2^{nd} Lab

Engine friction

Objective

Understanding the engine friction concept, and studying some empirical methods to calculate engine friction.

Discussion

- What is friction work?
- What are the different methods to calculate Friction?

What is friction work?

The friction work, defined as the difference between the work delivered to the piston while the working fluid is contained within the cylinder (i.e., during the compression and expansion strokes) and the usable work delivered to the drive shaft, is expended as follows:

1. To draw the fresh mixture through the intake system and into the cylinder, and to expel the burned gases from the cylinder and out of the exhaust system.It is usually called the **pumping work** $\mathbf{W_p}$.
2. To overcome the resistance to relative motion of all the moving parts of the engine. This includes the friction between the piston rings, piston skirt, and cylinder wall; friction in the wrist pin, big end, crankshaft, and camshaft bearings; friction in the valve mechanism; friction in the gears, or pulleys and belts, which drive the camshaft and engine accessories. It is usually called the **rubbing friction work** $\mathbf{W_{rf}}$.
3. To drive the engine accessories. These can include: the fan, the water pump, the oil pump, the fuel pump, the generator, a secondary air pump for emission control, a power-steering pump, and an air conditioner. It is usually called the **accessories work** $\mathbf{W_a}$.

Total friction work W_{tf}: The total friction work is the sum of these three components,

$$W_{tf} = W_a + W_{rf} + W_p$$

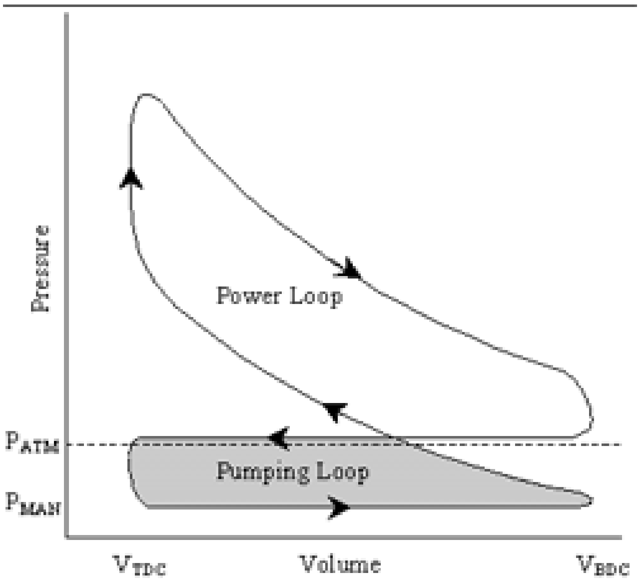
The total friction work per cycle for a given engine geometry will vary with the speed.

It is convenient to discuss the difference between indicated and brake output in terms of mean effective pressure, **mep**, the work per cycle per unit displaced volume:

$$\text{mep} = \frac{W_c}{V_d}$$

If the work is expressed by power it will be:

$$power = mep \times V_d \times \frac{N}{i \times 60}$$



Gross indicated mean effective pressure, $imep_g$: The work delivered to the piston over the compression and expansion strokes, per cycle per unit displaced volume.

Net indicated mean effective pressure, $imep_n$: The work delivered to the piston over the entire four strokes of the cycle, per unit displaced volume.

From the above definitions it follows that

$$tfmep = Pmep + rfmep + amep$$
$$imep_g = imep_N + Pmep$$
$$bmep = imep_g - tfmep$$
$$bmep = imep_N - rfmep - amep$$

$tfmep$ is total friction mean effective pressure

$Pmep$ is pumping mean effective pressure

$rfmep$ is rubbing friction mean effective pressure

$amep$ is accessories mean effective pressure

Measurement methods

A true measurement of friction in a firing engine can only be obtained by subtracting the brake power from the indicated power determined from accurate measurements of cylinder pressure throughout the cycle. However, this method is not easy to use on multicylinder engines, both because of cylinder-to-cylinder differences in indicated power and due to the difficulties in obtaining sufficiently accurate pressure data.

A. Measurement of f_{mep} from i_{mep}

$$imep_g = \frac{\int pdv_{compression+expansion}}{V_d}$$

$$Pmep = \frac{\int pdv_{suction+exhaust}}{V_d}$$

$$imep_N = imep_g - Pmep$$

$$\eta_m = \frac{bmep}{imep_N}$$

$$imep_N - bmep = (rfmep + amep)$$

B. Direct motoring test:

Drive an unfired engine with an electric motor; By measuring the electric power input to the motor driving the engine it can be a good approximation of the friction power lost.

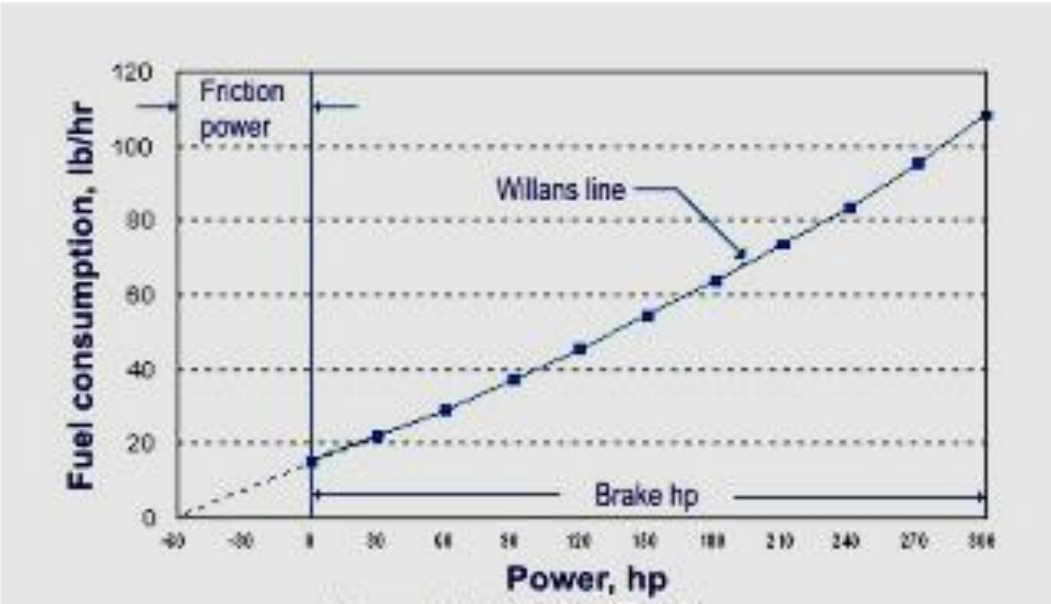
$$w_m = w_f = f_{mep} \times V_d \times \frac{N}{2}$$

Engine temperatures should be maintained as close to normal operating temperatures as possible, so the test procedure can be:

- Run the engine at normal fired mode.
- When the engine reached steady state condition turn off the engine
- Immediately test the engine using electric motor for brief time (the time which the engine temperature is as fired temperature).

C. Willans line:

A plot of fuel consumption versus brake output obtained from engine tests at a fixed speed is extrapolated back to zero fuel consumption.



D. Morse test

In the Morse test, individual cylinders in a multicylinder engine are cut out from firing, and the reduction in brake torque is determined while maintaining the same engine speed. The remaining cylinders drive the cylinder cut out. Care must be taken to determine that the action of cutting out one cylinder does not significantly disturb the fuel or mixture flow to the others.

Steps:

1. Operate the engine at a constant speed (RPM) and determine the Brake power that out from the engine.

$$IP_{all} = BP_{all} + Friction \rightarrow 1$$

2. Cut the spark of one cylinder so the engine power and so its speed, so we increase the speed to the previous value by increasing the throttle valve opening.

$$IP_{n-1} = BP_{n-1} + Friction \rightarrow 1$$

Subs 2 from 1

$$IP_{all} - IP_{n-1} = BP_{all} - BP_{n-1}$$

3. This value "reduction in brake power" represents the value of the indicated power for the cylinder we cut the spark from it

$$BP_{all} - BP_{n-1} = IP_{cyl.1}$$

4. Repeat what we have done on all the rest cylinders.
5.

$$IP_{all} = \sum IP_{cyl.}$$

6.

$$Friction = IP_{all} - BP_{all}$$

Calculating the engine friction using Willians line method

We will fix the speed N

Procedure

1. Start the engine, let it to warm up and reach steady state.
2. Load the engine with 5 Lb with respecting the const. N(rpm) and measure fuel mass flow rate.
3. Increase the load to 10Lb and also make sure that the speed is constant and measure the fuel mass flow rate.
4. Repeat for 15Lb and 20Lb and put the results in the table.

N_1 = rpm , N_2 = rpm

V_f = 16 ml , r_{fuel} = 830 Kg/m^3

m^o_f = Density *(V_f / time)

BP(KW) = load(lb) * N(rpm) * 0.746 / 2800

For N_1 =

Load(Lb)	5	10	15	20
Time				
Bp				

For N_2 =

Load(Lb)	5	10	15	20
Time				
Bp				

Requirement

1. Draw the willians line and calculate the friction power at N_1,N_2
2. Make comments for the two Willians lines