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RESEARCH ARTICLE OPEN ACCESS

Reduction of Emission through Triple-Bed 3-way Catalytic Converter

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ABSTRACT
Catalytic converter is an automotive emission control device which converts the harmfull pollutants into less toxious compounds. In general , in 3-way catalytic converter the reduction and oxidation both does not occur simultaneously with their highest efficiency. In lean condition the oxygen is available but reduction of NOx occur inoxygen free environment. In rich condition the oxygen is less but for oxidation of CO and HC, itrequire the sufficient amount of oxygen. To overcome this difficulty of three way catalytic converter we innovate the **Triple-Bed 3-way Design of catcon**in which three separate chambers in a common housing which give both reduction and oxidation reactions simultaneously at a efficient level.
Keywords – catcon, triple-bed, emission.

I. Introduction

There are mainly 3 basic types of emission produced from petrol engine.

- Carbon Monoxide (CO)
- Hydrocarbon (HC)
- Oxides of Nitrogen (NOx)

Carbon Monoxide (CO)

- Extremely toxic emission resulting from the release of partially Burned fuel.
- A rich air-fuel would increase CO ; lean air-fuel mixture would lower CO emissions.
- CO prevents human blood cells from carrying oxygen to body tissue.

Hydrocarbons (HC)

- Resulting from the release of unburned fuel into the atmosphere.
- Produced by incomplete combustion of charge. Mostly related to ignition problems.
- Effect could be eye, throat, and lung irritation, and possibly cancer.

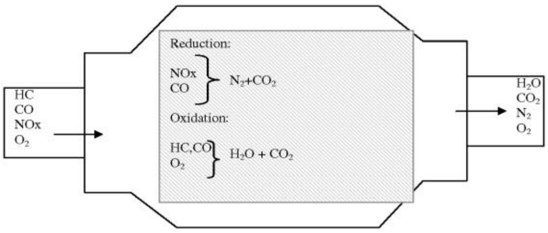
Oxides of Nitrogen (NOx)

- Produced by extremely high temperatures during combustion.
- An engine with high compression ratio, lean air-fuel mixture will produce high combustion heat, resulting formation of NOx.
- With enough heat (above 1400ºC), nitrogen and oxygenin air-fuel mixture combines to form NOx emissions.

3-Way Catalytic Converter

In generally, 3-way catalytic converter more efficient than other type of catcon such as pellets type and monolithic 2-way which are only efficient for oxidation.

The 3-way catalytic converter contain oxidation(Pt/Pd) and reduction(Rh) catalyst which treats emission efficiently. **Oxidation will only occurwhen there is enough free O_2, reduction will only occur in a relative absence of free O_2. T**he drawback of this converter is both reactionscan not occur athighest efficiency at the same time.



Triple-Bed Catalytic Converter

- In this catalytic converter, first part of converter is a 3-way catalyst chamber in which ceria acts as a buffer.The second part of converter is consist of two way, one is for reduction and another for oxidation.

Reactions in 3-way chamber

$CO + O_2 \rightarrow CO_2$

$HC + O_2 \rightarrow CO_2 + H_2O$

$NOx + CO \rightarrow N_2 + CO_2$

In oxidation chamber

$CO + O_2 \rightarrow CO_2$

$HC + O_2 \rightarrow CO_2 + H_2O$

In reduction chamber

$NO + CO \rightarrow N_2 + CO_2$

$NO_2 + CO \rightarrow N_2 + CO_2$

- Before the two chambers a valve is provided in order to control the flow of exhaust gases in lean and rich condition through the reduction and oxidation chambers respectively.

- First oxidation and reduction takes placein 3-way chamber.
- When condition of charge is lean, reductionof NOx will occur in reduction chamber.
- When condition of charge is rich, oxidation of CO and HC will occur in oxidation chamber.

Oxidation and reduction will occur simultaneously in an efficient manner, so that pollutants are eliminate almost completely.

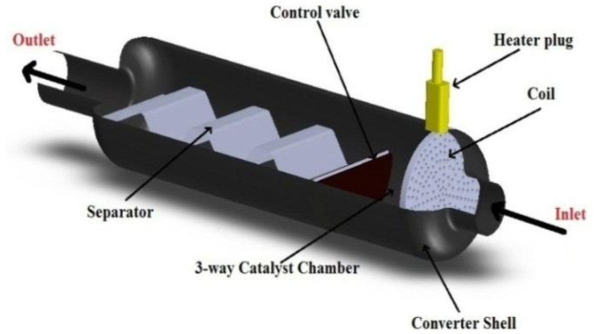
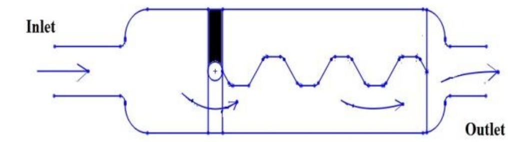
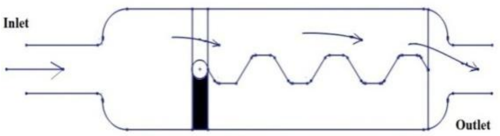


Fig. model of triple bed converter in solid works



Gases passing from reduction chamber



Gases passing from oxidation chamber

II. Design Calculation

Shape of catalytic converter

The cylindrical shape should consider due to ease of fabrication and good rigidity.

Volume Flow Rate = Swept Volume* NO. of intake stroke per hour

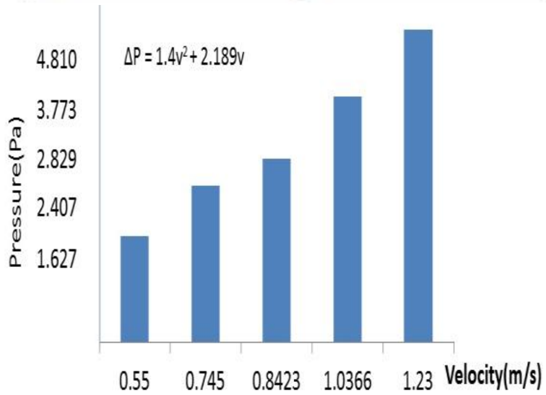
= (∏/4)*d^2 *L*(RPM/2)*60

= (∏/4)*$(0.07925)^2$*(0.06187)*(3800/2)*60

= 34.77m^3 /hr.

Volume flow rate of exhaust = Area of convertor shell * velocity of exhaust gases

Velocity (m/s)	Pressure (Pa)
0.55	1.62
0.745	2.40
0.842	2.82
1.036	3.77
1.23	4.81



Flow through Catalytic Convertor In ANSYS CFX

We tried to study flow of various gases through porous media or ceramic monolith substrate in CFX to design our catalytic convertor. Exhaust gases flows in through the inlet with a uniform velocity of 20 m/s having temperature 673.15 K, passes through a ceramic monolith substrate with square shaped channels, and then exits through Ceramic Monolith Substrate the outlet. The substrate is impermeable in the X and Y direction, which is modeled by specifying loss coefficients 2 orders of magnitude higher than in the Z direction.

The catalytic convertor geometry was prepared in ANSYS Design Modelor as shown below.

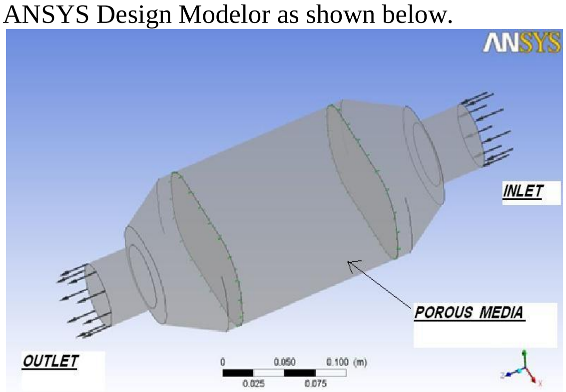


Figure: - CATCON showing various regions and direction of flow of gases

Finer meshing of the CATCON was done to calculate exact results.

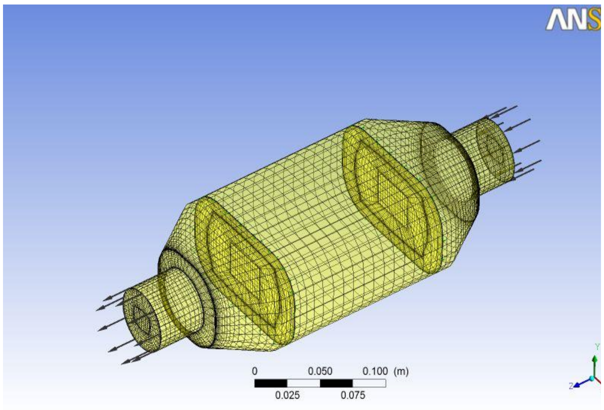
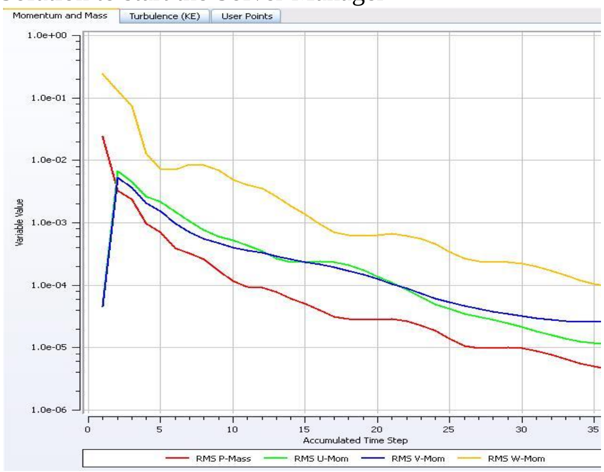


Figure: - Mesh of CATCON

Various parameters were selected and applied according to the requirement such as

- MATERIAL – CO2 IDEAL GAS (CALORICALLY PERFECT GAS)
- CELL ZONE CONDITIONS WERE EDITTED
- BOUNDARY CONDITIONS
- heat transfer set to isothermal during the flow
- Fluid Temperature to 450 [C]
- Turbulence to k-epsilon
- Streamwise Loss to Linear and Quadratic Resistance Coefficients
- CFX automatically creates a Fluid-Porous interface between the Default Domain and Substrate.

Solution to start the Solver Manager



Results in CFD-Post were checked and analyzed for co2 gas flow through the porous media to justify the maximum back pressure generated in the exhaust flow and pressure drop through the substrate was also analyzed AS shown in figures below.

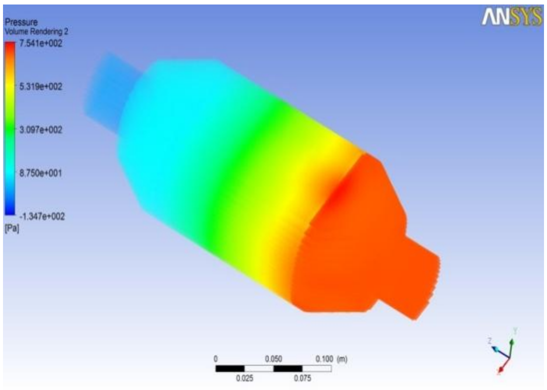


Figure: - pressure contours

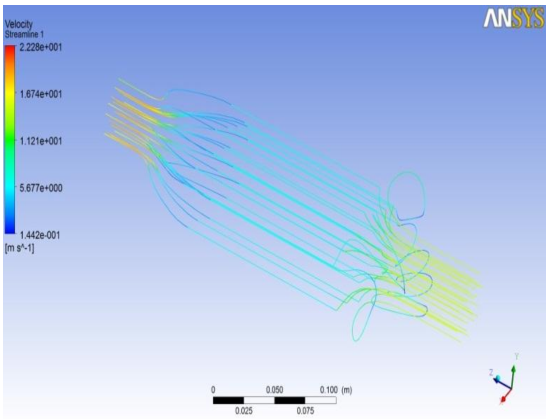


Figure: - velocity streamlines of gas

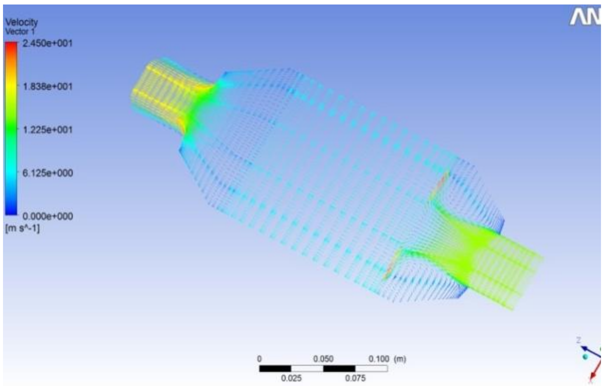


Figure: - velocity vectors of gas flow

III. Catalysts

In 3-way chamber - Pt/Pd and Rh
In oxidation chamber - Pt and Pd

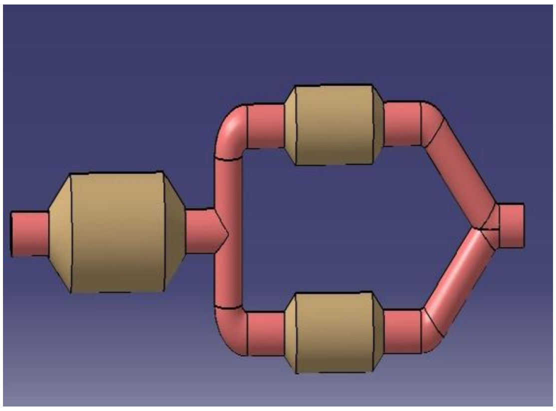


Fig. CAD model of triple bed catalytic converter

In reduction chamber - Pt and Rh
Palladium has higher specific activity than Pt for oxidation of CO.

- Pt is more active than Pd for the oxidation of paraffin hydrocarbon.
- The valve will control mechanically through accelerator pedal, but for proficient reduction the valve will control together with closed loop controlled system.

IV. Advantages

- Life of catcon enhanced because thermal loading in chamber decline.
- Concurrently both reactions occur at all proportion of charge so that maximum level of efficiency achieved.