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Original Research Paper

Engineering

Analysis of exhaust gas flow in a Three way Catalytic Converter of a Diesel Automobile using CFD Software

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ABSTRACT Stringent Euro pollution norms stipulated for exhaust emissions in a diesel automobile has inspired many researchers all over the world. The exhaust gas flow was studied for four different diffuser geometries. To obtain realistic values of geometric dimensions, reverse engineering technique was used on a second hand Catalytic converter purchased from market. The number of cells per square centimeter and the sectional dimension of square channels of monolith were measured. The geometry was constructed in ICEM CFD software. The catalytic converter was fitted on a single cylinder diesel engine in the Laboratory. Finally these realistic values of exhaust gas flow, Engine speed, pressures and velocities were used along with the geometry for running the FLUENT CFD software. This exercise was repeated for the four different geometries of diffuser. Thus using computer analysis and experiments, diffuser geometries were optimized. The triangular, circular and hexagonal cross sections of monolith channels are being analyzed in the CFD laboratory at present. The present paper reports results obtained on Square channels only, with an aim to obtain minimum back pressure on the engine.

KEYWORDS : Engine, Pollution, CFD, Three Way Catalytic Converter

Reverse engineering

Reverse engineering is the process of discovering the technological principles of a device, object, or system through analysis of its structure, function, and operation.[1] It often involves taking something (e.g., a mechanical device, electronic component, software program, or biological, chemical, or organic matter) apart and analyzing its workings in detail to be used in maintenance, or to try to make a new device or program that does the same thing without using or simply duplicating (without understanding) the original.

A secondhand catalytic converter was brought and reverse engineering was done on it by cutting it open by gas cutting. After the gas cutting was done the catalytic converter was taken out from the body and its design was studied, and dimensions of some important components were noted. Later these realistic dimensions are used for CFD model.

After carrying out Reverse engineering below parameters are obtained.

Table 1

Sl. No.	Parameter	Description
1	Type	3 – way catalytic converter
2	Shape	Elliptical
3	Major axis	150 mm
4	Minor axis	75 mm
5	Mesh sizes	1 mm
6	Production	Pressing

Fig. 1: The catalytic converter

Fig. 2: Section showing honeycomb structure

Laboratory Experiments:

To study the exhaust flow an experiment was done on the 4-stroke single cylinder diesel engine available in the laboratory.

A single cylinder, vertical, four stroke diesel engine available in thermal engineering laboratory has been modified for carrying out test along with catalytic converter.

The exhaust pipe just before muffler has been cut and flanges were welded to match the flanges on the catalytic converter. A hard PVC seal is kept between the flanges to avoid leakages. The modified test setup is shown in the figure below:

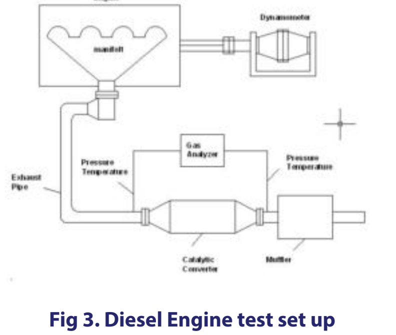

Fig 3. Diesel Engine test set up

Observations noted during the experiment:
Velocity of gas at exhaust = 5.8 m/sec, Diameter of exhaust of pipe =30mm, Length between inlet of exhaust to outlet = 415mm, Mean effective pressure Indicated mean effective pressure (Pmi) = 2.16 bar, Break mean effective pressure (Pnb) = 0.26 bar, Friction mean effective pressure (fmi) = 1.90bar
Using these experimental results, the initial conditions to be used while analyzing flow were decided as follows:
Mean Effective pressure at entry of Catalytic converter: 1.9 bar
Velocity of exhaust gases: 5.8.m/sec

Experimental results:
Tables

Temperature Measurement

- T1=Temperature of cat.con. engine started
- T2=Temperature of cat.con. 60 second after engine started
- T3=Temperature of cat.con. 120 second after engine started

TIME	TOP TEMP.	MIDDLE TEMP.	BOTTOM TEMP.
0	43	43	42
60	82	72	61
120	106	100	90

Table 2

Temperature values of catalytic converter according to the time difference.

Pressure and different types of loads applied on the engine with the attachment of catalytic converter. The graph is shown below

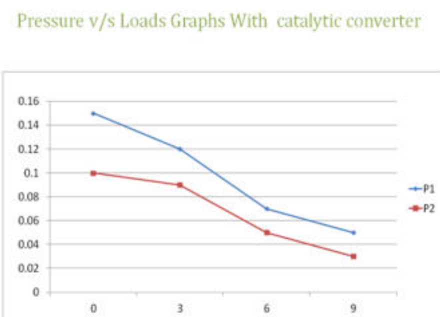

Fig 4

Pressure and different types of loads applied on the engine without the attachment of catalytic converter. The graph is shown below.

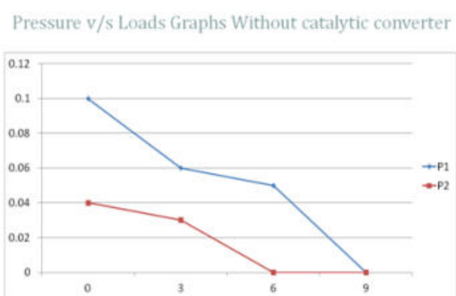

Fig 5

Table of gas flow and the velocity of a diesel engine at various loads.

Table of Gas flow (Q) m3/min

Load in Kg	Gas flow Q in m3/min	Velocity in m/sec	Gas flow in m3/min	Velocity in m/sec
0	1196	1.69	1323	1.87
3	1004	1.42	1072	1.51
6	855	1.21	957	1.35
9	840	1.18	821	1.16

Table 3

The gas flow and velocity with catalytic converter graph are shown below

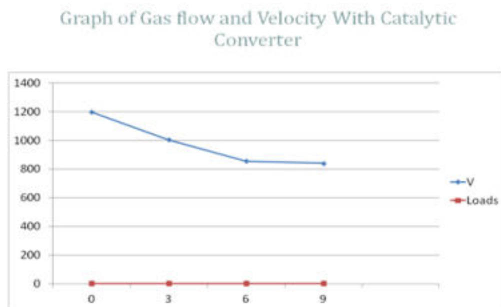

Fig 6

The gas flow and velocity without catalytic converter graph are shown below.

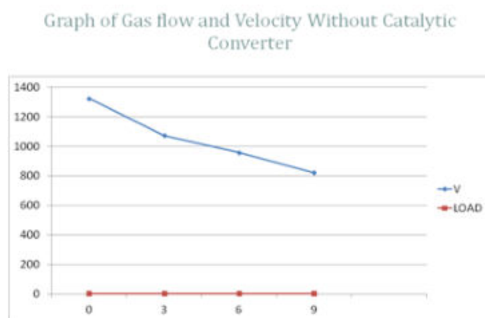

Fig 7

The experimental setup in lab with the attachment of catalytic converter to the diesel engine.

Fig 8

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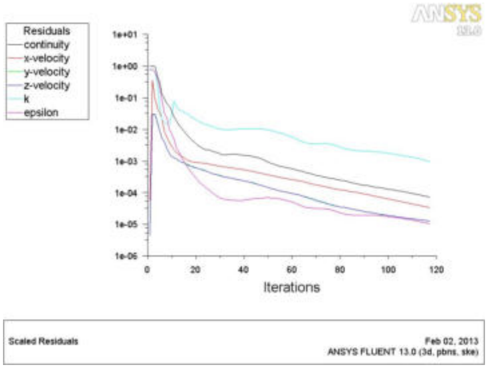
CFD ANALYSIS RESULTS

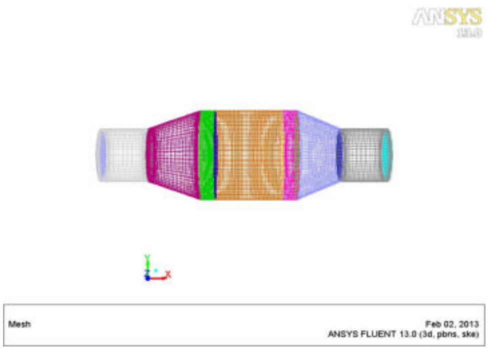
CASE 1 55 MM DIFFUSER

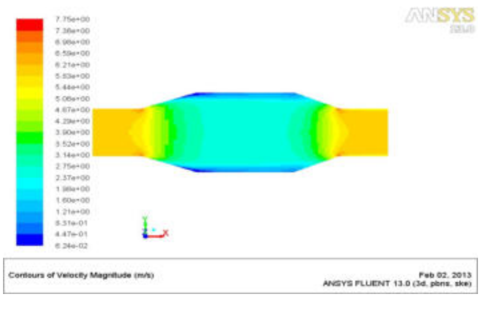


CONTINUITY=7.3322e-05, X-VELOCITY = 3.3355e-05, Y-VELOCITY= 1.2730e-05, Z-VELOCITY= 1.2757e-05, K=9.7563e-04,

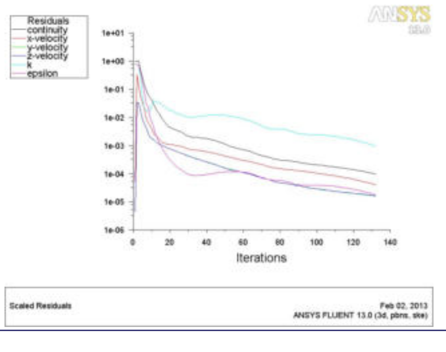
Mass flow rate	Kg/ Sec	Total Pressure	Pascal
Inlet	20729.93	Inlet	24.687746
Outlet	-20729.902	Outlet	22.197897
Net	0.0273575	Net	23.442823

VELOCITY = 6 m/s
PRESSURE = 0 Pascal
DENSITY = 1.225 (Kg/m3)
VISCOSITY = 1.7894e-05
Total Mesh part





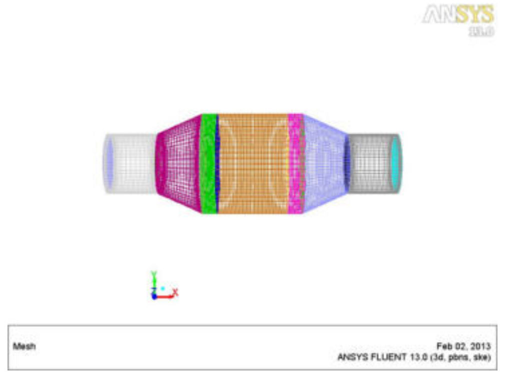
CASE 2 45 MM DIFFUSER



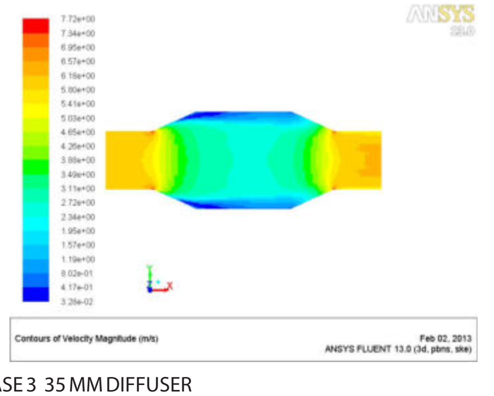
CONTINUITY=9.7782e-05, X-VELOCITY = 4.0935e-05, Y-VELOCITY= 1.6128e-05, Z-VELOCITY= 1.6289e-05, K=9.5250e-04,

Mass flow rate	Kg/ Sec	Total Pressure	Pascal
Inlet	20729.93	Inlet	25.009565
Outlet	-20729.902	Outlet	22.22412
Net	0.0273575	Net	23.615993

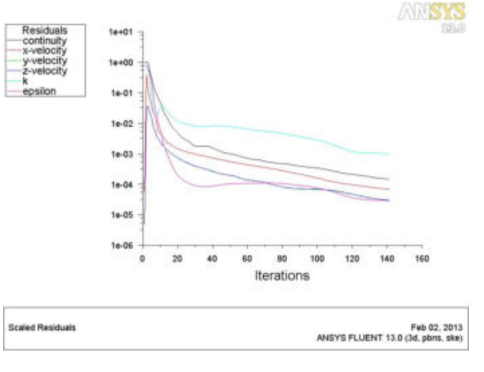
VELOCITY = 6 m/s
PRESSURE = 0 Pascal
DENSITY = 1.225 (Kg/m3)
VISCOSITY = 1.7894e-05
Total Mesh part



Velocity graph



CASE 3 35 MM DIFFUSER



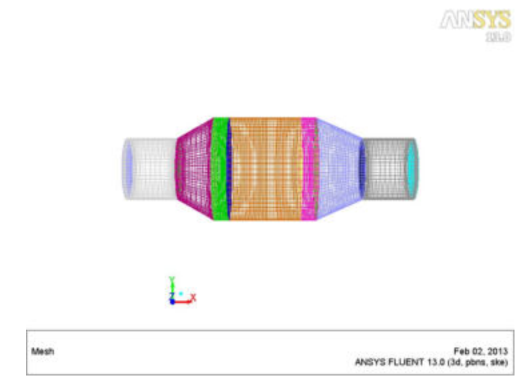
CONTINUITY=1.4643e-05, X-VELOCITY = 6.9784e-05, Y-VELOCITY= 3.0994e-05, Z-VELOCITY= 3.1154e-05, K=9.8716e-04,

Mass flow rate	Kg/ Sec	Total Pressure	Pascal
Inlet	20729.93	Inlet	26.290632
Outlet	-20729.861	Outlet	22.242544
Net	0.068359355	Net	23.266592

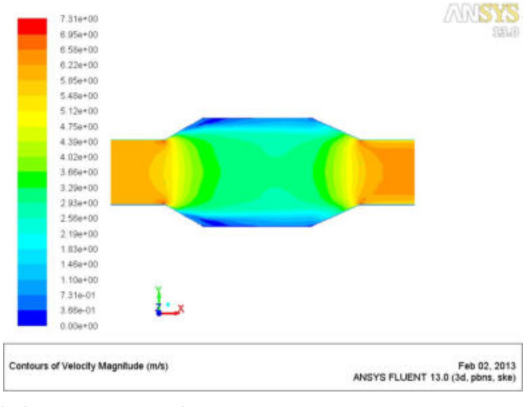
VELOCITY = 6 m/s
PRESSURE = 0 Pascal

DENSITY = 1.225 (Kg/m3)
VISCOSITY = 1.7894e-05

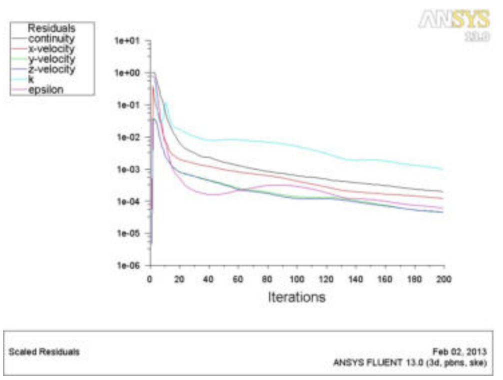
Total Mesh part



Velocity graph



CASE 4 25 MM DIFFUSER



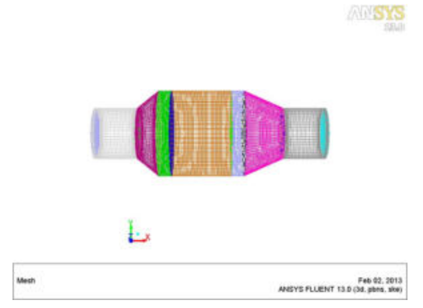
CONTINUITY=1.9716e-05, X-VELOCITY = 1.2034e-05, Y-VELOCITY= 4.4121e-05, Z-VELOCITY=4.4917e-05, K=9.9906e-04,

Mass flow rate	Kg/ Sec	Total Pressure	Pascal
Inlet	20729.93	Inlet	27.073812
Outlet	-20729.861	Outlet	22.341034
Net	0.068359355	Net	23.266592

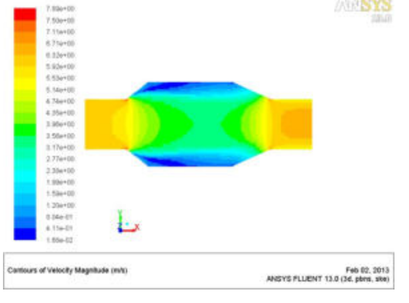
VELOCITY = 6 m/s
PRESSURE = 0 Pascal
DENSITY = 1.225 (Kg/m3)
VISCOSITY = 1.7894e-05

Total Mesh part

CONTINUITY=1.9716e-05, X-VELOCITY = 1.2034e-05, Y-VELOCITY= 4.4121e-05, Z-VELOCITY=4.4917e-05, K=9.9906e-04,



Velocity graph



CONCLUSIONS

The experimental set up used 35 mm diffuser (measured from the Catalytic converter mounted on the engine). The CFD simulation gave the pressure drop of around 4048 Pa. This is about 0.04 kg/cm2 which is matching with the experimentally measured value of pressure drop. Comparatively the pressure drop was decreasing with increasing length of diffuser. The table below shows the values for the four cases studied in CFD.

Case No	Diffuser Length (mm)	Pressure drop (Pa)
1	55	2165
2	45	2785
3	35	4048
4	25	4732

It can be seen that to get minimum pressure drop through Catalytic converter, it is essential to provide a long inlet diffuser, which help in flow stabilization. The lesser the pressure drop, the better will be the efficiency of the engine. If the diffuser is 55 mm, it gives about 47% less pressure drop.

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