Subject Name: **Basic Civil Engineering & Engineering Mechanics**

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UNIT-3

TYPES OF LIFTING MACHINES –

These days, there are many types of lifting machines which are available in the market. But the basic principle, on which all these machines are based, is the same. It will be interesting to know that engineers who have designed (or invented) these machines have tried to increase the velocity ratio of their respective lifting machines. A little consideration will show, that if the efficiency of a machine remains almost the same, then increase in the velocity ratio must increase its mechanical advantage. The increased mechanical advantage, of a machine, means the application of a smaller force to lift the same load; or to lift a heavier load with the application of the same force.

The following lifting machines, which are important from the subject point of view, will be discussed in the following pages:

1. Simple wheel and axle.
2. Differential wheel and axle.
3. Weston's differential pulley block.
4. Geared pulley block.
5. Worm and worm wheel.
6. Worm geared pulley block.
7. Single purchase crab winch.
8. Double purchase crab winch.
9. Pulleys: (a) First system of pulleys. (b) Second system of pulleys. (c) Third system of pulleys.
10. Simple screw jack.
11. 11. Differential screw jack.
12. 12. Worm geared screw jack

SIMPLE WHEEL AND AXLE-

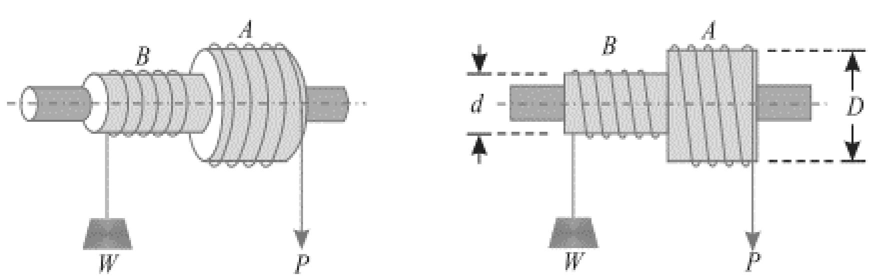


Fig. 11.1. Simple wheel and axle.

In Fig. 11.1 is shown a simple wheel and axle, in which the wheel A and axle B are keyed to the same shaft. The shaft is mounted on ball bearings, order to reduce the frictional resistance to a minimum. A string is wound round the axle B, which carries the load to be lifted. A second string is wound round the wheel A in the opposite direction to that of the string on B.

Let

D = Diameter of effort wheel,

d = Diameter of the load axle,

W = Load lifted, and P = Effort applied to lift the load.

One end of the string is fixed to the wheel, while the other is free and the effort is applied to this end. Since the two strings are wound in opposite directions, therefore a downward motion of the effort (P) will raise the load (W).

Since the wheel as well as the axle are keyed to the same shaft, therefore when the wheel rotates through one revolution, the axle will also rotate through one revolution. We know that displacement of the effort in one revolution of effort wheel A, = πD

And displacement of the load in one revolution = πd .

$$\therefore \qquad \text{V.R.} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}} = \frac{\pi D}{\pi d} = \frac{D}{d}$$

$$\text{Now} \qquad \text{M.A.} = \frac{\text{Load lifted}}{\text{Effort applied}} = \frac{W}{P} \qquad \text{..as usual}$$

$$\text{and efficiency} \qquad \eta = \frac{\text{M.A}}{\text{V.R.}} \qquad \text{...as usual}$$

A simple machine is a device with the help of which heavy loads are lifted by applying small effects in a convenient direction. Pulley used to lift water from a well and screw jacks used to lift motor car are some of the common examples of simple machines. In this chapter some of the terms connected with simple machines are explained first followed by the description of the characteristic features of levers, systems of pulleys, wheel and axle, Weston differential pulley block, inclined plane, simple screw jack, differential screw jack and winch crab.

6.1 DEFINITIONS

The terms commonly used while dealing with simple machines are defined below:

Load: This is the resistance to be overcome by the machine.

Effort: This is the force required to overcome the resistance to get the work done by the machine.

Mechanical Advantage: This is the ratio of load lifted to effort applied. Thus, if *W* is the load and *P* is the corresponding effort, then

Mechanical Advantage=W/P

Velocity Ratio: This is the ratio of the distance moved by the effort to the distance moved by the load in the same interval of time. Thus,

Velocity Ratio=D/d

Where, *D* – **distance moved by effort**

d – **distance moved by the load.**

Input: The work done by the effort is known as input to the machine. Since work done by a force is defined as the product of the force and the distance moved in the direction of the force,

Input = $P \times D$ **...(6.3)**

If force *P* **is in newton and distance** *D* **is in metre, the unit of input will be N-m. One N-m work is also known as one Joule (J).**

Output: It is defined as useful work got out of the machine, ***i.e.,*** **the work done by the load. Thus,**

Output = $W \times d$ **...(6.4)**

Efficiency: This is defined as the ratio of output to the input. Thus, if we use notation η for efficiency,

$$\eta = \frac{\text{Output}}{\text{Input}} = \frac{W \times d}{P \times D} = \frac{W}{P} \times \frac{d}{D}$$

$$= \text{Mechanical Advantage } (MA) \times \frac{1}{\text{Velocity Ratio } (VR)}$$

$$= \frac{MA}{VR} \quad \text{...(6.5)}$$

i.e., $$\text{Efficiency} = \frac{\text{Mechanical Advantage}}{\text{Velocity Ratio}}$$

Ideal Machine: A machine whose efficiency is 1 (*i.e.,* 100%) is called an ideal machine. In other words, in an ideal machine, the output is equal to the input. From eqn. (6.5), in an ideal machine,

Velocity Ratio = Mechanical Advantage

Ideal Effort: Ideal effort is the effort required to lift the given load by the machine assuming the machine to be ideal.

For ideal machine,

$$VR = MA$$

If P_i **is the ideal effort, then**

$$VR = \frac{W}{P_i}$$

$$P = \frac{W}{VR}$$ ...(VR

Ideal Load: Ideal load is the load that can be lifted using the given effort by the machine, assuming it to be ideal.

For the ideal machine,

$$VR = MA$$

If W_i is the ideal load, then

$$VR = \frac{W_i}{P}$$

$$W_i = VR \times P \quad \text{...(6.7)}$$

6.2 PRACTICAL MACHINES

In practice, it is difficult to get an ideal machine. Friction exists between all surfaces of contacts of movable parts. Some of the work done by the effort is utilized to overcome frictional resistance. Hence, the useful work done in lifting the load is reduced, resulting in reduction of efficiency.

Let P = **actual effort required**

P_i = **ideal effort required**

W = **actual load to be lifted**

W_i = **ideal load to be lifted**

SIMPLE LIFTING MACHINES: Laws of machines, reversible and irreversible machines, velocity ratio, limiting values of mechanical advantage and efficiency of machines, various types of simple machine.

LIFTING MACHINE:

Lifting machines are the devices which are used for materials handling in the industries. They are used for shifting heavy components, heavy machines, etc. from one place of shop to the other place. They are used in loading and unloading cargo for ships at the harbors. Even for loading and unloading heavy loads in goods trains lifting machines are used. In a simple lifting machine, the effort is applied at one point of the machine and the heavy load is lifted at the other point of the machine. The peculiarity of a lifting machine is that by applying smaller force, large loads can be lifted

It is a device, which enables us to lift a heavy load W, by a comparatively small effort P. The following terms are commonly used in lifting machines

1. Mechanical advantage (M.A.) - It is the ratio of load lifted (W) to the effort applied (P).

2. Velocity ratio (V.R.) - It is the ratio of the distance moved by the effort (y) to the distance moved by the load (x).

3. Input of the machine. It is the work done on the machine. It is equal to the product of effort and the distance through which it moves (i.e. P x y).

4. Output of the machine. It is the work done by the machine. It is equal to the product of load lifted and the distance through which it has been lifted (i.e. W x X).

5. Efficiency of the machine. It is ratio of output to the input of the machine. Mathematically, efficiency of the machine,

6. Ideal machine- If the efficiency of the machine is 100 %, i.e. if output is equal to input, then the machine is said to be a perfect or ideal machine.

7. Reversible machine. If a machine is capable of doing some work in the reversed direction, after the effort is removed, then the machine is known as reversible machine. The condition for a machine to be reversible is that its efficiency should be more than 50 %.

8. Non- reversible or self-locking machine. If a machine is not capable of doing some work in the reversed direction, after the effort is removed, then the machine is known as non-reversible or self-locking machine. The condition for a machine to be non-reversible or self-locking is that its efficiency should be less than 50 %.

9. Law of the machine. It is the relationship between the load lifted (W) and the effort applied (P). It is given by the equation,

P = m.W+C
where
m = A constant (called coefficient of friction) which is equal to the slope of the line AB as shown in Fig. 1.23, and
C = Another constant, which represents the machine friction.

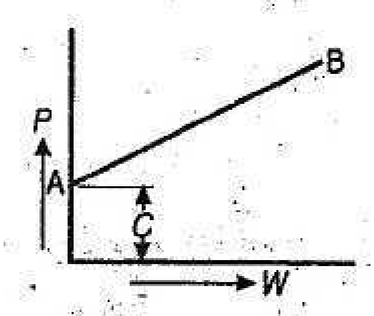


Fig. 1.23

10. Maximum mechanical advantage. The maximum mechanical advantage of a lifting machine is given by
Max. M.A. = 1 / m

11. Maximum efficiency- The maximum efficiency of a lifting machine is given by

$$\text{Max. } \eta = \frac{1}{m \times V.R.}$$

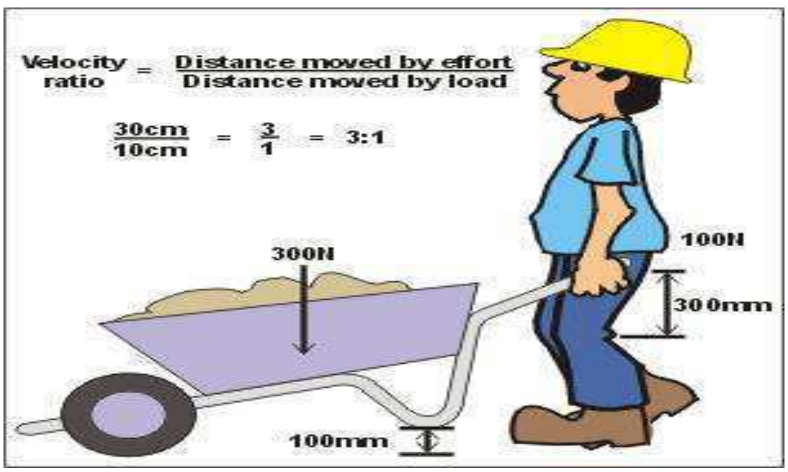
Mechanical Advantage (MA)

Mechanical advantage is defined as the ratio of resistance overcomes to the effort applied. The simple machine requires force to do work. The resistive force to be overcome is called load and the force applied to overcome the load is called effort.

$$\text{Mechanical Advantage (MA)} = \frac{\text{load (L)}}{\text{effort applied (E)}}$$

$$\text{MA} = \frac{\text{L}}{\text{E}}$$

Velocity Ratio:



Velocity ratio of simple machine is the ratio of distance travelled by the effort to the distance travelled by the load in the machine. As velocity ratio or ideal mechanical advantage is a simple ratio of two distances, it also does not have the unit. The friction is not involved in it.

If a machine overcomes a load 'L' and the distance travelled by the load is 'Ld'. Similarly, the effort applied in the machine is 'E' and the distance travelled by effort is 'Ed', and 'T' is the time taken then

$$\text{Velocity of load} = \frac{\text{Ld}}{\text{T}}$$

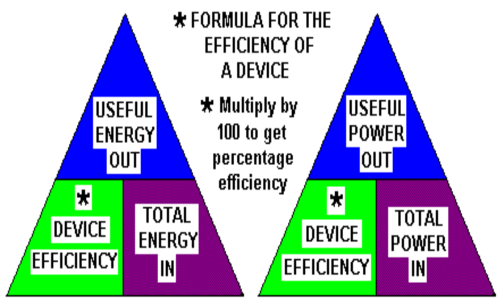
$$\text{Velocity of effort} = \frac{\text{Ed}}{\text{T}}$$

$$\frac{\text{Velocity of effort}}{\text{Velocity of load}} = \frac{\text{Ed/T}}{\text{Ld/T}}$$

$$\text{Velocity ratio (VR)} = \frac{\text{Distance moved by effort (Ed)}}{\text{Distance moved by load (Ld)}}$$

$$\text{Velocity ratio (VR)} = \frac{\text{Ed}}{\text{Ld}}$$

Efficiency:



If a machine overcomes a load 'L' and the distance travelled by the load is 'Ld', the work done by the load is L × Ld. It is also called output work or useful work. Therefore,

Output work = L × Ld

Likewise, the effort applied to overcome the load is E and the distance covered by effort is Ed, the work done by effort is E × Ed. It is also called input work. Therefore,

Input work = E × Ed

The efficiency of a simple machine is defined as the ratio of useful work done by a machine (output work) to the total work put into the machine (input work).

$$\text{Efficiency } (\eta) = \frac{\text{output}}{\text{input}} = \frac{\text{L} \times \text{Ld}}{\text{E} \times \text{Ed}} \times 100\%$$

$$\text{Efficiency } (\eta) = \frac{\text{L} \times \text{Ld}}{\text{E} \times \text{Ed}} \times 100\%$$

$$\eta = \frac{\text{MA}}{\text{VR}} \times 100\%$$

For ideal or perfect machine, work output is equal to the work input. Ideal machines are those imaginary machines which are frictionless. In practice, the work output of a machine is always less than work input due to the effect of friction. If the frictional force in the machine increases the efficiency decreases because machines are frictionless in practice, the efficiency of a machine can never be 100%.

Types of Simple Machines: •

Inclined planes:
- **Ramp**
- **Wedge**
- **Screw ƒ**

Levers:
- **Lever**
- **Wheel & Axle**
- **Pulley**

Ramp or Inclined Plane

A flat surface that is higher on one end - slanting surface connecting a lower level to a higher level. •
You can use this machine to move an object to a lower or higher place. •
Inclined planes make the work of moving things easier - allows us to raise an object with less effort than if we lifted it directly upward. •
You would need less energy and force to move objects with an inclined plane. •
Trade-off: The way an inclined plane works is that to save effort, you must move things a greater distance ƒ The longer the distance of the ramp, the easier it is to do the work. It will take a much longer time to do the work •
The shallower the ramp, the easier it is to move the object. The trade-off is that you must move the object farther to lift it to the same height.

Examples:

Ramp, Slanted Road, Path up a Hill, Slide

Wedge:

A wedge is a simple machine used to push two objects apart

A wedge is usually made up of two inclined planes. These planes meet and form a sharp edge. This edge can split or push objects apart. A wedge is an inclined plane which moves •A wedge can also be used as a lifting device, by forcing it under an object • Most wedges (but not all) are combinations of two inclined planes. Can also be round, like the tip of a nail. The narrower the wedge (or the sharper the point of a wedge), the easier it is drive it in and push things apart • Trade-off: To split something apart really wide, you have to push the wedge a long distance. Generally it can be anything that splits, cuts, or divides another object including air and water

Examples:

Knife, Axe, Teeth, Forks, Nails

Screw: •

An inclined plane that winds around itself ƒ a wedge at the tip • A screw has ridges and is not smooth like a nail • Some screws are used to lower and raise things • They are also used to hold objects together • A screw is like the ramp —the width of the thread is like the angle of an inclined plane ƒ The wider the thread of a screw, the harder it is to turn it. ƒ Trade-off: The distance between the threads depends on the slope of the inclined plane - the steeper the slope, the wider the thread ƒ Screws with less distance between the threads are easier to turn

Examples:

Jar Lids, Light Bulbs, Stools, Clamps, Jacks, Wrenches, Spiral Staircase

Lever: •

A lever is a board or bar that rests on a turning point. This turning point is called the fulcrum An object that a lever moves is called the load. The load is a force or object which must be overcome by the lever. The applied force or effort or input force is the force you use to move the lever lifts or moves loads. By changing the position of the fulcrum, you can gain extra power with less effort. The closer the object is to the fulcrum, the easier it is to move. Most common simple machine because just about anything that has a handle on it has a lever attached. The arm length of the lever is determined by the position of the fulcrum Used to transfer force •It can be used to increase the force that is applied, or make something move in a different direction, or through a greater distance. It can be used to lift something that is far away. It is the same principle as the inclined plane - the greater the distance over which the force must be applied, the smaller the force required to do the work (lift the load) • Force moves over a longer distance. Depending on where the fulcrum is located. A lever can multiply either the force applied or The distance over which the force is applied.

Wheel & Axle: •

A wheel with a rod, called an axle, through its center lifts or moves loads. The axle is a rod that goes through the wheel. This lets the wheel turn. The wheel & axle can be used as a tool to multiply the force you apply or to multiply the distance traveled. A lever that is able to rotate through a complete circle (360°). The circle turned by the wheel is much larger than the circle turned by the axle. The increased distance over

which the force is applied as the wheel turns results in a more powerful force on the axle, which moves a shorter distance • Trade-off: The larger the diameter of the wheel, the less effort you need to turn it, but you have to move the wheel a greater distance to get the same work done.

Examples:

Cars, Roller, skates, Door knobs, Gears

Pulleys: •

Instead of an axle, the wheel could also rotate a rope or cord. This variation of the wheel and axle is the pulley. In a pulley, a cord wraps around a wheel as the wheel rotates, the cord moves in either direction. When a hook is attached to the rope you can use the wheel's rotation to raise and lower objects. The rope fits on the groove of the wheel • One part of the rope is attached to the load • When you pull on one side of the pulley, the wheel turns and the load will move • Pulleys let you move loads up, down, or sideways •Pulleys are good for moving objects too hard to reach places. A pulley makes work seem easier because it changes the direction of motion to work with gravity. A pulley saves the most effort when you have more than one pulley working together. Trade-off: as you increase the number of pulleys, you also increase the distance you have to pull the rope ƒ In other words, if you use two pulleys, it takes half the effort to lift something, but you have to pull the rope twice as far Three pulleys will result in one-third the effort — but the distance you have to pull the rope is tripled!

Types of Pulleys:

1. **Fixed pulleys**
2. **Movable pulleys**
3. **Single Pulleys**
4. **Combination pulleys**

Examples:

Flag Poles, Sailboat, Blinds,

