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Prediction and Reduction of Nox Emission Using Bio Fuel In Multi Cylinder Diesel Engine by Injecting Ammonia With SCR

(Mango seed as a biofuel)

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Abstract:-Nowadays tail pipe emission controls have become one of the most significant challenges in internal combustion engines. Oxides of nitrogen (NOx) are one of the major hazardous pollutants that come out from diesel engines tail pipe emission. Oxides of nitrogen (NOx) in the atmosphere cause very serious environmental problems, such as photochemical oxidant, acid rain, and global warming. There are multiple techniques existing for NOx control however each technique has its own advantages and disadvantages. At present, there is no single optimal technique that could control NOx without causing other side effects. Technologies available for NOx reductions either raise other polluting gas emissions or increase fuel consumption. Injection of aqueous solutions of Ammonia in the tail pipe of a diesel engine for the decrease of oxides of nitrogen (NOx) has been carried out in a four stroke, multi cylinder, water cooled, constant speed diesel engine. Four observations has been made for the exhaust emission NOx analysis of concentration of ammonia solution B25, B50, B75, and B100 by weight with different pressure of ammonia solution as reductant by fitting Marine Ferromanganese nodule as SCR catalyst. It was observed that 21% of NOx reduction achieved. High values of NOX reduction can be obtained with ammonia as a reducing agent with a standard SCR catalyst. The process was cautiously investigated for possible secondary emissions and it is shown that ammonia-SCR does not lead to relevant emissions of nitrogen dioxide, nitrous oxide, hydrogen cyanide and isocyanic acid.

Keywords: - Nox, emission, ammonia, biodiesel,

I. INTRODUCTION

The energy requirement has been increased exponentially over the past decades owing to industrialization and the change of subsequent lifestyle. Most of these energies are generated from fossil fuels such as coal, natural gas, gasoline and diesel. Almost 90% of the existing energy source is based on the combustion of fossil fuels and biomass [1]. In last few decades, the environmental effects of pollutant emission from combustion sources are becoming increasingly serious. The ongoing emission of NOx is a serious persistent environmental problem due to; it plays an important role in the atmospheric ozone devastation and global warming [2]. NOx is one of the most important precursors to the photochemical smog. Component of smog irritates throat and eyes stir up asthmatic attacks, decrease visibility and also damages plants and materials. By dissolving with water vapor NOx form acid rain which has direct and indirect effects both on human and plants. The idea of using urea SCR systems for the reduction of NOx emissions in diesel engines is two decades old. Ever since then, many applications have been developed by researches, some of which have reached commercialization there are several techniques for NOx removal. Selective catalytic reduction (SCR) of NOx with Urea is considered as promising technology for NOx reduction in diesel engine tail pipe emission. The main requirements for an SCR catalyst of automotive applications are high volumetric activity, stability over a wide temperature range (180–650°C), and high selectivity with respect to the SCR reaction, in the last years, a main challenge was the development of catalysts with higher volumetric activity and this has been achieved by increasing the intrinsic activity of the catalyst formulation and by increasing the cell density of the monoliths [3]. An SCR (Selective Catalytic Reduction) exhaust gas after treatment system which uses a urea solution as a reducing agent has a high NOx reduction potential and is a well-known technique for stationary applications [4]. Ammonia has been ruled out as a reducing agent, due to toxicity and handling issues, and urea appears to be the reductant of choice for most applications, stored on board in an aqueous solution. To overcome the difficulties associated with pure ammonia, urea can be hydrolyzed and decomposed to generate ammonia.

$$CO\ (NH_2)_2 \Rightarrow NH_3 + HNCO\ [1]$$
$$HNCO + H_2O \Rightarrow NH_3 + CO_2\ [2]$$

It seems that urea, as ammonia source, is the best choice for such applications because urea is not toxic and also can be easily transported as a high-concentration aqueous solution. As a result, NOx can be reduced with not only ammonia but also the urea itself and its decomposition by product, HNCO, as shown in reactions [5].

$$2CO\ (NH_2)_2 + 6NO \Rightarrow 5N_2 + 2CO_2 + 4H_2O\ [3]$$

4HNCO + 6NO ⇒ 5N2 + 4CO2 + 2H2O [4]

4NH3+ 4NO + O2⇒ 4N2+ 6H2O [5]

II. MANGO SEED OIL AS A BIO DIESEL

The exhaust emissions of a Diesel direct injection engine fueled with mango seed oil methyl ester were studied at several steady-state operating conditions. Emissions were characterized with neat biodiesel from used mango seed oil and conventional Diesel fuel. Results revealed that the use of biodiesel resulted in lower emissions of CO (up to 58.9%), CO2 (up to 8.6%, excepting a case which presented a 7.4% increase), NO (up to 37.5%), and SO2 (up to 57.7%), with increase in emissions of NO2 (up to 81%, excepting a case which presented a slight reduction). Biodiesel also presented a slight increase in brake-specific fuel consumption (lower than 8.5%) that may be tolerated due to the exhaust emission benefits. Combustion efficiency remained constant using either biodiesel or Diesel fuel. The proposed alternative for Diesel fuel could significantly decrease the enormous amount of waste frying oil, furthermore becoming less dependent on fossil oil imports and decreasing environmental pollution.

S.N.	Property	Diesel	Biodiesel
1	*Density at 15°C gm/cc*	*0.830*	*0.8955*
2	*Kinematic Viscosity at 40°C mm²/sec*	*4.59*	*12.74*
3	*Calorific Value KJ/Kg*	*42700*	*39370*
4	*Flash Point °C*	*75*	*68*
5	*Fire Point °C*	*81*	*78*
6	*Cloud Point °C*	*-15*	*+ 10*
7	*Pour Point*	*-4*	*+3*
8	*Cetane Index*	*45 to 55*	*42*

Table 1 Property of Biodiesel (Without Additives) and Diesel

III. SELECTIVE CATALYTIC REDUCTION (SCR)

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) or urea as a reductant occurs preferentially to the oxidation of NH3 or urea with oxygen. The efficiency of SCR for NOx reduction also offers without a fuel penalty. 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 NOx by engine measures alone. Particulate emissions (PM) are also decreased and SCR catalytic converters can be used alone or in combination with a particulate filter. For source applications ammonia is used as a selective reductant, in the presence of excess oxygen, to convert over 70% (up to 95%) of NO and NO2 to nitrogen over a specified catalyst system. Different precursors of ammonia can be used; but for vehicles the most common option is a solution of urea in water carefully metered from a separate tank and injected into the exhaust system where it hydrolyses into ammonia ahead of the SCR catalyst. Urea solution is a stable, non- flammable, colorless fluid containing 32.5% urea which is not classified as hazardous to health and does not require any special handling precautions.

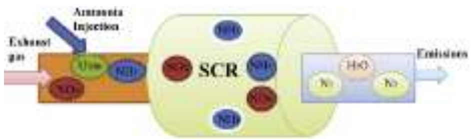

Figure 1 SCR system with ammonia injection

Several types of catalysts are used, the choice of which is determined by the temperature of the exhaust gases. In many countries, SCR catalysts were mainly based on vanadia. However, if DPFs are used in combination with SCR systems, zeolites are preferred due to the better high temperature durability needed when exotherms associated with DPF regeneration can expose SCR catalysts to temperatures up to 800°C. Currently copper- zeolites have the best low temperature performance and iron-zeolites have the best high temperature performance. Optimized operation of SCR catalysts depends on control of adsorbed urea and use of oxidation catalysts to deliver the appropriate NO2/NOx ratio. To determine the type of catalyst to be used that depend on exhaust gas temperature, reduction of nitrogen oxides required, oxidation of SO2 and the concentration of other exhaust gas constituents.

IV. EXPERIMENTAL SETUP

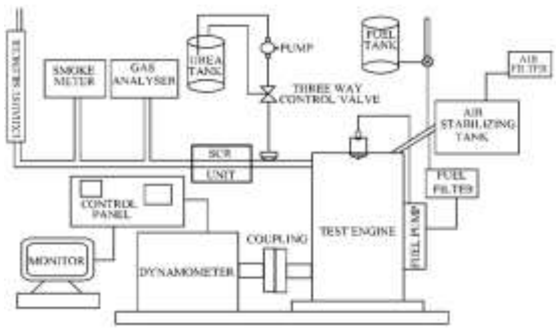

Figure 2 Schematic of Experimental Setup

Injection of aqueous solutions of urea from a separate urea tank in the tail pipe of test the diesel engine for the reduction of oxides of nitrogen (NOx) was carried out in a four stroke, multi cylinder, water cooled, constant speed diesel engine with eddy current dynamometer. Four observations were made for the exhaust gas analysis of various concentration of urea solution 0%, 10%, 20%, and 30% by weight with different flow rates of urea solution by fitting Marine Ferromanganese nodule as oxidant catalyst. The technical specifications of the engine are given in Table I, and the schematic of the experimental setup is shown in Figure.

Table 2 Multi Cylinder Four Stroke Diesel Engine Specification

S. No	Particulars	Specification
1	Model & Make	1.5 Diesel BS-III & HM
2	Maximum Power(kW)	26.5
3	Maximum Speed(rpm)	4000
4	Cylinder Bore(mm)	88.9
5	Stroke Length(mm)	101.6
6	Connecting Rod Length(mm)	177.8
7	Cubic Capacity	2531
8	Compression Ratio	18.1:1
9	No. of Strokes	4
10	No. of Cylinders	4
11	Cooling	Water Cooled
12	Type of Fuel	Diesel

V. RESULTS AND DISCUSSIONS

The output obtained from the experiment is plotted to determine the effect of the injection of Ammonia solution at various concentration and flow rate as reductant and marine ferromanganese nodule as SCR on the NOx emission analysis of the test engine. Graphs (10.1-10.4) shows the variation of oxides of nitrogen (NOx) with respect to blends of mango seed oil with diesel at various load B25, B50, B75 and B100. As expected the variation of oxides of nitrogen shows a decreasing trend with increasing in biodiesel content for the various techniques employed. The SCR technique is the upcoming technology which is meant for reducing NOx. The technique involves spraying of ammonia solution with various pressure flow rate 1.5, 2.0 and 2.5 bar. For the engine under consideration spraying 30 ml/min was found to be appropriate at various loads 20, 60, 80 and 100 as can be seen ammonia pressure flow rate 2.0 bar gives lowest oxides of nitrogen as compared to all other pressure and all other techniques. The percentage reduction in (NOx) with SCR for B25, B50, B75 and B100 is 19.3%, 35.08%, 52.56% and 61.57% respectively as compared with conventional Multi Cylinder Diesel with various loads.

5.1. Oxides of Nitrogen (NOx) v/s Various Loads without Ammonia and SCR

Figure 3: Shows NOx emissions with various loads of diesel fuel without Ammonia solution and SCR at constant speed of the engine. From the graph it is observed that the NOx emission increases with the increase of load due to high combustion temperature in the combustion chamber. The percentage of Oxides of Nitrogen (NOX) obtained without SCR and Ammonia for B25, B50, B75 and B100 is 53.23%, 69.41%, 77.7% and 98.3% respectively as compared with Multi Cylinder Diesel with various loads.

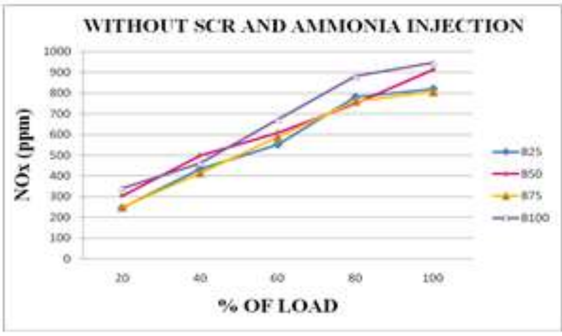

Figure 3 Oxides of Nitrogen (NOx) v/s Various Loads without Ammonia and SCR

5.2 Oxides of Nitrogen (NOx) v/s Various Loads with 1.5 Bar Ammonia Solution with SCR

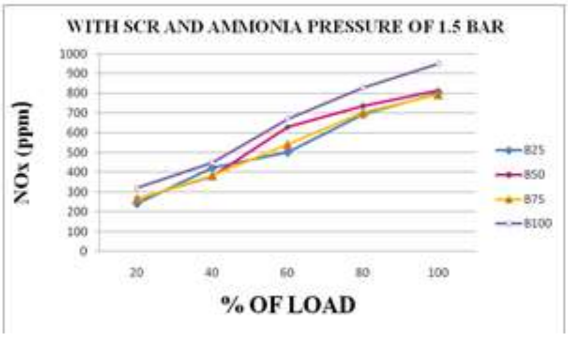

Figure 4 Oxides of Nitrogen (NOx) v/s Various Loads with 1.5 bar Ammonia Solution with SCR

Figure 4 Shows NOx emissions with various loads of diesel fuel at 1.5 bar Ammonia solution with SCR at constant speed of the engine. From the graph it is observed that the NOx emission decreases with the injection pressure of 1.5 bar Ammonia solution. The percentage of Oxides of Nitrogen (NOX) obtained with SCR and Ammonia at pressure of 1.5 Bar for B25, B50, B75 and B100 is 21.4%, 53.41%, 62.74% and 69.75% respectively with Multi Cylinder Diesel with various loads.

5.3. Oxides of Nitrogen (NOx) v/s Various Loads with 2.0 Bar Ammonia Solution with SCR

Figure 5: Shows NOx emissions with various loads of diesel fuel at 2.0 bar Ammonia solution with SCR at constant speed of the engine. From the graph it is observed that the NOx emission decreases with the injection of 2.0 bar Ammonia solution. The percentage of Oxides of Nitrogen (NOX) obtained with SCR and Ammonia at pressure of 2.0 Bar for B25, B50, B75 and B100 is 19.3%, 35.08%, 52.56% and 61.57%

respectively with Multi Cylinder Diesel with various loads. It observed that as the Ammonia flow rate increases NOx reduction increases due to better mixing of the exhaust gases in the tail pipe.

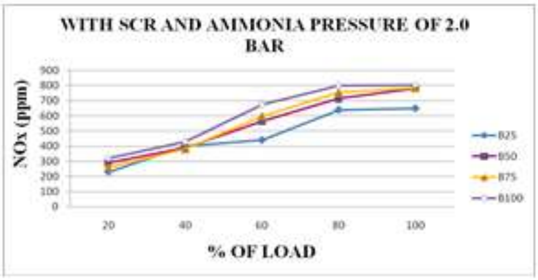

Figure 5 Oxides of Nitrogen (NOx) v/s Various Loads with 2.0 Bar Ammonia Solution with SCR

5.4. Oxides of Nitrogen (NOx) v/s Various Loads with SCR at 2.5 Bar Ammonia Injecting Pressure

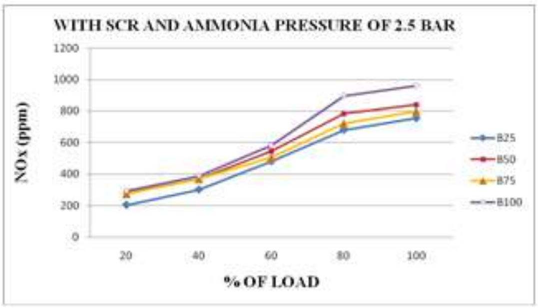

Figure 6 Oxides of Nitrogen (NOx) v/s Various Loads with SCR at 2.5 Bar Ammonia Injecting Pressure

Figure 6 Shows NOx emissions with various loads of diesel fuel at 2.5 bar Ammonia solution with SCR at constant speed of the engine. From the graph it is observed that the NOx emission decreases while compare with without SCR and ammonia injection. The percentage of Oxides of Nitrogen (NOX) obtained with SCR and Ammonia at pressure of 2.5 Bar for B25, B50, B75 and B100 is 32.58%, 58.21%, 68.67% and 75.07% respectively with Multi Cylinder Diesel with various loads From the graph it is observed that the NOx emission gets sudden increase while injecting the Ammonia solution at 2.5 Bar. Due to increase in the pressure of Ammonia solution its leads to long term usage problems inside the engines such as higher carbon deposits, lubricating oil degradation and enhanced engine wear.

VI. CONCLUSION

Thus, the performance of Four different samples of mango seed oil blend with Diesel in the ratio of B25, B50, B75 and B100 absorbed the NOX emission level with various ammonia flow rate 1.5, 2.0 and 2.5 Bar and also did the same work with and without SCR setup by ammonia Injecting are considered and the performance of the Multi cylinder Diesel Engine. The SCR gives lowest emission and drastic reduction in NOx as compared to all other techniques at various loads. However, there is a slight penalty on the performance and Combustion characteristics. Among the entire ammonia flow rate, the 2.0 bar gives lowest emissions and better performance at various loads. The usage of SCR with injection of diesel engine seems to be a variable alternative to enhance the eco-friendliness of our globe and thereby has a good chance to reduce acid rain. Therefore, from this project it can be concluded that Ammonia flow rate at 2.0 bar can be used in various loads along with SCR technique without any major modifications on the engine, as it provides substantial reduction in NOx especially in the case of stationary engines which has been employed in the present study. Thus, I concluded that the Best Technology for reducing the Oxides of Nitrogen (NOx) from Multi cylinder diesel Engine is Ammonia Injecting with Selective Catalyst Reduction is the best single optimal Technology for reducing Oxides of Nitrogen (NOX) Emission from Multi Cylinder Diesel Engine.

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