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Condition monitoring and fault diagnosis of a boiler feed pump unit

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Present work highlights an experimental investigation to monitor vibration condition of boiler feed pump (BFP) unit, which is a part of BFP train of a large utility thermal power plant. BFP is supported by 2 bearings. Tri-axial measurements were made at bearing supports for 12 months. Displacement and velocity were measured along horizontal, vertical and axial directions. Based on signature analysis, causes for excessive vibrations were diagnosed. Remedial measures were applied to ensure safer and fault free operation of BFP unit.

Keywords: Boiler feed pump, Condition monitoring, Signature analysis

Introduction

Successful implementation of a condition monitoring programme allows machine to operate without halt[1-5]. Maintenance management based on operating condition of equipment or condition based maintenance (CBM) includes detection of developing failure conditions at an early stage, diagnosis of causes of developing failure conditions and carryout remedial measures for safer operation. As part of CBM, methods that have been developed to assess health of equipment or system include monitoring of vibration & noise, temperature, oil, leakage, crack, stress, performance etc[6,7]. Of all these, vibration level measurements and signature analysis are most commonly used methods for monitoring health of a machine. By comparing machine signals in normal and faulty conditions, detection of faults like unbalance, rotor rub, shaft misalignment, gear failures and bearing defects can be defected[8-11].

Boiler Feed Pump (BFP)

BFP (Fig. 1), a centrifugal pump with barrel casing design, is used to pump water at high pressure to boiler placed at a high altitude. Pressurizing of water is incrementally done from 7.5 kg/cm^2 to 17.5 kg/cm^2 in booster pump and from 17.5 kg/cm^2 to 180 kg/cm^2 at BFP. Present work deals with diagnostic studies of BFP shaft supported by 2 bearings.

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Experimental

Single channel vibrometer (frequency, 0.18-75.3 Hz) measured displacement and velocity on monthly intervals for one year. Instrument is mounted on 4 bearing supports along horizontal (H), vertical (V) and axial (A) directions; A being in line with axis of pump shaft.

Modeling of Pump Shaft

BFP shaft was modeled as an equivalent shaft (length 1705 mm, diam 91.807 mm) and then descritised by 3-D beam element. Boundary conditions were applied at bearing supports. First 10 natural frequencies were computed using Subspace iteration and Lanczo's methods[12-15]. Frequencies obtained from Rayleigh-Ritz equation are well above calculated values. Reference values of displacement and acceleration were calculated at each natural frequency corresponding to a velocity of 8.13 mm/s as per ISO 2372, which ensures trouble free operation of shaft (Table 1).

Results and Discussion

Triaxial measurement of displacement, velocity and acceleration were recorded every month at two bearing supports (Tables 2 and 3). Looking into velocity history at Bearing 9 (Fig. 2a), vibrations are observed well within

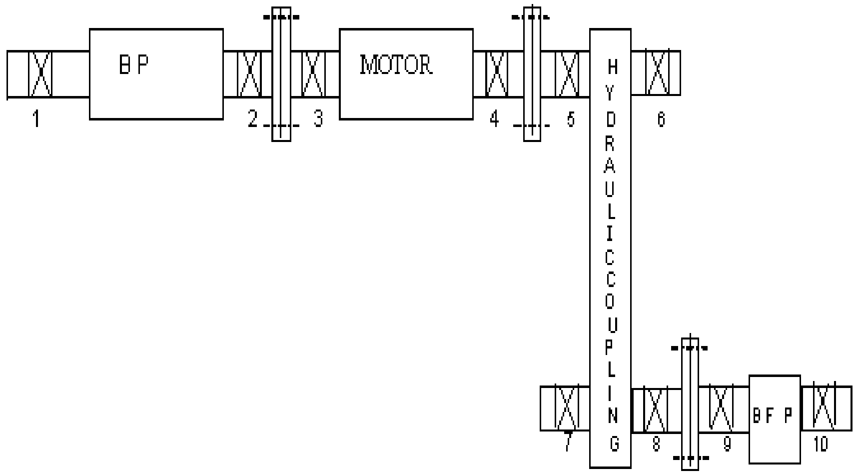


Fig. 1—Line diagram of BFP train [1) Booster pump non-driving end (BPNDE), 2) Booster pump driving end (BPDE), 3) Motor booster pump end (MBPE), 4) Motor main pump end (MMPE), 5) Input shaft driving end (IPSDE), 6) Input shaft non-driving end (IPSNDE), 7) Output shaft motor end (OPSME), 8) Output shaft pump end (OPSPE), 9) Boiler feed pump shaft drive end (BFPDE), and 10) Boiler feed pump shaft non-drive end (BFPNDE)]

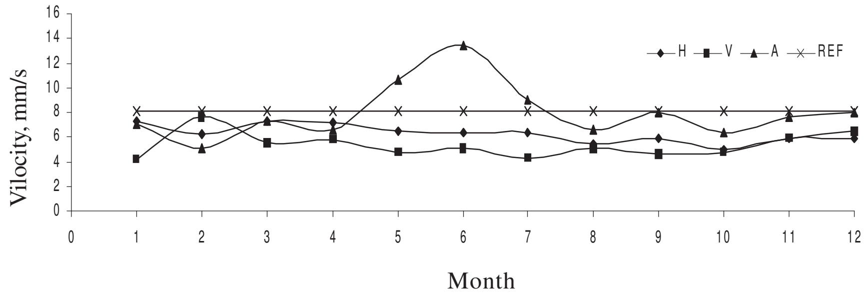
Table 1-Reference values of displacement and acceleration

Natural frequency	Frequency Hz	Displacement μm	Acceleration m/s^2
1	27.71	43.78	1.33
2	110.57	10.97	5.29
3	247.79	4.90	11.86
4	438.32	2.77	20.98
5	681.12	1.78	32.59
6	975.55	1.24	46.68
7	1322.0	0.92	63.26
8	1720.0	0.71	82.31
9	2170.0	0.56	103.84
10	2833.0	0.43	135.57

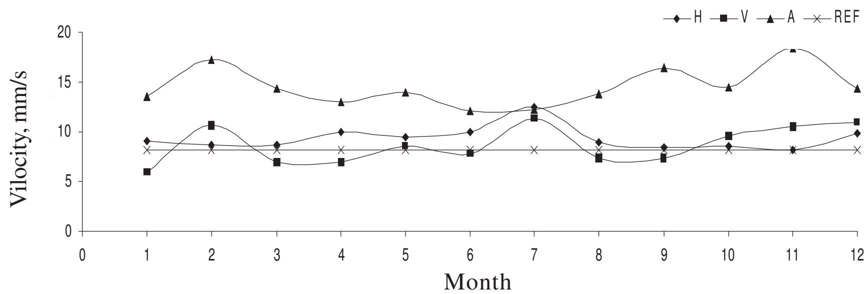
the limit till May. During May to July, velocity exceeded limit along direction A, whereas H and V direction measurements were well within the limits. Fault has been identified as soft footing and base frame found distorted. Realignment of frame reduced velocity intensities during remaining period of investigation. Looking into velocity history at bearing 10 (Fig. 2b), velocity intensity exceeded limiting value during January along A and H directions respectively. For February, July, October, November and December, velocities exceeded in all three directions. During August and September, a similar trend as that of March and April was observed. At bearing 10, footing was found improper and soft and rotor bent. Reference values computed for trouble free velocity of displacement

Table 2 — Tri axial measurements at bearing-9

Month	Displacement μm			Velocity mm/s			Acceleration m/s^2		
	H	V	A	H	V	A	H	V	A
Jan	24.1	11.2	7.6	7.33	4.15	7.13	2.23	1.54	6.69
Feb	14.1	17.3	12.5	6.29	7.65	5.11	2.81	3.38	2.09
Mar	26.2	14.1	9.26	7.32	5.59	7.28	2.05	2.22	5.72
Apr	23.3	13.1	9.02	7.19	5.77	6.57	2.22	2.54	4.79
May	20.6	11.6	12.6	6.51	4.79	10.7	2.06	1.98	9.09
Jun	21.9	12.1	14.3	6.33	5.08	13.4	1.83	2.13	12.56
Jul	20	12.3	17.2	6.39	4.29	9.01	2.04	1.50	4.72
Aug	17.6	16	16.2	5.49	5.1	6.61	1.71	1.63	2.70
Sept	19	13.4	10.7	5.87	4.58	7.96	1.81	1.57	5.92
Oct	9.86	16.3	14.6	4.99	4.79	6.42	2.53	1.41	2.82
Nov	13	17.3	16.7	5.96	5.94	7.63	2.73	2.04	3.49
Dec	13.3	18.8	15.6	5.96	6.45	7.95	2.67	2.21	4.05

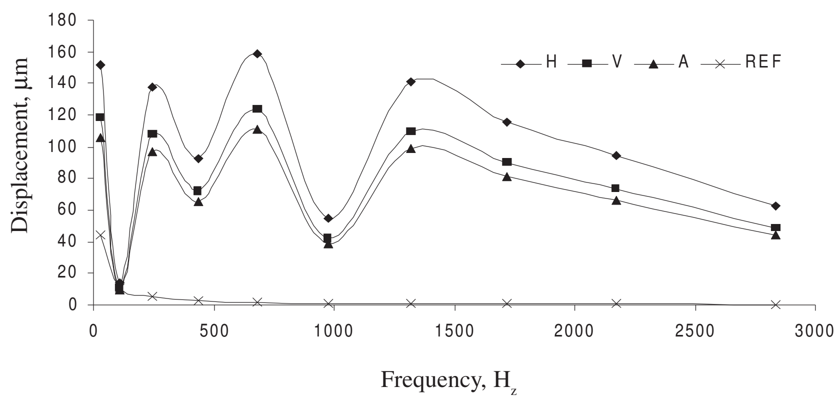


a)



b)

Fig. 2—Velocity history at: a) bearing-9; b) bearing-10



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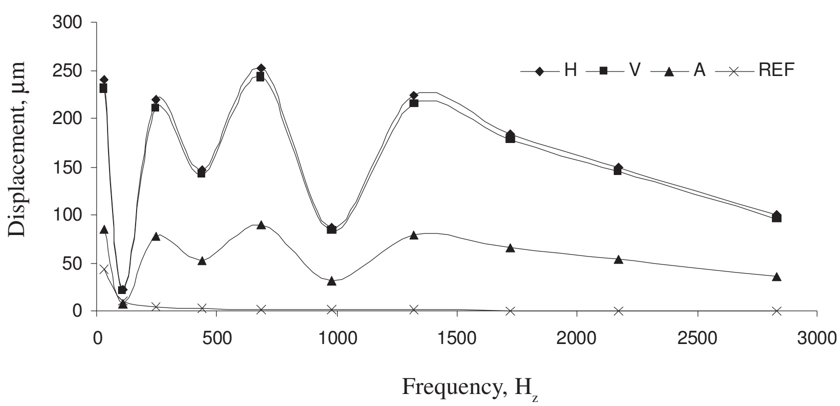
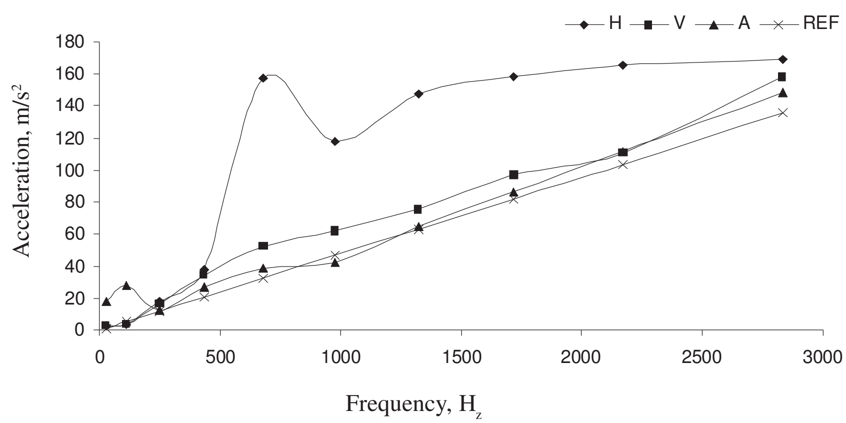


b)

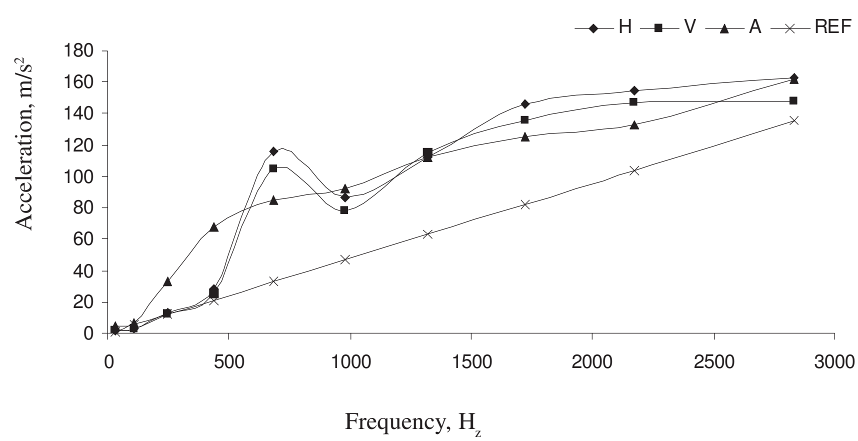
Fig. 3—Displacement signature at: a) bearing-9; b) bearing-10

Table 3-Tri axial measurements at bearing-10

Month	Displacement µm			Velocity mm/s			Acceleration m/s^2		
	H	V	A	H	V	A	H	V	A
Jan	25.8	19.5	7.44	9.07	5.95	13.6	3.19	1.82	24.86
Feb	22.4	24.9	9.13	8.66	10.6	17.2	3.35	4.51	32.40
Mar	29.3	18.6	8.42	8.66	6.98	14.3	2.56	2.62	24.29
Apr	27.6	24.6	7.94	9.98	6.91	13	3.61	1.94	21.28
May	26.3	21.7	8.12	9.52	8.56	13.9	3.45	3.38	23.79
Jun	38.6	19.4	8.62	10	7.71	12.1	2.59	3.06	16.98
Jul	40.9		13.9	12.5	11.3	12.2	3.82	2.74	10.71
Aug	30	26.4	12.6	8.91	7.4	13.8	2.65	2.07	15.11
Sept	28.5	25.4	9.06	8.36	7.41	16.5	2.45	2.16	30.05
Oct	22.2	37.1	15.2	8.6	9.61	14.5	3.33	2.49	13.83
Nov	26.4	34.6	13.1	8.22	10.5	18.4	2.56	3.19	25.84
Dec	35.5	41.7	12.2	9.84	10.9	14.3	2.73	2.85	16.76



a)



b)

Fig. 4—Acceleration signature at: a) bearing-9; b) bearing-10

(Fig. 3) and acceleration (Fig. 4) show that at lower modes of frequencies, displacement and accelerations are well within the limits.

Conclusions

Condition monitoring for BFP of a large utility thermal power plant was carried out by vibration measurements and signature analysis to ensure safer operation of the unit. Causes for excessive vibrations at specified locations (9 and 10 bearing) were identified in form of soft footing and bent rotor during periodic monitoring. Remedial measures taken were realignment of frame and replacement of existing footing structure with new one.

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