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19th June 2011

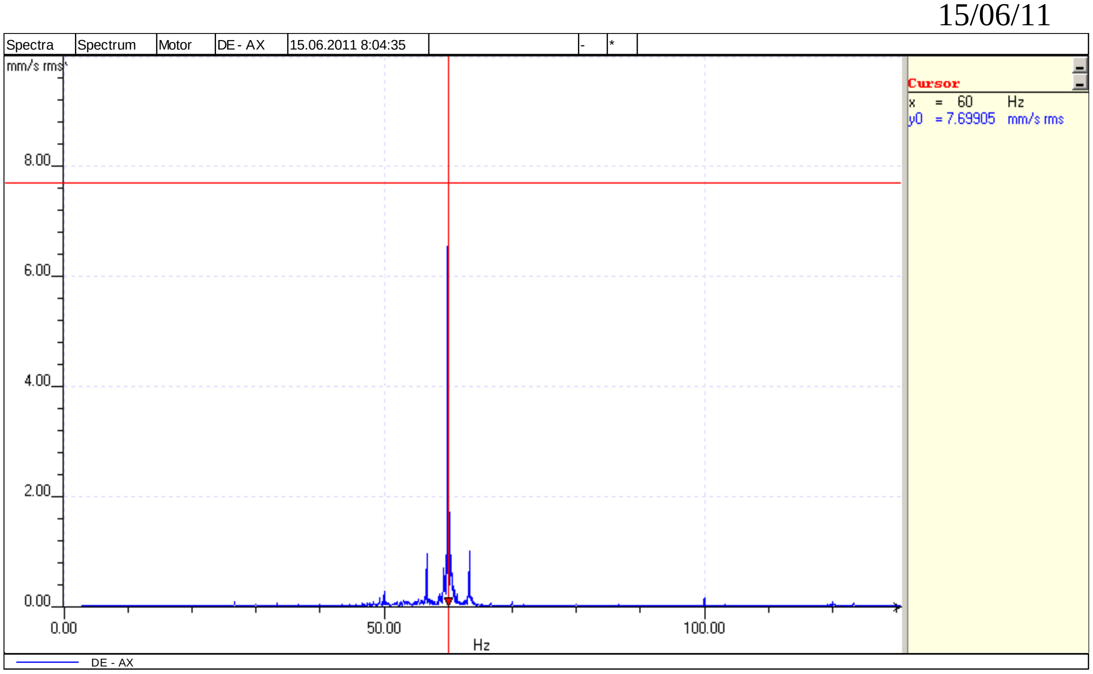
Att: XXXXXXXXXX

Ball Mill Pedestal Vibration

The highest amplitude of vibration on the ball mill drive was recorded in the axial position on the drive end motor bearing; with a amplitude of 7.7 mm/s rms at 60Hz. The source of the vibration emanates from the pinion gear mesh frequency (GMF) i.e. 18 teeth X 200 rpm ÷ 60 = 60Hz. However, GMF by itself is not a defect frequency. GMF will always be present in the spectrum regardless of gear condition. Its amplitude may vary, however, depending on the gear condition.

In plot #1 side bands at a frequency equal to the operating rpm (3.33Hz) are in evidence, this is another pointer to the source of vibration recorded on the DE pedestal. In gear analysis, sidebands can prove to be very valuable when diagnosing gear defects. Sidebands will show up as frequencies on either side of the GMF. The side band frequency spacing will be equal to the turning speed of either the input shaft speed or the output shaft speed. The spacing of the sidebands will be equal to the turning speed of the gear that possesses the defect. Side bands will appear most commonly because of wear, looseness and eccentricity.

Plot #1 15/06/11



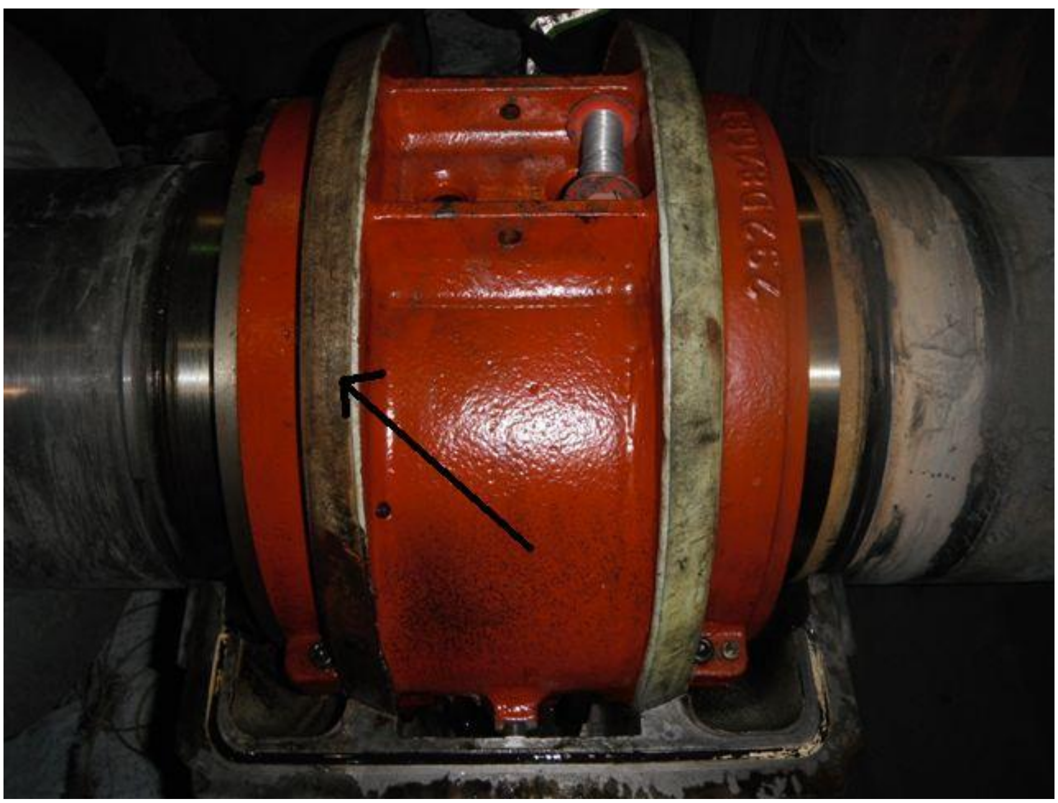
The presence of sidebands is important; however the amplitude of the sidebands relative to the GMF amplitude is more significant than the amplitude of the GMF. If the amplitude of the sidebands approaches the amplitude of the GMF the defect could be severe.

The GMF recorded in the axial axis on the drive end pedestals of the sag mill, ball mill and regrind mill are 1.52, 1.03 and 0.48 mm/s respectively. As per my explanation above, this type of frequency is inherent in helical gear drives; the mystery is how this amplitude is being transmitted and an amplified by a factor of seven on the drive end ball mill motor bearing. The most probable answer is resonance; resonant frequencies occur naturally in all structures, but do not appear in the spectral data unless some other frequency excites the resonance. Waveform and phase analysis along with “bump” tests would have helped to confirm resonance, unfortunately these tests were not possible with the equipment available.

The vibration history data available commenced in March of 2010 and the high axial vibration amplitude was already in evidence; it is unlikely that this has been a problem since the mill was commissioned 15 years ago, therefore a physical inspection was necessary to look for changes/wear in the motor.

The following problems were found when the mill was inspected all of which could contribute to the resonance amplification:
The motor drive end bearing diameter is worn approximately 2mm and excessively loose in the bearing pedestal, in photograph #1 the worn bearing insulation can be seen. The polished areas on the edges of both insulation rings indicate that the bearing has been rocking in the pedestal (see photo #2). The internal diameter of the drive end bearing pedestal appears to be worn. Evidence of fretting can be seen in photo #3, the amount of wear is not known because measurement was not possible because of the shaft.

<u>Photo #1</u>



<u>Photo #2</u>

Photo #3

The webbing on the sole plate (photo #4) directly underneath the drive end motor pedestal was cracked and one sole plate hold-down bolt underneath the pedestal was loose

Photo #4

The bearing insulation resistance was 0Ω @ 9V (with a fluke meter), this is allowing circulating currents to pass through the bearing affecting the viscosity of the oil and causing electrical etching/scoring of the bearing journal. The bearing temperature gauge and the RTD probes are not insulated! Therefore even if the bearing insulation had been sound the bearing would still have been grounded through the probes. Photo #5 shows contamination and dirty oil on the RTD probe.

Photo #5

Other observations:

One of the motor drive end oil rings had loose screws, the holes in the brass are elongated and the screws nearly worn through, see photo # 6 & 7.

Photo #6

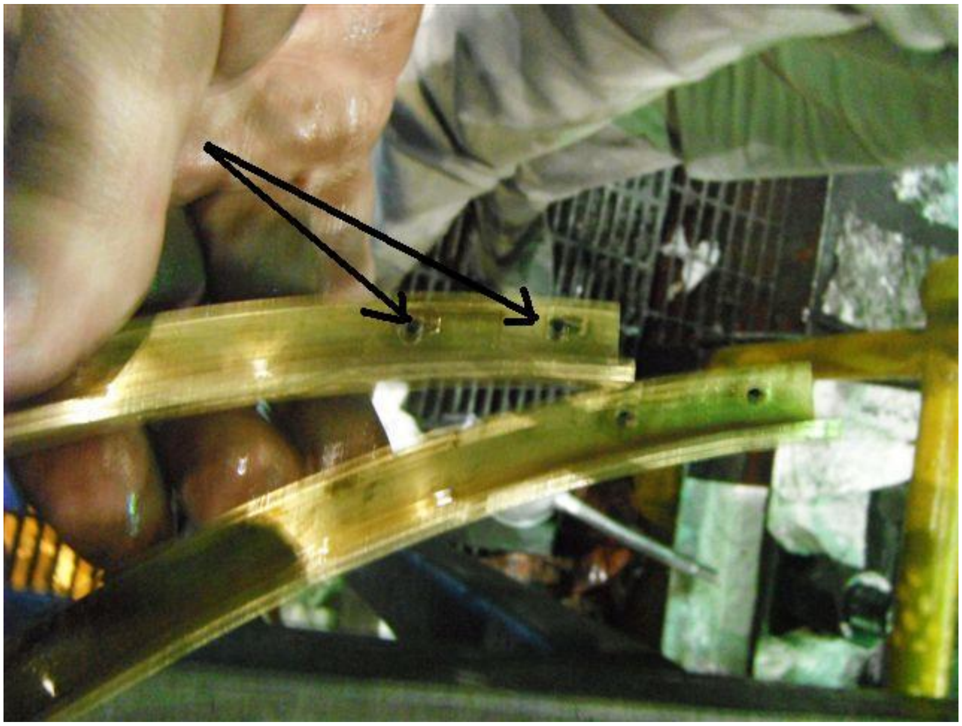
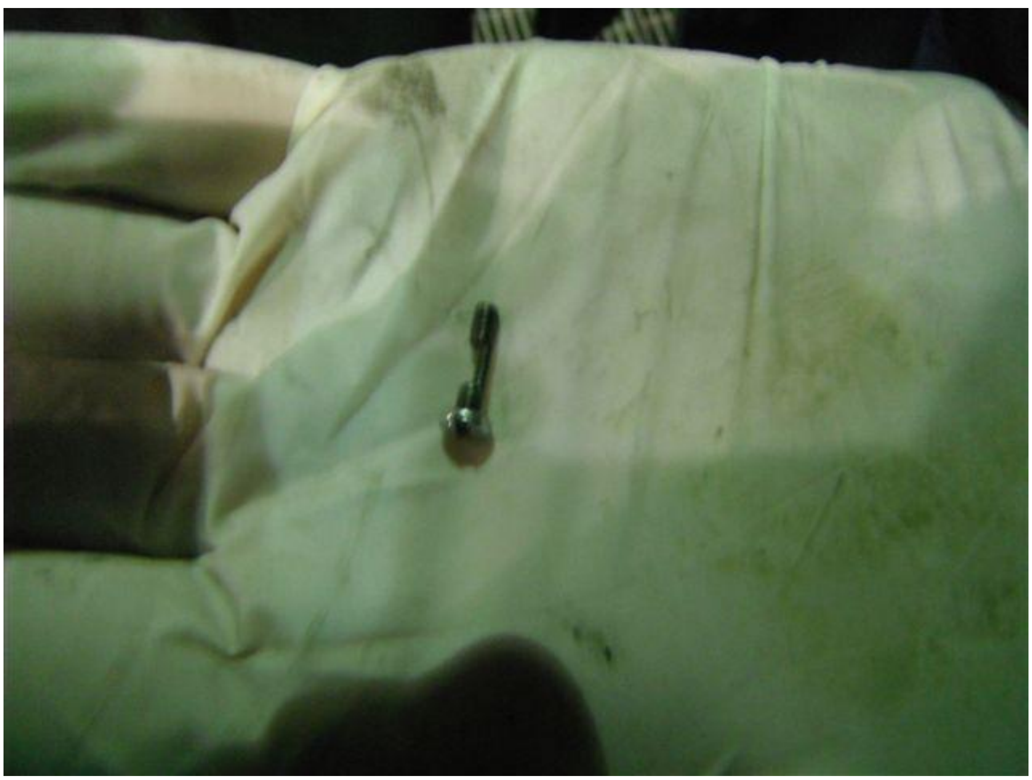


Photo #7



Bearing Dimensional Measurement and Clearances

Motor Drive End Bearing

Horn Clearances
(Between journal & babbit)

Babbit Outer Casting to Pedestal
Side Clearance

O/B

0.0065” **Bottom Shell** 0.0065”

0.0065” 0.0065”

I/B

Journal to Babbit
Top Clearance

ODE

0.018”

0.009” 0.012”

DE

0.017”

0.013” 0.013”

O/B

0.0015” **Bottom Shell** 0.0015”

*0.017” *0.0065”

I/B

Babbit Outer Casting to Pedestal
Top Clearance

DE

* >0.030”

*>0.030” *>0.030”

ODE

*0.025”

0.014” 0.015”

* = out of spec’
! The total pedestal to bearing clearance on inboard side is approx’ 2mm

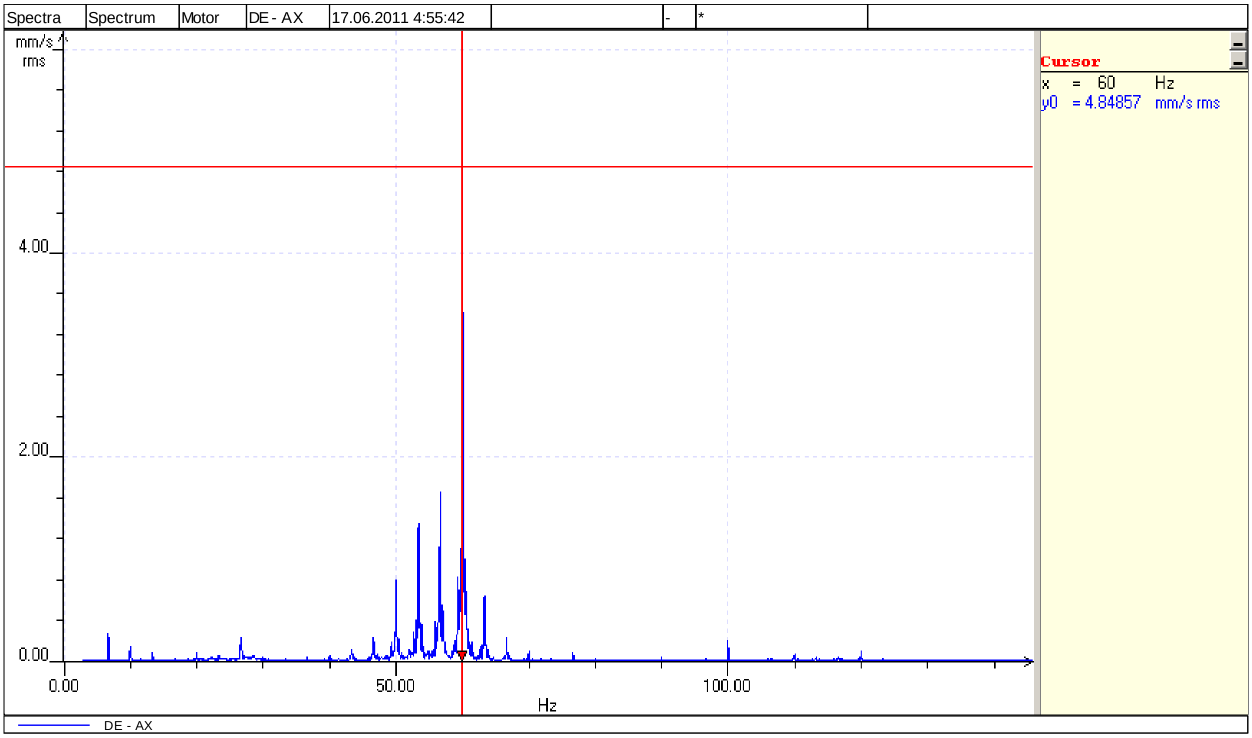
Journal Shoulder to babbit face gap: Outboard = 0.240” (both sides) Inboard = 0.355” (both sides)

It wasn’t possible to determine the amount of wear in the drive end pedestal, therefore we decided to reinstall the old bearing rather than risk damaging the new one. There was heavy contact on one end of the bottom babbit shell and too much side contact; I scraped the babbit to improve the fit but due to time constraints did not re-check the fit with Persian/engineers blue. Due to the amount of outer diameter wear, the bottom babbit shell could not be rolled into place as normal. The shaft was lifted approx’ 0.030” and both halves of the bearing clamped together with a soft top shim of 0.050” between the journal and top babbit. The shaft was then lowered into place, this ensured good contact along the bottom of the journal. The horn clearances were recorded @ 0.0065” ± 0.0005”. The top internal babbit clearance was 0.018” at both ends.

Shaft “Lift”
The oil wedge lifted the motor shaft 0.005”

Vibration Amplitude after Re-Assembly:
After re-assembly with the broken web welded, sole plate bolt tightened and old babbit bearing scraped and re-installed. The drive end motor pedestal vibration amplitude at 60Hz in the axial direction dropped to 4.85 mm/sec rms (see plot #2), I expect this amplitude to drop again when the new pedestal and babbit is installed in July.

Plot #2 17/06/11



Recommendations:

Replace the RTD's and temperature gauge probes with an insulated type. During normal operation the opposite drive end bearing is insulated and the drive end bearing is grounded, this prevents shaft currents from circulating. The reason that both bearings are insulated is so that when the grounding bolt (located in the top of the drive end bearing pedestal) and the axial locking device are removed the insulation resistance can be measured and recorded during your regular PM's. The resistance should be a minimum of 2 MΩ @ 100V.

If you wish to do more than trend vibration levels, and have minimal diagnostic capabilities, upgrade your vibration analysis hardware and software. The ability to carry out waveform, phase analysis in addition to spectral analysis will greatly help Oleg with trouble shooting, I have given him a list of recommended software and hardware upgrades.

A "Hi-torque" should be used in future for the opposite drive end sole plate bolts, access is very restricted.

The motor windings are very dirty (see photo # 8), If possible it would be beneficial to clean the windings with dry-ice blasting, I have had a great deal of success cleaning windings up to 13.8Kv. With newer dry ice machines, the pressure can be turned down low enough so as not to be detrimental to the winding insulation, compressed air alone will not remove dust that is contaminated with oil. I could recommend a company but I am not sure if they could help because of the logistics of getting machines and ice to the mine site. Let me know if you would like me to pursue this avenue further for you.

Photo #8

New Babbit and Pedestal Dimensions

New Babbit Bearing:
ID = 13.018” (Both ends)   OD = 23.992” (Both Ends)

New Pedestal
ID = 23.9937” (Both Ends)

Babbit to Pedestal Clearance – 0.0017”

Pedestal Removal during July Shutdown

The width of the pedestal is 20” and the space between the pedestal and rotor with the guards removed is 22”, this will enable easy removal/replacement of the drive end pedestal. However; the hoist rope could conceivably rub on the stator windings and provision should be made to protect them. With the rotor shaft jacked and blocked and labyrinth seals removed, the bottom half of the pedestal could be moved along the shaft with the hoist and with the aid of come-along attached to one side lowered and swung from beneath the shaft.
Note: in addition to the babbit bearing and pedestal replacement a new oil ring should also be installed.

Photo #9

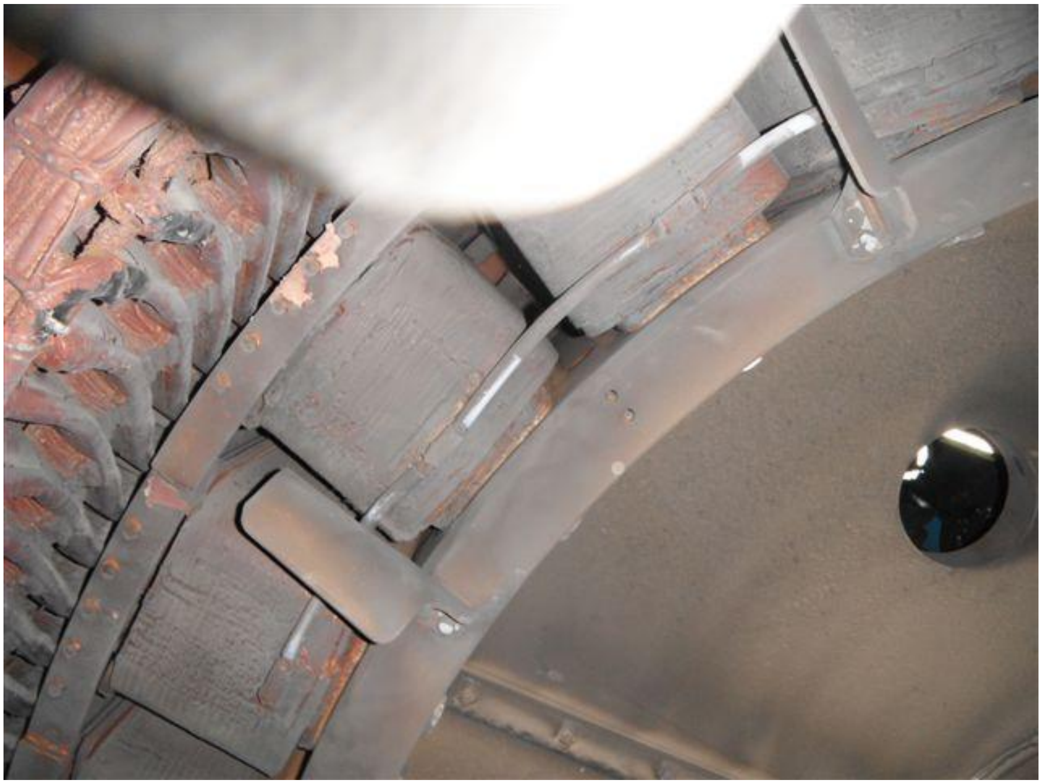
Re-Grind Mill – Inspection

Due to time constraints we could only do a limited inspection of the regrind mill.

General Observations:

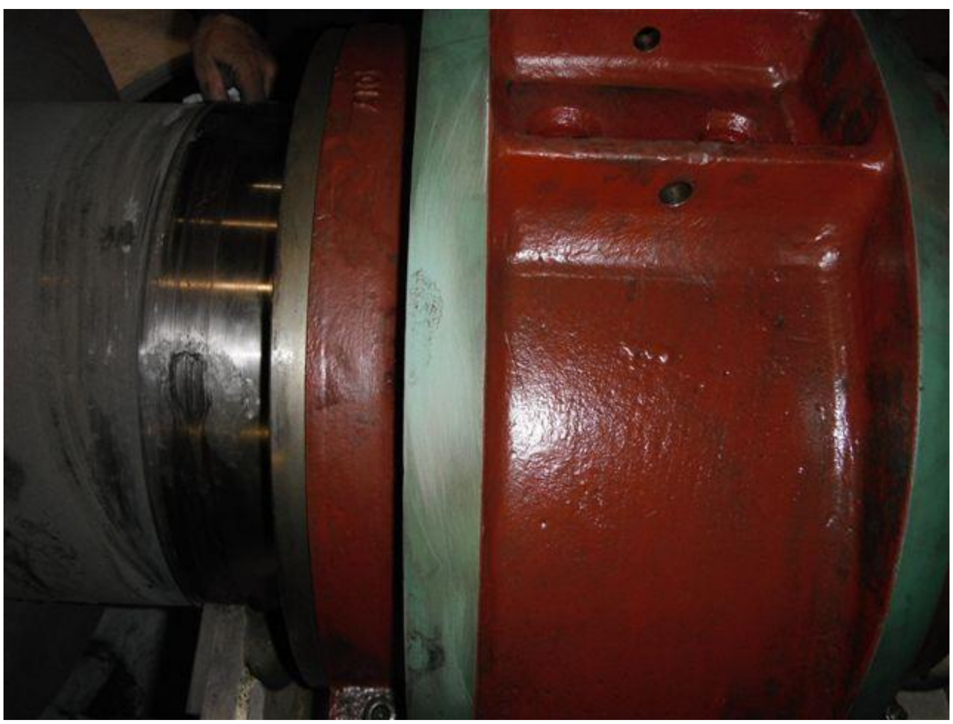
Varnish/paint on the amortissuer winding was peeling (see photo #10), this is not unusual and not normally a problem; however, the peeling is in the same location on both ends of the winding and at no other location. This could be just a coincidence and of no concern but it could also be an indication of winding problems. Broken rotor bars or broken rotor bar to end ring brazed joints would cause localized heating and the paint/varnish to burn. The rotor bar to end ring connection was tested using NDT equipment and no cracks were found. If the rotor bars are broken inside the pole piece the motor will lose starting torque, therefore it would be prudent to monitor and trend “run up” time. Removing a pole piece and replacing broken bars on site would be very difficult because of the weight of the pole and re-locating pole face shims during re-assembly.

Photo #10



Metal had "picked up" on the shaft in the outboard labyrinth area (photo # 11); I checked the shaft to pedestal labyrinth clearance with feeler gauges when re-assembled and found adequate clearance, therefore the metal build up must have been from a previous failure.

Photo #11



Fretting marks are in evidence on both the bearing insulation (photo #12) and top bearing cap (photo #13 & 14). I measured the clearance between the bearing and the pedestal and found it to be within spec' i.e. Outboard 0.015" and Inboard 0.018" initially it appeared that insulation had failed but after cleaning the insulation integrity was found to be good. We are uncertain why this has happened in such a short time, there are a few possibilities i.e. vibration – another resonance problem, or circulating currents, with the axial locking device removed and RTD's / Temp probes removed the insulation was good – 1GΩ @ 250V. However, the probes are not insulated and there will be circulating currents going through the bearings.

Photo # 12

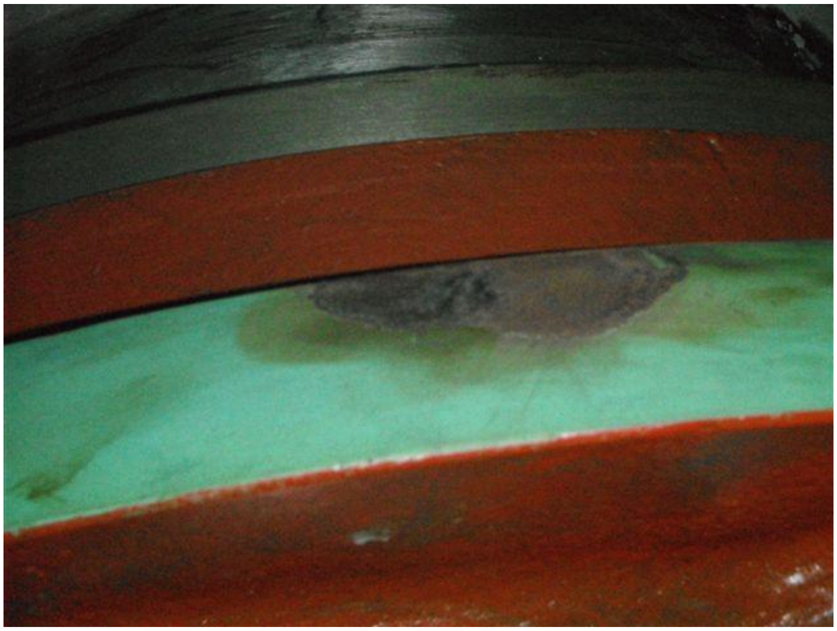
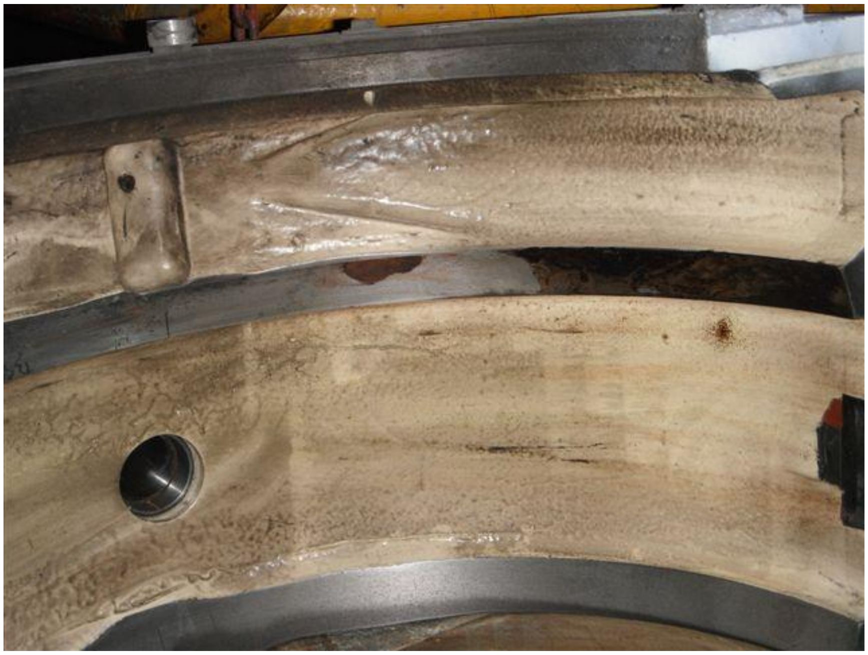


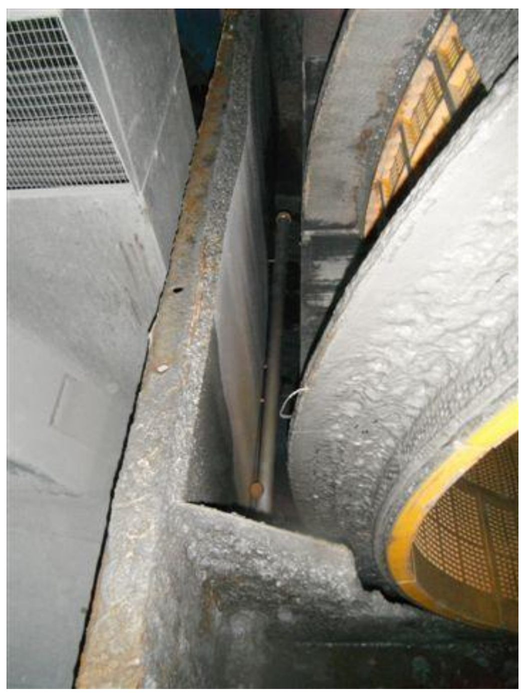
Photo #13

Photo #14



For Future Reference
Photo # 15 is of the ball mill wall that will have to be modified at some point in time to accommodate re-torquing of the stator feet or rotor/stator air gap alignment.

Photo # 15



I trust that this full fills your requirements but if you have any further questions please do not hesitate to contact me.

Regards: Rob Brentnall