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DETECTING CLASSIFIER-COAL MILL DAMAGE USING A SIGNAL VIBRATION ANALYSIS

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Abstract -- *A classifier plays a crucial role in the cement industry. It is in charge of separating coal that has been smoothened out and is ready to be burned although the coal is still rough after going through the grinding process. It takes a long time to burn coal that is not perfectly processed with a classifier. Therefore, it will reduce the amount of cement production, and the factories will release more energy. The closed arrangement and the number of components in the unit classifier requires a sophisticated method to detect damage that occurs early. Vibration analysis is a method that has been effectively employed in detecting the initial damage that occurs to the engine, especially the classifier. This study was aimed at detecting the location of the damage occurring in the classifier by using a vibration signal analysis and by measuring the magnitude of vibration and presenting it to the frequency domain (spectrum) form using Fast Fourier Transform. Engine condition assessment referred to ISO 10816-3 standard in velocity and displacement modes. Based on data spectrum analysis, the dominant damage laid in the unbalanced rotor. Spectrum characteristics of the damage appeared to be in the spectrum line worth 438.01 μm at a 3.5-Hz frequency (1X) radially. This analysis proved to be supported by the decrease in vibration value to 18.65 μm after balancing the Classifier rotor.*

Keywords: *Classifier; Vibration analysis; Cement industry; Spectrum*

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INTRODUCTION

Coal is one of the most critical energy resources in the world. Coal has played a crucial role for centuries; not only does it generate electricity, but it also becomes the primary fuel resources for industrial activities such as in the cement industry. Based on its quality, there are four types of coal, namely lignite (low-quality), sub-bituminous (medium-quality), bituminous (high-quality), and anthracite (very-high-quality). Most of the high-quality coal is exported, and the other is used in the cement industry. Therefore, so far in Indonesia, most of the combustion processes in the kiln use sub-bituminous coal. There are no cement industries that use low-quality coal (lignite) for the combustion process in the kiln. In the cement manufacturing industry, coal is used as fuel in the kiln to form clinker, which is the basic ingredient of cement. This combustion operation in the kiln determines the process of the other units, and it requires heat energy whose value may account for 30% of the overall operating cost (Puspitorini & Damayanti, 2013; Ning et al., 2019; Ditaranto & Bakken, 2019).

A classifier is one of the engine units in coal processing that serves to process coal to be ready to be used as fuel in the cement production. Coal that has been milled from the ball mill enters the classifier and separates coal material into fine and non-fine materials. Coarse coal will be sent back to the coal mill with conveyor assistance to be re-milled. Smooth materials will be sent to the cyclone. For the classifier to operate correctly, we must do the maintenance in maintaining the engine performance aimed at avoiding disturbances during the cement production process. Damage to machines in the industry, especially in the classifiers, will reduce the quality of cement production that will automatically reduce profits and will even result in substantial losses. The production process will also be able to stop operating if one engine in the series of machines does not correctly function (Bhatt, Dadiala, & Barve, 2018; Cortinovis et al., 2013).

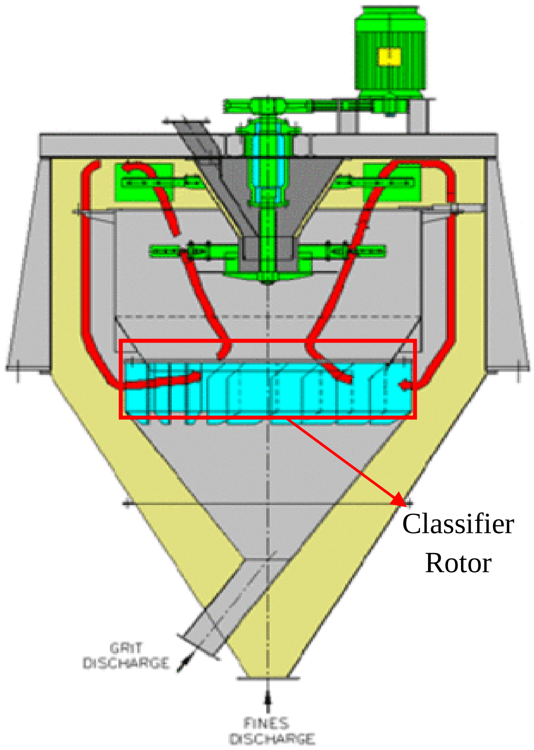

Figure 1. Classifier Structure

Therefore, maintaining the reliability of the engine performance in industrial plants is a top priority to maximize product quality to produce maximum profits for the company (Ataş et al., 2014). Fig. 1 shows the structure of the classifier.

Vibration analysis is one of the essential monitoring techniques applied in real life. Most of the defects encountered in the rotating machines result in different vibration patterns (vibration characteristics) and, therefore, most damage can be identified by using a vibration signal analysis technique (Smith, Fan, Peng, Li, & Randall, 2016; Vishwakarma, Purohit, Harshlata, & Rajput, 2017) Vibration Monitoring is the ability to record and identify vibration sources, so it makes this technique very powerful to monitor the rotating machines.

Vibration analysis is usually applied using a transducer to measure acceleration, speed, or displacement (Priyandoko & Fun, 2017; Subekti, 2018). The choice depends on the frequency that is analyzed. Acceleration covers areas ranging from 0 to 20 kHz. Speed includes frequencies typically from 2 Hz to 2 kHz. Displacement, absolute position size, covers frequencies from 0 to 200 Hz. The frequency of the classifier is 3.5 Hz or 210 RPM; the frequency leads to the type of displacement. Signals are usually processed and stored using a spectrum analysis method that takes the incoming signal and breaks it into their respective frequencies using Fourier analysis. It depends on its ability to connect unique frequencies to specific components such as bearings or Gears (Kulkarni & Wadkar, 2016) All engines on the moving parts produce sound and vibration. Each machine has a specific vibration sign that is related to the construction and state of the engine. Changes in vibration characteristics can be used to detect initial defects before they become fatal (Aherwar & Khalid, 2012; Diwakar, Satyanarayana, & Kumar, 2012). In their previous studies, the researchers were equipped with the standards used to diagnose the engine's conditions. The level of damage based on vibration signals still needs to be known to prepare for the next step. The diagnosis also needs to be verified.

Taking into consideration the importance of the classifier on the smoothness of the cement manufacturing process and the ability of a vibration signal analysis method to determine the problem point in the machine, this study was aimed at determining the source of damage occurring in the classifier by using vibration signals that had been processed using the Fast Fourier Transform method, so repairs could be conducted on the problematic component. Furthermore, to produce accurate conclusions, we re-measured the vibration after the repairs were made to determine whether or not the vibration level complied with to the ISO standard.

MATERIALS AND METHOD

The implementation of this study was divided into several stages as Fig. 2 showed us. In general, the stages were the preparation of classifiers, data collection, data analysis, and analysis results.

The first step to be taken was to check and ensure whether the classifier was in good condition and could properly function and could be safe for measurement. We took notes on the classifier data including power, rotor speed, rotor weight, rotor diameter, and rotor thickness to obtain input on the measuring instruments and to make them a reference when we analyzed the data spectrum.

Measurements were carried out at each main bearing location, including the DE bearing located in the upper position (Driven End Bearing) and the NDE located in the lower position (Non-Driven End Bearing). At each point, measurements were carried out on the vibration amplitude and spectrum. These measurements included motors and rotors.

We measured the initial vibration with overall vibration first, and then we identified the source of the most dominant cause of vibration problems with the spectrum. Fig. 3 showed the Classifier-Coal Mill machine being measured. There were three main components, namely motor, gearbox, and rotor. The motor was on the top and was connected to the gearbox via the clutch; the motor rotation after reaching the gearbox would be forwarded to the rotor. The rotor was located inside and was closed by the casing. Measurements were conducted using two modes, velocity and displacement modes; moreover, since the speed of the rotor was lower than 600 RPM, the measurement employed a displacement mode. During the measurement, the motor was run at the maximum speed resulting in speed at the rotor amounting to 210 RPM. Measurements were made for two directions, namely radial and axial at the NDE motor, DE motor, Upper and lower bearing Classifier with the overall and spectrum measurement parameters.

After the classifier was prepared, the vibration sensor was installed at a predetermined point, namely in each classifier bearing. Tools were arranged based on the needs to produce accurate data. Then, the classifier was run at a normal speed without any workload. When the classifier ran stably, we measured the vibration and spectrum values for each bearing.

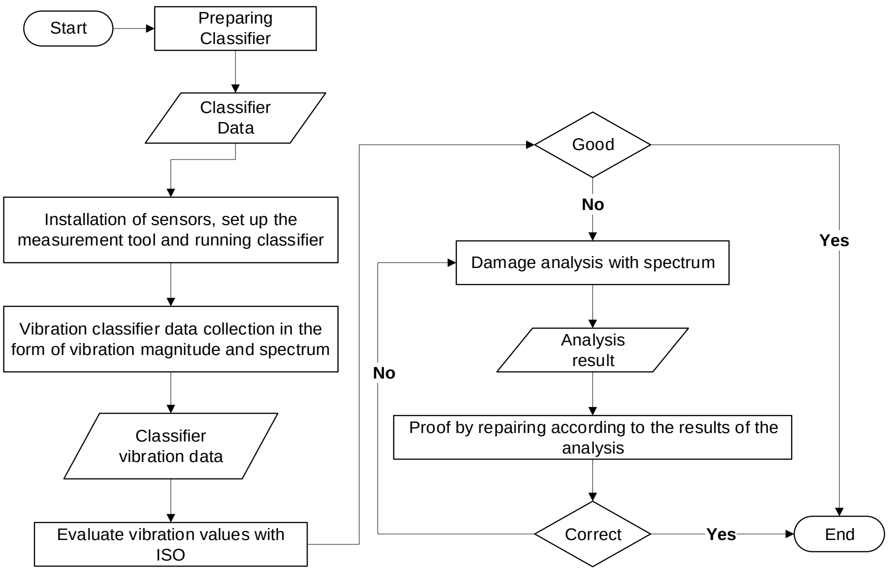

Figure 2. The Study's Flowchart

Figure 3. Photograph of Classifier – Coal Mill Measurement

ISO 10816 provides criteria to assess the vibration levels when measurements are made directly at the measurement site. The specified criteria apply to the machine devices the power of which is over 15 kW and the operating speeds of which range from 120 r/min to 15 000 r/min.

This ISO standard type of velocity that Fig. 4 showed us was employed to assess vibrations in a machine with a rotational speed amounting to 600 rpm or more; in general, the vibration rating used mm/s RMS (Root Mean Square) units, while the ISO 10816-3:2009 displacement type as Fig. 5 showed us was used to assessing vibration in a machine with a rotational speed amounting to lower than 600 rpm; the unit often used in these measurements was micrometer (μm) RMS.

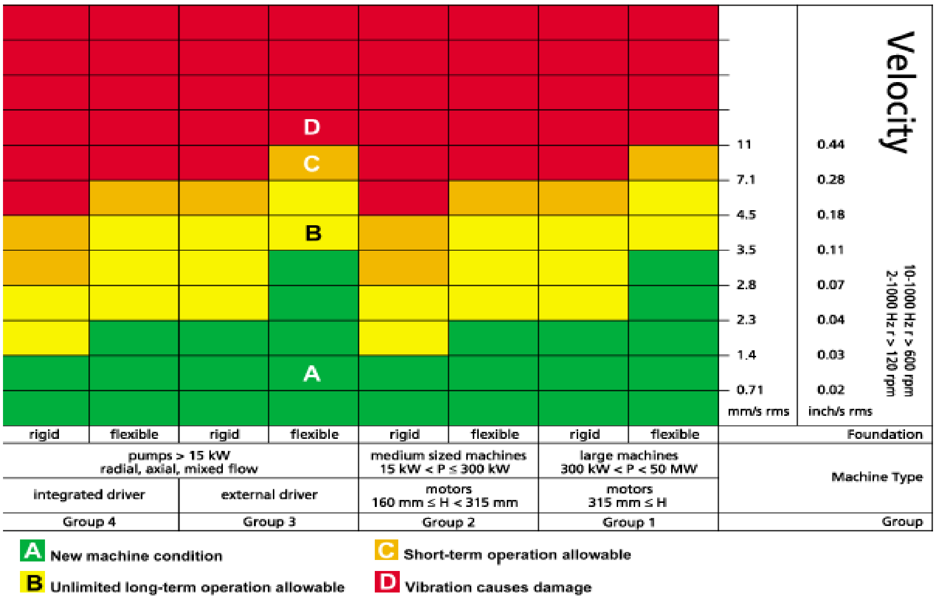

Figure 4. Standard ISO 10816-3:2009 (Velocity)

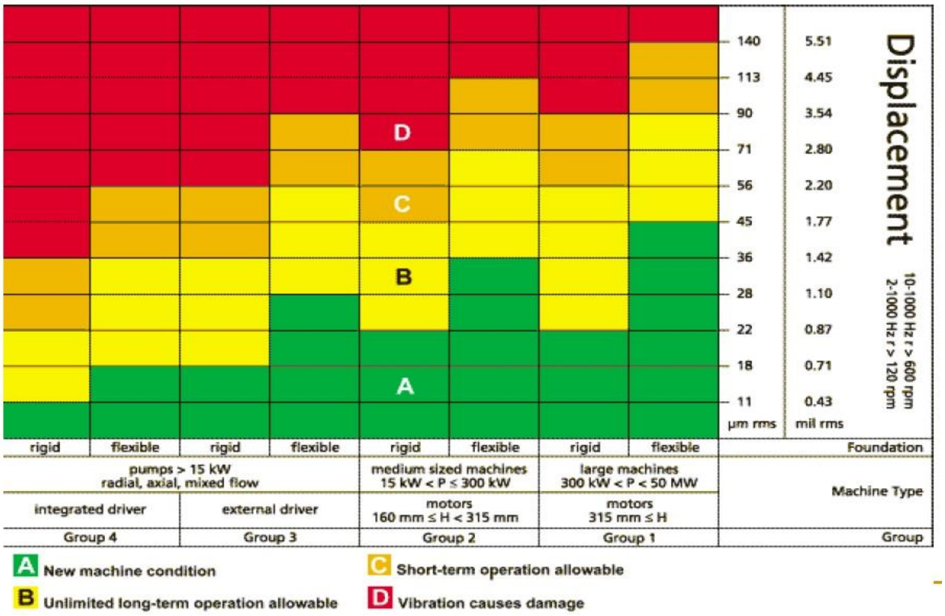

Figure 5. Standard ISO 10816-3:2009 (Displacement)

The measurement data that had been stored were evaluated based on the ISO standards. The vibration values were examined one by one to see whether the value indicated that the vibration was still in good condition or not. If the vibration value was good, we did not make the analysis on the damage and did not carry out the repairs is. On the other hand, if the value indicated that the vibration was in bad condition, we would analyze it by using the spectrum data aimed at finding the location of the damage. Repairs would be carried out based on the results of the analysis, and we would evaluate whether the classifier conditions were better after the repairs. If not, we would then re-analyze the spectrum.

RESULTS AND DISCUSSION

Measurement and inspection with the data spectrum were beneficial in conducting vibration monitoring activities or analyzing a problem on the machine since the data were very accurate and could be guidelines to retrieve the data on the machine. Most of the latest techniques for the engine diagnostics were based on the analysis of vibration signals taken from the engine casing. The main target was to detect the presence and type of damage in the early stages of emergence, to monitor its evolution, and to estimate the remaining life of the engine so that we could select an appropriate repair plan.

Table 1. Vibration amplitude on the motor

Section	Measurement Point		Standard Vibration			Status
	Radial (mm/s)	Axial (mm/s)	Alarm	Warning	Pre-warning	
DE	1.60	0.83	>7.1	>4.5	>2.3	Good
NDE	1.26	1.10				Good

Table 2. Vibration amplitude on the rotor

Section	Measurement Point		Standard Vibration			Status
	Radial (µm)	Axial (µm)	Alarm	Warning	Pre-warning	
UPPER	379.49	34.26	>113	>71	>36	Alarm
LOWER	79.32	-				Warning

Table 1 showed the overall vibration value on the motor side and compared the three ISO standard classes, including pre-warning, warning, and alarm. The overall vibration value was still lower than 2.3 mm/s. Moreover, Table 2 showed the overall vibration value on the side of the rotor classifier. Compared to the standard value, the vibration in the lower bearing rotor was in the warning category with the value amounting to 79.32 µm and was in the alarm category at the upper bearing point with the value amounting to 379.49 µm. The source had been traced, so it would not damage other components. When tracking the location of the damage, we could use the frequency domain to review the frequency points that had large magnitudes.

Fig. 6 and Fig. 7 showed the spectrum of motor measurements. Since the overall value of the overall vibration on the motor was only 1.6 mm/s, ISO 10816-3 (Velocity) standard stated that the vibration was still in good condition. Fig. 6 showed that at the radial NDE point, three dominant vibrational magnitudes were referring to frequencies amounting to 8.75 Hz, 10.75 Hz, and 97.50 Hz respectively.

The cage frequency (FTF) was 10.40 Hz, and this value approached the magnitude of the dominant vibration amounting to 10.75 Hz, so there was an indication of damage to the cage bearing. The same magnitude characteristics were also shown in the DE measurements of the motor bearings; the dominant frequencies were 8.75 Hz, 10.75 Hz, and 97.50 Hz respectively, so they indicated damage to the cage bearing, as Fig. 7 showed us.

Fig. 8 showed the vibration with a very large magnitude occurring in the upper bearing classifier. The value of the vibration magnitude was 438.01 µm, the frequency of which was 3.5 Hz, so the vibration exactly showed a fundamental classifier frequency. Moreover, Fig. 9 showed the vibration characteristics in the lower bearing classifier. The enormous magnitude is seen in the 3.5-Hertz frequency line with the value amounting to 79.32 µm. There were no significant differences between the two spectrums. The data could confirm the analysis of the problems occurring in the classifier. The largest magnitude vibration occurred in the upper side of the rotor. Referring to the ISO standard, the vibration value was in the alarm position, and immediate repairs had to be conducted precisely in the upper bearing with the amplitude amounting to 438.01 µm on the radial axis.

Based on findings from (Aherwar & Khalid, 2012; Xiang & Wong, 2019), damage commonly occurring in the rotor and shaft was unbalanced with 1X characteristics appearing on the frequency (spectrum) domain.

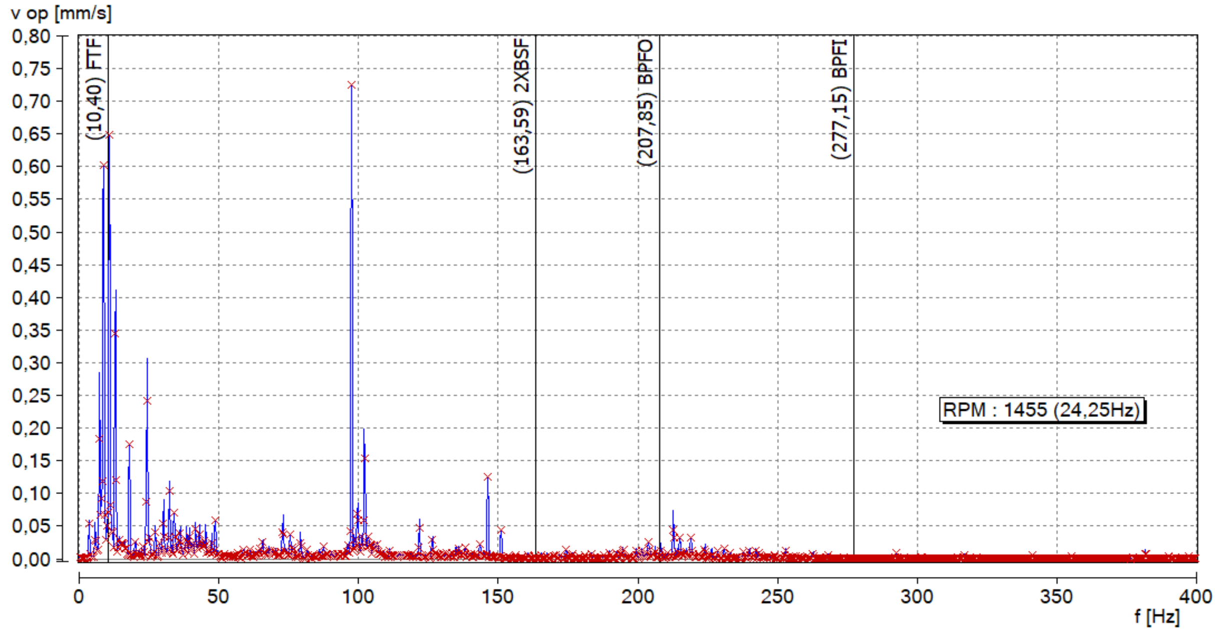

Figure 6. NDE Radial Motor Spectrum

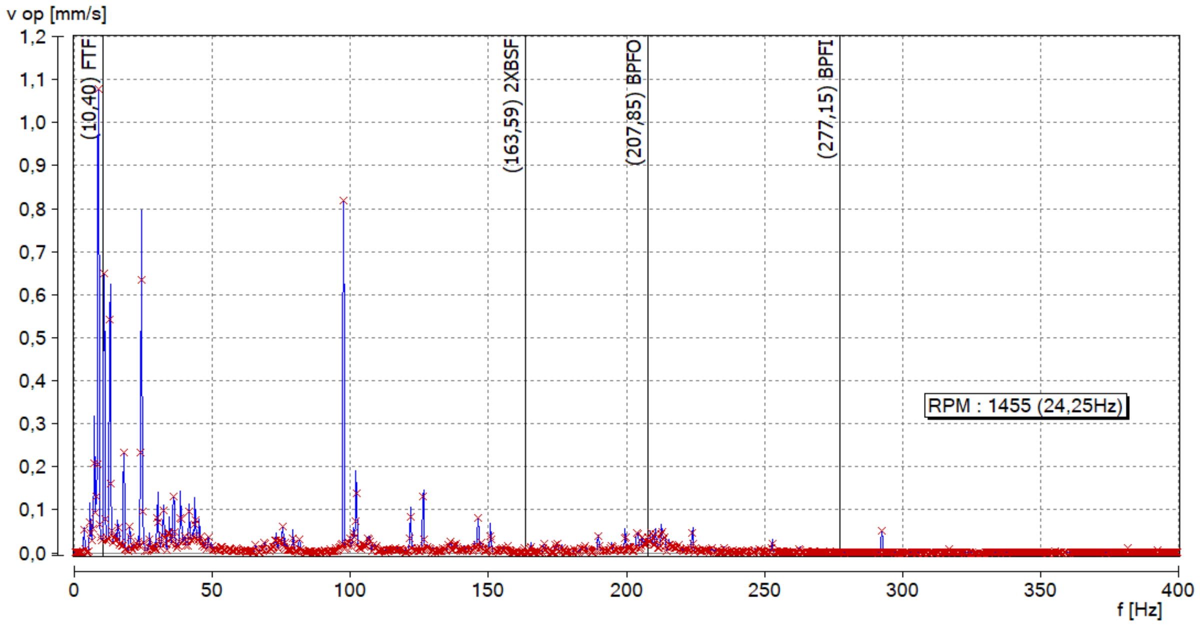

Figure 7. DE Radial Motor Spectrum

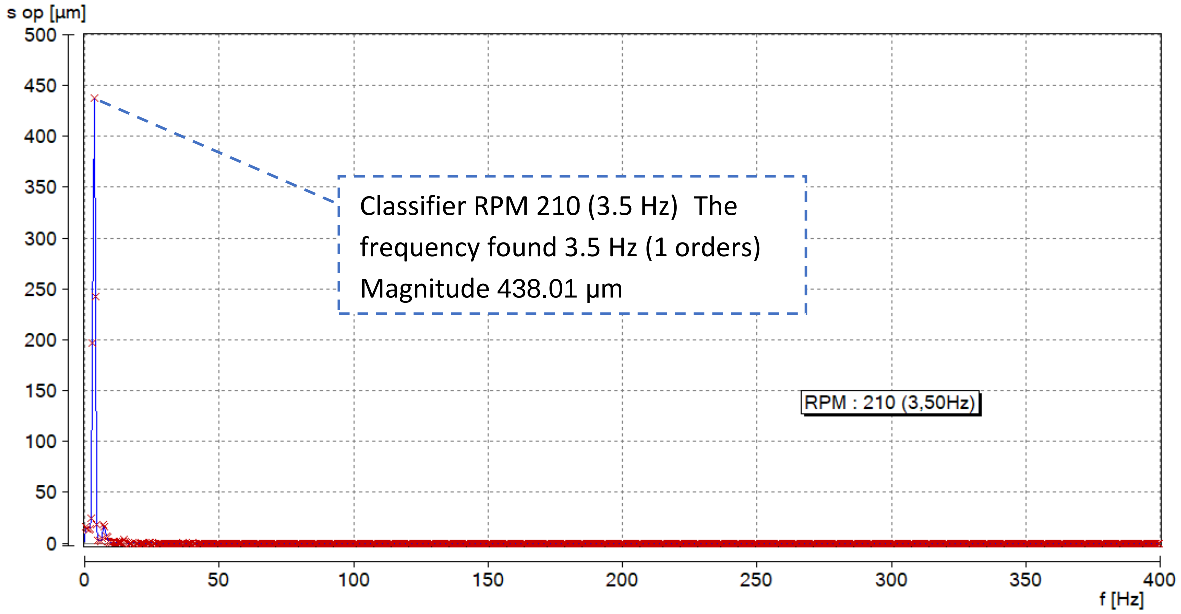

Figure 8. Upper Bearing Radial Spectrum

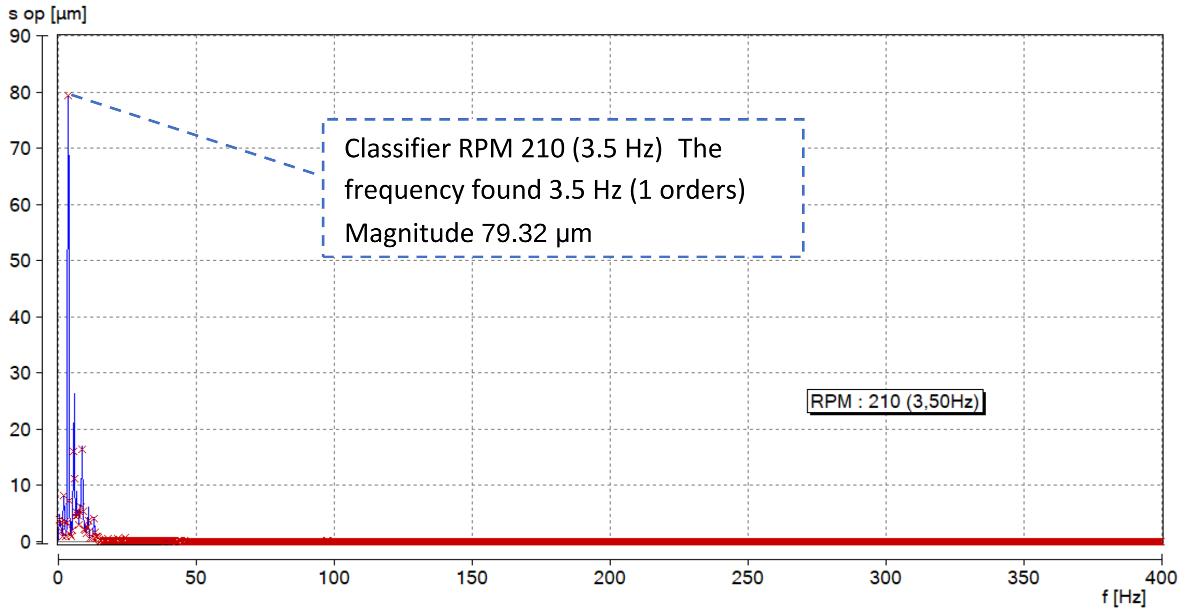

Figure 9. Lower Bearing Spectrum

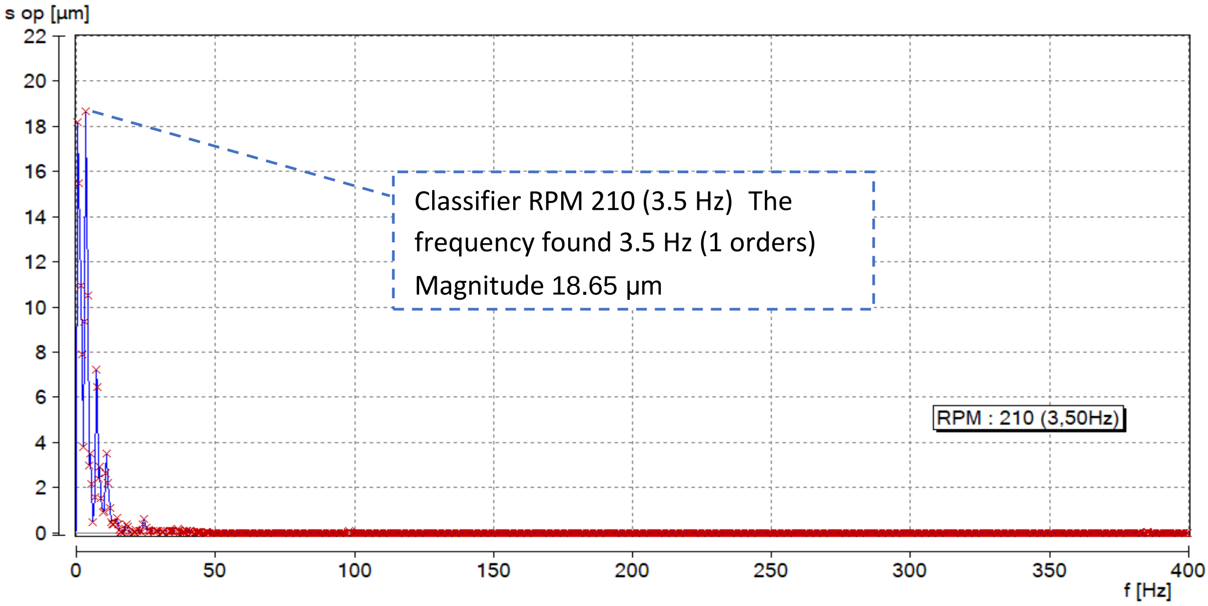

Figure 10. Upper Bearing Radial After Balancing

On the upper and lower bearing rotor of the radial axis, the largest vibratory value was 438.01 µm at a 3.5-Hz (1X) frequency, so we could draw a conclusion that there was a large vibration in the rotor due to unbalance. Unbalance was the shift of the center of mass from its center of rotation, so it resulted in a high vibration. The amplitude of the vibration was proportional to that of the rotation (it was the square of the rotation). We could overcome a problem with the unbalanced rotor by balancing the rotor. Another kind of damage that usually occurred was no misalignment on the shaft when it was viewed from the data spectrum, as Fig. 8 and Fig. 9. Misalignment had a characteristic in the appearance of 1X, 2X and sometimes 3X frequency lines.

After balancing the rotor, we made the measurement again at the radial bearing up point with the spectrum results that Fig. 10 showed us. Magnitude still existed; however, its value had changed.

Table 3. On-site balancing result

Measurement Step	Upper Bearing Radial
Before Balancing	438.01 µm
After Balancing	18.65 µm

The initial largest vibration value was 438.01 µm, after the balancing, it decreased to 18.65 µm as Table 3 showed us. These facts confirmed that the results of the vibration analysis were correct. When we referred to the ISO standard with the classifier specification being in the flexible group 2, it means that the vibration value of the classifier could be operated.

CONCLUSION

The source of damage to the Classifier could effectively be detected by using vibration signals in the form of overall vibration values and frequency domains. We could determine the level of damage to the Classifier by comparing the overall vibration value to the ISO 10816-3 standard. The source of a problem in the Classifier could be found by looking at the location of the frequency having the largest magnitude.

The classifier had the largest overall vibration in the upper bearing rotor amounting to 379.49 µm, and the vibration was already in the alarm category. In other words, the engine was in bad condition. The analysis of the frequency domain showed that there was an unbalanced rotor since the largest magnitude appeared to be at the 3.5-Hertz (1X) frequency. The analysis proved to be correct since after we conducted the balancing, the vibration of the rotor at the upper bearing decreased from 438.01 µm to 18.65 µm.

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