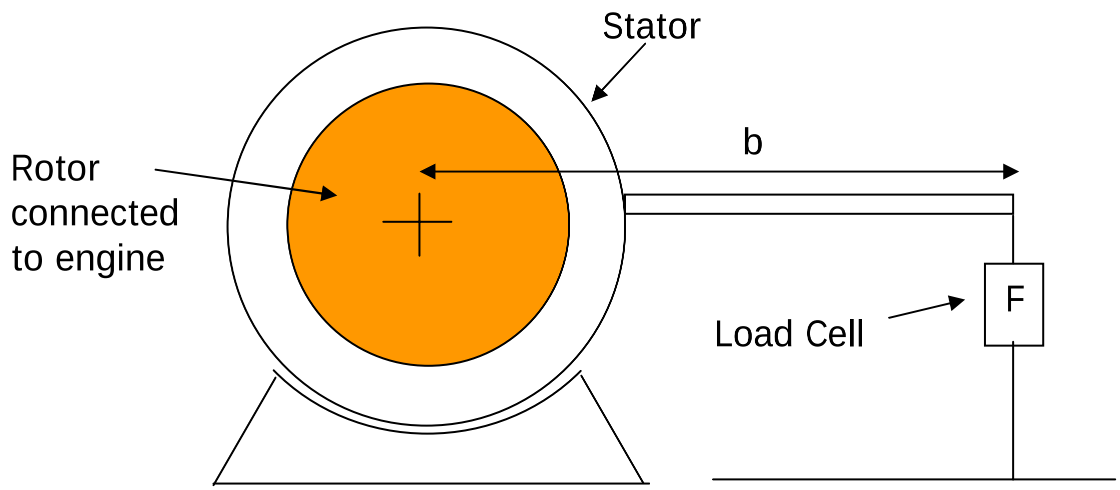
ME 410 Day 3

Topics

- Torque and Brake Power
- Work per cycle and Indicated Power
- EES Introduction. Demonstration and Practice

Homework 2.3 Use EES.

1. Torque



A fluidic or electrical coupling transmits forces between rotor and stator.

The torque is

$$T = F\,b$$

Also called brake torque since it is measured with a dynamometer.

Measure of an Engine's capacity to do work, e.g. can it pull a fully loaded boat trailer up a ramp. (Note speed of doing this not important.)

Somewhat confusingly, torque has the same units as work.
Brake Torque units

- in-lb or ft-lb
- N-m

Brake Power

Recall the famous dynamics formula for power transmitted in a rotating shaft. That formula is applicable here.

$$P = T\,\omega$$

where P is the power and ω is angular velocity in rad/sec. Many times with engines it's more convenient to use rev/sec.

$$P = 2\,\pi\,N\,T$$

N is angular speed in rev/sec or rev/min (rpm)

Brake Power Units

- hp = 550 ft-lb/sec
- kW (kilowatts)

Horsepower:

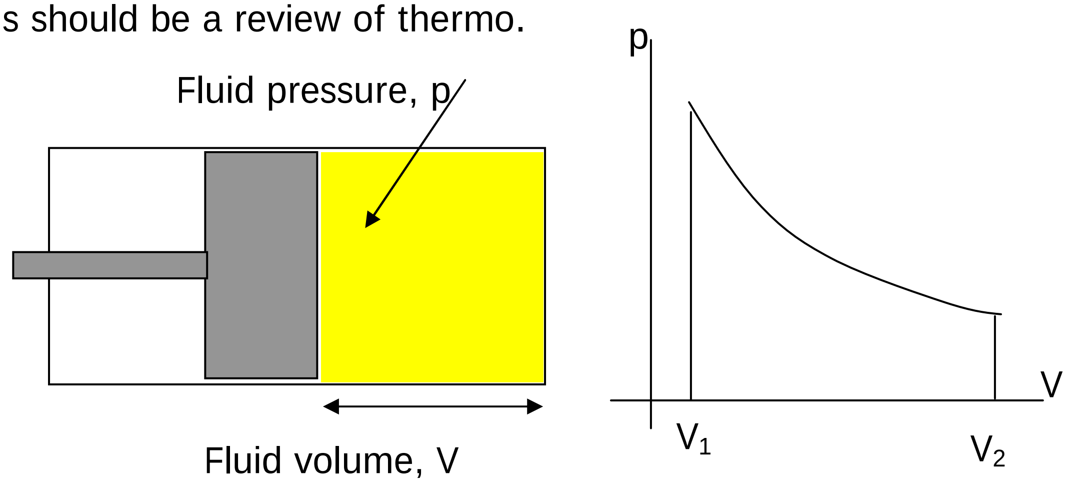
$$P(hp) = \frac{N(RPM)\,T(ft - lb)}{5252}$$

Other such formulas are derived. See text.

We refer to this power as brake power. Sometimes we use the symbol. P_b.

2. Work per Cycle

This should be a review of thermo.



We consider the work done by the pressure of a gas acting on a piston. Let the piston be the system.

The work done by the gas on the piston is the integral,

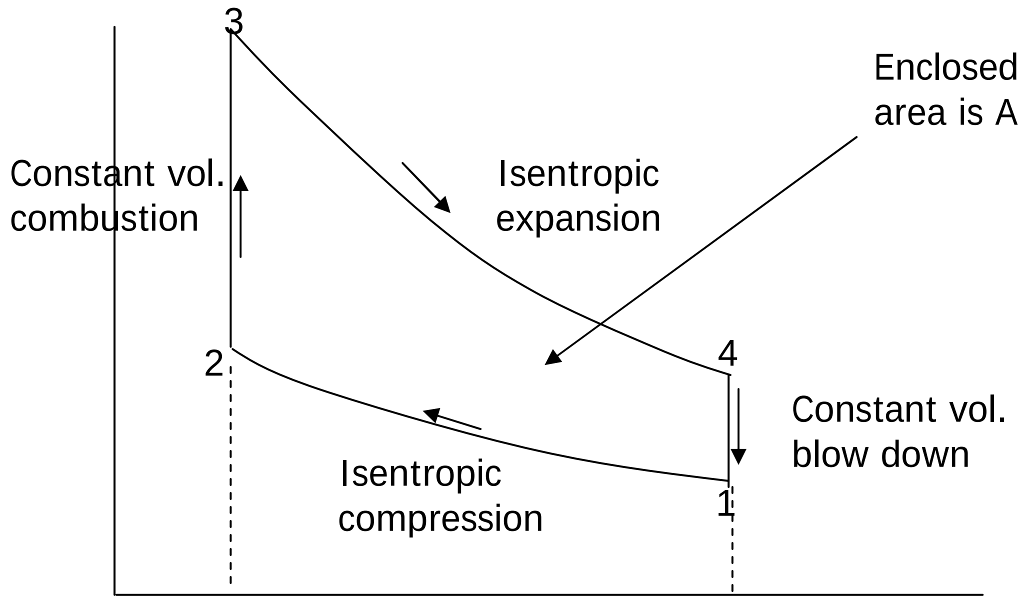
$$W_{1\rightarrow 2} = \int_{V_1}^{V_2} p\,dV$$

This integral has a meaning. It is the area under the p(V) curve between 1 and 2.

The pressure p is taken to be positive. So,

- If $V_2 > V_1$ the pressure produces a volume expansion. This is positive work.
- If $V_1 < V_2$ there is a volume contraction despite the pressure. This is negative work. I.e. piston does work on gas.

Next, consider an idealized SI engine cycle.



(This is a starting point, rough approximation to what happens.)

In the spirit of the previous slide, the net work of the cycle follows the closed path in pV space,

$$W_{c,i} = \oint_{1,2,3,4,1} p\,dV$$

or in terms of more familiar integrals,

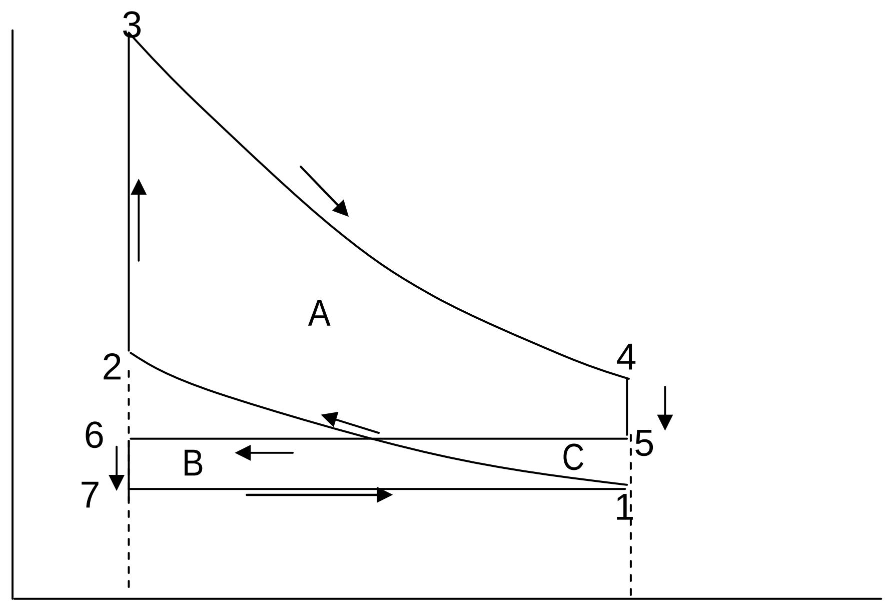
$$W_{c,i} = \int_{V_1}^{V_2} p\,dV + \int_{V_2}^{V_3} p\,dV + \int_{V_3}^{V_4} p\,dV + \int_{V_4}^{V_1} p\,dV$$

$$W_{c,i} = \int_{V_1}^{V_2} p\,dV + \int_{V_3}^{V_4} p\,dV = \int_{V_3}^{V_4} p\,dV - \int_{V_2}^{V_1} p\,dV$$

In other words, $W_{c,i} = A$, the area enclosed by the path.

Work done by gas on piston during compression and power strokes.

Next, consider idealized SI with throttling.



New strokes:

- 4-5 constant volume blowdown
- 5-6 constant pressure exhaust stroke
- 6-7 constant volume intake
- 7-1 constant pressure intake stroke

If SI is throttled that means that the pressure at 1 is below atmospheric, where the exhaust pressure is assumed to be.

$$W_{c,in} = -\int_{V_2}^{V_1} pdV + \int_{V_3}^{V_4} pdV - \int_{V_5}^{V_6} pdV + \int_{V_7}^{V_1} pdV$$

$$W_{c,in} = (A + C) - (B + C) = A - B$$

I.e. the area A minus the area B. This is called the net work per cycle.

We distinguish it from the gross indicated work per cycle which is delivered to the gas at compression and delivered from the gas to the piston at expansion.

$$W_{c,ig} = A + C$$

The subscript "i" means "indicated." This is the work done at the piston. It is not the work done on the brake. More on this later.

Indicated Power / Cylinder

$$P_i = \frac{W_{c,i} N}{n_R}$$

Recall that N is the number of revs per time.

- $n_R = 1$ for a two stroke engine
- $n_R = 2$ for a four stroke engine

Example Problem

A 4-cylinder, 4-stroke engine is delivering indicated power of 100 hp at 4000 rpm. What is the indicated work per cycle?

The EES solution to the problem will be demonstrated and given.

"Day 3 Example Problem"

"A 4-cylinder, 4-stroke engine is delivering indicated power of 100 hp at 4000 rpm. What is the indicated work per cycle in each cylinder?"

```
n_cyl = 4
n_R  = 2                                        "[rev]"
N = 4000*convert(rev/min,rev/sec)               "[rev/sec]"
P_i = 100* convert(hp,ft-lbf/sec)               "[ft-lbf/sec]"

P_i =n_cyl* ( W_i * N /n_R )
```