PERFORMANCE ANALSYIS OF GASOLINE ENGINE

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Objective

This experiment aims to investigate the operation and energy distribution of an air-cooled single-cylinder gasoline engine under varied loads and RPM ranges. On the basis of data acquired from the functioning of a Honda GX100 engine attached to a dynamometer, this will be decided.

Theory

1. **Air flow rate:**

$$\dot{m}_{air} = \frac{\rho_{air} DN}{120}$$

Equation 1

Here,

$\dot{m}_{air}$ = Air flow rate (kg/s)

ρ_{air} = Density of the air =1.2 $\frac{kg}{m^3}$

D = Displacement of the engine =100 cc =10^{-4} m^3

N = Engine's rotation per minute (RPM)

2. **Fuel flow rate:**

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

Equation 2

Here,

$\dot{m}_{gas}$ = Fuel flow rate (kg/s)

ρ_{gas} = Density of the gasoline $\left(\frac{kg}{m^3}\right)$

ΔV = Change in the volume of fuel (m^3)

Δt = Change in the time (s)

3. **Shaft power:**

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

Equation 3

Here,

$\dot{Q}_{shaft}$ = Shaft power (W)

N = Engine's rotation per minute (RPM)

T = Torque (N-m)

4. **Heat rate provided by gasoline:**

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

Equation 4

Here,

$\dot{Q}_{in}$ = Heat rate provided by gasoline (W)

$\dot{m}_{gas}$ = Fuel flow rate (kg/s) (Equation 2)

LHV_{gas} = Lower heating value of gasoline = $45.2\ \frac{kJ}{g} = 45.2 * 10^6\ \frac{J}{kg}$

5. **Engine efficiency:**

$$\eta_{th} = \frac{\dot{Q}_{shaft}}{\dot{Q}_{in}} * 100$$

Equation 5

Here,

η_{th} = Engine efficiency (%)

$\dot{Q}_{shaft}$ = Shaft power (W) (Equation 3)

$\dot{Q}_{in}$ = Heat rate provided by gasoline (W) (Equation 4)

6. **Mean effective pressure:**

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

Equation 6

Here,

MEP = Mean effective pressure (Pa)

T = Torque (N-m)

V = Volume = 0.0001 m^3

7. **Brake specific fuel consumption:**

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

Equation 7

Here,

bsfc = Break specific fuel consumption $\left(\frac{\text{g}}{\text{W}-\text{hr}}\right)$

$\dot{m}_{\text{fuel}}$ = Fuel flow rate (g/hr) =($\dot{m}_{\text{gas}}$*3600*1000) $\frac{\text{g}}{\text{hr}}$

$\dot{Q}_{\text{shaft}}$ = Shaft power (W) (Equation 3)

8. **Heat rejected in the exhaust:**

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

Equation 8

Here,

$\dot{Q}_{\text{exhaust}}$ = Heat rejected in the exhaust (W)

$\dot{m}_{\text{air}}$ = Air flow rate (kg/s) (Equation 1)

c_p = specific heat capacity of air = 1006 $\left(\frac{\text{J}}{\text{kg.K}}\right)$

ΔT = Difference of the average temperature of the exhaust and the ambient air temperature (K)

9. **Heat rate rejected by the fin:**

$$\dot{Q}_{\text{fins}} = \dot{Q}_{\text{in}} - (\dot{Q}_{\text{shaft}} + \dot{Q}_{\text{exhaust}})$$

Equation 9

$\dot{Q}_{\text{fins}}$ = Heat rate rejected by the fin (W)

$\dot{Q}_{\text{in}}$ = Heat rate provided by gasoline (W) (Equation 4)

$\dot{Q}_{\text{shaft}}$ = Shaft power (W) (Equation 3)

$\dot{Q}_{\text{exhaust}}$ = Heat rejected in the exhaust (W) (Equation 8)

Apparatus and procedure

On a Honda GX-100 (Figure 2) coupled to a dynamometer on a test platform, the experiment is run. The controller receives data from the dynamometer, which monitors the crankshaft's energy production. The spinning component of the dynamometer is supported by bearings on either side. The dynamometer offers an electromagnetic braking force between the casing and the spinning component while an engine is being evaluated. The arm on the casing that connects with the load cells prevents rotation of the dynamometer. The dynamometer controller uses a signal from the load cell to display the engine's torque output. Engine speed is also measured using a dynamometer. A magnetic pickup on the device's casing transmits a signal to the controller. On the controller's display, RPM, or revolutions per minute, is used to denote this. The fuel flow rate is determined using a stopwatch and the burette. This process is made simple by the burette, the engine's fuel tank. There are two ways to quantify something: Find out either (1) how long the engine needs to burn a specific amount of fuel or (2) how much petrol is consumed in a specific amount of time. Calculations will benefit from the ability to convert fuel volume into a mass of fuel per unit of time.

Figure 1: Experimental Apparatus

1. **Honda GX100 engine**

Figure 2:Honda GX100 engine

2. Dynamometers

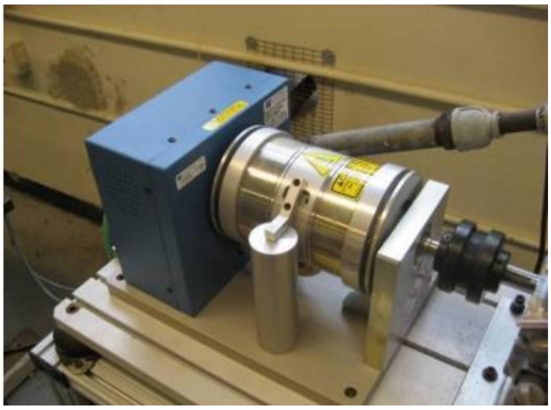


Figure 3: Dynamometers

Dynamometers, often known as dynos, are tools used to measure the torque and rotational speed of any prime mover. The output shaft of the instrument being evaluated is linked to the spinning component of the dyno (see Figure 3). In order to simulate a load on the machine, the dyno offers braking action. Dynos use a range of techniques, including electromagnetic, hydraulic, mechanical friction, and others, to provide the braking force. The required braking force can be determined in many ways. The amount of force required to stop the dyno housing from spinning is often estimated to calculate the braking force, which is then measured using a load cell transducer and data gathering tools. It is possible to measure current output using an electromagnetic dyno's current metre, however this method is less precise than measuring braking force. The device is frequently cooled using air, water, or oil in order to disperse the heat produced by the prime mover's force against the resistance of the dyno.

This experiment employed an electromagnetic, air-cooled dynamometer. This dyno's speed, torque, and power may be shown on a panel next to the test stand.

3. Hydrometer

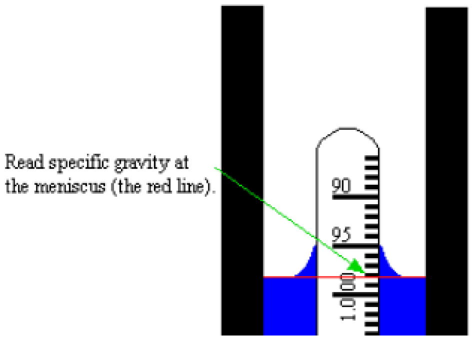


Figure 4: Hydrometer

By placing a hydrometer into a graduated cylinder, the specific gravity of the fuel may be calculated (SG = 0.74 for water, which has a density of 1000 kg/m3). The graduated cylinder is filled with petrol until the hydrometer's bottom is at least half an inch distant from the graduated cylinder's bottom. Figure 4 demonstrates how to position the instrument on a flat surface and how to obtain the reading at the base of the meniscus.

4. **Thermocouple readers**

Figure 5: Thermocouples reader

To accurately measure air temperature, the thermocouple reader is calibrated to the Kelvin scale. Once the engine has been started and has warmed up, the throttle is used to control engine speed. A type K thermocouple reader is fitted to the exhaust pipe and is monitored after the working temperature, which is between 200°C and 250°C, has been reached (Figure 5).

Result and Discussion

Table A: Variable Speed, Constant Load Test

Speed	Torque T	Power $\dot{Q}_{shaft}$	$\dot{Q}_{in}$	η_{th}	MEP	b.s.f.c	$\dot{Q}_{exhau}$	$\dot{Q}_{fins}$	$\dot{m}_{air}$	m_{fuel}	ΔT
RPM	**N-m**	**W**	**W**	**%**	**kPa**	$\frac{g}{W-hr}$	**W**	**W**	$\frac{kg}{s}$	$\frac{kg}{s}$	**K**
1500	1.8	282.74	2507.24	11.28	226.19	0.71	372.72	1851.78	0.0015	5.547E-05	247
2000	1.8	376.99	2547.02	14.80	226.19	0.54	496.96	1673.06	0.0020	5.635E-05	247

2500	1.8	471.24	3085.80	15.27	226.19	0.52	621.21	1993.36	0.0025	6.827E-05	247
3000	1.8	565.49	3731.71	15.15	226.19	0.53	878.24	2287.99	0.0030	8.256E-05	291
3500	1.8	659.73	4700.80	14.03	226.19	0.57	1161.93	2879.14	0.0035	0.000104	330
4000	1.8	753.98	5333.60	14.14	226.19	0.56	1408.40	3171.22	0.0040	0.000118	350

Table B: Constant Speed (1500 RPM), Variable Load Test

Load	**Torque T**	**Power $\dot{Q}_{shaft}$**	**$\dot{Q}_{in}$**	**η_{th}**	**MEP**	**b.s.f.c**	**$\dot{Q}_{exhau}$**	**$\dot{Q}_{fins}$**	**$\dot{m}_{air}$**	**m_{fuel}**	**Δ T**
%	**N-m**	**W**	**W**	**%**	**kPa**	**$\frac{g}{W-hr}$**	**W**	**W**	**$\frac{kg}{s}$**	**$\frac{kg}{s}$**	**K**
0.75	1.35	212.06	2228.81	9.51	169.65	0.84	354.62	1662.14	0.0015	4.931E-05	235
1.00	1.80	282.74	2507.24	11.28	226.19	0.71	372.72	1851.78	0.0015	5.547E-05	247
1.25	2.25	353.43	3820.30	9.25	282.74	0.86	377.25	3089.62	0.0015	8.452E-05	250
1.50	2.70	424.12	3820.30	11.10	339.29	0.72	434.59	2961.60	0.0015	8.452E-05	288
1.75	3.15	494.80	4222.58	11.72	395.84	0.68	473.83	3253.96	0.0015	9.342E-05	314
2.00	3.60	565.49	5333.60	10.60	452.39	0.75	520.61	4247.51	0.0015	0.000118	345

Sample calculation:

Table A

1.

- $\dot{m}_{air}$

$$\dot{m}_{\text{ air}} = \frac{\rho_{\text{air}} DN}{120}$$

Or

$$\dot{m}_{\text{ air}} = \frac{1.2 * (10^{*4}) * 1500}{120}$$

Or

$$\dot{\mathbf{m}}_{\textbf{ air}} = \mathbf{0.0015}\frac{\mathbf{kg}}{\mathbf{s}}$$

- **Power ($\dot{\mathbf{Q}}_{\textbf{shaft}}$)**

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

Or

$$\dot{Q}_{\text{shaft}} = \frac{2\pi * (1500) * 1.8}{60}$$

Or

$$\dot{\mathbf{Q}}_{\textbf{shaft}} = \mathbf{282.74\ W}$$

- **$\dot{\mathbf{Q}}_{\textbf{in}}$**

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

Or

$$\dot{Q}_{\text{in}} = (5.547 * 10^{-05}) * (45.2 * 10^{6})$$

Or

$$\dot{\mathbf{Q}}_{\textbf{in}} = \mathbf{2507.24\ W}$$

- **$\boldsymbol{\eta}_{\textbf{th}}$**

$$\eta_{\text{th}} = \frac{\dot{Q}_{\text{shaft}}}{\dot{Q}_{\text{in}}} * 100$$

Or

$$\eta_{\text{th}} = \frac{282.74}{2507.24} * 100$$

Or

$$\boldsymbol{\eta_{th} = 11.28\ \%}$$

- **MEP**

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

Or

$$\text{MEP} = \frac{4\pi * 1.8}{0.0001}$$

Or

$$\text{MEP} = 226194.67\ \text{Pa}$$

Or

$$\mathbf{MEP = 226.19\ kPa}$$

- $\dot{\mathbf{Q}}_{\mathbf{exhaust}}$

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

Or

$$\dot{Q}_{\text{exhaust}} = 0.0015 * 1006 * 247$$

Or

$$\dot{\mathbf{Q}}_{\mathbf{exhaust}} = \mathbf{372.72\ W}$$

- $\dot{\mathbf{Q}}_{\mathbf{fin}}$

$$\dot{Q}_{\text{fins}} = \dot{Q}_{\text{in}} - (\dot{Q}_{\text{shaft}} + \dot{Q}_{\text{exhaust}})$$

Or

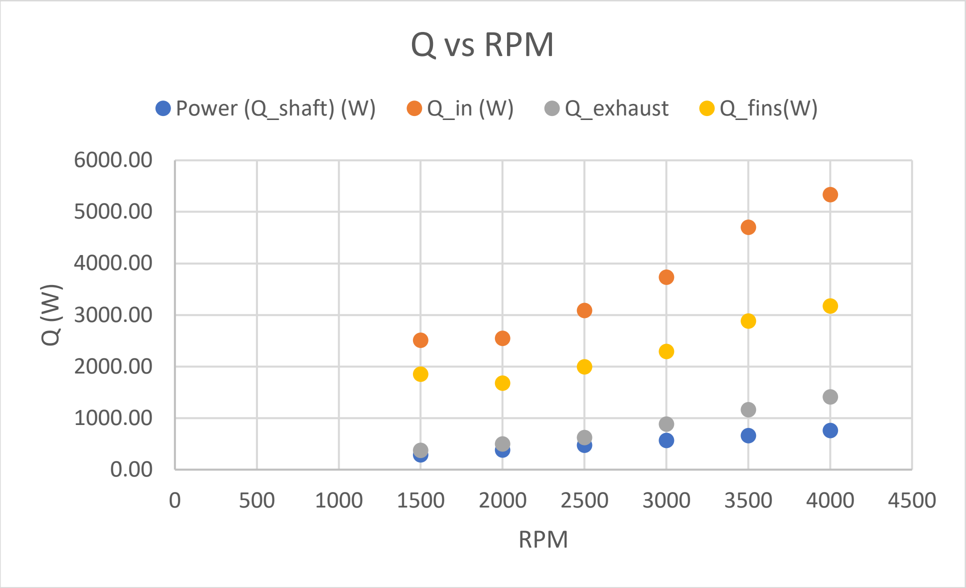
$$\dot{Q}_{\text{fins}} = \mathbf{2507.24} \ - (\mathbf{282.74} + \mathbf{372.72})$$

Or

$$\dot{\mathbf{Q}}_{\mathbf{fins}} = \mathbf{1851.78\ W}$$

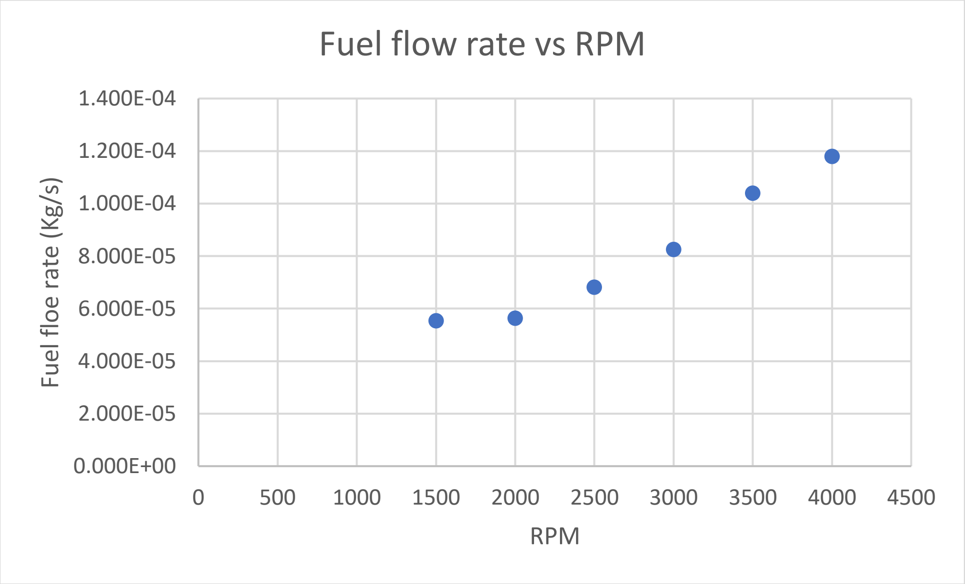
Graphs

From Table A:



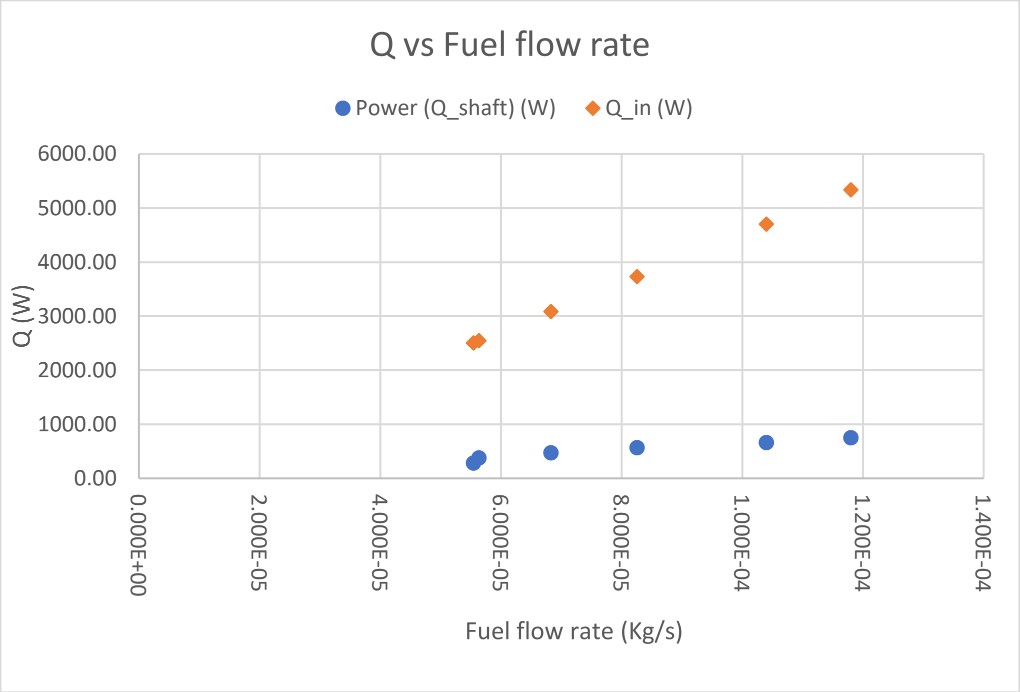
Graph 1: $\dot{Q}_{shaft}, \dot{Q}_{in}, \dot{Q}_{exhaust}$ vs RPM (Table A)

The graph 1 shows that, with an increase in engine RPM at a fixed load, $\dot{\mathrm{Q}}_{\mathrm{shaft}}$, $\dot{\mathrm{Q}}_{\mathrm{in}}$, and $\dot{\mathrm{Q}}_{\mathrm{exhaust}}$ as well as the difference between any two powers among the other four powers all increased as well.



Graph 2: Fuel flow rate vs RPM (Table A)

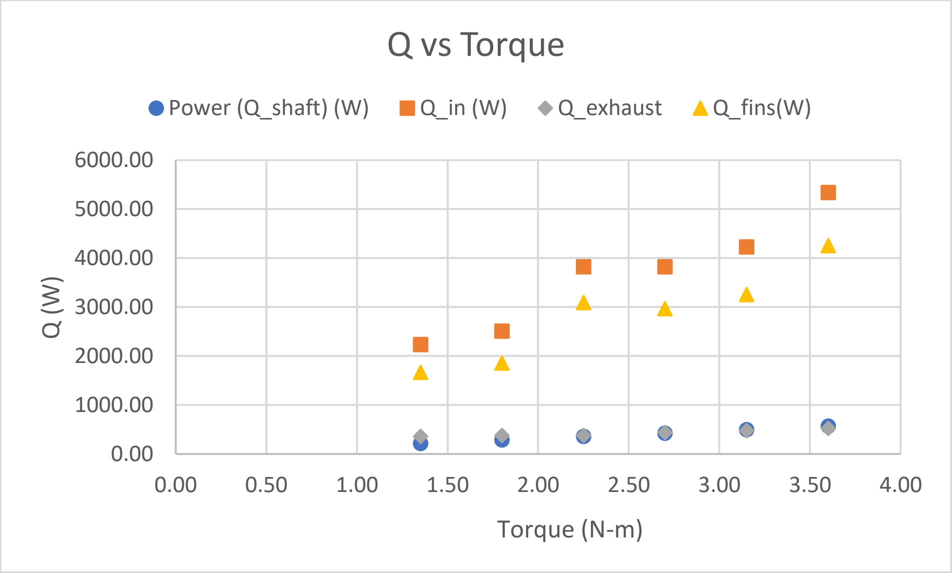
Fuel flow rate increased nonlinearly as engine RPM increased at constant load. It may be seen in graph 2.



Graph 3: $\dot{Q}_{shaft}$, $\dot{Q}_{in}$ vs fuel flow rate (Table A)

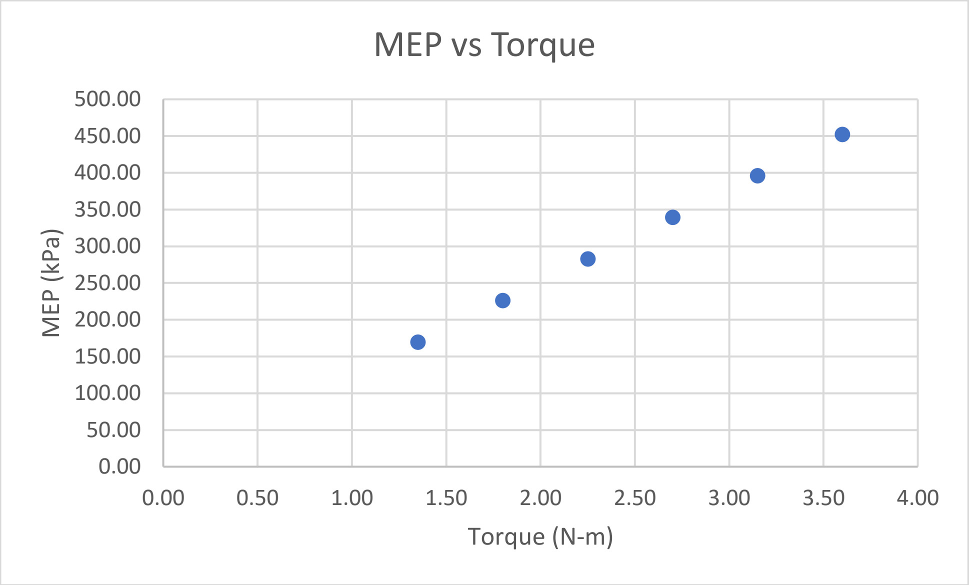
The values of $\dot{Q}_{shaft}$ and $\dot{Q}_{in}$ increased linearly with the fuel flow rate, $\dot{Q}_{shaft}$ increased more quickly than $\dot{Q}_{in}$ at constant load. The graph 3 illustrates that.

From Table B:



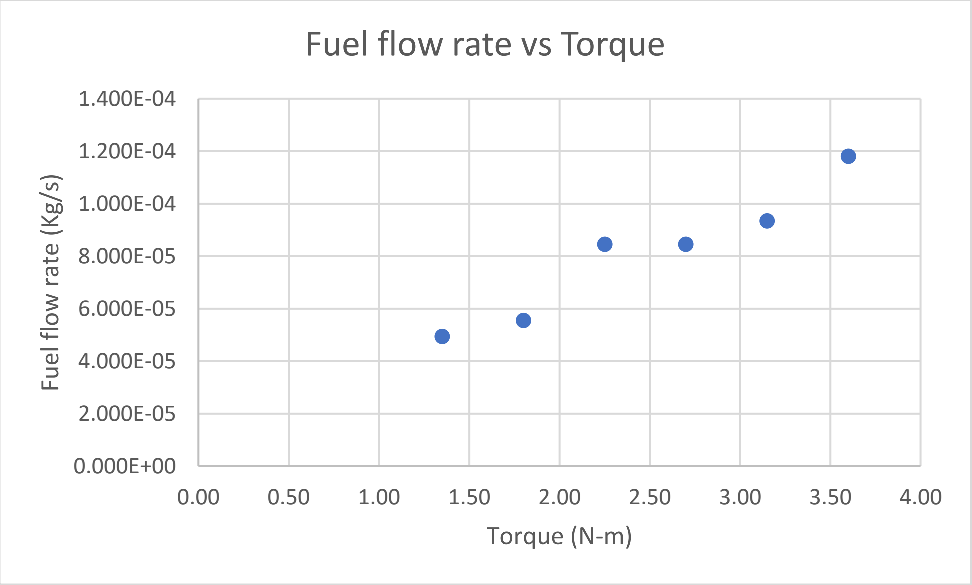
Graph 4: $\dot{Q}_{shaft}$, $\dot{Q}_{in}$, $\dot{Q}_{exhaust}$ vs Torque (Table B)

The graph 4 shows that, with an increase in engine RPM at a constant speed, $\dot{Q}_{shaft}$, $\dot{Q}_{in}$, and $\dot{Q}_{exhaust}$ as well as the difference between any two powers among the other four powers all increased as well.



Graph 5: MEP vs Torque (Table B)

MEP increased linearly as torque increased at constant engine speed. It may be seen in graph 5.



Graph 6: Fuel flow rate vs Torque (Table B)

Fuel flow rate increased non-linearly as torque increased at constant engine speed. It may be seen in graph 6.

Conclusion

1) The efficiency first increased with the value of engine speed at constant load, as shown in Table A, before it started to decline with the value of engine speed at constant load. The maximum trend could be seen in the efficiency fluctuation with engine speed values under constant load. When the load remained steady, the engine efficiency reached its optimum at 2500 rpm. Similar to this, there was an approximate maximum trend in the efficiency fluctuation with the values of % load at constant engine speed. The engine's greatest efficiency for a constant speed situation was 11.72% with 175% load. The efficiency from table A (11.28%) was equal to the value from table B for the same loading scenario (Load = 100% and engine speed = 1500 RPM).
2) To obtain reliable result:
    i. The calibration of the dynamometer, hydrometer and thermocouple must be maintained.
    ii. Repetition of measurement for same load or same engine speed for both the loading condition.
    iii. Consistency during the experiment conduct to reduce the chances of human error.
    iv. Right use of significant no. during calculations of various parameter of engine.

3) Long before it reaches the ideal operating temperature, an engine must be completely lubricated. Long periods of inactivity cause the oil in engine to drain to the bottom of the oil pan. Once the engine is running, the oil pump swiftly and evenly circulates oil throughout the motor, lubricating all the required moving parts. This help to give the reliable result of performance of the engine.

Reference

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