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MAINTENANCE STRATEGIES COST REDUCTION AND QUALITY IMPROVEMENT



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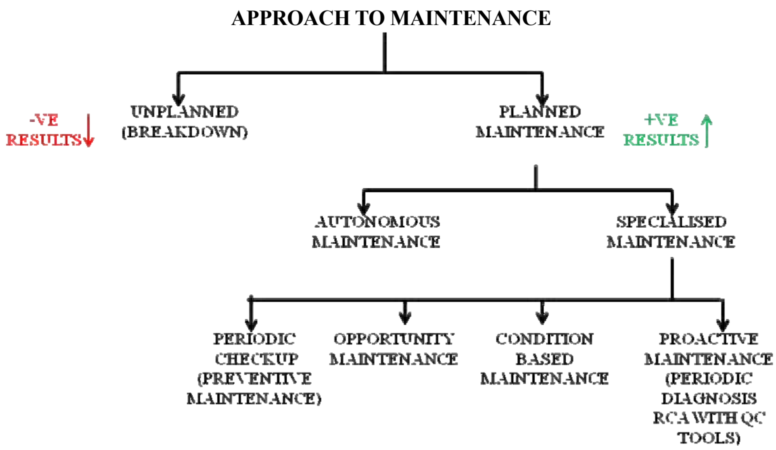
Abstract :

In today's Scenario, all corporate are mainly focusing on cut down in input cost in their operational functions. They are inclined to adapt changes in their routine method with the use of updated technologies in all fields. Paper industries having more and more revolving equipment's by its functional requirements are liable to get into defects with so many variables behind them. Machineries as that of fixed cost in costing should perform at its optimum efficiency. Deterioration needs to be monitored day in and day out so that corrective action can be taken at the right instance.

INTRODUCTION

- Manufacture of pulp, paper, and paperboard consumes over $7 billion worth of purchased fuels and electricity per year.
- Energy efficiency improvement is an important way to reduce these costs and to increase predictable earnings, especially in times of high energy price volatility.
- At a time When research on the economics of all measure as well as on their applicability to different production practices is needed to assess their cost effectiveness at individual plants it is very important to share our bad experiences and how we had successfully overcome.
- **This can contribute mutually of our paper curriculum for which IPPTA is one of the QC tool.**
- The challenge of maintaining high product quality while simultaneously reducing production costs can often be met through investments in energy efficiency.
- Energy efficient technologies can often offer additional benefits, such as quality improvement, increased production, and increased process efficiency, all of which can lead to productivity gains.
- **For the above challenges, contribution of a service department plays a major roll.**
- **Approach towards a Zero Accidents, Zero Breakdown, ZeroCustomer complaints inspired to take on good maintenance practices.**

MAINTENANCE REGIMES



PREVENTIVE MAINTENANCE

Preventive maintenance activities is a systematic inspection, detection, correction and prevention of incipient failures before they become major failure.

Preventive maintenance activity is based on,

- Mandatory recommendation from the supplier.
- Based on MTBF(Mean Time Between Failures)
- Frequent parts change

This maintenance practice is purely random. This is also one of the costlier maintenance practice.

PREDICTIVE MAINTENANCE

Predictive maintenance techniques are designed to help determine the condition of in service equipment in order to predict when maintenance should be performed. This approach promises cost saving over routine or time based preventive maintenance because **tasks are performed only they are warranted.**

Predictive maintenance technique includes,

- Vibration Monitoring
- Thermo graphic inspection
- Oil analysis
- Shock pulse (Identification of Lubrication characteristics)
- Ultrasonic testing
- Time and frequency analysis

PROACTIVE MAINTENANCE

- It is a preventive maintenance strategy for maintain the reliability of machine or equipment. The purpose of proactive Maintenance is to view machine failure and similar problems that can be anticipated and dealt with before problems occur. All predictive maintenance observations should be assessed and cause of concern should be eliminated in proactive maintenance.
- Proactive maintenance primarily defines the root cause of machine failure and dealing with those issues before problems occurs.

CBM STRATERGIES

Condition Monitoring cell was developed in SPB.

Followed by 4 Mechanical engineers and 1 Electrical engineer to carryout the department activities headed by AGM Mechanical.

- Vibration analysis
- Thermography
- Laser alignment
- Ultrasonic thickness testing
- In house dynamic balancing of rolls
- Ultrasonic leak detecting

PLANNING AND SCHEDULING

HIGHLY CRITICAL EQUIPMENTS

- Production will come to stand still
- No erected spares available
- Pose unsafe condition to personnel and equipment
- High cost involving for restarting
- Time taken for restarting equipment will be depending on severity of the problem.

CRITICAL EQUIPMENTS

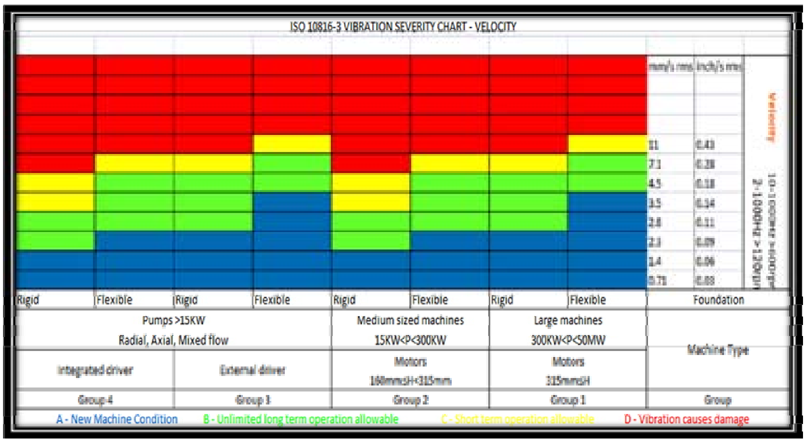
- Production will come to standstill.
- Erected spare available.
- Time taken for restarting the system prevails.

NON-CRITICAL EQUIPMENTS

- Equipment whose failure will not affect production.
- Equipment can be put up in service without any expenditure.

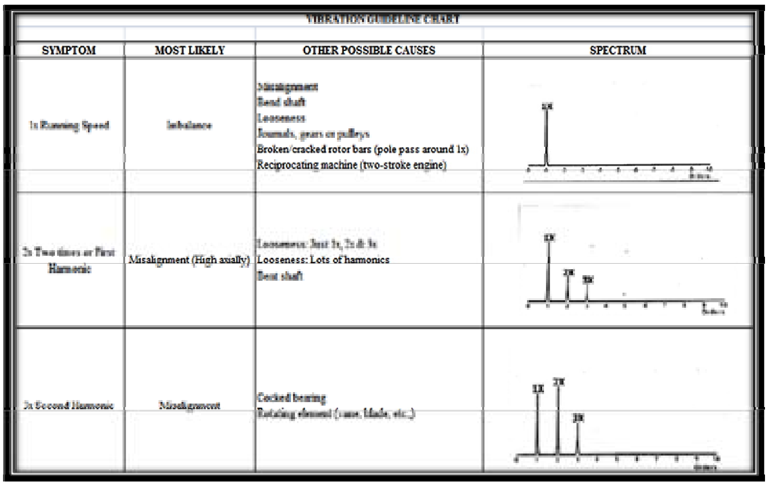
A literature review on Vibration measurements – ISO guidelines

ISO 10816 - 3 VIBRATION SEVERITY CHART - VELOCITY



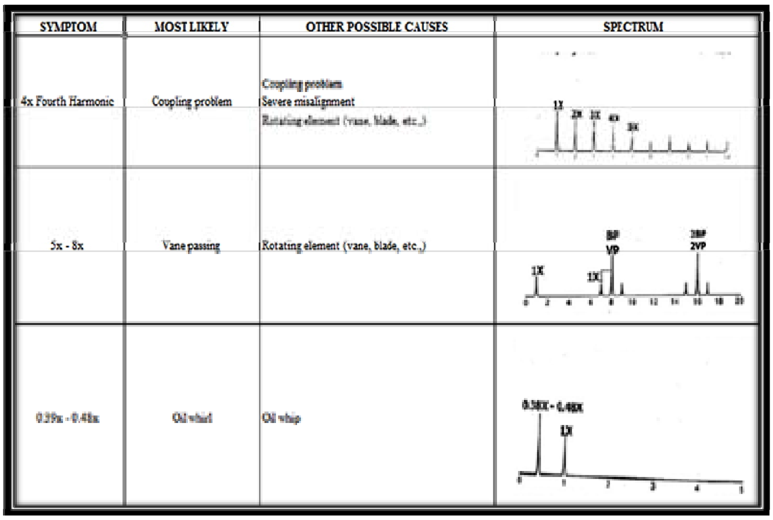
VIBRATION GUIDELINE CHART

With the following charts preliminary findings are obtained

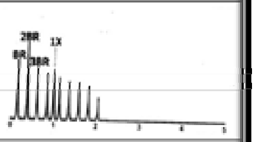
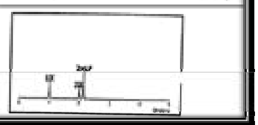


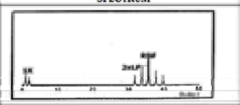
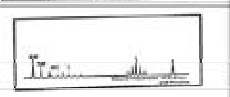
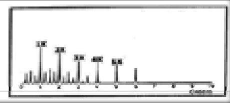
VIBRATION GUIDELINE CHART

SYMPTOM	MOST LIKELY	OTHER POSSIBLE CAUSES	SPECTRUM
1x Running Speed	Imbalance	Misalignment Bend shaft Looseness Journals, gears or pulleys Broken/cracked rotor bars (pole pass around 1x) Reciprocating machine (two-stroke engine)	1X
2x Two times or First Harmonic	Misalignment (High axially)	Looseness: Just 1x, 2x & 3x Looseness: Lots of harmonics Bent shaft	1X 2X 3X
3x Second Harmonic	Misalignment	Cocked bearing Rotating element (vane, blade, etc.)	1X 2X 3X



SYMPTOM	MOST LIKELY	OTHER POSSIBLE CAUSES	SPECTRUM
4x Fourth Harmonic	Coupling problem	Coupling problem Severe misalignment Rotating element (vane, blade, etc.)	1X 2X 3X 4X 5X
5x - 8x	Vane passing	Rotating element (vane, blade, etc.)	1X 1X BP VP 2BP 2VP
0.39x - 0.48x	Oil whirl	Oil whip	0.38X - 0.48X 1X

SYMPTOM	MOST LIKELY	OTHER POSSIBLE CAUSES	SPECTRUM
0.5x Half Running speed	Rub	Rotor rub (Sleeve bearing) Severe looseness (0.5x, 1x, 1.5x...) Drive belt resonance (could be >1x) Reciprocating machine (four stroke engine)	
Sub synchronous	Belt wear Harmonics	FFT Fundamental train frequency Flow turbulence Transducer problem (Ski slope) Eccentric rotor (pole pass frequency) Hunting tooth problems (HTF)	
100 or 120Hz Line synchronous frequency	Rotor problem	Stator eccentricity Eccentric rotor (pole pass sidebands) Shorted laminations Phasing problems (1/3 PPF side bands)	

SYMPTOM	MOST LIKELY	OTHER POSSIBLE CAUSES	SPECTRUM
Synchronous Higher frequencies	Gears	Fan speed x # blades (Aerodynamic) Cavitation, Impeller x # vanes (Hydraulic) Loose rotor bars (2xLF around RBPF)	
Non - Synchronous Higher frequencies	Bearing defects Lubrication	Inner race - BPI (1x side bands) Outer race BPO Ball spin - BS (FT side bands) Cage FT (Sub-synchronous)	
Harmonics	Looseness	Bearing wear (Non-synchronous) Misalignment (1x - 4x) Rotor rub Journal bearing wear Belt wear (BR harmonics) Gear faults (harmonics of gearmesh) Broken/cracked rotor bars (1x & PPF sidebands)	

CONDITION MONITORING PRACTICES AT OUR MILL SITE

VIBRATION ANALYSER

Vibration analysis is a non-destructive technique which helps early detection of machine problems by measuring vibration.\

Following problems can be indentified and rectified using Vibration analyser.

- Improper lubrication/un appropriate lubrication
- Unbalance
- Misalignment
- Weak structures / Mechanical Looseness
- Bend shaft
- Antifriction Bearing Defects
- Problems of Hydrodynamic & Aerodynamic Machines.
- Gear Problems

TIMELY CORRECTIONS - BY CONDITION MONITORING

CASE STUDY-1

A STUDY ON PAPER MACHINE AT TIRUNELVELI

- Severe vibrations of the rollers and structure of the press section of the paper machine at speeds more than 680 meters per minute (MPM) were reported.
- Machine production was low.

TEST CARRIED OUT TO FIND SOLUTION FOR PROBLEM

- Overall vibration measurement and Vibration spectral analysis at steady state operating conditions.

VIBRATION PHASE MEASUREMENT CHART

With the following charts preliminary findings are obtained

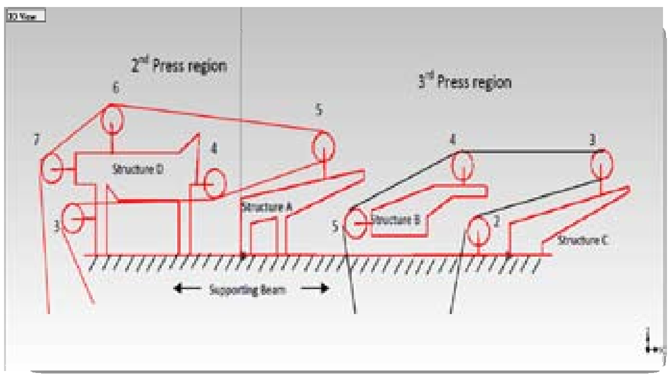
Problems	Symptoms	Phase Checking
Ski slope	High near 0Hz decaying down across the spectrum	
Raised noise floor	Bottom of the spectrum raised	
Dynamic Imbalance	1X radial (V&H). Levels highest in horizontal axis (due to greatest flexibility)	0-180Deg phase difference across machine. 90Deg±40Deg between vertical and horizontal
Static Imbalance	1X radial (V&H)	In phase across machine 90Deg±30Deg between vertical and horizontal
Couple Imbalance	1X radial (V&H)	Out of phase across machine 90Deg±30Deg between vertical and horizontal
Imbalance: Overhung Machines	High 1X axial, 1X radial (V&H)	Axial phase readings in-phase
Imbalance: Vertical Machines	1X radial (horizontal)	Phase readings similar in same direction at different points on machine
Eccentric Rotor or Gear	1X radial (V and H)	
Eccentric Sheaves	1X radial (Vand H). Levels highest in direction of greatest belt tension	Phase between vertical and horizontal axis could 0Deg or 180Deg
Misalignment	1X and 2X (and 3X and 4X...). Axial and radial (V&H)	
Angular Misalignment	High axial vibration: 1X strong but 2X and 3X can also be strong	180Deg across coupling in axial direction
Parallel Misalignment	2X radial, smaller 1X radial (V&H)	180Deg across coupling in radial direction
Bent Shaft	1X axial	Close to 180Deg phase difference between bearings
Cocked Bearing	1X, 2X and 3X axial	180Deg phase difference on either side of the shaft
Rotating Looseness	1X harmonics radial (0.5X harmonics when severe)	
Structural Looseness	1X horizontal	180Deg phase difference between the machine and the base in the vertical direction
Pedestal Bearing Looseness	1X, 2X and 3X radial (0.5X peak when severe)	180Deg phase difference between the bearing and the base
Rotor Rub	1X harmonics (0.5X harmonics when severe)	
Journal Bearing Clearance	1X harmonics. Similar to rotating looseness. Vertical vibration is higher than horizontal	

Problems	Symptoms	Phase Checking
Oil Whirl	0.38X - 0.48X in radial	
Resonance	Hump' in spectrum typically in one direction only	
Rolling Element Bearing Wear	Peak (with harmonics) at non-synchronous frequencies	Defect on Inner Race (BPI) - [illegible] Defect on Outer Race (BPO) - [illegible] Defect on Cage (FT) - [illegible] Defect on Ball (BS) - [illegible] Where d - Ball Diameter D - Pitch Diameter n - Number of Balls A - Contact angle BPI - [illegible]
Vane pass / Blade pass	Peak at vane pass or blade pass frequency	Vane pass - No of vanes x RPM Blade pass - No of blades x RPM
Flow turbulence	Random vibration in the range 50 to 2000CPM	
Cavitation	High frequency 'Noise'	
Reciprocating Machines	0.5X peak for a four stroke engine 1X peak for a two-stroke engine	
Stator Eccentricity	Twice line frequency (100 or 120Hz) radial	
Soft foot	Twice line frequency (100 or 120Hz) radial	
Eccentric Rotor	Pole pass sidebands around 1X and 100/120Hz	
Rotor Bow	1X radial	
Cracked or Broken Rotor Bars	Pole pass sidebands 1X and harmonics	
Loose Rotor Bars	100/120 Hz sidebands around rotor bar pass frequency	Rotor bar pass frequency - Number of rotor bars x Running speed
Loose Rotor	High 1X and harmonics	

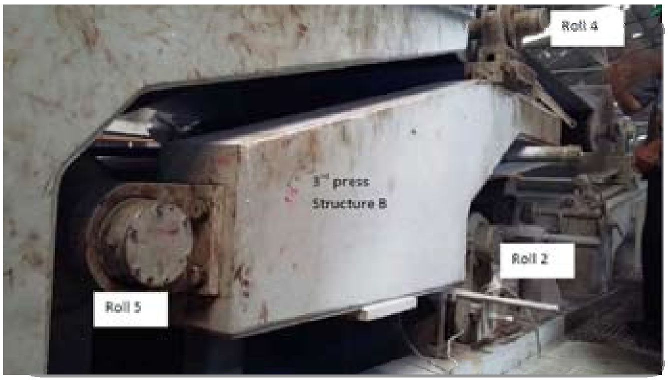
Problem	Symptoms	Phase Checking
Loose Stator Windings	High 100/120 Hz radial High coil pass frequency 1X sidebands (AC synchronous motors)	High coil pass frequency - Number of stator coils x RPM Number of stator coils - Number of poles x Number of coils per pole
Lamination problems	High 100/120 Hz radial	
Loose connections	High 100/120 Hz with 16.67 / 20 Hz sidebands	
Gear Tooth Wear	1X sidebands around the gearmesh frequency. Harmonics of gearmesh frequency	Gearmesh - Number of teeth x shaft speed Out put speed - Input speed x Input teeth/output teeth
Gear Tooth Load	High gearmesh frequency	Gearmesh - Number of teeth x shaft speed Out put speed - Input speed x Input teeth/output teeth
Gear Backlash	1X sidebands around the gearmesh frequency. High gear natural frequency	Gearmesh - Number of teeth x shaft speed Out put speed - Input speed x Input teeth/output teeth
Eccentric Gears	1X sidebands around the gearmesh frequency	Gearmesh - Number of teeth x shaft speed Out put speed - Input speed x Input teeth/output teeth
Misaligned Gears	1X sideband around the gearmesh frequency Harmonics of gearmesh	Gearmesh - Number of teeth x shaft speed Out put speed - Input speed x Input teeth/output teeth
Cracked or broken Gear Tooth	High 1X radial Gear natural frequency 1X sidebands around the gearmesh frequency	
Hunting Tooth Frequency	Hunting tooth frequency and 2XHT	
Coupling Faults	1X and 2X	Coupling not true - Vibration pattern similar to angular misalignment Coupling imbalance - High 1X and 2X radial components Coupling wear - Symptoms of misalignment and looseness

- Frequency response function measurements on various structures when machine is in OFF condition.
- Coast down measurements when machine speed is decreased from maximum possible operating speed to zero speed.
- Operational deflection shape (ODS) analysis is carried out from the FFT spectrum data at steady state operating conditions to visualize the deflection pattern of various structures of press section.

TYPICAL PRESS SECTION ARRANGEMENT



PHOTOGRAPH OF 3RD PRESS SECTION VIEWING FROM NDE SIDE

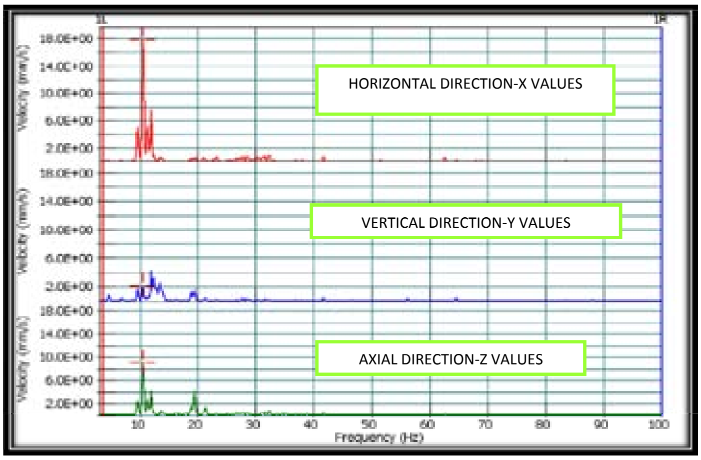


INITIAL VIBRATION MEASUREMENT RESULTS IN 3RD PRESS ROLLS @ 680MPM

EQUIPMENT NAME	NON DRIVR END			DRIVE END		
	X	Y	Z	X	Y	Z
ROLL NO 2	4.6	3.7	2.6	4.2	3.1	1.4
ROLL NO 4	23.2	8.5	12.8	9.7	10	6.3
ROLL NO 5	16	2.7	6.4	3.6	2.1	2.6

Note: Threshould Limit For Vibration Is 4.8mm/Sec

SPECTRUM OF ROLLS IN 3RD PRESS IN X Y AND Z DIRECTION



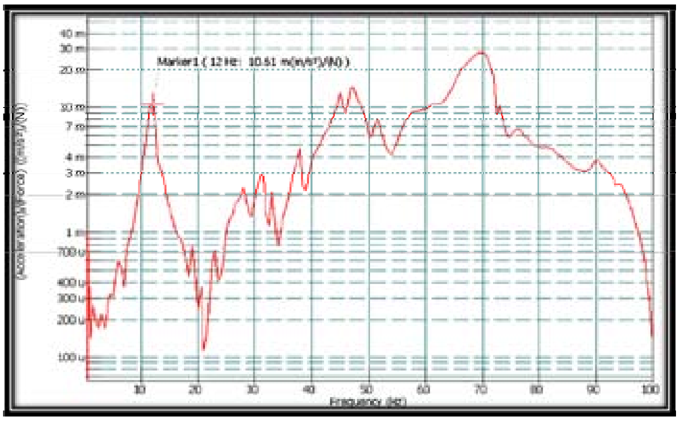
Note: Major Values Are At The Frequency Of 11 Hz In X Direction In The Above Spectral Data.

FREQUENCY RESPONSE FUNCTION (FRF) BUMP TEST FINDINGS

- Since vibrations are predominant at one frequency (10.5 Hz), structural resonance was suspected to be one of the reasons.
- Frequency Response Function (FRF) for each structure was measured with an instrumental hammer at various structural locations, including the location of high vibrations.

FREQUENCY RESPONSE FUNCTION (FRF) MEASUREMENTS (CONTD.,)

- Operating speed of many rolls of the press section, at a machine speed of 680 mpm, is 564 rpm and 635 rpm (for Timken roll and spherical roll respectively).



- Fundamental excitation frequencies of these rolls are 9.4 Hz and 10.5 Hz at these speeds. 10.5 Hz is very close to the resonance speed (720 rpm, 12 Hz from Bump test graph).
- **Roll rotation frequencies are exciting the structural resonances and thus amplifying the vibration of structure B at this speed range.**
- In order to reduce the vibration levels at speeds above 680 rpm, it is required to shift the resonant frequency of the structure to a higher value.
- It was decided to increase the stiffness of the structure B of 3rd press section as it was not supported at the NDE side

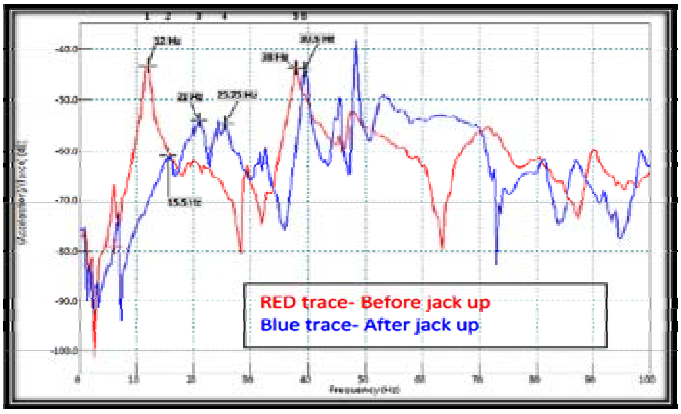
REMEDIAL ACTION

- As a temporary measure, two jacks were provided for the structure with overhang at NDE, to improve the rigidity.
- Vibration levels were measured after jacking up the structure to check the effectiveness of the additional support.
- Significant reduction in vibration levels, from 16.8 mm/s to 5.8 mm/s, was observed after jacking up the overhung portion of the 3rd press structure.

FRF MEASUREMENT ON STRUCTURE AFTER CORRECTION ON THE STRUCTURE B

- Hammer test was carried out to identify the resonance frequencies of structure B after jacking up at NDE side.
- Typical FRF spectrum for structure B are shown in fig.,
- It may be observed that the 12 Hz resonance frequency got shifted to 15 Hz with the jack up condition with significant reduction in compliance in structure B

FRF SPECTRUM OF STRUCTURE B BEFORE AND AFTER JACKING UP



RESULTS AFTER RECTIFICATION

EQUIPMENT NAME	DRIVE END			NON DRIVE END		
	X	Y	Z	X	Y	Z
ROLL NO 2	2.6	2.7	1.6	1.2	2.1	1.4
ROLL NO 4	3.5	2.8	3.2	2.7	2.8	3.3
ROLL NO 5	3.2	2.7	3.4	3.6	2.1	2.6

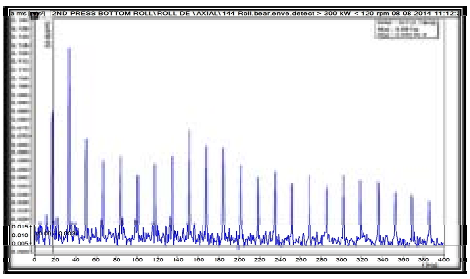
- From vibration severity point of view, with permanent support provided for structure B
- From the spectrum (15Hz) machine is safe to run at 850mpm
- The machine speed increased to 730 mpm from 680 mpm.

CASE STUDY-2

Equipment Name: Paper Machine - 1 - 2nd Press Bottom Roll

Vibration level and spectrum at abnormal condition :

LOCATION	VIBRATION VELOCITY IN MM/SEC.		
	HORIZONTAL	VERTICAL	AXIAL
ROLL DE	3.05	2.19	8.26
ROLL NDE	3.36	2.31	9.33



OBSERVATION AND RECOMMENDATIONS

OBSERVATIONS:

- Heavy vibration observed.
- Bearing outer race coincides in the spectrum.

Recommendations:

- To change the bearing.

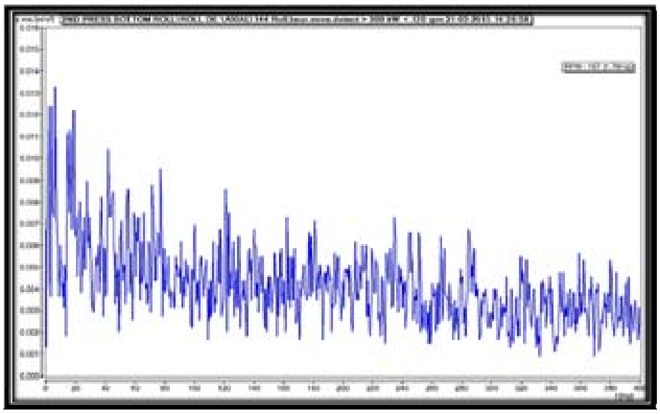
Corrective Action:

- Roll Changed.

(Removed bearing after dismantling seems to have a crack in the outer race)

AFTER RECTIFICATION

Location	Vibration Velocity In mm/sec		
	Horizontal	Vertical	Axial
ROLL DE	0.97	1.26	1.23
ROLL NDE	1.36	1.28	1.16



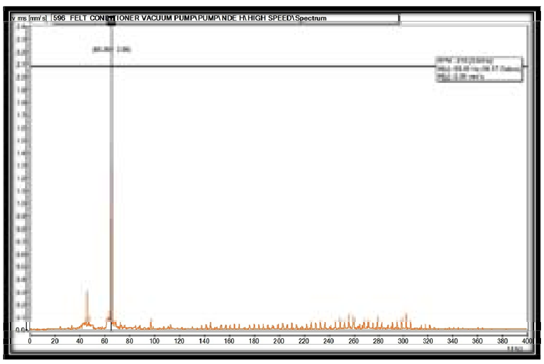
CASE STUDY-3

Equipment Name: Felt conditioner vacuum pump in PM-5

OBSERVATIONS:

- Vibration with knocking sound.
- Peak observed at 65Hz.

Spectrum:



OBSERVATIONS AND FINDINGS

LOCATION	VIBRATION VELOCITY IN MM/SEC.		
	HORIZONTAL	VERTICAL	AXIAL
PUMP DE	3.52	5.01	3.10
PUMP NDE	9.81	10.27	6.30

VANE PASS FERQUENCY CALCULATION

VANE PASS FREQUENCY (VPF) = NO:OF:VANES * RPM / 60

NO OF:VANES: 18

RPM : 22

VPF = 18*222 / 60

VPF = 66.5Hz WHICH IS COINCIDING WITH THE SPECTRUM PEAK, CONFORMING VANE PASS FREQUENCY

CAUSES AND RECOMMENDATIONS

Attributed Causes from the findings:

- Rotor looseness
- Crack in the vanes.

Recommendations:

- Rotor Vanes Crack need to be checked.

Corrective Action - 1

- Rotor sent out to identify cracks by the department.
- Dynamic Balancing carried out.
- Problem not get rectified.

After Corrective action:

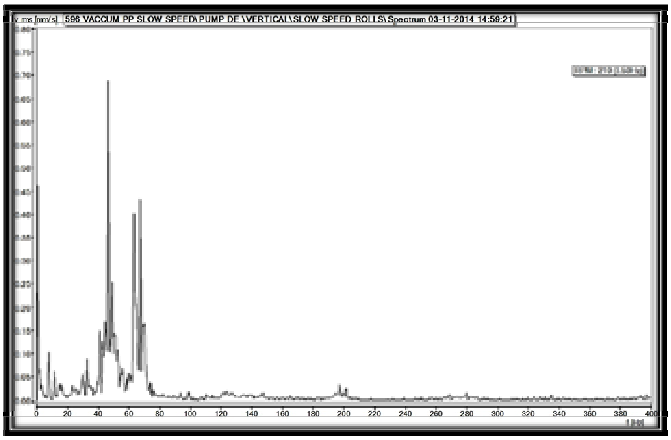
- Same issue continued.

Corrective Action - 2

- Rotor looseness condition was checked.
- Observed looseness between shaft and vanes.
- Shaft was reconditioned by the department.

Spectrum:

After shaft correction was done pump was running normal. Vibration values are within the allowable limit.

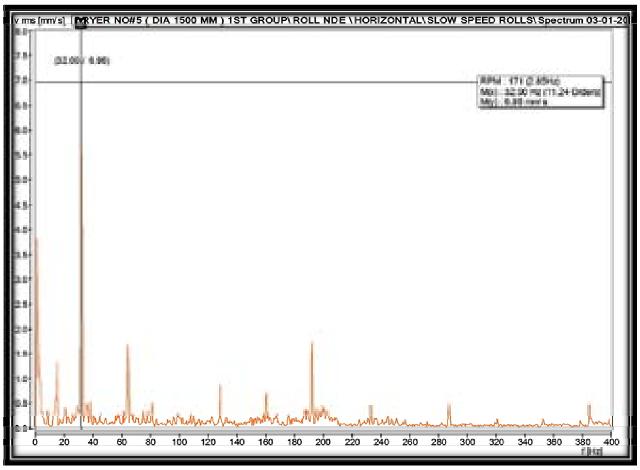


CASE STUDY-4

Equipment Name: PAPER MACHINE -5 / Dryer No:5

Vibration Level and Spectrum at abnormal condition

LOCATION	VIBRATION VELOCITY IN MM/SEC		
	Horizontal	Vertical	Axial
Roll NDE	10.16	10.76	7.86



OBSERVATION AND RECOMMENDATION

Problems identified:

- Observed vibration with knocking sound.
- Spectrum peak coincides with ball pass frequency outer race.

Possible Cause:

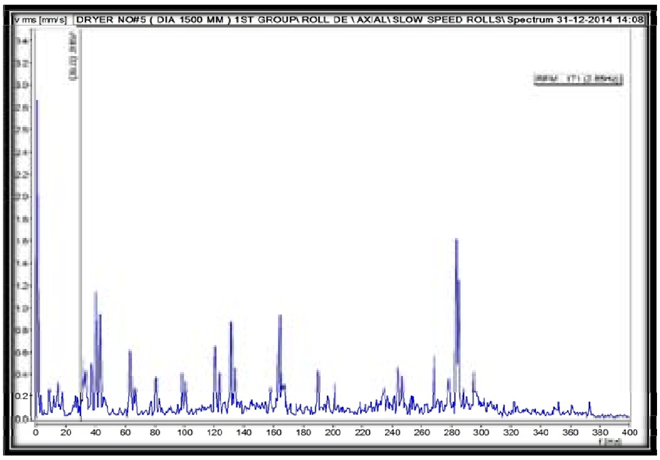
- Symptom indicates defect in the bearing.

Corrective action:

- Dryer bearing was replaced with new one.

AFTER RECTIFICATION

LOCATION	VIBRATION VELOCITY IN MM/SEC.		
	Horizontal	Vertical	Axial
Roll NDE	2.25	1.46	2.02



(Removed bearing after dismantling seems to have a crack in the outer race)

CASE STUDY-5

Equipment Name- SRP Boiler ID fan

Vibration level and Spectrum at abnormal condition

LOCATION	VIBRATION VELOCITY IN MM/SEC.		
	Horizontal	Vertical	Axial
Fan DE	4.40	1.82	2.65
Motor DE	3.73	1.35	2.76

OBSERVATION AND RECOMMENDATION

Problems identified:

- Observed high vibration in horizontal direction.
- Knocking sound in the blower.

Possible Cause:

- Unbalance
- Looseness.

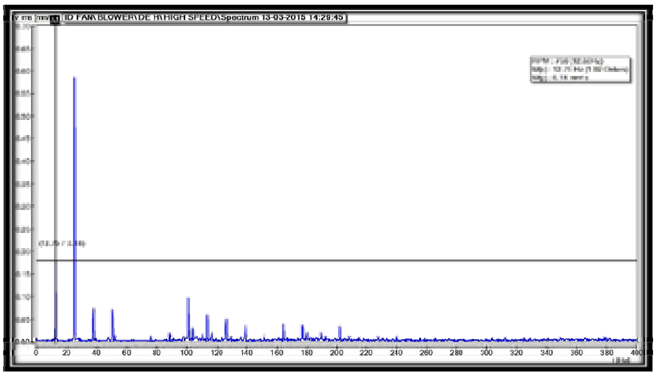
Corrective action:

- Ash particles are removed from the blower by cleaning in a planned shut .

AFTER RECTIFICATION

After rectification blower is running normal.

LOCATION	VIBRATION VELOCITY IN MM/SEC.		
	HORIZONTAL	VERTICAL	AXIAL
Blower NDE	1.18	0.57	0.86
Blower DE	0.6	0.14	0.62



BENEFITS:

PERIOD	MECHANICAL DOWNTIME
JAN-16 to July-16	0.94
Aug-16 to Feb-17	0.93
March-17 to July-17	0.77