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Reduction of Carbondioxideemissions from Diesel Passenger Vehicle Exhaust Tail Pipe by Capturing Method Using Activated Aluminawith Analyzed Reactor Chamber

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Abstract: *Emissions from various fossil fuels makes environment depletion and usage of automobiles are increasing day by day. Heavy usage of automobiles has many disadvantages and it is the main reason in its negative effect on environment. Carbon monoxide (CO), Hydrocarbons (HC), Oxides of Nitrogen (NO_x), Particulate Matter (PM), Sulphur dioxide (SO_2). Carbon dioxide (CO_2) which are coming out with a large extent from internal combustion (IC) engines causes harmful to environment as well as human being.However different types of catalytic converters are implemented for the reduction of exhaust emissions but all the types of the systems are to reduce NOx, CO, HC and PM only. Rest of the converted CO_2 emissions are coming out with a large extend this leads effect on human & environment system. CO2 is very important greenhouse gases which is said to be responsible for approximately 60% of global warming. CO_2 is one among the greenhouse gases responsible for enhanced greenhouse effect. Fossil fuel combustion produces maximum amount of CO_2. Reduction of CO_2 from internal combustion engines is expected to control CO_2 emission. As a part of our continued effort to control atmospheric CO_2, we have undertaken a study of CO_2 absorption using Activated Alumina. For controlling of CO_2, preparation of new reactor assembly design (Catalytic converter) is one of the method in which Activated Alumina will be taken as a catalyst because Alumina has the tendency to absorb CO_2 and it is low cost in production. The reduction process is taken as Capturing method the experiment is carried out by the optimization of a reactor assembly design. Various calculations have been done on the designing of CO_2 chamber using CATIA V5, CFD and the results can be shown by testing of catalytic converter on Diesel operated vehicle. Finally the results will be the controlling of CO_2 emissions of11.6% by capturing method using Activated alumina catalyst.*

Keywords: *Carbon dioxide, Activated Alumina, Capturing method, Flow meter, Gas analyzer*

I. Introduction

The planet is getting warmer day by day. Most climatologists regard the final decade of the twentieth century as the warmest in the past millennium. Even minor alterations in global temperature will trigger a series of weather extremities and alter the climatic patterns of the planet. Global warming effects on earth are caused by several factors. To understand the overall effects of global warming on earth, we have to understand the contributions and effects of each component of the planet. The gases produced from vehicles, power plants and other sources are building up in the atmosphere, acting like a thick blanket over our planet. Climate change can be reduced by decreasing the emission of heat-trapping gases particularly CO_2 to the atmosphere. The production of CO_2 from various sectors and consumption of CO_2 through natural process are not proportional leading to an unbalanced residual growth of CO_2 in the atmosphere. It has been clearly identified that additional effective technologies are needed to control CO_2 in the atmosphere. The effect of extra carbon dioxide from various sources in the planet is that the overall temperature of increasing global warming. The action taken to control CO_2emissions is from the Automobile sector is by capturing technique. This is through carbon capture or storage mechanism [1, 2]. In the current study, absorption of CO_2 is achieved in a diesel engines using Alumina derived from different sources. The reduction of CO_2 by absorption on Alumina and activated Alumina and absorption/adsorption are compared. The extra carbon dioxide increases the greenhouse effect. More heat is trapped by the atmosphere, causing the planet to become warmer than it would be naturally. The increase in global temperature this causes is called global warming. In diesel engines the carbon particle or soot content varies from 60 – 80% depending on the fuel used and the type of engine. Most of the contaminants are adsorbed on to the soot. Carbon dioxide emissions from the diesel engines are to be controlled by a capturing method.
Since carbon-dioxide is one of the major green-house gas released as a result of partial combustion.In present study diesel engines CO_2, HC and CO are much lesser than the petrol engines. The performance and emission characteristics of diesel engines is classified [3, 8].In diesel engines reduction of PM and NOx is very difficult task. Due to this DPF is installed in the after treatment system to reduce the above emissions. A multi-

functionalconverter is developed for the exhaust gas purification. Here the testing of this converter is done on the 2.2L operated vehicle running at a constant speed of 60km/hr, therefore the NOx and PM rates are reduced respectively 98% and 99.1%. Due to the efficient heating of exhaust gas by heating 110^0 -370^0C in the converter by the addition of H_2 in the exhaust gas [7, 9, 10]

Rajadurai et.al[4] classified reducing carbon-dioxide from engine exhaust different adsorption rates were observed with respect to various sources such as coconut shell 9.8%, coconut trunk stem 8.4%, he also concluded carbon-dioxide absorption efficiency differs with resident time happened due to high mass flow rate. KOH and activated wood charcoal increases the absorption efficiency.

ValentinasMukunaitiset.al [6] classifies that the average fuel consumption and CO_2 emissions using diesel is lesser than the petrol in characteristics by 27% and 17%. But when burnt the diesel of one litre the 2.7kg of CO_2 releases and one litre of petrol gives 2.4kg of CO_2. If the engine displacement is high then the fuel consumption and CO_2 emissions are also high.

II. Details Of Engine

1. Tabulation 1Engine Specifications

Engine Manufacturer	Volkswagen jetta TDI
Displacement	1968cc
No of cylinders	4
Compression ratio	10.5:1
Bore	82.5mm
Stroke	92.8mm
Horse power	150@3500 RPM.
Max Power	138bhp@4200rpm
Max Torque	320Nm@1750rpm
Emission norms	Bharat Stage-IV

Figure 1: Volkswagen Jetta Engine

2. AVLDigas Gas Analyzer

Figure 2: Gas Analyzer

Gas Analyzer is a Testing Device which is used to measure the Quantity of Particular Exhaust gases. The main purpose is to measure the relative volume of certain gaseous constituents in the exhaust gases of motor vehicles. The gases that measures are CO_2, CO, NO_x, HC, and O_2. LAM air fuel ratio is calculated from CO, CO_2, HC, and O_2 constituents and displayed.

III. Adsorption Material()

[5]Activated alumina has high porous structure, high surface area-to-mass ratio and pole-molecular absorbent property, as well as great properties like high selectivity, high rate of absorbent, high resistant to thermal stock etc.

Figure 3: Activated Alumina Balls

1. Tabulation 2Chemical Properties

PROPERTIES	VALUES
Particle form	Spheres
Particle Size	5-8mm dia balls
Surface area (min)	360–430 m^2/gms
Pore Volume	0.4 – 0.5 cc/gms
Bulk density	750-850 gms/lit

IV. Design Concept

The catalytic convertor is designed with the following three objectives:-

- Simple construction(No complicated construction)
- To obtain a greater Surface area.
- To reduce the back pressure.

The network output per cycle from the engine is dependent on the pumping work consumed, which is directly proportional to the backpressure. To minimize the pumping work, backpressure must be low as possible. The backpressure is directly proportional to the catalytic converter design. The catalytic substrate and shape of the inlet cone does not contribute to the backpressure.The cylindrical shape was considered due to ease of fabrication, minimum assembly time, rigidity and easier maintenance [16, 17]

1. Space Velocity: The space time necessary to process one reactor volume of fluid.
Calculation for Determination of Diameter and Length
Space velocity = Flow rate volume / Volume of Catalyst
Since Space velocity is considered as 16000 m/hr
Now Flow rate volume = Swept volume x No of intake stroke per hour
Flow rate volume= $\frac{\pi}{4}\times(82.5)^2 \times (92.8) \times 1500/2\times60 = 44.427\ m^3$
Catalysts volume = Volume flow rate / Space Velocity
= 44.78 /16000
Volume of Catalyst = $0.0027m^3$

2. Wire mesh Dimension

Wire mesh is the cylindrical type of shell which is placed in between inlet and outlet of the cone. Activated alumina will be placed inside this shell.

$V_{catalyst} = 0.785 \times D^2 \times L$

Where D= Diameter of the catalyst
L= Length of the Catalyst

L= 3D (Assume)
$0.0027 = 0.785 \times D^3 \times 3$
D = 0.103m
L = 3D
L = 3 × 108
L = 309mm

I. Experimental Layout

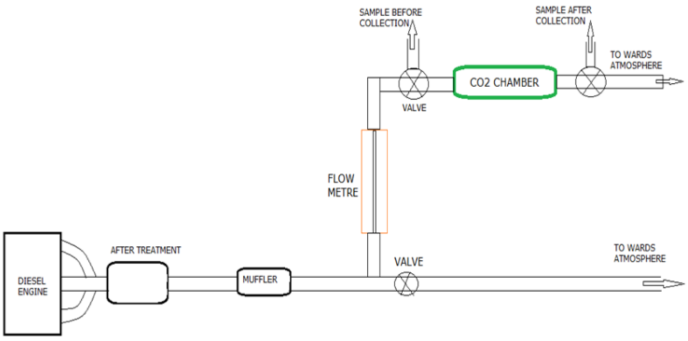

Figure 4: Assembly Layout

The Layout of this experiment is carried out by connecting from the exhaust tailpipe i.e. after the muffler tailpipethe passing flow pipe is connected. The flow meter is connected to this passing flow pipe. The gas flow passing through the flow meter and after the CO_2 chamber.The Sample will be collected before and after the CO_2 chamber with the help of valves placed in before and after the CO_2 chamber

Initially, exhaust gases coming out of the engine are directed toward the Alumina absorbent reactor chamber by passing through flow meter. Here the valve before CO_2 chamber is taken for collecting sample.

From the above figure shows the experiment conducting layout of capturing CO_2 gas. The Carbon dioxide reduction process is done by the capturing method where Activated Alumina is used for the Adsorption of CO_2 from the exhaust of a muffler using a CO_2 adsorption chamber

V. Modellingdesign Validation

The CO_2 Chamber is designed by using Catia V5 software and flow analysis is carried out for estimating the back pressure and uniformity index of reactor chamber along with catalyst used. So that the design will be validated

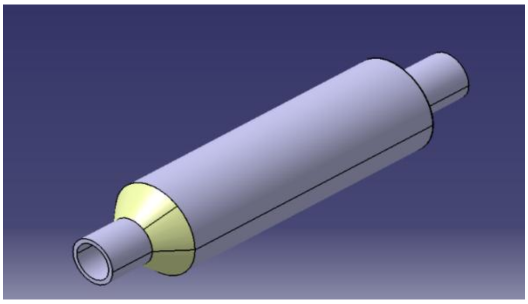

Figure 5 Modelling of reactor chamber

1. CFD Analysis (flow uniformity)

To validate any Chamber design, it is necessary to confirm the Pressure drop and flow uniformity index. We validated our design by analyzing it through CFD.

It is subjected to computational fluid dynamics analysis using Fluent 14.0. Boundary conditions of whole reactor chamber in the presence wire-mesh package containing Activated Alumina balls. Boundary conditions for inlet condition is taken as195kg/hr. Mass flow rate of exhaust gas and temperature 200°C. In the chamber containing Alumina balls boundary conditions were taken based on its porosity value, inertial resistance and viscous resistance as follows 0.89, 28.356kg/m^4 and 2048.65kg/m^3/s respectively. Since the exhaust tail gas flowing through the converter chamber holding Activated Alumina depends on porosity and resistance value of the material. Outlet pressure of 1atm and temperature of 30°C were taken as preferred outlet boundary conditions were noticed for analysis. Figure 6 gives the outline for the boundary conditions for analysis to conclude the design validation

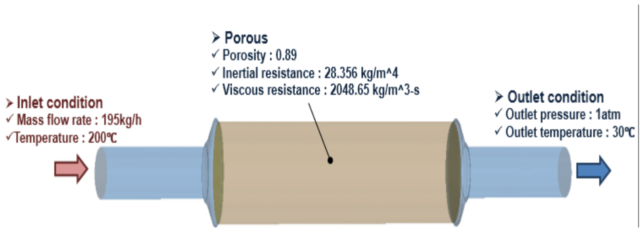

Figure 6 Boundary condition for Reactor chamber

Table 3 Boundary Condition

Domain	Type	Value
Inlet	Mass Flow rate	195kg/h
Outlet	Pressure	1atm
Inlet	Temp	200^0
Outlet	Temp	30^0
Alumina Chamber	Porosity	0.89

2. Pressure Drop

Below figure 7show the pressure drop obtained in both cases:
Case A – Alumina Chamber, (Flow through top to bottom.)
C0ase B – Alumina Chamber, (Flow through only cone.)

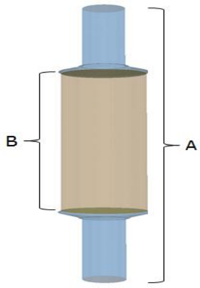

Figure 7 Alumina chamber

In figure 8, analysis report explains the pressure drop of the exhaust tail gas flowing through the reactor chamber. Exhaust gas entering the reactor chamber possess the flow velocity between 25.859m/s to38.898m/s, while it enters the Alumina chamber it drops to 0.08m/s this velocity drop is due to passing through solid adsorbent material. When the gas reaches the exit, velocity increases to 64.776m/s as its peak velocity. It measures to pressure drop of 75.04586 mbar.

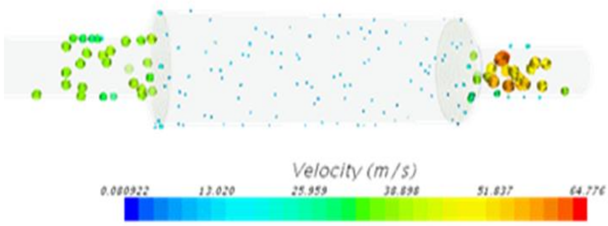

Figure 8. Flow analysis of Reactor

Below, Figures 9 shows the pressure drop between two cases. For Case A, the observed pressure drop is 75.045mbar; for Case B, the observed pressure drop is 65.538mbar. The calculated pressure drop is within target criteria. Hence, it will not affect engine performance.

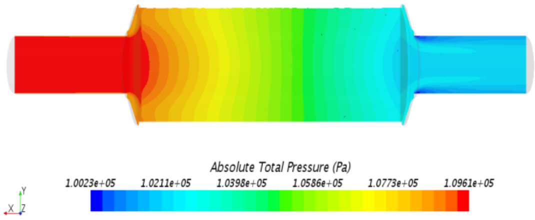

Figure 9 Absolute pressure drop

3. Uniformity Index

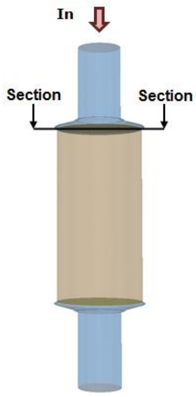

Figure10 CFD Uniformity plane Section at Inlet of Alumina Chamber

Below, Figures 11show the uniformity plot of Activated Alumina chamber, respectively. The reactor chambers' uniformity is 0.889, however, the target is > 0.90 for initial confirmation of the analysis. To reach the uniformity target, inlet and outlet cone optimization is done

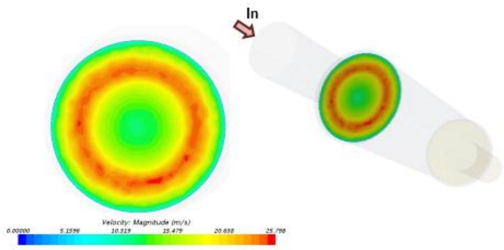

Figure 11 uniformity plot of Alumina Reactor front face

VI. Prototype Fabrication

Initially a 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 during the time of testing

The material used for reactor chamber is Stainless Steel and the chamber is made by values obtained from the calculations done on the above

Table 4 Activated Alumina Chamber details

Shell Dimension	D 100 ×L 300 mm
Shell Volume	2355 cm^3
Cross Sectional Area	78.5 cm^2
Wire Mesh Weight	162 gm
Wire Diameter	0.8 mm
Material used	Activated Alumina spheres
Alumina spheres Size	6-8mm
Alumina Quantity	2kg

Figure 12 Reactor chamber

Figure 13 Wire mesh filled with Catalyst

Figure 14 Catalyst Immersed in Chamber

VII. Experimental Procedure

The procedure of conducting experiment to reduce CO_2 by capturing method is done on the Diesel operated vehicle. Volkswagen Jetta TDI 2.0l with automatic transmission is used. The emission levels are taken by the Gas analyzer in terms of percentage by volume for CO_2 releasing from the exhaust of the vehicles.

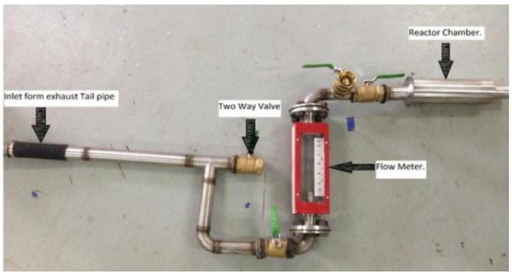

Figure 15 Assembly of Layout with CO_2 reactor

The experiment is carried out by the procedure that is shown in the below steps

- Connect the experiment layout to exhaust tailpipe
- Check the layout that there should be no leakage of flow through pipe
- Now the Engine is started and kept in idle condition
- The engine rpm will have 800rpm
- The flow meter shows the mass flow rate. Now take the reading of mass flow rate
- After 15 minutes the readings to be taken with the help of gas analyzer
- The sample readings to be taken before and after the CO_2 chamber

- Now raise the rpm about 1600 and wait for 2 minutes
- After this the readings are noted as fallowed by the above steps
- The engine rpm is now raised again by 2400 and kept at 2 minutes
- As like the same procedure the readings are taken

Finally the amount of CO_2 available in the exhaust gas can be adsorbed by the catalyst.

VIII. Results

The results of CO_2 capturing before and after the CO_2 reactor chamber containing Activated alumina is taken by varying the engine speed.
Below tables shows the results of Reactor chamber by using Diesel operated vehicle
Tabulation 5, 6, 7 shows the emission results by varying speed
Tabulation 8 shows the results of average value of CO_2 emissions.

Tabulation 5 Emission Test 1

S.No	Condition	RPM	HC	CO	CO_2	O_2	NO_X	LAM
1	Ideal (15min)	800	21	0.02	2.57	17.45	145	6.326
2	Aft (5min)	800	22	0.02	2.20	17.53	145	6.424
3	Aft (2min)	800	22	0.01	2.19	17.55	143	6.505
4	Aft (2min)	800	22	0.01	2.20	17.55	143	6.461
5	Final(Without Reactor)	800	26	0.02	2.25	17.54	152	6.401

Tabulation 6 Emission Test 2

S.No	Condition	RPM	HC	CO	CO_2	O_2	NO_X	LAM
1	Ideal (15min)	1800	29	0.05	4.0	14.7	45	3.519
2	Aft (5min)	1800	27	0.04	3.7	15.0	45	3.707
3	Aft (2min)	1800	26	0.04	3.5	15.0	45	3.601
4	Aft (2min)	1800	26	0.03	3.5	14.9	46	3.613
5	Final	1800	30	0.04	4.0	14.98	47	3.615

Tabulation 7 Emission Test 3

S.No	Condition	RPM	HC	CO	CO_2	O_2	NO_X	LAM
1	Ideal (15min)	2400	28	0.02	3.7	14.7	70	3.615
2	Aft (5min)	2400	25	0.01	3.5	14.9	75	3.84
3	Aft (2min)	2400	26	0.01	3.5	15.0	75	3.83
4	Aft (2min)	2400	25	0.01	3.4	15.0	76	3.81
5	Final	2400	28	0.02	3.7	14.98	78	4.00

Tabulation 8 CO2 Test results

S.No	Condition	RPM	CO_2	Difference	Percentage
1	After	800	2.56	0.37	14.4
	Before		2.196		
2	After	1800	4.0	0.5	12.5
	Before		3.56		
3	After	2400	3.7	0.3	8.1
	Before		3.46		

Therefore overall reduction of CO2 gas from the Volkswagen Jetta TDI engine is 11.6 %

IX. Conclusion

The results of CO_2 reduction Emission from diesel operated vehicle using Activated Alumina is summarized.Reduction of CO_2 from the Diesel engine is done by the adsorption technique. By varying the engine speed before and after the Reactor chamber the Sample readings are taken. The emissions like HC, CO and NOx is also reduced along with CO_2. The final conclusion of this paper is the emission of Carbon dioxide from the vehicle is reduced by maximum of 11.6 %. As our design of CO_2 chamber we have added 2 kilograms of Activated Alumina balls and make the gases pass into the reactor chamber containing Activated Alumina balls. By passing the gases the emissions are controlled along with CO_2. Due to this we came to know that there will be no effect on reaction of other gases while adsorption as well as in the environment. Finally the CO_2Emissions from the Diesel operated vehicle is controlled.

Acknowledgement

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