Emission control from automobiles exhaust using dual absorbent

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Abstract- In this study main purpose of the project is to reduce the pollution which is caused due to vehicles exhaust gas and ensure the environment pollution free. Aim to maximize the efficiency of emission control as compare to other Reduce the back pressure and increase the efficiency of an engine. Vehicle exhaust gases like carbon dioxide (CO₂), hydrocarbon (HC) and carbon monoxide (CO) are highly toxic. These components are the major problem to environment and health. Therefore, our main concern is designing of packed column and analyze the dual absorbent system to reduce the toxic of emission of gases. In this study we are using a group of two absorbent named ZSM-5 and MORDENITE having catalyst PLATINUM materials with the ability to absorb CO₂, carbon monoxide, NOx and HC which is coming out from the vehicular engine after the exhaust process. The dual absorbent was able to remove CO up to 88.04%, HC up to 68%, NOx up to 75.96% and CO₂ up to 69.38% for 10min.

Keywords: ZSM-5, MORDENITE, BACK PRESSURE.

1. INTRODUCTION

Automobiles sector is one of the main reasons behind air pollution. Air pollution target to the atmosphere by harmful gases which are not good for health of any living things like human animal, plants etc. Transport sector is widely recognized as the large source of air pollution in the world. In automobile sector nearly all the vehicles emit harmful gases by combustion of fossil fuel. When fossil fuel is completely burn then they emit CO₂ and H₂O from vehicle exhaust system. Carbon monoxide and hydrocarbon in the form of vapors is also produce when fuel is not completely burn in the combustion chamber. The (NOx) releases from the exhaust gases of a diesel engine are generally composed of more than 90% (NOx). The (SCR) is the after-treatment technology being acquired for the diesel vehicle (HDD) manufacturers for meeting diesel emission standards that will become
cornpulsory worldwide in the next few years. In the past Z.W. et. al [1] This project tells us about the adsorption of NO by activated carbon in marine diesel engines. And it's Mounted on the surface of Ac where the N₂ inlet. Raddy et. al [2] It provides a method to increase the adsorption capacity of an emission control system by heating a small part of the adsorbing material. Wee Kong Piu et.al [3] This is all about the reduction of Vic’s by adsorption system. Carbon powder is used to adsorb the VOC emission. Chang et.al [4] This project shows the chemical adsorption of NO₂ by using an activated carbon system. The new idea is the size of grits in cross-sections area which can able to adsorb NO₂. Sameer et.al [5] In this experiment they have successfully controlled emission of carbon dioxide from the diesel operated engines, which is about 9.266% of the overall emission from a vehicle. Through this other gas has also been controlled like hydro carbon, nitrogen, carbon monoxide and particulate matter. Austin Shepherd et.al [6] According to this project, activated carbon has been shown to be applicable for treatment of a wide variety of environmental contaminants. This system is very easy to install and it's a cheaper way to control VOC emission. In this project they are working on the adsorption by various cross sections of carbon.

2. RESEARCH GAP
Many researchers had experimentally investigated, the pollutant’s emission control by absorption using activated carbon, with 27% efficiency. Also, some researchers experimentally found that, pollutant’s emission control by absorption is one of the causes of back pressure in exhaust system which has negative impact on the engine efficiency. And to avoid it some researchers had done the study of dual pipe exhaust system. But no research work has been done on the pollutant’s emission control by dual absorbent with maximum efficiency, and also it may resolve the problem of back pressure in single way exhaust system.

3. OBJECTIVES OF THE STUDY
- Study of different types of absorbents materials.
- Numerical study on variation of velocity, temperatures, pressure and mass flow rate in dual absorbent system.

4. BASIC WORKING PRINCIPAL
Carbon filter absorbs pollutants in the fluid, which are trapped inside the pore structure of carbon filters as it has been treated to have a more in surface area than non-treated carbon particles stored in five components in the exhaust system as shown in the schematic diagram that is exhaust manifold, catalytic converter, dual absorbent filter, and a muffler connected with a tailpipe. At the end of the exhaust stroke of the engine hot exhaust gases and sound waves are generated and sent to the exhaust system through valves after that exhaust gas enters into catalytic converter at high temperature, pressure, and sound wave, at the outlet of the catalytic converter low temperature and pressure of exhaust gases are released and enters into dual absorbent system ZSM-5 and MORDENITE are there in the filter along with platinum catalyst. When exhaust gases enter into the first block of the filter then nitrogen molecules reactZSM5 absorbent and form oxide of nitrogen to reform into and oxygen. After that gas enters into the second chamber of the filter there is mordenite which reacts with carbon monoxide to oxygen to form carbon dioxide and release into the environment which is less harmful.
Fig-1 Block Diagram of An Exhaust System with the Dual Absorbent Filter

5. MATERIAL SELECTION

An exhaust filter used to reduce harmful gases from the exhaust of the vehicle. Among all materials, we selected mordenite and ZSM-5 because both are the best absorbents materials which are absorbing most of NOX and hydrocarbons. Both the absorbent reacts lastly with emotive gases and produce Oxygen ($O_2$). From the materials group of platinum (Pt.), copper (Cu), rhodium (Rh), Iron (Fe), we select ‘Pt’ because it reduces most of CO, CO$_2$, and other harmful gases and also works as a catalyst. We found that these materials are suitable for dual absorbent system with better efficiency.

6. RESEARCH METHODOLOGY

- Suitable material should be selected as per the requirements.
- The Properties of the material should be studied before the selection of the material.
- The CAD model should be prepared in order to avoid complexity.
- Analysis should be performed by considering all various factors (temperature and pressure).
- Compare the requirement of the product with the result of the product

Make suitable design for the filter. With the CAD model software was created on Creo software. The size of the filter was considered based on the exhaust pipe. The model created with two different kinds of in-fill patterns of circular and conical along with the Solid model.
7. Calculations for Dual Absorbent System

At the inlet (ideal conditions) of the dual absorbent filter the concentration of HC, NOx, CO, CO$_2$ are 0.35 mg/l, 0.52 mg/l, 2.61 mg/l, 77.4 mg/l respectively. And the Mass flow rate = 0.04 kg/sec.

7.1 Calculation for the actual area of absorbent disc and pore

Now from the design geometry, we know –

Diameter of discs(D) = 125mm (0.125m)

Diameter of pores(d) = 5mm (0.005m)

Thickness of discs(t) = 2.5mm (0.0025m)

Number of pores(n) = 44

So, Area of the discs = $3.14 \times D^2 / 4$

$= 3.14 \times (0.125)^2 / 4$

$= 0.0123 \text{ m}^2$ \hspace{1cm} eq. (1)

And

The area of the pore = $3.14d^2 / 4$

$= 3.14 \times (0.005)^2 / 4$
From eq. (1) and (2) we can say

Actual disc area = area of the disc - n× (area of the pore)

\[ \text{Actual disc area} = 0.0123 - 44\times (0.0196\times10^{-3}) \]

\[ = 0.0123 - 0.0008635 \]

\[ = 0.0114365 \text{ or } (11.44\times10^{-3}m^2) \]

eq. (3)

Now actual contact area of pores = n× (area of cylindrical pore)

\[ \text{Actual contact area of pores} = 44\times (2\times3.14\times r\times h) \]

\[ \text{[Note: } h=t\text{]} \]

\[ = 44\times2\times3.14\times0.005/2\times0.0025 \]

\[ = 0.001727 \text{ or } (1.727\times10^{-3}m^2) \]

eq. (4)

7.2 Calculation for the actual contact area of absorbent disc

Now from the eq. (3) and (4) whole contact area of the discs = (2×Actual disc area) + (Actual contact area of pores)

\[ \text{Whole contact area of discs} = (2\times11.44\times10^{-3}+(1.727\times10^{-3}) m^2) \]

\[ = 24.604\times10^{-3} m^2 \]

eq. (5)

7.3 Calculation for the filtration rate

\[ \text{Filtration rate} = \frac{\text{mass flow rate}}{\text{contact area}} \]

\[ = 0.04 \text{ kg/sec}/24.607\times10^{-3}m^2 \]

\[ = 0.04\times103/24.607 \text{ Filtration rate} \]

\[ = 1.6 kg/m^2\cdot\sec \]

eq. (6)

After passing through ZSM-5 disc the pollutants concentrations are HC=0.28mg/l, NOx=0.208mg/l, CO=1.04mg/l, CO2=38.7mg/l, with the same filtration rate as eq. (6).

As we know both the disc has the same dimension as eq. (5)

After passing through mordenite disc the pollutants concentrations are HC = 0.112mg/l, NOX =0.125mg/l, CO =0.132mg/l, CO2 =23.7mg/l.
7.4 Calculation for the reduction efficiency for each pollutant

\( \eta \) Efficiency = \( \left[ \frac{(C_{\text{in}} - C_{\text{out}})}{C_{\text{in}}} \right] \times 100 \)

Now for NOx

\[ \eta = \left( \frac{0.52 - 0.125}{0.52} \right) \times 100 \]
\[ \eta = 75.96\% \]

for HC

\[ \eta = \left( \frac{0.35 - 0.112}{0.35} \right) \times 100 \]
\[ \eta = 68\% \]

For CO

\[ \eta = \left( \frac{2.16 - 0.312}{2.16} \right) \times 100 \]
\[ \eta = 88.04\% \]

For CO\(_2\)

\[ \eta = \left( \frac{77.4 - 23.7}{77.4} \right) \times 100 \]
\[ \eta = 69.38\% \]

8. NUMERICAL ANALYSIS AND RESULTS

In numerical analysis four major flow characteristics (pressure, temperature, mass flow rate and velocity) were studied. In the context of computational fluid dynamics analysis, 3D meshing has opted for better result. We consider to do h type of mesh refinement. In mesh refinement we observe the meshing with differentiating in different size of element (differentiate in 2mm, 3mm and 4mm with different shape) and found that 4 mm size with tetrahedral shape of meshing gives us maximum contact area of absorption to get better result.

| Particulars          | value            |
|----------------------|------------------|
| Mesh element size    | 4 mm             |
| Number of nodes      | 11491            |
| Number of elements   | 50793            |
| Element shape        | tetrahedral      |
| Type of analysis     | computational fluid dynamics |
Fig-4 Tetrahedral meshing of solid modal

Boundary condition

- Inlet velocity-20m/sec
- Inlet Temperature-700K

System performances are examined by calculating parameters like velocity, temperature, mass flow rate, and pressure.

The experiment is conducted in the following cases to estimate the performance of the filter.

Case1: Velocity variation inside Dual absorbent system

The variation of velocity after exhaust gas passes through the dual absorbent system is shown in fig:5

- Inlet velocity magnitude in dual absorbent system =20m/sec
- Inside average velocity magnitude in dual absorbent system =7m/sec
- Outlet velocity magnitude in dual absorbent system=19m/sec

Case2: Mass flow rate distribution

The variation of mass flow rate after exhaust gas passes through the dual absorbent system is shown in fig:6

- Inlet mass flow rate magnitude in dual absorbent system =0.03738kg/sec
• Inside average mass flow rate magnitude in dual absorbent system = 0.0377 kg/sec

• Outlet mass flow rate magnitude in dual absorbent system = 0.03782 kg/sec

![Fig-6 Mass Flow Rate Distribution](image)

**Case 3: Temperature variation inside the dual absorbent**

The variation of temperature after exhaust gas passes through the dual absorbent system is shown in fig:7

• Inlet temperature magnitude in dual absorbent system = 700k

• Inside average temperature magnitude in dual absorbent system = 571k

• Outlet temperature magnitude in dual absorbent system = 690k

![Fig-7 Temperature Variation Inside Dual Absorbent](image)

![Fig-8 Plot of temperature at inlet and outlet](image)
Case4: pressure inside the dual absorbent

The variation of pressure after exhaust gas passes through the dual absorbent system is shown in fig:9

- Inlet pressure magnitude in dual absorbent system = 60 pascal
- Inside average pressure magnitude in dual absorbent system = 87 pascal
- Outlet pressure magnitude in dual absorbent system = 55 pascal

CONCLUSIONS

The dual absorbent filtering system much better to reduce emission gases from the engine exhaust using the adsorption technique and by using this the backpressure will also reduce. From the above calculations, conclude that Reduction of NOx in dual absorbent system is 75.96%.

Reduction of HC in dual absorbent system is 68% and Reduction of CO in dual absorbent system emission is 88.04% and Reduction of CO₂ in dual absorbent system emission is 69.38%.

In this study, it has been presented a dynamic work effort to reduce pollutants (CO₂, CO, NOx, CMCN, etc.) emission from the exhaust system using adsorption techniques through the exhaust pipe. It’s been found that there are approx. 60-80% reduction in pollutants emission using dual absorbent filtering system. Also, engine performance does not affect because there is no generation of backpressure, which leads an engine to better efficiency and make equipment environmentally good. From the above analysis calculations, conclude that Outlet velocity in dual absorbent system is 19 m/sec, Outlet temperature in dual absorbent system 690 k, Outlet mass flow rate in dual absorbent system 0.03782 kg/sec and Outlet pressure in dual absorbent system is 55 pascal.
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