

***“High Vibrations & Component Failure In  
Turbomachinery Due to Magnetic Currents”  
: Its Detection, Diagnosis & Correction***

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# Abstract

Objective : To share with users of Turbomachinery the fact that High Speed Turbomachinery with components possessing Residual Magnetism produces high shaft voltages & high current, which can lead to severe problem like high Vibrations, damage to the machine components and can cause heavy production loss.

Scope : The Case Study details this typical problem due to residual magnetism in Synthesis Gas Compressor at National Fertilizers Limited, Panipat Unit, INDIA, in which the problem lead to repeated overhauls of compressor, replacement of three numbers of rotors, damage to number of bearings & Oil film seal rings . It details work associated in diagnosis of the problem, measure taken for temporary relief, so as keep machine running and final work done for permanent solution of the problem.

# Abstract - cont'd

Result of the Case Study:

**The machine behaved normally after the rectification job, at low vibration levels.**

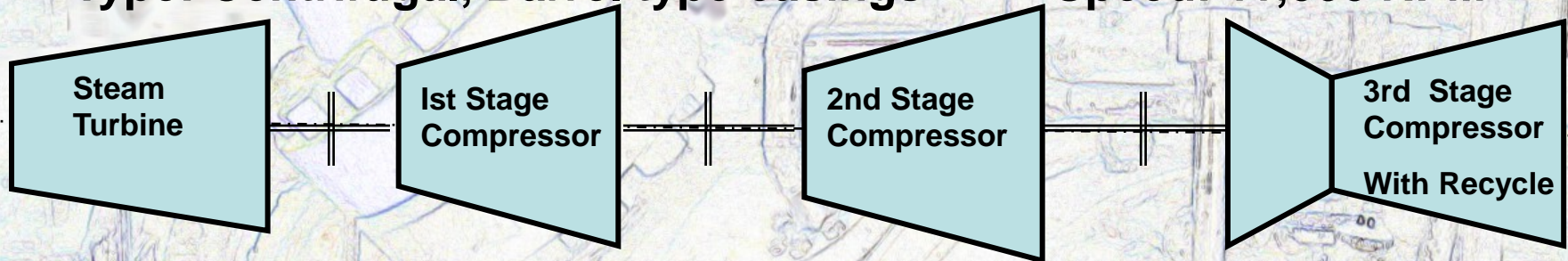
Lesson Learnt :

**The Residual Magnetism can cause typical problems in Turbo machines, like High Vibrations, Component Failure, causing severe limitations in machine. Its early detection is typical but ways are there to detect it. The users of Turbomachinery & the Maintenance Team have to take precautions so as to prevent introduction of Residual Magnetism in the machine**

# Synthesis Gas Compressor – A brief Description:

Type: Centrifugal, Barrel type casings

Speed: 11,000 RPM



End shaft Seals: Floating type Oil Barrier Seals

Journal bearings: Tilting pads type

STAGES	1st	2 <sup>nd</sup>	3rd and recycle stage	
<i>Model</i>	BCL-507	BCL-407a	2BCL-407b	
<b>Gas Handled</b>	Syn. Gas (H <sub>2</sub> +N <sub>2</sub> )	Syn. Gas (H <sub>2</sub> +N <sub>2</sub> )	Syn. Gas (H <sub>2</sub> +N <sub>2</sub> )	Recycle Gas
<b>Capacity (Dry) Nm<sup>3</sup>/ Hr.</b>	99,960	99,960	99,960	4,64,300
<i>Intake Conditions:</i>				
<b>Pressure (kg/cm<sup>2</sup> abs.)</b>	37.5	80	146	219
<b>Temperature (Deg.C.)</b>	33	41	41	34
<i>Discharge Conditions:</i>				
<b>Pressure (kg/cm<sup>2</sup> abs.)</b>	81.6	148.5	221	235
<b>Temperature (Deg.C.)</b>	144	133	113	43.5

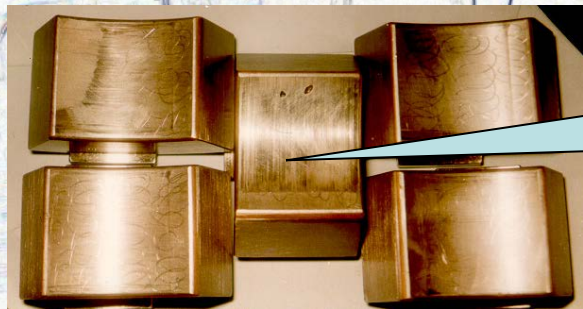
# Beginning of Problem:

High vibrations used to appear on Intake end of second stage of Compressor, BCL-407a.

Vibrations used to attain high value of 5 mills / 125 microns (shaft vibration as on monitor)

Whereas shaft vibration on discharge end was normal (0.4 mills)

Inspected bearings and observed rubbing / babbitt removal in bottom tilting pads of Intake end journal bearing



Replaced the journal bearing with new one

# Status after Bearing Replacement:

- Vibrations at intake end decreased to 2 mills (50 microns) & at discharge end was 0.4mills.
- But again within a span of one to two months the vibrations used to increase to 4.0 mills at intake end whereas the discharge end it was normal .
- Vibration magnitude:

<i>First stage</i>		<i>Second stage</i>		<i>Speed/ load</i>
<i>Discharge end</i>	<i>Intake end</i>	<i>Discharge end</i>	<i>Intake end</i>	
0.7 mills	1.2 mills	0.4 mills	4.0 mills	11200 RPM / 100% load

- The clearance of journal bearing at Intake end used to increase to 0.20 to 0.22mm against maximum allowable value of 0.15mm.
- We could not increase the machine load beyond 100%as beyond this load, vibrations used to increase further on second stage

# OVERHAULING OF COMPRESSOR

The second stage of compressor was opened for overhauling in plant turnaround

**Observations:** Corrosion (metal removal) marks were observed on rotor shaft at the seat of thrust collar.



**Work Done:** Rotor replaced with spare rotor  
Assembly was made with new journal bearings & oil seal rings

## Status after the Overhauling:

Normal vibrations upto 66% load

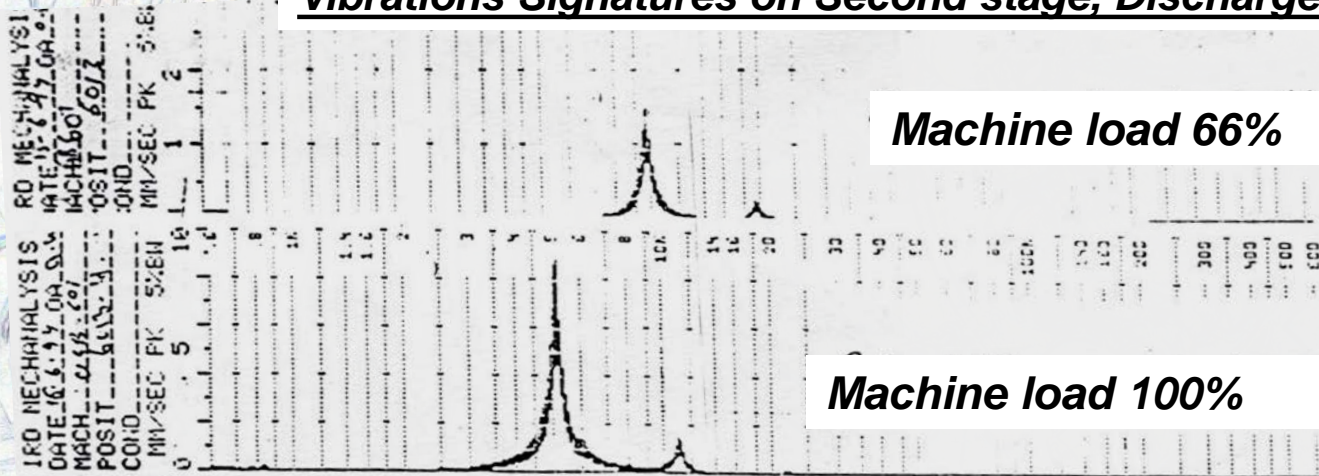
High vibrations at discharge end beyond 66% load

Normal Vibrations on intake end

# Status after the Overhauling- Cont'd:

First stage		Second stage		Speed/ load
Discharge end	Intake end	Discharge end	Intake end	
0.6 mills	1.1 mills	0.4 mills	0.3 mills	3000 RPM
0.6 mills	1.4 mills	0.7 mills	0.4 mills	9000 RPM
1.0 mills	1.3 mills	0.9 mills	0.4 mills	10580 RPM / 66% load
0.8 mills	1.3 mills	4.5 mills	0.6 mills	11200 RPM / 100% load

## Vibrations Signatures on Second stage, Discharge end



Observ

At 100% load peak component appeared at 0.44 times the running speed

At 66% load this component at 0.44 times RPM disappeared

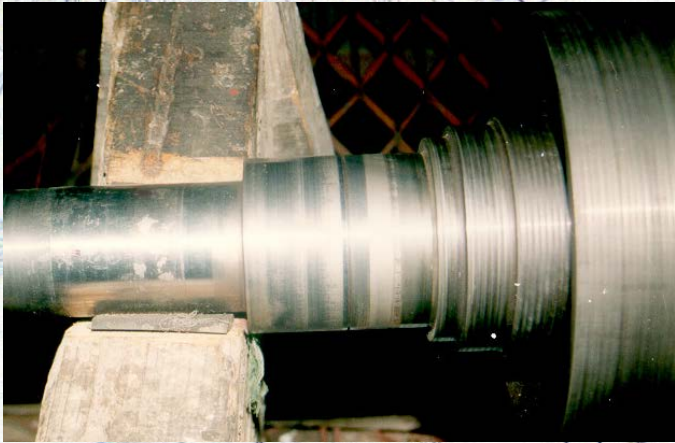


# Second Overhauling of Compressor

We kept running the machine on low load & then again opened the second stage for overhauling.

**Observations:**

**The labyrinth seal of balance drum was rubbed / damaged & rubbing on gas seal & balance drum seal area on rotor**



**The alignment was checked & found to be within design limits.**

**The assembly was made with spare repaired rotor, new bearings & oil seal rings**

# Status after Second Overhauling:

- On restart after overhauling the *vibrations* were:

First stage comp.		Second stage comp.		Machine Load
Discharge End	Intake End	Discharge End	Intake End	
1.5 mills	1.7 mills	0.5 mills	0.4 mills	106%
1.2 mills	1.3 mills	2.1 mills	0.4 mills	106%
1.0 mills	1.4 mills	2.9 mills	0.8 mills	108%

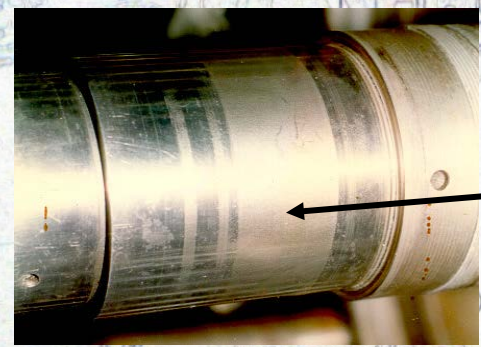
- Slowly within few days seal drain rates in second stage compressor started increasing, indicating high clearance in floating type oil seal rings
- Decided to inspect the oil seal rings & bearings of first & second stages

# Observations on Bearings & Seals Inspection

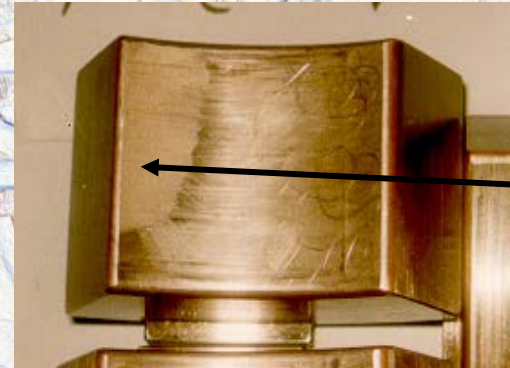
- Frosting, grooving & burning marks & spark damage was observed on babbitt of H.P. seal rings with deep babbitt removal



Heavy frosting on rotor shaft journal on half of circumference



Frosting on Shaft Journal



Frosting on Journal Bearing Pads

Thrust bearing pads (first stage) had deep grooves, frosting and burning marks



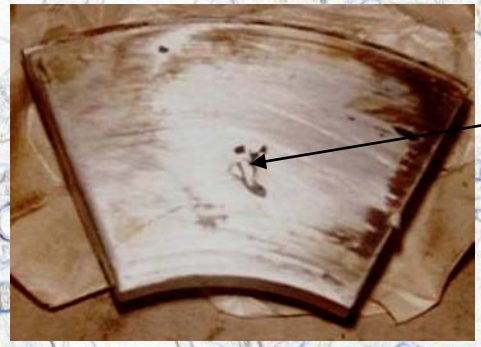
# Diagnosis

The pattern of damage was giving clear symptoms & evidence

The frosting on half of shaft circumference, burning marks, repeated failure of oil seals, bearings, high vibrations, which persisted even after change of rotors, oil seal rings & bearings were showing high probability of high electromagnetic current discharge through these components.



Melting pits & arcing grooves on Babbitt of seal ring



Frosting & burn spots on Thrust Bearing Pads

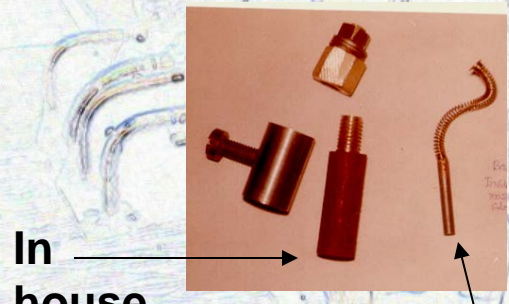
Spark tracks on back seating area of journal bearing pad

All above were distinctive features & indicators of Electromagnetic shaft currents.

# CORRECTIVE ACTION PLANNED

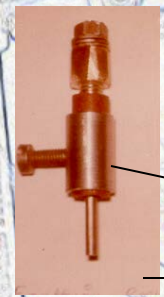
We decided to fix shaft grounding brushes in second stage of compressor (as these were not provided initially on compressor or turbine ), for following reasons:

- To detect the presence of shaft currents & voltages & to measure them
- Shaft grounding brushes could help us in providing relief to some extent in case of presence of high shaft currents .
- Carbon Bronze spring loaded sticks in stock (provided by OEM of oxygen compressor for their machine) were fitted in in-house fabricated holder & was installed on second stage compressor on upper half of journal bearing cap of intake end (in plane of vibration probes).

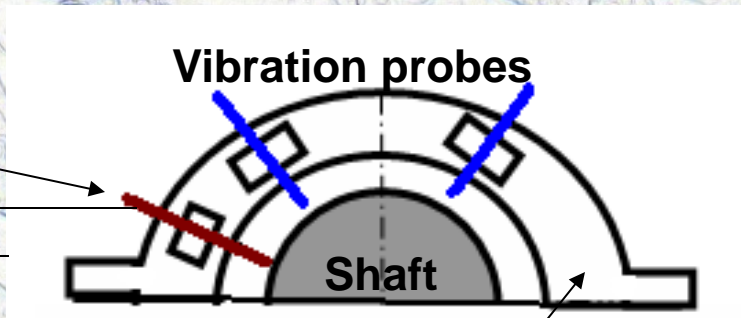


In house made holder

Carbon bronze grounding brush with spring



New installed grounding brush



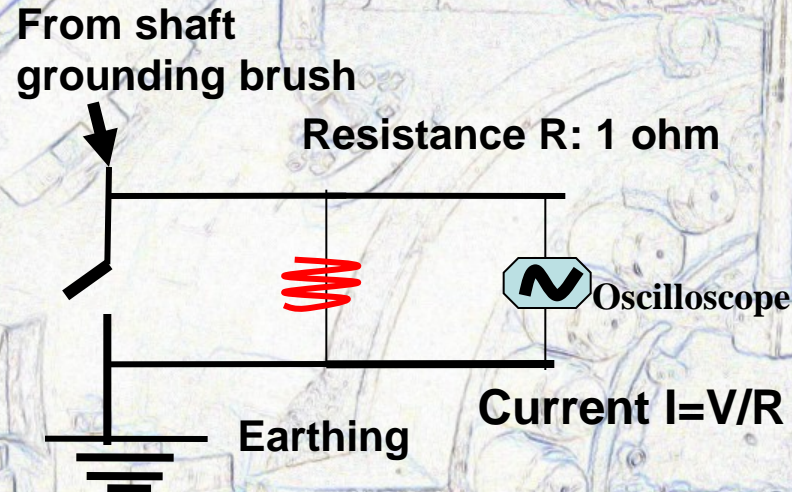
Vibration probes

Shaft

Bearing Bracket

# Results with Grounding Brush installation on second stage

Measured Shaft current by connecting Oscilloscope. High voltage spikes were observed. Indicated presence of High electromagnetic shaft currents



Vibration magnitude:

First stage comp.		Second stage comp.		Machine Load	Speed
Discharge End	Intake End	Discharge End	Intake End		
0.8 mills	3.0 mills	1.2 mills	1.3 mills	106%/	11280

**Result:** The vibrations of second stage came down. But vibrations on first stage started increasing.

**Action:** We installed similar shaft grounding brush on First stage.

**Result:** The vibrations on First stage came down.

# Permanent Solution to the Problem

- As shaft grounding brushes can help in milder cases , but are not permanent solution to the problem of electromagnetic in nature.
- The complete relief from problem was only by degaussing of magnetized parts, which could include rotors and static components (of compressors and turbine).
- During plant turnaround all the three stages of compressor & its drive steam turbine was opened.
- Magnetic survey of all internals like rotor, diaphragms, turbine glands blade carriers , bearing, bearing casing, couplings, seals etc. was done .

# Permanent Solution to the Problem - Cont'd:

*Residual magnetism found before degaussing:*

Rotor	120 Gauss	Against allowable value of max. 3 to 5 Gauss.
Casings	60 Gauss	
Bearing casing of second stage	200 Gauss	
Seals	15 Gauss	
Coupling	35 Gauss	

These residual magnetic field levels were brought down to below acceptable levels by demagnetization using Auto Demag machine i.e. less than 2 gauss in close clearance areas like bearings, Journals & seals and 8 gauss in other areas

**Result:** Machine behaved normally with low vibrations levels after this.



# ANALYSIS

## Lets review 'HYSTERISIS' Phenomenon

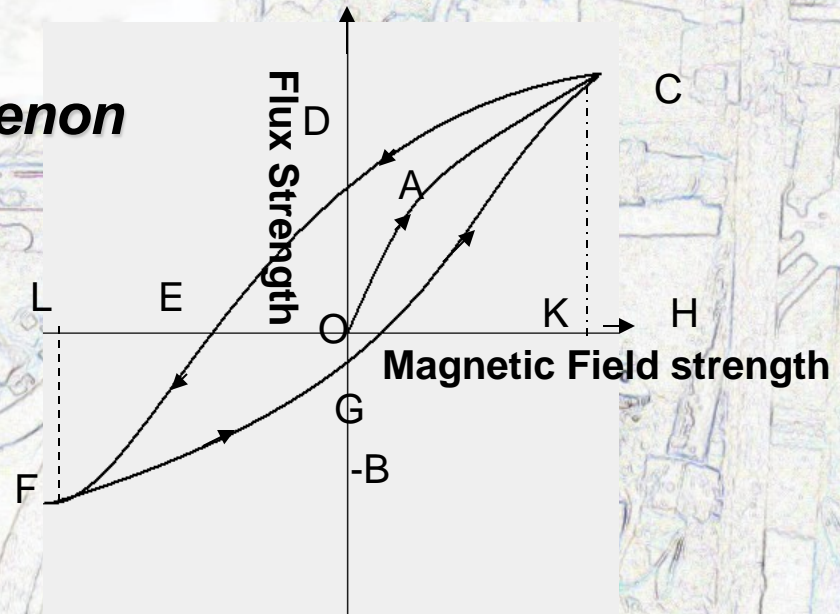
H: Induction force in oersted  
(proportional to Current)

B: Magnetic field in Gauss

OD: Residual magnetism, when  $I=0$

OC: Induced Magnetism

OF: Induced Reverse Magnetism



If we take a coil with demagnetized closed ring in it & pass an electrical current through that coil, then it produces a magnetic field perpendicular to that coil.

If this magnetic induction is quickly removed then the closed ring retains this magnetism which is called Remanent Flux Density or Residual Magnetism, which will be proportional to the current that was passed through this coil.

This phenomenon is known as '**HYSTERISIS**'

# **ANALYSIS - Cont'd**

## **'HYSTERISIS' in Turbomachinery:**

**The phenomenon of Hysterisis can occur in Turbomachinery mainly due to electric welding carried around the machinery, like on its pipeline, casing etc.**

**In case of electric welding we immediately drop the welding holder away from job which causes removal of current quickly, which is worst condition for magnetic field and results into residual magnetism somewhere in its components, which may be rotor, bearing, diaphragm, gland etc.**

**When such machines with components that stores a magnetic field runs at high speed, these machines become generators.**

**These currents generated in Turbomachinery will discharge through bearings, seals etc. which have minimum clearance and damage these components.**

**Every machine however, has a shaft voltage threshold beyond which problem will ensure.**

# CONCLUSION:

- In our case an Electric Arc Welding was done around the Synthesis Gas Compressor train , on nozzle of reference gas lines on second stage, just before start of the problem
- This probably introduced the residual magnetism & caused the repeated failures of components and high vibrations in the machine due to electromagnetic currents.

## *Reason for Increase in problem severity:*

Initially we were not getting full symptoms of electromagnetic currents due to weak voltage.

Finally residual magnetism must have reached a level where the fields are strong enough to reorient themselves in such a manner as to allow self excitation in the area.

The vibrations, which in turn resulted into rubbing of rotating parts with static one e.g. with labyrinth of balance drum which must have resulted in sudden alignment of all small magnets in steel components, causing increase in magnitude of field strength .

## **CONCLUSION- Cont'd:**

**High voltage must have been generated thus breaking resistance of oil film of bearings & oil seal rings.**

**This results into flow of high shaft currents between static & rotary parts with which magnetic fields got intensified more with time.**

**Damages & problem started getting severe with time & clear peculiar symptoms of electromagnetic shaft currents like frosting , spark tracks, melting pits & arcing grooves started appearing on oil seal rings & bearings.**

**Spark roughening of surfaces of the seal bore (which has design clearance of 0.06 to 0.08 mm) starts promoting oil whirl.**

**Spark damages occur on the contact surfaces of these oil seal rings. This surface roughness created on its face restricts its free floating action with which it starts behaving like lightly loaded bearings thus further promoting the severity of oil whirl.**

**This resulted into increase in vibration level typically with frequency of 0.42 to 0.44 times running speed.**

# Lessons Learnt

- *Shaft brushes can help to ground shaft currents up to a point.*
- *They can do nothing about currents which are circulated within rotor or stator.*
- *The primary value of brush is that it permits monitoring of current level traveling between rotor & stator and to warn of current & voltages built up.*
- *This makes possible to prepare for thorough demagnetization during scheduled shutdown before a failure can occur'.*

**- Sohre, John S.**

The only way to eliminate shaft currents is to eliminate the magnetism, and to keep unit free of magnetic components which is introduced and place restriction on welding procedures around the unit. Thorough demagnetizing the complete train and it is consequently an expensive & time consuming solution, specifically when in today's era we are moving towards zero maintenance & no Shutdowns approach.

# Recommendations based upon experience

*In order to avoid such severe problem due to residual magnetism in Turbomachinery one should take following precautions:*

- Weld with precaution around rotating equipment (proper grounding)
- Checking for Magnetism should be mandatory for all overhauls.
- When bearing hubs are heated for shrink fittings on the shaft by induction heating then its full demagnetization should be ensured
- Discharge of high electrostatic currents through ground brushes continuously for a longer time should be avoided.
- Rubbing inside i.e. between rotating land stationery parts to be avoided.