

# ANALYSIS OF EXHAUST SYSTEM OF DIESEL ENGINE USING SOLID WORKS MODELLING

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**Abstract :** Exhaust emission is main reason of health problems now a days because about 71% of pollution is generated by the exhaust of vehicles only. Normally exhaust gases contains hydro carbons and carbon monoxides. This harmful gas can damage environment and health problems are generated. In this study the vibration and noise generated by the exhaust gases and exhaust noise is mainly focused. In this study the exhaust muffler vibration and backpressure analysis are carried out using solid works modelling.

**KEY WORDS:** exhaust system, diesel engine, three -wheeler engine, solid works, analysis

## I INTRODUCTION

US Patent is registered by Milton O. Reeves and Marshall T. Reeves of Columbus, Indiana of the Reeves Pulley Company on 11 May 1897 for the development of the exhaust muffler under the title "Exhaust muffler for internal combustion engines". US Patent Office application No: 582485. Muffler is not main part of the exhaust system used to reduce the pollution caused by the engine. It is used to reduce the noise and vibration caused by the exhaust gas pressure. The key functions of automotive engine exhaust system are to carry out hot noxious exhaust gases from engine to atmosphere and significantly attenuating noise output from the engine through muffler, quickly and efficiently.

Exhaust gases create the pulses coming out through manifold the pulses generate the back pressure and noise inside the muffler. Back pressure should be avoided by modifying the muffler design, but unfortunately some amount of back pressure is always present inside the engine this back pressure generated inside makes negative impact on engine causing the damage to the muffler and exhaust system assembly. In muffler the sound or noise is cancelled by the destructive interference of opposite phase and same frequency of the sound wave. This sound wave is trapped inside the muffler and cancel each other by overlapping the frequencies.

Many researchers have published papers for designing and modification in muffler assembly. C.P. OM ARIARA GUHAN has studied the muffler design in CFD tool analysis for light motor vehicles by adopting the volume optimization method. [4] Several such exhaust systems that utilize various designs and construction methods:

1. Vector muffler - for larger diesel trucks, uses many concentric cones, or for performance automotive applications, using angled baffles to cause exhaust impulses to cancel each other out.
2. Spiral baffle muffler - for regular cars, uses a spiral-shaped baffle system
3. Aero turbine muffler - creates partial vacuums at carefully spaced out time intervals to create negative back pressure, effectively 'sucking' the exhaust out of the combustion cylinder. [5]

## II. REVIEW

**C.P. OM ARIARA GUHAN, G. ARTHANAREESWARAN, K.N. VARADARAJAN, S. KRISHNAN<sup>[1]</sup>:**

In this research C.P. OM ARIARA GUHAN and team carried out the research to reduce weight and economic cost by reducing weight and size of muffler. By using ANSYS CFD analysis the size of the muffler is reduced by 15% and weight by the 2% then previous. Muffler size is reduced without changing the holes in inlet pipes and baffle position, the back pressure increased from 2.655 kPa to 2.949 kPa. The pressure drops improved to 6.89% in down sized muffler compare with existing muffler is achieved. Flow properties have been analysed by using CFD for the new optimized design. Based on optimization, prototype has been built and physical test has been conducted in vehicle level. The physical test results have been validated against CFD results.

During the analysis C.P. OM ARIARA and other have reduced the exhaust muffler and increased the no of perforation hole inside the inlet pipe of the muffler. This has led to increase in sound wave cancellation and reduction in the engine noise. The noise

analysis is based on the back pressure and velocity of the gases from the redesign of the engine it is found that by increasing the holes from 49 to 70 the amount of back pressure is reduced from 2.9425 to 2.556 k pa inside the engine.

**Dr. Igor Anilovich ,Michael Schellong, John W. Siekkinen ,John F. Van Gilder<sup>[2]</sup>:**

In the diagnostic using Exhaust system performance diagnostics (ESPD) is tool used to check the malfunction of the primary and secondary oxygen sensor. The ESPD algorithm contains three consecutive stages when different kinds of fuel to air equivalence ratio (EQR) are commanded, it is plausibly integrated with CTC architecture to minimize negative driveability and emission impacts during diagnostic intrusive actions. The generated ESPD diagnostic permits the recognition of all the OBDII required breakdowns for the Exhaust system parts. It was accomplished by separating part recognition from typical torque control action, which does negative impact the part output. Subsequently, the new diagnostic is executed. Close ESPD and torque control association during the diagnostic Intrusive activities disposed of the negative outflow emission and driveability impacts. The proposed ESPD test arrangement, i.e. DFCO followed by taken after by fuel advancement guarantees the minimum NO<sub>x</sub> discharge effect of the Intrusive test. Likewise, joining three separate intrusive segment diagnostics in one test series limits the overall nosiness, too. The robustness has been achieved via fuel control compensation the developed in ESPD diagnostic allows the detection of all the OBDII required malfunctions for the main exhaust system. Close ESPD and torque control interaction in diagnostic intrusive actions eliminate the negative emission and driveability impacts.

**D.T. Oloruntoba And A.P.I. Popoola<sup>[2]</sup>:**

In the research carried out by D.T. Oloruntoba and A.P.I Poppola , they found the Life of exhaust tube is depending on heat generating through pipe and the surrounding temperature or heat exposed during the run time. Experiment carried out on four different representative material specimens and induced stresses are generated on them. Research was carried out to reduce failure done by the corrosion of exhaust pipe material under high temperature and chloride environment. This high temperature causes the stress generation across the exhaust component. For the experimental analysis some test like micro hardness testing and study of surface nephology is carried out.

To eliminate this problem zinc coating is carried out on the high stressed exhaust pipe. Due to coating the crake formation is trapped inside of the coat and prevents the failure of pipe. Coating offered some restrictions to the failure of engineering materials subjected to induce thermal and tensile stresses. Low carbon steel of 40 mm 25 mm 4 mm was prepared for heat treatment and zinc electrodeposition. The chemical composition of the low carbon steel was carried out by polishing the surface of the sample to get a mirror like surface then mounted on the spark stand in Atomic mass spectrometer. It is concluded that the use of zinc electrodeposition inside the low carbon sample the corrosion and crack formation can be eliminated because the long use o=use of material lead to ferrite and perlite formation inside the material which acts as anodic or cathodic site.

**Jingxiang Li , ShengdunZhao<sup>[4]</sup>:**

In this research article exhaust valve Impulse noise is reduced. Impulse exhaust noise is generated inside the engine by the sudden discharging flow impact of pneumatic system gases with enough gas characteristics including high sound pressure and high noise. Research paper presents a novel approach to suppress the peak sound pressure as a major indicator of impulsiveness of the impulse exhaust noise by an optimization of the opening process of valve. A modified servo-direct-driven valve was designed and assembled in a pneumatic system for the verification experiments comparing with an original solenoid valve. The experiments were carried out with a simple pneumatic system composed of an air compressor, an air treatment device including filter, relief valve and lubricator (FRL), a modified 3-Port servo-direct-driven valve and a cylinder with fixed volume. By conducting the experimental analysis relation between the peak sound pressure of impulse noise and the maximum pressure derivative inside the cylinder has been derived.

A modified valve driven by a servomotor despite an original solenoid valve is designed for the validation of experiment. By the optimized control of valve governing process, experiment results showed that the air pressure inside the cylinder could be reduced linearly during the pre-discharge process. The exhaust time, meanwhile, can be controlled independent to the initial cylinder pressure. In short, the work presented in paper provides an optimization of valve opening process under the constrain to expected exhaust time to suppress the peak Sound Propagation Level and the impulsiveness of the impulse exhaust noise and provide reference for the future studies on the unsteady exhaust noise control.

**Mr. Sanchit Babarao Dhotre1 Prof. S.L.Shinde<sup>[5]</sup>:**

In this research paper pressure propagation in lined and non-lined muffler is studied. It is carried out to analyse the damping of pressure propagation of harmonic wave. is surface of total acoustic pressure field for concerned geometry of the muffler for the

case of empty muffler without any absorbing material and with a layer of lining on the chamber's upper and lower walls. For both cases, the graphical representation corresponds to frequency of 1250 Hz. From the research it is concluded because of the natural frequency of the silencer is lower than the frequency of vibration the muffler is getting damaged a new muffler design using the FEA model analyses is designed.

During the experimental analysis following steps are carried out as muffler selection, test ring for muffler ,mounting of FFT analyser and data collection. Fast Fourier transfer(FFT) analyser is used for experimental validation. By the analysis it is assumed as vibration will be less than the existing one.

**N.S.Ahirrao , Dr.S.P.Bhosle , Dr.D.V.Nehete<sup>[6]</sup> :**

Vibration lead to fatigue failure which is harmful to engine supporting structures. The Impact forces and thus large stresses, which can cause both vibrations and early failure of the mechanisms. The internal combustion engine is the concentrated mass and if it is not supported properly, it will cause vibrations and this vibration is transferred to the supporting structures. Vibration measurement with accelerometer and FFT analyser is a key element in identifying the correct reason for engine vibrations structures. If we take care for all kind of misalignments, even then there is always a possibility of structural vibrations due to looseness.

The focus of the research was carried out to Find out the frequency response curves to detect the frequency and related peak values and determining of compression/tightening levels of bolts on foundations for adjusting the stiffness value. By the FFT analyser the values of the sound level are found 100 and 82 decibel (dB) respectively for the rpm of the diesel engine before and after the tightening of bolts.

**Potente, Daniel <sup>[7]</sup>:**

The research carried out was focused in design concepts and types of muffler design in the paper. Absorptive and reactive muffler are used in heavy trucks should be designed in a way that minimum noise and vibration should be developed in exhaust side of the muffler.

The Insertion loss of SAE vehicle has been measured to access the style of muffler and its attenuation characteristics. Exhaust noise measurement is measured at .05 m and angle

45 degree with help of microphone at exhaust outlet. It is found that absorptive muffler is best for the sound attenuation and rectification of waves.

**Shital Shah, Saisankaranarayana Kuppili, Kalyankumar Hatti, Dhananjay Thombare <sup>[8]</sup>:** In this research paper represented by Shital Shah and her colleagues presented the research paper for design and development of an exhaust muffler. It is mainly focused on the design of reactive muffler to optimise and redesign the existing muffler by shortening the cycle time for validation. Exhaust noise is the one of the noise pollutions causing problems hence to reduce the noise pollution and maintain the noise dB within the environmental condition. Exhaust systems are developed to attenuate the noise intensity in minimum required level. The practical approach is applied, and further software validation is generated. By this approach any one can understand the muffler design concept.

For the development of the prototype model first the benchmarks are developed and CFD analysis Transmission loss and CFD flow analysis is carried out and the transmission losses are calculated. For the software validation of the design the CAE analyse is carried out for Practical resulting in a Practical approach/methodology. For prototype manufacturing parameters such as welding parameters, leakage proof design and acoustic performance are considered. CFD analysis is considered as in 1,2,3,4, stages of different chambers. Linear step for analysis is done under 10 to 2000 Hz. Zigzag hole series are considered for sound acostication.

**P. Srinivas, Venkata Ramesh Mamilla, G. Lakshmi Narayana Rao, Sowdager Moin Ahmed<sup>[9]</sup>:**

In this research article the existing muffler design is changed to reduce the back pressure and stress inside the muffler chamber. To perform the CAE simulation extra expansion chamber is introduced inside the muffler. Dynamic analysis is carried out to determine the mode shapes and stresses and deformations in the muffler using CAE analysis. For the analysis different muffler parameters such as muffler configuration, exhaust pipe and exhaust outlet are considered for design.

Solid works flow simulation 2010 add in package is used for nerverier stocks equation. Simulation Using the Solid works flow simulation software, the existing design of the muffler is changed. An additional chamber in exhaust muffler is generated for the exhaust gas expansion. This incorporates the reduction in back pressure and develop new muffler design for expansion of gases.

In this design transmission losses are as 42.48 which are more and in satisfactory limit. Also Stress and deformation analysis is carried out using CAE analysis.

**A.R. shivram , R. Rajvel ,N. Jaykumar ,N. Vinothkumar:**

In this study exhaust back pressure study is carried out using experimental setup. The study was experimentally made by changing the length of exhaust pipe of .0250 m,0.500 m,1 m and 2 exhaust gas back pressure increases as the combustion efficiency decreases.

Single cylinder diesel engine with computerised test ring is used for experimental study. For the study different results are concluded from fuel consumption v/s load and brake thermal efficiency V/s load charts are studied. From the study it is seen that volumetric efficiency increase with increase in exhaust pipe length. From the experiment it is concluded that the volumetric efficiency and brake thermal efficiency is maximum at 250mm length and less in 2 m length of exhaust pipe. With increase in volumetric efficiency back pressure decreased.

**Murari Mohon Roy, Mohammad Uzzal Hossain Joinder and Md. Shahzaib Uddin<sup>[10]</sup>:**

Research carried out by the Mulari moons ropy and the main interest of area of the research was to identify the effect of back pressure on the exhaust and engine performance. Research was carried out on different load and speed using experimental setup. During the research it is found that brake thermal efficiency and BSFC remain constant for the back-pressure range till 40 mm of Hg and NOx and co emission are remain less or negligible during study. Experimental study includes the analysis at 0,40,60 and 80 mm of hg back pressure and the rpm at the range 650,900 and 1500 on 4 stroke diesel engine. respectively. Brake thermal efficiency is almost constant for low, medium and high engine loading condition with backpressure at low engine speed of 600 rpm. At 950 rpm, it slightly decreased for low, medium and high load condition.

It is seen that BSFC has no significant change for low speed condition of 600 rpm. At 950 rpm BSFC increased with the increase in backpressure for all load condition. At 1200 rpm at low load condition BSFC also increased with backpressure. It is concluded that till certain limit of 40 mm of hg there is no significant change in odour level with increasing back pressure.CO is low for all loading condition in diesel engine.

**OVIDIU VASILE,GILBERT-RAINER GILLICH<sup>[11]</sup>:**

Research and analysis are carried out for the development and improvement in design of exhaust muffler the research carried out is based on the acoustic pressure losses and transmission losses generated inside the muffler body. Using Finite Element Analysis method, the research was carried out in which transmission losses calculated on 650 to 30000 Hz frequency. The analysis is carried out by using Delany-Bazley number in the FEA module concluded data give the transmission losses for the muffler with absorbing material is less compare to the non-absorbing material. At the frequencies higher than 1250 Hz Plots behaviour is more complicated and lesser damping in nature.

### III. CONCLUSION

- 1) By Implementing new coating method to the engine valves reduction of engine back pressure can be achieved.
- 2) Another study that can be used to improved efficiency of muffler and reduced backpressure is the additional chamber for reduction in back pressure of the Exhaust gases.
- 3) Research was to identify the effect of back pressure on the exhaust and engine performance. Research was carried out on different load and speed using experimental setup. This study can be used to reduce emission of gases.

### VI. FUTURE SCOPE

From the literature review it is found that the expansion of exhaust muffler of with addition of chamber is not validated by the experimental set up. For exact measure of back pressure measurement this setup can be performed experimentally.

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## REFERENCES

- [1] Ujjal Kalita, Abhijeet Pratap, Sushil Kumar, "Absorption Materials Used In Muffler," International Journal of Mechanical and Industrial Technology, Punjab, 2015.
- [2] S.H. Lee a,b, E.S. Kim a, J.Y. Park a, J. Choi, "Numerical analysis of thermal deformation and residual stress in automotive muffler by MIG welding," Journal of Computational Design and Engineering, Korea, 2018.
- [3] Shital Shah, Saisankaranarayana Kuppili, Kalyankumar Hatti, Dhananjay Thombare, "A Practical Approach towards Muffler Design,Development and Prototype Validation," SAE international, india, 2010.
- [4] Alfred, Samuel, "Researches on the Physics behind cooking as a pastime," 20 June 2017. [Online]. Available: <https://www.quora.com/What-are-the-dangers-of-continuing-to-drive-a-car-with-an-exhaust-pipe-that-is-rusted-through>. [Accessed 25 october 2018].
- [5] P. Srinivas, Venkata Ramesh Mamilla, G. Lakshmi Narayana Rao, Sowdager Moin Ahmed, "Design and Analysis of an Automobile Exhaust Muffler," Research gate, 2016.
- [6] Potente, Daniel, "General Design Principles for an Automotive Muffler," research gate, Australia, 205.
- [7] M. Philip Hubert Smith, "Exhaust and Intake Systems",3rd illustrated reprint," Foulie, 1976.
- [8] OVIDIU VASILE,GILBERT-RAINER GILLICH, "Finite Element Analysis of Acoustic Pressure Levels and Transmission loss With Muffler," researh gate, romania, 20132.
- [9] N.S.Ahirrao, Dr.S.P.Bhosle , Dr.D.V.Nehete, "Dynamics and Vibration Measurements in Engines," Science direct, India, 2018.
- [10] Murari Mohon Roy, Mohammad Uzzal Hossain Joardder and Md. Shazib Uddin, "Effect of Engine Backpressure on the Performance and Emissions of a CI Engine," JIMEC'7, bangladesh, 2010.
- [11] S.L.Shinde, Mr. Sanchit Babarao Dhotrel Prof., "Analysis of Automotive Exhaust Muffler Silencer Using FEA and Experiment," IJFEAT, india, 2016.
- [12] Marsiial, Milton O. Reeves, "Exhaust Muffler for Engines," Indiana, May 11 1897.
- [13] Jingxiang Li, ShengdunZhao, "Optimization of valve opening process for the suppression of impulse exhaust noise," ELSEVIER, china, 2014.
- [14] D.T. Oloruntoba, A.P.I. Popoola, "Effect of coating on induced thermal and tensile stress on fracture of exhaust pipe material," Elsever, South Africa, 2014.
- [15] Dr. Ken Russel, "W a v e s Types of Waves Wave speed Longitudinal Waves," Isabelle Rickey, 2014. [Online]. Available: <https://slideplayer.com/slide/1607446/.html>. [Accessed october 2018].
- [16] Dr. Igor Anilovich, Michael Schellong,John W. Siekkinen, "exhaust system performance dignosis," IFAC, germany, 2010.
- [17] C., P. Om Ariara Guhan; G, Arthanareeswaran; K, N Varadarajan; S, Krishnan, "Exhaust System Muffler Volume Optimization of Light Commercial Vehicle Using CFD Analysis," elsevier, india, 2018.
- [18] Christopher George Therully,H G Vinod Raj, "Energy Efficient Design and Modification of an Automotive Exhaust Muffler for Optimum noise transmission loss and back pressure:A review," IOP Conference Series: Materials Science and Engineering, Karnataka, 2018.