IMPROVING EQUIPMENT AVAILABILITY AND RELIABILITY THROUGH CONDITION MONITORING AT COLD ROLLING MILL COMPLEX OF TATA STEEL

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Abstract:

Maintenance of plant and equipment is carried out to increase the availability and reliability, so that it will continue to operate satisfactorily for the entire life-cycle of the equipment with required cost effectiveness. There are three main categories of maintenance strategies:

- Corrective or Breakdown Maintenance
- Preventive (Periodic or Fixed Time Based) Maintenance
- Condition Based Maintenance (CBM) or Proactive Maintenance

In CBM, Maintenance is carried out only when there is a need, as indicated by the measurement and analysis, using some of the several available condition monitoring techniques. These techniques include use of parameters like vibration and noise, temperature, lubricant condition, wear debris analysis, corrosion, pressure, flow and other performance parameters.

This paper deals with condition monitoring techniques being used at CRM for different equipment and its benefits.

Introduction

Managing industry in 21st century is a challenging task. Last few decades can be earmarked for the all round industrial development. Continuous improvement in the area of technology, productivity and quality has resulted in a cutthroat competition in the industries. Today, industries are striving to achieve improvement in efficiency in all the fronts to have more competitive edge over other similar industries. Therefore each operation in business is critically examined to enhance profitability. To be more competitive industry, one must be concerned about the following:

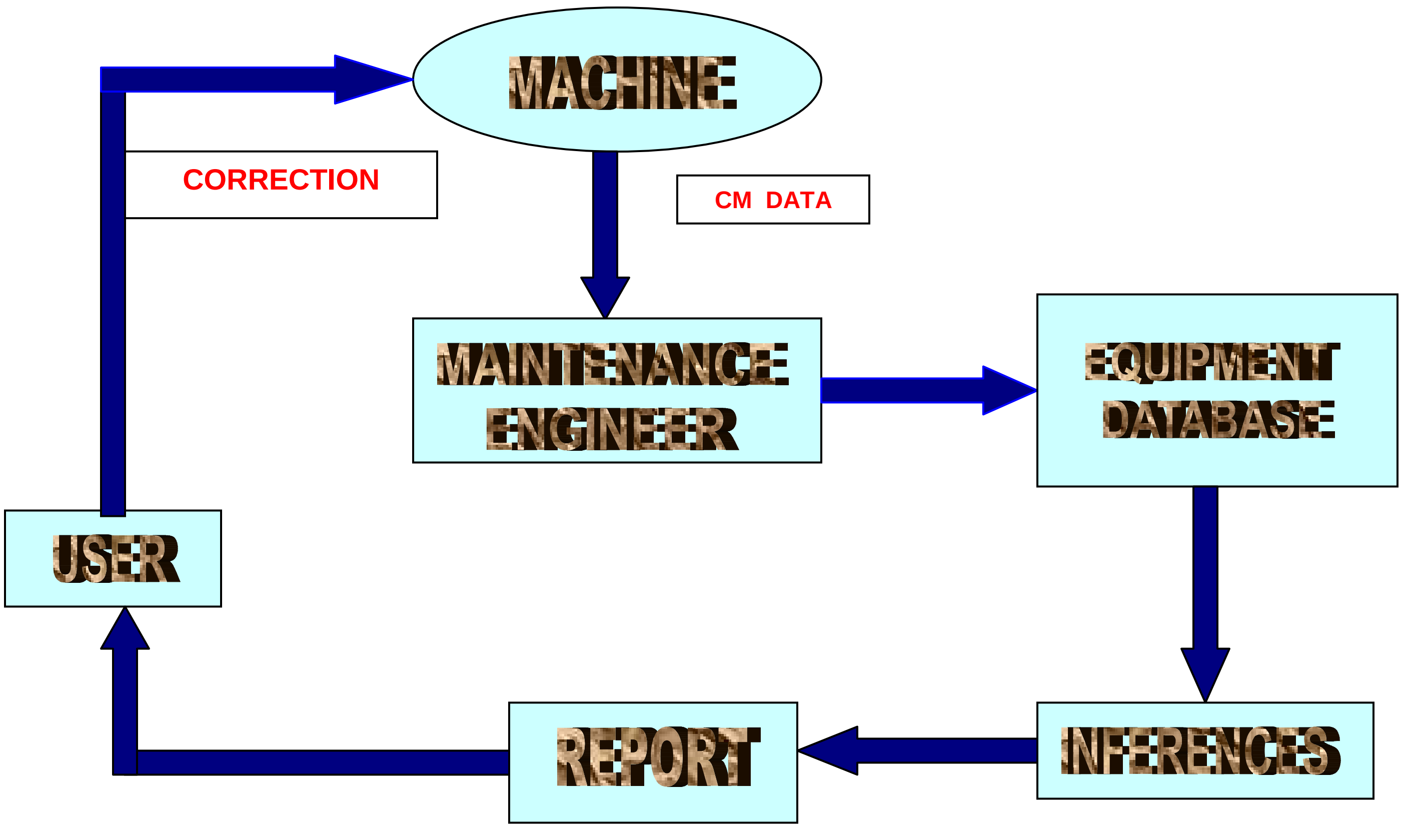
- Product quality
- Productivity
- Customer satisfaction
- Cost of manufacturing

Improvement in Product quality, productivity and reduction in cost of manufacturing can be achieved by switching over to new and economic technology and by increasing the equipment availability and reliability. The cost of product must be lowest with highest grade of quality. Here, maintenance is playing important role in any business. Plainly stated, the growing cost of maintenance is a serious business aspect and maintenance is the largest single controllable expenditure in a plant or industry.

Predictive maintenance generally known as condition based maintenance and proactive maintenance management is becoming the system of choice for the industry to achieve higher machine reliability and in turn to be cost competitive in the market. The gains offered by condition monitoring and proactive maintenance go far beyond traditional preventive and breakdown maintenance. Condition based maintenance is a holistic multidiscipline based on system thinking. It encompasses instrumentation, engineering, information technology and management. Role of Condition monitoring activities to achieve higher level of Equipment Availability and Reliability in CRM of Tata Steel is discussed in brief in the following paper.

Condition monitoring

Condition monitoring involves determining the condition of a machine and its rate of change of measured parameters in order to determine the maintenance requirement. The condition of machine may be determined continuously or at regular intervals by monitoring measurable parameters.



CBM is carried out for two main reasons:

1.To detect sudden changes in condition that could lead to catastrophic failure, particularly for machinery that could represent a threat to the health and safety of people, or cause an environmental incident. This is known as 'Machinery Protection' or 'Protective Monitoring'.

2. To identify the early onset of incipient failures so that a prediction can be made about their most likely progress and suitable actions can be planned. This is known as 'Predictive Monitoring' or 'Predictive Maintenance', and is often abbreviated to 'PDM'.

Potential benefits:

In the year 1988, Technology for Energy Corporation studied impact of condition monitoring over 500 plants in USA, UK Canada and Australia. A significant fact emerged out that systematic implementation of condition monitoring can reduce the maintenance cost of about more than 50 percent. Other benefits achieved by the plants having condition monitoring activities are as follows:

- Reduction in forced shutdown
- Reduction in spares inventory
- Reduction in shutdown time
- Improvement in machine reliability and availability
- Increasing equipment operating life
- Improvement in safety margin
- Improvement in machine performance & output quality
- Increasing bottom line profit

Condition monitoring techniques:

A wide range of Condition monitoring techniques is available and some have become standards in many industries. Those "standard" technologies include vibration analysis, ultrasound, oil analysis, wear-particle analysis, Industrial Videoscope System and thermography.

Vibration analysis is used primarily with rotating equipment to find problems such as out-of-balance, looseness, misalignment, gear teeth defects, bearing defects and system resonance. Generally periodic readings are taken and recorded. Maintenance personnel then compare these readings to a baseline. When vibration reaches a certain level, then root cause of high vibration is analyzed and corrective action plan is drawn. This reduces the amount of reactive maintenance and ensures the replacement occurs with minimum impact on the production or facility schedule.

Ultrasound function is primarily used for leak detection, particularly for steam and air leaks. Ultrasound is also used to detect cavitation problems in hydraulic pumps. Other applications include the detection of electrical problems. Loose connections in junction boxes and bus bars can be monitored for the sounds of arcing. This technique is useful in power distribution centers and motor control rooms.

Oil and Wear-Particle Analysis: Oil analysis and wear-particle analyses are actually two very different technologies. Oil analysis determines the condition of a lubricant. Wear-particle analysis determines the condition of equipment based on the concentration of wear particles in the lubricant.

Industrial Videoscope System: This equipment utilizes most advanced opto-digital technology, which takes inspection to a new level of capability and versatility. It has a flexible tube with a camera, which has a diameter of few millimeters (4.4 mm and 6 mm). This insertion tube can be taken to areas, which are inaccessible otherwise and can capture and reproduce images as accurately as possible. This System has been used widely at CRM for inspection of gearboxes and bearings.

Thermography supports maintenance of industries that have high temperature processes. The technology helps pinpoint areas where refractory material is wearing and allows repairs prior to catastrophic failures. The technique is also used to find electrical components that are hotter than normal. Such a condition usually indicates wear or looseness. Thus, thermography allows performing maintenance on particular electrical components. Other applications include the monitoring of outdoor wiring such as overhead transmission lines, which wear due to environmental conditions.

Condition Monitoring practices in CRM -Tata Steel:

The Cold Rolling Mill at TATA STEEL was commissioned in April 2000 .It has been built with state-of-the-art technology with following facilities—

Facilities	Suppliers
1. PL-TCM: 1.2 mtpa capacity	MHI and HITACHI, Japan
2. Batch Annealing Furnace, 0.8 mtpa	LOI, Germany
3. Skin Pass Mill, 0.8 mtpa	IHI, Japan
4. CGL-1 : 0.1 mtpa	FPE , India
5. CGL-2 : 0.3 mtpa	CMI, Belgium
6. Recoiling Line 1 & 2 & 3	DBI, USA, & Bronx
7. Coil Packaging Line	ITW & Indomag

CRM equipments are very complex and extremely costly. This necessitates that the equipment and machineries must give higher availability and reliability with ensured productivity. Right from the beginning, a lot of stress has been given on condition monitoring activities at CRM and it has resulted in substantial amount of savings in the tune of few millions of rupees by avoiding catastrophic failures and extension of process equipment life.

Condition monitoring activities at CRM may be differentiated, based on four major aspects:

- **Off line monitoring**
- **On-line surveillance system**
- **Pro-active condition monitoring**
- **Computerization of CM activities**

Off line monitoring –

State of the art Condition monitoring instruments are being regularly used in off line data capturing in the different work areas to ensure the healthy condition of equipment. Thermal imaging, Vibration analysis, Industrial Videoscope System, Ultrasounds, Oil analysis and Ferrography techniques are being used regularly at CRM.

Following instruments have been procured by CRM.

1) Ferrography Machine (Located at MED, Mechanical)
2) CSI Vibration Data Collector compatible with CSI Vibration Analysis Software at MED
3) Shock Pulse Meter
4) Machine Checker
5) Vib-10
6) Infrared Thermometer
7) Oil View (Located at MED, Mechanical)

8) Laser Alignment Instrument
9) Particle Counter

Following condition monitoring techniques are being used by CRM personnel.

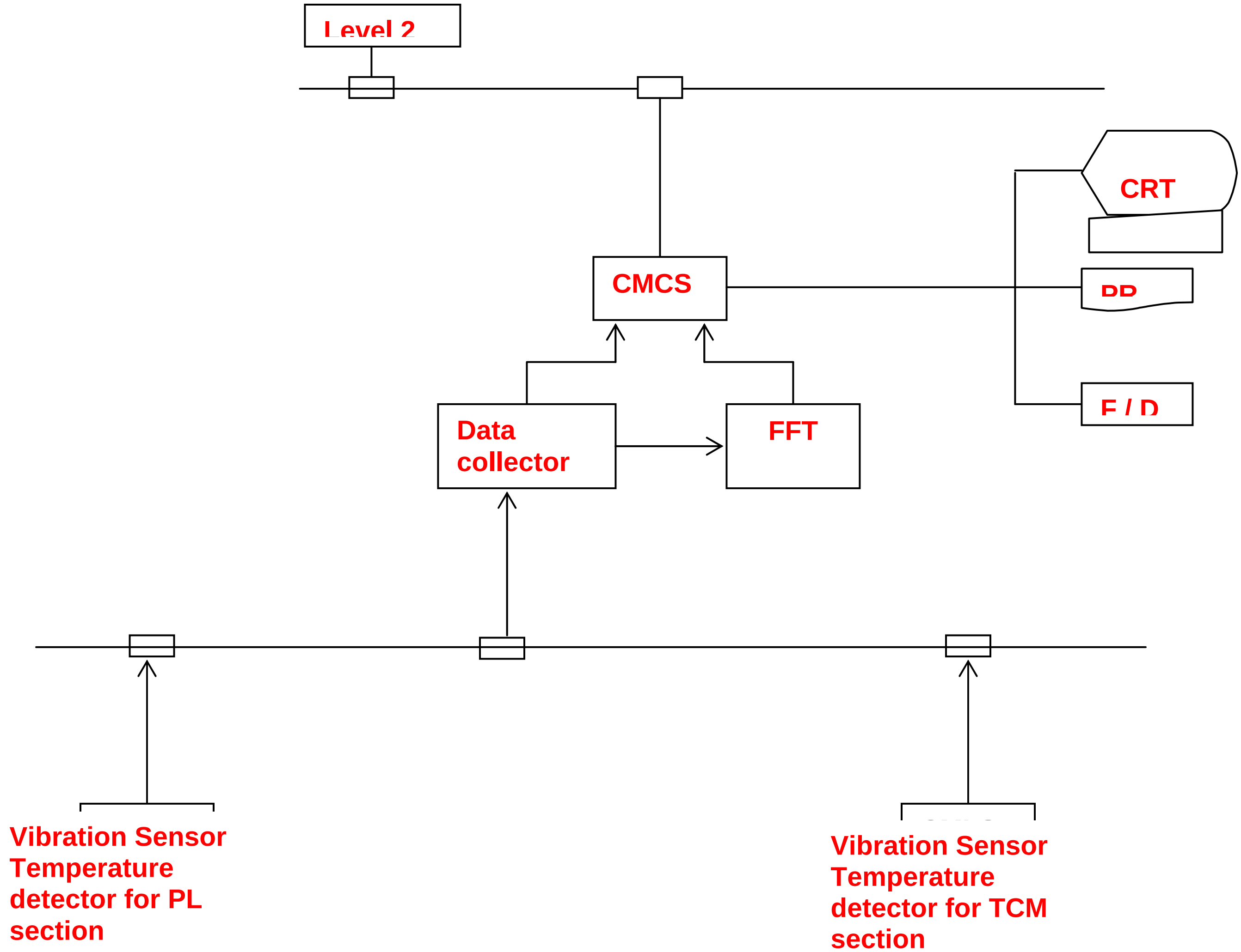
1) Vibration Analysis
2) Oil Cleanliness check by Particle Counter
3) Temperature measurement by infrared gun
4) Alignment by Laser Alignment Instrument

Central Condition Monitoring Group from MED, Mechanical is providing support in the following areas.

1) Vibration Analysis
2) Thermography
3) Ultrasonic Thickness Measurement
4) DP Test
5) Ultrasonic Testing
6) Noise Measurement
7) Ferrography
8) Oil Testing
9) Industrial Videoscope System

On-line surveillance system –

Pickling Line and Tandem Cold Mill at CRM Complex is installed with surveillance and full-fledged vibration spectrum monitoring systems, to ensure the highest level of availability and reliability of mill. This system allows on-line trend monitoring of temperature and vibration. System configuration is given below.



This system consists of the following devices which are connected on LAN (FALCOnet).

(1) CMLS (Condition Monitoring Local Station)

The components are given as follows.

(a) PHENIX-IV

PHENIX-IV is a vibration meter that can switch up to 16 electrical charge input signals transmitted from piezoelectric acceleration sensor. It divides an input signals into individual frequency components of Low, Medium and High, detects the average and peak value through Averaging and Peakhold circuits and provides an output by converting them in to 12 bits digital values.

(b) PHENIX-II

PHENIX-II is a data acquisition unit that has up to 16 insulation analog input points and provides an output by converting voltage from the temperature sensor encoder or current sensor encoder into 12 bits digital values.

(2) CMCS (Cont. FFT)

CMCS (Cont. FFT) provides capabilities of editing or storing measuring data which are transmitted from each CMLS, and executing FFT calculation as needed. It can connect to up to 144 CMLSs.

(3) CMCS (Win) provides capabilities of entering parameters required for the equipment diagnosis, or displaying the result of diagnosis and diagnosis requests with graphs. It corresponds to a man-machine interface for the system.

CMLS Function:

1) Data sampling sub-system

   Vibration: Average and peak value during certain period

2) Data check sub-system, including check of speed condition
3) Data conversion sub-system
4) Data transfer sub-system to CMCS

CMCS Function:

1) Data transfer sub-system
2) Data correction sub-system
3) Data averaging sub-system for 1 hour, 1day and 1 month
4) Data check sub-system for 1 day data
5) General diagnosis sub-system
   - Average, peak value check
   - Peak / Average value check
   - Trend check for vibration and temperature
6) Data filing sub-system
7) Alarm report, daily report and monthly report
8) Trend graph display for vibration and temperature

9) FFT Analysis and diagnostic result by the operator's request

Following equipments have been provided with sensors:

SR. NO.	EQUIPMENT	MOTOR			Mechanical
		Bearing Vibration	Air Temp. in air gap between stator and rotor	Winding temp.	Vibration
1	Pay-off Reel	2		1	1
2	Bridle No. 1	4		2	1
3	Tension Leveller Roll	2		1	1
4	Bridle No. 3	2		1	1
5	Bridle No. 4	4		2	1
6	Bridle No. 5	4		2	1
7	Bridle No. 6	8		4	4
8	PL Entry Hyd. Pumps	7		7	7
9	Mill Stand 1	2	1	1	1
10	Mill Stand 2	2	1	1	1
11	Mill Stand 3	2	1	1	1
12	Mill Stand 4	2	1	1	1
13	Mill Stand 5	2	1	1	1
14	Tension Reel	4	2	2	2
15	TCM Main Hyd.	6		6	6
16	Roll Coolant	6		6	6

	Pumps				
17	Fume Exhaust Blowers	2		2	2

Pro-active condition monitoring

Oil particle monitoring and oil contamination monitoring of hydraulic and lubricant oil are being regularly carried out at CRM as pro-active measure to ensure the life of costly components. We have achieved and maintained oil cleanliness level of NAS class - 2 in some hydraulic systems. Our hydraulic oil cleanliness level in all systems is below NAS-5. This has resulted in ten-fold increase in the life of hydraulic components and avoidance of unforeseen stoppages of mills because of malfunctioning of hydraulic systems.

Computerization of CM activities –

Database for all CRM Equipment which are covered under CBM, has been created in CSI Vibration Analysis Software at MED. FFT vibration signatures taken with the help of data collector are down loaded to RBMWARE (CSI Software). Data trending and Diagnosis is done through the software. Also CRM personnel can see equipment health data like Vibration Overall values, Vibration Trends, Temperature Trends, Ferrography observations etc. in their own computer through Tribology Work Bench (TWB), an in-house developed maintenance engineering software.

Saving Through Implementation Of Condition Monitoring:

A systematic practice of condition monitoring in different process equipment helped CRM to achieve substantial bottom line benefits. In the year **2002- 2003** benefits on account of implementation of condition monitoring activities was more **than Rs. 1 Crore.** Benefits of Condition Monitoring activities can be broadly classified in the following heads:

A. **Cost Saving By Preventing Failures. – CGL1 Furnace, CGL1 Blowers**

B. **Life Extension of Process Equipment. –CGL1 & 2 Pot**

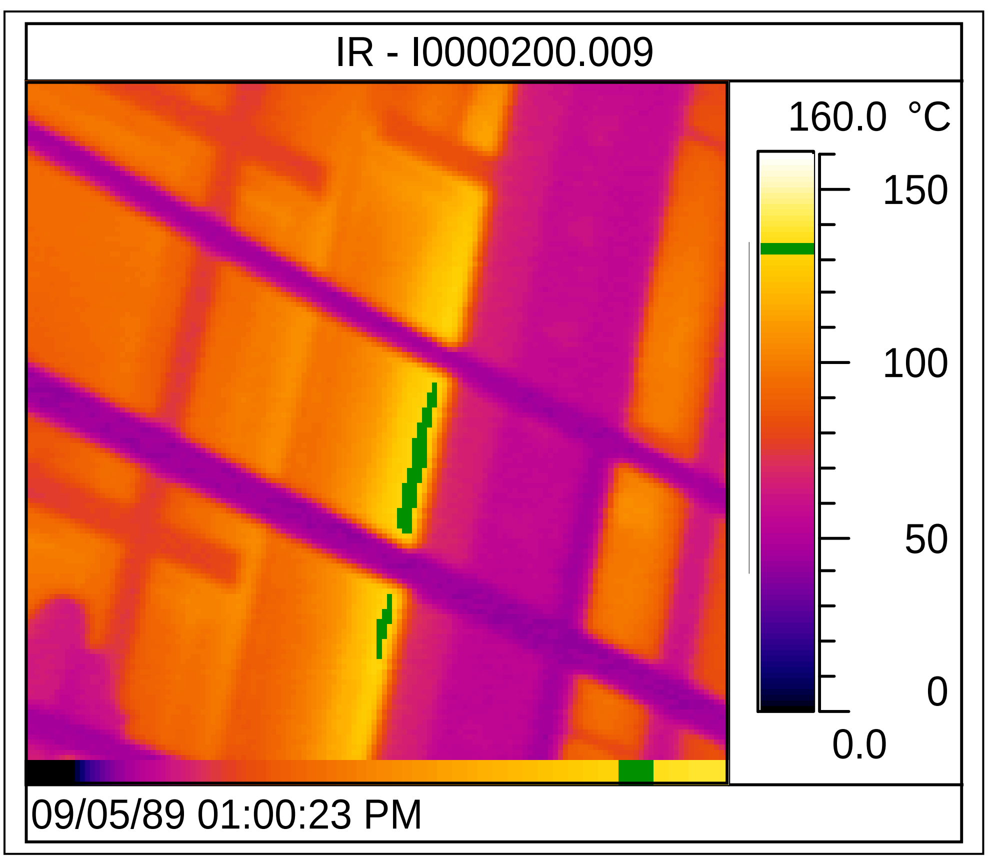
C. **Performance improvement. – Laser Alignment, Balancing, Industrial videoscope system**

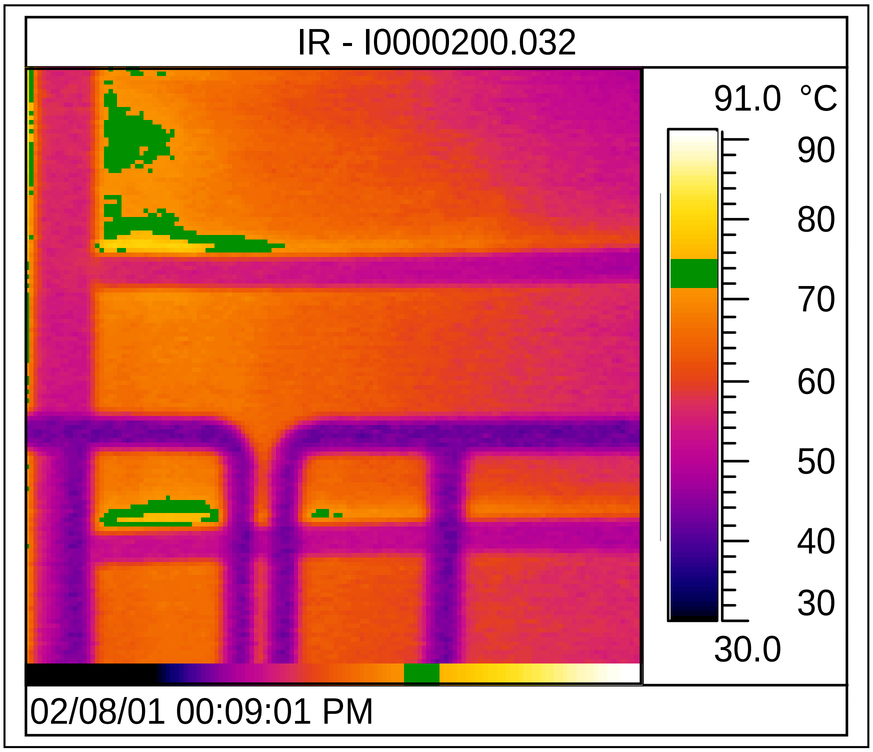
Few cases are mentioned below in brief.

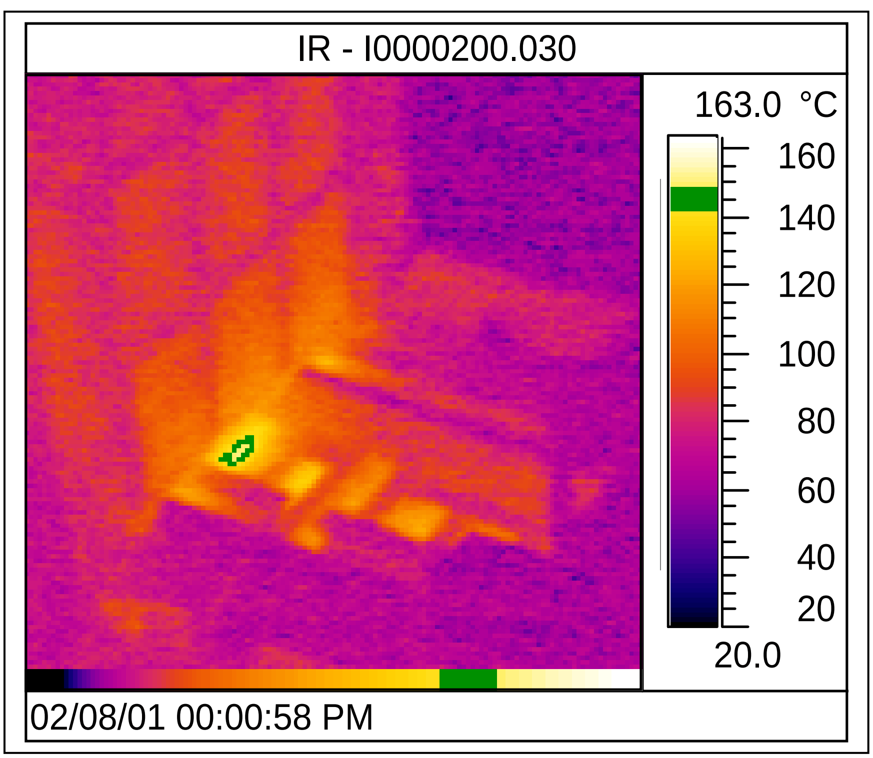
A) Cost Saving By Preventing Failures

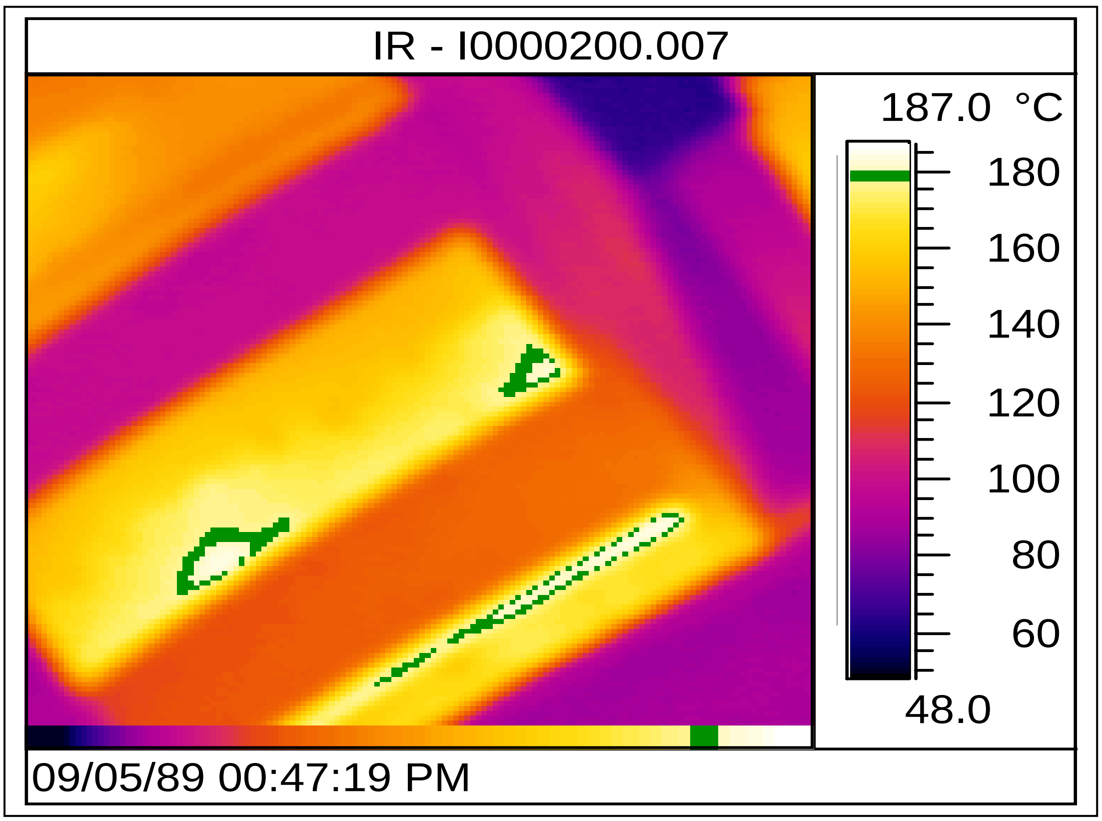
Thermal imaging of CGL1 Furnace before MSD and repair during MSD

In last two major shutdowns of CGL1, before shutdown, thermography of entire annealing furnace was done and based on this, area of refractory wear were identified. Based on this information, refractory material was arranged well in advance and repairs were done during the shutdown. By doing this, we could prevent any line stoppage because of furnace refractory wear.




IR - I0000200.032
91.0 °C
90
80
70
60
50
40
30
30.0
02/08/01 00:09:01 PM


IR - I0000200.030
163.0 °C
160
140
120
100
80
60
40
20
20.0
02/08/01 00:00:58 PM

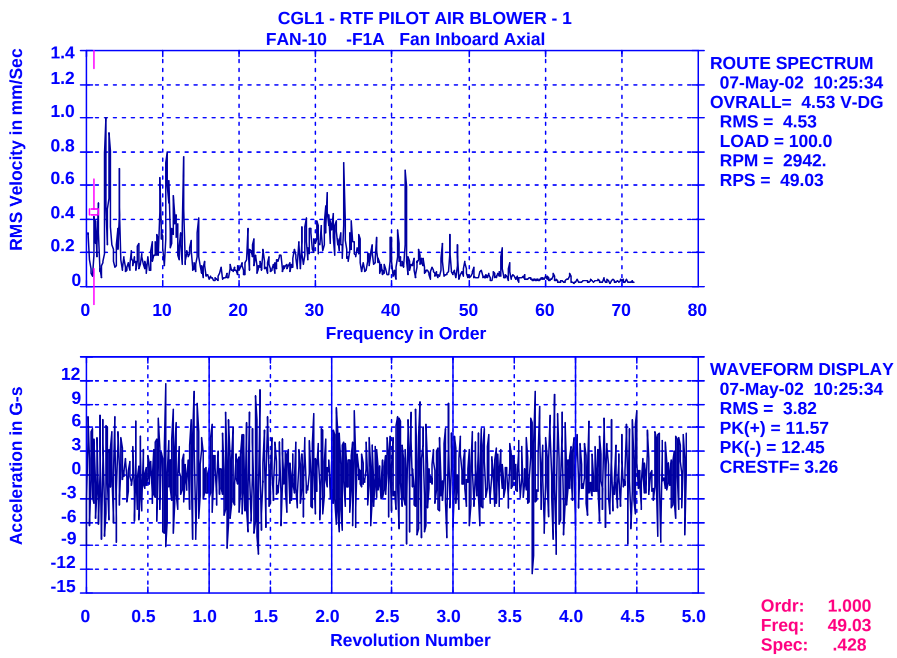


Ultrasonic Thickness Measurement of Radiant Tubes of CGL1:

In major shutdowns, Ultrasonic Thickness Measurement of Radiant Tubes is also done. If any alarming reduction in thickness is found in any one of the radiant tubes, it is changed to prevent failure during line running.

FFT VIBRATION SPECTRUM AND SHOCK PULSE MONITORING OF CGL1 & 2 BLOWERS.

FFT vibration Spectrum analysis, Trend monitoring and SPM techniques are being regularly carried out to assess the health condition of antifriction bearings of CGL1 AND CGL2 BLOWERS. Proper diagnosis of FFT spectrum of vibration helped to detect bad bearing and subsequently corrective action prevented catastrophic breakdown in many Blowers.



suggested for bearing change.

After removing the bearing from the system we found that bearing was badly damaged.

Following is the data of line outage (CGL1) because of blowers before Condition Monitoring was implemented:

Sr. No.	Description	Month	Outage (Hours)
1.	Chromate Exhaust Blower	March,01	4
2.	Blower 3	May,01	3
3.	Preheat Combustion Blower 1	July,01	4
4.	Blower 1	Sep,01	3

Average monthly outage = 14/7 = 2 hrs.

After implementation of Condition Monitoring of Blowers, there has not been any line outage because of Blowers.

Down time cost of one hr. in CGL1 = Rs. 56,000

Saving = Rs. 1, 12,000 / month = Rs. 13,44,000 / year

B) Life Extension of Process Equipment –

CGL1 Pot

In CGL1, Zinc Pot is changed every six month. Once it comes out, wear assessment is being carried out by doing ultrasonic thickness measurement at various locations. After that, Pot is repaired by depositing metal at portions where thickness has gone down. After repair, pot thickness is again measured at various locations before it is declared fit for use.

One no. of CGL1 Pot has already been repaired by this method and put in service. Repair of 2nd pot is presently going on.

Saving: 14 Lakh (Cost of new pot in CGL1 = 14.4 Lakh, Cost of manpower and consumable = 40,000 Rs.)

CGL2 Pot Repair

Auxiliary Pot No. 2 of CGL2 had leaked in the month of January 2002. The walls on the four sides were more or less seriously corroded; the affected walls showed signs of hemispherical depressions of varying sizes, up to a particular level in the pot. The inter-compartmental steel barriers acting as stiffeners for the longer sides of the pot were also badly eaten up; here too the depressions were of the same nature, commonly known as golf –ball depressions. The pot wall had drastically thinned down in the area of the failure. The 50-mm thick wall had come down to 13 to 17 mm in places where there was still some material left.

Apart from measuring the thickness of the wall along the line cut open in the middle, for getting it repaired, the entire pot was checked by ultra sonic probe to ensure the soundness of the undamaged portions. The results did not show any major deviation.

The next step after the observations was to find the possible causes of the failure. The potential causes that were thought of having caused the failure were

A. Wrong material selection for the pot
B. Wrong fabrication process/ tools used (welding electrodes)
C. Bath temperature exceeding the safe limit of 480 ^{o} C
D. High bath temperature combined with turbulence in the bath, aggravating the erosion of iron by the Aluminium in the bath
E. Localised hot spot in specific areas on the shell of the pot
F. Lack of temperature control on the bath and the different zones.
G. Combination of two or more of the above causes.

To investigate A (the material quality), samples drilled out from the rim of the auxiliary pot no.2 were sent for metallurgical analysis. Substantial differences were found from the ideal chemistry of the pot material. However, the laboratory analysis matched the composition of the suppliers' specifications as given in the Test Certificate, but differed from that of ARMCO steel, traditionally known as the ideal material for zinc pot. As we gathered, the material for the pot was imported from Thyssen, Germany, while the pot was fabricated at TATA Growth Shop.

Fe	C	Mn	S	P	Si
T.C.	0.057	0.38	0.0073	0.011	0.009
ACTUAL	0.04	0.37	0.011	0.013	0.015
ARMCO	0.015	0.08	0.015	0.02	Trace

This comparison underlines the doubt as to whether the composition certified by Thyssen was ideally suitable for such applications.

The next task was to organize the repair of the pot. It had to be done in-situ as the only available crane did not have the capacity of lifting the 60 tonne weight (30t of the pot and 30t of the solidified zinc). This proved to be a challenge in more than one way:

i. Space available was at a premium
ii. Working conditions in the cellar were fairly hazardous
iii. Time available to cut out the defective part and replace with an appropriate material matching in every respect with the parent material was only 10 days, (7th- 17th January, 2002).
iv. Repairing involved certifying the material, testing the material, preparing it , bringing it to the site, getting the old surface ready, welding it in extremely carefully and thoroughly, do necessary testing subsequently to verify the soundness

Contrary to the apprehensions, getting the right material for the repair proved to be the surest and the easiest of tasks. While the parent material was originally imported from Thyssen, Germany, the replacement material was specially cast and rolled in LD #2, Slab caster to a plate of thickness of 50 mm. The plates were collected from the transfer bar of the TISCO Hot Strip Mill and supplied to Tata Growth Shop for fabrication. Non-destructive testing carried out on the plates made sure that there was no flaw with the slabs meant for repair. Suitably sized plates were cut out from the mother plates, edge finished, and then put into the right place for making up the slot cut out from the middle of the damaged pot. The four curved corners were critical, as matching the profile of the plate with the rest of the pot was a difficult task. This was accomplished with the help of a template made at site and then used in the Growth Shop doing the required preparations. After the welding repair was done, the joints were tested by dye penetration test and all the debris were cleared from the inside the pot.

After the repair job was over, the pot was stress relieved by heating to 400 deg C, in two days time and then leaving it to cool by natural convection.

Then came the task of the actual heating up of this auxiliary pot with zinc ingots inside. An exhaustive temperature control and measurement system was developed for heating up. Necessary feedback obtained from the readings of the thermocouples helped monitor the heating up the zinc filled pot.

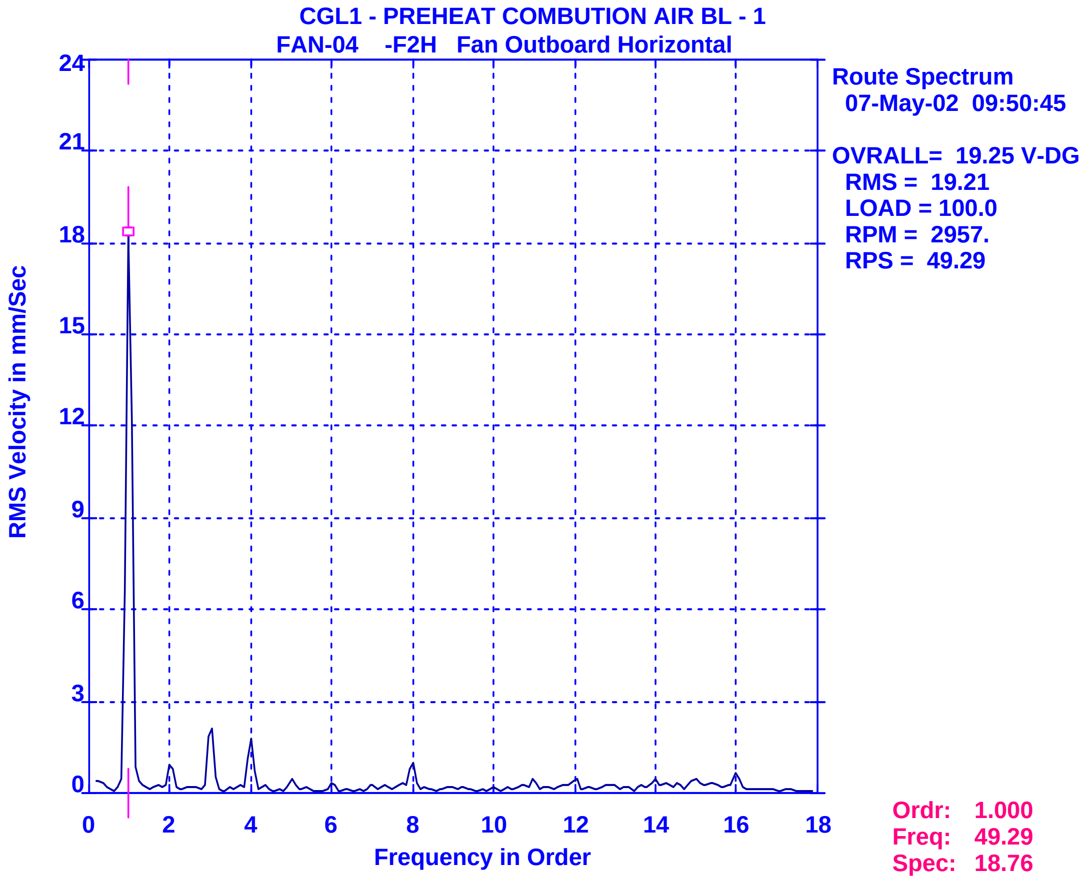
Saving: 15.5 Lakh (Cost of New CGL2 Pot)

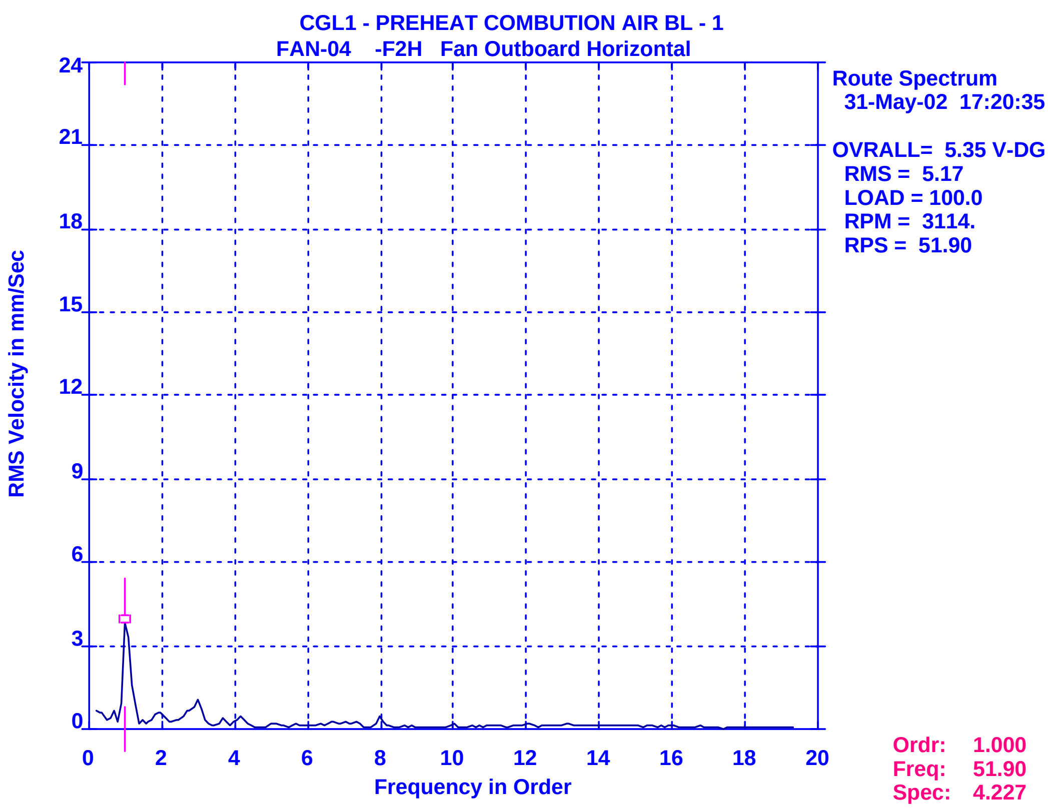
TOTAL SAVINGS BY IMPLEMENTING CONDITION MONITORING AT CGL: 42.94 LAKH

C) Performance Improvement

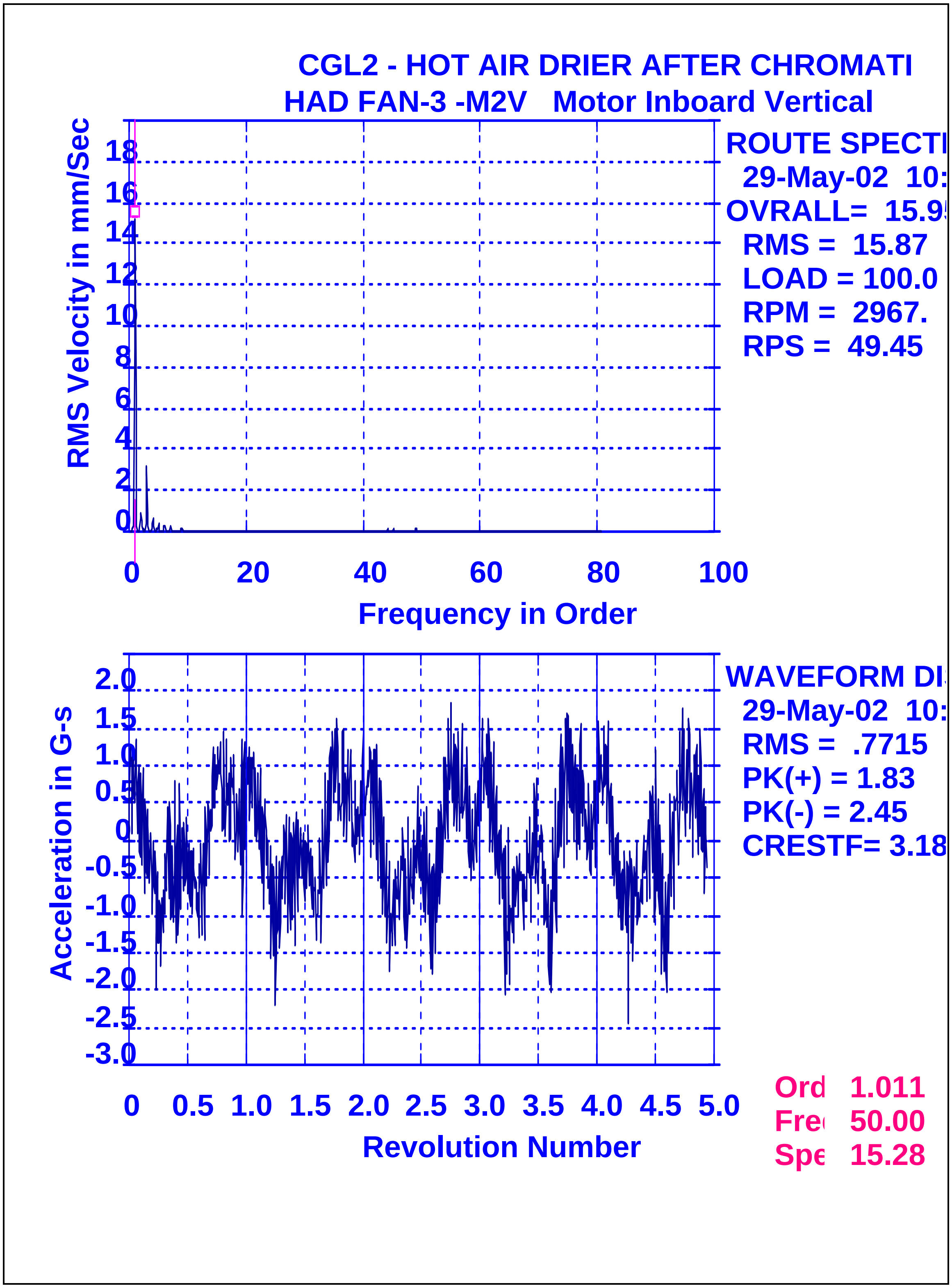
Regular vibration monitoring of blowers and necessary correction (Balancing, alignment, Foundation correction etc.) has resulted in performance and reliability improvement of Blowers.

1) CGL1 Preheat Combustion Air Blower 1 Spectrum before and after Balancing


CGL1 - PREHEAT COMBUTION AIR BL - 1
FAN-04 -F2H Fan Outboard Horizontal
RMS Velocity in mm/Sec
0
3
6
9
12
15
18
21
24
0
2
4
6
8
10
12
14
16
18
Frequency in Order
Route Spectrum
07-May-02 09:50:45
OVRALL= 19.25 V-DG
RMS = 19.21
LOAD = 100.0
RPM = 2957.
RPS = 49.29
Ordr: 1.000
Freq: 49.29
Spec: 18.76


CGL1 - PREHEAT COMBUTION AIR BL - 1
FAN-04 -F2H Fan Outboard Horizontal
RMS Velocity in mm/Sec
0
3
6
9
12
15
18
21
24
0
2
4
6
8
10
12
14
16
18
20
Frequency in Order
Route Spectrum
31-May-02 17:20:35
OVRALL= 5.35 V-DG
RMS = 5.17
LOAD = 100.0
RPM = 3114.
RPS = 51.90
Ordr: 1.000
Freq: 51.90
Spec: 4.227

2) Spectrum showing foundation bolt loose. Motor foundation bolt was found loose and crack.



We have also been using Laser Alignment Tool extensively, which has resulted in reliability improvement of rotating equipment. Alignment time has also reduced drastically by using this equipment, which has resulted in increased availability of equipment.

Industrial Videoscope System has been used widely at CRM for condition monitoring of Gearboxes and Bearings.

Recently, this instrument was used for inspection of SPM Tension Reel Motor Bearings.
Scoring marks have been observed in Rollers and Races of SPM Tension Reel Motor Bearings (Both Drive Side and Non Drive Side) through Videoscope which shows initial deterioration of the bearings. Ferrography reports also show bearing particles in the oil. Based on this observation, we have changed over to new synthetic oil for lubrication and bearing are under constant watch for any further deterioration.

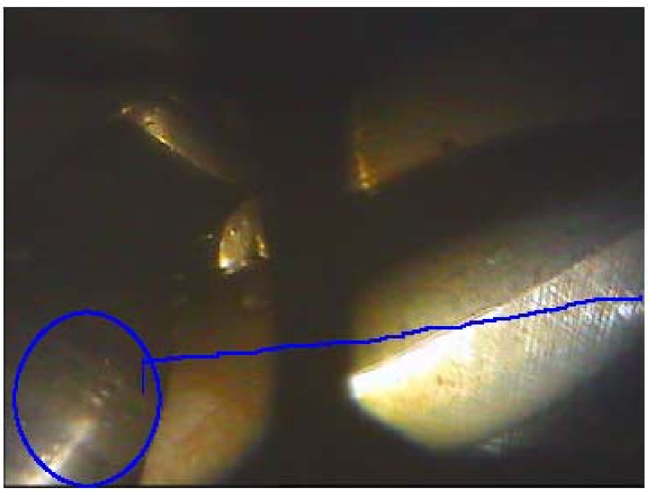
Some of the Photographs taken from Videoscope are shown below.

PART:

OUTER RACE TRACK

OBSERVATION:

SLIGHT PITTING MARKS PRESENT



PART:

ROLLING ELEMENT

OBSERVATION:

SLIGHT PITTING MARKS PRESENT ON PERIPHERY

CONCLUSION:
INITIAL DETERIORATION OBSERVED.

Conclusion:

Condition monitoring and pro-active maintenance is today a key part of industrial asset management. Now, Maintenance is not considered as a necessary cost but as a strategic asset. Maintenance influences the entire operation, from product quality to on-time delivery. Poor maintenance procedures lead to substantial amount of cost expenditure for repairing and poor quality and lost production — whereas good maintenance practices can cut production costs immensely. Predictive maintenance is designed to help organization to optimize the effective use of machines and assets in order to maintain a cost competitive advantage in their respective market place.

References:

1. C. Mishra, J.K. Takkar and T.C. Alexander, Tata Search, 1997- Achieving Breakthroughs in Maintenance
2. G.R.P. Singh, A.K. Chaterjee, H.K. Gupta, A. Ranjan and H.C. Kharkar, Tata Search,2000- Maintenance System Design for Cold Rolling Complex