ANALYSIS OF FLOW CHARACTERISTICS IN CATALYTIC CONVERTER USING COMPUTATIONAL FLUID DYNAMICS

PROJECT REPORT

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In the partial fulfillment for the award of the degree

Of

MASTER OF ENGINEERING IN CAD/CAM

Department of Mechanical Engineering

KUMARAGURU COLLEGE OF TECHNOLOGY
COIMBATORE – 641 006

ANNA UNIVERSITY: CHENNAI 600 025

JUNE 2008

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BONAFIDE CERTIFICATE

Certified that this project report entitled **"Analysis of flow characterstics in catalytic converter using computational fluid dynamics"** is the bonafide work of **Mr. V.Ramshankar, Register No. 71206402006** who carried out the project work under my supervision. Certified further, that to the best of my knowledge the work reported here in does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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in the National Conference on
Recent Advancements in Mechanical Engineering - RAME - '08

Organised by the Department of Mechanical Engineering
On 4th April 2008

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This is to certify that Mr/Ms/Mrs V. RAMSHANKAR has participated and presented a paper titled Analysis of flow charactristics in catalytic converter using computational fluid dynamics in the 2nd National Conference on "ADVANCES IN MECHANICAL SCIENCES" during 27- 28, March 2008.

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Abstract

ABSTRACT

Catalytic converter in an automobile's exhaust system is made up of a finely divided platinum–iridium catalyst and provides a platform for exothermic chemical reaction where unburned hydrocarbons completely combust. Many investigations have been done in various countries to reduce the pollutants emission from the engines. The main objective of the analysis is to use the power of fluent to analyze the catalytic converter and to compare the efficiency of square and hexagonal cell catalytic converter. In the catalytic converter for the various inlet velocity the mesh density is also varied for the square cell and hexagonal cell catalytic converter. Due to the various velocities and mesh density the mass flow rate also vary for the square and hexagonal cell converters. Here comparison is made for the both type of converters. The velocity and the pressure graph shows that for the higher inlet velocity the pressure in the outlet is high. For the square cell honeycomb the mass flow rate is high compare to the hexagonal cell honeycomb. From our analysis is found that the hexagonal and square cell honey combs for the different velocities hexagonal cell honey comb gives the low mass flow rate .so that hexagonal type honey comb gives the better performance compare to square type honey comb. It improves the efficiency of the catalytic converter.

ஆய்வுச்சுருக்கம்

கேடலிட்டிக் கன்வர்டர் என்பது வாகனங்களில் வரும் புகையை தூய்மை செய்ய உதவும் ஒரு பாகம் ஆகும். இதனுடைய செயல்திறனைப்பற்றி பல நாடுகளில், பல ஆராய்ச்சிகள் நடக்கின்றன. இந்த ஆய்வின் முக்கிய நோக்கமானது புளூவண்ட் மென்பொருளின் துணையோடு கேடலிட்டிக் கன்வர்டரின் செயல்திறனை ஆராய்ந்து அதன் திறனை அதிகரிக்கும் வழியை கண்டறிவதாகும்.

இதில் இரண்டு வகையான கன்வர்டர்கள் பயன்படுத்தப்படுகின்றன. ஒன்று சதுர வடிவ துளை கொண்டது. மற்றொன்று அறுகோண வடிவ துளை கொண்டது. இந்த இரண்டு வகையான கன்வர்டர்களும் வெவ்வேறு விதமான திசைவேகத்திற்கும், வெவ்வேறு விதமான அடர்த்திக்கும் ஆய்வு செய்யப்படுகிறது.

இந்த இரண்டு வகையான கன்வர்டர்களின் ஆய்வு முடிவுகளை ஆராயும்பொழுது அறுகோண வடிவு துளை கொண்ட கன்வர்டர் குறைந்த மாஸ் புளோரேட்டை தருவதால் கன்வர்டரின் செயல்திறனை இது அதிகரிக்கும். ஆகையினால் அறுகோண வடிவ துளை கொண்ட கன்வர்டர் சிறந்த செயல்திறனை கொடுக்கும்.

Acknowledgement

ACKNOWLEDGEMENT

I take this opportunity to publicly express my gratitude to all those people who have supported my work during this project.

My heartfelt gratitude to my guide, **Mr. T. Venugopal**, Lecturer, Department of Mechanical Engineering, Kumaraguru College of Technology, for contributing to my project work in numerous ways through his constant source of motivation, wise counsel and encouragement which has been an inspiration throughout the work for the successful completion of this project work.

I am grateful to **Dr. C. Sivanandan**, Dean and Head of the Department, Department of Mechanical Engineering for his valuable suggestions and timely help towards my project. I wish to express my deep sense of gratitude to **Dr. Joseph V. Thanikal**, Principal, Kumaraguru College of Technology for patronizing me, besides providing all assistance.

Words are inadequate in offering my thanks to **Dr. P. Palanisamy**, Professor, our class advisor and the **faculty members** of the Department of Mechanical Engineering, Kumaraguru College of Technology for their encouragement and cooperation in carrying out my project work. My sincere thanks also to all my **friends** for their help in all the matters during my project work.

Finally, I would like to thank my dearest ones, my mother **P.Vanamala** and my dear sister **Ms. A. Keerthika** for their support and encouragement throughout the different stages of my project work.

V.RAMSHANKAR

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CHAPTER 1

INTRODUCTION

1.1 AIR POLLUTION

Air is contaminated by so many harmful pollutants. Among the various sources of pollutants, internal combustion engines of automobiles constitute a major role in air pollution. Three major automotive pollutants are carbon monoxide (CO), unburned hydrocarbons (HC), and oxides of nitrogen (NO_x). When air and gasoline are mixed and burned in the combustion chambers, the by-products of combustion are carbon, carbon dioxide (CO_2), CO, and water vapor.

Gasoline is a hydrocarbon fuel containing hydrogen and carbon. Since the combustion process in the cylinders is never 100% complete, some unburned HC are left over in the exhaust. Some HC emissions occur from evaporative sources, such as gasoline tanks and carburetors. Oxides of nitrogen (NO_x) are caused by high cylinder temperature. Nitrogen and oxygen are both present in air. If the combustion chamber temperatures are above 1,371°C, some of the oxygen and nitrogen combine to form NO_x. In the presence of sunlight, HC and NOx join to form smog.

People have started feeling the impact of pollutants on their health. Governments of various countries formulated their emission norms to bring the pollutants level under control. The emission norms have become very stringent which force the manufacturers of various engines to design and produce their products comply with the norms.

1.2 RESEARCH ON POLLUTION CONTROL

Many investigations have been done in various countries to reduce the pollutants emission from the engines. Exhaust gas reciculation, water spray injection inside the combustion chamber, catalytic coating inside the combustion chamber, additives with fuel and exhaust pipe post combustion using catalytic converters are popular in reduction of pollutants and are widely used since for a long time. Catalytic converters are being under research to improve the performance still better and better. Various catalysts materials are developed and used in research.

The catalytic converter does a great job at reducing the pollution, but it can still be improved substantially. One of its biggest shortcomings is that it only works at a fairly high temperature. When you start your car cold, the catalytic converter does almost nothing to reduce the pollution in your exhaust.

One simple solution to this problem is to move the catalytic converter closer to the engine. This means that hotter exhaust gases reach the converter and it heats up faster, but this may also reduce the life of the converter by exposing it to extremely high temperatures. Most carmakers position the converter under the front passenger seat, far enough from the engine to keep the temperature down to levels that will not harm it.

Preheating the catalytic converter is a good way to reduce emissions. The easiest way to preheat the converter is to use electric resistance heaters. Unfortunately, the 12-volt electrical systems on most cars don't provide enough energy or power to heat the catalytic converter fast enough. Most people would not wait several minutes for the catalytic converter to heat up before starting their car. Hybrid cars that have big,

high-voltage battery packs can provide enough power to heat up the catalytic converter very quickly.

Catalytic converters in diesel engines do not work as well in reducing NOx. One reason is that diesel engines run cooler than standard engines, and the converters work better as they heat up. Some of the leading environmental auto experts have come up with a new system that helps to combat this. They inject a urea solution in the exhaust pipe, before it gets to the converter, to evaporate and mix with the exhaust and create a chemical reaction that will reduce NOx. Urea, also known as carbamide, is an organic compound made of carbon, nitrogen, oxygen and hydrogen. It's found in the urine of mammals and amphibians. Urea reacts with NOx to produce nitrogen and water vapor, disposing more than 90 percent of the nitrogen oxides in exhaust gases

1.3 RESEARCH ON CATALYTIC CONVERTER

Stringent emissions standards with more than 95% conversion efficiency requirements call for advanced ceramic catalyst supports with thinner walls, higher cell density and optimum cell shape. The extrusion technology for cellular ceramics has also made significant progress which permits the manufacture of advanced catalyst supports.

Similarly, modifications in cordierite chemistry and the manufacturing process have led to improved microstructure from coatability and thermal shock points of view. The design of these supports, however, requires a systems approach to balance both the performance and durability requirements.

1.4 NEED FOR STUDY ON FLOW CHARACTERISTICS

A world wide demand for environmental protection has enforced more stringent legislation of automotive exhaust emissions. Thus, the requirement of the high performance catalytic converter tends to be imperative. Not only high conversion efficiency but also a long durability and low flow resistance are essential to automotive catalytic converters. Flow uniformity is critical to ensure a long converter life. Poor flow distribution within the monolith could reduce catalyst longevity by locally removing out the precious metal coatings whilst causing deteriorations in emissions.

Equally important is the fact that high flow resistance of the converter system will limit the peak power of the engine and penalize the vehicle fuel economy. Therefore, it is necessary to investigate the flow characteristics of the converters and then optimize them.

1.5 APPLICATION OF COMPUTATIONAL FLUID DYNAMICS TOOLS

Design of catalytic converters involves various parameters and thus the fabrication and verification of their performance by varying the parameters in different combinations involves a lot of time and cost. In order to reduce the effort to optimize the performance, numerical simulation tools play an important role.

Chapter 2

CHAPTER 2

LITERATURE SURVEY

M. Bernaschi, S. Succi, G. Bella, and H. Chen.(1999). Monolith is characterized by the cell density (expressed as Cells Per Squared Inch), the substrate wall thickness and the cell hydraulic diameter, length and shape. The cell density determines the available geometric surface area, which is directly proportional to the active catalytic area by means of the coating properties. The cell density also contributes to determine the frontal area: it influences the resistance to the flow and then the engine backpressure for a given catalyst volume. A high CPSI is then required to optimize the surface available for the chemical reactions. On the other side, a elevated cells per square inch also gives great pressure drop and manufacturing costs with some influences on the mechanical durability.

Numerical analysis has been performed by simulating heat and mass transfer processes in a single channel of a catalytic converter. Calculations have been done by using the CFD package FLUENT 6.1. FLUENT simultaneously solves the momentum, continuity, and energy equations by means of a control volume based technique. A passive scalar equation has been also resolved to follow the evolution of a pollutant species in the domain.

It was concluded that substrate materials influence the channel cross-section shape as well. ceramic monoliths are usually produced by extrusion and their typical shape is square or hexagonal, whereas metal substrates are usually produced by stacking different metal foils and their shape may be sinusoidal (usually referred as corrugated) or triangular.

With respect to the same overall channel characteristics (i.e. the hydraulic diameter D_h), the various cross section shapes show a different behavior in terms of heat and mass transfer properties.

As for a defined engine, catalyst volume and weight are determined by converter performances, a proper comparison among different substrate materials should also be made taking into account the shape effect. The compared analysis of different cell shapes performance are important to determine the best compromise between the two counter-acting processes: the pollutant conversion rate, directly proportional to the surface characteristics, and the pressure drop, which has an inverse dependence on D_h.

Kerwin Strauss, Alan C Brent and Sibbele Hietkamp (1999). The number of factors have contributed activities to optimize the design of close coupled catalytic converter. Two important factors of them are flow distribution and pressure drop within the exhaust system. An uniform distribution of the exhaust gases across the frontal area of the catalytic monolith permits the achievement of the maximum conversion efficiency and enables a consistent space velocity and smaller temperature gradients in the catalytic converter.

This also has a positive influence on the aging and durability performance of the catalytic converter. But, the velocity distribution within closed coupled catalytic converter usually is not uniform due to the limitations of junction and manifold curvature.

The numerical study of a three dimensional compressible flow in a Close-coupled Catalyst Converter (CCC) system was performed to investigate the flow characteristics and the flow distribution of exhaust gases. An exclusively experimental optimization of these design parameters is extremely time consuming and expensive.

However, through CFD analysis, the design and optimization of the exhaust manifold and catalytic converter system can be achieved more effectively. Hence, CFD analysis of fluid flow in I.C. engine has been performed as a useful tool of engineering with the help of high performance computers and accurate numerical scheme.

It was concluded that unsteady flow analysis shows that severe interferences of each pulsating exhaust gas flow as well as geometric factors (junction, mixing pipe, cell shape etc.) influence greatly on the flow uniformity and flow characteristic in substrate. The results can be applied for the catalytic converter design.

R.E. Hayesa, , L.S. Mukadia, M. Votsmeierb, and J. Gieshoffb (2000). In this a mathematical model of the flows in honeycomb monolith was established by an equivalent continuum approach, and the commercial code STAR-CD was utilized to simulate multi-dimensional steady turbulent airflows in catalytic converters with different configurations. In order to verify the computing model, a pitot tube was used to measure the velocity distribution in the converter.

Conducted simulation which shows that, the larger the inlet cone angle the more the pressure loss and maldistribution in converters, however, when the angle enlarges enough its effect on flows will be obviously decreased thereafter.

An enhanced diffusion header has benefits to the flow characteristics. Compared with the inlet cone angle, the outlet cone angle has little influences on the performance of flows. The spherical shape of the front face of monoliths proposed by authors is capable of improving the flow distribution.

It was concluded that the monolith location has no significant effects on the flow quality. In addition, the larger the gap between two monoliths the more uniform the flow distribution for the second monolith but the less for the first. These results offer a practical guide to the optimum design of automotive catalytic converters.

The purpose of this study is to use multi-dimensional CFD tools to set up the fluid dynamic mathematical model of catalytic converters and study the structural effects on the flow distribution as well as pressure loss in converters.

Griselda Corro, M. Paz Elizalde and Angeles Velasco (2002) stated in their literature, hexagonal cell substrates have been promoted to be beneficial for the reduction of NOx emissions of gasoline direct injection engines. The uniform washcoat thickness in a hexagonal cell can improve sulfur desorption, which enhances the durability of NOx-storage performance of the catalyst.

Conducted experiments by considering all these advantages of thin wall and ultrathinwall substrates, design trade-offs, as well as the potential benefits of a uniform washcoat thickness, a ceramic substrate was designed integrating all three properties, i.e. a high cell density, ultrathin walls, and a hexagonal cell geometry. Square cell ceramic substrate more washcoat may be found in the corners. However, for NO_x-adsorber applications an even washcoat distribution is desired

It was concluded that this could be achieved by changing the cell shape to hexagonal geometry. Therefore, substrates with hexagonal cells were also considered for the design phase. Effect of Cell Geometry on Emissions Performance of Ceramic Catalytic Converters

Y O.D. Makinde. Developing ultra thin wall ceramic substrates is necessary to meet stricter emissions regulations, in part because substrate cell walls need to be thinner in order to improve warm-up and light-off characteristics and lower exhaust system backpressure. whereas square cells are used world-wide in conjunction with oxidation and/or three-way catalysts, hexagonal cells, with features promoting a homogeneous catalyst coating layer, have found limited use as a NO_x absorber due to its enhanced sulfur desorption capability. Substrates having square cell structure are the worldwide standard with oxidation and/or three-way catalysts.

It was concluded that for NO_x adsorption systems, the hexagonal cell, which can provide a more homogeneous washcoat layer, is in limited use.

A. P. Martin, N. S. Will and A. Bordet Johnson Matthey P. Cornet, C. Gondoin and X. Mouton Renault.et.al (1998). Calculating the uniformity for the different pipe diameters by creating computational models using PHOENICS and STAR-CD which solve equations of motion for incompressible, turbulent flows.

The effect of including a non-adiabatic reaction model into a flow model has been shown to have little effect on the flow distribution predictions. The models for this study were therefore limited to modeling the flow patterns and were not concerned with heat transfer and chemical reaction.

It was concluded that all the models can be assumed as incompressible flow. The k-e model was used to model turbulence. Axial fluxes within the monolith were set to zero. The flow within the monolith channels can be treated as being laminar and so the Hagen-Poiseuille equation was used to model pressure loss in this region.

Cristian Ciardellia, Enrico Tronconia, Daniel Chatterjee . Multi dimensional calculation method to simulate the warm-up characteristics of closed coupled catalytic converter systems. First one dimensional gas exchange simulation and three dimensional exhaust gas flow were combined to simulate the pulsating flow caused by the gas exchange process the gas flow calculation and the heat transfer calculation were then combined to simulate the heat transfer in the exhaust manifold and the catalyst under pulsating flow.Close-coupled catalyst placed just downstream of the exhaust manifold was affected by exhaust pulsation.

It was concluded one dimensional gas exchange simulation was run to obtain data at both inlet and outlet of the catalyst for one cycle. Velocity, temperature and density were obtained at the inlet of the catalyst and pressure and temperature data were obtained at the outlet. Next a three dimensional calculation was executed using the results of one dimensional calculations as boundary conditions.

It was concluded that the flow was assumed to be compressible, and the mass, momentum, energy, turbulence energy, and its dissipation (k-ε) model were used. The law of wall was used at the wall boundary and upwind differencing scheme was sued.

Fluctuations in pressure in the exhaust manifold at various crank angles was measured with piezo electric transducer and compared with predicted results. To predict the warm-up characteristics, chemical reactions were not considered and hence a dummy catalyst with double metals was used. a simplified catalyst honeycomb was used to reduce the complexity arising when using large computational grids and too much processing time. In heat transfer simulation, widths are 0.5mm ceramic carrier lattice with approximately 5,000,000 grids were considered. For the flow calculation, honey comb is modeled as the porous medium without fine grid based on the assumptions of one dimensional flow and pressure loss determination by mean velocity at each cell.

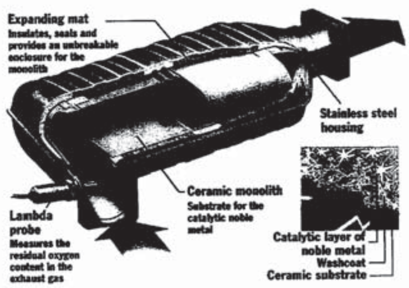
Chapter 3

CHAPTER 3

CATALYTIC CONVERTER

3.1 BASICS

The term Catalytic Converter covers the stainless steel box mounted in the exhaust system. Inside the cover is the catalyst, a ceramic or metallic base with an active coating incorporating alumina, ceria and other oxides and combinations of the precious metals platinum, palladium and rhodium. The base can be protected from vibration and shock by a resilient ceramic or metallic 'mat'



AN EXPLODED VIEW OF CATALYTIC CONVERTER

Catalytic converters, fitted in series with the exhaust pipe of gasoline fueled vehicles, convert over 90 percent of hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NO_x) from the engine into less harmful carbon dioxide (CO_2), nitrogen and water vapour. Since catalytic converters were first fitted to cars in 1974, more than 12 billion tons of harmful exhaust gases have been prevented from entering the earth's atmosphere. More than 96 percent of cars manufactured today are equipped with catalysts.

Catalytic converters can either be an oxidation or three-way type. Oxidation catalysts convert carbon monoxide (CO) and hydrocarbons (HC) to carbon dioxide (CO_2) and water, but have little effect on nitrogen oxides (NO_x) and particulate matter. Three-way catalysts operate in a closed-loop system together with a lambda, or oxygen, sensor to regulate the air/fuel ratio on gasoline engines. The catalyst can then at the same time oxidize CO and HC to CO_2 and water while reducing NO_x to nitrogen.

Most cars today are equipped with a three-way catalytic converter. The term Three-way refers to the three emissions it helps to reduce, carbon monoxide, hydrocarbons or volatile organic compounds (VOCs) and NOx molecules. The converter uses two different types of catalysts, a reduction catalyst and an oxidization catalyst. Both types consist of a base structure coated with a catalyst such as platinum, rhodium and/or palladium. The scheme is to create a structure that exposes the maximum surface area of the catalyst to the exhaust flow, while also minimizing the amount of catalyst required.

The inside of the catalytic converter is a honeycomb set of passageways or small ceramic beads coated with catalysts. A chemical reaction takes place to make the pollutants less harmful. There are many passages for the exhaust gases to flow, to allow for the maximum amount of surface area for the hot gases .

3.2 DESIGN OF CATALYTIC CONVERTER

In designing an efficient and durable catalytic converter, the first step is to identify the vehicle specific objectives with respect to:

a) Engine emissions
b) Available space
c) Converter size, contour and location
d) Fuel management
e) Acceptable power loss.

Including the design of the catalytic converter in the early stages of a vehicle's development can help in optimizing the performance and cost of the emissions-control system.

3.3 CATALYZED MONOLITH NOMENCLATURE

The common nomenclature is to state the wash coat loading in grams per cubic inch (g/in^3.) and in grams of catalytic component (especially for precious metals) per cubic foot (g/ft^3) of monolith. The monolith or honeycomb volume is calculated based on its cross-sectional area and length. The cell density is always stated when describing the finished catalyst dimensions. This is also very important when a space velocity is stated

Chapter 4

CHAPTER 4

CATALYTIC CONVERTER SUBSTRATE

4.1 MONOLITHIC MATERIALS AS CATALYST SUBSTRATES

Monolithic or honeycomb materials offer a number of advantages over more traditional pellet-shaped catalysts and are now widely used as supports in environmental applications. It is unitary structure composed of inorganic oxides or metals in the structure of a honeycomb with uniform sized and parallel channels that may be square, sinusoidal, triangular, hexagonal, round and so on.

The catalyzed coating is composed of a high-surface-carrier such as Al_2O_3 impregnated with a catalytic components. This is referred to as the catalyst wash coat. Monoliths offer a number of engineering design advantages that have led to their widespread use in automobile applications. One of the most important is low pressure drop associated with high flow rates.

The monoliths have a large open frontal area and with straight parallel channels offer less resistance to flow than does a pellet type catalyst. Low pressure drop translates to lower compressor cost for stationary applications and greater power saving for mobile sources. Other advantages include excellent attrition resistance, god mechanical properties, compact, and freedom in reactor orientation.

4.2 REQUIREMENTS FOR SUBSTRATES

1. It must be coatable with high BET area washcoat.
2. It must have low thermal mass, low heat capacity, and efficient heat transfer to permit gaseous heat to heat up the catalyst carrying washcoat quickly, notably during light off.
3. It must provide high surface area per unit volume to occupy minimum space while meeting emission requirements.
4. It must withstand high-use temperature.
5. It must have good thermal shock resistance due to severe temperature gradients arising from fuel mismanagement and/or engine malfunction.
6. It must minimize backpressure to conserve engine power for rapid response to transient loads.
7. It must have high strength over the operating temperature range to withstand vibration loads and road shocks.

A ceramic honeycomb catalyst structure of a catalytic converter

4.3 DESIGN AND SIZING OF SUBSTRATES

The cell size has a strong bearing on cell density (n), geometric surface area (GSA), open frontal area (OFA), hydraulic diameter (Dh), bulk density (ρ), thermal integrity factor (TIF), mechanical integrity factor (MIF), resistance to flow (R_f), bulk heat transfer (H_s), and lightoff (LOF),which in turn affect both the performance and durability of the catalytic converter.

TIF is a measure of temperature gradient the substrate can withstand prior to fracture; MIF is a measure crush strength of the substrate in the diagonal direction; R_f is a measure of backpressure; H_s is a measure of steady state heat transfer and LOF is a measure of light off performance.

An ideal substrate must offer high D_h , GSA, OFA, TIF, MIF ,Hs and LOF values and low ρ , and R_f values. For good light off performance, the substrate must have high LOF value. For conversion efficiency under steady state or warmed up conditions, the substrate must have high n, high GSA, and high Hs values.

For low backpressure the substrate must have high OFA, large D_h, and a low R_f value. And finally for high mechanical and thermal durability the substrate must have high MIF and TIF values.

Chapter 5

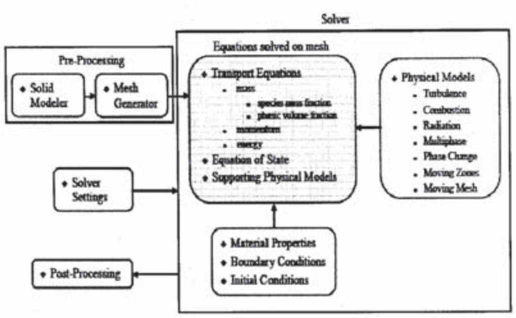
CHAPTER 5

COMPUTATIONAL FLUID DYNAMICS

5.1 What is Computational fluid dynamics?

- Computational Fluid Dynamics (CFD) is the science of predicting fluid flow, heat transfer, mass transfer, chemical reactions, and related phenomena by solving mathematical equations that represent physical laws, using a numerical process
  - Conservation of mass, momentum, energy, species, ...
- The result of CFD analyses is relevant engineering data:
  - Conceptual studies of new designs
  - Detailed product development
  - Troubleshooting
  - Redesign
- CFD analysis complements testing and experimentation
  - Reduces the total effort required in the laboratory

5.2 CFD modeling overview



5.3 CFD Analysis: Basic steps

5.3.1 Problem Identification and Pre-Processing

- Define your modeling goals.
- Identify the domain you will model.
- Design and create the grid.

5.3.2 Solver Execution

- Set up the numerical model.
- Compute and monitor the solution.

5.3.3 Post-Processing

- Examine the results.
- Consider revisions to the model.

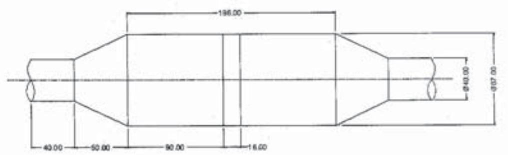
Chapter 6

CHAPTER 6

MODELING AND ANALYSIS

6.1 MODEL

The 2-D model of Maruti Zen catalytic converter is done by using GAMBIT (Geometry And Mesh Building Intelligent Toolkit).



ALL DIMENSIONS ARE IN mm

Fig.1DIMENSION OF THE CATALYTIC CONVERTER

6.2 GEOMETRIC PROPERTIES OF CELL SUBSTRATE

6.2.1 CELL DENSITY:

The cell density is defined as the number of cells per square inch of the cross-sectional area.

6.2.2 GEOMETRIC SURFACE AREA(GSA):

The geometric surface area is defined as the wall area over which the washcoat is applied per unit volume.

6.2.3 OPEN FRONTAL AREA (OFA):

Open frontal area is expressed by the ratio of open cell area to the unit-cross sectional area.

6.3 PARAMETERS OF SQUARE AND HEXAGONAL CELL

The geometric parameters which define the cells are the cell spacing L, wall thickness t and fillet radius R.

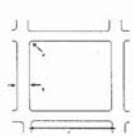


Fig.2 SQUARE CELL GEOMETRY

Fig. 3 HEXAGONAL CELL GEOMETRY

6.4 GAMBIT

The 2D model of the Maruti Zen catalytic converter is modeled by using GAMBIT which is a preprocessor for FLUENT. The quadrilateral mapped mesh is generated and the mesh is examined for its quality. The mesh generated model is shown in figure

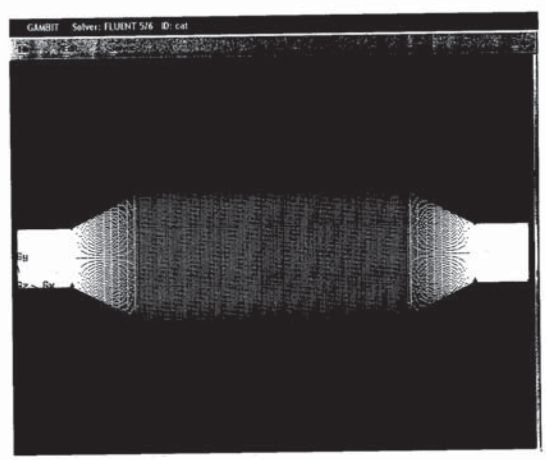


Fig.4 MESH GEOMETRY

The enlarged view of the mesh geometry is shown in figure After examining the mesh quality, the FLUENT 5/6 solver is chosen and the boundary type conditions and continuum conditions are given. Then the boundary zone assigned model is exported as the 2D mesh file.

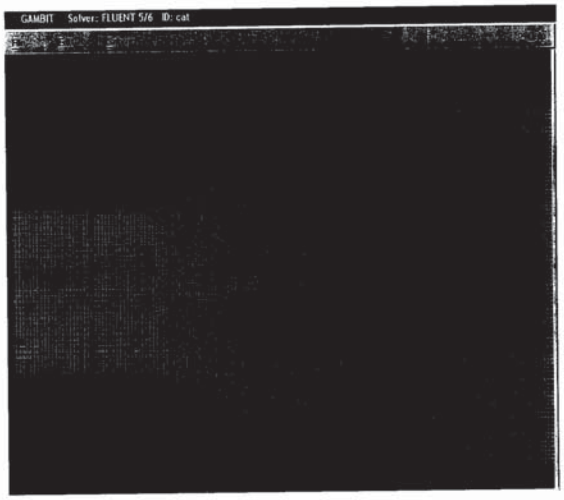


Fig.5 ENLARGED VIEW OF THE MESH GEOMETRY

6.5 FLUENT

6.5.1 INTRODUCTION

FLUENT is a state-of-the-art computer program for modeling fluid flow and heat transfer in complex geometries. Fluent provides complete mesh flexibility, solving your flow problems with unstructured meshes that can be generated about complex geometries with relative ease. Supported mesh types include 2D triangular/quadrilateral, 3D tetrahedral/hexahedral/pyramid/wedge, and mixed (hybrid) meshes. Fluent also allows you to refine or coarsen your grid based on the flow solution.

This solution-adaptive grid capability is particularly useful for accurately predicting flow fields in regions with large gradients, such as free shear layers and boundary layers. In comparison to solutions on structured or block structured grids, this feature significantly reduces the time required to generate a ``good" grid. Solution-adaptive refinement makes it easier to perform grid refinement studies and reduces the computational effort required to achieve a desired level of accuracy, since mesh refinement is limited to those regions where greater mesh resolution is needed.

Fluent is written in the C computer language and makes full use of the flexibility and power offered by the language. Consequently, true dynamic memory allocation, efficient data structures, and flexible solver control are all made possible. In addition, fluent uses a client/server architecture, which allows it to run as separate simultaneous processes on client desktop workstations and powerful compute servers, for efficient execution, interactive control, and complete flexibility of machine or operating system type.

6.6 SOLVER EXECUTION

6.6.1 Import and scale mesh file.

The 2D double precision version of the FLUENT is imported from its preprocessor GAMBIT. The grid is checked for the domain extents and the volume statistics. All physical dimensions initially assumed to be in *meters* and the grid is scaled accordingly.

6.6.2 Physical models.

A 2D segregated solution method, implicit solution formulation and a steady state flow is opted with absolute velocity formulation. The standard model is selected under the viscous model for the turbulent flow calculation with the standard wall function as the near wall treatment. The energy equation is enabled. The fluid medium is assumed as the ideal gas and the fluid properties are given as specified in table

TABLE.1 PROPERTIES OF THE FLUID

Specific heat capacity (j/kg.K)	1047
Thermal conductivity (W/m.K)	0.0454
Viscosity (kg/m-s)	2.93e-05
Molecular weight (kg/kgmol)	28.966

The operating pressure and temperature is set as 101325 Pascal and 300K. The inlet velocity is set as 17 m/sec. The intensity and hydraulic diameter is set for the turbulence specification method and the turbulence intensity is taken as 5%.

Assuming the inlet exhaust gas temperature as 300° C and volumetric efficiency as 80%. At the outlet the pressure is set as 0 gauge pressure. Exhaust flow after the devices is vented to the environment and the backflow temperature as 273 K.

The substrate region is treated as the laminar and porous zone. The porosity and the viscous resistance values are given as in table .The porosity is calculated using the formula given below:

$$\Psi = (1 / l^2)*a$$

Where, l = length of the cell in mm.

a = shape factor in mm.

Where, a = shape and friction factor (for square cell = 14.2 and Hexagonal cell = 15.0)

The solution is initialized. The simple scheme was used for pressure-velocity coupling. The following under-relaxation factors are used:

Pressure: 0.25

Momentum: 0.6

Turbulence k: 0.7

Turbulence e: 0.7

Turbulent viscosity: 0.9.

For this standard condition taken catalytic converter which has the square type honey comb is analyzed. Same catalytic converter is also analyzed for various velocities (17, 20 and 23 m/s)and for different mesh density. These three velocities are also taken and analyzed for the hexagonal type catalytic converter for various mesh density. The analyzed diagrams and graphs are plotted below.

TABLE .2

MASS FRACTION ON DIFFERENT VELOCITY OF SQUARE AND HEXAGONAL CELLS

VELOCITY (M/S)	17	20	23
MASS FRACTION ON SQUARE CELLS (L = 0.45)	3.26E-01	1.68E-01	2.13E-.1
MASS FRACTION ON HEXAGONAL CELLS (L=0.45)	1.83E-01	2.00E-01	2.13E-01
MASS FRACTION ON SQUARE CELLS (L =0.5)	4.00E-01	2.80E-01	2.59E-01
MASS FRACTION ON HEXAGONAL CELLS (L=0.5)	2.23E-01	2.46E-01	2.58E-01

Result of square and hexagonal cells (l = 0.45)

Velocity = 17

Fig.6 Contours of static pressure

Fig.7 Velocity magnitude

Velocity = 20

Fig.8 Contours of static pressure

Fig.9 Velocity magnitude

Velocity = 23

Fig.10 Contours of static pressure

Fig.11 Velocity magnitude

Hex 0.45 velocity 17

Fig.12Contours of static pressure

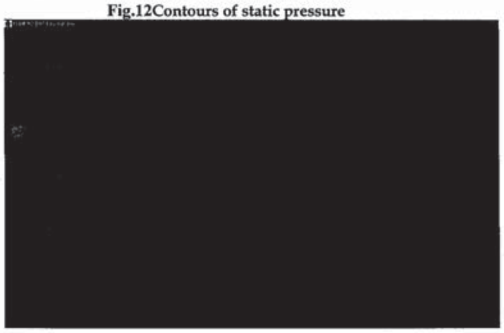


Fig.13 Velocity magnitude

Velocity=20

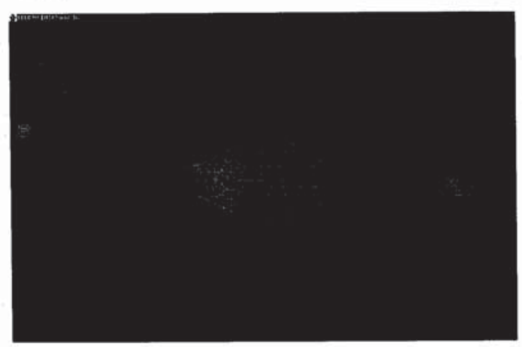


Fig.14 Contours of static pressure

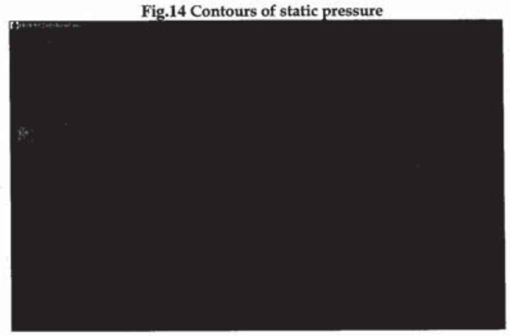


Fig.15 Velocity magnitude

Velocity = 23

Fig.16 Contours of static pressure

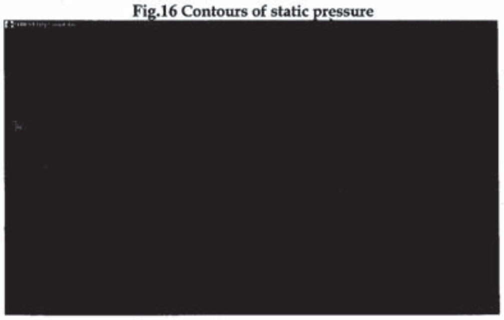


Fig.17 Velocity magnitude

Result of square and hexagonal cells (l = 0.5)

Velocity 17

Fig.18 Contours of static pressure

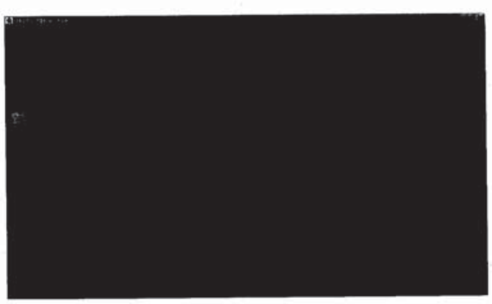


Fig.19 Velocity magnitude

Velocity 20

Fig.20 Contours of static pressure

Fig.21 Velocity magnitude

Velocity 23

Fig.22 Contours of static pressure

Fig.23 Velocity magnitude

Hex 0.5
Velocity 17

Fig.24 Contours of static pressure

Fig.25 Velocity magnitude

Velocity 20

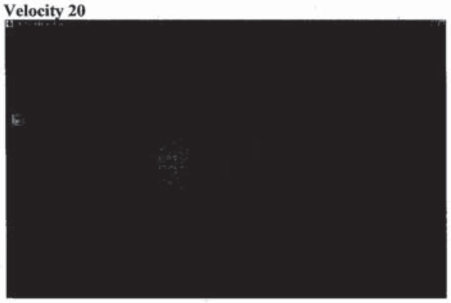


Fig.26 Contours of static pressure

Fig.27 Velocity magnitude

Velocity 23

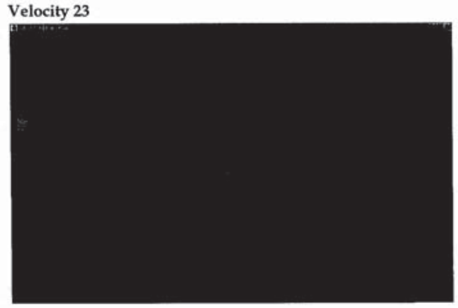


Fig.28 Contours of static pressure

Fig.29 Velocity magnitude

Chapter 7

RESULT AND DISCUSSION

Catalytic converters are very much used to control the pollution caused by means of automobiles. Honeycomb of the hexagonal and square type are compared for the three different velocities .in the square type low velocity analysis shows that the mass flow rate is low compare to the higher velocities. Mid velocity the mass flow is minimum.

Hexagonal type catalytic converter low velocity analysis shows the mass flow rate is little bit high compare to square type honeycomb. Higher velocity mass flow rate is low compare to square type. Velocity and pressure graph for the square type shows that the velocity is minimum and the pressure is high in the outlet.

Comparing the graphs of velocity and pressure the mass flow rate is low in the hexagonal type catalytic converter. It shows that honeycomb which has the hexagonal type gives the better performance

CONCLUSION

Comparing the hexagonal and square type honey combs for different mesh density and different velocities hexagonal cell honey comb gives the low mass flow rate compare to square cell catalytic converter .so that hexagonal type honey comb gives the better performance compare to square type honey comb. It improves the efficiency of the catalytic converter. Efficiency is increased similarly pollution caused by the automobile is also reduced.

Chapter 8

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