Original Article
ISSN (Online): 2582-7472

ShodhKosh: Journal of Visual and Performing Arts
January-June 2023 4(1), 1145–1151

A REVIEW OF THE EXHAUST MUFFLERS USED IN AGRICULTURAL TRACTORS TO LOWER THE SOUND PRESSURE LEVEL

Vijai Kumar[1], John Robins Bentham[2], Kshitij Kumar[3], Kapil Kumar[4]*, Mohd. Murtaja[5], Priyanka Singh[6]

[1]*Assistant Professor, Deptt. Of Agricultural Engineering. SCRIET, CCS University Meerut
[2] Assistant Professor, Deptt. Of Agricultural Engineering. SCRIET, CCS University Meerut
[3] Assistant Professor, Deptt. Of Agricultural Engineering. SCRIET, CCS University Meerut
[4] Assistant Professor, Deptt. Of Agricultural Engineering. SCRIET, CCS University Meerut
[5] Assistant Professor, Deptt. Of Electronics and Instrumentation Engineering. SCRIET, CCS University Meerut
[6] Assistant Professor, Deptt. Of Electronics and Communication Engineering. SCRIET, CCS University Meerut

ABSTRACT

In this review paper, different types of agriculture tractors exhaust muffler systems used to reduce the sound pressure level exhaust back pressure and effect of environmental conditions has been studied. The objective of the study waste decide the various parameters of exhaust muffler which reduces a large amount of sound pressure level with increase in exhaust back pressure and decrease in fuel consumption at different engine speeds. The results showed that combination type of exhaust muffler is more efficient than reactive and absorptive exhaust muffler. New designed exhaust muffler will be reducing sound pressure level tractor. Exhaust system is also preferable for new research work in agriculture tractor for better ergonomics and performance.

Keywords: Exhaust Muffler, Fuel Consumption, Sound Pressure Level and Exhaust Back Pressure

Corresponding Author
Vijai Kumar, vijayboby143@gmail.com

DOI
10.29121/shodhkosh.v4.i1.2023.3090

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

1. INTRODUCTION

Internal combustion engine generates the acoustic pulse by combustion process and are typically equipped with an exhaust muffler to suppress the acoustic pulse generated by the combustion process. A high intensity pressure wave generated by combustion in the engine cylinder propagates along the exhaust pipe and radiates from the exhaust pipe termination. The pulse repeats at the firing frequency of the engine which is defined by f= (engine rpm x number of cylinders)/120 for a four stroke engine. The frequency content of exhaust noise is dominated by a pulse at the firing frequency, but it also has a broadband component to its spectrum which extends to higher frequencies. Measurements of the exhaust pipe pressure pulse on a Continental O-200 engine show that the majority of the pulse energy lies in the frequency range of 0-600 Hz. Exhaust mufflers are designed to reduce sound levels at these frequencies. Generally, sound

level of more than 90 db is injurious for Human being. The main sources of sound in an engine are the exhaust sound and the sound produced due to friction of various parts of the engine. The exhaust sound is the most dominant. To reduce this sound pressure level, various kinds of Mufflers are usually used. Concern about problems of sound level in the workplace and in the living space has escalated since the amendment of the Walsh–Healy Act of 1969 there is a real danger of permanent hearing losses when a person is exposed to sound level above a certain level. Most agricultural field and industries are strongly motivated to find an effective, economical solution to this problem. The level of exhaust sound Reduction depends upon the construction and the working procedure of mufflers. Some of the mufflers used in the agricultural tractors were reviewed to select the best design parameters for mufflers design.

2. DESIGN REQUIREMENT OF MUFFLERS

In general, sound waves propagating along a pipe can be attenuated using either a dissipative or a reactive muffler. In all muffler designs the tailpipe length can have an important effect. The tailpipe itself acts as a resonant cavity that couples with the muffler cavity. The attenuation characteristics of a muffler are modified if the design tailpipe is not used. Also, the effect of exhaust gas flow speed has a detrimental effect on the muffler performance. Beranek, 1998, gives examples in which the muffler attenuation is reduced from 35 dB to 6-10dB when the flow speed is increased from zero to 230 ft/sec. In typical industrial or diesel truck engine applications the exhaust flow speed can be 164 ft/sec to 390 ft/sec. The effect of flow is related to the interaction of sound with turbulence and will be dependent on the internal design of the muffler.

3. REACTIVE MUFFLERS

Reactive silencers, which are commonly used in automotive applications, reflect the sound waves back towards the source and prevent sound from being transmitted along the pipe. Reactive silencer design is based either on the principle of a Helmholtz resonator or an expansion chamber, and requires the use of acoustic transmission line theory. In a Helmholtz resonator design a cavity is attached to the exhaust pipe. At a specific frequency the cavity will resonate and the waves in the exhaust pipe are reflected back towards the source. However there are also pass band frequencies where the resonator has no effect and so resonator muffler design is targeted to specific frequencies where the majority of the attenuation is required. In some designs, the muffler has several resonators of different sizes to target a range of frequencies. Expansion chamber mufflers reflect waves by introducing a sudden change in cross sectional area in the pipe. They do not have the high attenuation of the Helmholtz resonator, but have a broadband frequency characteristic, with pass bands when half the acoustic wavelength equals the cavity length. Their performance also deteriorates at higher frequencies when the cross axis dimension of the muffler is 82% of the acoustic wavelength (Davis, Stokes, Moore and Stevens, 1954). Some expansion chamber muffler systems are also packed with sound absorbing material which helps to improve the high frequency attenuation. The flow speed is reduced and this reduces the vortex shedding that can cause problems in the design shown in Figure.1

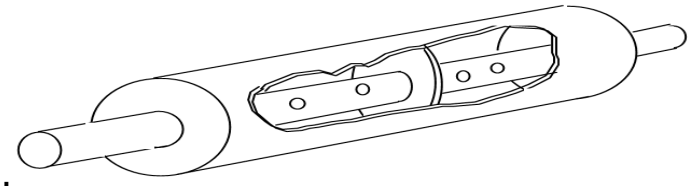

Figure 1 Sectional view of a reactive muffler with two cavities and no flow restriction

4. DISSIPATIVE MUFFLER

A dissipative muffler uses sound absorbing material to take energy out of the acoustic motion in the wave, as it propagates through the muffler. This type of muffler design uses only absorption of the sound wave to reduce the noise level without messing with the exhaust gas pressure. This is known as glass pack muffler and it reduces backpressure but producing higher noise. The sound produced by this type of muffler is much higher compared to the other type of muffler. In Figure 2 the design differs in as much that there is no direct path for the exhaust gases to flow through the muffler

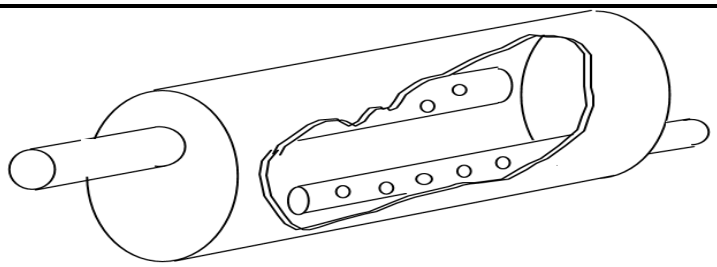

Figure 2 Sectional view of a typical automotive reactive muffler in which there is no direct passage between the inlet and the exit

Selection criteria for mufflers

a) Measurement exhausts system backpressure of engine.
b) A free-flowing air intake and exhaust system in tractor.
c) Exhaust Muffler must be built tough to handle high pressure exhaust gasses,
d) Number of inlets, single or dual system.
e) Diameter of pipe, Inlet and outlet.
f) Size of the muffler.

Material used, stainless steel muffler offers superior corrosion resistance, durability, and life span than the aluminized steel muffler.

5. REVIEW OF LITERATURE

Basic design features of mufflers

Reeddy 2012 explains design and optimization of exhaust muffler in automobiles by study of Muffler dimensions were measured through the Benchmarking, to create CAD models. The CAD models were created in CATIA V5 R19, later these CAD models of muffler were exported to HYPER MESH for pre-processing work. Free analysis was carried out on this muffler by FEA Method using NASTRAN Software. In order to determine the resonance frequencies, were then compiled to determine which peaks were the most significant for the system. From the data, side baffles were selected as weak parts of the muffler. In order to minimize the effects of these resonance frequencies, the suggested design improvement was to add thickness and also add damping to the system. Bilski 2013 presents the assessment of the operator's exposure to audible and infrasonic noise in 32 selected modern wheeled agricultural tractors designed and produced by world-renowned companies in normal working conditions. The tractors have been in use for no longer than 4 years, with rated power of 51 kW to up to 228 kW (as per 97/68 EC). The measurements were made in different typical work conditions inside and outside of tractors cabs. The results indicated that exposure levels to noise perceived by the operators (Lex,Te between 62,3 and 84,7 dB-A) and can make a small risk of potential adversely effects on hearing during tasks performed inside the closed cab. The measured audible noise levels can potentially develop the non-auditory effects. Analyzed tractors emit considerable infrasonic noise levels that tend to exceed the occupational exposure limits (both inside and outside the driver's cab). The applicable standards for low frequency noise and its measurement methods for vehicles, including agricultural tractors, should be scientifically revised. In the last years there has been a noticeable technical progress in reduction of audible noise exposure at the tractors operator's workplaces with simultaneously lack of important works for limitation of exposure to infrasound. Author discusses possible health and ergonomic consequences of such exposure.

Performance of the mufflers

Noweir 1984 studied the performance of the efficiency concordance with the work discipline and work attendance of people working at a sound pressure level of 80–99 dBA. In this study, it was found that the people exposed to a sound pressure level of 90–99 dBA showed a lower efficiency, less discipline and less attendance to the work than the ones exposed to 80–89 dBA sound pressure level. Miyakita, et al 1997 determined effect of noise on the number of persons exposed to loss of hearing at levels above 40 dB at a frequency of 4 kHz; and as a result, estimated that 360,000 people working in agricultural facilities in Japan impaired their hearing abilities. Baker 2002 was found that it may cause health problems to the farmers in the long run. The machines used in agricultural operations such as tractors, combines, sellers,

elevators, driers, etc. expose noise of high level. More hearing loss was encountered among people who work in agricultural facilities than other jobs. Singh, G., et al 2022 Exhaust sound pressure level is known to be one of the harmful pollutants. This sound pressure could be reduced sufficiently by means of an exhaust muffler. The aim of this research was to evaluate the back pressure and afterword validation and theoretical results such as sound pressure level, engine performances of the existing and selected other exhaust mufflers to provide a new design of muffler for better efficiency. Experiment has been carried out with existing exhaust muffler and other six muffler of different tractor under at no load condition, 1/4 load condition, 1/2 load condition, 3/4 condition in the laboratory and full load condition. They suggested that interchange ability of exhaust muffler to reduce sound pressure level may advisedly affect engine performance by increasing back pressure and brake specific fuel consumption. McBride et al 2003 was found that high noise feature makes the agriculture the second biggest sector after the construction sector, which causes the loss of hearing in Japan. According to the test results and survey made on farmers and agricultural workers, it was found that hearing loss occurs in people who were exposed to a sound pressure level of 84.8–86.8 dBA., Martin 2004 states that ‘‘the beginning region of impairment involves the sensitive mid-frequency range, primarily between 3 and 6 kHz, and the corresponding impairment was classically described as the 4-kHz notch. This particular pattern of maximal hearing loss, with little or no loss below 2 kHz, typically appears regardless of the noise exposure environment. Hearing loss was not observed at frequencies below 1000 Hz and was sharpest above 2000 Hz for a male industrial worker. Patients working in different sectors showed that the hearing loss might not be observed below 2000 Hz in different work environments while others might experience hearing loss at about 1000 Hz. The sensitivity was also affected by gender and the number of years worked in a particular environment. Kumar, N., et al 2018 Tractor mufflers constructed with amalgamation of perforated ducts, baffles or perforated baffles and expansion chambers for acoustic attenuation are commonly used. Poorly designed mufflers provide limited noise reduction and high back pressure, resulting in low fuel efficiency. Sound pressure mapping technique was adopted to identify major contributor of noise for a 47.6 PS tractor. An experiment was carried out to evaluate different muffler designs with regard to sound pressure levels and exhaust back pressure at varying operating conditions. Each muffler design produced noise greater that 90 dBA Leq at operator's ear level at rated engine speed, and was more than the exposure limit of noise for 8-h work day recommended by ISO and OSHA. Long exposure of this noise might cause occupational disease to operator. Noise reduction was observed in one of the mufflers near rated engine speed with low back pressure with better fuel efficiency. Sound pressure at operator ear level, back pressure and fuel consumption were found within 90.3–92.8 dBA, 1.765–2.157 kPa and 2.65–3.35 l.h−1, respectively, near engine rated speed. Rahman et al 2005 reported in an inherent drawback of IC engines that it was a major source of noise pollution. Attaching a muffler in the exhaust pipe was the most effective means of reducing noise. But muffler requires specific design and construction considering various noise parameters produced by the engine. In our country, the conventional design does not include much of a parametric noise analysis or other engine characteristics. A muffler for stationary petrol engine has been designed and manufactured. The performance characteristics, i.e. noise reduction capability of the muffler was tested and compared with that of the conventional muffler Fig 3.

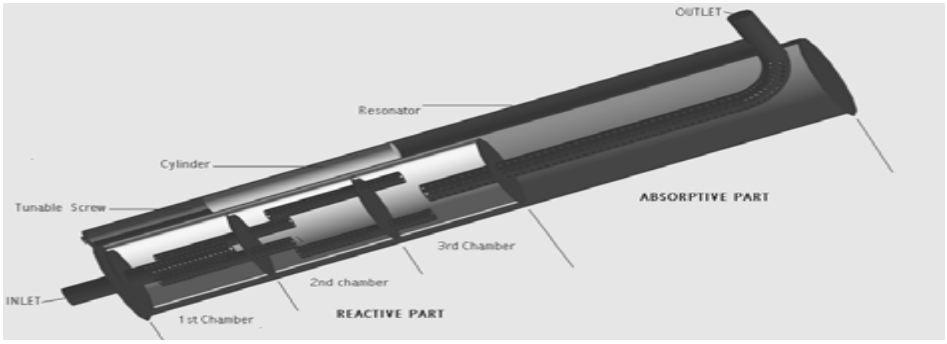

Figure 3 Three-dimensional cut view of the muffler

Dewangan et al 2005 conducted an investigation to determine the noise propagation (under stationary condition) and noise at operator’s ear level of popular 18.7 and 26.1 kW tractors and 4.6 and 6.7 kW hand tractors during field operations with various implements. It was observed that both tractors produced the noise of 92 dBA Leq in the working zone of operator. The sound pressure level (SPL) of the hand tractor was about 2 dBA Leq higher than that of the tractor. The SPL during field operations at operator’s ear level increased with increase in engine speed and forward speed.

Furthermore, the SPL was higher for field operations corresponding to the implement requiring higher draft. It was observed that the SPLs of the tractors and hand tractors were more than the exposure limit of noise for 8-h workday recommended by ISO and OSHA. Mesquita et al 2005 showed that axial and centrifugal fans are very used in industries in general great applicability in the product development as well as ambient comfort. Among the operational problems in these equipments, the noise frequently arises as principal causes. The fundamental approach was the utilization of absorptive, parallel, or circular baffle-type silencer. The features of this type of silencer were good high-frequency attenuation and minimal aerodynamic pressure loss. In this context, this work presents a review of the common noise sources in fans and the procedures for noise attenuation. Finally, an application case was presented to illustrate the use of dissipative silencer. Wang et al 2010 study on the model analysis of an automobile exhaust muffler based on PRO/E and ANSYS in order to improve design efficiency. The solid model was created by PRO/E and model analysis was created out by ANSYS to study the vibration of the muffler, so as to distinguish working frequency from natural frequency and avoid resonating. Data exchange between PRO/E and ANSYS using IGES (Elementary graphics exchange specification) format for data exchange specification. Muffler natural frequencies modal shapes have been calculated by the FEM analysis software named ANSYS. So the muffler vibration could be intuitive analyzed. The natural frequencies and mode shape were considered during the design of the muffler, so to avoid the resonance occurred in exhaust system. Mehmet et al 2010 introduced diesel engine exhaust system design with help of the three-dimensional model of the system had been constructed by using "ANSYS Workbench", the mathematical models via Finite Element Method (FEM) had been done via "ANSYS ICEM CFD" and, the Computational Fluid Dynamics (CFD) analyses covering back pressure and thermal analyses had been performed by using "ANSYS CFX 12" program. He concluded that the dimensions and internal structure of the dry and wet-type silencers which were the main components of the exhaust system and the physical properties of the insulation material had been determined based on acoustic, back pressure and thermal analyses and, the layout of the diesel engine in the engine room. From the results of the back pressure analyses, it was seen that the total back pressure in the whole exhaust system was within the limits of the given diesel engine criteria and, the board outlet temperature of the exhaust system was substantially low. Yasir et al 2011 perform a new testing method for lifetime prediction of automotive exhaust silencers. The purpose of this paper was to highlight the problems associated with daily routine corrosion tests performed in an automotive exhaust industry. Estimation of the life time of a complete system under real conditions is always uncertain and often leads to a disagreement Studies carried out on the silencers have shown that the new component testing method could be used for life time estimation of parts having different material and design combinations. On the basis of obtained results it could be stated that the new testing setup could be applied for different materials and design rankings. Chaudhri et al 2011 reviewed paper different types of mufflers and design of exhaust system belonging engine had been studied. The object of this study was deciding muffler design which one reduces a large amount of noise level and back pressure of engine. In designing, there was different parameter which had to take in to the consideration. These parameters affect the muffler efficiency. Fig. 4 shows the muffler inner structure

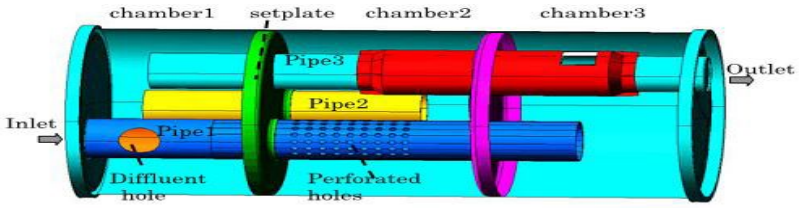

Figure4 muffler inner structure

Shao et al 2011 study on an Exhaust Muffler Using a Mixture of Counter phase Counteract and Split-gas Rushing. In order to solve the problems of traditional exhaust silencers with poor characteristics of noise reduction in low-frequency range and high exhaust resistance, a new theory of exhaust silencer of diesel engine based on counter-phase counteract and split-gas rushing had been proposed. In single-cylinder diesel engine CG25 as the experimental engine. He measured the exhaust noise and its spectra. He conducted on this noise experiment that the CG25 single cylinder diesel engine shows new muffler's good insertion loss characteristic in the wide range of engine speed comparable to the original passive muffler especially in the range of 500 Hz. The original muffler could only reduce the high-frequency noise components, it cannot reduce, even strengthen the noise of frequency below 500 Hz, proved conventional muffler with poor capacity

of lowering the low-frequency noise again. The new exhaust mufflers were obviously effective in controlling the low-frequency exhaust noise, which proved correctness of the new theory not only proved that the new mufflers had very good performance for low-frequency noise reduction, but also proved that using split-gas rushing can lower the air flow speed thus lowering the air regeneration noise.fig 5shows the new design of muffler.

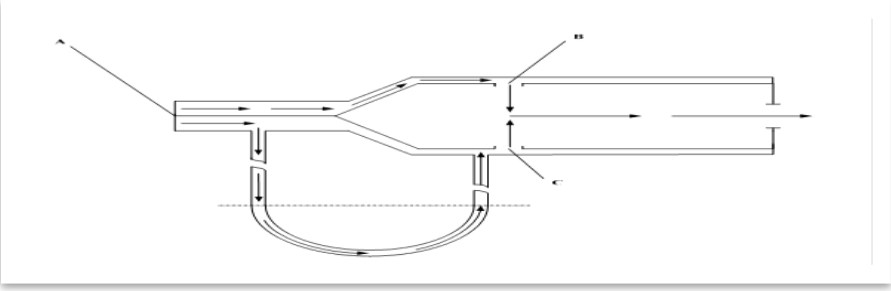

Figure5 Principle of the muffler using reversed-phase cancelling

Ameen et al. 2013did experimental test for noise attenuation in gasoline engine with different types of mufflers and compared between three different types of an exhaust muffler for noise attenuation of single cylinder four stroke air-cooled gasoline engine. A set of conclusions achieved about the effect of the mufflers chamber's expansion ratio, chambers length, and wall thickness. Sound attenuation of 12.5, 15 and 16 dB A was achieved with, Multi-chamber Reactive Muffler, Concentric-tube Resonator Muffler and Combined Reactive and Dissipative Muffler.

6. CONCLUSION

This paper had introduced different types of agriculture field tractor exhaust muffler and their designing methods. After studying these methods and procedures for designing an exhaust muffler, we conclude that combination type of exhaust muffler is more efficient than reactive and absorptive exhaust mufflers. New designed exhaust muffler will reduce sound pressure level tractor. Exhaust system is also preferable for new research work in agriculture tractor.

CONFLICT OF INTEREST

None

ACKNOWLEDGEMENTS

None

REFERENCES

Alexandre Luiz Amarante Mesquita., André Luiz Amarante Mesquita., Ernesto Arthur Monteiro Filho., 2005. Use of Dissipative Silencers for Fan Noise Control. Mechanical Engineering Department, Federal University of Pará, Belém, PA, 66075-110, Brazil

Bartosz Bilski., 2013 Exposure to audible and infrasonic noise by modern agricultural tractors Operators. University of Medical Sciences in Pozna_n, Department of Preventive Medicine, ul. Smoluchowskiego 11, 60-179 Poznan, Poland. Applied Ergonomics

Baker, D.E., 2002. Noise: the Invisible Hazard. Department of Agricultural Engineering,University of Missouri-Columbia.

Chisholm, C.J., Bottoms, D.J., Dwyer, J.A., Lines, J.A., Whyte, R.T., 1992. Safety, health and hygiene in agriculture. Safety Science 15 (4–6), 225–248.

Ehsan Sabah M. AL-Ameen., 2013 Experimental Test for Noise Attenuation in Gasoline Engine with Different Types of Mufflers Journal of Engineering and Development, Vol. 16, No.4, Dec. 2012 ISSN 1813- 7822

K.N. Dewangan., G.V. Prasanna Kumar., V.K. Tewari., 2005. Noise characteristics of tractors and health effect on farmers. Department of Agricultural Engineering, North Eastern Regional Institute of Science and Technology, Nirjuli-791 109, Itanagar, Arunachal Pradesh, India. Applied Acoustics 66 (2005) 1049–1062

Lonsbury-Martin, B.L., Martin, G.K., 2004. Noise-induced hearing loss. Chapter one hundred and twenty eight. In: Cummings (Ed.), Cummings Otolaryngology Head & Neck Surgery, fourth ed., pp. 2906–2925.

McBride, D.I., Firth, H.M., Herbison, G.P., 2003. Noise exposure and hearing loss in agriculture: a survey of farmers and farm workers in the southland region of New Zealand. Journal of Occupational and Environmental Medicine 45 (12), 1281–1288.

Miyakita, T., Ueda, A., 1997. Estimates of workers with noise-induced hearing loss and population at risk. Journal of Sound and Vibration 205 (4), 441–449.

Noweir, M., 1984. Noise exposure as related to productivity, disciplinary actions, absenteeism, and accidents among textile workers. Journal of Safety Research 15 (4), 163–174.

Mr. Jigar H. Chaudhri, Prof. Bharat S. Patel, Prof. Satis A. Shah., 2014.Muffler Design for Automotive Exhaust Noise Attenuation - A Review, Int. Journal of Engineering Research and Applications www.ijera.com ISSN: 2248-9622, Vol. 4, Issue 1(Version 2), January 2014, pp.220-223

M. Rahman, T. Sharmin, AN F M E. Hassan, and M. Al Nur., 2005. Department of Mechanical Engineering Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh. Proceedings of the International Conference on Mechanical Engineering 2005 (ICME2005) 28- 30 December 2005, Dhaka, Bangladesh

Noweir, M., 1984. Noise exposure as related to productivity, disciplinary actions, absenteeism, and accidents among textile workers. Journal of Safety Research 15 (4), 163–174.

Kumar, N., Tewari, V. K., & Singh, G. (2018). Performance evaluation of tractor mufflers for human comfort. *Journal of Agricultural Engineering*, *55*(2), 1-12.

Yhdego, M., 1991. Assessment of noise pollution in friendship textile mill limited, Ubongo-Dar es Salaam. Environment International 17 (5), 479–485.

M rajasekhar reddy & 2 k .madhava reddy. 2012 design and optimization of exhaust muffler in automobiles international journal of automobile engineering research and development (ijauerd) ISSN 2277-4785 vol.2, issue 2 Sep 2012 11-21

Mehmet Avcu, Şadi Kopuz and Mehmet Teke. 2010 diesel engine exhaust system design Journal of Naval Science and Engineering 2010, Vol. 6, No.1, pp. 39-58. [5]

Ying Li Shao (.2011) A Study on Exhaust Muffler Using a Mixture of Counter phase Counteract and Split-gas Rushing. © 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of [CEIS 2011] [6]

Shi wu, Dongkai Jia, Yuntong Jia, Ke Wu. (2011) Structural Design and Testing Study of Truck Muffler. (2011) International Conference on Electronic &Mechanical Engineering and Information Technology ©2011 IE [7] 2011, Jun Chan and Xiong Shi*.CFD Numerical Simulation of Exhaust Muffler. 2011 Seventh International Conference on Computational Intelligence and Security.

Singh, G., Shrivastava, P., & Tewari, V. K. (2022). Measurement of back pressure and fuel consumption in different exhaust mufflers of agriculture tractor for achieving low sound pressure level. *RASSA Journal of Science for Society*, *4*(2and3), 109-117.

Davies, D.D., Jr.; Stokes, G.M.; Moore, D.; and Stevens, G.L., Jr. (1954). Theoretical and experimental investigation of mufflers with comments on engine-exhaust muffler design. NACA-TR-1192.

Beranek, L., "Noise and Vibration Control", McGraw-Hill, Cambridge, MA, 1988.