Analysis of Sound Propagation in Finned Tube Bundle of HRSG in Power Plant

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ABSTRACT

The HRSG (Heat Recovery Steam Generator) generates high noise level due to the exhaust noise from gas turbine and is reduced as passing HRSG component. The HRSG consists of four major components - inlet duct, main casing, outlet duct and stack. Occasionally, additional noise reduction structures such as inlet shroud and silencer are required to satisfy the noise limit level. Thus, the prediction of noise level may lead to significant design problem. In this paper, we developed prediction method for the noise reduction level of main casing. The main casing consists of finned tube bank which is considered as a silencer. The FEA (Finite Element Acoustic) is applied to noise attenuation process of tube bundle. The test in actual finned-tube bank is performed for the validation of analysis.

Keywords: HRSG, Tube bundle, Noise prediction, Sound attenuation, FEA method

1. INTRODUCTION

A HRSG (Heat Recovery Steam Generator) performs as part of a combined cycle power plant for boiling water and function as reducing gas turbine exhaust noise emissions. Typical industrial gas turbine noise emissions for current large gas turbine approach sound power level of 150 dB(A) [1~2].

The HRSG's customer has demanded to decrease noise level due to the environment issue. This demand has also mandated the need for the reduction of near-filed and far-field noise propagated from HRSG. An error in the prediction of noise attenuation by HRSG can result in a plant does not meet environmental regulation and safety standard. It is generally contractual responsibility of the supplier of HRSG to limit gas turbine exhaust noise at power plant site [2].

Unfortunately, unnecessary margin in the noise specification, particularly in the lower frequency range, can result in significant costs for noise attenuation equipment. The finned tube bundle insertion loss determined the specification of stack silencer for reducing stack noise. In this reason, the accuracy of prediction noise is important in the design stage.

The main mechanism of HRSG noise attenuation is propagation loss due to resistivity of the tube bundles. In this study, we have calculated insertion loss for HRSG tube bundles by FEA method and verified by the test.

2. ANALYSIS METHOD OF SOUND ATTENUATION IN TUBE BUNDLES

2.1 Previous method

A heat exchanger tube bundle can be considered as a silencer that provides impedance

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mismatching for the acoustic energy along the tube bundles. Previous method of the analysis follows an experimental approach. Figure 1 present the measured insertion loss of each series of tubes. Linear and log scale plots of this data show a logarithmic relationship.

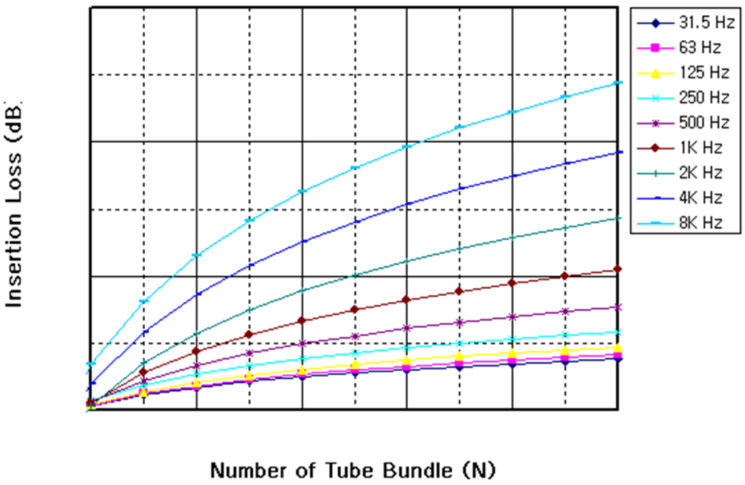


Figure 1 – The IL of finned tube bundle

However, the previous method cannot reflect the tube specifications and the spaces between tube rows. The FEA method which considers the specification and spaces has been established to calculate insertion loss of tube bundle.

2.2 Finned tube modeling for FEA analysis

The finned tubes are widely used in industrial applications such as an air heaters, gas coolers and boiler. However, it is difficult to create model the finned tube since the size is very small. In this paper, an effective diameter is applied to the finned tubes. As fins are added to a solid tube, the effective diameter is larger than solid tube diameter, but it is smaller than the outer fin diameter (solid tube diameter + fin’s height) [3]. The effective diameter is calculated by below equation proposed by Mair et al [4].

$$D_e = \frac{1}{s}\left[(s-t)D + tD_f\right] \qquad (1)$$

D_e: Effective diameter
D: Diameter of solid tube
D_f: Outer fin diameter (D + fin’s height)
s: Spacing between fins
t: Thickness of fin

2.3 Analysis model and condition

Figure 2 shows the schematic of tube bundle, which has transverse and longitudinal spaces. In this paper, we modeled 6 cases of the finned tube bundle. Each model has different spacing, fin height, fin density and diameter of solid tube. Fins are considered as parameter of effective diameter.

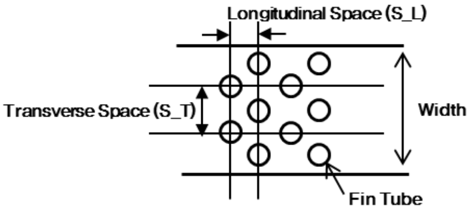


Figure 2 – The diagram of finned tube bundle

Figure 3 shows the FEA model of finned tube bundle and is modeled as solid tube using effective diameter by equation (1).

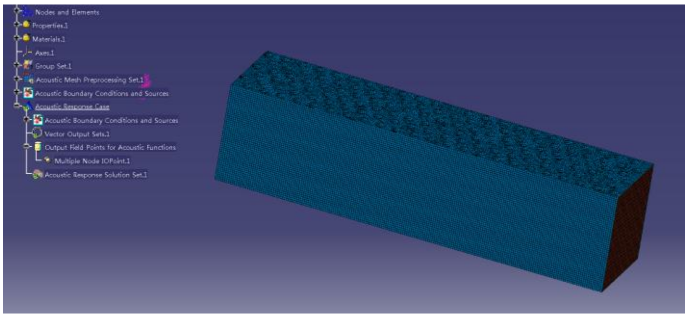


Figure 3 – FEA Model

Analysis of FEA method was performed the following process:

1. Setting boundary condition for inlet is using acoustic boundary condition for excitation.
2. Setting boundary condition for outlet is using AML (Acoustic Matching Layer) for calculation.
3. The insertion loss is calculated by the sound pressure level difference of tube bundle and installation of substitution (empty in a cavity) replacing the tube bundle.

2.4 Result of analysis

Figure 4 shows the insertion loss of tube bundles by FEA analysis. The analysis frequency range is under 1000 Hz due to Computer memory.

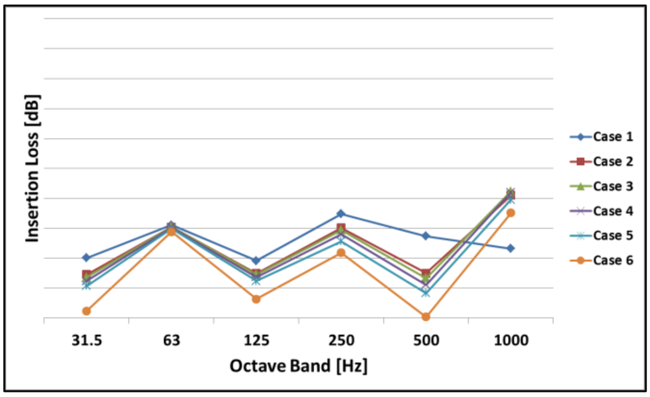
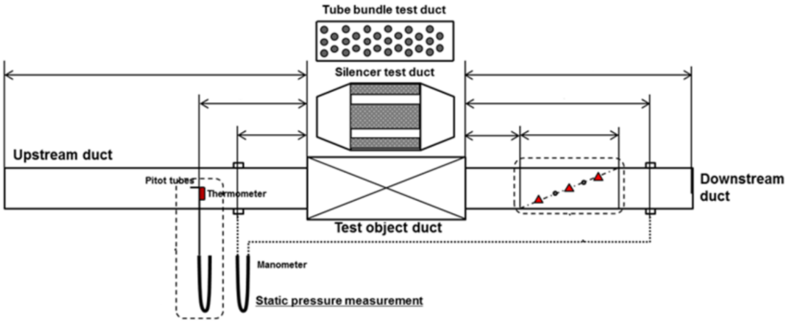


Figure 4 – FEA Model

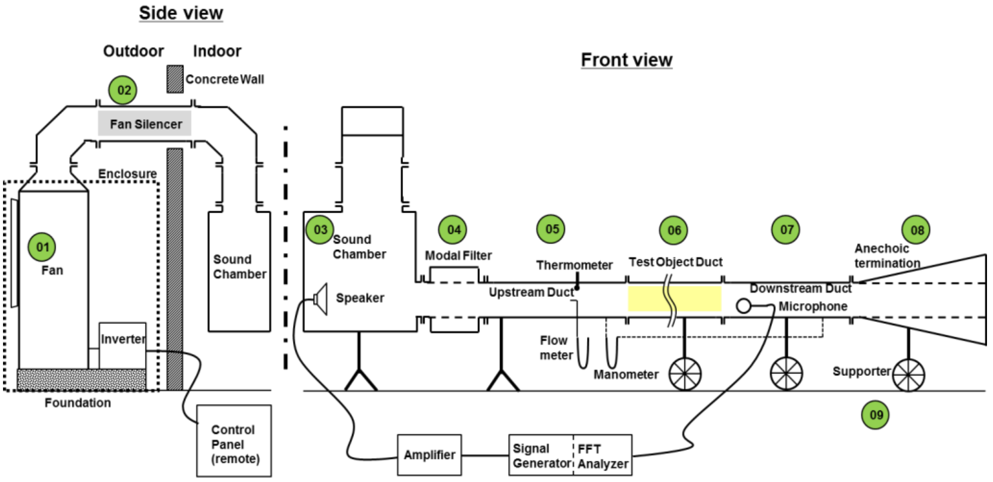
3. TEST OF TUBE BUNDLE

3.1 Test set up

The validation test was performed based on ISO 7235 and the diagram of test rig in Figure 5 [5].



(a) Tube bundle in test rig



(b) The diagram of test rig

Figure 5 – The diagram of test rig

The test was carried out to determine the insertion loss of finned tube bundle of noise excited by the sound source equipment (speaker) in the frequency range of analysis. The test was performed without flow condition. Figure 6 shows the actual finned tube bundle and measurement sensor in test rig.


(a) Actual finned tube bundle for test (b) Microphone in test rig

Figure 6 – The diagram of test rig

The insertion loss shall be determined from spatially average sound pressure level at identical point (at red triangle in figure 5). D_i, reduction in the level of the sound power in the duct behind the tube bundle due to the insertion of the tube bundle into the duct in place of substitution duct, by the equation

$$D_i = L_1 - L_2$$

L_1: The level of the sound power in the frequency band considered, propagating along the test duct or radiating into the connected reverberation room when the test object is installed.

L_2: The level of the sound power in the frequency band considered, propagating along the test duct or radiating into the connected reverberation room when the substitution duct replace the test object.

3.2 Result of test

The sound source was white noise with a sound power level of approximately over 100 dB. Measurement of sound pressure level was taken at different locations along the inside of test duct.

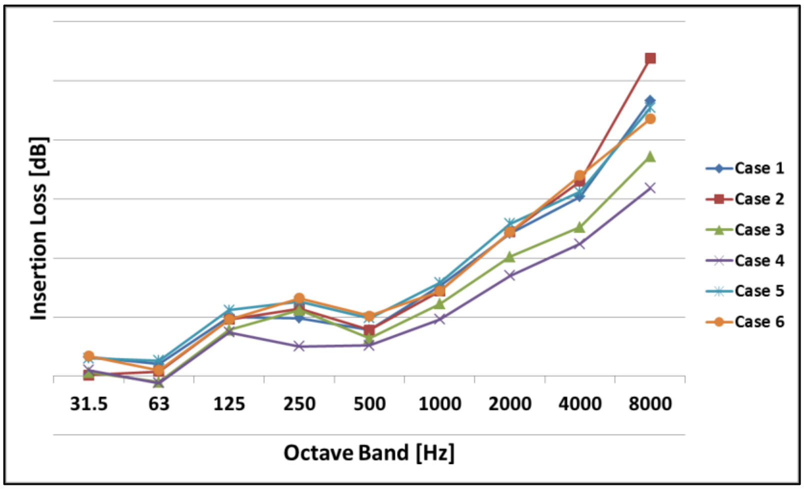


Figure 7 – The IL of finned tube bundle by test (without flow)

Figure 7 shows the results of sound pressure level attenuation inside the test duct and averaged results. The results show a small attenuation at low frequencies through the tube bundles but much larger attenuation at high frequencies. In the absence of flow, there was no flow induced noise. Flow induced noise would reduce the sound attenuation at high frequencies under operational conditions.

3.3 Comparing of analysis and test

Figure 8 shows the comparison between the calculated and measurement results of finned tube bundle. The Y axis is difference between calculation and test value. It can be found that the predicted results show good agreement with the test results. The maximum difference is approximately 3dB below 500 Hz, and is less than 4 dB in 1000 Hz.

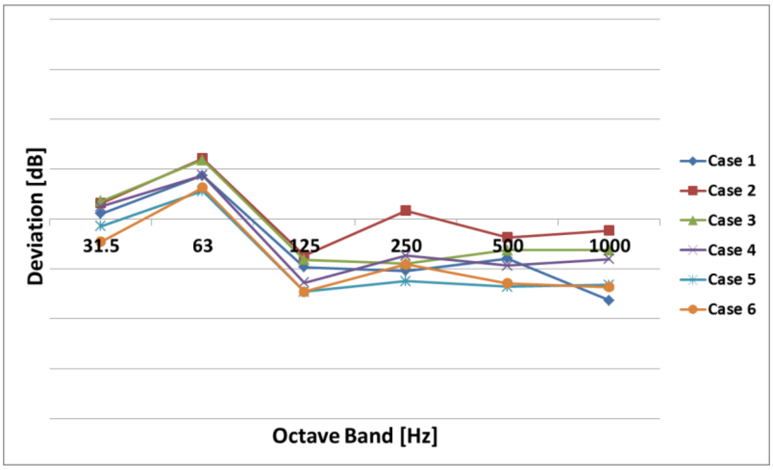


Figure 8 – The difference between analysis and test

4. SUMMARY

The prediction of sound attenuation using FEA method for finned tube bundle was developed. The FEA analysis was validated by the test using real finned tube bundle. Through comparison of the predicted value and the measured data from the test, it was found the maximum difference of below 500 Hz SPL approximately 3 dB. As a result, the IL value from FEA method can be used as noise prediction tools in the design stage.

Future work is planned to calculate the sound attenuation in the flow condition and validated by actual field data.

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