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Urea Act as a Catalyst No_x Reduction in SCR System for Diesel Engine

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***Abstract*: Diesel engines are preferred in automobile industry, locomotive industry, power generation etc. because of its high thermal efficiency and break power output. Hazardous pollutants are emitted by diesel engine and an oxide of nitrogen (NOx) is one of the most harmful pollutants which come out from diesel IC engine through its tail pipe. Emission of nitrogen oxide (NOx) also contribute significantly to our environment, which is a savior environmental problem of NOx which reacts with air to form nitric acid (HNO_3), contributing to soil eruption and water acidification in sensitive and metropolitan areas. Various advance technology available for NOx reduction, either increases emission of gases like CO, CO_2, NOx, HC, PM etc. on raises fuel consumption in an IC engine. Selective catalyst reduction systems (SCR) are the most effective and commonly used post combustion NOx reduction processes available in automobile and power generation sector. SCR utilizes a chemical reaction where vaporized ammonia (NH_3) is collected from the mixture of Urea and distilled water. In this method various catalysts are injected into the exhaust gases. The prime objective is to convert nitrogen oxide (NOx) to nitrogen (N_2) and water (H_2O). The distinct design of SCR system is developed by addition of use various catalysts injected in tail pipe through feed pump of this SCR system. It has been observed that the NOx level is reduced due to new SCR system. This process is called as deNOxtation process. In this SCR system denotation level has been reduced, and also contribute to reducing NOx by 65 to 70%.**

***Keywords*: Exhaust gas emission, Diesel emission control system; advance SCR, Urea, Catalyst, Ammonia (NH3)**

1. Introduction

As per the Honorable Supreme Court decision the emission norms in India will be changed with effect from the year 2020.The details of emission norms in India are as below.

Table 1
Emission norms

stage	date	CO	HC	HC+NOx	PM
		Gram/km			
Compression ignition (diesel engine)					
BS IV	2010	0.5	-	0.3	0.025
BS VI	2020	0.5	-	0.17	0.0045
Euro 6	2014	0.5	-	0.17	0.005
Spark ignition (petrol engine)					
Bs IV	2010	1	0.1	0.08	-
Bs VI	2020	1	0.1	0.06	0.0045
Euro 6	2014	1	0.1	0.06	0.005

The stringent limits of emission standards legislation are found in euro norms Selective Catalytic Reduction (SCR) methodology has been used in automobile sector. From long time The maximum NOx conversion efficiency of SCR depends upon temperature and mass flow rate (m_f) of an exhaust gas emission.in todays scenario the necessity for the SCR technology is continuously increasing due to the fact that the emission legislation has been expanded into the non-road market. To convert nitrogen oxides (NOx) into the nitrogen (N_2) and water (H_2O) separation is the main objective of this distinct SCR technology system. This system is more efficient than existing SCR systems. The key is to reform the chemical reaction that is called as deNOxtation process.

Ammonia (NH_3) or urea (NH_2- CO-NH_2) is mostly used as reducing agent in SCR system. When urea and distilled water combined as a mixture, then formation of ammonia (NH_3) is formed and it is injected in tail pipe through feed pump. Automobile manufactures focused their attention towards the further improvement of the technique to make it suitable for automobiles having diesel engines. Reduction of catalytic converter volume at low temperatures and the suitable dosing strategy for NH_3 at frequently on diesel engines is possible with the help of digital exhaust gas analyzer involved with new SCR systems. Additionally, the risk associated concerning storing and handling of gaseous NH_3 is significant. It is not commonly used as a reducing agent directly because; ammonia is very toxic in nature. For reasons of toxic nature of NH_3 and handling and storing problems, urea is the best preferred substitute for NH_3 as a reducing agent in automotive applications [1].

The major pollutants emitted by the diesel engines are NOx, particulate matters, and smoke and soot particles. Amongst all other emissions, NOx_x is one of the most harmful emissions from diesel engine. It plays a vital role in the atmospheric ozone depletion and global warming. It is also most precursors to the photochemical smog. Component of smog irritate eyes and throat, stir up asthmatic attacks, decrease visibility and damages plants life as well as human life and materials as well. By dissolving NO_x with water vapors NOx_x from acid rain which has direct and indirect effects on environmental aspects [9].

This SCR technology, it permits the NO_x reduction reaction to take place in an oxidizing atmosphere. It is called as selective because the catalytic reduction of NO_x with ammonia(NH),

urea, monomethylamine, di-methylamine, try methylamine, cyanuric acid, carbonates, ammonium carbonate, ammonium bicarbonate, etc. SCR is a technology for reduction of the concentration of NOx at the outlet of the combustion chamber, in which the injection of urea solution in the tail pipe of a four stroke CI engine [9].

Urea has been selected for reluctant in new design of SCR system because it distinguished feature. To overcome the difficulties associated with pure ammonia, urea solution is selected reluctant. Urea can be hydrolyzed and decomposed to form aqueous ammonia (NH_3). An injected aqueous solution of urea is decomposed into ammonia and water vapour, and then decomposed ammonia reacts with oxides of nitrogen and reduced into eco-friendly nitrogen (N_2) and water vapour (H_2O).

Following are chemical reactions which are carried out in new design of SCR system.

$$(NH_2).2CO + 7H_2O \rightarrow [(NH_2)2CO.7H_2O] \quad (1)$$
$$(NH_2)2CO.7H_2O] \rightarrow HNCO + NH_3 + 7H_2O \quad (2)$$
$$4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O \quad (3)$$
$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O \quad (4)$$

The above concept of reaction using urea in modified SCR systems for the reduction of NO_x emissions in diesel engines. Many advancement has been done in this technology but still controlling the level of NOx is a challenge for the researcher.

2. Literature survey

In this study of urea–SCR, the selective catalytic reduction using urea as reducing agent has been investigated for about 10 years in detail and today it is a well-established technique for DeNOx of stationary diesel engines. This paper is focused on the fundamental problems and challenges of urea-SCR system are extended to mobile applications [1].

The author has presented the choice of catalyst types to reduce the NOx emissions down to Euro V level. A unique urea injection system is also presented, which is based on a mass produced dosing pump that is combined with an electronic control unit. The results of this study indicated that it is possible to have a NO_x conversion above 80% with ammonia slip below 10ppm using 30 liters of urea on 130 cpsi catalysts for a 12-cylinder diesel engine [2].

In this research work it is being investigated that Selective Catalytic Reduction technology increasingly is being applied for controlling emissions on oxides of nitrogen from coal-fired boilers. The vanadium and titanium oxides are commonly used in the vandia-titania SCR catalyst for NO_x reduction [3].

The author prepared injection of aqueous solutions of urea in the exhaust for the reduction of NO_x in a single cylinder light duty DI diesel engine. Several kinds of concentration of urea solution varying from 10 to 40% by weight with different flow rates of urea solution varying from 250ml/hr to 750ml/hr are tested by fitting vanadium as catalyst which improved the chemical reactions even at a lower temperature of 190°C. Results showed that a maximum of 27.46% of NO_X reduction was achieved with an optimised flow rate of 0.75lit/hr with 10% urea concentration [4].

The performance, combustion and emission characteristics on CI engine fuelled with cotton seed oil blends of 25%, 50% 75% and 100% in volume are presented in the investigation. Due to increase of oxides of nitrogen compared to neat diesel, the Selective catalytic Reduction system was implemented in exhaust pipe. The results of this paper indicated that the amount of oxides of nitrogen was decreased rapidly on injection of 30% concentration of urea solution [5].

In the research work presented by ghosh the injection of aqueous solution in the tail pipe of a diesel engine is evaluated four observations were made for the exhaust emission NO_x analysis of concentration of urea solution 0 to 30% by weight with different flow rates of urea solution as reluctant by fitting marine ferromanganese nodule as SCR catalyst. It was observed in the study that 64% of NO_x reduction was achieved [6].

This investigation suggested that the use of SCR technology and impact of biodiesel on the diesel engine combustion process and pollutant formation. This paper is more concerned with an experimental investigation to study the diesel engine emission characteristics using Mahua biodiesel with the help of a Three Way Catalytic converter with Diesel Exhaust Fluid (DEF) by running the engine. Almost 90% NOx emissions got reduced and the emission values recorded were much less when compared to Bharat stage- IV Norms for selected engine at all operated loads with retrofit arranged [7].

In this study of Pongamia pinata methyl ester (PPME) chosen as an alternative fuel for diesel engines. Injection of aqueous solutions of urea in the tail pipe of a diesel engine fuelled with Pongamia pinata methyl ester (PPME) for the reduction of oxides of nitrogen (NO). Four observations were recorded for various concentration of urea solution 0%, 10%, 20%, and 30% by weight with different flow rates of urea solution as reductant by fitting Marine Ferromanganese nodule as SCR catalyst which improves the chemical reactions. 64% NO_x reduction achieved with the urea flow rate 0.60 lit/hr, 30% concentration of urea solution and marine ferromanganese nodule as SCR [8].

This present effort of Selective Catalytic Reduction (SCR) technique of reduction of NOx which is most suitable for automobile diesel engines to meet the upcoming stringent emission norms. Direct measurement of ammonia storage may increase the opportunities for significant improvement. Although the technology is more efficient, there are several drawbacks like ammonia slip, deposit formation, etc. that are associated with it. It requires up gradation of technology. In order to avoid these problems mixers are most commonly used in SCR systems [9].

This research work compared the optimal SCR performance with one and two injectors for two different applications with split SCR catalyst, the global optimal dosing control were applied in using dynamic programming and the resulting NOx

and NH_3 emissions from those control were compared to quantify possible benefits from the added degree of freedom provided by the second injector [10].

Many of the researchers have attempted to preside the solution to NOx emission from the CI engine. But no research provided the efficient design of SCR system using urea solution. An attempt has been made in this research work to design completely new SCR system to reduce the level of NOx emission from the engine.

Following table refers to the pollution board of India for BS-IV norms.

Table 2
BS-IV emission norms

Standard	Test Cycles	CO	HC	NOx	PM
		g/kWh			
BS IV	European Steady-state Cycle (ESC)	1.5	0.46	3.50	0.02
	European Transient Cycle (ETC)	4.0	0.55	3.50	0.03

The NO_x value of different EURO norm are plotted in figure 1 .it is observed that the stringent control uses kept on the NO_x in the euro norm and the level of NOx in EURO VI is reduced shown 0.4g/kwh.

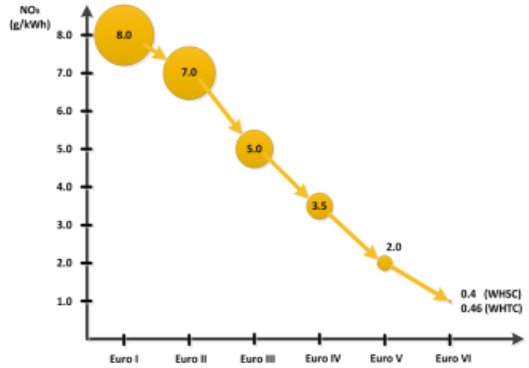

Fig. 1. NO_x emission standard according to EURO Standards [10]

3. Experimental setup

The complete unique design of SCR system is developed at the automobile engineering department Government Polytechnic Nagpur, consists of 2 catalytic converters instead of single catalytic converter. Two catalytic converter arranged in a series connection in order to reduce the NOx emission as shown in experimental block diagram. Pulse width module electronics circuit is used to control the injection timing. In this circuit, in-built RC timer circuit is integrated.

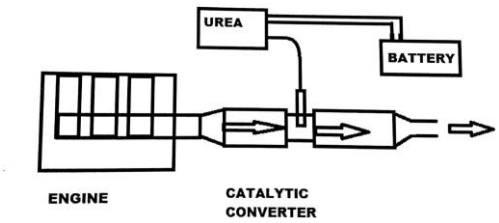

Fig. 2. Block diagram of New SCR System

Injector (solenoid type valve) is used to create high pressure in pump and to inject the aqueous ammonia in tail pipe. Injection system is fixed between the two catalytic converter for injection purpose. High pressure feed pump i9s attached with high pressure pipe to supply urea solution through injection system and all the setup connected to the DC battery. Experimental setup is shown in fig 2.

Fig. 3. $DeNO_x$tation injection system

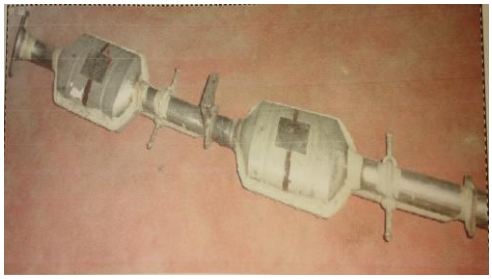

Fig. 4. Catalytic converter connected in series for New SCR

Fig. 5. New SCR System

4. Methodology and Experimentation

Before starting the engine, urea solution is to be prepared for different concentration varying with 20grams, 30grams and 40grams by weight along with 1litre of distilled water. Also it is ensured that all the connection of control circuit board should be properly enact. The modified SCR system is soot free and properly functioning. Before starting the operation is replaced the existing SCR with is replaced SCR system in diesel vehicle.

The pilot experimentation done and recorded a reading with the help of flue gas analyzer.

Table 3
Gas Analyzer Specification

Gas analyzer	NOx, Co, HC, raw gas analyzer
NOx measurement	AVL –FTIR
In cylinder pressure measurement	AVL smart sampler
SCR catalyst	5.66"X7.5" ,400cpsi

A. 20gm of urea/ lit of distilled water

NOx = 1.20 PPM (Part per million)

B. 30gm of urea/ lit of distilled water

NOx = 0.90 PPM (Part per million)

C. 40gm of urea/ lit of distilled water

NOx = 0.65 PPM (Part per million)

The instruments are used for the measurement of the exhaust gas emission. The calibration is done with the help of SCR system.

The observation recorded are given in the table.

Table 4
Exhaust Gas Analysis

Conc. of urea solution	NOx	CO
20g/lit of distilled water	1.20ppm	0.27ppm
30g/lit of distilled water	0.90ppm	0.24ppm
40g/lit of distilled water	0.65ppm	0.21ppm

The experimentation was conducted on no load condition on the following CI engine.

Table 5
Engine Specification (CI)

Test condition	330kw, AVL transient dynamometer
Engine specification	6 cylinder ,inline common rail
Bore length	103 mm
Stroke length	114 mm

5. Results and Discussions

The output obtained from the experiment is plotted to determine the effect of the injection of urea solution at various concentration and to obtain the value of corresponding NO_x as discuss above.

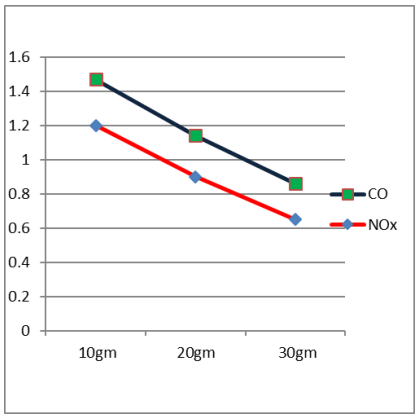

Fig. 6. Amount of NO_x and CO vs. concentration of urea in grams

The percentage improvement in NO_x and CO reduction is compared that to new SCR system is very closer to the Euro VI emission norms, which is highly beneficial for the proposed norms in India. This system will find a wide application in the automobile industry.

6. Conclusion

From the research study it can be concluded that,

- Urea acts as a good catalyst for the NOx reduction in diesel engine.
- Due to Urea injection in New SCR system in the tail pipe 67.5% NOx reduction has been achieved.
- Simultaneously CO also gets decreases.
- By using new SCR system, the most harmful gases should be minimized. Pollution should be controlled. The vehicle performance will be increased.
- The pollution can be controlled with this proposed system and vehicle performance can also be improved.

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