**SPARK IGNITION INTERNAL COMBUSTION ENGINE**

## PURPOSE AND OBJECTIVES:

This laboratory involves analysis of different forms of energy during the operation of a spark ignition internal combustion engine. The main objectives are:

1. To operate a spark ignition internal combustion engine and examine its performance by changing engine speed and compression ratio.
2. To quantify magnitudes of useful work, mechanical losses, heat losses, and miscellaneous losses.
3. To understand the First Law of Thermodynamics that applied to a spark ignition internal combustion engine.

## EQUIPMENT:

The experiment consists of a four-stroke, single-cylinder engine with a swept volume of 0.148 L (65.1 mm bore, and 44.4 mm stroke), and compression ratios of 8.5:1, 7:1, and 5.5:1. The engine runs on 91 octane gasoline. Determining the magnitudes of energy input, energy output, and various losses occurring in the engine cycle as a function of rotational speed is useful since the efficiency of the engine is dependent upon these quantities. The figure below shows a schematic diagram illustrating the system, including its boundary, and all forms of energy which are of interest.

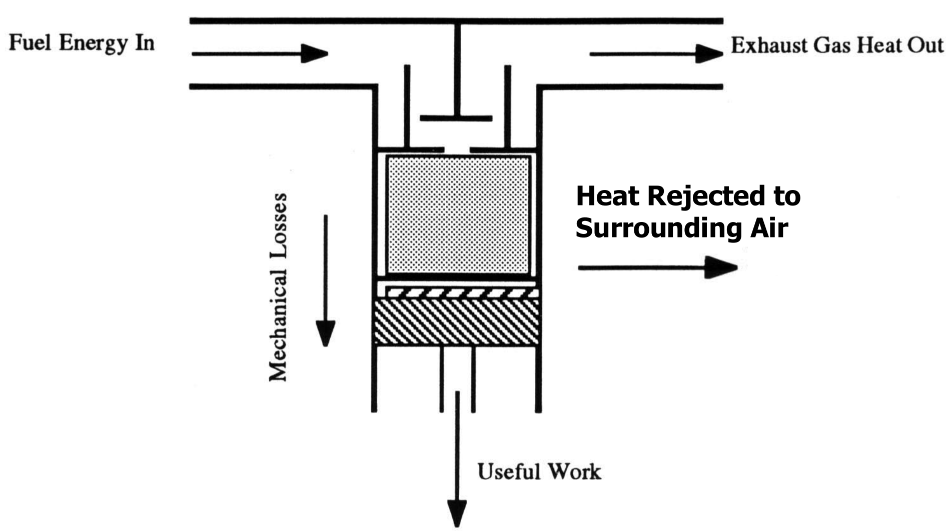


**Figure 1. General Engine Schematic**

## PERFORMANCE ANALYSIS:

The *fuel energy in* is the amount of energy contained in the fuel entering the engine. The same amount of energy will be assumed to be released by the air-fuel combustion process.

$$\dot{E}_{in} = \dot{m}_{fuel} LHV \quad \text{[kW]} \tag{1}$$

The magnitude of fuel energy rate is the product of the mass flow rate of fuel and its lower heating value of **44.0 MJ/kg** for regular gasoline. The Fuel density is **726 kg/m$^3$**.

*Fuel volumetric flow rate* is determined by measuring the volumetric amount of fuel used over a measured time interval during engine operation. This can be done with the fuel measurement tube on the test stand (CT 159).

$$\dot{m}_{fuel} = \dot{V}_{fuel} \rho_{fuel} \quad \text{[kg/s]} \tag{2}$$

The *power output* is calculated using a dynamometer (HM 365) connected to the engine via a belt and two pulley system. This dynamometer acts as the braking unit which applies the load to the engine. The dynamometer consists of a three-phase, asynchronous electric motor. An asynchronous motor produces a torque when the rotating speed of the rotor is different from the synchronous frequency speed in the stator. Sensors within the dynamometer are used to determine the current engine speed and torque output, which can be used to determine the brake power output.

*Mechanical losses* are due to the inertial forces and friction required to move the crankshaft and piston of the engine. To determine these, the dynamometer is operated as a motor which rotates the engine crank shaft with no fuel supplied to the engine and with no combustion processes within. Mechanical losses are then determined at different speeds by recording the torque required to operate the dynamometer.

*Heat losses* are determined after all other contributions to the energy balance are determined. The losses are calculated as one term, and equal to the positive amount of energy that must be added to the losses in order to satisfy the energy conservation equation at steady-state. Steady state conditions prevail when no additional energy is stored or accumulates in the combustion chambers of the engine.

First Law (Energy Equation) for engine system:

$$\dot{E}_{in} = \dot{W}_{net} + \dot{E}_{heat\ losses} + \dot{E}_{mech.\ losses} + \dot{E}_{misc.} \tag{3}$$

In addition to heat rejected to the surrounding air through convection, miscellaneous heat losses consist of all forms of energy which contribute to the energy balance but are not taken into account in the analysis. These include exhaust gas heat out, radiation heat loss to the surroundings, strain energy resulting in expansion of the materials and the built-up residual stresses, combustion inefficiency, and imperfect fuel-air mixing.

## <u>PROCEDURE :</u>

**Part 1:** Performance Characteristics and Energy

Performance characteristics and different forms of energy are to be determined at 5 different engine speeds. The speed is controlled using the dynamometer while the throttle is kept in the open position. Changing the speed on the dynamometer without changing the throttle position will also cause a change in torque because the dynamometer acts as a brake while the engine is running. Measurements of all quantities listed below need to be made at <u>five speeds</u> ranging from 2,000 to 3,000 RPM while the throttle on the engine is in the fully-open position:

(1) rotational speed of drive and brake unit in RPM
(2) torque in N·m
(3) volumetric amount of fuel used over a measured time interval
(4) time interval over which the volumetric amount of fuel measured was used
(5) compression ratio used: ______
(6) inlet air temperature and inlet air pressure
(7) fuel and exhaust air temperatures

**After all measurements are taken at all five speeds, care should be exercised to unload the engine before the dynamometer is shutdown.**

<u>**Part 2**: Determining Mechanical Losses</u>

As mentioned earlier, this is done by operating the dynamometer as a motor which rotates the engine crank shaft with no fuel supplied to the engine and without any internal combustion process. All of the load is then due to the friction and inertia required to move the crank shaft and piston of the engine. Mechanical losses are then determined at different speeds by recording the torque required to operate the drive and brake unit.

For the four rotational speeds used above, note the following quantities:

(1) rotational speed in RPM
(2) torque in N·m

The speed and torque are needed to compute the power required to overcome friction and inertia. Because the friction and inertial loading vary almost linearly with RPM, determine a best fit linear regression line comparing speed and torque of the four measured data points using Matlab. **You will use this linear regression to determine the mechanical losses at the speeds used in Part 1 of the procedure.** The measured losses are used solely to determine the linear regression.

## DATA ANALYSIS:

Write a Matlab code that calculates the following quantities from the raw data at each speed:

i. Engine output power in kW and horsepower.
ii. Rate of energy input to the engine in the fuel in kW and horsepower (note that a 1 cm drop in the flow tube has a volume of 5.1 $cm^3$).
iii. Rate of mechanical losses due to friction and inertia in kW and horsepower at each engine speed [RPM] using linear interpolation and/or linear extrapolation.
iv. Miscellaneous loss rate (heat rejected plus other losses) in kW and horsepower
v. Thermal efficiency in %
vi. Mean Effective Pressure in kPa and psi
vii. Ideal Otto cycle thermal efficiency for the engine assuming the ratio of specific heats = 1.33

## REQUIRED PLOTS:

In cases, data must be plotted as individual markers (use open circles for markers unless specified otherwise). Theoretical relationships are plotted using a solid black line. For all plots, axes must be appropriately labeled with the correct units. For plots 1b, 1d, and 1e, include a legend. In your CANVAS submission, be sure that your plots are numbered and ordered according to the list below.

1a. Torque [Nm] versus engine speed in RPM (data only)
1b. Power output [kW] versus engine speed in RPM (data + theoretical)
1c. Fuel flow rate/useful power [kg/s*kW] versus engine speed in RPM (data only)
1d. Thermal efficiency [%] versus engine speed in RPM (data + theoretical)
1e. Plot each of the following [kW] versus engine speed in RPM on a single plot (data only):
- Rate of fuel energy input (open circles)
- Frictional and inertial losses (open squares)
- Miscellaneous loss rate (open diamonds)

1f. Mean Effective Pressure [kPa] versus engine speed in RPM (data only)

## SHORT-ANSWER QUESTIONS:

2a. Discuss the percent contribution of each of the terms in the energy balance. Identify the terms that have the greatest and least contributions to the energy out of the system. How does this affect the efficiency of the engine?

2b. Write a statement that describes the comparison of the calculated efficiency with that of an ideal Otto cycle [quantify the discrepancy with a percentage]. What assumptions have you made in the air standard analysis that might cause such discrepancies?

2c. What would you recommend in order to improve the efficiency of the engine? For example, how would turbo-charging, inner cooling, split-fire spark plugs, and other hardware alterations change the efficiency of the engine?

2d. Combustion of fossil fuels releases carbon dioxide, which is a greenhouse gas, into the environment. A diagram of carbon lifecycle is shown below, illustrating how auto emissions tends to alter the natural balance. Suggest 2 solutions for reducing greenhouse gas emissions from combustion engines.