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Performance Investigation of a VCR Engine Using Water Containing Mixture of Dimethyl Ketone & Gasoline as a Fuel.

Bishnupriya Mishra[1], Sabyasachi Aich[2*], Soumya Ranjan Pradhan[3], Jayashree Nayak[4], Sunita Panda [5]

[1]Mechanical Engineer & TPM, Mansoura for Resins & Chemical Industries, Egypt.

[2*]Assistant Professor, IGIT Sarang, Odisha, India

[3]Asistant Professor, IGIT Sarang, Odisha, India

[4]Assistant Professor, IGIT Sarang, Odisha, India

[5]Assistant Professor, IGIT Sarang, Odisha, India

Corresponding Author*: - *Sabyasachi.biet@gmail.com

Contributing Author: -bishnupriya.mishra92@gmail.com, soumyapradhan@igitsarang.ac.in, nayak.jayashree@gmail.com, sunita81panda@gmail.com

Abstract: -

In recent years, the heavy reliance on fossil fuels for transportation has contributed to oil shortages and environmental challenges, especially due to emissions from vehicles. These emissions include unburned hydrocarbons, nitrogen oxides, carbon monoxide, sulphur dioxide and unregulated pollutants like polycyclic aromatic hydrocarbons, aldehydes, acids, and greenhouse gases. The extensive use of fossil fuels causes environmental damage and poses health risks. Due to increasing fuel costs and deteriorating air quality, researchers have investigated the use of acetone as an alternative fuel to enhance engine efficiency and lower emissions. Acetone, also known as dimethyl ketone, is an organic solvent primarily used in varnishes and paints and offers advantages over ethanol, such as higher density, calorific value, a high-octane number, and a low latent heat of vaporization. However, water content in acetone can hinder its use in internal combustion engines. This investigation analyzes the performance and combustion properties of a gasoline engine utilizing fuel blends. with 18.5% acetone, 1.5% water, and 80% gasoline (A18.5W1.5), and 18% acetone, 2% water, and 80% gasoline (A18W2), comparing them to pure gasoline. The findings suggest that the A18W2 blend demonstrates superior combustion timing and increased brake thermal efficiency compared to the other test fuels, establishing water-containing acetone-gasoline blends as a viable alternative fuel option.

Keywords: - Acetone, Alternative fuel, Blends, Engine performance, Fuel properties, Gasoline, Spark-ignition engine.

1. INTRODUCTION

In the initial decades, excessive use of fossil fuels in transportation triggered the oil scarcity and environmental issues. Vehicle exhaust is a major source of atmospheric pollution, emitting pollutants like NOx, CO, SO2, and unregulated emissions including acids and greenhouse gases [6]. An experimental study finds dimethyl ketone or acetone as an alternative fuel, producing less pollution than gasoline or diesel. Acetone, a widely recognized organic solvent and key component in paints, offers benefits such as cost-effectiveness, less hazardous, easy accessibility, water solubility, elevated octane number, density, calorific value and decreased latent heat of vaporization [7]. Consequently, acetone shows potential as an alternative fuel for internal combustion engines. The study assesses the attainment characteristics of a SI engine carrying various acetone-gasoline mixture, including G100 (pure gasoline), A18.5W1.5 (18.5% acetone with 1.5% H_2O and 80% petrol), and A18W2 (18% acetone with 2% H_2O and 80% petrol) [7].

2) MATERIALS & METHODOLOGY

To conduct this experiment three specific test fuels were utilized: G100, which is 100% pure gasoline, A18.5W1.5, a blend containing 18.5% acetone, 1.5% water, and 80% gasoline, and A18W2, consisting of 18% acetone, 2% water, and 80% gasoline. These fuel blends are designed to investigate the influence of acetone and varying water content on fuel stability compared to pure gasoline.

The method used to assess stability is gravitational testing, which is a technique employed to examine how well the components of a fuel mixture remain mixed when subjected to gravity over time. During the test, fuel blends are allowed to sit undisturbed under the influence of gravity for 24 Hrs. If separation occurs, it indicates instability, meaning that certain components (like water or acetone) may separate from the gasoline due to differences in density or miscibility. By employing gravitational testing, we aim to evaluate the homogeneity and phase stability of each fuel blend, ensuring optimal performance under various conditions. Below are the characteristics of acetone and gasoline:

Table: 1

Parameters	**Gasoline**	**Dimethyl ketone or Acetone**
Chemical Name	C_8H_{18}	C_3H_6O
Oxygen (%)	0	27.5
Density (M/V) (kg/m3)	730	790
Octane Number ((R + M)/2)	90	117
Latent Heat (kJ/kg) at 298 K.	380–500	518
Self-ignition Temperature (^{0}C)	228–470	465
Stoichiometric A/F Ratio	14.7	9.6

3)

EXPERIMENTAL INVESTIGATION

The engine was coupled with flywheel and then with hydraulic dynamometer to varying resistance load. A spring balance weighing machine was connected to the resistance load of hydraulic dynamometer. A U-tube Manometer is linked to an air surge tank in order to gauge its air consumption. There is dual set-up for fuel supply to the Engine with a T -type control valve to flow the different fuel. The T-type control valve final outlet is connected to again a 3-way control valve in which One end is attached to a burette to measure the fuel consumption rate, while the other end, with a control valve, is connected to the engine. Under conditions of constant equilibrium, the rates of fuel consumption and air consumption, along with the temperature of exhaust gas and combustion parameters, were documented across a range of loads, spanning from no load to full load.

Engine Details - This setup features a single-cylinder, air-cooled, four-stroke petrol engine paired with a DC generator equipped with a water rheostat loading system. Here, load on the engine can be increased by increasing the depth of immersion of copper plate into the sodium chloride solution. A calorimeter is providing at the exhaust path to help in analyzing heat balance.

The engine specifications are as follows;

Table: 2

Company	Kirloskar
Specification	A solitary cylinder, four-stroke engine equipped with direct fuel injection and liquid cooling.
Bore × length of the stroke in mm^2	80×110
Compression ratio	16:1
Speed (Rated)	1500 rpm
BHP (Rated)	5 kW
Break drum arm length in mm	335
Orifice diameter in mm	20

(1. CI engine, 2. Container of exhaust gas, 3. gas analyzer, 4. Tube for supply of fuel, 5. Container of fuel, 6. Biodiesel tank,7. Surge tank for air, 8. Manometer, 9. Hydro dynamometer, 10. Two-sided valve for the selection of diesel or biodiesel.)

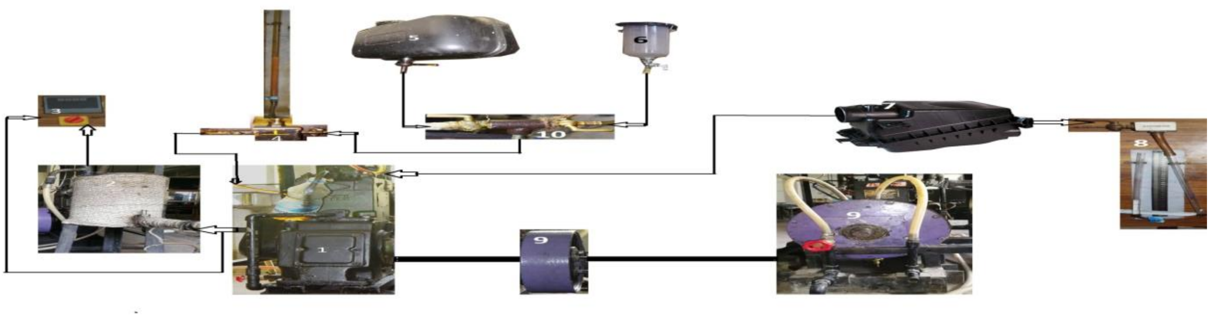


Fig-1: Diagram of the Experimental Setup

4. RESULTS: -

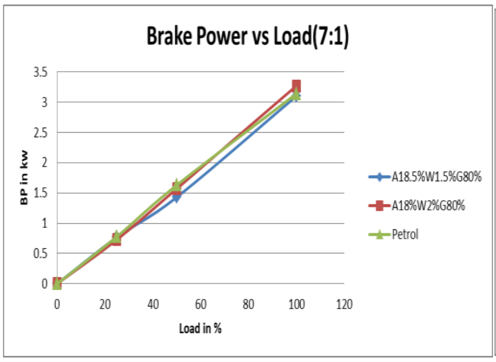


Fig-2: BP Vs LOAD at CR 10

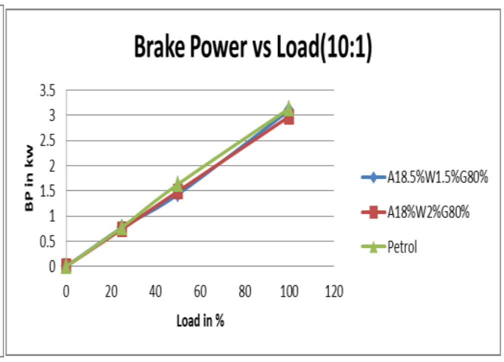


Figure-3: BP Vs LOAD at CR 7

Figures 2 and 3 A18W2 elaborates blend of 18% acetone, 2% water, and 80% gasoline, demonstrates superior engine performance compared to G100 (pure gasoline) and A18.5W1.5 (18.5% acetone, 1.5% water, and 80% gasoline). It produces 8.57% more brake power than G100 and 18.75% more than A18.5W1.5, resulting in a brake thermal efficiency (BTE) of 44.4%, significantly higher than G100 (39.3%) and A18.5W1.5 (37.2%). This improved performance is linked to better combustion efficiency, enhanced the oxygen content in acetone facilitates more complete combustion, leading to more efficient conversion of fuel into usable power. Thus, A18W2 offers better combustion quality, higher power output, and greater fuel efficiency than the other tested fuels

.

	BP **10:1**	BTE **10:1**	BP **7:1**	BTE **7:1**
G (100)	3.41	0.32	3.41	0.29
A18W2	3.10	0.29	3.27	0.25
A18.5W1.5	2.98	0.29	3.10	0.23

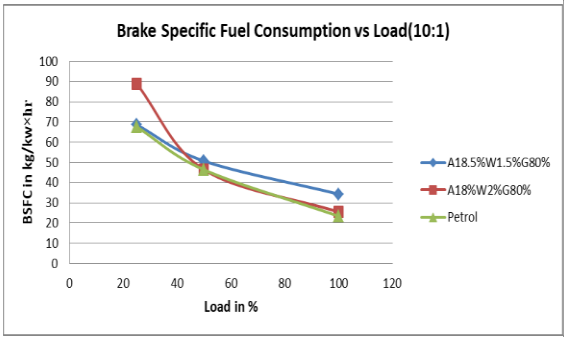


Fig-4: BSFC Vs LOAD at CR 10

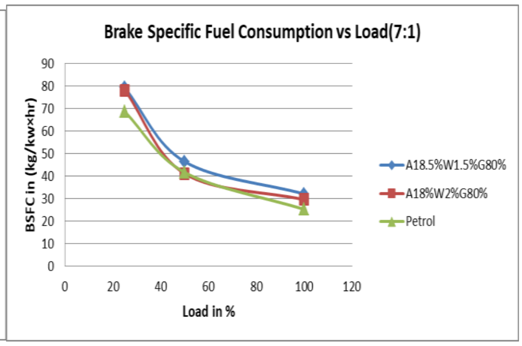


Fig-5: BSFC Vs LOAD at CR 7

The data presented in Figures 4 and 5 clearly illustrate that blend fuels containing acetone exhibit a elevated BSFC contrasted with pure gasoline, primarily because of their lower energy content. Among the tested fuels, A18.5W1.5 stands out with the lowest energy content, which results in a comparativelyhigher BSFC when compared to the other fuels in the study.

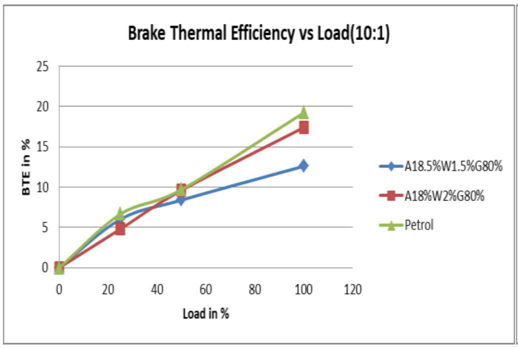


Fig-6: BTE Vs LOAD at CR 10

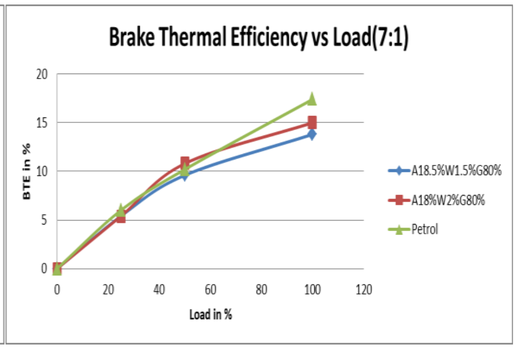


Fig-7: BTE Vs LOAD at CR 7

The findings are presented in Figures 6 and 7, and they clearly indicate that gasoline exhibits the highest brake thermal efficiency among all the tested fuels. This trend is further evident in the graphical representation, where the A18W2 blend stands out with a notably higher brake thermal efficiency In comparison to other test fuels, this performance improvement is due to its higher oxygen content and lower carbon count.

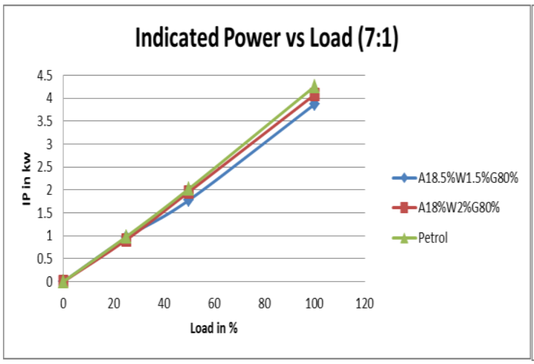


Fig-8: IP Vs LOAD at CR 10

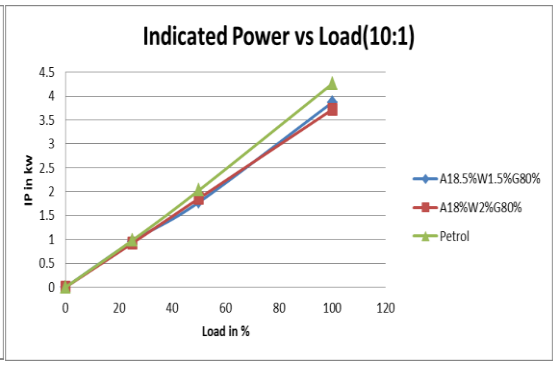


Fig-9: IP Vs LOAD at CR 7

Figures 8 & 9 offer a clear insight into the relationship between load and indicated power, demonstrating that as the load increases, the indicated power also follows suit. Our test results further reveal that gasoline leads the way in terms of indicated power. Additionally, A18.51W1.5 exhibits the highest I.P at a compression ratio of 10:1, while A18W2 excels in I.P at a compression ratio of 7:1, outperforming the other tested fuels. These findings suggest the potential for the development of maximum power, ultimately contributing to an enhancement in combustion quality.

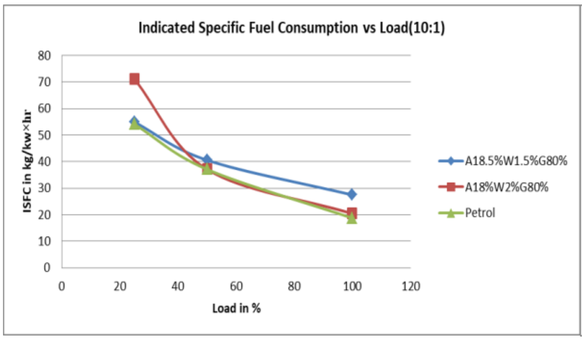


Fig-10: ISFC Vs LOAD at CR 10

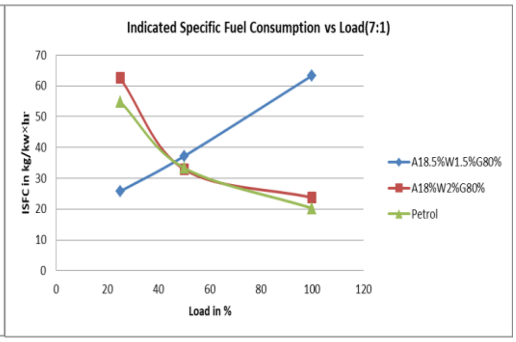


Fig-11: ISFC Vs LOAD at CR 7

The Brake Specific Fuel Consumption (BSFC) gauges the fuel usage per unit of power generated by an engine. Fuels with lower energy content generally lead to higher BSFC, as more fuel is required to achieve the same energy output compared to higher-energy fuels.

For acetone-containing blends like A18.5W1.5 (composed of 18.5% acetone, 1.5% water, and 80% gasoline), several factors contribute to its higher BSFC in comparison to pure gasoline (G100):

1. **Reduced Energy Density**: Acetone has a lower energy density (or calorific value) than gasoline, meaning it contains less potential energy per unit of volume or mass for conversion into mechanical work. Since A18.5W1.5 consists of a substantial amount of acetone (18.5%) and a minor amount of water (1.5%), the overall energy content is diluted. Consequently, the engine must consume more of this blend to produce the same amount of power as gasoline, resulting in a higher BSFC.
2. **High Indicated Fuel Specific Consumption (IFSC)**: Similar to BSFC, IFSC measures fuel consumption in relation to the engine's indicated power (IP) — the theoretical power generated within the cylinder before accounting for mechanical losses. Due to A18.5W1.5's lower energy density, more fuel is required in the cylinder to sustain the same indicated power. As a result, A18.5W1.5 exhibits relatively high IFSC because a greater quantity of fuel is needed to produce the same power.
3. **Impact of Water Content**: The 1.5% water in A18.5W1.5 further reduces its energy content, as water does not combust. Although water can aid in combustion by improving air-fuel mixing and reducing combustion temperatures (helping lower emissions), its presence generally decreases the fuel's available energy, requiring additional fuel to achieve the intended power output.
4. **Comparison with Other Blends**: Among the tested blends, A18.5W1.5 has the highest acetone and water content, making it the least energy-dense fuel in the study. This accounts for its higher BSFC and IFSC relative to other blends, such as A18W2, which contains less acetone and therefore a slightly higher energy density. The increased amounts of acetone and water reduce the blend's energy yield per unit, necessitating more fuel to sustain engine performance.

In summary, the elevated BSFC and IFSC of A18.5W1.5 result from its reduced energy density, leading the engine to consume more fuel to deliver equivalent power. This is largely due to the lower energy content of acetone compared to gasoline, compounded by the diluting effect of water in the blend.

ISFC: -

	10:1	7:1
PETROL	18.72	20.26
A18W2G80	20.38	23.71
A18.5W1.5G80	27.45	25.74

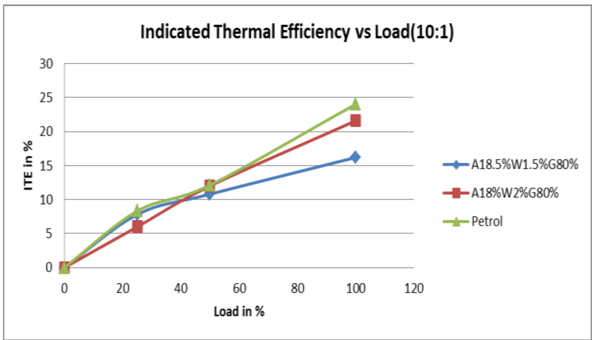


Fig-12: ITE Vs Load at CR 10

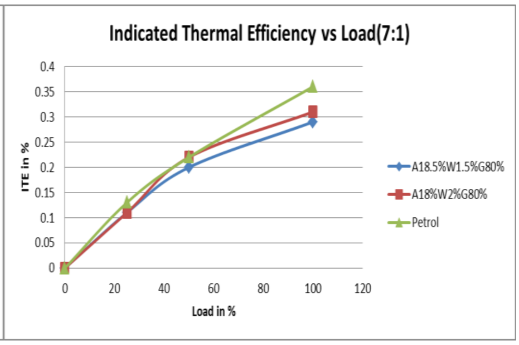


Fig-13: ITE Vs Load at CR 7

Indicated thermal efficiency offers a perspective on the power produced by the engine within the cylinder concerning the heat supplied through fuel. Figures 11 and 12 clearly indicate that as the load increases, indicated thermal efficiency also rises. Our current test results reveal that gasoline stands out with the highest indicated power, and following closely, A18W2 exhibits the highest indicated thermal efficiency among the tested fuels. This performance distinction suggests the potential for achieving maximum power output, contributing to an enhancement in combustion quality.

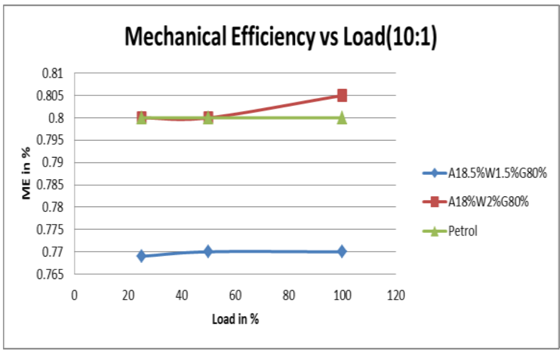


Fig-14: ME VS LOAD at CR 10

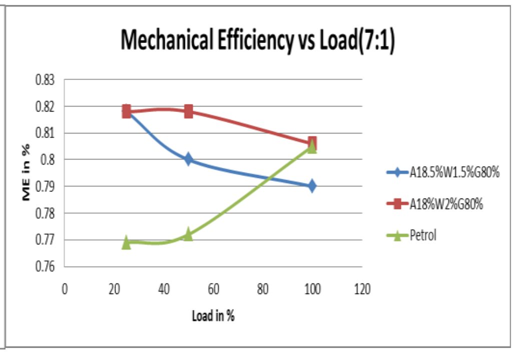


Fig-15: ME VS LOAD at CR 7

Figures 14 suggests that while A18W2 shows marginally better mechanical efficiency due to factors like **lower heating value, higher viscosity, and higher density**, the overall difference between the test fuels is small. This is because the **Brake Power remains constant** for all fuels (due to constant engine speed), and the **Indicated Power** doesn't vary enough to cause a significant difference in mechanical efficiency. Therefore, the blend's properties influence mechanical efficiency, but under the conditions of the experiment, these influences are not dramatic.

MECHANICAL EFFICINCY: -

	10:1	**7:1**
PETROL	0.80 %	0.805 %
A18.5W1.5	0.77 %	0.79 %
A18W2	0.805 %	0.806 %

Fig.15 explains about the A18W2 fuel blend contributes to improved mechanical efficiency primarily through reduced frictional losses and enhanced combustion. Acetone's lower latent heat of vaporization and the cooling effects of water minimizes internal friction, while the higher combustion temperature promotes more efficient exhaust gas expulsion. These factors combine to allow the engine to extract more mechanical work from the available energy, resulting in higher brake power and lower energy losses to friction and heat. Ultimately, the engine operates more efficiently, with greater power output and longevity, thanks to the higher mechanical efficiency provided by the A18W2 blend.

MECHANICAL EFFICIENCY: -

	10:1	**7:1**
PETROL	0.49 %	0.48 %
A18.5W1.5	0.48 %	0.61 %
A18W2	0.46 %	0.57 %

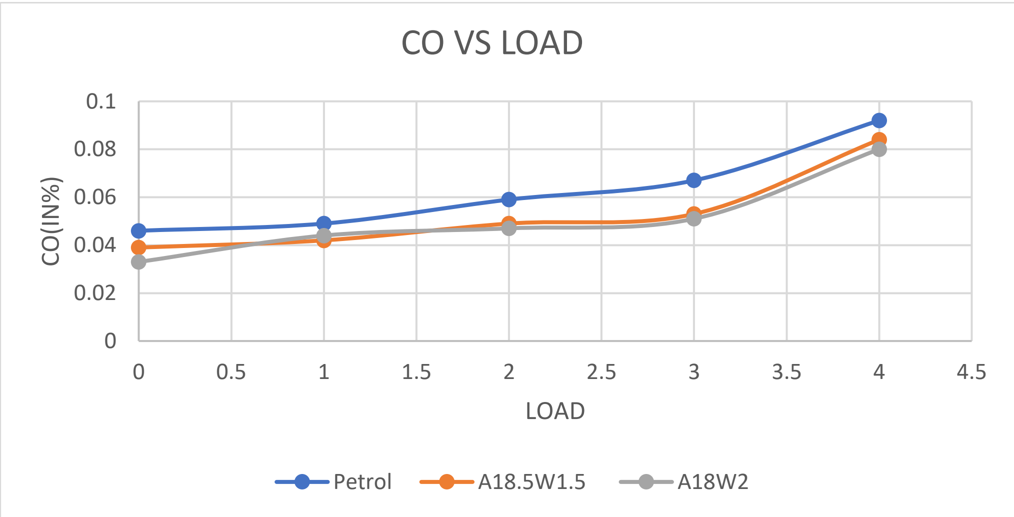
ENGINE EXHAUST EMISSION ANALYSIS

Emissions denote the discharge of greenhouse gases and their precursors into the atmosphere within a defined area and timeframe. The primary sources of global climate change are fossil fuels, especially coal, oil, and natural gas, which collectively contribute to more than 75 percent of global greenhouse gas emissions, with carbon dioxide (CO2) accounting for almost 90 percent of that total. Exhaust emissions from vehicles include unburned air from the atmosphere, carbon dioxide, water vapor, and a variety of compounds in both particulate and gaseous forms. The majority of these emissions stem from incomplete fuel combustion.

CARBON MONO-OXIDE (CO) EMISSIONS: - Figure 15 displays the carbon monoxide (CO) emissions from an engine running on both pure petrol and various petrol blends. The findings show a clear increase in CO concentration as engine load rises across all fuels tested. Notably, higher engine loads resulted in a substantial increase in CO emissions, which is linked to the need for a richer fuel mixture that causes incomplete combustion. At the maximum load of 4 kg, pure petrol produced the highest CO emissions at 0.092%, while the lowest emissions of 0.033% were observed with the A18W2 blend. When comparing CO emission levels, the petrol blends demonstrated an average reduction relative to pure petrol, with decreases of approximately 15.21%, 28.2%, and 5.97% for Petrol, A18.5W1.5, and A18W2, respectively. This reduction is primarily due to the higher oxygen content and lower carbon-to-hydrogen ratio present in the biodiesel blends, which promote more efficient combustion in the engine cylinder. For detailed emissions data of the tested fuels, please refer to Table-3, while Figure 15 visually represents the CO emissions ratings for the test fuels.

CO EMISSION			
LOAD	Petrol	A18.5W1.5	A18W2
0	0.046	0.039	0.033
1	0.049	0.042	0.044
2	0.059	0.049	0.047
3	0.067	0.053	0.051
4	0.092	0.084	0.08

Table-3 CO Emission values of different test fuels



HYDROCARBON (HC) EMISSION: -

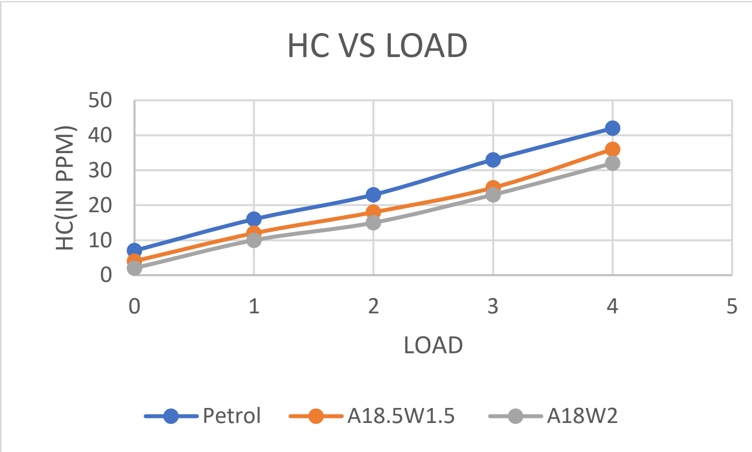
Hydrocarbon (HC) emissions represent a crucial aspect of emission analysis. The primary factor contributing to hydrocarbon emissions is incomplete combustion. Figure 16 unmistakably illustrates that HC emissions are evident, underscoring the significance of addressing incomplete combustion in the context of emission control.

HC EMISSION			
LOAD	Petrol	A18.5W1.5	A18W2
0	7	4	2

1	16	12	10
2	23	18	15
3	33	25	23
4	42	36	32

Table-4 HC Emission values of different test fuels

Hydrocarbon (HC) emissions tend to be lower at both no-load and partial-load conditions compared to higher engine loads. This pattern occurs due to the limited oxygen availability needed to complete the combustion reaction when more fuel is injected under elevated load conditions. At the maximum load of 4 kg, pure petrol recorded the highest HC emission level at 42 ppm, while the A18W2 blend had the lowest at 32 ppm. HC emissions consistently decreased as the proportion of biodiesel in the petrol blends increased. This trend is largely due to the greater oxygen content found in biodiesel compared to diesel fuel, which facilitates cleaner and more complete combustion. As a result, biodiesel blends such as A18W2, B18.5W1.5, and petrol demonstrated average reductions in HC emissions of 34.78%, 21.5%, and 65.6%, respectively. For specific HC emission values of the various test fuels, please see Table-4. The analysis presents the HC emission category ratings for the different test fuels.



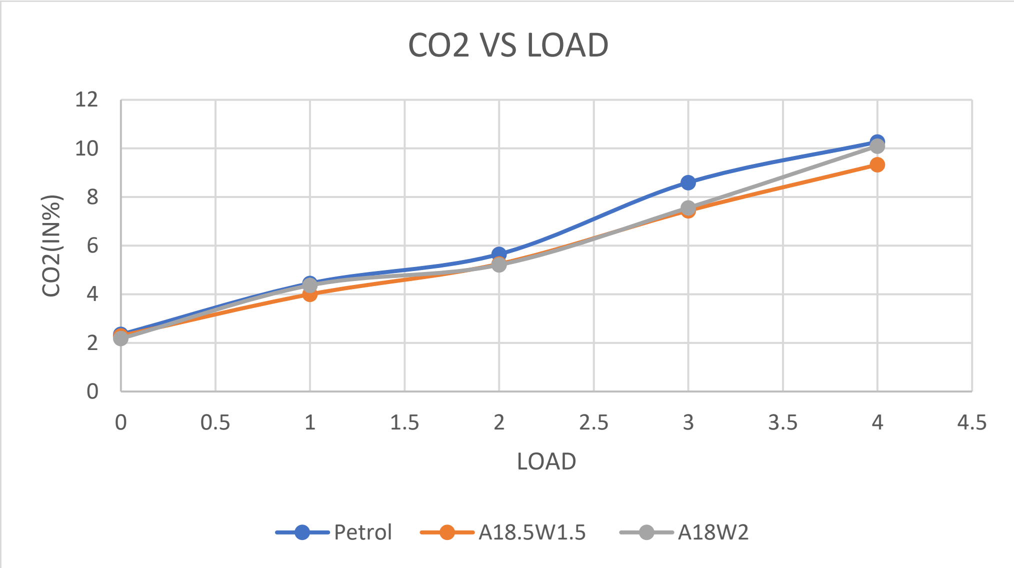
CARBON DIOXIDE (CO_2) EMISSIONS

Changes in CO2 emissions have been observed across various engine loads when testing different fuels, as shown in Figure 17. Over the entire range of loads measured, both pure diesel and diesel-biodiesel blends exhibited an increase in CO2 emissions. At the maximum load of 4 kg, diesel fuel recorded the highest CO2 emission at 10.27%, whereas the lowest emissions of 9.33% were noted for the A18.5W1.5 blend. The petrol blends A18W2, A18.5W1.5, and petrol displayed average reductions in CO2 emissions of 1.78%, 10%, and 1.35%, respectively. This decrease may be attributed to incomplete combustion, particularly at higher engine loads, coupled with a lower carbon-to-hydrogen ratio. Nonetheless, this reduction indicates a positive effect on reducing greenhouse gas emissions. For CO2 emission values of various fuels, refer to Table-8, and Figure 17 illustrates the fuel ratings based on CO2 emissions.

CO2 EMISSION			
LOAD	**Petrol**	**A18.5W1.5**	**A18W2**
0	2.35	2.29	2.18
1	4.45	4	4.37
2	5.65	5.25	5.21

3	8.6	7.44	7.56
4	10.27	9.33	10.1

Table-5 CO2 emissions values of different test fuels

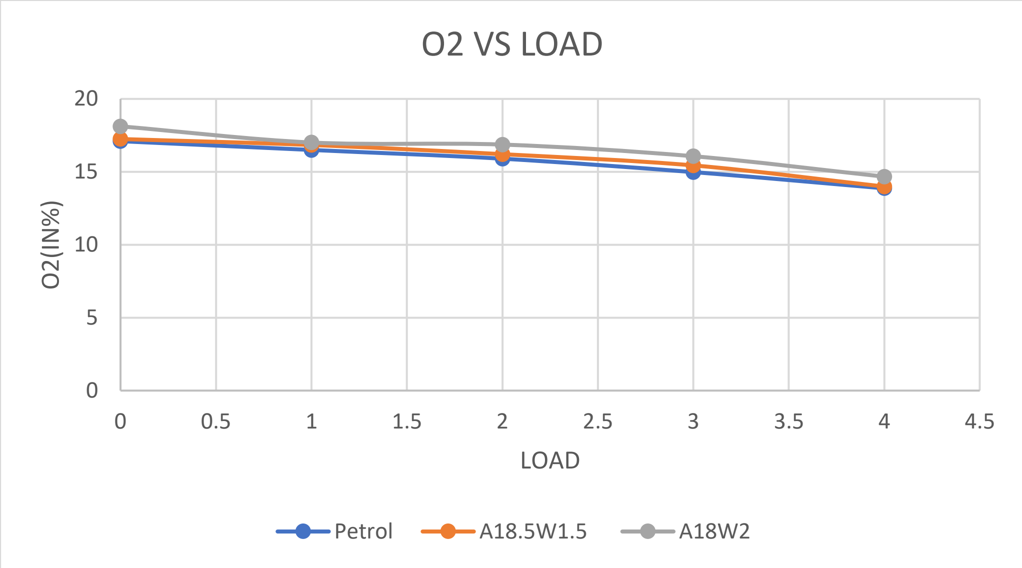


EXHAUST OXYGEN (EO)

Figure 18 depicts the changes in EO (Oxygen Concentration) levels across various engine loads for the fuels tested. EO concentrations indicate the percentage of oxygen in the sample and illustrate the shift from a rich mixture to a lean one. The graph demonstrates a steady decline in EO levels as engine load increases for all fuels examined. At the maximum load of 4 kg, the A18.5W1.5 fuel showed the highest EO value at 14.67%, while the lowest recorded value was 5.93%. Notably, all petrol blends displayed higher EO concentrations compared to pure petrol, with increasing bio-blend substitution in petrol leading to expanded EO levels. This phenomenon could be attributed to factors such as incomplete combustion or potential leaks in the exhaust system or manifold. The EO values for different fuels are detailed in Table-6, and the fuel ratings based on EO concentration are presented in table– 6.

O2 EMISSION			
LOAD	**Petrol**	**A18.5W1.5**	**A18W2**
0	17.1	17.25	18.12
1	16.5	16.84	17.01
2	15.9	16.21	16.87
3	14.98	15.44	16.07
4	13.87	13.99	14.67

Table-6 EO values of different test fuels

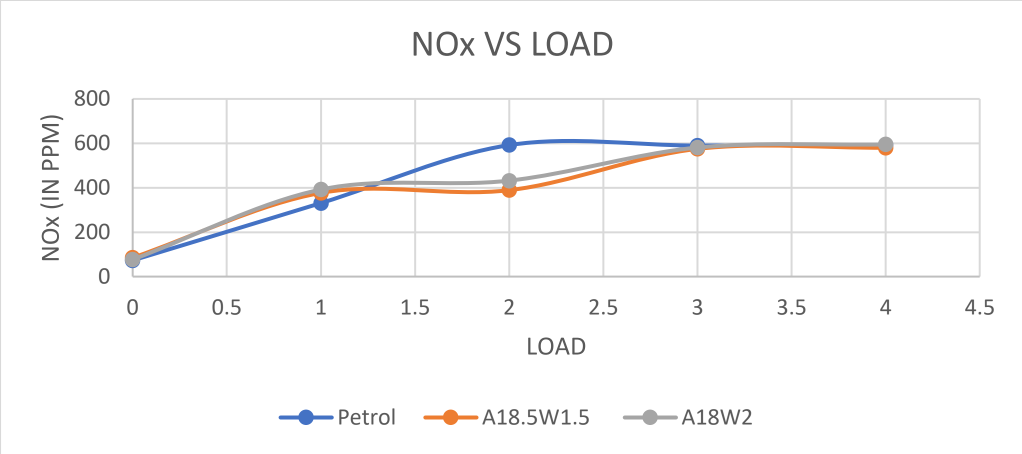


NITROGEN OXIDE (NO_X) EMISSIONS

Variations in NOx emissions have been noted at different engine loads for the various fuels tested, as illustrated in Figure 19. Throughout the entire range of operational loads, NOx emissions from pure diesel and petrol blends increased. At the highest load of 4 kg, the B15D85 blend recorded the highest NOx emission at 595 PPM, while the A18.5W1.5 blend had the lowest at 532 PPM. Average decreases in NOx emissions of 2.54%, 1.52%, and 30.67% were observed for the diesel-biodiesel blends A18W2, B18.5W1.5, and petrol, respectively. This reduction may result from incomplete combustion, particularly at higher engine loads, and a lower carbon-to-hydrogen ratio could also contribute. Nonetheless, this decrease indicates a positive effect on mitigating greenhouse gas emissions. For the NOx emission values of the different fuels, refer to Table-7. The ratings for the various fuels in the NOx emissions category are provided in the analysis.

Table-7 NOx values of different test fuels

NOx EMISSION			
LOAD	**Petrol**	**A18.5W1.5**	**A18W2**
0	73	85	77
1	331	377	392
2	592	389	432
3	590	575	581
4	593	580	595



5. CONCLUSION

In the course of our current investigation, numerous tests were conducted using a solitary cylinder, 4-stroke engine equipped with direct fuel injection and liquid cooling. We utilized various fuel blends, including pure gasoline (G100), A18.5W1.5 (consisting of 18.5% acetone with 1.5% H_2O, and 80% petrol), and A18W2 (comprising 18% acetone with 2% H_2O and 80%). From our experimental findings, we draw the following conclusions:

1. The Brake Specific Fuel Consumption (BSFC) for fuel blends that include acetone was higher than that of pure gasoline, primarily due to their lower energy content, with A18.5W1.5 showing the highest BSFC. In contrast, A18W2 demonstrated a greater Brake Thermal Efficiency (BTE) compared to the other tested fuels, which can be attributed to its relatively higher oxygen content and lower carbon numbers. This property enhances combustion quality, thereby improving BTE. The Indicated Specific Fuel Consumption (ISFC) trend increases with the rising water percentage in the A18W2G80 blend at a compression ratio of 7. The presence of water absorbs available energy during combustion, converting it into vapor, which leads to increased fuel consumption.
2. The Indicated Power (IP) of gasoline surpassed that of acetone-containing blend fuels. IP also exhibited variations at different Compression Ratios (CR) with higher IP indicating increased power generation within the engine cylinder, thus improving combustion quality.
3. The Mechanical Efficiency of dimethyl ketone containing mixture of fuels outperformed that of petrol. At different CR and mechanical efficiency exhibited variations driven by the cumulative impact of a reduced heating value, elevated viscosity, and heightened density inherent in acetone-gasoline blends with water content. These alternative fuels hold great potential for utilization in the coming years. By increasing public awareness about these alternatives, we can expedite the development of both these fuels and the technologies required to support their utilization.

6. DECLARATIONS

Funding and/or Conflicts of Interests/Competing Interests

We declare that no external funding was received for this study. We also confirm that there are no conflicts of interest or competing interests associated with this work.

Data Availability Statement

The data generated and analysed during this study are available from the corresponding author upon reasonable request.

7. REFERENCE

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