Investigation of after treatment technique to mitigate emission in IC Engine

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Abstract: Environmental pollution is a wide-reaching problem and it is likely to influence the health of the living population to a great extent. We need to mitigate the effects of harmful emissions before it is ungovernable. This project will concentrate on the reduction of NOx using ceria alumina catalyst, on a diesel engine as 5.2 kW water-cooled single-cylinder diesel engine. Solution and catalyst will play an important role in this process. Usually, the material is of high cost, here we have to choose low-cost material and solution. This leads to reduced nitrogen oxide (NOx) after treatment. Selective catalytic reduction (SCR) based on a solution like aqueous urea. This paper discusses the development of a static mixer and SCR reactor compatible with CI engine.

Keywords: IC engine, Ceria Alumina, NOx emission, SCR, catalyst.

1. Introduction
During the last few decades, there has been an exponential increase in the automotive industry. Hence our atmosphere has been severely affected by the concentration of toxic pollutants which is due to the burning of fossil fuels [1]. Some of the major pollutants are Nitrogen oxides, Hydrocarbons, Sulphur oxides, etc. which are the major contributors to the greenhouse effect. These harmful gases also affect the respiratory system of all living things dramatically. Climate change isn’t happening, it has already happened. We need to mitigate these harmful gases released before it’s too late. The elimination of these gaseous pollutants can be done by controlling the exhaust gases released from the engines [2].

With stringent BSVI regulation emission limits for diesel engines, the legislative enforced demands will exceed the needs for an efficient exhaust after-treatment system for India. The Nitrogen oxides content in the emission is the main difference between the BSVI and BSIV. As per BSVI norms, carbon monoxide emission and NOx is reduced by 30% and 80% respectively. The Hydrocarbon and particle emission limits are set in BS 6 norms. Hence the BSVI version preferably reduce the sulphur content in the fuel itself and also additionally create urea water solution and SCR system to achieve the NOx reduction norms and the emission of HC and CO2 from the exhaust gases [3].

SCR system and urea injector are used in the way to reduce NOx emission. Urea is injected through an external source into the exhaust system to react with unburnt carbon materials and ammonia reacts with the SCR system to NOx reduction in the emission. The SCR system efficiency reduces NOx
emission without fuel in the engine. These allow controlling the diesel engine to develop the NOx, fuel consumption and Particle emissions [4].

SCR technology reduces the NOx emission up to 90% without using the diesel engine fluid. In the world year of 2010, a heavy-duty vehicle is set a limit for NOx emission to the standard for all automobile industries to reducing the nitrogen, particulate emission to a maximum level of zero. SCR system technology also reduces the HC and CO emission in the range of 50% and emission of Particulate emission in the range of 40%. SCR technology is the most effective cost-saving catalyst in which the application reduces the NOx reduction in heavy-duty vehicles. In light-duty vehicles, the turbocharger performs the application of NOx reduction [5].

2. Literature Survey

In the future biodiesel plays an important role in reducing pollution to the environment to prevent the cause of greenhouse effect and global warming and climate change. It is the best alternatives to fossil fuel and it’s been fast grown among the fuel for reducing the NOx emission. Compared to diesel and petrol engines, biodiesel is the best fuel for reducing the NOx, HC and carbon dioxide emission from the exhaust system. The major cause of the NOx emission is smog and acid rain. The technology improvement in the NOx emission is the best way to protect this disaster from nature. The three mechanisms of the NOx emission is caused by thermal, prompt, and fuel. In which the nitrogen reacts with the oxygen at the high combustion temperature which forms the emission of the thermal NOx. By this chemical reaction, the NOx is formed 16 from the fuel and diesel engine which is harmful to the environment. The dominant mechanism in the biodiesel-fuelled engine is thermal and prompt NOx. During the combustion process, the unburnt carbon gases flow through the exhaust system of the engine. These particles bonded with nitrogen and form the NOx which is emitted through the tailpipe of the system. To reduce the emission further technologies are implemented to protect the world from disaster and prevent the environment [6].

A control methodology for Specific Reactant Decrease is introduced and its presentation as for gulf NOx scatterings is tried. This procedure is dependent on an eyewitness and the following circle utilizes the estimation of NOx fixations upstream and downstream of the SCR impetus. For reasons for cost decreases identified with after-treatment frameworks, a virtual NOx sensor is created and used to assess the SCR bay NOx focus. A vigor investigation of the regulator toward NOx estimation or assessment blunders is evaluated in reproduction. The outcomes acquired by scattering the upstream NOx focus signal are looked at and the necessary precision of the airway sensors is given in the viewpoint of supplanting the upstream NOx estimation by a virtual sensor [7].

An examination on the impacts of urea infusion timing and divider temperatures to anticipate NOx decrease effectiveness is reproduced utilizing a business code of STAR-CCM+. In this investigation, the test and reproductions work to acquire steady and stable conditions in the SCR framework were led. Since the steady condition can improve the consistency of urea distribution in the framework. This information clarifies if the transmission of gas response in recreation was insecure beneath the 20s of time. That marvels likewise happen in the genuine condition. The flimsy condition impacts the temperature and gas stream in the framework. The urea will be caught at the divider and hard to vanish in the SCR framework. Delayed responses create an immense issue in the SCR framework, the caught urea will amass and meddle the gas wind stream. Hence, in view of this information, the best planning for urea infusion was following 20 seconds of motor turn-over up. The subsequent semi-consistent spatial smelling salts circulations could be assessed over cross segments along with the fumes gas framework over consistent stream amounts [8].

The environment is polluted by the unburnt carbon gases, hydrocarbon and carbon dioxide, NOx emission from all heavy-duty vehicles and light duty vehicle, power plant and off-road equipment. These problems are faced by over worldwide of which consists of developed and developing countries. Air pollutant is a major problem is faced and causes the global warming and climate change. This large amount of CO, HC, NOx, and particulate matters are reduced by using three ways of catalytic convertor. Experimentally the analysis is done with neem blend biodiesel for effective
reduction in the NOx emission and unburnt carbon gases from the exhaust system. Neem-diesel blend is the alternative burnt material like petrol and diesel. Petroleum industries, gasoline and diesel engine cause more pollutants from the world's transportation energy. This collection of Neem oil is used as biodiesel for gasoline and diesel engines for controlling the emission control from the exhaust system [9].

The impacts of blending units on blending qualities in marine particular reactant decrease framework were mathematically explored utilizing ANSYS Familiar with a request to foresee NOx decrease proficiency and to propose plan rules for the conservative framework. The whirl type blender and the blending chamber were considered as the blending units. If there should arise an occurrence of utilizing the blender, it instigated an extraordinary turbulent stream and distribution zone. It caused that UWS can be blended in a brief distance and the response paces of urea deterioration expanded. Notwithstanding, NH3 change productivity was not moderately high since its impact was not kept up downstream. If there should be an occurrence of utilizing the blending chamber, it showed great blending execution. In any case, it was hard to plan a minimized framework because of the significant distance to blend. If there should be an occurrence of utilizing both blending units, it showed the benefits of every gadget, which were the brief distance to blend and keeping up great blending execution. The impact of length of the chamber and interfacing pipe on NOx decrease proficiency was examined to propose the plan rules [10].

The action of the V2O5/TiO2 catalyst could be improved by either Nb or Sb doping. Increased Nb stacking resulted in increased N2 selectivity. When both are stacked on a catalyst, the NO shift is significantly higher than when either Sb or Nb is stacked on the catalyst. Sb oxides and Nb oxides have a strong collaborative effect, which can help the catalyst work better. Sb and Nb expansion would also help protect against K2O damage. Nb and Sb are mainly found in the form of Nb5+ and Sb5+ on the Sb and Nb stacked catalyst surface. Sb expansion increased the redox capacity of the catalyst surface and improved the feebly reinforced oxygen, both of which are essential for the SCR response [11].

Cu-Fe/ZSM-5 catalysts showed high NOx conversion compared with single metal exchanged ZSM-5 catalysts. Analysis of NOx conversion, catalyst reducibility, and acid sites indicated that the reducibility of the catalyst plays a more important role than its acidity. The co-presence of copper increased the reducibility of Fe in Cu-Fe/ZSM-5 catalyst and increased low-temperature NOx conversion. NOx conversion over xCu-yFe/ZSM-5 prepared by solid-state ion-exchange revealed that 1wt% copper loading is enough to improve low-temperature NOx conversion without significantly affecting the high-temperature performance. On the basis of the above results, we conclude that by varying the amount of copper and iron in the catalyst and thereby adjusting the reducibility of the catalyst it is possible to control the NOx conversion temperature window [12].

SCR technology is one of the main mature exhausts after-treatment technologies that have been shown to minimize the NOx emission of tailpipes by 90%. The system is composed of an upstream pipe urea injection and a downstream SCR converter. In order to ensure the desired output, a swirl mixed flow of Urea and exhaust gas in front of the SCR substratum, which is typically limited by the packaging of concept design, is essential. The present paper uses the three-dimensional Computational Fluid Dynamic (CFD) method to discuss the geometrical impact on flow mixing. Adding a flow mixer will achieve the mixing enhancement. The number of blades inside the mixer and vane angle, swirl mixer position and flow also shows the effect of downstream fluid mixing along with the flow directions. The results of the flow are more improved by adding a delta wing mixer. This delta swing mixer generates the turbulent flow is useful for mixing within the shortest distance from the SCR system [13].

3. Experimentation

The test engine is shown in figure 1. The casing to hold the mould is shown in the figure 2 and 3. The preparation of mould is shown in figure 4. The modified SCR setup is shown in figure 5 and its dimensions are shown in figure 6.
The chemicals required for the mould preparation were bought. These chemicals are

- Propylene oxide
- Aluminium Chloride Hexahydrate
- Leishman’s Stain
- Tin
- White cement

For the formation of Ceria-Alumina, these are the chemicals required. Aluminum chloride hexahydrate and tin metal were dissolved in 20 mL ethanol using a Stir bar. After the salt is dissolved completely, 4.5 mL of Propylene oxide was added. It was kept undisturbed for 24 hrs to attain the gel formation. After 24 hours the gel form was mixed with white cement in a beaker. For the shape of the mould the composition was transferred into a cylindrical structure. It was left to dry for another 48 hours until the complete mould was formed.
The effectiveness of the SCR system with urea water solution is the most effective challenge of mixing the urea water solution with unburnt carbon gases to form NH3 which is evenly distributed on the SCR catalyst. This optimization is of the mixer is designed to determine the flow of uniformity. Based on this vane angle of the swirl mixer is designed to meet the uniformity flow of the mixing ammonia into the SCR catalyst system unit to achieve maximum NOx emission reduction. Minimum pressure drop is analyzed by the turbulent flow of the Mixer performance.

This system includes the Swirl mixer (figure 7), SCR unit, and Ad-blue solution injector. The pressure sensor is used to measure the pressure before the mixing ratio and after the swirl mixer. The turbulent flow is generated from the vane angle to form a uniform flow of ammonia through SCR unit to reduce the emission of the exhaust gases.

Study the engine specification and then run the engine with constant speed with neat diesel and calculating the time taken for 10cc fuel consumption and total fuel consumption, specific fuel consumption, brake power and exhaust gas temperature using this values we calculated the performance and combustion characteristics of the engine. Comparing the properties of neat diesel and with and without SCR (using with Urea Alumina) and repeating the same procedure with this some of characteristics will change, comparing that characteristics with neat diesel and Single and double mould SCR setup and repeating the same procedure and calculating the same characteristics. And compare the engine performance and emission characteristics with varying loads. The exhaust is connected to the gas analyzer and smoke meter for comparing the characteristics of Diesel only, single and double mould in the SCR setup. The quantity of emissions released from the engine is calculated and displayed as shown in figure 8. Similarly the procedure is repeated for smoke analysis also using the smoke meter in figure 9. The values for each SCR setup is calculated and the comparison is done for the same.
4. Results and Discussion

Figure 10 shows the NO outflow for diesel, diesel with single mould and diesel with double mould for the top load conditions. The quantity of NO is observed to increase when the load also increases. The amount of NO emissions at full load for diesel only, diesel with single mould and diesel with double mould was found to be 1153 ppm, 746 ppm and 720 ppm respectively and at the lowest load, the NO emissions were found to be 99 ppm, 72 ppm and 54 ppm respectively. Hence we can conclude that 35.39% and 35.77% of NO emission was reduced for the top load. Hence the double mould has proven to be effective. Therefore at the highest load, we can observe that NO emissions are reduced by 35.77%. Similarly, for the lowest load, there is 45.45%. Therefore we can conclude that there is an overall decrease of 35% when SCR is introduced. But double mould SCR setup performed slightly better than single mould setup.
In figure 11, the HC emissions for diesel only, diesel with SCR Single Mould and Double mould is represented. We can clearly see that the setup with only diesel has the most emissions compared to others. Inefficient fuel burning and lower in-chamber temperatures are the primary explanations behind the HC emanations. The HC graph like others has increased as the brake power increased with and without mould. HC. The amount of HC emissions at full load for diesel only, diesel with single mould and diesel with double mould was found to be 39 ppm, 28 ppm and 24 ppm respectively and at the lowest load, the NO emissions were found to be 14 ppm, 10 ppm and 9 ppm respectively. For single mould, we can conclude that 28.20% and 28.5% of HC emission was reduced for the highest and lowest load respectively. For double mould, at the highest load, we can observe that HC emissions are reduced by 38.4%. Similarly, for the lowest load, there is 35.7%. Therefore we can conclude that there is an overall decrease in HC emissions when SCR is introduced. But double mould SCR setup performed slightly better than single mould setup.
In figure 12, the CO emissions for diesel only, diesel with SCR Single Mould and Double mould is represented. We can clearly see that the setup with only diesel has the most emissions compared to others. In urban communities, however, much 95% of all CO emissions may come from engine vehicle fumes. Different wellsprings of CO outflows incorporate modern measures, non-transportation fuel burning, and regular sources, like timberland rapidly spreading fires. The amount of HC emissions at full load for diesel only and diesel with single mould was found to be 0.12% and 0.07% respectively and at the lowest load the NO emissions were found to be 14 ppm and 10 ppm respectively. Hence we can observe that 41.66% of CO emission is reduced when the load is maximum. Similarly when there is minimal load 33.33% of CO emissions were reduced when single mould was introduced. CO has increased for diesel fuel for increasing loads. For double mould, we can see the CO has reduced comparatively with no mould. Hence the double mould has proven to be effective. CO emissions at full load for diesel only and diesel with double mould was found to be 0.12% and 0.064% respectively and at the lowest load, the CO emissions were found to be 0.03% and 0.01% respectively. Therefore at the highest load, we can observe that CO emissions are reduced by 46.66%. Similarly, for the lowest load, there is 66.66% reduction. Therefore we can conclude that there is an overall decrease in CO emissions when SCR is introduced. But double mould SCR setup performed slightly better than single mould setup.

In figure 13, the smoke intensity emissions for diesel only, diesel with SCR Single Mould and Double mould is represented. The amount of smoke opacity at full load for diesel only and diesel with single mould was found to be 81.2, 68.5 and 60.5% respectively and at the lowest load, the smoke intensity emissions were found to be 17.5, 9.2 and 6.7 respectively. At maximum load, we can see that smoke intensity is reduced by 15.64% and for the minimal load, it is found out that there is 47.42% reduction in smoke intensity when there is a single mould. At the highest load, we can see that smoke intensity is reduced by 26.10% and for the minimal load, it is found out that there is 51.4% reduction in smoke intensity when there is double mould. The emission result obtained from the engine test with exhaust from the smoke meter, the smoke intensity was the decreasing when single and double moulded SCR setup was introduced. But comparatively, emissions for the double mould setup was slightly lower.
According to figure 14, the BTE is represented for different brake power for diesel only, single and double mould SCR setup. We can clearly see that there is a negligible difference for all three setups. Generally, when a mould is added to the exhaust there is a back pressure created. This might affect the engine performance. But since there is a negligible difference in the brake thermal efficiency. Hence, we can say that the back pressure does not have a huge effect on the engine performance.

5. Conclusion
1. NOx emission at full load is 1153ppm and reduces to 746 ppm for single mould and reduces to 720 ppm for double mould catalyst.
2. HC emission at full load is 39 ppm and reduces to 28 ppm for single mould and reduces to 24 ppm for double mould catalyst.
3. CO emission at full load is 0.12% and reduces to 0.07% for single mould and reduces to 0.064% for double mould catalyst.
4. Smoke intensity at full load is 81.2% and reduces to 68.5% for single mould and reduces to 60% for double mould catalyst.

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