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A Review on Performance Enhancement of Catalytic Conveter by Making Geometrical Changes

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ABSTRACT

Now a days the global warming and air pollution are big issues in the world. The 70% of air pollution is due to emissions from an internal combustion engine. Catalytic monolith converters have been used for nearly four decades to reduce the toxicity of exhaust gases from the internal combustion engine powering automotive/machines The harmful gases like NOX, CO, unburned HC and particulate matter increases the global warming, so catalytic converter plays an vital role in reducing harmful gases, but the presence of catalytic converter increases the exhaust back pressure due to this the volumetric efficiency will decrease and fuel consumption is higher. So analysis of catalytic converter is very important. The scarcity and high demand of present catalyst materials necessitate the need for finding out the alternatives. So this paper is based on to find the possibility regarding to reduce emission and converted into high rate.

Keywords: *Catalytic convertor, CFD, Substrate, Porous zone, Emission*

1. INTRODUCTION

An exhaust system is a gadget utilized as a part of vehicle to control emanations by changing over dangerous results from ignition (happening in the I.C engine) to less harmful substances by moving synthetic responses through catalyzed. The responses change contingent on the sort of substrate or catalyst altered. Albeit exhaust systems are essentially utilized as a part of exhaust system in cars, trains, planes, generator sets, mining hardware, and other motor fitted gadgets. They are likewise utilized on some wood stoves to control discharges. There are three sorts of exhaust system 1) reduction catalytic converter 2) oxidization catalytic converter 3) three-way catalytic converter (TWC). An oxidation catalyst is a gadget that is set on the end of fumes pipe of an auto. The oxidation catalyst is the second phase of the catalytic converter. It diminishes the hydrocarbons and carbon monoxide by oxidizing them over a platinum and palladium impetus1.

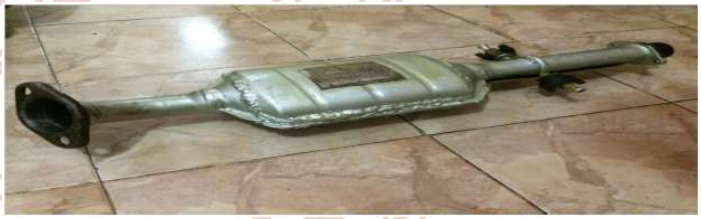

Figure 1 Assembled Catalytic convertor [1]

1.1 BASIC CONVERSION OF CATALYTIC CONVERTER

3- Way converters working as two catalyst process: 1. Reduction and 2. Oxidation- and a sophisticated oxygen storage/engine control system to convert three harmful gasses- HC, CO and NOX. This is not an easy task: the catalyst chemistry required to clean up NOX is most effective with a rich air/ fuel bias. To operate properly, a three- way converter first must convert NOX (with a rich air/ fuel bias), then HC and CO (with a lean bias).

Figure 2 Basic Conversion of Catalytic Converter

1.2 DANGERS OF POLLUTANTS

Without the redox process to filter and change the nitrogen oxides, carbon monoxides, and hydrocarbons into less harmful chemicals, the air quality (especially in large cities) would reach a harmful level to the human being.

Nitrogen oxides- these compounds are in the same family as nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide. When NOx is released into the air, it reacts with organic compounds in the air and sunlight, the result is smog. Smog is a pollutant and has adverse effects on children's lungs.

Carbon monoxide- this form of CO2 is a harmful variant of a naturally occurring gas. Odorless and colorless, this gas does not have many useful functions in everyday processes.

Hydrocarbons- inhaling hydrocarbons from gasoline, household cleaners, propellants, kerosene and other fuels can cause death in children. Further complications can be central nervous system impairments and cardiovascular problems.

1.3 METHODOLOGY

Emission control is one of the biggest challenges in today's automotive industry. Emission control can be achieved either by controlling combustion or by treating the exhaust gas. The latter is comparatively easier since there is less or no need to modify the engine itself. One such after treatment method is the use of catalytic converter. But, the 3-way converter is expensive due to use of both platinum and palladium/rhodium. One of the alternatives is the use of selective catalytic reduction, i.e., reduction of a particular mission based on the type of the engine used. The flow distribution across the monolith frontal area depends on the geometry of a specific design of inlet diffuser

II.LITERATURE REVIEW

For analyzing the catalytic convertor the various researches have been study some of these are explained here.

YUGAL KISHORE ET. AL 2017 carried out a 3D CFD analysis on three way monolithic converter on the basis of it various 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 have study on emission control of catalytic convertor by using copper oxide. The main aim of this work is to fabricate 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 LOZHKIN ET AL 2017 The purpose of investigation was the development of mathematic model of catalysis process in the 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. In this context, they present an efficient approach to overcome the difficulties in the modeling of a monolith converter. Then study the computational efficiency of the reduced model for monoliths comprising O (10^4) channels. 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 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 value of a catalyst distribution function over the monolith volume and

total catalytic surface area over the total monolith volume. [5]

THUNDIL KARUPPA RAJ.R ET 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]

MINGCHEN ET 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]

CHAKRAVARTHY ET 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]

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]

KARVOUNIS & ASSANIS, 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 flow distribution 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]

CHEN ET 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]

LIU ET 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]

BENJAMIN ET 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]

SHAMIM ET 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]

BELLA ET 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.[15]

D. REICHERT ET AL,2009 present paper on study of the reaction of NOx and soot on Fe2O3 catalyst in excess of O2.This paper presents characteristics of a new catalytic converter based on ferric oxide (α-Fe2O3) in relation with NOx and soot reduction in emission.[18]

STEFFEN WAGLOEHNER ET AL 2012 present paper on study on the mechanism of the oxidation of soot on Fe2O3 catalyst. For the removal of soot from the exhaust of diesel engines so called diesel particulate filters (DPF) are currently applied. These filters operate with high efficiency by forcing the exhaust to flow through their porous walls. In this paper we conclude a scheme of global reactions describing the mechanism of the catalytic soot oxidation on Fe2O3. [19]

NARENDRASINH R. MAKWANA ET AL 2013 present paper on development and performance analysis of nickel based catalytic converter. There are several types of problems associated with noble metal based catalytic converter. These factors encourage for the possible application of non-noble metal based material such as nickel as a catalyst. They have used Nickel as the oxidizing agent because of its nonpoisonous nature, low cost and availability makes it preferred carrier in oxidation from the stationary pollution sources.[20]

G. C. KISKU, ET AL 2014 present paper on catalytic converter based on non-noble material. This paper review problems associated with noble metal based catalytic converter. Catalytic converter may be due to factors converter meltdown, carbon deposit, catalyst fracture and Poisoning. The converter becomes too hot and melts inside so that the small particles come apart on the inside. The broken pieces can move around and get in position to plug up the flow of exhaust through converter. This meltdown is caused by converter having too much work to do. [21]

2.1 COMPARITIVE SUMMARY OF LITERATURE REVIEW

AUTHOR'S	CONCLUSIONS
YUGAL KISHORE ET. AL 2017	• 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.
S.P. VENKATESAN ET AL 2017	• The main aim of work is to fabricate system, where the level of intensity of toxic gases is controlled through chemical reaction to more agreeable level. • System acts itself as an exhaust system; hence there is no needs to fit separate the silencer.

A.K. SHARMA ET AL 2016	• Study the computational efficiency of the reduced model for monoliths comprising $O(10^4)$ channels. • The computational penalty for reduced model is much less as compared to the full model, making it a possible candidate for detailed monolith simulations.
G. C. KISKU, ET AL 2014	• Catalytic converter may be due to factors converter meltdown, carbon deposit, catalyst fracture and Poisoning. • The converter becomes too hot and melts inside so that the small particles come apart on the inside.
NARENDRASINH R. MAKWANA ET AL 2013	• They have used Nickel as the oxidizing agent because of its nonpoisonous nature, low cost and availability makes it preferred carrier in oxidation from the stationary pollution sources

Table 2.1 Comparative analysis of literature review

III. CONCLUSION

As this is a well-known fact that the world is facing serious problems like global warming acid rain etc. due to heavy emissions emitted from automobiles and industries. So this becomes a special area of interest for engineers and scientist to reduce the emissions which causes such serious problem.

- Manufacturing and testing of catalytic convert is a costly affair which involves great deals of time and money to perform the testing of working of catalytic converter
- But using simulation software like Ansys gives us an opportunity to investigate the performance of catalytic converter for even very small dimensional changes without any great cost involved.
- Increasing mass flow rate the pressure drop increases linearly.
- Increasing substrate length improves the performance of converter.
- The results obtained from CFD are reliable to one which s obtained by experimental setup with appreciable amount of minimal error.

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