Shape Optimization of Three-chamber and Side-inlet Mufflers with perforated Tubes Using Simulated Annealing Method

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ABSTRACT

Research on new techniques of multi-chamber mufflers equipped with a side inlet has been well addressed and developed; however, the research work of multi-chamber mufflers in conjunction with side inlet and internal perforated tubes which may efficiently increase the acoustical performance is rare. Therefore, the main purpose of this paper is to not only analyze the sound transmission loss ($STL$) of three-chamber side mufflers with a perforated tube but also to optimize their best design shape under a limited space. In this paper, both the generalized decoupling technique and plane wave theory in solving the coupled acoustical problem are used. The four-pole system matrix in evaluating the acoustic performance is also deduced in conjunction with a simulated algorithm (SA). To verify the liability of the $SA$ technique, the noise minimization of mufflers at a targeted frequency is exemplified first. To appreciate the acoustical performance of various multi-chamber mufflers with/without inner perforated tube, two kinds of mufflers — a one-chamber side muffler and a three-chamber side muffler hybridized with a perforated tube — are introduced and assessed. In eliminating the broadband exhausted noise emitted from an air compressor’s inlet. Before the $SA$ operation can be carried out, the accuracies of the mathematical models have to be checked by experimental data.

The result reveals a three-chamber side muffler hybridized with a perforated tube exhibits an excellent acoustical ability beyond the other mufflers. Consequently, the approach used seeking the optimal design of the $STL$ proposed in this study is indeed easy, economical and quite effective.

Keywords: Multi-chamber, Internal Perforated Tube, Four-pole Transfer Matrix Method, Space Constraints, Simulated Annealing.

1. INTRODUCTION

As the constrained problem is mostly concerned with the necessity of operation and maintenance in practical engineering work, there, therefore, is a growing need to optimize the acoustical performance under limited space. In previous work, the shape optimization of a side inlet/out simple-expansion muffler has been discussed [1, 2]. Moreover, a mechanism of two-chamber muffler equipped with an internal non-perforated tube has been addressed [3]. However, the acoustical performance is still insufficient within space-constrained criteria. The assessment of a new acoustical element — internal perforated tube — was started and discussed by Sullivan and Crocker in 1978 [4]. Based on the coupled equations derived by Sullivan and Crocker, a series of theory and numerical techniques in decoupling the acoustical problems have been proposed [5, 6, 7, 8, 9]; Considering the flowing effect, Munjal [10] and Peat [11] broadcast the generalized decoupling and numerical decoupling methods. However, the application of a perforated tube in the side muffler is rarely tackled. To increase the acoustical performance, a three-chamber side muffler hybridized with an inner perforated tube which may dramatically depress the sound energies is proposed.

The simulated annealing (SA) method, a stochastic relaxation technique oriented by Metropolis et al. [12] and developed by Kirkpatrick et al. [13] imitating the physical process of annealing metal to reach the minimum energy state, is applied in this work. In this paper, to facilitate the evaluation of the muffler performance in acoustic, a four-pole system matrix in evaluating the acoustic performance ($STL$) is also deduced. By adjusting the muffler’s shape and using the $SA$ method and numerical decoupling methods, the optimal acoustical performances of mufflers can be achieved.

Figure 1 Elevation drawing of an air compressor room.

2. MATHEMATICAL MODELS

In this paper, a side-inlet muffler was adopted for the noise elimination on the constrained air compressor room shown in Figure 1. As indicated in Figure 2, this three-chamber side muffler system hybridized with a perforated tube consists of eleven acoustical elements. Five kinds of muffler components, including a straight duct, a side duct, an extended duct, a perforated tube, and a contracted duct are recognized, symbolized as I, II, III, IV and III, and shown in Figure 3. In Figure 4, the