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CO_2 Capture Using Activated Alumina in Gasoline Passenger Vehicles

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ABSTRACT
Now a days there is a tremendous change in the climatic conditions due to global warming and greenhouse gases results in the floods, draughts and famine. Due to increase in the usage of fossil fuels, the emission of harmful gases into the atmosphere and results in global warming and greenhouse effect. Carbon Dioxide is one of the major component of Greenhouse gases results in greenhouse effect. Major amount of Carbon Dioxide releases from the combustion of fossil fuels which are emitting from the Vehicles and Industries. For the control of the emission of the carbon dioxide into the atmosphere we have chosen for adsorption of Carbon Dioxide from the exhaust of the gasoline vehicles using Activated Alumina. For this Alumina is phase transformed to Gamma – Alumina (Activated Alumina) which can adsorb the Carbon Dioxide from the gases and can be recycled without causing any effect to the neighbouring gases and material used. The gasoline vehicle used for testing is following the EURO – V emission norms and the Carbon Dioxide content releasing from the vehicle is reduced to 7.6%.
***Keywords**:* Carbon dioxide, Activated Alumina, Adsorption.

I. INTRODUCTION

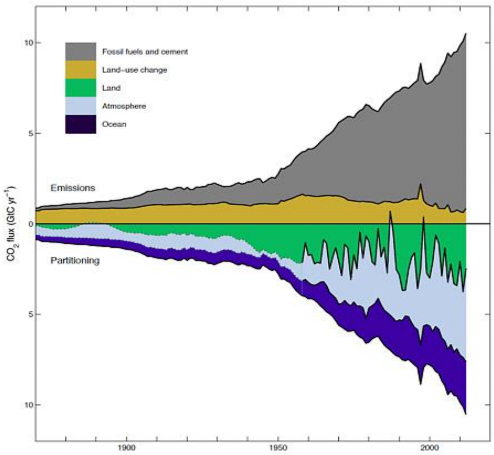
Emission is the production or discharge of something, especially gas or radiation into the atmosphere. Emission from the fossil fuel combustion is one of the most dangerous pollutant causing agent into the atmosphere. Due to the vigorous growth of the automobiles in the environment there is a rapid increase in the harmful gases into the atmosphere. These harmful gases are effecting the climatic cycle of the environment. Carbon dioxide is one of the major pollutant causing from the emission. Many researches are made to quickly identify the carbon dioxide emission from the vehicles in many ways and an initial measurement of the carbon dioxide concentration in the exhaust system of a commercial diesel engine using the optical fibre sensor was discussed[1,2].

Carbon dioxide is a greenhouse gas which causes global warming by increasing its percentage in the environment. However there are many naturally reducing sources of carbon dioxide from the atmosphere, these natural sources are fails to balance the excess amount of carbon dioxide in the atmosphere. This results in Global warming and greenhouse effects.

Due to this some artificial methods are being adopted for the control of the carbon dioxide emission into the atmosphere. On balancing the percentage of carbon dioxide from the atmosphere may change the climatic conditions and set to normal.

For this, an adsorption of carbon dioxide using Zeolite 13X, Zeolite 4A and Activated Carbon have been investigated at a room temperature and pressure of 1bar [3]. A computational study of adsorption in zeolites using various compositions have been studied [4,5]. CO_2 emission reduction from the exhaust of a diesel engines using modified charcoal is also a kind of technique to adsorb CO_2 from the exhaust emission [6]. This captured CO_2 ultimately should be reused so the wastage or pollution cannot be found [7].

Figure :1. Carbon Dioxide Production and



Reduction

This activated alumina is having an adsorptive capacity of carbon dioxide because of its higher pore size with higher surface area and the catalyst is having the hydroxyl group in it so, the carbon dioxide can be easily adsorbed by the catalyst and because of the adsorption process the captured CO_2 can be reused in some other way.

For this usage of the catalyst a reactor chamber have to be made. Where the catalyst is finely wire-meshed in three equal compartments separated by wire-mesh and then sealed to avoid the dispersing of the material inside the reactor chamber.

II. ENGINE OVERVIEW

TABLE – I

Engine Specifications – FORD ECOSPORT (EURO – V)	
Fuel type	Gasoline
Cylinders	4L
Displacement	1498cm^3
Bore X Stroke length	79 X 76.5mm
Compression ratio	11.0:1
Power	82 KW @ 6300RPM 112HP @ 6300RPM 110BHP @ 6300RPM
Torque	103 lb-ft @ 4300RPM 140Nm @ 4300RPM
Fuel System	Direct Injection
CO_2 Emission	149g/Km

III. SCHEMATIC REPRESENTATION OF CO_2 REDUCTION IN GASOLINE ENGINE

The Gasoline engine's exhaust gas is passed through the after treatment system to remove CO, HC and NO_x by the following reactions:

$$2CO + O_2 \rightarrow 2CO_2$$

$$2C_yH_n + \left(\frac{n}{2} + 2y\right) O_2 \rightarrow 2yCO_2 + nH_2O$$

$$2NO + 2CO \rightarrow N_2 + 2CO_2$$

From the after treatment system the following gases are emitted into the atmosphere due to the RED-OX reactions carried by the ATS. The gases are CO_2, H_2O, N_2 and O_2 etc. The obtained flue gases are passed to the reactor chamber for the capture of CO_2 as shown in Figure 2.

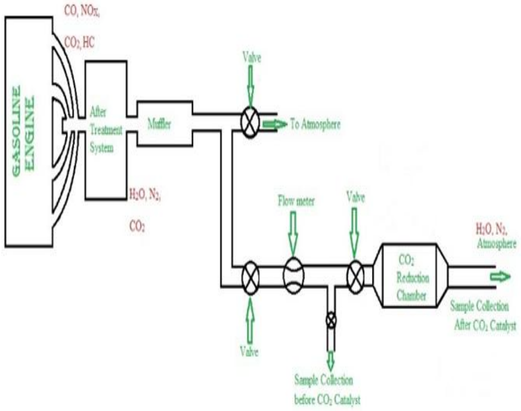


Fig: 1. Schematic Layout of CO_2 Adsorption System

The carbon dioxide reduction is the process of adsorbing the emission of Carbon dioxide from the exhaust of a muffler using a CO_2 adsorption chamber.

IV. MATERIAL USED FOR ADSORPTION PROCESS

The material used for capturing of CO_2 from the emission is Activated Alumina. Basically Alumina is having the capability of adsorbing the carbon dioxide from mixture of gases because of its hydroxyl group. To make the alumina better adsorbent alumina is subjected to phase transformed to obtain the Gamma – alumina which is having the high porosity and surface area, these will help to adsorb the carbon dioxide in a better way.

TABLE – II

Type	**Alumina**	**γ - Alumina**
Surface Area (m^2/g)	10 - 100	>200
Pore Diameter	10nm -1.2μm	7-13 nm
Pore Volume (cc/gm)	0.49 - >0.83	0.6 – 1.05
Packing density (Kg/m^3)	550 – 780	430– 690

Fig .3 Activated Alumina balls

Figure 3 shows Activated Alumina balls sample which is used as a catalyst for the adsorption of carbon dioxide from the exhaust emission.

V. DESIGN CALCULATIONS OF THE REDUCTION CHAMBER

For the adsorption of carbon dioxide from the exhaust and to hold the catalyst a reactor chamber have to be prepared. This reactor chamber should not create the higher back pressure inside the reactor so that the chamber is made based on the design calculations of the muffler [8] because of the similar work is carried-out by the chamber used in the process of capturing the CO_2.

a) Space Velocity

The space time necessary to process one reactor volume of fluid. It is also called as holding time or residence time.

Assuming Space velocity = 30000 lit/Hr

$$Space\ Velocity = \frac{Volume\ flow\ rate}{Reactor\ volume}$$

Volume flow rate
= Swept volume * No. of intake strokes per hour

$$= \pi * \left(\frac{bore}{2}\right)^2 * Stroke\ length * \frac{N}{2} * 60$$

$= 3.14 * (0.079/2)^2 * (0.0765) * (6300/2) * 60$

Volume flow rate = 70.8 m^3

Reactor Volume = Volume flow rate / Space velocity
= 70.8/30000

Reactor Volume = 0.002356 m^3

b) Shell Dimension

1. The Shell is the central cylindrical part between the inlet and outlet cones.
2. This part contains Gamma Alumina pellets.

$V_{catalytic\ reactor} = \frac{\pi}{4} * D^2 * L$ mm^3

Where D – Diameter of the Reactor
L – Length of the Reactor (assume L=3D)

$V_{catalytic\ reactor} = 0.7853 * D^2 * 3D$

$0.002356 = 0.7853 * 3D^3$
D = 0.1000m = 10cm
L = 3D = 3*10 = 30cm

VI. MODEL AND DESIGN VALIDATION

For validating the design, a model is designed using Solidworks software and flow analysis is carried-out for estimating the back pressure and uniformity index of reactor chamber along with catalyst used.

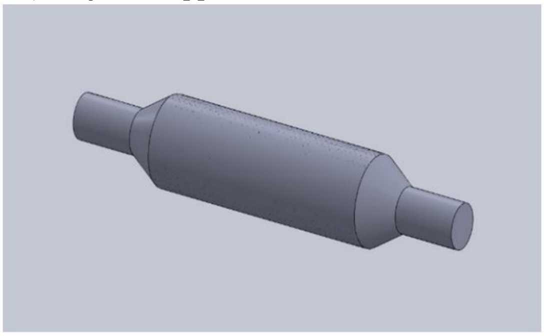


Fig .4 Model of Reactor Chamber

The figure 4 shows the design model of the reactor chamber in 3- Dimensional view and the figure 5 shows the flow inside the reactor chamber using CFD analysis in Star CCM+ software.

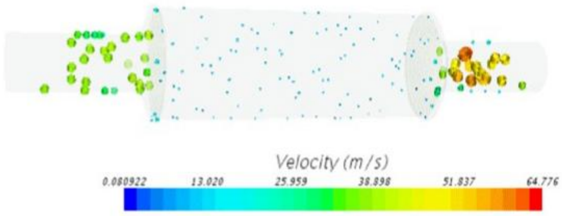


Fig . 5 Flow analysis of Reactor Chamber

The input parameters considered for the analysis of the reduction chamber and the results obtained are shown in the following table III.

TABLE – III

Description	Units
Inlet mass flow rate	195kg/h
Inlet Temperature	200^0 C
Outlet pressure	1 atm
Pressure Drop	75.04586mbar
Uniformity index	0.8898563

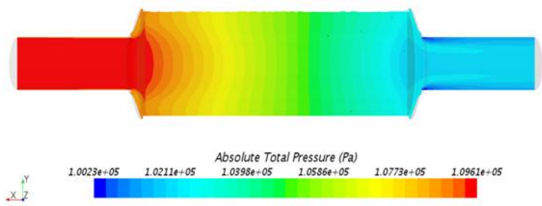


Fig :6 Pressure drop in Reactor Chamber

Figure 5 shows the pressure drop value throughout the chamber i.e., from inlet of the chamber to the outlet of the chamber is ΔP = 75.04586mbar.

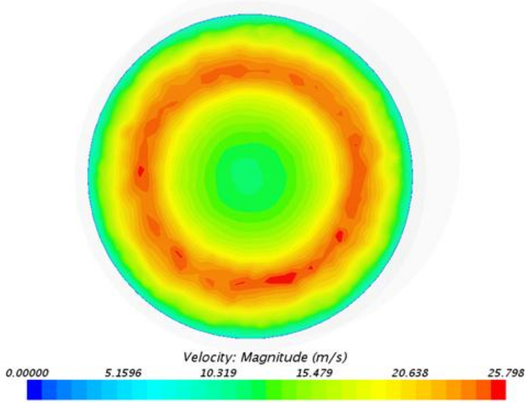


Fig : 7 Uniformity Index of Reactor Chamber

Figure 6 shows the uniformity index of reduction chamber where the catalyst placed, is obtained as UI = 0.8898563.

I. Wire mesh

Wire mesh is prepared in order to hold the material to be inserted in the chamber. The mesh should not exceed the diameter of the catalyst so that the catalyst should not come out of the chamber when testing the catalyst.

Fig : 8 Reactor Chamber and Wire mesh

Fig : 9 Opening for Catalyst Insertion

Fig : 10 Wire mesh filled with Catalyst

Fig : 11 Trap inserting in chamber

The material used for making the reactor chamber is Stainless steel and the chamber made with the dimensions obtained from the design calculations.

VII. WORKING OF VEHICLE

The vehicle used for testing is gasoline engine – FORD ECOSPORT 1.5L with automatic transmission. Testing is carried-out by checking the exhaust emission at various rpm levels using gas analyser at the end of tail pipe. The emission gases from the exhaust system are CO, CO_2, HC and NO_x.

The emission levels are calculated by the gas analyser in terms of percentage by volume for CO and CO_2 and in terms of ppm by volume for NO_x and HC releasing form the exhaust of the vehicles.

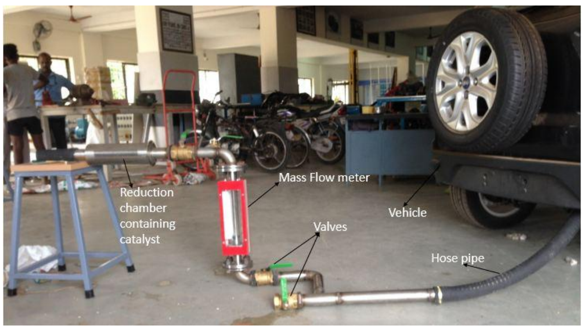


Fig : 12 Vehicle assemble with CO_2 adsorption chamber

As per the layout given in figure 2 the set-up is made and assembled as shown in the figure 12 and this set-up is fixed at the end of the tail pipe so that all the emission gases from the exhaust will be passed to the chamber containing catalyst. So that the amount of CO_2 available in the exhaust gas can be adsorbed by the catalyst and rest of the gases will come out of the reactor chamber.

VIII. RESULTS AND DISCUSSION

The results of CO_2 absorption before and after the reactor chamber containing catalyst used with various engine speeds in zero load conditions.

TABLE IV

S.No.	Condition	RPM	Mass Flow Rate	CO2	Difference Between Before and After Reducer	%age Reduction
1	Before	700	5800	14.1333	1.04	7.35
	After	700	5800	13.0933		
2	Before	1800	35000	14.17	0.897	6.33
	After	1800	35000	13.2733		
3	Before	2500	60000	14.15	0.9366	6.61
	After	2500	60000	13.18		

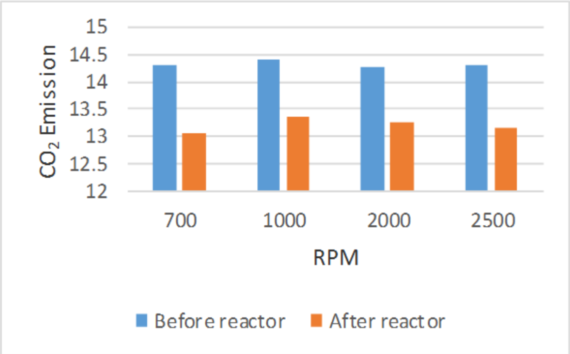


Fig: 13 CO2 Absorption Efficiency of Charcoals

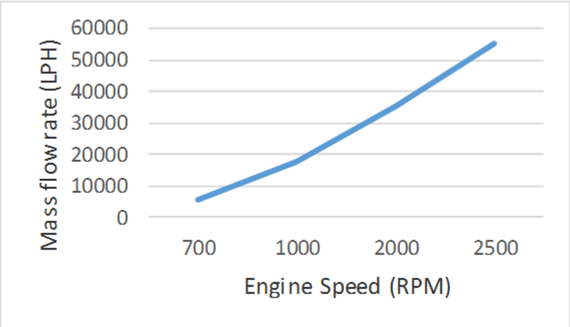


Fig : 14 RPM Vs Mass flow rate chart

IX. CONCLUSION

From the results, the paper concludes that the emission of Carbon dioxide from the vehicle is reduced by maximum of 7.6% and apart from the reduction of carbon dioxide emission some amount of Hydrocarbons has been reduced by 4ppm. This process of adsorption won't affect the increase in emission of other gases. Due to the adsorption process we can recycle the catalyst used and the adsorbed carbon dioxide can be utilized so this process of adsorption will not affect the environment.

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