© 2018 IJRTI | Volume 3, Issue 6 | ISSN: 2456-3315

CFD ANALYSIS OF EXHAUST BACKPRESSURE FOR FOUR-STROKE CI ENGINE

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Abstract: **This study is to provide details understanding for exhaust back pressure optimization of compression ignition (CI) engine. Diesel engines having less operation cost due to this these are mostly used in commercial vehicles, now days fuel consumption and engine durability plays a vital role for the overall vehicle performance. Exhaust system main function is to through away burnt gases without any leakage from combustion chamber of engine to atmosphere. Optimization of exhaust system is crucial, to achieve higher engine power output, compact components packaging, tougher emission norms and less fuel consumption. CFD analysis is used to find out pressure variation pattern due to major exhaust system component placement in complete system. Back pressure of exhaust system is increased by muffler placement toward engine and reduces by muffler moving away from engine.**

Index terms: **Back pressure, Exhaust system, CFD (computation fluid dynamics).**

I. INTRODUCTION

Main purpose of exhaust system is to transport combustion gases from engine combustion chamber to tail pipe. The complete system is designed to moves away burnt gases from the engine manifold to tail pipe. The system includes Exhaust manifold, resonator, catalytic converter, muffler and tail pipes. Exhaust system design is completely depends on engine performance design, overall vehicle packaging and exhaust emission and outlet regulations

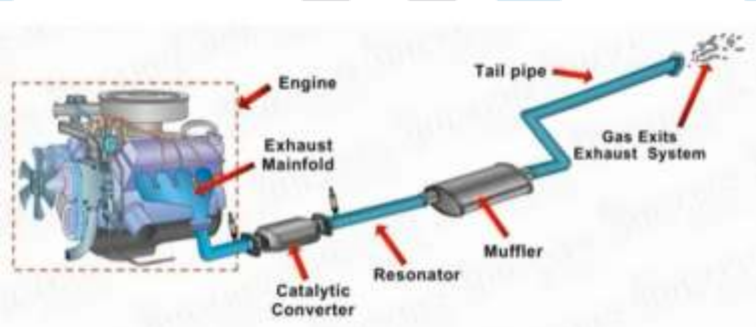


Fig-1
Typical exhaust system (mechschool.com)

In diesel engine, only one power stroke is useful for work output out of four stokes. Other stocks are ideal and consuming power to complete other operations. Power consumption occurs in these stocks due to other pumping work, its friction loss and back pressure in exhaust system. To minimize these losses in these stoke will be actual gain for engine performance and its output. To reduce back pressure in engine, effective and efficient system of exhaust gas removal from engine is required.

Objective of this study is

- Find out pattern between the exhaust backpressure levels and component placement occurred in exhaust flow design
- Study of parameter affecting exhaust backpressure
- Study of current and modified exhaust system back pressure by computation fluid dynamics (CFD) analysis.

II. LITERATURE REVIEW

This paper heading suggests computational fluid dynamics analysis perform on exhaust system to find out back pressure patterns by vital exhaust system components placement in entire system.

- Understand complete exhaust system design parameter and its components functions.
- Understand back pressure terminology in exhaust system and its effect on engine performance

Exhaust back pressure

Exhaust back pressure is defined as exhaust gas pressure that is produced by the engine to overcome the hydraulic resistance of the exhaust system in order to discharge the gases into the atmosphere (Chaudhari et al. 2015). It is the pressure difference at exhaust manifold and atmospheric is called exhaust back pressure.

Exhaust back pressure limit

Engine manufacturer defined exhaust back pressures limit as per its engine components and valves manufacturing and performances. Engine back pressure limit depends on many factors

1) Exhaust emission
2) Exhaust temperature
3) Turbo charger performance
4) Fuel consumption

Large engine has low back pressure due to its valves overlap timing and high turbo boost pressure. On contrary small engine having high back pressure due to very less valve overlap timing and without turbo charge.

The Swiss VERT program determined maximum back pressure limits in order to allow DPFs (Diesel particulate filters) to be fitted to a wide variety of equipment and engines [Mayer 2004].

VERT maximum recommended exhaust back pressure

Engine Size	Back Pressure Limit
Less than 50 kW	40 kPa
50-500 kW	20 kPa
500 kW and above	10 kPa

Exhaust back pressure effect

High back pressure is mostly used term for exhaust system design. Increased exhaust back pressure has number of effects on the diesel engine performance, as follows:

1. Increased pumping work
2. Reduced intake manifold boost pressure
3. Cylinder scavenging and combustion effects
4. Turbocharger problems

Engine to be work hard to pump out exhaust gases out of combustion chamber due to increased back pressure. Pressure ratio between turbo charger air compression and turbine is get reduced. To maintain engine output power, this is increasing fuel flow and reduced air flow to combustion chamber. Increased fuel combustion and increased back pressure increases exhaust gas temperature. This leads to increase in wear and component reliability.

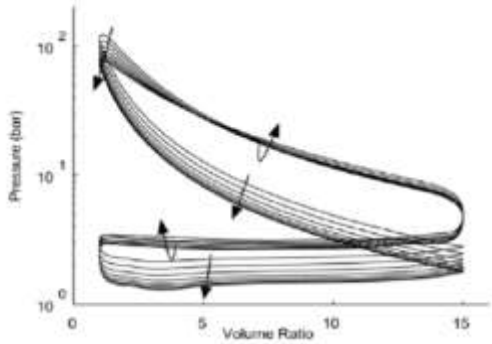
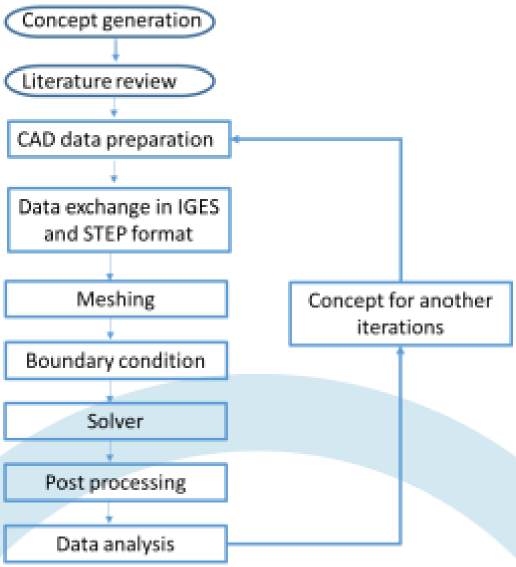


Figure-2. The P-V diagram for a cylinder, for various backpressure. Arrows show direction of change with increasing backpressure (Hield, 2011).

III. METHODOLOGY:

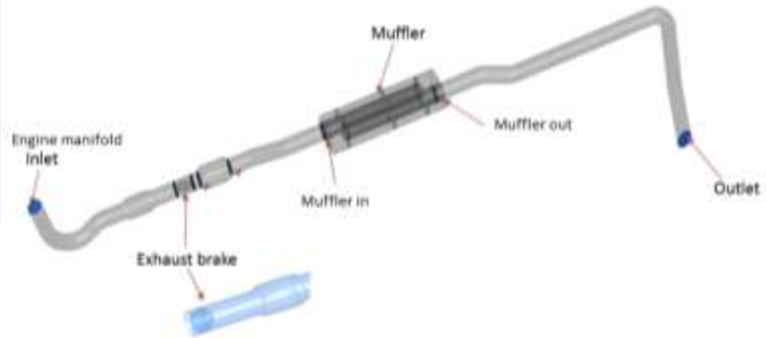
For CFD analysis, following methodology used to know back pressure pattern with respect to its component placements in the system



Flow chart for CFD analysis

IV. ANALYSIS

Geometry and CAD data



Boundary conditions

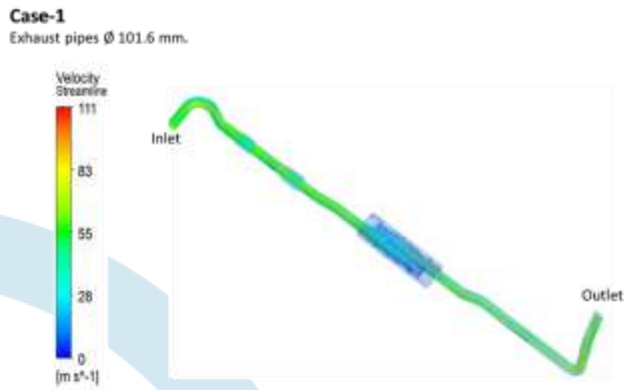
- Flow is turbulent and steady.
- Gas flow rate 919 kg/hr
- Exhaust outlet is open to atmosphere.
- Exhaust gas properties at 500 °C

Property	Value	Units
Dynamic viscosity	3.6e-05	kg/m-s
Density	0.58	kg/m^3

Case-1 Exhaust pipe Ø 101.6 mm.

Pressure Contours

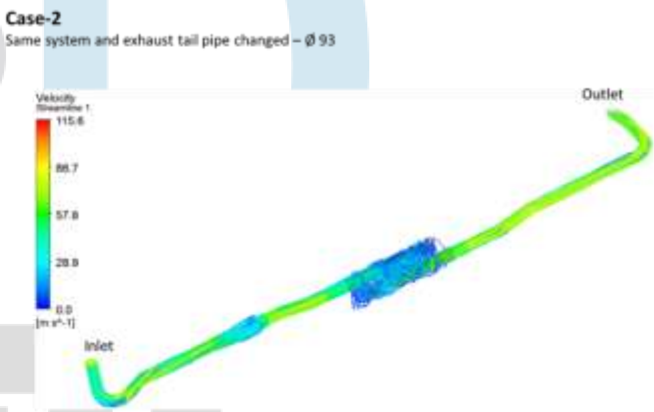
Velocity Contours



Case-2 Exhaust pipe Ø 93 mm

Pressure Contours

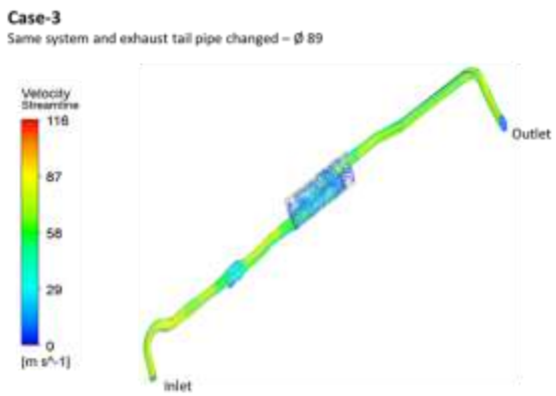
Velocity Contours



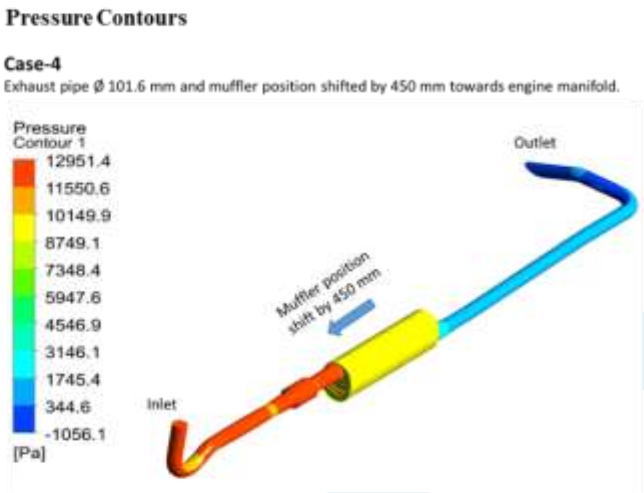
Case-3 Exhaust pipe Ø 89 mm

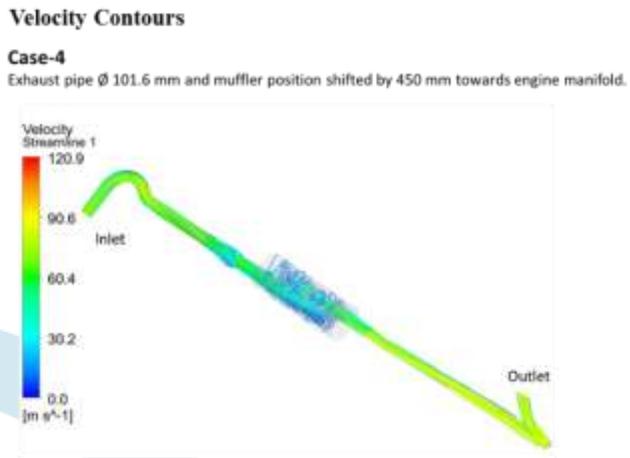
Pressure Contours

Velocity Contours

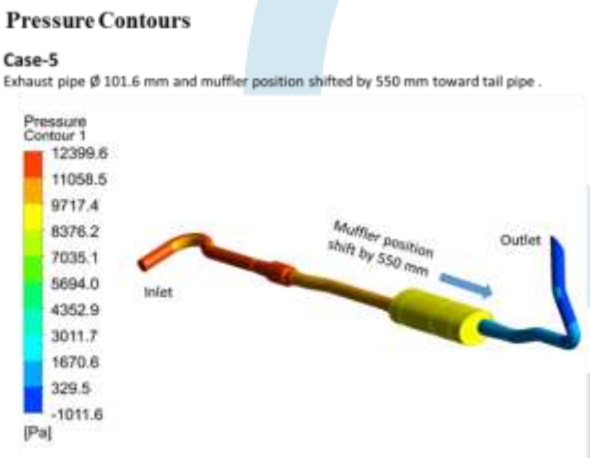


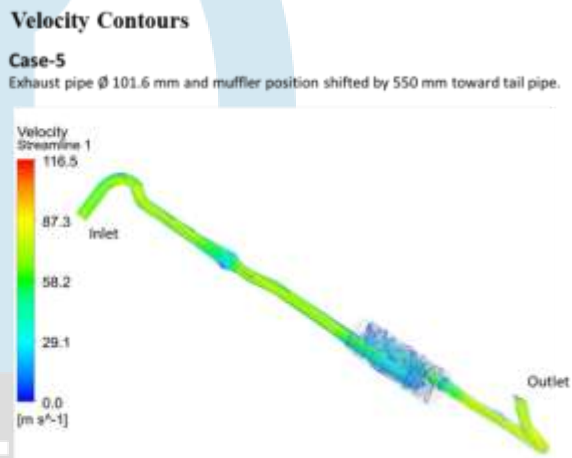
Case-4 Exhaust pipe Ø 101.6 mm and muffler position shifted by 450 mm towards engine manifold.





Case-5 Exhaust pipe Ø 101.6 mm and muffler position shifted by 550 mm towards tail pipe.





V. RESULTS & CONCLUSION

	Pipe Diameter in mm				
	Case-1 Ø101	**Case-2 Ø93**	**Case-3 Ø89**	**Case-4 Muffler shifted by 450 mm towards engine manifold**	**Case-5 Muffler shifted by 550 mm towards engine manifold**
Inlet to Muffler In (Pa)	1095	1379	1364	996	1518
Muffler in –Muffler Out (Pa)	9317	9556	9609	9891	9427
Muffler Out- Outlet (Pa)	607	835	1067	1138	772
Total pressure drop(Pa)	**11019**	**11770**	**12040**	**12025**	**11722**

Comparison table for exhaust back pressure

The difference between these results is showing case 2 and case 5 results are matching as well as case3 and case 4 results are matching. This means 450 mm muffler placement w.r.t case 1 toward engine side gave similar back pressure of Ø89 and muffler placement 550 mm away from engine match result of Ø93 pipe.

This means exhaust back pressure increase by muffler placement toward engine and vice versa. Back pressure is also increase by reducing exhaust pipe diameter. Exhaust back pressure can managed by its vital component placement as well as by change its exhaust pipe diameter.

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