Gasoline Engine Simulation Software: A Comparison Review

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Abstract. In this review, a survey of previous studies has been conducted on the use of simulation software to evaluate the performance of spark igniting engines. Some of the gaps in the simulation software used by researchers requiring further research and consideration of their potential impact on the writing of the topic under discussion. The results of the simulation software have led to the ability of these models to predict engine performance, and show good agreement between the experimental results and the results predicted by the simulation software. These findings increase the reliability of simulation software, which can replace the experimental tests and in turn reduce the cost. This will also provide a platform for the researchers to expand their experimental through varying the different parameters instantaneously to get the optimum performance criteria.

1. Introduction

For some sectors, such as transport, gasoline engines contain specifications that enhance their use, particularly for vehicles with high acceleration capacity in a relatively short time [1-4]. Around the beginning of the 20th century, low octane fuel was used to power gasoline engines due to the higher compression ratio. The current design however needs a high octane number fuel to achieve the high performance necessary [5-6]. The fuel burning in the spark ignition engines is caused by a spark plug in the engine head cylinder and the ignition engines are called a spark because of this fact. The fuel used in such spark-ignition engines is petrol, and therefore the spark-ignition engines are also known as petrol engines. The spark ignition is either two-stroke or four-stroke engine [7-10]. The stroke is the angle over which the piston travels through the cylinder in one direction. For four-stroke engines, the crankshaft rotates two cycles to allow the fuel burn. The power is generated every two cycles of the crankshaft as shown in Figure 1, meaning that the fuel pumped into the cylinder is burned for every four-piston movement hits [11-15]. The crankshaft rotates one cycle in two-stroke engines to allow the fuel burn. The power generated every cycle of the crankshaft as shown in Figure 2, which means that the fuel pumped into the cylinder is burned for every two-piston movement strokes. Thus, it is safer to have two-stroke engines twice the power of four-stroke engines for the same engine size [16,17].

Alternative fuels are currently focused on by many researchers due to the limited sources of fossil fuel and their rapidly increasing prices [18-23]. However, the utilization of these fuels still limited due to their characteristics that should suit the design of the IC engine which is fabricated based on fossil fuel properties [6], [24-29]. Many attempts were conducted to improve the different alternative fuels properties to meet that of mineral fuel [30-40]. Recent studies found that fuel additives are the most viable suggestion to improve fuel properties within the fuel standard specifications [41-47]. Different types of additives have been suggested and investigated by the researchers to operate the CI engine and SI engine [48-57]. Investigation of these additives implies a costly engine test rig in addition to the utilization of...
fuel and additives blend to operate the engine which needs for a relatively long time to complete the test [58-65]. Furthermore, the accuracy of the experimental tests depends on many factors including the lab test conditions which may vary from test to another depending on the environmental conditions [66-68]. Therefore, simulation software implementation can provide an important platform for the researchers to provide a viable and cheap way for engine test and data collection.

One of the researcher's main issues is improving the performance of internal combustion engines. Experimental experiments are costlier than theoretical studies. The use of theoretical techniques also enables us to obtain all the data needed for the cylinder, which could not be measured.

**Figure 1.** Four-stroke engines power cycles.

**Figure 2.** Two-stroke engines power cycles.
2. GT-power simulation

Theoretical research was performed by Osama H. Ghazala & Gabriel Borowski [69] to check the effect of water injection on spark-ignition engine output and emissions. Four-cylinder spark ignition engine model has a GT-power configuration. Results show improved engine performance and decreased emissions when the water mass flow rate rises when opposed to gasoline. Additionally, the injected water has lowered the temperature within the cylinder, cooled parts of the engine, avoided knock, and increased engine longevity.

SAIF Salih & Dan DelVescovo [70] developed and validated the GT-power fuel research engine (CFR-Cooperative Fuel Research Engine) one-dimensional engine model according to RON and MON standard conditions (ASTM 2699 and ASTM 2700 respectively) and using experimental data from applicable research into the N-heptane and ISO-octane fuel mixture (PRF, PRFS, and TPRFS). To validate this technique according to the protocols of ASTM 2699 and ASTM 2700, (TSFS) fuels were used. The results gave the (PRF) and a set of standard fuels (TSFS) containing octane numbers 90 to 100 strong approval for those tests.

S. N. Soid et al. [71] conducted a study to boost methane engine performance by adjusting the cam timing angle of both the intake and the exhaust valves. An engine model based on a single-cylinder gasoline engine, 4-stroke, Modenas Kriss 110 CC size, was built using the GT-Power to analyze engine performance. The findings were that the methane engine produced about 20.1 percent less for brake torque, brake power, brake mean effective pressure compared to the gasoline engine, and 12 percent less for peak pressure inside the cylinder. He found that if the valve timing differs, retarding at approximately 10 degrees when the exhaust valve was opened would lead to the highest braking power in the 5-10 percent range. The average percentage error between the experimental data and GT-Power simulations is around 4.1 percent for brake torque, brake power, brake mean effective pressure, and peak pressure inside the cylinder is about 5 percent. This renders the model robust for simulation use.

Amir-Hassan Kakee [72] studied improving the timing of the exhaust valve and inlet, as well as the timing of the XU7/L3 engine's spark and air-to-fuel ratio, designed the GT-Power engine model, and then improved it using MATLAB. Using the algorithm and the most straight down algorithm, tests at full load display a 5 percent and 5.1 percent decrease in fuel consumption, in addition to a 5.65 percent and 6 percent increase in brake torque. The optimization of these models reduced this model error relative to the experimental findings. The overall error rate is less than 2 percent between the model and the experimental results.

Shaiful aiman M. & sharp Nizam M. S. [73] conducted a study on the combustion of spark engine and performance of engines using hydrogen gas. By implementing the tested GT-Power model, this work contributes to knowledge of hydrogen feed spark engine and confirms previous findings on hydrogen activity in internal combustion engines. The result of this study is that the hydrogen engine has lower braking torque, braking power, mean effective pressure, and lower BSFC than the gasoline engine. But it is more efficient since the BSFC is less.

Hadi Adibi-ASL [74] studied the spark ignition engine modeling based on mathematical analysis, including predicting the emission of control applications, a gasoline engine model is developed based on mathematical control application laws and real-time simulations. This model was built in the environment MapleSim. The model must be accurate enough with adequate speed for real-time simulation purposes to capture the combustion properties and predict emission gasses. Part of the results of the simulation is checked with the results of the GT-Power simulation. The model proposed is ideal for designing spark-ignition engines, for example, emission control. Symbolic sensitivity analysis can also be tested with ease using MapleSim 's symbolic design in modeling to test the impact of parameters on engine performance.

3. CFD simulation:

Simeon Penchev Iliev et al. [75] was able to study the development of a one-dimensional combustion model for a four-stroke spark engine, to predict the effect of different fuels on engine performance, emissions, and BSFC under different engine operating conditions. This used the computational fluid dynamics simulator CFD to evaluate the output characteristics and emissions of different combinations of
ethanol-gasoline from 30% ethanol (E0), 5% ethanol (E5), 10% ethanol (E10), 20% ethanol (E20), 30% ethanol (E30), and 50% ethanol (E50) (depending on size). And under full load conditions at velocities ranging from 1000 to 6,500 rpm. The findings were that the ethanol-containing gasoline showed lower braking power, lower brake torque, and higher BSFC. When the ratio of ethanol increases, CO and HC decrease, and NOx increases.

Ashish J. Chaudhari et al. [76] study on spark ignition engine simulation Models: a performance comparison test and a one-dimensional model of any hydrocarbon fuel based on the webe heat release feature of the simulation. To model the engine cycle he developed the Annand model of heat loss. Using the experimental results they were able to validate the simulation findings. They found that the peak pressure at low intake pressure is similar to the experimental trend during the combustion landing. With speed increasing from 1,000 rpm to 4,000 rpm, the braking thermal efficiency drops from 25% to 17%. They then managed to perform a 2D CFD simulation on the experimental engine they set up at rated engine rpm (1.8 HP at 3600 rpm). CFD results with the simulation model show that at low speeds (1000 rpm), the maximum cylinder pressure prediction is approximately 8% higher for CFD analysis. This disparity was around 3 percent higher (3600 rpm). We then used the simulation model to test and equate the braking power to the experimental findings and the CFD studies. They found that both forecasts complied well with the experimental results.

Kota Sridhar et al. [77], conducted a study to simulate four-stroke internal combustion engine. Simulation of all motions of drag, compress, stretch and exhaust were included in this study. They have made extensive use of CFD analysis to improve each of those processes. The simulation model they were able to develop successfully captures a single-cylinder spark engine which runs as fuel on the two-cylinder C6H14. Observe the effect at various angles of rotation at a different time of flow. At a different flow time, they were able to find the maximum and minimum values for volume and static pressure rate, mass, and static temperature, the predicted mass fracture distribution, and the hexane fuel static heat distribution (C6H14). The CFD model's operating range was broad and the measurement period was limited, making the simulation software ideal for use with thermodynamic cycle simulations in ignition engines working with the hexane fuel (C6H14) combustion optimizer. Thanks to its simplicity the model can be used to enhance functionality for a wide variety of different fuels.

The results from this study can be supported by the work of S. AdiLOğlu et al. [78] whom studied the development of a one-dimensional four-stroke spark engine model for predicting the impact of different fuels on engine performance, BSFC, and emissions. They used the CFD Computational Fluid Dynamics Simulator software to evaluate engine characteristics for various types of ethanol-gasoline (E0, E5, E10, E20, E30, E50), methanol-gasoline (M0, M5, M10, M20, M30, and M50) (by percentage size). They contrasted the results obtained from simulating the engine by combining the different fuel provided by gasoline. CO and HC emissions are decreased when blended fuels are increased, and there is also a substantial rise in NOx emissions when blended fuels are increased by up to 30 percent E30 (M30). The increase in the proportion of ethanol and methanol has resulted in a substantial rise in NOx emissions. C.D. Rakopouloua et al. [79] studied the theoretical and experimental study of hydrogen fuel spark engines, focusing on combustion efficiency, heat transfer and heat loss to cylinder walls, and performance where the air-to-fuel ratio and compression ratio varied, was presented. In addition to the experimental study, the theoretical findings obtained from the CFD simulation were used to gain a more comprehensive view of the process of heat transfer and the efficiency of the combustion of hydrogen for the different cases they tested. They drew the following from the results of these tests:

A low fuel/air ratio means the temperature of burning gas is maintained at a constant level and the temperature loss is very small. The higher the load and usage of similar mixtures, the higher the wall and gas temperatures within the container, the higher the temperature and the less pollutants. Because of the high rate of hydrogen combustion and subsequent high temperature.

The output of combustion increases marginally but the indicated output is decreased by the loss of a higher temperature.
Yujuun Wang [80], presented a test study and modeling a spark engine output and emissions which works with natural gas hydrogen mixtures. Based on a multi-dimensional CFD system, as well as comprehensive reaction couplings to test H2 / CNG engine combustion. They were able to use experimental data to verify the model. Results reflected: The simulation cylinder pressure shows strong agreement with the experimental results, and the model well anticipates CO and NOx emissions, where CO emissions are reduced and NOx emissions are increased in pregnancy from 15% to 20% for HCNG and CNG. But there are slightly higher NOx emissions at the HCNG engine.

4. ANN simulation:
G. Najafi et al. [81], investigated the method and theory of evaluating the performance and emissions of pollutants caused by a four-stroke spark engine running on an ethanol-gasoline mixture of (0 percent, 5 percent, 10 percent, 20 percent) using the ANN system were examined. Experimental tests have shown that fuel usage combined with ethanol and gasoline improves the brake torque and brake power. They found that the common, BSFC for ethanol blends, while the brake thermal efficiency, increased. They assessed concentrations of CO and HC in the exhaust pipe and found that by using ethanol blends, they were that. Once ethanol was added CO2 and NOx were shown to increase. Using a mixture of gasoline, ethanol, and different speeds, they then used the ANN Program to predict the relationship between brake power, brake torque, BSFC, and brake thermal efficiency. The findings have been that the ANN Program Model can predict engine output and exhaust emissions in the range 0.97-1 with a correlation coefficient (R). The MRE values were 0.46-5.57 percent in the range, while the RMSE was too low.
H. Serdar Yu’cesu et al. [82], conducted a comparison of the statistical and experimental performance analysis of a spark-ignition engine using ethanol-gasoline mixture fuel has been studied. The analysis was composed of two cases: Experimental analysis for a four-stroke spark engine in which they were able to test lead-free gasoline blends with ethanol (E10, E20, E40, E60) in one cylinder. By adjusting the ignition timing, relative air-fuel ratio, and compression ratio at a constant speed of 2,000 rpm with wide-open throttle (WOT), they managed to conduct the tests then. Instead, check the variables in the experimental form on brake torque and BSFC. Study of mathematical modeling: they used the ANN system to calculate the engine torque and BSFC according to the ignition timing, Relative air-fuel ratio, and compression ratio at a constant speed of 2,000 rpm and when the WOT is widely opened to varying densities. They found the best theoretical analytical results to be appropriate, allowing for brake torque and BSFC to be obtained at least as accurately as the experimental error.

5. FORTRAN simulation:
Yakup Sekmenb & Perihan Sekmena [83], performed a mathematical simulation of a single-cylinder four-stroke spark motor with real air cycle and fuel cycle research. We were able to use FORTRAN in this study to model the complex thermal process and performance analyzes of different engine speeds (1,800, 2400 with 3600 1 / min) Some EAC over-air variables (0,95-1,05) rotate the CA pitch angle one degree at full load And CR 8:1 constant pressure ratio for a gasoline four-stroke engine and one cylinder. They were able to measure engine output parameters; effective brake pressure, brake power, brake thermal efficiency, BSFC, and evaluate with the software the values of the higher cylinder maximum pressures, temperatures, and pressures. Such variations are shown graphically with the rotation angle, engine rpm, and overflow factor. For previous studies, the measured results showed strong support. They also found that different pressures, load ratios, and engine sizes could be set using this simulation program.

6. Visual Basic simulation:
Maher A. R. SADIQ Al-Baghdadi [84] developed, tested, and validated a mathematical model against experimental data to simulate a 4-stroke cycle of the gasoline, ethanol, or hydrogen-fed spark engine as a single fuel or liquid. Using Visual Basic. The first Thermodynamic law and the conservation of energy and mass laws were introduced in the mathematical model. The results of this study suggested the ability of the model to satisfactorily predict performance and emissions. There was a strong agreement between the model results and the experimental findings. The key conclusions from this analysis are as follows:
Hydrogen can be used without significant changes as an additional fuel in modern spark engines and can help to provide a substantial portion of the available oil and save our atmosphere from harmful pollutants. Ethanol can be used in modern spark ignitors as a fuel replacement of up to 30 percent gasoline without significant adjustments. It also improves output power and reduces NOx emissions for a hydrogen-fuelled fuel engine.

Additional hydrogen improves combustion, particularly in the event of subsequent combustion, reduces ignition delay, increases forward flaming speed, and reduces combustion time. The timing of the spark is thrown off. Ethanol mixing reduces carbon monoxide, oxides of nitrogen, and a maximum temperature. Osama H. Ghazal [85] conducted a theoretical study to check the effect of different fuels on the performance of gasoline engines at different engine speeds. To display the effect of different fuels on it, it measured the braking power, brake torque, and BSFC. He used Visual Basic using an arithmetic system.

He developed and measured a model for a single-cylinder gasoline engine for simulation. Performance review reveals that methanol braking power is 30 percent higher at 1,000 rpm and 16 percent higher than methane at 6,000 rpm. The increase in BSFC is around 100 percent at 1000 rpm and 115 percent at 6,000 rpm for the same compared to gasoline. The rise in gasoline brake thermal efficiency is about 11 percent compared to methane at 1000 rpm and methanol at 7 percent compared to methane at 4,000 rpm. He concluded that using methanol as fuel at high engine speed for a gasoline engine is high braking thermal efficiency and high braking power. In low and medium engine speed gasoline fuel is more powerful.

7. MATLAB-Lotus Engineering - Scilab simulation:
Talal Yusaf et al. [86] studied the performance and emissions of ethanol derived from potato waste (bioethanol) and its gasoline mixtures (E5, E10, E15, E20), and experimentally and theoretically tested and compared with gasoline fuel. We adapted the four-stroke gasoline engine cycle model in the theoretical study which works with gasoline-ethanol blends. They then developed a mathematical model using the MATLAB software to predict the efficiency of the engine at different mixture ratios, using the first law equations of thermodynamics and conservation law. They were able to experiment with mixtures that included 5, 10, 15, and 20 ethanol (depending on the percent size). The findings showed an increase in gasoline-ethanol would increase the power of the engine and the torque. They found that the use of space fuels decreased by 5 percent and 10 percent ethanol for the ethanol mixture while the braking thermal efficiency improved.

Osama H. Ghazal [87] presented a theoretical analysis of the effect of various fuel systems and heat transfer models on the performance of a single-cylinder spark engine with four-stroke. For varying engine speeds. The simulation of methane combustion with various models of heat transfer combined with different fuel injection techniques has provided a deeper understanding of and heat transfer cycle inside the internal combustion engine as reflected in engine output. Using Lotus Technologies for simulation. Models of heat transfer for petrol engines are used in the simulation of Annand and Woschni. Results show that the use of the Woschni gasoline engine with methane fuel is recommended for all engine speeds because it has a high breakout power, high-profit thermal efficiency, and reduced BSFC. This is well-matched with the heat transfer process for the petrol fuel.

Dr. Christian von Kerczek et al. [88] have studied the theory of thermodynamics, which explains the main physical processes that exist inside the internal combustion engine, which is a four-stroke spark-ignition engine while running at a constant speed. We were able to numerically create and apply a mathematical model of dynamic thermal theory through a computer program named "Schildab." The result is a computer simulation of the internal combustion engine "Adebatli engine". They were able to use this computer simulation to produce some relatively accurate estimates of engine output over a range of engine speeds, with significant effects of heat, spark timing, other aspects of valve timing, valve size, and fuel types. Comparing these values to the values achieved in the heat transfer model for the final system, they concluded that the brake thermal efficiency values are small. For 6,000 rpm, for these simulations, thermal efficiency contributes to (Q=0) being 77 percent.
8. Simulation by mathematical model:
Haifeng Liu et al. [89] conducted a theoretical study on a brake thermal efficiency of spark engine using a one-dimensional simulation based on the first law of thermodynamics. And assess the energy balance through various variables such as compression ratio (CR), heat transfer parameters, drag charge characteristics, and combustion stages. We have been shown to have an impact on the limits of brake thermal efficiency. The results show that for the selected heat transfer coefficient, the CR is optimal for maximum efficiency. Ideal CR decreases with increased heat transfer factor, and high CR with low heat transfer factors can achieve significantly high efficiency. High density and special heat for the haulage, plus a shorter burn time with the correct CA50 (turning angle at 50 percent of total heat release), will greatly improve the engine brake thermal efficiency. Methanol demonstrates excellent scalability in rising the maximum temperature inside the cylinder, and comparatively more effective than other fuels tested. All these operations with a high-pressure CR system result in high temperatures inside the cylinder.
A. Gómez et al. [90] studied modeling and improvement of the Otto cycle using ethanol-gasoline blends, in this study, were able to present a mathematical model to determine the ratio of air-to-fuel degradation from biodiesel to ethanol-gasoline in the range of 0 percent to 100 percent of ethanol moles in blending. The model is based on a chemical combustion study of any gasoline-ethanol structure. They then developed an Autocycle study with an optimum air-to-fuel ratio model and compression ratio. Results showed that the ratio of air-to-fuel degradation in the biofuel mixture of gasoline-ethanol is not linear. The maximum difference between the expected and calculated air-to-fuel ratios was 7 percent in the full range of the mix. The analysis of the Otto cycle, using the derived equation, shows that power and torque decrease when the engine grows with ethanol.
A. E. Khalifa et al. [91], performed experimental and theoretical studies to investigate and compare the effect of the use of gasoline mixtures, i.e. 91 octane and 95 octane, on the output and exhaust emissions of a spark-ignition engine at various engine speeds and loads. They found that they provided high power and a lower BSFC when using octane fuel 91 compared to 95 at engine speeds below 3500 rpm. Mixtures do not show a propensity to knock. All fuels show similar patterns in the exhaust for CO, CO2, and NOx, though unburned HC is marginally higher when 91 octane is used. They found a significant decrease in CO2 concentration, an increase in BSFC of co in the higher speed range between 3,500 and 5,000 rpm. Results showed that both fuels have comparable engine performance, with slight variations.
N. Homdoung et al. [92] presented a practical and theoretical analysis of mathematical models to predict a single-cylinder spark-ignition engine with CR 14:1 output. Usage of gaseous fuel derived from biomass coal. They succeeded in simulating maximum load and varying engine speeds. The simulation results were tested using experimental data for a four-stroke spark engine operating on gasoline and a gasoline/ethanol mixture. The total percentage of braking power, brake torque, brake thermal efficiency, and BSFC was 6.5 percent. Through the test, they found that the model adopted for this work was acceptable and could be used to predict the gas-produced engine output. The average percentage of brake power error, brake torque, braking thermal efficiency, BSFC, was 3.30%, 3.32%, 6.50%, 3.07%, respectively.
K Rezapour et al. [93], Provided a mathematical model of a four-stroke dual-fuel spark ignition engine for comparative studies and study. The model can predict the temperature and brake thermal efficiency, braking power, braking torque, BSFC, mean effective brake pressure, the concentration of carbon dioxide, hydrogen oxide, and nitrogen oxides. They examined the impact of engine rpm, parity, and efficiency variables using gasoline and CNG compressed natural gas fuels. They also tested the model with experimental data using results obtained from a two-fuel engine. Results demonstrate this model's ability to maximize engine efficiency and reduce emissions. CNG also produces less braking power (15.5 percent) than gasoline. The brake mean effective pressure of the engine when fed with CNG is less than gasoline at most (percent 17). The CNG's brake thermal efficiency (percent 4.5) is lower than a gasoline engine. The BSFC for a CNG engine is lower (percent 9) than gasoline.
Zografakis Georgios [94] studied a mathematical simulation and experimental of the flow and combustion processes in a four-stroke spark engine. Use the gasoline engine cycle pattern. He modeled the combustion as a method of spreading a radiant flame. Throughout combustion, assume that the cylinder
charge consists of the field of burned and unburned gases. Created a computer code for the mathematical course model. Using this code, measure the variables that define the combustion cycle and engine output in operation. Simulations were conducted for one engine cycle and the results obtained were given fair approval by the theoretical modeling and experimental data.

Hakan Bayraktar [95] conducted a theoretical and experimental study into the use of gasoline and ethanol blends in the spark ignition system. In the theoretical analysis, he adapted the gasoline engine cycle model with ethanol mixture. He then carried out the experimental study using mixtures containing 1.5, 3, 4.5, 6, 7.5, 9, 10.5, and 12 (depending on volume) ethanol. The experimental analysis was carried out using up to 21 percent (using volume percent) ethanol. Then, with each mixture, run the engine at 1,500 rpm for a compression ratio of 7.75 and 8.25 with the throttle fully open. He then compared the results obtained from theoretical and empirical studies graphically. Experimental tests have shown that the 7.5 percent ethanol combination of different forms was the most suitable blend for engine performance and, on the other hand, emissions (CO). Theoretical calculations revealed that the 16.5 percent ethanol mixture was the most appropriate mixture for gasoline engines.

Abd Alla [96] simulated a four-stroke spark-ignition petrol engine, simulated using mathematical expression assuming a closed system. brake mean effective pressure, brake thermal efficiency, and BSFC. For one cylinder, four-stroke, 76.2 mm diameter, 111.1 mm stroke, and 507 cm³ sweep. Fuel is given an octane value of 43.5 MJ / kg. It found that the effects of the simulation were affected by many factors: The effect of compression: He tested the simulation model with a compression ratio of 5:1 to 11:1, and drew several conclusions that the brake thermal efficiencies are increasing with an increase in compression ratio. Increasing the brake mean effective pressure with increased compression and torque and power increases, as it increases by 12 percent from 5:1 to 11:1. Conclude that the BSFC popular with increased compression. Profit in BSFC is around 21.5 percent of the compression ratio of 5:1 to compression ratio 11:1.

Effects of parity: The mean effective brake pressure peak is 14.52 bar when the equivalence ratio is 1.15, compared to 13.95 bar when the equivalence ratio is one. He noted that brake power is increased at rated speed, brake torque, or brake mean effective pressure by 4 percent and that the thermal gain is 31 percent when parity is 1.

Effects of spark timing: Note that the optimum value of spark timing is 20 ° (TDC) and the brake thermal efficiency is decreased after 20 °.

Effects of the combustion period: The optimum combustion time value was around 30 degrees.

Pressure Index effects (N): Reduced brake thermal efficiency, with a low-pressure indicate.

Table1 presents a summary of simulation software utilized by different researchers with the adopted parameters and key findings of each research.

| Source | simulation software | Parameters | Key Findings | percentage error |
|--------|---------------------|------------|--------------|------------------|
| [71]   | brake torque, brake power, brake mean effective pressure | The results showed that, if the valve timing differs, retarding at approximately 10 degrees when the exhaust valve was opened would lead to the highest braking power in the 5-10 percent range. | Average percentage error between the experimental data and GT-Power simulations is around 4.1 percent for brake torque, brake power, mean effective brake pressure, and peak pressure inside the cylinder is about 5 percent. This renders the model robust for simulation use. | brake torque, brake power, brake mean effective pressure |
brake torque, BSFC

Using the algorithm and the most straight down algorithm, tests at full load display a 5 percent and 5.1 percent decrease in BSFC, in addition to a 5.65 percent and 6 percent increase in torques.

The overall error rate is less than 2 percent between the model and the experimental performance.

brake torque, BSFC

Experimental Results showed that fuel usage combined with ethanol and gasoline improves the torque and braking power. They found that the common, BSFC for ethanol blends, while the brake thermal efficiency, increased. They assessed concentrations of CO and HC in the exhaust pipe, and found that by using ethanol blends, they were that. Once ethanol was added CO2 and NOx were shown to increase.

The findings have been that the ANN Program Model can predict engine output and exhaust emissions in the range 0.97-1 with a correlation coefficient (R). The MRE values were 0.46-5.57 percent in the range, while the RMSE was too low.

9. Conclusion

The current research compares the different software used by researchers to simulate the spark-ignition engine and evaluate thermal efficiency. There are common points among researchers that affect engine performance include the compression ratio, fuel types, spark timing, and intake air-to-fuel ratio, in the use of the Woschni model for heat transfer. They also found that this simulation software can predict the engine performance parameters sufficiently and acceptable. These findings increase the reliability of simulation software, which can replace the experimental tests and in turn reduce the cost. This will also provide a platform for the researchers to expand their experiment through varying the different parameters instantaneously to get the optimum performance criteria.

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