Lab 2: MECHANICAL EFFICIENCY

This laboratory concerns itself with measurement of friction in a engine power unit.

The power available at the piston head is designated indicated power, P_i. The power produced at the flywheel or some other driver where the power may be measured is called brake power, P_b. There is a definite power loss between these two, composed of bearing and gear friction, pumping losses and some heat dissipation. The term that includes all of these losses is called friction power, P_f. Thus:

Equation [1] $P_i = P_b + P_f$

Friction power may be determined by measuring the power required to "motor" the power unit. Specially adapted equipment is required. A most desirable arrangement is to use an electric absorption dynamometer which may be wired to "motor" the unit being tested.

An alternate method is to determine friction by inference. If the number one injector is disconnected during the test, then for a four cylinder engine, with 3 cylinders firing ($P_{b(234)}$ is the Power measured at the dyno):

Equation [2] $P_{b(234)}= P_{i(234)} - P_{i(1234)}$

The output for a four cylinder engine, with all 4 cylinders firing (B_p is the Power measured at the dyno):

Equation [3] $P_{b(1234)}= P_{i(1234)} - P_{i(1234)}$

Therefore, the P_i for one cylinder may be determined by subtracting equation (2) from (3) giving:

Equation [4] $P_{b(1234)} - P_{b(234)} = [P_{i(1234)} - P_{i(1234)}] - [P_{i(234)} - P_{i(1234)}]$
$= [P_{i(1)}]$

If the assumption is made that the power output of the engine is uniform, the total $P_i = n*I_p(1)$, where n is the number of cylinders. The total friction power (P_f) may be calculated from equation (1). This procedure is applicable for an engine of any number of cylinders.

Since P_f varies with engine speed, it is important that constant speed, wide-open-throttle tests be run with the load being varied to maintain constant speed.

Note: A major assumption is that the same amount of fuel is being injected into each cylinder at a particular rpm. Therefore the inference method only works when the engine is in the load control range and NOT WHEN OPERATING IN THE GOVERNOR CONTROL RANGE. Therefore, all data in the governor control range **MUST** be omitted when you determine the friction power by inference.

The theory behind the P_i can be extended to apply the indicated mean effective pressure (IMEP) for that engine.

The student should recognize, of course, that this value represents only the average working pressure existing in the cylinder during the cycle. Observation of a typical indicator diagram will show that both higher and lower pressures will exist at specific points in the cycle. In this lab we will only be concerned with power equations and MEP equations. Engine mechanical efficiency is represented by the ratio of P_b to P_i, M.E. = P_b/P_i.

Procedure:

1. Place engine under load and operate until thoroughly warmed.
2. Starting at wide open throttle, no load, run a power test with all cylinders firing. Record Engine speed, Engine load, and air flow. Repeat step (2) increasing load each time, and record all data for 10 speeds, between high idle and 1500 rpm.
3. Disconnect one injector and run a power test with only 3 cylinders firing. Record Engine speed, Engine load, Fuel consumption and air flow. Use dynamometer load to achieve proper speed.
4. Reconnect the injector and run the engine for 5 minutes before shutting down.

Report of Friction Hp:

1. On one graph plot the **brake mean effective pressure** versus rpm/1000 (x-axis) observed with 4 cylinders firing (one curve) and 3 cylinders firing (second curve). (Calculate the BMEP from the measured Brake Power for both 3 & 4 cylinder tests, using the overall engine displacement for both) **Remove all data points in the Governor control range**.

2. Use the trend line procedure in Excel to fit a separate second order curve ($y=a_o+a_1*x+a_2*x^2$), where x= (Nrpm/1000) to the 3 and 4 cylinder curves. The indicated mean effective pressure at any rpm can be calculated by

   Equation [5] **IMEP= 4*[(Equation for 4 cylinders)-(Equation for 3 cylinders)]**

   Since FMEP = IMEP - BMEP, the FMEP can be calculated for each RPM setting (excluding the governor control range) by subtracting the actual BMEP (4 cylinder tests) from the IMEP calculated using Equation 5.

   Add the curve of FMEP in to the graph above. Use the polynomial trendline to fit a second order curve the Friction Mean Effective Pressure. (Note: This curves is valid for all speeds both in the load and governor control range)

3. For each engine test speed in the 4 cylinder tests (including data points in the governor control range)
   a) Calculate for the engine FMEP (use polynomial above)in both the governed and load control range,
   b) friction power, brake and indicated power in both the governed and load control range:
   c) Mechanical Efficiency (M.E.)
   (Show sample calculations for each step)

4. On a second graph plot curves of P_b, P_i, and P_f vs. engine rpm for the four cylinder tests, in both the governed and load control range.

5. List all factors that compose P_f in a diesel engine.

6. Why does the P_f increase with rpm?

7. Plot a graph of actual air consumption for the four cylinder tests (one curve) and the three cylinder tests. Will the pumping losses be equal in the three and four cylinder tests. Explain why you think actual air consumption for the 3 cylinder tests are lower than for the four cylinder tests.

Engine Tests

Run #	Dynamometer Load (lbs)	Engine Speed (rpm)	Airflow meter reading	Air Flow (Cfm)	Air Flow (lb/min)
1					
2					
3					
4					
5					
6					
7					
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