Parametric Analysis of a Four Stroke Gasoline Engine.

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Abstract: This paper deals with the parametric analysis of a four stroke gasoline engine. An Opel O.H.V engine mounted in a heat engine laboratory was used for the exercise. As the engine was running, the speed was recorded with a digital tachometer at a time frame of 20 seconds. The volume of fuel consumed was also noted by the reading of a burette mounted and filled with petrol. The torque on the engine was recorded by placing a known weight on a dynamometer. The engine was run on different selected gears of 1,2,3,4, and the readings noted. The measured values were used to evaluate other engine parameters and results tabulated. Results show that: Brake power increases with increasing engine speed and increases more with increasing load; Mass flow rate increases with increasing brake power at a particular load and gear; The quantity of fuel consumed is more when engine speed increases but decreases with increasing gear when the engine is loaded; Heat supplied by fuel increases with increasing engine speed at a particular load and gear; Indicated power increases with increasing engine speed; Torque increases with increasing load.

Keyword: gasoline engine, dynamometer, torque, load, tachometer.

1.0 Introduction

An internal combustion engine is a heat engine that burns fuel and air inside a combustion chamber located within the engine proper. The operation of the internal combustion reciprocating engine employs either a four-stroke cycle or a two stroke cycle. A stroke is one continuous movement of the piston within the cylinder (Heiser H, 1995). In the four stroke cycle, the downward movement of a piston located within a cylinder creates a partial vacuum. Valves located inside the combustion chamber are controlled by the motion of a camshaft connected to the crankshaft. The four strokes are called, in order of sequence, intake, compression, power, and exhaust (Maleer V.L, 1987). On the first stroke the intake valve is opened; atmospheric pressure forces a mixture of gas and air to fill the chamber. On the second stroke the intake and exhaust valves are both closed as the piston starts moving upward. The mixture is compressed from normal atmospheric pressure (1kg/sq cm) to between 4.9 and 8.8 kg/sq cm. During the third stroke the compressed mixture is ignited – either by compression ignition or by spark ignition. The heat produced by the combustion causes the gases to expand within the cylinder, thus forcing the piston downward. The piston’s connecting rod transmits the power from the piston to the crankshaft. On the fourth stroke the exhaust valve is opened so that the burned gases can escape as the piston moves upward (Hillier V.A.W. and Patrick F, 1988); this prepares the cylinder for another cycle.

2.0 Basic parameters used to express the performance of internal combustion engine

2.1. Brake power (B.P). The brake power is the power of the engine as obtained using a dynamometer or brake (Taylor C.F, 1985). This is giving by

$$B.P. = \frac{2\pi NT}{60} = \frac{2\pi NWR}{60} \quad (1)$$

2.2. Indicated power (I.P). This is defined as the rate of work done by the gas on the piston (Mohnot S.R, 2001). This is giving by

$$I.P. = \frac{P_1 LAN}{120} \quad (2)$$

Where P_I is pressure at the free surface which normally equal the atmospheric pressure (101.325 kNm^{-2})

2.3. Volume Flow Rate, Q. This is the amount of fuel consumed in specific time. (Maleer V.L, 1987). This is giving by

$$Q = \frac{V_f}{t} \quad (3)$$

2.4. Mechanical Efficiency ,$\eta_{mech.}$ This is the ratio of brake power to indicated power (Newten K , et.al 1996). This is giving by

$$\eta_{mech} = \frac{B.P.}{I.P.} \quad (4)$$

2.5. Fuel Mass Flow Rate, $m_{f.}$ This is the product of volume flow rate, Q and density of fuel (Mohnot S.R 2001).It is giving by

$$m_f = Q\rho_{petrol} = Q(s.g_{fuel})(\rho_{water}) \quad (5)$$

2.6. Specific Fuel Consumption (S.F.C.). This is the total mass of fuel consumed in one hour divided by the energy developed (KWh) during the period (MaryilsamyK,et.al,2005). This is giving by

$$S.F.C. = \frac{m_f}{B.P.} \quad (6)$$

2.7. Thermal Efficiency ,ηth. This is giving by

$$\eta_{th} = \frac{B.P.}{m_f c_f} 100\ \% \qquad (7)$$

Where c_f is fuel calorific value (43950 KJ/kg)

2.8. Heat supplied by fuel, H_f. This is the product of fuel mass flow rate and fuel calorific value (Mohnot S.R , 2001)

$$H_f = m_f c_f \qquad (8)$$

3.0 Materials Used.

3.1 Dynamometer: The super flow 902 hydraulic dynamometer used in the laboratory was positioned at a known distance 0.30m to the gear box. Based on the force recorded in the load cell and known distance, a torque can be calculated. This torque is recorded along with the angular velocity of the crankshaft (engine speed) and together they define power.

3.2 Crankshaft position sensor: This is a digital sensor that is excited by a trigger wheel attached to the crank shaft. The trigger wheel has 360 teeth with three missing teeth at TC of the number 1 cylinder. The digital signal goes high when a tooth passes by it and low in the absence of a tooth.

3.3. Engine: The engine tested in the laboratory is a 4-stroke spark ignition engine (opel model) The specifications and published performance data are listed below.

Engine Type ---2003 4.21 OHV 12- Value V6,
A ---Cylinder area---------$7.07 \times 10^{-4} m^2$
L ---Connecting Rod length ---0.135mm
a --- Crank radius ----- 47.5mm
r – Compression ratio ----- 9.2:1
D_V—Displacement volume ---- 699.1 cm^3
C_V – Clearance volume ----- 85.3cm^3

3.4 Burette and Stopwatch: These are used to measure the fuel flow rate into the engine.
3.5 Super flow air meter: This measures volumetric air flow into the engine.
4.0 Experimental Methods

4.1 Fuel consumption tests

The fuel consumed by a motor vehicle engine account for the largest part of the vehicle operating cost.

The quantity of fuel consumed by the engine on a test bed is easily carried out by using fuel measuring device like burette.

The burette filled with petrol was connected to the carburetor with a hose. The positive terminal of the tachometer was connected to the engine distribution coil, while the negative terminal of the tachometer was connected to the engine chassis.

The engine was started and the initial level of petrol in the burette was recorded immediately and timing started. Also the final level of petrol was recorded when the stopwatch reached the required period (time). The difference in reading between the initial and final levels of petrol gave the volume of petrol consumed.

4.2 Determination of Brake Power at varying gear and speed and at varying load.

The engine was loaded with a load measured using a spring balance. Then it was started at a known gear and speed, and the initial level of petrol in the burette was recorded immediately and timing started. Also the final level of petrol was recorded when the stopwatch reached the required time (20 seconds). Mathematically,

$$BrakePower(B.P.) = \frac{2\pi NT}{60} = \frac{2\pi NWR}{60} \quad (9)$$

Where N is the engine speed (rpm)
T is the torque (Nm)
W is the load (N)
R is the shaft radius (m)

4.3 Determination of Engine Torque

Engine torque is the product of load measured using a spring balance and radius of the rotating shaft. Mathematically,

Torque, T = WR =mgR (10)

Where W is the weight of the body in Newton

g is gravitational acceleration ($10m/s^2$)
R is shaft radius (i.e. 0.0005m-measured with vernier caliper)

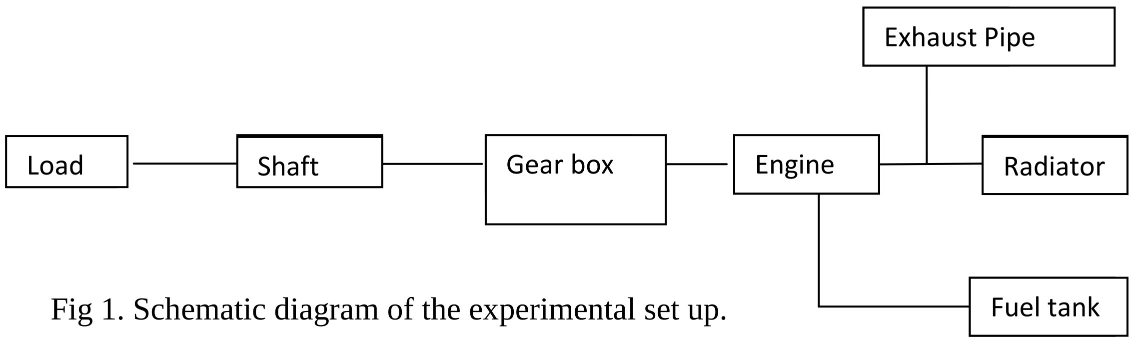

Fig 1. Schematic diagram of the experimental set up.

5.0 Results and Discussions

Actual speed values obtained ---700—1000RPM

Stroke length -----0.135m

Fuel used -----petrol

Specific gravity of fuel ----- 0.75

Fuel calorific value -----43950 kJ/kg (Maleer V.L , 1987)

Radius of rotating shaft -----0.0005m (measured with vernier caliper)

Number of cylinder -------4

Indicated pressure --- 101.325kpa

Table 1 Experimental Result

Gear	Load, W(N)	Speed, N(rpm)	Time, t (sec.)	Volume of fuel consumed, V_f (ml)
1	30	700 800 900 1000	20	20.00 22.50 26.55 28.00
2	30	700 800 900 1000	20	18.65 20.00 23.55 26.00

3	30	700 800 900 1000	20	16.30 20.00 22.00 25.55
4	30	700 800 900 1000	20	15.00 19.40 20.55 24.00
1	50	700 800 900 1000	20	20.00 21.00 24.50 26.40
2	50	700 800 900 1000	20	17.50 19.00 22.25 26.00
3	50	700 800 900 1000	**20**	14.00 18.35 20.00 24.55
4	50	700 800 900 1000	20	13.45 16.00 18.00 22.15

5.1 Analysis of Results

With load, W = 30N and speed N =700 rpm

B.P = $\frac{2\pi NWR}{60}$

T = WR = 30 × 0.5 × 10^{-3} = 0.015 Nm.

B.P = $\frac{2\times\pi\times700\times0.015}{60}$ = 1.10KW

When V_f = 20 ml = 2.0 ×10^{-5} $m^{3,}$ t = 20 secs.

$$Q = \frac{V_f}{t} = \frac{2.0\times10^{-5}}{20} = 1.0\times10^{-6}\ m^3/s$$

m_f = Q × Sg × 1000 (Where 1000 is the density of water in kg/m^3)

= 1.0 ×10^{-6} ×0.75 ×1000 = 7.5 ×10^{-4} kg/s = 0.045 kg/min = 2.7 kg/h.

$H_f = m_f \times c_f$ = 0.045×43950 = 1977.75KJ/min = 32.96KJ/s

S.F.C = $\frac{mf\ (kg/h)}{B.P(kw)}$

= $\frac{2.7}{1.10}$ = 2.45kg/KWh.

$\eta_{th} = \frac{B.P}{Hf} \times 100\%$

$= \frac{1.10}{32.96} \times 100\% = 3.34\%$

I.P = $\frac{P_1 LAN}{120}$

$= \frac{101.325 \times 0.135 \times 7.07 \times 10^{-4} \times 700}{120}$ = 0.0564KW

$n_{mech} = \frac{B.P}{I.P} = \frac{1.10}{0.0564} = 19.50\%$

with load,W = 50N, and speed, N = 800rpm

B.P = $\frac{2 \times \pi \times 800 \times 50 \times 0.5 \times 10^{-3}}{60}$ = 2.09KW

When V_f =21ml =2.1 × 10^{-5} $m^{3,}$

t =20secs.

$Q = \frac{Vf}{t} = \frac{2.1 \times 10^{-5}}{20}$ $=1.05 \times 10^{-6}\ m^3/s$

m_f= Q × sg × 1000

= 1.05 ×10^{-6} 0.75 ×1000

= 7.9 × 10^{-4} kg/s

= 2.84kg/h

H_f =mf× c_f

=0.045 × 43950

= 124.605 KJ/min

= 34.62 KJ/s.

S. F. C. = $\frac{2.84}{2.09}$

=1.36 Kg/KWh

$\eta_{th} = \frac{2.09}{32.96} \times 100\%$

$=6.04\%$

$\eta_{mech} = \frac{2.09}{0.0564} = 37.06\%$

Table 2.The result of engine parameters calculated at gear 1 , load W =30N, time t = 20 seconds

Parameter	Symbol	Unit	1	2	3	4
Volume of fuel consumed	V_f	ml	20.00	22.50	26.55	28.00
Engine speed	N	rpm	700	800	900	1000
Brake power	B.P	KW	1.10	1.26	1.41	1.57
Indicated power	I.P.	KW	0.0564	0.0645	0.0725	0.0806
Specific fuel consumption	S.F.C	Kg/KWh	2.45	2.41	2.54	2.21
Mechanical Efficiency	η_{mech}	%	19.50	19.53	19.45	19.48
Volume flow rate	Q	m^3/s	$1X10^{-6}$	1.13×10^{-6}	$1.3\ 3\times 10^{-6}$	1.40×10^{-6}
Mass flow rate	m_f	Kg/h	2.70	3.04	3.58	3.78
Heat supplied by fuel	H_f	KJ/S	32.96	37.08	43.76	46.15
Thermal efficiency	η_{th}	%	3.34	3.40	3.22	3.40
Torque	T	Nm	0.015	0.015	0.015	0.015

Table 3. The result of engine parameters calculated at gear 2 , load W = 30N, time t =20seconds.

Parameters	Symbol	Unit	1	2	3	4
Volume	V_f	Ml	18.65	20.00	23.55	26.00
Engine speed	N	Rpm	700	800	900	1000
Brake power	B.P	KW	1.10	1.26	1.41	1.57
Indicated power	I.P	KW	0.0564	0.0645	0.0725	0.0806
Specific fuel consumption	S.F.C	Kg/KWh	2.29	2.14	2.26	2.24
Mechanical efficiency	η_{mech}	%	19.50	19.53	19.45	19.48
Volume flow rate	Q	m^3/s	$9.33x10^{-7}$	1×10^{-6}	$1.18x10^{-6}$	1.30×10^{-6}
Mass flow rate	m_f	Kg/h	2.43	2.7	3.18	3.51
Heat supplied by fuel	H_f	KJ/s	30.74	32.96	38.82	42.85
Thermal efficiency	η_{th}	%	3.58	3.82	3.63	3.66
Torque	T	Nm	0.015	0.015	0.015	0.015

Table 4.The result of engine parameters calculated at gear 3 , load W =30N, time t = 20 seconds

Parameter	Symbol	Unit	1	2	3	4
Volume of fuel consumed	V_f	ml	16.30	20.00	22.00	25.55
Engine speed	N	rpm	700	800	900	1000
Brake power	B.P	KW	1.10	1.26	1.41	1.57
Indicated power	I.P.	KW	0.0564	0.0644	0.0725	0.0806
Specific fuel consumption	S.F.C	Kg/KWh	2.00	2.14	2.11	2.20
Mechanical Efficiency	η_{mech}	%	19.50	19.57	19.45	19.48
Volume flow rate	Q	m^3/s	$8.15x10^{-7}$	$1.0x10^{-6}$	$1.10x10^{-6}$	$1.28x10^{-6}$
Mass flow rate	m_f	Kg/h	2.20	2.70	2.97	3.45
Heat supplied by fuel	H_f	KJ/S	26.86	32.97	36.26	42.11
Thermal efficiency	η_{th}	%	4.10	3.82	3.89	3.72
Torque	T	Nm	0.015	0.015	0.015	0.015

Table 5.The result of engine parameters calculated at gear 4 , load W =30N, time t = 20 seconds

Parameter	Symbol	Unit	1	2	3	4
Volume of fuel consumed	V_f	ml	15.00	19.40	20.55	24.00
Engine speed	N	rpm	700	800	900	1000
Brake power	B.P	KW	1.10	1.26	1.41	1.57
Indicated power	I.P.	KW	0.0564	0.0645	0.0725	0.0806
Specific fuel consumption	S.F.C	Kg/KWh	1.85	2.08	1.96	2.06
Mechanical Efficiency	η_{mech}	%	19.50	19.53	19.45	19.48
Volume flow rate	Q	m^3/s	$7.50x10^{-7}$	$9.70x10^{-7}$	$1.03x10^{-6}$	$1.20x10^{-6}$
Mass flow rate	m_f	Kg/h	2.03	2.62	2.77	3.24
Heat supplied by fuel	H_f	KJ/S	24.72	31.97	33.87	39.56
Thermal efficiency	η_{th}	%	4.45	3.94	4.16	3.97
Torque	T	Nm	0.015	0.015	0.015	0.015

Table 6. The result of engine parameter calculated at gear 1 , load W = 50N, time t = 20 seconds

Parameters	Symbol	Unit	1	2	3	4
Volume of fuel consumed	V_f	ml	20.00	21.00	24.50	26.40
Engine speed	N	rpm	700	800	900	1000
Brake power	B.P	KW	1.83	2.09	2.36	2.62
Indicated power	I.P	KW	0.0564	0.0645	0.0725	0.0806
Specific fuel consumption	SFC	Kg/KWh	1.29	1.36	1.40	1.36
Mechanical efficiency	η_{mech}	%	32.45	32.40	32.55	32.51
Volume flow rate	Q	m^3/s	1.0×10^{-6}	1.05×10^{-6}	$1.23\times1O^{-6}$	1.32×10^{-6}
Mass flow rate	m_f	Kg/h	2.7	2.84	3.31	3.56
Heat supplied by fuel	H_f	KJ/s	32.96	34.61	40.38	43.51
Thermal efficiency	η_{th}	%	5.55	6.04	5.84	6.02
Torque	T	Nm	0.025	0.025	0.025	0.025

Table 7. The result of engine parameters, calculated at gear 2, load W = 50N time t = 20 seconds

Parameters	Symbol	Unit	1	2	3	4
Volume of fuel consumed	V_f	ml	17.50	19.00	22.25	26.00
Engine speed	N	rpm	700	800	900	1000
Brake power	B.P	KW	1.83	2.09	2.36	2.62
Indicated power	I.P	KW	0.0564	0.0645	0.0725	0.0806
Specific fuel consumption	S.F.C	Kg/KWh	1.28	1.23	1.27	1.34
Mechanical efficiency	η_{mech}	%	32.45	32.40	41.25	46.45
Volume flow rate	Q	m^3/s	$8.75x10^{-7}$	9.50×10^{-7}	1.11×10^{-6}	1.30×10^{-6}
Mass flow rate	m_f	Kg/h	2.35	2.57	3.00	3.51
Heat supplied by	H_f	KJ/s	28.69	31.37	36.67	42.85

fuel						
Thermal efficiency	η_{th}	%	6.37	6.66	6.44	6.11
Torque	T	Nm	0.025	0.025	0.025	0.025

Table 8.The result of engine parameters calculated at gear 3 when load W =50N, time t = 20 seconds

Parameter	Symbol	Unit	1	2	3	4
Volume of fuel consumed	V_f	ml	14.00	18.35	20.00	24.55
Engine speed	N	rpm	700	800	900	1000
Brake power	B.P	KW	1.83	2.09	2.36	2.62
Indicated power	I.P.	KW	0.0564	0.0645	0.0725	0.0806
Specific fuel consumption	S.F.C	Kg/KWh	1.03	1.19	1.14	1.46
Mechanical Efficiency	η_{mech}	%	32.45	32.40	32.55	32.51
Volume flow rate	Q	m^3/s	$7.0x10^{-7}$	$9.18x10^{-7}$	$1.0x10^{-6}$	$1.23x10^{-6}$
Mass flow rate	m_f	Kg/h	1.89	2.48	2.70	3.31
Heat supplied by fuel	H_f	KJ/S	23.07	30.24	32.96	40.46
Thermal efficiency	η_{th}	%	7.93	6.91	7.16	6.48
Torque	T	Nm	0.025	0.025	0.025	0.025

Table 9.The result of engine parameters calculated at gear 4 when load W =50N, time t = 20 seconds

Parameter	Symbol	Unit	1	2	3	4
Volume of fuel consumed	V_f	ml	13.45	16.00	18.00	22.15
Engine speed	N	Rpm	700	800	900	1000
Brake power	B.P	KW	1.83	2.09	2.36	2.62
Indicated power	I.P.	KW	0.0564	0.0645	0.0725	0.0806
Specific fuel consumption	S.F.C	Kg/KWh	0.99	1.03	1.04	1.15
Mechanical Efficiency	η_{mech}	%	32.45	32.40	32.55	32.51
Volume flow rate	Q	m^3/s	$6.73x10^{-7}$	$8.0x10^{-7}$	$9.0x10^{-7}$	$1.11x10^{-6}$
Mass flow rate	m_f	Kg/h	1.82	2.16	2.45	3.00
Heat supplied by fuel	H_f	KJ/S	22.17	26.37	29.67	36.51
Thermal efficiency	η_{th}	%	8.25	7.92	7.95	7.18
Torque	T	Nm	0.025	0.025	0.25	0.025

6.0 Observation

During the experiment it was observed that some engine parameters like Indicated Power, Volume flow rate and Torque were not affected by either load or gear.

6.1 Conclusion

Based on the analysis carried out, results show that: Brake power increases with increasing engine speed and increases more with increasing load; Mass flow rate increases with increasing brake power at a particular load and gear; The quantity of fuel consumed is more when engine speed increases but decreases with increasing gear when the engine is loaded; Heat supplied by fuel increases with increasing engine speed at a particular load and gear; Indicated power increases with increasing engine speed; Torque increases with increasing load.

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