Research Article

Modelling & Simulation for Friction & Wear Coefficient of Materials

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Abstract: Friction and wear can be defined as the responses of a tribo-system. Coefficient of friction and wear define the state of contact of bodies not the material properties of the bodies. Although in some special cases of contact, they can be treated as the material properties of the bodies. Both friction and wear can be treated as two kinds of responses from one tribo-system and are related with each other in each and every state of contact. The friction and wear are mainly dependent on the characteristics of two sliding surfaces. The difficulty to predict and to clarify with more accuracy such phenomenon reveals the complex nature of the surfaces, which can be evaluated through material properties such as microstructure, presence of organic molecules and oxides, water vapor, geometrical irregularities and other impurities which can be absorbed from the atmosphere. The main challenge in developing software solutions in this field has been how to appropriately represent complex tribological phenomena through easy-to-use software. The expertise in tribology has shown that by replacing the constant coefficient of friction, which is commonly used in metal forming simulations, with realistic and highly accurate friction and lubrication data results in metal forming simulations of greater accuracy with enhanced simulation functionalities. The present paper introduces a computation model & Simulation for finding out the Coefficient of Friction & Wear of a material pair for different loading condition.

Key Words: Friction, Load, Micrometre, Modelling, Simulation, Wear

I. Introduction

Friction is the force that occurs between two contact surfaces in relative motion, whereas wear is the phenomenon of mechanical and/or chemical damage that affects the quality of the materials in contact with each other. Friction occurs between moving parts and is commonly analysed in parts that come into contact with one another during operation, such as power trains in automobiles. The friction causes heat generation and wear in these parts. Heat generation and wear derived from friction account for most mechanical system failures, and economic losses due to such failures are not small. To reduce such losses, tribological tests are conducted to evaluate parts and properties of the parts materials.

With the increment of engineering applications, it is important to understand the properties of new materials which can sustain the various working conditions. Tribological properties of materials are determined by either measuring of friction force in contact area or by measuring wear of one element of tribo- mechanical system. The Parametric study of materials provided the implementation of the same. It is hard to understand how friction and wear arises without knowing how surfaces interact when brought into contact. It is well known that real engineering surfaces are not perfectly smooth. Even highly polished surfaces possess some degree of roughness. Surface roughness has a significant effect on how loads are transmitted at the contact interface between solid bodies. Because of roughness, only parts of the surfaces are actually in contact, and the real contact area is only a fraction of the apparent contact area [1-11].

Considering the complexity of the tribological system, it may be pertinent to point out that friction and wear characteristics of materials are not their intrinsic or inherent properties but are highly system dependent.

Modelling friction and wear is a challenge for the future, yet design engineers require that information now. Such information must be made available because of the considerable impact it will have on today's technology. The problem is to decide whether it will be obtained with the help of Tribologists or in spite of them, If Tribologists, concerned with dry friction problems and wear, acknowledge this need, they can still play a part in introducing their understanding in the modelling [2]. If not, computer codes will continue, as they do now, to offer formulae chosen without discrimination, but which, because of their very existence, will be used in industry at large setting a trend which will take years to reverse [2,12].

II. Friction Force Measurement & its Simulation.

When two solid bodies in contact are subjected to forces that tend to produce relative sliding motion, stresses develop on the interfaces that tend to oppose that motion. The phenomenon is called friction and is often discussed in terms of the resultant of the stresses, i.e., friction force. The usual measure of sliding friction is the coefficient of friction, i.e., the ratio between the friction force and the normal contact force. Often two values of the coefficient of friction are quoted: the coefficient of static friction, which applies to the onset of sliding, and the coefficient of kinetic friction, which applies during sliding motion.

The classic friction laws apply to nonlubricated contacts between metallic bodies and can be summarized as follows: (i)the friction force is independent of the apparent area of contact; (ii) the friction force is proportional to the normal contact force; and (iii)the friction force is independent of the sliding velocity [1].

2.1 Experimental study to find Coefficient of Friction:

In our study the Second Law of Friction is consider for the study purpose. The friction force is find out with respect to the load by performing the Experimental study on Pin & Disc Machine. The Experimental results are taken from the Earlier Research [3] & a Mathematical Model & simulation work is done to verify the experimental results. The Table 1 shows the specifications of Pin & Disc used for the Experiment & Simulation study.

Table. 1 Specification of Machine Parameters

Parameter	Unit	Min	Max
Pin Size	mm	6	6
Disc Size	mm	100X6	100X6
Wear track Diameter	mm	20	80
Disc Rotation	RPM	480	480
Normal Load	N	5	30
Wear	Micrometer	0	2000

The Fig 1 shows a Line Diagram of Machine & Pin used for the study [4].

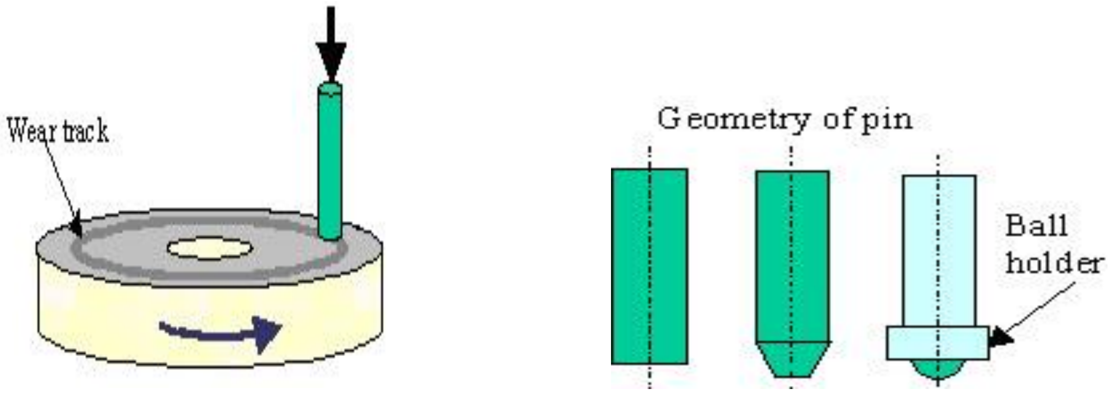


Fig 1 Line Diagram of Machine & Pin

2.2 Mathematical Modelling & Simulation for Coefficient of friction:

The coefficient of friction (COF) is calculated as a Ratio of the frictional force to the applied normal load as

COF = Tangential frictional force/ Normal load

Hear to find the coefficient of friction a Mathematical Model is formed by taking tangential force and normal load as variable. The mathematical modelling is prepared by using Java Script & the out is shown in Fig. No. 2 in the HTML file.

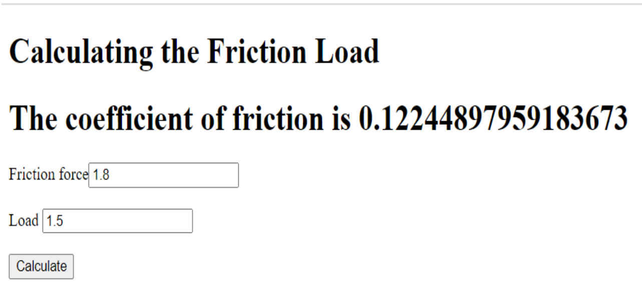
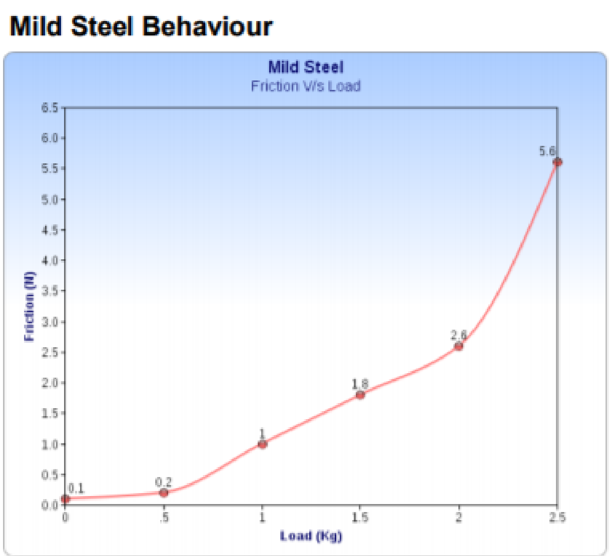


Fig No. 2 HTML File for finding Coefficient of Friction

2.3 Finding Coefficient of friction from the Mathematical Model:

The experimental result of friction force with varying applied load is taken from the graph shown in Figure No. 3.[3] for the material mild steel V/s mild steel.



(a)Friction V/s Load

Fig. No. 3 Experimental Value of Friction Force V/s Load

By using the prepared mathematical model, the value of Coefficient of friction can be find out by simulating the model with different applied load. The same results are tabulated in Table No. 2.

Table No. 2 Experimental Value of Friction Force & Coefficient of Friction

Load Applied (Kg)	Friction Force Generated (N)	Coefficient of Friction
0.5	0.2	0.04
1.0	1.0	0.10
1.5	1.8	0.12
2.0	2.6	0.13
2.5	5.6	0.22

III Wear rate Measurement & its Simulation

Wear can be defined as the loss or displacement of material from a solid surface as a result of mechanical action. Material can be lost in the form of debris, whereas material can be displaced by the transfer of material from one surface to another.

Wear is almost inevitable when two solid surfaces in contact move relative to each other and can appear in many ways depending on the material properties of the contact surfaces, the environment, and the running conditions. The wear rate of a surface is conventionally defined as the volume or mass lost from the surface per unit of distance slid [5].

Wear measurement is carried out to determine the amount of materials removed (or worn away) after a wear test, (and in reality after a part in service for a period of time). The material worn away can be expressed either as weight (mass) loss, volume loss, or linear dimension change depending on the purpose of the test, the type of wear, the geometry and size of the test specimens, and sometimes on the availability of a measurement facility [6,9].

3.1 Experimental study to find Coefficient of Wear:

The plunger moment as an indication of wear rate is sensed by LVDT [7]. As wear occurs its plunger lifts up and this movement is displayed as wear on controller. The least count of LVDT is 1 micrometre, the initial position of plunger measurement is kept at midpoint of to have both +ve & -ve wear readings.The maximum wear rate measurement possible is +/-2mm. In addition to the wear as indicted by LVDT, the wear on specimen may also be computed by measuring the initial & final. The Experimental results are taken from the Earlier Research [3] & a Mathematical Model & simulation work is done to verify the experimental results. The details of Pin & Disc is shown in Table No.1 and Line diagram for the setup is also shown in Fig. No.1.

3.2 Mathematical Modelling & Simulation for Coefficient of Wear:

Based on Experimental data, the amount of wear is usually proportional to the applied load W and the sliding distance x and inversely proportional to hardness H of the worn out surface. Thus, the volume of wear V can be expressed as [8,10]

$$V = k^* W^* x/H \qquad \text{-----------------(1)}$$

where k is the wear coefficient depend up on the material pair and their smoothness.

or $$k= V^*H/W^*x \qquad \text{-------------------- (2)}$$

The volume of wear can be calculated as depth wear loss Δh, times apparent sliding area A, [13,14]

So, $$k= \Delta h^*A^*H/W^*x \qquad \text{--------------(3)}$$

Hear to find the wear coefficient k a Mathematical Model is formed by taking Δh & W as variable. The mathematical modelling for Equation 3 is prepared by using Java Script & the output is shown in Fig. No. 4 in the HTML file.

Hear A is taken as $\pi/4\ d^2$,d as the diameter of Pin which is taken as 6mm, H hardness of mild stee which is taken as 130 BHN , x is distance travelled which can be found out as $\pi DNT/60000$ m, where D is diameter of disc which is taken as 60mm, N is Disc rotation which is taken as 480rpm, T is time for rotation which is taken as 60 sec. Δh & W is variable. The material pair is mild steel V/s mild steel.

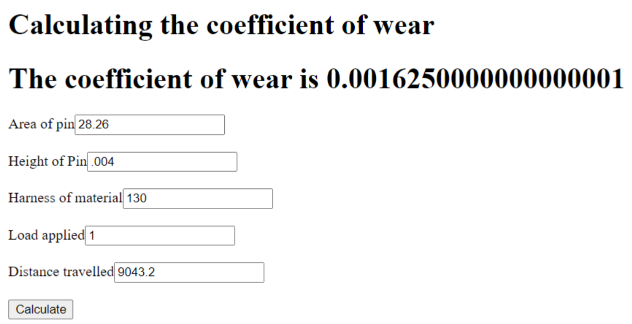


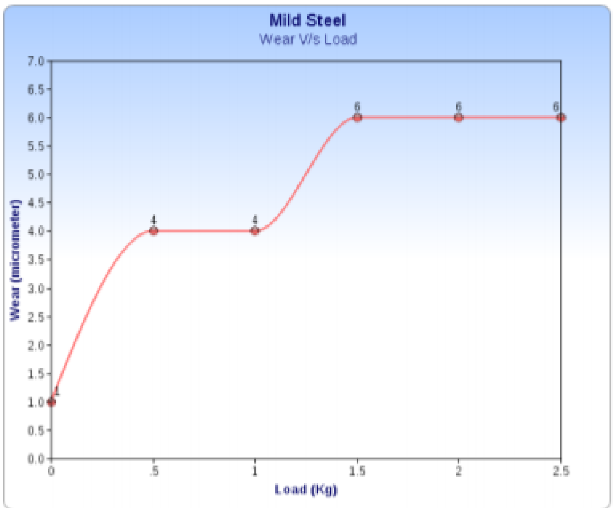
Fig No. 4 HTML File for finding Coefficient of Wear.

3.3 Finding Coefficient of Wear from Mathematical Model :

The experimental result of wear rate of pin in micrometre is taken from the graph shown in Figure No. 3. The same results are tabulated in Table No. 3. [3]

Table No. 3 Experimental value of Wear rate & Wear Coefficient

Load Applied (Kg)	Wear Rate in Micrometre	Wear Coefficient(kx10^{-4})
0.5	4	3.25
1.0	4	1.62
1.5	6	1.62
2.0	6	1.21
2.5	6	0.97



(b) Wear V/s Load

Fig. No. 5 Experimental Value of Wear rate V/s Load

By using the prepared mathematical model, the value of Coefficient of wear can be find out by simulating the model with different applied load. The same results are tabulated in Table No. 3.

IV. Discussion on Results

The research presented here is to find out the coefficient of friction and coefficient of wear by preparing a mathematical model and simulating with reference to varying load from the data obtained by performing the Experimental studies performed on Pin & Disc apparatus. For finding out the coefficient of friction the two-material combination taken is mild steel v/s mild steel. Load on the pin is varied from 500g to 2.0 Kg. The machine gives only the Friction force generated because of contact between the two materials. so an attempt is made to prepare a mathematical model which gives the value of coefficient of friction by simulating under varying load condition. The results shows that the coefficient of friction varies from .04 to 0.22. This value also matches with the standard value of coefficient of friction as prescribed by ASTM (G219 -18 Standard).

For finding the coefficient of wear the same material combination mild steel v/s mils steel is taken. The load applied on pin is varies from 500g to 2.0 Kg. The machine gives wear of the pin in micrometre. To find the wear coefficient this wear rate is used and a mathematical model is prepared and simulate at different load condition. The Equation No. 3 is used to find the coefficient of wear. The results shows that the coefficient of wear varies from .97x10^{-4} to 3.25x10^{-4}. This value also matches with the standard value of coefficient of wear as prescribed by ASTM (G40 Standard).

V. Conclusion

Both friction and wear are intimately related to the local stresses and deformations of the interacting surfaces. Modelling friction and wear is a challenge for the future, yet design engineers require that information now. Such information must be made available because of the considerable impact it will have on today's technology. The general trend toward increased use of computer models and simulations during product development calls for accurate and reliable product models. The function of many products relies on contact interfaces between interacting components. Simulating the behaviour of such products requires accurate models of both components and interfaces. The present work prepares a mathematical model for finding out the coefficient of friction and wear on different load condition. The model is simple and ready to use and can be useful for the researcher and industry people to get these values of coefficients for different operating conditions. Further investigations on the different material pair can extend the present

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