

REDUCTION OF EMISSIONS IN DIESEL ENGINES AND CATALYTIC CONVERTER IN GASOLINE ENGINES

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Abstract: The main concern of today's automobile industry is to reduce the amount of emissions (HC, CO, NO_x) to meet stringent emission norms. These emission norms can be obtained by modification in in-cylinder combustion process or after treatment process. It's not possible to achieve the emission norms by in-cylinder process alone. So, in this project, we make an attempt to reduce the emissions by the after treatment process. The scope of our project is to reduce emissions in both gasoline and diesel engines. In the after treatment process, Selective Catalytic Reduction (SCR) technology dominates the heavy duty diesel engines and catalytic converter plays an important role in the current era of gasoline engines.

In this an attempt made to reduce NO_x emissions by SCR technology. In this work, we used Zeolite ZSM-5 as catalyst which was assisted by urea injection in the exhaust tail pipe. It has been observed that 10 to 12% of NO_x was reduced compared to existing engine set-up.

Key Words: emission, Exhaust gases, Combustion, SCR technology, Catalyst.

1. INTRODUCTION:

The rise in civilization is closely related to improvements in transportation. In the development of transport the internal combustion engines, both petrol and diesel engines, occupy a very important position. The petrol and diesel engines, occupy a very important position. The petrol engine has provided reliable small power units for personalized transport and in this way revolutionized the living habits of people to a great extent. The diesel engine has provided the power units for transportation system, i.e. buses, and goods transportation system, i.e., trucks. Indeed the petrol engine powered automobile and diesel engine powered buses and trucks are the symbols of our modern technological society.

However, in recent times the internal combustion engine powered vehicles have come under heavy attack due to various problems created by them. The most serious of these problems is air pollution. Air pollution can be defined as addition to our atmosphere of any material which will have a deleterious effect on life upon our planet.

The engine emissions can be classified into two categories:

- Exhaust emissions and
- Non-exhaust emissions

The major exhaust emissions are

- Unburnt hydrocarbons, (HC)
- Carbon monoxide and carbon dioxide
- Oxides of Nitrogen, (NO_x)
- Oxides of sulphur, (SO₂ & SO₃)
- Particulates
- Soot and smoke

The first four are common to both SI and CI engines and the last two are mainly from CI engines.

The main non-exhaust emissions are:

- Unburnt hydrocarbons from fuel tank
- Unburnt hydrocarbons from the crankcase blow by.

Hydrocarbon Emissions:

Exhaust gases leaving the combustion chamber of an SI engine contain up to 6000 ppm of hydrocarbon components, the equivalent of 1-1.5% of the fuel. About 40% of these constitute the unburnt components of the

fuel. The other 60% consists of partially reacted components that were not present in the original fuel. These consist of small non-equilibrium molecules, which are formed when large fuel molecules break up (thermal cracking) during the combustion reaction. It is often convenient to treat these molecules as if they contained one carbon atom, as CH_1

Hydrocarbon emissions will be different for each gasoline blend depending on the original fuel components. Combustion chamber geometry and engine operating parameters also influence the HC components spectrum.

Hydrocarbon formation:

The causes for hydrocarbon emissions from SI engine are:

- Incomplete combustion
- Crevice volumes and flow in crevices
- Leakage past the exhaust valve
- Valve overlap
- Deposits on walls
- Oil on combustion chamber walls

Incomplete combustion:

Even when the fuel and air entering an engine are at the ideal stoichiometric condition, perfect combustion does not occur and some HC ends up in the exhaust. The reasons are:

- **Improper mixing:** Due to incomplete mixing of the air and fuel some fuel particles do not find oxygen to react with. This causes HC emissions.
- **Flame quenching:** As the flame goes very close to the walls it gets quenched at the walls leaving a small volume of unreacted air-fuel mixture. However, this mixture near the wall that does not originally get burned as the flame front passes will burn later in the combustion process due to additional mixing, swirl and turbulence.

2. SELECTIVE CATALYTIC REDUCTION:

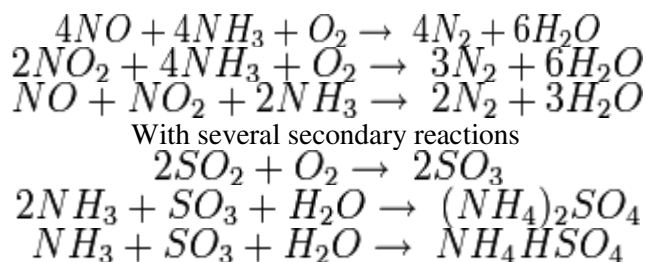
Selective Catalytic Reduction is a means of converting nitrogen oxides (NO_x) with the aid of a catalyst into diatomic nitrogen, N_2 , and water, H_2O . A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is absorbed onto a catalyst. Carbon dioxide, CO_2 is a reaction product when urea is used as the reductant.

Selective catalytic reduction of NO_x using ammonia as the reducing agent was patented in the United States by the Engelhard Corporation in 1957. Development of SCR technology continued in Japan and the US in the early 1960's with research focusing on less expensive and more durable catalyst agents.

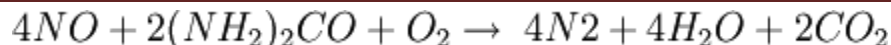
Commercial selective catalytic reduction systems are typically found on large utility boilers, industrial boilers, and municipal solid waste boilers and have been shown to reduce NO_x from 70-95%. More recent applications include large diesel engines, such as those found on large ships, diesel locomotives, combustion turbines, and even automobiles.

2.1 REACTION:

The NO_x reduction reaction takes place as the gases pass through the catalyst chamber. Before entering the catalyst chamber the urea or aqueous ammonia is injected and mixed with the gases. The chemical equation for a stoichiometric reaction using either anhydrous or aqueous ammonia for a selective catalytic reduction process is as follows:



The reaction for urea instead of either anhydrous or aqueous ammonia is as follows:



The ideal reaction has an optimal temperature range between 675 and 840°F, but can operate from 450 to 840°F with longer residence times needed. The minimum temperature is affected by the various fuels, gas constituents and catalyst geometry. Other possible reductants include cyanuric acid and ammonium sulphate

2.2 CATALYSTS:

SCR catalysts are manufactured from various ceramic materials used as a carrier, such as titanium oxide, and active catalytic components are usually either oxides of base metals (such as vanadium and tungsten), zeolites, and various precious metals. All catalyst components have their own unique advantages and disadvantages.

Base metal catalysts, such as the vanadium and tungsten, lack high thermal durability, but are less expensive and operate very well at the temperature ranges most commonly seen in industrial and utility boiler applications. Thermal durability is particularly important for automotive SCR applications that incorporate the use of a diesel particulate filter with forced regeneration. They also have a high catalyzing potential to oxidize SO₂ into SO₃, which can be extremely damaging to its acidic properties.

Zeolite catalysts have the potential to operate at significantly higher temperatures than base metal catalysts, with the ability to withstand long term operational temperatures of 1200°F, and transient conditions of up to 1560°F. Zeolites also have a lower potential for potentially damaging SO₂ oxidation.

Recently developed iron and copper exchanged zeolite urea SCR's have been developed with approximately equal performance to that of vanadium urea-SCR's if the fraction of the NO₂ is 20% to 50% of the total NO_x

The two most common designs of SCR catalyst geometry used today are honeycomb and plate. The honeycomb form usually is an extruded ceramic applied homogeneously throughout the ceramic carrier or coated on the substrate. Plate type catalysts have lower pressure drops and are less susceptible to plugging and fouling than the honeycomb types, however plate type configurations are significantly larger and more expensive. Honeycomb configurations are significantly smaller than plate types, but have higher pressure drops and plug much more easily.

Concentration (wt %)	32.5
Density at 20`C	1.09
Freezing point	-11`C
PH	8.8
Colour	Colourless
Odour	Odourless
Specific gravity	1.1

3. EXPERIMENTAL PROCEDURE:

The engine is started and retained at idle condition for about 10 minutes for warm-up. After the operating temperature is attained, the engine is tuned to run at half throttle condition and various loads such as 80, 160, 240 and 320 Nm are applied using an eddy current dynamometer.

At each rated load, the emission readings are taken at three salient points such as:

- Before catalyst
- After catalyst without urea injection
- After catalyst with urea injection

These emissions reading are noted by use of MRU 1600L exhaust gas analyzer. Temperature readings at various loads are taken by thermocouple.

Similarly, the loads are applied for the full throttle condition such as 105, 210, 315, and 420 Nm and the corresponding emission readings at three salient points are noted.

The fuel consumption values are recorded from the fuel flow meter at corresponding load values at both half and full throttle conditions. Then the readings are tabulated to compare the emissions.

4.0 RESULTS AND DISCUSSION:

Reading For SCR At Half Throttle Condition

Table .21 Emissions at half throttle using diesel as fuel						
Load (Nm)	Speed (rpm)	Fuel consumption (sec)	NO Before catalyst (ppm)	NO After catalyst (ppm)	NO With Urea (ppm)	Temperature (°C)
80	1508	66.6	530	530	520	181
160	1455	44.9	924	915	877	251
240	1382	35.7	1512	1475	1289	314
320	1271	30	1783	1699	1498	396

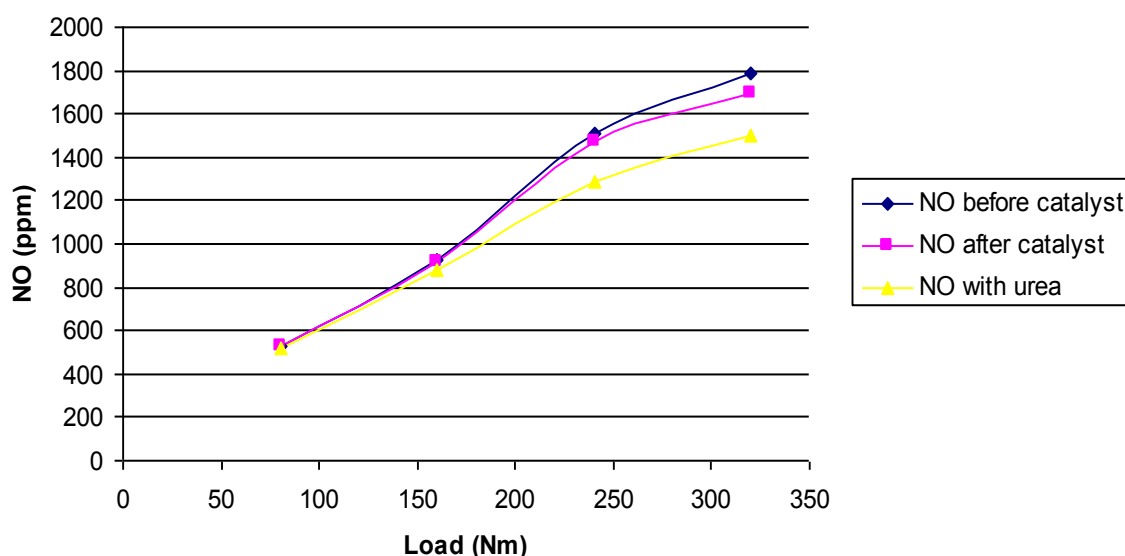


Figure.1 NO vs load at half throttle

Figure .1 shows the emissions at half throttle using diesel as fuel and it is evident that NO reduces as the load increases with injection of urea. However, at low load condition, the NO emission remains the same even when the urea injected, because of the low temperature. At high load conditions, the temperature is high enough for the Zeolite ZSM-5 catalyst to get activated and the reaction takes place between ammonia and oxides of nitrogen leaving a low NO emission.

Hence, it is clear that as the temperature rises, more amount of urea (NH₂-CO-NH₂) gets dispersed into ammonia (NH₃) and gets adsorbed in the catalyst. Further, ammonia reacts with oxides of nitrogen to form nitrogen and water vapour.

At the maximum load, the NO_x conversion efficiency is maximum. About 10 to 15% of the NO_x has been converted to harmless nitrogen and water vapour. But as the load decreases, the conversion of the NO_x decreases because of the inefficiency of the catalyst due to drop in temperature. At a load of 240 Nm the conversion efficiency is about 10% and at 160 Nm it decreases to 5%.

5. CONCLUSION:

NO_x reduction of 10 to 12% is achieved at full throttle condition when urea is injected in the exhaust pipe line. As temperature of the exhaust increases, NO_x conversion efficiency increases.

The newly designed catalytic converter (1.8gms/cft and Pt/Rd of 2:1) is more efficient than the existing catalytic converter (0.5gms/cft and Pt/Rd of 5:1) at cold start conditions. The maximum conversion of CO occurs at 300th sec (71% efficiency) and HC occurs at 100th sec (49% efficient) from the cold start.

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