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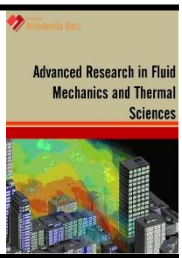

Experimental Investigation of Thermally Induced Vibration in Sulphur Recovery Unit (SRU)

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ABSTRACT

Hotspot related problem can be detrimental to Sulphur Recovery Unit (SRU) material lifespan. One of the causes of the hotspot is susceptible high vibration level of multi components in SRU. In this project, the vibration level of the sulphur recovery unit was experimentally measured. The main objective of the measurement is to technically assessed the unit for maintenance management purpose. Two types of measurements were performed. Firstly, bump tests were conducted to accurately determine the natural frequency of the oxygen intake pipeline. Secondly, the vibration level is then mapped to various components in the system according to the process conditions. By analysing this map, the correlation between the vibration levels, natural frequency and process conditions that can cause excessive vibration of the SRU can be specifically verified.

Keywords:
Hotspot, Sulphur Recovery Unit (SRU) , Vibration level

1. Introduction

In oil refining process, there are various method developed for removing acidic gases. Hydrogen Sulphide (H_2S) and Carbon Dioxide (CO_2) are the examples of the acid gases that are generated in large quantities from the results of desulphurization of natural gas [1,2]. Meanwhile, a small quantities of impurities such as N_2, NH_3, CS_2, COS and hydrocarbons are also derived from these gases [3]. H2S and CO2 can be converted into syngas in order to remove these acidic gases. The element of sulphur from these acid gases can be recovered by various methods such as direct oxidation, Unisulf, Takahax, Selectox and Claus process [4,5]. Claus process generally is the most popular method to maximize the elemental sulphur production from acid gases [6].

Sulphur Recovery Unit (SRU) is the most commonly utilized in the relevant oil and gas industry to process acid gases in the natural gas processing units [1]. The acid gas that is Hydrogen Sulphide (H_2S) is sent to SRU to produce elemental sulphur [7,8]. The main components of SRU are a burner, a

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reaction furnace, a waste heat boiler (WHB) and a train of sulphur condensers. In SRU, the stream of acid gas at specified pressure is supplied to the reaction furnace burner together with the correct ratio of air. The function of this stream of air is to oxidize the feed of contaminates. Then, the acid gases will be combusted at temperatures ranging from 975 to 1300 °C in the reaction furnace [9].

Combustion noise and vibration can be detrimental to engines, reactors and combustors lifespan. Among key factors that affects the combustion noise and characteristics are the heat release rate (HRR) and combustion duration [10-14]. In this research, the vibrational level for two Sulphur Recovery Units (SRU) were experimentally examined. The first SRU is referred as SRU Train-1 while the latter is named as SRU Train-2. Generally, the geometry of the SRU is shown in Figure 1. Prior to the measurement, Computational Fluid Dynamics (CFD) simulations were performed to provide overall condition of combustion and air velocity inside the SRU. The sample of results is shown in Figure 2. In this project, two types of measurements were performed. Firstly, the bump test was conducted to accurately determine the natural frequency of the oxygen intake pipeline. Secondly, the vibration level is then mapped to various components in the system according to the process conditions. The main objective of the measurement is to technically assessed the unit for maintenance management purpose. It is widely known that vibration-based fault diagnosis played a critical role in preventive maintenance of important machineries [15].

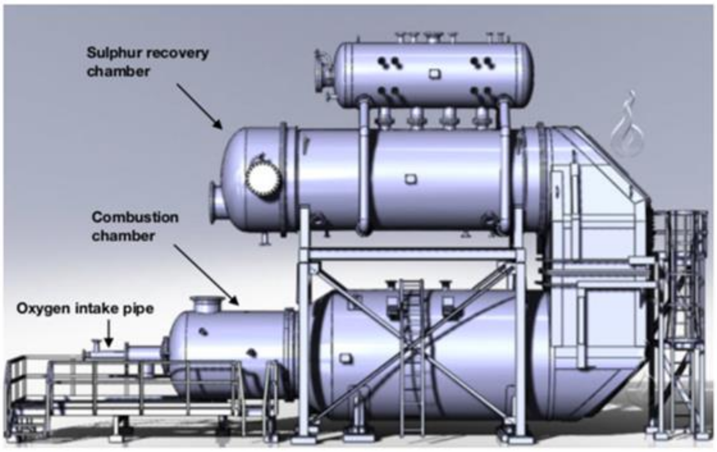


Fig. 1. Image of Sulphur Recovery Unit

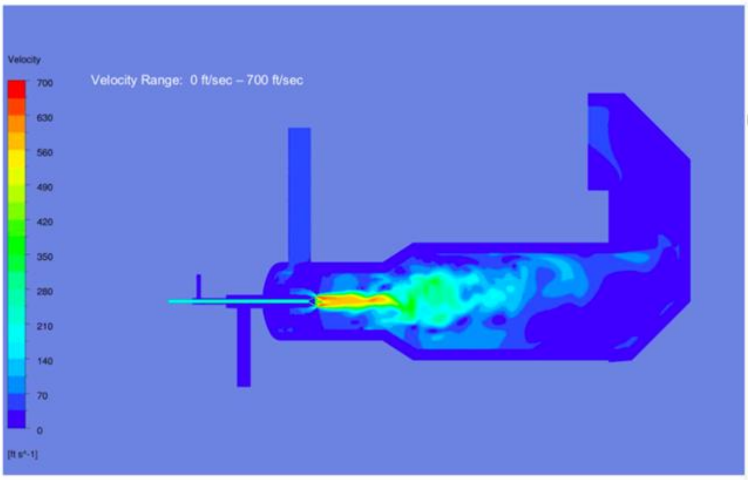


Fig. 2. Computational Fluid Dynamics (CFD) simulation results of velocity contour of the SRU

2. Research Methodology
2.1 Process Conditions

The process load was varied in order to observe the vibration level on each load. The load of each train was set to 80, 110, 130 and 153 Metric Tonnes per Day (MTD). It is observed that the intake oxygen is direct relationship with the set load as depicted in Figure 3.

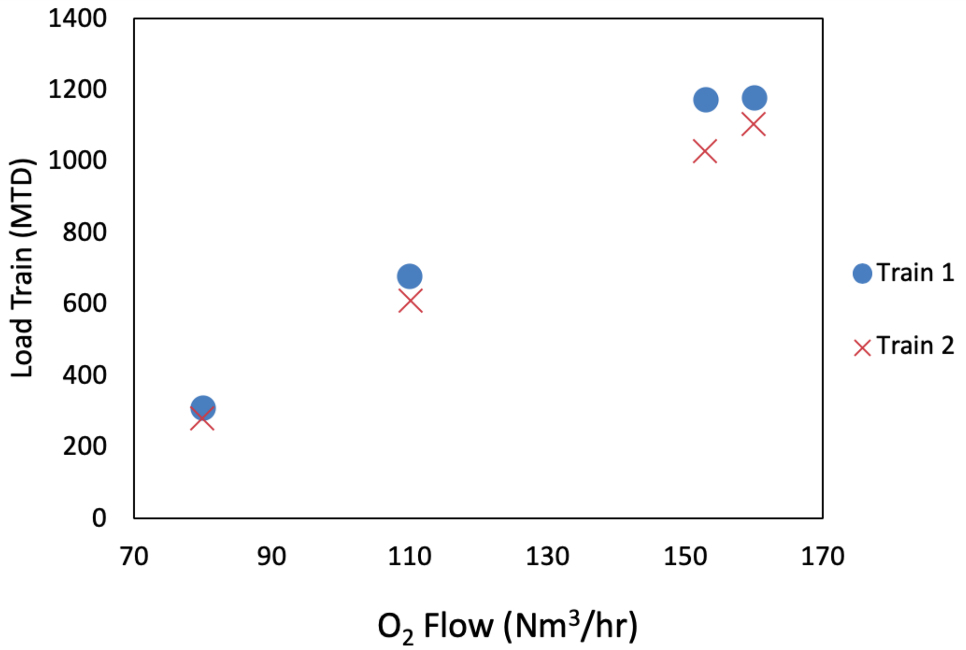


Fig. 3. Process load with respect to the oxygen flow mass for two trains

2.2 Experimental Setup

Three units of ICP 100 mV/g CTC industrial accelerometers were utilized to record the vibration amplitude. The conversion of analog to digital signal was performed using VABBIT PRO MDS 2124 XT 4-channel data acquisition system. For the bump test, ICP 0.25 mV/N Dytran Impulse Hammer was used while to measure the noise level, ICP 50.7 mV/Pa ROGA Instrument Microphone was utilized. The overall value and the vibration level in frequency spectrum was measured in root mean square (RMS) velocity unit (mm/s) while the frequency range was set from 0 to 400 Hz. The line resolution was set at 1600 lines (frequency solution of 0.25 Hz) with hanning windowing type. The data was averaged with ten linear averages.

2.3 Measurement Locations

Three main locations were measured. These locations are the oxygen intake pipe, combustion chamber and surrounding machineries (air supply pump and SRU downstream incinerator). The following tri-axial coordinate system has been used during the measurement.

i. X- Horizontal, Perpendicular to the combustion vessel
ii. Y- Vertical, Perpendicular to the combustion vessel (in line with gravity)
iii. Z- Axial, Parallel to the combustion vessel

Particularly, for the oxygen intake pipe (and other pipes), the agreement for the coordinate is as follows

i. X- Horizontal, Perpendicular to oxygen flow
ii. Y- Vertical, Perpendicular to oxygen flow

For ease of use, if one is facing the pipe, the x-axis is directed perpendicular to the height of the observer. This view is also parallel with the flow of the pipe. For the vertical pipe, both x- and y-axis were directed towards the radius of the pipe, which is still perpendicular to the flow. Figure 4 illustrates the axis of measurement at the pipes while Figure 5 and Figure 6 shows the location of the measurements.

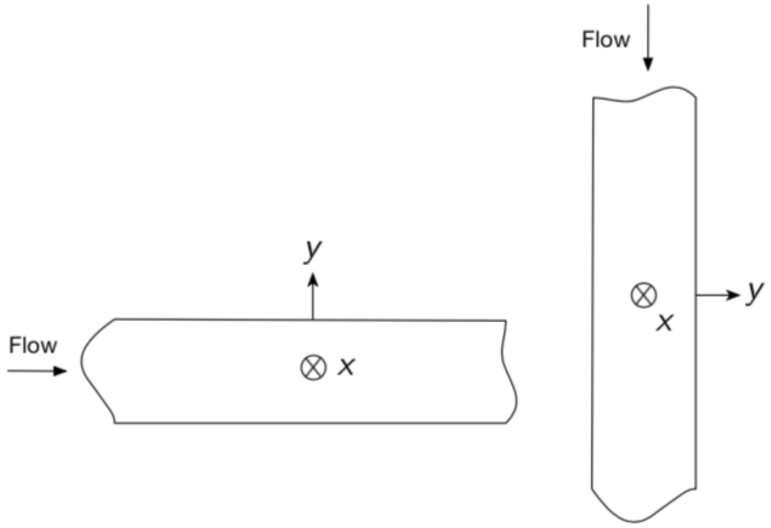


Fig. 4. Axis of measurement at the pipes

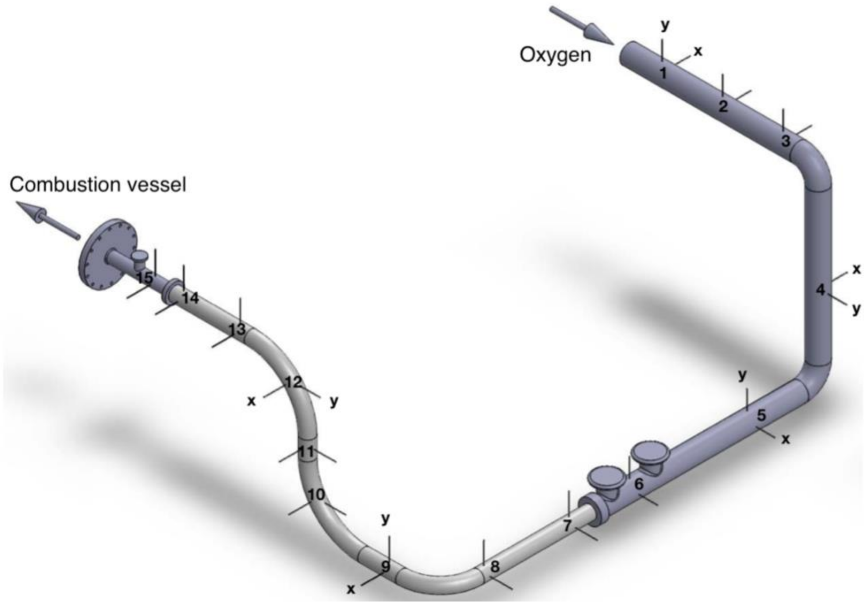


Fig. 5. Location of measurement at the oxygen intake pipe

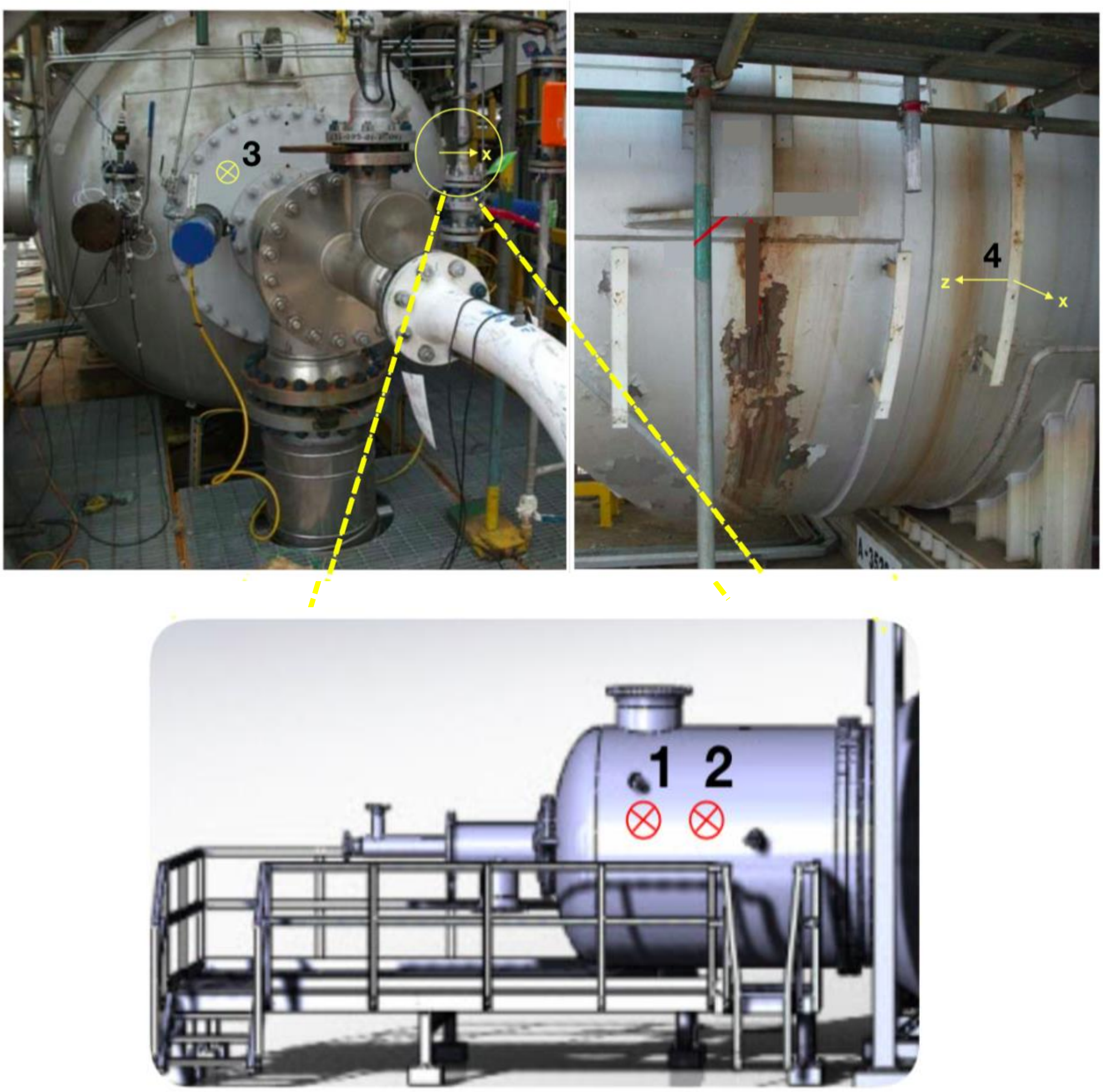
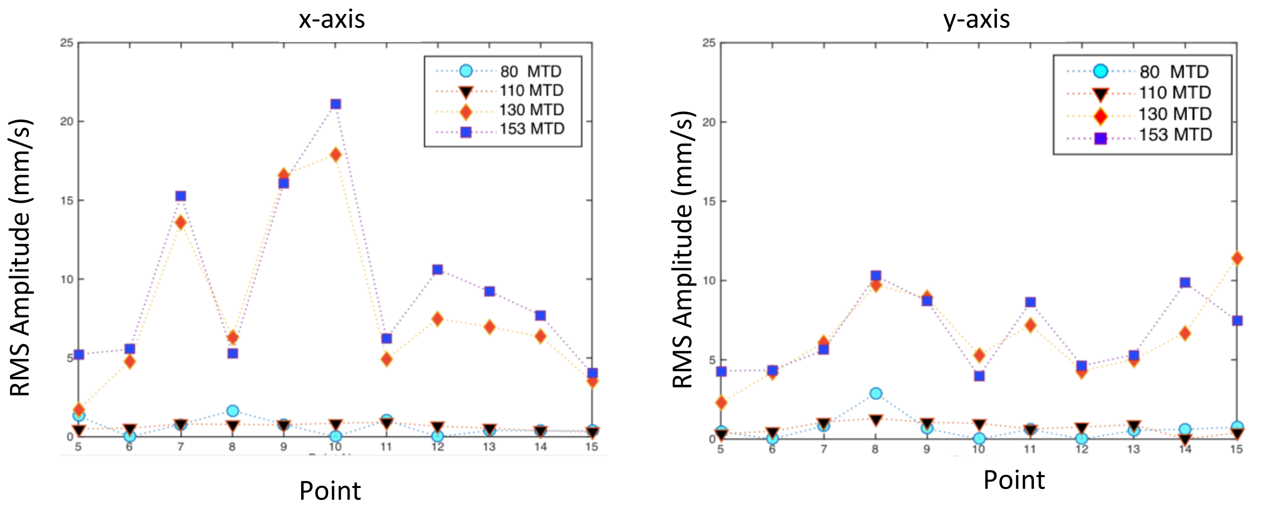


Fig. 6. Location of measurement at the combustion chamber and vessel

3. Results and Discussions

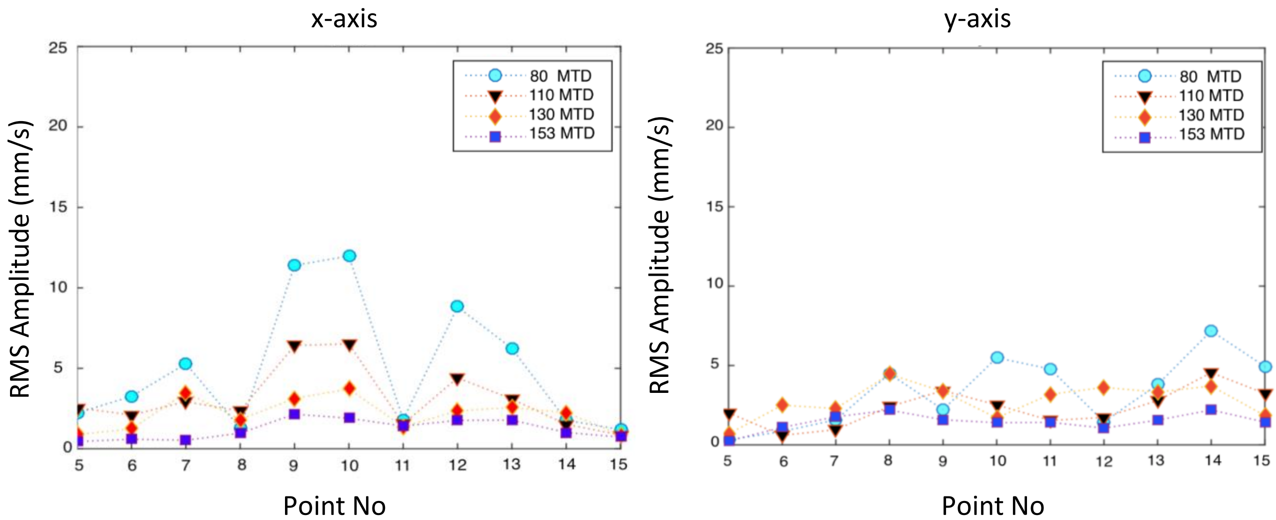
3.1 Vibration level of Oxygen Intake Pipe

Meanwhile, Figure 7 shows the overall vibration amplitude along the oxygen intake pipe in radial directions (x and y axes) for different process loads at SRU Train 1. It can be obviously seen that high vibration (> 10 mm/s) occurs at process load of 130 and 153 MTD (both processes had similar vibration level). Below these loads that are 80 MTD and 100 MTD respectively, the vibration was relatively low. The x-direction recorded greater vibration amplitude than the y-direction. At SRU Train 2 the vibration amplitudes were lower than those at SRU Train 1 as seen in Figure 8. However, the greatest amplitude was recorded at the lowest process load, which is 80 MTD. The vibration of the pipe at this process load was observed to be intermittent, where the pipe had relatively low vibration at certain time range, and then followed by high vibration excitation also at certain time range. This event was repeated at irregular time interval. The results shown in in Figure 8 was recorded during the high vibration. During low vibration, the measured signal was lower than 5 mm/s.



(a) (b)

Fig. 7. Overall vibration amplitude of the oxygen intake pipe at Train 1 for different process loads



(a) (b)

Fig. 8. Overall vibration amplitude of the oxygen intake pipe at Train 2 for different process loads

3.2 Overall Vibration of Combustion Chamber and Vessel

Measurement were also taken at some locations on the combustion chamber and vessel. The locations of measurement are as shown in Figure 6. Point 1 and 2 were the measurement taken at the right-side of the combustion chamber in x-direction while point 3 was taken at the front of the chamber at z-direction. Point 4 was measured at the surface of the combustion vessel. The overall vibration amplitude are presented in Table 1 and Table 2, respectively. From the results, it can be seen that there is consistency with results from oxygen pipe vibration level shown in Figure 7 and Figure 8. This consistency suggests that the occurrence of vibration in the chamber results to the vibration of the oxygen pipe or vice versa.

Table 1
Overall vibration level (in mm/s) on combustion chamber and vessel for SRU Train 1

Point No	80 MTD	110 MTD	130 MTD	153 MTD
1x	0.9	0.49	9.3	N/A
2x	0.6	0.4	N/A	N/A
3z	0.4	0.0	7.35	N/A
4x	0.0	0.0	0.0	1.6
4z	0.0	0.0	0.0	0.8

Table 2
Overall vibration level (in mm/s) on combustion chamber and vessel for SRU Train 2

Point No	80 MTD	110 MTD	150 MTD	153 MTD
1x	0.9	0.49	9.3	N/A
2x	0.6	0.4	N/A	N/A
3z	0.4	0.0	7.35	N/A
4x	0.0	0.0	0.0	1.6
4z	0.0	0.0	0.0	0.8

3.3 Noise from Combustion Chamber

Measurement of radiated sound pressure (noise) from the combustion chamber was also taken to investigate its relation with the measured vibration. The ROGA ICP acoustic microphone was used as the sensor. At Train 1, the measurement was conducted with the microphone facing the chamber at distance of around 1.5 metre as shown in Figure 9. At Train 2, additional measurement was taken at the side of the combustion chamber. The observer was on ground, the sensor was at the height of ear with distance around 3 metres. The frequency component of 63 Hz with its harmonics can be observed from the measured data, which was also found in the measured vibration data.

Fig. 9. Location of acoustic microphone to measure the radiated sound pressure from the combustion chamber

The sample of the results are presented in Figure 10. This finding suggests that the source of vibration is most likely due to the process inside the combustion chamber. The sound pressure produced from the inner combustion process excites the body as well as the oxygen pipe, which then vibrates these structures with frequency of 63 Hz.

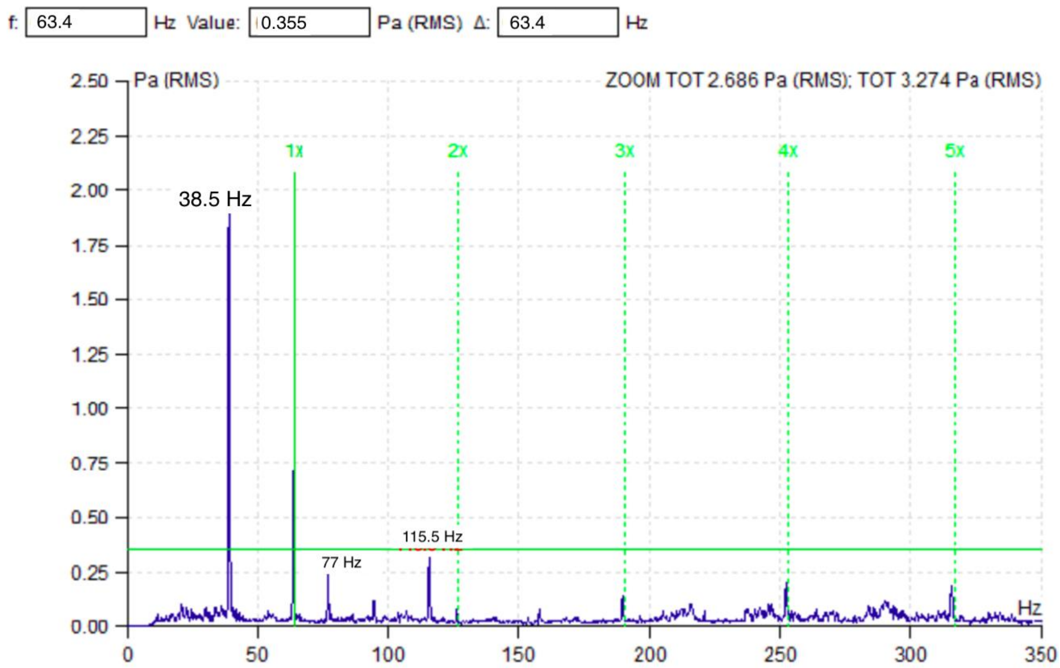


Fig. 10. Sample measured data of radiated sound pressure at the combustion chamber (for Train 1, 130 MTD)

3.4 Measuring Natural Frequencies of Oxygen Pipe

Measurements were performed to determine the natural frequency of the oxygen pipe. The purpose of this measurement is to rule out whether the pipe is vibrating at its natural frequency that can cause large vibration due to resonance. The sample of the results for the frequency spectrum obtained from the bump test at the respected location is shown in Figure 11. From the obtained results, the natural frequencies are mostly at lower frequencies below than 63.5 Hz. Hence, the pipe was not vibrating at its natural frequency.

4. Conclusions

At high process load of 130 and 160 MTD, the level of vibration of the oxygen intake pipe at Train 1 was significantly greater compared to those at Train 2. At lower process loads of 80 and 110 MTD, Train 1 has lower vibration level than Train 2. For both trains, the vibration is dominant in x-direction. At Train 2, irregular event of large vibrations was recorded at low process load of 80 MTD. Across the measurement points and with different process loads, the main frequency of vibration was at 63.5 Hz followed by the harmonics. This frequency component was not found in Train 1 for loads 80 and 110 MTD. The combustion chamber exhibited vibration level which was consistent with the vibration of the oxygen pipe (large vibration of pipe recorded large vibration at the chamber body).

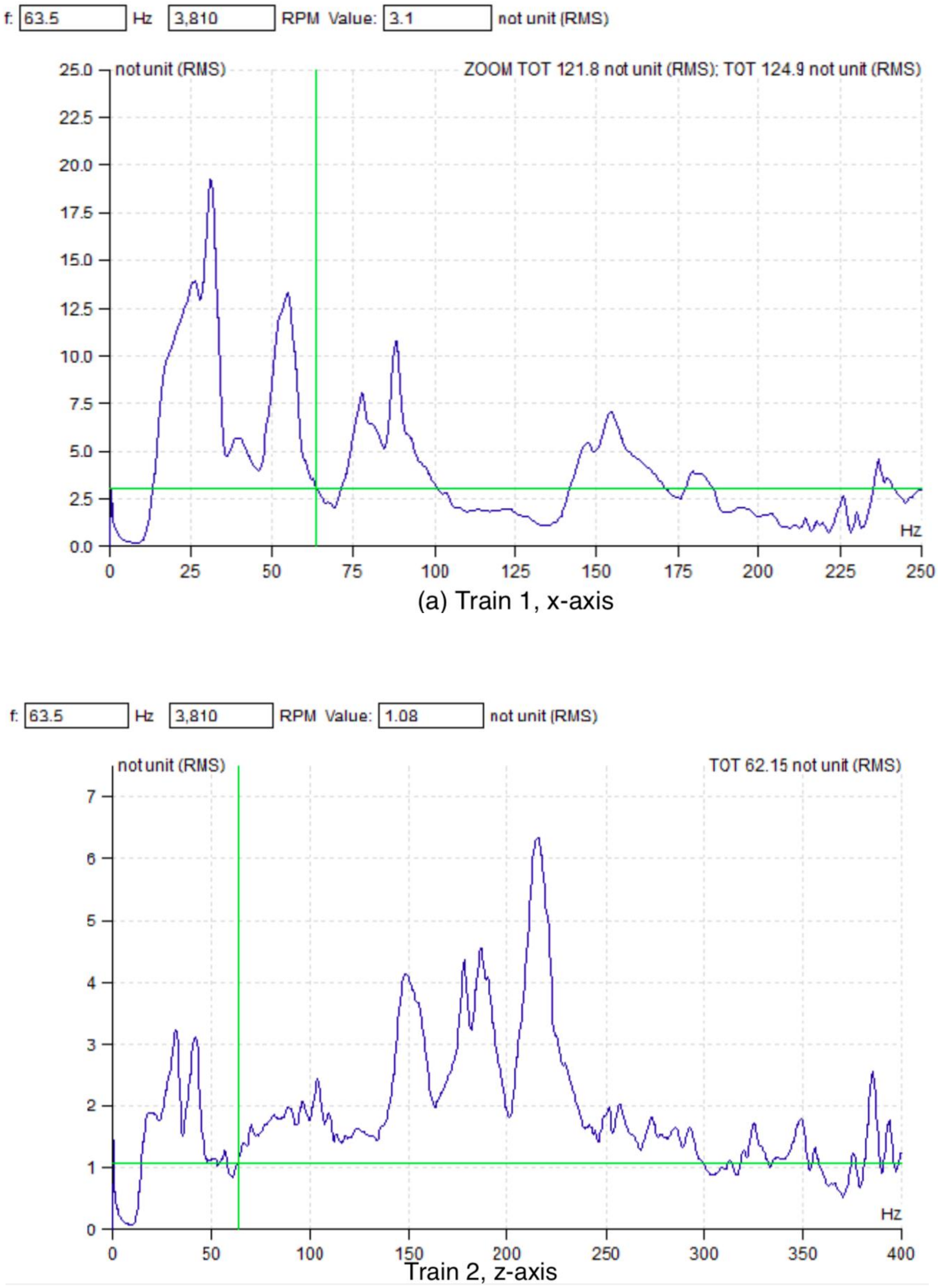


Fig. 11. Sample of the results for the measured spectra (bump test)

The same component of 63.5 Hz was also recorded at both x- and z-axis. Low vibration level was recorded at the combustion vessel. Apart from that, the measurement data of the radiated noise from the combustion chamber reveals the frequency component of 63.5 Hz. This is the frequency of the sound pressure resulting from the combustion, which indicates the source of vibration is most likely comes from the burning process inside the chamber. This frequency might coincide with the acoustic mode of the chamber or the natural frequency of the chamber structure that excite the body of the chamber, where the vibration energy is then transferred to the oxygen line. This single frequency dominant vibration in the furnace is termed as combustion-driven oscillation. The factors that influence the oscillation are the firing rate, fuel type, fuel/air ratio, the acoustic lengths of the burner and the vessel, and the acoustic damping [16].

Lastly, the bump test shows that the main natural frequency of the oxygen pipe are below 63.5 Hz, indicating that vibration of the oxygen line was not in resonance. However, the ideal bump test as well as the frequency response function (FRF) should be conducted when there are no external forces in the pipe structure.

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