CHAPTER 2

THEORY

Laws of Friction

The two basic laws of friction state that the frictional resistance (1) proportional to the normal load and (2) is independent of the area of contact.[1] (Fig. 2-1.)

For a pair of surfaces, the ratio of the frictional resistance (F) to the load (W) is constant, and this constant is called the coefficient of friction (μ). A body may be placed in any position but the friction will remain the same.

Static-Kinetic Friction

When there is relative motion between the bodies, the resistance is called kinetic friction. The force required to maintain sliding is significantly lower than the force required to initiate sliding.

The maximum force of static friction between two surfaces is proportional to the normal force between the surfaces.[2]

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[1] Peter Freeman, Lubrication and Friction (London: Sir Isaac Pitman & Sons Ltd., 1962, p. 119.

[2] George Shortley and Dudley Williams, Principles of College Physics (Tokyo: Maruzen Company, Ltd., 1959), pp. 88-89.

The coefficient of friction (μ_s) defined as $F = \mu_s W$ depends on the materials and roughness of the surfaces but is independent of the area of contact between the surfaces.

The force of kinetic friction between two surfaces is proportional to the normal force between the surfaces.[3] The coefficient of friction (μ_K) defined as $F = \mu_K W$ depends on the materials and roughness of the surface but is independent of the area of contact of the surfaces and of the relative velocity of the surfaces.

These laws hold approximately for a wide range of materials and over a wide range of experimental conditions.

For most materials the coefficient of kinetic friction is at least partly an empirical function of relative sliding velocity. It is almost impossible to predict what quantitative relationship exists between friction and sliding velocity since the temperature at the surfaces is a direct variable. There is also experimental evidence to show that as the velocity is increased a proportional reduction in friction does not occur and that at a high velocity friction appears to remain constant.

Coefficient of Kinetic Friction[4]

As a body in contact with a second body begins to move the

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[3] Ibid., pp. 88-89.

[4] J.C. Kar and C. Dutta, Note on the Dynamical Coefficient of Friction (Calcutta: Indian J. Theor. Phys., 1957), pp. 19-20.

coefficient of friction between them begins to decrease from the limiting coefficient of static friction (μ_s). This decrease continues with the increase of relative velocity (v) and consequent decrease of grip at the surface of contact, till a constant value (μ_K) is reached at a high relative velocity. This variation of the coefficient of friction (μ) with relative velocity (v) may be represented by a curve as shown in Fig. 2-2.

The empirical formular for the coefficient of friction (μ) is $\mu = \mu_K + (\mu_S - \mu_K) e^{-kv}$. k is a constant.[5]

Stick-Slip Friction

At slow sliding speeds, the sliding between surfaces is not a continous process but proceeds in a succession of jerks, which is called stick-slip motion. (Fig. 2-3.)

The static phase can be explained as due to the higher static friction and the slip phase due to the lower kinetic friction during the rapid movement of the slip. At slow sliding speeds, with absence of frictional heating, then the resultant shear strength of metallic junctions may be greater than that occuring at higher speeds of sliding. This means that the kinetic friction is lower than the static friction.

Surface Temperature

When two surfaces are in sliding contact, mechanical energy

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[5] Ibid., pp. 19-20.

is converted into heat energy and the temperature increases. The peak temperatures are in the order of the temperatures of melting-points of the metals concerned and the local hot spots may be capable of momentarily softening or melting the metal junctions.[6] This softening has the effect of lowring the shear strength of the welded junctions and suggests an explanation of the fact that the kinetic friction is usually lower than the static friction. The temperatures of the sliding surfaces are dependent on a variety of factors, the most important of which are :-[7]

1. Thermal conductivity and emissivity of the sliding surfaces.
2. Area of the surfaces in contact and bulk dimensions of the bodies.
3. Coefficient of friction.
4. Sliding velocity.
5. Temperature of the environment.

The generation of high local temperatures during sliding may initiate :-[8]

1. Seizure of metals.
2. Frictional welding of plastics.
3. Surface flow metals during polishing.

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[6] Peter Freeman, op.cit., p. 127.

[7] Ibid., p. 127.

[8] Ibid.

Mechanism of Metallic Friction (Fig. 2-4.)

Friction between unlubricated surfaces is caused by two main factors. The first factor is the adhesion which occurs at the regions of real contact; these adhesions, welds or junctions have to be sheared if sliding is to occur. If A is the true area of contact and S the average shear strength of the junctions, this part of the friction may be written $F_{adhesion} = A\ S$. The second factor is either the ploughing, grooving or cracking of one surface caused by the asperities of the other, which is called the deformation term P. Then if there is negligible interaction between these two processes, the relation will be[9]

$$F = F_{adhesion} + F_{deformation} = A\ S + P$$

The factors of major importance here are the area of real contact A, the strength of adhesion between the surfaces, the shear strength S of the interface, possible interaction between A and S, the deformation component P and possible interactions between this and the adhesion component of friction.

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[9] F.P.Bowden and D.Tabor, Friction, lubrication and wear a survey of work during the last decade (Cambridge: Brit. J. Appl. Phys., vol. 17), pp. 1521-1522.

Influence of Vibration[10]

Tests to determine starting friction show coefficients of friction to be much higher in the absence of vibration than in its presence, and that friction decreases as the disturbance by vibration increases. Vibration similarly reduce the friction of motion so long as metallic contact is present to any considerable degree.

[10] Kent's Mechanical Engineers' Handbook, Design and Production Volume (New York: John Wiley & Sons, Inc. 1961), pp. 7-31.

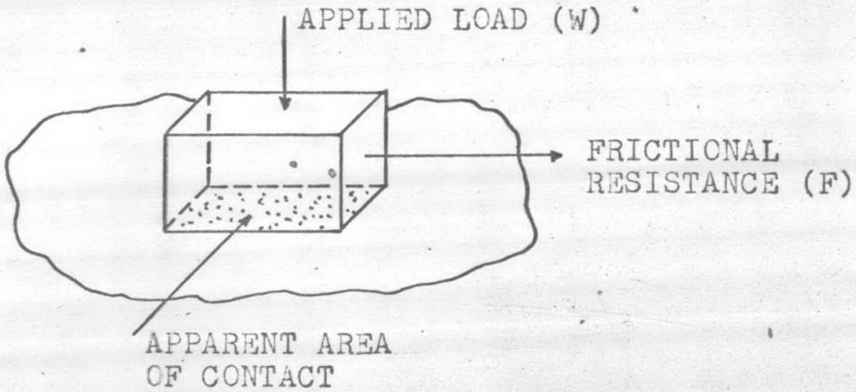

Fig. 2-1. LAWS OF FRICTION.

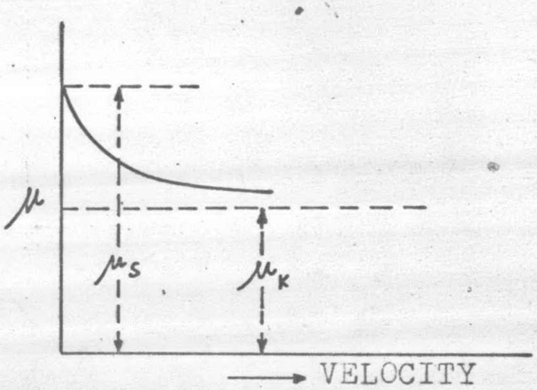

Fig. 2-2. COEFFICIENT OF DYNAMIC FRICTION.

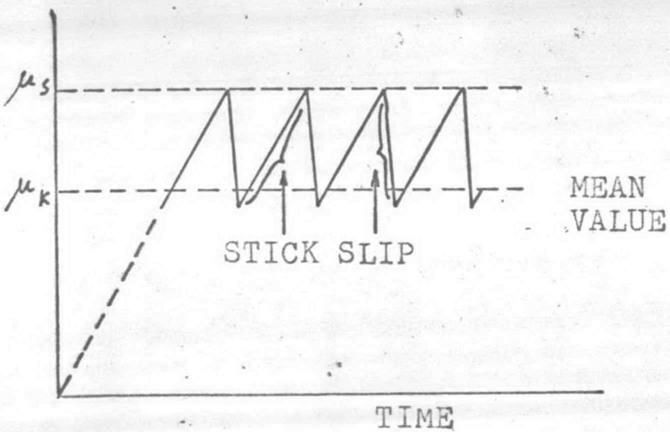

Fig. 2-3. STICK-SLIP MOTION.

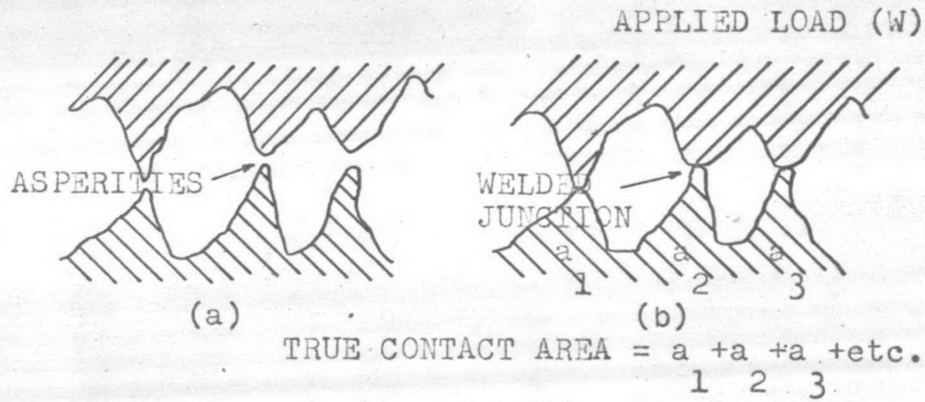

Fig. 2-4. (a) CONTACT OF FLAT METAL SURFACES.
(b) SAME SURFACE UNDER LOAD.

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