SAN FRANCISCO STATE UNIVERSITY
SCHOOL OF ENGINEERING

FINAL EXAM PROJECT (Spring 2023)

DUE: 5/22 AT 7:00PM

Abstract: Students will analyze the performance of a Honda GX100 gasoline engine. This final project will require knowledge of thermodynamics, power systems, and heat transfer, along with the ability to organize data and make plots to reach sound conclusions. Two scenarios will be examined: 1) variable load with constant speed and 2) variable speed with constant load. Students will then be able to determine relationships such as the percentage of energy into the engine that is used for mechanical power, as well as how much energy was rejected by the exhaust and cooling fins, among others.

Objective: The objective of this experiment is to determine the performance and energy allocation in an air-cooled single cylinder gasoline engine when under variable load and RPM range conditions. This is to be determined from data obtained by running a Honda GX100 engine attached to a dynamometer. Measurements will be taken of the engine speed, exhaust temperature, mass flow rate of air and fuel, and power output at the crankshaft.

Experimental apparatus: The experiment is performed on a Honda GX-100 (Figure 1) connected to a dynamometer on a test stand (see Figure 2). The dynamometer absorbs power from the crankshaft and provides a reading on the controller of that amount of energy. The rotating part of the dynamometer is supported on either side by bearings. When an engine is under test, the dynamometer provides an electromagnetic braking force between the case and the rotating assembly. The rotation of the entire dynamometer is prevented by an arm on its case which acts on a load cell. The load cell then transmits a signal to the dynamometer controller which in turn displays the torque output of the engine on the controller's display. Engine speed is measured by the dynamometer as well. A magnetic pickup on the case of the device transmits a signal to the controller. This is then displayed on the controller's display and is measured in rotations per minute, RPM. Fuel flow rate is measured using the burette and a stopwatch. This procedure is simple because the burette is the fuel tank for the engine. Measurements can be taken in two ways: 1) measure the time the engine takes to consume a given quantity of fuel or 2) measure the amount of fuel consumed in a specified amount of time. The volume of fuel can be converted to a mass of fuel per unit time, which will be useful in calculations.

Figure 1: Honda GX100 engine

Figure 2: The experimental apparatus

Dynamometers: Dynamometers, also known as dynos, are devices used to measure torque output and rotational speed of any prime mover. The rotating portion of the dyno (see figure 3) is attached to the output shaft of the machine under test. A braking action is supplied by the dyno to simulate a load on the machine. Dynos provide the braking force in one of several ways: electromagnetic, hydraulic, mechanical friction, and others. The braking force required is measured in some manner. A common way to measure the braking force is to measure the force required to restrain the dyno housing from rotating with a load cell transducer; this is very accurate and can be used in conjunction with a data acquisition system. Alternatively, the current generated by an electromagnetic dyno can be measured to determine the braking force, but this method is not as accurate. All the energy from the prime mover fighting the resistance of the dyno generates a significant amount of heat which must be dissipated to the environment; usually the devices are cooled by air, water, or oil.

The dynamometer in this experiment is electromagnetic and air-cooled. This dyno is controlled via a panel near the test stand and will display *power*, *torque*, and *speed.*

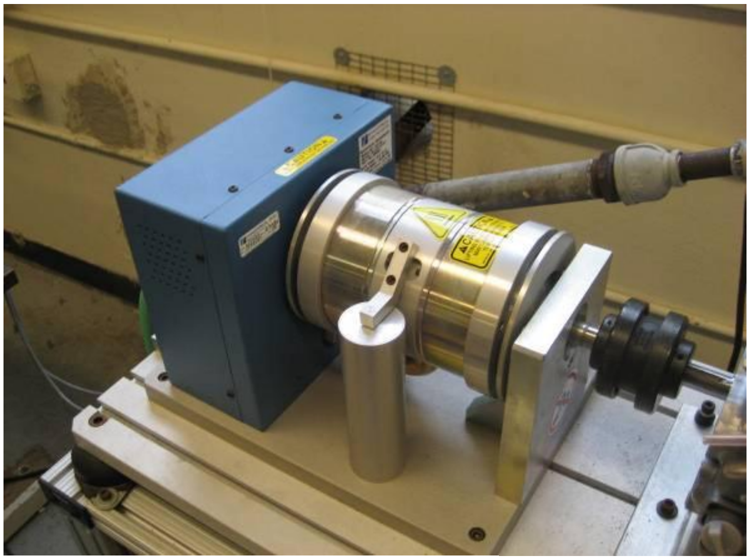

Figure 3: The dynamometer

The specific gravity of the gasoline (SG = 0.74 for ρ_{water} = 1000 kg/m^3) is measured by placing a hydrometer in a graduated cylinder. The graduated cylinder is filled with gasoline until the bottom of the hydrometer is at least a half inch from the bottom of the graduated cylinder. The contraption is placed on a level surface and the reading is taken at the bottom of the meniscus, see Figure 4.

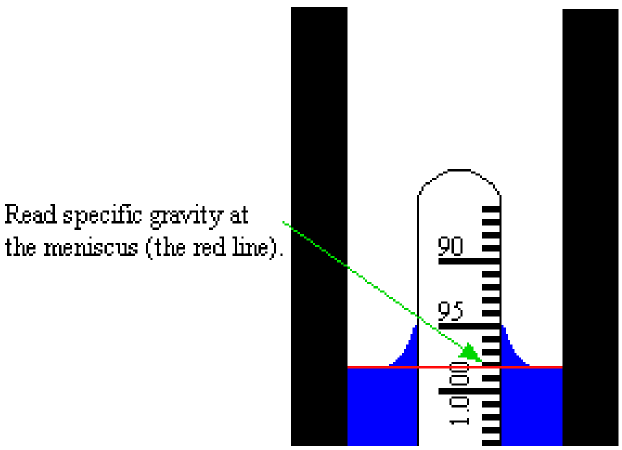

Figure 4: Reading a hydrometer

Air temperature measurement is taken with the thermocouple reader, making sure it is set to the correct scale, i.e. Kelvin.

After the engine is started and begins to warm up, the throttle is used to control the engine speed. A type K thermocouple reader is placed at the exhaust pipe (Figure 5) and is monitored until the operating temperature of approximately 200°C to 250°C is reached.

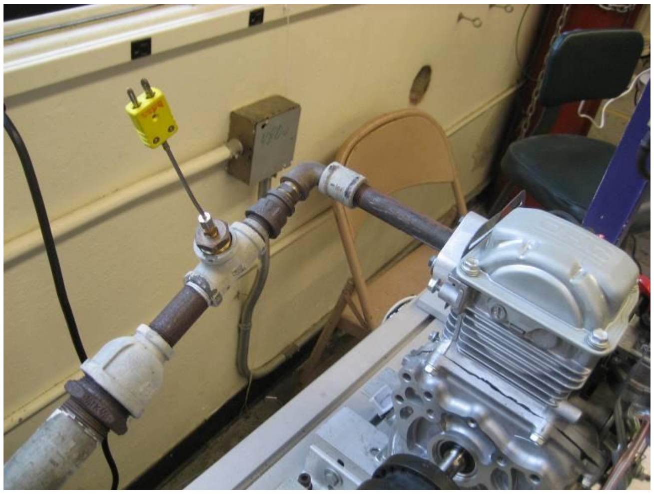

Figure 5: location for the thermocouple reader to measure the exhaust temperature

A. Variable Speed, Constant Load Test

Fill in the following table (you will also need this to plot your results):

Speed (RPM)	Torque (N·m)	Power ($\dot{Q}_{shaft}$) (W)	$\dot{Q}_{in}$ (W)	η_{th} (%)	MEP (kPa)	bsfc (g/W·hr)	$\dot{Q}_{exhaust}$ (W)	$\dot{Q}_{fins}$ (W)	$\dot{m}_{air}$ (kg/s)	$\dot{m}_{fuel}$ (kg/s)	ΔT (K)
1500	1.8									5.547E-05	247
2000	1.8									5.635E-05	247
2500	1.8									6.827E-05	247
3000	1.8									8.256E-05	291
3500	1.8									0.000104	330
4000	1.8									0.000118	350

Let $\dot{m}_{air} = \dfrac{\rho_{air} D N}{120}$

where D is the displacement of the engine (approximately 100 [cc] or 10^{-4}m^3) and 120 is the product of 2 and 60, a constant for four stroke engines. The 2 is present in the denominator because engine will only draw air every second revolution. The 60 is required because the rotational speed of the engine, N, is always expressed in rotations per minute. The units of the mass flow rate will be in [kg/s] or [lb/s]. Take ρ_{air} = 1.2 kg/m^3.

Using the mass flow rate of the air, compute the energy required to raise the ambient air to the temperature of the exhaust during combustion. Due to the fluctuating temperatures of the exhaust during each test, an average temperature will need to be computed for the following calculation:

$$\dot{Q}_{exhaust} = \dot{m}_{air} c_p \Delta T$$

where ΔT is the difference of the average temperature of the exhaust and the ambient air temperature. The specific heat capacity, c_p, of air is 1006 [J/kg·K] or 0.2388 [Btu/lb·°R]. Then mass flow rate of the fuel can be found by the following equation:

$$\dot{m}_{gas} = \frac{\rho_{gas} \Delta V}{\Delta t}$$

which is a function of the density of gasoline, ρ_{gas}, and change in volume of fuel, ΔV, during the time, Δt. Be sure to not lose track of the units!

Next, use an appropriate lower heating value, *LHV*, for gasoline. The following are good estimates: 18,500 [Btu/lb], or 45.2 [kJ/g]. Compute the total energy provided by the gasoline using:

$$\dot{Q}_{in} = \dot{m}_{gas} LHV_{gas}$$

The lower heating value is used because the latent heat of evaporation for water and other combustion products is not recovered, which is common for internal combustion engines. Condensation of the products of combustion is impractical because they are corrosive and will drastically decrease the service life of the equipment. The shaft power can be computed using the torque by:

$$\dot{Q}_{shaft} = \frac{2\pi TN}{60}$$

Now that the energy input to the engine is known, and the portion that has been converted to mechanical energy is known from the data acquired by running the dynamometer, we can assume the remainder must have been rejected to the ambient by the cooling fins, $\dot{Q}_{fins}$.

$$\dot{Q}_{in} = \dot{Q}_{exhaust} + \dot{Q}_{shaft} + \dot{Q}_{fins}$$

Using this data, the efficiencies can be computed for each part of the experiment using the thermal efficiency equation:

$$\eta_{th} = \frac{\dot{Q}_{shaft}}{\dot{Q}_{in}}$$

Brake specific fuel consumption, *bsfc*, is useful for comparing the fuel efficiency of engines over a wide range of displacements. Brake specific fuel consumption can be computed using following equation:

$$bsfc = \frac{\dot{m}_{fuel}}{\dot{Q}_{shaft}}$$

for metric the units, convert the fuel flow rate, to [g/hr], so that *bsfc* will have units of [g/W·hr]. For Standard units, use fuel flow rate in [lb/hr] and shaft work in [hp] so that *bsfc* will have units of [lb/hp·hr].

Mean effective pressure, *MEP*, is the average pressure which, if imposed on the pistons uniformly from the top to the bottom of each power stroke, would produce the measured power output. It is useful for comparison of engines over a range of displacements. For a four stroke engine it is defined as:

$$MEP = 4\pi \frac{T}{V}$$

where T is the torque in [N·m] and V is the volume [0.0001 m^3] which gives the *MEP* units of [Pa]. Mean effective pressure can also be used to evaluate claims made by manufactures or engine builders. One such analysis is to compare the required *MEP* for horsepower or watt ratings at different RPMs to other similar engines.

B. Constant Speed (1500 RPM), Variable Load Test

Fill in the following table (you will also need this to plot your results):

% Load	Torque (N·m)	Power ($\dot{Q}_{shaft}$) (W)	$\dot{Q}_{in}$ (W)	η_{th} (%)	MEP (KPa)	bsfc (g/W·hr)	$\dot{Q}_{exhaust}$ (W)	$\dot{Q}_{fins}$ (W)	$\dot{m}_{air}$ (kg/s)	$\dot{m}_{fuel}$ (kg/s)	ΔT (K)
0.75	1.35				169.64					4.931E-05	235
1	1.8				226.19					5.547E-05	247
1.25										8.452E-05	250
1.5										8.452E-05	288
1.75										9.342E-05	314
2										0.000118	345

Results:

From table A:

-Plot $\dot{Q}_{shaft}$, $\dot{Q}_{in,}$ $\dot{Q}_{exhaust,}$ $\dot{Q}_{fins}$ vs. RPM (preferably on a single graph)

-Plot fuel flow rate vs. RPM

-Plot $\dot{Q}_{shaft}$, $\dot{Q}_{in}$ vs. fuel flow rate (preferably on a single graph)

From table B:

-Plot $\dot{Q}_{shaft}$, $\dot{Q}_{in,}$ $\dot{Q}_{exhaust,}$ $\dot{Q}_{fins}$ vs. torque (preferably on a single graph)

-Plot MEP vs. Torque

-Plot fuel flow rate vs. Torque

Conclusion Questions:

1) Comment on the efficiency of the engine for both loading cases (Table A vs. Table B). How could we improve the efficiency of the engine? Do these results make sense?

2) What are some of the things we would need to be conscious of in our experiment to obtain reliable results?

3) Why may it be important to allow an engine to warm up before placing it under test (in terms of reliable results)?