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Investigation of UREA-SCR in C.I. Engine Fuelled with Diesel and Jatropha Blends

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ABSTRACT

An Experimental Investigation was conducted to examine the performance and exhaust emission of diesel Engine by using Selective Catalytic Reduction (SCR) concept fuelled with diesel and Biodiesel namely Jatropha (25% of Jatropha and 75% Diesel blends). A test was conducted in four cylinder direct injection diesel engine with different loading condition. And the urea with distilled water solution was sprayed at the Exhaust manifold before it enters the SCR setup for different concentrations and the emission parameters were investigated are CO, HC, NO_X and Smoke Opacity. Results showed that Biodiesel reduced the NO_X and other emission. The result showed that the Biodiesel derived from jatropha oil showed comparable performance in the Selective Catalytic Reduction system (SCR). Results indicated that a maximum of 73.94% of NO_X reduction was achieved with constant flow rate of 0.75 lit/hr with a urea concentration of 32.5% by means of the Titanium dioxide catalyst in Selective Catalytic Reduction (SCR) System.

Keywords: Selective Catalytic Reduction (SCR); Biodiesel; Diesel; Oxides of Nitrogen (NO_X); Unburned Hydrocarbon (HC); Carbon Monoxide (CO).

I. INTRODUCTION

In the last few decades many attempts were made wide to protect life on earth. One of the main areas where a lot of attention is being paid is the vehicular pollution. Light and heavy duty vehicle manufactures face serious challenges from National Ambient Air quality standards (NAAQS) to combat at stringent levels stipulated.

Among the various types of internal combustion engines, petrol and diesel are well established. The diesel engines have become more popular because of their better torque characteristics. The use of diesel engines has increased exponentially in the last decade. Diesel engines are widely used owing to their high thermal Efficiency and low Maintenance.

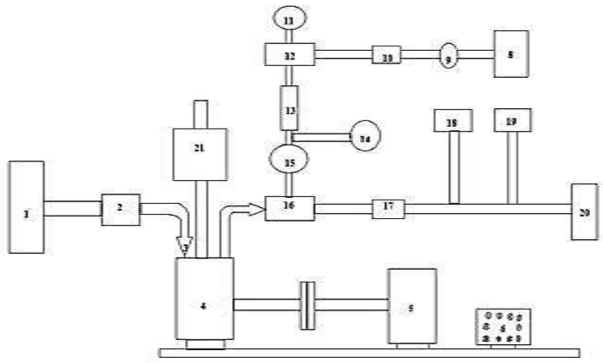
Inspite of these benefits Diesel engine emission case serious human discomforts all over the world. Oxides of Nitrogen and particulates are the major pollutants from the diesel engines. Reducing Oxides of Nitrogen and particulate matter in exhaust gas of diesel Engine has become very important to protect environment and to save energy.

The Primary objective of this project is to control the NO_X formation in the diesel engines using the Selective Catalytic Reduction System (SCR).

The SCR method is capable of oxidizing the Greenhouse gas (NOx) which is a by product of C.I. engines at high temperatures. Diesel Engine trucks are the workhorses of today's society, delivering the majority of goods used all over the world [3-6]. Now, after two decades of dramatic emissions reductions by developing so many different kinds of technologies, heavy truck industry has been challenged to develop even cleaner diesel engine exhaust gases to reduce environmental pollution. The leading solution is Selective Catalytic Reduction (SCR) - an emissions-reduction technology with the ability to deliver near-zero emissions of nitrogen oxides (NOx), a smog-causing pollutant and greenhouse gas. SCR reduces NOx emissions to high levels, while at the same time delivering excellent fuel economy and reliability but the system doesn't change the design or operation of the basic engine setup and only need some extra fitting to a vehicle which is being used already. This technology just treats the exhaust gas coming out of C.I. engine with high performing oxidizing catalyst. The SCR system itself requires very little maintenance and no driver action while the truck is operating [7-10]. The Objective of this Experiment is to determine the maximum reduction of NO_X emission using the Selective Catalytic Reduction (SCR) System.

II. EXPERIMENTAL SETUP AND PROCEDURE

The Experiment was conducted in a light duty stationary single cylinder, four stroke, air cooled, direct injection Kirloskar Engine of 4.4kW as shown in the Figure and photographic view of the setup is shown in appendix. The engine was connected to an electrical dynamometer and AVL FGA and AVL smoke meter. The torque can be varied from the control panel.



1. Air tank
2. Air filter
3. Inlet Valve
4. Engine
5.Electrical Dynamometer
6. Loading device
7. Exhaust Valve
8. Urea tank
9. Motor
10. Pressure relief Valve
11. Battery
12.Relay
13.Heater
14.Pressure guage
15.Solenoid Valve
16.Mixing Chamber
17.SCR catalyst
18.CRYPTON Gas Analyzer
19.AVL Smoke meter
20.Exhaust gas
21. Jatropha tank

Figure 2.1. Schematic diagram of Selective catalytic reduction system

Engine Specifications

The Selective catalytic Reduction system incorporate engine specifications are given below: **Table 2.1.1** Engine Specification

1.	Type	Four Stroke, Single Cylinder vertical Air Diesel
		Engine
2.	Rated Power	4.4 kW
3.	Rated Speed	1500pm
4.	Bore Dia (D)	87.5 mm
5.	Stroke (L)	110 mm
6.	Compression ratio	17.5:1
7.	C.V. of Fuel	42500 kj/kg
8.	Density of Diesel	860 kg/m3
9.	Density of Jatropha	932.9 kg/m3
10.	Fuel injection	Direct injection
11.	Dynamometer Type	Electrical Dynamometer

Table 2.2.1 Properties of Urea solution

1.	Chemical Formula	(NH3)2CO.7H2O
2.	Molecular Weight (g/mol)	60.06
3.	Concentration	32.5
4.	Density (15°C)	1.085 kg/1t
5.	Appearance	Clear Transparent
6.	Smell	Odorless
7.	Acidity (PH)	9-11
8.	Freezing Point	-11°C (12°C)
9.	Self-Ignition Temperature (°C)	630

2.2 Properties of Aqueous Urea Solutions

The properties of as aqueous solutions of urea used in Selective Catalytic Reduction is given in the table

2.3 Components and connections

Experimental setup consists of various components listed in the following table

- Motor (0.75 lit/hr)
- Relay and control switch
- Copper Heater (80°C, 12 volts)
- Pressure relief valve
- Pressure valve (20 bar)
- Nozzle Injector
- valve (12 volts)
- Five gas
- Five gas Plastic storage tank (2litre)
- Copper tubes

An aqueous urea solution is stored in plastic container, which pressurized by motor and allows flow through a copper tube towards heater and passed towards solenoid valve through pressure valve and finally preheated aqueous urea solution is injected in tail pipe of engine through nozzle injector.

2.4 AVL Smoke meter

The smoke present in engine exhaust gas is measured by an AVL 437 C Smoke meter in opacity (%). The specification of AVL Smoke meter is given below

2.5 CRYPTON 295 Five Gas Analyzer (FGA)

The various gases are present in Engine Exhaust gases were measured by using CRYPTON 295 Five Gas Analyzer (FGA). The Technical specification of CRYPTON 295 Five Gas Analyzer (FGA) is given as below table

2.6 Experimental Procedure

In this Experiment urea solution must be atomized and injected into the exhaust manifold at a constant pressure of 6 bar throughout the experiment this is achieved by adjusting the flow control valve and pre-setting the injection pressure. Urea solution of concentration varying with 30%, 32.5% and 35% by weight should be prepared before starting the engine. The heater has provided to pre-heat and vaporize the urea solution the timed spray of urea solution is to be controlled by 12V solenoid valve.

Figure 2.2. Photographic view of SCR

In our research we are going to do experiments on Diesel Engines which will be fuelled with diesel and then the Diesel and Jatropha curcas are been blend. The Jatropha curcas used is 25 percent Esterified and 75 percent of Diesel and hence no need of heating the fuel before using it since the viscosity of the fuel reduces after etherification. Urea solution with water is also used Selective catalytic Reduction (SCR) of NOx by Urea over catalyst has become one amongst the main solutions to realize these aggressive reductions. As such, organic compound solution is injected into the exhaust gas manifold, gaseous and rotten to ammonia via compounding with the hot exhaust gas before passing through an SCR catalyst. Organic compound mixers, during this regard, are crucial to ensure made evaporation and compounding since its liquid state poses significant barriers, especially at temperature conditions that incur unsought deposits. A ceramic honeycomb composite structure adapted to be used as a catalyst support comprises a ceramic honeycomb body and ceramic layers integrally provided thereon having surfaces including therein microscopic holes, a sum of volumes of the holes 5 microns or more being coated with titanium dioxide which is the very good oxidizing catalyst this setup is fixed after Urea injection. At first engine in fuelled with Diesel and by varying the load must be gradually increased from 0% to 100% (0%, 25%, 50%, 75%, and 100%) and Urea concentration in water solution as like 30%, 32.5%, 35% and three readings are taken. The emission parameters such as Unburned Hydrocarbon, Carbon

Monoxide, Carbon-di-oxide, oxides of Nitrogen, and Smoke Opacity were recorded for every load Again the engine should be fuelled with Biodiesel same as above concentrations of urea solution three readings are taken.

2.7 Process of Selective Catalytic Reduction system

An aqueous solution of urea injection in engine tail pipe carried out four different steps, as given below:

A. Hydrolysis of urea

First step of SCR process is hydrolysis of urea. In this a crystal chemically bounded urea (32.5%) is added with (67.5%) of water and stirred up to from aqueous solution. Due to high solubility and weak chemical bond of urea, water is easily mixed to form aqueous solution.

(NH2)2CO + 7H2O   (NH2)2 CO. 7H2O]

B. Evaporation of urea

Second step of SCR process is evaporation of urea. In this an aqueous solution of urea is evaporates due to thermal activity of Exhaust Gas Temperature. Due to evaporation of urea, it starts to decompose in by products of isocynanic acid and ammonia. This process was carried out before aqueous solution of urea reaches honeycomb catalyst bed.

$$[(NH_2)2CO.7H_2O] \longrightarrow HNCO + NH_3 + 7H_2O$$

C. Reduction of NO_X

Third step of SCR process is reduction of NO_X . IN this method, by products of decomposed ammonia is readily reacts with Oxides of Nitrogen present in exhaust gases to form clean environment free nitrogen gas and water vapor.

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

D. Oxidation of excess ammonia

Final step of SCR process was oxidation of ammonia. In this method, excess ammonia present in exhaust gases are readily reacts with oxygen to form clean nitrogen and water vapor.

$$4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O$$

III. RESULTS AND DISCUSSIONS

Experiments were conducted at various concentration of urea solution from varying 30% to 35% with constant flow rate of 0.75 liters per hour. The figures indicate that variation of various Engine emissions with respected to Engine load for various concentration of urea solution.

3.1 Variation of Oxides of Nitrogen with injection of urea solution

Figure: 3.1 shows the variation of NO_X emission with engine load of diesel fuel with various concentrations of urea solution and a constant flow rate 0.75lit/hr with SCR at constant speed of the engine. From the graph it shows that the NO_X emission decreases drastically by introducing titanium dioxide as SCR in exhaust pipe in engine.

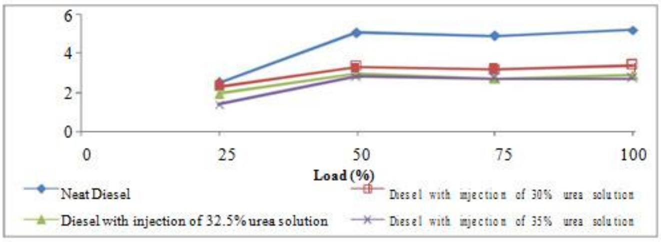


Figure 3.1 Variation on oxides of Nitrogen with Engine Load (Varying urea concentration)

A varying of urea concentration solution was prepared and injected in engine exhaust pipe with a constant flow rate of 0.75lit/hr and constant pressure of 6 bar inducing the reduction of NO_X emission rate gradually decreasing due to presence of SCR catalyst and reducing ammonia gas present in urea solution.

3.2 Variation on Unburned Hydrocarbon with injection of urea solution

A variation on HC emission with engine load of diesel fuel with various concentration of urea solution and a constant flow rate 0.75 lit/hr with SCR at constant speed of the engine. From the graph it shows that the HC emission as SCR in exhaust pipe in engine

3.3 Variation on Unburned Hydrocarbon with Engine Load (Varying urea concentration)

A varying of urea concentration solution was prepared and injected in engine exhaust pipe before catalytic converter chamber with a constant flow rate of 0.75lit/hr and constant pressure of 6 bar inducing the variation of HC emission rate equal to normal steady state diesel engine emission, due to absence and reduction of oxygen content in exhaust gas in SCR system.

3.4 Variation of Smoke Opacity with Injection of urea solution

A variation of smoke opacity emission with engine load of diesel fuel with various concentration of urea solution and a constant flow rate 0.75 lit/hr with SCR at constant speed of the engine. From the graph it shows that the smoke emission decreases drastically by introducing titanium dioxide as SCR in exhaust pipe in engine. A varying of urea concentration solution was prepared and injected in Engine tail pipe before SCR catalyst with a constant flow rate of 0.75 lit/hr and constant pressure of 6 bar. This inducing the variation of Smoke emission rate decreases while compared neat diesel engine emission, due to decreasing of exhaust gas temperature in SCR system.

3.5 Variation of Oxide of Nitrogen with engine load for varying urea concentration (Biodiesel)

A variation of NO_X emission with engine load of Biodiesel fuel with various concentration of urea solution and a constant flow rate 0.75lit/hr with SCR at constant speed of the engine. From the graph it shows that the NO_X emission decreases drastically by introducing titanium dioxide as SCR in exhaust pipe in engine.

A varying of urea concentration solution was prepared and injected in engine exhaust pipe with a constant flow rate of 0.75lit/hr and constant pressure of 6 bar inducing the reduction of NO_X emission rate gradually decreasing due to presence of SCR catalyst and reducing ammonia gas present in urea solution.

3.6 Variation of Unburned Hydrocarbon with engine load for varying urea concentration (Biodiesel)

The variation on HC emission with engine load of Biodiesel fuel with various concentration of urea solution and a constant flow rate 0.75 lit/hr with SCR at constant speed of the engine. From the graph it shows that the HC emission as SCR in exhaust pipe in engine.

A varying of urea concentration solution was prepared and injected in engine exhaust pipe before catalytic converter chamber with a constant flow rate of 0.75lit/hr and constant pressure of 6 bar inducing the variation of HC emission rate equal to normal steady state Biodiesel engine emission, due to absence and reduction of oxygen content in exhaust gas in SCR system.

3.7 Variation of Carbon Monoxide with engine load for varying urea concentration (Biodiesel)

A variation of Co emission with engine load of diesel fuel with various concentration of urea solution and a constant flow rate 0.75 lit/hr with SCR at constant speed of the engine. From the graphs that the CO emission gradually decreases with increasing drastically by introducing titanium dioxide as SCR in exhaust pipe in engine.

A varying of urea concentration solution was prepared and injected in engine tail pipe before SCR catalyst with a constant flow rate of 0.75 lit/hr and constant pressure of 6bar inducing the variation of CO emission rate increase with increasing compared to normal steady state diesel engine emission., due to absence and reduction of oxygen content in exhaust gas in SCR system.

3.8 Variation of Smoke Opacity with engine load for varying urea concentration (Biodiesel)

Figure: 3.8 shows that variation of smoke opacity emission with engine load of Biodiesel fuel with various concentration of urea solution and a constant flow rate 0.75 lit/hr with SCR at constant speed of the engine. From the graph it shows that the smoke emission decreases drastically by introducing titanium dioxide as SCR in exhaust pipe in engine.A varying of urea concentration solution was prepared and injected in Engine tail pipe before SCR catalyst with a constant flow rate of 0.75 lit/hr and constant pressure of 6 bar. This inducing the variation of Smoke emission rate decreases while compared neat diesel engine emission, due to decreasing of exhaust gas temperature in SCR system.

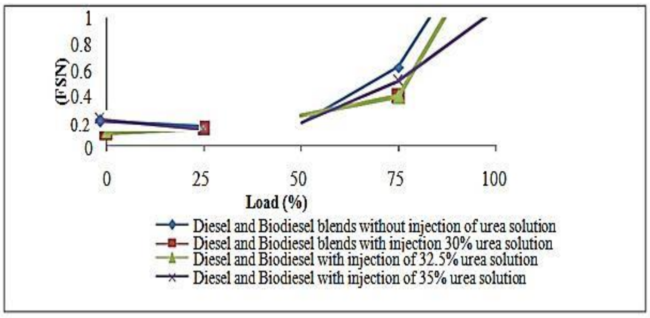


Figure 3.2. Variation of Smoke Opacity with engine load for varying urea concentration (Biodiesel)

IV. CONCLUSIONS

1.The selective catalytic reduction is an after-treatment process and it reduced the NO_X emission. The result reported that the titanium content strongly influences the thermal stability of Selective Catalytic Reduction system catalysts. The titanium catalyst surface in selective catalytic reduction system support influencing selectivity for the reduction of oxides of Nitrogen (NO_X) by ammonia.

2.Based on about result it is concluded that Biodiesel reduced maximum NO_X than the Diesel, urea injected with titanium dioxide as Selective Catalytic Reduction system in the Exhaust pipe gives a reduction of 66% in neat diesel while it is 73.94% in Biodiesel with urea concentration of 32.5%. The above result indicated that urea injected with titanium dioxide as selective Catalytic Reduction catalyst, the level of Unburned Hydrocarbon and Carbon Monoxide are also been reduced than the conventional diesel emission.

Thus, the experiments concluded that the NO_X reduction in the exhaust from C.I Engine was achieved by Selective Catalytic Reduction system (SCR) at the Exhaust manifold when a CI engine fuelled with Biodiesel compare to neat Diesel.

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