

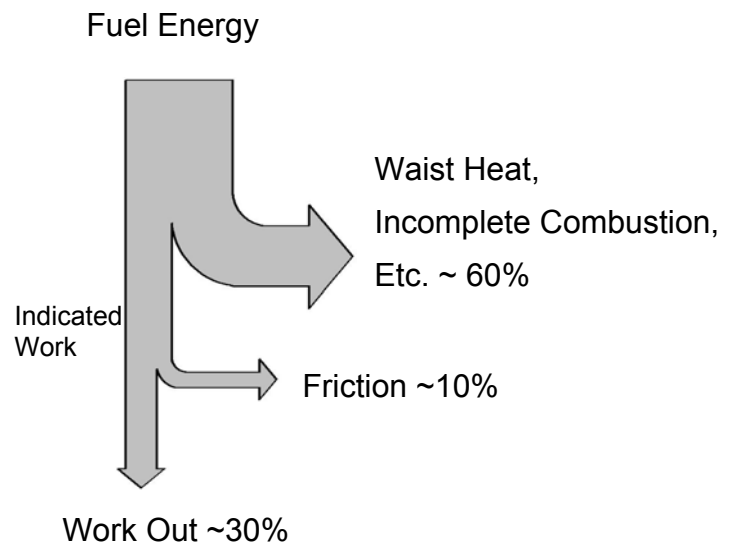
Internal Combustion Engines: Performance Measurements

Since their invention over 100 years ago internal combustion engines have grown to be a part of our everyday life. We depend on them for mobility and power. This lab investigates the performance (power and efficiency) of a typical small four-stroke, petrol engine.

The Internal combustion Engine takes in Air and Fuel, and burns it to produce mechanical power. Most of the energy, however, is wasted as heat. That is why engines usually have large radiators. Of the energy present in the combustion chamber (indicated power) only some gets converted to useful output power. The rest is dissipated as friction in the engine, and results in more thermal losses.

A lot of engineering research goes into improving the overall efficiency of an engine, so that we can get more work out, for the same amount of fuel burned. This can be accomplished by reducing friction, or improving the thermodynamic design of the engine to increase the indicated work available.

Energy Flow in an Internal Combustion Engine



POWER

The power output of an engine is often called the Break Power as it is measured with a device called a Break, or a Break Dynamometer. Our engine is equipped with a dry-friction type break dynamometer. The dynamometer applies a load to the engine and measures the resulting torque. Torque is related to power via:

$$P_b = T * \omega$$

P_b = Power (ie. Break Power) in Watts

T = Torque of shaft in Nm

ω = Rotational Speed of shaft in rad/sec

There is a term called “Indicated Power” P_i which is the power released in the combustion chamber by the burning of the fuel. Break Power is always less than the Indicated Power because some of the Indicated Power is consumed overcoming Friction with in the engine:

$$P_b = P_i - P_f$$

P_i = Indicated Power

P_f = Frictional Power

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The Frictional power of an engine can be determined by spinning the non-running engine with an external motor, and measuring the resulting torque (and thus power). The overall mechanical efficiency of an engine η_m is then the power output (ie. Break Power) divided by the power input (Indicated Power):

$$\eta_m = P_b / P_i$$

The overall fuel conversion efficiency η_t (some times called the Break thermal Efficiency) is the power output divided by the chemical energy of the fuel consumed. Chemical Energy of the fuel can be calculated by multiplying the mass consumed per unit time (ie. mass flow rate \dot{m}_f) times the Heating Value (the chemical energy) of the Fuel Q_{lhv} :

$$\eta_t = P_b / (\dot{m}_f * Q_{lhv})$$

A convenient way of comparing engines of different sizes is to compare their “Break Specific Fuel Consumption”, or **BSFC**, which is the Fuel Consumption rate divided by the power output:

$$\text{BSFC} = \dot{m}_f / P_b$$

Air Fuel Ratio (AFR) is simply calculated as follows:

$$\text{AFR} = \text{Mass}_{\text{air}} / \text{Mass}_{\text{fuel}} = \dot{m}_{\text{air}} / \dot{m}_f$$

In this lab you will measure the Engine speed, Torque, Air Flow Rate, Exhaust Temperature and Fuel consumption at various engine speeds. From this data you should calculate the following:

Engine speed (rpm)

Break Power (kW)

Indicated Power (kW) ← Base this on the known frictional Power of the engine

Mass Flow Rate of Air (gm/sec)

Mass Flow Rate of Fuel (gm/sec)

Air/Fuel Ratio (mass ratio)

BSFC (kg/kWh)

Break Thermal Efficiency

Mechanical Efficiency

Additionally plot the following versus engine speed (rpm):

Break Power

Air/Fuel Ratio (mass ratio)

BSFC

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Break Thermal Efficiency

Mechanical Efficiency

To perform your calculations you may use the following data:

Q_{lhv} petrol = 42 kJ/g Chemical Energy of Fuel

$\rho_f = 712 \text{ kg/m}^3$ Density of Fuel

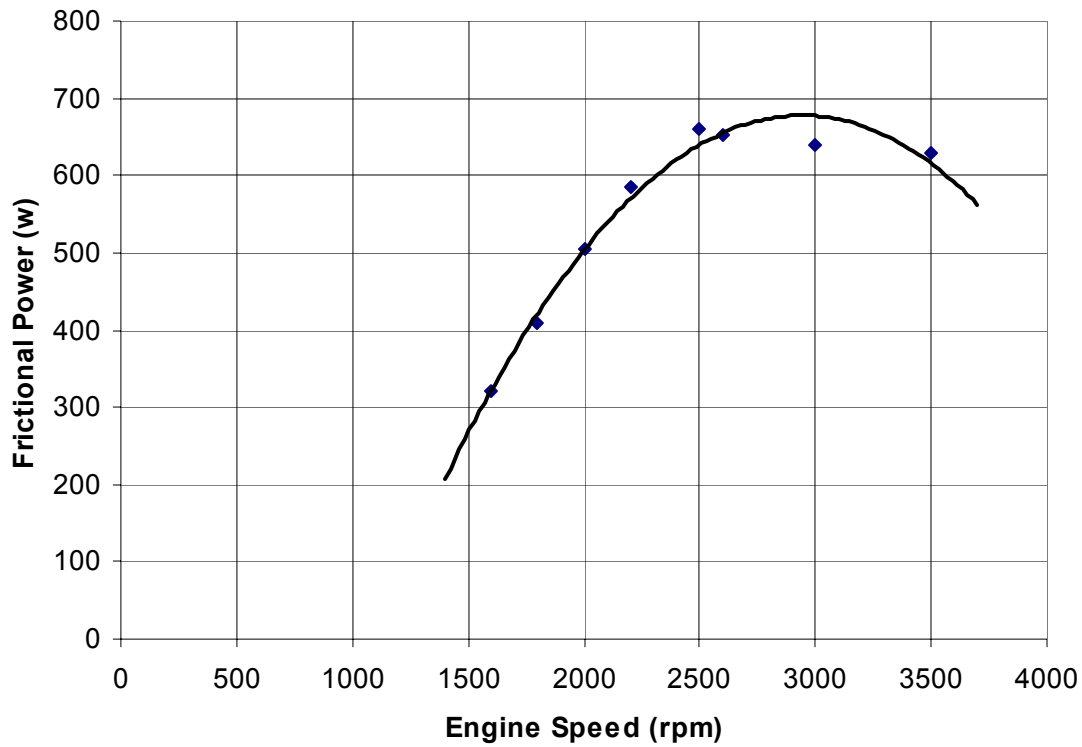
Additional write up notes:

- Lab reports are due 1 week from the lab date
- Hand in one report per group
- Graphs must be printed from a computer (ie. use XL or whatever graphing program you like). Please see guide (below) on graph preparation.
- **NOTE: COPYING = FAILURE !** I will be checking each and every report. If your report is a copy or another report, both groups fail.

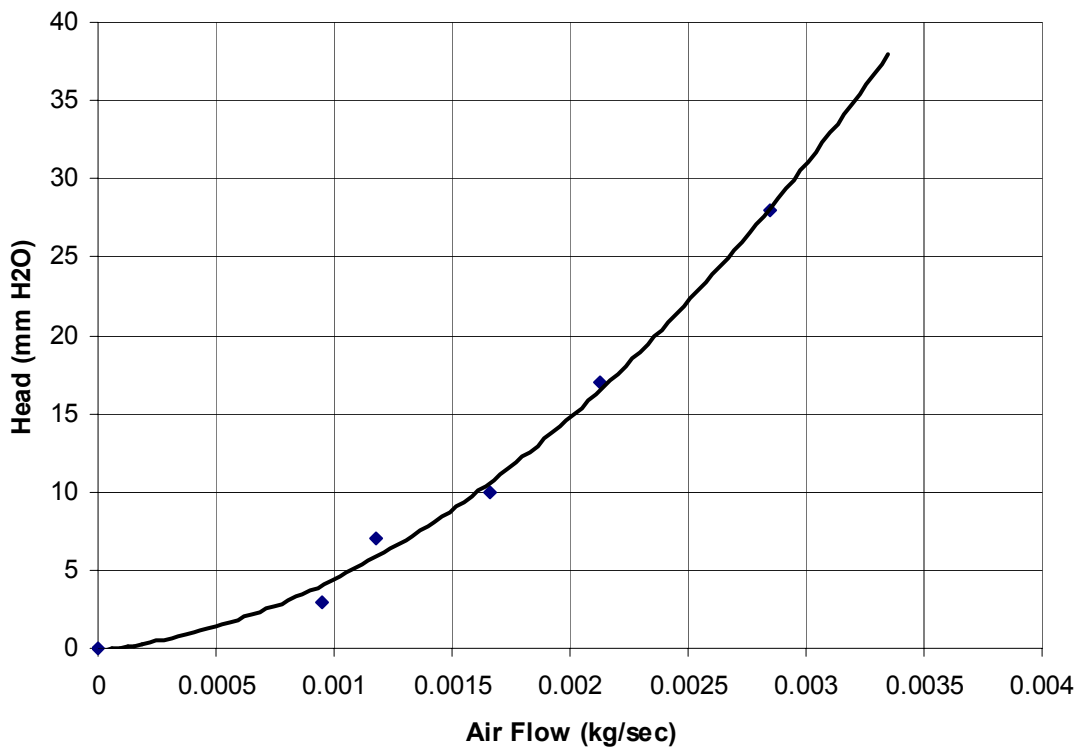
This document can be found at: www.skyshorz.com under University/Resources for Students

Useful Data

Frictional Power required by the test engine as a function of engine speed:



Manometer Head as a function of Air Flow:



Brief guide to good graphs for technical reports

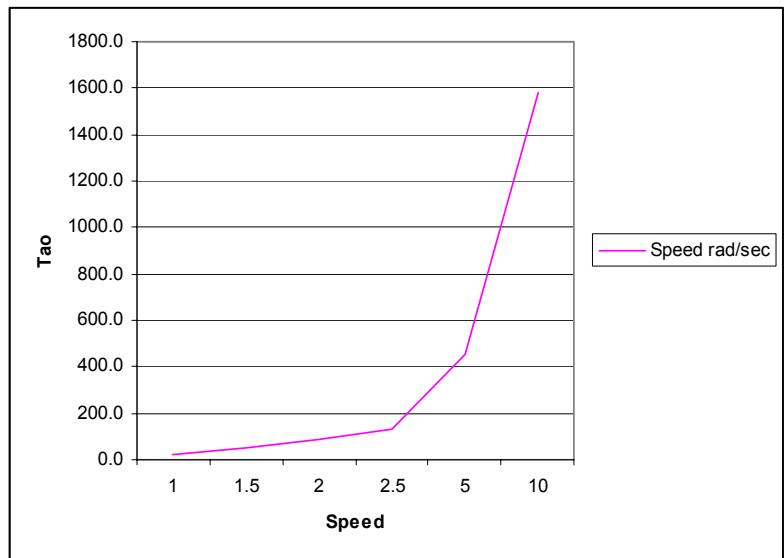
Graphs are one of the best ways to communicate engineering data, so it is important you get it right! Here is a set of data, and good and bad examples of graphs made from it.

Sample Data Set:

Torque Nm	Speed rad/sec	Speed rpm
25.0	0.104667	1
51.9	0.157	1.5
87.1	0.209333	2
130.1	0.261667	2.5
453.0	0.523333	5
1577.4	1.046667	10

This first graph has several problems:

- 1) it is not an X-Y plot, it plots Y versus X categories, so the horizontal axis is not constant. This is very misleading
- 2) We don't need a legend is there is only 1 graph!
- 3) What are the units and labels? They should be Speed (with appropriate units) and Torque (Nm).
- 4) The speed is in rad/sec. Use standard unites (ie. rpm for speed)
- 5) Why is there a box around the graph? This forces the graph into a smaller area, turn the box off.
- 6) The vertical axis should not have the ".0" digit on it.
- 7) The horizontal axis should have a ".0" digit:
1.0, 1.5, 2.0, 2.5 etc.
- 8) The color of the line is too light to see. Assume that the viewer will always see the plot in black and white.

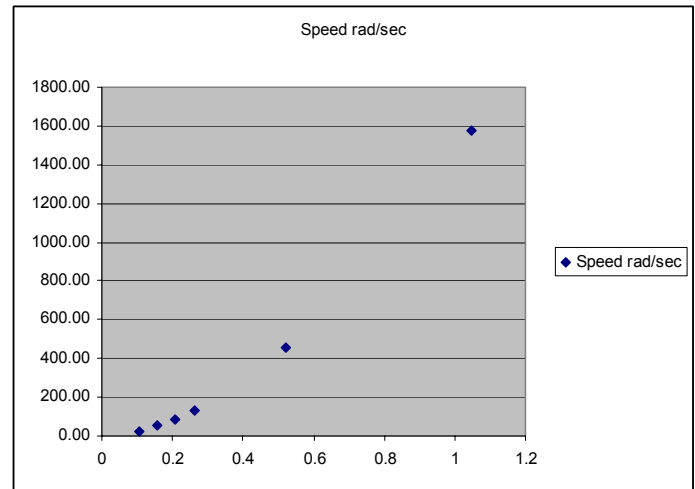


Bad Graph #1

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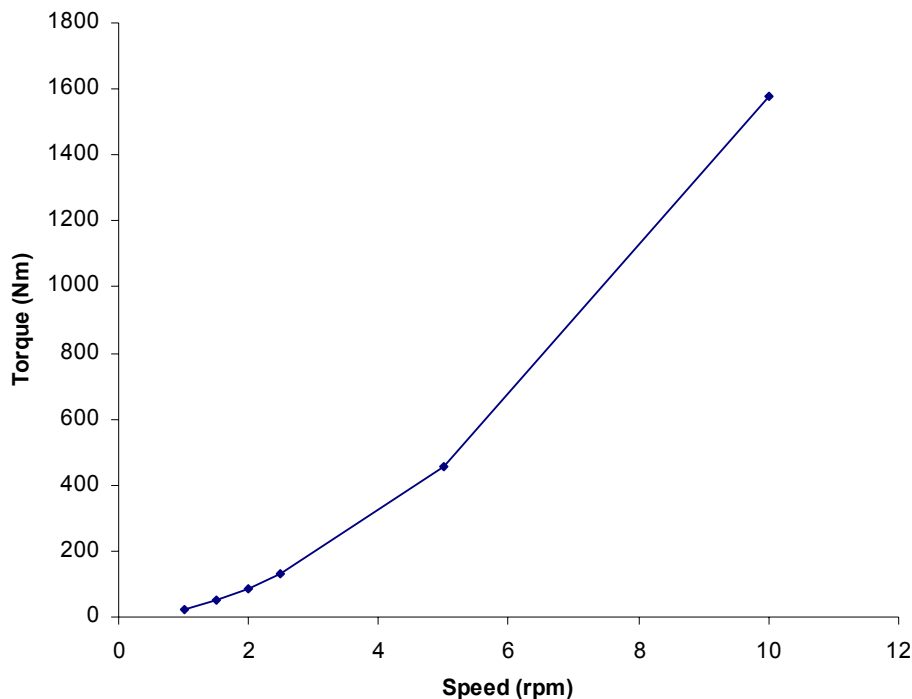
Some of the previous errors exists, some new ones are present. At least this plot is an X-Y graph.

- 1) Lose the legend.
- 2) Lose the box.
- 3) Lose the grey background
- 4) Data that is spread out might need a line to "connect the dots"
- 5) There are no labels or units
- 6) The over title is best done OUTSIDE the graph (ie in the body of the text of the report) to avoid encroaching on the graphs space
- 7) Extra ".00" on the vertical axis
- 8) Inconsistent digits on horizontal axis.
- 9) Rarely will we need grid lines
- 10) It is too small!



Bad Graph #2

This last plot is a much more professional and informative graph, even though the same data is presented. It does require a label, preferably with a caption explaining it:



Torque of the positioner versus Rotational Speed

All of these graphs take up the same space. Can you see the difference? Please try to make your graphics as clear as possible. This will help your reports immensely!