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Research Article

Experimental and simulation study to determine the effect octane number on performance in SI engine

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Abstract

Experimental and Simulation investigations are carried out to study and compare the effect of using four cylinder, four-stroke spark ignition (SI) engine fuelled by four grades of gasoline used in Iraq, RON75, RON80, RON85 and RON92on the performance of SI engine at different engine speeds and loads". "Simulation combustion model Lotus Engine Simulation (LES) can predict the engine performance when compared with the experimental findings". "(LES) The program was used to study the effect of some parameters in experimental testing, this program gives the best performance of the engine at maximum brake power, and the same input data were fed to the program where they were taken from the data of experimental results". "Results show that the engine performances for both fuels are compatible, with marginal differences, under the tested operating conditions". Higher power and less specific fuel consumption are observed when fuels of octane number 92 are used compared with octane 75 blends. "

Keywords: *Gasoline, octane number, antiknock additive*

1. Introduction

Downsizing the engine and reducing fuel consumption and emissions are the major goals in the field of internal combustion engines today (Anderson JE, *et al*, 2012), (Heywood JB,1988).The internal combustion engine, powering 90% of world vehicles, is the main driver in the transportation sector from which20% of total world energy is consumed. The engine performance, thermal efficiency and pollutant emissions have a significant impact extending to the environment (IEA Key World Energy Statistics, 2013). Researcher studied the effect of octane number of the fuel on the performance of the spark ignition engine. The study included the preparation of fuel with octane number (70, 75, 80, 85, and 90). The results show that the engine performances are increased step by step according to the increases of the octane number of fuel (Dr. Mohammed Hassan Aboud, 2006). also tested the influence of two octane gasoline fuels, which are RON91 and RON95, on engine performance using a low compression ratio engine (8.0:1). They noticed that RON91 gasoline produced 4.2–4.8% higher power and 5.6% lower BSFC than RON95 fuel. The results also showed that lower emissions were detected by using RON91 fuel with 5.7% and 3.4% of CO and HC respectively (Sayin C, *et al*, 2005). This system allows an increase of the compression ratio, which in turn reduces the specific fuel consumption. The antiknock quality of a fuel is usually quantified through either the Research Octane Number (RON) or the Motor Octane Number (MON). Higher values of these octane numbers reduced a better antiknock quality of the fuel (Kamil M , *et al*, 2013), (Abdullah NR, *et al*, 2014).When engine was fueled octane, engine performance parameters such as break thermal efficiency increases with increasing (RON) octane number while bsfc decreased. The results show that the concentration of exhaust emissions decreases with increases (RON) octane number (Mohammed Kadhim Allawi, 2016).

The addition of oxygenates to gasoline offers many advantages, among which: more complete combustion and reduction of carbon monoxide emission, being a renewable energy source, increased octane number, and increased volatility (McNair H.M, *et al*, 2001) .Gasoline with higher octane number has numerous benefits including reduced exhaust emissions and engine noise, improved cold starting and engine durability (Brown S, *et al*, 1999). Octane requirement to avoid knocking is related to the engine type and engine operating conditions. Research octane number (RON) and motor octane number (MON) are measures of fuel anti-knocking performance. American cars use an octane scale derived from the average of both RON and MON (Saudi Aramco, 2008). Researcher showed that the engine performances of both fuels are comparable, with marginal differences, under the tested operating conditions, practically for engine speeds less than 3500 rpm. Higher power and less specific fuel consumption are observed when octane 91

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fuel is used compared with octane 95 blend (A. E. Khalifa, *et al*, 2015).

2. Experimental Setup

2.1 Engine

The experimental work was performed in the internal combustion engine Laboratory. The engine used in the experimental work is spark ignition engine (SI engine) 4-stroke, 4 cylinders. The displacement volume for this engine is 2000 cc. The engine was coupled to a hydraulic dynamometer to measure the brake torque. Further details on the engine specifications and parameters listed in Table1 while Fig. 1 shows a Schematic sketch of the rig used in the test.

Table 1: Specification of the Engine

Descriptions Parameter	Descriptions Parameter
Engine type	4cyl., 4-stroke
Engine model	gasoline engine rig
Combustion type	water cooled, natural aspirated
Swept volume	541cm^3
Valve per cylinder	two
Bore	83 mm
Stroke	92 mm
Compression ratio	9.8
Max power	135kW at 5500 rpm
Max Torque	300Nm at 1200 rpm

2.2 Measuring parameters

The following engine parameters were measured: brake torque (using hydraulic dynamometer), air consumption (using induction air system consists of air box, orifice and the manometer), fuel consumption (using glass tube and stop watch) and engine speed (using tachometer).

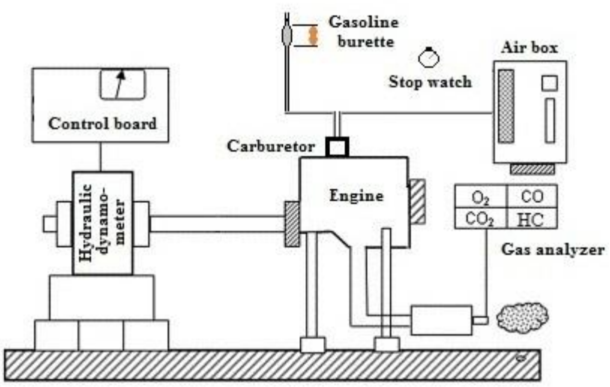

Figure 1: Schematic of experimental apparatus

3. Engine simulation

In this study, LES is used for simulation and computation. LES is a simulation program capable of predicting the complete performance of an engine system. This program can be used to predict the full-and part-load performance of the engine under steady-state and transient operating conditions. Instantaneous gas property and heat transfer data in manifolds and cylinders of engine can be calculated for stratified or turbocharger or supercharger matching conditions. LES needs to have engine and manifold specifications; cylinder bore, stroke and connecting rod dimension, compression ratio, valve sizes and valve timing data, intake and exhaust port flow data, intake and exhaust manifold dimensions, maps defining the performance of turbines and compressors, engine speed, heat release data, characterizing the combustion event, air/fuel ratio and inlet air temperature and pressure. Fuel type and properties are defined for physically completion of model and then operating conditions are required to run the engine simulation model (Getting Started Using Lotus Engine, 2001). A S.I engine laboratory was modeled with LES software in this study. A general layout of SI engines is shown in Fig. 2.

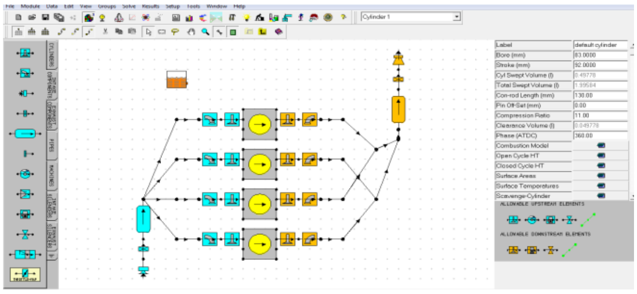

Figure 2: Engine geometry

The defining features of the S.I engine laboratory and the main parameters used in the (LES) input file are detailed below in Tables (1), Fig (3) and Fig (4).

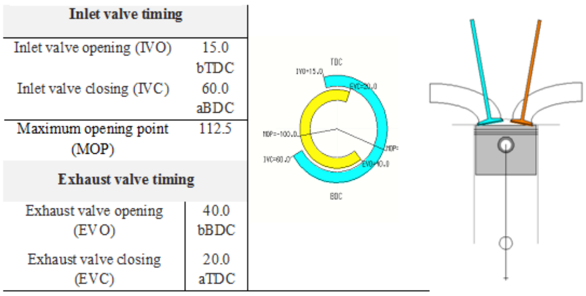

Figure 3: Inlet and exhaust valve timing (S-I engine)

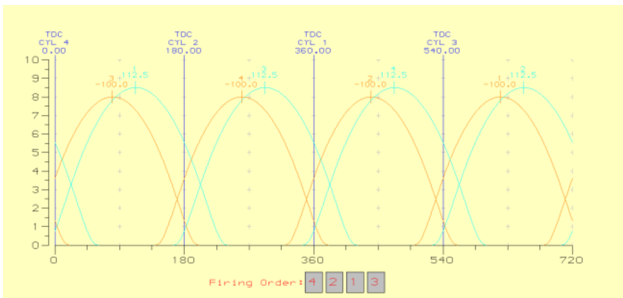

Figure 4: The Valve Event Display

4. Test procedure

The following steps were performed to carry out the experimental and simulation work.

4.1 Experimental work

1) Different samples were used in the study. Gasoline was obtained from the IRAQ Oil Refinery Company (RON75, RON80, RON85 and RON92).
2) Preparing the engine and the measurement devices to record the data for (1300 to 2100) rpm.
3) Measuring engine speed, brake torque, the pressure differential between the atmosphere and pressure inside the air box and time of fuel consumed.

4.2 Engine simulation

Steps to build the program, Multi-cylinder model, produced, starting from the single cylinder model, to calculate the results for cycle-averaged data, such as volumetric efficiency, BSFC, torque, and power, and intra-cycle data, like pressure, temperature, and mass flow rate are available to.
1- Defining the Fuel and Fuel System
2-Adding a Cylinder
3- Adding Valves
4- Adding Ports,
5- Adding Inlet and Exit Boundaries
6- Defining Steady-state Test Condition Data
7-Copying Model Segments
8- Creating the 4-2-1 Exhaust Manifold &Adding Pipes
9-Selecting the Firing Order
10- Saving a Model,
11- Running the Multi Cylinder Model.
12- Loading the Model.

5. Results and discussion

The engine performance parameters such brake thermal efficiency, brake power and Volume efficiency increase with increasing octane number while braking specific consumption decreases. The variation between experimental and simulation values was due to the mechanical losses, fresh charge losses and leakage.

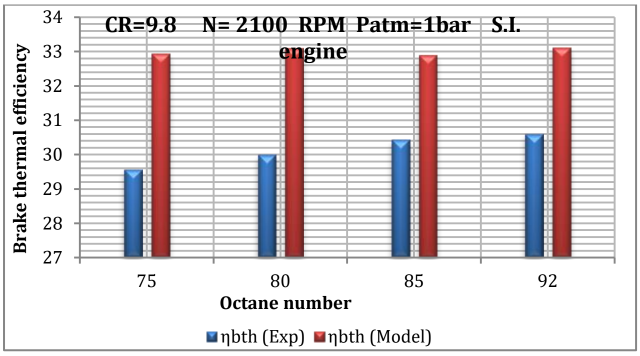

Figure 5 Relationship between ηbth and Octane number

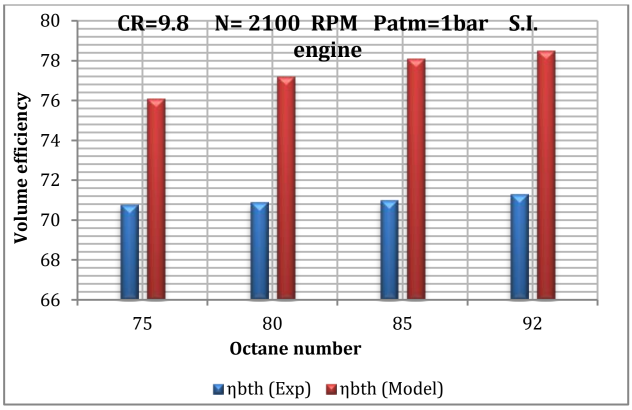

Figure 6: Relationship between Volume efficiency and Octane number

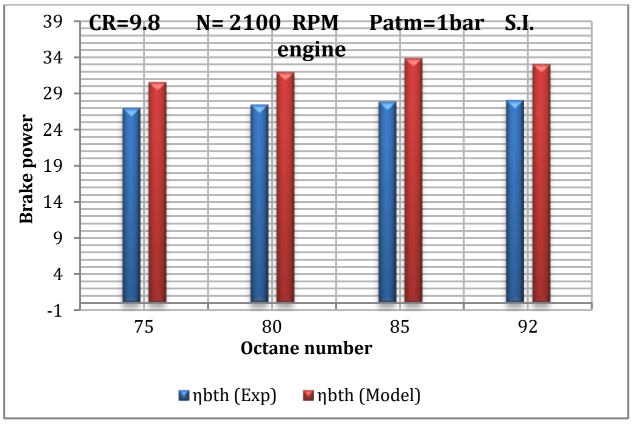

Figure 7: Relationship between Brake power and Octane number

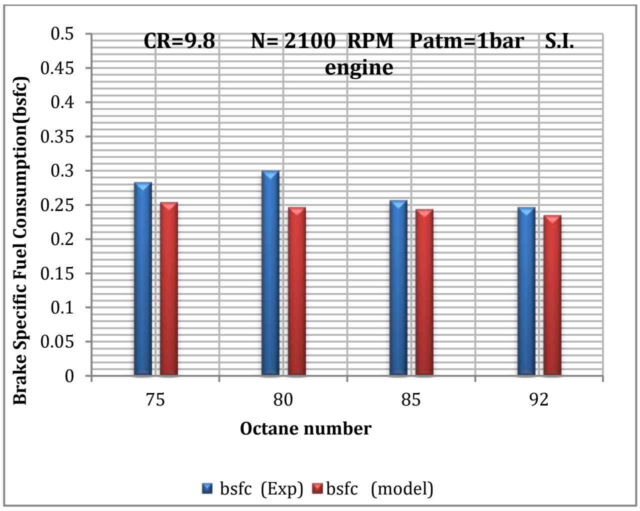

Figure 8: Relationship between bsfc and Octane number

Fig. 9 represents the effect of engine speed on the thermal efficiency of various fuels octane number. It is shown in the figure that thermal efficiency increases with the increase in engine speed and it is because of this reason, less quantity of heat is being lost through the cylinder wall, at higher speed. Maximum thermal efficiency was obtained for O.N 92 at engine speed of 1500 rpm. It is interesting to note that thermal efficiency of O.N 92 fuel is higher than the base fuel.

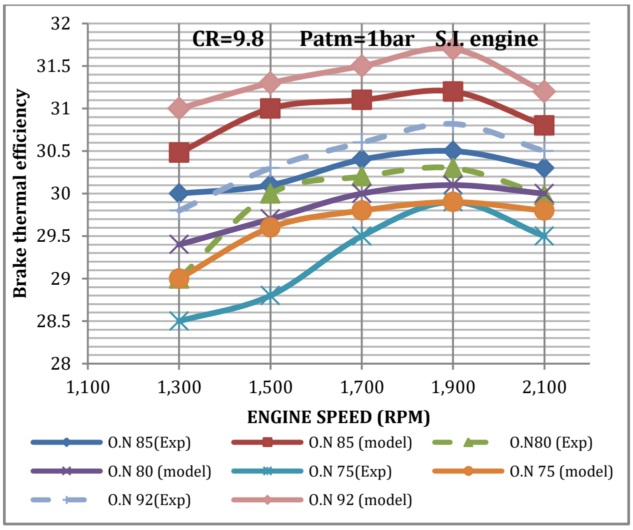

Figure 9: Brake thermal efficiency versus engine speed

Fig. 10 represents the change in volumetric efficiency with the change in engine speed at variable load values for all tested fuels. It is shown in the figure that volumetric efficiency of (O.N 83 and O.N 92) are maximum among all the fuels which can explained that as liquid fuels have high latent heat of vaporization, they produce a cooling effect on the intake charge during vaporization. Therefore, there will be an increase in intake charge density and consequently in volumetric efficiency. The small variation between experimental and simulation values was due to the losses of fresh charge and frictional flow.

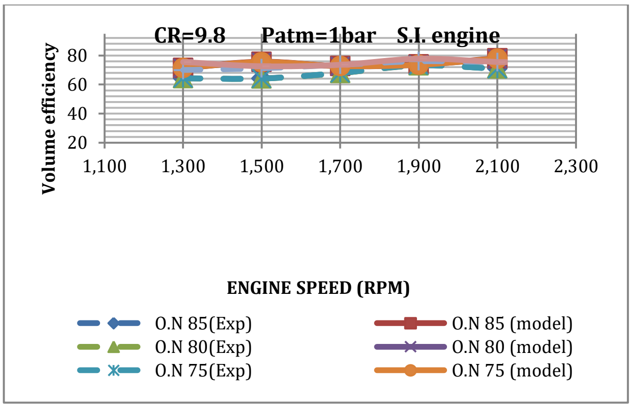

Figure 10: Volume efficiency versus engine speed

Fig.11 shows the direct relation between the engine speed and the brake power it can be seen that increasing the speed lead to increase the pressure differential between the atmosphere and cylinder pressure at the beginning of intake stroke then increasing the mass of fresh charge and the energy release. The small variation between experimental and simulation values was due to the losses of fresh charge by evaporation, leakage and unburned hydrocarbon inside the combustion chamber.

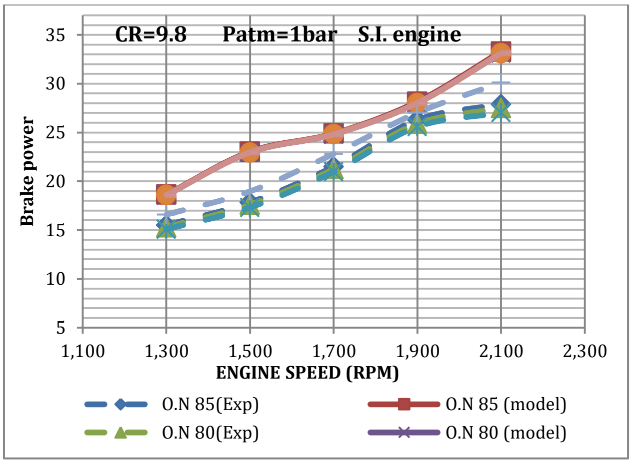

Figure 11: Brake power versus engine speed

Fig.12. Explains the brake specific fuel consumption as a function of engine speed. Fuel consumption decreases as engine speed increases due to the shorter time for heat loss during each cycle. At higher engine speeds, fuel consumption again increases because of high friction losses. The small difference between the experimental values of all parameters and the simulation ones is due to the several losses such as leakage, evaporation, thermal and mechanical losses.

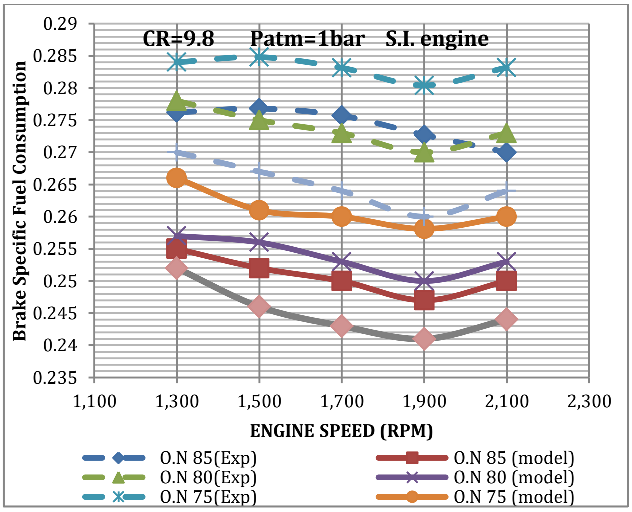

Figure 12: Brake specific fuel consumption versus engine speed

Conclusion

In this study, it was seen that when an engine was fueled octane number

1- Engine performance and brake thermal efficiency increase by rising of octane number, while considerable reduction occurs in brake specific fuel consumption.

2- Program gives the best performance of the engine at maximum brake power.

3- The apparent deviation between experimental and simulation values was due to the losses of the SI engine.

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The following equations were used in calculating engine performance parameters

Nomenclature		
Symbol	Meaning	Unit
A/F	Air to fuel ratios	
Bp	Brake power	KW
bsfc	Brake Specific fuel consumption	kg/(kW.hr)
O.N	Octane number	/
R O.N	Research octane number	/
M O.N	Motoring octane number	/
HC	Unburned hydrocarbons	Ppm
Ho	Differential manometer	Cm
$\dot{m}a$	Air mass flow rate	kg/sec
$\dot{m}f$	Fuel mass flow rate	kg/sec
L.C.V	Lower calorific value	(kJ/kg)
T	Torque of engine	(N.m)
N	rotational speed	(rpm)
CR	Compression Ratio	/
S.I.engine	spark ignition engine	/
(LES)	Lotus Engine Simulation	/

1- The brake specific fuel consumption.

$$\text{bsfc} = \frac{\dot{m}f}{bp} \times 3600 \quad kg/(kW.hr) \ldots..(1)$$

2- Brake thermal efficiency is defined as in Eq.

$$\eta\text{bth} = \frac{bp}{\dot{m}f\ L.C.V} \ldots\ldots\ldots\ldots (2)$$

3- Air mass flow rate

$$\dot{m}a, act = \frac{12\sqrt{h_o}}{3600} \times \rho\ air\ \ \frac{kg}{}\ sec \ldots\ldots\ldots\ldots(3)$$

4- Fuel mass flow rate

$$\dot{m}f = \frac{vf \times 10^{-6}}{time} \times \rho_f \quad \text{kg/sec} \ldots\ldots\ldots\ldots(4)$$

5- Air-fuel ratio

$$\text{A/F} = \frac{\dot{m}a}{\dot{m}f} \ldots\ldots\ldots\ldots \quad (5)$$

6- Brake power

$$\text{bp} = \frac{2\pi \times N \times T}{60 \times 1000} \quad \text{kW} \ldots\ldots\ldots\ldots(6)$$