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Investigation and Resolution of Governing Valve Linkage Failure for Compressor Drive Steam Turbine

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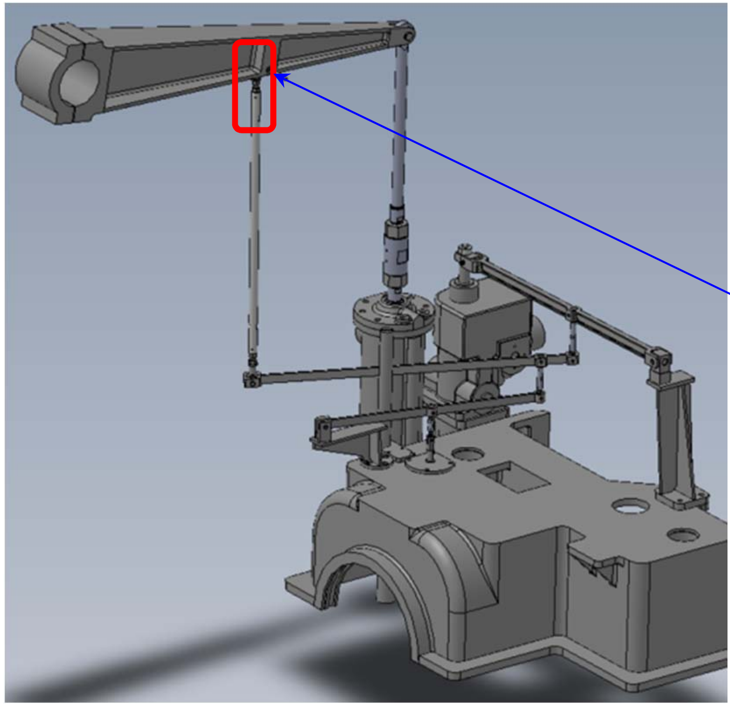
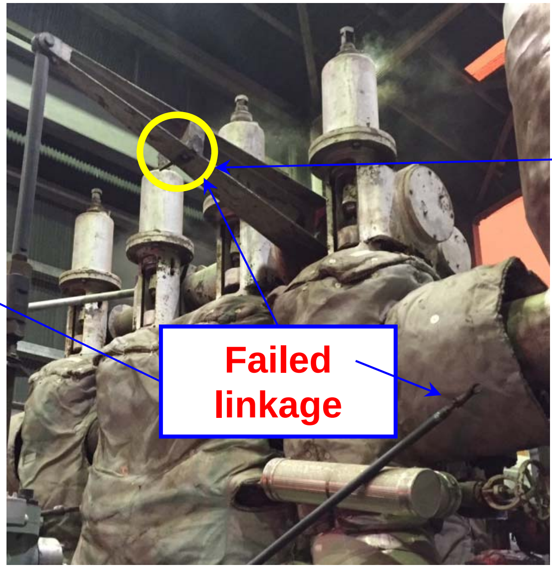
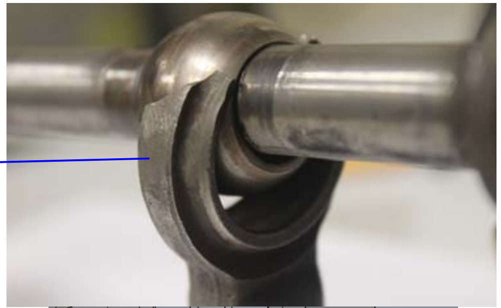
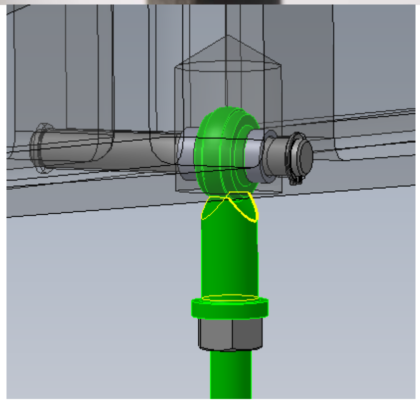








The rod end bearing failure occurred in 2017 after the Turbine had been in operation for 9 years.

Governing Linkage Outline

Similar trouble had happened around 2006 in other plants. Countermeasure → Bearing size up from M8 to M16

Size	Static Limit Load		Radial Static Ultimate Load	Notes
	Radial	Axial		
	(kN)		(kN)	
M16	8.33	N/A	33.34	3.5 times larger area than M8.
M8	2.69	N/A	11.76	

Similar trouble

This turbine reconfigured the bearing size to M16 in 2008.
→ The M16 bearing failed in 2017 after 9 years of operation.

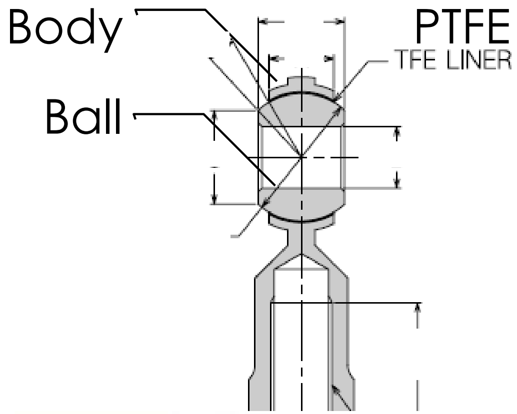
Rod-end Bearing Design

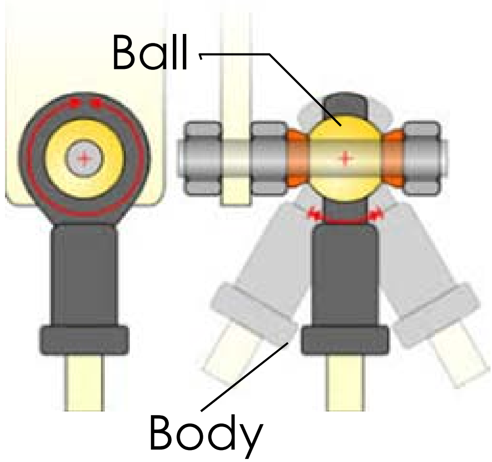
Material specification:

M8 and M16 are same design

They are comprised of the same materials.

Material	PARTS	Hardness (HV)
Martensitic stainless	Ball	≥ 653
Austenitic stainless	Body	≤ 200
PTFE	Liner	N/A

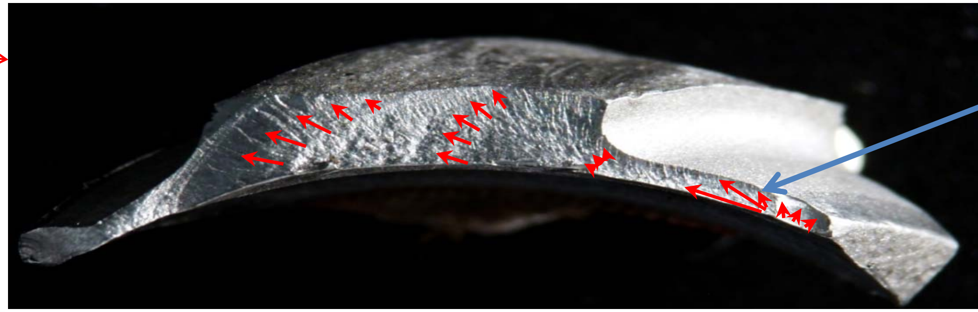




Fracture Analysis

Fractured

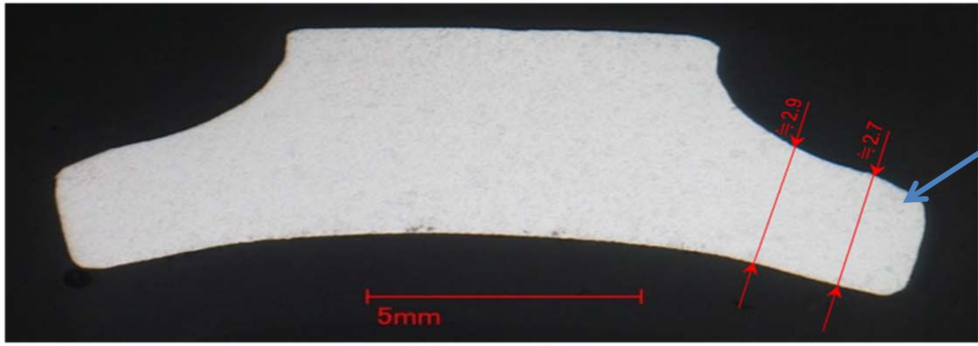
Failed Body



1mm remains

New

Unused Body



Y-Y cross section

Approx. 3mm

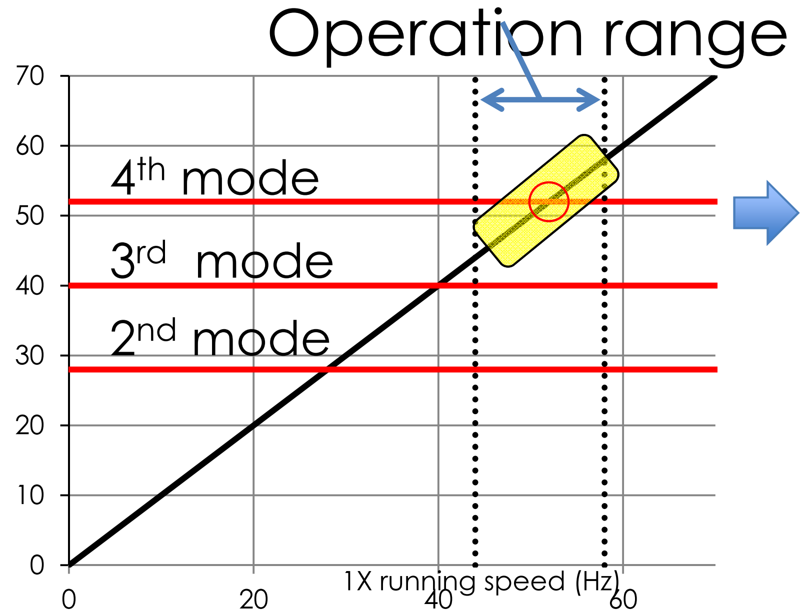
Worn out thickness was roughly 2mm and striation pattern was observed which helped us identify high cycle fatigue fracture .

Troubleshooting

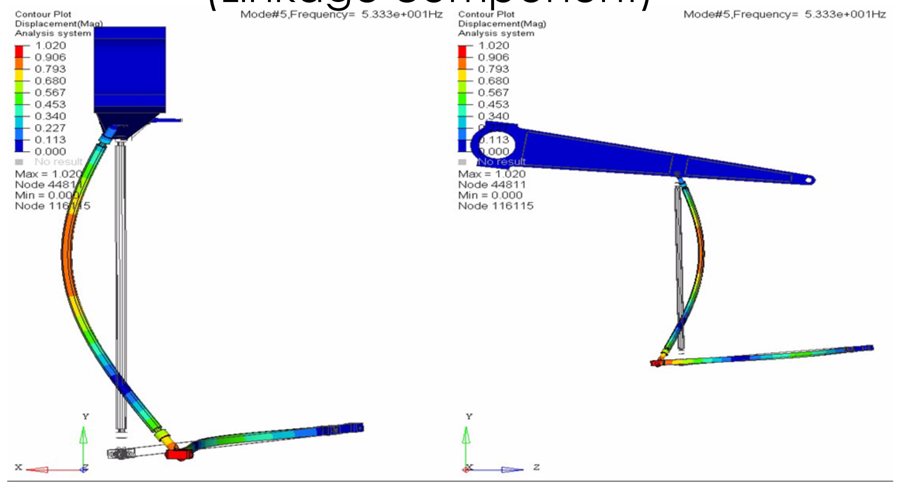
Problem	Possible Causes	Possibility
Bearing failure	High shock load	**Low**
	Improper strength at design stage	**Low**
	Corrosive fracture under severe environment	**Low**
	Vibratory stress	**High**

- Strength and shock load were verified to be within criteria.

Possible Cause



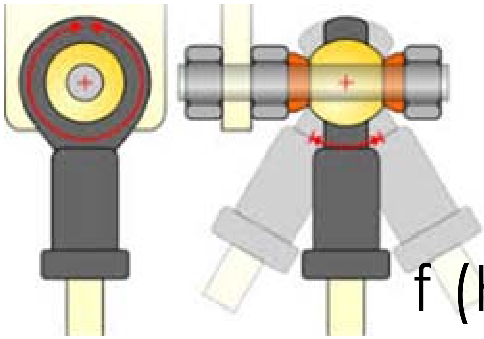
4th vibration mode
(Linkage component)



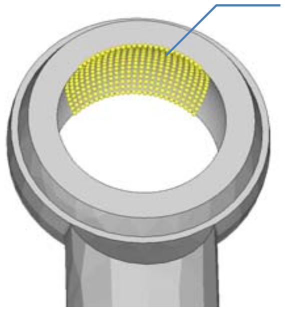
Fatigue fracture pattern and vibration analysis indicated that the 4th resonance mode falls in the Turbine operation range.

Scenario

- PTFE liner wore out due to resonance vibration (4^{th} mode).

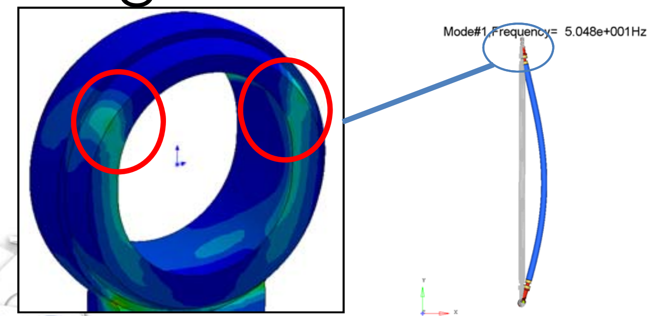


f (Hz)



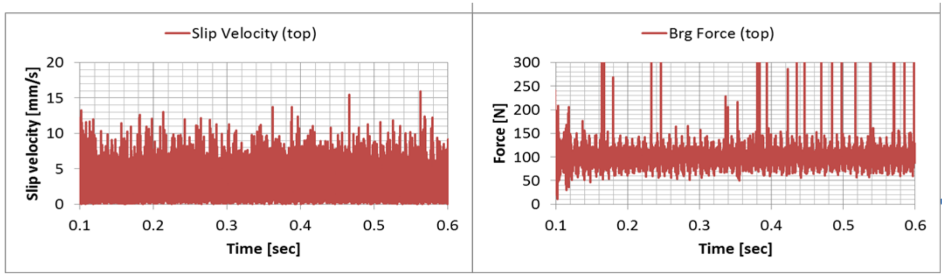
Ball and body doesn't slip

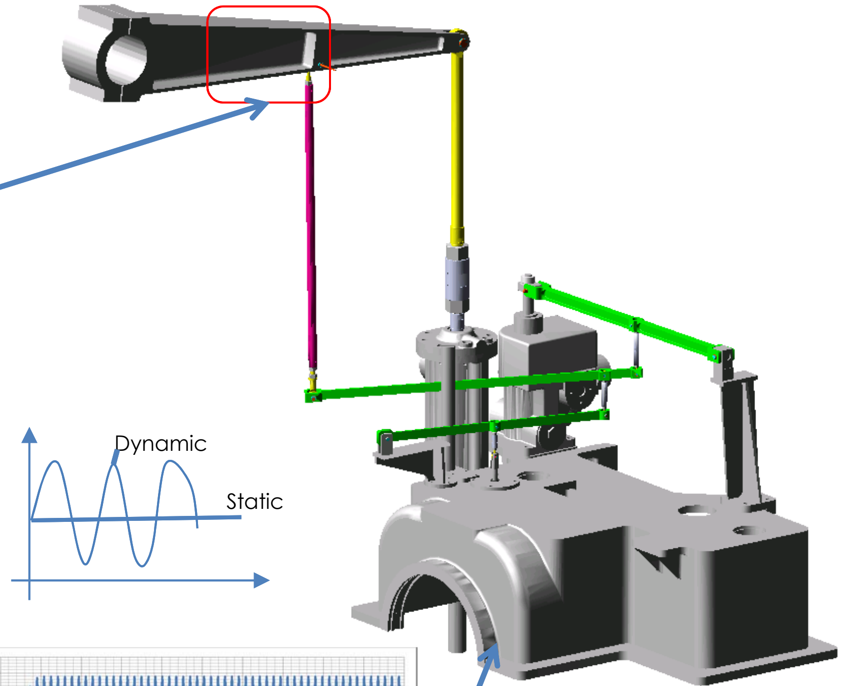
- Bending stress occurred due to resonance vibration.



Failed due to repeated bending stress

Motion Analysis

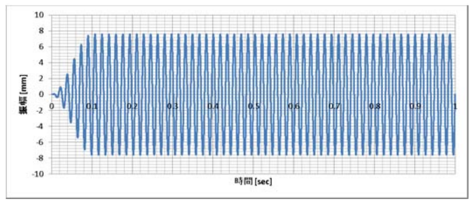




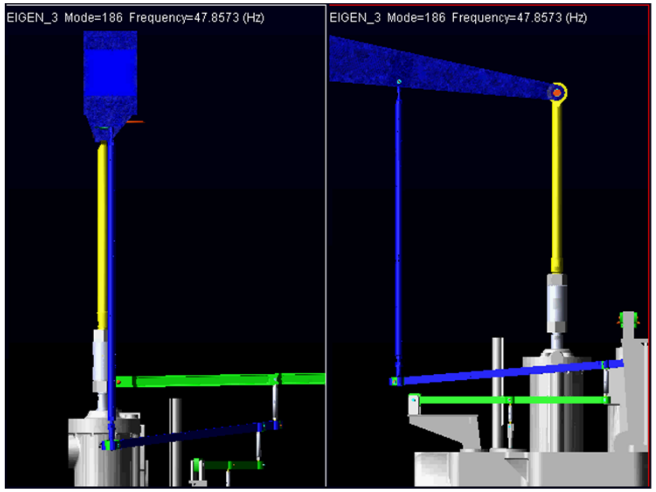
Output data
(Sliding velocity and force)

Excitation force was estimated using motion analysis with the help of static force.

Input value
Measured Vibration on pedestal.



Bearing life estimation



1. Excited force was estimated with motion analysis.
2. Damping at resonance frequency was confirmed with hammering test.

(4^{th} mode : 51.6Hz)

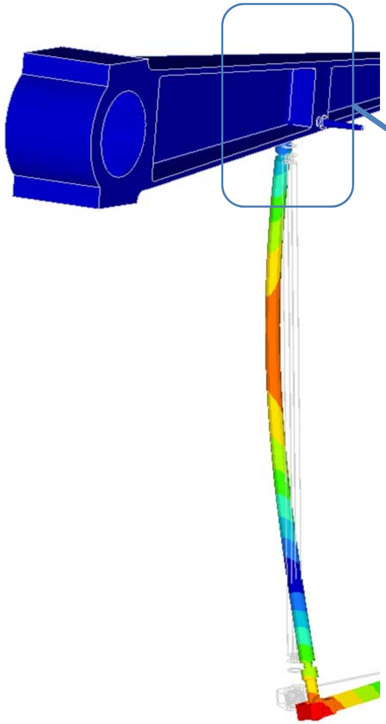
Resonance mode

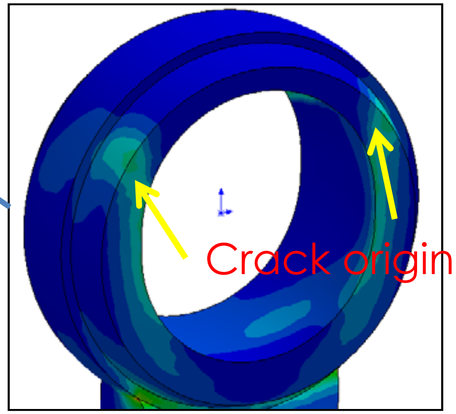
MAX.	3498 r.p.m
NOR.	3331 r.p.m
MIN.	2665 r.p.m

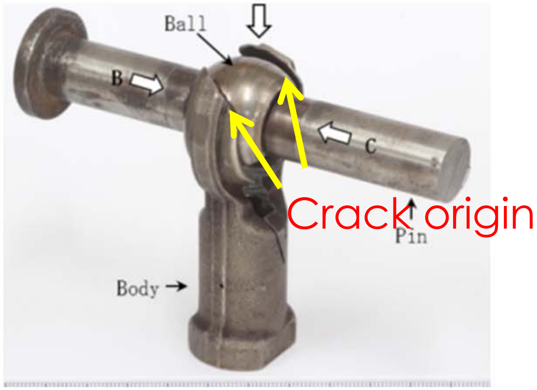
Slip velocity (5.6 mm/sec),
Lh = 16,644 hr (1.9 years)

Under resonance condition, PTFE liner will wear out within 1.9 years of operation.

Stress Analysis





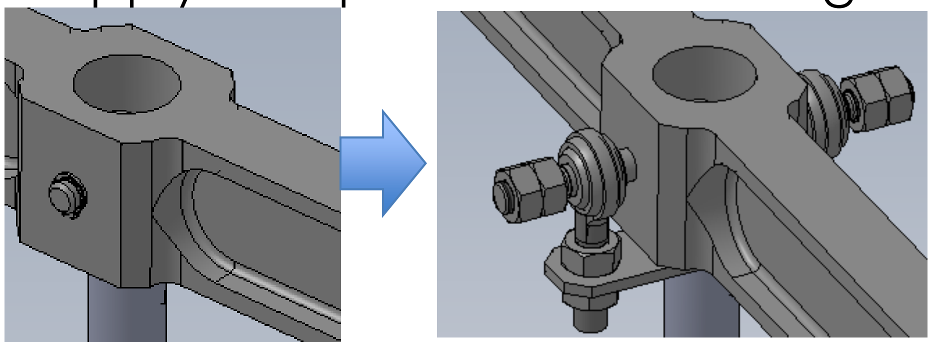


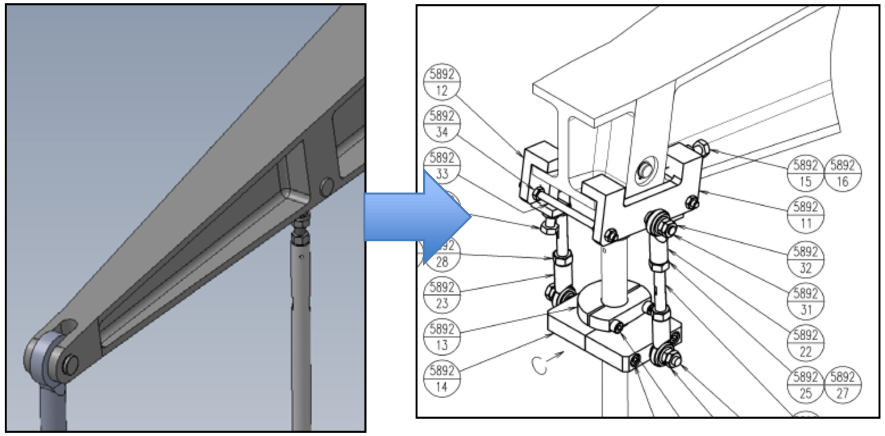
The peak stress points due to vibration at resonant frequency was found using FEA. They match the crack origin point of the failed bearing.

Recommendations

- *Plan 1:* Provide separation margin from resonant excitation frequency. -> *(it is no longer operation range.)*
- *Plan 2:* Improve system integrity using a redundant system.

Apply multiple rod end bearings





Recommendations

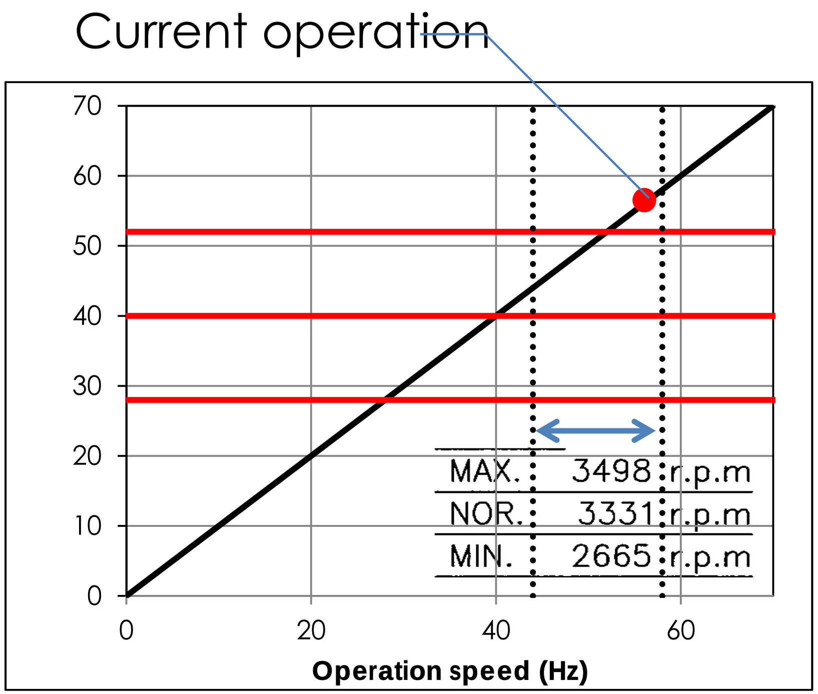
- Plan 3: Replace with Direct-drive actuator (Linkages are minimized).

Conventional Actuator
(Before Revamp)

Direct-drive Actuator
(After Revamp)

TPS

Results after maintenance



As a result of modification (Plan 1), turbine operation speed is far away from the resonance frequency.
No issues experienced after the maintenance.

Plan 2 will be carried out during next Turbine maintenance.

Plan 3 with Direct Drive Actuators.

Lessons Learned

- Bearing Life should be considered at the design stage and bearing should be replaced at every maintenance .
- Understand dynamic behavior of linkage system and enforce sufficient separation margin (Authors recommend 5% for similar situations) on damaging modes.
- Root cause analysis and Motion Analysis to know the dynamic force for multiple linkage is an useful tool in understanding the failure modes of Linkages and bearings.

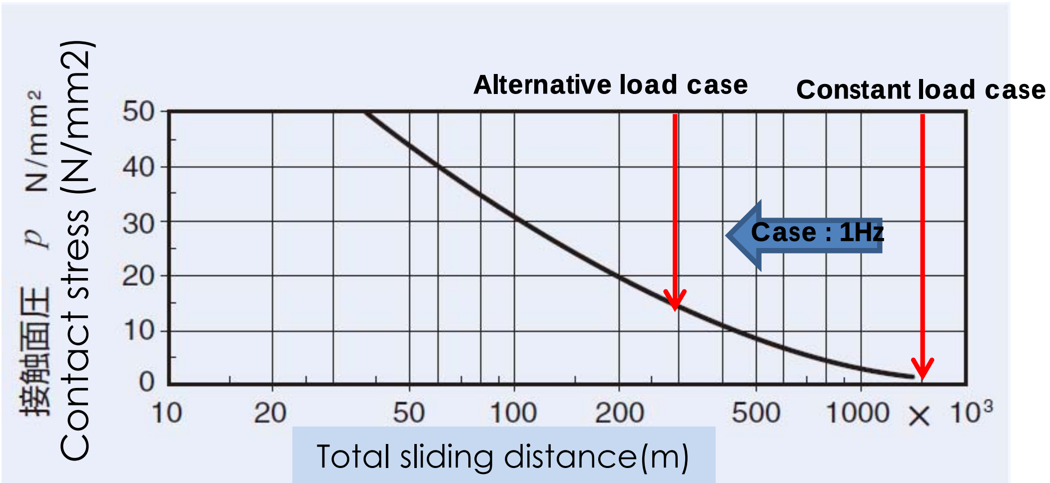
Thank You…

Questions???

For Q and A

Bearing Life to be determine

Highly depends on contact stress , slip velocity & frequency



Load condition factor 荷重方向	Constant 一定	Alternative 交番
荷重方向係数 b_1	1	0.2[1]