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Effect of Hydrogen Fuel Used in Internal Combustion Engine to Improve the Efficiency of Spark Ignition Engine

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Abstract

The rise in concern over the health and environmental consequences of emissions from transportation, industry, and other utilities has led to a growing interest in alternative fuels. Hydrogen gas, a prospective substitute fuel for internal combustion engines, has the capability to enhance engine efficiency and diminish fuel usage and emissions. Petrol was employed in one phase, while hydrogen (H_2) and benzene were utilized in the other phase to assess the performance of the test engine. The flow rate of hydrogen gas was adjusted to 0.1 and 0.2 liters per minute (LPM). The two models underwent testing at engine speeds of 2000 and 2250 rpm, with varying engine loads (0, 2, 4, 6, 8, 10, and 12 N.m) and compression ratios (6:1, 7:1, and 9:1). The initial trials involved a comparison between pure petrol and dual fuel. The laboratory has achieved numerous exceptional test outcomes. Dual fuel operation at 2000 rpm resulted in a significant improvement in brake thermal efficiency, with an increase of 9.5% and 10.6%. The specific fuel consumption had a reduction of 11.3% and 14.1%, although the volumetric efficiency marginally fell, varying between 1.9% and 2.6%. The brakes achieved thermal efficiencies of 9.6% and 10.7%, resulting in a drop in specific fuel consumption of 11.4% and 14.3%. The volumetric efficiency experienced a minor decrease, ranging between 2.2% and 2.5% at 2250 rpm. Additionally, lower exhaust gas temperatures were observed at each test site. This has demonstrated that hydrogen fuel is a cost-efficient substitute for conventional petrol, without requiring any modifications to the engine. This has significant economic importance.

Keywords: CI_engine, Engine performance, Hydrogen fuel, gasoline fuel.

تأثير استخدام وقود الهيدروجين في محرك الاحتراق الداخلي على تحسين كفاءة محرك الاشتعال بالشرارة

الخلاصة:

تزايد الطلب على الوقود الاحفوري وتقليل الانبعاثات الناجمة عن وسائل النقل والصناعة والمرافق الأخرى إلى زيادة الاهتمام بالوقود البديل. يتمتع غاز الهيدروجين، وهو وقود بديل محتمل لمحركات الاحتراق الداخلي، بالقدرة على تعزيز كفاءة المحرك وتقليل استخدام الوقود والانبعاثات. تم استخدام البنزين في مرحلة واحدة، بينما تم استخدام الهيدروجين (H2) والبنزين في المرحلة الأخرى لتقييم أداء محرك الاختبار. تم تعديل معدل تدفق غاز الهيدروجين إلى 0.1 و 0.2 لتر في الدقيقة (LPM). خضع النموذجان للاختبار بسرعات محرك 2000 و 2250 دورة في الدقيقة، مع أحمال محرك متفاوتة (0 و 2 و 4 و 6 و 8 و 10 و 12 نيوتن متر) ونسب ضغط (6: 1 و 7: 1 و 9: 1). تضمنت التجارب الأولية مقارنة بين البنزين النقي والوقود المزدوج. حقق المختبر العديد من نتائج الاختبار الاستثنائية. أدى التشغيل بالوقود المزدوج عند 2000 دورة في الدقيقة إلى تحسن كبير في الكفاءة الحرارية للفرامل، بزيادة قدرها 9.5٪ و 10.6٪. انخفض استهلاك الوقود النوعي بنسبة 11.3٪ و 14.1٪، على الرغم من أن الكفاءة الحجمية انخفضت بشكل طفيف، تتراوح بين 1.9٪ و 2.6٪. حققت الفرامل كفاءات حرارية بنسبة 9.6٪ و 10.7٪، مما أدى إلى انخفاض في استهلاك الوقود النوعي بنسبة 11.4٪ و 14.3٪. شهدت الكفاءة الحجمية انخفاضًا طفيفًا، يتراوح بين 2.2٪ و 2.5٪ عند 2250 دورة في الدقيقة. بالإضافة إلى ذلك، لوحظت درجات حرارة أقل لغاز العادم في كل موقع اختبار. وقد أثبت هذا أن وقود الهيدروجين هو بديل فعال من حيث التكلفة للبنزين التقليدي، دون الحاجة إلى أي تعديلات على المحرك. وهذا له أهمية اقتصادية كبيرة.

1. Introduction

Fossil fuels are necessary due to the increasing global need for industry and energy use. In order to meet the increasing energy requirements and mitigate the negative impact of emissions, it is imperative to identify alternative fossil fuels that are affordable, secure, and readily accessible. Hydrogen gas that is free of carbon burns in a manner that is both environmentally friendly and highly efficient. Hydrocarbons emit carbon monoxide and various contaminants. Alternatively, hydrogen gas in its pure form can serve as a standalone energy carrier or be combined with gasoline and diesel to enhance engine efficiency and minimize the release of exhaust emissions[1]. An individual cylinder four-stroke diesel engine was operated at 1000, 1250, and 1500 rpm under different loads and with hydrogen gas at flow rates of 2%, 4%, 6%, 8%, and 10%. Increase your speed by 80%. Volumetric efficiency decreased by 35% due to the load. By introducing a 10% concentration of hydrogen2, the thermal efficiency increases by 40%, the BMEP (brake mean effective pressure) decreases by 25%, and the fuel consumption decreases by 35% [2]. An investigation was conducted on spark ignition (SI) engines operating with hydrogen, petrol and methane at stoichiometric conditions. A study investigated the utilization of hydrogen at concentrations of 5%, 10%, 15%, and 20%. The amount of hydrogen is inversely proportional to the braking force. Augmenting the initial reduces the latter. At 3000 and 7000 rpm, the braking force experienced a reduction of 0.56 and 1.33 watts, respectively. Hydrogen reduces the energy density of the combination, hence decreasing its quality. The peak cylinder temperature and power output declined as the engine surpassed 5,000 rpm while maintaining the same hydrogen mass ratio[3].An investigation was carried out during the summer to examine the effects of combining pure hydrogen with petrol fuel on the performance and emissions of a petrol engine operating at

3,000 rpm. The addition of 3% and 6% hydrogen energy to petrol enhances brake thermal efficiency by 23% and 28% respectively, reduces specific energy consumption by approximately 15% and 22%, and decreases brake NOx emissions by 51% and 61% in the original Wankel engine. By augmenting the H/C ratio of the hybrid fuel by the addition of hydrogen, the reduction of CO_2 emissions is facilitated. The hydrogen-gasoline blend exhibited a higher brake mean effective pressure (BMEP) compared to a standard petrol engine, indicating improved stability[4]. Novel hydrogen combustion methods have been developed for internal combustion engines, exhibiting exceptional efficiency and negligible emissions. A study was conducted on a diesel engine with a gas injector in the intake port to evaluate the performance of the hydrogen engine at various loads, injection rates, and speeds. Engine testing demonstrates that hydrogen yields fewer emissions than diesel when the engine is subjected to high levels of stress. Prior to the implementation of diesel fuel injection and ignition, the occurrence of pre-ignition was identified when employing a high-input hydrogen power component. An investigation was conducted to examine the impact of fire surface temperature on the occurrence of pre-ignitions in various hydrogen engine operating circumstances, by analysing the hydrogen introduced during aberrant combustion. Conversely, elevated hydrogen levels enhance the rate at which flames propagate, resulting in enhanced combustion, heightened thermal efficiency, and diminished emissions of unburned hydrogen[5]. A dual-fuel combustion engine is created by burning hydrogen and diesel fuel simultaneously at a consistent rate. Diesel power is utilized in conjunction with hydrogen power at load levels of 25%, 50%, and 75%. This study examines the potential effects of improved hydrogen energy distribution on engine performance and emissions. HES effectively mitigates the release of nitrogen oxide (NOx) pollutants during operations at low and medium levels of power output. Under high loads, the motor has a deceleration of 75% load with a 20% decrease in its hydraulic efficiency system (HES). Hydraulic energy storage (HES) diminishes the thermal efficiency of the brakes in relation to fuel consumption. The thermal efficiency is 3%. Under identical test conditions, there is a 4.5% drop in volumetric efficiency, a 9% rise in NO_X emissions, and a decrease in emissions of other pollutants[6].The authors conducted an empirical study to determine the speed at which a laminar flame propagates in mixes of petrol, ethanol, hydrogen, and air. We carried out the analysis under different initial pressures ranging from 0.1 to 0.3 MPa, with a constant initial temperature of 593 K and varying valence. The range of ratios is between 0.75 and 1.5. The mixing method relies on the theory of energy substitution, and it involves testing the mixing ratios of various components. The results of the study on ternary fuel blends indicate that the addition of ethanol has a notable impact on the laminar expansion flame speed. Specifically, we measure the flame speed at 2.24

m/s for a mixture containing 20% H2, 16% E, and 64% G at fixed hydrogen blend ratios, and 2.68 m/s for a mixture containing 20% H2, 32% E, and 48% G. We took these measurements for a stoichiometric mixture at a pressure of 0.1 MPa. The initial pressure's impact on the velocities of both extended and non-extended flames is identical for dual fuel assemblies. The equivalency ratio more significantly affects the flame speed at the point where it reaches its highest value during stoichiometric combustion[7]. The results indicate that the gasoline engine can effectively operate using H2 gas as a supplementary fuel for all activities that the gasoline engine can accomplish Without requiring any modifications to the engine and the results indicate that the gasoline engine can effectively operate using H2 gas as a supplementary fuel for all activities that the gasoline engine can accomplish Without requiring any modifications to the engine.

2. Experimental Procedure

This experiment examines the impact of introducing hydrogen gas into an engine on its sustained performance as a fuel for internal combustion engines. The experiments quantified the impact of introducing dual fuel on the levels of exhaust emissions. These measurements served as the foundation for other metrics. The experiments were conducted at two different rotational speeds, namely 2000 and 2250 rpm, with three different compression ratios: 6:1, 7:1, and 9:1. The engine loads were modified at 0, 2, 4, 6, 8, 10, and 12 Newton meters. Hydrogen gas (H_2) is introduced into the combustion chamber at flow rates of 0.1 and 0.2 liters per minute. The injection technique combines hydrogen gas with air. Every test point requires a volume of 20 cubic centimeters of liquid fuel. Laboratories employ safety protocols to guarantee the well-being of workers. The tester utilizes an engine data panel and an exhaust gas analyzer to measure data during tests.

2.1. Experimental setup

This study conducted two distinct and independent tests. The hydrogen production system underwent initial and subsequent testing on an Italian water-cooled four-stroke engine (PRODIT GR306/0001) capable of operating on both diesel and petrol fuels with a lever mechanism approach. Table (1) presents the precise technical specifications pertaining to the engine. Figure (1) depicts the motor configuration used in this study, while the second Figure (2) presents a schematic diagram of the motor systeWe performed a comprehensive series of tests and calibrations to fully understand the functioning of the dry-cell electrophoresis apparatus. s. The quantity, temperature, and concentration of sodium hydroxide in the electrolyte determine the production level. Improve the operational environment for electrical appliances. The device possesses an autonomous solar power system. We conducted the testing in a controlled environment, allowing the engine to warm up with a light load for 15 to 20 minutes. We took this action to preserve thermal balance and establish a consistent operational condition. The preliminary pilot experiments only used gasoline to generate baseline test outcomes for further comparisons. Multiple inquiries have been conducted to determine the optimal compression ratio (CR) for the gasoline employed. The measured pressure ratios ranged from 6:1 to 9:1. The goal was to determine the maximum achievable compression ratio (HUCR). In order to determine fuel consumption, it is necessary to compute the duration required to deplete a uniform volume of 20 cm3 of petrol for each experimental group. The H_2 gas produced by the engine's electrical separator was channelled into the intake manifold to act as additional fuel. Test accessories are employed to quantify essential parameters such as fuel flow rate, air flow rate, torque, rotational speed, engine coolant temperatures, exhaust gas temperature, and fuel and air temperatures. The results were then used to confirm the engine's capabilities. The experiments were repeated three times, and the average data are reported to reduce experimental variability. The hydrogen generator was powered by pre-charged batteries obtained from the solar cell. There were no instances of engine knock, pre-ignition, or any other associated issues detected during the testing procedure. Three sets of experiments were conducted using the following procedure: At first, the engine operated exclusively on gasoline as its fuel source. The experiment examined the impact of several loads (ranging from 0 to 12 N.m in increments of 2 N.m) and two rotational speeds (2000 and 2250 rpm) on an internal combustion engine. The engine had changing compression ratios of 6:1, 7:1, and 9:1, while the speed of the engine remained constant throughout the experiment. In the second scenario, the engine employed a dual fuel system that involved the use of both petrol and a flow rate of 0.1 litres per minute of H_2 petrol. In the third scenario, the engine functioned by utilising a dual fuel system that consisted of petrol and a flow rate of 0.2 litres per minute of H_2 gas. At the same speeds and pressure differences as previously mentioned.

Table (1): The technical specifications of the engine

Manufacturer	Prodit	No load speed range	500-3600 RPM (Otto cycle)
Cycle	Otto Or Diesel four strokes	Load speed range	1200-3600 RPM (Otto cycle)
Number of cylinders	1 vertical	Intake start	54º before T.D.C
Diameter	90 mm	Intake end	22º after T.D.C
Stroke	85 mm	Exhaust start	22º before T.D.C
Compression ratio	4÷17.5	Exhaust end	54º after T.D.C
Maximum power	4 kW 2800 rpm	Fixed spark advance	10º (spark ignition)
Maximum torque	28 N.m at 1600 rpm	Swept volume	541 cm^3

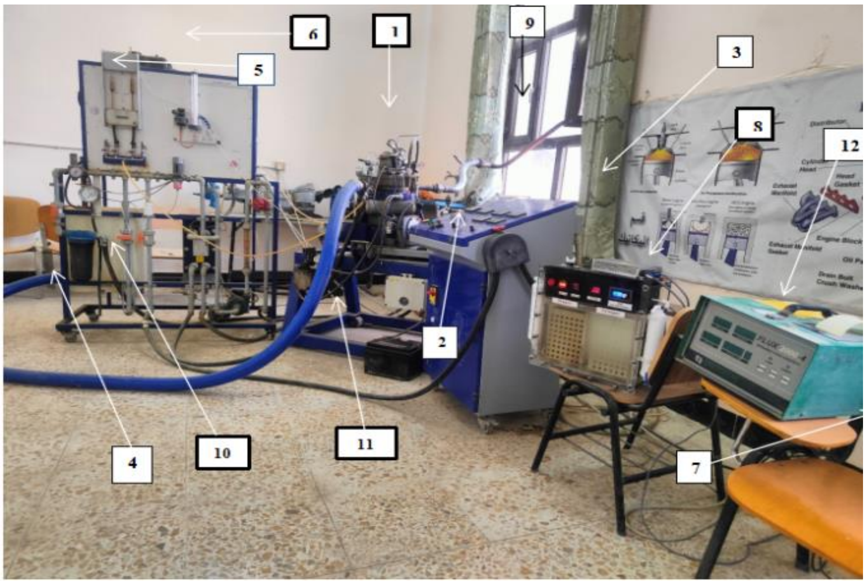

Fig. (1): A photograph of the laboratory unit

1. Engine	2. Dynamometer	3. Control panel
4. Engine cooling unit	5. Fuel engine unit	6. Air processing system
7. Foam extinguishers	8. H_2 generator	9. Exhaust
10. Orifice tank	11.Intakemanifold	12.Gas Analyzer

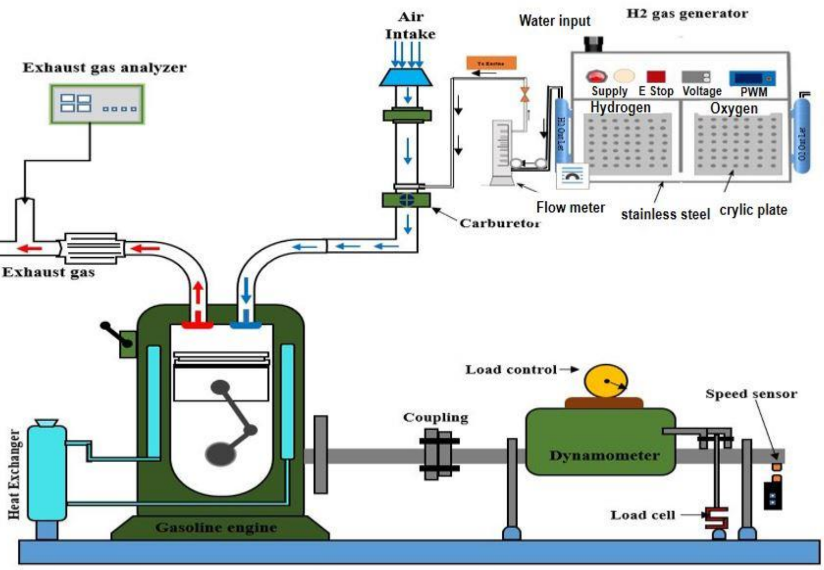

Fig. (2): Schematic diagram to the experimental setup

2.2. Hydrogen generators

The H_2 generating subsystem comprises a water electrolyzer, a solar cell power source, a flame arrester, an electrical safety interlock, a bubble tank, a PWM circuit, a voltage and current metre, and a gas flow metre with a range of 0 to 1 LPM. The generator comprises a variable number of cells, which is contingent upon the required quantity of gas. The solar cell produces the electrical current that energises the system. A crucial phase in the analytical process involves using an electrolyte, namely a NaOH catalyst, to enhance the production of H_2 gas. The material is ion-conductive, facilitating unhindered ion mobility. We refer to it as a "catalytic reformer" due to its ability to accelerate the production of gas. Water electrolysis generates hydrogen and oxygen. Electrolysis is used to separate water molecules, as shown in equation (1). The creation of hydrogen gas exhibits a linear relationship with the electric current used. Figure (3) depicts the essential elements of the system.

$$H_2O + \text{electricity} \rightarrow H_2 + \frac{1}{2}O_2 \qquad (1)$$

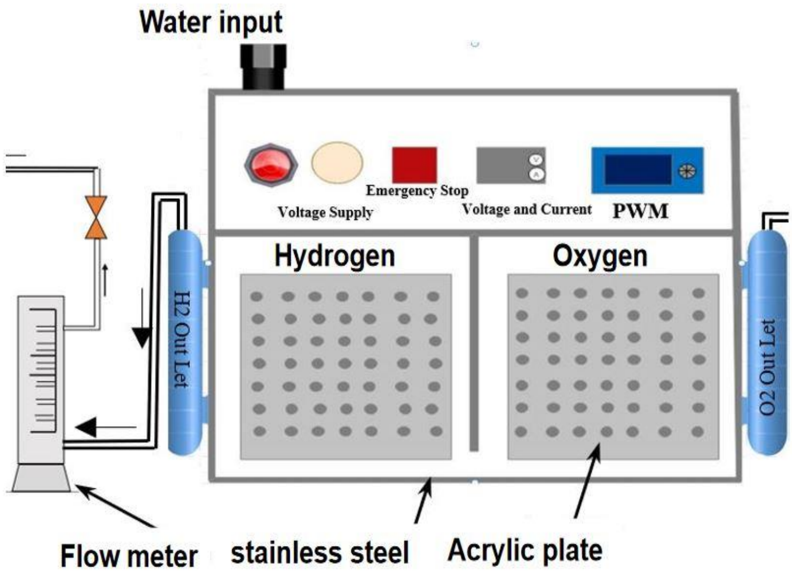

Fig. (3): Schematic diagram of the H_2 gas generator system

3. Results and Discussion

A study was undertaken to investigate the impact of utilizing pure petrol and petrol augmented with hydrogen as fuel in a single-cylinder petrol engine on the combustion process. The study's experimental results demonstrated the computation of crucial parameters, such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and volumetric efficiency (VE). Analyzed were the test results of the hydrogen generator to verify the precision of the operational parameters of the hydrogen generation system. The engine underwent three similar tests, all performed under identical conditions. Implementing a data averaging technique mitigates experimental uncertainty stemming from equipment failures, fluctuations in surrounding factors, and human error. The following section will outline the outcomes derived from the functioning of the hydrogen generator (dry cell). The engine test results are additionally displayed. The engine underwent testing at two different rotational speeds, specifically 2000 and 2250 revolutions per minute (rpm), while utilizing different compression ratios (6, 7, and 9) and weights ranging from 0 to 12 Newton meters (N.m). The flow rates of H_2 were 0.1 liters per minute (LPM) and 0.2 LPM. Graphs are presented in relation to loads to allow comparisons and simplify complexity.

3.1. The impact of introducing hydrogen gas on brake thermal efficiency (BTE)

The thermal efficiency of an engine is a vital factor to consider when evaluating its economic and overall performance. One can achieve enhancements by either improving the fuel quality or optimising the combustion process. We conducted a study to investigate the relationship between the thermal efficiency of the brakes and different loads, while maintaining a constant engine speed. The brakes in the hydrogen enrichment process exhibit superior thermal efficiency when compared to a single gasoline engine. The brake thermal efficiency exhibits a consistent upward trend with increased hydrogen gas flow rates (0.1 and 0.2 L/min) in comparison to pure petrol across all test locations. During engine testing, the brake thermal efficiency (BTE) rose by 4.3% and 7% at an engine speed of 2000 rpm and a compression ratio of 6:1, as depicted in Figure (4). In addition, when the engine runs on a combination of two fuels and has a compression ratio of 7:1, the brake thermal efficiency (BTE) increases by 5.37% and 9%, respectively, as depicted in Figure (5). Similarly, when the compression ratio is 9:1, the BTE (brake thermal efficiency) increases by 5.43% and 10.6%, as shown in Figure (6). Testing at 2250 rpm showed a significant improvement in brake thermal efficiency compared to pure gasoline. When conducting tests using a compression ratio of 6:1 and operating in dual fuel mode, the brake thermal efficiency (BTE) increased by 5.22% and 6.74%, respectively, as depicted in Figure (7). A compression ratio of 7:1 resulted in a 6% and 9.6% increase in BTE rates, respectively, as depicted in Figure (8). When exposed to a pressure ratio of 9:1, the brake thermal efficiency shows a respective increase of 7.6% and 11.3%, as depicted in Figure (9). The results indicate that using hydrogen gas as fuel for the engine enhances the thermal efficiency of the brakes under all operating conditions. he data shows that the most significant improvement in brake thermal efficiency occurs at a rate of 10.6% when the engine is running at 2000 rpm and at a rate of 11.3% when it works at 2250 rpm. Incorporating an additional 0.2 litres per minute of hydrogen gasoline into the gasoline fuel mixture achieves this improvement. This is consistent with the findings of other researchers [10, 11, 12, 13, 14].

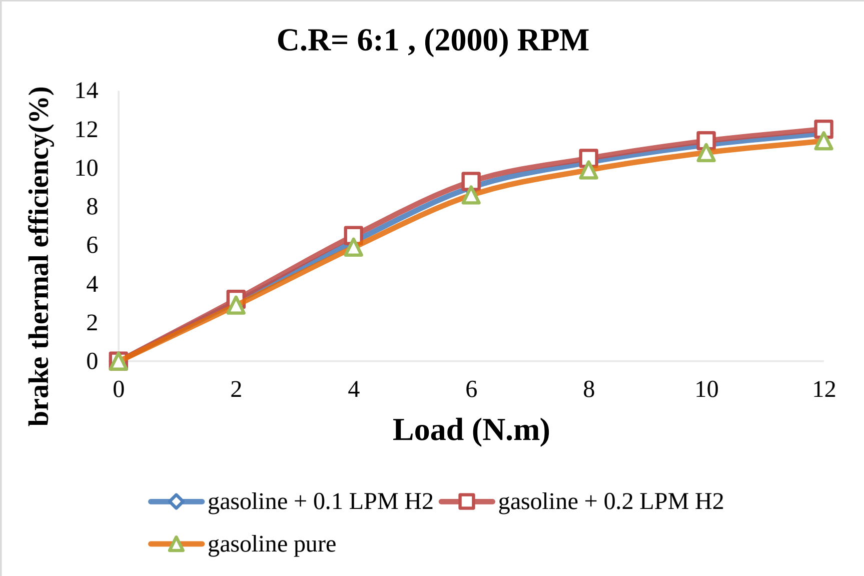

Fig. (4): Variation of brake thermal efficiency with load for different mixing rates of H_2 at constant speed (2000 rpm).

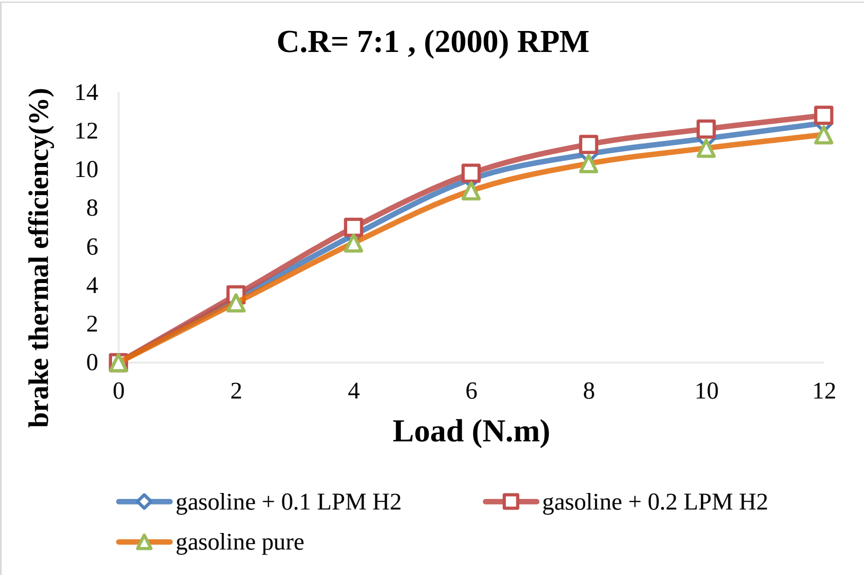

Fig. (5): Variation of brake thermal efficiency with load for different mixing rates of H_2 at constant speed (2000 rpm).

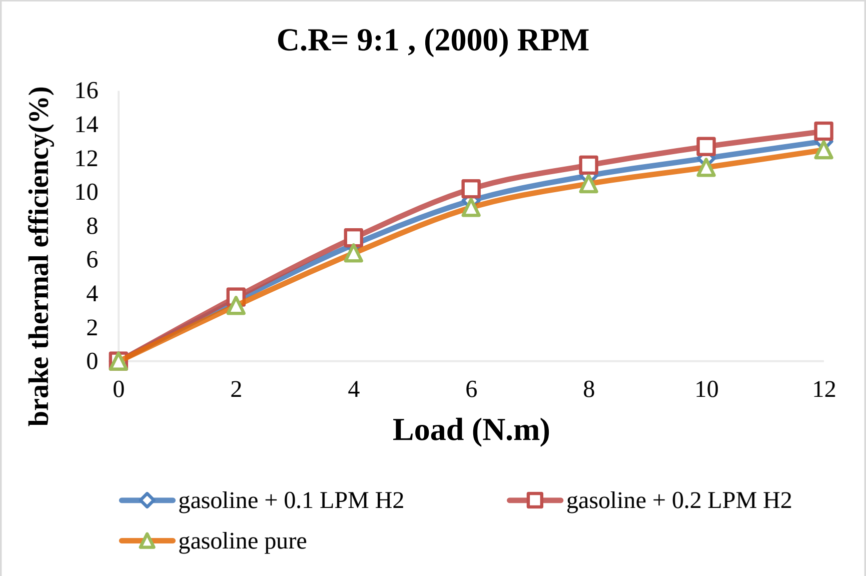

Fig. (6): Variation of brake thermal efficiency with load for different mixing rates of H_2 at constant speed (2000 rpm).

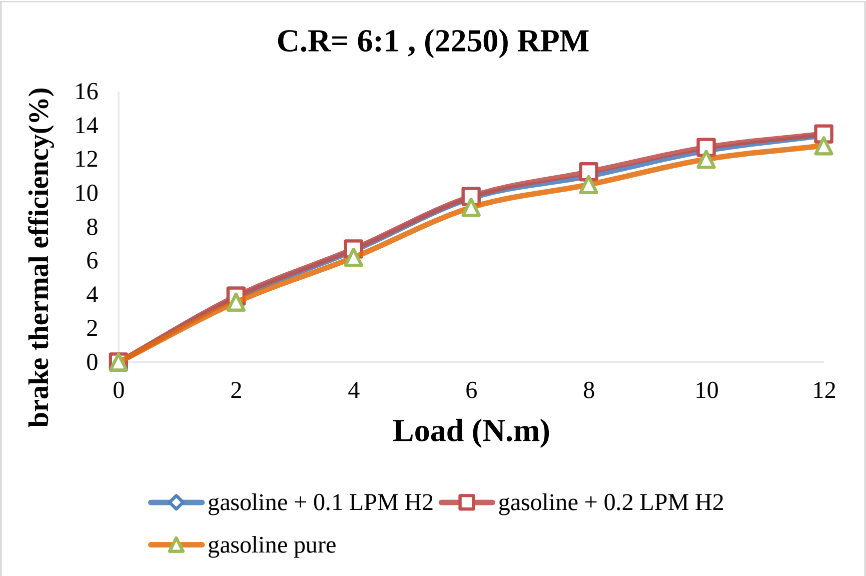

Fig. (7): Variation of brake thermal efficiency with load for different mixing rates of H_2 at constant speed (2250 rpm).

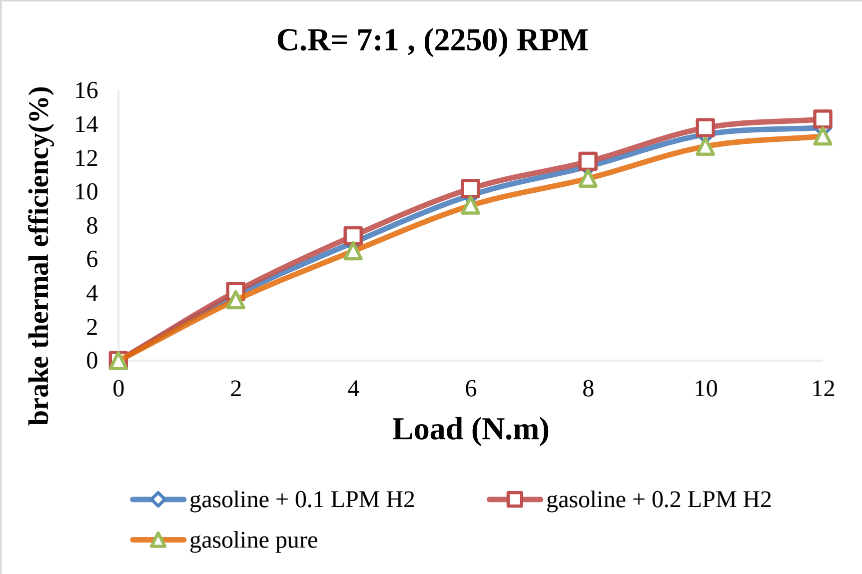

Fig. (8): Variation of brake thermal efficiency with load for different mixing rates of H_2 gas at constant speed (2250 rpm).

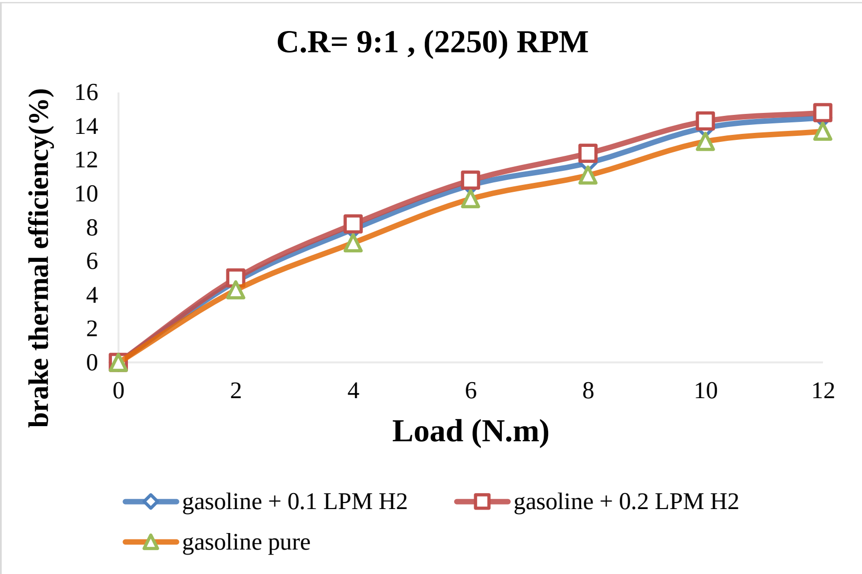

Fig (9): Variation of brake thermal efficiency with load for different mixing rates of H_2 gas at constant speed (2250 rpm)

3.2. The impact of introducing hydrogen petrol on Brake Specific Fuel Consumption (BSFC)

Brake fuel efficiency refers to the proportion of gasoline used by an engine in relation to its power output. The study conducted experiments on a spark ignition engine by adjusting the compression ratio (CR) to achieve the desired compression ratio for dual fuel utilization without experiencing backfire problems. Differences introduced different quantities of hydrogen gas into conducted the experiments at two specific engine speeds, 2000 and 2250, while exposing the engine to varying amounts of stress. We present the results from two sets of tests. We conducted the preliminary tests at a speed of 2000 revolutions per minute (rpm). Petrol fuel set the standard for comparison. We add hydrogen gas as an additional fuel at flow rates of 0.1 and 0.2 litres per minute, respectively. The brake fuel consumption rates decrease by 6.4% and 9% when the compression ratio is 6:1, as depicted in Figure (10), and they further decline to 7.7% and 11.3% at a compression ratio of 7:1, as depicted in Figure (11). The bracketing the compression ratio at 9:1 led to a reduction in brake fuel consumption of 11.6% and 14.2%, respectively, as shown in Figure (12). We revealed the results of the subsequent series of tests at a speed of 2250 rotations per minute. Reducing the compression ratio from 7:1 to 6:1 results in a 7.1% and 10.7% decrease in the brake fuel consumption rates, respectively, as depicted in Figure (13,14). when the compression ratio changes from 7:1 to 9:1, there is a decrease in brake fuel consumption rates of 11.9% and 14.3%, as depicted in Figure (14,15). Empirical data clearly shows that using H_2 petrol reduces brake-specific fuel consumption (BSFC). The engine operating in dual fuel mode exhibited a significant decrease in brake-specific fuel consumption (BSFC) of 14.2% at 2000 rpm and 14.3% at 2250 rpm. Empirical evidence demonstrates that brake-specific fuel consumption (BSFC) decreases as the amount of H_2 gas delivered to the engine through the air intake manifold increases. Hydrogen acts as a catalyst for gasoline, improving the combustion process and increasing efficiency. In all test scenarios, the brake-specific fuel consumption (BSFC) value consistently shows a reduction.

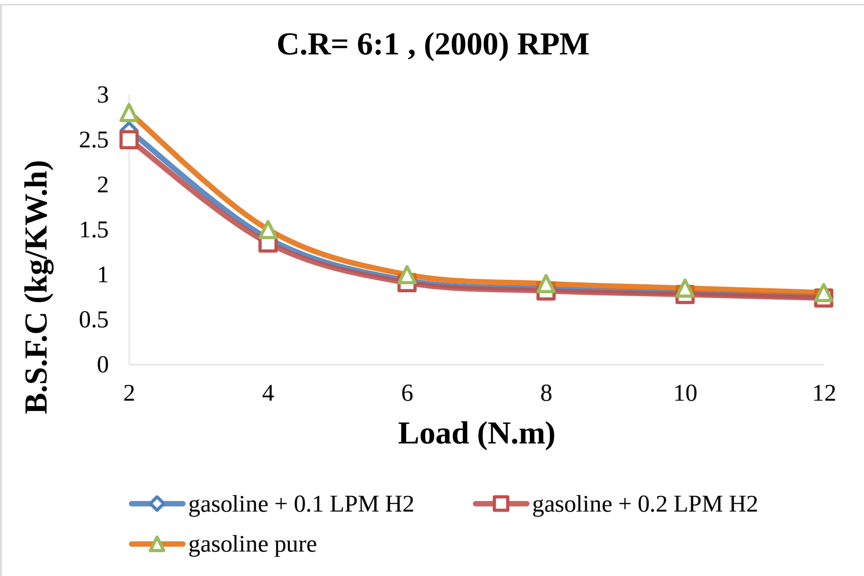

Fig. (10): Variation of the BSFC with different loads and mixing of different amounts of H_2 gas at a constant speed of (2000 rpm).

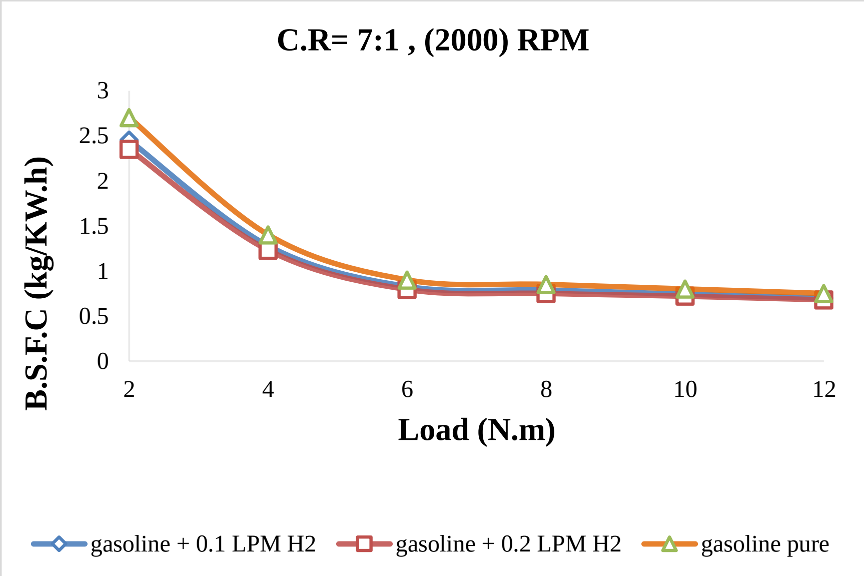

Fig. (11): Variation of the BSFC with different loads and mixing of different amounts of H_2 gas at a constant speed of (2000 rpm).

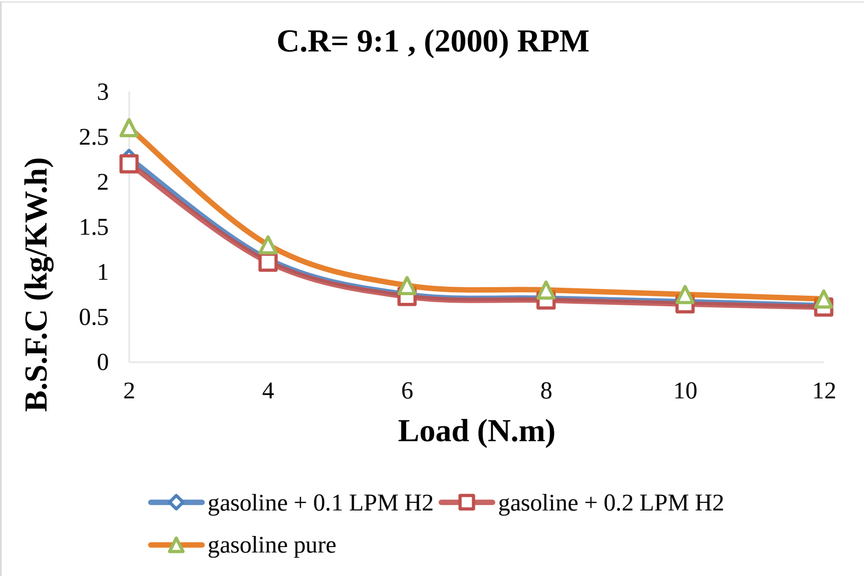

Fig. (12): Variation of the BSFC with different loads and mixing of different amounts of H_2 gas at a constant speed of (2000 rpm).

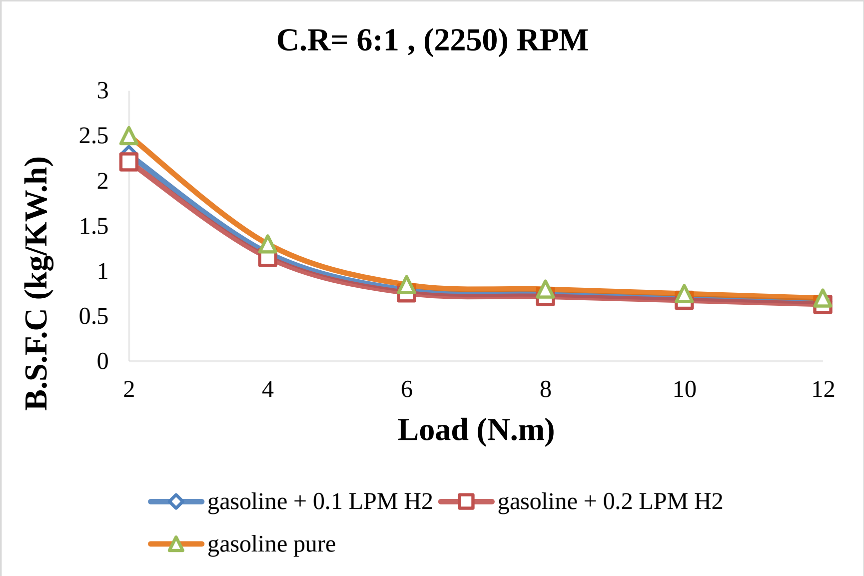

Fig. (13): Variation of the BSFC with different loads and mixing of different amounts of H_2 gas at a constant speed of (2250 rpm).

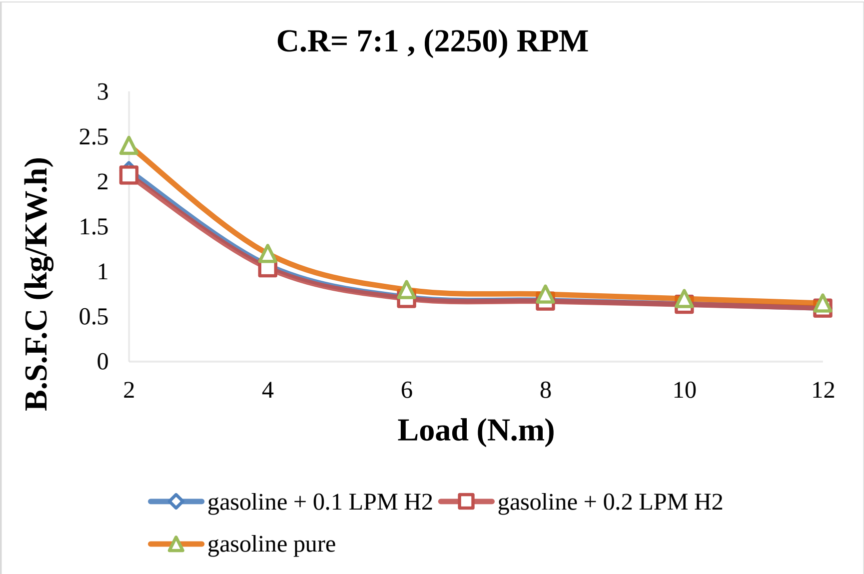

Fig. (14): Variation of the BSFC with different loads and mixing of different amounts of H_2 gas at a constant speed of (2250 rpm).

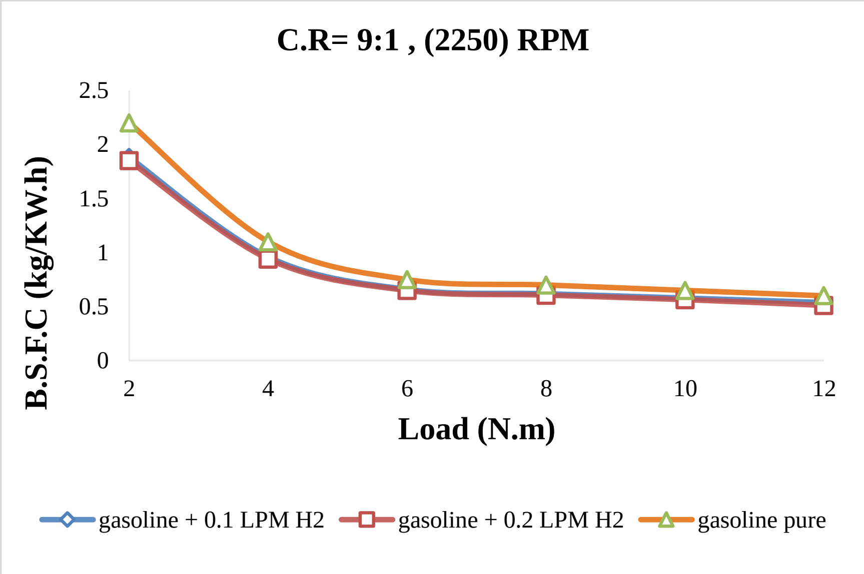

Fig. (15): Variation of the BSFC with different loads and mixing of different amounts of H_2 gas at a constant speed of (2250 rpm).

3.3. The impact of introducing hydrogen gas on volumetric efficiency

The injection of H_2 gas into the engine intake manifold has a direct impact on the engine's volumetric efficiency. Tests revealed a marginal decrease in volumetric efficiency while the engine operated at constant speeds of 2000 and 2250 rpm with varying compression ratios. Injecting H_2 petrol into the air intake manifold at flow rates of 0.1 and 0.2 litres per minute reduces the volumetric efficiency compared to using only petrol fuel. We conducted tests on an engine running at 2000 revolutions per minute (rpm). The volumetric efficiency decreases by 1.3% and 1.78% when the compression ratio is 6:1, as depicted in Figure (16) by 1.38% and 1.88% when the compression ratio is 7:1, as depicted in Figure (17) and by 1.5% and 2.6% when the compression ratio is 9:1, as depicted in Figure (18). demonstrates a significant increase in speed to 2250 on the second test. When the compression ratio is 6:1, the volumetric efficiency decreases by 1.9%, as depicted in Figure (19). The decrease at 7:1 varies from 1.7% to 2.2%, but at 9:1, it ranges from 1.9% to 2.7%, as depicted in Figure (20,21). The test results show that when the conditions are the same, there is a maximum reduction in volumetric efficiency of 2.6% at 2000 rpm and 2.7% at 2250 rpm. Several variables, including altered loads, engine speeds, and hydrogen mixing ratios, influence the volume of air entering the combustion chamber. The enhanced combustion efficiency leads to elevated temperatures on the cylinder walls, resulting in a decrease in volumetric efficiency during operation. The decline in hydrogen density is the main factor contributing to the decrease in volumetric efficiency while introducing H_2 gas. The lower density of hydrogen causes it to occupy a larger space in the air, displacing part of the air from the cylinder, whereas fuel droplets occupy a smaller volume in the combustion chamber. Therefore, hydrogen takes up more space, resulting in a reduction in the volume of air that enters the cylinder. This is consistent with the findings of other researchers [14, 17, 18].

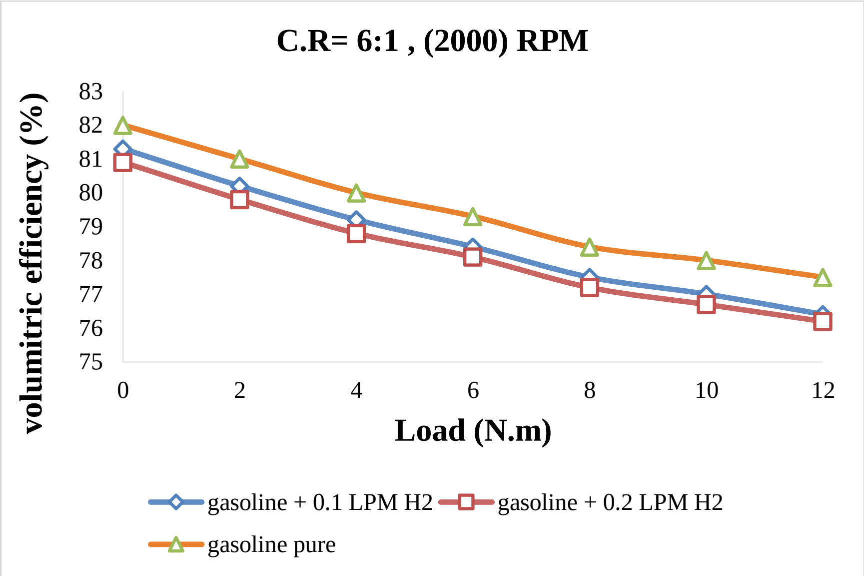

Fig. (16): Variation in volumetric efficiency depending on the load, and at constant speed of (2000 rpm) when H_2 gas is added in different quantities.

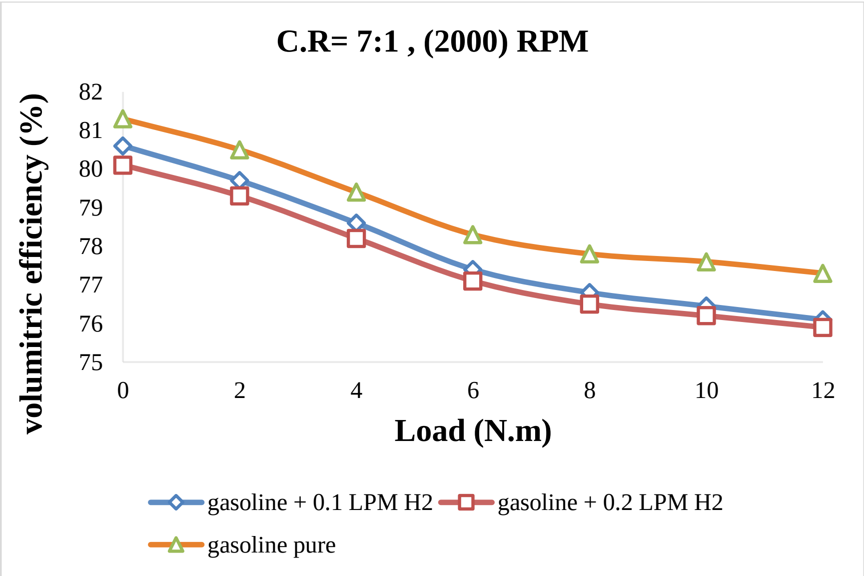

Fig. (17): Variation in volumetric efficiency depending on the load, and at constant speed of (2000 rpm) when H_2 gas is added in different quantities.

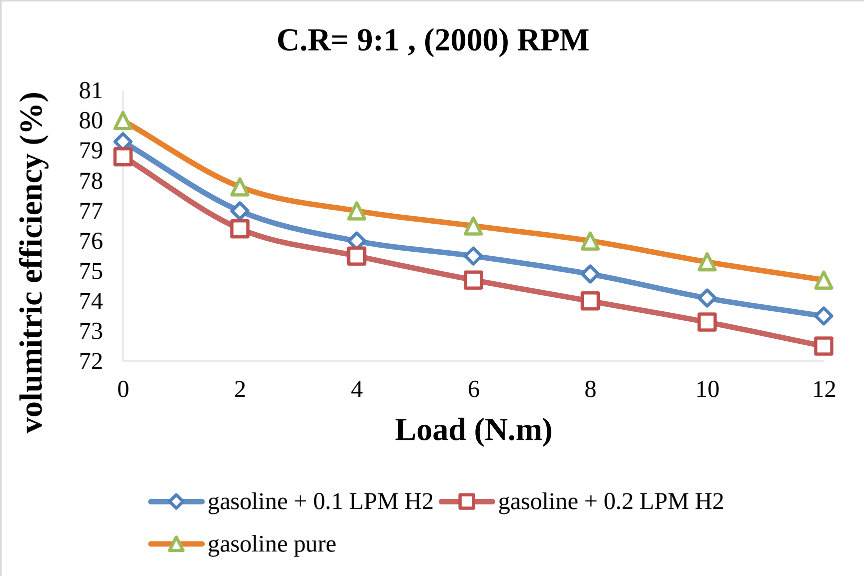

Fig. (18): Variation in volumetric efficiency depending on the load, and at constant speed of (2000 rpm) when H_2 gas is added in different quantities.

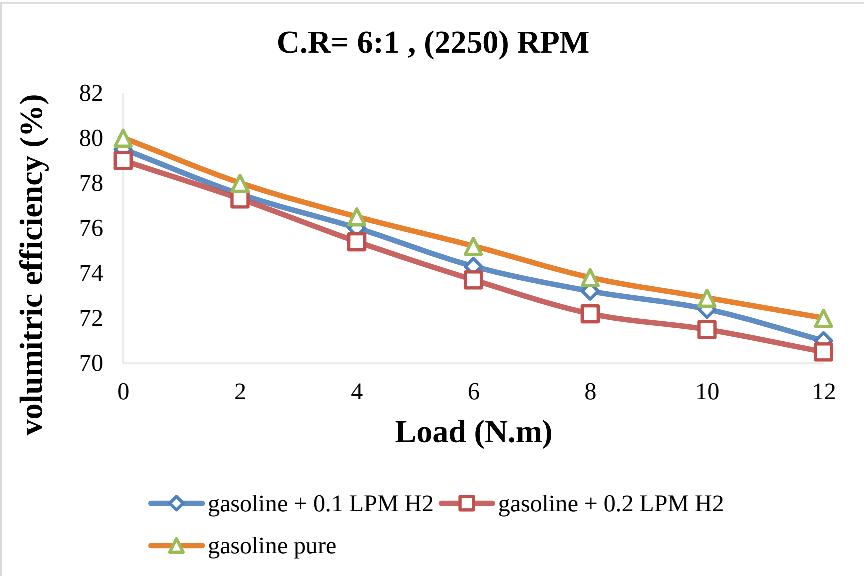

Fig. (19): Variation in volumetric efficiency depending on the load, and at constant speed of (2250 rpm) when H_2 gas is added in different quantities.

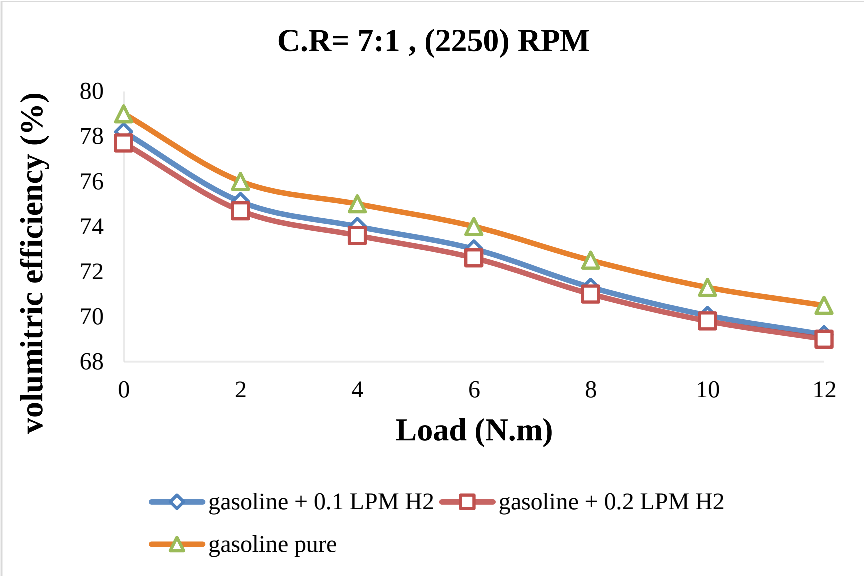

Fig. (20): Variation in volumetric efficiency depending on the load, and at constant speed of (2250 rpm) when H_2 gas is added in different quantities.

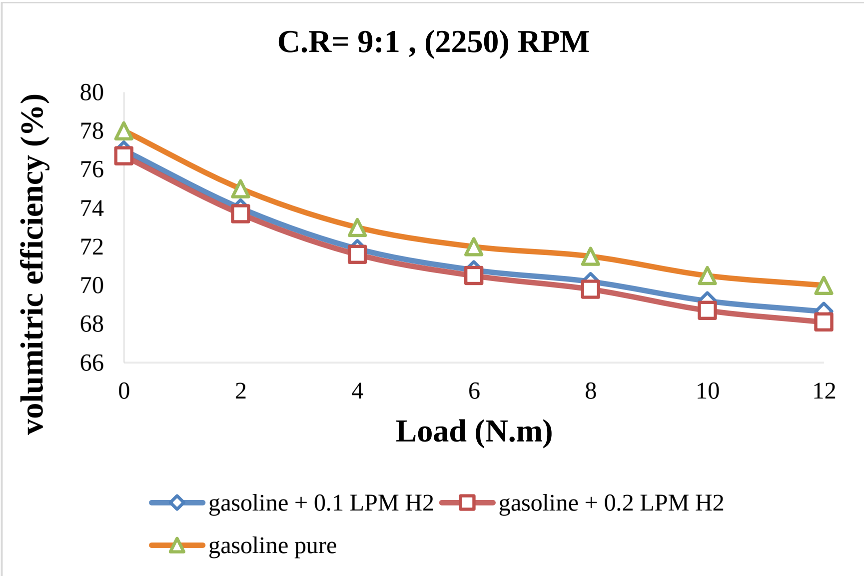

Fig. (21): Variation in volumetric efficiency depending on the load, and at constant speed of (2250 rpm) when H_2 gas is added in different quantities.

4. Conclusions

This research provides important results regarding the combustion of gasoline and hydrogen in a gasoline engine. Introducing hydrogen (H_2) produced by the electrolysis of water into gasoline improves engine efficiency without requiring any engine modifications. The experiments involved using 20 cc of gasoline and varying flow rates of H_2 gas (0.1 and 0.2 liters per minute). We ran the engine at 2000 and 2250 rpm, with weights ranging from 0 to 12 N.m at 2 m intervals, and compression ratios of 6, 7 and 9. This research yields multiple conclusions: The results indicate that a gasoline engine can operate effectively using H_2 gasoline as additional fuel for its normal functions without requiring any modifications to the engine. All trials showed a significant increase in brake thermal efficiency, with the largest gain measured at 11.3%. In addition, there was a notable reduction in brake fuel use, with the largest reduction being 14.3% compared to pure gasoline. The results indicate that the dual fuel approach provides greater economic benefits. Adding hydrogen gas to gasoline resulted in lower volumetric efficiency as a result of the lower density of hydrogen, which resulted in a lower amount of air in the mixture. At 2000 and 2250 rpm, the maximum value decreased by 2.5% and 2.6%, respectively. All trials showed a significant increase in brake thermal efficiency, with the largest gain measured at 11.3%. In addition, there was a notable reduction in brake fuel use, with the largest reduction being 14.3% compared to pure gasoline. The results indicate that the dual fuel approach provides greater economic benefits. Adding hydrogen gas to gasoline resulted in lower volumetric efficiency as a result of the lower density of hydrogen, which led to a decrease in the amount of air present in the mixture. At 2000 and 2250 rpm, the maximum value decreased by 2.5% and 2.6%, respectively. The study found that a compression ratio of 9:1 produced the highest achievable compression ratio, also known as the maximum usable compression ratio (HUCR). The compression ratio resulted in the most efficient operating conditions when using a mixture of gasoline and 0.2 liters of H_2 gas. The revised design of the hydrogen generator incorporates pulse width modulation (PWM) technology to precisely regulate the amount of gas needed for the engine. The revised design of the hydrogen generator incorporates pulse width modulation (PWM) technology to precisely regulate the amount of gas needed by the engine.

Author Contribution Statement: Sarmad A. Jassim contributed to conception of the study, data processing, data analysis and interpretation. Rafid M. Hannun contributed to research design, literature review, drafting the manuscript, and revision and proofreading. All authors have read and approved the final version of the manuscript.

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