Analytic Investigations on the Causes of Furnace Rumbling at Hsieh-Ho Unit 1

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1. Research Background

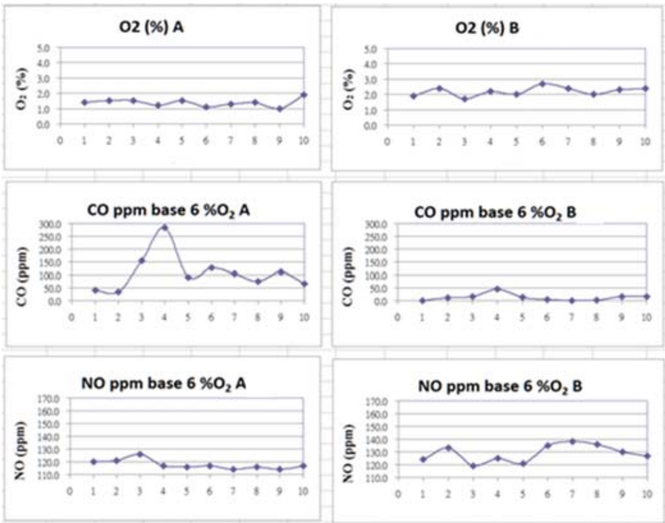
Since the second half of 2017 and in cooperation with Hsieh-Ho Power Plant, TPRI utilized combustion balancing and online optimization technology on solving the furnace rumbling problems and improving the combustion performance of Hsieh-Ho Power Plant Unit 1. In March 2018, the problem which lasted for 17 years had finally got resolved, and subsequently we conducted some analytic investigations to clarify the causes of the said rumbling.

Unit 1 has to operate at high loads in the summer. Furnace rumbling occurs whenever its combustion performance is not steady or imbalanced. Based on the experiences accumulated over the past years, furnace rumbling and combustion performance are inter-related closely. Thus, it stands a good chance that we may observe some controlling factors during the process of combustion optimization. The combined factors are identified as follows:

2. Analytic Approach

(1). Combustion Adjustment

Changes before and after the adjustments in the range of 366MW-400MW are as follows.



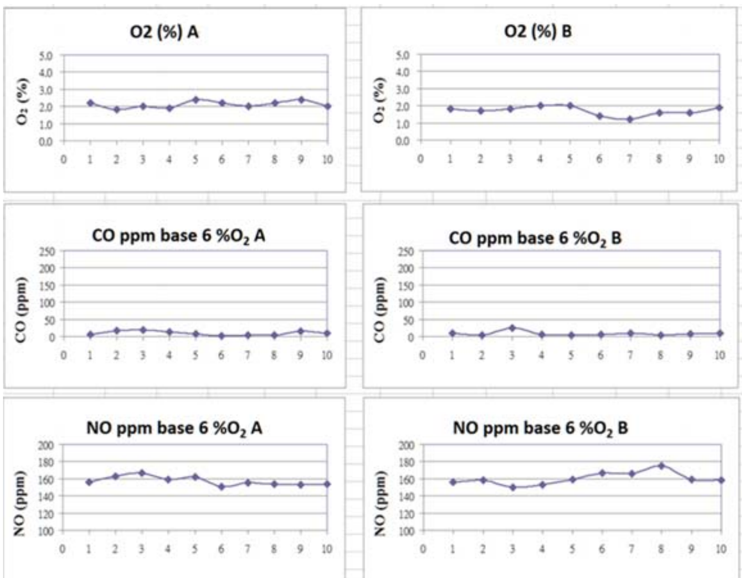
[Before Adjustment]

Time: 13:30; Date: 3/3/2018
Load: 366MW
Oil Temp: 105℃; dP: 1.65kg/cm2

[Flue Duct Gas Composition]
O2: 1.38/2.20 %
CO: 109/12.6 ppm)

[BNR 10F Vibration]: High vibration
Average: 127μm; Peak: 475μm

[After Optimal Adjustment]



Time: 10:30; Date: 3/8/2018
Load: 381MW
Oil Temp: 98.3°C; dP: 0.9 kg/cm^2
O2 Trim: 55% (optimum setting)

[Flue Duct Gas Composition]
O2: 2.1/1.7 %
CO: 9.5/8.1 ppm)

[BNR 10F Vibration]: Improved
Average: 7.5μm; Peak: 105μm

The above observations imply that the vibrations of the two separation walls between combustion chambers were induced by imbalanced flow and vibrations of the windbox induced by unstable combustion.

(2). Furnace Vibration Spectrum Analysis

Vibration spectrum analysis was conducted subsequently aiming at the boiler. It was found that there were three natural low-frequency vibrations on the windbox, respectively 1Hz, 6Hz, and 31Hz, as shown in Figure 1. Figure 1 shows a more pronounced vibration around 6Hz on the oil feed pipes to the burners. Since the vibrations of the feed pipes were not affected by combustion adjustments, it is believed that the vibration was from the feed pipe itself. Thus, the frequency differentials from the 24 pipes all together could induce either large or small periodic vibrations and resulted in furnace rumbling.

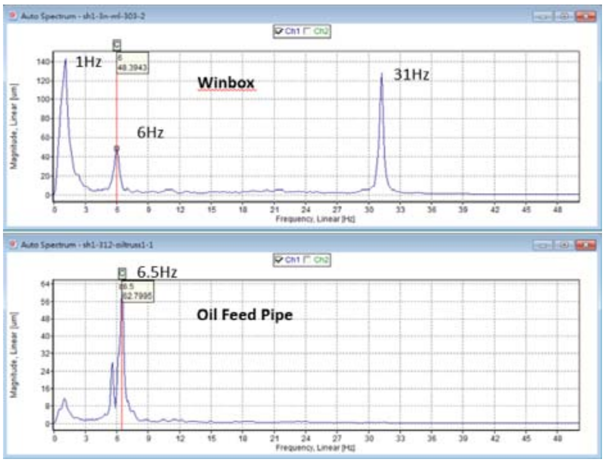


Figure 1 Boiler three low-frequency vibrations

Figure 2 shows the impacts of combustion adjustments on the three natural frequencies. After the combustion adjustments, the averaged vibration had been reduced from 142µm to 24µm, a 83% reduction for 1Hz. In addition, the averaged vibration had been reduced from 128µm to 11µm, a 91% reduction for 31Hz. As shown in Table 1, the averaged vibrations for 1Hz and 31Hz had been significantly reduced after combustion adjustments. However, the averaged vibration in the vicinity of 6Hz remained at 45µm.

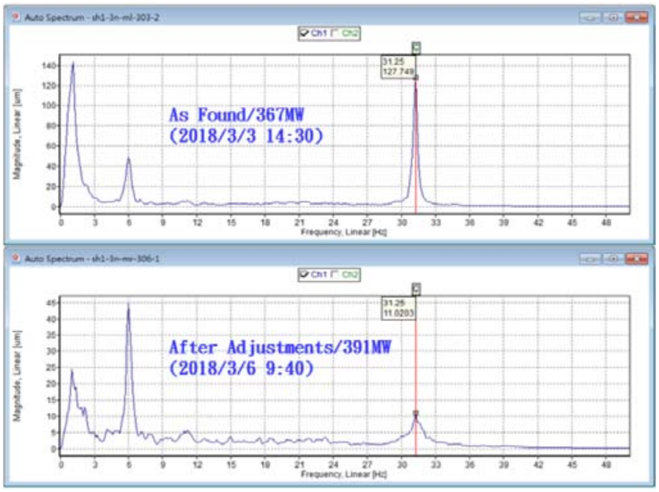


Figure 2. Impacts of combustion adjustments

Table 1. Changes of natural vibrations after combustion adjustments

Hsieh-Ho Unit 1	As Fonud	After Optimal Adjustments	Vibration Reduction
Test Date	3/3/2018	3/6/2018	
Load	367MW	391MW	
Average Vibration at 1Hz	142μm	24μm	-83%
Average Vibration at 6Hz	45μm	45μm	No Effect
Average Vibration at 31Hz	128μm	11μm	-91%

(3). Furnace Structure Vibration Model

In order to identify the sources of the two natural vibrations, 1Hz and 31Hz, a furnace structure vibration model (abaqus) had been constructed, as shown in Figure 3. Analysis of the model indicates that there are 5 modes of natural vibration, respectively 0.27, 0.74, 1.1, 1.19 and 1.39Hz. The strongest vibration is 1.1Hz. Based on the above analysis, the vibration sources related to combustion performance are identified as follows:

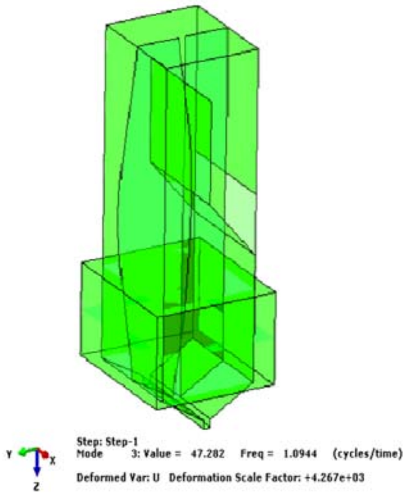


Figure 3. Furnace structure vibration model (1.1Hz)

3. Conclusions

Based on the aforementioned combustion adjustments, furnace vibration spectrum and furnace structure model analysis, we conclude that the causes of the rumbling are due to a combination of factors:

(1) After installing De-NOx burners, the furnace heat transfer due to combustion delay got worse gradually and resulted in high temperature and high velocity flows.
(2) The changes of furnace thermal flow field had negative effects on the burners' optimal combustion conditions.
(3) Under high load (high gas flow) conditions, the unique natural frequency of the furnaces were apt to induce vibrations of the followingequipment:
   - Windbox vibration (31Hz), under poor combustion performance;
   - Vibration of separation walls (1Hz), when furnace flow was imbalanced.
(4) In addition, there were vibrations of oil feed pipes in the vicinity of 6Hz. The alternate rumbling of the 24 oil pipes provided periodic vibrations of different intensity .

Clarifying the causes and identifying the controlling factors of the rumbling of Unit 1 serves as a good reference for same furnace design units.

a. Two separation walls between combustion chambers, induced by imbalanced flow near 1Hz; and
b. Windbox body, induced by unstable combustion in the vicinity of 31Hz.