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Stray Currents and their Damaging Effects on Rotating Machinery

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Biography: Dian J. Hanekom

Dian is a Rotating Equipment Engineer with 30 years experience in the Petrochemical and Nuclear industry currently working for TASNEE Co. in Saudi Arabia. His main expertise in rotating machinery is design, reverse engineering, vibration analysis, reliability engineering, best practices and project specifications. His specialties are dry-gas-seals, lube-oil-systems, centrifugal compressors and steam turbines.

Abstract

Stray currents manifest in rotating machinery as a result of specific abnormalities in machines related to flux imbalance, residual magnetism, electrostatic build-up and induced voltages. Discharges of these voltages in components can be very harmful and sometimes catastrophic. Typical damage include pit marks, spark tracks, frosting and electric erosion in components such as bearings, seals and gear teeth. The presentation summarize, typical damage caused by stray currents, diagnostic techniques to identify the problem, remedies to resolve the problem and highlights several case studies.

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- ❑ Introduction to Stray Voltages and Stray Currents
- ❑ Identification and Location of Stray Current Damage
- ❑ Symptoms Particular to Electromagnetic Stray Currents
- ❑ Diagnostic Techniques
- ❑ Remedies
- ❑ Case Studies
- ❑ Conclusion

Introduction

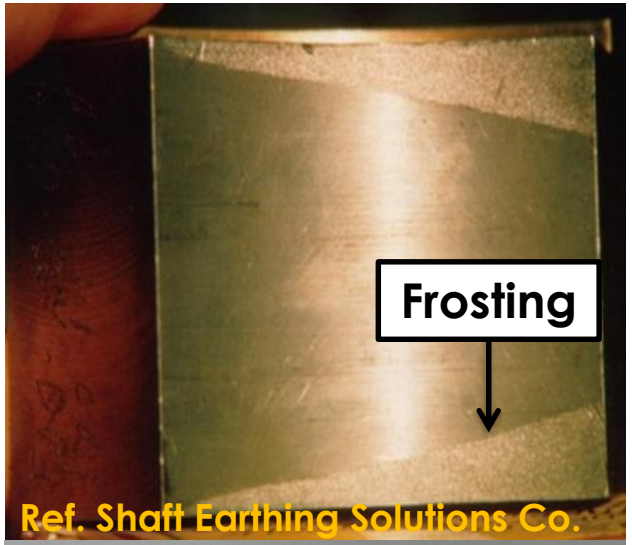
- **Stray voltages** are the occurrence of electrical potential between two objects that ideally should not have any voltage difference between them;
- These voltages can discharge as **Stray Currents**;
- Stray currents manifest itself in rotating machinery as a result of specific abnormalities related to: -
  - flux imbalance;
  - residual magnetism in parts;
  - electrostatic build-up in machines; and
  - induced voltages in electrical motors.

Introduction (Cont.)

- The field levels due to residual magnetism in machinery occurs NOT from design, but from manufacturing techniques (magnetic beds), inspection techniques (MPI inspections) or external influences like welding or lightning strikes.
- Gauss levels in parts have been measured from 2 to 100's of gauss. These levels can increase in machines during operation where the magnetic material provides a closed path and reduced air gaps.

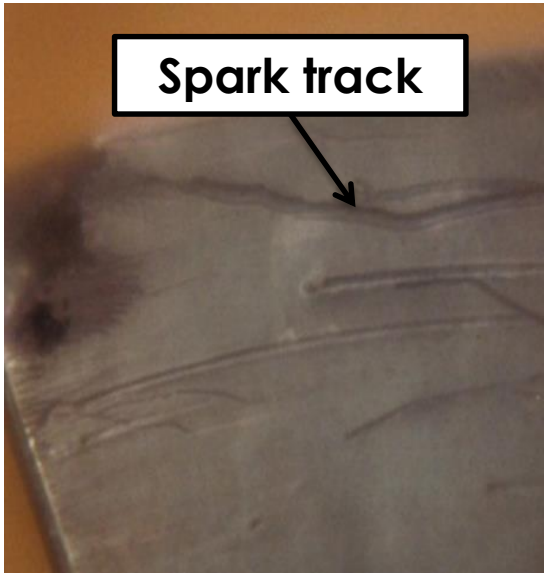
Identification and Location of Stray Current Damage (SCD)

- **Frosting** forms a uniform, continuous, satin-like surface, similar to sand blasting or shot-peened surface. It looks very much like a piece of frosted or etched glass, hence the term "frosting" or "spark etching".
- This kind of damage can be found on radial and thrust pads.



Identification and Location of SCD

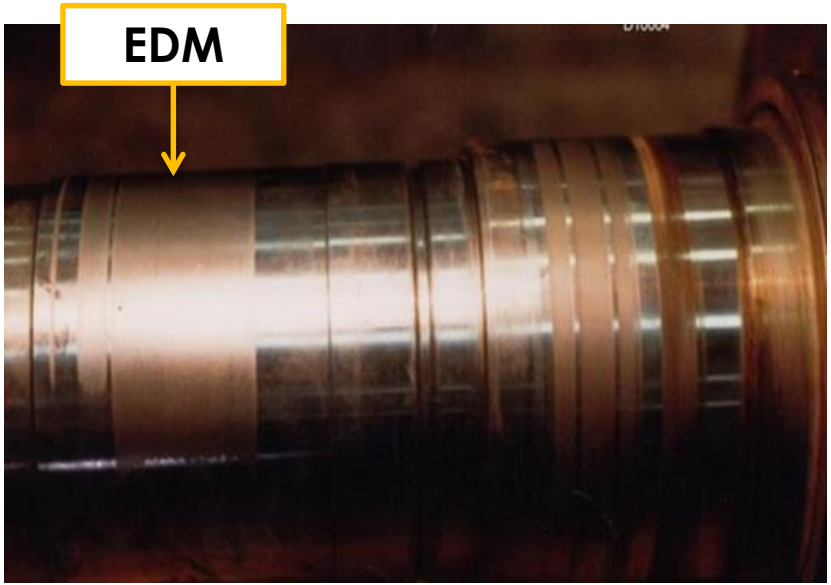
- **Spark tracks.** May be very fine, like 50 - 125 µm deep, an appearance like if drawn with a sharp needle, or may be as much as 3 mm wide. Tracks vary in length typically 3 mm to several centimetres long. Tracks may also zigzag like lightning strikes. Shining melted surface can be found at the bottom of the track.



Ref. Shaft Earthing Solutions Co.

Identification and Location of SCD

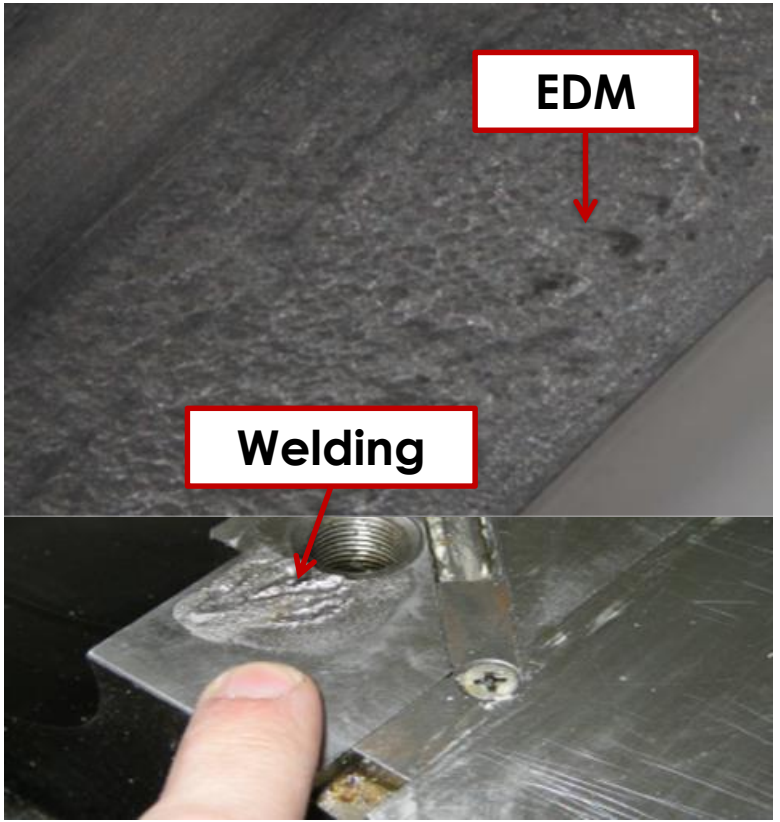
- **Electro-discharge-machining (EDM)** also called **"current etching",** or "spark etching", or "spark coining". The term refers to noticeable hard metal removal by the spark erosion process, example shaft frosting.



Ref. Shaft Earthing Solutions Co.

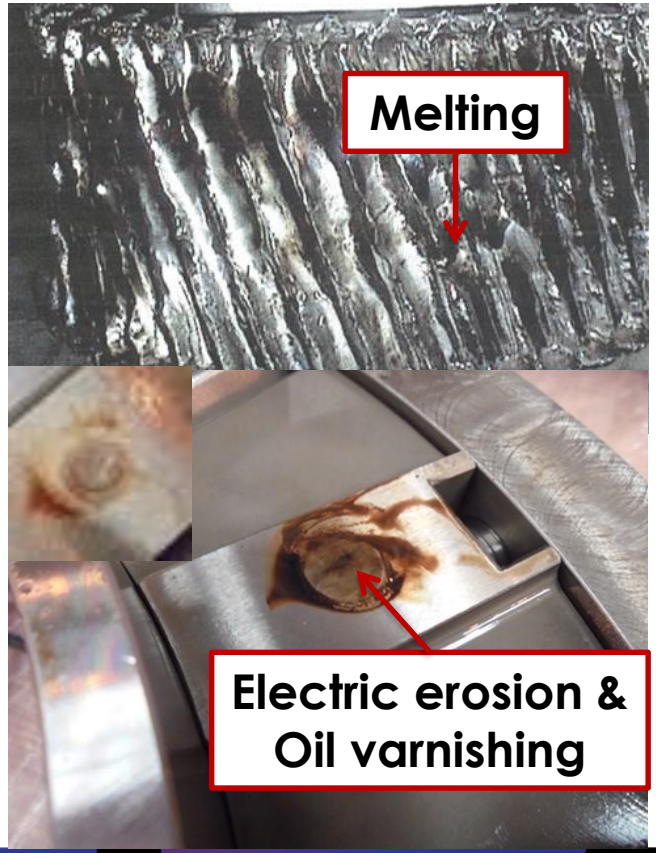
Identification and Location of SCD

An example of **EDM** is the erosion of floating carbon ring seals, both between carbon and shaft and carbon and carrier ring. Stray currents may form a closed loop between the seal, shaft and bearing housing, which can result in welding marks.



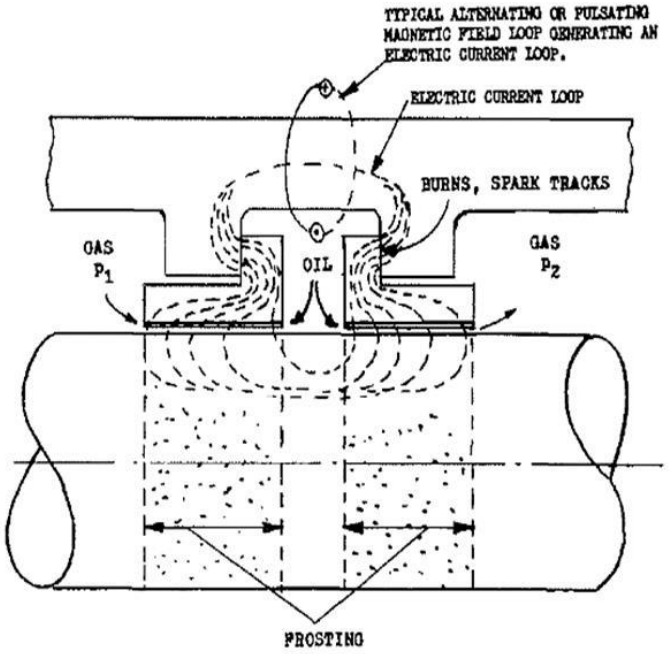
Identification and Location of SCD

- **Burned spots, welding, and arcing** of contacting parts. This occurs at contact areas, for example at the back of pivot points of thrust or tilting pad shoes, resulting in electric erosion and oil vanishing. Also, look for connecting parts on the shaft, example inner- and outer ring of timing gears, coupling gears and thrust collar sleeves.



Symptoms Particular to Electromagnetic Shaft Currents

- It is important to note that these current loops cannot be grounded since they are short-circuited within them-selves, they don't really care whether there is a ground or not. This makes careful de-magnetization of stator and rotor components imperative.

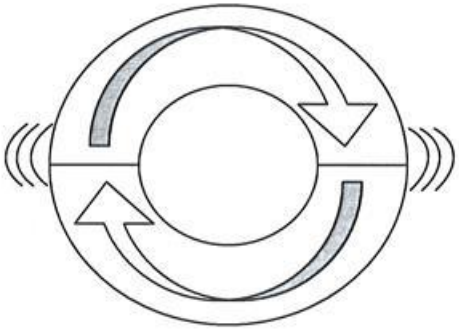


Reference: Sohre & Nippes

Diagnostic Techniques

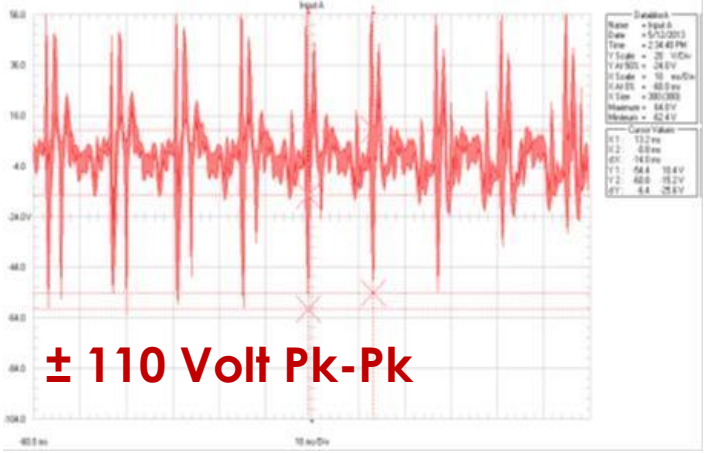
- **Electromagnetic Activity Testing (EMA).** **EMA testing** is conducted by recording the magnetic flux circulating in the machine using an electromagnetic microphone held at the split-line of casings and bearings. When the flux circulates within the housing the tiny gap in the split offers reluctance to the magnetic field and distorts the field. This forces the magnetic field to exit the metal path and rejoins after the split. An audible humming sound is recorded.

Electromagnetic microphone



Diagnostic Techniques (Cont.)

- **Shaft Voltage** measurements works on the principal that a hand held earth brush is put on the shaft with a wooden stick while the machine is running. The voltage is then recorded using an oscilloscope, while the voltage is pulled from the shaft via lead wires;
- An accurate assessment of shaft end-to-end voltage .



Diagnostic Techniques (Cont.)

- **Gauss levels of components** can be measured and evaluated in accordance with established industry best practices.

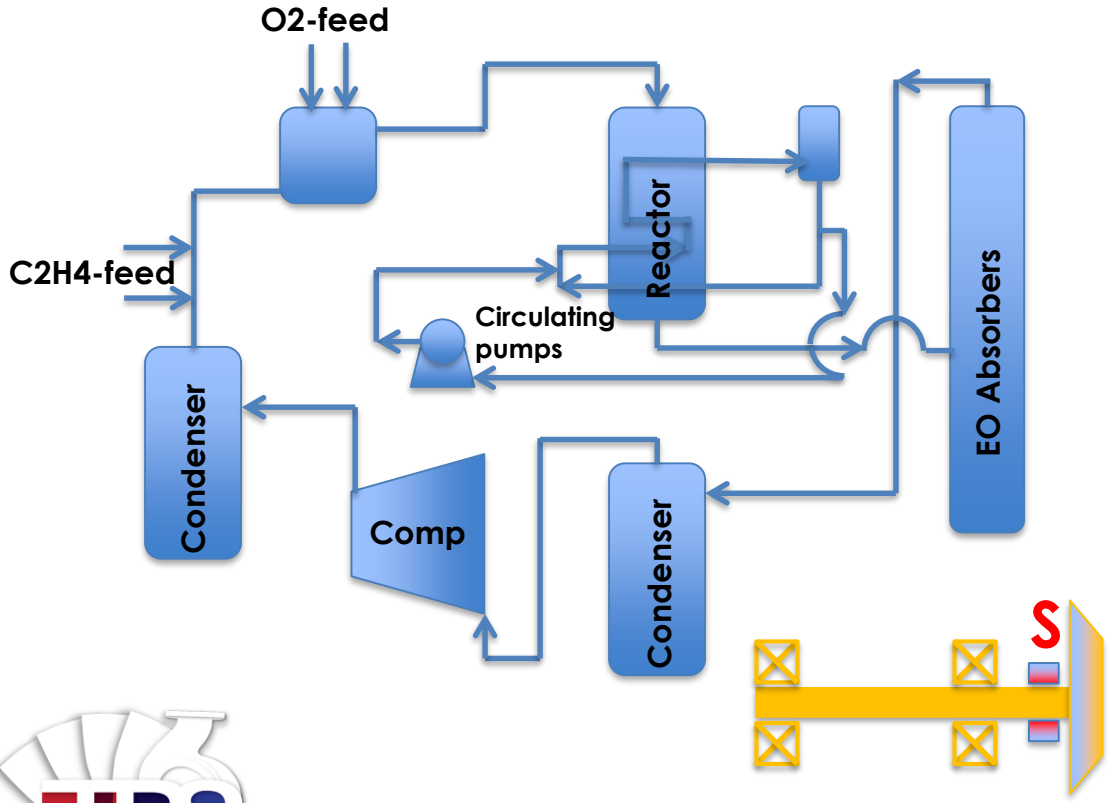
This method is quantitative, but you need to disassemble the complete machine (driver and driven) and measure the gauss levels of each component individually to be successful.

Remedies

- **Demagnetization** is imperative for new parts and machines with existing magnetism problems. This can be achieved by rapping a coil around the component and using full wave DC demagnetization techniques to reverse the magnetic fields.
- **Earth Brush Installation** is essential for machines that have already developed a problem. The location of earth brushes is dependent on the layout of the machine, bearing type, coupling type, train length and accessibility.

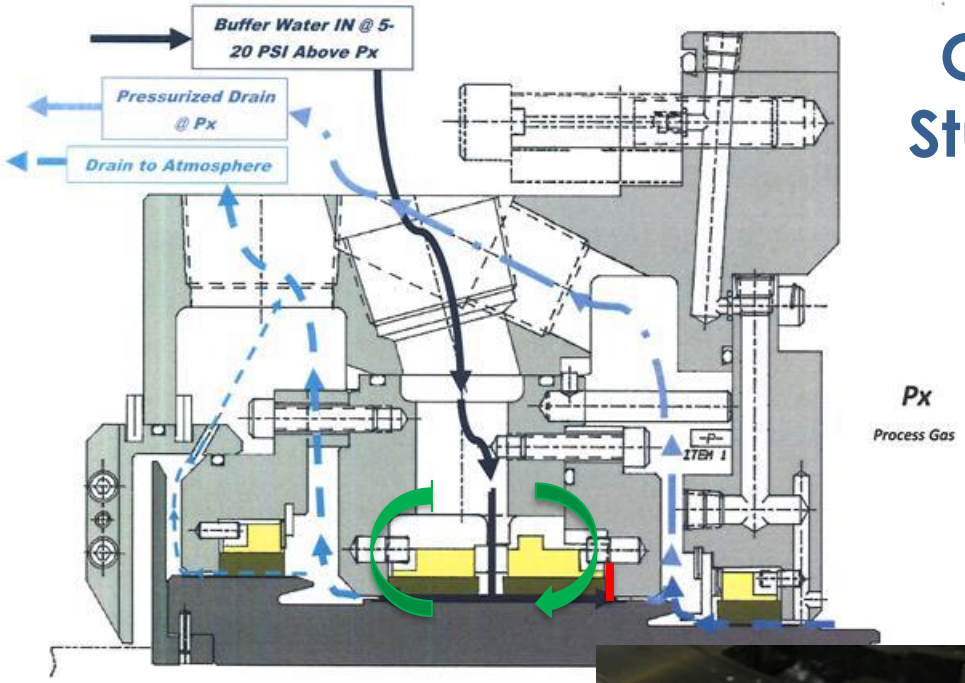
Maximum Allowable Free Air Gauss Levels	
Gauss Level	Component
± 2 Gauss	Bearings & seals
± 4 Gauss	Casing and stationary components
± 2 Gauss	Shaft & rotating components
Ref.: - API 612 - 7th Add., par 16.2.2.4.1, Table 6	

Case Study 1 – Recycle Gas Compressor Seal Failure



- Shaft failure;
- Temperature buildup;
- Welding marks noticed;
- Rotor/seal replacement;
- 120 V shaft voltage;
- 2 yr later demag.;
- EDM on seal carrier ring;
- Demagnification, brush installation & monitoring.

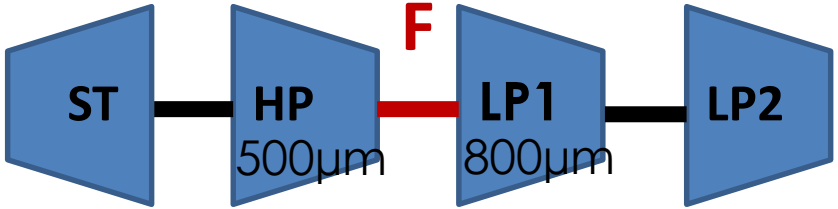
Case Study 1

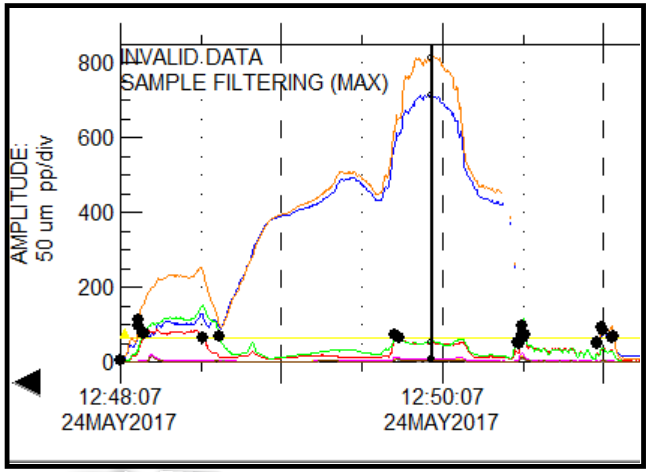


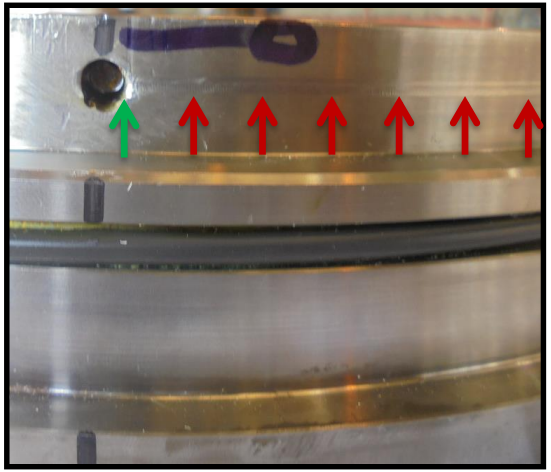
Rub induced circulating currents

Shaft failure in seal area

Case Study 2 – Product Compressor Coupling Failure

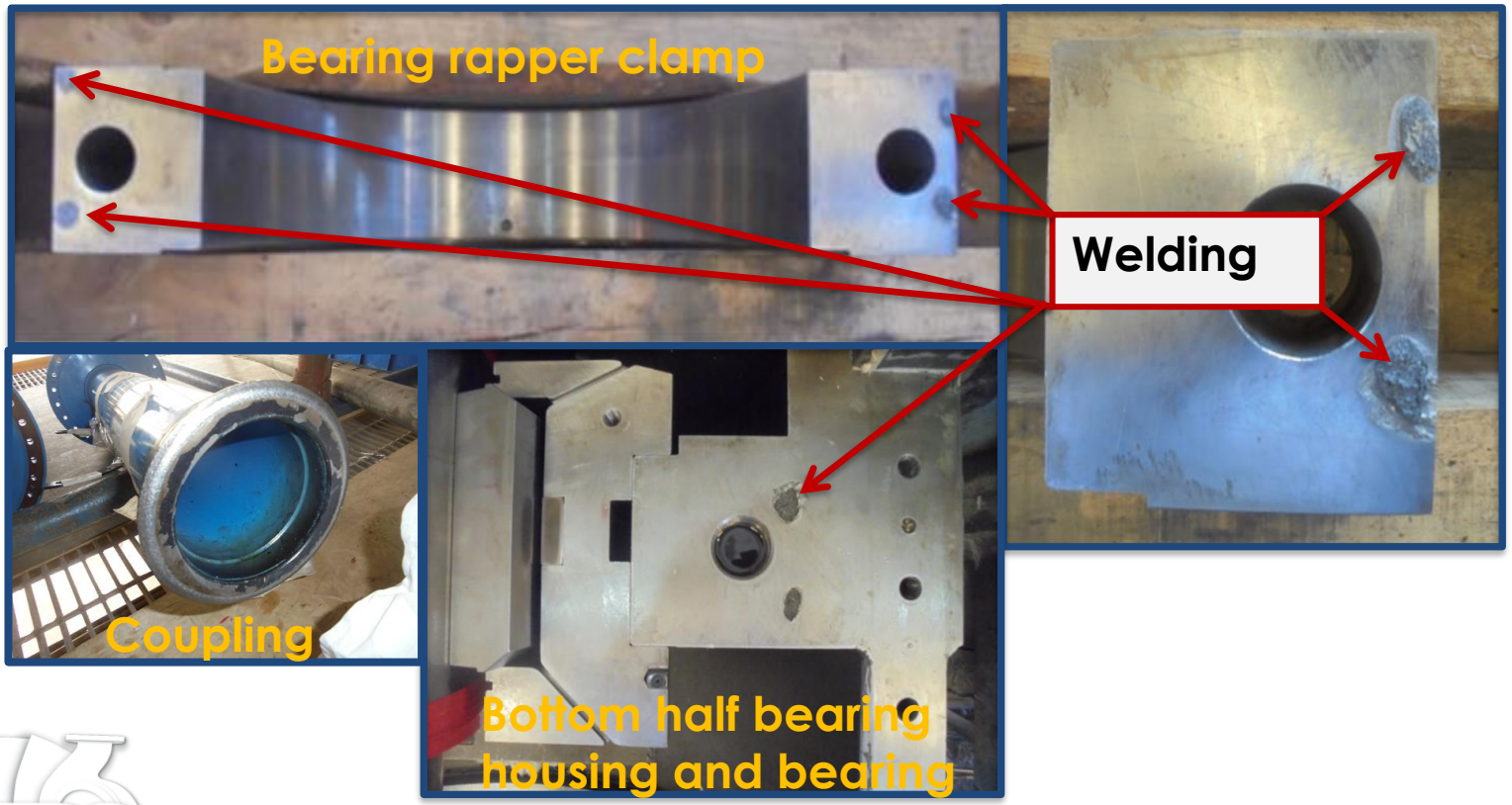






- Coupling failed between HP & LP1
- Vibration reached 800 µm LP1-DE, & 500 µm HP-DE
- Heavy rub in process seal area Cl. 0.63 to 0.84
- DGS rotates 270-degrees.

Case Study 2 – Product Compressor Coupling Failure



Conclusions

- Stray currents can be very harmful and destructive to rotating machines;
- Stray current damages can be identified by microscopic inspections of parts, gauss level measurements and shaft voltage measurements;
- Severe stray current damage, example molten parts and welding marks, appears to go with severe rub situations;
- Stray current problems can be resolved by proper demagnification and placing of shaft earth brushes.

Thank You

Acknowledgements: - Mr. Gys van Zyl for reviewing and editing of presentation.

References: - Electromagnetic Shaft Currents and Demagnetization on Rotors of Turbines and Compressors, by John S. Sohre & Paul S. Nippes.