

NEAR FIELD SOUND OF A HRSG

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1. INTRODUCTION

The prediction of near field sound for large heat recovery steam generators (HRSG) is largely based on empirical data based on historical data. One of the reasons is that the underlying source mechanisms are rather complex. The unsteady pressure field inside the HRSG is a combination of turbulent and acoustic pressures. The former are linked to the unsteady flows and the former are sound emitted from the gas turbine exhaust as well as flow generated sound inside the HRSG. Acoustic data for gas turbine units are often available in terms of octaves, rendering more detailed studies virtually impossible as the input data must be synthesized from the sparse data. This note provides some more detail that may be used to determine the sound pressure of the acoustic near field.

2. NEAR FIELD SURVEY

The methodology is based on a series of field measurements comprising both single microphone surveys and cross-spectral density/transfer functions measurements. The locations of the measurements (field points) on which form basis of the analysis are shown in figure 1. Accelerometers were placed off-diagonal on the panels to ‘catch’ a large number of panel modes. The surface pressure was measured with a 1/2” condenser microphone held in place by a compact holder secured on a magnet. The near field microphone was held 1m from the surface.



Figure 1. Measurement locations (not to scale)

2.1 Single microphone surveys

Overall levels are plotted in Figure 2. The levels diminish with distance from the gas-turbine connection. The local cross-sectional area could have been used; however, the odd-shaped elbow provides scope for ‘creativity’.

From the perspective of occupational health, only A weighted levels are required, while for off-site assessments

octave band level usually suffice. The octave spectra scale approximately as $\Phi(N)=A\log(N)+B$, where N in the octave band index (16 Hz \rightarrow N=1).

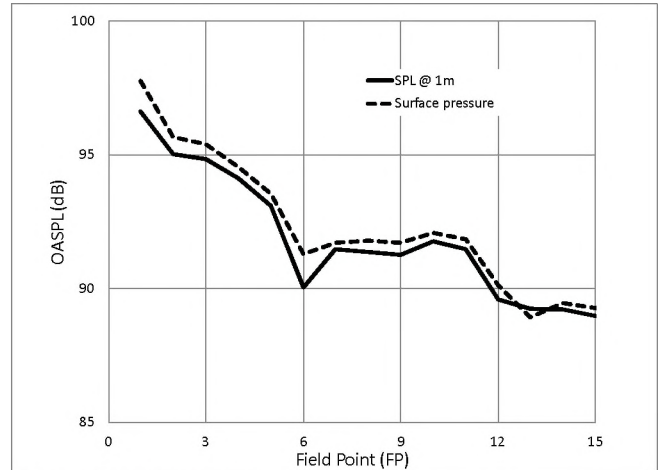


Figure 2. OASPL in the near field.

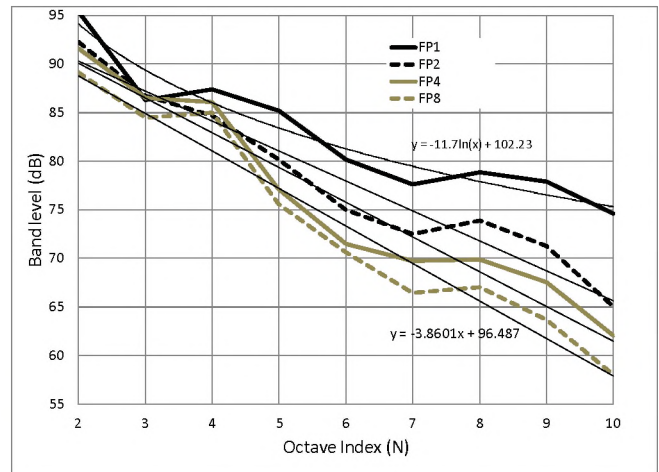


Figure 3. Typical octave band spectra

3. MULTI-TRANSDUCER SURVEYS

The exterior sound field is generated by the motion of the HRSG walls. If the walls were perfectly rigid, then the surface velocity (\mathbf{u}) is zero and the local acoustic flux (\mathbf{up}) is zero irrespective of the unsteady pressure (p).

It is common practice to assume that the near field sound pressure is determined by the local normal displacement of the panels. Most practitioners have developed empirical schemes that relate the interior pressure to the panel response. Modern CFD codes can be configured to model

the low frequency regime ($f < 30\text{Hz}$), but the detailed predictions are difficult to validate.

One approach, that has yielded good results, consists of subdividing the HRSRG into a series of virtual ducts of varied cross-sections. The panel excitation consists of the local sound pressure, deduced from one dimensional duct acoustics, and a correction factor for the local boundary layer. The latter is only important in the diffuser. Self-noise from the heat exchanger tube bundles can be added, but does not figure prominently in the near field.

Over the frequency range of interest ($\sim 16\text{ Hz} - 1000\text{ Hz}$) it is generally assumed that near the radiation field near panels is dominated by plane waves and the radiated power by a panel of area A is $|u|pA$. This can be checked by simultaneous measuring the cross-spectral density of the panel acceleration and the near-field sound.

3.1. Acceleration-sound transfer function

The cross-spectral density of the panel vibration and the radiated sound is given by $\Phi_{ap}(f)$ and is a complex valued function. As only sound levels are of interest here, the magnitude suffices (note: $\Phi_{ap}(f) = |\Phi_{ap}(f)|e^{i\theta(f)}$). The transfer function is obtained by dividing by the ‘source spectrum’. The latter is always real, so there are no further manipulations. The transfer functions are obtained by dividing the cross –spectral density with the power spectral density of the acceleration. The curves are similar in shape and amplitude, and their ensemble average is shown in figure 4.

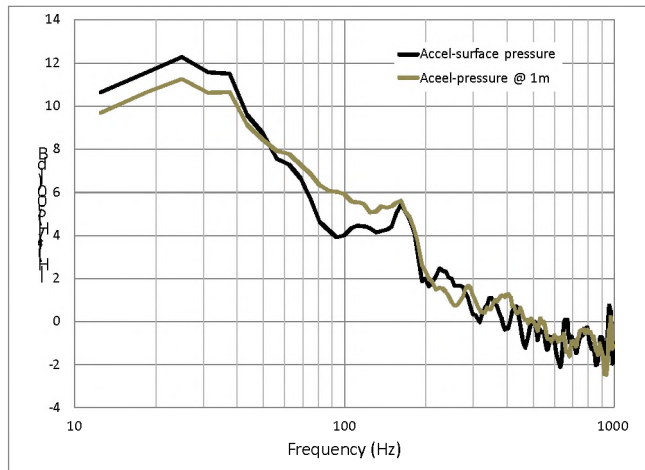


Figure 4. Normalized transfer functions

Even though the near field pressure ought to be dominated by the local panel motion, there are other, uncorrelated contributions from the entire side of the HRSRG. In principle it is possible to identify the contribution of multiple sources [1]. However, this requires a considerable amount of instrumentation and even with modern data acquisition systems is time-consuming.

3.2. Coherence function for acceleration and sound

The coherence function provides some of the indication of assumed linear input/output model. The coherence function is $C_{ap}(f) = |\Phi_{ap}(f)|^2 \{|\Phi_{aa}(f)||\Phi_{pp}(f)|\}^{-1}$. For a noise free linear process $C_{ap}(f) = 1$; otherwise $0 < C_{ap}(f) < 1$. Some typical coherence functions are shown in figure 6.

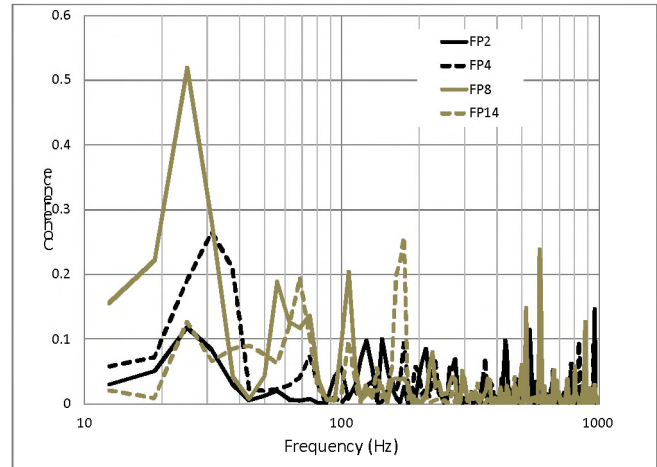


Figure 5.

Significant coherence is only evident at low frequencies. The running integrals in Figure 6 provide a different perspective. Frequency bands with low coherence contribute only a little to the integral. Substantial contributions are found in regions

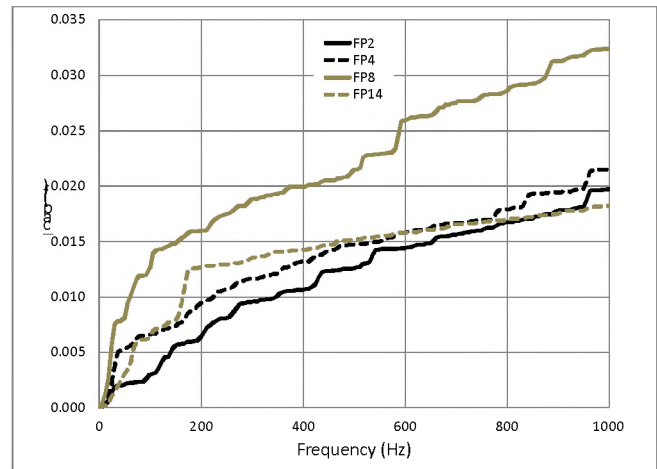


Figure 6.

4. CONCLUDING REMARKS

Coherence measurements of the panel acceleration and near field pressures do not support the assumption of local source dominance.

REFERENCES

Bendat, J.S., Piersol, A.G. *Random Data*, 2nd ed. Wiley Interscience, 1986