Al-Qadisiyah Journal for Engineering Sciences 15 (2022) 229–237

Contents lists available at http://qu.edu.iq

Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: http://qu.edu.iq/journaleng/index.php/JQES

Influence of intake air temperature on the performance of gasoline engines using a different type of fuel

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A R T I C L E I N F O

Article history:
Received 31 August 2022
Received in revised form 29 October 2022
Accepted 05 December 2022

Keywords:
SI_engine
Engine performance
Intake temperature
Octane number
gasoline fuel
Ricardo wave software

A B S T R A C T

The aim of the present study is to investigate the effect of Intake air temperature on the performance of gasoline engines. Various factors are taken that affect the performance of four-stroke gasoline engines. Changes in air intake temperature have a significant impact on the performance of a petrol engine. Consequently, an increase or decrease in the global ambient temperature will impact the performance and air quality of gasoline engines in particular. therefore, this investigation will discover the hot value of intake air temperatures that affects engine performance. This study tested two Kurdistan-Iraq gasoline kinds at different intake temperatures (25Cº, 35Cº, 45Cº, and 50Cº). Experiments utilized a four-stroke spark ignition _engine that operated at various rates of speeds (1300, 1500, 1800, 2000, 2300, and 2500 revolutions per minute) under a half load with a 50% throttle opening. The experimental outcomes were compared with Ricardo Wave software simulations. The Ricardo Wave's theoretical outcomes were in good agreement with the experiment data it showed a near 5% to 10% variance between simulation and practical data. Additionally, utilizing fuels having higher RON increases brake power owing to gasoline's greater hydrogen content and the engine's high octane fuel requirement. Also, lower inlet air temperatures would be denser (more oxygen) and offer a larger mass flow during each piston cycle. Hence, due to those factors, brake power was enhanced by reducing intake temp and raising RON. Generally, the experiment results demonstrated that utilizing higher octane number gasoline under lower intake temperature improved engine performance which demonstrates higher power, torque, and efficiency with lower bsfc compared to utilizing higher intake temperature and lower octane gasoline.

1. Introduction

The engine is a system that converts a fuel's chemical energy to thermal energy and then utilizes that energy to achieve mechanical work [1]. More than a century had passed since the invention of the IC_E. Now it is the primary source of propulsion power for vehicles, motorcycles, locomotives, and many other machines Zareei et al.[2]. Currently, the S.I_engines utilized in vehicles by different manufacturers were not well suited to our climatic conditions. As a warm country, ours has a wide temperature range difference, ranging between (0 to 50) degrees Celsius in different parts of the country. Considering this wide range of temperatures, it's tough to conclude what temperature seems to be most suitable for engine operating

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https://doi.org/10.30772/qjes.v15i4.806

Nomenclatures:

BP	Brake power (kw)	M	RON 92.2 experimental fuel
bsfc	Brake specific fuel consumption (kg/kw.hr)	m·f	fuel mass flowrate (kg/s)
BTE	Brake thermal efficiency (%)	N	engine speed (rpm)
C.V	the fuel calorific value (Mj/kg)	RON	research octane number
Exp	Experimental data	S	RON 96.4 experimental fuel
IC_E	Internal combustion engine	Sim	Ricardo wave simulation data
L	the dynamometer load (N)	SI_engine	Spark ignition engine
LES	Lotus Engine Simulation	T	the engine torque (N.m)

conditions and provides us the optimum performance in terms of brake power and bsfc. Mishra, P. [3]. This variation in temperature range will have an impact on fuel combustion as well since SI engines release thermal energy when fuel ignites inside the engine cylinder. Then, quick chemical processes take place, but the length of time it takes to combine the right amount of fuel and air relies mostly on the type of fuel utilized and how it is transported to the combustion chamber. For this purpose, the gasoline utilized in internal combustion engines must meet certain specifications. Chaichan et al. [4]. A study by Allawi et al.[5] that compared the performance of gasoline fuel RON 77, RON 82, RON 87, and RON 93 produced in Iraqi oil refineries. Four-cylinder, four-stroke, 2000cc SI_engine was utilized. Researchers compared experimental data with Lotus Engine Simulation models. The LES theoretical results were close to the test data. Raising octane improved BTE, volumetric efficiency, and brake power. Improvements in gasoline fuel fineness with higher octane levels led to a decrease in bsfc measurements between RON 93 and RON 77. Prihatno, A. et al. [6] Investigate how octane impacts the SI_engine. The Investigation utilized octane-rated gasoline (92, 90, and 88). The study was using a 150cc automatic motorcycle. The findings indicate a linear rise in engine performance as gasoline octane rises, and test data for (92 and 88) indicate that brake torque, power, exhaust gas temperature, and brake thermal efficiency rose correspondingly with octane raising. Also, the bsfc was dropped. Ibraheem et al. [7] Study how temperature impacts gasoline engine performance. Four-cylinder SI_engine was utilized for the engine test rig. between 10 to 50 degrees Celsius. Experiments found that when the intake air temperature rises, brake power drops and fuel consumption rises. And lowering ambient air temperature improved brake thermal efficiency. Also, combustion and exhaust gas temperatures rise with ambient air temperature. Pal, R. [8] Utilize a gasoline-powered car with varied speeds and temperatures throughout the year to evaluate the impact of air temperature on vehicle performance. The vehicle's thermal efficiency and mileage improved from January to March and October, according to the study. Thermal efficiency and mileage declined from October to December and March to June. March was the best month for mileage and thermal efficiency. The bsfc increased during October-December and March-June. while the bsfc dropped from June through October. In March, engine fuel consumption was the lowest.

This work intends to investigate the influence of different types of fuel along different inlet temperatures on the performance of the engine through experiments and numerical simulations. with utilizing a laboratory rig four-cylinder spark-ignition engine.

2. Material and method

The studies were conducted utilizing two different grades of gasoline from Iraq on a laboratory test bed manufactured by Cussons Technology model: p8610 utilizing an engine category (Reliant 848cc) four-stroke four-cylinder, water-cooled petrol engine rig. Table 1 displays the SI_engine rig's parameters. Fig. 1 depicts the engine rig utilized during this study also Fig. 2 displays the schematic diagram of the engine setup. To determine the brake torque and additional engine properties, the engine was linked with a hydraulic dynamometer. To evaluate gasoline consumption and flow rate, a fuel measuring pipette and stopwatch had been used. An induction air system with a fixed slop manometer with the orifice had been used to evaluate the consumption of air. The experiments employed gasoline with two different octane ratings. In order to find out the fuel characteristics, the two types of gasoline were tested in the Ministry of Natural Resources laboratory (MNR-Lab) in Erbil. The results of these tests are detailed in Table 2, which provides a list of the various characteristics of gasoline that have been utilized during the experimental tests. The two types of gasoline are identified by the symbols (S) for RON-96.4 and (M) for RON-92.2 respectively. The experimental tests were done with a constant throttle opening (50%) during engine speeds ranging between 1300 rpm to 2500 rpm at half load conditions under various intake temperatures of (25Cº, 35 Cº, 45 Cº, and 50 Cº). As the tests were carried out in May, a temperature lower than 25 degrees Celsius was not an option. The temperature conditions had been maintained by utilizing an air dryer heater, as demonstrated in Fig. 1, and 2 It was joined to a duct that terminated at a gap of 20 cm before the intake manifold. The maximum temperature of the air heater was 65 C°, while the maximum gained hot air temperature was 50 C° due to heat losses through the duct. Two thermostats were utilized to adjust the heat acquired by the electric heater while it passed through the duct.

Table 1. P8610 - Engine technical data. [9]

Engine type	Reliant, 4-stroke, water-cooled, spark ignition engine
No. of cylinder	4-In Line
Firing order	1 – 3 – 4 – 2 (No.1 at the free end)
Bore	62.52 mm
Stroke	69.09 mm
Capacity	848 cm3
Compression ratio	9.5:1
Maximum power	30kw at 5500rpm
Maximum torque	63Nm at 3500rpm
Recommended fuel	Premium grade gasoline, octane rating RON 98
Ideal speed	900 rpm

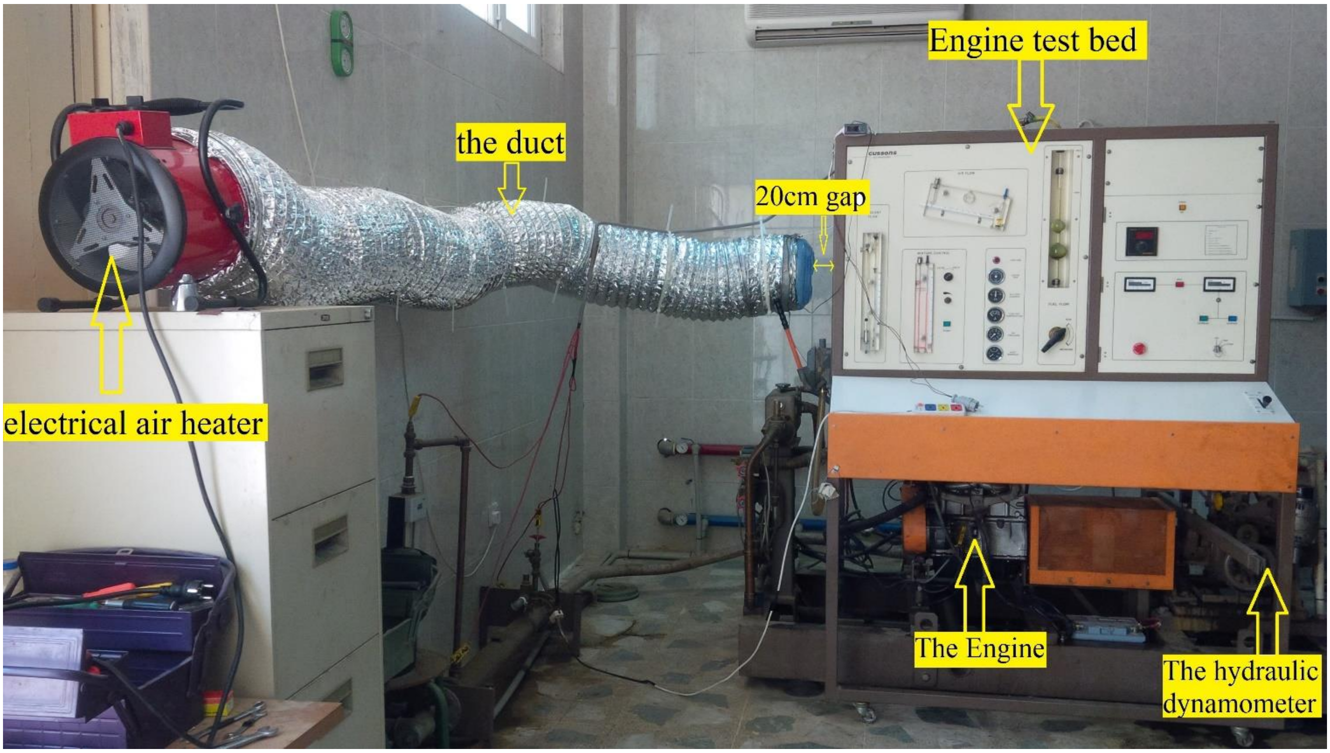

Figure 1. Engine test rig

Table 2. Gasoline usage properties

	Unit	S	M
Octane number	------	96.40	92.20
Specific Gravity@15.5C°	------	00.76	0.737
Total Sulfur content	wt ppm	40.00	29.00
Vapor Pressure at 37.8C°	Kpa	47.00	49.00
Benzene, C_6H_6	Vol%	00.55	00.73
Aromatics content	Vol%	29.00	27.50
Olefin content	Vol%	08.10	01.70
Saturated compound	Vol%	53.00	65.00
Oxygen content	Mass%	02.07	01.30
Methanol, CH_3OH	Vol%	00.00	00.00
Ethanol, C_2H_5OH	Vol%	01.70	01.60
MTBE, Methyl tertiay butyl ether	Vol%	07.30	03.80
Initial boiling point, IBP	C°	49.00	42.00
Final boiling point, FBP	C°	195.0	186.0

3. Theoretical simulation

The engine had been simulated in Ricardo Wave depending upon the measured geometrical characteristics and additional data from the user manual of the engine, **Fig. 3** demonstrates the modelled engine in Ricardo Wave [10]. Ricardo WAVE software makes several assumptions for fulfilling auto-convergence criteria, and after all backend operations have been finished, the brake power and torque with other measurements from the test rig being are matched with simulation outcomes Gilani, R.[11], as explained in the following sections. In the simulating conditions, two fuel files with octane numbers 97 and 93 have been created to simulate real fuel usage. The simulation fuel file (RON97) was used to simulate the real fuel usage of the fuel (S), while the simulation fuel file (RON93) was used to simulate the real fuel usage of the fuel (M). The simulation test was also done with an intake temperature of (25Co, 35 Co, 45 Co, and 50 Co) for both simulation fuel files. This has been done to find out the variance between theoretically and experimentally determined findings for two fuel types.

4. Performance parameters

In order to calculate the engine brake power (BP), torque (T), brake thermal efficiency (BTE), brake specific fuel consumption, the following formulae should be utilized:

a) Brake power

Brake power could be defined as the quantity of work accomplished in a given period of time or the rate at which work is accomplished.

$$BP = \frac{2\pi NT}{60*1000} \quad (1)$$

b) Brake-specific fuel consumption

The brake-specific fuel consumption (bsfc) measures how efficiently the engine utilizes the gasoline it consumes.

$$bsfc = \frac{\dot{m} f}{BP} \quad (2)$$

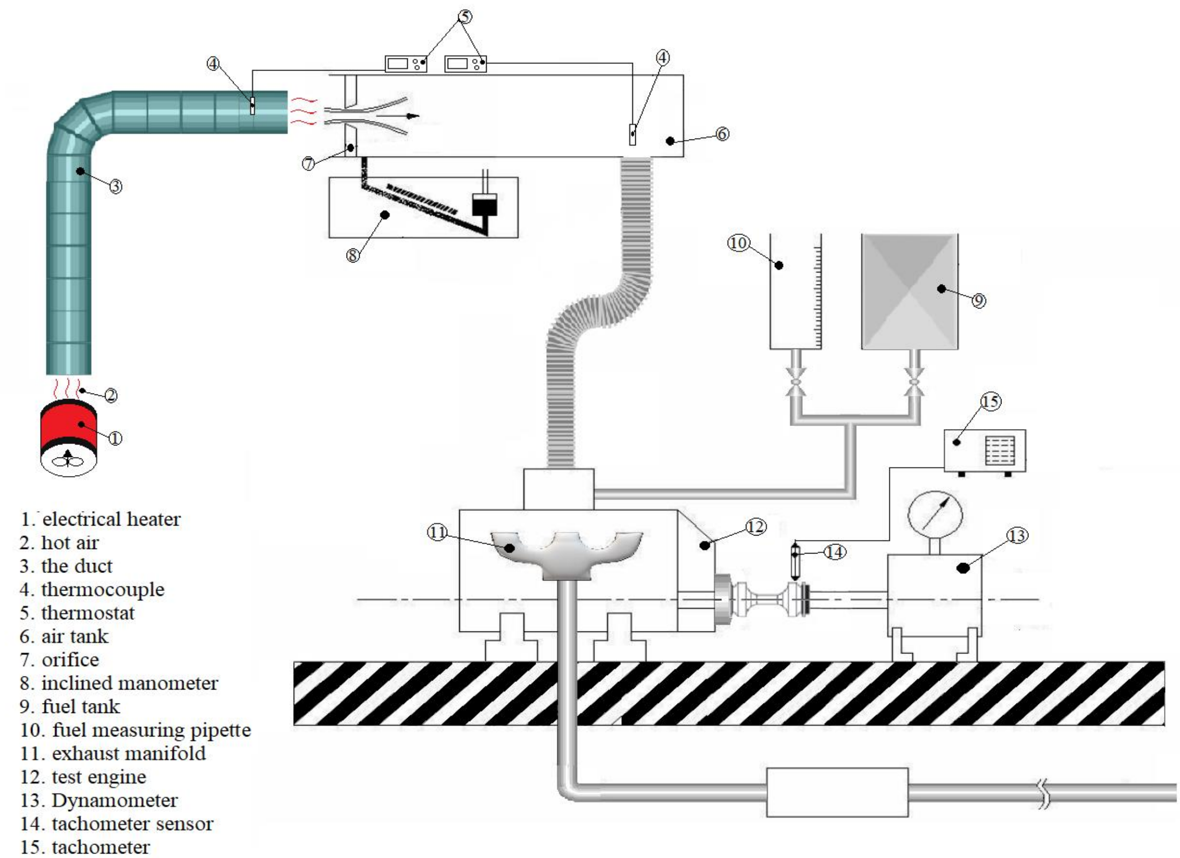

Figure 2. Engine test set up

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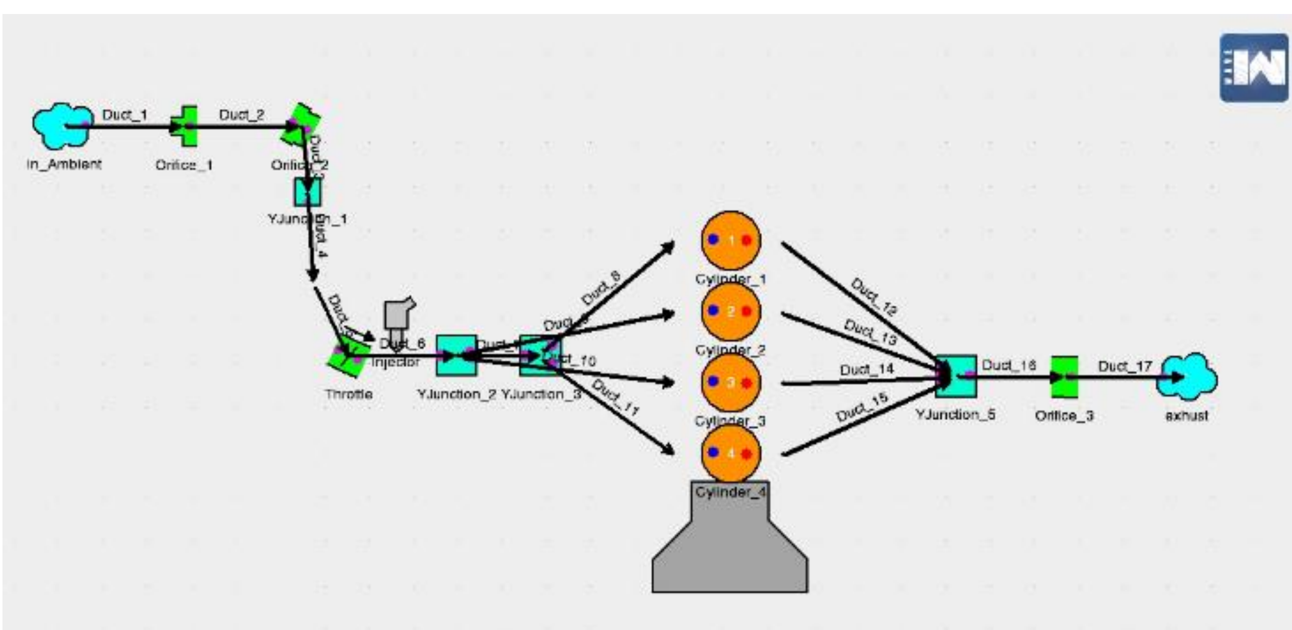

Figure 3. Modeled engine in Ricardo wave software

c) Brake thermal efficiency

The (BTE) is a ratio that refers to the relationship between the brake power produced by the engine and the fuel energy that is delivered to the engine.

$$BTE = \frac{BP}{\dot{m}f * C.V} \quad (3)$$

d) Torque

The term "torque" refers to the capacity of the engine to transfer the generated power, and it is evaluated. A dynamometer is the instrument of choice for measuring the torque produced by an engine.

$$T = L * r \quad (4)$$

Where:

r: is the torque arm = 0.254 m [9]

5. Results and discussions

Engine performance was tested by using two types of gasoline fuel (S, M) under five different engine speeds (1300, 1500, 1800, 2000, 2300, 2500) temperatures (25, 35, 45, and 50 °C) Brake power (BP (kw)) and torque (T (N.m)), brake specific fuel consumption (bsfc (kg/kw.hr)), brake thermal efficiency (BTE (%)) were all determined. All findings were taken immediately from test data or computed utilizing Ganesan [12].

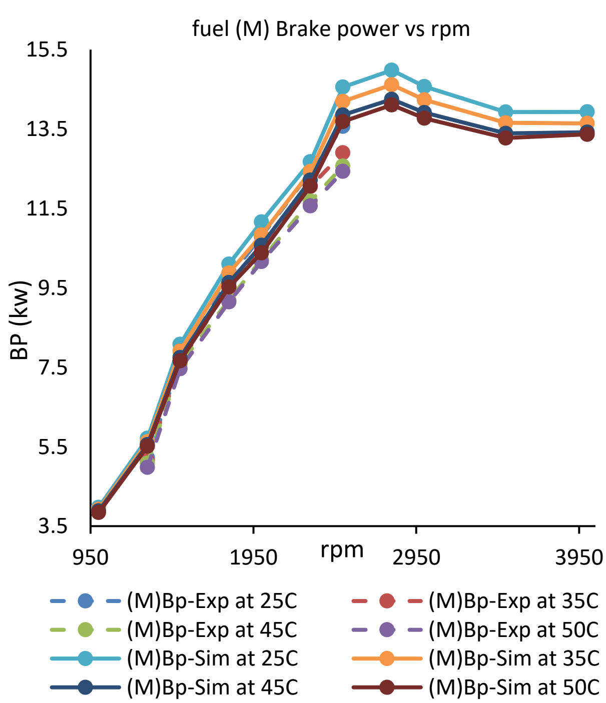

Figure 4. Fuel (S) theoretical and experimental brake power vs speed

This experiment data was matched with simulation outcomes, where the theoretical outcomes were in good match with the experimental outcomes. It showed a near 5% to 10% variance between simulation and practical data. This variance was due to the fact that the simulation's findings didn't consider the engine's losses caused by utilizing an old lab engine. The following figures demonstrate the outcomes of the combined and computed data from the experiments and the simulation program:

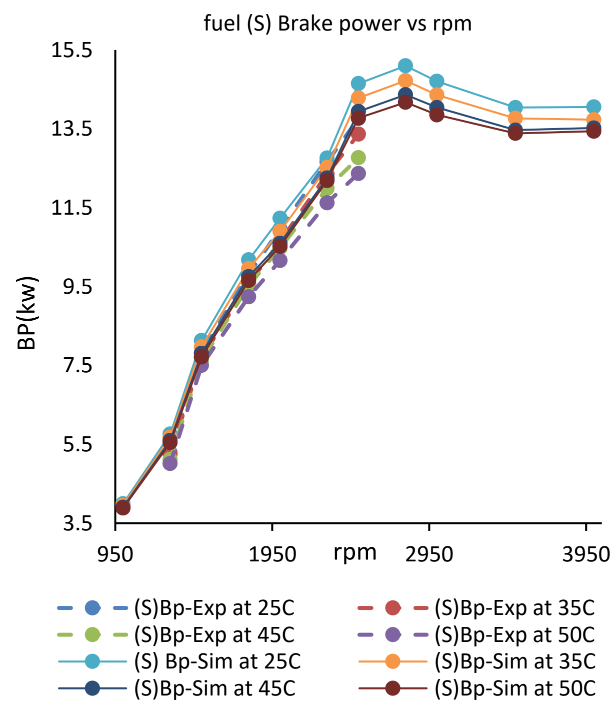

Figure 5. Fuel (M) theoretical and experimental brake power vs speed

Fig. 4, and 5 illustrate the connection between engine speed (rpm) and brake power, when utilizing different fuels and intake temperatures. increasing the octane number increases brake power by (2 % for all speed ranges) when utilizing (S) gasoline in comparison to fuel (M). however, in the simulation model, the BP was larger by (0.75%) when utilizing the RON97 model in comparison to the RON93 model at various engine speeds. The results demonstrated that the brake power dropped as the inlet air temperature rose, and the BP was reduced for fuel (S and M) by (%2 for speed below 2000 rpm and 3% for speed above 2000 rpm) for every 10-degree increase in temperature. **Fig. 6** demonstrate a comparison of BP between (25C° and 50C°) degrees, the BP was decreased by (5% during speeds below 2000 rpm and 9% for speed above 2000 rpm) when fuel (S) was utilized, and reduced by (5% for speed below 2000 rpm and 8% for speed above 2000 rpm) when fuel (M) was utilized.

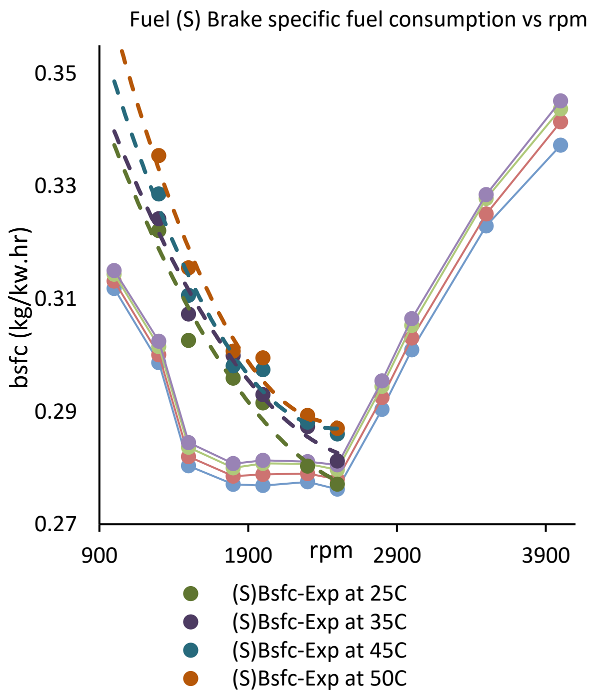

Figure 6. Brake power vs speed at (25C° and 50C°)

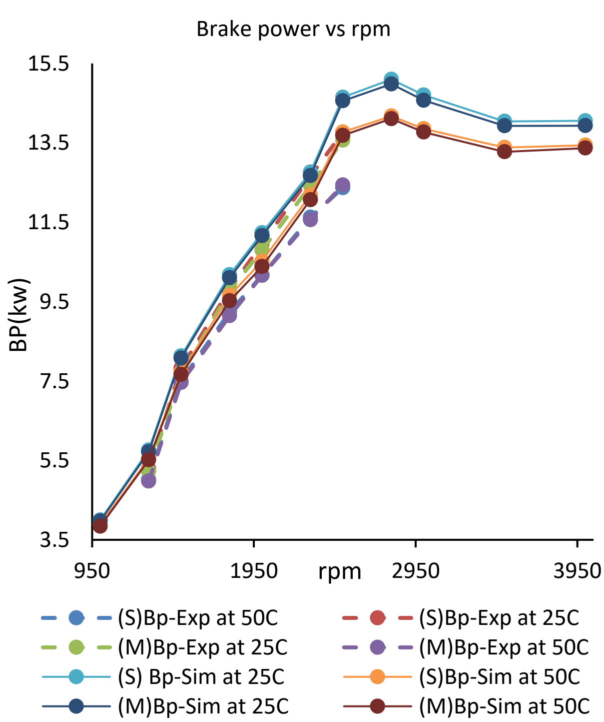

Figure 7. Fuel (S) theoretical and experimental brake-specific fuel consumption vs speed

As demonstrated in **Fig**. **7** and **8**. For higher octane number the bsfc was lower by (2% during engine speeds below 2000 rpm and to %4 for engine speed above 2000 rpm) for fuel (S) in comparison with fuel (M). However, in the simulation model, the bsfc for RON97 was lower than for RON95 by 0.7 percent. the bsfc incensement with increasing inlet air temperature was (1% for all speed ranges) higher for fuel (S) also the bsfc increased by (1.5 % for all speed ranges) with utilizing fuel (M) in each 10-degree temp incensement. As descript in **Fig. 9** The bsfc in comparison at two diff temp of (25C° and 50C°) was shown an increment by (4.5% for all engine speed) for fuel (M) and (%3 for all engine speed) for fuel (S).

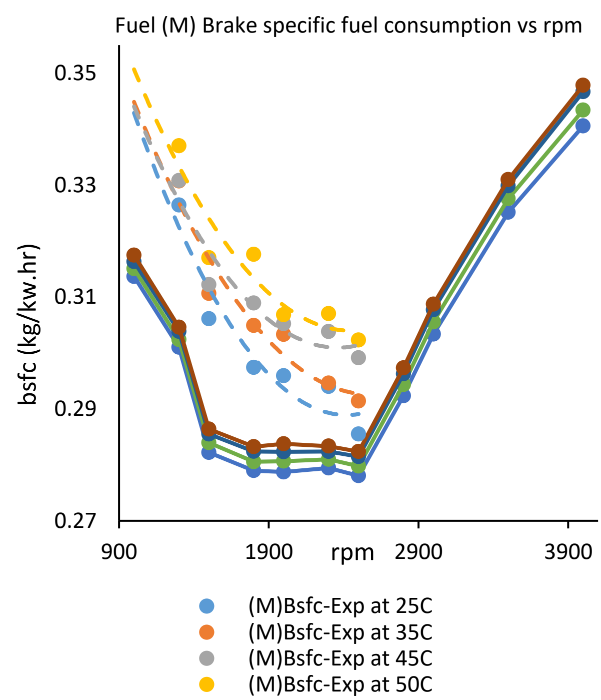

Figure 8. Fuel (M) theoretical and experimental brake-specific fuel consumption vs speed

Fig. 10, and 11 presented the connection between brake thermal efficiency and engine speed (rpm) utilizing various fuels and intake temperatures. In comparison to fuel (M) the BTE increased with fuel (S) by (1% during speeds below 2000 rpm and to 3% for speeds above 2000 rpm) however in the simulation model, the BTE was larger by (0.2%) when utilizing the RON97 model in comparison to the RON93 model. the BTE was reduced by about (1% for all speed ranges) for fuel (S) and by (1.5% for all speed ranges) when fuel (M) was utilize with an increment for every 10 degrees in ambient air temperature. In a comparison of BTE between temperatures of (25C° and 50C°) as displayed in Fig. 12, the findings indicate that the BTE became lower by (3% for all speed ranges) for fuel (S) and (5% for all speeds range) lesser while fuel (M) was utilized

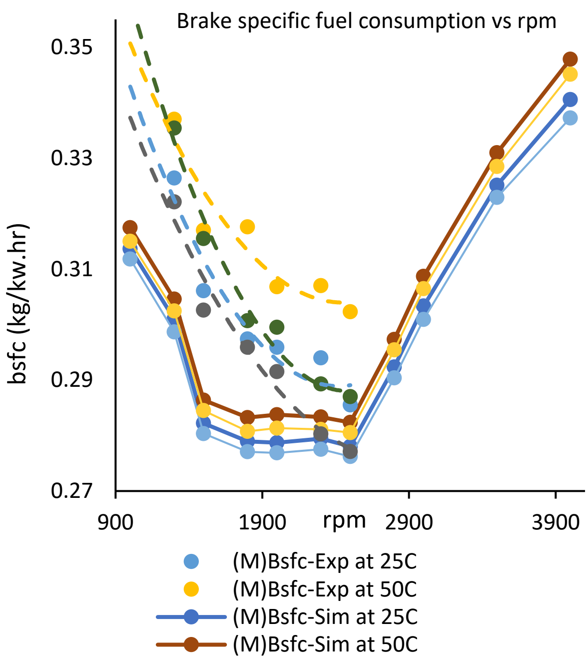

Figure 9. Theoretical and experimental brake-specific fuel consumption vs speed at (25C° and 50C°)

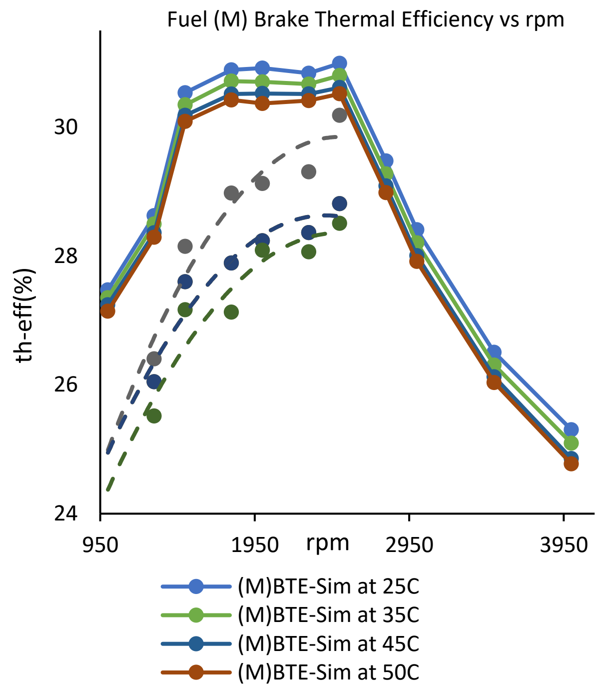

Figure 11. Fuel (M) theoretical and experimental brake thermal efficiency vs speed

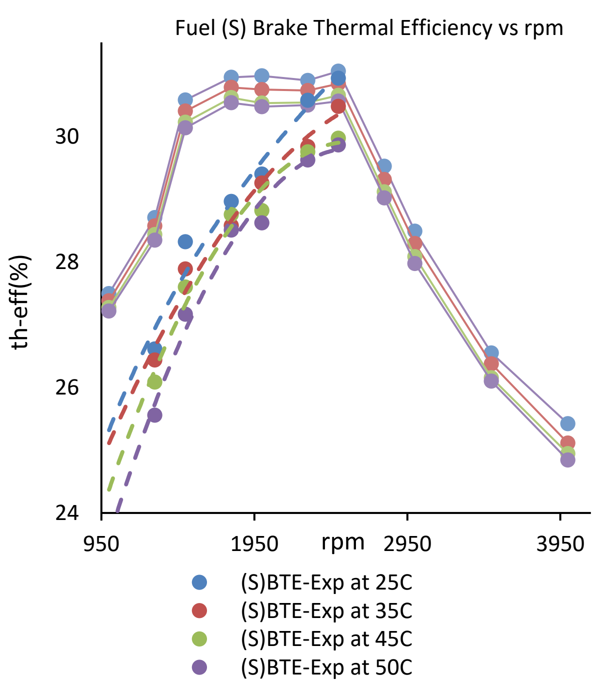

Figure 10. Fuel (S) theoretical and experimental brake thermal efficiency vs speed

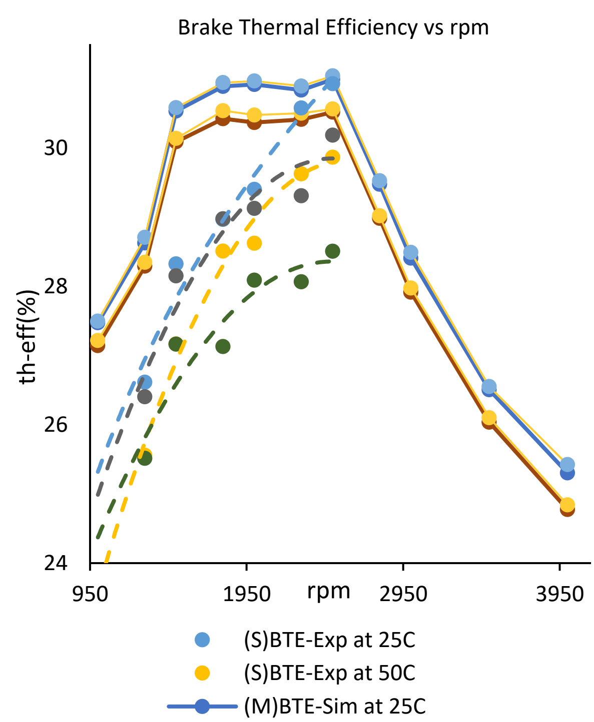

Figure 12. Theoretical and experimental brake thermal efficiency vs speed (25C° and 50C°)

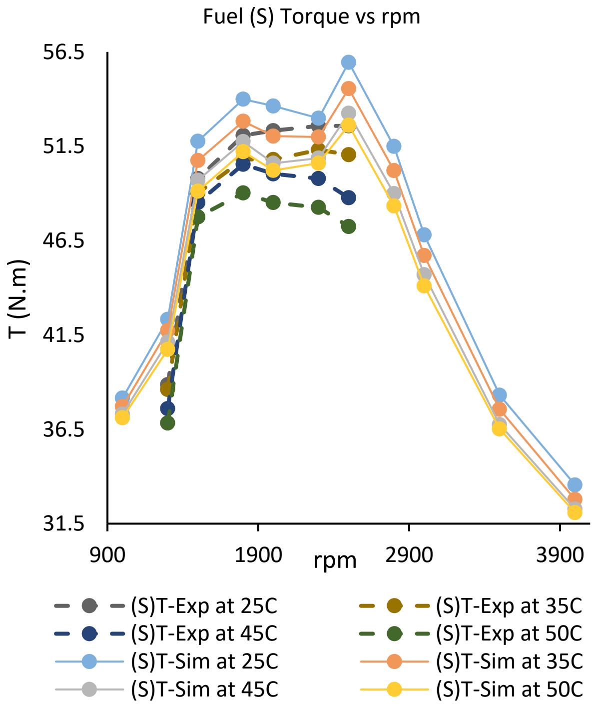

Figure 13. Fuel (S) theoretical and experimental torque vs speed

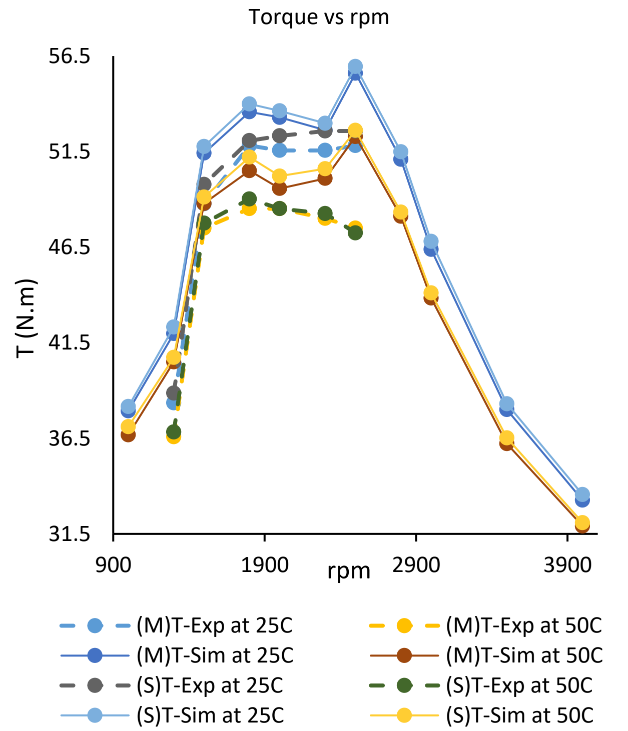

Figure 15. Theoretical and experimental torque vs speed at (25Cº and 50Cº)

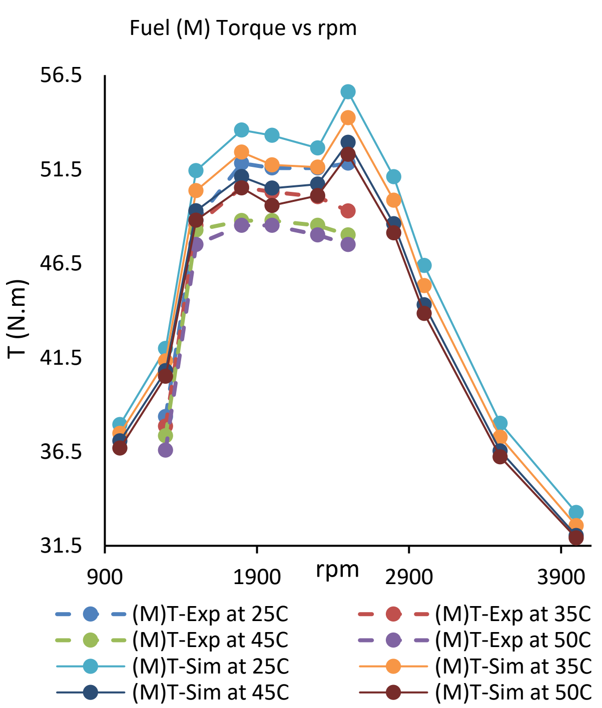

Figure 14. Fuel (M) theoretical and experimental torque vs speed

As demonstrated in **Fig. 13** and **14** the torque was improved with using fuel (S) by (2% for all engine speed) in comparison with fuel (M). also in the simulation model, the torque for RON97 model was higher than RON93 model by 0.75 percent. And for the temp effect, it was observed that the torque was reduced by (%2 during speeds below 2000 rpm and 3% for speeds above 2000 rpm) for both fuels (S and M) for each 10-degree rise in temperature. in a comparison between temp (25Cº and 50Cº) as displayed in **Fig. 15**, the torque was lower by (5 % during speeds below 2000 rpm and to 9 % for speeds above 2000 rpm) for fuel (S) and by (5 % during speeds below 2000 rpm to 8 % for speeds above 2000 rpm) for fuel (M).

6. Conclusion

Experimental research had been done on the engine performance while utilizing (M), and (S) gasoline types at various intake temperatures (25C°, 35C°, 45C°, and 50C°). On a realistic engine model, the study had been theoretically and empirically investigated. The experimental and simulation findings underwent analysis. The following are the main conclusions reached by this study:

- The performance of gasoline engines is influenced by the octane rating and intake temperature.
- Ricardo Wave software had been utilized to predict engine performance. The experimental values in this study were lower than the theoretical software calculations because of the losses in a gasoline engine. The variation between numerical and experimental results in all cases and conditions was around 5% to 10%.

- The brake power was lower with increasing inlet temperature due to the inlet temperature effect on the ignition point. While lowering the inlet air temperature raises the BP because denser (more oxygen) air allows for a greater mass flow during each piston cycle. Additionally, utilizing fuels having a higher RON increases BP owing to gasoline's purity, high quality, and its greater hydrogen content. Hence, due to these factors, brake power was enhanced by reducing intake temperature and raising RON.
- The bsfc was strongly dependent on engine power. As mentioned in the previous point, when BP is decreased, the engine utilizes a lower amount of fuel mass per unit of power, which produces a lower amount of bsfc; in this case, the bsfc was decreased by raising RON and reducing intake temperature. According to the results, the bsfc was lower above an engine speed of 2000 rpm for both fuels, and that was due to less friction power.
- With increased RON and decreased intake temperature, the brake thermal efficiency (BTE) was noticeably improved.

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