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Development of noise prediction program for Heat Recovery Steam Generator

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Abstract

It is usually contractual responsibility of the supplier of heat recovery steam generator (HRSG) to limit combustion turbine exhaust noise at cogeneration sites. Thus, it is necessary to predict noise level from HRSG in the design stage. HRSG is usually composed of an inlet duct, main casing, outlet duct and stack. To satisfy noise criterion, additional noise suppression equipments are sometimes required - duct shroud and silencer. In this paper, noise prediction algorithm for HRSG was presented given the gas turbine sound power entering. The algorithm includes the noise abatement of not only the basic components of HRSG but also additional noise reduction equipments. For the convenient use, graphic user interface was used for noise prediction program for HRSG, named NP-HRSG. In order to verify the accuracy of the noise prediction algorithm, predicted noise levels from actual HRSG installation are compared with measured data. Through this comparison, it was observed that the maximum difference between the predicted and measured results in near-field overall sound pressure level is less than 3dBA.

1. Introduction

Recently, market demands for heat recovery steam generator (HRSG) have been increased due to ever-increasing concern about environment and its high efficiency. These demands have also mandated the need for the reduction of near-field and far-field noise propagated from HRSG. It is generally contractual responsibility of the supplier of HRSG to limit combustion turbine exhaust noise at cogeneration sites. Thus, it is necessary for the supplier to predict the noise level from HRSG in the design stage.

From a noise generation viewpoint, HRSG equipment by itself is a passive device. The acoustic energy radiated by given boiler unit is created by gas turbine combustion process and exhaust gas flow stream. The noise associated with these two sources propagates through HRSG that is generally composed of inlet duct, main casing containing tube banks, outlet duct and stack. In order to satisfy noise regulation, additional noise suppression systems are sometimes required. Therefore, noise prediction algorithms must include functions to compute the noise reduction through these equipments. In addition, the transmission loss of the walls of each equipment and sound attenuation through atmospheric propagation should be also included by algorithm in order to predict near-field and far-field noise levels from HRSG.

2. Basic elements of noise prediction algorithm

2.1 Transmission loss of a duct wall

Commonly used insulation walls for HRSG are categorized into three types, which are single, double and triple layer insulations. When a high transmission loss structure is required, a double wall or triple wall is less heavy and more cost-effective than a single wall. Empirical formulas [1] on the transmission loss of multiple walls have been discussed and presented. These formulas, however, overestimate the transmission loss of the duct wall of HRSG because these models do not consider flanking and excitation by gas flow. Thus, calculation of the transmission loss of the duct wall of HRSG used in this work is based on the mass law with upper limits, which are varied, depending on the wall types and locations.

2.2 Insertion loss of tube bundles

A heat exchanger tube bank can be considered as a silencer that provides an impedance mismatch for the acoustic energy traveling along the tube bank. Sound-attenuating process of tube bundles is so complex that numerical or theoretic approach is almost impossible at present states. Thus unique 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 as the best data fit. An equation relating TL to the number of HRSG tube rows can be developed for each octave band, as are also shown in Fig. 1.

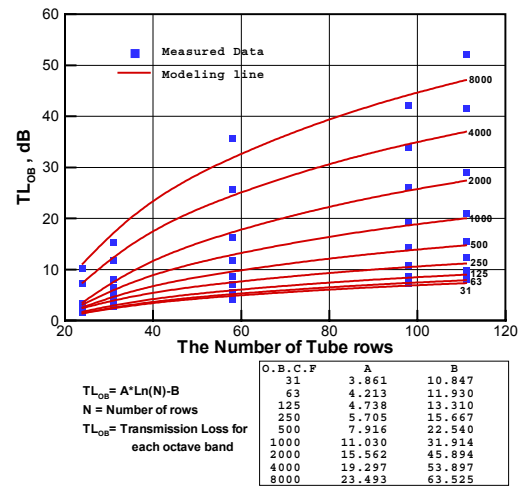


Fig. 1 The TL of Tube bundles

2.3 Insertion loss of duct silencer

The parallel-baffle-type silencer is the most widely used for HRSG because of its good acoustical performance and low cost. If flow noise is negligible, the insertion loss of silencer generally consists of the loss at the entrance of the silencer (ΔL_{ENT}), the loss due to the sound absorbing baffles (ΔL_I), and the loss at the exit of the silencer (ΔL_{EX}). The entrance and exit loss for silencers inserted in ducts are usually small and can either neglected or considered as the safety margin. The silencer attenuation ΔL_I is proportional to its length l and to the lined perimeter of passage, P , and inversely proportional to the cross-sectional area of passage, A .

$$\Delta L_I = (P / A) l L_h \quad (1)$$

where L_h is the parameter that depends in a complex manner on the geometry of the passage and the baffle, on the acoustical characteristics of the porous sound absorbing material filling the baffles, on frequency, and on temperature. In this work, the methods provided by Ramakrishnan & Watson [2] and Galaitsis & Vér [3] was used for the calculation of L_h .

2.4 Attenuation through outdoor sound propagation

The expression relating far-field sound pressure level, L_p , and sound power level, L_w , for a single source is;

$$L_p = L_w - K - D_{IM} - A_E \quad (2)$$

where K is a geometric spreading factor, D_{IM} is a directivity index, and A_E is an excess attenuation factor. There are five sources, which are inlet duct, main casing, outlet duct, stack and stack exit, contributing to sound in far field. The directivity index is only non-zero for the stack exit. The empirical model of Sutton [4] was used for the directivity index of the stack exit. The excess attenuation factor is defined as the sum in decibels of five separate terms, which are the attenuation due to air absorption, barriers, forests, reflection in the ground plane and meteorological effects such as wind and temperature gradients. In this work, however, the attenuation due to air absorption was only considered under the assumption that there are no forests, barriers, reflection in the ground plane and meteorological effects. The formula provided in ISO9613 [5] was used for the calculation of the attenuation due to air absorption.

3. Example Calculation

Calculation procedure for predicting the noise level from HRSG are demonstrated using the NP-HRSG program and the input data obtained from the actual HRSG equipments located in the west of Incheon city of Korea, which will be named West-Inchon HRSG in following subsection for convenience.

3.1 Input data

The noise propagating into HRSG is created by a Gas Turbine. A turbine manufacturer should provide octave band sound power levels at the gas turbine exhaust, which are shown in the upper part of Fig. 2. Required input data of an inlet duct are the dimensions of the inlet duct and the material properties of the duct wall, as shown in the lower part of Fig. 2. The type of insulation of the inlet duct is one layer and internal insulation. The composition of ceramic and mineral wool was used as the heat shielding and sound absorbing material. The required input data types and the values of the data of the main casing in West-Inchon HRSG data are similar to those of inlet duct. But the information about the number of tube rows in each main casing section, which are divided by the wall types, is needed. The input data types of the outlet duct and stack are same to those of inlet duct. Because there are no additional sound-suppressing equipments in West-Inchon HRSG, data of additional duct shroud and duct silencer are not required.

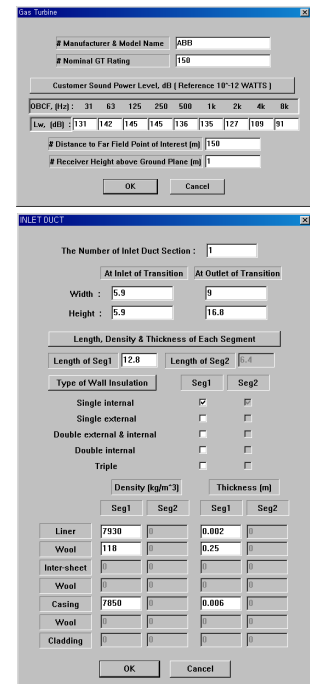


Fig. 2 Input windows

3.2 Output results

The left part of Fig. 3 shows A-weighted exhaust gas power levels at each components of West-Inchon HRSG. Because, if there is no inlet duct silencer, noise reduction mechanism does not exist between exit of the gas turbine and the inlet duct, exhaust gas power levels of the inlet duct are same to those of the gas turbine. Noise reduction through the main casing can be attributed to the insertion loss of tube bundles. First part of the main casing contains 31 tube rows and second part 82 tube rows. Overall transmission losses, defined as the ratio of incident acoustic power to radiated sound power, are 4.8 (dBA) for first part and 8.6 (dBA) for second part. The 90-degree turn and area constriction from the horizontal to vertical stack are considered as noise reduction elements from the main casing to the outlet duct and the stack. The right part of Fig. 3 shows far field sound pressure levels. It can be found that main contribution to far-field noise is made by the noise source at the exit of stacks. Thus, if the

predicted far noise level may exceed noise criteria, the installation of duct silencer in the stack can be considered as one of the noise suppression methods. Figure 4 shows the comparison between the calculated and measured results of overall SPL at 1 meter apart from the duct walls of each components of West-Inchon HRSG. It can be found that the predicted results show good agreements with the measured. The maximum difference is less than 3 (dBA).

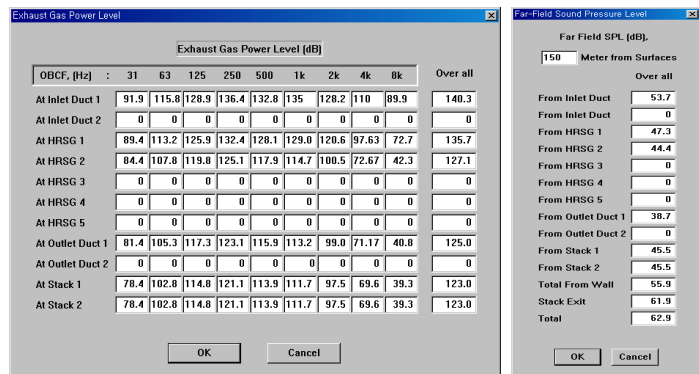


Fig. 3 Calculation results in output windows

Conclusions

The noise prediction algorithm for HRSG was developed. This algorithm can be used as noise prediction tools in the design stage and was provided in a form that can be readily used by engineers. This algorithm also cover the prediction of noise attenuation by the noise suppression apparatus such as duct shroud and silencer, which are needed if the predicted noise level exceed noise criterion. Through the comparison of the predicted value and the measured data from the West-Inchon HRSG, it was found that the maximum difference of overall SPL is just less than 3 dBA.

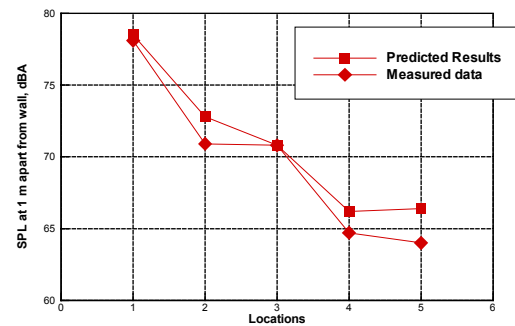


Fig. 4 The comparison of predicted and measured results
 1: inlet duct, 2: first part of main casing, 3: second part of main casing, 4: outlet duct, 5:stack

Acknowledgements

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References

1. D. A. Bies and C. H. Hansen, "Acoustic enclosures and barriers" Chap. 8 in *Engineering Noise Control – Theory and Practice*, E & FN Spon, London, 1996.
2. R. Ramakrishnan and W. R. Watson, "Design curves for rectangular splitter silencer", *Applied Acoustics*, 1992, 35, 1-24.
3. A. G. Galaitsis and I. L. Vér, "Passive silencers and lined ducts", Chap. 17 in *Noise and Vibration Control Engineering – Principles and Applications*, edited by L. L. Beranek and I. L. Vér, Wiley, New York, 1992.
4. M. Sutton, "Noise directivity of exit stack", Final year thesis for the Honors Degree of Bachelor of Engineering, University of Adeliaide, South Australia, 1990.
5. Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere, International Standard ISO 9613-1: 1993, International Organization for Standardization, Geneva, Switzerland, 1993.