CEE 271 APPLIED MECHANICS II

Lecture 13: Power and Efficiency

Department of Civil & Environmental Engineering

University of Hawai'i at Mānoa

Today's Objectives

- Determine the power generated by a machine, engine, or motor.
- Calculate the mechanical efficiency of a machine.

Outline (Pre-Job Brief)

- Define & Find Power
- Define & Find Efficiency
- Examples and Questions
- Summary and Feedback

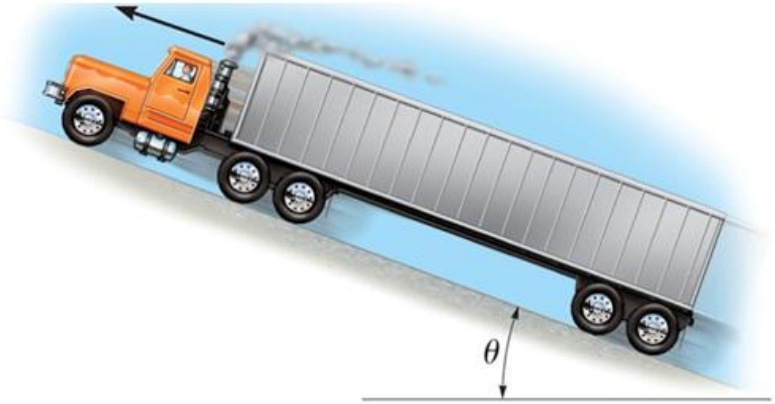
Power & Efficiency

Applications

Engines and motors are often rated in terms of their power output. The power output of the motor lifting this elevator is related to the vertical force ***F*** acting on the elevator, causing it to move upwards.

Given a desired lift velocity for the elevator (with a known maximum load), how can we determine the power requirement of the motor?

Applications (continued)



The speed at which a truck can climb a hill depends in part on the power output of the engine and the angle of inclination of the hill.

For a given angle, how can we determine the speed of this truck, knowing the power transmitted by the engine to the wheels? Can we find the speed, if we know the power?

If we know the engine power output and speed of the truck, can we determine the maximum angle of climb for this truck ?

Power and Efficiency

Power is defined as the amount of work performed per unit of time.

If a machine or engine performs a certain amount of work, dU, within a given time interval, dt, the power generated can be calculated as

$$P = dU/dt$$

Since the work can be expressed as $dU = \boldsymbol{F} \cdot d\boldsymbol{r}$, the power can be written

$$P = dU/dt = (\boldsymbol{F} \cdot d\boldsymbol{r})/dt = \boldsymbol{F} \cdot (d\boldsymbol{r}/dt) = \boldsymbol{F} \cdot \boldsymbol{v}$$

Thus, power is a scalar defined as the product of the force and velocity components acting in the same direction.

Power

Using scalar notation, power can be written

$$P = \boldsymbol{F} \cdot \boldsymbol{v} = F\, v \cos\theta$$

where θ is the angle between the force and velocity vectors.

So if the velocity of a body acted on by a force ***F*** is known, the power can be determined by calculating the dot product or by multiplying force and velocity components.

The unit of power in the SI system is the Watt (W) where

$$1\ \text{W} = 1\ \text{J/s} = 1\ (\text{N} \cdot \text{m})/\text{s}\ .$$

In the FPS system, power is usually expressed in units of horsepower (hp) where

$$1\ \text{hp} = 550\ (\text{ft} \cdot \text{lb})/\text{s} = 746\ \text{W}\ .$$

Efficiency

The mechanical efficiency of a machine is the ratio of the useful power produced (output power) to the power supplied to the machine (input power) or

$$\varepsilon = (\text{power output}) / (\text{power input})$$

If energy input and removal occur at the same time, efficiency may also be expressed in terms of the ratio of output energy to input energy or

$$\varepsilon = (\text{energy output}) / (\text{energy input})$$

Machines will always have frictional forces. Since frictional forces dissipate energy, additional power will be required to overcome these forces. Consequently, the efficiency of a machine is always less than 1.

Procedure for Analysis

Find the resultant external force acting on the body causing its motion. It may be necessary to draw a free-body diagram.

Determine the velocity of the point on the body at which the force is applied. Energy methods or the equation of motion and appropriate kinematic relations, may be necessary.

Multiply the force magnitude by the component of velocity acting in the direction of $\boldsymbol{F}$ to determine the power supplied to the body ($P = F\ v \cos\theta$).

In some cases, power may be found by calculating the work done per unit of time ($P = dU/dt$).

If the mechanical efficiency of a machine is known, either the power input or output can be determined.

Examples & Questions

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