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A Critical Review of Transmission Loss and Acoustic Methods for Performance Evaluation of Muffler-Part: 1

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Abstract: **In this paper, the different methods used for transmission loss and acoustic methods of exhaust muffler were presented from compulsive abstracts published in the articles.**

Keywords: **Muffler, Transmission Loss, Acoustic**

1.INTRODCUTION

Zhenlin Ji, Yiliang Fan[1] presented in their technical paper muffler acoustic characteristics of duct. Using Visual basic and plane wave theory , the performance evaluation of duct system was studied . By transfer matrix method, the transmission loss and insertion loss was simplified. Bryce Gardner, Abderrazak Mejdi, Chadwyck Musser, Sébastien Chaigne, Tiago De Campos Macarios [2] presented in their technical paper the propagation of acoustics wave transmission within a duct system with vibro-acoustic modelling subject to non-uniform flow. Modeling of the acoustic propagation within a duct was studied for design analysis.

Adrien Mann, Min-Suk Kim, Barbara Neuhierl, Franck Perot, Robert Powell, Thomas Rose, Jan Krueger [3] presented in their technical paper Boundary Element Methods was applied successfully to achieve the required acoustic tuning.

Giulio Lenzi, Giovanni Ferrara, Andrea Fioravanti [4] presented in their technical paper acoustic performance of mufflers was described using single inlet and outlet Insertion Loss and Transmission Loss . These parameters represent the acoustic damping on the engine emission and on the incident pressure wave respectively. By using multi-inlet these parameters depend also on the sources characteristics and the acoustic performance was experimentally evaluated in terms of reflection and transmission coefficients of each port of the muffler. These coefficients are used to evaluate the Insertion Loss of the manifold muffler taking into account specific sources on the inlets. The characteristic coefficients are also used to predict the acoustic emission of the manifold muffler using a known engine source on the two inlets.

Abhishek Verma, M. L. Munjal[5] presented in their technical paper , the noise attenuation characteristics of a three-chamber U-bend hybrid muffler. Acoustic performance was quantified by the Transmission Loss parameter. Transfer Matrix and Finite Element Method have been used for the prediction of the of the muffler. Presence of perforated baffles necessitates use of the Integrated Transfer Matrix approach for the one-dimensional analysis because the sound fields in the adjacent chambers would be multiply coupled with each other, and for the 3D FEM analysis LMS Virtual Lab software has been used. The mean flow distribution in each of these configurations has been evaluated by means of a lumped flow resistance network. The resulting values of the grazing flow and bias flow have been used to calculate the perforates' acoustic impedance.

Andrea Fioravanti, Giulio Lenzi, Giovanni Vichi, Giovanni Ferrara, Stefano Ricci, Leonardo Bagnoli[6] presented in their technical paper the effect of the manufacturing characteristics and the attenuation of the acoustic waves due to the fluid viscous-thermal effects .

HakSon Han, ChulMin Park, JeongHoi Heo, Sang Kyu Kang[7] presented in their technical paper the achievement of dynamic sound quality through exhaust system design. The exhaust noise target was determined by means of transfer path analysis focusing on the noise source and how it's impacted by the muffler design. The exhaust system was commonly modeled as a combination of source strength and impedance. We obtained the source character by the wave decomposition method using two microphones and six loads ultimately leading to an optimized design of the inner muffler structure.

Dr B.Venkataraman , Gokul Raj [8] presented in their technical paper the experimental performance evaluation of both absorption and reflective mufflers which are calculated by sound transmission loss experiment technique .

Kalyan S. Hatti, Arunkumar S, A. S. Deshpande, U. M. Bhushi [9] presented in their technical paper the contribution of each, Design of Experiments was carried out for individual elements. Based on this, prototypes were manufactured to accommodate different configuration changes specified in the DOE. For all the prototypes, Insertion Loss and Transmission Loss tests are conducted and the results are analyzed to yield the contribution of each acoustic element towards the overall exhaust noise attenuation by the muffler of interest.

M. L Munjal, V. Vamsi Krishna[10] presented in their technical paper a flow-resistance network approach for three-pass double reversal muffler with three perforated pipes arranged along the major axis of an elliptical shell with two short end-inlet/outlet chambers at the two ends makes use of the electrical circuit analogy in order to evaluate the mean flow distribution, which was then extended to evaluate the overall back pressure of the muffler. Transfer matrices for the three constituents chambers have been combined appropriately in order to the predict the overall transfer matrix and thence Transmission Loss as well as Insertion Loss of the muffler.

Santha Kumar S, Nayankumar Solanki [11] presented in their technical paper a study noise created by the exhaust engine running from 2000 rpm to 4000 rpm. Vehicle level experiments were carried out to root cause the noise source and identify optimization, which will not impact other parameters like exhaust back pressure, emission and vehicle pass-by noise. The study was focused on perforated pipes in mufflers internals with different perforation patterns, hole sizes, hole shapes and addition of glass fiber mat.

Hans Boden [12] presented in their technical paper the techniques used for characterization of IC-engines as acoustic sources of exhaust and intake system noise. To evaluate insertion loss of mufflers or the level of radiated sound information about the engine as an acoustic source model used in the low frequency plane wave range with the linear time invariant of one-port model. The acoustic source data was obtained from experimental tests.

Giovanni Ferrara, Lorenzo ferrari, Giovanni Vichi, Giulio Lenzi, Davide Biliotti[13] presented in their technical paper to analyze the acoustic characteristics of both industrial and application mufflers. The physical phenomena of muffler connected to the acoustic response was studied to calibrate numerical models.

Giovanni Ferrara, Lorenzo ferrari, Giovanni Vichi, Giulio Lenzi, Davide Biliotti [14] presented in their technical paper the one dimensional numerical method, which has been successfully applied by industrial designers to the fluid-dynamic design of the engine, was considered to be inaccurate in the evaluation of the acoustic behavior of the muffler for medium-high frequencies. On the other hand, an extension of the applicability of these codes in the medium-high frequencies would be desirable.

Shitalkumar Ramesh Shah, Gangadhar GS[15] presented in their technical paper was to propose a practical approach to design, develop and validate muffler practically which will give advantage over conventional method.

Daniela Siano, Fabio Auriemma , Fabio Bozza, Hans Rammal lng [16] presented in their technical paper the 1D-3D acoustical analysis of a commercial muffler, has been improved and experimentally validated. Features related to the manufacturing process, like the coupling of adjacent surfaces and the actual shape of components, have been noticed to heavily affect the muffler behavior.

Abolfazl Eskandari, Mostafa haghroosta, Kia Valefi [17] presented in their technical paper the vehicle was selected and measures have been taken to improve its noise and vibration behavior. By implementing suspension techniques, some of the vibration characteristics of drive train and its influence on the interior noise at different engine speeds and under road load have been investigated. In addition, the effect of double layer instead of single layer muffler skin on the cabin noise has been probed.

P. S. Yadav, A. A. Gaikwad, S. A. Kunde, N. V. Karanth [18] presented in their technical paper the sound source was modelled by acoustic impedance and volume velocity of the engine. Since it was difficult to estimate the sound source impedance of the exhaust by measurements either with direct or indirect methods as both are prone to errors and difficult to implement, the empirical equations are used to define exhaust source, to have reasonable accuracy.

P. Chaitanya, M. L. Munjal[19] presented in their technical paper the design or tuning of extended concentric tube resonators. One dimensional control volume approach was used to analyze this muffler configuration. It was validated experimentally making use of the two source-location method.

Muhammad Yasir, GregorMori, HelmutWieser,Martin Schattenkirchner, andManuel Hogl[20] presented in their technical paper 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 was always uncertain and often leads to a disagreement. A new testing setup was built in which simulation of external and internal corrosion with additional thermal cycles can be performed simultaneously. Simulation of all real conditions makes this test totally versatile and unique among all the existing testing methods. All test results were investigated quantitatively and a direct comparison was made between some field systems with different mileage and total life. Conformity was accomplished between the results from corrosion tests and parts from the vehicles. 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 can be stated that the new testing setup can be applied for different materials and design rankings.

Raimo Kabral, Hans Rämmal, Jüri Lavrentjev, Fabio Auriemma[21] presented in their technical paper the acoustic transmission loss was a parameter often used in engineering to describe the passive acoustic performance of exhaust system elements. However, in order to provide a complete acoustical characterization of silencers and silencer components the acoustic 2-port elements (the scattering matrix or alternatively the transfer matrix) should be additionally analyzed. In this paper the scattering matrixes are studied systematically for several small engine silencer elements in a variety of operating conditions.

A.J. Torregrosa, A. Broatch, N. Djordjevic, D. Moreno [22] presented in their technical paper the effect of the geometrical parameters such as hole diameter and porosity on the acoustic response of non-concentric perforated duct muffler has been investigated experimentally using a modified impulse method. The experimental study showed that the acoustic behavior was basically determined by one single geometrical parameter: the modified porosity defined as the ratio between the perforated area and the tube cross section area.

Sifa Zheng, ZhongXu Kang, XiaoMin Lian [23] presented in their technical paper hybrid three-dimensional approach was developed to carry out the acoustic calculation of muffler matching with the engine. The acoustic source characteristics of engine are computed with one-dimensional methods and acoustic four pole parameters of muffler are computed with three-dimensional methods and insertion loss of a muffler equipped with Selective Catalytic Reduction in a heavy duty vehicle was evaluated .

Ovidiu Vasile, Darian Onchis-Moaca[24] presented in their technical paper the pressure-wave propagation in a muffler for an internal combustion engine in case of two combined mufflers geometry.The approach was generally applicable to analyzing the damping of propagation of harmonic pressure waves. The paper purpose is to show finite elements analysis of both inductive and resistive damping in pressure acoustics. The main output was the attenuation and acoustic pressure levels for the frequency range 50 Hz–3000 Hz.

Sifa Zheng, Peng Hao, Heng Xia, Xiaomin Lian, Keqiang Li [25] presented in their technical paper the comprehensive performance evaluation method was proposed to describe the muffler's influence on a commercial vehicle's noise emission, sound quality and exhaust back pressure under multiple working conditions. The weighted insertion loss and linearity coefficient were defined based on the test data of the exhaust noise under different engine loads and speeds.

Chulho Yang, John George, Thomas Wahl, Hao Jin [26] presented in their technical paper theoretical study on shell vibration has been conducted to investigate applicability of an analytical technique to predict and solve the NVH issues of an automotive muffler.

Ketan G. Kshirsagar, Scott R. Kiel, Mohan D. Rao [27] presented in their technical paper describes the design, development and validation of a muffler for reducing exhaust noise from a commercial tele-handler. It also describes the procedure for modeling and optimizing the exhaust muffler along with experimental measurement for correlating the sound transmission loss . The design and tuning of the tele-handler muffler was based on several factors including overall performance, cost, weight, available space, and ease of manufacturing. The analysis for predicting the STL was conducted using the commercial software LMS Virtual Lab , while the experimental validation was carried out in the laboratory using the two load setup.

J. Liu, D. W. Herrin [28] presented in their technical paper an incident wave decomposition method was proposed which was based on acoustic wave decomposition concepts instead of an electric circuit analogy providing a more straightforward approach to investigating the effect of acoustic load selection.

Abhishek Vishwakarma, P. Chandramouli, V. Ganesan[29] presented in their technical paper one-dimensional analysis was performed to analyze a three-pass muffler with perforated tubes for Transmission Loss, Effect of mean flow on transmission loss inside the muffler was studied. To account for the three-dimensional nature of acoustic waves at higher frequencies, a three dimensional finite element analysis was done using SYSNOISE. The Transmission loss results of the three-dimensional analysis were compared with those of one-dimensional analysis for no flow case and shown to agree reasonably for lower frequency range.

Dirk Wiemeler, Alexander Jauer, Jan-Friedrich Brand[30] presented in their technical paper the broad band and random character of this specific type of noise, an exact prediction based on Navier-Stokes equations was derived. Empirical approaches with varying quality levels were developed. These empirical approaches allow estimations of the flow noise from the early concept phase up to detailed design refinements and optimizations within the development. The main influence factors on flow noise such as temperature, mass flow and muffler design are outlined. The estimation of flow noise is based on empirical data and/or linear predictions with parametric single sources.

Zhenlin Ji, Shengli Su, Chen Liu[31] presented in their technical paper one-dimensional time-domain approach and the three-dimensional finite element method are used to predict and analyze the acoustic attenuation performance of three-pass perforated tube mufflers with and without end-resonator. The transmission loss results obtained from the 1-D time-domain approach agree reasonably well with the FEM predictions within the plane wave region, while the 1-D results derive the FEM predictions at higher frequencies. The FEM was then used to investigate the effects of internal structure on the acoustic attenuation performance of the mufflers, while the 1-D time-domain approach is employed to examine the influence of high temperature gas flow on the acoustic attenuation performance of the mufflers within the plane wave region.

Zhenlin Ji [32] presented in their technical paper multi-chamber muffler with selective sound-absorbing material with one-dimensional analytical approach based on the plane wave propagation theory and three-dimensional substructure boundary element method were developed to predict the acoustic attenuation characteristics of the multi-chamber muffler. The effects of flow-resistivity of sound absorbing material, porosity of perforation and geometrical parameters on the acoustic attenuation performance of the multi-chamber hybrid muffler are investigated in detail

Robert Fairbrother, Eric Varhos[33] presented in their technical paper a linear acoustic model for perforates has been applied to the perforated sections of the automotive muffler. This includes different configurations of the muffler both with and without flow. The perforate model with flow requires the correct flow distribution throughout the muffler in

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terms of through flow and grazing flow for each perforated section.

Hocheol Suh and Sejong Park Kyoungsuk Park Wanho Jeon and Janghyung Cho [34] presented in their technical paper flow filed and tried to establish an analyses procedure for flow noise phenomenon. The steady and unsteady flow field was calculated by a commercial CFD code, SC Tetra V6. Flow noise generated from the muffler was calculated by acoustic analogy of Ffowcs-Williams and Hawkings. The strong fluctuation of pressure inside the muffler generates the strong broadband noise and we have validated the flow noise generation problem in the muffler with experimental data. Flow noise is generated as a broadband noise from 1000 to 4000Hz frequency range.

R. N. Hota, M. L. Munjal [35] presented in their technical paper hybrid approach combines the time-domain analysis of the non-linear, variable-geometry exhaust source with the frequency-domain analysis of the muffler by means of a two-load method that evaluates the frequency-domain source characteristics making use of the time-domain model. The un-muffled exhaust noise is predicted by means of the commercial software AVL-BOOST and the muffled exhaust noise was then predicted by means of the source characteristics along with the transfer matrix.

M. Rahman, T. Sharmin, A F M E. Hassan, and M. Al Nur[36] presented in their technical paper the performance characteristics, i.e. noise reduction capability of the muffler, has been tested and compared with that of the conventional muffler.

S. N.Y. Gerges and R. Jordan F. A. Thieme J. L. Bento Coelho J. P. Arenas[37] presented in their technical paper the principles of TMM for predicting the transmission loss of a muffler are summarized. The method was applied to different muffler configurations and the numerical predictions are compared with the results obtained by means of an experimental set up. Only stationary, non-dissipative mufflers are considered. The limitation of both the experimental method and the plane wave approach are discussed. The predicted results agreed
reasonably well with the measured results in the low frequency range where the firing engine frequency and its first few harmonics are the main sources of noise.

M. L. Munjal[38] presented in their technical paper a hybrid approach has been mooted where the time-domain analysis of the exhaust source was combined with the frequency-domain analysis of the exhaust muffler making use of the discrete fourier transform pair. The paper reviews all these developments and presents the state of the art for estimating unmuffled exhaust noise and insertion loss of commercial mufflers

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