MODIFICATION CHANGES AND EXPERIMENTAL ANALYSIS IN THE THREE WAY CATALYTIC CONVERTER

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ABSTRACT–The catalytic converter is a device which converts harmful exhaust gases from internal combustion engine into harmless gases. Harmful gases like NOX, CO, unburned HC etc. are converted into N2, CO2, H2O respectively. Internal Combustion engines generate undesirable emissions during the combustion process, which include, NOX CO, unburned HC, smoke etc. Apart from these unwanted gases, it produces Particulate Matter (PM) such as lead, soot. All these pollutants are harmful to environment and human health. They are the main causes for greenhouse effect, acid rain, global warming.

INDEX TERMS– Minimum 7 keywords are mandatory, Keywords should closely reflect the topic and should optimally characterize the paper. Use about four key words or phrases in alphabetical order, separated by commas.

2.Introduction

Energy sources can be classified into three groups is fossil, renewable, and fossil. The term fossil refers to an earlier geological age. Fossil fuels were years ago and are not renewable. The fossil energy sources are petroleum ,coal, natural gas, ot shale, and tar sands. Today, most of the energy we use comes from fossil fuels. While fossil fuels are still being created today by underground heat and pressure, they are being consumed more rapidly than they are being created. For that reason, fossil fuels are considered non-renewable; they are not replaced as soon as we use them. The renewable energy sources such as biomass, hydro, wind solar (thermal and photovoltaic). Geo thermal, marine, and hydrogen will play an important role in the future. As per US department of energy the world oil supply will reach its maximum production and midpoint of depletion sometime around the year 2020. The depleting reserves and environmental issue in addition to the ozone depletion concern have pushed the world towards searching for the alternative energy sources Future projection indicated that the only feasible option is the production of synthetic fuels derived from nonpetroleum sources. Fissile material scan sustain a chain reaction with neutrons of any energy. Thus the predominant neutron energy may be typified by either slow neutrons (i.e. a thermal system) or fast neutrons Hence fissile materials can be used to fuel: a thermal reactor, with neutron moderator, a fast reactor, with no moderator, a nuclear explosive. Environmental concerns have increased significantly in the world over the past decade, particularly after the Earth Summit '92. Excessive use of fossil fuels has led to global environmental degradation effects such as greenhouse effect, acid rain, ozone depletion, climate change, etc. There is a growing realization worldwide that something constructive has to be done soon to reduce thegreenhouse gases (GHG) emissions Use of various fossil fuels such as petroleum products and coal lead to several environmental problems such as reduction in underground-based carbon energy sources. Serious modifications in earth's surface layer, subsidence of ground surface after ex-traction of fuels and minerals etc. Usage of these fossil fuels has led to increase inCO2 levels in atmosphere from 280 PPM in pre-industrial era to 350 PPM now. These CO2 levels are still climbing as a function of fuel burnt leading to greenhouse effect, acid rains, smog and change of climate world-over. These environmental implications are being felt in day-to-day life in the form of charging weather patterns, more severe winters and summer globally, foggy conditions in several parts of the world for a prolonged period during winter months. The combustion of fossil fuel has an adverse effect on human health through increased air pollution in cities, acid rains, build ups of carbon dioxide, changing heat balance of the earth, etc. In fact, projections for the 30-year period from 1990 to2020, indicate that vehicle travel, and consequently fossil-fuel demand, will almost triple and the resulting emissions will pose a serious problem. The main reason for increased pollution levels, in spite of the stringent emission norms that have been enforced, is the increased demand for energy in all sectors and, most significantly the increased use of automobiles. The global population of motor vehicles on the roads today is half a billion, which is more than 10 times higher than what was in 1950.Emissions of many air pollutants have been shown to have variety of negative effects on public health and the natural environment. Emissions that are principal pollutants of concern include:

Hydrocarbons–

A class of burned or partially burned fuel, hydrocarbons are toxins. Hydrocarbons are a major contributor to smog, which can be a major problem in urban areas. Prolonged exposure to hydrocarbons contributes to asthma, liver disease, lung disease. and cancer. Regulations governing hydrocarbons vary according type to of engine and jurisdiction; in some cases, "non-methane hydrocarbons" are regulated, while in other cases, "total hydrocarbons" are regulated. Technology for one application (to meet a non-methane hydrocarbon standard) may not be suitable for use in an application that has to meet a total hydrocarbon standard. Methane is not directly toxic, but is more difficult to break down in a catalytic converter, so in effect a "non-methane hydrocarbon" regulation can be considered easier to meet. Since methane is a greenhouse gas, interest is rising in how to eliminate emissions of it.

• **Carbon monoxide(CO)-**A product of incomplete combustion, carbon monoxide reduces the blood's ability to carry oxygen; overexposure (carbon monoxide poisoning) may be fatal. Carbon Monoxide poisoning is a major killer.

• **Nitrogen oxides (NO.)-** Generated when nitrogen in the air reacts with oxygen at the high temperature and pressure inside the engine. NO, is a precursor to smog and acid rain. NO, is a mixture of NO, NO, and NO, NO, is extremely reactive. It destroys resistance to respiratory infection. NO, production is increased when an engine runs at its most efficient (i.e. hottest) part of the cycle.

• **Particulate matter-** Soot or smoke made up of particles in the micrometre size range: Particulate matter causes negative health effects, including but not limited to respiratory disease and cancer.

Sulphur oxide (SO)- A general term for oxides of sulphur, which are emitted from motor vehicles burning fuel containing sulphur. Reducing the level of fuel sulphur reduces the level of oxide emitted from the tailpipe. Refineries generally fight requirements to do this because of the increased costs to them, ignoring the increased costs to society as a whole.

There are various techniques to control the exhaust emission controls which are listed below:

1) Using catalytic converter
2) Exhaust gas recirculation
3) Fuel energizer

3.Number of Simulation

A single phase single species incompressible flow simulation with Air as the working fluid will be carried out in two stages:

Stage1: The mesh configuration will be chosen as MC - 1 and three geometrical variants will be considered, with inlet and outlet conical portion length as:

• 70 mm

2. Literature survey

A paper was published on the topic.

2.1

Catalytic Converter for Automotive Exhaust Emission

By Prof. BHARAT S PATEL, Mr. KULDEEP D PATEL in International Journal of Applie
Engineering Research,

Conclusion was,

Among all the types of technologies developed so far, use of Metal Monolith type catalytic converters is the best way to control auto exhaust emission.

Three-way catalyst with stoichiometric engine control systems remain the state of art method for simultaneously controlling hydrocarbon, CO and NOX emissions from vehicle.

The economic reasons, limited resources of platinum group (noble) metal and some operating limitations of platinum group metal based catalytic converters have motivated the investigation of alternative catalyst materials.

2.2

A paper was published on the topic

"DEVELOPMENT AND PERFORMANCE ANALYSIS OF NICKELBASED CATALYTIC CONVERTER"

By Narendrasinh R. Makwana, Prof.Chirag M. Amin, Prof.Shyam K. Dabhi, in International Journal of Advanced Engineering Technology

Conclusion was,

Study introduces a simple low cost; non noble (nickel) based catalyticconverter to reduce diesel engine exhaust emission.

Though not a noble metal, nickel works as a catalyst for the conversion ofpollutants in exhaust but in a limited proportion.

2.3

A review paper was published on the topic

"Development of Automobile Catalytic Converter during Last Four Decades"

By K. SrinivasaChalapathi, Dr.Ch.Bhavanarayana Murthy, Dr. B. SudheerPrem Kumar in International Journal for Research in AppliedScience& Engineering Technology (URASET)

Conclusion was

Studies both experimentally and through computer simulation of the monoliths were carried out. Initially corrugated metal sheets were used for fabrication of metal monoliths coated with Platinum/Rhodium/Palladium

Later ceramic monoliths were extruded and used. As this extrusion of ceramic materials and using noble

metals as catalysts are highly expensive, the most recent papers are devoted for finding alternative catalysts which are cost effective.

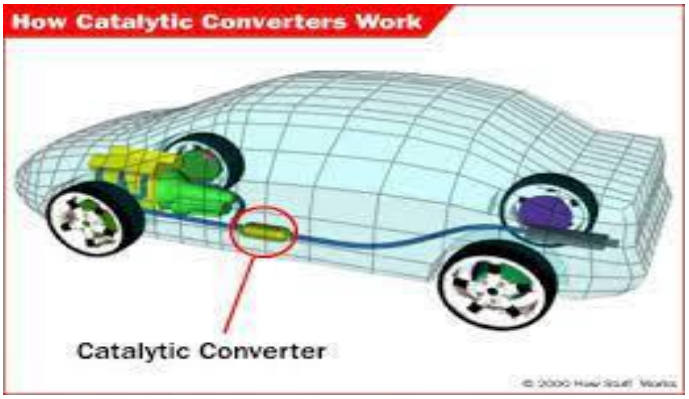
6.Catalytic Converter

3.1 What is Catalytic Converter?

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.
A catalyst is a substance that causes or accelerates a chemical reaction without itself being affected. .A catalytic converter is a device used to reduce the toxicity of emissions from an internal combustion engine.

3.2How catalytic converters look like?
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,

7.Where is it located?
The converter is between the exhaust system the engine and is normally in front of the middle of the vehicle. As shown below, there are normally oxygen sensor ports either on the converter or two placed on either side of the converter, for testing purposes.



8. Types of catalytic converter.

1. OxidationConverter:
This type is also known as a two-way catalytic converter, hecause it can only operate with hydrocarbons (unburned fuel) and carbon monoxide (caused by partially-burned fuel) 's mostly used in diesel engine. This type of catalytic converter is widely used on diesel engines to reduce hydrocarbon and carbon monoxide emissions.

1. Oxidation of carbon monoxide to carbon dioxide:
$2CO + 0_2 \rightarrow 2CO$,
2 Oxidation of hydrocarbons (unburnt and partially burnt fuel) to carbon dioxide and water $CH2(3x+1)2$ O, $xCO_2 + (x+1) H_2O$ (A combustion reaction)

2.ReductionConverter:
This type is also known as a three-way catalytic converter, because it can only operate with hydrocarbons (unburnedfuel) carbon monoxide(caused by partially-burned fuel), NOx In a three-way catalytic converter (TWC), three exhaust emissions (NOx, HC, and CO) are converted to carbon dioxide (CO_2) and water (H_2O). It consists of following process.
1. Reduction of nitrogen oxides to nitrogen and oxygen.
$2NOx = x02\ N2$
2. Oxidation of carbon monoxide to carbon dioxide:
$2C\ 0+02\ 2CO2$
1. Oxidation of unburnthydrocarbons (HC) tocarbon dioxide and water.

$C\ xH2x+2+2x02+xCO2 + 2xH20$

3. Dual Bed Converter
This is perhaps one of the most efficient converters. The dual-bed uses a combination of two and three way catalytic converters housed in a single unit. Both converters are connected through a chamber where incoming emissions are mixed. An air line plugs into the mixing chamber to force air into the chamber to react with the combined emissions and help reduce hydrocarbon and carbon monoxide emissions.

4. Monolithic converters:
The monolithic catalytic converter uses ceramic material made in a honeycomb pattern to control the exhaust gases flowing through it. The catalytic elements in the ceramic are enclosed in stainless steel. When ceramic beads are used instead of a honeycomb structure, the unit is known as a pellet catalytic converter.

8.1Catalytic Material

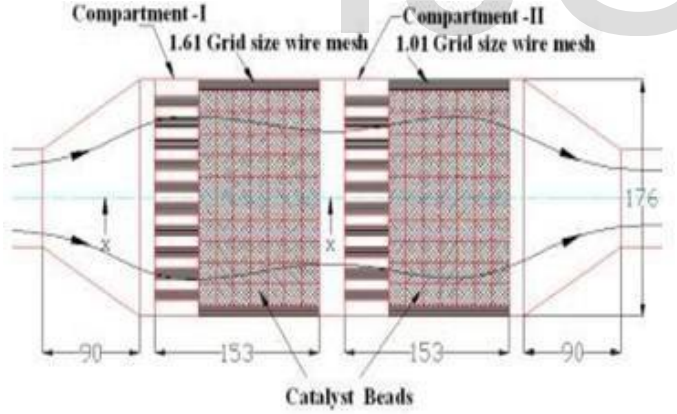
A catalytic is a substance that causes chemical reaction without being changed by the reaction. Noble metals are used as catalysts.

• Oxidation converters: - 70% platinum & 30% palladium.

• Reduction converters: - it consists of platinum & rhodium.

8.2 Construction of catalytic converter:

Geometric Modelling:-
The Catalytic converter consists of
Inlet Duct
Inlet Conical Portion
First Compartment
Second Compartment
Outlet Conical Porttion
Outlet Duct



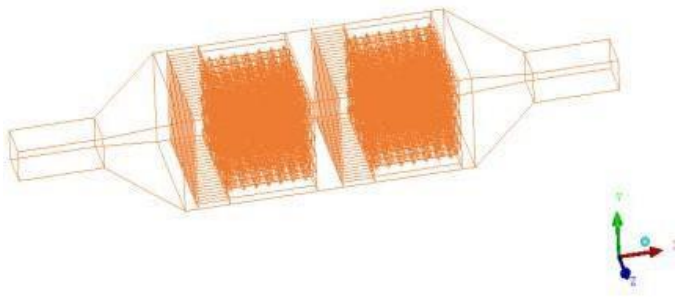


Fig.1 (a) Two dimensional geometry of catalytic converter
(b) Three dimensional model of catalytic converter.

The inlet duct and outlet duct both having rectangular cross section and they are 110 mm long. The rectangular cross section is 58 mm × 36 mm. the both inlet and outlet conical section length of the device is varied for obtaining minimum back pressure. The conical section length is 70 mm the length of the catalytic converter (excluding inlet & outlet duct and conical section) is 374 mm, to meet the less ground clearance available in present vehiclesthe height of the catalytic converter is restricted to 110 mm. which is having constant rectangular cross section of size 176 mm × 110 mm. the catalytic converter consist of two compartments. The gap between the compartments is 34 mm, the compartment is being placed 17 mm from the conical section.

5.WIRE MESH SPECIFICATIONS

In this analysis, the selected steel wire mesh grid sizes are 1.96, 1.61, 1.01 and 0.65 mm. The specifications of these wire meshes are shown in Table 1. Three models are made, each using two different grid size wire meshes placed in two separate compartments. The details of wire mesh grid sizes used in different models are shown in table 2.

Table 1: Wire Mesh Specifications

Sl. No.	Wire mesh/gap size (mm)	Wire diameter (mm)	Open Area / porosity (%)	Weight (kg/m3)	Mesh per inch	Cells per square inch	Viscous resistance [x 10^7](1/m 2)
Normal				Transverse			
1	1.96	0.58	59.3	1.71	10	100	3.846	3846

Table 2: Wire Mesh Grid Sizes

Model Name	Wire mesh grid size in compartment 1 (mm)	Wire mesh grid size in compartment 2 (mm)
MC - 1	1.	1.
	96	61

The geometrical model of catalytic converter is meshed in ICEM CFD. The complete geometry is very big because of the modeling of the catalyst bead surfaces. Therefore, only a half-section across a vertical plane cutting through the geometry will be modeled. This is required to reduce the total cell count and hence the computational effort.

Material

Air will be the working fluid considered to be operating at 3500 C and 1.35 bar. The material properties under these conditions are

Table 3: Material Property

Density=1.225kg/m3
Specific Heat= 1006.43 j/kg-k
Thermal Conductivity =0.0242 w/m-k
Boundary conditions

Boundary conditions

Boundary conditions are a set of properties or conditions on surfaces of domains, and are required to fully define the flow simulation.

The types of boundary condition used are:

- Inlet
- Outlet
- Wall

Inlet

An inlet boundary condition is used where the flow ispredominantly directed into the domain. The inlet boundary condition is velocity inlet. The engine selected for this study is a four stroke twin cylinder (80mm bore and 110mm stroke length) water cooled diesel engine. The velocity at the inlet is taken 6m/s.

Outer Wall

At outer wall the heat transfer coefficient is taken as 20 w/m2-k

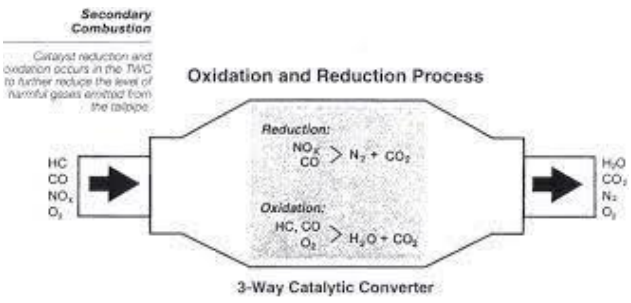
3.4 working of catalytic converter:-

In the catalytic converter, there are two different types of catalyst at work:

1. Reduction catalyst.
2. Oxidation catalyst.

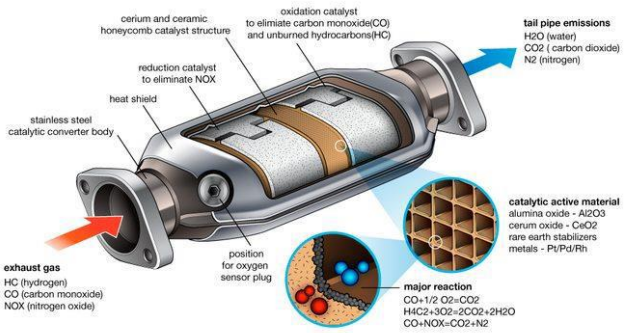
Both types consist of a ceramic structure coated with a metal catalyst, usually platinum, rhodium and/or palladium.

1. Reduction catalyst:



The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to help reduce the NOx emissions When an No or NO2 molecule contacts the catalyst, the catalyst rips the nitrogen atom out of the molecule and hold on to it, freeing the oxygen in the form of 02. The nitrogen atoms bond with other nitrogen atoms that are stuck to the catalyst, forming N2. For example: 2NO-> N2+O2 or2NO2 => N2 + 202

3.5The Oxidation Catalyst



An oxidation catalyst is a flow through exhaust device that contains a honeycomb structure covered with a layer of chemical catalyst. This layer contains small amounts of precious metal-usually platinum or palladium-that interact with and oxidize pollutants in the exhaust stream (CO and unburned HCs), thereby reducing poisonous emissions. Sometimes called an Oxy Cat when used on a diesel engine, it works together with the DPF and EGR valve to remove the bulk of unburned hydrocarbons, soot and NOx from diesel exhaust. The oxidation catalyst is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a platinum and palladium catalyst. This catalyst aids the reaction of the CO and hydrocarbons with the remaining oxygen in the exhaust gas.

For example: 2CO+02 > 2C02

4.Problem Statement

- The main challenges associated with the catalytic converters are: Catalytic Converter was to reduce/minimize the backpressure regarding to the engine and the body .

5.Objective And Scope

- The main objective of this project is to reduce the harmful emission of the automobiles through cost effective measures.

- Also to fabricate the converter by replacing the expensive metals by Mesh made up of Copper for reducing the harmful gases.

For flow calculations the differential conservation equations are integrated over a given control volume.

$$\frac{d}{dt}\int_{V(t)} \rho dV + \int_{s} \rho(U-W)\,dn = 0$$

Continuity equation
Momentum equation

$$\frac{d}{dt}\int_{V(t)} \rho U dV + \int_{s} \rho(U-W)U dn = \int_{s} \tau dn - \int_{s} \rho\overline{U \times U}\,dn + \int_{V} S_m\,dV$$

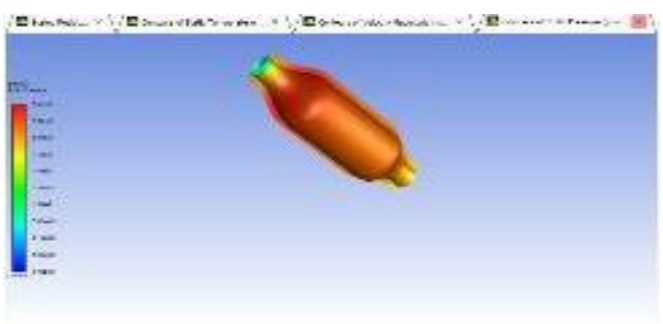
The Turbulence model used in this project work is k•ε RNG turbulence model. It is appropriate toaccount for high velocities and strong streamline curvature in the flow domain. The differential transport equation for the turbulence kinetic energy and turbulence dissipation are given below.
Turbulence.

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + P_k - \rho\epsilon$$

$$\frac{\partial(\rho\epsilon)}{\partial t} + \frac{\partial}{\partial x_i}(\rho\epsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial \epsilon}{\partial x_j}\right] + \frac{\epsilon}{k}(C_{1\epsilon}P_k - C_{2\epsilon}\rho\epsilon)$$

Kinetic energy
Turbulence dissipation

Experimental results:-
In this stage we have consider the steel wire mesh configuration as MC-1 of catalytic converter having conical portion length as 70 mm respectively. In this section Velocity and pressure contour plots on the symmetry planevectors path and Path lines originating from inlets, is plotted for this converter, pressure drop is also calculated for it.



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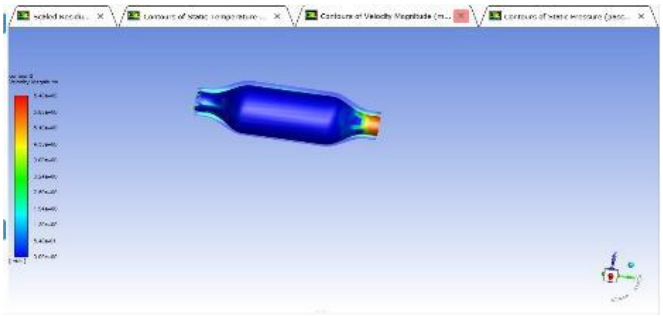

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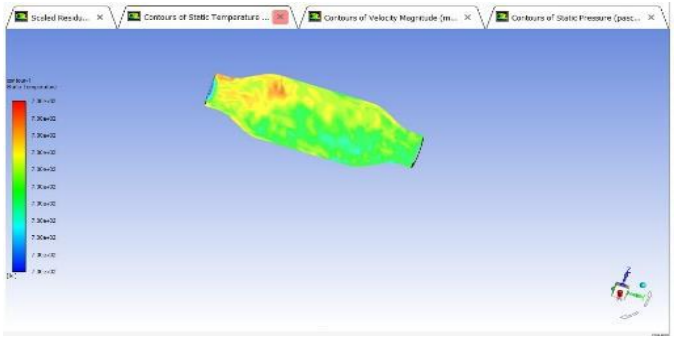

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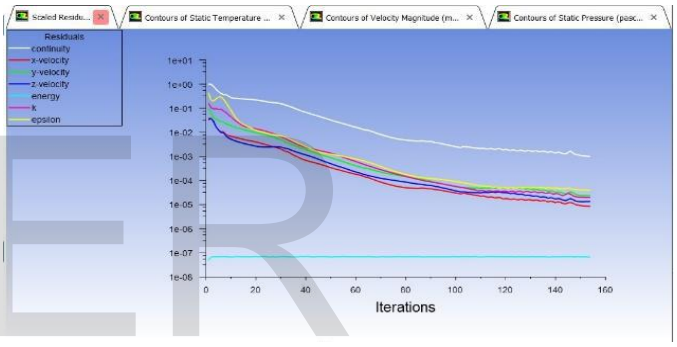

D

a. Pressure countours
b. Velocity countour
c. Temperature countour
d. iteration

Table 4: Pressure drop for catalytic converter

Position	Pressure Drop
0	0
100	0.04542
200	0.03409
300	0.3127
400	0.3189
500	0.5298
600	0.5943
700	0.6649
734	0.6792

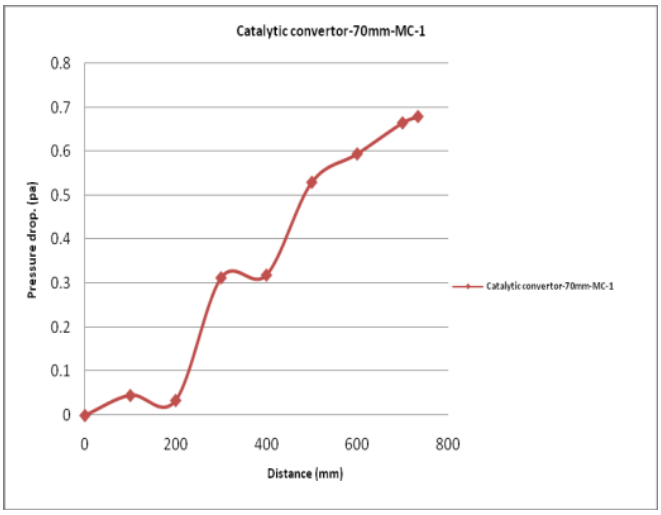

Fig.6 Pressure Drop Vs Distance of Catalytic Converter

Fig. 6 shows the variation of pressure drop along the distance of catalytic converter. As we see in the graph there is less pressure drop up to 200mm. after 200 mm there is sudden increase in the pressure drop. The sudden increase in pressure drop takes place due to presence of steel wire mesh. The steel wire mesh resist the motion of the air due to that there is sudden decrease in pressure drop takes place and again there is decrease in pressure drop after 400mm this is happen due to the air enters the second compartment and in second compartment again there is a presence of catalyst beads and steel wire mesh.

We can see from graph that the catalytic converter has the less pressure drop then the available converters in the market, except during length between 300 to 400 mm so the total pressure drop of catalytic converter model is less, so it is considered for further study. We can see from graphs that as the conical portion length increasing the pressure drop also increasing.

Conclusion:-

It is concluded that the catalytic converter made in this project has the lowest pressure drop then the normal catalytic converter available in the market. Also the fuel consumption consume is also less in this. The wire mesh design helps to limit the pressure drop to the minimum level resulting in better engine performance. The wire meshing are very hard, no wear and tear of this can take place, and hence long life of converter is assured.

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