Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2011
(ICMERE2011) 22- 24 December 2011, Chittagong, Bangladesh

ICMERE2011-PI-041

Improved Automobile Emission Purification System by Designing Modified Catalytic Converter

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Abstract: *For increasing of vehicles, air is polluted by different harmful gases such as carbon mono-oxide, nitrogen-oxide and unburned hydro –carbon fuels. Catalytic converter systems decrease air pollution from harmful tailpipe emissions .The objective of the paper is to illustrate the process of converting harmful gases into harmless gases by a catalytic converter with all time working .The paper highlights the modification of catalytic converter for working at the beginning when temperature is very low. In this process initial temperature is proved by electric energy which is essential for proper working at beginning. More over temperature is kept at optimum level by insulating .In experiment a coiling and coating type catalytic converter is done. Experiment is carried out to analyze the performance characteristics and behavior of the three-way coiling and coating catalytic converters (TWCCC) especially its efficiency in reducing the amount of pollutants.*

Keywords: Catalytic Converter, Exhaust Emission, Conversion Efficiency, Coiling and Coating, Electric Energy.

1. INTRODUCTION

Atmospheric air is considered to be a mixture of gases like nitrogen, oxygen, hydrogen, argon, neon, krypton, helium, ozone and xenon. There is a perfect balance of these gases which is essential for human beings as well as the living things. Pollution causes imbalance by increasing carbon monoxide, carbon dioxide, nitrogen oxides and sulfur dioxide. Most of these gases are harmful for human beings. There are many methods of purification. At present, the purification of exhaust gases is done by catalytic conversion where catalyst is used to convert the harmful gases into less harmful gases .The catalytic conversion system is a critical system of the emission control on most I.C engine. The catalytic converter has been in use for the past 30 years as an efficient and economic solution for the reduction of pollutants emitted by the internal combustion engine, the latter being the power train for most all vehicles in use today. The catalytic converter is widely used as an emissions control unit in automobiles and some industries. It uses one or more catalysts such platinum, palladium and rhodium to burn off many impurities in exhaust fumes [1]. To work effectively, the converter needs to reach a temperature of 300^0 C or more.

In this process, initial temperature (T) is proved by electric energy which is essential for proper working at beginning. More over temperature is kept at optimum level by insulating. At the normal period, the coating with copper wire and coating of binder increase the temperature, so better purification system is obtained. So, all of these make it improved emission purification system at early starting and normal ending time [2, 6].

2. AUTOMOBILE EMISSION

The main emission from an engine is:

Nitrogen gas: Air is about 78% nitrogen gas and most of this passes right through the car engine.

Carbon dioxide: This is one product of combustion. The carbon in the fuel bonds with the oxygen in the air. In recent years, the U.S Environmental Protection Agency (EAP) has started to view carbon dioxide product of perfect combustion as a pollution concern. Carbon dioxide does not directly impair human health. But it is a "green house gas" that traps the earth's heat and contributes to the potential for global warming.

Hydrocarbons: Hydrocarbon emission results when fuel molecules in the engine do not burn or burn only partially. Hydrocarbon reacts in the presence of nitrogen oxides and sunlight to form ground level ozone, a major component of smog ozone, irritates the eyes, danger the lungs and aggravates respiratory problems. It is our most widespread and intractable urban air pollution problem. A number of exhaust hydrocarbons are also toxic with the potential to cause cancer.

Water vapor: This is another product of combustion. The hydrogen in the fuel bonds with the oxygen in the air.

These emission are mostly benign (although carbon dioxide emissions are believed to contribute to global warming), however because the combustion process is never perfect, some smaller amount of more harmful emissions are also produced in car engines.

Carbon monoxide: A poisonous gas that is colorless and odorless. it is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide (CO_2), carbon monoxide (CO) reduces the flow oxygen in the bloodstream and is particularly dangerous to persons with heart disease.

Hydrocarbons or volatile organic compounds (VOC'S): Produced mostly from unburned fuel that evaporates. Sunlight breaks these down to form oxidants, which react with oxides of nitrogen to cause ground level ozone, a major component of pollution.

Oxides of nitrogen: Contributes to smog and acid rain, and also causes irritation to human mucus membranes. These are the three main regulated emission, and also the ones that catalytic converters are designed to reduce. Under the high pressure and temperature conditions in an engine nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as NO_X [1, 5].

3. PURIFICATION SYSTEM OF CATALYTIC CONVERTER

A three way catalytic converter system has three simultaneous tasks where the used catalyst is Platinum or Palladium and Rhodium, Platinum or Palladium for oxidations and Rhodium for reduction reaction.

(1) Reduction of nitrogen oxides to nitrogen and oxygen

$$2NO_x \longrightarrow xO_2 + N_2$$

(2) Oxidation of carbon monoxide to carbon dioxide.

$$2CO + O_2 \longrightarrow 2CO_2$$

(3) Oxidation of unburned hydrogen (unburned and partially-burnt fuel) to carbon dioxide and water.

$$2C_x H_Y + (2x + \frac{y}{2})\, O_2 \longrightarrow 2x\, CO_2 + y\, H_2O$$

These three reactions occur most efficiently when the catalytic conversion receives exhaust from an engine running at the stoichiometric point [1, 3].

4. IMPROVED PURIFICATION SYSTEM

4.1 Modification Of Catalytic Converter At Starting And Ending Period

At the starting and ending period the converter needs to reach a temperature of 300^0 C or more. In this process initial temperature is proved by electric energy which is essential for proper working at beginning. Here D-Series Diesel Oxidation Catalyst model are taken as a references which includes Zeolite-based hydrocarbon traps for excellent low temperature activity.

Table1: D-Series Diesel Oxidation Catalyst [4]

Model	DL42	DL62	DL102	DL152	DH222	DH312
A.mm	267	280	325	356	406	498
Inches	10.5	11.0	12.8	14.0	16.0	19.6
B.mm		290	335	335	382	432
Inches		11.4	13.2	13.2	15.0	17.0
C.mm		142	168	185	220	220
Inches		5.6	6.6	7.25	8.7	8.7
D.mm	86	102	127	152	203	203
Inches	3.4	4.0	5.0	6.0	8.0	8.0
E(ID)	As per Customer specifications					

4.2 Modification Of Catalytic Converter At Normal Period

At the normal period, the coating with copper wire and coating of binder increase the temperature, so better purification system .The MINE-X^{R}SV Catalytic Purifier Dimensions may be taken as standard for normal period.

5. APPARTUS SELECTION

5.1 Catalyst Selection

Table 2: Common Catalysts Used

Reaction	Catalysts	Oxidation/ Reduction number
Oxidation	Ag, Au, Pd, Pt	1.4
	Al, Rh, Be	1.5
	Cr, Mn, Fe	1.6
Reduction	Zn, Si	1.7
	Ni, Cu	1.8

Lower oxidation number better oxidation purification such as Pd, Pt .Higher reduction number better reduction purification such as Ni, Cu.

5.2 Binder Selection For Coating

Plaster of Paris is used for the coating. This binder is used to hold powder material to metal surface.

5.3 Catalytic Converter Body Selection

The catalytic converter consists of i) Stainless steel (S.S), ii) Connecting pipe, iii) Oxidation chamber, iv) Reduction chamber and other accessories.

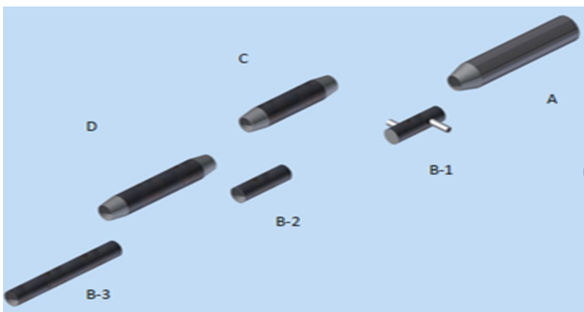

Fig1: Dissemble of the catalytic converter body

5. CONSTRUCTION

Table3: Summary of Components and Chemicals

Structure parts	Quantity	Materials and chemicals
Combine chamber	1	Stainless steel (Cr, Ni)
Oxidization chamber	1	Cast iron
Reduction chamber	1	Cast iron
Connecting pipe	3	Cast iron
Oxidizing catalysts	2	Copper oxide, copper wire

6. EXPERIMENTAL SET UP

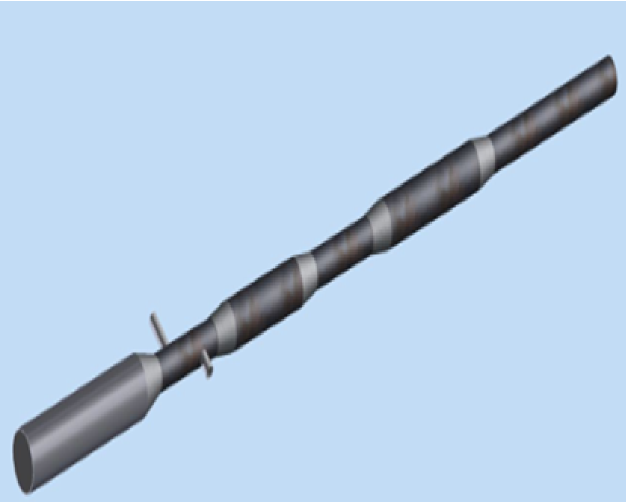

Fig 2: Assembly view of catalytic converter

For effective performance of the converter three chambers (combine, oxidation and reduction) are connected with three connecting pipes.

7. WORKING PROCEDURE

- Selecting the pipes with required dimension.
- Cutting the pipes with required length.
- To construct the complete structure the pipes are connecting by threading .It is mainly done for increasing the flexibility.
- To make a layer of binder powder inside the pipes.
- For producing the oxidization chamber, oxidization catalysts (Aluminum) are mixed with binder powder.
- To increase the contact area small piece of aluminum pipes (diameter) are used.
- For producing the reduction chamber, reduction catalysts **(Cu_2O)** are mixed with binder powder.
- To increase the contact area copper wire are used.
- First we placed the oxidization chamber then placed reduction chamber.
- Between these two chambers a connecting pipe with small diameter is used.
- A connecting pipe is also placed to connecting combine chamber and oxidization chamber with the exit manifold, through which exhaust gases from flow through both oxidization chamber & reduction chamber. So desired chemical reaction take place.
- For sufficient oxygen circulation, two pipes of diameter (1.27cm) is join with 1st connecting rod by welding
- For reducing the heat transfer provide a insulation outside the converter.

Fig 3: Constructed Catalytic Converter

8. PERFORMANCE TEST

Table 4: Data sheet for Diesel Engine with ORSAT exhaust gas analyzer

Obs. No.	Speed, N (r. p. m)	Inlet Temp. Of the system (° C)	Outlet Temp of the system (° C)	Before Conversion			After Conversion		
				% of CO_2	% of O_2	% of CO	% of CO_2	% of O_2	% of CO
1	1658	130	138	8.8	2.0	0.9	14.80	2.8	0.26
2	1735	145	151	8.7	1.9	1.4	13.00	2.3	0.72
3	1803	152	161	8.9	1.85	1.2	13.45	2.3	0.56
4	1910	165	174	8.9	2.0	1.0	14.85	2.9	0.28
5	2013	183	195	8.7	1.6	1.1	14.70	2.5	0.38
6	2177	197	208	8.9	2.0	1.4	15.75	2.9	0.58
7	2188	205	231	9.0	2.1	0.42	16.35	3.2	0.02
8	2231	207	239	9.4	1.9	0.85	17.00	2.8	0.05

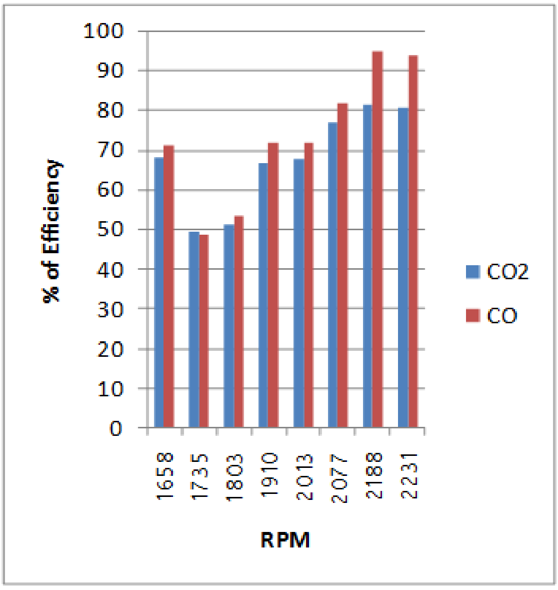

Fig4: Comparison of conversion efficiency

Results for the elimination of both oxidation and reduction reactions are often at temperature between 350-400^{0}C. But, in presence of limitations, it is not possible to require the inlet temperature between 350-400^{0}C. During the performance test, it is found from diesel engine the temperature range is 130-210^{0}C.

Due to the any poisons (S,P,As,Zn,Pb,H_2S,Fe_2O_3,etc) may reduce the reduction capacity of copper, and poisons (As,C_2H_2,CO,H_2O,etc) may reduce the oxidation capacity of aluminum.

Contact area is the most important factor of performance, with increasing the contact area efficiency also increase.

Temperature is the key of the conversion, so a better insulation may reduce the heat loss rate and improve the efficiency.

If any catalysts having oxidation number 1.4 (Pt, Pd, Ag, Au) may provide the better oxidation.

In the result, it is observed that after conversion % of CO are respectively 0.26, 0.28, 0.02 & 0.05 at the inlet temperature respectively 130, 165, 205, & 207^{o}C, which below world standard rating for automobile-2010 (0.45%).

10. CONCLUSION

The different types of converter have been extensively studied. An economical catalytic converter has constructed. In this model, local and available catalysts and structure materials have used. This model provides satisfactory efficiency, but there is a scope of further development of performance of this model with using better catalysts and structure materials.

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12. NOMENCLATURE

Symbol	Meaning	Unit
T	Temperature	(K)
RPM(N)	Revolution Per Minutes	m/s