CONTROL AND REDUCTION OF EMISSIONS USING CATALYTIC CONVERTER

L.VENKATESH[1], R.LOGESHKUMAR[2], G.JAYAPRAKASH[3], N.DINESH[4]

[1,2,3,4]Department of Mechanical Engineering, Sri Ramakrishna Engineering College, Vattamalaipalayam , NGGO Colony (Post), Coimbatore-022, Tamil Nadu, India.

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ABSTRACT - The aim of this paper is to survey on the catalytic converter & to reduce the toxic emissions. 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 anti-impact on air properties, atmosphere and human physical conditions that leads in severe norms of pollutant emission. There are numbers of new technologies going on in the development of engine design, use of substitute fuels; fuel additives, modification of the combustion process etc. are measured to eliminate the emission levels of the engine. This paper explains automobile exhaust emissions and its knock, automobile exhaust pollutants levelled with platinum catalyst in catalytic converter, story of catalytic convertor, categories of catalytic convertor, and disadvantages of catalytic convertor and also attainments of catalytic convertor.

INTRODUCTION:

Eugene Houdry, French mechanical engineer has developed the catalytic converter and skilled in catalytic oil sanitising who lived in the United States around 1956.When the outcome of early studies of air pollution in New Jersey, He has been awarded U.S Patent for his work.Catalytic converters were further introduced by engineers including John J. Mooney and Carl D. Keith at the Engelhard Corporation in 1973.Dr. William C. Pfefferle developed a catalytic converter for gas turbines in the early 1976s.

The focus of the automobile emission control setup is the catalytic converter. From the mid-1976's, catalyst prepared on passenger vehicles, from the two-way catalyst to today's developed three-way catalyst, has reduce toxins by higher than 1.6 billion tons in the United States. The advancement of catalyst repeatedly have been greeted as best of the great automobile technology milestones. They have also been advanced for use on road vehicles.

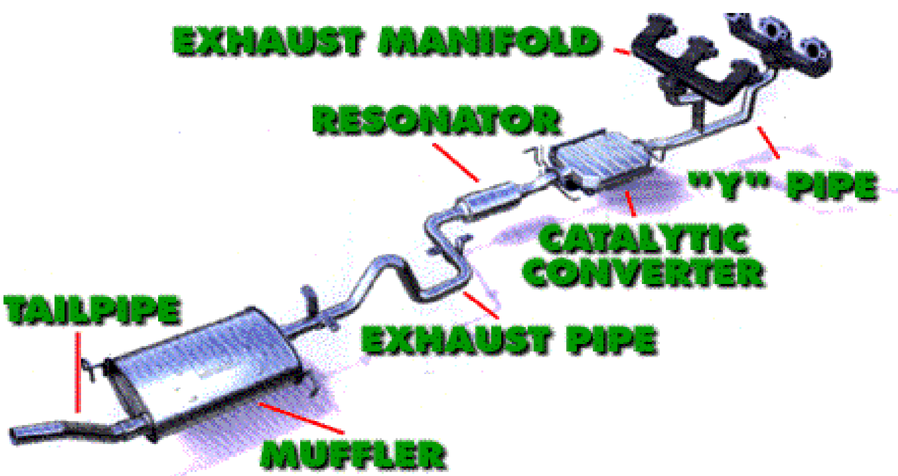

Fig 1: Position of catalytic converter in a vehicle

CONSTRUCTION:

The Construction of a Catalytic Converter is shown in terms of parts as following

SUBSTRATE:

For automobile catalytic converter, the main part is usually a ceramic monolith with a honeycomb shape. Metallic foil monolith are made of Kanthal (FeCrAl) are used where particularly high heat resistance is needed. Either material is designed to give a large surface area.

THE WASH COAT:

The wash coat is a carrier for catalytic material and used to emit the material over a large surface area. Aluminium oxide (Al2O3), Titanium oxide, Silicon dioxide, or a mixture of silica and alumina may be used. Catalytic materials are suspended in wash coat to applying to the main part. The coat must gain its surface area and prevent sintering of the catalytic metal particles even at the high temperature (1000 degree Celcius).

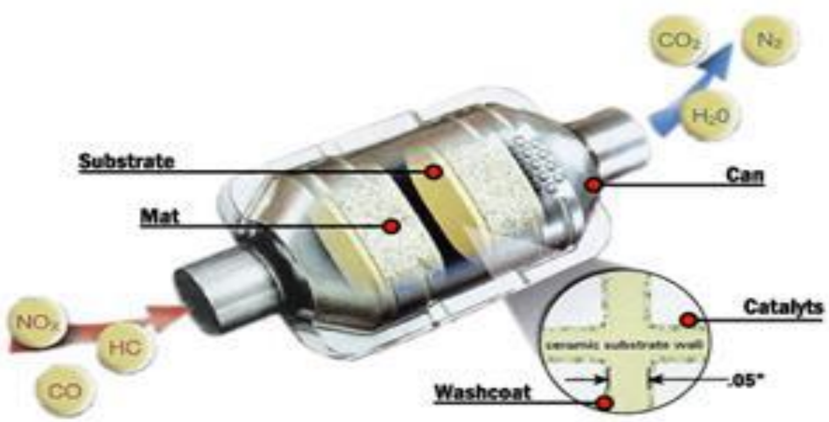

Fig 2: Ceramic- Core converter

TYPES OF CATALYTIC CONVERTER:

The catalytic converters are classified into two types –

TWO –WAY:

A 2-way (or oxidation, sometimes called an "oxi-cat") catalytic converter has two common tasks:
1. Oxidation of carbon monoxide to carbon dioxide:

$$2CO + O_2 \rightarrow 2CO_2$$

2. Oxidation of hydrocarbons (unburned and partially burned fuel) to carbon dioxide and water:

$$C_xH_{2x+2} + [(3x+1)/2]\ O_2 \rightarrow xCO_2 + (x+1)\ H_2O \text{ (a combustion reaction)}$$

This type of catalytic converters is widely used on diesel engines to minimize the hydrocarbon and carbon monoxide emissions. They have been also used on gasoline engines in American- and European -market automobiles until 1986. Because of their inability to stop oxides of nitrogen, they were controlled by three-way converter.

THREE – WAY:

Three-way catalytic converters (TWC) have the additional advantage of controlling the toxins of nitric oxide and nitrogen dioxide (both together abbreviated with NOx and not to be confused with nitrous oxide), which are precursors to acid rain and smog. Since 1986, three-way (oxidation- reduction) catalytic converter has been used in vehicle emission control systems in the United States and Europe; many other countries have also adopted vehicle emission regulations that in effect require three-way converters.

Fig. 3: A three way catalytic converter

The reduction and oxidation catalysts are contained in a same housing; however, in some instances, they may be housed separately. A three-way catalytic converter has three simultaneous equations:

- Reduction of nitrogen oxides to nitrogen and oxygen: $2NOx \rightarrow xO2 + N2$-
- Oxidation of carbon monoxide to carbon dioxide: $2CO + O2 \rightarrow 2C$
- Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water:

$$CxH2x{+}2 + [(3x{+}1)/2]\ O2 \rightarrow xCO2 + (x{+}1)H2O.$$

These three reactions occur most efficiently when the catalytic converter receives exhaust from an engine running just above the stoichiometric point.

LITERATURE SURVEY:

Martin Rybicki et.al [1] the control and the reduction of the emissions made by vehicles are, and have been, an import issue over the last 6 decades. The first restrictions were introduced by the government of California (USA) in the early 1960s. In 1976 the European Community passed first law regarding exhaust gas emission. Today, there is the *Euro* 5 standard and the next *Euro* 6 standard will be compulsory in 2014 in Europe. Many other countries nowadays use or introduce similar restrictions. To reduce of the concentration of CO, NO_x and $C_xH_y$in the exhaust gas, there is a technical solution, namely in most cases two catalytic converters are installed in the exhaust pipe system. The function of the catalytic converters depends strongly on the temperature in the converters. There is a lower limit (about 606 °C) for a good function and an upper limit to avoid damages. In particular, right after engine start there is a critical time interval where the temperature in the converters is not enough.

A method of heating after the engine start is the combustion of toxic gas in the catalytic converters. Modern exhaust systems can control the ratio of oxygen and fuel in the combustion chamber of the engine. By choosing a ratio with more fuel and less oxygen some unburnt fuel flows to the catalytic converters where it can be used for an exothermic reaction [6]. Clearly, there is a competition between reaching fast the optimal converter temperature and using very little unburnt fuel in the exhaust gas.

In addition, we do not only need an appropriate model but also a model which allows fast direct simulations in order to be able to apply optimization tools, which typically need several simulations during the optimization. In this sense [1], this paper can be seen as a prototypical example for optimization in a compressible gas dynamic setting with the additional requirement of very fast simulation.

We studied how to ensure reaching an optimal temperature in a catalytic converter of an exhaust pipe after the engine start by controlling ratio of unburnt gas in the gas mixture. This was achieved using the formal continuous adjoin for the calculation of derivatives in a projected gradient algorithm.

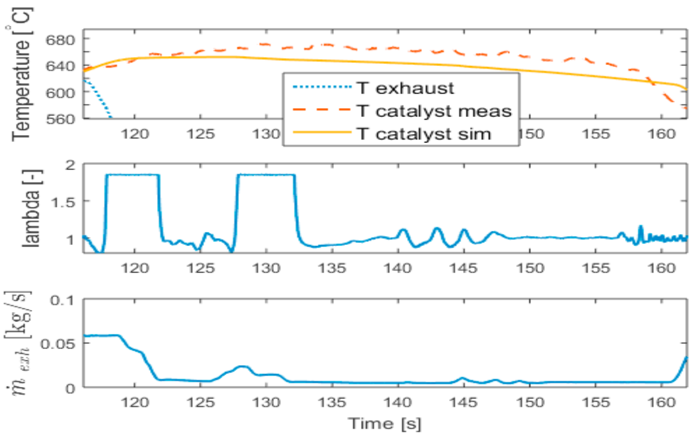

Fig.4: Catalyst cooling down during fuel cut-off

Stefano Sabatini et.al [2] Future controlling of emissions standards and the fleet wide average fuel efficiency target on production vehicles by 2026 have spurred great interest from automotive companies toward the modelling, control and optimization of engine and after treatment systems. The Three Way Catalyst (TWC) has been extensively used to minimize oxides of nitrogen (NOx), and to oxidize hydrocarbons (HC) and carbon monoxide (CO) in current generation vehicles.

Modern TWC converters are capable of conversion efficiencies approaching 100% when the catalyst is properly heated and the air fuel ratio is controlled in a narrow band around the stoichiometric value. However, conversion efficiency describes only the steady state behavior of the TWC while tail pipe emissions are highly affected by transient variations of the pre-catalyst air fuel ratio. The dynamic behavior of the TWC is dominated by its ability to store and release oxygen. For this reason [5], a considerable number of empirical oxygen storage models have been developed.

The model has been validated with experimental tests reflecting real vehicle operations. The heat produced by the chemical reactions is lumped into a single term so that no concentration information about the species upstream the catalyst is required.

A.K.Sharma et.al [3] Mathematical modeling and simulation have found widespread use in the research and development of monolith converters. The mathematical modeling that seeks to provide geometrical resolution and resolve the essential physics that occur within a monolith has been found to be a challenging task We have studied the validity and scalability of a computationally-efficient reduced single channel model for multiple channels, allowing us to model and simulate a full-size monolith converter comprising O (10 4) channels. The reduced monolith model captures all the essential physics –in particular the conjugate heat transfer across the channels and most importantly, it does so at a significantly reduced computational cost as compared to solving the full set of equations.

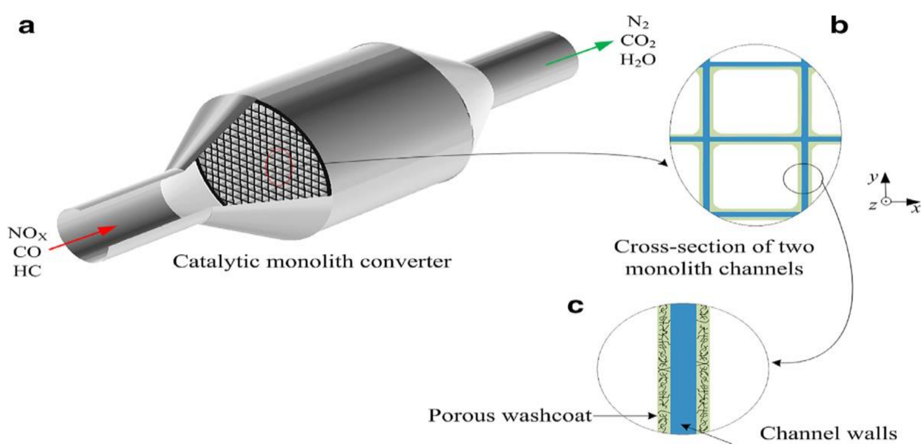

Fig. 5: (a) Schematic for a catalytic monolith converter, (b) cross-section of the monolith channels, (c) the channel walls and wash coat.

The scalability and associated low computational cost should allow for various studies on monolith converters e.g., modeling of statistical and/or random variations and perturbations in the operating conditions and material properties increasing during manufacture and assembly.

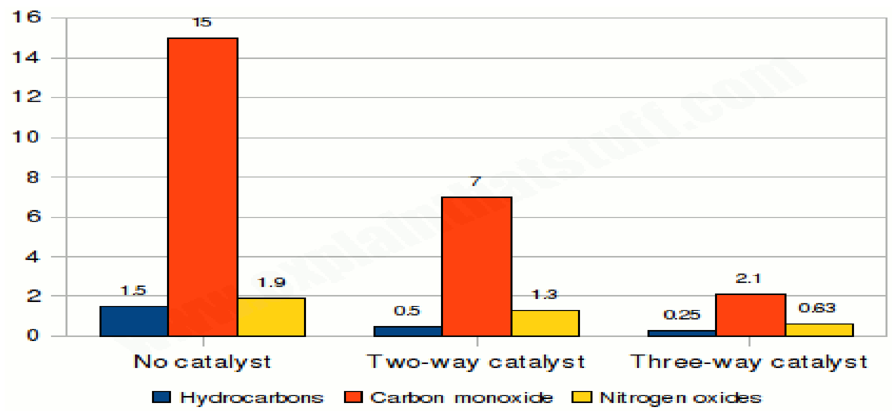

Fig. 6: Effectiveness of catalytic converters

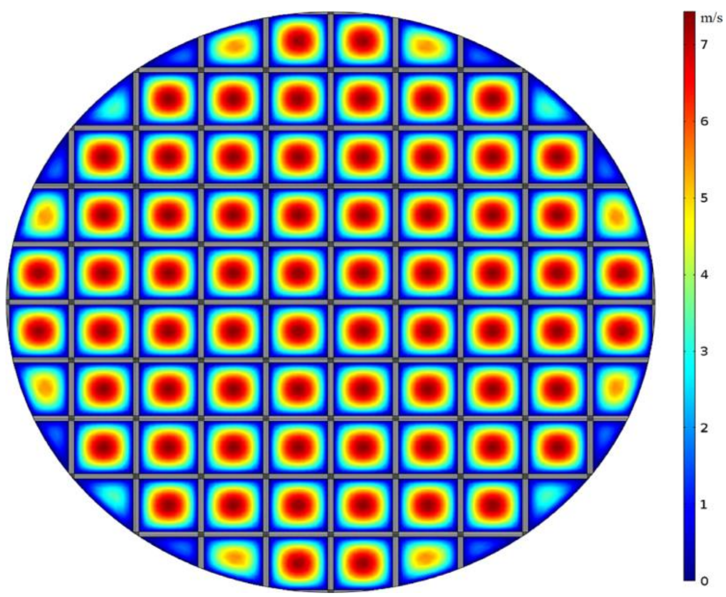

Fig.7: Axial velocity profile on a *xy* cross-section at $z = L/2$ of a 88-channel monolith.

Further, the reduced model would also be helpful to efficiently extend the monolith models to include complex reaction kinetics involving surface because it only needs to resolve a cross-section at a time as the space-marcher iterates along the channels with significantly reduced memory requirements. Once the dependent variables have been found in the first cross-section, those values serve as good initial guesses for the next cross-section in the stream wise direction and should so speed up the calculation of the reaction kinetics.

Pierre Michel, Alain Charlet, et.al[4]the electrical hybridization of a conventional car power train can decrease the fuel consumption by various means, namely recuperative braking, Stop & Start or energy management. However, the energy management strategy impacts the Hybrid Electric Vehicle operation particularly in terms of pollutant emissions. For a gasoline engine, the 3WCC temperature dynamics plays a role in pollutant emission. Historically, the optimal energy management strategies were built to ensure minimal fuel consumption, for a trip known a priori, most often a driving cycle. Usually this is done by using either Dynamic Programming (DP), derived from Bellman's principle (Bellman, 1956), or the Pontryagin Minimum Principle (PMP) (Pontryagin, 1962), from quasi static HEV models. The only dynamics considered in these off-line strategies concerns the Battery State of Charge (SOC).

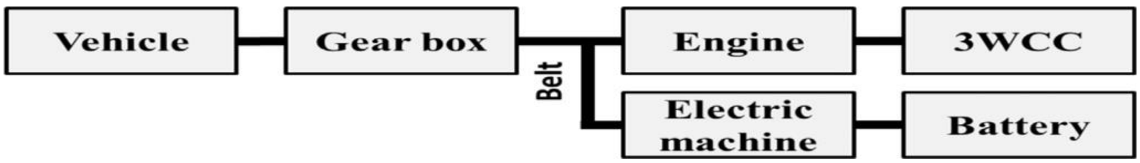

Fig. 8: HEV parallel mild-hybrid architecture.

A 3way CC multi model has been built from physical equations, integrating the 3WCC temperature dynamics and a pollutant emission conversion map .The validated model, with suitable complexity and performances, was included in a high-fidelity gasoline-HEV power train model. Next, a pollutant constrained optimal energy management was derived from the Pontryagin Minimum Principle. The approach allowed the joint minimization of pollution and fuel consumption with only one parameter to tune, by considering all test and adzed pollutant emissions. In simulations, the proposed strategy reduced significantly the vehicle CO and NOX emissions for a minor fuel consumption increase. Analyzing the HEV operation ensuring these results permitted to define a 3WCC smart heating.

Fan Zeng, Keith L. Hohn et.al [5] the ability of a 3-way catalytic converter to treat the exhaust from a natural-gas fuel engine was explained by numerical method. A comprehensive and thermodynamic consistent surface reaction mechanism describing the surface reactions in the 3 way catalytic converter was built by compiling elementary-step reaction kinetics involving CH4, CO, formaldehyde, NO, NH3and N2O from literature sources. The reaction parameters are taken from literatures and fitting calculations. The mechanism was implemented in a one-dimensional PFR model describing a single channel of the catalyst. The simulation results were evaluated by comparison with field data collected from a TWC operated isothermally at steady-state. The model predicted the major trends in formation of all species in the TWC over a wide range of air to fuel ratios. Sensitivity analysis was utilized to study the key reaction steps that impact the exhaust emission mole fraction. It was found that methane, NO, CO and formaldehyde are most sensitive to the corresponding adsorption steps, while NH3and N2O are sensitive to the reactions that relate to their formations, such as reactions involving surface hydrogen atoms for NH3and NO for N2O.

CONCLUSION:

Today's vehicles are meeting emission standards that require minimize of up to 99% of toxic elements compared to the uncontrolled stages of automobiles sell in the 1960's.Ecological and Health concern result in higher stringent emissions regulations of pollutant emissions from automobile engines. Uses of metal monolith type CC are the accurate way to stop the auto exhaust emissions. Due to economic reasons, availability of platinum metal and some operating limitations of platinum group metal based catalytic converters have motivated towards the investigation of other catalyst materials. These catalytic converters have also been developed for applications on trucks, buses and motorcycles as well as on construction equipment etc. In 2005, 96% of the new cars sold in the U.S. where use with a catalytic converter, and worldwide over 86%of the new cars sold had a metal monolith type catalytic converter.

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