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Design and Analysis of Nano Based Catalytic Converter in Automobiles for Pollution Control

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Abstract: ***The large increase in the number of automobiles in India during the past decade has created a serious environmental problem especially in metropolitan cities. In view of this, emission standards were introduced in 1991 and they were made more stringent. The proposed one due in 2005 is expected to be more difficult to be met without any exhaust gas after treatment devices. Design and optimization of the catalytic converter is crucial for the automotive industry to meet the stringent emission standards because of different raw emission and inlet flow conditions for different type of vehicles. Moreover, the performance of the catalytic converter depends not only on the type of catalyst impeded but also on the operating condition of the engine. Hence computer simulation models are often used to minimize the cost and narrow down the range of engine testing. Such models are found to be of considerable use in the design and development of catalytic converters for vehicles. Kinetic rate constants, heat and mass transfer are key parameters that affect accuracy in the model prediction.***
Keywords: Ceramic coating, Plasma spray coating method, Engine performance and Emission characteristics.

I. INTRODUCTION

A catalytic converter is a vehicle emissions control device that is used to convert toxic byproducts of combustion occurring in the exhaust of an internal combustion engine to less toxic substances by performing catalysed chemical reactions. The reactions tend to vary depending upon the type of catalyst installed. The purpose of using catalytic converter in spark ignition and compression ignition engines is same i.e to convert the harmful combustion byproducts into harmless products. Modern gasoline engines with closed loop emission controls produce exhaust i.e. near chemical stoichiometry and at temperature of 375°C to 850°C. The exhaust contains significant amount of hydrocarbon (HC), carbon monoxide (CO) and oxides of nitrogen (NO_X) that must be reduced using catalytic converter. The Three Way Catalysts are advanced system for emission treatment of gasoline vehicles that significantly reduce the emissions of carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx) in atmosphere.

A. Catalysis

Catalysis is the process in which the rate of a chemical reaction is increased by means of a chemical substance known as a catalyst. Unlike other reagents, a catalyst is not consumed during the chemical reaction. Thus, the catalyst may participate in multiple chemical transformations, although in practice catalysts are secondary processes.

B. Catalytic Converter

A catalytic converter is a device used to reduce the toxicity of emissions from an internal combustion engine (Fig.1). A catalytic converter converts the harmful toxic combustion products and its byproducts into less-toxic substances (Apostolescu et al. 2005). 1. It is the most effective after treatment process for reducing engine emission. 2. Catalytic converter is generally called as three way catalytic converter because it promotes in reduction of HC, CO and NOx. 3. It consists of steel container of honeycomb structure inside which contains porous ceramic structure through which the gas flows. 4. It consists of small embedded partials of catalytic materials that promote oxidation reaction in exhaust gas. 5. Catalytic converter uses alumina as base material because it can withstand high temperature.

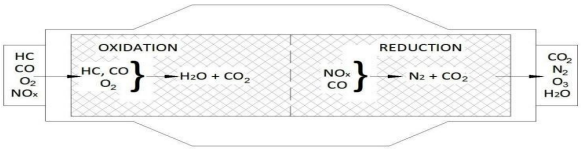


Fig 1 Catalytic process

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C. Catalytic Materials

Many types of material often used as catalyst in the recent years. Proton acids are probably the most widely used catalysts, especially for the many reactions involving water, including hydrolyses and its reverse. Multifunctional solids often are catalytically active, e.g. zeolites, alumina, certain forms of graphitic carbon etc. Transition metals such as platinum, paladium, rhodium, iron, silver are often used to catalyses redox reactions

D. Three-Way Catalytic Converter

Three-way catalytic converter is widely used in the automobile industries. The three-way catalytic converter is scheduled to perform three simultaneous tasks (Fig.2 and Fig.3).

1) Reduction of nitrogen oxides to nitrogen and¬ oxygen $2NO_x \rightarrow xO_2 + N_2$

2) Oxidation of carbon monoxide to carbon dioxide¬ $2CO + O_2 \rightarrow 2CO_2$

3) Oxidation of unburnthydrocarbons (HC) to¬ carbon dioxide and water $C_xH_{2x} + 2xO_2 \rightarrow xCO_2 + 2xH_2O$

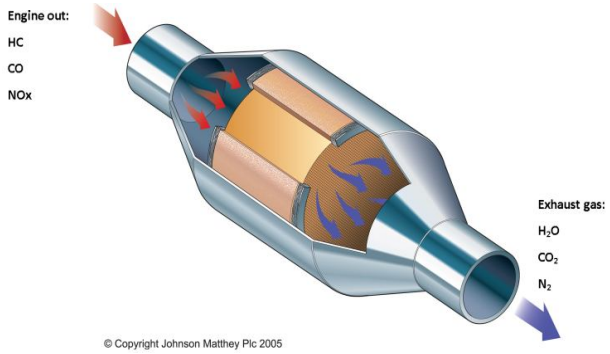


Fig 2.Three way oxidation reduction catalytic converter

II. PROCESS OF MANUFACTURE

The process of manufacturing of catalytic converters are illustrated below, First Inlet cone was fabricated for converter housing then exhaust gases from the engine are admitted through inlet cone outlet cone was fabricated. Eco-friendly exhaust gases come out at this end. Cylindrical spacer and two circular housing with provision for putting pellets were fabricated. Pellets of different catalytic materials were developed. The components were assembled and fitted to engine exhaust manifold**.** Next, honeycomb cores are manufactured via the expansion process and the corrugation process from composite materials such as glass-reinforced plastic, also known as fiberglass carbon fiber reinforced plastic, Honeycombs from metals like aluminum are today produced by the expansion process. Continuous in-line production of metal honeycomb can be done from metal rolls by cutting and bending. Thermoplastic honeycomb cores usually from polypropylene are usually made by extrusion processed via a block of extruded profiles or extruded tubes from which the honeycomb sheets are sliced. Recently a new, unique process to produce thermoplastic honeycombs has been implemented, allowing a continuous production of a honeycomb core as well as in-line production of honeycombs with direct lamination of skins into cost efficient sandwich panel. Today, a wide variety of materials can be formed into a honeycomb composite.

III. PREPARATION OF ZINC ELECTRO PLATING

Zinc electro plating is created by applying zinc to steel sheet and strip by electro-deposition. Similar to sheet galvanizing, the operation is continuous and coating thickness is minimal. Applied in a steel mill, sheet or strip is fed through entry equipment into a series of washes and rinses then into the zinc plating bath. The most common zinc electrolyte-anode arrangement uses lead-silver, or other insoluble anodes and electrolytes of zinc sulfates. Soluble anodes of pure zinc are also used. The coating develops as positively charged zinc ions in the solution are electrically reduced to zinc metal and deposited on the positively charged cathode (sheet steel).

Grain refiners may be added to help produce a smooth, tight-knit zinc coating on the steel. Zinc coatings are applied to sheet steels and wire; and therefore, are used in similar applications to continuous sheet galvanizing or wire galvanizing. The most common applications are in automobile and appliance bodies and fasteners. Furthermore, to extend the service life, zinc coatings can be treated to make them suitable for painting, and this is often recommended due to the extremely thin zinc coating.

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IV. ANALYSIS OF CATALYTIC CONVERTER

A. Meshing of Catalytic Converter

Meshing the catalytic converter is one of the most critical aspects of engineering simulation. Too many cells may result in long solver runs, and too few may lead to inaccurate results. ANSYS Meshing technology provides a means to balance these requirements and obtain the right mesh for each simulation in the most automated way possible. ANSYS Meshing technology has been built on the strengths of stand-alone, class-leading meshing tools. The strongest aspects of these separate tools have been brought together in a single environment to produce some of the most powerful meshing available to mesh the catalytic converter.

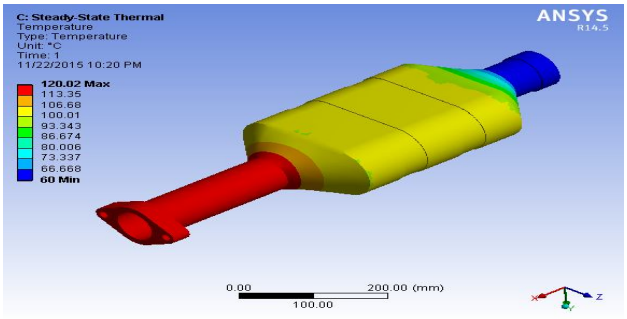


Fig 4 Analysis view of stainless steel catalytic converter

B. Boundary Conditions for Zinc Coated Catalytic Converter

The catalytic converter has the boundary condition inlet temperature as 120°c and outlet temperature as 60°c and also includes the fixed supports like holding the catalytic converter. The chosen material was zinc.

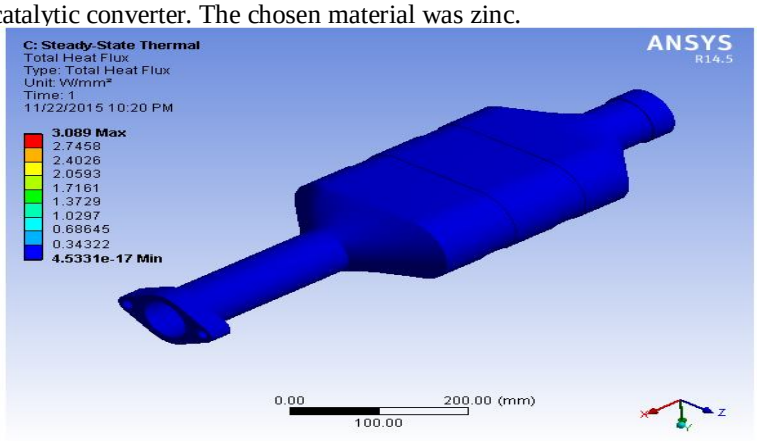


Figure5.Analyzing view of zinc catalytic converter using

TABLE1
Temperature values of zinc coated catalytic converter

MATERIAL: ZINC			
SNO.	Type of the analysis	Maximum value(^{0}c)	Minimum value (^{0}c)
1.	Total heat flux	3.089	4.5331e-17

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V. NANO COATING METHODS

Zinc corrosion products develop naturally on the surface as the coating is exposed to natural wet and dry cycles in the atmosphere and are often referred to as the zinc patina. The zinc patina acts as an additional barrier between the steel and the environment. In addition to the natural barrier protection of the coating and patina, zinc also protects the base steel catholically.

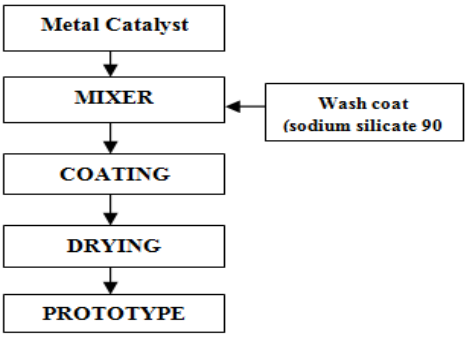


Fig 6. Summary of Catalyst

A. Coating Process

Sodium silicate solution was used in wash coat material to increase the coating strength. Ninety grams of sodium silicate solution were added into 10.0 gm of Al2o3 nanoparticles to get 10% Al2o3 nanoparticles slurry. The slurry has been mixed by using a mechanical homogenizer for two hours. Coating of catalyst (Al2o3 nanoparticles slurry) is done by dip coating method, and it has been kept in an oven at 120˚C for 5 hours. Aluminium oxide nano particles, served dual functions: a reduction catalyst and an aluminium substance for the wash coat. Rutile form of Al2o3 was chosen because of its thermal stability from 600◦C and high durability.

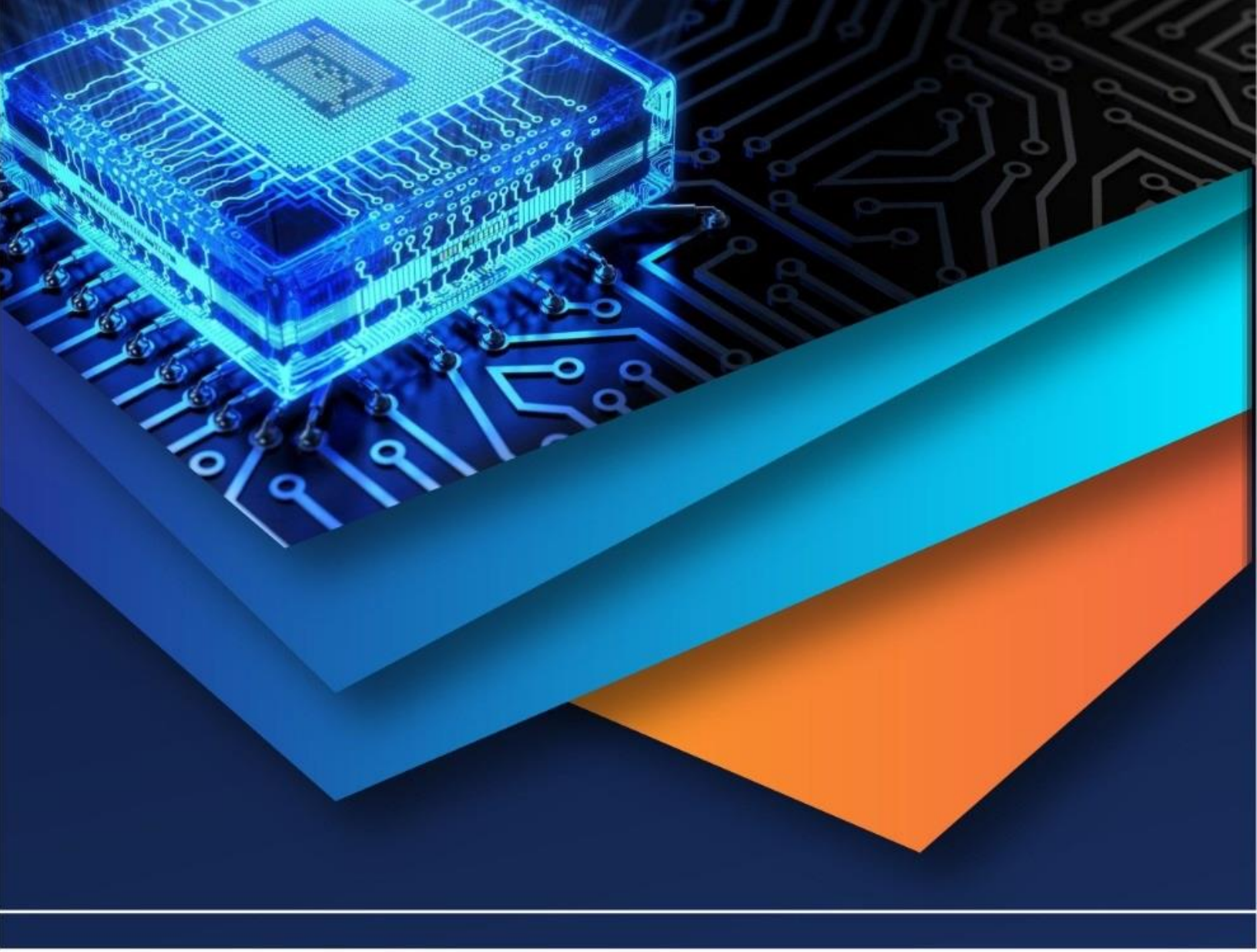
VI. CONCLUSION

It has been observed here in structural analysis of both different type catalytic converter materials where stress developed at discontinuity. These stresses is not depend only upon inside pressure of exhaust gases but also extremely affected by temperature of gases. Total deformation is much larger at used temperature parameter. There were generated different types of stress, strains, and the deformation. The results of the silencer perforated and non- perforated were analyzed. The proposed method is very effective in the prevention of environmental pollution contributed from two-wheeler automobiles. It involves the use of copper nano-particle which is cheaper than the platinum, palladium and rhodium nano-particles used in automobiles. This paper opens a gateway to study the changes in the concentration of exhaust emissions due to the nano-material copper coating. The modeling will help in understanding the mathematical nature of the process and simulation will help in predicting the results with ease.

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