Technical Note: Effects Due to Exhaust and Tail Pipes on Insertion Loss of Mufflers

B. Rajavel and M. G. Prasad

Noise and Vibration Control Laboratory, Department of Mechanical Engineering, Stevens Institute of Technology, Hoboken NJ-07030

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In this study, the influence of exhaust pipe lengths on insertion loss(IL) which has not been analyzed in previous studies is investigated. IL is calculated analytically for a simple expansion chamber including source impedance, exhaust and tail pipe lengths. The prediction of frequencies based on models of quarter wave tube and half wave tube for exhaust and tail pipe resonances agree well with the effects seen in experimentally measured IL.

1. INTRODUCTION

It is well known that the IL of an automotive muffler system depends on the characteristics of the source in upstream and the termination condition in downstream of a muffler.1 The interaction of the source with the given muffler will have a significant effect on the performance of the muffler system. A preliminary study on the influence of source-muffler interaction on IL has been reported by Rajavel et al.[2] In this work, the effects due to exhaust pipe lengths for various source impedances on the IL of mufflers are studied. The influence of tail pipe length on IL is also investigated. Studies are based on a simple expansion chamber system, so that the extent of the influence due to the interaction of source, exhaust pipe, muffler, tail pipe, and termination condition on IL can be observed easily.

2. EXHAUST SYSTEM MODEL SETUP FOR INSERTION LOSS STUDY

The setup consists of an electro acoustic driver, an exhaust pipe, a simple expansion chamber and an open-ended tail pipe. The expansion chamber has a length (L_x) of 0.156 m and a diameter of 0.146 m. The inlet and outlet pipe diameters are 0.048 m. The expansion ratio of the chamber is 9.25. The schematic of the setup with electrical analog is shown in Figs. 1a, 1b, and 1c. The present study is carried out for three types of source impedances, namely, zero, infinite, and experimentally measured for the ALTEC290B electro acoustic driver.[3] The resistive and reactive parts of measured source impedance (normalized) values are shown in Fig. 1d. The well known expression used in this study for IL is based on electrical analogy model,[2] which is given by,

$$IL = 20\log_{10}\left|\frac{\tilde{A}\tilde{Z}_r + \tilde{B} + \tilde{C}\tilde{Z}_e\tilde{Z}_r + \tilde{D}\tilde{Z}_e}{\tilde{A}'\tilde{Z}_r + \tilde{B}' + \tilde{C}'\tilde{Z}_e\tilde{Z}_r + \tilde{D}'\tilde{Z}_e}\right| dB, \quad (1)$$

where $\tilde{Z}_e$ and $\tilde{Z}_r$ are source and radiation impedances, respectively, and $\tilde{A}$, $\tilde{B}$, $\tilde{C}$, $\tilde{D}$ are the four pole parameters[4] of the expansion chamber, including both the exhaust and tail pipe. The parameters with primes ($'$) are for the straight pipe with a total length equal to those of exhaust, chamber, and tail pipes.

3. INFLUENCE OF EXHAUST PIPE LENGTH ON INSERTION LOSS

The influence of exhaust pipe lengths on IL values for three source impedance cases is studied. For a given source impedance (Z_e), the exhaust pipe lengths (L_u) are varied to study their effect on the IL. For this study, three exhaust pipes (L_u) with lengths of 0.15 m, 0.6 m, and 1.2 m with equal diameters of 0.048m, and a tail pipe (L_t) with lengths of 0.5 m with diameter of 0.048 m are used. The speed of sound of 344 m/s is assumed for this study.

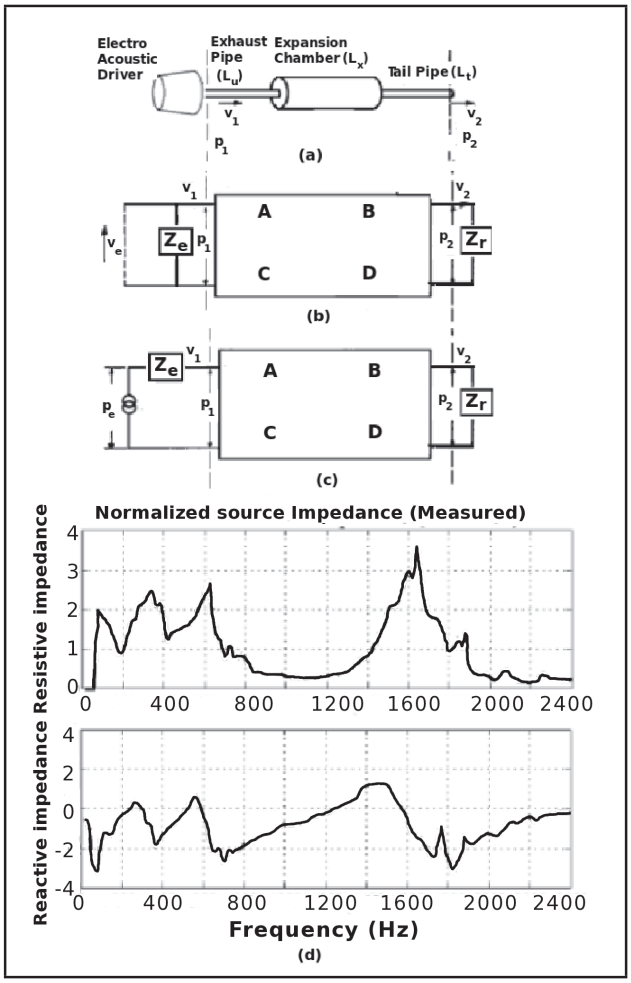

Figure 1. Figure (a) shows the physical model setup; (b) shows the volume velocity source analog; Figure (c) shows the pressure source analog; Figure (d) shows the experimentally measured source impedance values for electro acoustic driver.[3]