ISSN : 2455-9679
Impact Factor : 6.008

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"A REVIEW ON CATALYTIC CONVERTERS THROUGH GEOMETRY CHANGES"

***Md Naim* [1], *Yogesh Kumar Tembhurne* [2]**

[1] *Research Scholar, Bhabha Engineering & Research Institute, Bhabha University, Bhopal, MP, India*

[2] *Professor, Bhabha Engineering & Research Institute, Bhabha University, Bhopal, MP, India*

ABSTRACT

Vehicle population is expected to rise nearly to 1600 million via the year 2036. Because of partial ignition in the engine, there are many inadequate burned products as Carbon monoxide, Nitrous oxides, hydro carbons, harsh substances, etc. The particular toxins have an impact on air properties, atmosphere and human physical conditions that leads in severe norms of pollutant emission. In the present time, the automobiles running on the roads have drastically increased in number due to the advancement in the sector with low cost to offer to the people. Though this has made the life sophisticated as well as has made our life easier in terms of travelling and transportation, this has dragged us towards a major issue regarding the pollution it causes to the atmosphere. The compression ignition engine that are used in the vehicles produces a large amount of obnoxious gases like NOX, HC, CO, etc. The existing catalytic converter that is used in order to convert this harmful gases are not meeting the demands of euro 6 emission standards as well as they are inadequate to work in very high temperature.

***Keyword**: Catalyst, CFD modeling, NOX, HC, CO*

I. INTRODUCTION

The internal combustion engine, either rotary or piston cylinder, is the primary power plant of today's world. Although it is used in both an on- and off-road capacity, automobiles are typically their primary customer. Because of their versatility, flexibility and low initial cost, automobiles dominate the market for passenger and transport freight. Furthermore, economic growth in developing countries like India, China, Brazil, and Chile has triggered an increase in the number of automobiles on the road. The combustion of carbonaceous fuel in these engines leads to the formation of various byproducts, released in air as exhaust gases. Since combustion occurs at a high temperature and pressure in fractions of a second, dissociation and incomplete combustion lead to partial and complete products of combustion. Exhaust species like carbon monoxide (CO), carbon dioxide (CO2), particulate matter (PM), water (H2O), oxides of nitrogen (NOx), oxides of sulfur (SOx) and hydrocarbons (HC) resulting from combustion pollutes the air and has drastic effects on human life and nature. When these pollutants are near the earth surface, they cause various health issues like asthma, respiratory problems, and irritation to the eyes and damage to the lungs. Away from the surface, they are directly responsible for acid rain and global warming. For example, Figure 1 and Figure 2 illustrate how the increasing number of automobiles around the globe has increased the total carbon dioxide footprint in the atmosphere. As a result, before irreparable damage is done to nature and mother earth, pollution must be controlled. Most of the cities have a large number of automobiles; as a consequence they suffer from problems of air pollution. People of all ages can be affected from air pollution and particularly from sources, such as vehicle exhausts and residential heating,

ISSN : 2455-9679
Impact Factor : 6.008

but mainly those with existing heart and respiratory problems are in an extra risk. Considering all the above, it can be concluded that transport has a great impact on the atmospheric environment and therefore it is necessary to reduce emissions from the road traffic.

CATALYTIC CONVERTOR

A catalytic converter is an air pollution abatement device that removes pollutants from motor vehicle exhaust, either by oxidizing them into carbon dioxide and water or reducing them into nitrogen and oxygen. The catalytic converter device uses a catalyst to convert three harmful compounds in the car exhaust into harmless compounds. The three compounds are:

- Hydrocarbons (HC)
- Carbon monoxide (CO)
- Nitrogen oxides (NOX)

In a catalytic converter, the catalyst (in the form of platinum and palladium) is coated onto a ceramic honeycomb or ceramic beads that are housed in a muffler-like package attached to the exhaust pipe. The catalyst helps to convert carbon monoxide into carbon dioxide. It converts the hydrocarbons into carbon dioxide and water. It also converts the nitrogen oxides back into nitrogen and oxygen

CONSTRUCTION

The catalytic converter's construction is as follows:

- Substrate: For automotive catalytic converters, the core is usually a ceramic monolith that has a honeycomb structure (commonly square, not hexagonal). The substrate is structured to produce a large surface area.
- Wash coat: A wash coat is a carrier for the catalytic materials and is used to disperse the materials over a large surface area. Aluminum oxide, titanium dioxide, silicon dioxide, or a mixture of silica and alumina can be used. The catalytic materials are suspended in the wash coat prior to applying to the core. Wash coat materials are selected to form a rough, irregular surface, which greatly increases the surface area compared to the smooth surface of the bare substrate. This in turn maximizes the catalytically active surface available to react with the engine exhaust. The coat must retain its surface area and prevent sintering of the catalytic metal particles even at high temperatures (1000 °C) [12]
- Ceria or ceria-zirconia: These oxides are mainly added as oxygen storage promoters.

Catalyst: Platinum is the most active catalyst and is widely used, but is not suitable for all applications because of unwanted additional reactions and high cost. Palladium and rhodium are two other precious metals used. Rhodium is used as a reduction catalyst, palladium is used as an oxidation catalyst, and platinum is used both for reduction and oxidation. Cerium, iron, manganese, and nickel are also used, although each has limitations. Nickel is not legal for use in the European Union because of its reaction with carbon monoxide into toxic nickel tetra carbonyl. Copper can be used everywhere except Japan [17].

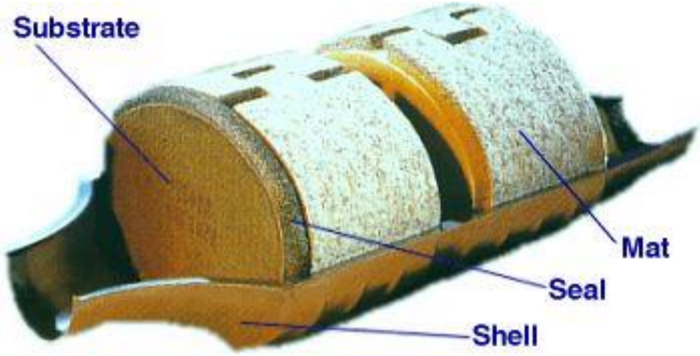

Figure 1 Construction of a catalytic converter

ISSN : 2455-9679
Impact Factor : 6.008

II. LITERATURE SURVEY

Yugal Kishore et.al. (2017) carried out a 3D CFD analysis on three way monolithic converter on the basis of itvarious conclusions have been drawn. The rates of conversion of NO, CO, C3H6 are the function of temperature. On increasing temperature the rate of surface reaction with the catalyst first increases and then become stable.[1]

S.P. Venkatesan et.al (2017) has study on emission control of catalytic convertor by using copper oxide. The main aim of this work is tofabricate system, where the level of intensity of toxic gases is controlled through chemical reaction to more agreeable level. This system acts itself as an exhaust system; hence there is no needs to fit separate the silencer. The whole assembly is fitted in the exhaust pipe from engine. In this work, catalytic converter with copper oxide as a catalyst, by replacing noble catalysts such as platinum, palladium and rhodium is fabricated and fitted in the engine exhaust. [2]

Vladimir Lozhkinet.al (2017) The purpose of investigation was the development of mathematic model of catalysis process inthe mode of heat rejection (discharge) of phase change storage device and substantiation of high efficiency of cleaning from harmful substances and possibility of device arrangement in the engine compartment of a bus instead of noise suppressor using calculation method proceeding from experimental data of converter operation in the city cycle. [3]

A.K. Sharma et.al (2016) A catalytic monolith converter usually comprises several hundred or thousands of channels. Mathematical modeling that seeks to resolve the coupled transport phenomena mass, momentum, species and heat on a discrete-channel scale is a computationally challenging task. The computational penalty for reduced model is much less as compared to the full model, making it a possible candidate for detailed monolith simulations.[4]

Young-Deuk Kim et.al (2009) in this case, the active metal distribution along the length of the converter may influence its performance. The optimal design of a longitudinal noble metal distribution of a fixed amount of catalyst is investigated to obtain the best performance of a dual monolithic catalytic converter. The optimal design for the optimal axial distribution of the catalyst was determined by solving multi-objective optimization problems to minimize both the CO cumulative emissions during the FTP-75 cycle, and the difference between the integral valueof a catalyst distribution function over the monolith volume and total catalytic surface area over the total monolith volume. [5]

Thundil Karuppa Raj.Ret.al (2008) analyzed that the design of catalytic converter has become critical which requires a thorough understanding of fluid flow inside the catalytic converter. In this paper, an attempt has been made to study the effect of fluid flow due to geometry changes using commercial CFD tool. The study has been conducted assuming the fluid to be air. The numerical results were used determine the optimum geometry required to have a uniform velocity profile at the inlet to the substrate.[6]

Mingchenet.al, (2008) Analyzed that a modeling approaches to the design optimization of catalytic converters is presented. The first step of the optimization is the model assisted sizing of catalysts. The second step deals with the flow optimization of the catalyst converter under the given geometric restraints. The substrate is modeled as porous media, where viscous and in it all resistances are specified via empirical formula. With the help of the CFD tool, the flow in the converter can be optimized using appropriate boundary layer control methods.[7]

Chenet.al (2004) utilized a 3D CFD flow modeling and a heterogeneous reaction model of the catalytic converter. They calculated the pressure and the velocity field with incorporating the flow resistance within the monolith substrate. They concluded that the flow field is influenced by the monolith substrate resistance for a specific geometry and Reynolds number. Moreover, the flow uniformity at the front face increased with increasing cell density of the monolith and decreased when increasing the flow Reynolds number.[11]

Chakravarthyet.al (2003) Utilizing multi-dimensional channel model. It was recorded that the ignition behavior can be dramatically affected by flow recirculation at the inlet of the substrate which lead to high flow misdistribution especially at lower exhaust temperatures. The study concluded that flow non-uniformity effects were more significant with increasing flow temperature. In addition, the pressure drop distribution remained constant and was dependent on the recirculation pattern at the front face of the monolith.[8]

ISSN : 2455-9679
Impact Factor : 6.008

Tsinoglouet.al (2003) studied the transient behavior of a 2D model using flow resistant model (FRM). They discussed about the effect of the inlet cone on flow patterns in the converter and transient heat transfer inside the converter without any reaction.[17]

Ekstrom and Andersson(2002) Experimentally investigated the pressure drop across the monolith brick of the catalytic converter. They investigated different types of bricks with different cell density, coating and wall thickness. They did not include combustion in their experimental work and used cold and hot air flow instead. They developed an empirical model that could predict the pressure drop with good agreement with experimental data and previous models and can be used for 1-D and 3-D CFD simulations. They found that the main sources of pressure drop are viscous and inertial effects.[9]

Liuet.al 2001 performed an experimental and a numerical study on the reverse flow catalytic converter for a natural gas/diesel dual engine. The simulation involved a 1-dimensional single channel model to monolith substrate. They concluded that the conversion efficiency of CO and HC was improved for the reverse flow catalytic converter for low inlet temperature and light engine load only when the catalytic converter initial temperature is high enough given that the converter initial temperatures was varied from 694 K to 919 K.[12]

Benjaminet.al (2001) simulated the flow distribution within the catalytic converter. They considered the entrance effects on the flow to accurately calculate the pressure drops. They concluded that treating the flow within a single channel as one-dimensional laminar flow under predicts the effect of flow misdistribution. Moreover, incorporation of pressure-drop improved the peak velocity predictions at the middle of the monolith of the catalytic converter.[13]

Shamimet.al (2002) developed a numerical simulation to predict the performance of the three- way catalytic converter. The model incorporates heat conservation and chemical reaction sub model with oxygen storage mechanism and it showed that the conversion efficiency was improved when operating under rich oxygen content. [14]

Taylor (1999) presented a CFD-based model to study on the effects of heat and mass transfer in the monolith, heat generation and heat loss, and reactions occurring in the monolith. The effect of these parameters on the performance of the converter has been discussed.[15]

Karvounis andAssasins, (1993)developed a finite element code to solve the flow field through the inlet diffuser, the ceramic brick and the nozzle sections of the catalytic converter for different flow rates and channels hydraulic diameters and investigated the effect of non-uniform inlet flowdistribution on the conversion efficiency of the catalytic converter. They predicted the reactant concentration across the honeycomb's outlet based on the velocity distribution at the inlet. However, the lower the hydraulic diameter of the channels, the higher the conversion efficiency and the pressure drop which can be decreased by shortening the catalytic converter monolith.[10]

Bellaet.al (1991) investigated the effect of flow uniformity on the conversion efficiency in their 3D model discussed earlier. When the flow was non-uniform, it became concentrated in the central region of the honeycomb which resulted in non-uniformity of the chemical reaction in the catalytic converter that caused noble metal depletion and lower conversion efficiencies.[16]

Zygourakis (1989) discussed the effect of flow distribution profiles on the light off behavior of a catalytic converter. He used a transient 2D model with heterogeneous approach for monolith brick and applied Voltz et al (1973) model for CO combustion. The effect of different patterns for gas flow (parabolic, uniform and pinwheel) on light-off and ambient heat transfer waspresented. [18]

Liu and Hayes (2006) presented a 3D model using both pseudo-homogeneous and heterogeneous model for monolith brick in FLUENT context. Methane ignition and CO combustion in a reverse flow catalytic reactor and the comparison between homogeneous and heterogeneous models for monolithic section has been studied. [19]

Bezzoet.al (2005) has used CFD codes to implement reaction, momentum, and mass and heat balance in the converter. Due to being computationally expensive, full use of CFD codes in converter modeling. [20]

III. PROBLEM FINDING OF REVIEW

The above-mentioned researchers had studied various aspects of catalytic converter and various methods to implement in catalytic converter to reduce emission rate in various catalytic converter. In some research works, the study was focused on to reduce emissions in catalytic converter. However, there was no work found which considered cumulative an attempt a work inthe field of geometry changes in catalytic converter in terms of emission reduction.

IV. COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics (CFD) is a computer-based simulation method for analyzing fluid flow, heat transfer, and related phenomena such as chemical reactions. This project uses CFD for analysis of flow and heat transfer. Some examples of application areas are: aerodynamic lift and drag. (i.e. airplanes or windmill wings), power plant combustion, chemical processes, heating/ventilation, and even biomedical engineering (simulating blood flow through arteries and veins). CFD analyses carried out in the various industries are used in R&D and manufacture of aircraft, combustion engines, as well as many other industrial products. It can be advantageous to use CFD over traditional experimental-based analyses, since experiments have a cost directly proportional to the number of configurations desired for testing, unlike with CFD, where large amounts of results can be produced at practically no added expense. In this way, parametric studies to optimize equipment are very inexpensive with CFD when compared to experiments.

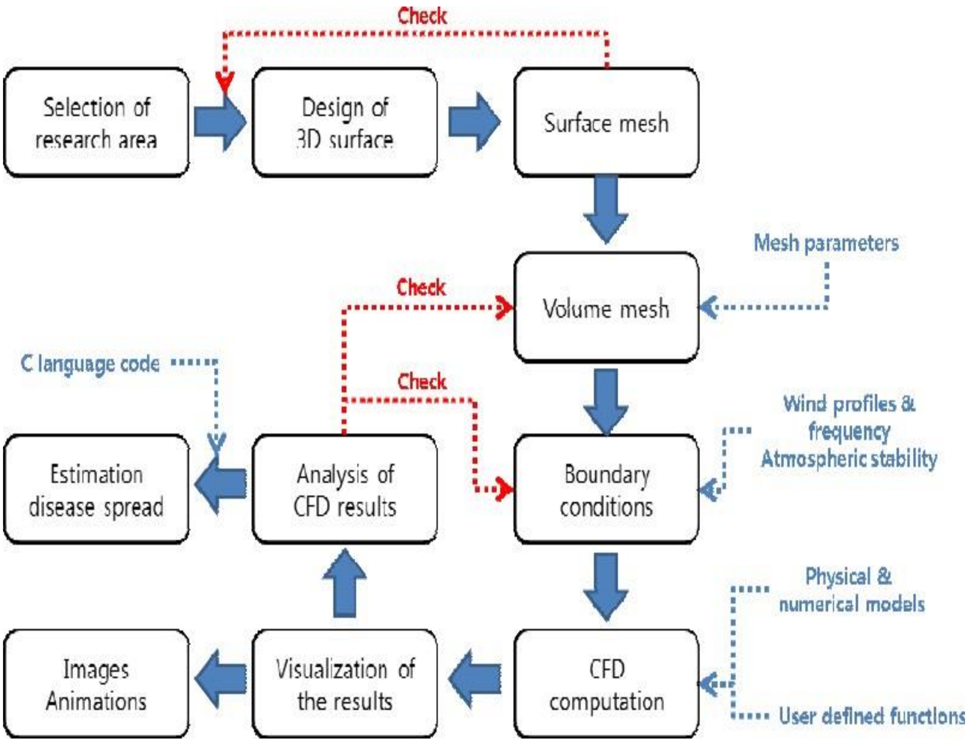

Figure 2 Flowchart showing research methodology [26].

V. CONCLUSION

The flow distribution in a catalytic converter assembly is governed by the geometry configurations of inlet and outlet cone section, the substrate and exhaust gas compositions and therefore a better design of the catalytic converter is very important.

REFERENCES

[1] Yugal Kishore et. al CFD analysis of three way monolithic catalytic converter using Ansys 14.5r, International Journal of Mechanical And Production Engineering, Volume5, Issue-11, Nov.-2017.

[2] S.P. Venkatesan et al I.C. Engine emission reduction by copper oxide catalytic converter. Materials Science

ISSN : 2455-9679
Impact Factor : 6.008

and Engineering 197 (2017) 012026 doi:10.1088/1757- 899X/197/1/012026

[3] Vladimir Lozhkinet al Catalytic Converter with Storage Device of Exhaust Gas Heat for City Bus. Transportation Research Procardia 20 (2017) 412 – 417

[4] A.K. Sharma et al Validity and scalability of an asymptotically re duce d single-channel model for full-size catalytic monolith converters Applied Mathematics and Computation 281 (2016) 186–198

[5] Young-Deuk Kim Optimal design of axial noble metal distribution for improving dual monolithic catalytic converter performance Chemical Engineering Science 64 (2009) 1373 – 1383

[6] ThundilKaruppaRaj.R and Ramsai.R “Numerical Study of Fluid Flow And Effect of Inlet Pipe Angle In Catalytic Converter Using CFD”, School of Mechanical and Building Sciences, VIT University, Vellore– 632 014,Tamil Nadu, INDIA.

[7] Ming Chen, Karen Schirmer “A modeling approach to the design optimization of catalytic converters of I.C. Engines” PROCEEDINGS OF ICEF03: 2003 Fall Technical Conference of the ASME Internal Combustion Engine Division, Pennsylvania,USA, September 7-10, 2008.

[8] Chakravarthy, V. K., Conklin, J. C., Daw, C. S., &D’Azevedo, E. F. (2003). Multidimensional simulations of cold-start transients in a catalytic converter under steady inflow conditions. Applied Catalysis A: General, 241(1–2), 289–306.

[9] Ekström, F., &Andersson, B. (2002). Pressure drop of monolithic catalytic converters experiments and modeling (No. 2002-01-1010). SAE Technical Paper.

[10] Karvounis, E., &Assanis, D. N. (1993). The effect of inlet flow distribution on catalytic conversion efficiency. International journal of heat and mass transfer, 36(6), 1495-1504.