The Measurement of Fuel Consumption under Hot Ambient Temperature in Kuwait City

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Abstract

The present work investigates the effect of high ambient temperature on the specific fuel consumption. When tested at low speed and low load, it was shown that the engine performance, the fuel consumption and the engine pollution were significantly affected. Urban cycle testwas used to measure the performance and consumption, which was adopted to suit these circumstances in Kuwait where the temperature reachesalmost 55°C in summer (in the shadow) especially in July and August. The current study reveals clearly the effect of ambient temperature on the performance criteria.

Keywords — *Fuel consumption, Kuwait, experimental, performance.*

I. INTRODUCTION

The experimental study for the driving cycle was tested on the ground and also on the laboratory using chassis dynamometer. In addition, the test was applied for typical day of the month where the temperature reaches high reading in order to compare and analyse the results and show the poor efficiency accordingly [1-2].

Fuel consumption in automotive field can be analysed in two methods:

- ***Units of fuel per fixed distance:*** The fuel used per distance such as liters per 100 km (L/100km)

This method is used in countries like South Africa, Australia, Europe, New Zealand and China [3].

- ***Units of distance per fixed unit of fuel:*** The distance travelled per unit of fuel used in km per liter (km/L)

This methodis used in Japan, USA and UK.

II. THEORETICAL CAR FUEL CONSUMPTION

When estimating the fuel consumption of a moving vehicle, the tests shouldbe carried out at different modes of operations by considering the vehicle speed in the range between20-120km/h and during high ambient temperature [4, 5].The car performance is given in the following procedures for vehicle fuel consumption at 50 km/h.

The vehicle performance tractive effort should be:

$$R_t = R_r + R_a + R_i + R_g \qquad (1)$$

Where:

Rr = Rolling resistance N

R_a = Air resistance N

R_i = Inertia force N

R_g = Gradient resistance N

In the case when vehicle travelling on level road, the performance tractive effort becomes:

$$R_t = R_r + R_a \qquad (2)$$

Thus, the rolling resistance on the level roadwould be:

$R_r = k_r\, mg$

Where:

kr = coefficient of rolling resistance

This can be found from Andreaus formula:

$$k_r = \frac{10^{-3}}{P^{0.64}}\left[20 + \frac{V^{3.7}}{1.294 \times 10^6 \times P^{1.44}}\right]$$

Where:

W= Car mass = mg (kg)

P = Inflation pressure (kp/cm^2)

V= car speed (km/h)

kr = 0.0142

R_r = 157 N

Air resistance at 50 km/h in general is given by:

$R_a = KAV^2$

Where:

K = Coefficient of air resistance= 0.3

A = Car frontal area m^2

V^2 = Car speed m/s

A - can be found from the empirical formula:

A = 0.78 B.H

Where:

B = Car width = 1.7 m

H = Car height = 1.4 m

A = 0.7 × 1.7 × 1.4

= 1.856 m^2

$\therefore\ R_a = 0.3 \times 1.856 \times 193.2^2$

= 194

$\because R_t = R_r + R_a$

= 360

$\therefore$ The tractive power $P_t = \frac{R_t.V}{1000}$

Where:

V = car speed m/s

$\therefore\ P_t = 5$kw

Where the engine brake power is given by:

$= \frac{P_t}{\eta_t}$

Where:

η_t = Transmission efficiency = 0.95

Thus, the engine brake power is:

P_b = 5.3 kw

But the car speed $v = \frac{\pi.d_t.Ne}{60.ig\ .ib}$

Where:

$i_g = Gear\ box\ ratio\ applied = 0.97$

$i_b = Back\ axle\ ratio = 3.944$

$d_t = Tire\ diameter = 0.6\ m$

$$V = \frac{50}{3.6} = \frac{3.14 \times 0.6\ Ne}{60 \times 0.97 \times 3.944}$$

$Ne = 1664$R.P.M

Engine brake power can be calculated from:

$$P_b = \frac{n \times \pi d_c^2 LNe\ P_m \times 10^2}{4 \times 2 \times 60}$$

Where:

n = number of engine cylinders

d_c = cylinder diameter

P_m = B.M.E.P

= Brake mean effective pressure (Bar)

Thus P_m = 2 bar

Referring to the performance map, given in ref (14), at the given values of Ne and Pm, the brake specific fuel consumption is given:

(B.S.F.C) = 520 g/kwh

$\therefore$The engine fuel consumption is:

M_f = B.S.F.C ×P_b

= 5.467

= 2.756 Kg/h

But, the car fuel consumption (L/100 Km)

$$Q_f = \frac{M_f \times 100}{\rho_f \times V}$$

Where:

ρ_f = fuel density

= 0.7294 kg/L

V = car speed Km/h

Thus, the car fuel consumption becomes:

$$Q_f = \frac{2.756 \times 100}{0.7294 \times 50}$$

= 7.55 L/100 km

III. EXPERIMENTALCAR FUEL CONSUMPTION

In order to compute the fuel consumption, different measurement modes were used to approximate the actual performance of the vehicle at normal driving condition. The test procedure was carried out over chassis dynamometer equipped with a very fast control system and electric inertia simulation. The chassis dynamometer can be adjusted in the range between (200 – 500 kg). The measurements were made using one real cycle to simulate the actual driving conditions. Typical driving cycle utilize to represent engine performance especially at traffic congestion [6].

A. Running cycles:

The following steps were taken in consideration while carrying out the test:

a. The road should be flat and there is no wind.
b. The test must be carried out on chassis dynamometer to improve repeatability.
c. Tire tread wearshould not be more than 25%.
d. Tire pressure should be set to a certain value.
e. Both front and rear brakes should be checked and adjusted.

The vehicle specification that has been usedin the test isgiven in Appendix (1).The cycle which consists of three stages and 25 different operations is shown in[4]. The cycle duration is (195) seconds and the car speed 50 km/h during the cycle [7-8].

B. The cycle operations:

1. Idling:

The engine fuel consumption can be calculated experimentally at idle speed.
The experimental results were found as follows:
Engine idling speed = 900 R.P.M
Engine fuel consumption = 0.956 Lt/h
Operation, 1, is considered as a sample of these types of operation.
Duration of this operation = 10S
Fuel consumption during this operation = 2.66×10^{-3} lit.

2. Uniform speed:

Operation, 2, is a sample of these types of operation.
Duration of operation = 6S
Car speed = 20 km/h
First gear is used
The car tractive effort in this case is given by:
$R_t = R_t + R_a$
$R_r = k_r mg$
= 168 N
$R_a = KAV^2$
$= 0.3 \times 1.82 \times \left(\frac{20}{3.6}\right)^2$
= 17 N
$\therefore\ R_t = 185\text{N}$
Where engine power $P_b = \frac{R_t v}{\eta_t * 1000}$
Where $\eta_+ = 0.94$, when the first gear is applied.
The engine speed $Ne = \frac{V \times 60 \times ig \times ib}{\pi d_t}$
= 2000 R.P.M
Thus, the engine power $P_b = \frac{n \times P_m \times 10^5 \times d_c^2 \times L \times N_e \times n}{60 \times 2 \times 10^3}$
Where the $P_m = B.M.E.P$
= 0.3 bar
From the performance map in ref [5], at the given values of Ne, P_m
The value of B.S.F.C. = 1200 g/kw
The rate of fuel consumption = BSFC $\times P_b$
= 1.11*1200 g/kw
= 1.34 kg/h
Also, the fuel consumption during the uniform speed operation is
= 2.23×10^{-3}lit
During this operation the distance covered = 0.34 km

3. Uniform acceleration:

This type of operation is a sample of uniform acceleration
Duration of operation = 5 S
Speed variation during operation = $(V_2 - V_1)$ = (20-0)
Mean speed during this operation
$= \frac{V_1+V_2}{2} = \frac{0+20}{2} = 10\text{km/h}$
Gear ratio applied at first gear
Tractive effort in this case is equal to:

$R_t = R_r + R_a + R_i$
Hence R_r= 168 N
Ra = 1.51 N
Where $R_i = M,g$ = Inertia force
M = car mass
= 1200 kg
g = car acceleration m/s²
$= \frac{V_2 - V_1}{t}$
= 1.06 m/s^2
Thus R_i = 1280 N
∴Rt = 168 + 1.51 + 1280
= 1450 N
Thus the mean engine power P_b
$= \frac{R_t.V}{\eta_t \times 1000} = 3.2\text{kw}$
= 4.2 kw
While the mean engine speed N_e
$= \frac{v \times 60 \times \circ ig \times ib}{\pi d_t}$
Ne = 1150

For a mean engine power, P_b, equal to 4.2 Kw, the brake mean effective pressure, P_m, will be 2.8 bar

From the performance map, in ref, at the given values of N_e and P_m the engine B.S.F.C = 450g/kwh

With the engine fuel consumption during the given operation

Thus the rate of = 450 $\times P_b$

Fuel consumption = 1.89 kg/h

Engine fuel consumption during the given operation is:

$$= \frac{1.89 \times time}{3600}$$

$$= 2.625 \times 10^{-3}$$

Distance covered during operation is

$$= 9.23 \times 10^{-3}\text{km}$$

C. Uniform retardation with the throttle pedal fully release:-

This condition is similar when the car decelerated on the level road or when it is running downhill. If the car runs on the level road,then the engine is driven by the inertia of the retarded vehicle. But, if the car is descending downhill then the component of the car weight down the gradient adds to the car inertia force. For the purpose ofexperimentally simulate the engine performance during these operations; this operation is used as a sample to indicate the estimation of the engine consumption during such operations.

Duration of operation = 3S

Speed change during operation (V_2+V_1) = 15+10 first gear is applied

The mean car speed during the operation is given by:

$V_m = \frac{V_1+V_2}{2} = \frac{15-10}{2} = 12.5$ km/h

The mean engine speed during the operation is:

$$N_m = \frac{V_m \times 60 \times ig \times ib}{\pi\, d_t}$$

= 1600 R.P.M

From Fig (1) at the given engine speed the corresponding fuel consumption is 1.04 Lit/h.

While the engine fuel consumption during this operation is:

$$= \frac{1.04 \times 3}{3600}$$

= 8.66×10^{-3}Lit

The distance covered during the operation = 0.01041 Km

D. Uniform retardation with the gear in neutral:-

These operations occur at the end of each stage of the three stages. The engine fuel consumption during the particular operation is estimated as the arithmetic mean of the engine fuel consumption at the beginning and at the end of the operation. And it is computed in the similar manner to that applied in the fourth type of operation, since at that given time the throttle pedal is fully released [9-13].

The engine fuel consumption at the end of the operation is equal to that obtained with the engine idling and is equal to 0.9427 Lit/s.

The duration of the operation = 2S

Speed change during the operation (V_2-V_1) = (0-10) km/h

First gear is applied.The engine revelation at the beginning of the operation is:

N_1 = 1300 R.P.M

From Fig (1) it is shown that at the given engine revolution, the corresponding fuel consumption is 1.05 Lit/h. But, the engine fuel consumption at the idling speed N_2 = 850 R.P.M is 0.9427 Lit/h.

But, the mean rate of fuel consumption during this operation = 0.9821 Lit/h

Also, the engine fuel consumption during this operation = 5.45×10^{-4} Lit.

Distance covered during operation = 8.33×10^{-3} km.

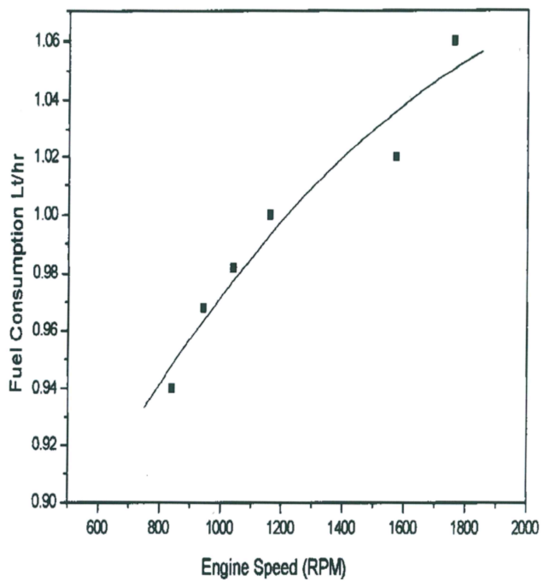

Figure 1: Fuel consumption at different engine speed

IV. CONCLUSIONS

In the current study, the fuel consumption was investigated throughout the different modes of operation of the driving cycle.The fuel consumption of the vehicle decreases in the urban driving cycles (constant driving) but,its increases in the suburban driving, when the driver follows a given speed/ time profile. The test results for this particular work have been computed and carried out on one urban cycle and it was tested at speed varying from 0 up to 50 Km/h in order to simulate the actual driving condition.

Better fuel economy was noticed at constant low engine speed; however, this was not the case when varying driving condition including acceleration and deceleration even though the average speed would be the same.

When tested athigh ambient temperature and when it was at idle speed (at rest), thevehicle was running unstable andrough. Moreover, unstable and less power propulsion was noticed also athigh ambient temperature in different conditions.

It was noticed that fuel consumption tends to increase when temperature approaches nearly 100°C. The efficiency decreases gradually as the average temperature increases during summer season between July and August. In general, the results show variation in power and efficiency for vehicle operation under these conditions.

The best working temperatures for consuming less fuel were noticed between 85-90°C. However, at high working temperatures No_2- nitrogen dioxide gasesare emitted. Such gasesareconsidered to be very dangerous on health.

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