OVERALL FACTORY AVERAGE SPECTRUM: GLOBAL VIBRATION INDEX FOR DIAGNOSIS AND PROGNOSIS OF LARGE SETS OF ROTATING MACHINERY

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Summary

Spectral analysis of rotating machinery requires studying the signals received from each machine, which converts hundreds of spectra to analyze, especially in big plants, where one can find a large number of similar machines. The maintenance departments require few indicators properly hierarchied with the appropriate information necessary for each organizational level, without exceeding the type and amount of information required at the higher levels. It is therefore, necessary for an indicator to show the current vibratory condition of the entire plant, where trends can be easily understood by people, who are not expert in detailed vibration analysis of spectra. The trend shown by the indicator should assess the success of the implementation of CBM and other maintenance programs in the plant, and these parameters should be easily displayable. Therefore, maintenance managers need this kind of indicators and scorecards to measure through simple methods for the success of their departments for achieving contribution to the company goals.

Key words: vibration, speed, acceleration, predictive maintenance, CBM, data collector, indicator.

INTRODUCTION

In general, the Predictive Maintenance (PdM) contributes in principle to detect the onset of a future failure, as well as provides the tools necessary to analyze the cause of the problem that is being developed. The final result will specify the proper timing to efficiently and effectively perform the necessary corrections to solve the problem identified.

PdM Program consists of three essential stages. detection, identification and correction Detection is the first step in the PdM, and is based on the evolution of one or more parameters selected properly according to their sensitivity to the changes in the condition of the equipment tested. Identification is the process after the problem has been detected; we must therefore, proceed to determine the cause of it, i.e. to identify which element or elements of the machine is or are the cause of the increase in the levels of vibration, in comparison to the accepted references that show a normal condition of mechanical equipment. This article will be presenting a methodology for obtaining such a reference in a dynamic way and adapted to the real condition of the entire plant, where the machine is working. Of course, knowing the cause of the problem and the location of it, allows the maintenance department to organize and implement efficient and effective work for eliminating the problem and their causes.

It is extremely important that identification of likely failure may be found even in its early developmental stage that will allow the maintenance team to perform intervention at the right time. As shown in figure 1, avoiding unnecessary losses and minimizing costs is possible through the intervention. However the decision to perform interventions are based on different thresholds from standards, based on experience or manufacture's recommendations; that is why many interventions are unnecessary as a result of false alarms due to wrong benchmarking points.

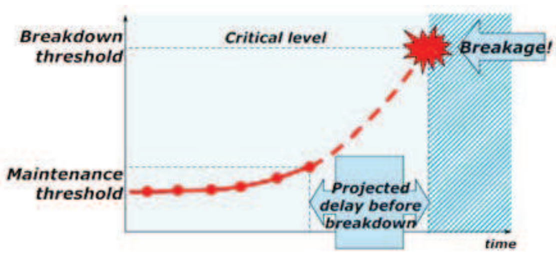

Fig. 1. Analysis of time history for significant parameters

On the other hand, a too optimistic threshold can cause a breakdown before detection. That is the main reason why these thresholds are usually very conservative.

1. INTUITIVE APPROACH

Over the years, either by direct contact or the use of subjective nature of any device, machine operators have used auditory verification techniques, which are "too subjective" to detect specific problems but effective to identify if the behaviour of machines is normal or no.

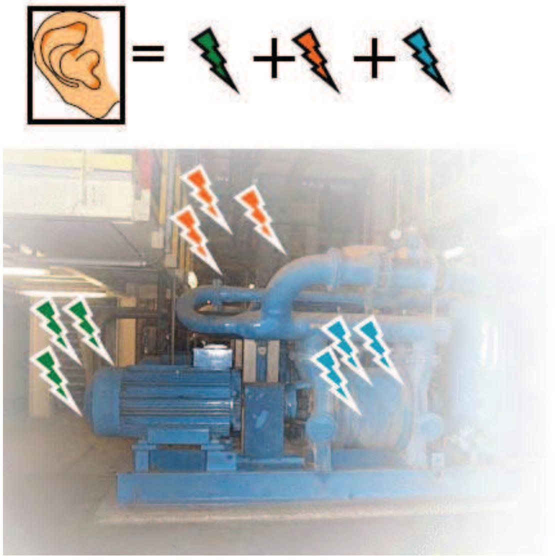

Fig. 2. Auditive perception of real condition of machinery

As a result of forces that occur between elements of a machinery and vibration generated by them, the outer surface of each of the pieces that make up the machine will be of varying shape and position. This causes changes in air pressure that generally surrounds the equipment. This pressure wave propagates in the air affects objects near the source of vibration.

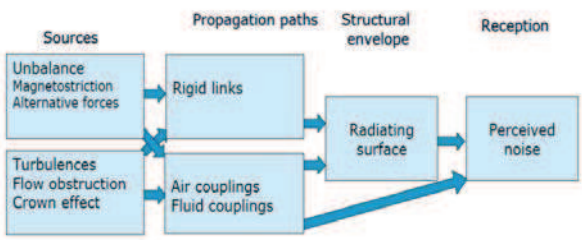

Fig. 3. Intuitive approach of vibration producing noise

One of these objects could be the tympanic membrane of the human ear, through which the rest of the system of the ear, the brain produces the sensation of sound. See Figure 2. In this way, the measurement of sound produced by a machine is the measure of vibrations caused by it. Measuring vibration by sound has the advantage that at the same time, measuring the vibration of all the items of machinery. But, it has one big disadvantage, like; in industrial production, often the sound surrounding comparable or superior to that from the machine needs to be analyzed.

Hence, traditionally, and unconsciously, the vibrations have been used as an indicator of the technical condition of machinery. Nowadays the measurement of vibrations to detect and identify failures and developed or early period of development and have real information about condition of machinery; which is world wide used and commonly accepted as best technique in rotating machinery.

The vibrations can be observed in time or frequency. In the measurement of the level of vibration, it is necessary to define the physical magnitude to be quantified to describe the vibration; and it can be used for displacement, velocity or acceleration, [1]. We will work from now on the frequency spectrum, because we can run the identification phase of the problem. As magnitude of vibration enlarges, use of speed to be widely used in the analysis for severity of rotating machinery.

In this paper, a methodology for obtaining a parameter of global machine condition is proposed. It provides information similar to that which would have an expert operator with his ear to hear the machine running. Moreover, this parameter will be generalized to obtain what would be a "hearing" simultaneous of all rotating machinery in the factory.

2. GLOBAL VIBRATION SPECTRUM

The use of levels of vibration produced by rotating machines, to determine the technical state of the latter, has a myriad of applications in the industrialized world, because for over three decades effectiveness and utility the information provided by the records of vibration have been proven.

All elements that compose machinery have some features depending on the design and operating speed. Some of these features are the characteristic frequencies, where this component vibrates if it is excited. This implies that, before attempting to identify problems in a machine, based on information supplied by the vibrations it is necessary to determine the frequency of diagnosis of all elements that can vibrate. These frequencies are those which are expected to obtain information on the spectrum of vibrations during the measurements that are made in properly selected points with the selected measurement tools. In this way, it will be necessary to find within the spectral records the frequencies of diagnoses that were previously identified during the casuistic analysis of the machine and observe the evolution of these frequencies.

In general, the forces between the contact elements in a machine during its operation, determine the life period of them. However, what is measured is not the magnitude of these forces, but the vibrations in the machinery. Unfortunately, identical condition of machines doesn't mean identical levels of vibration and this is a common mistake in the traditional vibration analysis creating lots of false alarms. If you change the mechanical fastening or the bench of a machine or two; they differ only in their base plate, the amplitude of the dynamic force may be the same on both machines, but not the vibrations measured in selected points.

2.1. Process for vibration diagnostics

The key for predictive maintenance is to monitor the evolution of the frequencies characteristic associated to all identified components using periodic measurements [4]; See Figure 4.

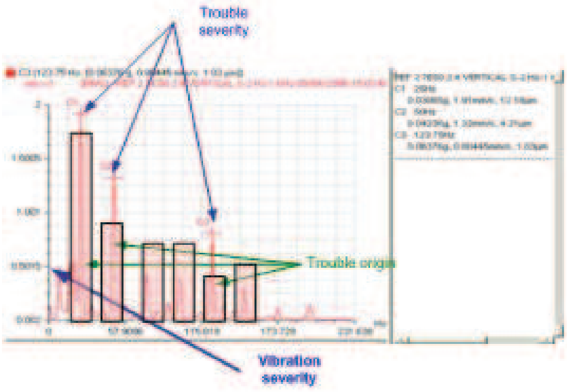

Fig. 4. Monitoring of frequencies band

This monitoring is not easy, if one takes into account the dynamic behaviour of machines characterized by the fact that:

1. Different temporary records can produce similar spectra.
2. For some frequencies, their corresponding amplitudes can be acceptable. However the same amplitude may be unacceptable for other frequencies within the same spectrum.
3. Several problems can be shown into the same frequency. For example, the unbalances, the deflection of a shaft, or the misalignment producing similar effects in the same frequency. Also, it can happen that a machine shows a frequency caused by any of the above mentioned problems. But, if this vibration is transferred from another machine connected in some way, then we can not trust in some vibration records, if we are not sure of the vibration source.
4. The analysis of a problem at a given frequency in many cases, dependent on the presence of one or more frequencies associated with it.

It is therefore extremely important to have spectra of a machine in different frequency ranges, even if it is possible to apply the technique of ZOOM in different frequency bands, necessary for the analysis of complex machines, [5]. Two stages of work are required: First one is called detection, which requires defining the reference spectrum, which is obviously a spectrum corresponding to vibrations recorded in the same point, where vibration usually is measured in machine, but this was obtained when it was estimated that the machine had a normal mechanical condition. Against this spectrum, by comparing the further measurements, we can detect if frequencies associated with machine components have increased to non-permissible levels, because it may indicate that it is developing a fault.

The second stage includes the identification of the problem. Previous results are the basis for this stage in order to find out where it is located; and what is the problem that has produced excessive levels of vibration. In general, the frequency measured is not deceived, but it can be analyzed incorrectly, measured inappropriately or incorrectly interpreted; due to which; the amplitudes can be overestimated or underestimated. Most of the severity charts included in vibration standards were designed for vibration levels caused by unbalances, [6]. However, for many years these charts have been used and currently are still in use in some cases. In addition, the efforts are always to have the maximum measurements; with each machine having ten or twenty measuring points, generating alarm in the most severe vibration points which do not always mean the most serious problem to be located there. This sort of arrangements produces a large number of false alarms in monitored processes, as discussed above. The consequence of this policy is that no attention is paid to machines with lower levels, but whose prognostics are worse with imminent failures, and there are more failures, even though their levels of vibration have not reached high values according to ISO standards. Galar [11] proposed OFVL (Overall factory Vibration Level) as a global indicator of the general state of large sets of rotating machinery. The use of this indicator instead of the most severe vibration point solves the false alarm problem.

2.2. Need for spectral benchmarks

OFVL provide useful information of the real severity of the machine. In fact, it is a good benchmark for prognosis. However, this reference doesn't provide any information about the causes of the potential failure and the methodologies to avoid it. That is why; diagnosis dynamic benchmark is needed not only to know the severity of the condition of each machine, but the evolution of different potential damages as imbalance, misalignment and so on.

For this purpose, averaging of real spectra becomes the best technique to create a vibration template for diagnosis. Averaging technique is widely used in the analysis of vibration. This is used when performing the operation, to ensure repeatability of the same, so that the collector performs several measurements and averaging. This methodology has a clear utility to prevent that a slip of the sensor causes an abnormal beating producing a false alarm. The average measures in a single machine can raise the quality of this measurement. However, we can and we must average the vibratory state of different machines, to have a benchmark, i.e. a template which provides complete information about the different problems that are being developed in the plant. So, the technician can analyze vibration spectra with his knowledge and expertise. Besides, he can use a benchmark produced by the current condition of the whole factory or area, as can be seen in figure below. This will reduce the hundreds and hundreds of spectra obtained to an average spectrum, which would give the vibration state of the plant as a whole, as well as you keep your knowledge in the calculation method and data collection without wasting of knowledge associated to specific people in the company. Clearly, this average should be weighted according to those parameters that make it more important or more critical than other machines. This weighted averaging method is proposed using a new parameter, the normalized averaged spectrum. Comparisons of individual spectra measured in each machine with this template will show the difference between the machine and the rest of equipments in the plant regarding the vibration conditions and possibility of failure appearance.

As a general guide, the strategy is generally used to relate the spectra measured with the reference spectrum. In other words, it is believed that the best indicator of the mechanical condition of the machine is given by the changes experienced by the vibration levels with respect to the reference spectra of the machine itself, as can be seen in Figure 5.

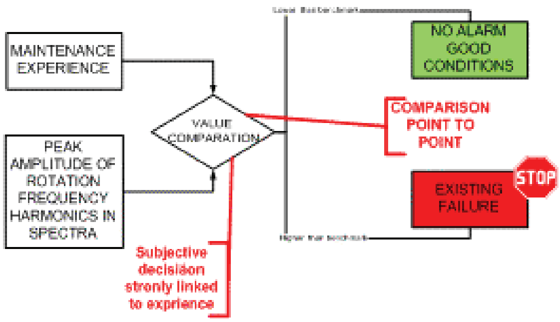

Fig. 5. Traditional method of measurement comparison based on maintenance worker's knowledge

Obtaining the reference spectrum is complex. We can use in new installations, the spectrum after the installation and start-up of machinery, but be sure that the machine is not in a period of infant mortality, where the spectra can be more alarming to the operation at maturity. This may be interesting to consider a spectrum of burn-in period, with eliminated child period of infant mortality, as suggested by the MIL-STD-2074 [7], to test reliability. Machinery that has a running time, unpredictable spectrum is considered. Even, after an overhaul, total reset of the machine may have natural frequencies of the plant or machinery coming, and some of defective parts.

2.3. Average of measured spectra

Suppose that $v(t)$ is a signal velocity of vibration at the time limited by an interval between 0 and T. Fourier transformation of this segment is expressed as follows:

$$V(f) = \int_0^T v(t) e^{-j2\pi ft} dt \qquad (1)$$

The segment $v(t)$ is limited between 0 and T, just as its Fourier transform is limited between-F and F. In practice, the sampled segment of finite length and the spectrum can be limited using a low pass filter. With these restrictions, it is only necessary to describe $v(t)$, a finite number of samples of the signal itself in time or its spectrum $V(f)$. Thus, if the $V(f)$ spectrum is sampled at intervals of frequencies equal to the so-called Nyquist interval, 1/T, within the –F to F, the number of samples required will be:

$$N = \frac{2F}{\frac{1}{T}} = 2FT \qquad (2)$$

Hence, we can see that the tool is interesting for analysis in the frequency domain of our signal, DFT (Discrete Fourier Transform), which provides a discrete spectrum, which is easy to be processed. No information is lost, if we use the minimum resolution defined by Nyquist sampling frequency in the discretization process. This discrete spectrum will be as follows, [2]:

$$V(k) = \frac{1}{N} \sum_{n=0}^{N-1} v(n) e^{-j\frac{2\pi kn}{N}}$$

$$v(n) = \sum_{k=0}^{N-1} V(k) e^{-j\frac{2\pi kn}{N}} \qquad (3)$$

$$n = 0,1,....., N-1$$

$$k = 0,1,...., N-1$$

With $v(n)$, the sampled vibratory signal, $V(k)$ the discrete spectrum, is obtained by DFT and; N is the number of discrete samples of a segment of the vibratory signal. This set of N discrete samples is often called segment. In the case of vibration processing, signals are real and discrete spectrum $V(k)$ is complex. . When, we do the DFT, using N as a power of two, better known as FFT (Fast Fourier Transform), it saves us time to process a very high, especially in portable collectors, which makes this FFT widely used for its simplicity throughout the vibration analysis, [3].

It is therefore proposed to use the spectrum-weighted average, which is normalized to the frequency of rotation, projecting the vibration spectrum on that template. The average normalized expression of the spectrum would be allocated as follows:

$$V_{media}(k)=\frac{\sum_{i=1}^{n} v_i\left(\frac{1}{N}\sum_{n=1}^{N-1} v(n)_i\, e^{-j\frac{2\pi kn}{N}}\right)}{\sum_{i=1}^{n} v_i}=\frac{\sum_{i=1}^{n} v_i V(k)_i}{\sum_{i=1}^{n} v_i}$$

$$n=0,1,.....,N-1$$
$$k=0,1,.....,N-1$$

$v(n)_i$ is the time segment of vibration measured on the collector at point i and $V(k)$ is the fast Fourier transform of this segment.

Where, v_i is the speed associated to the point i. $v(n)_i$, at point i, where n is the total number of measured points on the machine in question: Horizontal, vertical and axial, not the housings of the bearings. N is the number of sampling points of the signal temporal result of sampling with the Nyquist frequency, as a minimum. Under the DFT (Discrete Fourier Transform), therefore, $V_{media}(k)$, must have these items for as little and not to lose information in the transformed. We'll therefore like to get an averaged spectrum as analyzed by the machine.

2.4. Importance of normalization and interpolation

Thus, we must normalize the spectrum in the frequency axis by the rotational speed, i.e. get the value of 1x frequency, the frequency of rotation, 2x etc. In this process, normalization will be necessary to interpolate a number of samples to achieve this shift in frequency that allows the matching frequency of rotation.

Be $V_1(k)$ FFT be of N samples with the frequency of rotation f_1

And; $V_2(k)$ FFT be of N samples with the frequency of rotation f_2

Obviously, in the standardization process, we will lose slight information of one of the spectra, to keep the number of samples N invariable. In this case, we can use two methods of work: Normalize the frequency higher, and therefore, interpolation, or normalized to the lower frequency and therefore sub sample with the loss of additional information. If you opt for the interpolation, we need to calculate the ratio of the higher frequency, compared with the lowest coming to interpolate a number of samples in the spectrum according to their relationship. Normally, the difference in the frequency of rotation is between machines that rotate at 1000 RPM and machines that rotate at 1500 RPM, (Karassik, 2001). In this case, the interpolation ratio of 1.5 is quite small, so that the methods of linear interpolation or cubic splines provide good results. When there is rotating machinery, such as; steam turbines that rotate at 4000 RPM or 4500, it is preferable for those machines, sub-sample at a frequency lower, which as mentioned is usually 1000 or 1500 RPM. The process of interpolation from 1000 RPM to 4000 RPM in all the machinery that is normalizing with respect to the frequency of rotation of the turbine would introduce too much distortion in the system.

Once interpolated spectrum, it should be noted that, it will increase in length of N samples to $N\frac{f_2}{f_1}$ samples, increasing the frequency usually represented 1 KHz to $\frac{f_2}{f_1}$ KHz, so the last step in this process of normalization will cut this spectrum obtained in the N sample, assuming that little loss of information at high frequencies. In the case of machines of different speeds (reducing or pulleys), help us to harmonics in the frequency of rotation and match them properly and are averaged. Similarly, the number of points, i.e. the spectral resolution of the DFT must be the same for all. This confirms that; analysis, which takes in more points in DFT for gear machines, must match the number of DFT points made in all spectra; otherwise, it will be impossible vectors resulting weighted average. With these assumptions, the resulting weighted average spectrum, which will call OFAS (Overall Factory Average Spectrum) respond to the following expression:

$$OFAS(k)=\frac{\sum_{i=0}^{n} P_i V_i(k)}{\sum_{i=0}^{n} P_i} \qquad (5)$$

Where, V_i is the average of the vibration machine i, as calculated above, P_i is the power installed in the machine i and n the number of machines included in the search for the global average spectrum of vibration. What we get is; therefore, an average spectrum, normalized to the frequency of rotation for the entire area of analysis that we are contemplating.

9. OFAS LIKE CBM TOOL

OFAS utilities are basically two, clearly differentiated: Firstly the OFAS is a standard template on which the current state of vibration of a machine at a particular time is projected. The condition of dynamic template, changing with time, is interesting to study. It may examine the deviations of vibration of the machine studied, with regard to general conditions at that particular time, and not with respect to static conditions, which are often not reproducible. Obviously, we need different templates in function of the age of machinery, because the vibration signature and the interpretation of this signature are changing during that time.

Secondly, we can obtain the trend of global problems that are manifested as harmonics rotation speed or highly localized in certain frequency bands, such as; imbalance, misalignment, clearances, hydraulic problems or problems of lubrication.

3.1. OFAS as standard reference template

The templates used in the early stages of operating the machine, often do not coincide with the pattern repeated after ten years of operation, because the signature of each machine gives it a hallmark, which is not a symptom of malfunction, but the result the configuration of the installation itself. In rotating machinery, it is important to take into account the dynamic nature of these projection templates, i.e., the signature of the machine changes over time and is influenced by factors, such as; repairs, the machinery that surrounds it, or the conditions of operation.

In this way, we can get different OFAS periodically measured as a result of data collection, which will mutate over time. We can calculate the OFAS for a particular type of equipment in the plant, for a given area or for the entire plant.

The OFAS, is an averaged variable, so the reliability of it depends on the items listed. Therefore, OFAS calculated using large rotating machinery which provides more reliable results. In Figure 8, we can see that the OFAS of a machine is calculated, i.e. by calculating the average spectrum of the measuring points. In this case, a motor coupled to a pump with the following control points: 1H, 1V, 1A, 2H, 2V, 3H, 3V, 4H, 4V, 4A.

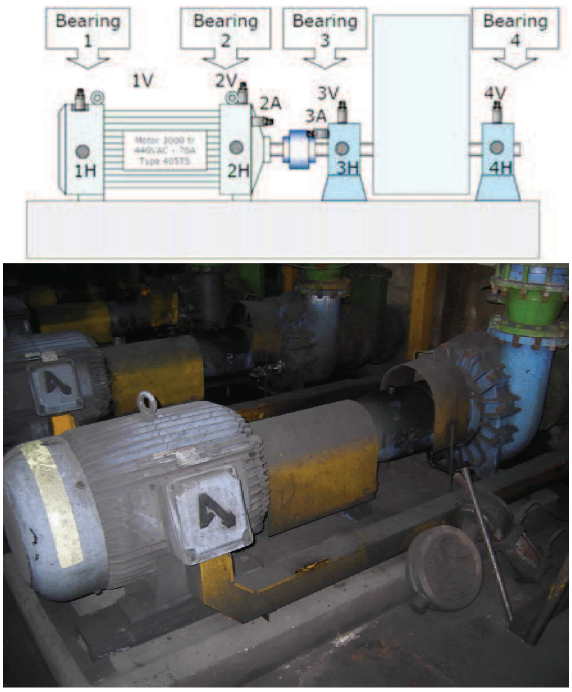

Fig. 6. Measurement points in a motor-pump

The OFAS of the machine will therefore be calculated using the following expression, because there is only one element driving (with a given power) and the motor and pump rotating at a single speed, as you can see in Figure 6.

$$OFAS(k) = \frac{V_{1H}(k) + V_{1V}(k) + V_{1A}(k) + V_{2H}(k) + V_{2V}(k)}{10} + \quad (6)$$
$$+ \frac{V_{3H}(k) + V_{3V}(k) + V_{4H}(k) + V_{4V}(k) + V_{4A}(k)}{10}$$

The other spectrum is the OFAS for all the pump rooms, where the machines are located as you can see in Figure 7 and OFAS of the whole rooms can be calculated simultaneously with the OFAS of our pump in order to do further comparisons.

Fig. 7. Pump room where the machine is located

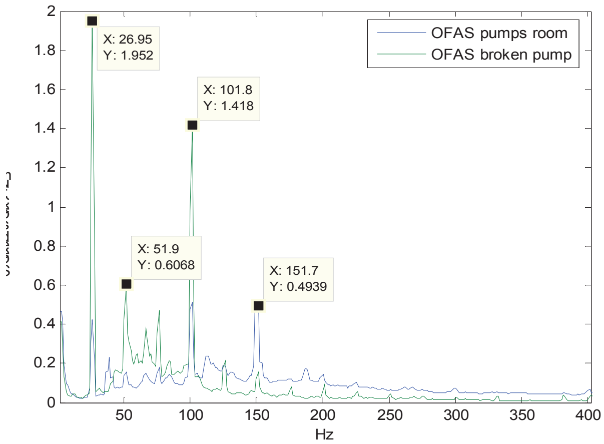

Fig. 8. OFAS of a pumps room versus OFAS of a broken pump

We can see that, the OFAS of our machine, compared with the overall plant OFAS, presents some important variations. In this case, the peaks of the 1x and 4x of our pump are several orders of magnitude higher than the average plant spectrum. So, we have a machine with a major breakdown; an imbalance in the rotor and the development of important clearances. Detailed analysis of spectra of this machine will give more information and can define the problem; the speed of OFAS machine in comparison with respect to global OFAS is obvious. This comparison is an additional advantage, as it not only perceives the existence of a fault; but, we also see the divergence with the rest of the plant, which eliminates the possibility of a crash on all machines.

In Figure 9, we can see another pump in the room with respect to global OFAS.

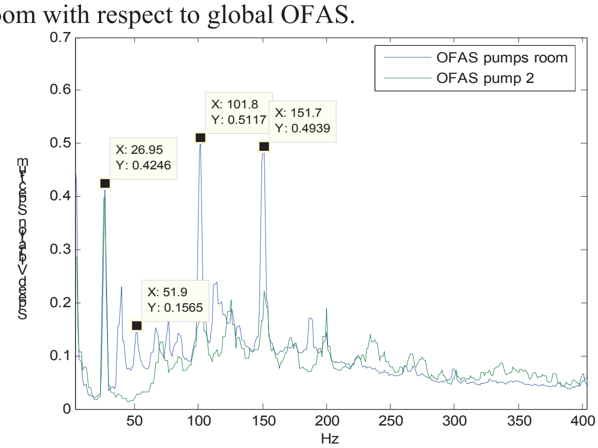

Fig. 9. OFAS of a pumps room versus OFAS of non broken pump

None of the peak stresses are above the global OFAS; so, this pump is below the signature characteristic of the vibration in the room at the time of measurement. It is therefore, a pump that is in normal use and below the levels of vibration of the machines that surround it.

3.2. OFAS as generalized fault diagnosis in factory

The second utility OFAS is the analysis of trends for the detection of pathologies generalized to the entire plant. Through this standardized and averaged spectrum, we can view the status of certain pathologies associated with harmonics of the frequency of rotation. It is important to note that, it is not going to get the information for immediate intervention, but the trend of a fault and its propagation. In Figure 10, we can observe the OFAS for the pump room; which we studied previously. The peaks at 1x, 4x y6x those remain high, despite the extent of the averaging effect softener, which may be indicative of several failures A progression upward with peak at 1x, may indicate excessive or unbalanced rotors defective benches in most cases. Peak 4x and 6x show us housings with early bearing clearances and hydraulic problems. The trend of these peaks and the averaged OFAS will tell us if a problem persists and increases or on the contrary is circumstantial.

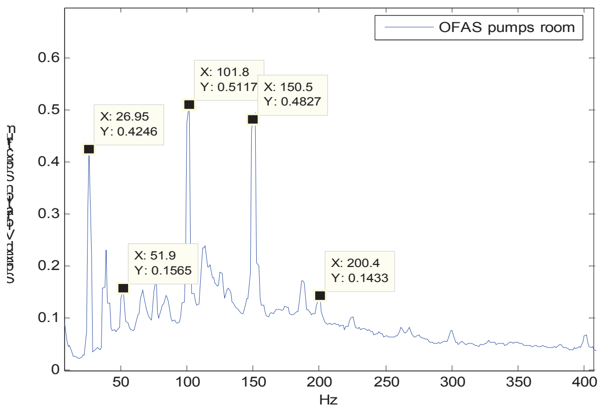

Fig. 10. OFAS of a pumps room

Specifically, we can visualize in the OFAS, the development of pathologies associated with multiples and fractions of the frequency of rotation, whose cumulative effect on the OFAS will indicate the severity of the problem. The OFAS, therefore, has some disadvantages, such as; non-occurrence of errors associated with absolute frequencies. For example, the failure of benches with soft foot is shown in 100Hz, which is delocalised and blurred in the standardization process. Therefore, it disappears from our field of observation. The average and frequency displacement became the 100 Hz peak invisible.

The other disadvantage is the coincidence of several types of failure in a single frequency, [9]. Can the typical peak at 1x, which if high, could raise pronounced imbalances or faulty benches? To this end, we compare the OFAS with some of the critical points of the machines, as supports of the pumps, to identify and segregate the source of the vibration. Despite the comments above with respect to the frequency of failure, i.e., the overlap of some diseases on the same frequencies, we can differentiate a number of interesting bands that will allow us to analyze the overall trend of problems at the plant. In the case of centrifugal pumps installed in sufficient number, normalized and averaged spectrum shows some data depending on whether the problems associated with the frequency of rotation and its harmonics. Flow problems, poor lubrication or poor design of the impellers and pipes of the plant will produce peaks in the reference frequencies. When these problems are restricted to a single machine, the effect of averaging, minimize alarm considerably. Similarly, excessive peaks 1x indicate general imbalance or hydraulic imbalance, pathology more common in the global plant. Similarly, frequency of 5x to 20x will give us a general state of the bearings, or at lower frequencies, we can see the general state of the housings of the bearings. Therefore, we need to identify problems associated with harmonics in the frequency of rotation, which in the spectrum to the same standard, have a cumulative impact on the OFAS. [10] describes some pathologies of rotating machinery, associated to harmonics or sub harmonics to be observable in OFAS.

Imbalance: The OFAS reflects a sharp peak at 1x on plants with high levels of imbalance or benches in a poor state.

Misalignment: The hallmark of the misalignment is the generation of the three harmonics in the frequency of rotation. If the frequencies 1x, 2x and 3x are present in OFAS, we must align the plant. In fact, most of the plants are lined up all the rotating machines at once with a given time period, or when there are symptoms of misalignment on the operation.

Bearing clearances with respect to the shaft: The OFAS provide this information in a quality parameter in the installation of the bearings by the maintenance team.

Bearing clearances with respect to housing: If there are clearly four harmonics of the frequency of rotation, then, it is very likely that the bearing is "loose" with regard to their accommodation.

Failures in gears: OFAS will have a reduced peak gear, but be abundant in number; it indicates a very poor state of gear machines in the plant.

Vibrations caused by oil whirlwinds: OFAS peak of 0.4x to0.5X to assess the quality of lubrication programme of the plant within the PM programme.

Bearings Defects: Many experts also agree in saying that the ruling is imminent in the bearing; when the highest peaks generated by it, decreasing in frequency to around 20X harmonic. Therefore, we see in our OFAS a band bearing terminal state to be monitored.

4. CONCLUSIONS

The development of indicators for maintenance requires scorecards tailored to the personnel who will use them in making decisions. Implementations of CBM and specifically the analysis of vibrations get detailed analysis of the state machinery; but, specific data are not exported to higher levels of the organization. Maintenance managers with hundreds of rotating machinery in-charge need a small set of indicators that presents trends appropriate to analyze at a glance the general state of health of the machinery of the plant. The OFAS is an appropriate scorecard for technicians and maintenance engineers and even the other managers and director of the department. It is therefore, a leading indicator of interest, which also provides references to determine the deviations from it. Once the hierarchical level of this indicator is established, it should highlight the two major advantages in implementation. On the one hand, we obtain the reference template on which to project our spectra. This template, in contrast to what the manufacturer tells us, will be dynamic and will change depending on operating hours and repairs incurred. It will be the signature of our own facility, a unique and irreproducible one, whose evolution is very interesting to evaluate the overall condition of the machines. Moreover, the evolution of OFAS shows the progress of some diseases. Therefore, it should be reflected by high peaks at 1x, 2x, 3x etc.... depending on the severity and repetition of some fault in the machinery. This is interesting, because, there are diseases such as misalignment, clearances or inadequate lubrication often repeated in a large number of machines, so that the appearance of these peaks in OFAS is a symptom of its existence. Therefore, the evolution of some peaks will be strongly correlated with the lubrication programme, annual alignment of the plant during maintenance stop, the general state of the structures and benches as well as the expertise of the maintenance team in assembling and handling bearings, shafts and housings.

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