Condition Monitoring of Vertical Auxiliary Cooling Water (ACW) Pump at Thermal Power Plant

Harsh Kumar Dixit[1]
Department of Mechanical Engineering
Malaviya National Institute of Technology, Jaipur
tcgupta.mech@mnit.ac.in

T.C Gupta[2]
Department of Mechanical Engineering
Malaviya National Institute of Technology, Jaipur
2014rme9552@mnit.ac.in

***Abstract*— Condition monitoring of vertical pump rotor can not only reduce expenses of maintenance of auxiliaries of power plants but also prevents likely shutdown of plant, thereby increases plant efficiencies. Rotor displacements and velocities are essential part of vibration analysis because they are having much influence on pump shaft vibration and also governing systems are available to minimize them before dangerous situation occurs. This paper includes analysis of vertical auxiliary cooling water pump (ACWP) and diagnosis of failure before such situation occurs. Influence of displacements and velocities on vertical pump rotor vibration have also analyzed.**

***Index Terms*— ACW Pumps, Condition Monitoring, Vertical Rotors, Power Plant**

I. Introduction

Now a days vibration monitoring is often use for rotor diagnostics due to their long lasting effects and precise measurements. On a horizontal rotor the weight is often sufficient to create a well-defined force on the bearings and the dynamic behavior is linear but in a high speed vertical machine the radial bearing load is low and there is more risk of lubricant film instability [4]. When the load is low, the bearing force on the rotor will often show a non-linear behavior. The non-linear behavior can give large relative motion between the rotor shaft and the bearing. However, the forces that generate the response are often small and defining absolute vibration limits in such cases can be difficult in the case of big vertical pumps. Vertical pumps are used mainly as water supply pumps at power plants in preference to horizontal pumps because of the spatial limitations. The general shape of a vertical pump consists of a long column with a large mass at each end [5]. Vertical pumps are particularly susceptible to a resonance condition created by the coincidence of the operating rpm with the Natural Reed Frequency (NRF) of the pump structure. Excessive resonant induced vibration occurs in a vertical pump when the natural frequency of the pump discharge head and vertical driver are the same as the speed of the pump and drive. The foundations on which the vertical pump is mounted do require consideration. As a rule, it is advisable to provide a foundation that represents less than 5% of the total deflection of the structural elements of the pump/drive. Typically a reinforced concrete foundation will comply with these criteria. If a pump assembly suspended on a long column or a high column above the floor with a heavy motor in the top shows vibration in service, this is quite a problem. Considerable mass forces are involved and the vibration can result in damage to the pumps or to the foundation. To correct the situation in the field is difficult [1]. The most frequent sources of disturbing forces that cause vibrations of vertical pumps are unbalance of the rotating parts, External vibrations transmitted by the foundation or by the pipeline, bearing vibrations and pressure pulsations. Each disturbing force can develop vibrations in every part of the pumps but generally the vibrations become excessive only if any of the disturbing Frequencies coincide with or are close to the natural frequency of a part of the pump. In this paper vibrational behavior of vertical auxiliary cooling water (ACW) pump have analyzed. Measurements (Displacements, Velocities) have taken at non-driving end (NDE), driving end (DE) and pump bearing (PB). The objective was to determine vibrational pattern of vertical pump rotor and to find most unstable region of the vertical pump shaft.

II. OBSERVATIONS & ANALYSIS

The observations are related to measurement of displacements and velocities at non-driving end (NDE), driving end (DE) and pump bearing (PB) of auxiliary cooling water pump (ACWP) at unit-6 at Kota Super Thermal Power Station (KSTPS). It has been observed that displacements and velocities were excessive at NDE as compare to DE and PB, because at bearings, due to lubrication and cooling, radial as well as axial displacements and velocities reduced considerably. It has also observed that during period of January 2013 to May 2016, many times maximum lateral displacement and velocities of vertical pump shaft was higher than its designated safe value of 50 microns and 4 mm/sec. To analyze this phenomenon, number of cases was taken into consideration. Displacements and velocities of vertical pump shaft were taken at radial and axial direction at NDE, DE and PB and analyze them in MATLAB™ to find interaction between radial and axial displacements and velocities at various positions in vertical pump rotor.

Fig.1.Vertical ACW pump at KSTPS (Unit-6)

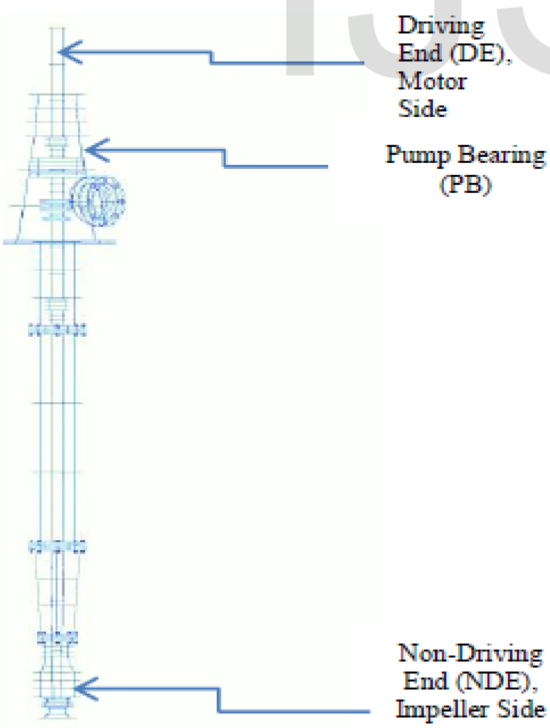
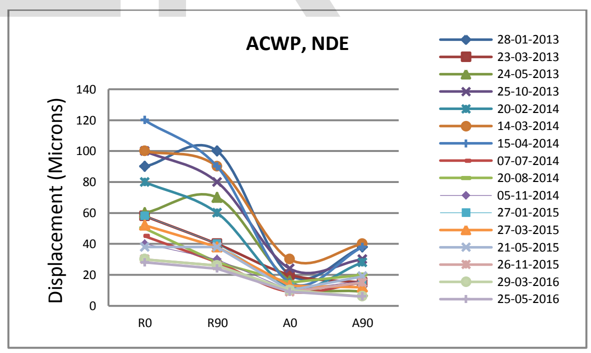


Fig.2.Measurement Locations at ACWP

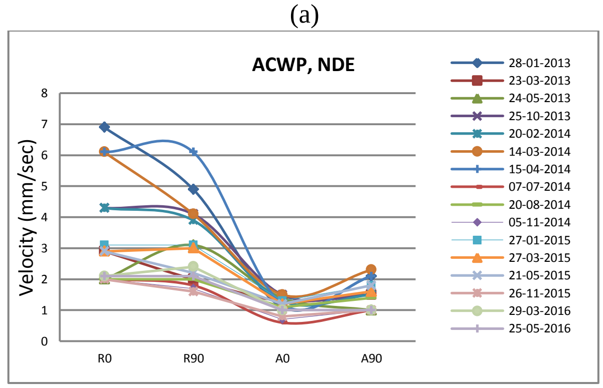
TABLE I
SPECIFICATIONS & THRESHOLD PARAMETERS

Type of Pump	Vertical Turbine and Self-Water Lubricating Pump
Manufacturer	Kirlosker Brothers (Pump) Crompton Graves (Motor)
Rated Capacity (m^3/hr.)	3000
Rated Speed of Pump Shaft (rpm)	940
Number of Stages	Single Stage
Pump Lubrication	Self-Water Lubrication
Size of Pump Column (mm)	Ø700
Size of Pump Discharge (mm)	Ø700
Impeller Diameter (mm)	Ø740
Impeller Shaft Diameter (mm)	Ø80
Motor Shaft Diameter (mm)	Ø125
Type of Shaft Coupling	Muff Coupling
Thrust Bearing Type	Mitchell Bearing
Coupling Between Pump and Motor	FlexiblePin-Bush Coupling
Total Weight of Driving motor (Kg)	6500
Number of Pumps	2 (1 Running, 1 Stand By)
Types of Sensor	Proximity Sensor
Location	Driving End, Non-Driving End, Pump Bearing Casing
Measuring Parameters	Displacement & Velocity
Maximum Permissible Displacement	50 microns
Maximum Permissible Velocity	4 mm/sec
Motor Horse Power (KW)	635

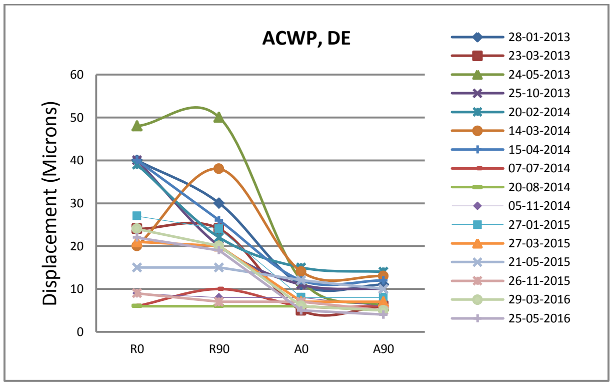
III. RESULTS



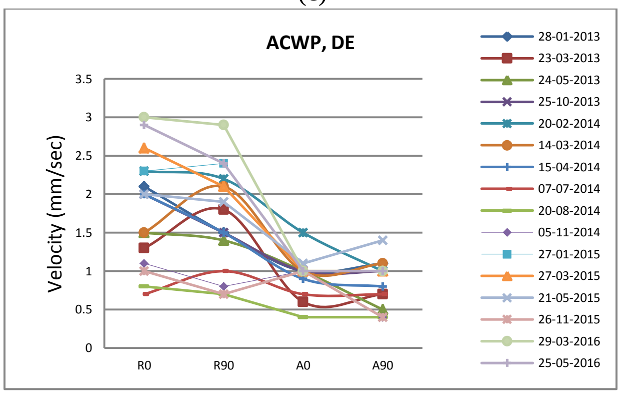
(a)



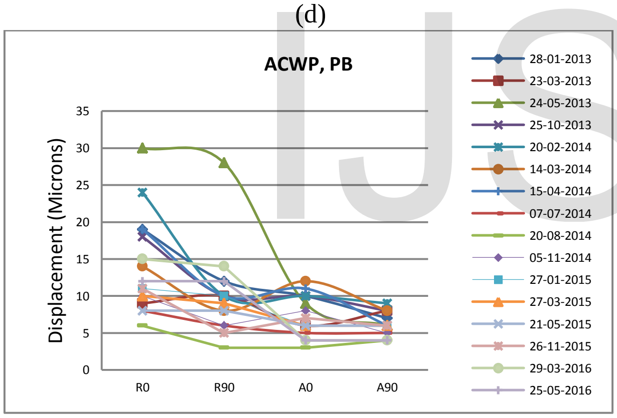
(b)



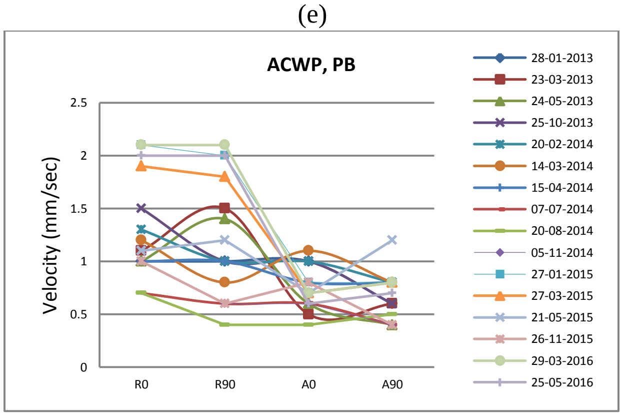
(c)



(d)



(e)



(f)

Fig.3. (a) Radial and Axial Displacements at NDE, (b) Radial and Axial Velocities at NDE, (c) Radial and Axial Displacements at DE, (d) Radial and Axial Velocities at DE, (e) Radial and Axial Displacements at PB, (f) Radial and Axial Displacements at PB

IV. SUMMARY & CONCLUSIONS

TABLE II

DISPLACEMENTS AT VARIOUS POSITIONS OF VERTICAL SHAFT CORRESPONDING TO MAXIMUM DISPLACEMENT (MICRONS)

DATE	BEARING LOCA.	MEAS. DIRECT.	MEAS. LOCA.	DISP
15/04/14	NDE	RADIAL	0º	**120***
			90º	90*
		AXIAL	0º	15
			90º	38
	DE	RADIAL	0º	14
			90º	26
		AXIAL	0º	12
			90º	12
	PB	RADIAL	0º	19
			90º	10
		AXIAL	0º	11
			90º	6
14/03/2014	NDE	RADIAL	0º	**100***
			90º	90*
		AXIAL	0º	30
			90º	40
	DE	RADIAL	0º	20
			90º	38
		AXIAL	0º	14
			90º	13
	PB	RADIAL	0º	14
			90º	8
		AXIAL	0º	12
			90º	8
25/10/2013	NDE	RADIAL	0º	**100***
			90º	80*
		AXIAL	0º	24
			90º	30
	DE	RADIAL	0º	40
			90º	26
		AXIAL	0º	10
			90º	10
	PB	RADIAL	0º	18
			90º	10
		AXIAL	0º	10
			90º	8
28/01/2013	NDE	RADIAL	0º	90*
			90º	**100***
		AXIAL	0º	20
			90º	38
	DE	RADIAL	0º	40
			90º	30
		AXIAL	0º	11
			90º	11
	PB	RADIAL	0º	19
			90º	12
		AXIAL	0º	10
			90º	7
24/05/2013	NDE	RADIAL	0º	60*
			90º	**70***
		AXIAL	0º	16
			90º	9
	DE	RADIAL	0º	48
			90º	50
		AXIAL	0º	12
			90º	6
	PB	RADIAL	0º	30

			90º	28
		AXIAL	0º	9
			90º	6

*Higher values than their permissible safe values. Bold font represents highest value at particular case.

TABLE III

DISPLACEMENTS AT VARIOUS POSITIONS OF VERTICAL SHAFT CORRESPONDING TO MAXIMUM VELOCITY (MM/SEC)

DATE	BEARING LOCA.	MEAS. DIRECT.	MEAS. LOCA.	VELO.
28/01/13	NDE	RADIAL	0º	**6.9***
			90º	4.9*
		AXIAL	0º	1.1
			90º	2.1
	DE	RADIAL	0º	2.1
			90º	1.5
		AXIAL	0º	1
			90º	1.1
	PB	RADIAL	0º	1
			90º	1
		AXIAL	0º	1
			90º	0.6
15/04/2014	NDE	RADIAL	0º	**6.1***
			90º	6.1*
		AXIAL	0º	1.2
			90º	2.1
	DE	RADIAL	0º	2
			90º	1.5
		AXIAL	0º	0.9
			90º	0.8
	PB	RADIAL	0º	1
			90º	1
		AXIAL	0º	0.8
			90º	0.8
14/03/2014	NDE	RADIAL	0º	**6.1***
			90º	4.1*
		AXIAL	0º	1.5
			90º	2.3
	DE	RADIAL	0º	1.5
			90º	2.1
		AXIAL	0º	1
			90º	1.1
	PB	RADIAL	0º	1.2
			90º	0.8
		AXIAL	0º	1.1
			90º	0.8
25/10/2013	NDE	RADIAL	0º	**4.3***
			90º	4.1*
		AXIAL	0º	1.5
			90º	1.5
	DE	RADIAL	0º	2
			90º	1.5
		AXIAL	0º	1
			90º	1
	PB	RADIAL	0º	1.5
			90º	1
		AXIAL	0º	1
			90º	0.6
24/05/2013	NDE	RADIAL	0º	2
			90º	**3.1**
		AXIAL	0º	1.4
			90º	1
	DE	RADIAL	0º	1.5
			90º	1.4
		AXIAL	0º	1
			90º	0.5
	PB	RADIAL	0º	1
			90º	1.4
		AXIAL	0º	0.6
			90º	0.4

*Higher values than their permissible safe values. Bold font represents highest value at particular case.

V. Conclusion

By observing all cases, following results has been concluded:

1. In auxiliary cooling water pump, maximum displacement and velocity of pump rotor is observed at NDE which validates the previous results [4]. Also in ACW pump, maximum displacement and velocity obtained along radial direction than axial direction.

2. The sequence of radial displacement of pump rotor is given by following sequence i.e. NDE Radial>DE Radial>NDE Axial>PB Radial>DE Axial>PB Axial. Hence it has concluded that vertical rotor of ACW pump is more unstable in NDE radial direction than other positions.

3. More often, displacements at 0 degree along radial direction is higher than 90 degree radial direction at NDE, while along axial direction displacement observed almost reverse. Along maximum displacement at 0 degree radial direction the axial displacement at 0 degree has found minimum. The same pattern is followed in velocity, also displacement and velocity at driving end (DE) and pump bearing (PB).

References

[1] Kovats, A. "Vibration of Vertical Pumps." (1962).

[2] McKendree, J. H., and L. A. March. "Vibration in vertical pumping systems." Transactions of the American Institute of Electrical Engineers. Part III: Power Apparatus and Systems 75.3 (1956): 1169-1177.

[3] Smith, Donald R., and Glenn M. Woodward. "Vibration Analysis of vertical pumps." Sound and Vibration 22.6 (1988): 24-30.

[4] White, Maurice F., Erik Torbergsen, and Victor A. Lumpkin. "Rotordynamic analysis of a vertical pump with tilting-pad journal bearings." Wear 207.1 (1997): 128-136.

[5] Lee, J. M., et al. "Vibration analysis of an idealized vertical pump model." Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science 219.2 (2005): 169-181.