A STUDY ON EMISSION FROM COMPRESSION IGNITION ENGINES AND CONTROL

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ABSTRACT

Environment gets polluted due to excess use of automobiles as many harmful particles like carbon dioxide, corbon mono-oxide, sulphur dioxide etc. are emitted as a result of incomplete combustion from internal combustion engine. To overcome this problem, a need to do modification in existing engines was realized. Hence, diesel engines were proposed but it was observed that these engines also yield higher emissions significantly NOx and PM. To reduce the NOx, Exhaust gas recirculation (EGR) technology was introduced. This technology was compatible with only small engines. Also, it was found that this technology increased emissions and more consumption of fuel. The current paper highlights the emission from compression ignition engines and control.

KEYWORDS: *Emission, Combustion, Temperature*

INTRODUCTION

These days, internal combustion engines are preferred in automobile industry due to their smaller size and power to weight ratio. There are many harmful emissions come from these IC engines. Some of these emissions are carbon monoxide, carbon dioxide, hydro-carbons and particulate matter. These pollutants are also very harmful for the environment as they pollute the air and it becomes very difficult for the human beings to take breathe in that kind of polluted environment.

There are many methods which are used to control the emissions from internal combustion engines. The process of controlling emission is performed by using homogeneous mixtures, lowering down the combustion temperature, mixing the proper proportion of air and fuel and improving ignition timing.

There are many methods to control emissions from compression ignited engines. Some of these methods are to use substrate and coating technology, Nonselective Catalytic Reduction, Selective Catalytic Reduction, Selective Catalytic Reduction and Homogenous Charge Compression Ignition etc.

It is observed that by using lean NOx catalyst, the emission of NOx can be reduced by 80 percent. An additional hydrocarbon is formed by injecting catalyst into fuel and this hydro-carbon is used to reduce the emission of NOx from the engines.

In some cases, the engines are modified so as to reduce the rate of emission. It is observed that due to modification of engine, if the emission of NOx reduces then the emission of PM is increased and if the emission of PM is reduced then the rate of emission of NOx is increased. Therefore, other methods were investigated to control these emissions from combustion engines.

In some cases, to lower the rate of emission from engines, homogeneous charge combustion is achieved at lower temperatures and the level of compression is made higher. As a result of this method, NOx is emitted in lower number. In this method, fuel and air are mixed together before pouring in cylinder. After that, compression is used to ignite the mixture of fuel and air.

Injection rate shaping is one more method to control emissions from engines. In this method, the flow of fuel is changed continuously at the time of injection. As a result of this varying fuel flow, the emissions of NOx and PM get reduced.

Hence, there are many methods which are used to lower the emission from combustion engines and we will highlight these methods in next section.

EMISSION CONTROL TECHNIQUES

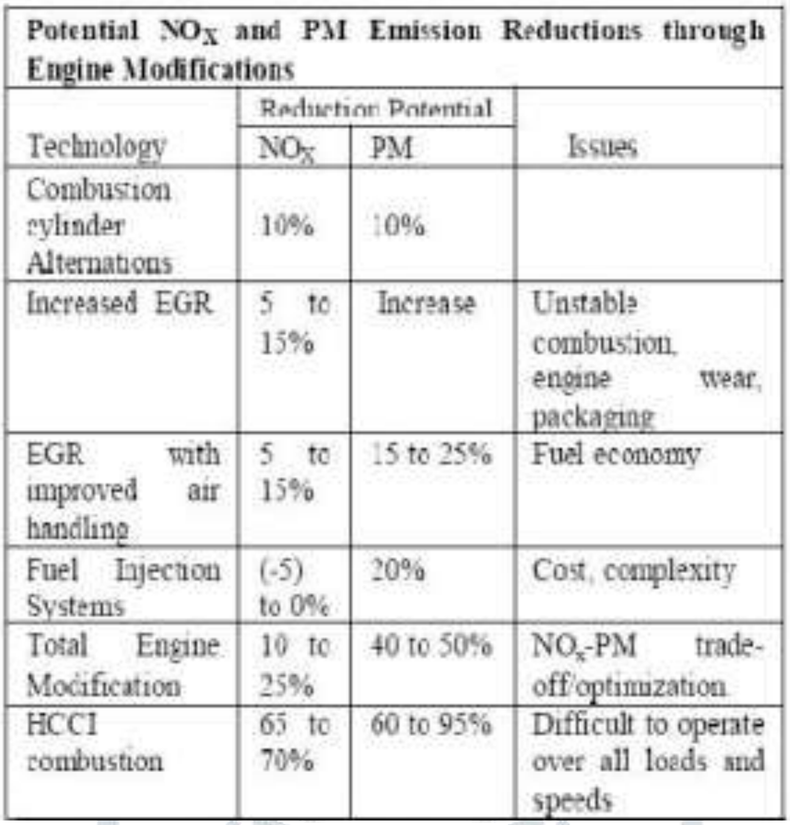
Various emission control technologies exist for IC engine which can afford substantial reduction in all pollutants listed above. However depending on whether the engine is being run rich, lean or stiochiometrically and the emission control technology used, the targeted emissions vary as do the levels of control.

A. MODIFICATION IN ENGINE DESIGN

Engine modification relate to changing the combustion process itself to reduce the formation of emissions. However, changes which decrease NOX often increase the engine-out emissions of PM, and vice versa.

For example, lowering the maximum temperature reached during combustion reduces NOX emissions, but inhibits the complete oxidation of soot, thereby increasing particulate emissions. This is known as NOX-PM tradeoff and presents a critical challenge to diesel emission reduction strategies. Changing the engine parameters may also effects fuel economy, requiring the optimization of NOX,PM, and fuel economy for the specific application.

Advanced fuel injection systems are a major enabler for diesel engines. New systems must allow for high fuel injection pressures (up to 1500 to 2000 times atmospheric, while traditional pump systems reach a maximum of about 900 times atmospheric) and flexible injection rate shaping while meeting demanding durability, cost, and packaging constraints.



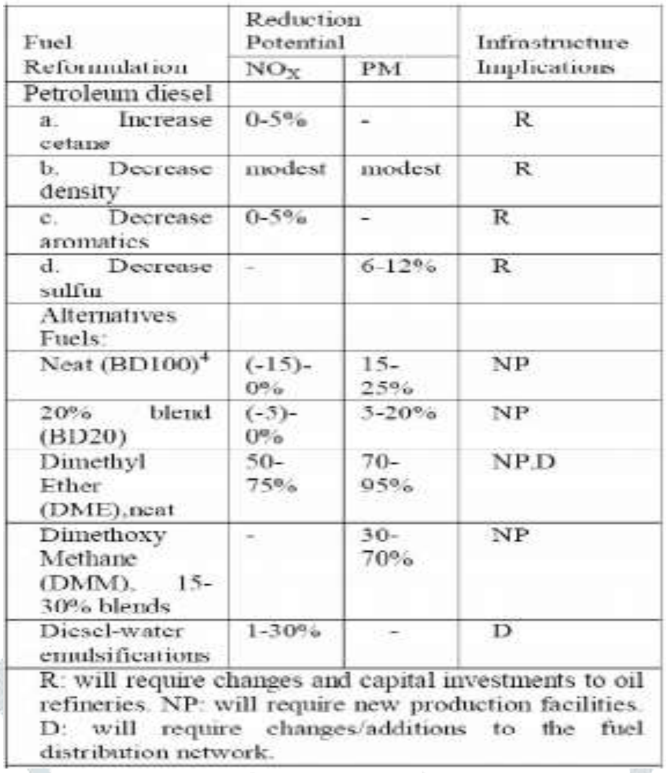
Potential NO_X and PM Emission Reductions through Engine Modifications

Technology	Reduction Potential		Issues
	NO_X	PM	
Combustion cylinder Alternations	10%	10%	
Increased EGR	5 to 15%	Increase	Unstable combustion, engine wear, packaging
EGR with improved air handling	5 to 15%	15 to 25%	Fuel economy
Fuel Injection Systems	(-5) to 0%	20%	Cost, complexity
Total Engine Modification	10 to 25%	40 to 50%	NO_x-PM trade-off optimization
HCCI combustion	65 to 70%	60 to 95%	Difficult to operate over all loads and speeds

High fuel injection pressures reduce particulate emissions by forcing smaller droplets in the fuel spray (called fuel atomization), which increases air-fuel mixing. Traditional injection systems build up the pressure for each injection using pumps powered directly by the engine, so that the pressure available for injection is limited by the engine speed. Such systems cannot reach sufficiently high pressures during all driving modes to achieve substantial emissions reductions.

B. REFORMULATION OF THE FUELS

Automobile engines and fuels are often considered distinct components by drivers. However, a more accurate view considers the two as one system, because the performance and emission characteristics of an engine are closely linked to fuel properties. Here we discuss the effects of diesel fuel parameters and alternative fuels on compression ignition engine emissions. Potential emission reductions associated with fuel reformulations are listed Table.

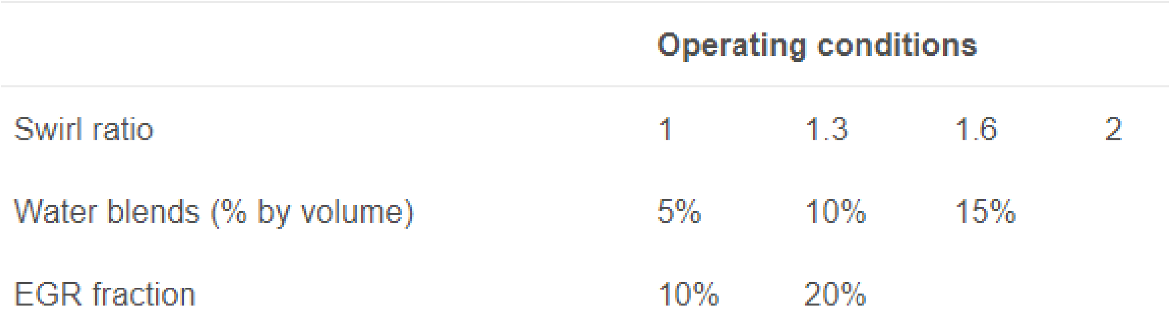


Fuel Reformulation	Reduction Potential		Infrastructure Implications
	NOx	PM	
Petroleum diesel			
a. Increase cetane	0-5%	-	R
b. Decrease density	modest	modest	R
c. Decrease aromatics	0-5%	-	R
d. Decrease sulfur	-	6-12%	R
Alternatives Fuels:			
Neat (BD100)^4	(-15)-0%	15-25%	NP
20% blend (BD20)	(-5)-0%	5-20%	NP
Dimethyl Ether (DME),neat	50-75%	70-95%	NP,D
Dimethoxy Methane (DMM), 15-30% blends	-	30-70%	NP
Diesel-water emulsifications	1-30%	-	D
R: will require changes and capital investments to oil refineries. NP: will require new production facilities. D: will require changes/additions to the fuel distribution network.			

C. EGR method

In EGR method, the percentage of exhaust gas recirculated in the engine is taken as 0%, 10% and 20%. Finally, reduction of emission is attempted by means of water introduced in the combustion chamber blended with the base fuel, diesel–methanol blend, in the ratio of 5%, 10% and 15% by volume.

Table 3 Details of operating conditions of emission-reduction techniques



	Operating conditions			
Swirl ratio	1	1.3	1.6	2
Water blends (% by volume)	5%	10%	15%	
EGR fraction	10%	20%		

D. Substrate& Coating Technologies

The technology of the substrates, on which the active catalyst is supported, has seen great progress. In 1974, ceramic substrates had a cell density of 200 cells per square inch (cpsi) of cross section (31 cells/cm2) and a wall thickness of 0.012 inch or 12 mil (0.305mm).

By the end of the 70's the cell density had increased through 300 to 400 cpsi and wall thickness had been reduced by 50% to 6 mil. Now 400, 600 and 900 and even 1200 cpsi substrates are available and wall thickness can be reduced to 2 mil–almost 0.05mm. This progress in ceramic and metal substrate technology has major benefits. A larger catalyst surface area can be incorporated into a given converter volume and this allows better conversion efficiency and durability. The thin wall reduce thermal capacity and limit pressure losses.

Figure 1: Ceramic Substrates

E. Nonselective Catalytic Reduction and ThreeWay Catalysts

NSCR has been used to control NOX emissions from rich-burn engines for over 15 years. The systems have demonstrated the ability to achieve greater than 98 percent reduction. Over 3000 rich burn IC engines have been equipped with NSCR technology in the U.S alone. Engines in excess of 250hp have been equipped with NSCR. In the presence of CO and NMHC in the engine exhaust, the catalyst converts NOX to nitrogen and oxygen. NSCR reduces NOX, CO, and NMHC emissions if an engine is operated stoichiometrically. NSCR used in this manner is defined as a three-way conversion catalyst. Three Way catalysts are the main auto catalyst technology used to control emission from gasoline engines. The catalyst uses a ceramic or metallic substrate with an active coating incorporating alumina, ceria and other oxides and combination of the precious metals platinum, palladium and rhodium. Three-way catalysts operate in closed-loop system including a lambda or oxygen sensor to regulate the air-to-fuel ratio on gasoline engines. The catalyst can then simultaneously oxidize CO and HC to CO2 and water while reducing NOX to nitrogen.

F. Selective Catalytic Reduction

SCR was originally developed and used to reduce NOX emissions from coal, oil, gas fired power stations, marine vessels and stationary diesel engines. SCR technology permits the NOX reduction reaction to take place in an oxidizing atmosphere. It is called “Selective” because the catalytic reduction of NOX with ammonia (NH3) as a reductant occurs preferentially to the oxidation of NH3 with oxygen. The reaction that occurs over the catalyst bed using ammonia is as follows:

$$4NO+4NH_3+O_2\rightarrow 4N_2+6H_2O$$

$$2NO_2+4NH_3+O_2\rightarrow 3N_2+6H_2O$$

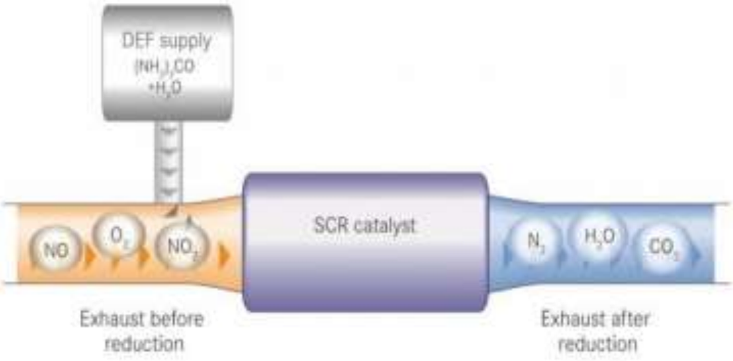


Figure 2: Selective Catalytic Reduction (SCR)

In Europe SCR technology is now fitted to most new heavy-duty diesel vehicles (i.e. truck and bus) and non-road mobile machinery such as construction equipment. A growing number of diesel light-duty vehicles and passenger cars are also equipped with SCR systems. The efficiency of SCR for NOXreduction also offers a benefit for fuel consumption. It allows diesel engine developers to take advantage of the trade-off between NOX, PM and fuel consumption and calibrate the engine in a lower area of fuel consumption than if they had to reduce NOXby engine measures alone. Particulate emissions are also lowered and SCR catalytic converters can be used alone or in combination with a particulate filter.

G. Oxidation Catalysts

Oxidation catalysts have been used on off-road mobile source lean-burn engines for almost 30 years. More recently, they have been applied to on-road lean-burn engines as well. In fact, over 350,000 oxidation catalysts were equipped to on-road diesel engines in 1994 alone. In the U.S, over 500 stationary lean-burn IC engines have been outfitted with oxidation catalysts. Oxidationcatalysts contain precious metals impregnated onto a high geometric surface area carrier and are placed in the exhaust stream. They are very effective in controlling CO and NMHC emissions. CO can be reduced by greater than 98 percent and NMHC emissions can be reduced by over 90 percent. They are also used to reduce particulate emissions of diesel engines by oxidizing the soluble organic fraction of the particulate reduction of over 30 percent can be achieved.

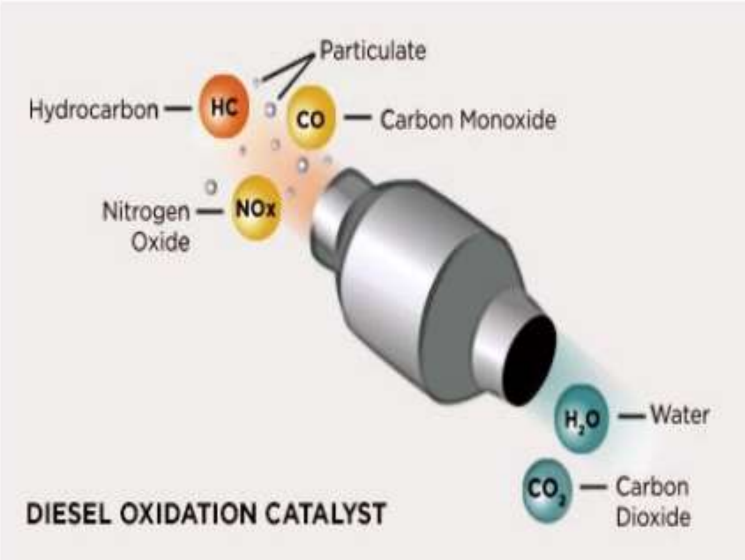


Figure 3: Oxidation Catalyst

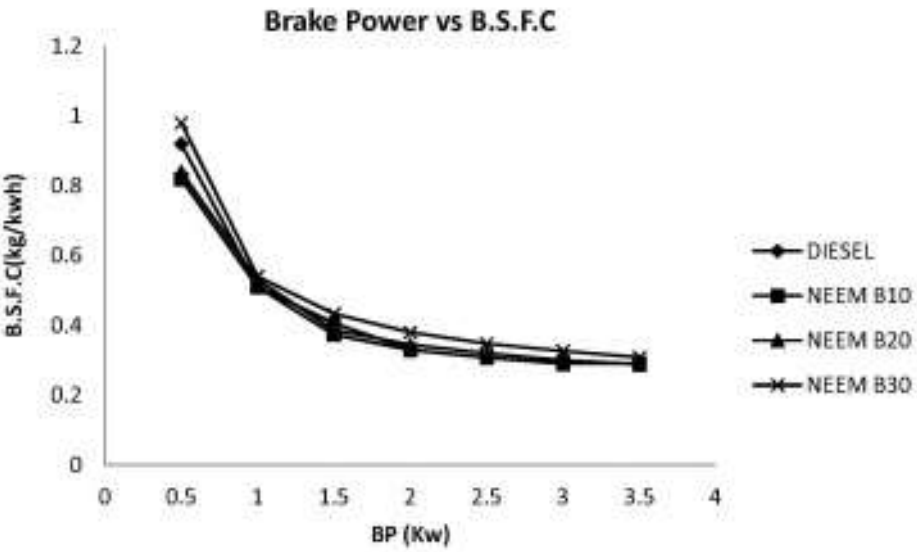
H. Lean NOX Catalyst

A small amount of diesel fuel (equivalent to approximately a three percent fuel penalty) can be injected upstream of the catalyst to provide the additional hydrocarbons needed to significantly reduce NOX emissions. At the same time, CO and NMHC emissions are reduced dramatically. Although a relatively new technology, one stationary diesel engine has been equipped with a Lean-NOX catalyst and NOX emissions are being reduced by 80 percent, CO by 60 percent and NMHC emissions by 60 percent.

DISCUSSION

Specific fuel consumption (kg/kwhr)

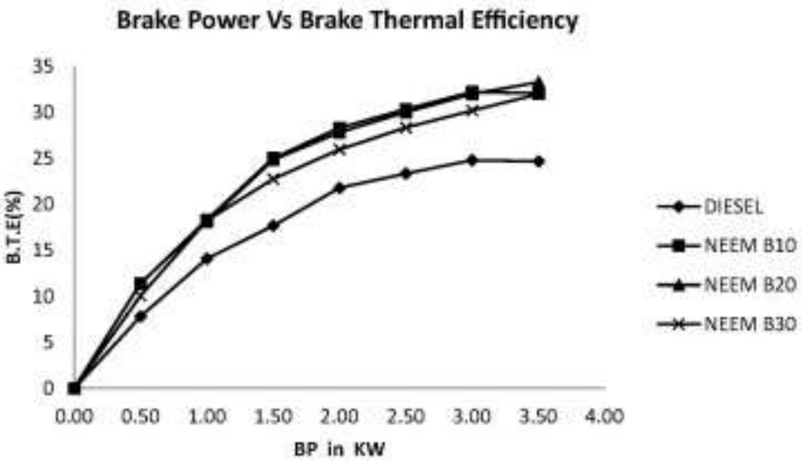
Graph 1 shows the brake specific fuel consumption of neem biodiesel blends as well as diesel as function of brake power. From the graph it is observed that the B.S.F.C for diesel as well as B10 blend is less than *t* B20 & B30 at all loads. As the concentration of neem biodiesel increases in the blends, it is found that B.S.F.C also increases. This can be attributed to the lower calorific values of B30 and B20 as for the same energy output more mass of fuel is consumed.



Graph 1: Variation of B.P vs B.S.F.C of biodiesel blends and diesel

Brake thermal efficiency (%)

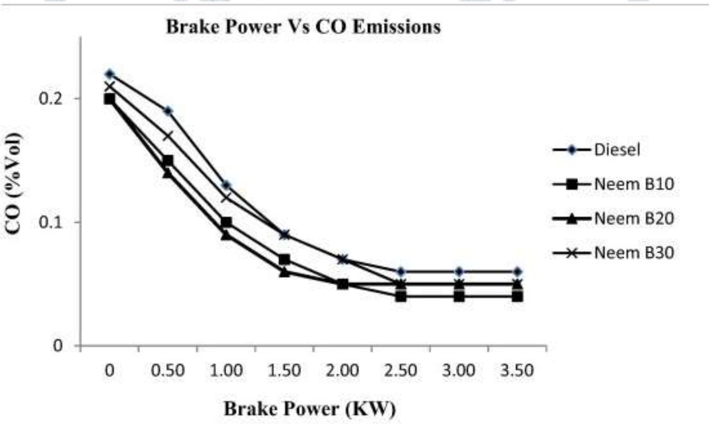
Graph 2 shows the comparison of brake thermal efficiency for neem biodiesel blends with diesel. From the graph it is clear that brake thermal efficiency of neem biodiesel blends are higher than that of diesel at all loads. It is also observed that at lower loads all the three blends are falling on the same curve. The reason that the blends are showing higher brake thermal efficiency can attributed to the higher oxygen content of the blends neem which ultimately improves the combustion efficiency. An average increase in brake thermal efficiency of B10 and B20 for all loads was noted to be 34% against diesel.



Graph 2: Variation of B.T.E vs B.P of biodiesel blends and diesel.

Co emissions

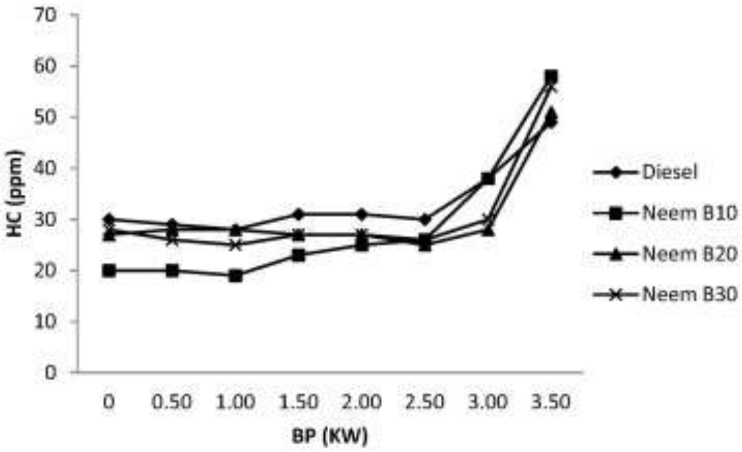
Graph 3 shows the variation of CO emissions of Neem seed blends and diesel against brake power. The main reason for CO emissions is incomplete combustion where the oxidation process does not occur completely. Since biodiesel contain extra oxygen content CO is converted into CO_2. The CO emissions were reduced for Neem blends compared to pure diesel. From Graph 3 it is clear that CO emissions of Neem B10 and Neem B20 are very less compared to Neem B30 and Diesel. Average reduction in CO emissions for B10, B20, B30 was 26%, 22%, 5% respectively.



Graph 3: Variation of CO emissions of biodiesel blends and diesel against load.

HC emissions

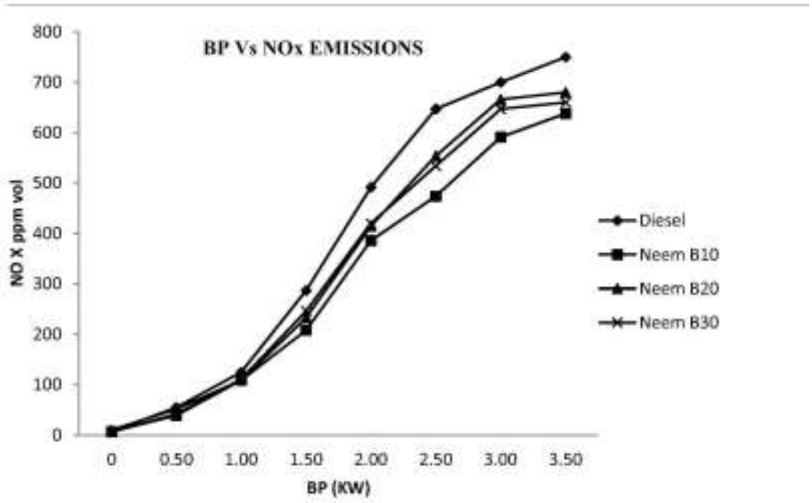
Graph 4 shows the variation of HC emissions against load variations. Hydrocarbon emissions are composed of unburned fuels as a result of insufficient temperature which occurs near the cylinder wall. In lean mixtures, flame speeds may be too low for combustion to be completed during the power stroke, or combustion may not occur, and these conditions cause high hydrocarbon emissions. On an average HC emissions are reduced compared to that of diesel by 17%, 10% and 9% for B10, B20, B30 respectively.



Graph 4. Variation of HC emissions of biodiesel blends and diesel against load

NO_X emissions

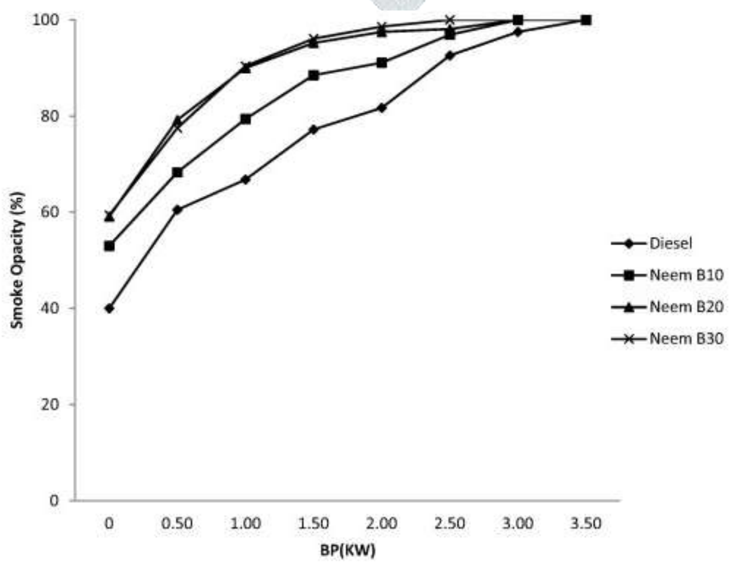
Graph 5 shows the variation of NO_X emissions of biodiesel blends and diesel against brake power. Generally nitrogen does not react with oxygen in the combustion chamber. However, high temperatures in the cylinders cause the nitrogen to react with oxygen and generate NO_X emissions. It is noted that the blends of Neem oil are emitting less NO_X as compared to diesel. It may be attributed to lower heat release rate of blends which leads to lower combustion temperatures. Lower heat release rate may be because of poor mixing of blends and air. On an average NO_X emissions are reduced compared to those of diesel by 21.875%, 8.375% and 18.875% for B10, B20, B30 respectively.



Graph 5. Variation of NO_X emissions of biodiesel blends and diesel against load

Smoke emissions

Graph 6 shows the variation of smoke emissions of Neem blends and diesel against brake power. The smoke emission increases for all the test fuels. It can be observed that smoke emission is higher with the blends than diesel. As the viscosity of the neem blends is higher the atomisation is not proper which results in slow combustion. It is observed that at higher loads smoke is equal in all the cases i.e. 100%. On an average smoke emission is increased compared to that of diesel by 12% for B10 and 21% for B20 and B30.



Graph 6. Variation of smoke emissions of biodiesel blends and diesel against brake power

CONCLUSION

Emission from mobile sources have raised health and environmental concerns, but a number of technologies exist that can greatly reduce NOX, CO, NMHC and PM emissions from IC Engines.

Continuous improvement in substrate and coating technologies, as part of an integrated system comprising electronic control, fuel quality and other modification in engine design, allows meeting more and more stringent combustion engines emissions legislations under a wide range of engine operating conditions.

Table 4 Emission reduction of optimum blends by applying different methods of emission reduction

Emission	D	D+M30[a] (optimum blend)	SR 1.3[b]	EGR 20%[b]	Water addition[b] (15% volume)
NO	0.00034	0.00012	0.00011	0.000077	0.000007
(Mass fraction)		(65% ↓)	(2.5% ↓)	(36% ↓)	(95% ↓)
Soot	0.00001	0.00005	0.00010	0.00005	0.00004
(Mass fraction)		(400% ↑)	(118% ↑)	(Same)	(14% ↓)
CO	0.0275	0.0088	0.0086	0.0094	0.0063
(Mass fraction)		(68% ↓)	(3% ↓)	(6% ↑)	(29% ↓)
HC	0.0180	0.0080	0.0090	0.0089	0.0051
(Mass fraction)		(56% ↓)	(12.5% ↑)	(11.2% ↑)	(36% ↓)

↑ Emission increases.

↓ Emission decreases.

[a] Comparison with diesel fuel.

The future Euro VI levels are set to 0.08g/kg, indicating remarkable 55% reductions from present Euro V norms for passenger cars and above 75% for heavy duty vehicles. This fact implies that NO reduction is very critical. Research attempts should emphasize and focus on effective techniques to meet the Euro VI standards in general and Euro V standards for India in particular.

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