CONDITION MONITORING OF PARR-1 ROTATING MACHINES BY VIBRATION ANALYSIS TECHNIQUE

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Vibration analysis is a key tool for preventive maintenance involving the trending and analysis of machinery performance parameters to detect and identify developing problems before failure and extensive damage can occur. A lab-based experimental setup has been established for obtaining fault-free and fault condition data. After this analysis, primary and secondary motor and pump vibration data of the Pakistan Research Reactor-1 were obtained and analyzed. Vibration signatures were acquired in horizontal, vertical, and axial directions. The 48 vibration signatures have been analyzed to assess the operational status of motors and pumps. The vibration spectrum has been recorded for a 2000 Hz frequency span with a 3200 lines resolution. The data collected should be helpful in future Pakistan Research Reactor-1 condition monitoring.

Key words: vibration analysis, fault diagnostics, fast Fourier transform, condition monitoring

INTRODUCTION

Online detection and diagnosis of problems in rotating machines through vibration analysis is obviously the most desirable way of rotating machinery maintenance [1-4]. If problems were to be detected early on, while the defects are minor and do not affect performance and, if the nature of the problem was to be identified while the machine was still operative, this could result in many benefits, such as a convenient shutdown schedule, reduced machinery downtime and prevention of extensive damage, savings in time and money, *etc.*

Numerous vibration techniques have been applied to fault diagnosis of rotating machinery. In the 1980's, Mathew and Alfredson [5] presented a review of vibration monitoring techniques in time and frequency domains for rolling element bearings. McFadden and Smith [4] and Kim [6] included classical non-parametric spectral analysis, principal component analysis, joint time-frequency analysis, the discrete wavelet transform, and a change detection algorithm based on residual generation. Lebold and McClintic [7] reviewed statistical methods for extracting vibration features for diagnosing gearboxes. Tandon and Choudhury [8] reviewed vibration and acoustic measurement techniques for the detection of defects in rolling element bearings. Chow [3] provided a brief review of model-based approaches and signal processing approaches in motor fault detection and diagnosis. Tandon [8] also showed that the probability density function is correlated with bearing defects. Mathew and Alfred [9] reported obtaining a near-Gaussian distribution for some damaged bearings. Andrade [10] proposed a comparison of the cumulative density function (CDF) of a target distribution with the CDF of a reference distribution and used the likelihood to successfully detect gear tooth fatigue crack. The root mean square (RMS) value and crest factor have been applied in diagnosing bearings and gears [9, 11]. The fast fourier transform (FFT) [12, 13] is the most conventional diagnosis technique and the technique used here for analyzing PARR-1 vibration data has been widely used to identify the frequency features of signals.

In this paper, first the results are taken and analyzed from a lab-based experimental setup so as to gain better insight into rotating machine faults. For this purpose, different faults are introduced into the lab-based setup and the spectrum is analyzed for gaining insight on PARR-1 data. After this exercise, PARR-1 vibration data is taken over a 2000 Hz frequency span and 3200 lines of resolution, for primary and secondary motors and pumps. Vibration signatures are compared with this standard for assuring PARR-1 rotating machines condition monitoring.

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LAB-BASED EXPERIMENTAL SETUP

A lab-based setup has been established to demonstrate some of the most commonly found faults in rotating machinery. First of all, no faults other than mechanical looseness, unbalance, and misalignment have been introduced into the setup. After this, an analysis of the actual spectrum of PA RR-1 rotating machines is done.

Mechanical looseness

Mechanical looseness can be categorized as structural looseness such as mounting base and rotating element looseness. Mounting base looseness will result in relative motion between the machine foot and base plate. This fault is simulated with a motor speed of 1500 rpm* which is equivalent to a fundamental frequency of 25 Hz. The harmonics of running speed frequency of 25 Hz is dominant in a faulty system. This signature characteristic corresponds to mechanical looseness.

Vibration due to unbalance

The unbalance of rotating machine components is, perhaps, the easiest problem to pinout with confidence. Simple unbalance, uncomplicated by other problems, can be readily identified by the vibration occuring at a frequency of 1XRPM of the unbalanced component. The presence of multiple frequencies (*i. e*., 2x, 3x, 4x, times rpm) usually indicates additional problems such as looseness, rubbing, *etc*. The unbalance was created by attaching a load to the motor shaft.

*rpm means revolutions per minute

Vibration due to misalignment

Misalignment is another of the common faults of rotating machinery. It is the result of incorrect machine alignment. Vibrational frequencies due to misalignment are usually 1x, 2x, and 3x rpm and may appear in any combination, depending on the type and extent of misalignment.

VIBRATION ANALYSIS RESULTS

A rational approach to successful and effective condition monitoring is that of trending the overall value measurements of machine condition over time and, compared with appropriate warning and alarm thresholds, rating these values as “good”, “satisfactory”, “unsatisfactory”, and “unacceptable”. In the case of excessive vibration, the root cause could be made clear by checking frequency peaks in the FFT vibration spectrum. The same technique has also been employed in our study where the spectra were collected for 48 predefined points, in accordance with ISO-10816-1. The measured values were then compared with their limits, in accordance with prescribed standards.

Vibration data was taken for primary motors A & B, secondary motors A & B, primary pumps A & B, and secondary pumps A & B. Detailed primary motor and primary pump A data is given in tab. 1. The data was taken for motor outboard horizontal, vertical, and axial locations and, similarly, motor inboard horizontal, vertical, and axial locations. In the case of primary pump A, overall vibration frequency falls into the good category of the ISO standard; primary pump B and secondary pump B overall vibration frequencies

Table 1. Vibrations of primary motor/pump – A rpm 1473 (24.6 Hz)

No.	Description	Vibration plane	Vibration velocity		Peak frequency [Hz]	Comments	Machine condition compared by ISO 10816-1
			Overall velocity [mms^{-1}]	Max velocity [mms^{-1}]			
1	Motor out board	Horizontal	0.927	0.5493	1440.63	Bearing frequency	Good
2	Motor out board	Vertical	0.580	0.2863	1441.25	Bearing frequency	Good
3	Motor out board	Axial	0.700	0.4298	343.75	Bearing frequency	Good
4	Motor in board	Horizontal	0.544	0.21	148	Impeller vane frequency	Good
5	Motor in board	Vertical	0.673	0.3529	1432.50	Bearing frequency	Good
6	Motor in board	Axial	0.452	0.1548	1433.13	Bearing frequency	Good
7	Pump in board	Horizontal	0.627	0.4587	148.13	Impeller vane frequency	Good
8	Pump in board	Vertical	0.907	0.6744	147.50	Impeller vane frequency	Good
9	Pump in board	Axial	1.090	0.6424	24.38	Unbalance	Good
10	Pump out board	Horizontal	0.677	0.6095	148.13	Impeller vane frequency	Good
11	Pump out board	Vertical	0.575	0.5598	148.13	Impeller vane frequency	Good
12	Pump out board	Axial	1.086	0.5931	24.38	Unbalance	Good

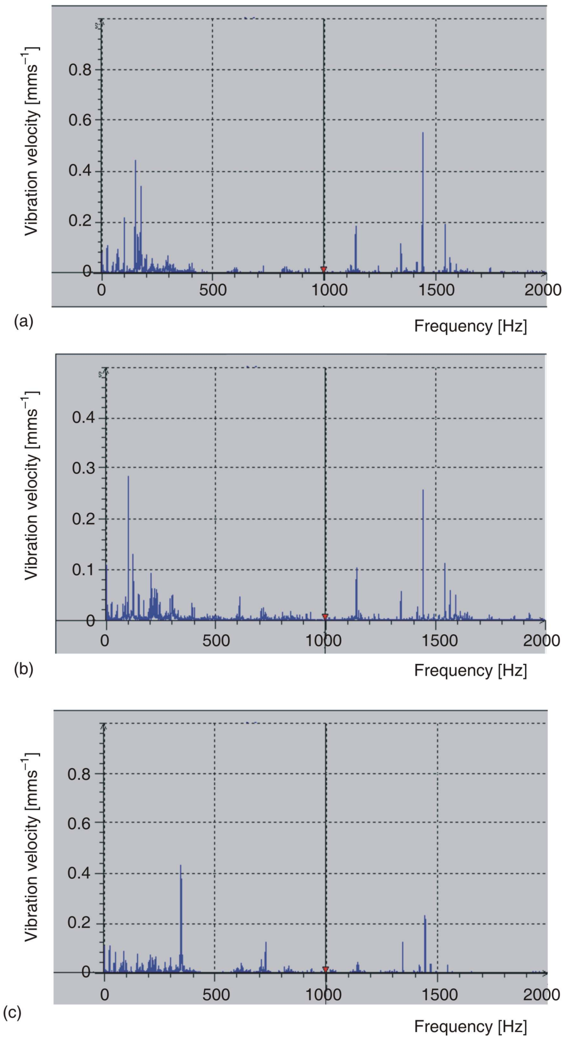

Figure 1. Primary motor A outboard spectra
Vibration plane: horizontal (a), vertical (b), and axial (c)

appear in certain areas of good and satisfactory. Secondary pump A overall vibration frequencies all lie in the satisfactory region, therefore continuous monitoring is required for this pump.

In fig. 1, only results for the primary motor A outboard are shown. From the graphs, it can also be concluded that the overall vibration remains within prescribed limits, but that in some cases routine check-ups are necessary.

CONCLUSION

Vibration data for primary and secondary PARR-1 motors and pumps have been generated with the help of a most recent handheld vibration monitoring system. The data has been generated for vertical, horizontal and axial positions and a total of 48 measurements were recorded. The data was analyzed using faulty data to characterize PARR-1 rotating machines. The data obtained will remain helpful throughout the life of the motors and pumps studied and will be helpful in future installations of new motors/pumps.

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МОНИТОРИНГ СТАЊА РОТАЦИОНИХ МАШИНА PARR-1 РЕАКТОРА ПОСТУПКОМ ВИБРАЦИОНЕ АНАЛИЗЕ

Вибрациона анализа је кључно средство за превентивно одржавање, које укључује анализу перформанси машина како би се детектовали и идентификовали потенцијални кварови пре него што дође до отказа у раду и могућег настанка великих оштећења. У том циљу, постављен је експериментални лабораторијски уређај за прикупљање података о стањима без грешке и стањима са грешком. Подаци су прикупљани и анализирани за примарни и секундарни мотор као и за пумпе Пакистанског истраживачког реактора PARR-1, у хоризонталном, вертикалном и аксијалном правцу. Анализирано је 48 вибрационих записа како би се проценило операционо стање мотора и пумпи. Вибрациони спектар снимљен је за фреквенцију од 2000 Hz при резолуцији од 3200 линија. Ови подаци биће корисни у одржавању PARR-1 реактора.

Кључне речи: вибрациона анализа, дијагностика квара, Фуријеова трансформација, мониторинг стања