ASIA TURBOMACHINERY & PUMP SYMPOSIUM
SINGAPORE | 22 – 25 FEBRUARY 2016
MARINA BAY SANDS

TEES TURBOMACHINERY LABORATORY
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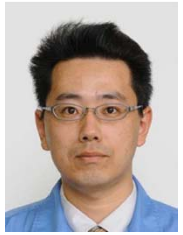
MITSUBISHI HEAVY INDUSTRIES COMPRESSOR CORPORATION

Steam Turbine Vibration Resonance of Pedestal, Vibration Investigation with Countermeasures in Singapore

Kyoichi Ikeno

Presenter/Author bios



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He has experience detail design of mechanical components with R&D for mechanical drive turbines for 22 years.

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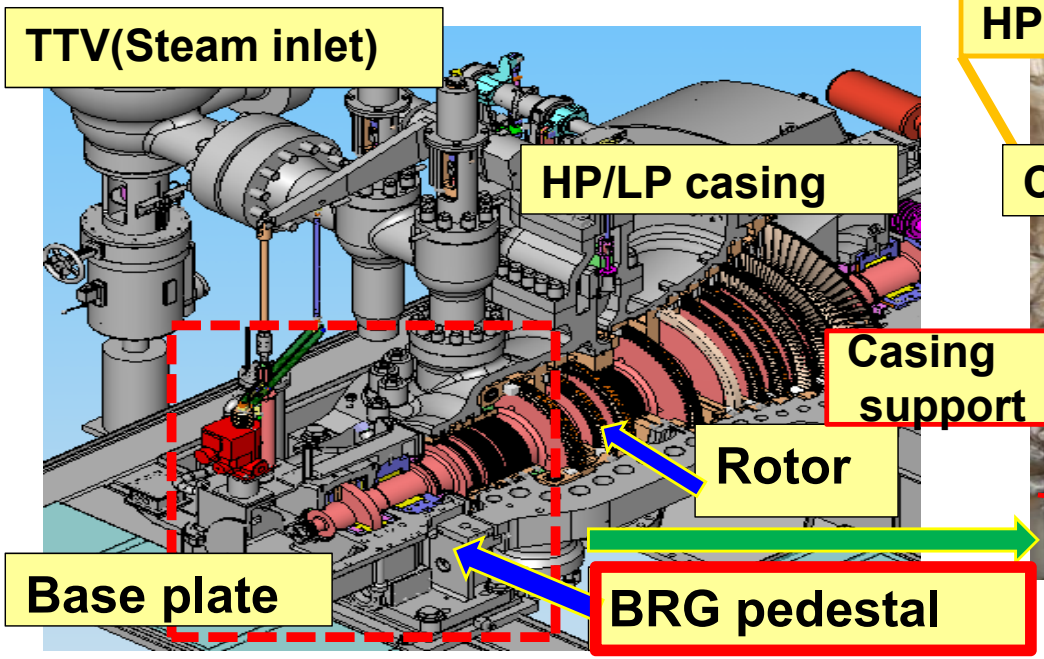
Preface

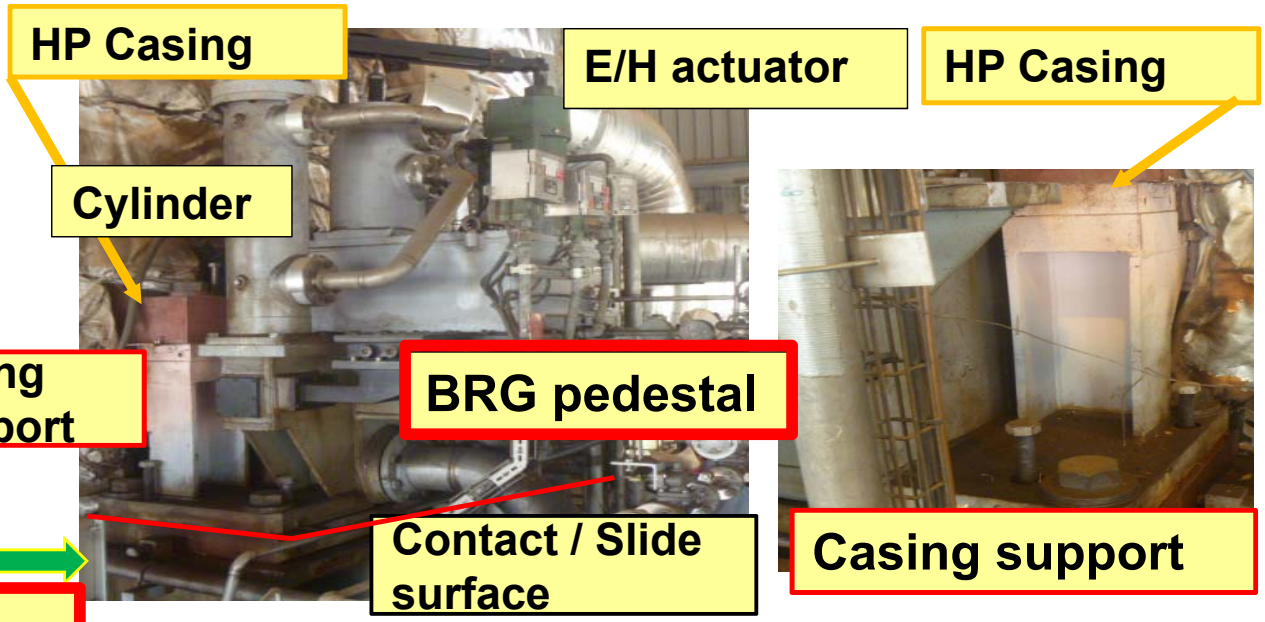
A Steam Turbine had been in operation for several years and this turbine experienced the wear damage of governor linkage.
Then, measured the vibration velocity profile on Governor side pedestal to identify the excited vibration mode and frequency.
According to collected data, investigated the possible root causes and conducted 3D vibration response analysis to the existing and the improved pedestal.
And, improved pedestal was supplied to the client and applied for actual machine during turnaround. And, finally, the advantage of new improved pedestal was confirmed.
This case study introduces the typical phenomena, RCA investigation, detail vibration analysis, countermeasures and verification results as technical process.

Contents

1. Specification of Steam turbine with Gov, side pedestal



Section drawing of turbine



Gov, side brg, pedestal with cover, linkage assembly

Turbine specification ;

Max, power ; 44MW
Speed ; 3451 – 4263rpm
Plant start ; from 2000

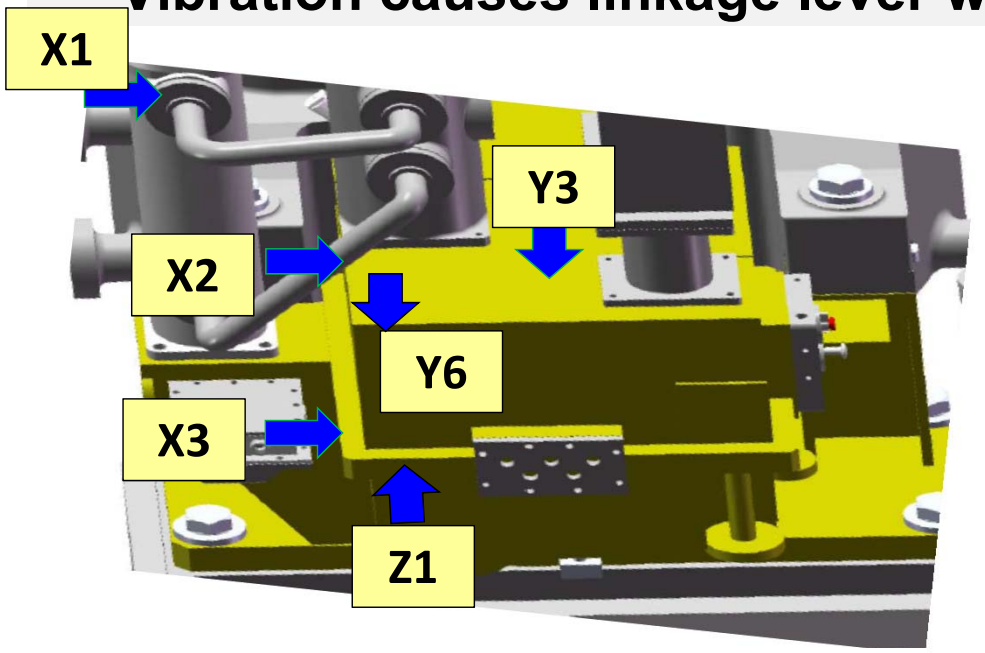
Major specification of bearing pedestal with cover assembly;

1) Fabricated welding structure
2) Separated fabricating casing support
3) Material is Carbon steel (Eq, ASTM A36)

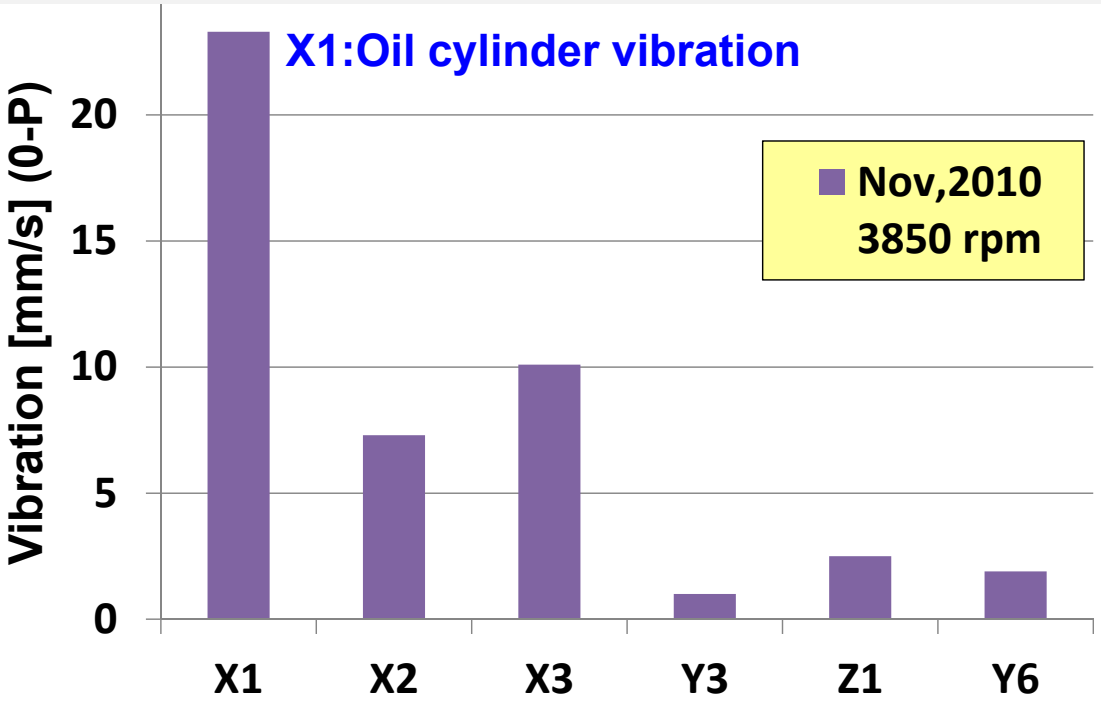
2.1 Background

Historical events at field ;

- **Turbine start up in 2000**
- **Gov, side pedestal Vibration increase from after 2nd turnaround 2009**
- **Vibration causes linkage lever wear and required control limit**



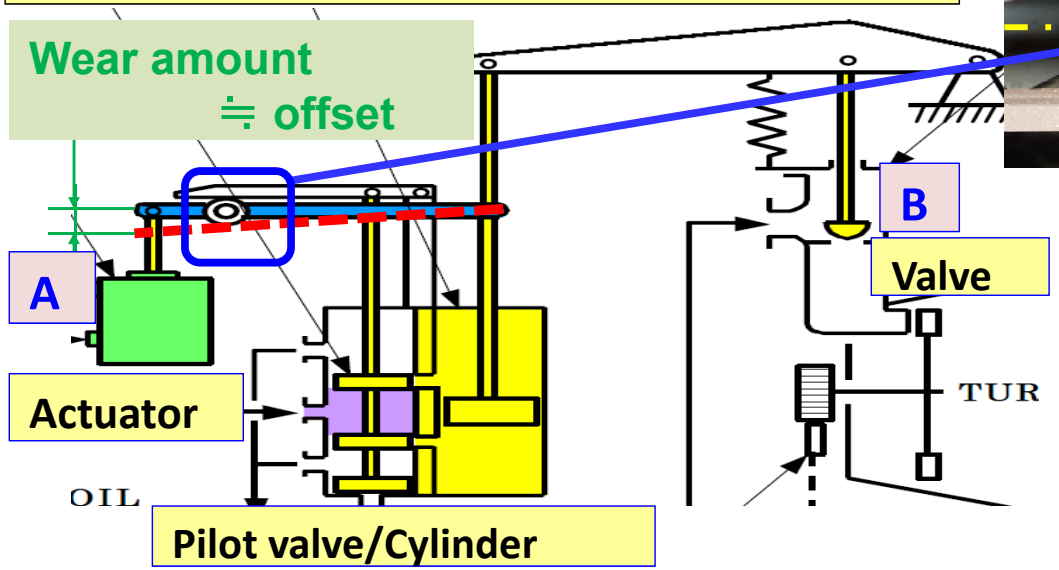
Site measurement points
(View from Gov, side)



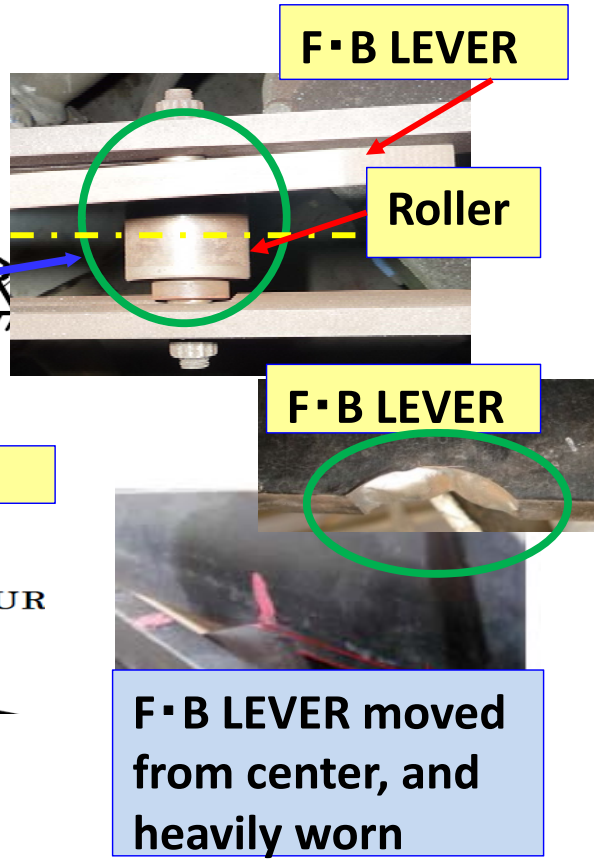
Pedestal vibration record in 2010

2.2 Background

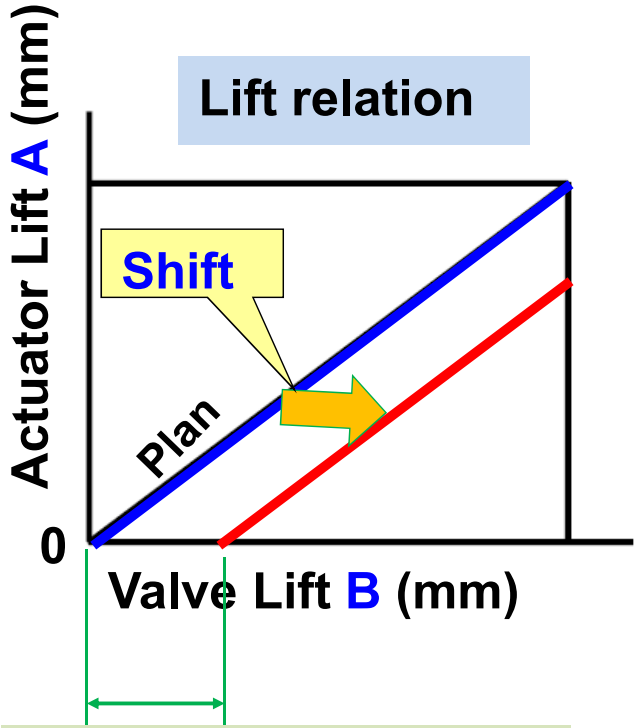
Impact of lever wear damage;
Offset the neutral point of pilot valve



Linkage lever arrange



F・B LEVER moved from center, and heavily worn

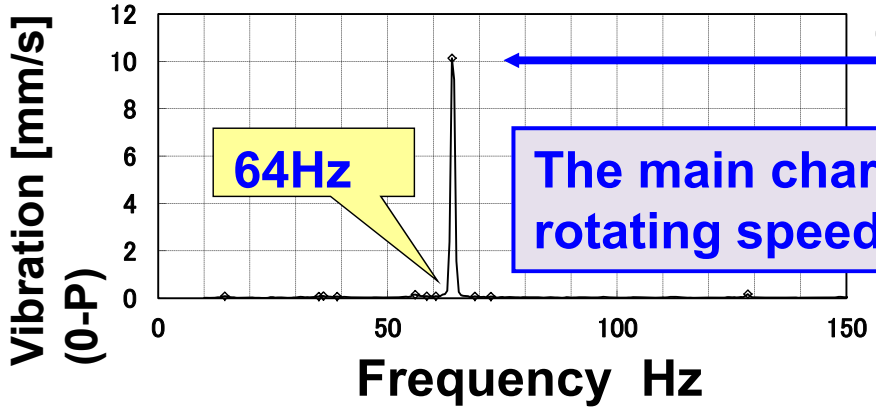


Impossible control lift

Operation condition ;
It was shifted actual inlet steam flow with valve lift B against E/H actuator lift A.
Also, Impossible control area occurred.

2.3 Background

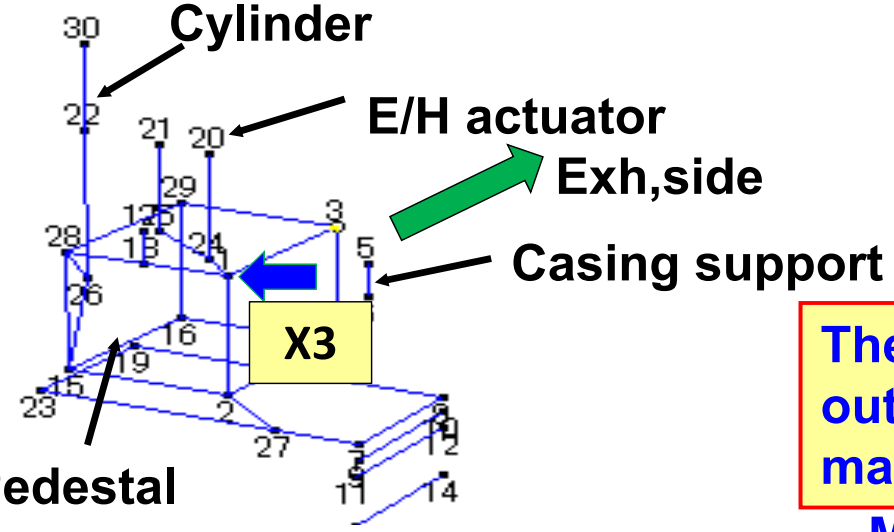
Site vibration measurement record ;



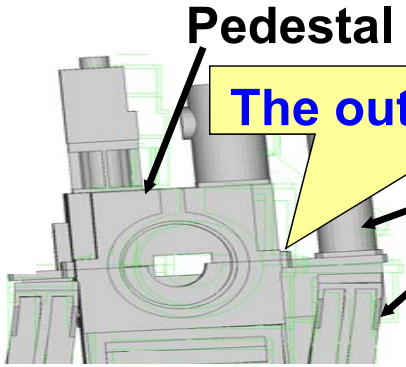
O.A ; 10 mm/s

X3 Spectrum plot @ 3850 rpm

The main characteristic is rotating speed



Site measurement points (No,30)



Measured vibration mode at 3850 rpm (59Hz)

The main characteristic of the vibration mode is an out-of –phase (counter-motion) mode between main pedestal and casing support

Measured vibration mode under operation (View from Exh, side)

3. Root Cause Analysis for Bearing Pedestal Vibration

Root cause failure analysis found on 3 main items as below;

1, Excessive external force

2, Increase of modal mass on bearing pedestal

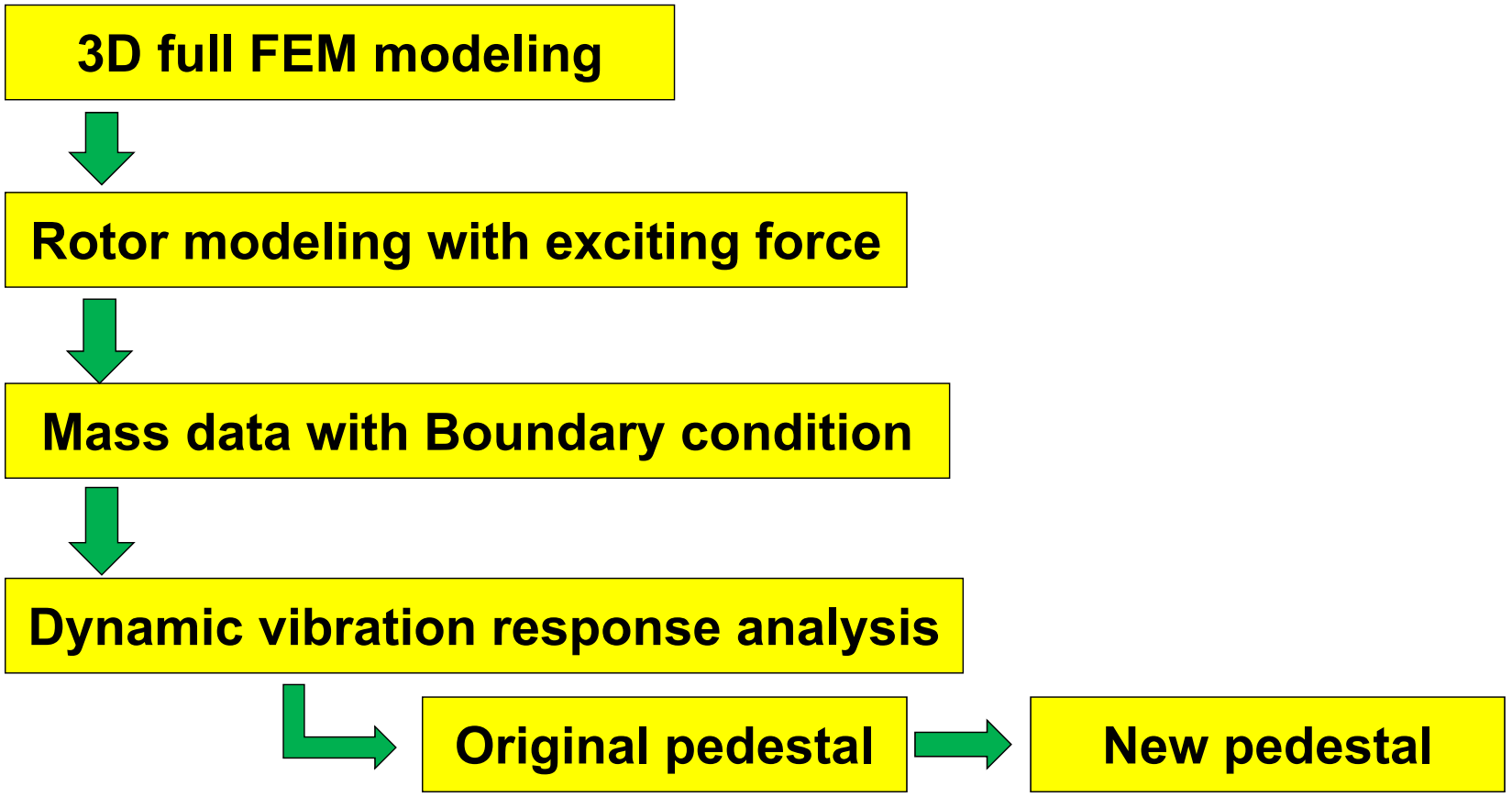
3, Decrease of dynamic stiffness

- **Foundation degradation with change of alignment condition**
- **Bearing pedestal stiffness**
- **Natural frequency excitation**

Resonance with rotating speed

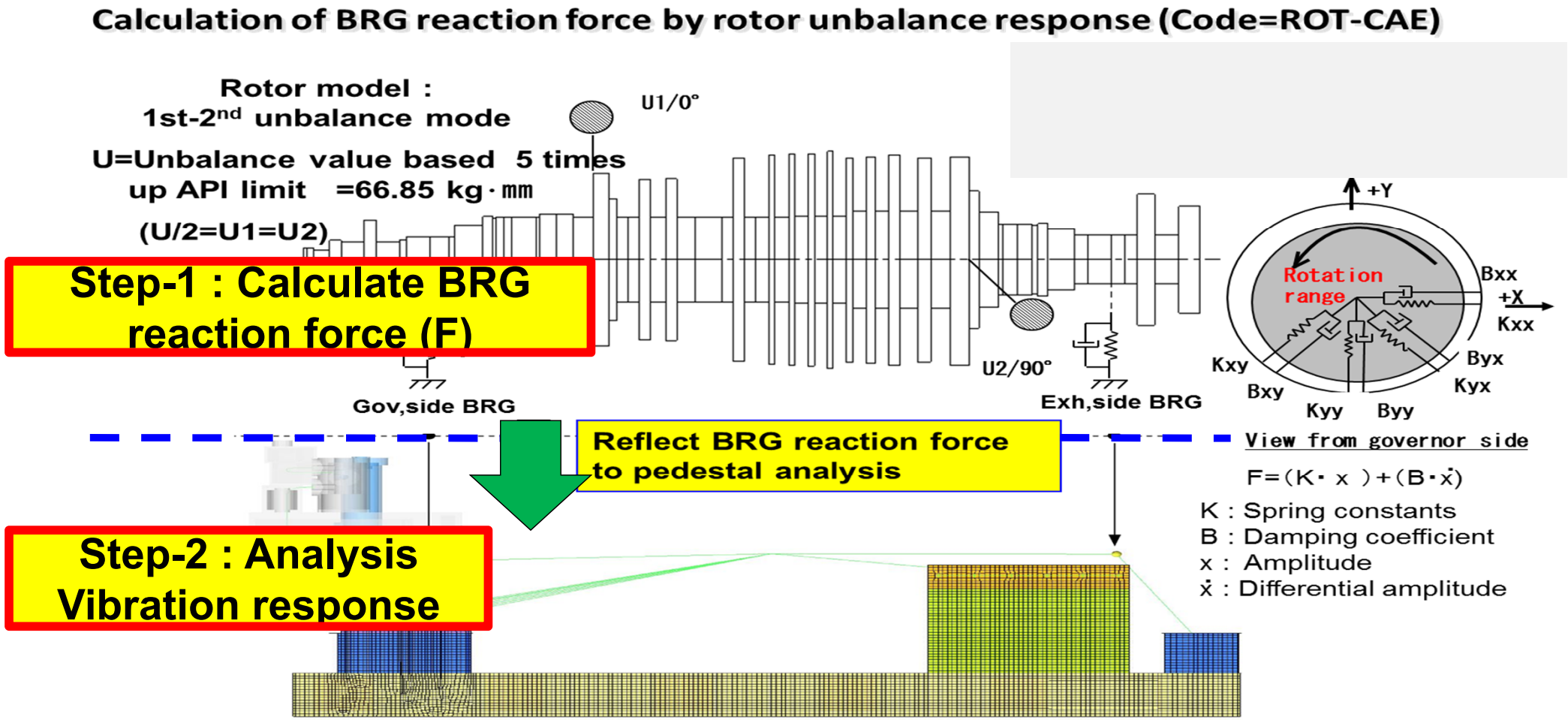
4.1 Response analysis of 3D Full modeling

In order to clarify the vibration mechanism, it performed vibration 3D response analysis(cod-Nastran) with current bearing pedestal.



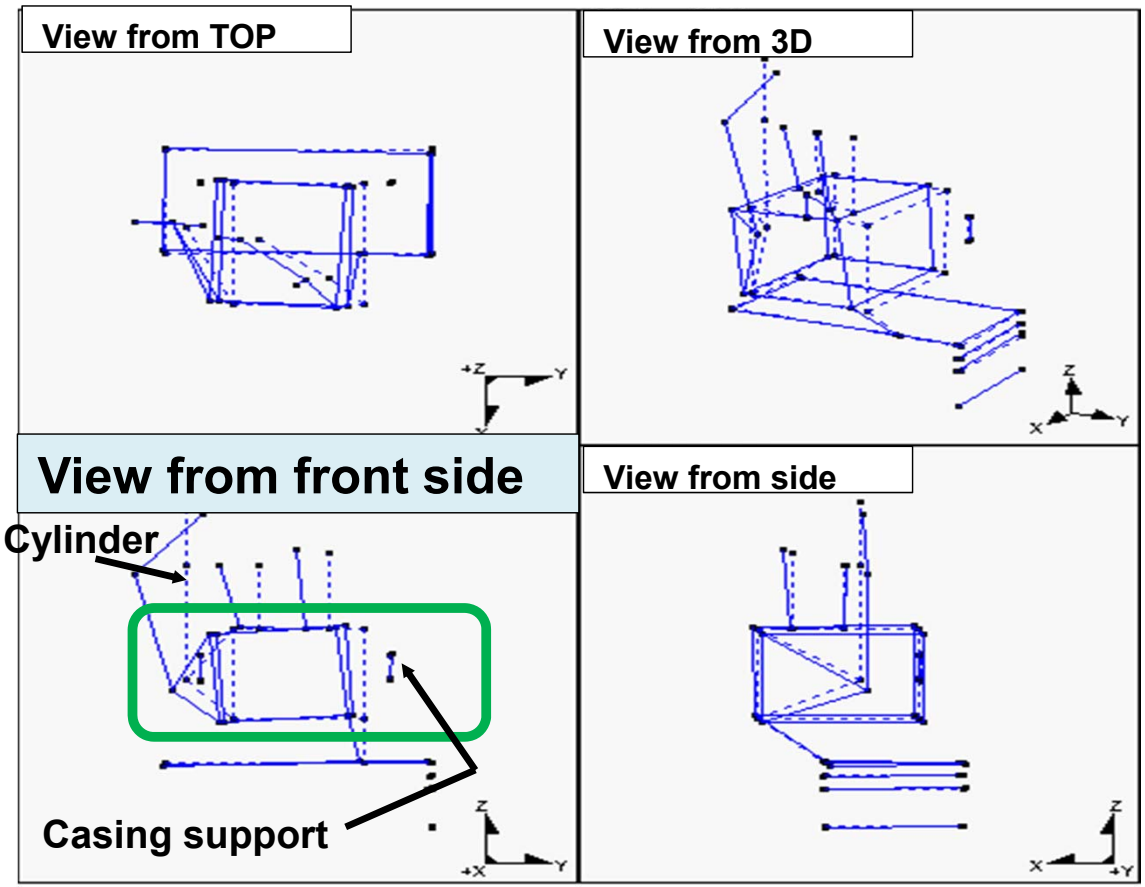
4.2 Response analysis of 3D Full modeling

Rotor modeling with excitation force calculation



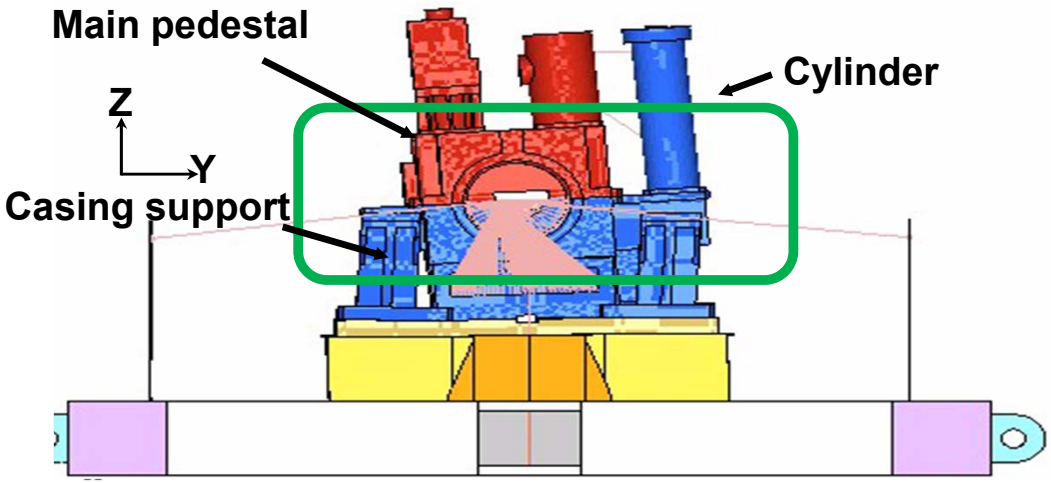
5.1 Analysis result of original pedestal in hot condition

Comparison between Measurement data and Analysis result by animation mode.



Measured vibration mode at site

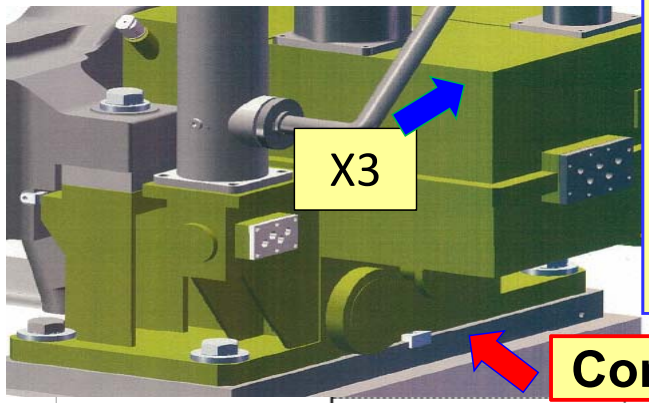
Result;
- **Well matched in both results.**
- **High responded Out-of-Phase mode between main pedestal and casing support.**



Analysis vibration mode result
(View from Exh, side)

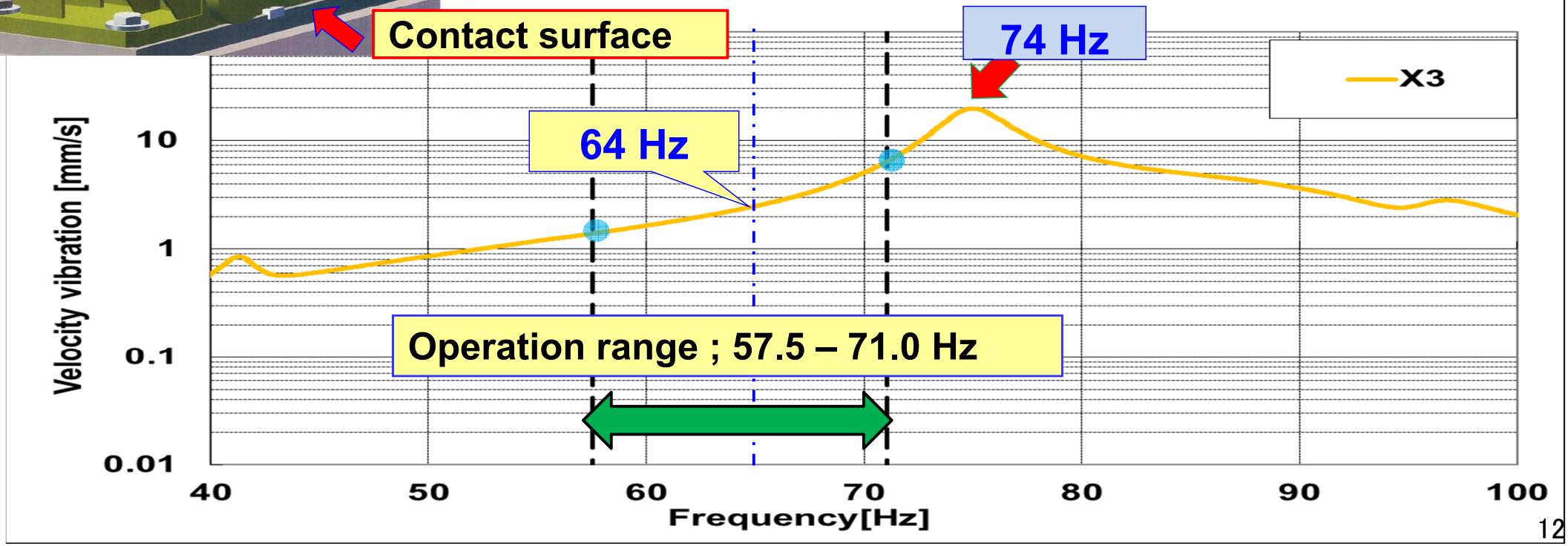
5.2 Analysis result of original pedestal in hot condition

Final analysis results of fabricated pedestal type



Result;

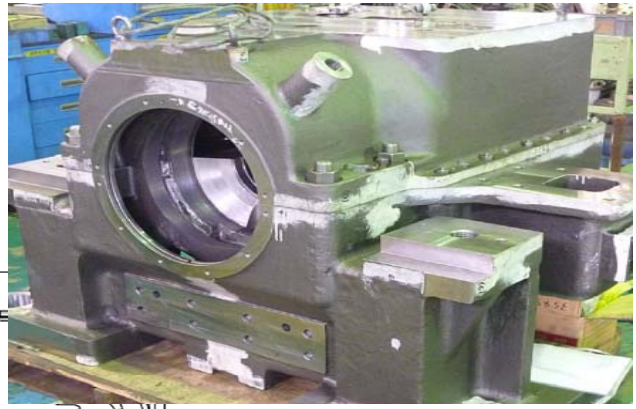
- **Natural frequency 74 Hz is close to the turbine operating speed range at hot condition.**
- **Vibration level in analysis is from 2 to 10 mm/s 0-P around normal to maximum speed as same as site vibration level.**

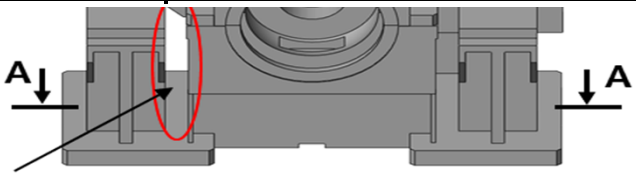


6. Comparison of original and improved pedestals

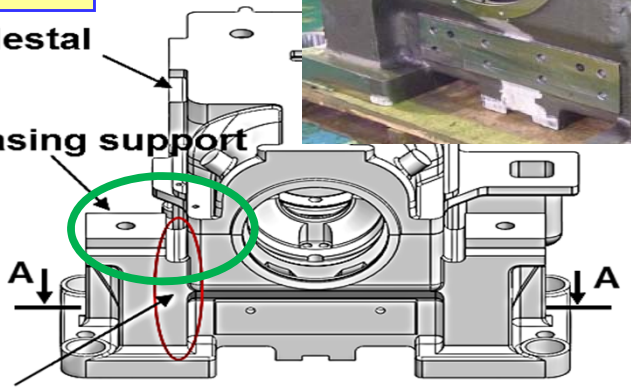
Requirement for new pedestal design;
1) Full contact condition of pedestal surface.
2) Rigidly connection between pedestal body and casing support without freestanding.

Existing pedestal & cover	New pedestal & cover
Carbon steel SS400 (Eq. ASTM A36)	Cast steel SC450 (Eq. ASTM27-93 Gr65)
Pedestal : 1590 kg	Pedestal : 1880 kg



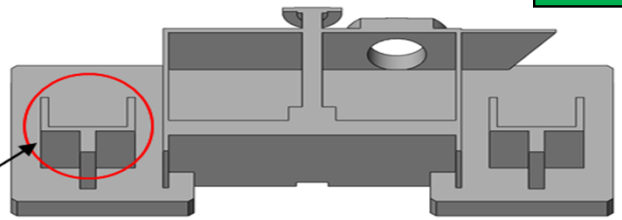


Free standing of pedestal and casing support

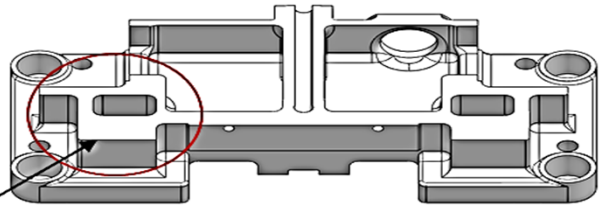


Integration between pedestal and casing support

Cross section A-A



Optimized thickness support



Robust support

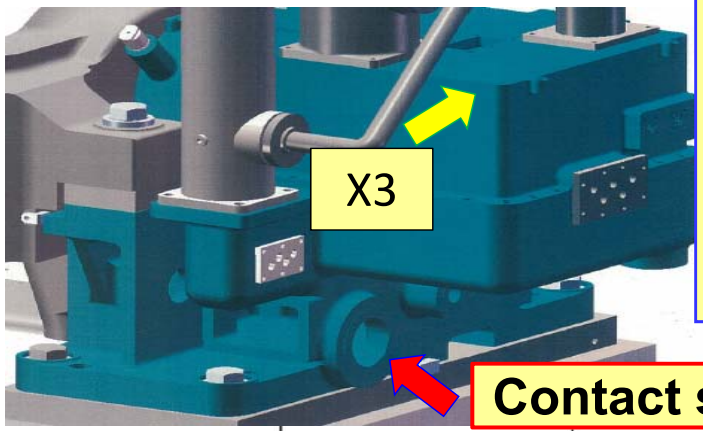
Old fabricated type

New casting type

Casting pedestal type has more high stiffness than original type

7.1 3D analysis result of improved pedestal in hot condition

Final analysis results of Casting pedestal type



Result;

a) Natural frequency 41.0Hz to be out of operation range, and satisfied with API standard (less than 48Hz).

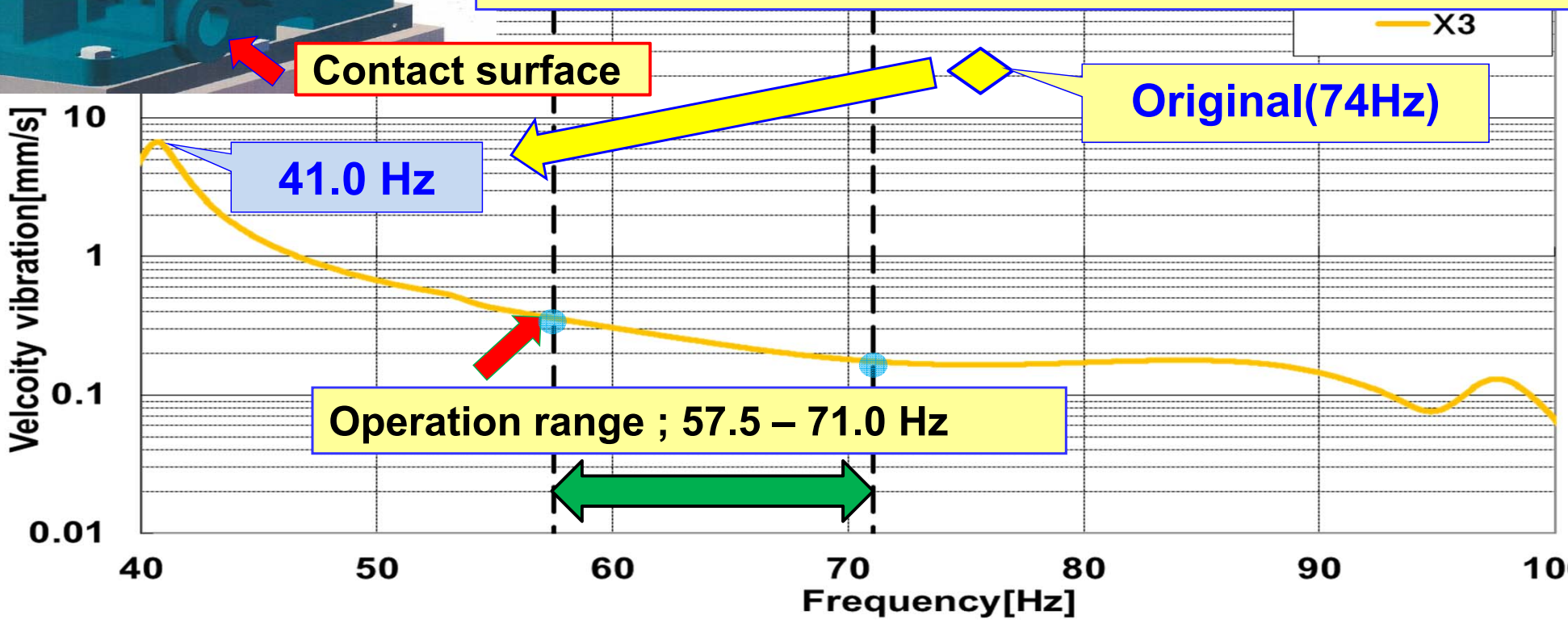
b) Vibration level in operation to be much lower at 0.2 to 0.4 mm/s 0-P even by 5-times of API unbalanced limit

Contact surface

Original(74Hz)

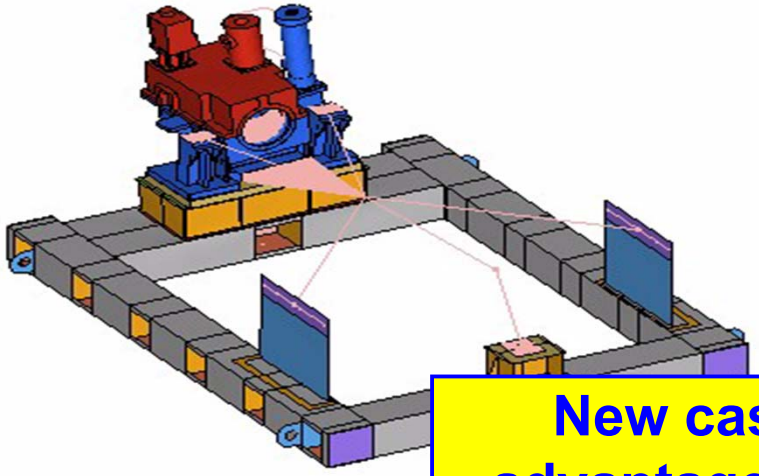
41.0 Hz

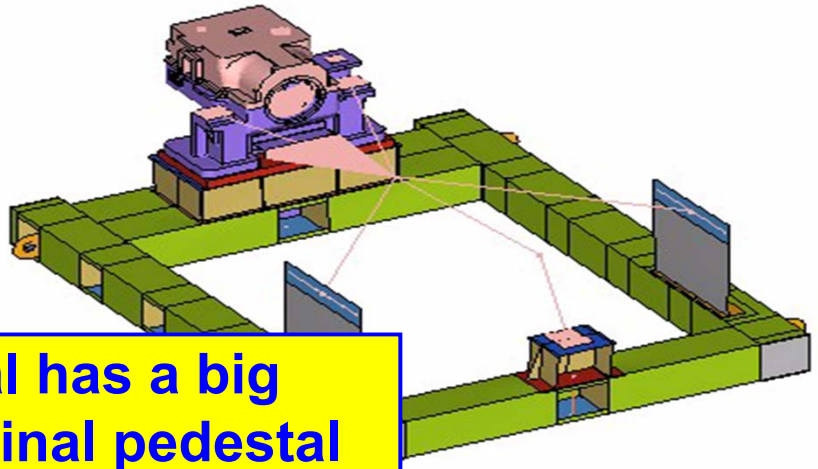
Operation range ; 57.5 – 71.0 Hz



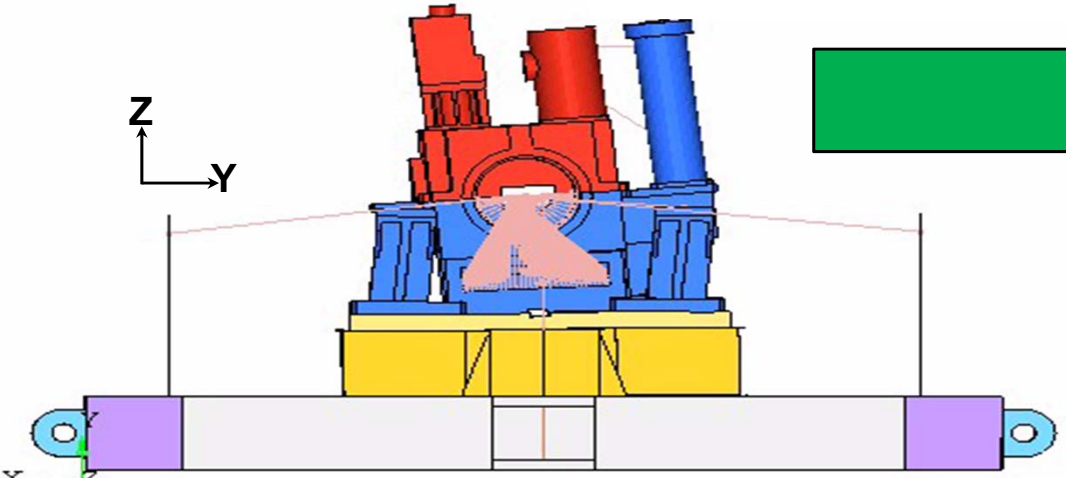
7.2 3D analysis result of improved pedestal in hot condition

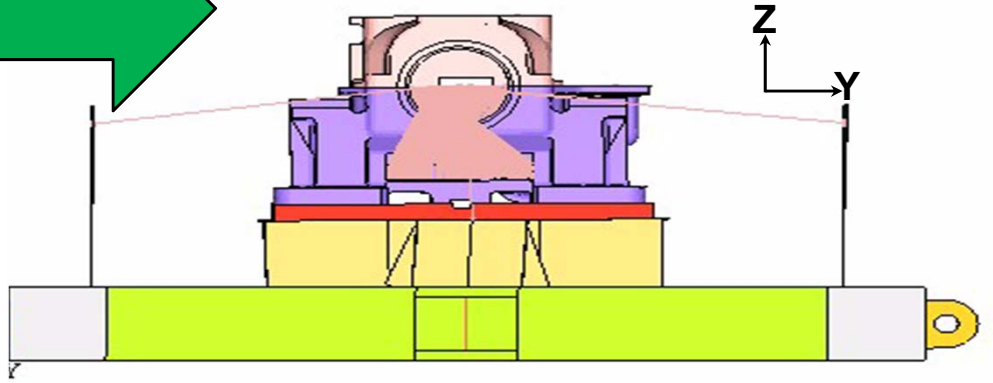
Following shows vibration mode of animation for original and improved pedestal .





New casting pedestal has a big advantage against original pedestal



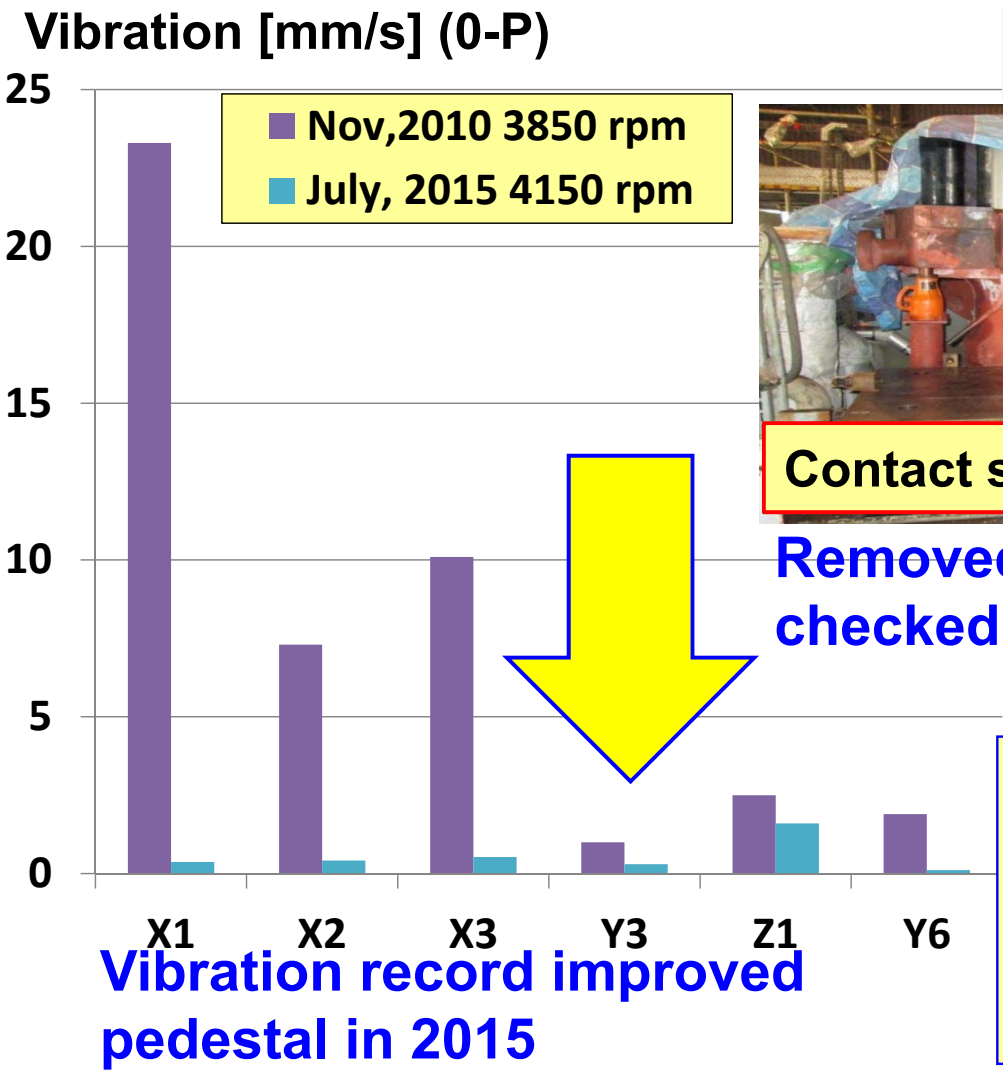


Original pedestal

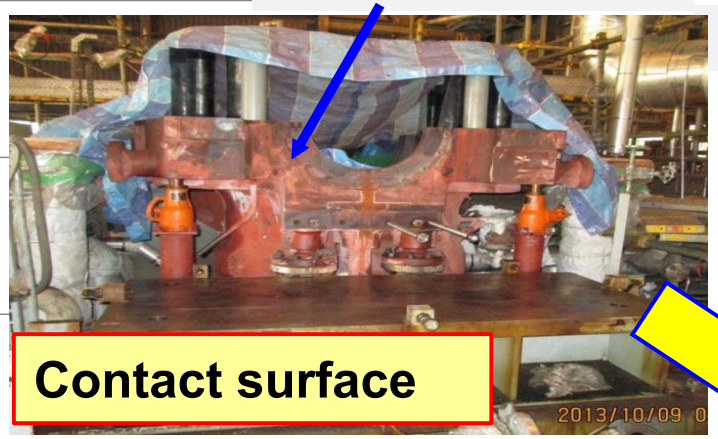
Improved pedestal

8. Site verification result for permanent solution

Result for applying of new improved pedestal



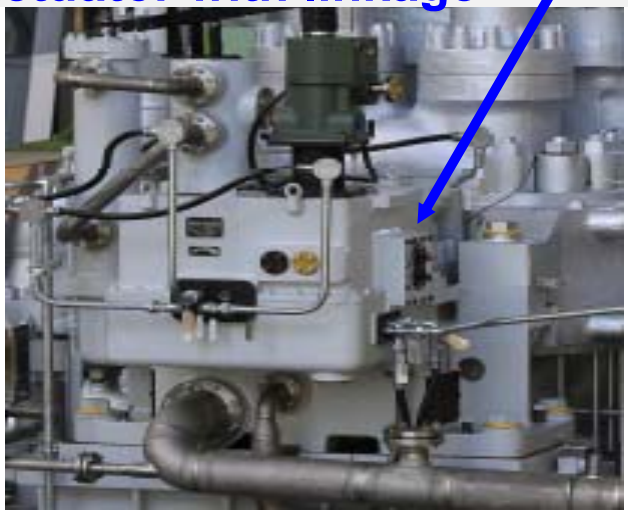
Vibration record improved pedestal in 2015



Removed old pedestal, checked alignment

Improved pedestal with cover

E/H actuator with linkage



Out view of similar turbine

Result ;
Vibration level in rotating speed to be much reduced, which means reduction of 1/10 (one-tenth) over compared with the existing pedestal vibration level.

9. Conclusion

(1) Summary of analysis result

Pedestal	Analyzed N•F	Vibration level in operation	Note
Fabricated type (Original design)	74.0Hz (Hot condition)	Maximum 10mm/s 0-P (H-direction)	
Casting type (Improved design)	41.0Hz	Less than 1mm/s 0-P (H-direction)	28% separation margin against 57.5Hz (Min. speed) satisfied with API standard of more than 16%

2) 3D response analysis was carried out using field measurement data.

- Analysis was confirmed root cause of site pedestal vibration.
- Analysis model used to design new bearing pedestal, and confirmed the expected vibration include separation margin.
- Improved bearing pedestal retrofit to similar machines. (KSA/Singapore/China)
- Field record verified the improved vibration response analysis.

10. Lessons Learned

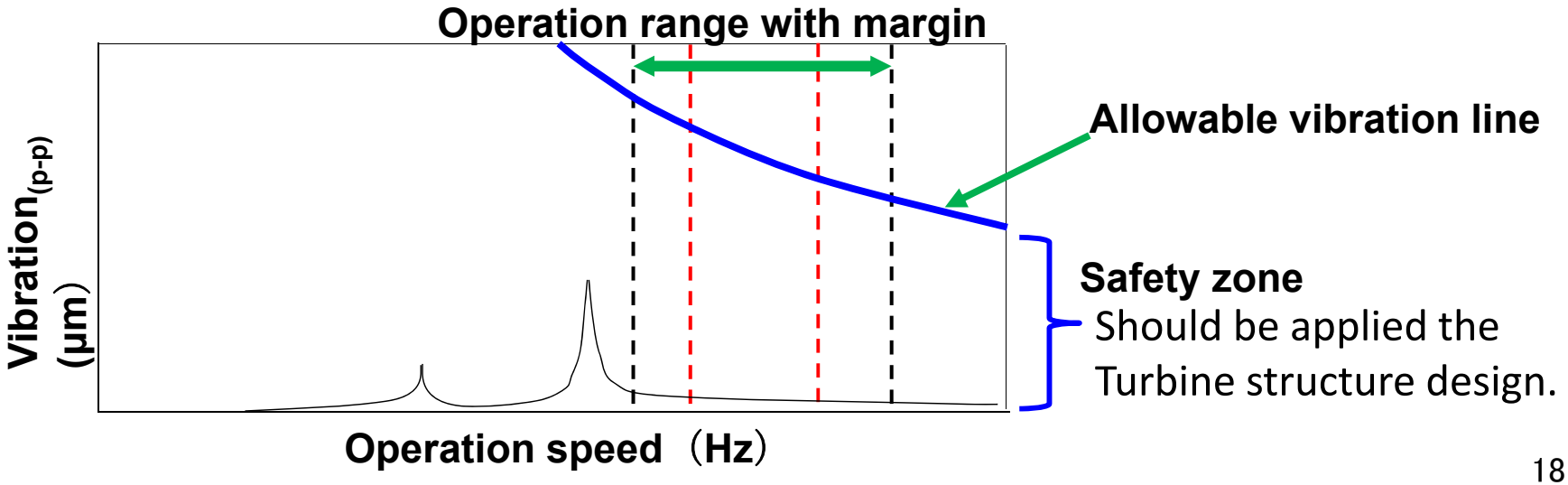
Requirement items to future structure design.

- **The robust design that can applicable a wide operation speed range.**

- **The high stiffness design include separation margin based on API.**

- **Utilize full 3D analysis based on actual structure modeling with loading data, and establishment of guidelines.**

Sample ; Design check sheet for Dynamic response analysis



Thank you for your attention