Engineering Mechanics

Chapter: 2 Friction

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In This Chapter We Cover the Following Topics

Please welcome for any correction or misprint in the entire manuscript and your valuable suggestions kindly mail us *brijrbedu@gmail.com*.

2.1 FRICTION

When two surfaces which are in contact with each other have relative motion or tendency of relative motion the frictional force act b/w them.
A force which prevents the motion or movement of the body is called friction or force of friction and its direction is opposite to the applied external force or motion of the body. Friction is a force of resistance acting on a body which prevents or retards motion of the body.
When a body slides upon another body, the property due to which the motion of one relative to the other is retarded is called friction. This force always acts tangent to the surface at points of contact with other body and is directed opposite to the motion of the body.

Analysis of Microscopic Level

Let us consider a block placed on a table. Due to microscopic irregularities friction force is present b/w the block & the table.

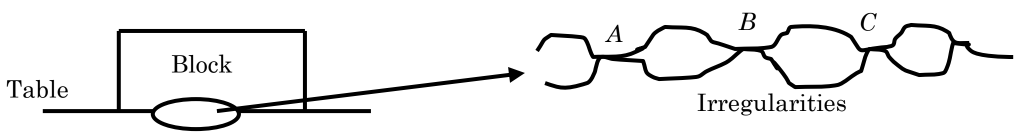

Diagram 2.1

At the contact point A,B,C,D a mechanical bond is formed which prevents the relative motion .

- The bond strength mainly depends on the normal reaction per contact point.
- Frictional force depends on the microscopic area.
- If we increase the microscopic area then the frictional force decreases.
- Powdering, polishing & oiling are three main method of decreasing the friction force. In all methods we decrease the microscopic area.

Q. How to find out the tendency of relative motion?

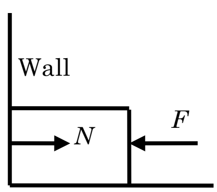

Diagram 2.1

Ans. First of all assumes friction force as to be equal to zero. If there is any tendency of relative motion then relative motion will start. Now apply to the friction force opposite to the direction of relative motion. The block is in contact with the wall if we apply a force F on the block then it will not have any tendency of Relative motion. Normal Reaction will balance force F & Frictional force is not required.

Types of Friction

1. Static friction

2. Kinetic friction

Static Friction

When two surfaces which are in contact with each other, have no relative motion, but have a tendency of relative motion. Then the friction force acting b/w them is called static friction.

- *Static friction force can change its magnitude & direction according to requirement*

Dynamic Friction

It is the friction experienced by a body when it is in motion. Then this type of friction is known as dynamic or Kinetic friction.

Static Friction > Dynamic Friction

Dynamic Friction is derived into two parts

Sliding Friction: It is the friction experienced by a body when it slides over another body.

Rolling Friction: It is the friction experienced by a body when it rolls over another body.

Sliding friction > Rolling Friction

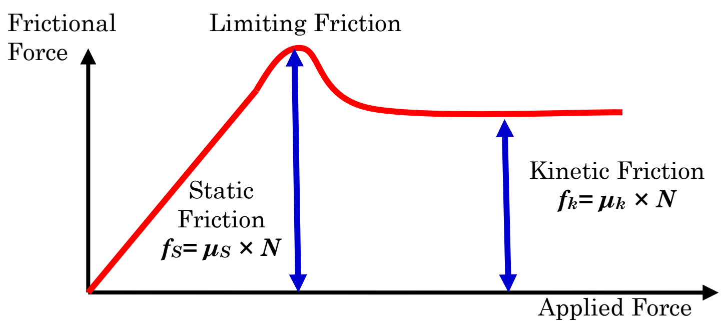

Diagram 2.3

Limiting Friction

The maximum value of force of friction which at along the common surface of contact b/w two bodies. When the body is just on the point of motion over the other is called limiting friction.

Direction of Friction

- The direction of friction is always opposite to the direction of motion of the body.
- Friction at parallel to the surface of contact &depending upon the nature of the surface of contact.
- Static friction force can change its magnitude & direction according to requirement.

It is more difficult to start the relative motion as compared to maintain it.

- The value of kinetic friction force always remains constant at $\mu.N$.
- The direction of kinetic friction force depends on the direction of relative velocity vector.

2.2 SOME BASIC DEFINITIONS

Coefficient of Friction

It is defined as the ratio of limiting friction to the normal reaction b/w two bodies.

μ = limiting force of friction /reaction

$$\frac{f_r}{N} = \mu$$

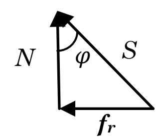

Diagram 2.4

Angle of Friction

It is defined as the angle made by the resultant of the normal reaction N & the limiting force of friction(f_r) with the normal reaction N.

$$\tan\varphi = \frac{f_r}{N} = \mu$$

Laws of Static Friction

1. The force of friction always acts in the direction, opposite to that in which the body tends to move, if the force of friction would have been absent.
2. The magnitude of the force of friction is exactly equal to the force, which tends to move the body.
3. The force of friction is independent of the area of contact b/w the two surfaces.
4. The magnitude of the limiting friction bears a constant ratio to the normal reaction.
5. The force of friction depends upon the roughness of the surfaces.

Laws of Kinetic or Dynamic Friction

1. The force of friction always acts in a direction, opposite to that in which the body is moving.
2. The magnitude of kinetic friction bears a constant ratio to the normal reaction b/w the two surfaces. but this ratio is slightly less than that in case of limiting friction.
3. For moderate speeds, the force of friction remains constant but it decreases slightly with the increase of speed.

Angle of Repose

The angle of repose is defined as the max. inclination of a plane at which a body remains in equilibrium over the inclined plane by the assistance of friction only.

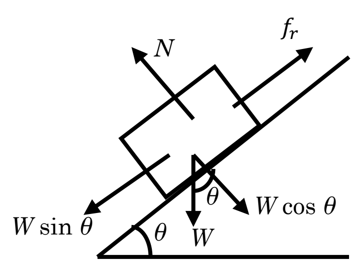

Diagram 2.5

Suppose, N = Normal reaction. φ = Inclination angle, f_r = frictional force.
Let the angle of inclination be gradually increased, till the body just starts sliding down the plane. This angle of inclined plane, at which a body just begins to slide down the plane, is called of repose.

$$W\sin\theta - f_r = 0 \quad [2.1]$$

$$W\cos\theta - N = 0 \quad [2.2]$$

From Eqns. (2.1), and (2.2), we get

$$\tan\varphi = \frac{f_r}{N} \quad [2.3]$$

$$\tan\theta = \frac{f_r}{N} \quad [2.4]$$

Form Eqns. (2.3), and (2.4), we get

$$\tan\varphi = \tan\theta$$

$$\varphi = \theta$$

hence, angle of repose = angle of friction

2.3 PROBLEMS OF LADDER

Let us suppose a ladder of weight W & length L is placed b/w wall & rough horizontal surface at an angle θ from horizontal surface. A man is stand on ladder at L_1 distance from horizontal, the coefficient of friction b/w wall & ladder is μ_B & b/w ladder & horizontal surface is μ_A. Find out the force which is prevent the motion/slipping of ladder.
Force balance in Horizontal direction:

$$N_B - f_{rA} - F = 0 \quad [2.5]$$

Force balance in vertical direction:

$$N_A + f_{rB} - W_1 - W = 0 \quad [2.6]$$

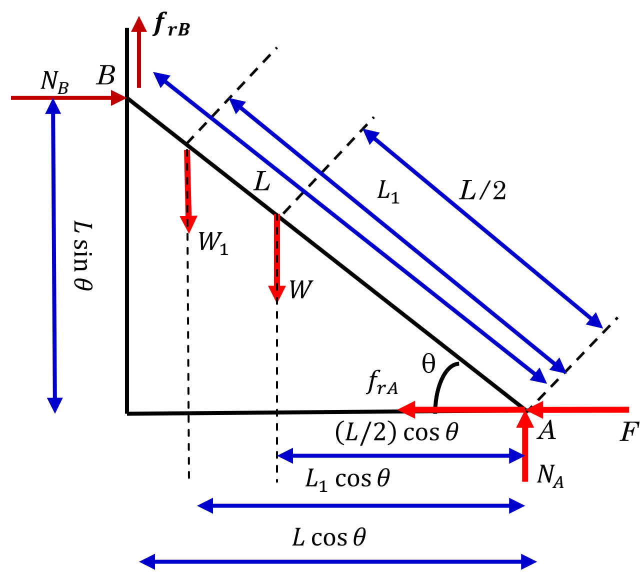

Diagram 2.6

Moment Equation (About Point A clockwise direction):

$$(N_B \times L\sin\theta) + (f_{rB} \times L\cos\theta) - (W_1 \times L_1\cos\theta) - \left(W \times \frac{L}{2}\cos\theta\right) = 0 \quad [2.7]$$

Note-

- If angle is given from wall then θ will be $90 - \theta$.
- If force is support the motion then direction force will be reverse.
- If surface of wall or horizontal is smooth then friction force is zero.

2.4 BELT FRICTION

Let us suppose a driven pulley rotating in the clockwise direction as shown in Diagram 2.7.

Consider T_1 = Tension in the belt on the tight side,
T_2 = Tension in the belt on the slack side, and
θ = Angle of contact in radians (i.e. angle subtended by the arc AB, along which the belt touches the pulley at the centre).

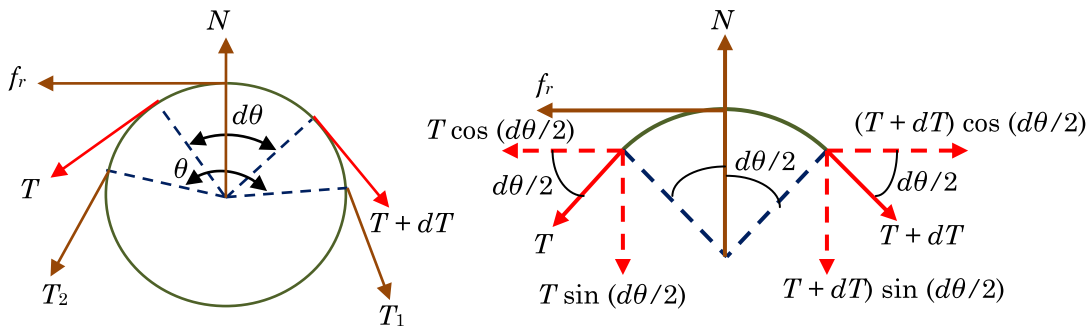

Diagram 2.7

Now consider a small portion of the belt PQ, subtending an angle $d\theta$ at the centre of the pulley as shown in Diagram 2.7. The belt PQ is in equilibrium under the following forces:

1. Tension T in the belt at P,
2. Tension $(T + dT)$ in the belt at Q,
3. Normal reaction N, and
4. Frictional force, $fr = \mu \times N$, where μ is the coefficient of friction between the belt and pulley.

Resolving all the forces horizontally and equating the same,

$$N = (T + dT)\sin\frac{d\theta}{2} + T\sin\frac{d\theta}{2} \qquad [2.8]$$

Since the angle $d\theta$ is very small, therefore putting $\sin d\theta/2 = d\theta/2$ in equation (2.8),

$$N = T.d\theta \qquad [2.9]$$

Now resolving the forces vertically, we have

$$f_r = \mu N = (T + dT)\cos\frac{d\theta}{2} - T\cos\frac{d\theta}{2} \qquad [2.10]$$

Since the angle $d\theta$ is very small, therefore putting $\cos d\theta/2 = 1$ in equation (2.10),

$$fr = \mu N = dT \qquad [2.11]$$

Equating the values of N from equations (2.9) and (2.11),

$$\mu.\ T.d\theta\ = dT$$

$$\frac{dT}{T} = \mu.d\theta$$

Integrating both sides between the limits T_2 and T_1 and from 0 to θ respectively,

$$\int_{T_2}^{T_1} \frac{dT}{T} = \mu \int_0^{\theta} d\theta$$

$$\ln \frac{T_1}{T_2} = \mu\theta \qquad \text{or} \qquad \frac{T_1}{T_2} = e^{\mu\theta} \qquad [2.12]$$

The above expression gives the relation between the tight side and slack side tensions, in terms of coefficient of friction and the angle of contact.