A PREDICTION OF ACOUSTICS CHARACTERISTICS FOR STEAM GENERATOR SYSTEM

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ABSTRACT

This paper presents a numerical analysis of the transmission loss (TL) for perforated steam generator system by adapting the theory of transmission of acoustic wave in an automotive exhaust pipe. The objective of this study is to develop a computer program to predict the transmission loss of a perforated steam generator and to investigate the influence of porosity and the effect of outlet-inlet parameters on the performance of steam generator. The efficiency and capabilities of the computing the transmission loss is compared to the experiment results obtained from the previous established research paper that the results give a good agreement. In this study two sets of results are presented. The first set illustrates the determination of the sound pressure level at one point and, then at another point after the sound wave traverses a certain distance. The second set of results describes the transmission loss of the acoustic wave after passing through steam generator.

Keywords: *Acoustics, Four-Pole Parameter, Porosity, Steam Generator, Transmission Loss (TL)*

1.0 INTRODUCTION

Noise emanating from turbine generators has become one of the most important sources of annoyance from noise, particularly in the large gas industrial area. Gas noise contributes significantly to the total noise emitted by the various types of generators. The suppressions of gas noise may not achieve satisfactory degree of quietness in all cases without attention to both inlet and outlet of a turbine gas. Therefore, reducing transmitted noise is an important step to achieving a tolerable level of noise output from the steam generator.

To properly predict the acoustic behaviour of a large system, such as the steam generator many factors need to be considered. Geometrical properties, absorptive material characteristics, flow effects, self-generated noise and source impedance are important factors to determine the acoustic behaviour [1]. However, numerical analysis of a steam generator is not an easy task since it involves huge geometrical data. Therefore in certain conditions, it is important to ensure that the numerical simulation for the results is available and can be obtained easily. Moreover, this system is not simple because the acoustics wave has a probability to propagate in a three-dimensional direction from the large-spaced ducting system.

Generally, there are three methods used for calculating Transmission Loss (TL); (1) the transfer matrix method (alternatively referred to as four-pole parameters method) [2, 3]; (2) the two-dimensional or three-dimensional analytical method [4, 5]; and (3) three-dimensional acoustic analysis (FEM, BEM or FEM/BEM), [6, 7]. Each of the methods gives similar results for TL, but there are differences in terms of computational time, ease of use and specific applications [8]. The transfer matrix or four-pole method is the most in commonly used and developed using plane wave theory.

The theory for acoustic wave from the automotive exhaust pipe may be applied to the steam generator and its ducting system. A previous study in [9] predicted a noise level of heat recovery stream generator by sound power entering to the inlet duct, main casing, outlet duct and stack. They used the transmission loss of multiple wall layers withadditional noise suppression equipment, duct shroud and silencer. A review of research project that conducted in [10] suggested guidelines for the prediction of noise in high recovery steam generator. They presented the method to reduce noise by considered a transmission loss through the inlet and outlet duct by measured the sound pressure level at a different locations along inside and outside of the steam generator.

In automotive exhaust system, the transmission loss offers the most easily predicted theoretically in analysing the acoustic transmission behaviour to the different configurations and parameters of the muffler [12, 13]. The transmission loss in muffler system can be used to analyze the effect of the inlet and outlet parameter of pipes, such as the diameter of the muffler, chamber length and baffle location [11]. Therefore, the theory of the exhaust muffler system can be used for prediction of acoustic behaviour of the steam generator system and complies with the physical parameters of the of the steam generator duct system.

The objective of this study is to develop the computer program to predict the transmission loss of a perforated steam generator and to investigate the influence of porosity, effect of outlet-inlet parameters on the performance of the steam generator. The efficiency and capabilities of the computing the transmission loss is compared to the results obtained from the previous research works establishedin [14].

Two sets of analysis are presented to depict acoustic transmission loss. The first set is to illustrate the sound pressure level at an arbitrary point. The second analysis is to determine the sound pressure level after a certain distance out from the said point, which will indicate the transmission loss after passing through the steam generator.

2.0 THEORY

The following paragraphs are discussions on the basic physical properties of sound and the numerical approach to describe the acoustic behaviour or sound transmission through fluid.

2.1 Propagation of Sound Energy

Sound propagates at approximately 343 ms^{-1} in air at a temperature of 20°C. The speed of sound however, varies according to the type medium, temperature and density. Sound emanates from a source in the form of spherical waves of energy which spread out into the medium it travels through. As the waves propagate further from the source into the medium, their curvatures straighten out into planes of wave energy. The power of the sound wave is the acoustical energy emitted per second by the source. It is strictly a property of the source which is not affected by the environment nor distance. Acoustic output power is usually compared to a reference power which is the least audible sound to the human ear, namely, 10^{-12}W. This ratio is the sound power level (SWL) which is a logarithmic measure.

The source must supply energy to satisfy the power demand of the wave field. The numerical range involve in measuring sound powers in logarithmic scale (SWL) is:

$$\text{SWL}=10\, log_{10}\left(\frac{\text{sound power output}}{10^{-12}\text{ watts}}\right) \text{ where the minimum}$$

$$=10\, log_{10}\ (\text{sound power in watts}) + 120 \text{ dB.} \tag{1}$$

2.2 Sound is a Linear Motion

As a sound wave propagates it disturbs the fluid from its mean state. These disturbances are always small. In the initial state, fluid is at rest with a uniform pressure, p_o and density, ρ_o. When it is perturbed by a sound wave pressure at position **x** and time t, the pressure changes to $p_o + p'(\mathbf{x},t)$ and the fluid particles move, very slowly, with the velocity $v(\mathbf{x},t)$. The ratio p'/p_o and p'/ρ_o are in most cases very much less than unity.

Though always weak, the range of amplitudes commonly experienced in sound waves is very great and it is convenient to express the pressure perturbation on the numerically more compact logarithmic scale. Again, somewhat confusingly the unit is termed the decibel, or dB. The sound pressure level (SPL) is a measure of the mean square level of fluctuation and is by convention defined as;

$$\text{SPL in dB} = 20\, log_{10}\left(\frac{p'_{rms}}{0.0002\ \mu\text{bar}}\right)$$

$$=20\, log_{10}\left(\frac{p'_{rms}}{2\times10^{-5}\ \text{N/m}^2}\right) \tag{2}$$

Where $p'^2_{rms} = p'^2$, is the mean value.

Consider the sound transmission in a layer of acoustic medium of finite length, L as shown in Figure 1. The input side is at $x = 0$ and the output side is at $x = L$.

$P_A = P_1 + P_2$	$p_1 = P_1 e^{j(\omega t - kx)}$	$P_B = P_1 + P_2$
$x = 0$	$\rightleftarrows$	$x = L$
$U_A = U_1 + U_1$	$p_2 = P_2 e^{j(\omega t + kx)}$	$U_B = U_1 + U_2$

Figure 1: A layer of acoustic medium

The right travelling wave is;

$$p_1 = P_1 e^{j(\omega t - kx)} \text{ and } ru_1 = P_1 e^{j(\omega t - kx)}, \tag{3}$$

Where; $r = \rho c$ and $k = c/\omega$.

Then, the left travelling wave is represented as;

$$p_2 = P_2 e^{j(\omega t + kx)} \text{ and } ru_2 = -P_2 e^{j(\omega t + kx)} \tag{4}$$

Applying the boundary conditions at the input point, where $x = 0$,

$$P_A = P_1 + P_2 \tag{5}$$

$$rU_A = (P_1 - P_2) \tag{6}$$

At the output point, where $x = L$, the total pressure and particle velocity become;

$$P_B = P_1 e^{-jkL} + P_2 e^{jkL} \tag{7}$$

$$rU_B = P_1 e^{-jkL} - P_2 e^{jkL} \tag{8}$$

Adding equations (7) and (8), we obtain;

$$P_1 = \frac{1}{2} e^{jkl}(P_B + rU_B) \tag{9}$$

Subtracting equation (8) from (7), we obtain;

$$P_2 = \frac{1}{2} e^{-jkl}(P_B - rU_B) \tag{10}$$

Substituting equations (9) and (10) in equation (5) results in;

$$P_A = P_B \cos kL + j\, U_B\, r_1 \sin kL \tag{11}$$

Substituting equations (9) and (10) in equation (6) results in;

$$U_A = \frac{j}{r} P_B \sin kL + U_B \cos kL \tag{12}$$

Equations (11) and (12) can be put in a matrix form as following;

$$\begin{Bmatrix} U_A \\ P_A \end{Bmatrix} = \begin{bmatrix} coskL & \dfrac{jsinkL}{\rho c} \\ j\rho csinkL & coskL \end{bmatrix} \begin{Bmatrix} U_B \\ P_B \end{Bmatrix} = \begin{bmatrix} \text{A} & \text{B} \\ \text{C} & \text{D} \end{bmatrix} \begin{Bmatrix} U_B \\ P_B \end{Bmatrix} \tag{13}$$

Where; A, B, C, D are called four-pole parameters and equation (13) is called four-pole equation [11], or the transfer matrix equation.

The equation relates two input and two output variables, the particle velocity and the acoustic pressure in this case. Notice that the formulation is in terms of the total velocity and pressure, not travelling wave components. It is general convention that subscripts *A* and *B* denote the input side and the output side, respectively. Similar derivations can be made for any other acoustic or mechanical systems, which can be represented by two variables at each side of the system.

2.3 Example Application to System Analysis

Cascading property is what makes the four-pole formulation so useful. To understand how it works, we consider the problem shown in the following Figure 2.

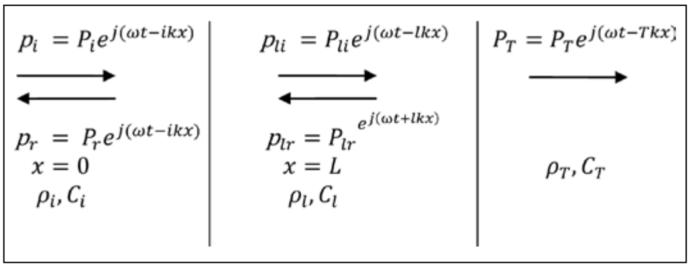


Figure 2: Sound transmissions through a layer of fluid

Noticing the fact that;

$$P_B = P_T \quad \text{and} \quad U_B = U_T \tag{14}$$

Equation (12) can be rewritten as;

$$\begin{Bmatrix} U_A \\ P_A \end{Bmatrix} = \begin{bmatrix} cosk_1L_1 & \dfrac{jsink_1L_1}{\rho c} \\ j\rho c sink_1L_1 & cosk_1L_1 \end{bmatrix} \begin{Bmatrix} U_B = U_T = \dfrac{P_T}{\rho_T c_T} \\ P_B = P_T \end{Bmatrix} \tag{14a}$$

From equation (14a);

$$U_A = \left(\frac{cosk_1L_1}{\rho_T c_T} + \frac{jsink_1L_1}{\rho_1 c_1} \right) P_T \tag{15}$$

$$P_A = \left(\frac{j\rho_1 c_1 sink_1L_1}{\rho_T c_T} + cosk_1L_1 \right) P_T \tag{16}$$

Since $U_A = U_i + U_r = \frac{P_i - P_r}{\rho_i c_i}$ and $P_A = P_i + P_r$, equations (15) and (16) can be arranged as;

$$P_i - P_r = \left(\frac{\rho_i c_i cosk_1L_1}{\rho_T c_T} + \frac{j\rho_i c_i sink_1L_1}{\rho_1 c_1} \right) P_T \tag{17}$$

$$P_i + P_r = \left(\frac{j\rho_1 c_1 sink_1L_1}{\rho_t c_t} + cosk_1L_1 \right) P_T \tag{18}$$

Adding equations (17) and (18)

$$2P_i = \left\{ \left(1 + \frac{\rho_i c_i}{\rho_T c_T}\right) cosk_1L_1 + j\left(\frac{\rho_i c_i}{\rho_1 c_1} + \frac{\rho_1 c_1}{\rho_T c_T}\right) sink_1L_1 \right\} P_T \tag{19}$$

Subtracting equation (18) from (17)

$$2P_r = \left\{ \left(1 - \frac{\rho_i c_i}{\rho_T c_T}\right) cosk_1L_1 + j\left(\frac{\rho_1 c_1}{\rho_T c_T} - \frac{\rho_i c_i}{\rho_1 c_1}\right) sink_1L_1 \right\} P_T \tag{20}$$

Dividing equation (20) by equation (19) we obtain the pressure reflection coefficient;

$$R = \frac{P_r}{P_i} = \frac{\left(1 - \frac{\rho_i c_i}{\rho_t c_t}\right) cosk_1L_1 + j\left(\frac{\rho_1 c_1}{\rho_T c_T} - \frac{\rho_i c_i}{\rho_1 c_1}\right) sink_1L_1}{\left(1 + \frac{\rho_i c_i}{\rho_T c_T}\right) cosk_1L_1 + j\left(\frac{\rho_i c_i}{\rho_1 c_1} - \frac{\rho_1 c_1}{\rho_T c_T}\right) sink_1L_1} \tag{21}$$

The analysis procedure can be applied to a multi-layer system using the cascading property as shown in the following section. The output variables of one acoustic element are the input variables of the next consecutive acoustic element. Figure 3 shows an example for sound transmission through three layers.

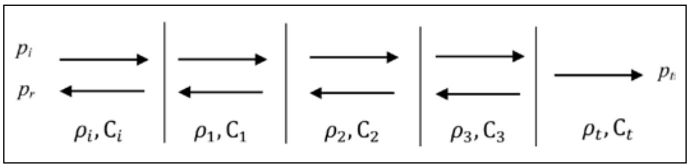


Figure 3: Sound transmission through three acoustic elements

Formulation without using the four-pole method (that is by describing the forward travelling wave and backward travelling wave components) will require solving for eight simultaneous equations. Because of the cascading property the four-pole equation can be written as follows;

$$\begin{aligned} \begin{Bmatrix} U_{A1} \\ P_{A1} \end{Bmatrix} &= \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{Bmatrix} U_{B1} = U_{A2} \\ P_{B1} = P_{A2} \end{Bmatrix} \\ &= \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{bmatrix} A_3 & B_3 \\ C_3 & D_3 \end{bmatrix} \begin{Bmatrix} U_{B3} \\ P_{B3} \end{Bmatrix} \\ &= \begin{bmatrix} A_T & B_T \\ C_T & D_T \end{bmatrix} \begin{Bmatrix} U_{B3} \\ P_{B3} \end{Bmatrix} \end{aligned} \tag{22}$$

Once the overall four-pole equation is obtained, the rest of the analysis procedure, for example calculating R, remains exactly the same. The system equation remains a 2x2 matrix equation, no matter how many layers exist. A_i, B_i, C_i, D_i denote four pole parameters of the i^{th} layer in the forms shown in equation (11) with L_i, ρ_i, c_i, for L, ρ, c. A_T, B_T, C_T, D_T, are the overall system four pole parameters that are obtained by multiplying the four pole matrices of the layers, which is called cascading.

2.4 Four-Pole Equation for Duct Acoustics [11]

The above procedure can be modified to derive four pole equations for duct systems. Referring to the duct system as shown in the Figure 4 (see page 44).

There are two different cross sectional areas S1 and S2.The continuity conditions between section 1 and section 2 are;

$$\begin{aligned} P_{B1} &= P_{A2} \\ S_1 U_{B1} = S_2 U_{A2} \quad &\text{or} \quad Q_{B1} = Q_{A2} \end{aligned} \tag{23}$$

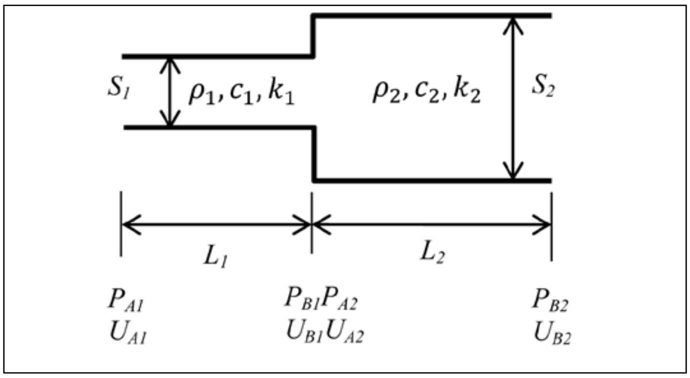


Figure 4: Sound transmissions through a duct of varying cross sections

The four pole equation therefore has to be formulated using the pressure P and the volume flow velocity $Q = SU$ as terminal variables. Multiplying equations (11) and (12) with S (cross sectional area);

$$SP_{Ai}=j\rho_i c_i S_i U_{Bi} sink_i L_i + P_{Bi} cosk_i L_i$$

$$P_{Ai}=\frac{j\rho_i\, c_i\, sink_i\, L_i}{S_i} Q_{Bi} + P_{Bi} cosk_i L_i$$

$$SU_{Ai}=S_i U_{Bi} cosk_i L_i + \frac{jS_i\, sink_i\, L_i}{\rho_i c_i} P_{Bi} \tag{24}$$

$$Q_{Ai}=Q_{Bi} cosk_i L_i + \frac{jS_i\, sink_i\, L_i}{\rho_i c_i} P_{Bi} \tag{25}$$

Converting equations (22) and (23) in the matrix form, the four pole matrix can now be written as:

$$\begin{Bmatrix} Q_{Ai} \\ P_{Ai} \end{Bmatrix} = \begin{bmatrix} cosk_i L_i & \frac{jS_i\, sink_i\, L_i}{\rho_i c_i} \\ \frac{j\rho_i c_i\, sink_i\, L_i}{S_i} & cosk_i L_i \end{bmatrix} \begin{Bmatrix} Q_{Bi} \\ P_{Bi} \end{Bmatrix} = \begin{bmatrix} A_i & B_i \\ C_i & D_i \end{bmatrix} \begin{Bmatrix} Q_{Bi} \\ P_{Bi} \end{Bmatrix} \tag{26}$$

The cascading property can now be applied exactly the same way as in the plane wave case for the Figure 5.

$$\begin{Bmatrix} Q_{A1} \\ P_{A1} \end{Bmatrix} = \begin{bmatrix} cosk_1 L_1 & \frac{jS_1\, sink_1\, L_1}{\rho_1 c_1} \\ \frac{j\rho_1 c_1\, sink_1\, L_1}{S_1} & cosk_1 L_1 \end{bmatrix} \begin{bmatrix} cosk_2 L_2 & \frac{jS_2\, sink_2\, L_2}{\rho_2 c_2} \\ \frac{j\rho_2 c_2\, sink_2\, L_2}{S_2} & cosk_2 L_2 \end{bmatrix} \begin{Bmatrix} Q_{B2} \\ P_{B2} \end{Bmatrix}$$

$$= \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} \begin{Bmatrix} Q_{B2} \\ P_{B2} \end{Bmatrix} \tag{27}$$

2.5 Formulation of Four-Poles in terms of Pressure Response Functions

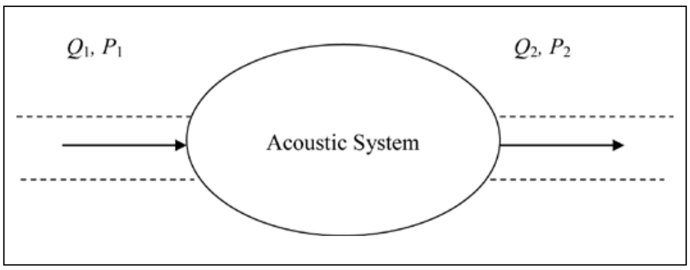


Figure 5: Schematic representation of an acoustic system

Four poles can be formulated in terms of the system response functions, pressure response function in our case. Let us consider a general acoustic system as shown in Figure 5. The four pole equation of the system is defined as;

$$\begin{Bmatrix} Q_1 \\ P_1 \end{Bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{Bmatrix} Q_2 \\ P_2 \end{Bmatrix} \tag{28}$$

In equation (28), P and Q are the harmonic amplitudes of the acoustic pressure and volume flow velocity, subscripts 1 and 2 indicate the input and the output sides respectively, and A, B, C and D are the four-pole parameters. It was shown that the four-pole parameters of any acoustic system could be formulated from the pressure response functions of the system. For example if the output port is blocked, $Q_2 = 0$ in equation (28); the first of equation (28) becomes;

$$Q_1 = BP_2 \tag{29}$$

Therefore, pole B is obtained as;

$$B = \frac{1}{P_2/Q_1} = \frac{1}{f_{21}} \tag{30}$$

Where f_{ij} is defined as the pressure response at point i when the system is driven by unit volume flow at point j, while the point i (on non-driving side) is blocked.

For example, f_{12} is the pressure at the input point in response to a unit flow input at the output point, while the output point is blocked. f_{12} and f_{22} are illustrated in Figure 6. From reciprocity, $f_{ij} = f_{ji}$, therefore only three of the four pressure responses are independent. Furthermore, if the system is symmetric about the input and output sides, $f_{11} = f_{22}$, therefore only two frequency response functions are independent.

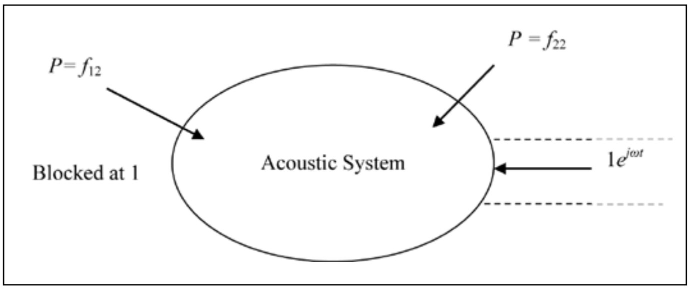


Figure 6: Illustration of two frequency response functions

If the input port is blocked, $Q1 = 0$; therefore the equation becomes;

$$0 = AQ_2 + BP_2 = AQ_2 + \frac{P_2}{f_{21}} \tag{31}$$

Since $P_2 = -Q_2 f_{22}$ (negative sign is because Q_2 is the outflow), we obtain;

$$A = \frac{f_{22}}{f_{21}} \tag{32}$$

Similarly, one can obtain;

$$C = -f_{12} + \frac{f_{11}}{f_{12}} f_{22} \tag{33}$$

Pressure response functions are functions of frequency; therefore four poles are also functions of frequency. Pressure response functions of a three-dimensional cavity, whose characteristic dimensions are large compared to the wavelength of interest, cannot be obtained easily because the singularity of the point source (i.e., f_{ii} becomes infinity). The source has to be modelled as a two-dimensional surface source, and the pressure response function has to be obtained in an average sense. The procedure is quite computational and very slow in convergence.

A much better solution is formulating four poles defining the system as shown in Figure 7, i.e., attaching short pipes to the input and output sides of the system. Use of such a system does not impose any practical limitation because three-dimensional cavities are always connected to other systems in such a manner.

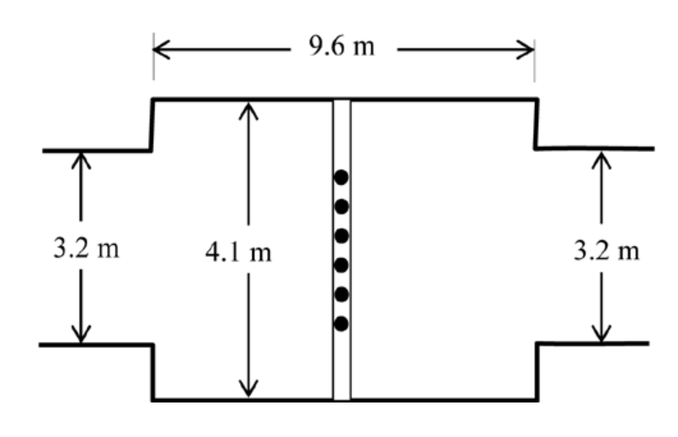


Figure 7: Typical of modelling for steam generator system

3.0 COMPUTER SIMULATION RESULTS

The analysis is categorised into two stages; firstly validation of the developed method and the second stage the analyses at steam generator is performed. The above procedures were automated into a computer program and the SPL values at various points are measured and discussed for the steam generator and gas turbine. From these results the transmission loss were computed.

3.1 Computer Simulation Validation

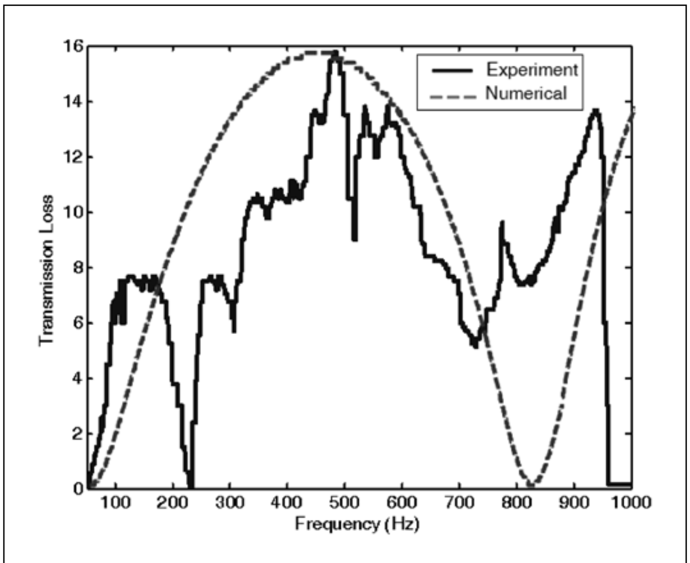


Figure 8: Comparisons of transmission loss between numerical and experiment in the [14]

The preliminary analysis is to validate an accuracy of the developed computer program with analysis of the transmission loss before the method is applied to other types of parameter settings and configurations. The validation of the computer simulations was carried out based on the comparisons of the transmission loss results from the similar parameter settings and configurations of perforated muffler that used in [14]. Next, the method is applied to the steam generator by changing the parameter values and configurations.

Figure 8 shows the results comparison between the experimental [14] and numerical results in predicting the transmission loss obtained from four-pole (or transfer matrix) method. The result demonstrated by the numerical simulated shows more consistent and closely matches with the experimental result. This proved that the developed method is reliable for the next investigation to predict the transmission loss in the steam generator.

3.2 SPL Level over a Distance

Table 1 shows the sound pressure level (SPL) for the inlet and outlet of a steam system obtained using computer simulation. Using the parameters of the mentioned system the SPL for the inlet and outlet can be predicted easily as shown in the second column of the table. The sound pressure decreases gradually as the sound travels over the distance concerned. It is found that the sound pressure drops to at 81.4 dBA at 15m, 85.9 dBA at 9m, and 104.9 dBA at 1m, respectively away from the main stack. However, at the outlet of the steam generator and gas turbine the sound pressure is a little higher as shown in the table.

Table 1: SPL level at outlet and inlet values at 15m, 9m and 1m away

CASE	Source SPL (dBA)	Simulation of SPL (dBA) 15m away	Simulation of SPL (dBA) 9m away	Simulation of SPL (dBA) 1m away
At outlet of gas turbine unit 4	158.4	94.8	99.3	118.4
At inlet of steam generator	153.9	90.3	94.8	113.9
At outlet of steam generator	148.5	84.9	89.4	108.5
At main stack	144.9	81.4	85.9	104.9

3.3 Transmission Loss

Figure 9 presents the computed transmission loss curve for steam generator with the parameters shown in Table 2.

Table 2: Actual parameters of steam generators

Parameter	Remarks
1. Porosity	45%
2. Length of porosity	3200 mm
3. Inlet Length	4084 mm
4. Outlet Length	4000 mm

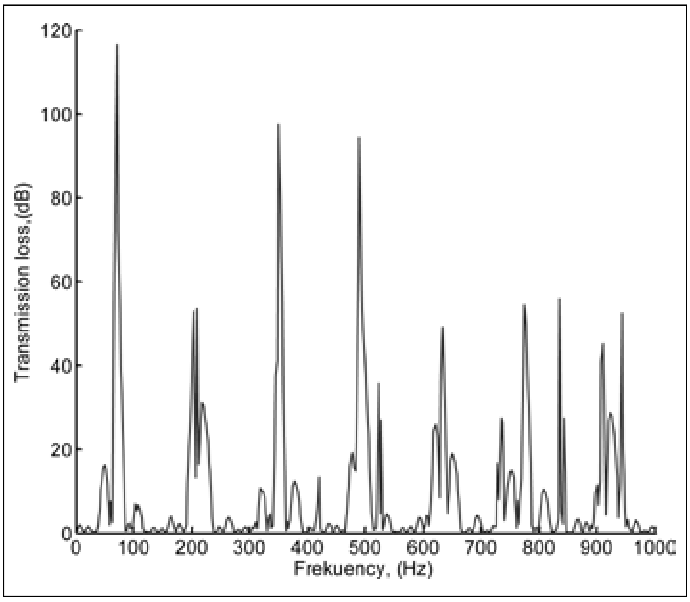


Figure 9: Transmission loss at original condition

We found the magnitude of transmission loss is further reduced at higher frequencies. Also we found that the plane wave propagates 3-dimensionally at all range of frequencies and there were many peaks of the transmission loss curve. This is because of the huge geometrical size of the steam generator which allowed the wave to propagate according to the large parameters.

3.4 Effect of Change in Inlet Length

In order to determine the characteristics of the wave at the inlet in a steam generator, several inlet lengths were identified. Four cases in terms of dimensions of inlet length of a steam generator were chosen for analysis as shown in Table 3.

Table 3: Length of inlet for the analysis

Cases	Length of inlet (mm)
Case 1	7000
Case 2	10000
Case 3	13000
Case 4	16000

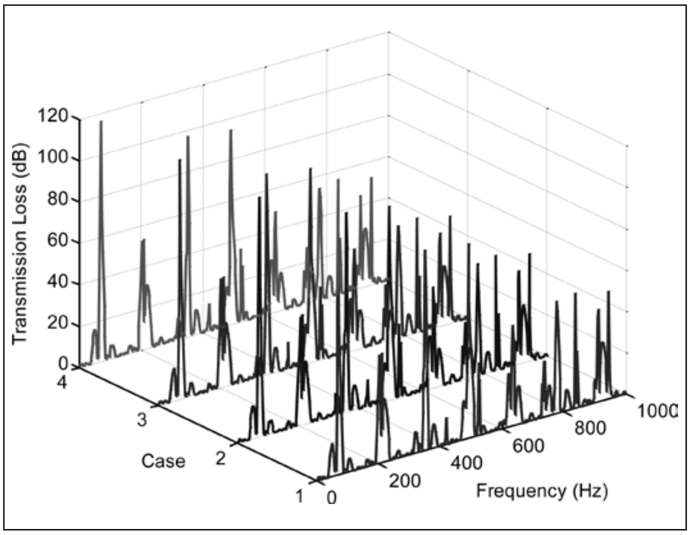


Figure 10: Transmission loss in various dimension of inlet length

The computed transmission loss for the various all inlet lengths are shown in Figure 10. However, the true frequencies of the transmission loss curve were not affected at all as is clearly shown in Figure 11. The average of transmission loss is constant even when the length of inlet is changed gradually.

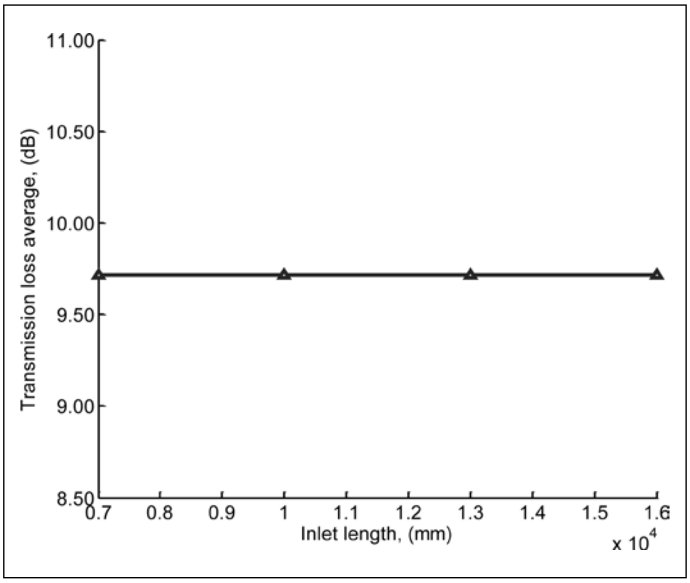


Figure 11: Average of transmission loss due to change of inlet length

3.5 Effect of Change in Outlet Length

In order to determine diagnose the characteristics of sound wave at the outlet in a steam generator, four cases in terms of dimensions of outlet length were chosen for analysis as shown in Table 4.

Table 4: Length of outlet for the analysis

Cases	Length of outlet (mm)
Case 1	2000
Case 2	3000
Case 3	4084
Case 4	5000

Figure 12 shows that the computed transmission loss depends on the various dimensions of outlet length in the steam

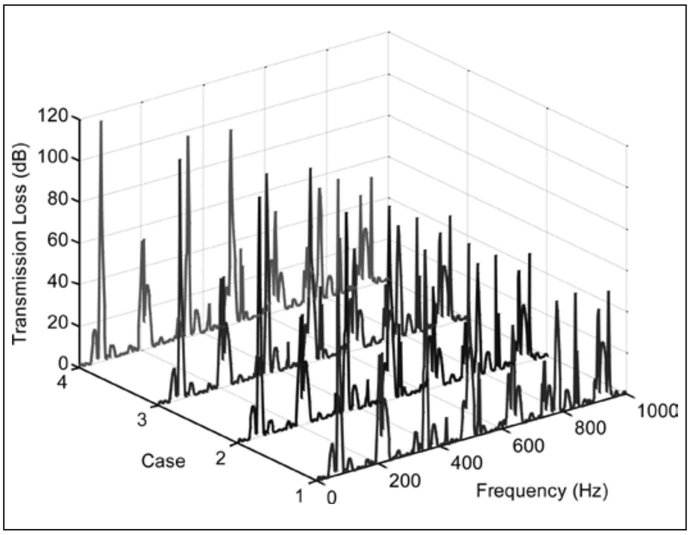


Figure 12: Transmission loss in various dimension of outlet length

generator. Figure 13 shows similar results as in Figure 11 whereby the outlet length did not influence the magnitude of the transmission loss curve.

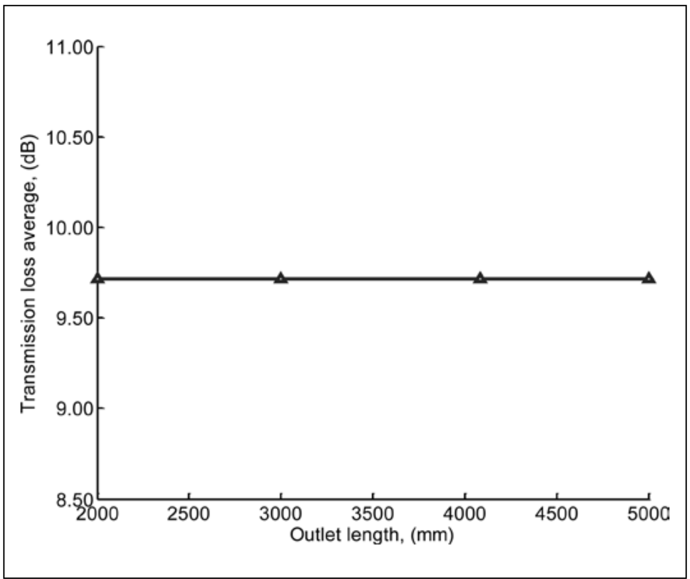


Figure 13: Average of transmission loss due to change of outlet length

3.6 Effect of Porosity

In order to diagnose the effect of porosity on transmission loss, a similar procedure on the same steam generator was performed. Table 5 shows the parameters involved in orders to calculate the transmission loss curve.

Table 5: Porosity case for steam generator

Cases	Porosity
Case 1	43%
Case 2	45%
Case 3	47%

Figure 14 presents the transmission loss computed for the various cases of porosity shown in Table 5. The transmission loss curve increases when the percentage of porosity increases.

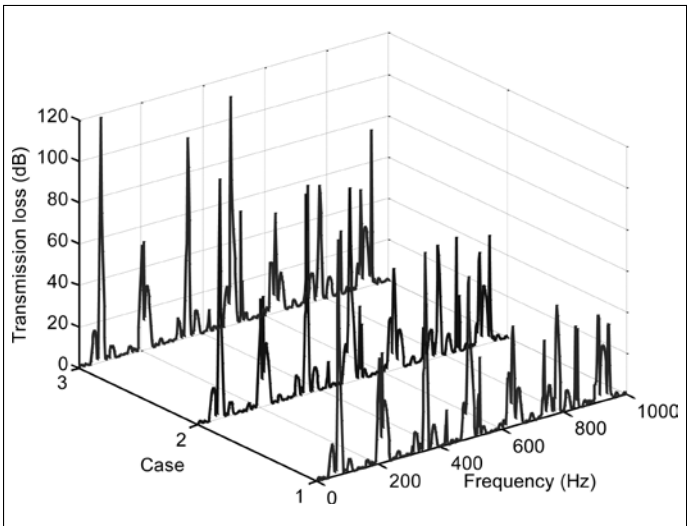


Figure 14: Transmission loss in various percentage of porosity

It is clear that an increase in porosity of the steam generator increases the magnitude of transmission loss. This is confirmed by the average transmission loss calculated as shown Figure 15. Increasing the percentage of porosity will change the steam generator into a simple generator whereby the geometry of the steam generator will act as an empty cavity system (100% porosity) thus produce a different transmission loss characteristic.

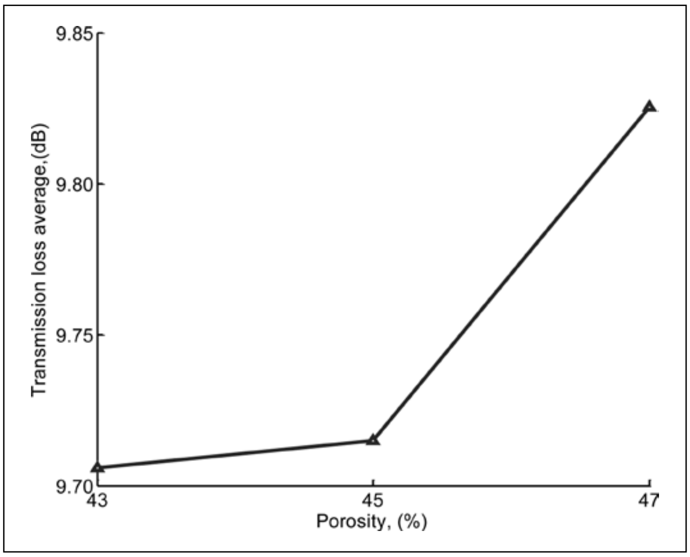


Figure 15: Average of transmission loss due to change in porosity percentage

3.7 Effect of Porosity Length

To identity the dimension for length of porosity in an actual steam generator is not an easy task. In order to predict the effect of porosity length, transmission loss for four cases were performed. The cases are shown in Table 6.

Table 6: Length of porosity

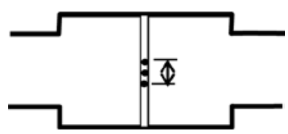
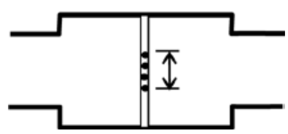
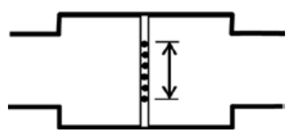
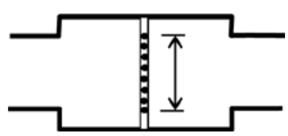
Cases	Remarks	
Case 1	100 mm	
Case 2	1200 mm	
Case 3	1900 mm	
Case 4	3200 mm	

Figure 16 shows the results of the transmission loss curve and Figure 17 shows the average of transmission loss due to change in porosity length. Both results show that, increasing the porosity length will produce a great change in transmission loss magnitude. This study took caution not to exceed a certain limit because over-increasing the length of porosity not only increases the magnitude of the transmission loss but will also change the geometry of the steam generator into the simple empty cavity as explained in the section 3.6.

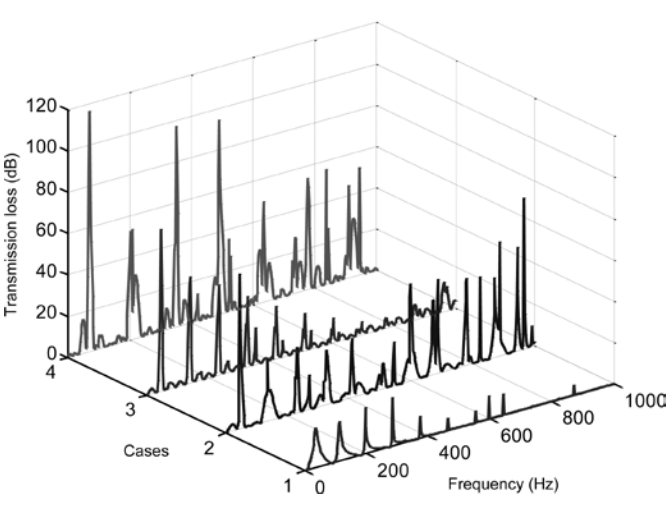


Figure 16: Transmission loss for various porosity lengths

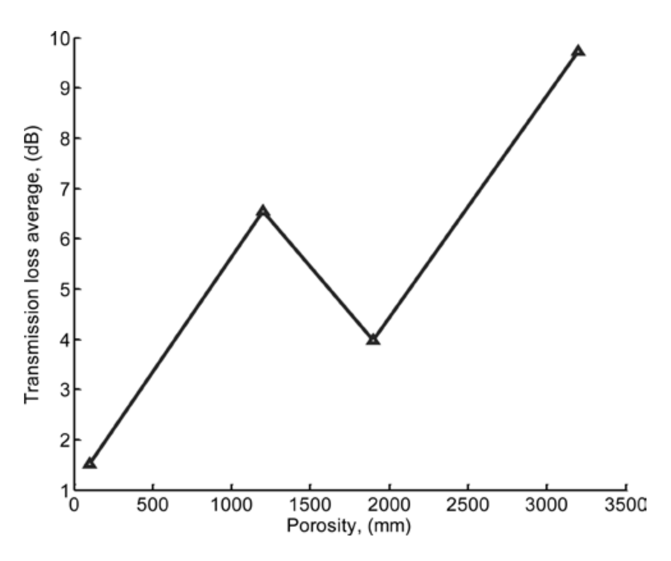


Figure 17: Average of transmission loss due to change in porosity length

4.0 CONCLUSION

The efficient analysis procedures to determine the characteristics of sound wave transmission and transmission loss using experimental parameters have been presented. Based on the study the following conclusions may be drawn:

1. A simple source programming has been developed to effectively predict noise problems in steam generators.
2. The sound pressure level (SPL) drops as the distance away from the source for both outlet and inlet steam generators. Thus, it is confirm that the sound of wave propagate as a linear motion.
3. The length of steam generator outlet does not influence the magnitude transmission loss curve.
4. Increasing the steam generator porosity increases the transmission loss. However, this statement is true for a limited porosity percentage.
5. Increasing the porosity length will result in a great change in transmission loss magnitude.

5.0 ACKNOWLEDGEMENT

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NOMENCLATURE

P	Pressure of particle
ρ	Density
x	Position at coordinate system
t	Time
L	Finite length
k	Wave number
ω	Harmonic pressure wave of frequency
U	Velocity of particle
S	Sectional area
Q	Volume flow velocity
A, B, C, D	Four-pole parameter matrices element

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PROFILES

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