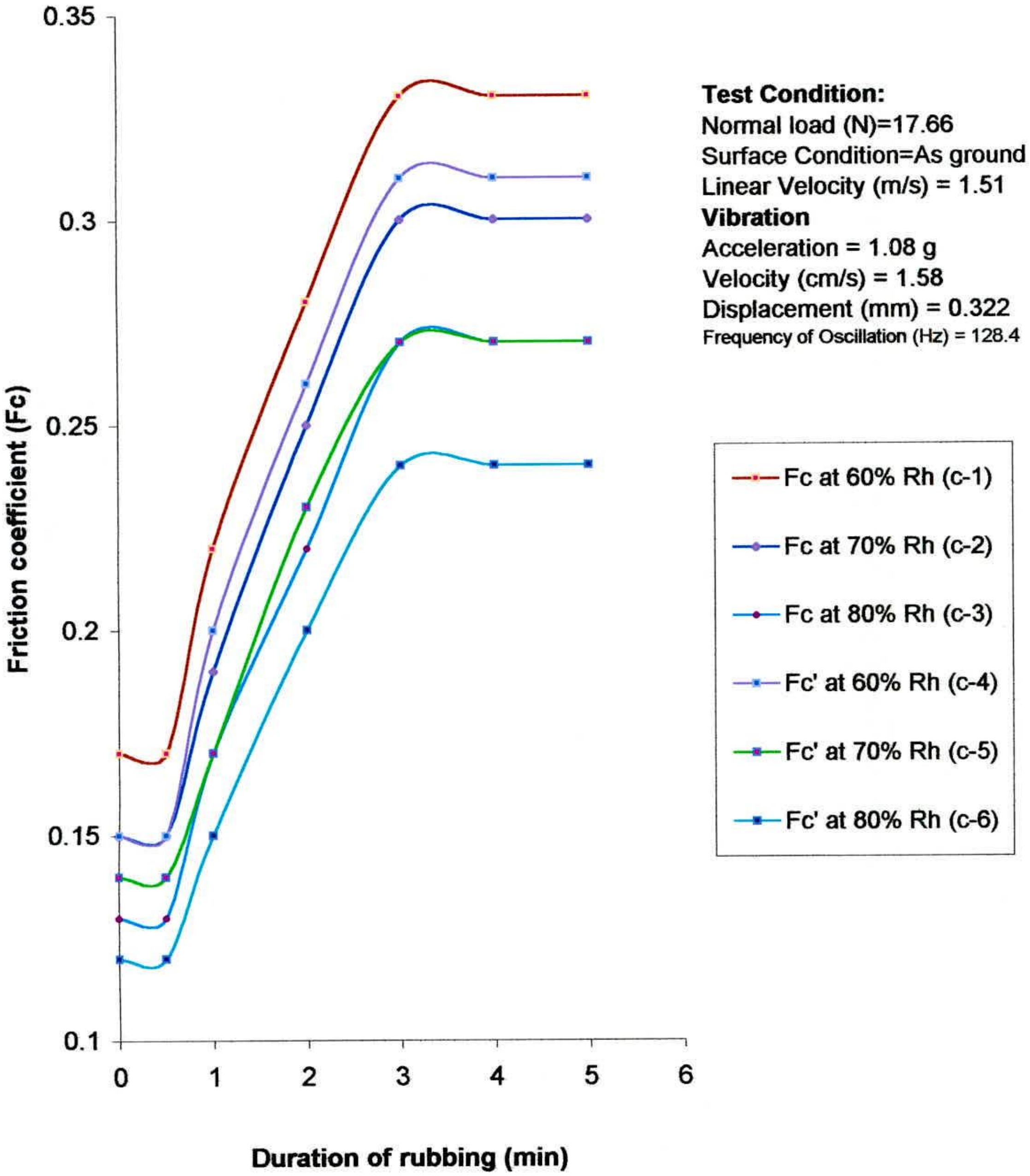


Fig.5.14: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 1.51 m/s, Normal load = 17.66 N, as ground)

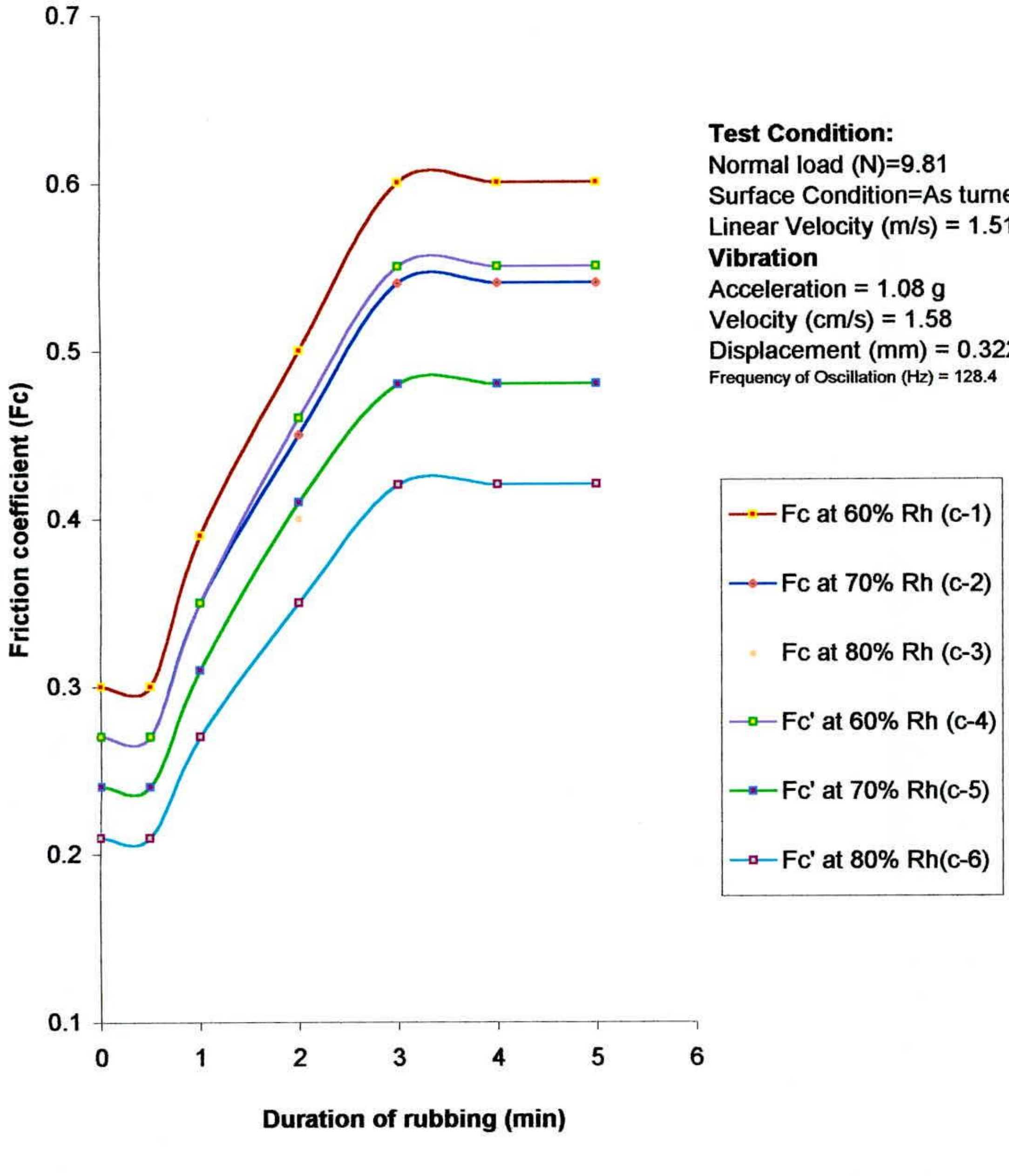


Fig.5.15: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 1.51 m/s, Normal load = 9.81 N, as turned)

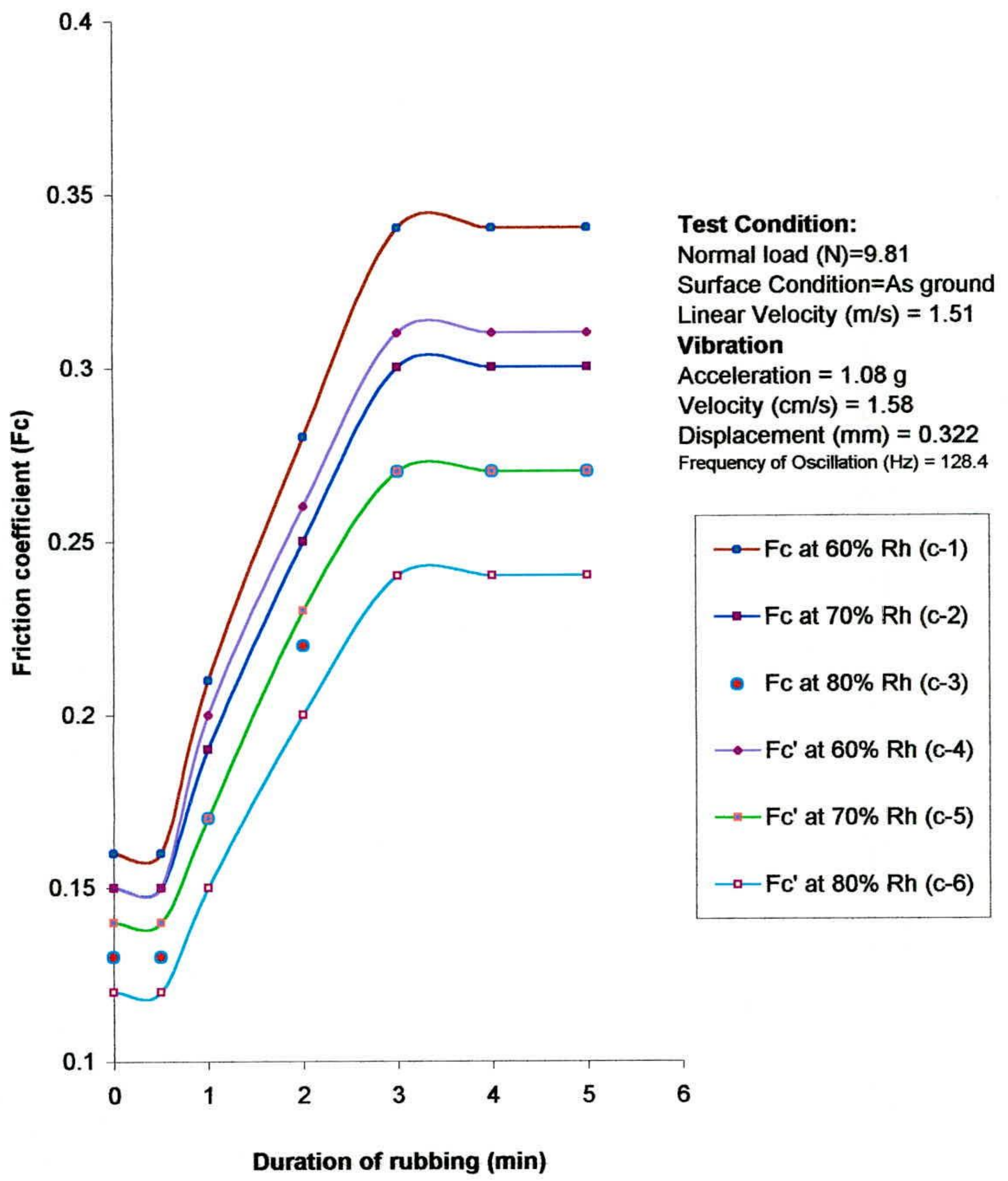


Fig.5.16: Duration of rubbing Vs Friction coefficient (0 & 128.4 Hz Frequency of Oscillation) at different humidity level (Velocity = 1.51 m/s, Normal load = 9.81 N, as ground)

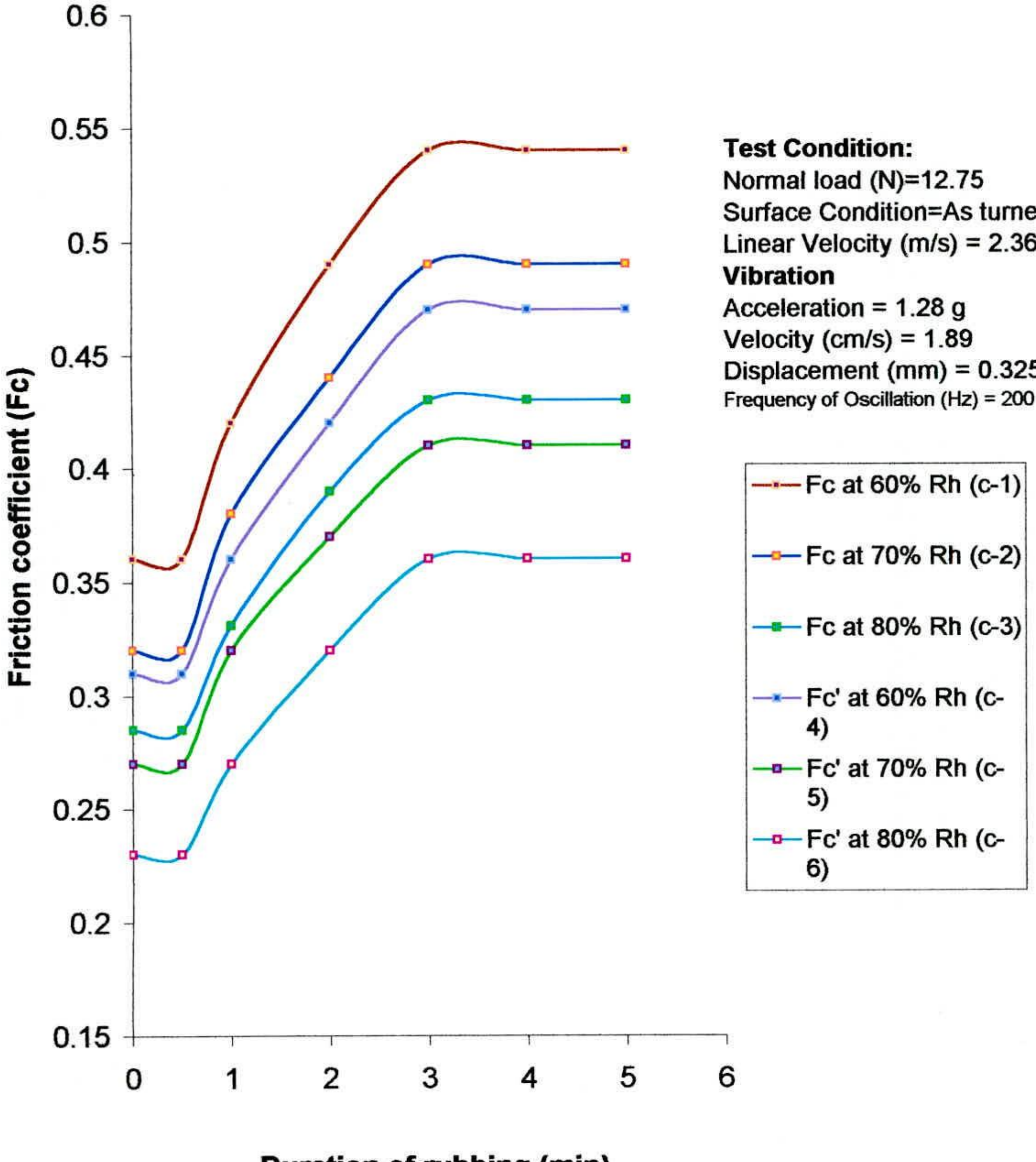


Fig.5.17: Duration of rubbing Vs Friction coefficient (0 & 200 Hz Frequency of Oscillation) at different humidity level (Velocity = 2.36 m/s, Normal load = 12.75 N, as turned)

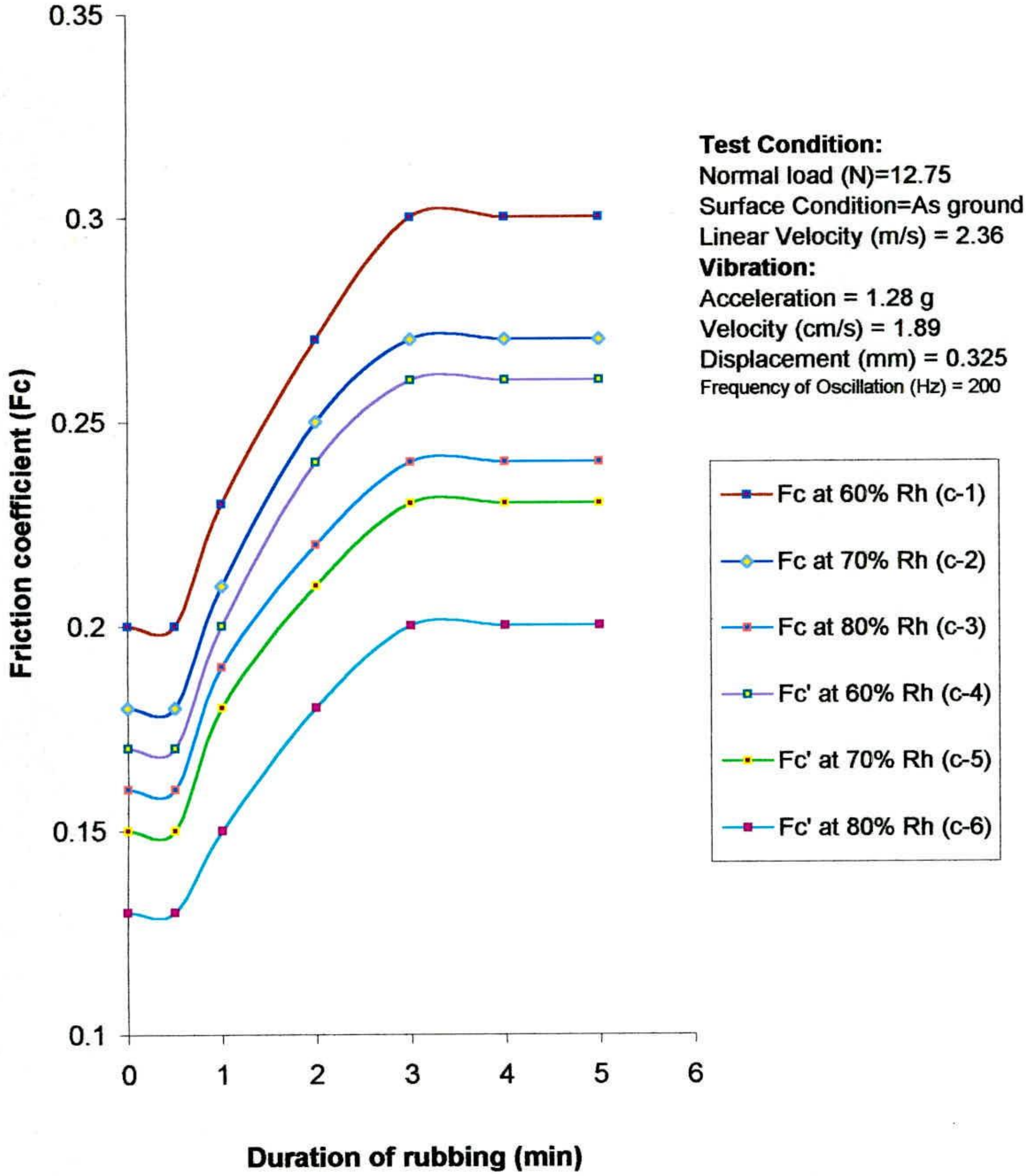


Fig.5.18: Duration of rubbing Vs Friction coefficient (0 & 200 Hz Frequency of Oscillation) at different humidity level (Velocity = 2.36 m/s, Normal load = 12.75 N, as ground)

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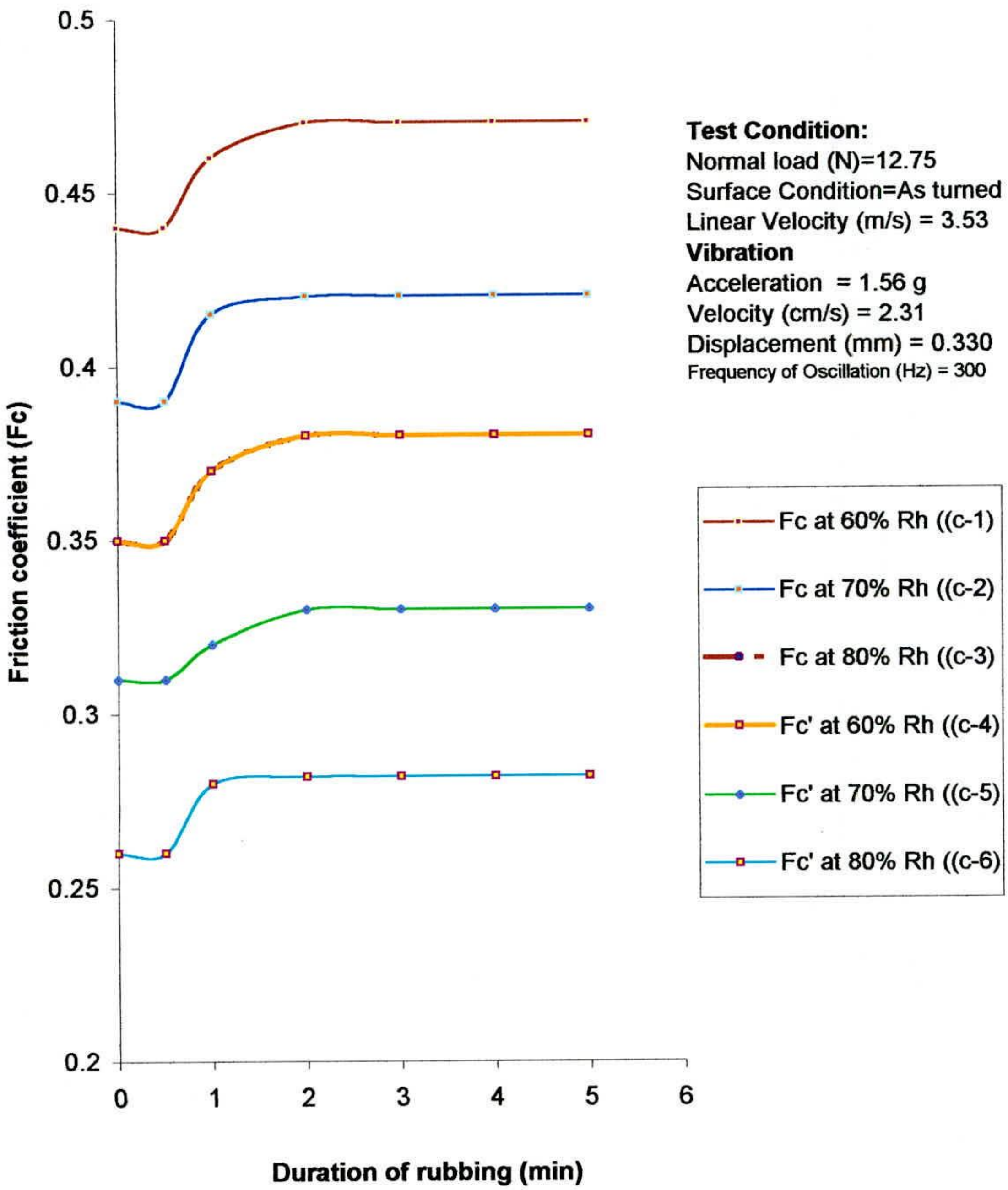

Fig.5.19: Duration of rubbing Vs Friction coefficient (0 & 300 Hz Frequency of Oscillation) at different humidity level (Velocity = 3.53 m/s, Normal load = 12.75 N, as turned)

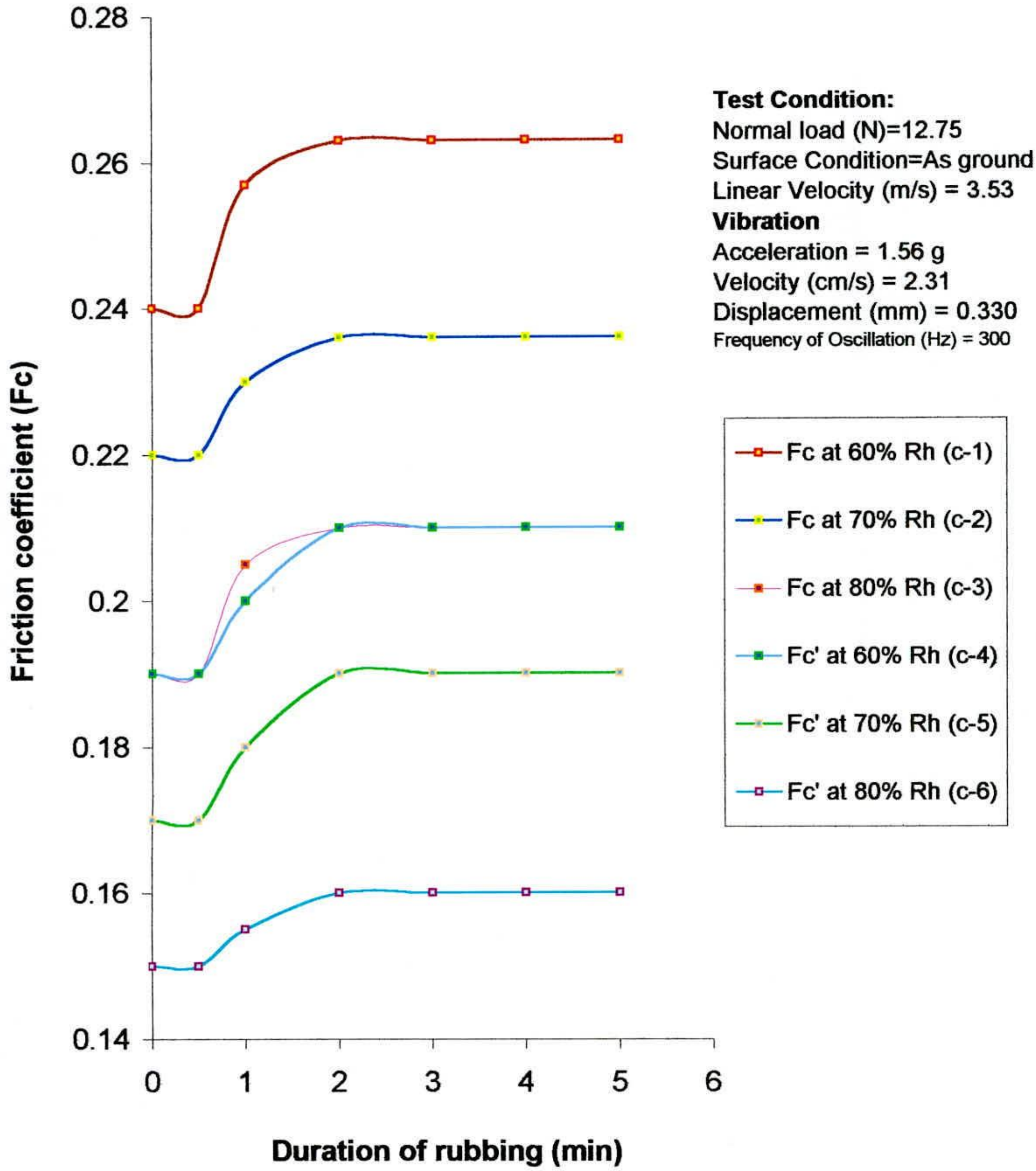

Fig.5.20: Duration of rubbing Vs Friction coefficient (0 & 300 Hz Frequency of Oscillation) at different humidity level (Velocity = 3.53 m/s, Normal load = 12.75 N, as ground)

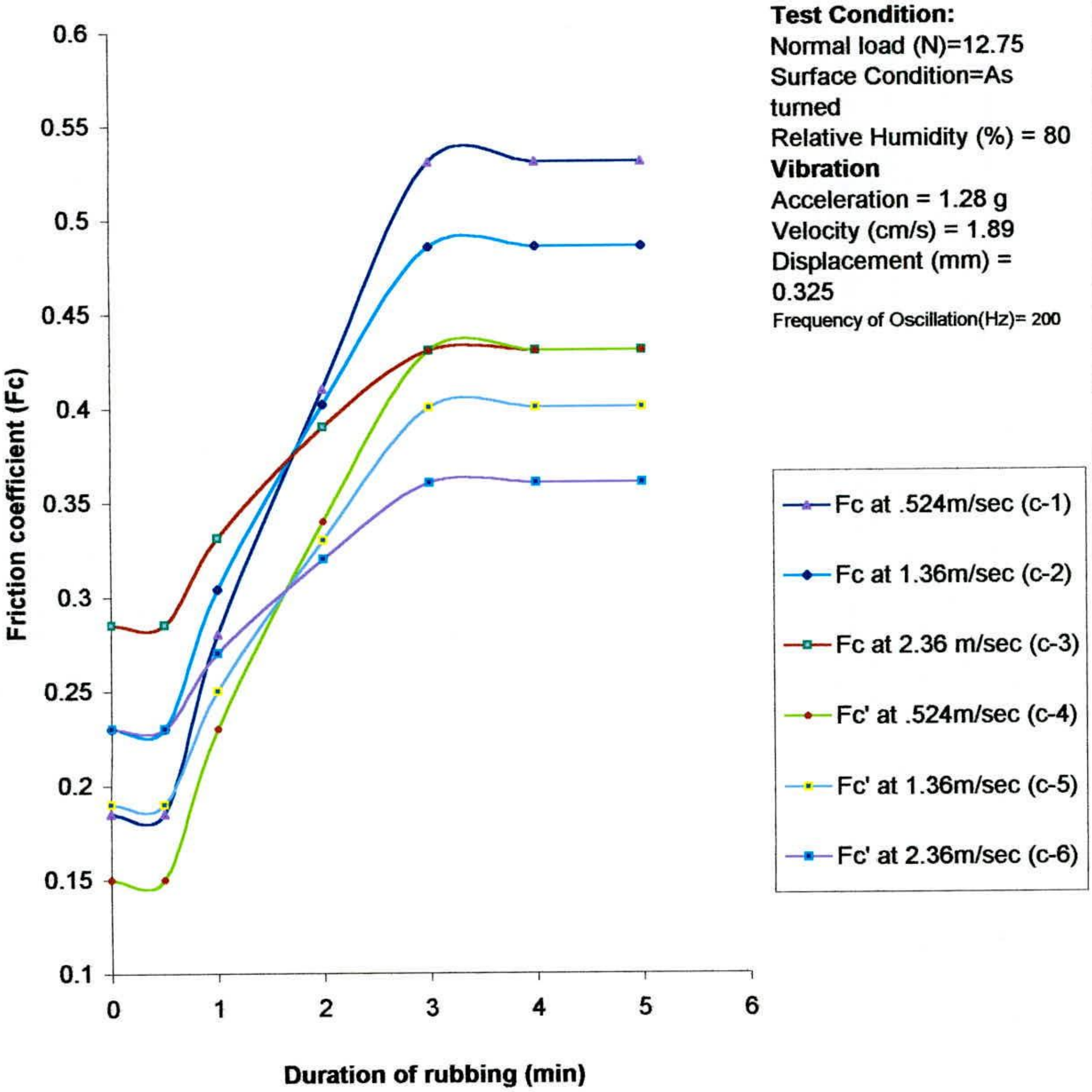

Fig.5.21 : Duration of rubbing Vs Friction coefficient (0 & 200 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 80%, Normal load = 12.75 N, as turned)

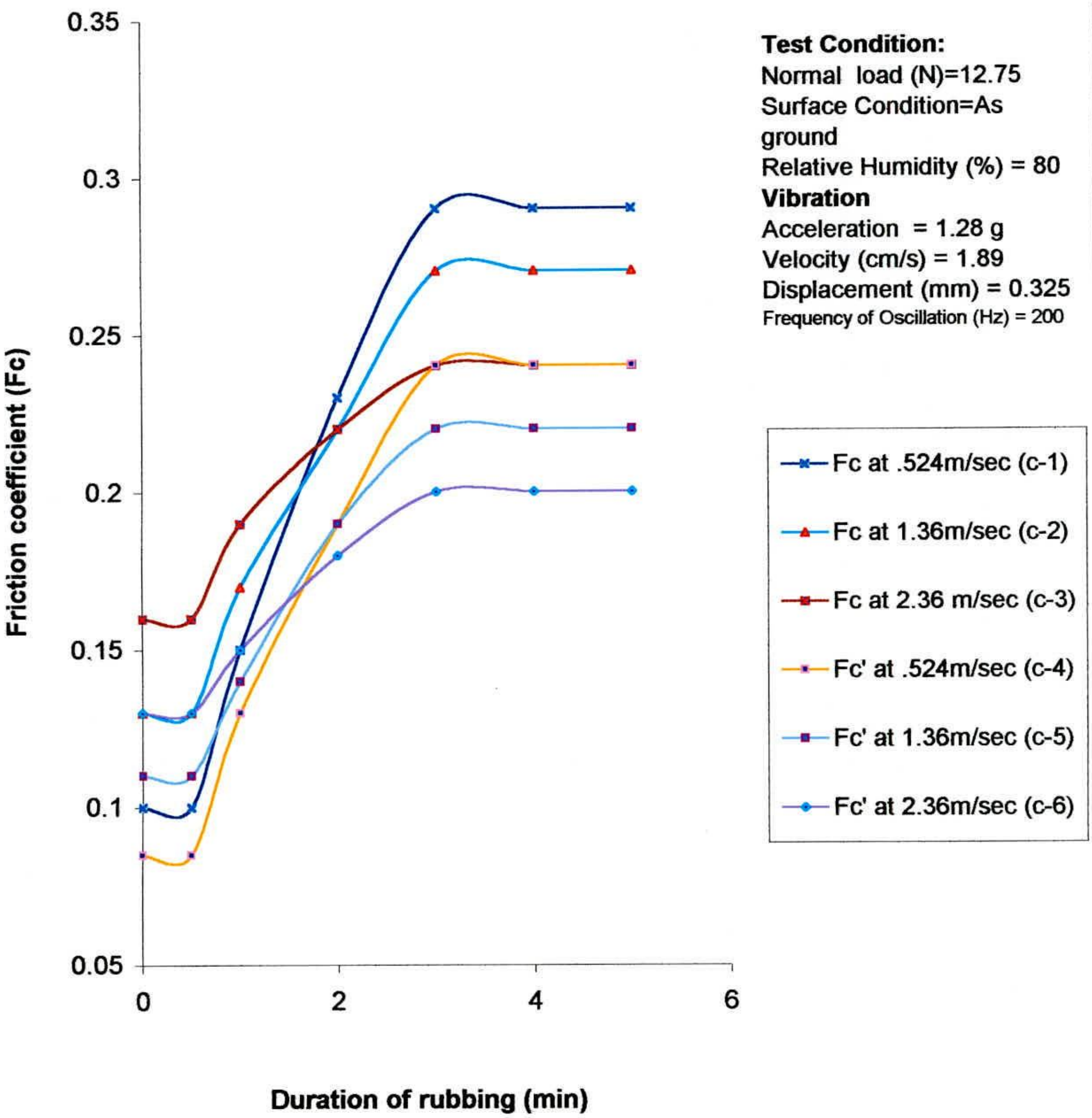

Fig.5.22: Duration of rubbing Vs Friction coefficient (0 & 200 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 80%, Normal load = 12.75 N, as ground)

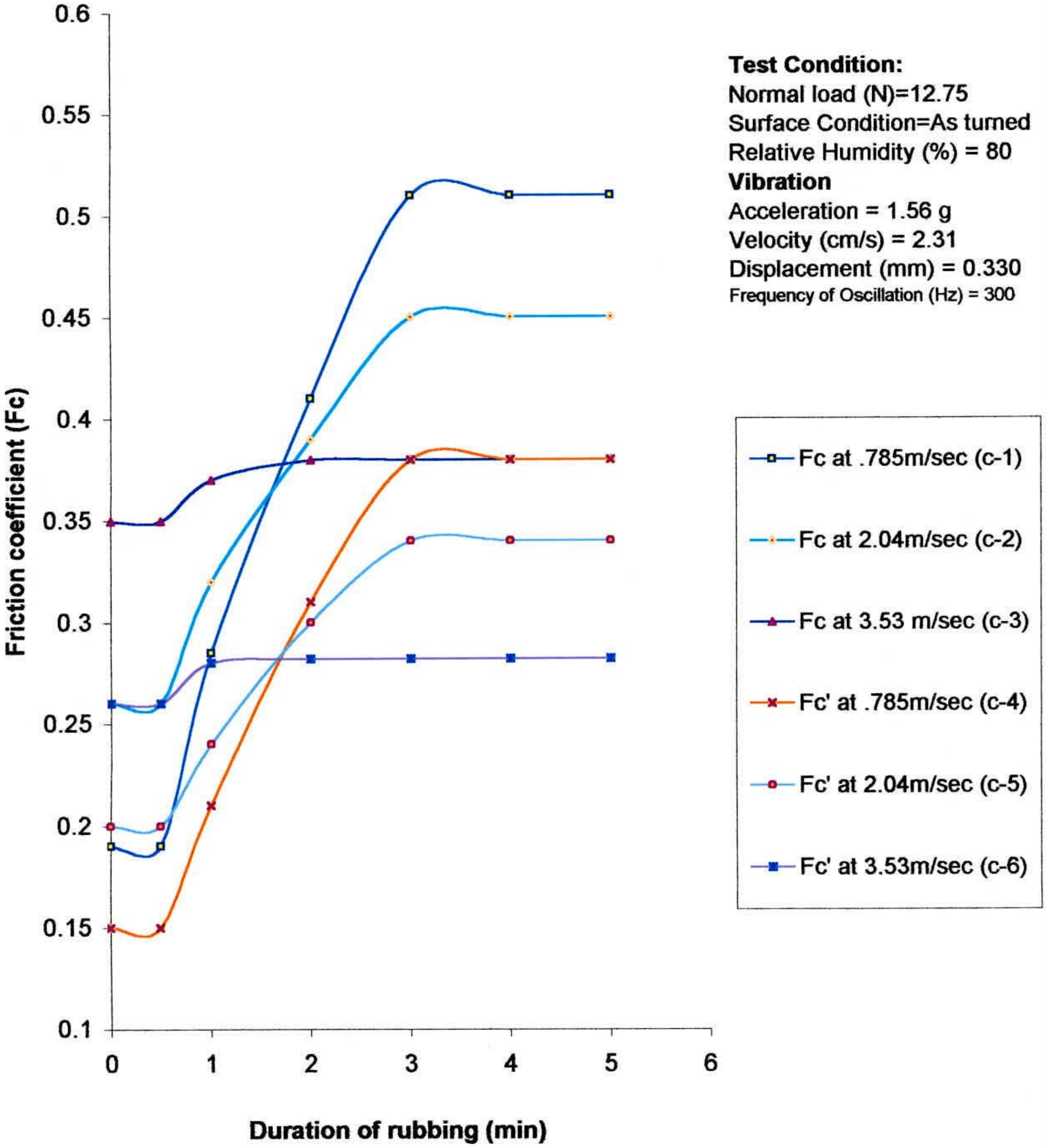

Fig.5.23: Duration of rubbing Vs Friction coefficient (0 & 300 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 80%, Normal load = 12.75 N, as turned)

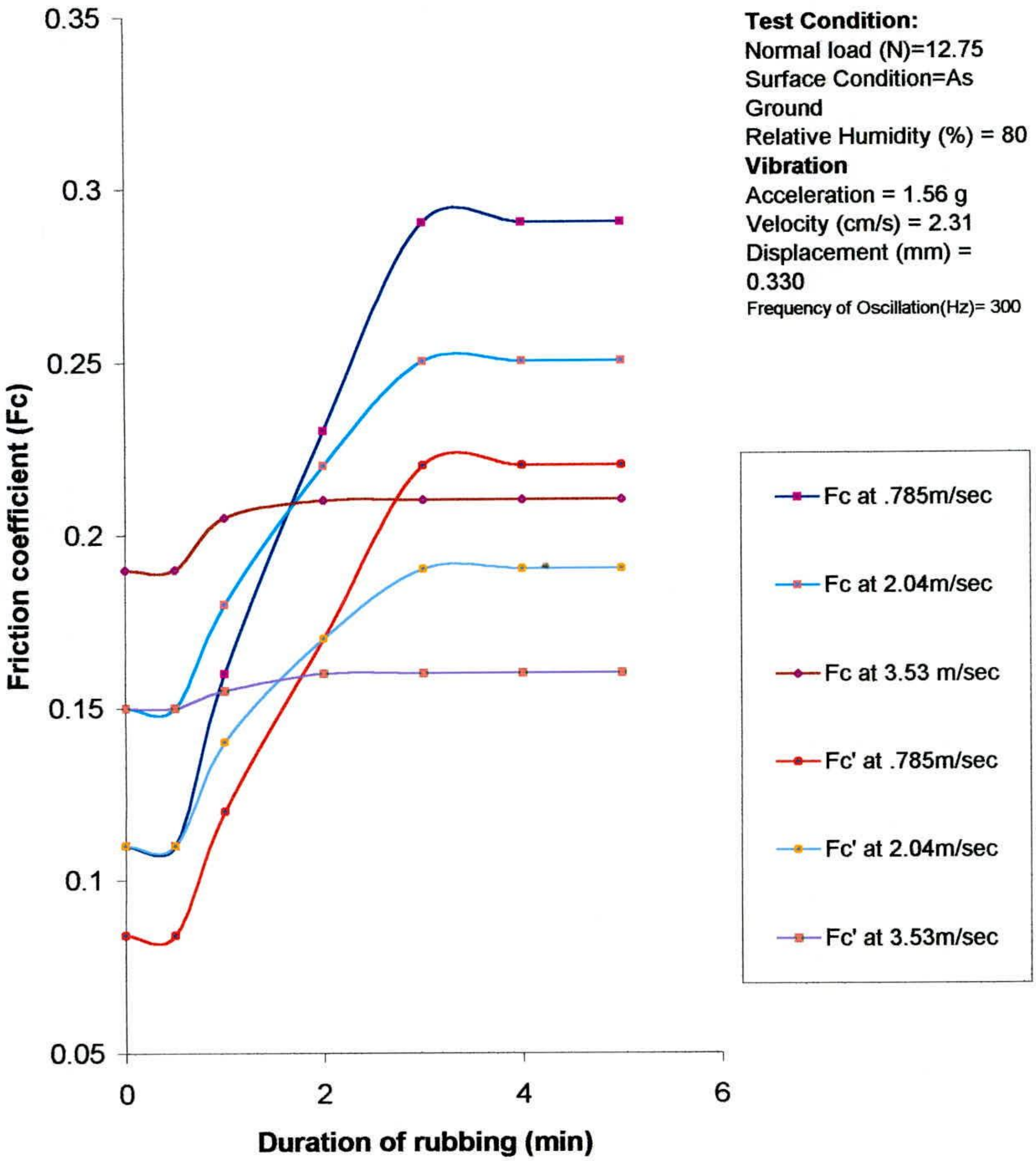

Fig.5.24: Duration Vs Friction coefficient (0 & 300 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 80%, Normal load = 12.75, as ground)

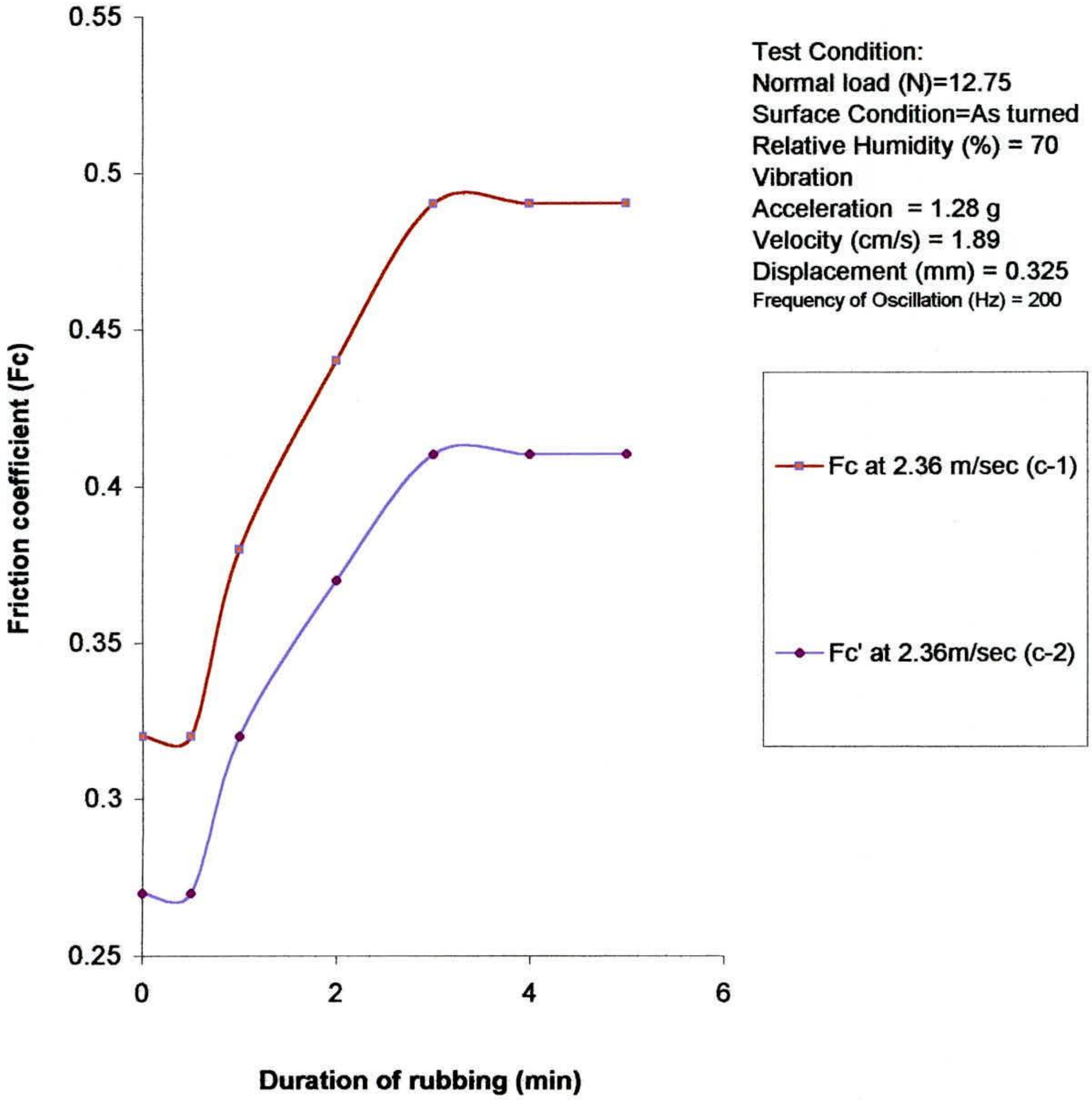

Fig.5.25: Duration of rubbing Vs Friction coefficient (0 & 200 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 70%, Normal load = 12.75, as turned)

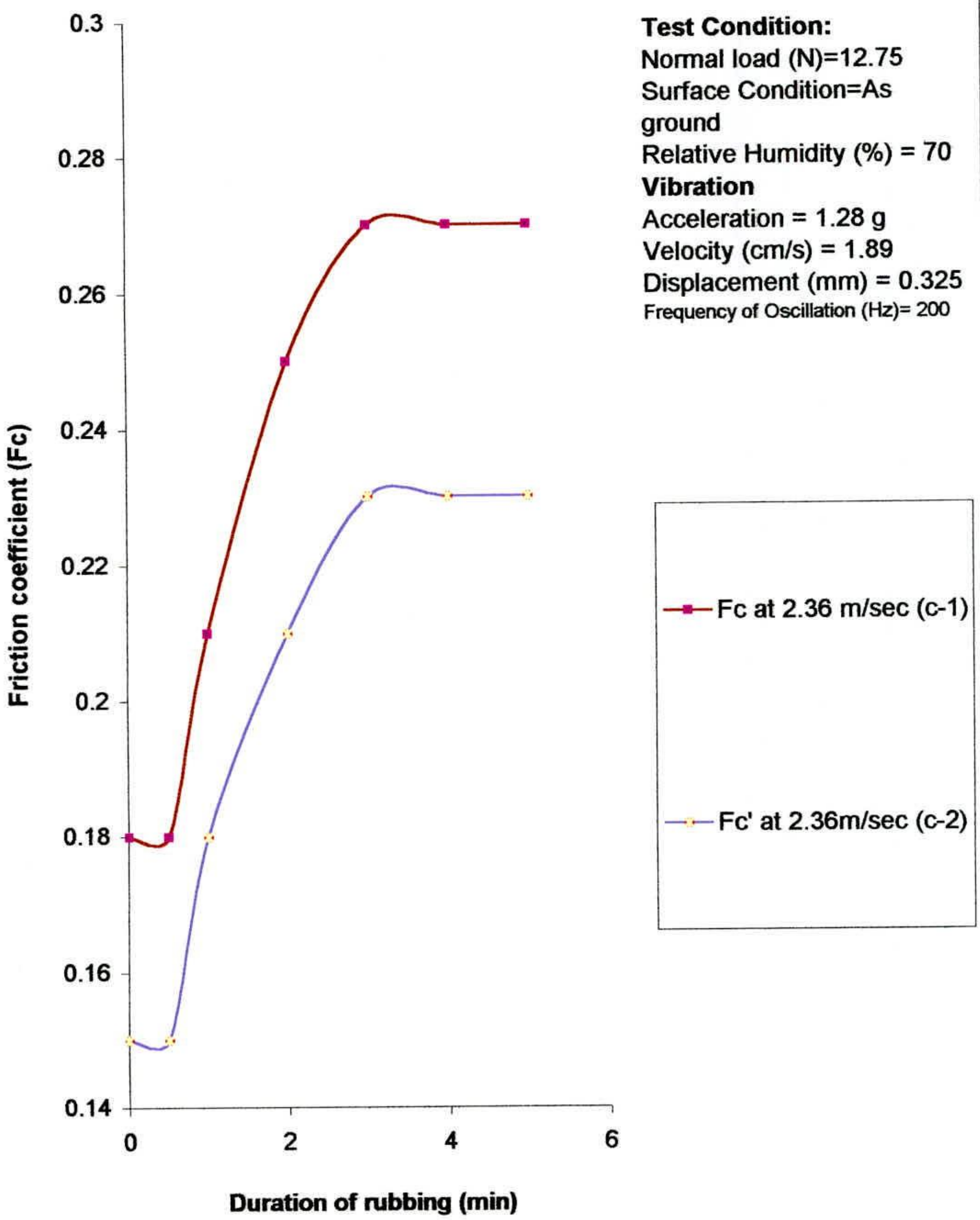

Fig.5.26: Duration of rubbing Vs Friction coefficient (0 & 200 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 70%, Normal load = 12.75, as ground)

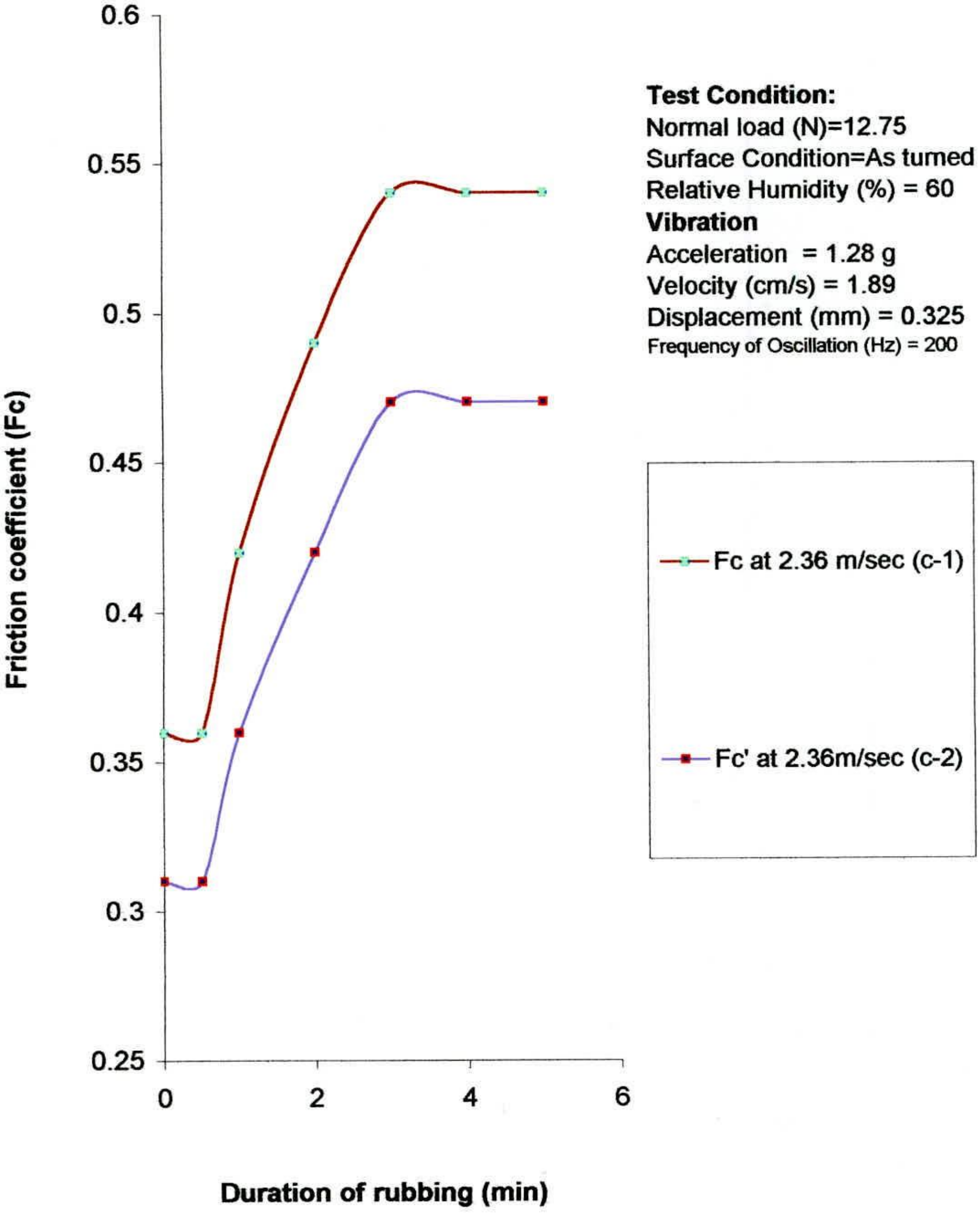

Fig.5.27: Duration of rubbing Vs Friction coefficient (0 & 200 Hz Frequency of Oscillation) at different linear velocity (Relative humidity =60%, Normal load = 12.75 N, as turned)

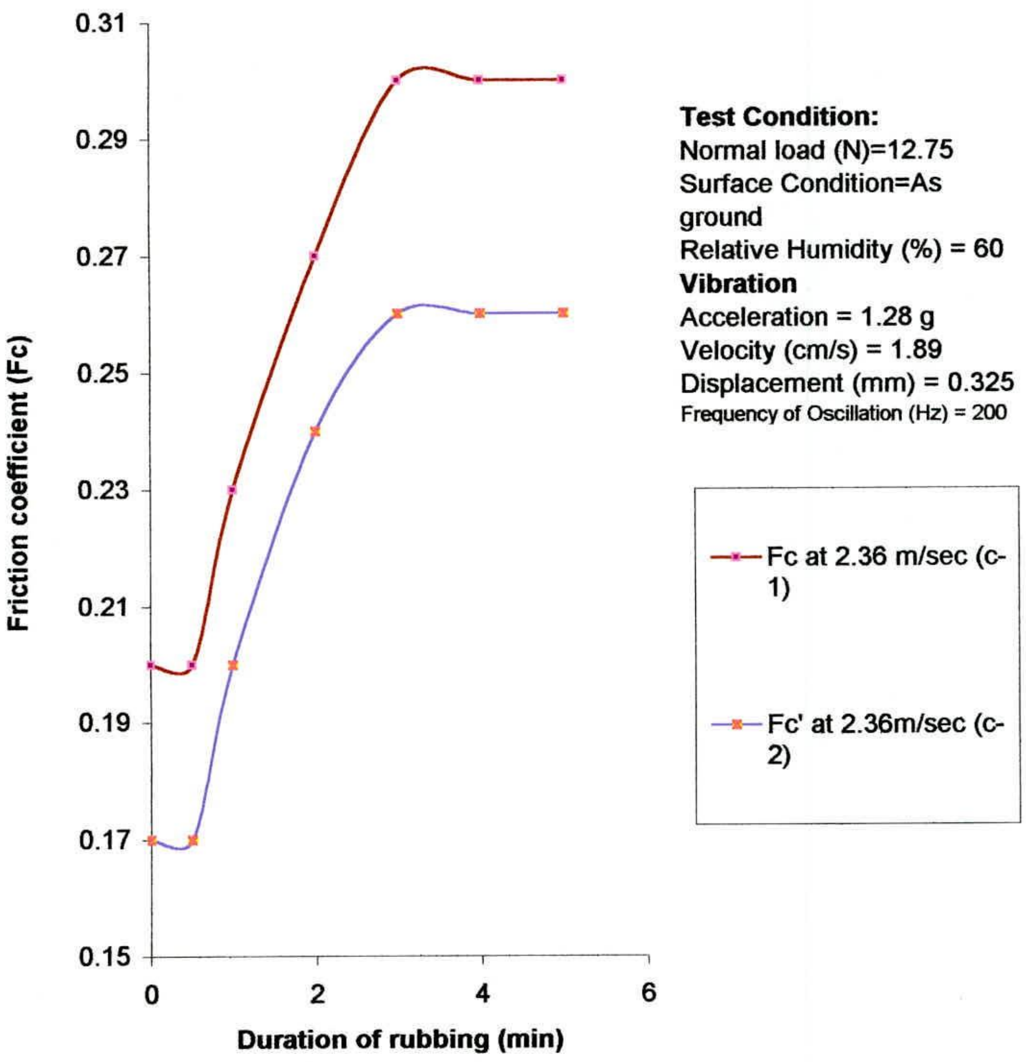

Fig.5.28: Duration of rubbing Vs Friction coefficient (0 & 200 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 60%, Normal Load = 12.75 N, as ground)

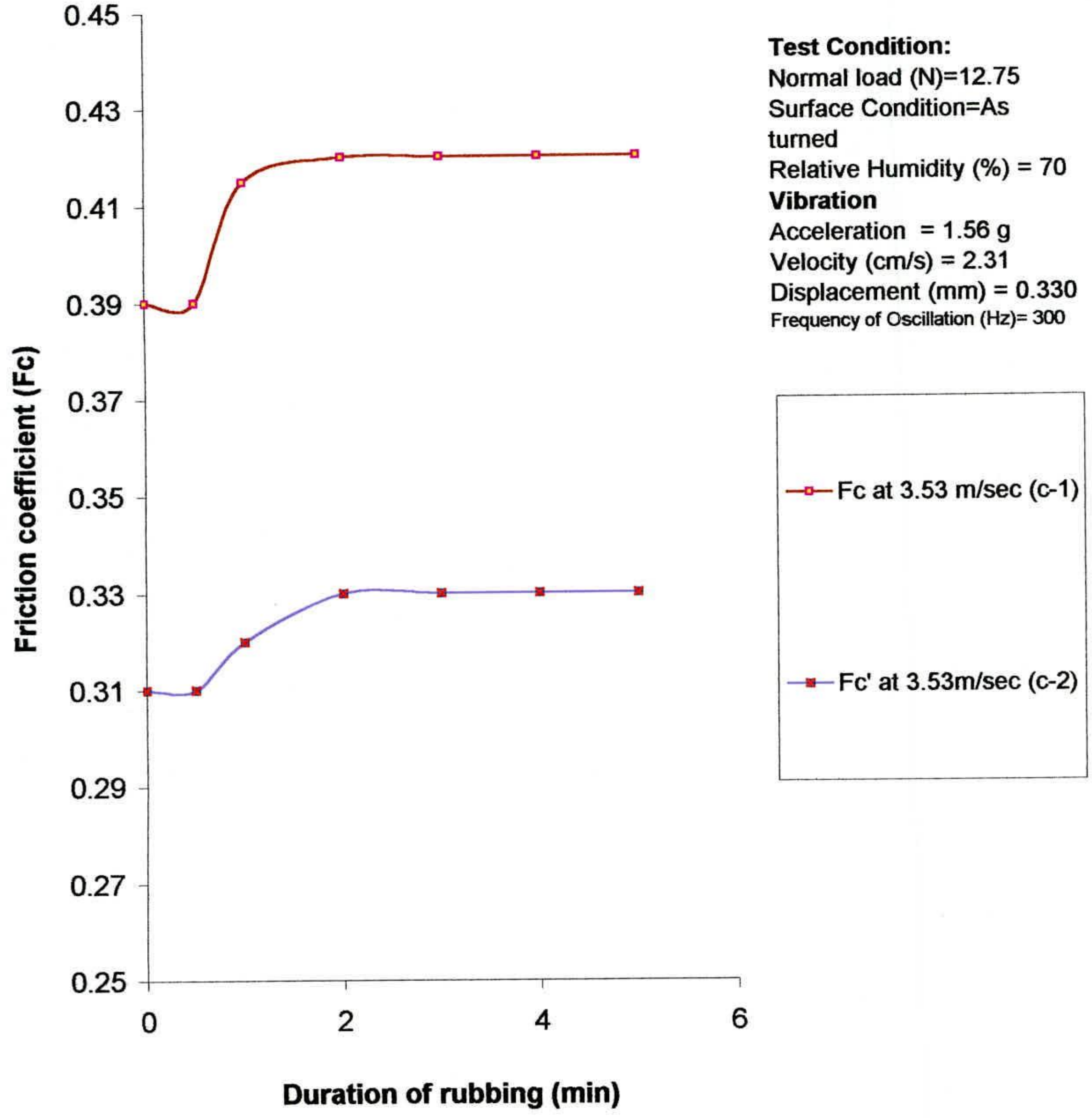

Fig.5.29: Duration of rubbing Vs Friction coefficient (0 & 300 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 70%, Normal load = 12.75 N, as turned)

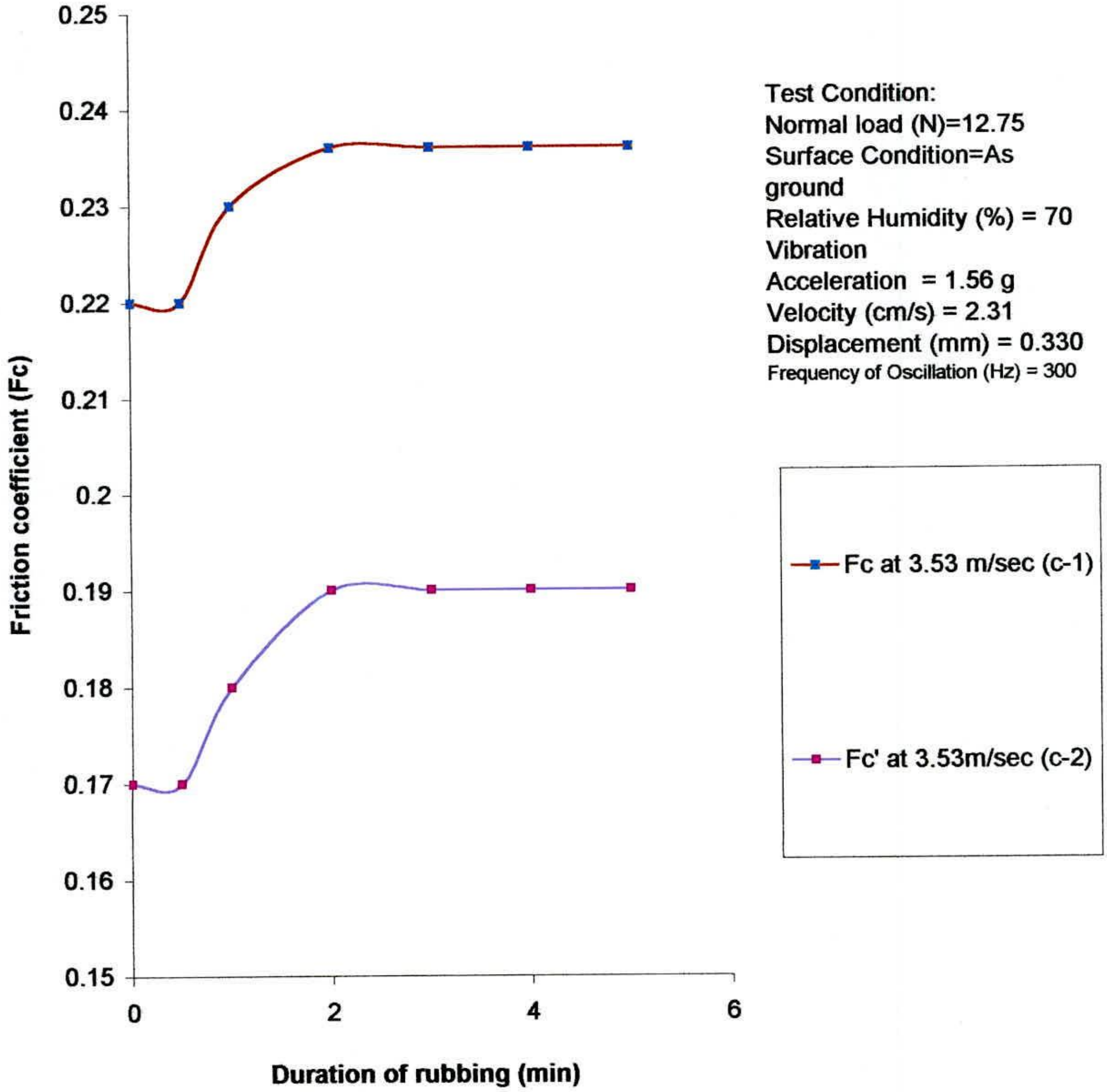

Fig.5.30: Duration of rubbing Vs Friction coefficient (0 & 300 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 70%, Normal load = 12.75 N, as ground)

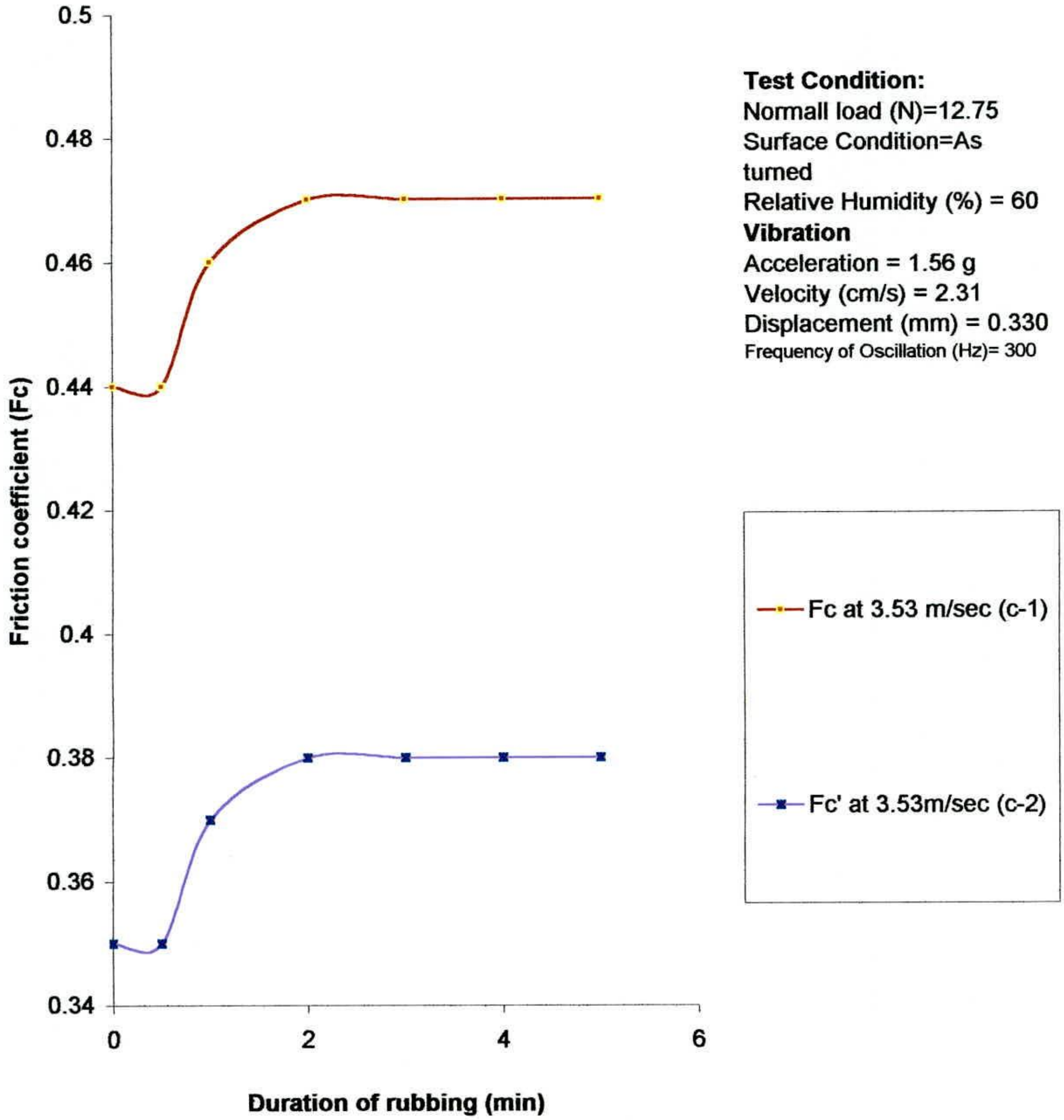

Fig.5.31: Duration of rubbing Vs Friction coefficient (0 & 300 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 60, Normal load = 12.75 N, as turned)

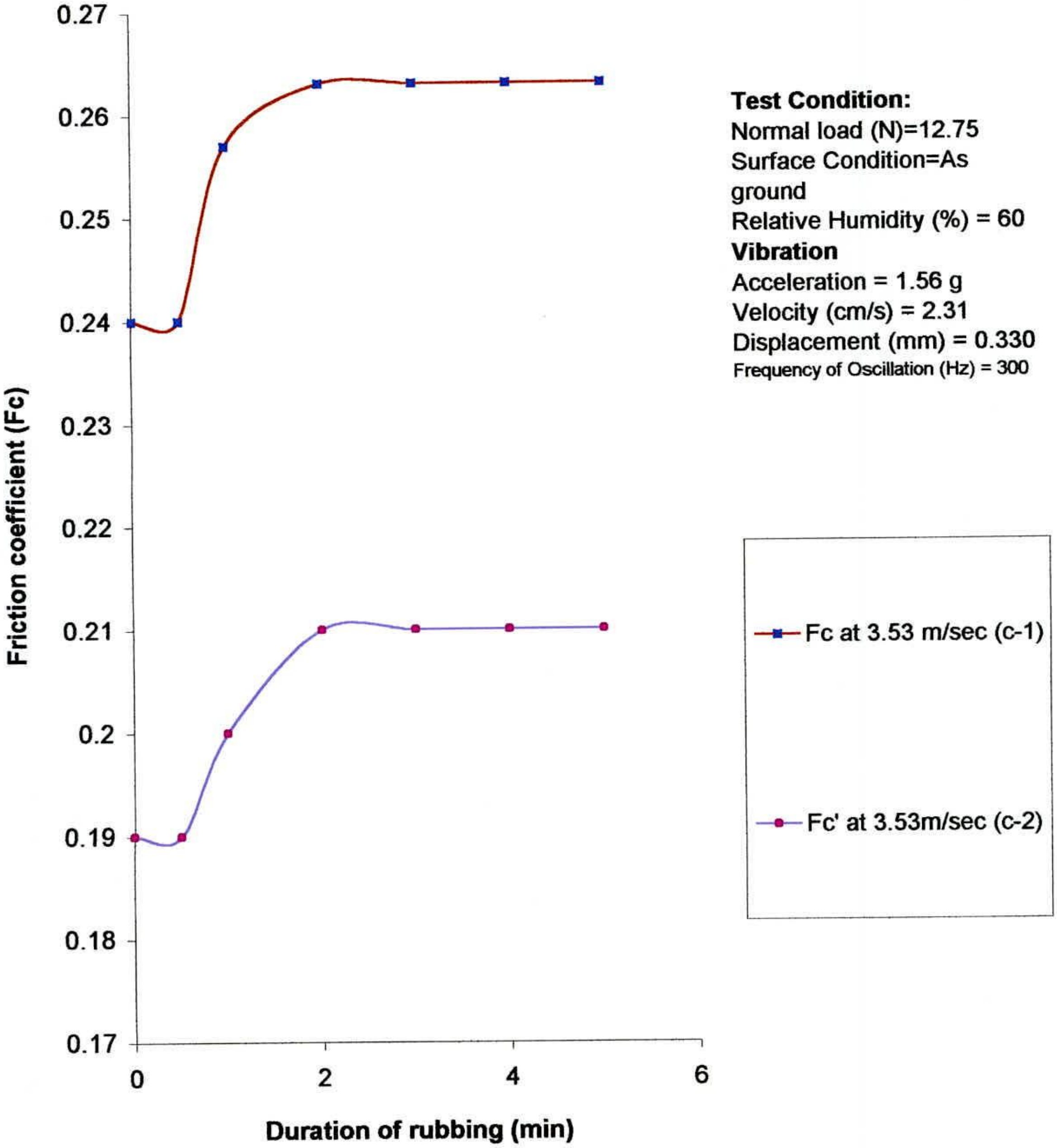

Fig.5.32: Duration of rubbing Vs Friction coefficient (0 & 300 Hz Frequency of Oscillation) at different linear velocity (Relative humidity = 60%, Normal Load = 12.75 N, as ground)

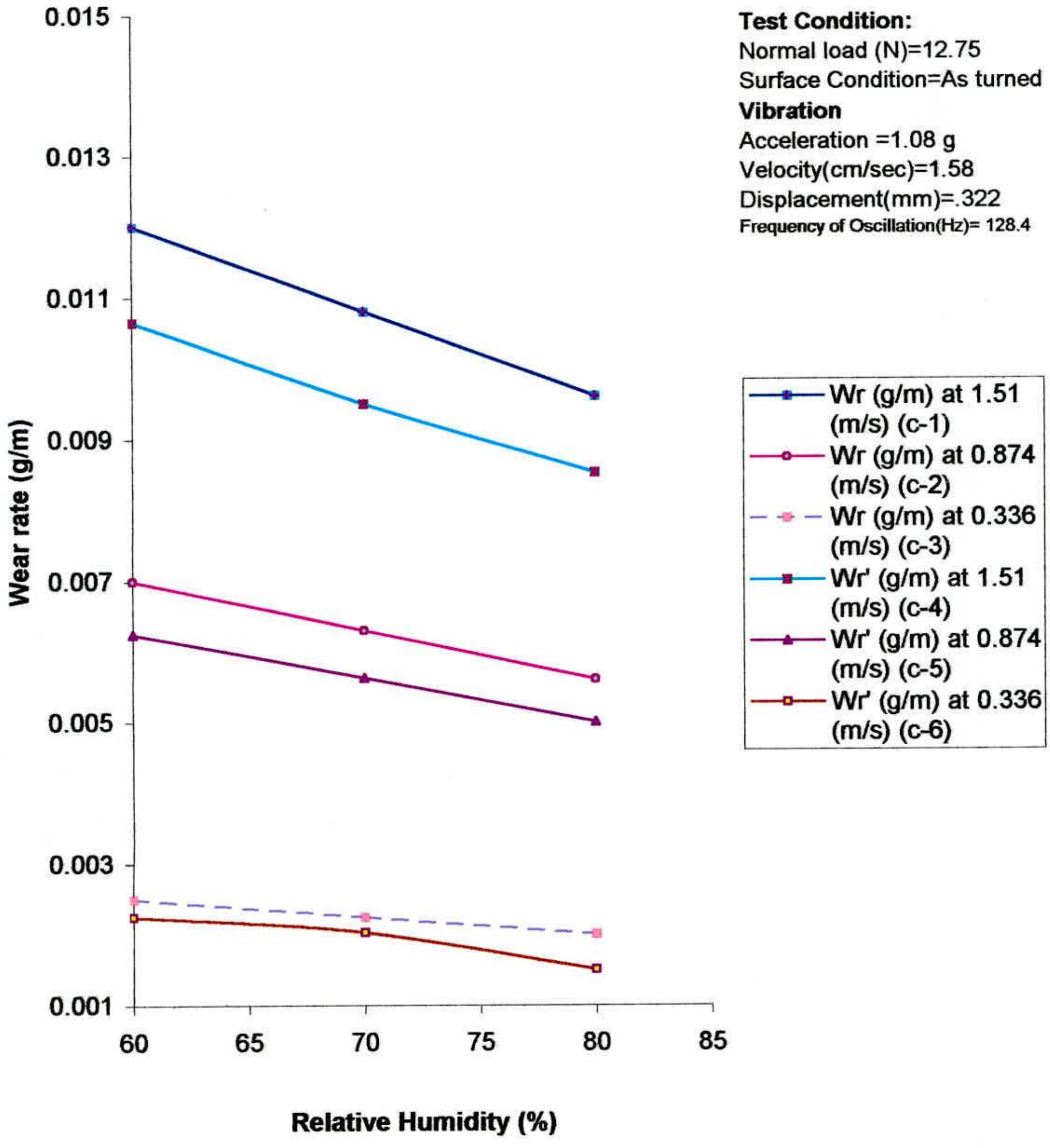

Fig. 5.33: Variation of wear rate (with vibration of 0 & 128.4 Hz) at different humidity (Normal load = 12.75 N, as turned)

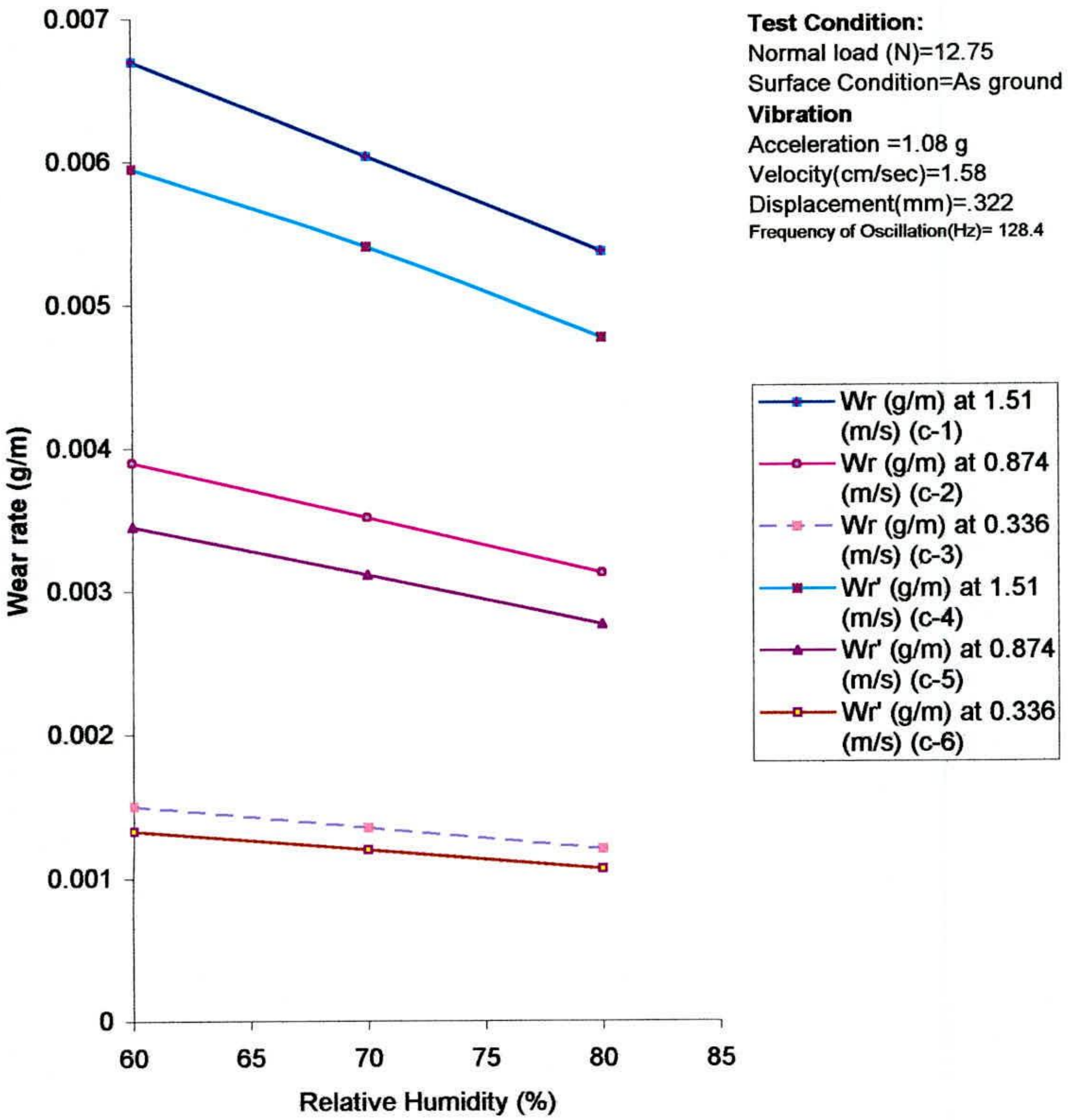

Fig. 5.34: Variation of wear rate (with vibration of 0 & 128.4 Hz) at different humidity (Normal load = 12.75 N, as ground)

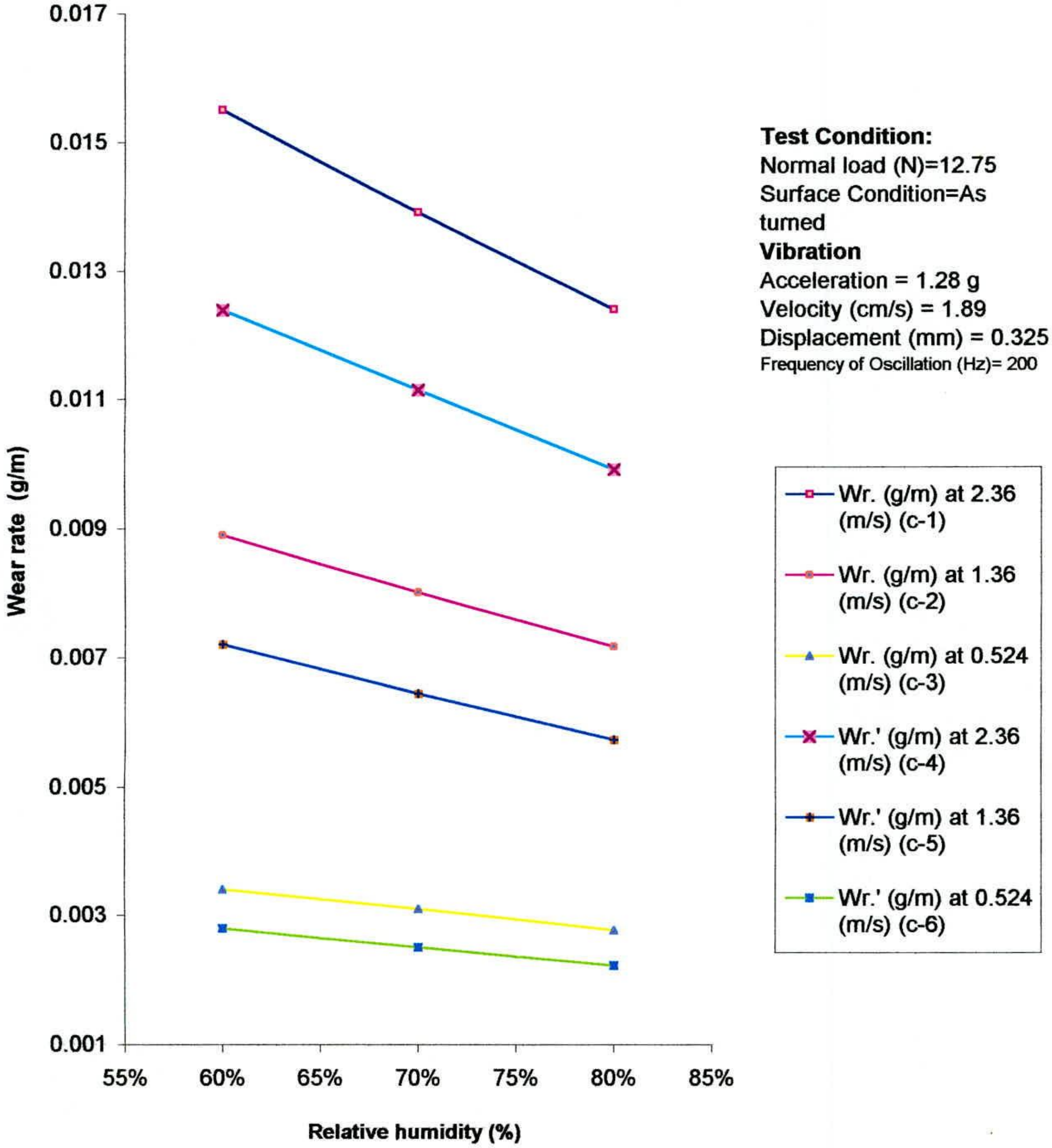

Fig. 5.35 : Variation of wear rate (with vibration of 0 & 200 Hz) at different linear velocity (Normal load = 12.75, as turned)

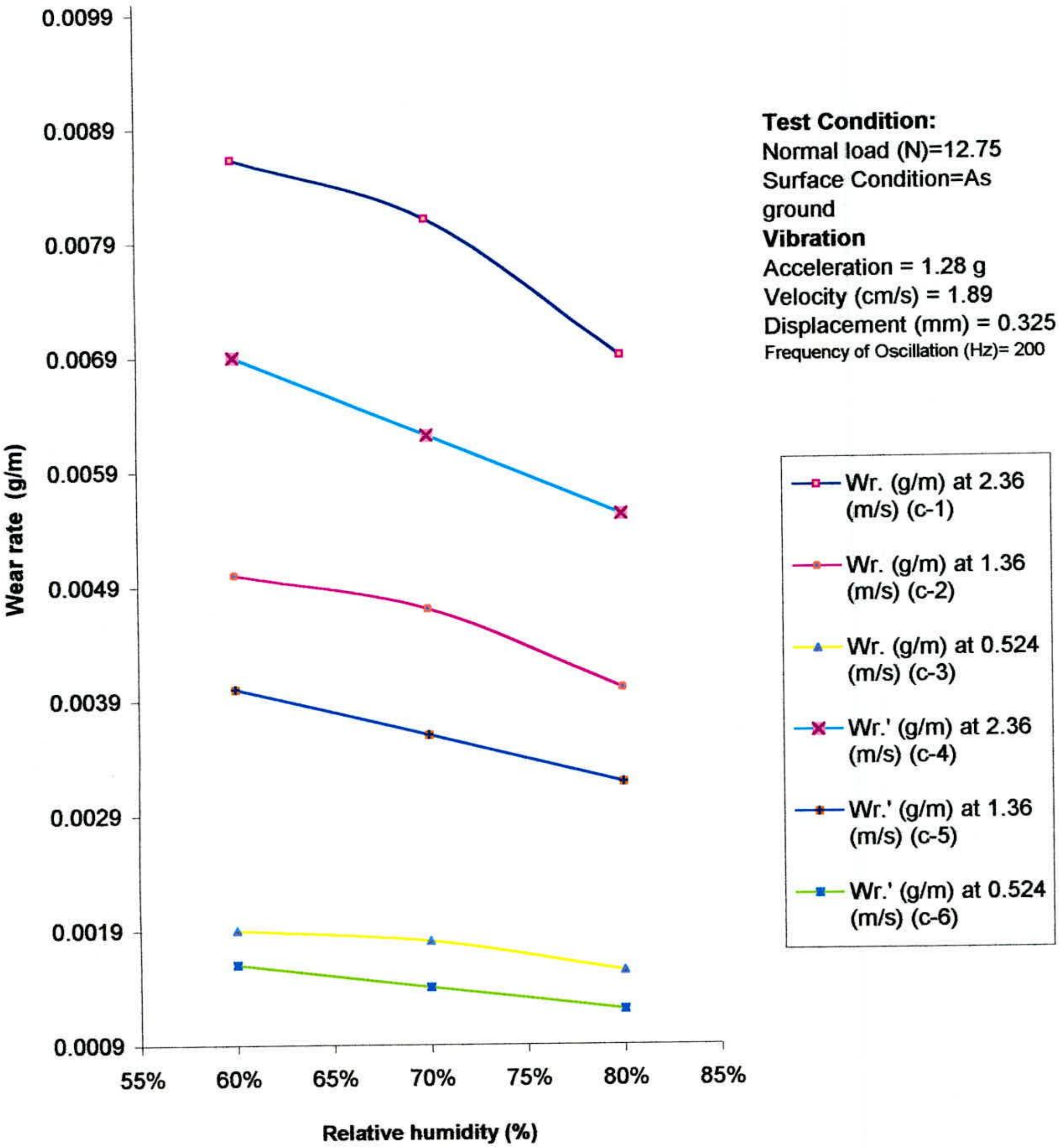

Fig. 5.36 : Variation of wear rate (with vibration of 0 & 200 Hz) at different linear velocity (Normal load = 12.75, as ground)

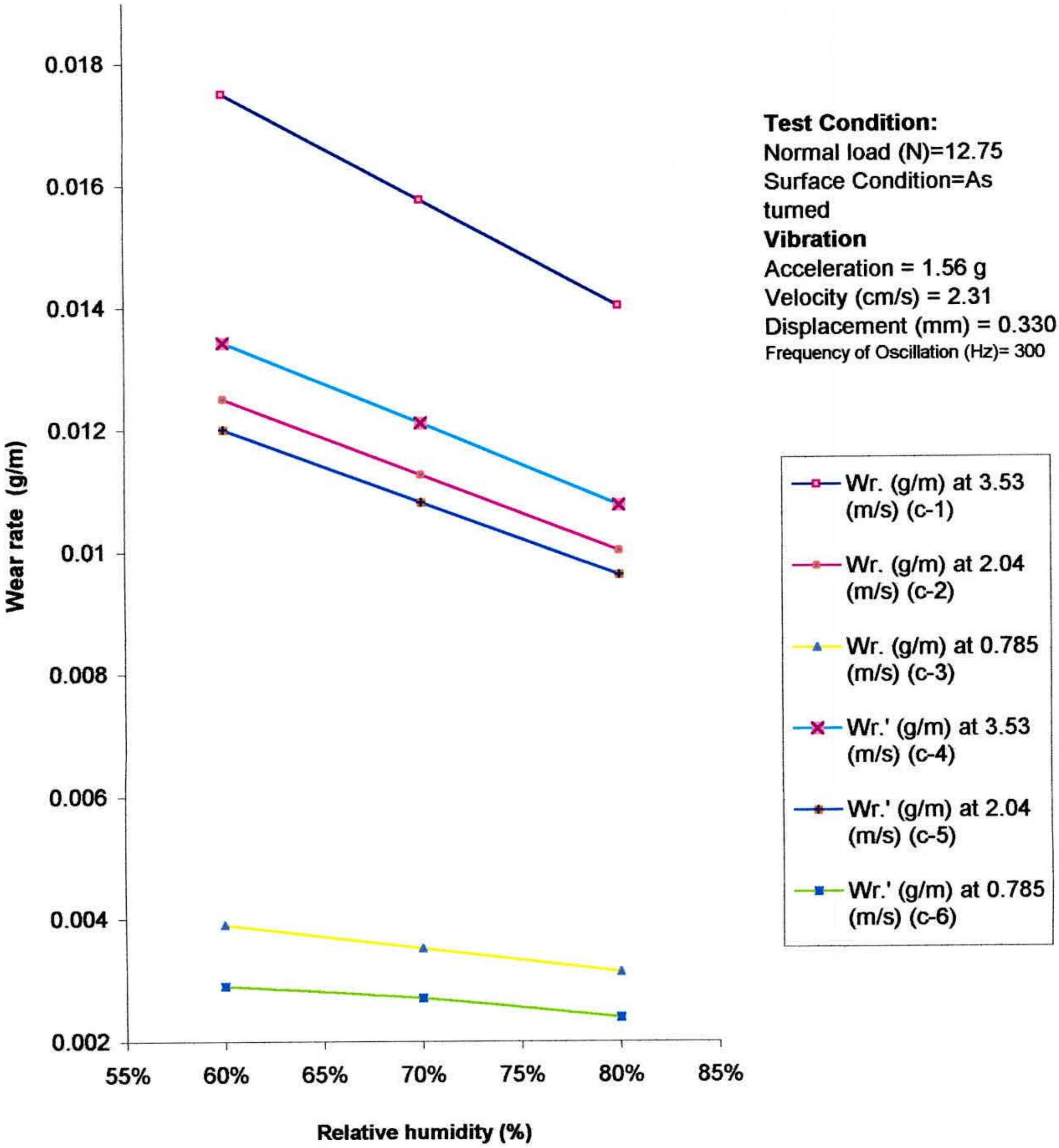

Fig. 5.37 : Variation of wear rate (with vibration of 0 & 300 Hz) at different linear velocity (Normal load = 12.75, as turned)

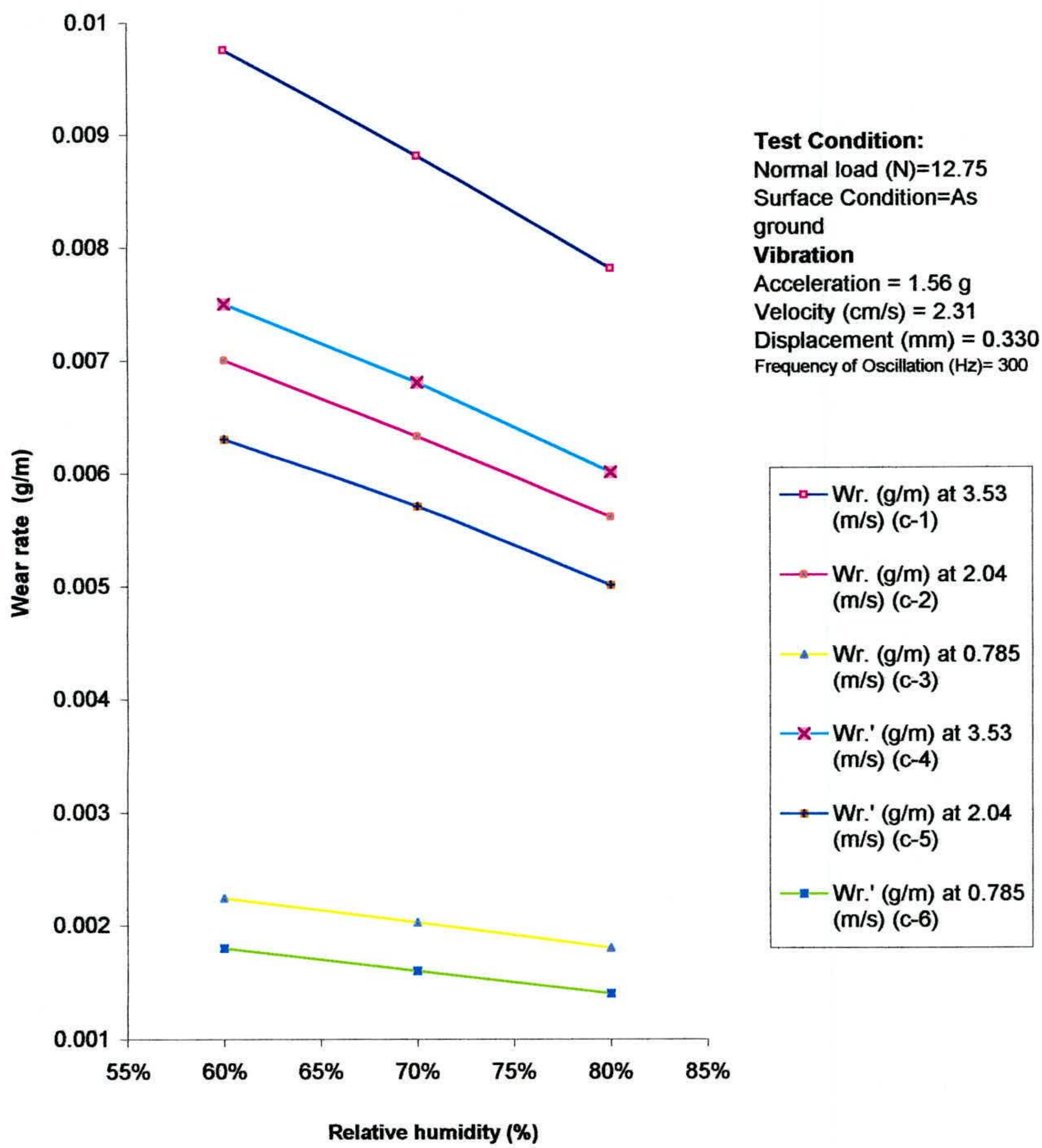

Fig. 5.38 : Variation of wear rate (with vibration of 0 & 300 Hz) at different linear velocity (Normal load = 12.75, as ground)

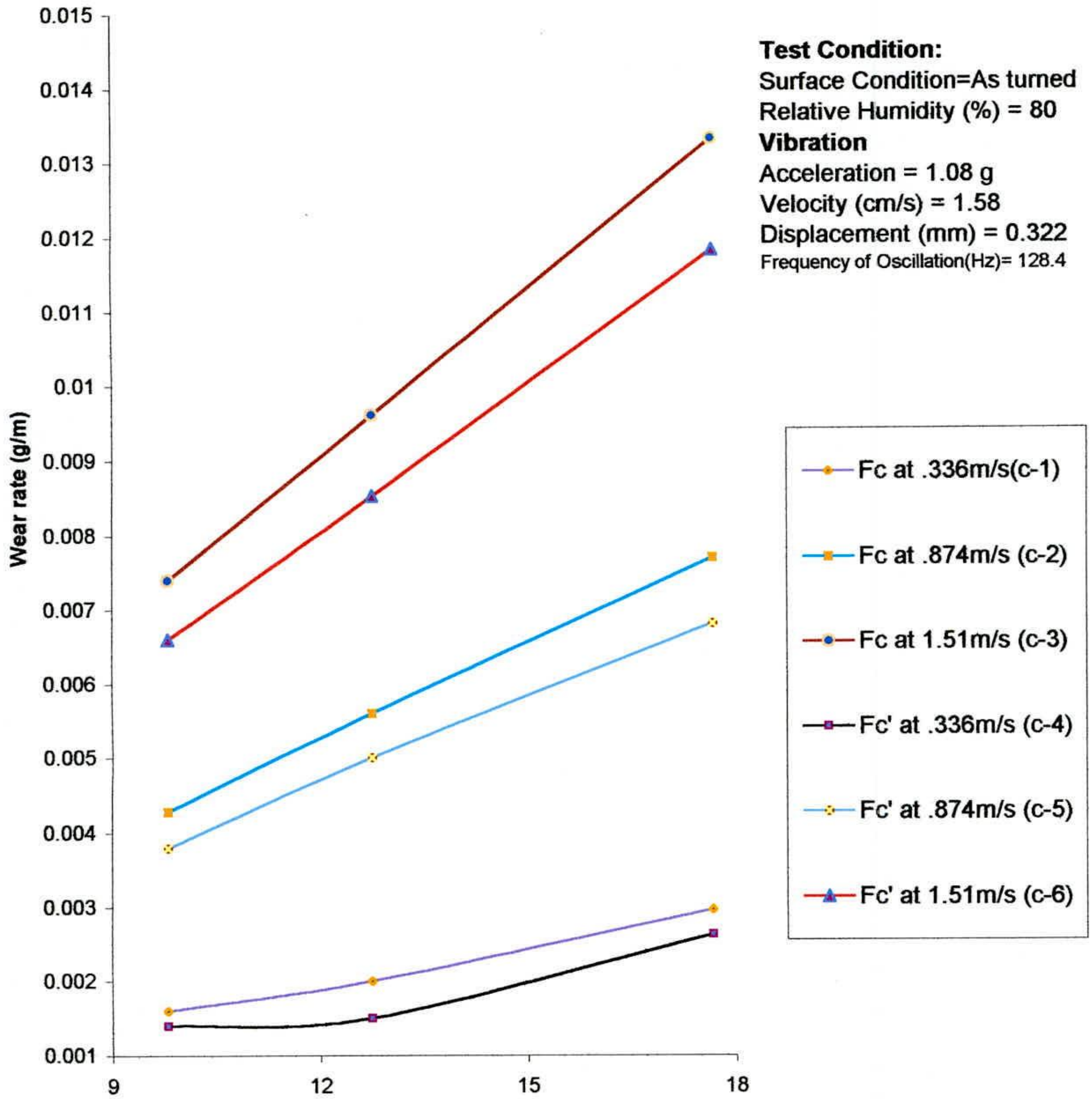

Fig.5.39: Variation of wear rate (with vibration of 0 & 128.4 Hz) at different Normal load (Relative humidity = 80%, as turned)

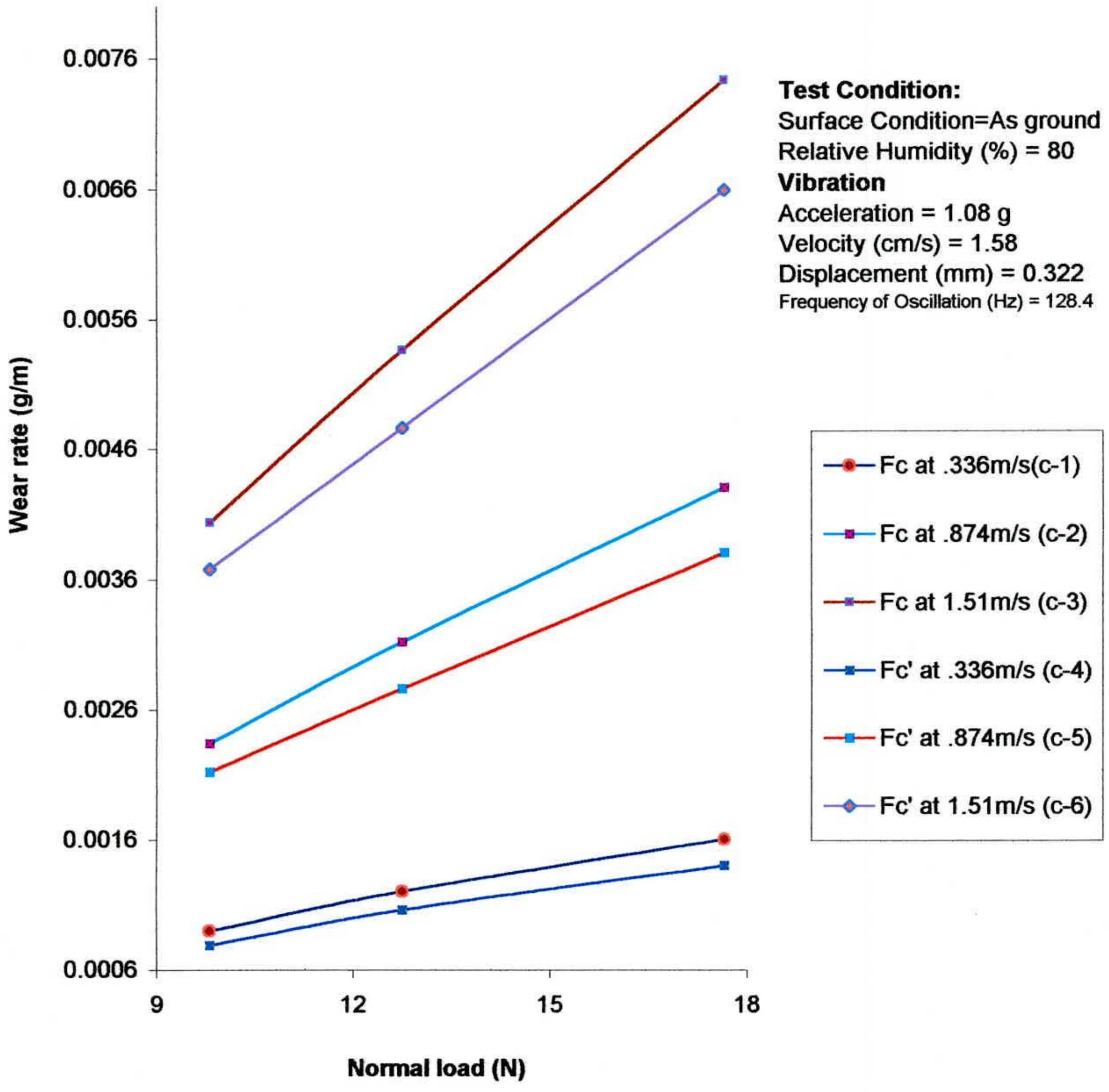

Fig.5.40 : Variation of wear rate (with vibration 0 & 120.4 Hz) at different Normal load (Relative humidity = 80%, as ground)

CHAPTER – VI

❖ Conclusions

CONCLUSIONS

From the results of this experimental study, the following conclusions have been drawn:

1. Friction co-efficient is more under vibration of 0 Hz frequency condition (without vibration) than that of higher frequency of vibration condition (with vibration).
2. The difference of friction co-efficient under vibrating and non-vibrating conditions increases with the increase of frequency of vibration.
3. Wear rate is more under vibration of 0 Hz frequency condition (without vibration) than that of higher frequency of vibration condition.
4. The difference of wear rate of non-vibrating and vibrating condition increases with the increase of frequency of vibration.
5. Friction co-efficient increases linearly with the duration of rubbing and becomes constant after a while.
6. Friction co-efficient and wear rate decrease with increasing relative humidity.
7. Friction co-efficient is almost the same or constant (under identical conditions) at different normal loads. But wear rate increases with the increasing normal load.
8. Rate of increase of friction co-efficient is more at lower linear velocity than that at higher linear velocity. But wear rate increases with increasing linear velocity.
9. The values of friction co-efficient and wear rate are less in case of ground surface compared to that of 'as-turned' surface for mild steel. The values of friction co-efficient is 40 – 45% and wear rate is 44% for ground surface compared to that of turned surface for mild steel.

Suggestion for future study

More studies and experimental accuracy would be needed to justify the outcome of the present study. Computerized system might be developed for easy recording and analysis.

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Appendices

APPENDICES

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 1

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-.5	3.04	0.23	7.020	2.671	0.0096
1	3.92	0.31			
2	5.10	0.40			
3	6.08	0.48			
4	6.08	0.48			
5	6.08	0.48			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 2

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-5	2.59	0.200	7.020	5.552	0.0056
1	3.68	0.290			
2	5.20	0.407			
3	6.47	0.507			
4	6.47	0.507			
5	6.47	0.507			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 3

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	2.22	0.17	7.020	6.8189	0.002
1	3.47	0.27			
2	5.30	0.42			
3	6.83	0.54			
4	6.86	0.54			
5	6.83	0.54			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 4

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-.5	1.70	0.13	7.020	4.592	0.00536
1	2.20	0.17			
2	2.85	0.22			
3	3.40	0.27			
4	3.40	0.27			
5	3.40	0.27			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 5

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-.5	1.45	0.11	7.020	6.202	0.00312
1	2.06	0.16			
2	2.91	0.23			
3	3.63	0.26			
4	3.63	0.26			
5	3.63	0.26			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 6

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-.5	1.25	0.098	7.020	6.900	0.0012
1	1.96	0.150			
2	2.94	0.232			
3	3.83	0.300			
4	3.83	0.300			
5	3.83	0.300			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 7

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	4.22	0.23	7.020	0.995	0.0133
1	5.44	0.31			
2	7.07	0.40			
3	8.44	0.48			
4	8.44	0.48			
5	8.44	0.48			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 8

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	3.53	0.20	7.020	5.006	0.00768
1	5.12	0.29			
2	7.26	0.41			
3	9.03	0.51			
4	9.03	0.51			
5	9.03	0.51			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 9

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-.5	3.00	0.17	7.020	6.722	0.00296
1	4.76	0.27			
2	7.42	0.42			
3	9.52	0.54			
4	9.52	0.54			
5	9.52	0.54			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 10

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-5	2.35	0.13	7.020	3.659	0.00742
1	3.04	0.17			
2	3.94	0.22			
3	4.71	0.27			
4	4.71	0.27			
5	4.71	0.27			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 11

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-.5	1.94	0.11	7.020	5.893	0.0043
1	2.84	0.16			
2	4.07	0.23			
3	4.95	0.28			
4	4.95	0.28			
5	4.95	0.28			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 12

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	0.52	0.029	7.020	6.859	0.0016
1	0.67	0.038			
2	0.88	0.050			
3	1.06	0.060			
4	1.06	0.060			
5	1.06	0.060			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 13

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.33	0.24	7.020	3.668	0.0074
1	3.02	0.31			
2	3.92	0.40			
3	4.68	0.48			
4	4.68	0.48			
5	4.68	0.48			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 14

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-.5	1.9	0.20	7.020	5.898	0.00428
1	2.85	0.29			
2	4.05	0.41			
3	5.00	0.51			
4	5.00	0.51			
5	5.00	0.51			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 15

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.71	0.17	7.020	6.859	0.0016
1	2.67	0.27			
2	4.12	0.42			
3	5.30	0.54			
4	5.30	0.54			
5	5.30	0.54			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 16

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-.5	1.28	0.13	7.020	5.190	0.00404
1	1.67	0.17			
2	2.16	0.22			
3	2.65	0.27			
4	2.65	0.27			
5	2.65	0.27			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 17

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-.5	1.12	0.11	7.020	6.406	0.00234
1	1.59	0.16			
2	2.28	0.23			
3	2.75	0.28			
4	2.75	0.28			
5	2.75	0.28			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 18

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	0.96	0.030	7.020	6.929	0.0009
1	1.48	0.038			
2	2.26	0.050			
3	2.96	0.060			
4	2.96	0.060			
5	2.96	0.060			

Test Condition:

Linear Velocity (m/s)	:	1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)	:	1.08
Surface Condition	:	As-turned	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	80	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 19

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-.5	2.70	0.21	7.020	3.160	0.00852
1	3.48	0.27			
2	4.53	0.35			
3	5.40	0.42			
4	5.40	0.42			
5	5.40	0.42			

Test Condition:

Linear Velocity (m/s)	:	0.874	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.08
Surface Condition	:	As-turned	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 20

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	2.30	0.18	7.020	5.709	0.005
1	3.27	0.26			
2	4.61	0.36			
3	5.75	0.45			
4	5.75	0.45			
5	5.75	0.45			

Test Condition:

Linear Velocity (m/s) : 0.336
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Condition of Vibration : With Vibration
Acceleration (g) 1.08
Velocity (cm/s) 1.58
Displacement (mm) 0.322
Frequency of Oscillation (Hz) 128.4

Table No.: 21

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.97	0.15	7.020	6.869	0.0015
1	3.09	0.24			
2	4.71	0.37			
3	6.06	0.48			
4	6.06	0.48			
5	6.06	0.48			

Test Condition:

Linear Velocity (m/s) : 1.51
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Condition of Vibration : With Vibration
Acceleration (g) 1.08
Velocity (cm/s) 1.58
Displacement (mm) 0.322
Frequency of Oscillation (Hz) 128.4

Table No.: 22

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-.5	1.51	0.12	7.020	4.864	0.00476
1	1.96	0.15			
2	2.55	0.20			
3	3.02	0.23			
4	3.02	0.23			
5	3.02	0.23			

Test Condition:

Linear Velocity (m/s)	: 0.874	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	1.08
Surface Condition	: As ground	Velocity (cm/s)	1.58
Relative humidity (%)	: 80	Displacement (mm)	0.322
No Lubrication		Frequency of Oscillation (Hz)	128.4

Table No.: 23

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	1.29	0.10	7.020	6.296	0.00276
1	1.83	0.14			
2	2.60	0.20			
3	3.24	0.25			
4	3.24	0.25			
5	3.24	0.25			

Test Condition:

Linear Velocity (m/s)	: 0.336	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	1.08
Surface Condition	: As ground	Velocity (cm/s)	1.58
Relative humidity (%)	: 80	Displacement (mm)	0.322
No Lubrication		Frequency of Oscillation (Hz)	128.4

Table No.: 24

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.11	0.086	7.020	6.913	0.00106
1	1.75	0.14			
2	2.63	0.21			
3	3.41	0.27			
4	3.41	0.27			
5	3.41	0.27			

Test Condition:

Linear Velocity (m/s)	:	1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.08
Surface Condition	:	As-turned	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 25

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-.5	3.74	0.21	7.020	1.675	0.0118
1	4.83	0.27			
2	6.28	0.36			
3	7.48	0.42			
4	7.48	0.42			
5	7.48	0.42			

Test Condition:

Linear Velocity (m/s)	:	0.874	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.08
Surface Condition	:	As-turned	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 26

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	3.19	0.18	7.020	5.237	0.0068
1	4.61	0.26			
2	6.38	0.36			
3	7.95	0.45			
4	7.95	0.45			
5	7.95	0.45			

Test Condition:

Linear Velocity (m/s)	: 0.336	Condition of Vibration	:	With Vibration
Normal Load (N)	: 17.66	Acceleration (g)		1.08
Surface Condition	: As-turned	Velocity (cm/s)		1.58
Relative humidity (%)	: 80	Displacement (mm)		0.322
No Lubrication		Frequency of Oscillation (Hz)		128.4

Table No.: 27

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-.5	2.65	0.15	7.020	6.756	0.00262
1	4.24	0.24			
2	6.53	0.37			
3	8.49	0.48			
4	8.49	0.48			
5	8.49	0.48			

Test Condition:

Linear Velocity (m/s)	: 1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	: 17.66	Acceleration (g)		1.08
Surface Condition	: As ground	Velocity (cm/s)		1.58
Relative humidity (%)	: 80	Displacement (mm)		0.322
No Lubrication		Frequency of Oscillation (Hz)		128.4

Table No.: 28

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-.5	2.09	0.12	7.020	4.039	0.00658
1	2.71	0.15			
2	3.53	0.20			
3	4.18	0.24			
4	4.18	0.24			
5	4.18	0.24			

Test Condition:

Linear Velocity (m/s)	:	0.874	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.08
Surface Condition	:	As ground	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 29

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	1.77	0.10	7.020	6.024	0.0038
1	2.45	0.14			
2	3.53	0.20			
3	4.41	0.25			
4	4.41	0.25			
5	4.41	0.25			

Test Condition:

Linear Velocity (m/s)	:	0.336	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.08
Surface Condition	:	As ground	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 30

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.52	0.086	7.020	6.879	0.0014
1	2.40	0.14			
2	3.73	0.21			
3	4.77	0.27			
4	4.77	0.27			
5	4.77	0.27			

Test Condition:

Linear Velocity (m/s) : 1.51
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Condition of Vibration : With Vibration
Acceleration (g) 1.08
Velocity (cm/s) 1.58
Displacement (mm) 0.322
Frequency of Oscillation (Hz) 128.4

Table No.: 31

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.08	0.21	7.020	4.030	0.0066
1	2.68	0.27			
2	3.48	0.35			
3	4.15	0.42			
4	4.15	0.42			
5	4.15	0.42			

Test Condition:

Linear Velocity (m/s) : 0.874
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Condition of Vibration : With Vibration
Acceleration (g) 1.08
Velocity (cm/s) 1.58
Displacement (mm) 0.322
Frequency of Oscillation (Hz) 128.4

Table No.: 32

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	1.79	0.18	7.020	6.024	0.0038
1	2.59	0.26			
2	3.53	0.36			
3	4.43	0.45			
4	4.43	0.45			
5	4.43	0.45			

Test Condition:

Linear Velocity (m/s)	:	0.336	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.08
Surface Condition	:	As-turned	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 33

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.47	0.15	7.020	6.879	0.0014
1	2.39	0.24			
2	3.66	0.37			
3	4.71	0.48			
4	4.71	0.48			
5	4.71	0.48			

Test Condition:

Linear Velocity (m/s)	:	1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.08
Surface Condition	:	As ground	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 34

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	1.16	0.12	7.020	5.353	0.00368
1	1.50	0.15			
2	1.96	0.20			
3	2.32	0.24			
4	2.32	0.24			
5	2.32	0.24			

Test Condition:

Linear Velocity (m/s)	:	0.874	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.08
Surface Condition	:	As ground	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 35

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	1.00	0.10	7.020	6.464	0.00212
1	1.41	0.14			
2	1.96	0.20			
3	2.46	0.25			
4	2.46	0.25			
5	2.46	0.25			

Test Condition:

Linear Velocity (m/s)	:	0.336	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.08
Surface Condition	:	As ground	Velocity (cm/s)		1.58
Relative humidity (%)	:	80	Displacement (mm)		0.322
No Lubrication			Frequency of Oscillation (Hz)		128.4

Table No.: 36

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-.5	0.84	0.086	7.020	6.941	0.001
1	1.35	0.14			
2	2.08	0.21			
3	2.68	0.27			
4	2.68	0.27			
5	2.68	0.27			

Test Condition:

Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 37

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	3.63	0.285	7.020	1.235	0.01238
1	4.26	0.331			
2	4.26	0.39			
3	5.54	0.43			
4	5.54	0.43			
5	5.54	0.43			

Test Condition:

Linear Velocity (m/s) : 1.36 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 38

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	2.94	0.23	7.020	4.099	0.00716
1	3.87	0.304			
2	5.12	0.402			
3	6.18	0.485			
4	6.18	0.485			
5	6.18	0.485			

Test Condition:

Linear Velocity (m/s) : 0.524 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 39

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	2.35	0.185	7.020	6.586	0.00276
1	3.53	0.28			
2	5.26	0.41			
3	6.71	0.53			
4	6.71	0.53			
5	6.71	0.53			

Test Condition:

Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 40

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.01	0.16	7.020	2.135	0.0069
1	2.37	0.19			
2	2.78	0.22			
3	3.09	0.24			
4	3.09	0.24			
5	3.09	0.24			

Test Condition:

Linear Velocity (m/s) : 1.36 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 41

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	1.64	0.099	7.020	5.388	0.004
1	2.16	0.110			
2	2.86	0.120			
3	3.45	0.120			
4	3.45	0.120			
5	3.45	0.120			

Test Condition:

Linear Velocity (m/s) : 0.524 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication :

Table No.: 42

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	1.32	0.10	7.020	6.778	0.00154
1	2.00	0.15			
2	2.94	0.23			
3	3.76	0.29			
4	3.76	0.29			
5	3.76	0.29			

Test Condition:

Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 43

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	5.03	0.23	13.000	0.822	0.0172
1	5.84	0.304			
2	6.89	0.403			
3	7.60	0.485			
4	7.60	0.485			
5	7.60	0.485			

Test Condition:

Linear Velocity (m/s) : 1.36 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 44

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	4.07	0.23	7.020	2.981	0.0099
1	5.37	0.304			
2	7.11	0.403			
3	8.56	0.485			
4	8.56	0.485			
5	8.56	0.485			

Test Condition:

Linear Velocity (m/s) : 0.524 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 45

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	3.29	0.186	7.020	6.423	0.0038
1	4.95	0.281			
2	7.26	0.410			
3	9.37	0.531			
4	9.37	0.531			
5	9.37	0.531			

Test Condition:

Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 46

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.84	0.16	7.020	0.2232	0.0096
1	3.34	0.19			
2	3.87	0.22			
3	4.22	0.24			
4	4.22	0.24			
5	4.22	0.24			

Test Condition:

Linear Velocity (m/s) : 1.36 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 47

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	2.31	0.13	7.020	4.759	0.006
1	3.00	0.17			
2	3.97	0.225			
3	4.76	0.27			
4	4.76	0.27			
5	4.76	0.27			

Test Condition:

Linear Velocity (m/s) : 0.524 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 48

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	1.77	0.10	7.020	6.684	0.00214
1	2.65	0.15			
2	4.07	0.23			
3	5.10	0.29			
4	5.10	0.29			
5	5.10	0.29			

Test Condition:
Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 49

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.80	0.285	7.020	0.237	0.00958
1	3.27	0.33			
2	3.85	0.39			
3	4.22	0.43			
4	4.22	0.43			
5	4.22	0.43			

Test Condition:
Linear Velocity (m/s) : 1.36 Condition of Vibration : Without Vibration
Normal Load (N) : 100
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 50

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	2.30	0.23	7.020	4.759	0.006
1	2.97	0.30			
2	3.92	0.40			
3	4.76	0.485			
4	4.76	0.485			
5	4.76	0.485			

Test Condition:
Linear Velocity (m/s) : 0.524 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 51

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	1.81	0.185	7.020	6.687	0.00212
1	2.79	0.28			
2	4.04	0.41			
3	5.21	0.53			
4	5.21	0.53			
5	5.21	0.53			

Test Condition:
Linear Velocity (m/s) : 1.36 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 52

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	1.60	0.16	7.020	3.161	0.006
1	1.86	0.19			
2	2.20	0.22			
3	2.37	0.24			
4	2.37	0.24			
5	2.37	0.24			

Test Condition:

Linear Velocity (m/s) : 1.36 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 53

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	1.28	0.13	7.020	5.763	0.003
1	1.69	0.17			
2	2.21	0.225			
3	2.67	0.27			
4	2.67	0.27			
5	2.67	0.27			

Test Condition:

Linear Velocity (m/s) : 0.524 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 54

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	0.99	0.10	7.020	6.831	0.001
1	1.50	0.15			
2	2.28	0.23			
3	2.84	0.29			
4	2.84	0.29			
5	2.84	0.29			

Test Condition:

Linear Velocity (m/s)	:	2.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 55

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.97	0.23	7.020	0.008	0.01
1	3.48	0.27			
2	4.07	0.32			
3	4.55	0.36			
4	4.55	0.36			
5	4.55	0.36			

Test Condition:

Linear Velocity (m/s)	:	1.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 56

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	2.41	0.19	7.020	4.686	0.006
1	3.19	0.25			
2	4.22	0.33			
3	5.06	0.40			
4	5.06	0.40			
5	5.06	0.40			

Test Condition:

Linear Velocity (m/s)	:	0.524	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 57

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	1.93	0.15	7.020	6.671	0.002
1	2.89	0.23			
2	4.32	0.34			
3	5.49	0.43			
4	5.49	0.43			
5	5.49	0.43			

Test Condition:

Linear Velocity (m/s)	:	2.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.28
Surface Condition	:	As ground	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 58

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	1.67	0.13	7.020	3.112	0.006
1	1.96	0.15			
2	2.30	0.18			
3	2.55	0.20			
4	2.55	0.20			
5	2.55	0.20			

Test Condition:

Linear Velocity (m/s)	: 1.36	Condition of Vibration	:	With Vibration
Normal Load (N)	: 12.75	Acceleration (g)		1.28
Surface Condition	: As ground	Velocity (cm/s)		1.89
Relative humidity (%)	: 80	Displacement (mm)		0.325
No Lubrication		Frequency of Oscillation (Hz)		200

Table No.: 59

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	1.35	0.11	7.020	5.723	0.003
1	1.79	0.14			
2	2.55	0.19			
3	2.84	0.22			
4	2.84	0.22			
5	2.84	0.22			

Test Condition:

Linear Velocity (m/s)	: 0.524	Condition of Vibration	:	With Vibration
Normal Load (N)	: 12.75	Acceleration (g)		1.28
Surface Condition	: As ground	Velocity (cm/s)		1.89
Relative humidity (%)	: 80	Displacement (mm)		0.325
No Lubrication		Frequency of Oscillation (Hz)		200

Table No.: 60

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	1.09	0.086	7.020	6.831	0.001
1	1.65	0.13			
2	2.43	0.19			
3	3.10	0.20			
4	3.10.	0.20			
5	3.10	0.20			

Test Condition:

Linear Velocity (m/s)	:	2.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 61

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	4.07	0.23	10.000	0.3712	0.014
1	4.77	0.27			
2	5.64	0.32			
3	6.38	0.36			
4	6.38	0.36			
5	6.38	0.36			

Test Condition:

Linear Velocity (m/s)	:	1.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 62

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	3.38	0.19	7.020	3.838	0.008
1	4.41	0.25			
2	5.84	0.33			
3	7.06	0.40			
4	7.06	0.40			
5	7.06	0.40			

Test Condition:

Linear Velocity (m/s)	:	0.524	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 63

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	2.65	0.15	7.020	6.542	0.003
1	4.07	0.23			
2	6.03	0.34			
3	7.60	0.43			
4	7.60	0.43			
5	7.60	0.43			

Test Condition:

Linear Velocity (m/s)	:	2.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.28
Surface Condition	:	As ground	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 64

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.31	0.13	7.020	1.639	0.008
1	2.65	0.15			
2	3.19	0.18			
3	3.53	0.20			
4	3.53	0.20			
5	3.53	0.20			

Test Condition:

Linear Velocity (m/s)	: 1.36	Condition of Vibration	:	With Vibration
Normal Load (N)	: 17.66	Acceleration (g)		1.28
Surface Condition	: As ground	Velocity (cm/s)		1.89
Relative humidity (%)	: 80	Displacement (mm)		0.325
No Lubrication		Frequency of Oscillation (Hz)		200

Table No.: 65

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	1.96	0.11	7.020	5.208	0.004
1	2.47	0.14			
2	3.34	0.19			
3	3.88	0.22			
4	3.88	0.22			
5	3.88	0.22			

Test Condition:

Linear Velocity (m/s)	: 0.524	Condition of Vibration	:	With Vibration
Normal Load (N)	: 17.66	Acceleration (g)		1.28
Surface Condition	: As ground	Velocity (cm/s)		1.89
Relative humidity (%)	: 80	Displacement (mm)		0.325
No Lubrication		Frequency of Oscillation (Hz)		200

Table No.: 66

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	1.52	0.086	7.020	6.753	0.002
1	2.31	0.13			
2	3.36	0.19			
3	4.24	0.24			
4	4.24	0.24			
5	4.24	0.24			

Test Condition:

Linear Velocity (m/s)	:	2.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 67

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.28	0.23	7.020	1.498	0.0078
1	2.68	0.27			
2	3.14	0.32			
3	3.54	0.36			
4	3.54	0.36			
5	3.54	0.36			

Test Condition:

Linear Velocity (m/s)	:	1.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 68

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	1.89	0.19	7.020	5.225	0.004
1	2.46	0.25			
2	3.28	0.33			
3	3.92	0.40			
4	3.92	0.40			
5	3.92	0.40			

Test Condition:

Linear Velocity (m/s)	:	0.524	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.28
Surface Condition	:	As-turned	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 69

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	1.51	0.15	7.020	6.749	0.002
1	2.26	0.23			
2	3.37	0.34			
3	4.24	0.43			
4	4.24	0.43			
5	4.24	0.43			

Test Condition:

Linear Velocity (m/s)	:	2.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.28
Surface Condition	:	As ground	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 70

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	1.30	0.13	7.020	3.848	0.004
1	1.50	0.15			
2	1.78	0.18			
3	1.96	0.20			
4	1.96	0.20			
5	1.96	0.20			

Test Condition:

Linear Velocity (m/s)	:	1.36	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.28
Surface Condition	:	As ground	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 71

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 408 m sliding (g)	
0-. 5	1.10	0.11	7.020	5.967	0.003
1	1.40	0.14			
2	1.82	0.19			
3	2.18	0.22			
4	2.18	0.22			
5	2.18	0.22			

Test Condition:

Linear Velocity (m/s)	:	0.524	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)		1.28
Surface Condition	:	As ground	Velocity (cm/s)		1.89
Relative humidity (%)	:	80	Displacement (mm)		0.325
No Lubrication			Frequency of Oscillation (Hz)		200

Table No.: 72

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 157.2 m sliding (g)	
0-. 5	0.84	0.085	7.020	6.863	0.001
1	1.28	0.13			
2	1.90	0.19			
3	2.35	0.24			
4	2.35	0.24			
5	2.35	0.24			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 73

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	3.43	0.26	15.000	0.174	0.014
1	4.13	0.32			
2	5.02	0.39			
3	5.74	0.45			
4	5.74	0.45			
5	5.74	0.45			

Test Condition:

Linear Velocity (m/s) : 2.04 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 74

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	3.43	0.26	7.020	0.900	0.01
1	3.63	0.28			
2	3.68	0.29			
3	3.68	0.29			
4	3.68	0.29			
5	3.68	0.29			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 75

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	2.53	0.19	7.020	6.285	0.003
1	3.64	0.285			
2	5.22	0.41			
3	6.54	0.51			
4	6.54	0.51			
5	6.54	0.51			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 76

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	2.48	0.190	10.000	1.739	0.008
1	2.62	0.205			
2	2.68	0.210			
3	2.68	0.210			
4	2.68	0.210			
5	2.68	0.210			

Test Condition:

Linear Velocity (m/s) : 2.04 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 77

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	1.91	0.15	7.020	3.593	0.006
1	2.31	0.18			
2	2.81	0.22			
3	3.22	0.25			
4	3.22	0.25			
5	3.22	0.25			

Test Condition:

Linear Velocity (m/s) : 0.785 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 78

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	1.42	0.11	7.020	6.596	0.002
1	2.05	0.16			
2	2.91	0.23			
3	3.68	0.29			
4	3.68	0.29			
5	3.68	0.29			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 79

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	6.18	0.350	21.000	0.244	0.0196
1	6.52	0.369			
2	6.62	0.0375			
3	6.62	0.375			
4	6.62	0.375			
5	6.62	0.375			

Test Condition:

Linear Velocity (m/s) : 2.04 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 80

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-5	4.59	0.26	10.000	1.432	0.014
1	5.65	0.32			
2	6.89	0.39			
3	7.95	0.45			
4	7.95	0.45			
5	7.95	0.45			

Test Condition:

Linear Velocity (m/s) : 0.785 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 81

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	3.36	0.077	7.020	5.984	0.004
1	5.03	0.081			
2	7.24	0.084			
3	9.01	0.084			
4	9.01	0.084			
5	9.01	0.084			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 82

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	3.44	0.105	12.000	0.457	0.011
1	3.64	0.206			
2	3.73	0.210			
3	3.73	0.210			
4	3.73	0.210			
5	3.73	0.210			

Test Condition:

Linear Velocity (m/s) : 2.04 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 83

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	2.65	0.15	7.020	2.124	0.008
1	3.18	0.18			
2	3.88	0.22			
3	4.41	0.25			
4	4.41	0.5			
5	4.41	0.25			

Test Condition:

Linear Velocity (m/s) : 0.785 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 84

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	1.94	0.11	7.020	6.455	0.002
1	2.83	0.16			
2	4.06	0.23			
3	5.12	0.29			
4	5.12	0.29			
5	5.12	0.29			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 85

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	3.44	0.35	12.000	0.436	0.011
1	3.62	0.37			
2	3.68	0.38			
3	3.68	0.38			
4	3.68	0.38			
5	3.68	0.38			

Test Condition:

Linear Velocity (m/s) : 2.04 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 86

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	2.55	0.26	7.020	2.246	0.008
1	3.16	0.32			
2	3.85	0.39			
3	4.45	0.45			
4	4.45	0.45			
5	4.45	0.45			

Test Condition:

Linear Velocity (m/s) : 0.785 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 80
No Lubrication

Table No.: 87

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	1.89	0.19	7.020	6.455	0.002
1	2.80	0.285			
2	4.02	0.41			
3	5.00	0.51			
4	5.00	0.51			
5	5.00	0.51			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 88

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	1.94	0.198	7.020	0.497	0.006
1	2.06	0.210			
2	2.08	0.212			
3	2.08	0.212			
4	2.08	0.212			
5	2.08	0.212			

Test Condition:

Linear Velocity (m/s) : 2.04 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 89

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	1.49	0.15	7.020	4.327	0.004
1	1.80	0.18			
2	2.16	0.22			
3	2.45	0.25			
4	2.45	0.25			
5	2.45	0.25			

Test Condition:

Linear Velocity (m/s) : 0.785 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 80
No Lubrication

Table No.: 90

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	1.08	0.11	7.020	6.690	0.001
1	1.57	0.16			
2	2.26	0.26			
3	2.84	0.29			
4	2.84	0.29			
5	2.84	0.29			

Test Condition:

Linear Velocity (m/s)	:	3.53	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.56
Surface Condition	:	As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	:	80	Displacement (mm)		0.330
No Lubrication			Frequency of Oscillation (Hz)		300

Table No.: 91

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	3.34	0.26	12.000	0.626	0.011
1	3.53	0.28			
2	3.59	0.282			
3	3.59	0.282			
4	3.59	0.282			
5	3.59	0.282			

Test Condition:

Linear Velocity (m/s)	:	2.04	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.56
Surface Condition	:	As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	:	80	Displacement (mm)		0.330
No Lubrication			Frequency of Oscillation (Hz)		300

Table No.: 92

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	2.60	0.23	7.020	1.145	0.01
1	3.09	0.24			
2	3.78	0.24			
3	4.32	0.24			
4	4.32	0.24			
5	4.32	0.24			

Test Condition:

Linear Velocity (m/s)	:	0.785	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.56
Surface Condition	:	As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	:	80	Displacement (mm)		0.330
No Lubrication			Frequency of Oscillation (Hz)		300

Table No.: 93

Duration of rubbing (min)	**Horizontal force (N)**	**Friction coefficient**	**Mass**		**Wear rate (g/m)**
			Initial mass (g)	**Mass after 235.5 m sliding (g)**	
0-. 5	1.91	0.15	7.020	6.459	0.002
1	2.73	0.21			
2	3.92	0.31			
3	4.91	0.38			
4	4.91	0.38			
5	4.91	0.38			

Test Condition:

Linear Velocity (m/s)	:	3.53	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.56
Surface Condition	:	As ground	Velocity (cm/s)		2.31
Relative humidity (%)	:	80	Displacement (mm)		0.330
No Lubrication			Frequency of Oscillation (Hz)		300

Table No.: 94

Duration of rubbing (min)	**Horizontal force (N)**	**Friction coefficient**	**Mass**		**Wear rate (g/m)**
			Initial mass (g)	**Mass after 1059 m sliding (g)**	
0-. 5	1.87	0.15	7.020	0.666	0.006
1	1.97	0.155			
2	2.02	0.16			
3	2.02	0.16			
4	2.02	0.16			
5	2.02	0.16			

Test Condition:

Linear Velocity (m/s)	:	2.04	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.56
Surface Condition	:	As ground	Velocity (cm/s)		2.31
Relative humidity (%)	:	80	Displacement (mm)		0.330
No Lubrication			Frequency of Oscillation (Hz)		300

Table No.: 95

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	1.44	0.11	7.020	3.960	0.005
1	1.74	0.14			
2	2.11	0.17			
3	2.42	0.19			
4	2.42	0.19			
5	2.42	0.19			

Test Condition:

Linear Velocity (m/s)	:	0.785	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)		1.56
Surface Condition	:	As ground	Velocity (cm/s)		2.31
Relative humidity (%)	:	80	Displacement (mm)		0.330
No Lubrication			Frequency of Oscillation (Hz)		300

Table No.: 96

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	1.08	0.084	7.020	6.690	0.001
1	1.54	0.12			
2	2.20	0.17			
3	2.77	0.22			
4	2.77	0.22			
5	2.77	0.22			

Test Condition:

Linear Velocity (m/s)	: 3.53	Condition of Vibration	:	With Vibration
Normal Load (N)	: 17.66	Acceleration (g)		1.56
Surface Condition	: As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	: 80	Displacement (mm)		0.330
No Lubrication		Frequency of Oscillation (Hz)		300

Table No.: 97

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	4.61	0.26	16.000	0.3268	0.015
1	4.95	0.28			
2	4.98	0.282			
3	4.98	0.282			
4	4.98	0.282			
5	4.98	0.282			

Test Condition:

Linear Velocity (m/s)	: 2.04	Condition of Vibration	:	With Vibration
Normal Load (N)	: 17.66	Acceleration (g)		1.56
Surface Condition	: As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	: 80	Displacement (mm)		0.330
No Lubrication		Frequency of Oscillation (Hz)		300

Table No.: 98

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	3.53	0.20	7.020	0.900	0.010
1	4.24	0.24			
2	5.30	0.30			
3	6.00	0.34			
4	6.00	0.34			
5	6.00	0.34			

Test Condition:

Linear Velocity (m/s)	:	0.785	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.56
Surface Condition	:	As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	:	80	Displacement (mm)		0.330
No Lubrication			Frequency of Oscillation (Hz)		300

Table No.: 99

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	2.65	0.15	7.020	6.2664	0.003
1	3.71	0.21			
2	5.47	0.31			
3	6.72	0.38			
4	6.72	0.38			
5	6.72	0.38			

Test Condition:

Linear Velocity (m/s)	:	3.53	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)		1.56
Surface Condition	:	As ground	Velocity (cm/s)		2.31
Relative humidity (%)	:	80	Displacement (mm)		0.330
No Lubrication			Frequency of Oscillation (Hz)		300

Table No.: 100

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	2.65	0.15	10.000	1.274	0.008
1	2.75	0.155			
2	2.83	0.16			
3	2.83	0.16			
4	2.83	0.16			
5	2.83	0.16			

Test Condition:

Linear Velocity (m/s)	: 2.04	Condition of Vibration	:	With Vibration
Normal Load (N)	: 17.66	Acceleration (g)		1.56
Surface Condition	: As ground	Velocity (cm/s)		2.31
Relative humidity (%)	: 80	Displacement (mm)		0.330
No Lubrication		Frequency of Oscillation (Hz)		300

Table No.: 101

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	1.96	0.11	7.020	2.246	0.008
1	2.47	0.14			
2	2.97	0.17			
3	3.36	0.19			
4	3.36	0.19			
5	3.36	0.19			

Test Condition:

Linear Velocity (m/s)	: 0.785	Condition of Vibration	:	With Vibration
Normal Load (N)	: 17.66	Acceleration (g)		1.56
Surface Condition	: As ground	Velocity (cm/s)		2.31
Relative humidity (%)	: 80	Displacement (mm)		0.330
No Lubrication		Frequency of Oscillation (Hz)		300

Table No.: 102

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	1.48	0.084	7.020	6.596	0.002
1	2.12	0.12			
2	3.04	0.17			
3	3.88	0.22			
4	3.88	0.22			
5	3.88	0.22			

Test Condition:

Linear Velocity (m/s)	: 3.53	Condition of Vibration	:	With Vibration
Normal Load (N)	: 9.81	Acceleration (g)		1.56
Surface Condition	: As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	: 80	Displacement (mm)		0.330
No Lubrication		Frequency of Oscillation (Hz)		300

Table No.: 103

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	2.57	0.26	7.020	1.104	0.008
1	2.75	0.28			
2	2.77	0.282			
3	2.77	0.282			
4	2.77	0.282			
5	2.77	0.282			

Test Condition:

Linear Velocity (m/s)	: 2.04	Condition of Vibration	:	With Vibration
Normal Load (N)	: 9.81	Acceleration (g)		1.56
Surface Condition	: As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	: 80	Displacement (mm)		0.330
No Lubrication		Frequency of Oscillation (Hz)		300

Table No.: 104

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	1.99	0.20	7.020	2.736	0.007
1	2.36	0.24			
2	2.98	0.34			
3	2.98	0.34			
4	2.98	0.34			
5	2.98	0.34			

Test Condition:

Linear Velocity (m/s)	: 0.785	Condition of Vibration	:	With Vibration
Normal Load (N)	: 9.81	Acceleration (g)		1.56
Surface Condition	: As-turned	Velocity (cm/s)		2.31
Relative humidity (%)	: 80	Displacement (mm)		0.330
No Lubrication		Frequency of Oscillation (Hz)		300

Table No.: 105

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-. 5	1.47	0.15	7.020	6.596	0.002
1	2.06	0.21			
2	3.04	0.31			
3	3.73	0.38			
4	3.73	0.38			
5	3.73	0.38			

Test Condition:

Linear Velocity (m/s)	: 3.53	Condition of Vibration	:	With Vibration
Normal Load (N)	: 9.81	Acceleration (g)		1.56
Surface Condition	: As ground	Velocity (cm/s)		2.31
Relative humidity (%)	: 80	Displacement (mm)		0.330
No Lubrication		Frequency of Oscillation (Hz)		300

Table No.: 106

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	1.47	0.15	7.020	1.746	0.005
1	1.52	0.155			
2	1.59	0.16			
3	1.59	0.16			
4	1.59	0.16			
5	1.59	0.16			

Test Condition:

Linear Velocity (m/s)	: 2.04	Condition of Vibration	: With Vibration
Normal Load (N)	: 9.81	Acceleration (g)	1.56
Surface Condition	: As ground	Velocity (cm/s)	2.31
Relative humidity (%)	: 80	Displacement (mm)	0.330
No Lubrication		Frequency of Oscillation (Hz)	300

Table No.: 107

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 612 m sliding (g)	
0-. 5	1.11	0.11	7.020	4.572	0.004
1	1.39	0.14			
2	1.67	0.17			
3	1.89	0.19			
4	1.89	0.19			
5	1.89	0.19			

Test Condition:

Linear Velocity (m/s)	: 3.53	Condition of Vibration	: With Vibration
Normal Load (N)	: 9.81	Acceleration (g)	1.56
Surface Condition	: As ground	Velocity (cm/s)	2.31
Relative humidity (%)	: 80	Displacement (mm)	0.330
No Lubrication		Frequency of Oscillation (Hz)	300

Table No.: 108

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 235.5 m sliding (g)	
0-.5	0.83	0.084	7.020	6.761	0.001
1	1.20	0.12			
2	1.68	0.17			
3	2.19	0.22			
4	2.19	0.22			
5	2.19	0.22			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 70
No Lubrication

Table No.: 109

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	3.41	0.27	7.020	2.128	0.011
1	4.41	0.35			
2	5.74	0.45			
3	6.85	0.54			
4	6.85	0.54			
5	6.85	0.54			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 70
No Lubrication

Table No.: 110

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	2.90	0.23	7.020	5.368	0.006
1	4.14	0.32			
2	5.84	0.46			
3	7.30	0.57			
4	7.30	0.57			
5	7.30	0.57			

Test Condition:
Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 70
No Lubrication

Table No.: 111

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	2.48	0.19	7.020	6.793	0.002
1	3.90	0.31			
2	5.94	0.47			
3	7.69	0.60			
4	7.69	0.60			
5	7.69	0.60			

Test Condition:
Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 70
No Lubrication

Table No.: 112

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	1.91	0.15	7.020	4.288	0.006
1	2.47	0.19			
2	3.21	0.25			
3	3.83	0.30			
4	3.83	0.30			
5	3.83	0.30			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 70
No Lubrication

Table No.: 113

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	1.63	0.13	7.020	6.100	0.004
1	2.32	0.18			
2	3.27	0.26			
3	4.08	0.32			
4	4.08	0.32			
5	4.08	0.32			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 70
No Lubrication

Table No.: 114

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.40	0.11	7.020	6.884	0.001
1	2.20	0.17			
2	3.33	0.26			
3	4.30	0.34			
4	4.30	0.34			
5	4.30	0.34			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 70
No Lubrication

Table No.: 115

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	4.75	0.27	7.020	0.243	0.015
1	6.12	0.35			
2	7.96	0.45			
3	9.50	0.54			
4	9.50	0.54			
5	9.50	0.54			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 70
No Lubrication

Table No.: 116

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.65	0.15	7.020	3.237	0.008
1	3.41	0.19			
2	4.43	0.25			
3	5.30	0.30			
4	5.30	0.30			
5	5.30	0.30			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 70
No Lubrication

Table No.: 117

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.63	0.27	7.020	3.247	0.008
1	3.39	0.35			
2	4.41	0.45			
3	5.26	0.54			
4	5.26	0.54			
5	5.26	0.54			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 70
No Lubrication

Table No.: 118

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	1.43	0.15	7.020	4.959	0.005
1	1.87	0.19			
2	2.43	0.25			
3	2.98	0.30			
4	2.98	0.30			
5	2.98	0.30			

Test Condition:

Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 70
No Lubrication

Table No.: 119

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	4.09	0.32	10.000	0.159	0.014
1	4.79	0.38			
2	5.59	0.44			
3	6.23	0.49			
4	6.23	0.49			
5	6.23	0.49			

Test Condition:

Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 70
No Lubrication

Table No.: 120

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.29	0.18	7.020	1.285	0.008
1	2.67	0.21			
2	3.13	0.25			
3	3.48	0.27			
4	3.48	0.27			
5	3.48	0.27			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 70
No Lubrication

Table No.: 121

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	5.05	0.390	17.000	0.321	0.016
1	5.30	0.415			
2	5.40	0.420			
3	5.40	0.420			
4	5.40	0.420			
5	5.40	0.420			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 70
No Lubrication

Table No.: 122

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	2.80	0.220	10.000	0.681	0.009
1	2.94	0.230			
2	3.01	0.236			
3	3.01	0.236			
4	3.01	0.236			
5	3.01	0.236			

Test Condition:

Linear Velocity (m/s)	: 1.51	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As-turned	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 70	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 128.4

Table No.: 123

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	3.07	0.24	7.020	2.671	0.010
1	3.97	0.31			
2	5.17	0.41			
3	6.16	0.48			
4	6.16	0.48			
5	6.16	0.48			

Test Condition:

Linear Velocity (m/s)	: 0.874	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As-turned	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 70	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 128.4

Table No.: 124

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	2.61	0.20	7.020	5.545	0.006
1	3.73	0.29			
2	5.26	0.41			
3	6.57	0.52			
4	6.57	0.52			
5	6.57	0.52			

Test Condition:

Linear Velocity (m/s)	: 0.336	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As-turned	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 70	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 128.4

Table No.: 125

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	2.24	0.18	7.020	6.816	0.002
1	3.51	0.28			
2	5.35	0.42			
3	6.93	0.54			
4	6.93	0.54			
5	6.93	0.54			

Test Condition:

Linear Velocity (m/s)	: 1.51	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As ground	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 70	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 128.4

Table No.: 126

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	1.73	0.14	7.020	4.574	0.005
1	2.23	0.17			
2	2.89	0.23			
3	3.45	0.27			
4	3.45	0.27			
5	3.45	0.27			

Test Condition:

Linear Velocity (m/s)	:	0.874	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)	:	1.08
Surface Condition	:	As ground	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	70	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 127

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	1.47	0.12	7.020	6.205	0.003
1	2.10	0.16			
2	2.94	0.23			
3	3.68	0.29			
4	3.68	0.29			
5	3.68	0.29			

Test Condition:

Linear Velocity (m/s)	:	0.336	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)	:	1.08
Surface Condition	:	As ground	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	70	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 128

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.27	0.099	7.020	6.900	0.001
1	1.98	0.16			
2	3.00	0.24			
3	3.87	0.30			
4	3.87	0.30			
5	3.87	0.30			

Test Condition:

Linear Velocity (m/s)	: 1.51	Condition of Vibration	: With Vibration
Normal Load (N)	: 17.66	Acceleration (g)	: 1.08
Surface Condition	: As-turned	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 70	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 128.4

Table No.: 129

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	4.24	0.24	7.020	1.018	0.013
1	5.47	0.31			
2	7.26	0.41			
3	8.49	0.48			
4	8.49	0.48			
5	8.49	0.48			

Test Condition:

Linear Velocity (m/s)	: 1.51	Condition of Vibration	: With Vibration
Normal Load (N)	: 17.66	Acceleration (g)	: 1.08
Surface Condition	: As ground	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 70	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 128.4

Table No.: 130

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.47	0.14	7.020	3.668	0.007
1	3.00	0.17			
2	4.07	0.23			
3	4.77	0.27			
4	4.77	0.27			
5	4.77	0.27			

Test Condition:

Linear Velocity (m/s)	: 1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	: 9.81	Acceleration (g)	:	1.08
Surface Condition	: As-turned	Velocity (cm/s)	:	1.58
Relative humidity (%)	: 70	Displacement (mm)	:	0.322
No Lubrication		Frequency of Oscillation (Hz)	:	128.4

Table No.: 131

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.33	0.24	7.020	3.668	0.007
1	3.04	0.31			
2	4.04	0.41			
3	4.71	0.48			
4	4.71	0.48			
5	4.71	0.48			

Test Condition:

Linear Velocity (m/s)	: 1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	: 9.81	Acceleration (g)	:	1.08
Surface Condition	: As ground	Velocity (cm/s)	:	1.58
Relative humidity (%)	: 70	Displacement (mm)	:	0.322
No Lubrication		Frequency of Oscillation (Hz)	:	128.4

Table No.: 132

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	1.37	0.14	7.020	5.145	0.004
1	1.67	0.17			
2	2.26	0.23			
3	2.66	0.27			
4	2.66	0.27			
5	2.66	0.27			

Test Condition:

Linear Velocity (m/s)	: 2.36	Condition of Vibration	:	With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	:	1.08
Surface Condition	: As-turned	Velocity (cm/s)	:	1.58
Relative humidity (%)	: 70	Displacement (mm)	:	0.322
No Lubrication		Frequency of Oscillation (Hz)	:	128.4

Table No.: 133

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	3.43	0.27	10.000	2.111	0.011
1	4.02	0.32			
2	4.70	0.37			
3	5.23	0.41			
4	5.23	0.41			
5	5.23	0.41			

Test Condition:

Linear Velocity (m/s)	: 2.36	Condition of Vibration	:	With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	:	1.08
Surface Condition	: As ground	Velocity (cm/s)	:	1.58
Relative humidity (%)	: 70	Displacement (mm)	:	0.322
No Lubrication		Frequency of Oscillation (Hz)	:	128.4

Table No.: 134

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	1.92	0.15	7.020	2.623	0.006
1	2.25	0.18			
2	2.64	0.21			
3	2.94	0.23			
4	2.94	0.23			
5	2.94	0.23			

Test Condition:

Linear Velocity (m/s)	:	3.53	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)	:	1.08
Surface Condition	:	As-turned	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	70	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 135

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	3.92	0.31	15.000	2.186	0.012
1	4.13	0.32			
2	4.22	0.33			
3	4.22	0.33			
4	4.22	0.33			
5	4.22	0.33			

Test Condition:

Linear Velocity (m/s)	:	3.53	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)	:	1.08
Surface Condition	:	As ground	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	70	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 136

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	2.20	0.17	10.000	2.798	0.007
1	2.32	0.18			
2	2.36	0.19			
3	2.36	0.19			
4	2.36	0.19			
5	2.36	0.19			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 60
No Lubrication

Table No.: 137

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	3.80	0.30	7.020	1.584	0.012
1	4.91	0.38			
2	6.38	0.50			
3	7.60	0.60			
4	7.60	0.60			
5	7.60	0.60			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 60
No Lubrication

Table No.: 138

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	3.24	0.25	7.020	5.185	0.009
1	4.60	0.36			
2	6.50	0.51			
3	8.11	0.64			
4	8.11	0.64			
5	8.11	0.64			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 60
No Lubrication

Table No.: 139

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	2.77	0.22	7.020	6.768	0.003
1	4.34	0.34			
2	6.60	0.52			
3	8.54	0.67			
4	8.54	0.67			
5	8.54	0.67			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Table No.: 140

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.12	0.17	7.020	3.985	0.007
1	2.75	0.22			
2	3.57	0.28			
3	4.26	0.33			
4	4.26	0.33			
5	4.26	0.33			

Test Condition:

Linear Velocity (m/s) : 0.874 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Table No.: 141

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	1.81	0.14	7.020	5.997	0.004
1	2.58	0.20			
2	3.64	0.29			
3	4.54	0.36			
4	4.54	0.36			
5	4.54	0.36			

Test Condition:

Linear Velocity (m/s) : 0.336 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Table No.: 142

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.55	0.12	7.020	6.869	0.002
1	2.45	0.19			
2	3.70	0.29			
3	4.79	0.37			
4	4.79	0.37			
5	4.79	0.37			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As-turned
Relative humidity (%) : 60
No Lubrication

Table No.: 143

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	5.28	0.30	10.000	2.299	0.017
1	6.81	0.39			
2	8.84	0.50			
3	10.55	0.60			
4	10.55	0.60			
5	10.55	0.60			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 17.66
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Table No.: 144

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.94	0.17	7.020	2.807	0.009
1	3.81	0.22			
2	4.92	0.28			
3	5.87	0.33			
4	5.87	0.33			
5	5.87	0.33			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As-turned
Relative humidity (%) : 60
No Lubrication

Table No.: 145

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.92	0.30	7.020	2.829	0.009
1	3.78	0.39			
2	4.91	0.50			
3	5.85	0.60			
4	5.85	0.60			
5	5.85	0.60			

Test Condition:

Linear Velocity (m/s) : 1.51 Condition of Vibration : Without Vibration
Normal Load (N) : 9.81
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Table No.: 146

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	1.60	0.16	7.020	4.710	0.005
1	2.08	0.21			
2	2.70	0.28			
3	3.32	0.34			
4	3.32	0.34			
5	3.32	0.34			

Test Condition:

Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 60
No Lubrication

Table No.: 147

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	4.54	0.36	12.000	1.026	0.016
1	5.32	0.42			
2	6.21	0.49			
3	6.93	0.54			
4	6.93	0.54			
5	6.93	0.54			

Test Condition:

Linear Velocity (m/s) : 2.36 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Table No.: 148

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.53	0.20	7.020	0.91	0.009
1	2.97	0.23			
2	3.48	0.27			
3	3.87	0.30			
4	3.87	0.30			
5	3.87	0.30			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As-turned
Relative humidity (%) : 60
No Lubrication

Table No.: 149

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	5.57	0.44	20.000	1.468	0.018
1	5.89	0.46			
2	5.98	0.47			
3	5.98	0.47			
4	5.98	0.47			
5	5.98	0.47			

Test Condition:

Linear Velocity (m/s) : 3.53 Condition of Vibration : Without Vibration
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Table No.: 150

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	3.10	0.240	12.000	1.675	0.00975
1	3.28	0.257			
2	3.36	0.263			
3	3.36	0.263			
4	3.36	0.263			
5	3.36	0.263			

Test Condition:

Linear Velocity (m/s)	: 1.51	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As-turned	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 60	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 128.4

Table No.: 151

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	3.49	0.27	7.020	2.196	0.011
1	4.51	0.35			
2	5.87	0.46			
3	7.00	0.55			
4	7.00	0.55			
5	7.00	0.55			

Test Condition:

Linear Velocity (m/s)	: 0.874	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As-turned	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 60	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 128.4

Table No.: 152

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	2.98	0.23	7.020	5.381	0.006
1	4.23	0.33			
2	5.98	0.47			
3	7.47	0.59			
4	7.47	0.59			
5	7.47	0.59			

Test Condition:

Linear Velocity (m/s)	:	0.336	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)	:	1.08
Surface Condition	:	As-turned	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	60	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 153

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	2.55	0.20	7.020	6.793	0.002
1	4.00	0.31			
2	6.08	0.48			
3	7.86	0.62			
4	7.86	0.62			
5	7.86	0.62			

Test Condition:

Linear Velocity (m/s)	:	1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	:	12.75	Acceleration (g)	:	1.08
Surface Condition	:	As ground	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	60	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 154

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	1.95	0.15	7.020	4.325	0.006
1	2.55	0.20			
2	3.28	0.26			
3	3.92	0.31			
4	3.92	0.31			
5	3.92	0.31			

Test Condition:

Linear Velocity (m/s) : 0.874
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Condition of Vibration : With Vibration
Acceleration (g) : 1.08
Velocity (cm/s) : 1.58
Displacement (mm) : 0.322
Frequency of Oscillation (Hz) : 128.4

Table No.: 155

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 262.2 m sliding (g)	
0-. 5	1.67	0.13	7.020	6.115	0.003
1	2.37	0.19			
2	3.36	0.26			
3	4.18	0.33			
4	4.18	0.33			
5	4.18	0.33			

Test Condition:

Linear Velocity (m/s) : 0.336
Normal Load (N) : 12.75
Surface Condition : As ground
Relative humidity (%) : 60
No Lubrication

Condition of Vibration : With Vibration
Acceleration (g) : 1.08
Velocity (cm/s) : 1.58
Displacement (mm) : 0.322
Frequency of Oscillation (Hz) : 128.4

Table No.: 156

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 100.8 m sliding (g)	
0-. 5	1.43	0.11	7.020	6.886	0.001
1	2.26	0.18			
2	3.40	0.27			
3	4.41	0.35			
4	4.41	0.35			
5	4.41	0.35			

Test Condition:

Linear Velocity (m/s)	:	1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)	:	1.08
Surface Condition	:	As-turned	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	60	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 157

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	4.77	0.27	7.020	0.225	0.015
1	6.18	0.35			
2	8.12	0.46			
3	9.71	0.55			
4	9.71	0.55			
5	9.71	0.55			

Test Condition:

Linear Velocity (m/s)	:	1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	:	17.66	Acceleration (g)	:	1.08
Surface Condition	:	As ground	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	60	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 158

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.65	0.15	7.020	3.169	0.009
1	3.53	0.20			
2	4.59	0.26			
3	5.47	0.31			
4	5.47	0.31			
5	5.47	0.31			

Test Condition:

Linear Velocity (m/s)	:	1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)	:	1.08
Surface Condition	:	As-turned	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	60	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 159

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	2.66	0.27	7.020	3.283	0.008
1	3.45	0.35			
2	4.51	0.46			
3	5.41	0.55			
4	5.41	0.55			
5	5.41	0.55			

Test Condition:

Linear Velocity (m/s)	:	1.51	Condition of Vibration	:	With Vibration
Normal Load (N)	:	9.81	Acceleration (g)	:	1.08
Surface Condition	:	As ground	Velocity (cm/s)	:	1.58
Relative humidity (%)	:	60	Displacement (mm)	:	0.322
No Lubrication			Frequency of Oscillation (Hz)	:	128.4

Table No.: 160

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 453 m sliding (g)	
0-. 5	1.48	0.15	7.020	4.936	0.005
1	1.96	0.20			
2	2.55	0.26			
3	3.04	0.31			
4	3.04	0.31			
5	3.04	0.31			

Test Condition:

Linear Velocity (m/s)	: 2.36	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As-turned	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 60	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 200

Table No.: 161

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	3.95	0.31	10.000	1.235	0.012
1	4.63	0.36			
2	5.41	0.42			
3	6.02	0.47			
4	6.02	0.47			
5	6.02	0.47			

Test Condition:

Linear Velocity (m/s)	: 2.36	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As ground	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 60	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 200

Table No.: 162

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 708 m sliding (g)	
0-. 5	2.20	0.17	7.020	2.135	0.007
1	2.59	0.20			
2	3.03	0.24			
3	3.37	0.26			
4	3.37	0.26			
5	3.37	0.26			

Test Condition:

Linear Velocity (m/s)	: 3.53	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As-turned	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 60	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 300

Table No.: 163

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	4.45	0.35	15.000	0.788	0.013
1	4.71	0.37			
2	4.79	0.38			
3	4.79	0.38			
4	4.79	0.38			
5	4.79	0.38			

Test Condition:

Linear Velocity (m/s)	: 3.53	Condition of Vibration	: With Vibration
Normal Load (N)	: 12.75	Acceleration (g)	: 1.08
Surface Condition	: As ground	Velocity (cm/s)	: 1.58
Relative humidity (%)	: 60	Displacement (mm)	: 0.322
No Lubrication		Frequency of Oscillation (Hz)	: 300

Table No.: 164

Duration of rubbing (min)	Horizontal force (N)	Friction coefficient	Mass		Wear rate (g/m)
			Initial mass (g)	Mass after 1059 m sliding (g)	
0-. 5	2.48	0.19	10.000	6.9825	0.008
1	2.62	0.20			
2	2.69	0.21			
3	2.69	0.21			
4	2.69	0.21			
5	2.69	0.21			