ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Improving NO-BSEC tradeoff in a single cylinder CI engine using acetone injection and cumene blending techniques

S.Madhan Kumar*, S.Thiyagarajan, S.Yokeshwaran, E.Joshua Paul
Department of Automobile Engineering, SRM University, Kattankulathur-603203
***Corresponding author: E-Mail: smkumar69@gmail.com**

ABSTRACT

An experimental study is carried out for achieving improvement in NO-BSEC tradeoff in a single cylinder CI engine. The improvement is achieved by using two different approaches, namely electronic injection of acetone in inlet manifold and cumene blending with diesel. Acetone having high latent heat of vaporization reduces NO emission. In this study, 20 % acetone is injected electronically in the inlet manifold at TDC. At full load, NO emission for diesel + 20% acetone injection is reduced by 8 % compared to diesel. BSEC is slightly improved for acetone injection due to low density of acetone. BSEC is reduced by about 7 % with acetone injection compared to diesel at full load condition. For further improvement in performance, 10 % cumene is blended on volume basis with diesel. At full load, BSEC is reduced by about 12 % compared to diesel at full load and NO emission is reduced by 5 % compared to diesel. D90C10 + 20% acetone improved BSEC by 5 % and NO is increased by 3 % compared to diesel + 20% acetone at full load. Impact of the various techniques on other performance and emission characteristics is also studied.

1. INTRODUCTION

Diesel engine is popular prime mover in India due to high thermal efficiency and higher torque. The stringent emission norms have led to advanced development in electronic fuel injection and after treatment systems like Selective catalytic reduction (SCR). The major problem with SCR system is backpressure which increases fuel consumption and thereby reducing the performance of the engine. Hence, a novel method to have a tradeoff between NO emission and fuel consumption is desired.

The literature showed that alcohol could be a potential fuel replacement in CI engine for NO emission reduction. However, due to low cetane number of alcohol fuel its usage in CI engine is limited to knock limit for particular alcohol. Studies related to many alcohols like methanol, ethanol, n-butanol and n- pentanol have been done in diesel engine and limited to 30 % of energy share with diesel due to knocking. Acetone is a byproduct during production of n-butanol and is a ketone group. Acetone has similar properties to alcohol which makes it a potential alternate fuel for NO emission reduction. NO emission is reduced by about 16 % with acetone-butanol-methanol combination with diesel. Acetone also aids in simultaneous reduction of NO and PM due to high latent heat of vaporization and low carbon content.

Cumene is a high-octane fuel and has a great potential for performance improvement. However, due to low cetane rating, its use is limited to only 5-10 % on volume basis. The present work focus on combining both approaches for achieving NO-BSFC tradeoff in a single cylinder CI engine. The study also discusses on other performance and emission characteristics.

Test fuels and experimentation: The physiochemical properties of diesel, acetone and cumene are shown in Table 1

Table.1.Properties of diesel, acetone and cumene

Property	Diesel	Acetone	cumene
Molecular Structure	$C_{14}H_{28}$	C_3H_6O	C_9H_{12}
Kinematic Viscosity, cST	3.6	0.34	0.85
Density@15ºC, g/cm3	0.840	0.791	0.862
Lower Heating Value, kJ/kg	42700	29600	40500
Calculated Cetane Index	52	-	-
Latent Heat of Vaporization, kJ/kg	250	551	290

A single cylinder four-stroke water cooled naturally aspirated direct injection compression ignition engine developing 3.7 kW power at 1500 rpm is used for the experimentation. The engine specifications are given in Table 2. The CO, HC, NO and CO_2 emission were measured using AVL five gas analyzer.

The experimental setup is shown in Figure 1. A separate electronic injector system was developed for injecting acetone. A submersible pump and tank were used and electronic injector was connected with ECU and the pump unit. The signal of TDC position was taken by using an optical sensor for defining the injection timing of acetone.

Table.2.Engine Specifications

Make and Model	**Kirloskar DM 8.5**
Engine Type	Single cylinder, water cooled, direct injection and constant speed
Rated Power @ 1500 rpm	3.7 kW
Bore (mm)	80
Stroke (mm)	110
Compression Ratio	16.5 : 1
Injection Pressure (bar)	200
Injection timing	23^{o}bTDC

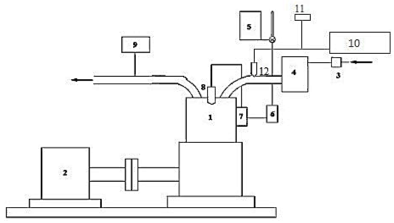

Figure.1.Schematic diagram of experimental setup

1. Engine 2. Electrical dynamometer 3. Air filter 4. Air box 5. Fuel tank 6. Fuel filter 7. Fuel pump 8. Fuel injector 9. AVL exhaust gas analyzer 10. Acetone injection system 11. ECU 12. Electronic injector for acetone

Initially the engine was tested with diesel as base fuel and obtained performance and emission characteristics at various load conditions. In the next stage, engine was tested with diesel and 20 % acetone injection in inlet manifold at various load conditions. Then 10 % cumene on volume basis is blended with diesel and tested along with 20 % acetone injection. All the performance and emission characteristics are compared at different load conditions. Tradeoff for NO and BSFC for all the techniques were studied.

2. RESULTS AND DISCUSSION

Brake thermal efficiency: Figure 2 shows the variation of brake thermal efficiency for diesel, diesel + 20% acetone and D90C10 + 20% acetone at various load conditions. At full load, BTE for diesel is 29.9 %, for diesel + 20% acetone is 32.3 % and for D90C10 + 20% acetone is 34 %. BTE for 20% acetone injection is increased by 5 % compared to neat diesel. This is probably due to low viscosity of acetone which resulted in better atomization, vaporization and mixture formation. The trend is similar for other load conditions also. Cumene is a major component in high octane rating fuels. Hence, blending 10% cumene with diesel improves the performance. BTE for D90C10 + 20% acetone is increased by 14 % compared to diesel and 5 % compared to diesel + 20 % acetone. BTE increase is higher at 75 % and 100 % loads and less for the lower loads. Cumene has better volatility which improves the combustion at all loads. The utilization of acetone and cumene were optimized for the maximum knock limit of the engine. Hence, 10% cumene is blended with diesel and 20% acetone is injected in inlet manifold.

Brake Specific Energy Consumption: BSEC variation for diesel, diesel + 20% acetone and D90C10 + 20% acetone for various load conditions are shown in Figure 3. BSEC for diesel is 11.97 MJ/kW-h, for diesel + 20% acetone is 11.12 MJ/kW-h and for D90C10 + 20% acetone is 10.58 MJ/kW-h at full load condition. BSEC is less for diesel + 20% acetone and D90C10 + 20% acetone at all load conditions compared to neat diesel. This might be due to low viscosity of acetone and hence the fuel injection rate is less in the inlet manifold. This reduces the overall BSEC for acetone injection at all the load conditions. At low loads, the variation is higher and the variation is reducing as the load is increased. This is probably due to increased injection rate of acetone at higher loads considering 20% on energy share basis.

Exhaust gas temperature: Figure 4 shows the variation of exhaust gas temperature for diesel, diesel + 20% acetone and D90C10 + 20% acetone for various load conditions. Exhaust temperature is higher for diesel + 20% acetone and D90C10 + 20% acetone compared to neat diesel at all load conditions. This is probably due to low cetane index for both acetone and cumene which increases the ignition delay and combustion is shifted towards the exhaust stroke and hence higher EGT. EGT is $260^{o}C$ for neat diesel, $264^{o}C$ for diesel + 20% acetone and $274^{o}C$ for D90C10 + 20% acetone.

NO Emission: The variation of NO emission for diesel, diesel + 20% acetone and D90C10 + 20% acetone for various load conditions are shown in Figure 5. Availability of oxygen and high combustion temperature are major cause for NO emission. NO emission for diesel is 3.7 g/kW-h, diesel + 20% acetone is 3.47 g/kW-h and for D90C10 + 20% acetone is 3.51 g/kW-h at full load condition. NO emission is reduced with acetone injection compared to neat diesel operation. This is probably due to high latent heat of vaporization of acetone which reduces the combustion temperature. NO emission for diesel + 20% acetone is reduced for all load conditions compared to neat diesel. However, NO emission is increased for D90C10 + 20% acetone compared to diesel + 20% acetone. This is probably due to improvement in combustion during cumene operation which increases the combustion temperature. Similar trends were observed for other load conditions also.

CO Emission: Figure 6 shows the variation of CO emission for diesel, diesel + 20% acetone and D90C10 + 20% acetone for various load conditions. Incomplete combustion due to lack of oxygen is major cause of CO emission. CO emission is reduced as the load increases for all the techniques. Minimum CO emission is emitted by diesel compared to diesel + 20% acetone and D90C10 + 20 % acetone. At higher load conditions, CO emission variations are minimal. At low loads, maximum CO emission is for diesel + 20% acetone may be due to reduced combustion temperature due to latent heat of vaporization of acetone. CO emission for D90C10 + 20 % acetone is slightly reduced compared to diesel + 20% acetone. This might be due to improved combustion as evident from thermal efficiency.

CO_2 emission: Figure 7 shows the variation of CO_2 emission for diesel, diesel + 20% acetone and D90C10 + 20% acetone for various load conditions. CO_2 emission is an indication of complete combustion. CO_2 is greenhouse gas major cause of global warming. The variation of CO_2 emission is minimum for all the techniques compared to diesel at all load conditions. The minimum CO_2 emission is observed for D90C10 + 20% acetone due to reduced number of carbon atoms in acetone and cumene which reduces the overall carbon content inside the combustion chamber and hence less CO_2 emission.

HC Emissions: Figure 8 shows the variation of HC emissions for diesel, diesel + 20% acetone and D90C10 + 20% acetone for various load conditions. HC emissions are due to incomplete combustion. HC emissions are higher for acetone and acetone with cumene technique compared to diesel. This might be due to reduced combustion temperature attributed to higher latent heat of vaporization of acetone. At low temperature, oxidation of HC will not happen effectively.

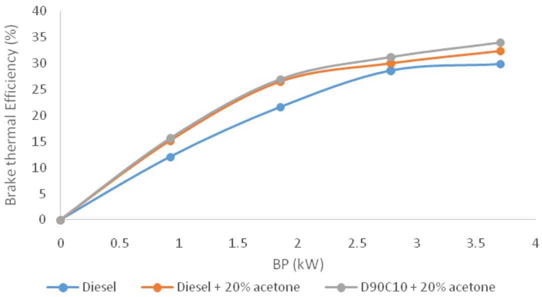

Figure.2.Variation of brake thermal efficiency at various load conditions

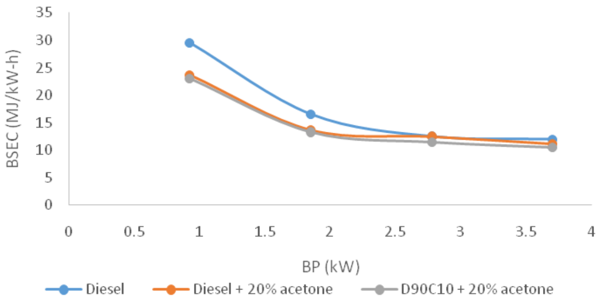

Figure.3.Variation of brake specific energy consumption at various load conditions

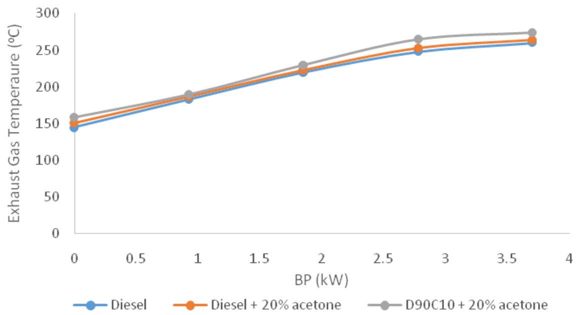

Figure.4.Variation of Exhaust gas temperature at various load conditions

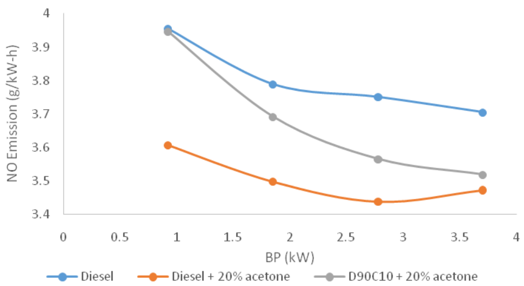

Figure.5.Variation of NO emission at various load conditions

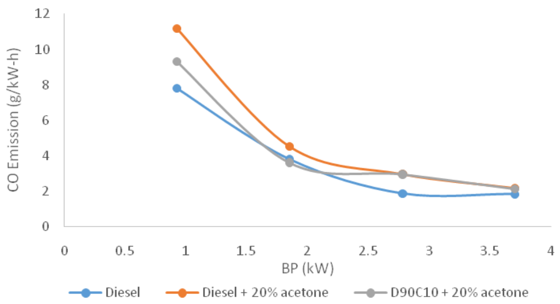

Figure.6.Variation of CO emission at various load conditions

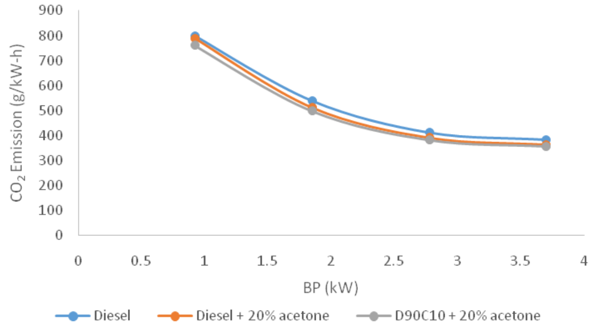

Figure.7.Variation of CO_2 emission at various load conditions

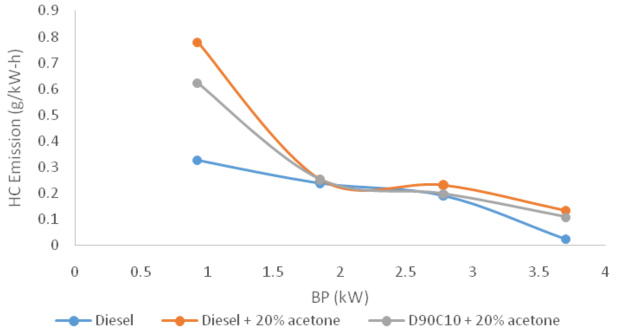

Figure.8.Variation of HC emissions at various load conditions

3. CONCLUSIONS

Based on the experimental studies conducted in a single cylinder CI engine using diesel, diesel + 20 % acetone and D90C10 + 20% acetone and the following conclusions are drawn:

- Brake thermal efficiency is improved by 8 % with 20 % acetone injection and improved by 13 % with D90C10 + 20% acetone compared to diesel at full load condition.
- NO emission is reduced by 7 % with acetone injection and 5 % with cumene blend and acetone injection compared to diesel.
- CO and HC emissions are higher for acetone injection and D90C10 with acetone injection due to reduced combustion temperature due to high latent heat of vaporization.
- CO_2 emission is reduced with acetone injection due to less number of carbon atoms.

The results shows that 20 % acetone injection with 10 % blending of cumene is possible technique for NO-BSFC tradeoff.

REFERENCES

Devaraj J, Effect of variable compression ratio on performance and emission for a diesel engine fuelled with waste plastic pyrolysis oil blended with diethyl ether. Journal of Chemical and Pharmaceutical Sciences, 8(2), 2015, 168-172.

Jegan Raj J, Study of emissions from diesel engine by addition of additives, Journal of Chemical and Pharmaceutical Sciences, 8(2), 2015, 283-287.

Karthik Nithyanandan Improved SI engine efficiency using Acetone–Butanol–Ethanol (ABE) Fuel, 174(15), 2016, 333–343.

Krishnamoorthi M, Optimization of Diesel Engine Fueled With Diesel-Mahua Biodiesel Diethyl Ether Blend to Improve Engine Performance by RSM, Journal of Chemical and Pharmaceutical Sciences, 8(4), 2015, 611-617.

Liangjie Wei n-pentanol addition on the combustion, performance and emission characteristics of a direct-injection diesel engine, 70(1), 2014, 172–180.

Prashant G.K, effect of methanol blend on the combustion parameters of dual fuel diesel engine, 103(35), 2016, 187–194.

Vijaya Kumar B, Magnetized-Nano Catalyst KF/CaO-Fe3O4for Biodiesel Production from Beef Tallow, Journal of Chemical and Pharmaceutical Sciences, 9(1), 2016, 193-195

Wilson P, The comparative study on diesel and photovoltaic water pumping system for different crops, Journal of Chemical and Pharmaceutical Sciences, 9(3), 2016, 432-436.