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Establishing a Diagnostic Technique for Identification of a Problematic Foundation

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Abstract: **— Diagnosis of a vibration problem when the machine has been assembled completely is often tedious. In fact there are several rotating components in a motor assembly which may be responsible for high amplitude of vibrations. In addition, any static component can also generate vibrations. When a rotating machine exhibit large vibrations, often the doubt goes to moving components or the bearings. Efforts are carried out to identify a problem in one of these components, but sometimes it may so happen that no fault is identified in rotating parts or bearings and still the vibrations become uncontrollable. This is exactly what happened in a motor in a Nuclear Power Station having 2 machines each of 236 MW rating. In place dynamic balancing was carried out but it did not help. Frequency analysis revealed some looseness in nuts and bolts but controlling them also could not reduce the vibrations. Ultimately, the recently developed technique of phase measurement and analysis was applied and the problem was diagnosed to be that of faulty foundation system. Appropriate corrections were then made and vibrations were brought down to permissible limits. This paper presents the methodology used in establishing the technique for identification of a problematic foundation, which can be used in case of motors, turbines, generators and alternators etc.**

Key words**:-- In place dynamic balancing, 1X and 2X components, unbalance, looseness, phase measurement, DE and NDE bearings, Spectrum.**

I. INTRODUCTION

It is often not the machine itself or the rotating components which causes high vibrations but sometimes the foundation can transmit and multiply the vibrations of the other machine components. Large amplitudes of vibrations were observed on a 1000 RPM, 1500 kW motor in a 236 MW Nuclear Power Plant. To establish the cause of this problem, frequency analysis of vibration amplitude was carried out using an analyzer. It was observed that 1X and 2X components were present in the spectrum. 1X component was comparatively high. Due to 2X component, investigations were made to confirm the presence of mechanical looseness but it could not be established.

In place dynamic balancing was then carried out but no substantial improvement was possible. As such, special investigations were necessitated. To establish the integrity of different parts of the foundation system, a newly developed technique known as phase analysis was applied. With this experimentation it was possible to diagnose a problem of poor machining in some components of the foundation. Necessary corrections were therefore made by improving the condition of machining and vibrations were controlled. The technique so established can easily be used in cases of all other types of rotating machines.

II. EXPERIMENTS FOR DIAGNOSIS:

2.1: The motor was run uncoupled at rated speed of 1000 RPM. The overall amplitude on DE bearing was 189 microns p-p. The frequency analysis revealed that 1XRPM component was 140 and 2X RPM component was 78 microns p-p.

2.2: Although 1XRPM component was highest which indicates the presence of high unbalance forces, it was decided to investigate the looseness first as 2XRPM component was also present. However all nuts and bolts were found in reasonably good condition indicating absence of looseness.

2.3: In-situ dynamic balancing was then carried out to control the 1XRPM component. However, there was not much response and even after best possible balancing, no improvement below 144 microns p-p was possible.

2.4: Since unbalance and looseness were ruled out, the doubt was now on machine foundation system. It was felt that the frequency analysis cannot spot problems

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of foundation as the foundation system is quite complex. The study was therefore made about the foundation.

It was observed that the foundation system is built-up from the assembly of different structures which are matched with one another. In order to provide strong support to the motor, the complete structure should vibrate together in phase if matching of components is satisfactory. This means that:

a) Vibration amplitude should be lowest at the bottom or base and should increase as the height is increased on the motor, and,
b) Phase angle should remain same in vertical directions at all locations of different heights.

To prove points a) and b), it was decided to carry out Phase Analysis. For this purpose, special equipment which can measure amplitude, frequency and phase was required. Bentley Nevada, USA make Digital Vector Filter 3 Analyzer was used for doing this test.

2.5: Points A, B, C, D, and E were selected at various heights of the motor from top of the drive end bearing to bottom most point of the frame. Measurements were taken in vertical direction. Amplitude of vibration and corresponding phase were measured at all the selected locations. Observations can be viewed on Fig. 1.

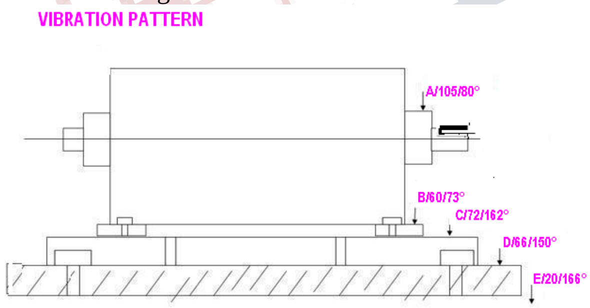

Fig. 1: Vibration & Phase Measurements before Making Corrections

It was observed that between the motor feet and base frame the readings are not consistent. At location B, the amplitude is 60 microns and phase is 73°. At location C, the amplitude should decrease and phase should remain same. But, the amplitude has increased to 72 microns and phase is 162° (changed by 109°). Refer Fig. 4.19. This particular type of behavior is not normal.

2.6: Investigations were made to pin point the cause of such behavior. The foundation was dismantled for making visual observations. It was observed that the motor feet were left un-machined. Also, the shims put between the motor feet and base frame were not proper. Many shims were placed one over another and a thickness of 0.12 mm was built-up.

2.7: For making improvements, the machine was dismantled, motor feet were machined and shimming was improved by placing only one plate of the required thickness. The machine was reassembled and run for observations.

2.8: The motor was run at rated speed of 1000 RPM and observations were taken. Refer Fig. 2 and Table 1 for observations. It can be observed that the 2X RPM component was fully eliminated. Only 1X RPM component was present.

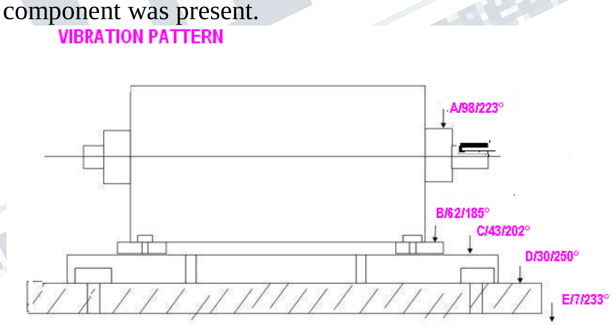

Fig. 2: Vibration & Phase Measurements after making corrections

2.9: The 1X component was easily balanced by placing 220 grams of weight on DE side fan and the vibrations were brought down to permissible levels.

III. RESULTS AND ANALYSIS:

3.1 Initially, the machine was run uncoupled at 1000 RPM (operating speed) and measurements were taken. DE Bearing vibrations were quite high compared to NDE Bearing. As such analysis was done on DE bearing. Mechanical looseness was checked and in-situ

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balancing was carried out. Observations are presented in Table 1 below:

Table 1: Vibration levels in Microns P-P of DE Bearing

Condition	Overall	1X	2X
Initial Run	189	140	78
After Balancing	144	105	62

3.2 As vibration amplitude could not reduce substantially after correcting unbalance and looseness, the checks were made on foundation. The phase measurements were taken which helped in identifying the problem area. Observations are presented in Fig. 1, Fig. 2 and Table 2.

3.3 Motor feet were found in un-machined or poorly machined condition. The feet were, therefore, machined and other improvements in foundation system were made. The vibrations reduced and only 1X component was now left. This was reduced by in-situ balancing. Results can be observed in Table 2.

Table 2: Vibration Levels in Microns P-P / Phase angle degrees, on DE side.

Condition	Location / Height (cm.)				
	A / 110	B / 35	C / 30	D / 20	E / 0
Initial Run	105/80°	60/73°	72/162°	66/150°	20/166°
After machining of feet & proper shimming	98/223°	62/185	43/202	30/250	7/233°
After final balancing	28/222°	12/221	10/212°	6/232°	2/233°

3.4 Variation of vibration levels in microns P-P with respect to height during initial and final runs is presented in Fig. 3 & Fig. 4.

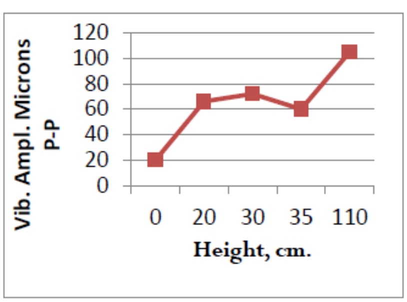

Fig.3*: Variation of Vibration with Height during Initial run*

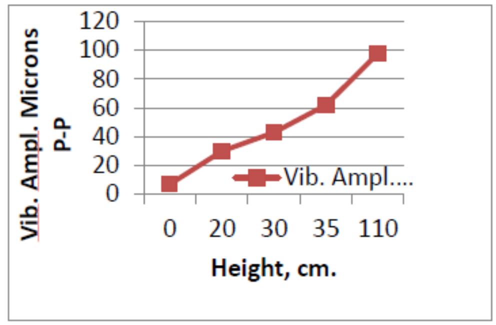

Fig.4: Variation of Vibration Amplitude after Final Corrections

It can be observed from these diagrams that the pattern of vibration from bottom to top was not as desired during initial run. However, after proper machining of the foundation this pattern has improved.

3.5 Variation of phase angles in degrees with respect to height during initial and final runs is presented in Fig. 5 and Fig. 6. It can be observed from these diagrams that the pattern of phase angles from bottom to top was not as desired during initial run. However, after improving foundation by machining etc. this pattern has improved.

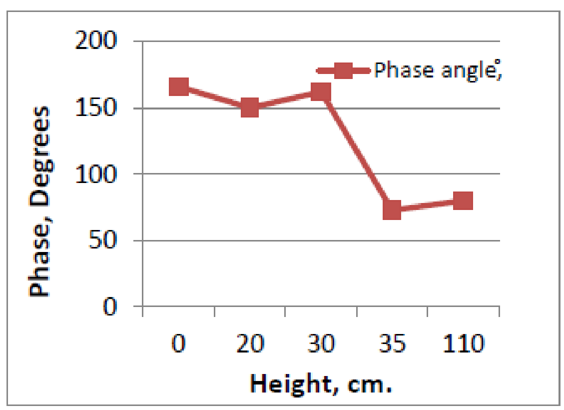

Fig. 5: Variation of Phase Angle with Height during Initial Run

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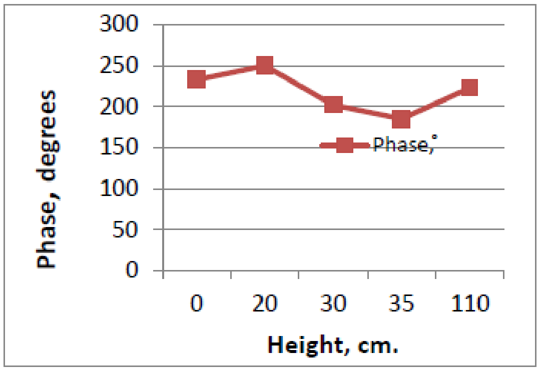

Fig. 6: Variation of Phase Angle with Height after Final Corrections

3.6 Vibration amplitude and phase angles at various heights under different operating conditions are shown in Fig. 7 and Fig. 8 respectively. It can be observed that there is improvement in trend after correcting foundation and conducting final balancing**.**

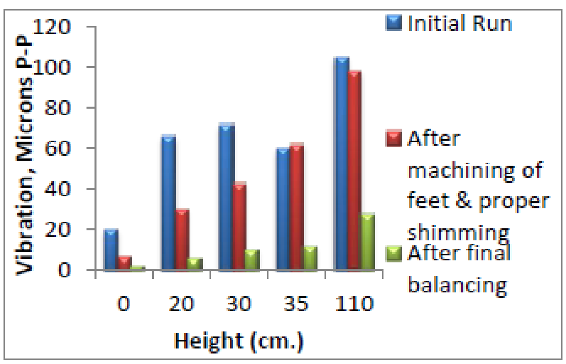

Fig. 7: Vibration Amplitude at Various Heights under Different Operating conditions

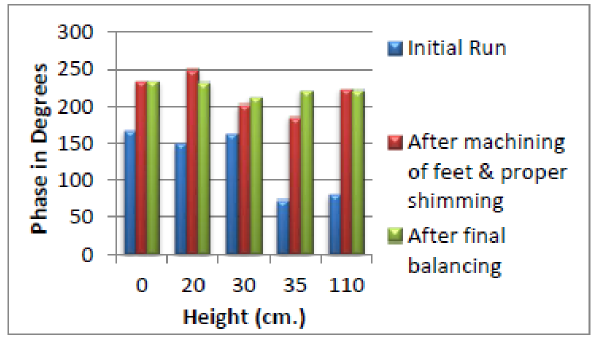

Fig 8: Phase Angles at Various Heights under Different Operating Conditions

IV. CONCLUSION

When simple frequency analysis does not help to identify the problem area in a motor foundation structure, other advance technologies are required for diagnosis. Phase Measurement and analysis technique has worked in this case to exactly detect the part causing the problem. Rather than measuring vibrations and phase angles on bearings, different locations in vertical directions were selected. Proper analysis of results obtained has given enough data for resolving the problem. The vibration levels achieved as a result of corrections necessitated by phase analysis is quite satisfactory for a 1000 RPM machine and meets all major international standards and norms.

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