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A Review on Selective Catalytic Reduction for NO_x Reduction

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ABSTRACT

The energy requirement has increased rapidly all over the world due to industrialisation and the changes of subsequent lifestyle. Most of this energy is generated from fossil fuels such as coal, natural gas, gasoline, and diesel. Almost 90% of the present energy source is based on the combustion of fossil fuels and petroleum based fuels. In the last few years, the environmental effects of pollutant emission from combustion sources have becoming serious attention towards global warming.

Diesel engines are widely used in many areas like automobiles, locomotives, marine engines, power generations etc., due to its high power output and thermal efficiency. Even though the diesel engines give more benefits, the human discomfort only caused by pollutant emission of these engines has to be considered. The major pollutant emissions of the diesel engines are NO_x, particulate matters, and smoke, soot particles.

Keywords-Pre-oxidation, Catalyst, Selective catalytic Reduction, Reductants.

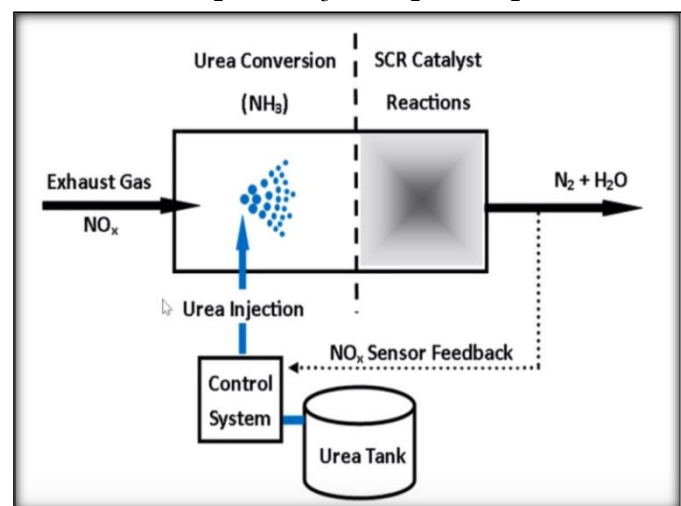
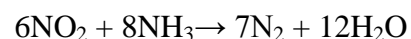
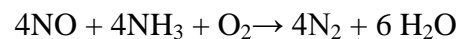
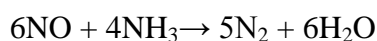
INTRODUCTION TO SCR

SCR means Selective Catalytic Reduction and it means of converting Nitrogen Oxide i.e. NO_x with the help of catalyst (which is used for increasing chemical reaction rate) into diatomic Nitrogen (N₂) and water (H₂O) [1].

SCR is a process for reducing the concentration of NO_x from the combustion exhaust, which involves the injection of aqueous solution of urea in the tail pipe of a four stroke, constant speed CI diesel engine.

Urea can be hydrolysed and decomposed to generate ammonia. An injected aqueous solution of urea solution is decomposed into ammonia and water vapour, and then decomposed ammonia reacts with oxides of nitrogen and reduced into eco-friendly nitrogen and water vapour.

The chemical reactions are as follows:-



As in fig. shown above a closed loop feedback system is used for the better results. In this the feedback sensor analyses the exhaust gases and gives information to the control system. The control

system controls the amount of urea injection in tail pipe of CI engine.

According to the output we can regulate the output emission for better conversion of NO_x into N₂ and H₂O.

EFFECTS OF POLLUTENTS ON HUMAN LIFE

Environmental pollution has become a modern social-economic problem that, particularly in countries with high degree of industrialization like USA, China, UK and India etc. has raised that much required to measures and to limit their harmful actions.

The major pollutant emissions of the diesel engines are NO_x, Particulate Matters (PM), Smoke and Soot particles Hydrocarbons (HC) Carbon Dioxides (CO₂). Although all other emissions, NO_x is one of the most important emission from diesel engine. It plays an important role in the atmospheric ozone destruction and global warming. It is also most precursors to the photochemical smog. Component of smog irritate eyes and throat, gear up asthmatic attacks, decrease visibility and damages plants and materials as well and also cause acid rain. The major sources of NO_x are as follows:-

1. Automobile Other Mobile Sources
2. Industrial Power Plants
3. Other Sources

METHODES TO CONTROL NO_x

There are several methods for controlling NO_x are as follows:

1. Reducing Peak temperature
 - a) Flue Gas Re-circulation(FGR)
 - b) Inject Water or Steam
 - c) Combustion Optimization
2. Chemical Reduction Of NO_x
 - Selective Catalytic reduction(SCR)
 - Selective Non-Catalytic Reduction (SNCR)
3. Injecting Air/fuel/Steam

In first type of method we get less NO_x reduction as in case of SCR and SNCR method so methods 2 are most suitable for NP_x reduction.

PARTS OF SELECTIVE CATALYTIC CONVERTER

- This project is requires two catalytic converters:-
 - i. Pre-Oxidation
 - ii. SCR

NO_x reduction done by the combined effect of pre-oxidation and SCR-catalyst.

Pre-Oxidation:- The selectivity for high NO₂ formation at lower temperature is the main purpose of this design.^[12-14]

- The primary effect of the pre-oxidation catalyst is to increase the NO₂ fraction of the exhaust this permitting the fast SCR reaction.
- The second effect is a considerable oxidation of hydrocarbon which inhibits the SCR reaction at low temperature; this will be also help increase the NO_x conversion at low temperature.

SCR: These are used for increasing chemical reaction rate. SCR catalysts are made 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, molybdenum and tungsten), zeolites, or various precious metals. Another catalyst based on activated carbon was also developed which is applicable for the removal of NO_x at low temperatures.^[3]

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.

Zeolites (The word 'zeolite' comes from the roots zeo (for boil) and lithos (for stone) in Greek) catalysts have the potential to operate at substantially higher temperature than base metal catalysts; they can withstand prolonged operation at temperatures of 900 K and transient conditions of up to 1120⁰K. Zeolites also have a lower potential for potentially damaging SO₂ oxidation.^[4]

Zeolites are a well-defined class of naturally occurring crystalline alumina silicate minerals. They have a three-dimensional structure arising from a framework of $[\text{SiO}_4]$ and $[\text{AlO}_4]$ coordination polyhedral linked by their corners.

The frameworks are generally very open and contain channels and cavities in which cations and molecules are located, both of which have enough freedom of movement to permit cation exchange and reversible dehydration.

Cu-ZSM-5 Catalyst: Cu-ZSM-5 has the advantage of being able to reduce NO_x both with and without the addition of a reducing agent [9].

Fe-ZSM5 Catalyst: Byrne et al. from Engelhard Corporation developed a commercial SCR catalyst for high temperature applications. This catalyst is based on a Fe promoted zeolite with three dimensional pore structures and a high module.

Feng and Hall[4] prepared an over exchanged Fe-ZSM5 catalyst using Fe oxalate precursor salt. They found the catalyst to be highly active at 500°C and stable in the presence of 10% HO_2 and 150 ppm of SO_2 . Only minimal loss in DeNO_x was observed after ageing for 2500 h^{-1} .

Long and Yang studied the catalytic performance of Fe-ZSM5 catalyst for SCR by NH_3 . A series of Fe exchanged molecular sieves were studied as catalyst for the SCR reaction. Both Fe-ZSM5 and Fe-mordenite catalysts were highly active for the SCR reaction. Nearly 100 % NO conversion was obtained at $400\text{-}500^\circ\text{C}$ at high space velocity.

Reducing Agents: Several reductants are currently used in SCR applications including anhydrous ammonia, aqueous ammonia or urea. All those reductants are widely available in large quantities are as follows:-

- a) **Pure anhydrous ammonia:** It is extremely toxic and difficult to safely store, but needs no further conversion to operate within an SCR. It is typically favoured by large industrial SCR operators.
- b) **Urea/aqueous ammonia:** It is used as a reducing agent. It produced in large scale worldwide (130 million tons/year). Urea is preferred among the N-containing selective

reductants for NO_x because of safety and non-toxicity. It is easy also to transport in the vehicle in an aqueous solution, which makes it also easy to dosage as required. All these advantages make urea solution the preferred reducing agent for nitrogen oxides.

CONCLUSION

Due to the global industrialization environmental pollution level and their rapid increase has forced various countries to enforce very strict emission norms. The after treatment device like EGR, SNR, NCR, SCR and particulate trap are required to achieve these emission norms. The conclusions are summarized as follows:-

- SCR can reduce NO_x emissions up to 90 % while simultaneously reducing HC and CO emissions by 50-90 %, and PM emissions by 30-50 %.
- SCR systems can also be combined with a diesel particulate filter to achieve even greater emission reductions for PM.
- In the commercial trucking industry, some SCR-equipped truck operators are reporting fuel economy gains of 3-5 %.

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