MIMLI DAS

Lecturer, Mechanical Engineering

ENGINEERING MECHANICS

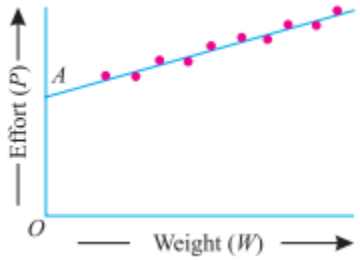
CHAPTER 10: SIMPLE LIFTING MACHINES

Lecture 2:

10.2 Law of Machine, problems:

Law of machine:

The term 'law of a machine' may be defined as a relationship between the effort applied and the load lifted. Thus for any machine, if we record the various efforts required to raise the corresponding loads, and plot a graph between effort and load, we shall get a straight line AB as shown in figure.



We also know that the intercept OA represents the amount of friction offered by the machine. Or in other words, this is the effort required by the machine to overcome the friction, before it can lift any load.

Mathematically, the law of a lifting machine is given by the relation :

$$P = mW + C$$

where P = Effort applied to lift the load, m = A constant (called coefficient of friction) which is equal to the slope of the line AB, W = Load lifted, and C = Another constant, which represents the machine friction, (i.e. OA).

Example 10.5 *What load can be lifted by an effort of 120 N, if the velocity ratio is 18 and efficiency of the machine at this load is 60% ?*

Determine the law of the machine, if it is observed that an effort of 200 N is required to lift a load of 2600 N and find the effort required to run the machine at a load of 3.5 kN.

Solution. Given: Effort (P) = 120 N ; Velocity ratio (V.R.) = 18 and efficiency (η) = 60% = 0.6.

Load lifted by the machine.

Let W = Load lifted by the machine.

We know that M.A. $= \frac{W}{P} = \frac{W}{120} = W/120$

and efficiency, $0.6 = \frac{\text{M.A.}}{\text{V.R.}} = \frac{W/120}{18} = \frac{W}{2160}$

$\therefore$ $W = 0.6 \times 2160 = 1296$ N **Ans.**

Law of the machine

In the second case, $P = 200$ N and $W = 2600$ N

Substituting the two values of P and W in the law of the machine, *i.e.*, $P = m\,W + C$,

$$120 = m \times 1296 + C \quad ...(i)$$

and $$200 = m \times 2600 + C \quad ...(ii)$$

Subtracting equation (i) from (ii),

$$80 = 1304\,m \quad \text{or} \quad m = \frac{80}{1304} = 0.06$$

and now substituting the value of m in equation (ii)

$$200 = (0.06 \times 2600) + C = 156 + C$$

$$C = 200 - 156 = 44$$

Now substituting the value of $m = 0.06$ and $C = 44$ in the law of the machine,

$$P = 0.06\,W + 44$$ **Ans.**

Effort required to run the machine at a load of 3.5 kN.

Substituting the value of W = 3.5 kN or 3500 N in the law of machine,

$$P = (0.06 \times 3500) + 44 = 254 \text{ N}$$ **Ans.**

Example 10.7. *What load will be lifted by an effort of 12 N, if the velocity ratio is 18 and efficiency of the machine at this load is 60 % ?*

If the machine has a constant friction resistance, determine the law of the machine and find the effort required to run this machine at (i) no load, and (ii) a load of 900 N.

Solution. Given: Effort (P) = 12 N ; Velocity ratio (V.R.) = 18 and efficiency (η) = 60 % = 0.6.

Load lifted by the machine.

Let W = Load lifted by the machine,

We know that M.A. $= \frac{W}{P} = \frac{W}{12} = W/12$

and efficiency, $0.6 = \frac{\text{M.A.}}{\text{V.R.}} = \frac{W/12}{18} = \frac{W}{216}$

$\therefore$ $W = 0.6 \times 216 = 129.6$ N **Ans.**

Law of the machine

We know that effort lost in friction,

$$F_{(\text{effort})} = P - \frac{W}{\text{V.R.}} = 12 - \frac{129.6}{18} = 4.8 \text{ N}$$

Since the frictional resistance is constant, therefore 4.8 N is the amount of friction offered by the machine. Now substituting the values of $P = 12$ and $C = 4.8$ in the law of the machine.

$$12 = m \times 129.6 + 4.8 \quad ...(\because P = mW + C)$$

or $$m = \frac{12 - 4.8}{129.6} = \frac{1}{18}$$

∴ Law of the machine will be given by the equation,

$$P = \frac{1}{18} W + 4.8 \qquad \textbf{Ans.}$$

Effort required to run the machine at no load

Substituting the value of $W = 0$ in the law of the machine (for no load condition),

$$P = 4.8 \text{ N} \qquad \textbf{Ans.}$$

Effort required to run the machine at a load of 900 N

Substituting the value of $W = 900$ N in the law of machine,

$$P = \frac{1}{18} \times 900 + 4.8 = 54.8 \text{ N} \qquad \textbf{Ans.}$$

Maximum mechanical advantage of a lifting machine:

We know that mechanical advantage of a lifting machine,

$$\text{M.A.} = \frac{W}{P}$$

For maximum mechanical advantage, substituting the value of $P = mW + C$ in the above equation,

$$\text{Max. M.A.} = \frac{W}{mW + C} = \frac{1}{m + \frac{C}{W}} = \frac{1}{m} \quad \ldots\left(\text{Neglecting } \frac{C}{W}\right)$$

Maximum efficiency of a lifting machine:

We know that efficiency of a lifting machine,

$$\eta = \frac{\text{Mechanical advantage}}{\text{Velocity ratio}} = \frac{\frac{W}{P}}{\text{V.R.}} = \frac{W}{P \times \text{V.R.}}$$

For *maximum efficiency, substituting the value of $P = mW + C$ in the above equation,

$$\text{Max. } \eta = \frac{W}{(mW + C) \times \text{V.R}} = \frac{1}{\left(m + \frac{C}{W}\right) \times \text{V.R.}} = \frac{1}{m \times \text{V.R.}} \quad \ldots\left(\text{Neglecting } \frac{C}{W}\right)$$

Example 10.9 *The law of a certain lifting machine is :*

$$P = \frac{W}{50} + 8$$

The velocity ratio of the machine is 100. Find the maximum possible mechanical advantage and the maximum possible efficiency of the machine. Determine the effort required to overcome the machine friction, while lifting a load of 600 N. Also calculate the efficiency of the machine at this load.

Solution. Given: Law of lifting machine $P = \frac{W}{50} + 8 = 0.02W + 8$; Velocity ratio (V.R.) = 100 and load (W) = 600 N.

Maximum possible mechanical advantage

Comparing the given law of the machine with the standard relation for the law of the machine (*i.e.* $P = mW + C$) we find that in the given law of the machine, $m = 0.02$. We know that maximum possible mechanical advantage

$$\text{Max M.A.} = \frac{1}{m} = \frac{1}{0.02} = 50 \qquad \textbf{Ans.}$$

Maximum possible efficiency

We know that maximum possible efficiency

$$= \frac{1}{m \times \text{V.R.}} = \frac{1}{0.02 \times 100} = \frac{1}{2} = 0.5 = 50\% \qquad \textbf{Ans.}$$

Effort required to overcome the machine friction

We know that effort required to lift a load of 600 N

$$P = mW + 8 = (0.02 \times 600) + 8 = 20 \text{ N}$$

and effort required to overcome the machine friction, while lifting a load of 600 N,

$$F_{(\text{effort})} = P - \frac{W}{\text{V.R.}} = 20 - \frac{600}{100} = 14 \text{ N} \qquad \textbf{Ans.}$$

Efficiency of the machine

We know that mechanical advantage of the machine while lifting a load of 600 N.

$$\text{M.A} = \frac{W}{P} = \frac{600}{20} = 30$$

and efficiency, $$\eta = \frac{\text{M.A.}}{\text{V.R.}} = \frac{30}{100} = 0.3 = 30\% \qquad \textbf{Ans.}$$

OBJECTIVE TYPE QUESTIONS

1. The efficiency of a lifting machine is the ratio of

(*a*) Its output to input

(*b*) Work done by it to the work done on it

(*c*) Its mechanical advantage to its velocity ratio

(*d*) All of the above.

2. If efficiency of a lifting machine is kept constant, its velocity ratio is directly proportional to its

(*a*) Mechanical advantage (*b*) Effort applied

(*c*) Machine friction (*d*) All of the above

3. In an ideal machine, the mechanical advantage is ..... velocity ratio

(*a*) Equal to (*b*) Less than (*c*) Greater than

4. A lifting machine having an efficiency less than 50% is known as

(*a*) Reversible machine (*b*) Non-reversible machine

(*c*) Ideal machine (*d*) None of the above

5. A weight of 1000 N can be lifted by an effort of 80 N. If the velocity ratio of the machine is 20, then the machine is

(*a*) Reversible (*b*) Non-reversible (*c*) Ideal

6. The maximum mechanical advantage of a lifting machine is

(*a*) $1 + m$ (*b*) $1 - m$ (*c*) $1/m$ (*d*) m

7. The maximum efficiency of a lifting machine is

(*a*) $1/m$ (*b*) V. R./ m (*c*) m/ V. R. (*d*) $1/(m \times \text{V. R.})$

ANSWERS

1. (*d*) **2.** (*a*) **3.** (*a*) **4.** (*b*) **5.** (*a*) **6.** (*c*) **7.** (*d*)