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THE COUNTERMEASURE FOR THE NOISE AND VIBRATION OF COMBUSTION TURBINE EXHAUST GAS DUCT

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ABSTRACT
An excessive noise and vibration was encountered in the combustion turbine exhaust gas duct connected to the heat recovery steam generator. This phenomenon was found only when water was added to the fuel injection to reduce NOx contents of the combustion turbine exhaust gas. To investigate the noise and vibration characteristics, measurement was performed around exhaust gas duct and gas turbine, and the acoustic analysis for the exhaust gas duct by SYSNOISE was carried out to check the cavity mode of the exhaust gas duct. From the measurement and analysis results, and the noneffective reinforcement on the duct wall panel, it was concluded that the severe noise and vibration occurred due to the acoustic resonance between the duct cavity mode and the excitation frequency induced by turbulent gas flow during water injection. Therefore the installation of baffle plates inside the duct was proposed to change the cavity mode of the exhaust gas duct. To confirm the effect of the baffle plates and the change of the noise and vibration phenomenon, noise and vibration measurement was carried out. From the measurement results, the vibration response of the duct wall panel was considerably reduced to 20 - 30% of the original ones and more than 10 dB(A) of noise level was reduced in sound pressure level.

1 - INTRODUCTION
An excessive noise and vibration was encountered in the combustion exhaust gas duct which is connected with a gas turbine and a heat recovery steam generator (HRSG). The HRSG generates steam using the exhaust gas of the gas turbine which is installed in combined cycle power plant. Fig. 1 shows the outside wall of the exhaust gas duct with a square section shape. The fuel of the gas turbine is diesel oil or low sulfur waxy residue. These problems occurred when water was added to the fuel injection to reduce NOx contents of the exhaust gas, whereas no problems in pure fuel injection. The phenomenon was identical in all three gas turbine units.

The characteristics of severe noise and vibration were investigated from the measurements and the acoustic analysis by SYSNOISE. A countermeasure was proposed to reduce the noise and vibration. Its effect was verified through the measurements.

2 - MEASUREMENT
In order to investigate the noise and vibration characteristics, the measurements were performed around the exhaust gas duct. Their levels were changed according to the rate of water injection so that measurement was carried out at the water injection rate of 0%, 25%, 50% and 70% to fuel.

From the measurement results in Fig. 2 and Fig. 3, the levels increased as water injection rate increased, and made maximum value at the rate of 50% and decreased as the water injection increased more. In addition, these levels were high in the inlet part of duct (gas turbine side) and gradually decreased as close to outlet part (HRSG side). The peak frequency, however, decreased as the water injection rate increased. That is, the peak frequency of 110-113Hz without water addition decreased to around 95 Hz with water addition.

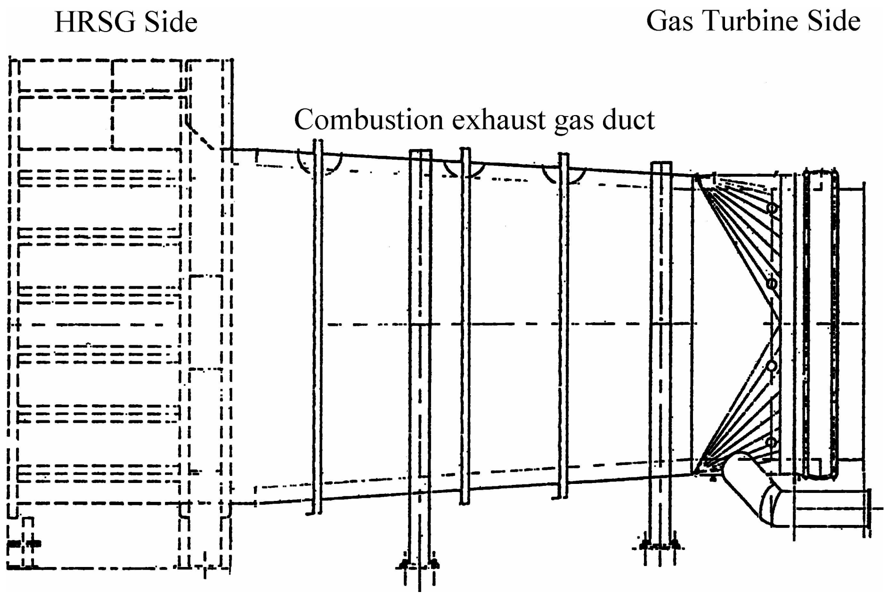

Figure 1: Combustion exhaust gas duct.

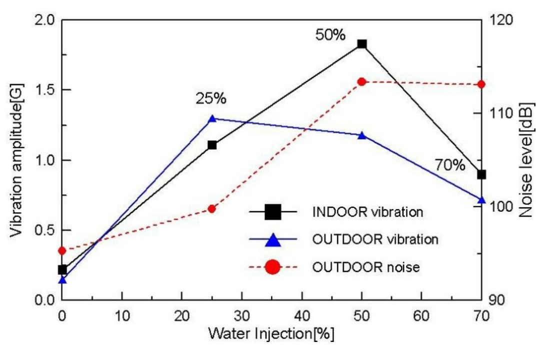

Figure 2: Variation of noise and vibration levels to water injection rate.

The peak frequency of noise coincided with that of vibration as shown in Fig. 4, which meant the noise and vibration was caused by the same reason.
Fig. 5 shows the measurement results of exhaust gas duct with the different capacity and size in the other power plant site where no severe noise and vibration during the water injection. Their characteristics and trends were compared with those of the troubled system. The noise and vibration did not suddenly increase in water injection. Its spectrum band was wide and the levels were much lower than those measured in the troubled system.

3 - ACOUSTIC ANALYSIS

To investigate the possibility of acoustic resonance with the duct cavity, the acoustic analysis for the exhaust gas duct was carried out by SYSNOISE. The exhaust gas duct was modeled with 3-D solid elements and it included only inlet part of the duct where severe noise and vibration occurred. The analysis was carried out in two temperature conditions, a real operation condition of gas turbine (exhaust gas temperature of 496°) and a stop condition (normal air temperature of 25°). Fig. 6 shows the calculated cavity mode of the exhaust gas duct for both conditions.
As shown in Fig. 6, the result of real condition is very close to the peak frequency measured in the water injection rate of 50%. To verify the acoustic resonance, the sound exciting test for duct inside by a sound generator was performed in stop condition. The test result of 59.5Hz as shown in Fig. 7 is very close to the calculated frequency of 58.5Hz.

4 - COUNTERMEASURE

From a series of noise and vibration measurements and acoustic analysis, the followings were summarized.

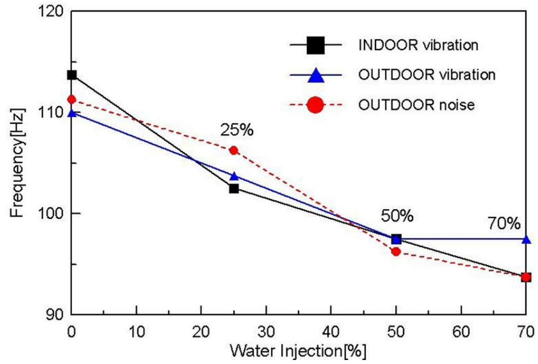

Figure 3: Variation of noise and vibration peak frequency to water injection rate.

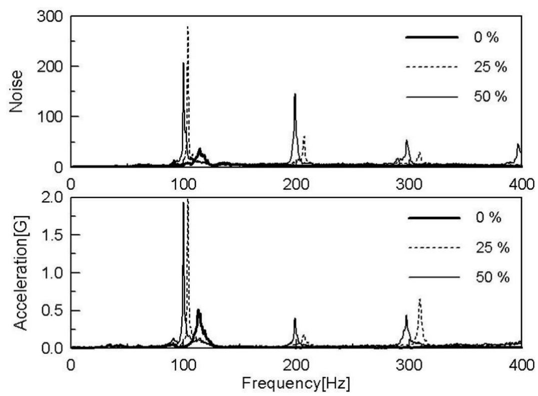

Figure 4: Noise and vibration measurement of the troubled exhaust gas duct.

- The severe noise and vibration occurred only in the water injection and the peak frequency and response levels were dependent on the water injection rate.
- The peak frequency of severe noise and vibration was very close to the calculated acoustic natural frequency of the duct in the real operation condition.

It was concluded that these problems occurred due to the acoustic resonance between the duct cavity mode and the excitation force induced by turbulent gas flow during water injection. Therefore the installation of baffle plates inside the duct was proposed to change the cavity mode of the duct. Fig. 8 shows the provision concept for the baffle plate and Fig. 9 shows the baffle plate installed inside the duct.

After the baffle plate was installed, the noise and vibration measurement was carried out to confirm its effects. Table 1 shows the comparison between two measurements, with and without baffle plate. The vibration response of the duct wall with baffle plate was considerably reduced to $20 - 30\%$ of the response without baffle plate, and the maximum 10 dB(A) was reduced in sound pressure level.

	Noise [dB(A)]		Vibration [G]	
	Without baffle plate	With baffle plate	Without baffle plate	With baffle plate
0% Water injection	90.0	88.7	0.5	0.45
25% Water injection	98.0	91.5	2.0	0.7
50% Water injection	104.0	94.4	1.9	0.65

Table 1: Effect of baffle plate (1G = 9.8 m/s^2).

5 - CONCLUSION

The severe noise and vibration occurred due to the acoustic resonance between the duct cavity mode and the excitation force induced by turbulent gas flow during water injection. These problems were considerably reduced after installation of the baffle plate in the combustion exhaust gas duct.

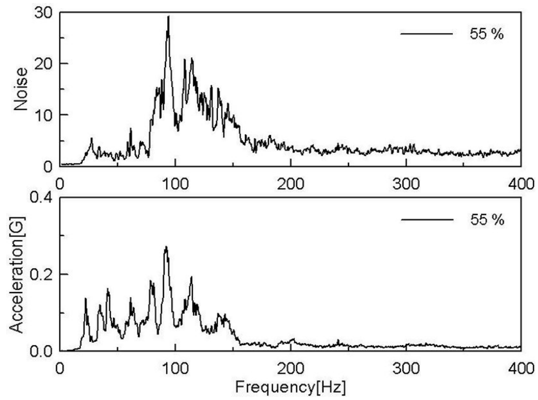

Figure 5: Noise and vibration measurement of the other power plant duct.

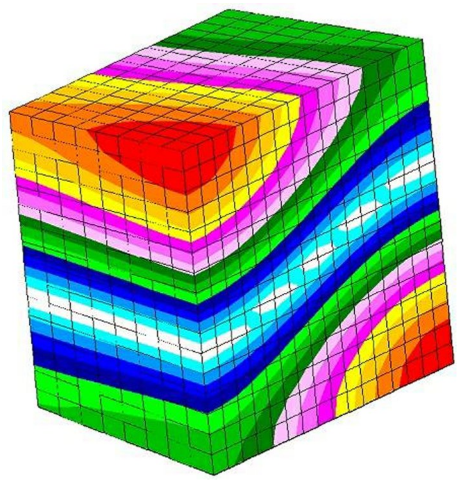

Figure 6: Cavity mode of duct (496°: 95.4 Hz, 25°: 58.5 Hz).

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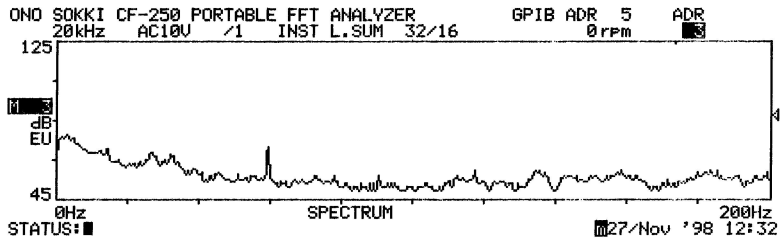

Figure 7: Result of the sound exciting test.

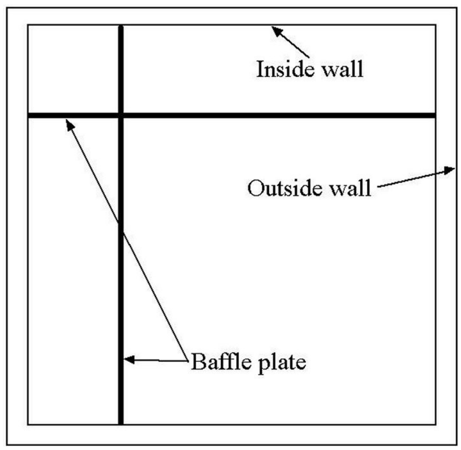

Figure 8: Provision concept for the baffle plate.

Figure 9: Baffle plate inside the duct.