KTU ENGINEERING MECHANICS BE100 Printed Notes [PDF/WORD]

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FRICTION

When a body moves or tends to move another body, a force opposing the motion develops at the contact surfaces. This force which opposes the movement or tendency of movement is called frictional force or simply friction.

Friction is due to resistance to motion offered by minutely projecting particles at the contact surfaces. If a surface is perfectly smooth, the frictional force will be zero.

Limiting friction.

Frictional force has a remarkable property of adjusting itself in magnitude to the force producing or tending to produce the motion so that motion is prevented. When the force tending the motion increases, the frictional force increases. But there is a limit beyond which magnitude of frictional force cannot be increased. This limiting value or maximum value of frictional force is known as limiting friction. It is the value of frictional force when motion is impending.

Static friction and dynamic friction

When the applied force is less than limiting friction, the body remains at rest and such frictional force produced is known as static friction.

When the applied force exceeds limiting friction, the body starts moving over other body and the frictional resistance experienced while the body is moving is known as dynamic friction.

Dynamic friction is found to be less than limiting friction. It is classified into two:

1. Sliding friction: friction experienced by a body when it slides over another body.
2. Rolling friction: friction experienced by a body when it rolls over a surface.

Coefficient of friction

The magnitude of limiting friction bears a constant ratio to the normal reaction at the contact surface i.e., the limiting friction is proportional to the normal reaction at the contact surface.

This ratio or constant of proportionality is known as coefficient of friction.

Referring fig, limiting friction, F is proportional to the normal reaction, N.
F = N
F = N

\[ \mu = \frac{F}{N}, \] where \( \mu \) = coefficient of friction.

**Laws of friction.**

(Coulomb’s laws of friction/ laws of dry friction)

- The force of friction always acts in a *direction opposite* to the direction in which the body moves or tends to move.
- Till the limiting value is reached, the magnitude of friction is exactly *equal* to the force which tends to move the body.
- The magnitude of limiting friction bears a constant ratio to the normal reaction between the contact surfaces and this ratio is called *coefficient of friction.*
- The force of friction depends upon the *roughness/ smoothness* of the surfaces.
- The force of friction is *independent of the area of contact* between the two surfaces.
- After the body starts moving, the dynamic friction comes into play. The magnitude of dynamic friction is *less than* that of limiting friction and it bears a constant ratio with normal force. This ratio is called *coefficient of dynamic friction.*

**Angle of friction**

Angle of friction is the angle between the normal reaction at the contact surface and the *resultant* of normal reaction and limiting friction. It is denoted by \( \phi \).

\[ \tan \phi = \frac{F}{N} = \frac{\mu N}{N} = \mu \]

Angle of friction = \( \tan^{-1} \mu \)
**Angle of repose**

It is the maximum inclination of a plane on which the body can *repose* (sleep) without applying external force.

Consider a block of weight $W$ resting on an inclined plane which makes an angle $\alpha$ with horizontal.

When $\alpha$ is small, the block rest on the plane. If $\alpha$ is increased gradually, the block will start sliding down at a particular stage i.e. when motion impends, $F = \mu N$.

Resolving forces along inclined plane

\[
\mu N - W \sin \alpha = 0
\]

\[
\mu N = W \sin \alpha
\]

Resolving forces perpendicular to plane

\[
N - W \cos \alpha = 0
\]

\[
N = W \cos \alpha
\]

Therefore, $\mu W \cos \alpha = W \sin \alpha$

\[
\tan \alpha = \mu = \tan \phi
\]

$\alpha = \phi$

*angle of repose = angle of friction.*

**Cone of friction**

Consider the limiting equilibrium of a body kept on a horizontal surface.

Let $P$ be the applied force and $N$ be the normal reaction.
Frictional force $F = \mu N$

The resultant of limiting friction and normal reaction makes an angle equal to angle of friction with normal reaction.

When the direction of force is changed, the direction of the resultant changes but the angle between $N$ and $R$ will be same.

Similarly when the direction of $P$ is gradually changed through $360^\circ$ the resultant $R$ generates a right circular cone with a semi cone angle equal to $\phi$.

This cone is called “friction cone” or “cone of friction”. The axis of cone will be normal reaction ($N$), generators are the resultant force ($R$) and the base radius equal to limiting frictional force ($F$).