Experimental Investigation of Vibrational Failures in Boiler Feed Pumps

S.Rajasekaran[1] **R.Sampath Kumar**[2] **R.Gurumani**[3]

[1]Senior Lecturer, Dept of Mech Engg., 3Prof & Head, Dept of Mech Engg

V.R.S.College of Engg. &Tech.,Arasur, Villupuram District, Tamil nadu

[2]Asst.Professor, Mailam Engineering College, Mailam. Tamil Nadu

E-mail: vsrs24@yahoo.co.in E-mail: ms_rajasekaran@yahoo.co.uk

Abstract:

The primary aim of the work is to report the major causes of boiler feed water pump failures that are found through vibration analysis. The strategy taken in this work is first, the vibration measurements of boiler feed pump are recorded and a database is assembled on pump failures and operational problems. Second this database is organized and vibration analysis is performed so that the major causes of failures are identified. And third, there causes are correlated for the purpose of isolating the design features and/ or operating parameter, primarily responsible for each of the failures categories. Finally the remedies, such as

(i) Checking the alignment of misaligned shaft,

(ii) Replacing the cartridges of main pump when unbalance exists,

(iii) Checking the bearings and lubrication oil supply etc., are suggested and the work is concluded.

This vibration analysis was done in Thermal power station-II at Neyveli Lignite Corporation, Neyveli. It has total capacity of 1440MW, which is having total 7 units of same capacity (210MW each). The first stage has 3 units and second stage has 4 units.

1.Introduction:

In thermal and nuclear power plant the boiler feed pump is one of the important machine, which is used to pump the feed water from the condenser to the boiler in water and steam circuit. The overall efficiency of the plant is depends on the operating condition and efficiency of boiler feed pump. The output of the plant is directly depends on the feed water pump. In most of the thermal & nuclear power plant they are using 2 BFP in operation and 1 BFP as standby. By using the vibration measurements and investigation the defects are found for the various ranges of vibration.

1.1 Thermal Cycle

The thermal cycle represents the feed water circulation, steam extractions; drain condensate flow etc., in a unit. The steam produced in the boiler drum is superheated in the super heater and passed to the High pressure (HP) turbine. The steam expands in the turbine and reheated in the reheater. The reheated steam is sent to the intermediate pressure (IP) turbine and then to low pressure (LP) turbine in which rotary motion is obtained which is given to the generator and hence power is produced. The expanded steam from the LP turbine is passed to the condenser where it is condensed using cooling water circulation. The condensate in the hot well of the condenser is pumped by the condensate extraction pump (CEP) up to the deaerator through ejector, gland steam condenser and LP heater where it is heated by extraction steam from the turbine. The deaerated feed water collected in the feed storage tank of deaerator is then pumped by boiler feed storage tank of deaerator is then pumped by boiler feed pump (BFP) to the boiler through HP heater and economizer. The whole process is repeated as before.The components involved in this thermal cycle are: Boiler, Turbine, Condenser, Boiler Feed pump, LP Heaters, HP Heaters, Water walls.

2. Boiler Feed Pump Description:

The FK 6D30 type boiler feed pump is a six stage horizontal centrifugal pump of the barrel casing design. The pump internals are designed as cartridge, which can be easily removed for maintenance without disturbing the suction and discharge piping work or the alignment of the pump and turbo coupling. The pump shaft is sealed at the drive end and non-drive end by mechanical seals, each seal being flushed by water in a closed circuit and is circulated by the action of the seal rotating ring. This flusing water is cooled by passing through a seal cooler, one per pump, which is circulated with dermineralised cooling water. The rotating assembly is supported by plain white metal lined journal bearing and axially located by the glacier double tilting pad thrust bearing. The various important parts of boiler feed pump are: Pump casing, discharge cover, Suction guide, Ring section assembly, Rotary assembly, Mechanical seals, Journal and thrust bearings, Bearings Housing, Flexible Coupling, etc.,

2.1 Feed Pump:

Boiler feed pump increases the pressure of the condensate leaving the condenser at a pressure of about 0.05ata and feeds it to boiler at high pressure of about 200ata. It is a six stage horizontal centrifugal pump of the barrel casing design. The flow rate of the pump is 420m^3/hr. It is driven by a squirrel cage induction motor of rating 4MW, through a hydro coupling arrangement.

2.1 Technical data of boiler feed pump:

Pump Type	:	FK 6D30
No. of stages	:	6
Direction of rotation viewed on drive end	:	Anti-clockwise
Square weight at suction temp. (Kg/m^3)	:	905
Liquid pumped	:	Boiler Feed Water
Suction Temperature (°c)	:	162.5
Differential Head (m)	:	2222
Design flow rate (m^3/hr)	:	420
Minimum recirculation flow (m^3/hr)	:	100
Efficiency (%)	:	81
Speed (RPM)	:	5300
Power (KW)	:	2840

3. Causes of Vibration:

With few exceptions, mechanical troubles in a machine cause vibration.

The following are the most common problems, which produce vibration.

- Unbalance of rotating parts
- Misalignment of couplings and bearings,
- Bend shafts,
- Bad bearings-antifriction type,
- Torque variations
- Electro magnetic forces
- Aerodynamic forces
- Hydraulic forces
- Looseness
- Rubbing
- Resonance

The cause of vibrations must be a force, which is changing in either its direction or its amount. The resulting characteristics will be determined by the manner in which the forces are generated.

4. Vibrometer:

To measure the vibration level in the various points of boiler feed pumps we are used the Vibrometer Sehench-25. The effective vibration velocity of all partial vibrations of a vibration mixture can be measured in three frequency ranges.

[a] Sum 10.....1000Hz-Standared measuring range for vibration severity
[b] Sum 3.....300Hz-Special measuring ranges
[c] Sum 3.....1000 Hz-Special measuring ranges

5. Vibration measurements & Readings:

The vibration measurements are recorded by using the vibrometer Schenck25 from the BFP of the first stage of TS-II is shown in the ***Table 1 & 2.*** Each unit of the power plant comprises of 3 pumps A, B & C in which one pump is kept as stand by and the other two are working. The readings are taken from 6 pumps. The measurements were taken on 9 bearings points of feed pump, hydrocoupling, motor and booster pump. The flow and load conditions have also been noted for each pump. The 9 bearings points are shown in the ***figure1.***

1. Non drive end of the feed pump,
2. Drive end of the feed pump,
3. Hydro coupling non-drive end,
4&5. Hydro coupling drive end,
6 &7. Two drive ends of Motor,
8. Drive end of booster pump.
9. Non-drive end of booster pump.

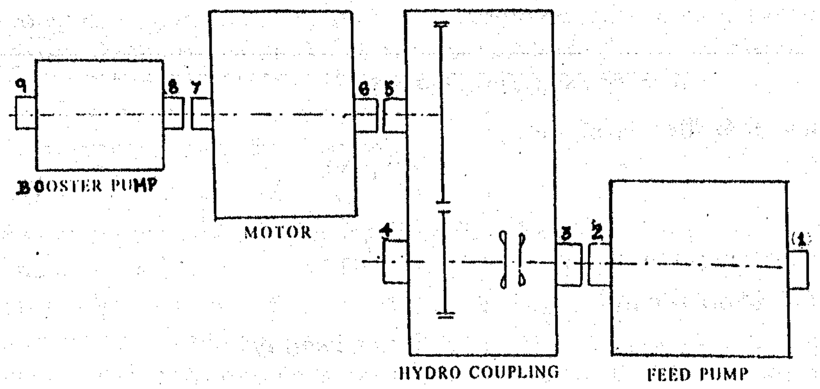

Figure1: Bearings points of Boiler Feed Pump

6.Vibration severity range classification:

The various industrial machines are classified according to international standards ISO-2372.It is described below.

Class I:

Individual parts of engine and machines, integrally connected with the complete machine in its normal operating condition, (Production electrical motors of up to 15Kw are typical examples of machines in this category)

Class II:

Medium sized machines (typically electrical motors with 15 to 75 KW output) without special foundations, rigidly mounted engines (or) machines (up to 300 KW) on special foundations.

Class III:

Large prime movers and other large machines with rotating masses mounted on rigid, heavy foundations, which are relatively stiff in the direction of vibration measurement.

Class IV:

Large prime movers and other large machinery with rotating masses mounted on foundations, which are relatively soft in the direction of vibration measurement (for example turbo-generator set, especially those with light weight sub-structure).

6.1 Vibration severity range (In accordance with ISO-2372)

The Table -3 indicates the range of vibration severity for four classes of machines. The severity is in terms of vibration velocity in peak& rms, values. The unit is mm/sec

6.2 Vibration frequency and causes:

Vibration frequency readings are noted when the vibration velocity exceeds the range of normal working condition. And this frequency is converted in to frequency ranges is shown on the Table-4

Instrument - Vibrometer
Displacement - mm
Velocity - - RMS - mm/sec

Table 1 BFP 4A

Point/Amplitude	1			2			3			4			5			6			7			8			9		
	H	V	A		H	V	A	H	V	A	H	V	A	H	V	A	H	V	A	H	V	A	H	V	A	H	V	A
Displacement (μm)	25	12	5	39	22	5	8	3	9	11	3	22	8	4	18	3	3	4	1	2	5	6	1	3	6	5	7	
Velocity (mm/sec) RMS	5.5	3.7	2.6	7.9	4.9	3.4	2.7	1.9	3.1	2.7	1.2	4.5	1.6	1.4	5.1	0.5	0.7	1.0	3.0	0.3	10	1.5	1.3	10	1.4	2.9	2.0	

Flow condition
Pump flow - 356m^3/h
Discharge pressure - 177 kg/cm^2
Current - 290 Amps
Scoop - 68%

Max. Velocity: 7.9 mm/sec occurs at a frequency 80.8 Hz
2.5mm/sec occurs at a frequency 1130 Hz.

Table 2 BFP 6B

Point/Amplitude	1			2			3			4			5			6			7			8			9			
	H	V	A	H	V	A	H	V	A	H	V	A	H	V	A	H	V	A	H	V	A	H	V	A	H	V	A	
Displacement (μm)	14	20	23	37	28	16	10	8	11	11	5	16	13	13	16	5	4	8	2	3	7	7	2	7	7	4	5	
Velocity (mm/sec) RMS	4.7	4.3	4.3	8.3	8.2	6.0	2.5	2.4	3.2	2.9	2.3	4.0	2.6	3.1	4.7	0.5	0.7	1.6	0.5	0.3	1.5	1.2	1.1	1.8	1.4	0.9	0.8	

Flow condition
Pump flow - 356m^3/hr
Discharge pressure - 177 kg/cm^2
Current - 265 Amps
Scoop - 66%
Unit load - 200 MW

Table-3 Range of Vibration Severity

<table>
<tr><th colspan="2">Range of vibration in velocity</th><th colspan="4">Examples of quality judgement for separate classes of machines</th></tr>
<tr><th colspan="2">Limit of Range mm/sec</th><th rowspan="2">Small machines Class - I</th><th rowspan="2">Medium machines Class - II</th><th rowspan="2">Large machines Class - III</th><th rowspan="2">Turbo machines Class - IV</th></tr>
<tr><th>PEAK</th><th>RMS</th></tr>
<tr><td>0.4</td><td>0.29</td><td rowspan="2">A</td><td rowspan="3">A</td><td rowspan="4">A</td><td rowspan="6">A</td></tr>
<tr><td>0.64</td><td>0.45</td></tr>
<tr><td>1.0</td><td>0.71</td><td rowspan="2">B</td></tr>
<tr><td>1.58</td><td>1.12</td><td rowspan="2">B</td></tr>
<tr><td>2.5</td><td>1.8</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>4.0</td><td>2.8</td><td rowspan="2">C</td></tr>
<tr><td>6.4</td><td>4.5</td><td rowspan="6">D</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>10.0</td><td>7.1</td><td rowspan="5">D</td></tr>
<tr><td>15.8</td><td>11.2</td><td rowspan="4">D</td><td>C</td></tr>
<tr><td>25</td><td>18</td><td rowspan="3">D</td></tr>
<tr><td>40.0</td><td>28</td></tr>
<tr><td>64.0</td><td>45</td></tr>
</table>

A-Good
B- Usable (normal Working condition)
C-Still acceptable
D-Un acceptable

7.Vibration Analysis and Recommendations:

The definition of the analysis is separating or breaking of any whole in to its parts, specifically with an examination of these parts to find out the nature, function, interrelations, this definition applies well to vibration analysis. Vibration analysis is simply a process of accurately obtaining vibration data, evaluating the data to identify the most significant characterizes and relating these characterizes to the features and details of the machine or system under steady to indefy the specific mechanical or operational defects. Vibrations analysis should thought out the "processes of elimination with objective being to reduce potentially long list of possible problem to the moving member of possibilities ideally ONE. The machinery classification (In accordance to the ISO -2372) indicates the boiler feed pump is under classes-III machines. For the classes-III machines, the vibration severity ranges is as follows (Accordance with ISO-2372)

Frequency in terms of RPM	Most likely causes	Other possible causes & Remarks
Ix RPM	Unbalance	Eccentric journals, gears or pulleys Misalignment of bent shaft if high axial vibration Bad belts if high 1x RPM of belt Resonance Reciprocating parts Electrical problem
2x RPM	Mechanical Looseness	Misalignment if high axial vibration Reciprocating forces Resonance Bad belt if 2x RPM of belt
3x RPM	Misalignment	Usually a combination of misalignment and excessive axial clearances (looseness)
Less than 1x RPM	Oil whirl (Less than ½ RPM)	Bad drive belts Background Vibration Sub harmonic resonance "Beat" Vibration
Synchronous (A.C.Line frequency)	Electrical Problems	Common electrical problems include broken rotor bars, eccentric rotor, and unbalanced phases in poly-phase systems, unequal air gap.

Table-4 Vibration frequency and causes

Velocity (RMS) conditions of feed pump

Up to 1.8mm/sec - Good condition

1.8 to 4.5 mm/sec - Normal-working condition

4.5 to 11.2 mm/sec - Still acceptable

Above 11.2 mm/sec - Unacceptable

Analysis proceeded by nothing the vibration machines are shown in the table. The analysis is the processes of elimination of objective being to reduce a number of possible problems to the minimum ideal one. It is useful for the frequency measurements.

Analysis of feed pump 4A:

For the velocity of 7.9mm/sec, the frequency is 80.8Hz (equal to 80.8x60=4848RPM). The pump RPM is about 4800. Therefore the frequency 1xRPM. Referring the chart giving on table 4 the most likely cases of vibration is UNBALANCE.

Analysis of feed pump 6B:

Similarly for the feed pump 6B the frequency of vibration is 1xRPM. Hence the case of vibration is UNBALANCE. For the other pumps the vibration measurements where matched with previous i.e., the reading taken earlier and they denote no any appreciable increase in vibration level. At present they are defect and normal.

Other Possible causes And Remedies:

Sl No	Causes	Remedies
1	Coupling Misalignment	The alignment should be checked and the necessary correction is to be made as applicable.
2	Dynamic Unbalance	Unbalance indicates problems in cartridge internals like deposit built-up, corrosion, wear,etc., when the vibration level increases beyond the permissible levels or approaches the protective limits, the pump cartridge needs to be replaced and the defective cartridge is to replaced.
3	Electrical Defect	The motor needs to be checked.
4	Oil whirl/bearing failures	The bearing and lubrication oil supply needs to be checked. The bearing clearance and proper fixing of bearing shells are to be corrected.
5	Foundation Defect	The foundation should be inspected for any defects (or) cracks (or) loosening of foundation bolts. And the supports are to be inspected to ensure the proper support.
6	Bend shaft	When the vibration level crosses the boundary limits due to bend shaft, which should be replaced (If the bend exceeds the limits 0.02mm).
7	Mechanical Looseness	When the vibration level approaches alarming levels, the cartridge to be removed and the internals should be repaired.

8.Conclusion:

Reliable feed water pump operation is essential to 210MW steam power plant. The plant availability is a direct function of feed water pump reliability. Improved reliability is required for feed water pump. When the usual condition monitoring of the feed pump indicates high vibration, vibration analysis is to be performed, whenever the high vibration is noted, there is some mechanical defects. The particular type of defects is found through vibration analysis (or) investigation. This investigation is not only used to find feed pump failures, but it may also be used for all other rotating machines. Hence this technique is very useful to any industry, which constitutes rotating machines.

9. Refereces:

1. IRD Mechanalysis Tnc. Instruction manual, IRD mechanalysis (INDIA) Ltd, Mumbai,
2. Voith Manuel, Bharat Heavy Electricals Ltd.,
3. Power plant engineering - By Domkundwar