Mechanical Engineering Department MEC 1405
Spark Ignition Engine Heat Balance

Object:
To perform a heat balance for a spark ignition (*i.e.* petrol) engine under loaded conditions.

Apparatus:
Ford 1.4 liter spark ignition engine controlled with Programmable ECU. Plint electrical dynamometer, tachometer, and torque measurement setup. Fuel flow rate measurement: calculated from fuel pulse width (Duration Of Injection DOI) and rpm. Air flow rate inducted by the engine measured by the Mass Flow Sensor connected to the Engine Control Unit. Air to Fuel Ratio sensor in exhaust, wideband Oxygen sensor. Exhaust gas temperature measurement with K type thermocouple. Engine cooling instrumented with water volume flow, cooling water in and cooling water out temperatures.

Theory:
By the Second Law of Thermodynamics we know that heat engines cannot change the input heat energy completely into work. Some heat must be rejected to the low temperature sink, *i.e.* the atmosphere. A quantification of the quantity of heat changed to work and the rejected portion of heat can be found experimentally by measurement of the necessary parameters.
Heat is delivered to the engine in the form of fuel, mass flow rate of fuel multiplied by the calorific value gives the heat input rate. Delivered work is measured by the dynamometer, termed the brake power (brake because a simple dynamometer is a brake). Heat rejected to cooling water measured by the sensible (*i.e.* temperature rise) heat gain of the cooling water. Heat rejected to exhaust is measured by sensible heat of the exhaust gases, calculated from exhaust gas temperature and exhaust gases flow rate.

Procedure:
The engine is started and warmed up. Engine is operated at chosen set point of load (*i.e.* torque) and speed (i.e. rpm). After equilibrium is reached, data is collected. Make yourselves comfortable with not missing any important parameters that need to be measured. Also appreciate any other heats or work transfer that the engine has with the environment, *i.e.* any other work or heat flows across our heat engine boundary.

If possible repeat the experiment for another set point of speed or load.

Analysis
Perform the heat balance on the engine.
Heat energy of fuel per second is $\dot{Q}_f = \dot{m}_f Q_{net,v}$. Use calorific value for fuel, $Q_{net,v}$, 44000kJ/kg, density of fuel 750kg/m^3. Specific heat capacity of water 4.2kJ/kgK. Specific heat capacity of exhaust gases depends on temperature and composition but may be taken as 1.2kJ/kgK. Engine power is calculated by $Power = 2\,\pi\,N\,\tau/60$, where N is the rpm, τ is the measured torque in Nm, and Power is the brake power in Watts.

Fuel flow has to be calculated from the Duration of Injection imposed by the ECU on the engine. This is the length of the fuel pulse imposed on each of the four injectors every

intake stroke. The fuel flow is 0.003ml per milli second of injection pulse but the injectors also have a small delay in their operation of around 0.5milisecond.
Thus, Fuel flow (g/s) = ((DOI -0.5ms) * 0.003 * 4 * RPM/2/60)*density

From the measured air flow rate and fuel flow rate calculate the air to fuel ratio (kg/s air divided by kg/s fuel).

<u>Conclusion:</u>

Were the 1st and 2nd Laws violated during the testes? Explain.
What is the engine efiiciency?
Comment on the air to fuel ratio
Comment on any other factors that affected the experiment.

Readings

Atmospheric Temperature, ^{o}C
Barometric Pressure, mmHg

	Set point one	Set point two
Engine Speed, RPM		
Fuel DOI ms		
AFR from wideband sensor		
Engine torque reading, Nm,		
Engine coolant flow, l/min		
Coolant temperature in, ^{o}C		
Coolant temperature out, ^{o}C		
Intake Air mass flow, MAF g/s		
Intake Manifold Absolute Pressure MAP kPa		
Exhaust gas temperature, ^{o}C		
Throttle Position %		