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Two Way Catalytic Converter for 305cc Gokart

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ABSTRACT: A catalytic converter is an emissions control device that converts toxic gases and pollutants in exhaust gas to less toxic pollutants by catalyzing a redox reaction. The need for designing the catalytic converters arises because of the increasing pollution caused by vehicles. During Earlier times there were no vehicles resulting in very scarce pollution, In recent times the Vehicles are increasing and the need to stop the carbon emission and other harmful gases are bound to increase. This paper focuses how to manufacture a catalytic converter and the effect of back pressure and various dimensions of a catalytic converter. The design of oxidation catalytic converters, 3-way catalytic converters and/or SCR systems involves the determination of the loading of precious metals, and wash coat formulations. Material choice, and geometric configuration of the components of exhaust systems, (including manifolds, diffusers, setting chambers, converter housings, substrates, and contractions), and the positioning of the converter in the exhaust lines are other important design aspects. Since the 1970s significant knowledge regarding the manufacturing and utilization of catalytic converters for internal combustion engines has been acquired. However, the design of catalytic converters is still more of an empirical practice than a science. The balance of the situation may need to be shifted toward the latter as the emission standards become more stringent.

KEYWORDS: Pollutants, Redox reaction, SCR system

I. INTRODUCTION

The catalytic converter has been in use for the past 30 years as an efficient and economic solution for the reduction of pollutants emitted by the internal combustion engine, the latter being the power train for almost all vehicles in use today. The widespread use of the catalytic converter was the response of the automotive industry to the legislation of developed countries, which poses limits to the most important gaseous pollutants emitted by both gasoline and diesel engines. Since the concern about the environmental impact of the emissions of the vehicles fleet is steadily growing—especially in urban areas, where air pollution has become a major issue—emission legislation becomes gradually stricter. Accordingly, this has led to continuous efforts of the automotive industry to improve the efficiency of the catalytic converter. Today's emission standards have been lowered so much that the catalytic converter technology has been pushed to its limits and it became apparent that, in order to build vehicles that comply with the legislation, automotive engineers should tune the whole system of engine, piping, and catalytic converter. Thus there emerged the need to view the catalytic converter as a component of an integrated *exhaust after treatment system* that should be designed very accurately. In this context, the role of modelling of the components of exhaust after treatment systems is becoming increasingly important, especially as regards the catalytic converter, which is the most crucial device of such systems. Since the introduction of catalytic converters in production vehicles, catalytic converter models have been appearing in the literature in parallel with the development of new catalytic converter technologies. Nevertheless, the accuracy, reliability, and application range of catalytic converter models is still questioned. The number of modelling applications in the automotive industry remains limited, especially when contrasted to the plethora of models that appear in the literature. It seems that a complicated landscape of approaches and methodologies has been created, causing an uncertainty as regards their validity and applicability. Most probably, this adversely affects their application in everyday practice, although modern modelling methodologies have been greatly improved and, in many cases, they have been successfully incorporated in the process of exhaust after treatment systems design.

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1.1 EMISSION REGULATION

Mature emission regulations for commercial vehicles, the world is currently governed by three major legislative standards:

- Environmental Protection Agency or EPA Standards
- California Air Resources Board or CARB Standards

European Commission or Euro Standards

	CO (g/kWhr)	HC (g/kWhr)	Nox (g/kWhr)	PM (g/kWhr)	Smoke (m ⁻¹)	Implementation Year
Euro I	4.5	1.1	9	0.4	NA	1993
Euro II	4	1.1	7	0.15	NA	1996
Euro III	2.1	0.66	5	0.1	0.8	2001
Euro III EEV	1.5	0.25	2	0.02	0.15	2003
Euro IV	1.5	0.46	3.5	0.02	0.5	2006
Euro V (proposed)	1.5	0.46	2	0.02	0.5	2009
Euro VI (g/km)	0.5	NA	0.08	0.005	NA	2014

The above data explains the need of pollution controlling devices in Automobile Industries and advancement in the preexisting technology.

For reduction in vehicular emissions, baseline technologies, mainly for CI engines-

- Direct injection
- Turbo-charging
- Air-to-air inter cooling
- Multi-valve cylinder head
- Soot Trap
- Catalytic converter
- Exhaust gas re-circulation (EGR) and SCR (for NO_x emission control)

II.BACK PRESSURE AND FACTORS AFFECTING IT:

During the exhaust stroke when the piston moves from BDC to TDC, pressure rises and gases are pushed into exhaust pipe. Thus the power required to drive exhaust gases is called exhaust stroke loss and increase in speed increases the exhaust stroke loss. The net work output per cycle from the engine is dependent on the pumping work consumed, which is directly proportional to the backpressure. To minimize the pumping work, backpressure must be low as possible. The backpressure is directly proportional to the catalytic converter design. The catalytic substrate and shape of the inlet cone contribute the backpressure. This increase in backpressure causes increase in fuel consumption.

Factors which affect the Back pressure

- Length of the substrate
- Diameter of the substrate
- Porosity of the substrate
- Velocity of exhaust flow
- Cone Angle

For the study for the governing factors various two dimensional models of catalytic converter were made and then CFD analysis was performed to visualise the exact dependence in various situations.

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2.1 Dependence of Back Pressure on Length of substrate

For this the CFD was performed at both high and low velocity to study the variation of back pressure .

At low velocity

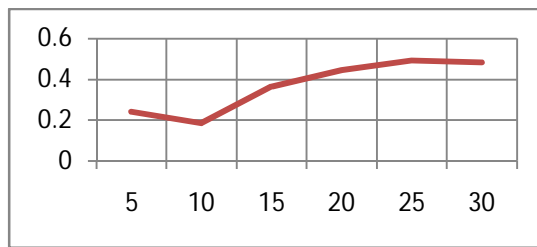


Figure 1 Variation in Back pressure VS Length(Pressure (pa)is shown in y axis and length(cm) in x axis).

At high velocity

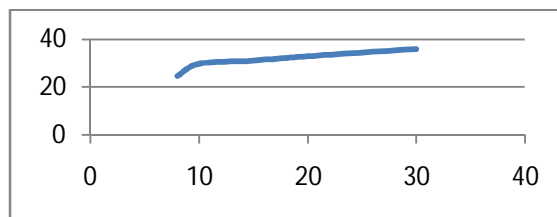


Figure 2 Variation in Back Pressure VS Length (Pressure (pa)is shown in y axis and length(cm) in x axis).

From the above analysis it is clear that Back Pressure increases with increase in length of substrate . The change in back pressure at low velocity is more sudden as compared to that accruing at high velocity .

2.2 Dependence of Back pressure on Diameter of substrate

Again for this CFD was performed at High and low velocity to study the variation.

At Low velocity

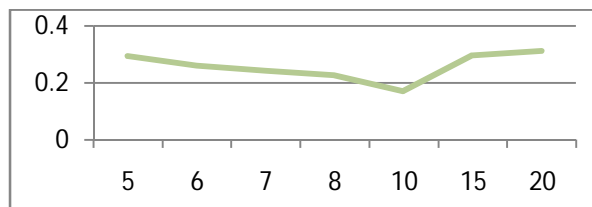


Figure 3 Back Pressure Vs Diameter of substrate(Pressure (pa)is shown in y axis and Diameter(cm) in x axis).

At High Velocity

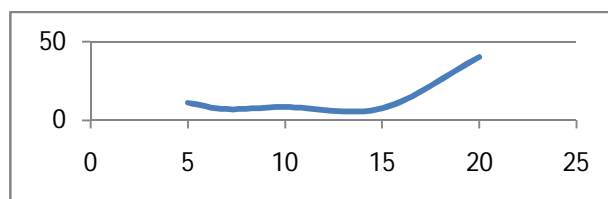


Figure 4 Back pressure Vs Diameter of substrate at High Velocity (Pressure (pa)is shown in y axis and Diameter(cm) in x axis).

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As we go on increasing the diameter of substrate back pressure decreases but at high velocity it tend to increase due to the vortex creation which increases the back pressure .

2.3 Porosity of Substrate

Porosity of substrate was changed to different values to study the change at different porosity value .

At Low Velocity

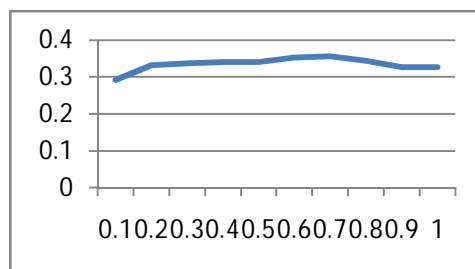


Figure 5 Back Pressure Vs Porosity (Pressure (pa)is shown in y axis and Porosity in x axis).

At High Velocity

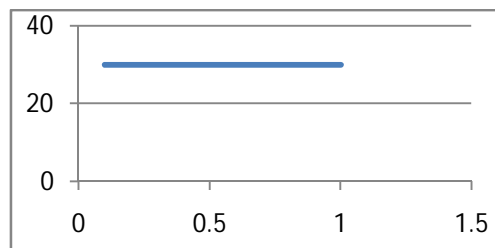


Figure 6 Variation of Back pressure Vs Porosity(Pressure (pa)is shown in y axis and Porosity in x axis).

Back pressure remains more or less constant with variation in porosity of substrate . It is seen as we increase the porosity ,velocity inside the substrate increases due to decrease in Net area .

2.4 Dependence on Cone angle

The main factor responsible for increase in back pressure inside the substrate in the formation of turbulent zones inside the substrate . This vortex creation causes the exhaust gas to rotate inside the substrate , adding to the existing back pressure and is considered as a kind of a loss. In order to remove this , a cone angle is given so that vortex creation could be avoided.

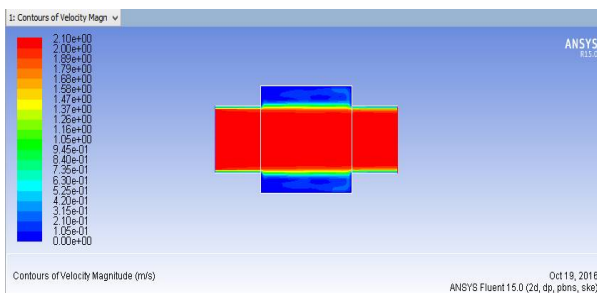


Figure 6 Velocity Profile before giving cone angle

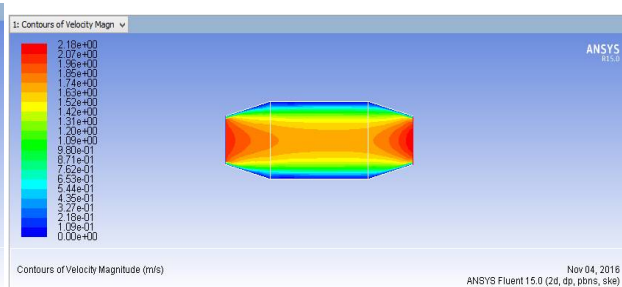


Figure 7 Velocity Profile after giving cone angle

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It is observed that velocity in the substrate with the cone angle shows a lower velocity than the one with no cone angle . This shows that cone angle is having a major influence on the Back Pressure of a catalytic converter .

III. BENCHMARKING

Table-1: Benchmarking of Catalytic converters

Vehicle name	Capacity in CC	Thickness in mm	L/D ratio
Tata Indigo	1193	4	0.75
Ford Ikon	1399	3	1.42
Hyundai ION	814	4	1.7
Honda City	1198	4	1.066
Maruti Omni	796	4	2.1
Tata Indica	1405	2	1.26

Hence from benchmarking of various catalytic converters we saw that L/D ratio ranges from 0.75 to max of 2.1 . From this we got our limits under which we are going to test our converters. when the thickness of can is taken into consideration , we saw that most of the companies are going for 4 mm catalytic converters , though Tata INDICA have used 2mm thick for their use .

IV. FINAL MODEL DESIGNING

From the results we got from benchmarking various available models of catalytic converters we got the idea of aspect ratio and using the values of space velocity as 20000 hr⁻¹ (IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 1, March, 2013 ISSN: 2320 - 8791) we tried to find the catalyst volume . Now ,

$$\text{Catalysts Volume} = \frac{\text{Volume flow rate}}{\text{Space Velocity}}$$

and,

$$V_{\text{catalyst}} = \frac{\pi}{4} * D^2 * L \text{ mm}^3$$

Now for Briggs and Stratton Engine , at 1500 rpm

$$v = 3.14 * \text{bore}^2 * \text{stroke} * \text{RPM} / (2*60)$$

$$= (3.14/4) * 79.2^2 * 61.9 * 1500/120$$

$$= 0.0152 \text{ m}^3 \text{ s}$$

$$= 13.72 \text{ m}^3 \text{ hr}$$

So we have ,

$$\text{volume flow rate } v = 13.72 \text{ m}^3 \text{ hr}$$

$$\text{space velocity} = 20000 \text{ hr}^{-1}$$

$$\text{Catalyst volume } V_{\text{catalyst}} = 6.86 * 10^{-4}$$

$$= 686.2 \text{ ml}$$

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Table - 2: Variants inspected

L/d ratio	Length in cm	Diameter in cm
0.75	7.89	10.52
1	9.55	9.55
1.3	10.38	8.75
1.5	12.52	8.35
1.8	14.13	7.85
2	15.17	7.58

Study I: In study I, the recirculation zone formation was studied. The models which will produce greater recirculation zone were omitted.

Study II: In study II, the models which had the lesser recirculation zones were studied for the flow pattern. The back-pressure characteristics of the models were modelled and the model having the lesser backpressure was taken for experimental study.

Velocity profile of all the models under study

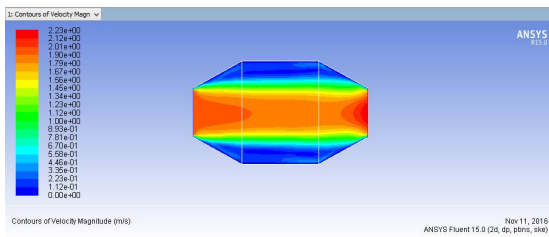


Figure 8 : Velocity profile of model 1

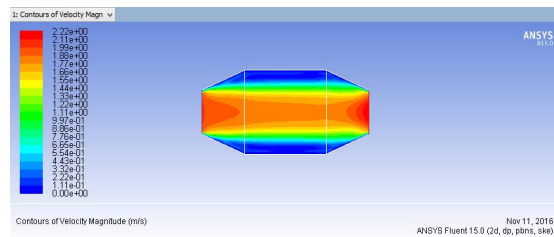


Figure 9: Velocity profile of model 2

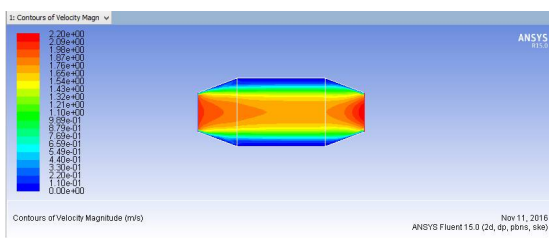


Figure 10 :Velocity profile of model 3

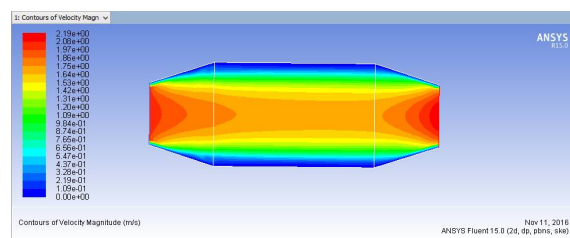


Figure 11 : Velocity profile of model 4

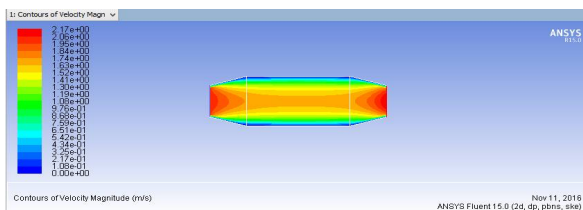


Figure 12 :Velocity profile of model 5

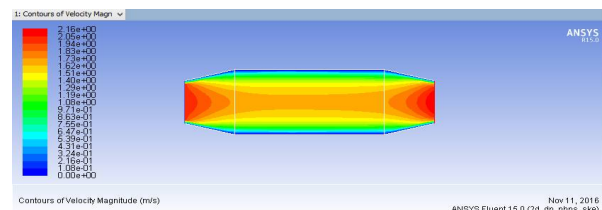


Figure 13:Velocity profile of model 6

It is observed that the recirculation zones in the models 1,2,and 3 are found to be higher than the models 4,5 and 6. The increase in recirculation causes the more in-active zones in CAT. This is termed as non-uniformity. The non-uniformity reduces the conversion of the harm gases. Also reduces the utilization of the noble materials. Also if the velocity is lower, the conversion of harmful gases increases as the gases get more time to combine.

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Table 3: Result evaluation

Model number	Back Pressure pa	Velocity m/s
1	0.613	1.79
2	0.543	1.77
3	0.514	1.65
4	0.521	1.64
5	0.527	1.63
6	0.550	1.62

Model no 6 is having the minimum velocity and an optimum back pressure and hence it was considered best for our go-kart

V. FINAL MODEL MANUFACTURING

We extracted the ceramic monolith from an old catalytic convertor of Maruti Esteem .At first we bisected the metal housing of the catalytic convertor in two halves horizontally with the help of a hand cutter .After completely removing the metal shell from the body of the catalytic convertor. We were left with the ceramic monolith that was packed with an expanding insulation mat. After complete inspection of the ceramic monolith we found that the substrate material was good enough to be used as the core material in another catalytic convertor. We then wrapped it with an expanding insulation mat that we made from glass wool. After the core was ready, we measured it with precision and used the measurement to design the metal housing in which the core would fit in accordingly. We used aluminium sheets to make the housing. The centre cylinder and the end cones were joined with the help of silver gas welding.



Figure 14: Final model manufactured

VI. RESULTS

type of vehicle	Emission Standards		Other matters
	As effective from 01 April 2008		
	Carbon Monoxide CO (% v/v)	Hydrocarbon HC (ppm v/v)	
Petrol motor bicycles and petrol motor 6 tricycles.		9000	Started, not running and 2500 RPM with NO LOAD.
Results of our vehicle	5.3	10,500	

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Abbreviations

% v/v - percentage as per volume ppm v/v - parts per million as per volume
RPM - Rounds per minutes.

VI. CONCLUSION

In the given paper the various factors that govern the flow of exhaust in the catalytic converter are studied and based upon the various experiments, we prepared our final model. The effect of parameters such as Diameter of catalytic converter, Length of catalytic converter, Substrate used and cone angle have been taken into consideration while designing our final model. We have observed a significant amount of reduction in % of CO and through a better substrate, we could achieve better results.

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