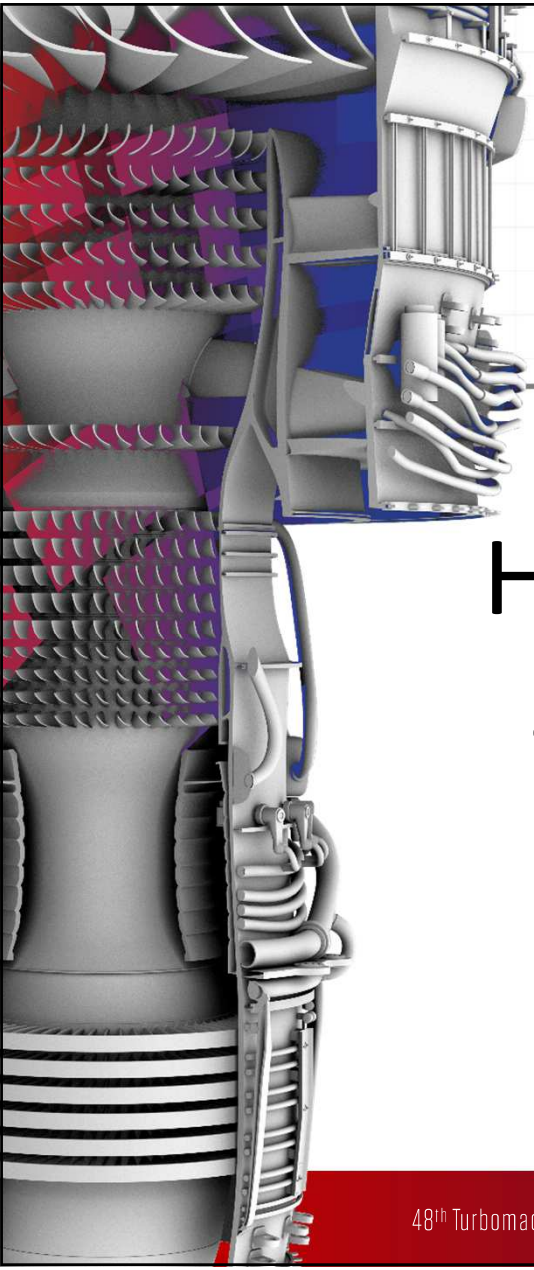


TURBOMACHINERY & PUMP SYMPOSIA

High Vibration at Low Speed on a 25 MW Turbogenerator System

- Authors: André A. T. Brandão (Petrobras)
- André O. Monteiro (Petrobras)
- Donald J. Paquette (Siemens)
- Joilson Rangel (Petrobras)
- Lucas S. Klaas (WEG)

Authors

Petrobras

André A. T. Brandão *is a diagnostic and basic design engineer for rotating equipment at Petrobras S.A. since 2013. He works with specification and vibration analysis of rotating machinery, mainly in downstream facilities. He received his B.S. degree and M.Sc. degree in Mechanical Engineering from University of Brasília.*

André O. Monteiro *is a Mechanical Engineer Petrobras S.A. He is responsible for the installation and comissioning of FPSO's rotating equipment in the shipyard. He obtained his B.S. in Mechanical Engineering from Federal University of Rio de Janeiro.*

Joilson S. Rangel *is a rotating machinary consultant working for Petrobras S.A. since 2001. He is responsible for tech support of rotating machinery, mainly in downstream facilities. He received his B.S. degree and M.Sc. degree in Mechanical Engineering from Federal University of Rio de Janeiro.*

WEG

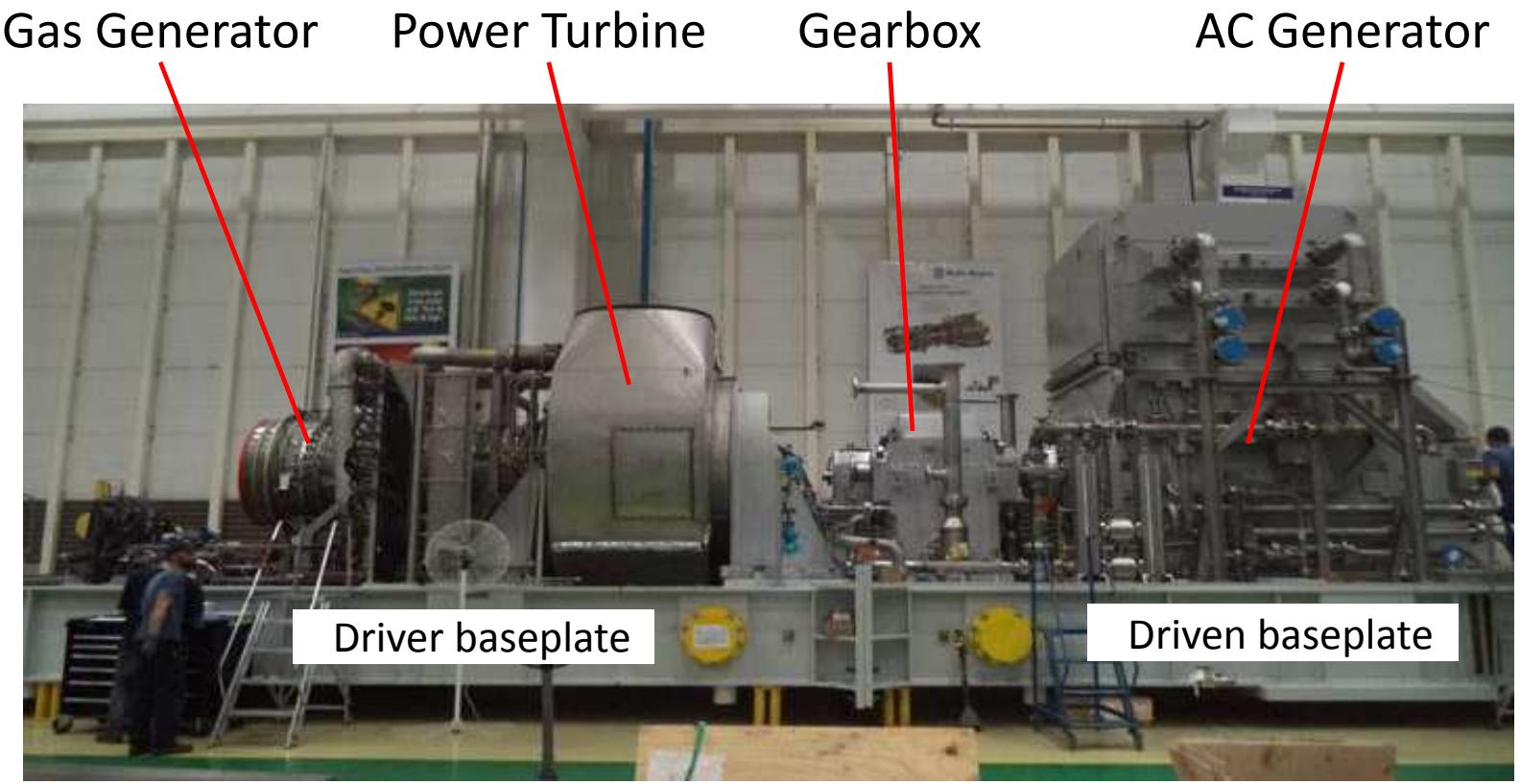
Lucas S. Klaas *is an engineer in the Energy division of WEG since 2008. He is responsible for vibration analysis of electric machinery. He received his B.S. degree in Mechanical Engineering from State University of Santa Catarina and M.Sc. degree in Material Science and Engineering from State University of Santa Catarina.*

Siemens

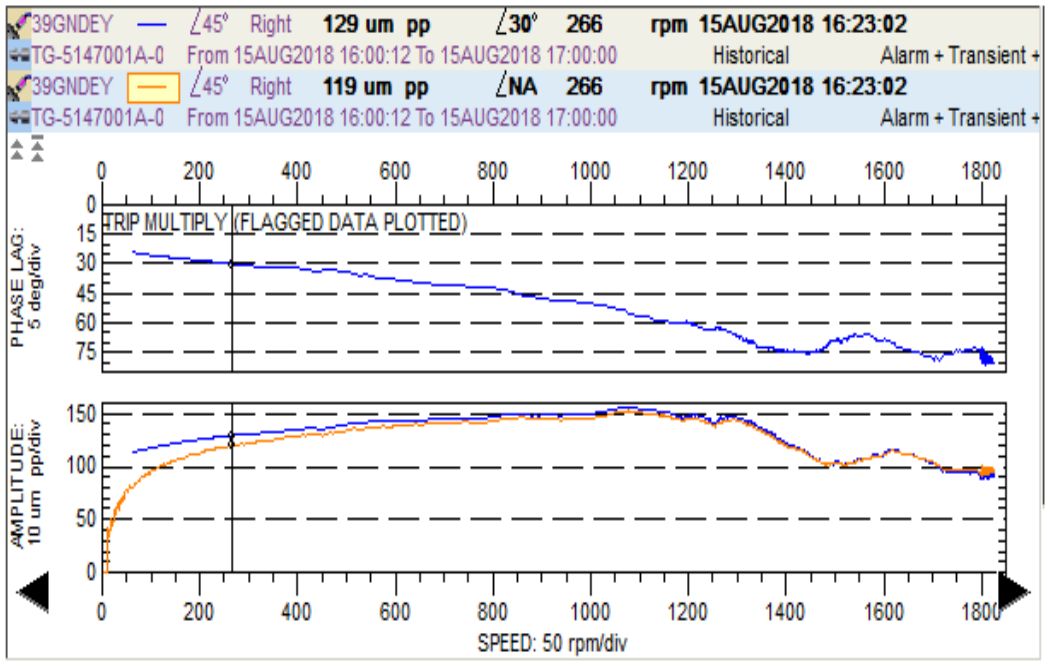
Donald J. Paquette *is an engineer in the Gas & Power division of Siemens in Orlando, Florida. He has worked in the turbomachinery industry for over 30 years and was recently named a Senior Key Expert for Fluid Film Bearings and Rotordynamics. Mr. Paquette received his BS degree in Fluid and Thermal Engineering from Case Western Reserve University, his ME degree in Mechanical Engineering from Worcester Polytechnic Institute, and his MBA from Ohio State University.*

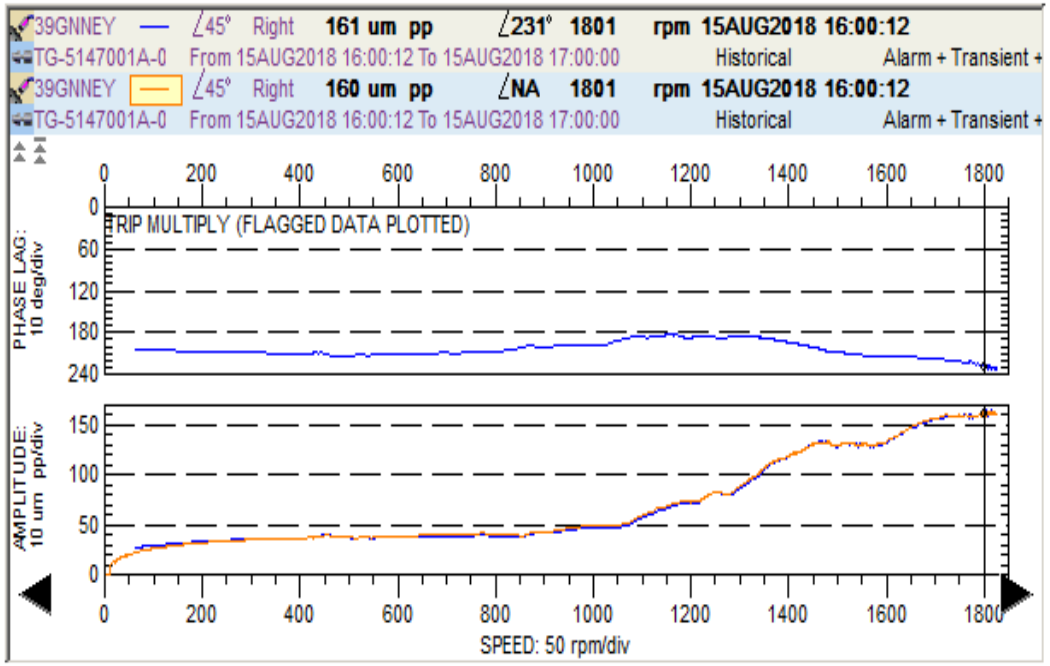
Introduction

- Four power generation packages were supplied for an FPSO vessel



Problem Statement





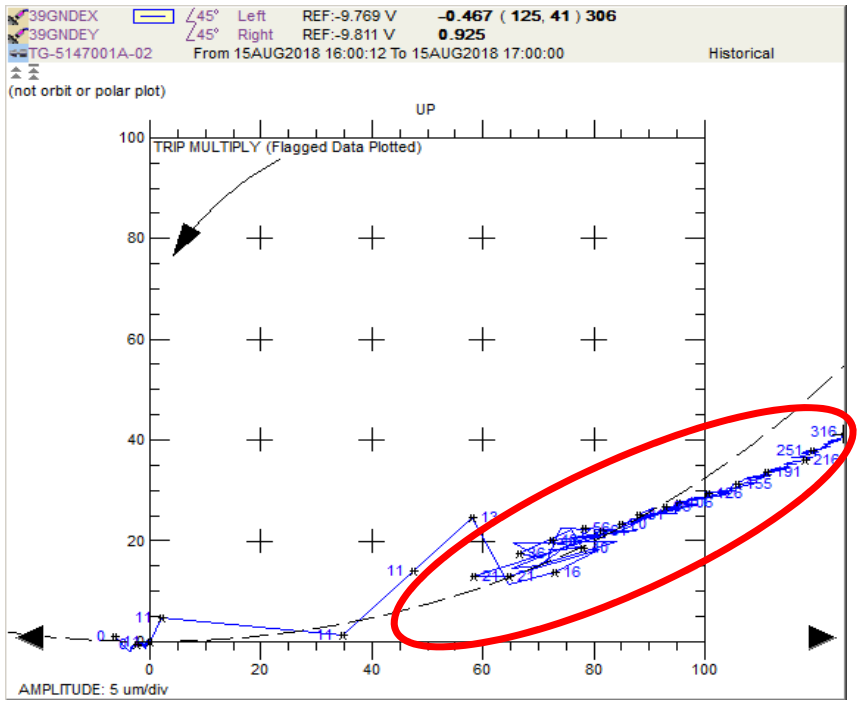
AC Generator Drive End:

130 µm pk-pk at slow roll

AC Generator Non-Drive End

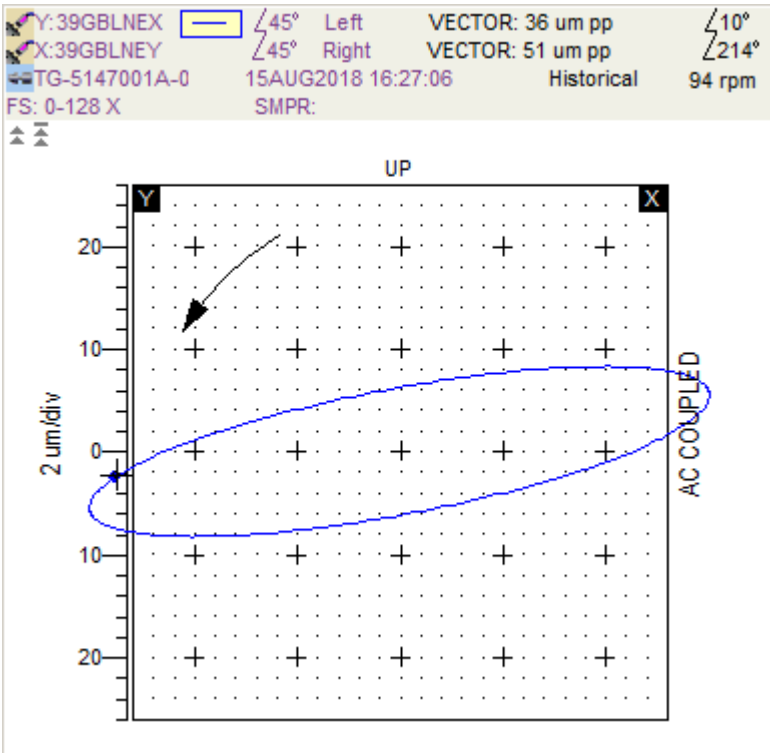
160 µm pk-pk at full speed

Other observations



AC Generator Drive End:

Inconsistent shaft centerline position during machine stop



Gearbox LS Shaft Non-Drive End:

High synchronous vibration at slow roll

Root Cause Analysis

What changed between factory string tests in 2014 and onshore commissioning in 2018?

Was vibration *real*?

Were probe areas damaged?

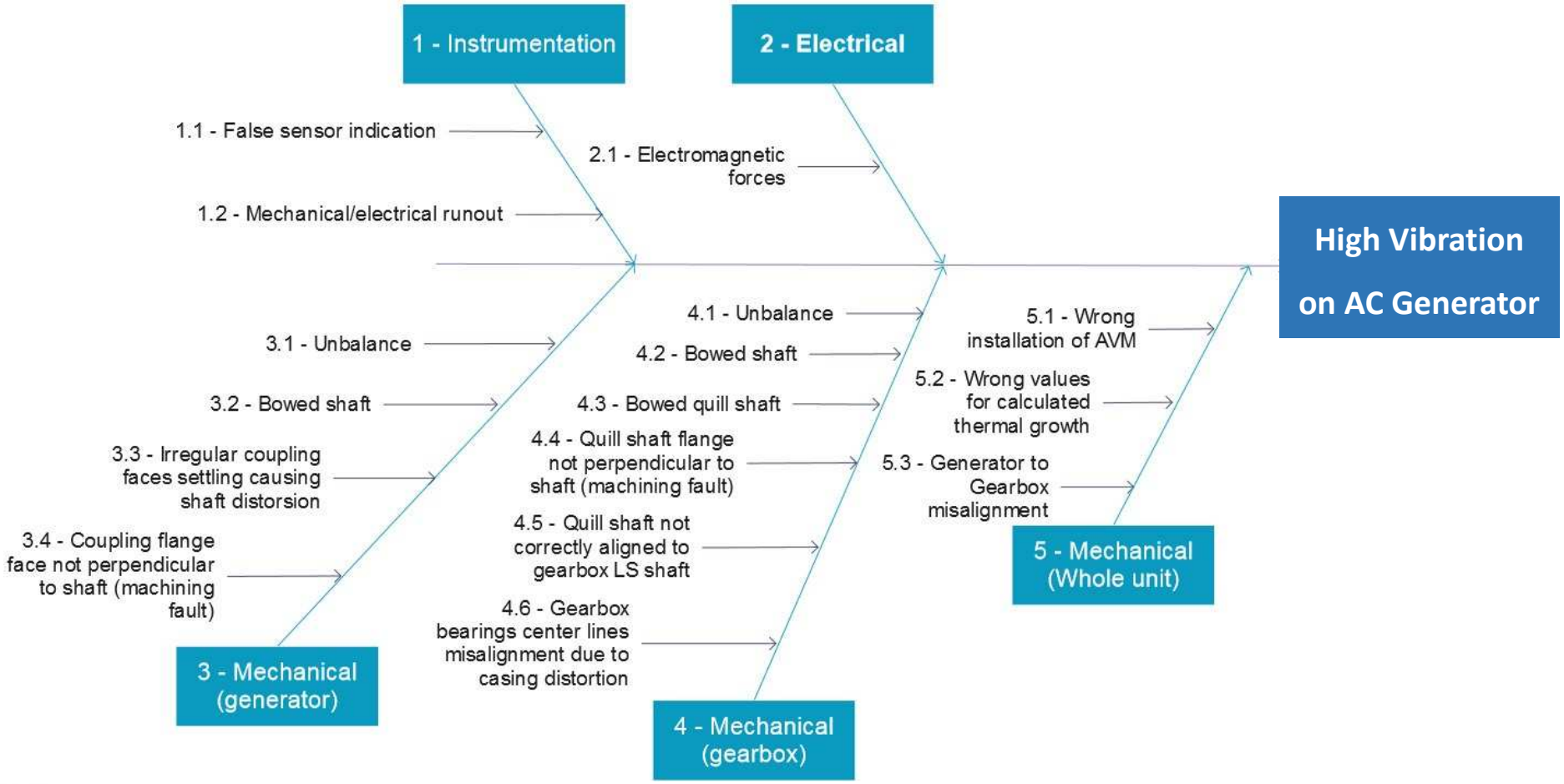
Was AC generator shaft bowed?

Did alignment change?

Package was shipped from factory with AC Generator ***coupled*** to gearbox, but was observed to be ***uncoupled*** when delivered to shipyard

- Why was it uncoupled?
- Is this significant?

Fishbone Diagram



Root Cause Analysis

Trim balancing

- AC generator trim balancing significantly reduced high speed vibration
- No improvement on low speed vibration

	Before balancing	After balancing	
DE	Low Speed – **130µm**	Low Speed – **130µm**	**no** improvement
	High Speed – **100µm**	High Speed – **90µm**	**small** improvement
NDE	Low Speed – **35µm**	Low Speed – **35µm**	**no** improvement
	High Speed – **160µm**	High Speed – **50µm**	**large** improvement

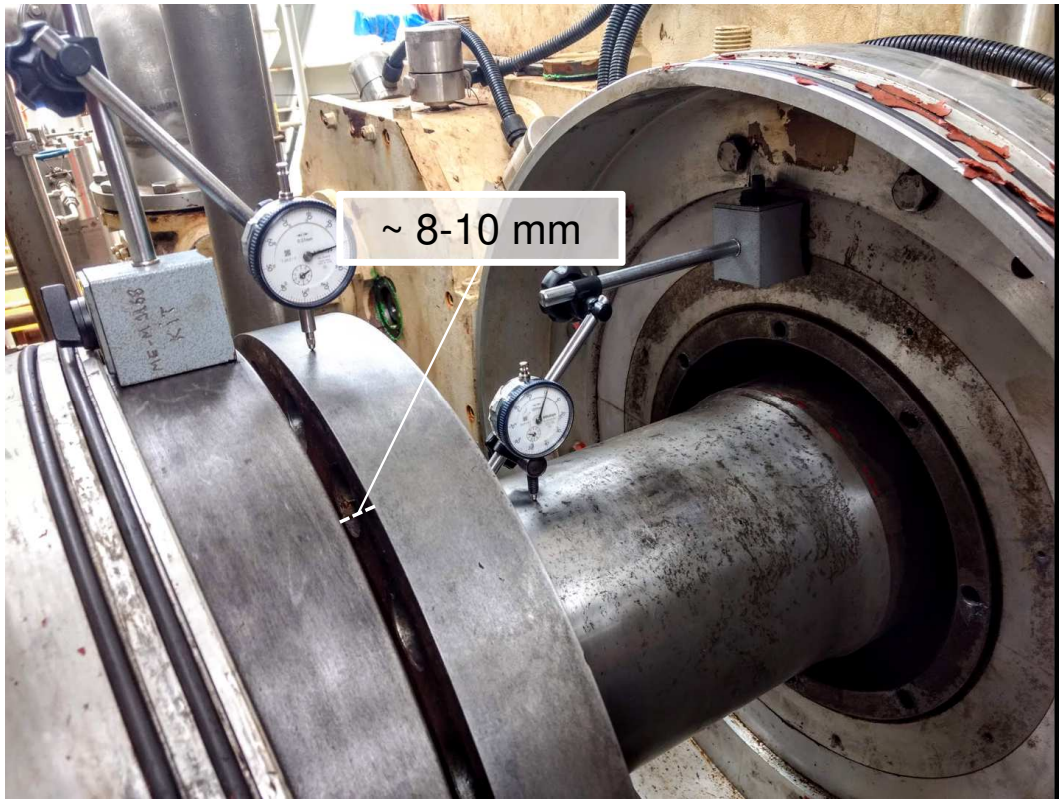
Root Cause Analysis

Alignment

- Small alignment correction had no effect on vibration

Run-out checks (Uncoupled)

- 8 – 10 mm max. gap between uncoupled flanges
- Quill shaft runout was acceptable
- No rotor bow
- Low *glitch* (electrical and mechanical runout) measured at probe areas



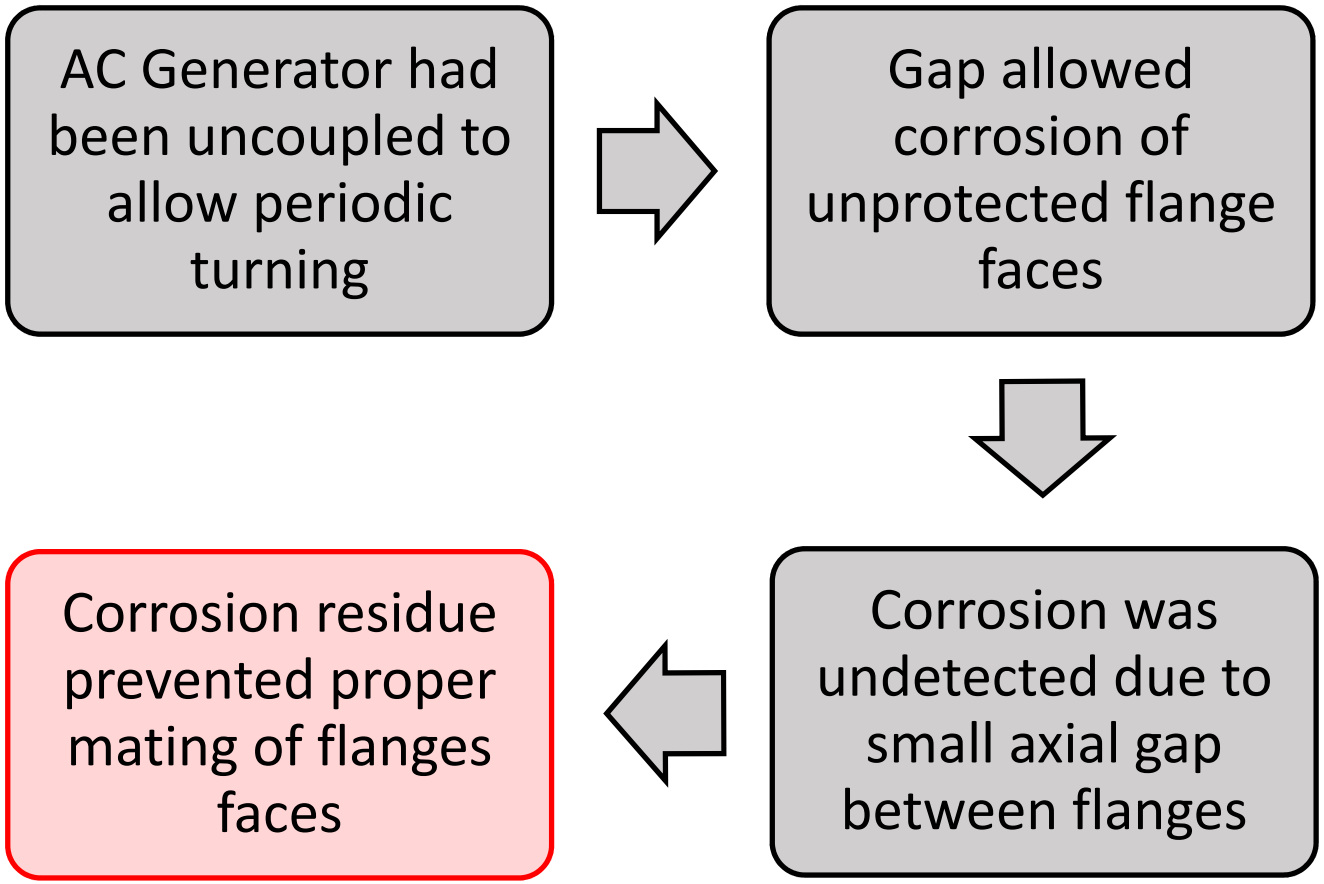
Root Cause Analysis

- None of the original symptoms were observed with the AC generator uncoupled
- Suggested problem could be with gearbox-to-AC generator interface
- Recommended inspection of spigot fit on flange faces requiring increased axial separation of flanges

Root Cause

Corrosion residue layer unevenly distributed on the flange face

Root Cause


AC Generator had been uncoupled to allow periodic turning
Gap allowed corrosion of unprotected flange faces
Corrosion was undetected due to small axial gap between flanges
Corrosion residue prevented proper mating of flanges faces

Solution

Flanges after cleaning

Solution

Low speed vibration after cleaning

	Before cleaning	After cleaning
DE	130 µm	**35 µm**
NDE	35 µm	**20 µm**

Lessons Learned – Installation

- Avoid long storage periods for machine trains mounted on skid
- When long storage is unavoidable, proper preservation should be applied
  - Volatile Corrosion Inhibitors (VCI) can be an alternative
- Flange faces must be inspected and, if needed, thoroughly cleaned before final assembly
  - This requires sufficient axial separation between flanges

Lessons Learned – Equipment design

- Design of the free shaft should consider all practical efforts to include enough axial play to allow inspection and to prevent impacts on spigot fit
  - Minimum recommended axial play: 3x spigot fit axial length

Thank You!