# A Review on various $NO_x$ emission reduction techniques for C.I. Engine

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**Abstract** – *We all familiars with IC engines like SI engine and CI engine. Out of these the CI engine having more thermal efficiency as its Compression Ratio is high. It is more beneficial to our national development because, CI (Diesel engine) is used in various applications like Automobile, Locomotive Marine Engine, Power Generators, Boiler mechanism. Even though, the CI engine is more beneficial but it also hazardous to human being because it creates emissions like $SO_2$, $NO_X$, HC, Particular Matters. The $NO_X$ is more harmful to human health because its oxides affects on Respiratory System of Human Body. Also it is hazardous to ecosystem like it increase the level of Ozone layer, due to $NO_X$ Smog and Acid Rain are happened and our environment system is disturbed. There are many techniques to reduce this $NO_X$ likes EGR, SCR system. But ECR system is less efficient, So our project intension is to control $NO_X$ emission by using SCR (Selective Catalytic Reduction). In our project we use DEF ( Diesel Exhaust Fluid ) as Catalytic Reducer and it will give 90% reduction of $NO_X$. It convert the $NO_X$ into fresh $N_2$ and water vapour ($H_2O$).*

**Key Words***:* ***(Diesel Engine,SCR system, DEF(Diesel Exhaust Fluid).***

## 1. INTRODUCTION

Internal Combustion Engines generates undesirable emissions during combustion process, Because of non-stoichiometric combustion. Due to incomplete combustion various harmful emissions are produced like Hydro carbons (HC), Oxides of Sulpher ($SO_2$),Oxides of Carbons ($CO_X$), Oxides of Nitrogen ($NO_X$) and Particular Matters. To control this emission now a day EGR (Exhaust Gas Recirculation) system is used, but its efficiency to control $NO_X$ is very less. This $NO_X$ is very harmful to human being and also environment. Our project aim is to control this $NO_X$ emissions by using SCR system with DEF. During the operation load of the engine, SCR reached efficiency over 90%. Used after treatment system is suitable for reduction of harmful pollutants according to the Tier 4f norm.

However, with the present technology this is not possible, and after-treatment of exhaust gases as well as in-cylinder reduction of emissions is very important. In case of after treatment it consists of mainly of the use of thermal or catalytic converters and particulate traps. Off late, the economic and industrial growth has caused significant reduction in the quality of ambient air. The main sources of emission from the engine are from the engine exhaust system and other from the crankcase. The former is the main cause of air pollution. The main constituents of the engine exhaust gases are unburnt hydrocarbons, carbon-dioxide, carbon monoxide, oxides of nitrogen and particulate matter. Diesel (compression-ignition) engines can be run at higher compression ratios, which result in higher thermal efficiencies compared to gasoline (spark-ignition) engines. As a consequence, Diesel engines can reduce greenhouse gas emissions based on the same mileage driven in comparison to gasoline engines. One challenge for the Diesel engine is the removal of NOx (nitrogen oxides) from the exhaust, which is a major source of acid rain and chemical smog. It can also cause respiratory problems for people. The selective catalytic reduction (SCR) of NOx is a promising technology for NOx reduction. Some of the major catalytic industries are Johnson Mathey India Pvt Ltd, Cats Direct, Emitec Emission Controls Private Limited, Automotiev Merchandising Corporation, Gencat Limited and Cummins India Limited.

### 1.1 EXHAUST GAS RECIRCULATION-

Exhaust gas recirculation (EGR), on diesel engines, can be used to achieve a richer fuel to air mixture and a lower peak combustion temperature. Both effects reduce $NO_x$ emissions, but can negatively impact efficiency and the production of soot particles. The richer mix is achieved by displacing some of the intake air, but is still lean compared to petrol engines, which approach the stoichiometric ideal. The lower peak temperature is achieved by a heat exchanger that removes heat before re-entering the engine, and works due to the exhaust gases' higher specific heat capacity than air. With the greater soot production, EGR is often combined with a particulate matter (PM) filter in the exhaust. In turbocharged engines, EGR needs a controlled pressure differential across the exhaust manifold and intake manifold, which can be met by such engineering as use of a variable geometry turbocharger, which has inlet guide vanes on the turbine to build exhaust backpressure in the exhaust manifold directing exhaust gas to the intake manifold. It also requires additional external piping and valving, and so requires additional maintenance.

## 2. SELECTIVE CATALYTIC REDUCTION-

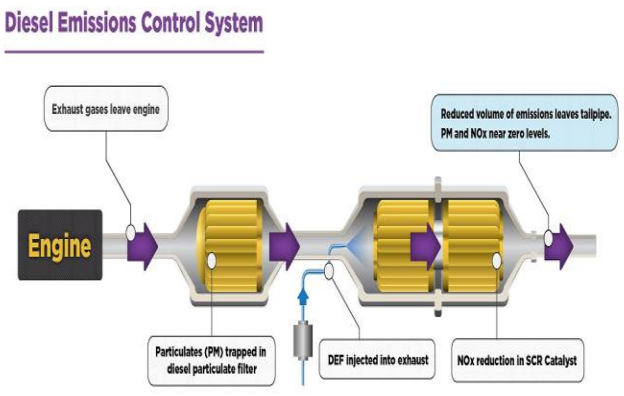


Fig1. Selective catalytic reduction process.

Selective Catalytic Reduction (SCR) is an advanced active emissions control technology system that injects a liquid-reluctant agent through a special catalyst into the exhaust stream of a diesel engine. The reluctant source is usually automotive-grade urea, otherwise known as Diesel Exhaust Fluid (DEF). The DEF sets off a chemical reaction that converts nitrogen oxides into nitrogen, water and tiny amounts of carbon dioxide (CO2), natural components of the air we breathe, which is then expelled through the vehicle tailpipe.

SCR technology is designed to permit nitrogen oxide (NOx) reduction reactions to take place in an oxidizing atmosphere. It is called "selective" because it reduces levels of NOx using ammonia as a reluctant within a catalyst system. The chemical reaction is known as "reduction" where the DEF is the reducing agent that reacts with NOx to convert the pollutants into nitrogen, water and tiny amounts of CO2. The DEF can be rapidly broken down to produce the oxidizing ammonia in the exhaust stream. SCR technology alone can achieve NOx reductions up to 90 percent.

## 2.1DIESEL EXAHAUST FLUID-

Diesel Exhaust Fluid (DEF) is a non-toxic fluid composed of purified water and automotive grade aqueous urea. DEF is available with a variety of storage and dispensing methods. Storage options consist of various size containers such as bulk, totes and bottles or jugs. The American Petroleum Institute rigorously tests DEF to ensure that it meets industry-wide quality standards. DEF is the reactant necessary for the functionality of the SCR system. It is carefully blended aqueous urea solution of 32.5% high purity urea and 67.5% of deionized water.

## 3. LITERATURE REVIEW-

a)A.Arulmurugu et al.(2014) The efficiency of selective catalytic reduction can be expected to increase by combination of both urea and zeolite chemical. By increasing the concentration of urea, NOx can be reduced. These can be analyzing by utilizing the various concentration of urea in selective catalytic reduction technology [1].

b)Vit Marek et al. (2016) Result confirmed that SCR catalytic converter significantly reduce $NO_X$ contents depending on not only amount of the exhaust gases and engine regime, but especially on temperature of exhaust, respectively on the temp. of SCR catalytic converter. Measurement was aimed on the most widely used engine regime, where $NO_X$ reduction is efficient and sufficient for compliance with the specified emission limits [2].

c)Varathavijayan et al .(2014) The efficiency of selective catalytic reduction can be expected to increase by combination of both urea and zeolites chemical. By increasing the concentration of urea, NOx can be reducing. These can be analyzing by utilizing the various concentration of urea in selective catalytic reduction technology. Zeolites mix with kaoline the binder to increase the separation process. Experimental test carried out due to various loads conditions. The results showed reduction of various exhaust gas not only $NO_X$. If using catalytic converter the most harmful gases should be minimized. Pollution should be controlled. The vehicle performance will be increased [3].

d)Xuqing Cai et al. (2017) In the catalytic DE nitrification technology at the low temperature, the low temperature selective catalytic reduction technology with NH3 as reducing agent is studied deeply. The low temperature and high efficiency makes the catalyst can be used in low dust and low sulfur environment. However, the low temperature catalyst for non-ammonia catalytic de nitrification is studied in recent years, there are a lot of problems need to be solved. For NH3-SCR technology, the catalyst preparation process need to be improved and the catalyst should be optimized. The metal ratio will be the focus of the future study. In the non-ammonia catalytic de nitrification technology, on the on hand it should be the development of highly selective catalyst to avoid the oxidation of hydrocarbons and CO; On the other hand, focusing on the de nitrification process innovation, such as nitrogen oxide adsorption reduction catalyst development [4].

e)Ajinkya B. Amritkar. et al( 2016). Formation of oxides of nitrogen is occurred at high temperature which is available in cylinder at the time of combustion. EGR reduces the rise in temperature by recirculation of exhaust gases, exhaust gas displaces fresh air-entering in the combustion chamber and hence air displacement lowers oxygen amount available for combustion in the intake mixture. Experiment shows that by increasing EGR flow rate local peak temperature of combustion chamber decreases which leads to break thermal efficiency, formation of NOx and formation of unburned hydrocarbon decreases [5].

f)K. Rajan et al. (2009) Methyl ester of sunflower oil was prepared with lye catalyst NaOH and methanol. Compared with conventional diesel fuel, the exhaust NOx was reduced about 25% at 20 % biodiesel blends with 15% EGR due to less oxygen available in the recirculated exhaust gases which lowers the flame temperature in the combustion chamber. SFME blend with 15% EGR, which improves the 4% of brake thermal efficiency and 10 % increase in BSFC due to lower calorific value of the biodiesel [6].

g) Kavati Venkateswarlu et al.(2013) With increase in percentage of the EGR, BTE increases initially and then decreases while BSFC decreases initially and then increases. The optimum EGR for maximum BTE and minimum BSFC is found to be around 15%. The peak pressure decreases slightly with the increase in percentage of EGR, further, it is found that the presence of EGR advances the ignition with increase in percentage of biodiesel. NOx and exhaust gas temperature decrease with increase in percentage of EGR and furthermore at a fixed EGR, they decrease with the increase in percentage of the biodiesel. CO and HC emissions are found increasing with increase in the percentage of EGR. However at a fixed EGR, they are found decreasing with the increase in percentage of biodiesel. The increase in smoke is insignificant initially, which however increases slightly with further increase in EGR which also increase with the increase in percentage of biodiesel [7].

h)Zuhdi Salhab(2012) It can be concluded from the measured results that employing EGR is an efficient technique in internal combustion engines (petrol, diesel, and gas engines) for NOx reduction as it was seen from figure 2. Further it was also indicated that the engine performance of the engine are slightly independent on EGR. Peak cylinder pressure and indicated mean effective pressure are reduced and ignition delay period was prolonged with 15% EGR [8].

## 4. TECHNICAL CHALLENGES FOR SCR

Major challenge of the SCR system is the replenishment of the urea solution. The urea solution is carried in an onboard tank which must be periodically replenished based on vehicle operation. For light-duty vehicles, urea refill intervals will occur around the time of a recommended oil change, while urea replenishment for heavy-duty vehicles will vary depending on the vehicle specifics and application requirements. While vehicles could continue to function normally even without the urea solution, the emissions system will not meet NOx reduction requirements. Manufacturers are currently working with the EPA to address these technology and emissions performance challenges. One concept is to establish a nationwide urea distribution infrastructure for consumers, while another option links the replenishment of urea with pre-existing scheduled maintenance intervals (i.e. oil changes). Other issues include the availability of space on vehicles to provide user-friendly access to the urea tank and other SCR components. In addition, proper storage of urea is required to prevent the liquid from freezing at temperatures below 12 degrees Fahrenheit. SCR technology may play a key role in achieving emissions reductions that allow light-duty diesel vehicles to meet the new, lower EPA emissions regulations to be phased in through 2009. SCR technology is one of the most cost effective and fuel-efficient technologies available to help reduce emissions. SCR can reduce NOx emissions up to 90 percent while simultaneously reducing HC and CO emissions by 50-90 percent, and PM emissions by 30-50 percent.

## 5. CHEMICAL REACTIONS

$$[NH_2]_2CO \rightarrow NH_3 + HNCO$$

$$HNCO + H_2O \rightarrow NH_3 + CO_2\uparrow$$

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

Where :- $[NH_2]_2CO$ = Urea
$NH_3$ = Ammonia
HNCO = Isocynide acid
$CO_2$ = Carbon dioxide
$H_2O$ = Water vapour
$N_2$ = Fresh Nitrogen

## 6. SCHEMATIC REPRESENTATION

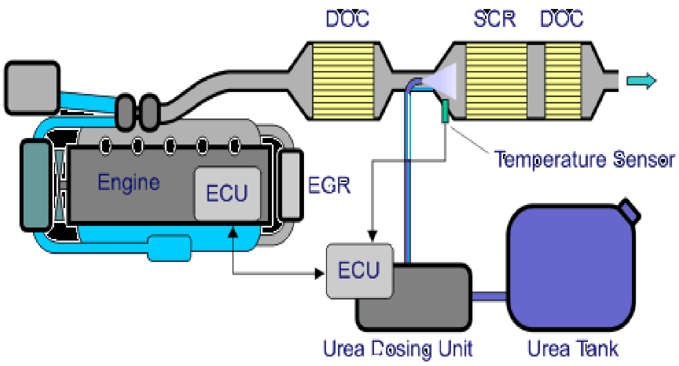


Fig2: Selective Catalytic Reduction process

## 6. CONCLUSIONS

By using Selective Catalytic Reduction process it is expected to reduce the $NO_X$ emission near by 90% and convert into fresh Nitrogen ($N_2$) and Water vapours ($H_2O$). So SCR is efficient than EGR system. These can be analyzing by utilizing the various concentration of urea in Selective Catalytic Reduction process.

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