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EVALUATION OF PIPE SILENCERS EFFICIENCY WITH INTERNAL GEOMETRY OPTIMIZED FOR NOISE CONTROL IN SPECIFIC FREQUENCY RANGES USING THE FINITE ELEMENT TECHNIQUE

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Abstract. *This paper presents a numerical analysis of the performance of an acoustic muffler. The goal was to establish the best configuration for the installation of two barriers, modifying the internal geometry of the muffler. To find a setting that maximizes the sound transmission loss (TL) was used a routine of optimization with genetic algorithms and simulations was conducted to assess the behavior of muffler through the finite element method. For the numerical analysis was necessary to establish some initial conditions, such as, input sound pressure, impedance and use an anechoic termination in the tube. We evaluated two functions goal in an optimization routine, the first seeking the maximum value of TL and the other by maximizing the area of the curve below the TL. Despite the expectation of obtaining different results, both methods achieved results very closely, even in processing time and the sound attenuation of the muffler was actually improved in a frequency range from pre-established.*

Keywords: *Transmission Loss 1, Numerical Analysis 2, Optimization 3, Acoustic Muffler 4)*

1. INTRODUCTION

The noise and the pollution emitted by exhaust systems of the vehicle and by major industries should be evaluated and controlled because they impact directly and on an increasing scale to the environment. The control of the noise sources can be done using acoustic filters, also known as silencers, being those of two types: passive (comprising the dissipative or reactive) and active. The acoustic performance is expressed in terms of some parameters being the main one by the sound transmission loss (TL).

In the design of the muffler, the TL can be estimated through analytical and computational methods, having highlights among these the finite element method (FEM).

In this context, the goal of this paper was to use an optimization routine to vary the internal geometry of a muffler of a chamber to tune the frequencies or frequency bands of interest for the control of noise and evaluate the performance using numerical simulations by the FEM. For this purpose, was developed a computational model using the ANSYS® and an optimization routine implemented in MATLAB®.

2. TRANSMISSION LOSS

Transmission Loss (TL) is independent of the source and presumes an anechoic termination at the downstream end. It is defined as the difference between the power incident on the muffler proper and that transmitted downstream into an anechoic termination (Munjal, 1987).

2.1 Decomposition Method

As shown in Figure 1, for one-dimensional sound traveling along a duct, a portion of this incident wave of loudness S_{AA} pass through acoustic filter generating the wave transmitted from S_{CC} intensity. The other portion of the incident wave is reflected with intensity S_{BB} because of the impedance change generated by the presence of acoustic filter. The use of this method implies the experimental realization of an anechoic termination (Nuñez *et al*, 2008).

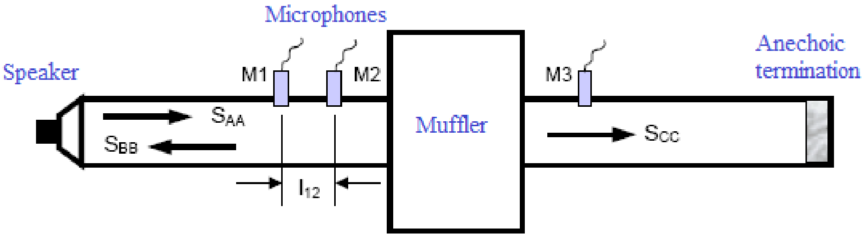

Figure 1. Setup of decomposition method.

The muffler TL is defined as the ratio of the sound energy of incident or reflected wave and sound energy transmitted wave, as shown in Eq. (1) (Nuñez *et al*, 2008).

$$TL = 10log_{10}\frac{A_i S_{AA}(f)}{A_o S_{CC}(f)} \tag{1}$$

where S_{AA} and S_{CC} are the sound intensity incident on the input and the intensity at the output of the acoustic filter respectively, A_i and A_o are the cross-sectional areas of the tail pipe and the exhaust pipe of the acoustic filter.

From the method of two microphones is possible to obtain portions of incident wave S_{AA} and reflected S_{BB}, as the Eqs. (2) and (3)

$$S_{AA}(f) = \frac{S_{11} + S_{22} - 2C_{12}cos(kl_{12}) + 2Q_{12}sin(kl_{12})}{4sin^2(kl_{12})} \tag{2}$$

$$S_{BB}(f) = \frac{S_{11} + S_{22} - 2C_{12}cos(kl_{12}) - 2Q_{12}sin(kl_{12})}{4sin^2(kl_{12})} \tag{3}$$

where S_{11} and S_{22} are the auto spectra of the total acoustic pressure at points 1 and 2, respectively; C_{12} and Q_{12} are the real and imaginary parts of cross spectrum between points 1 and 2; k is the wave number; and l_{12} is the distance between the two microphones (Tao e Seybert, 2003).

The S_{CC} value of Equation (1) is obtained by the auto spectra of microphone 3, since it has an anechoic termination at the tail pipe of the acoustic filter (Nuñez *et al*, 2008).

3. COMPUTATIONAL PROCEDURE

The muffler was set using the geometry of a pipe with a reactive acoustic filter, as shown in Fig. 2.

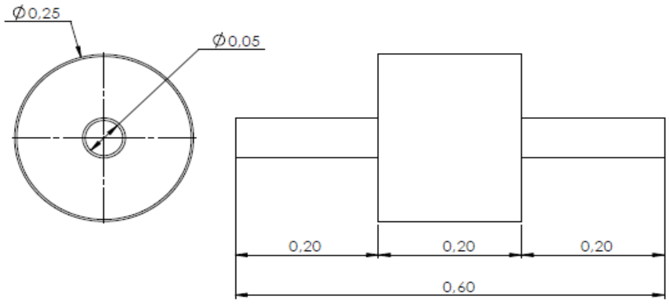

Figure 2. Pipe model with the reactive acoustic filter (dimensions in meters).

The numerical modeling of the muffler was made in the program ANSYS® and estimated the TL using the decomposition method, being pre-defined a range of frequencies for optimization. In possession of such data, the numerical model was developed using an APDL language programming which makes possible perform an interface with the mathematical model implemented in MATLAB®, used by the optimization routine (Fig. 3).

For the implementation of this routine was defined that two barriers would be installed inside the expansion chamber whose heights are the variables (Fig. 4). The ranges of values adopted for the handling of barriers on the y-axis were selected according to the dimensions of the muffler.

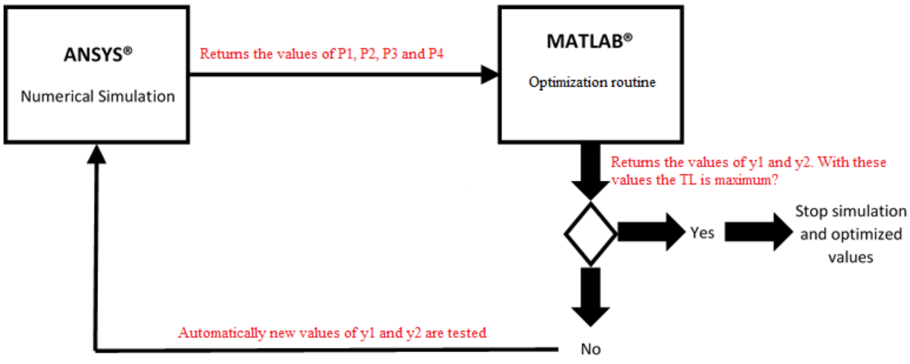

Figure 3. Flowchart of routine performance analysis and optimization of the muffler.

As shown in Figure 3, for the optimization of the parameters y_1 and y_2, the ANSYS® get the pressure values at points 1, 2, 3 and 4 to MATLAB® which plots the graph of TL and analyzes if this is maximum if not the maximum value, automatically the program returns new values for y_1 and y_2 starting the cycle again.

Were performed two different optimizations, one in relation to the maximum value of the TL and the other by maximizing the area under the curve of the TL. Finally was evaluated the performance of the muffler with optimized internal geometry, checking if the behavior would be similar to the expected according to the theory.

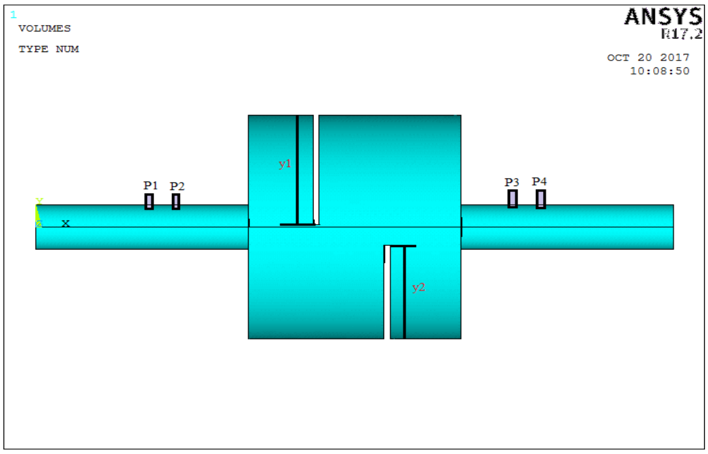

Figure 4. Parameters used in the routine for the optimization of acoustic muffler.

4. RESULTS AND DISCUSSION

It has been estimated numerically the TL of the muffler in your initial configuration (Fig. 5).

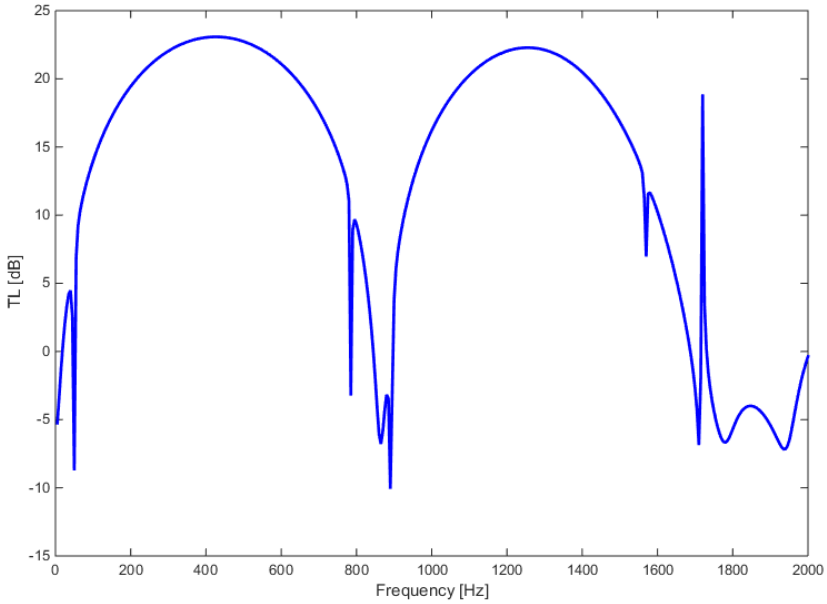

Figure 5. Estimated attenuation for the initial configuration of the muffler.

The analysis of Figure 4 shows that the muffler has a TL approximately 21 dB. The range chosen was between 700 to 1400 Hz for optimization of the attenuation. With the application of optimization routines, the best configuration of the muffler by the maximum value of TL resulted in the heights of its two internal barriers in y_1=0,11711 m and y_2=0,09079 m. Already by the method of maximizing the area under the curve of the TL the heights of the two internal barriers were y_1=0,12212 m and y_2=0,10461 m. Finally, we compared the attenuation of the muffler after the application of the techniques of optimization of their internal geometry with the initial configuration (Fig. 6).

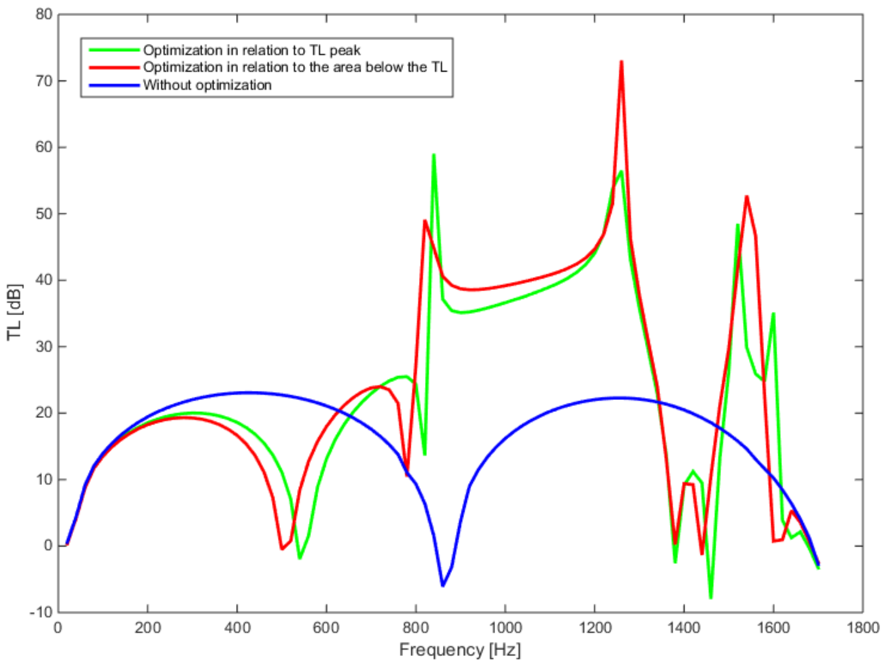

Figure 6. Comparison of attenuation of the muffler on your initial configuration and internal geometry optimized by the two methods described.

The analysis of Figure 5, for both functions objective adopted, there was a satisfactory result, with the increase of the average attenuation of the muffler within the frequency range of interest of approximately 21,0 dB for 40,0 dB. The peaks on the graph of the TL on the optimized muffler are related to the natural frequencies of the chambers created by the insertion of barriers, where the attenuations will be maximum.

5. CONCLUSIONS

In this work was developed a methodology for optimization using genetic algorithms for determination of expansion chamber geometry of a reactive acoustic muffler to improve noise attenuation in a particular frequency band. Analyzing the results it can be concluded that the objective of this work was achieved, the template with optimized internal geometry presented an acoustic performance approximately two times higher when compared to the model which the expansion chamber does not suffer changes.

6. ACKNOWLEDGEMENTS

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8. RESPONSIBILITY NOTICE

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