METS III

MIDDLE EAST TURBOMACHINERY SYMPOSIUM

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Large Steam Turbine Vibration Resonance of Pedestal and Linkage System RCA, Detail Vibration Investigation/Measurement at Site and Countermeasures

MITSUBISHI HEAVY INDUSTRIES COMPRESSOR CORPORATION

TEXAS A&M UNIVERSITY

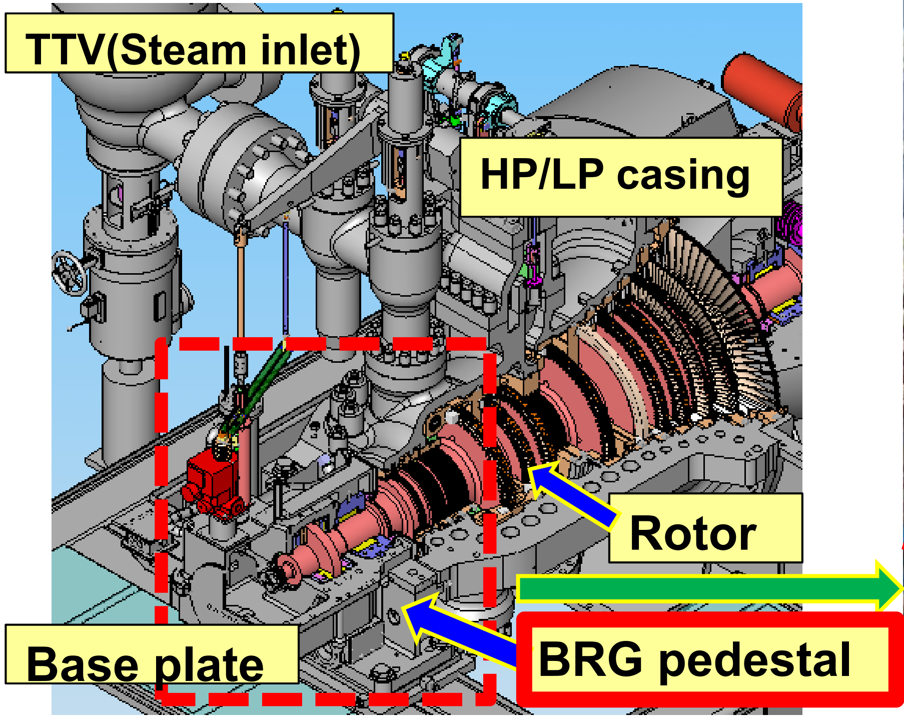
TEES TURBOMACHINERY LABORATORY TEXAS A&M ENGINEERING EXPERIMENT STATION

Preface

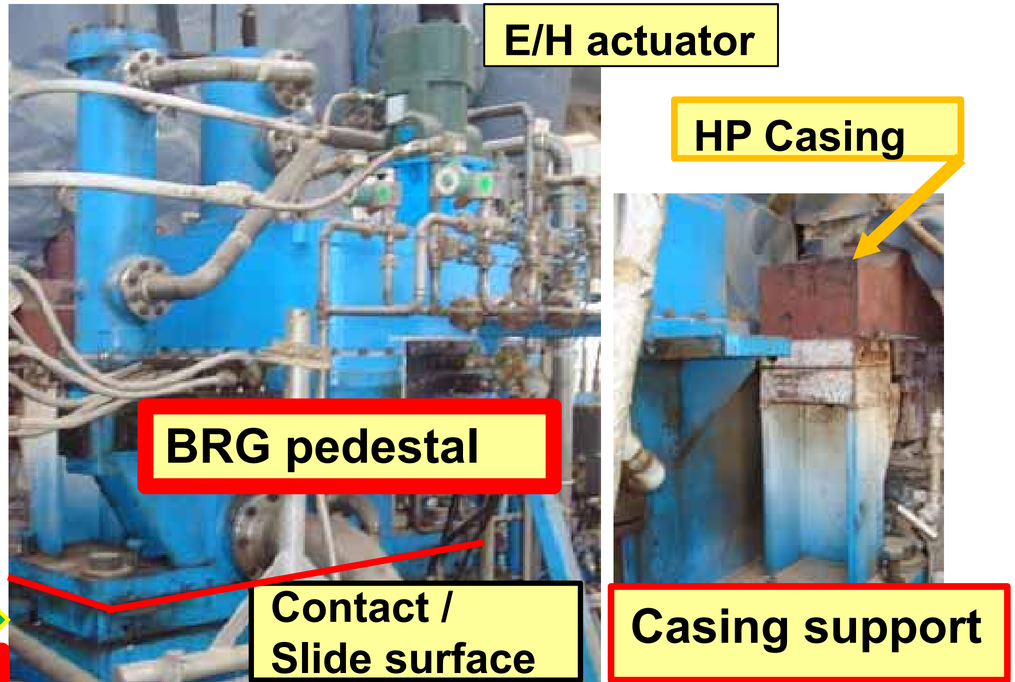
A Large Steam Turbine had been in operation for several years and this turbine experienced the wear damage of governor linkage.
Then, measured the vibration velocity profile on Governor side pedestal to identify the excited vibration mode and frequency.
According to collected data, investigated the possible 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 ; 60MW
Speed ; 2830 – 3845 rpm
Plant start ; from 2002

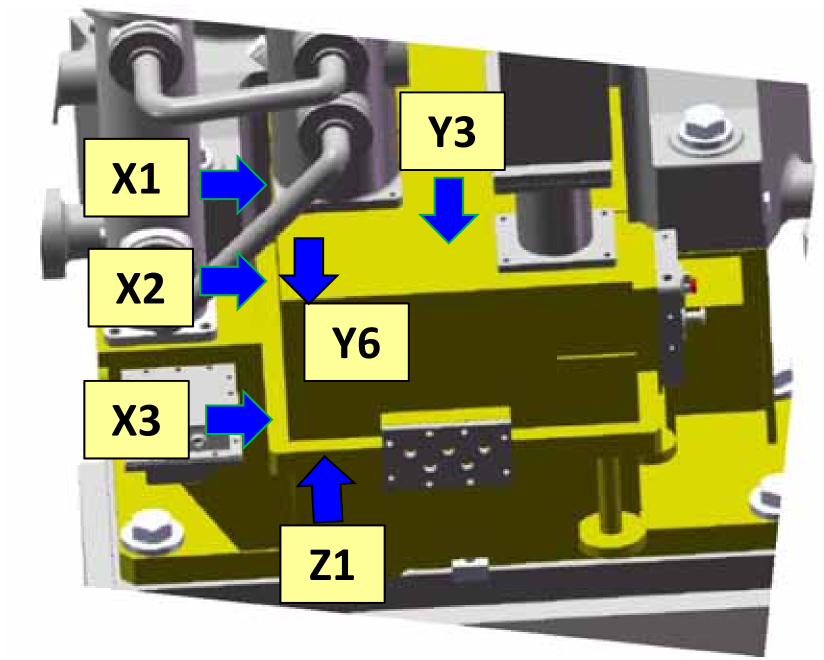
Major specification of bearing pedestal with cover assembly;

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

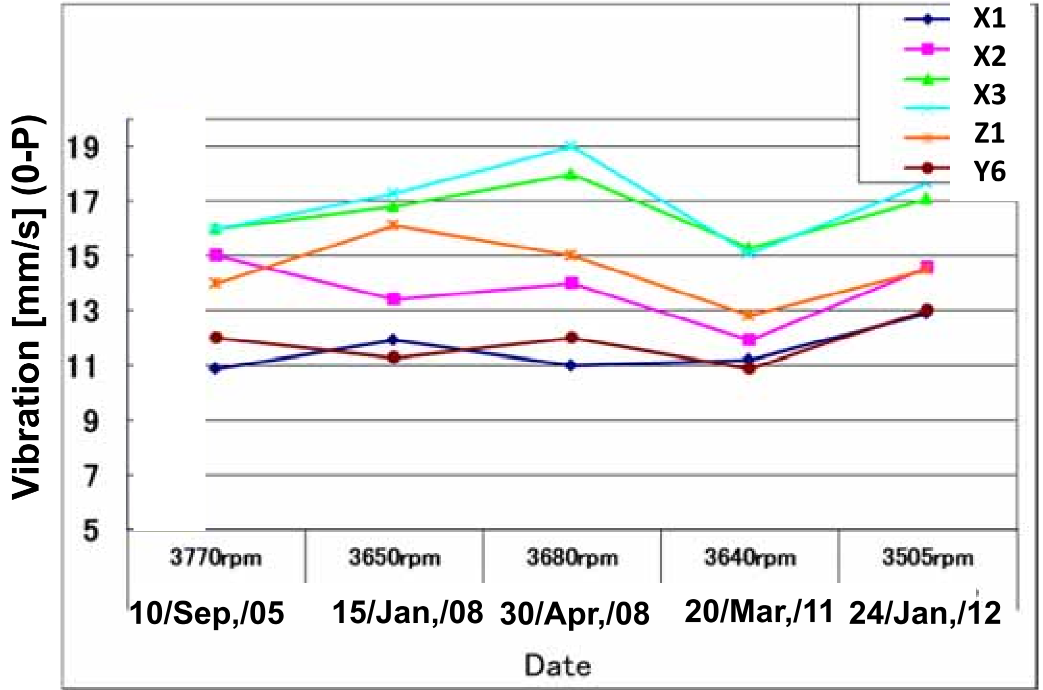
2.1 Background

Historical events at field ;

- **Turbine start up in 2002**
- **Gov, side pedestal Vibration increase from around 2005**
- **Vibration up to 20 mm/s in 2012 by turbine load/speed up**
- **Vibration causes linkage lever wear and required control limit**

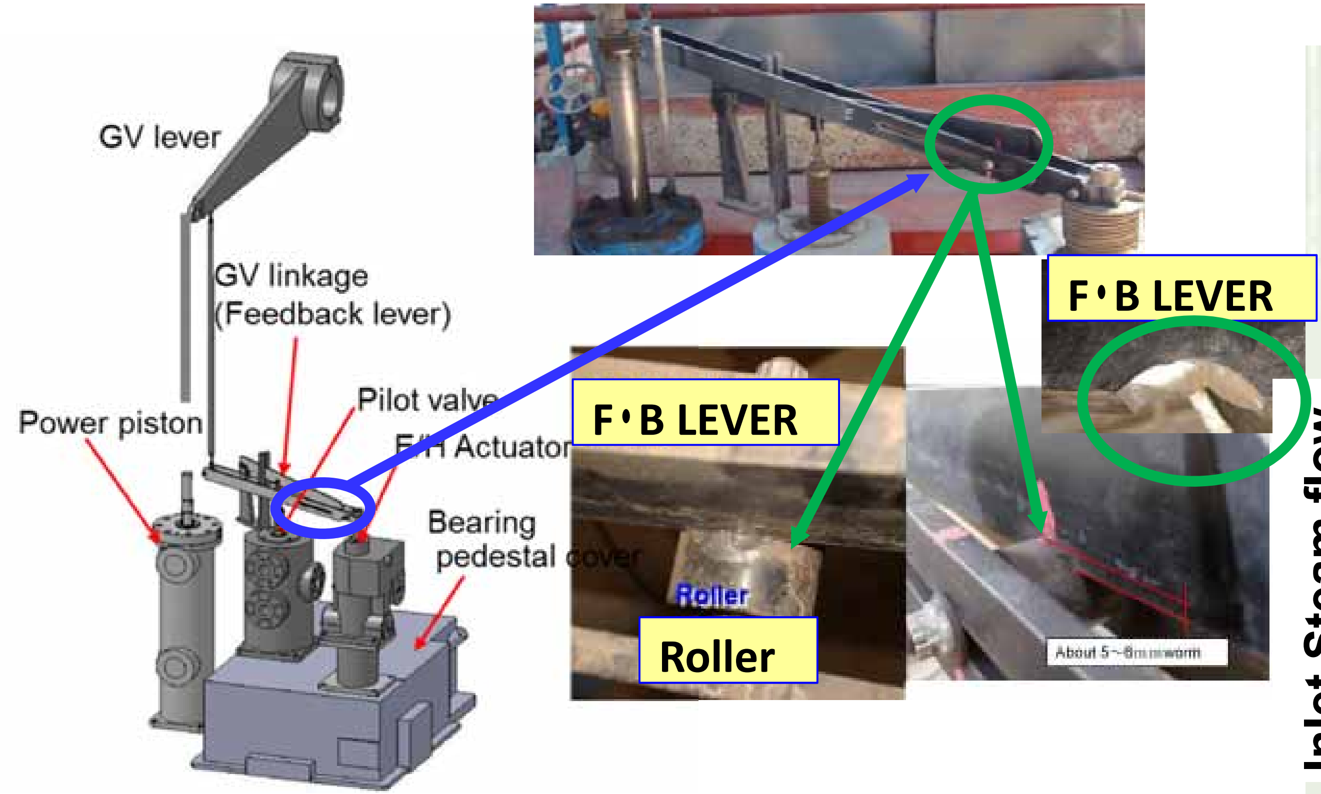


Site measurement points
(View from Gov, side)



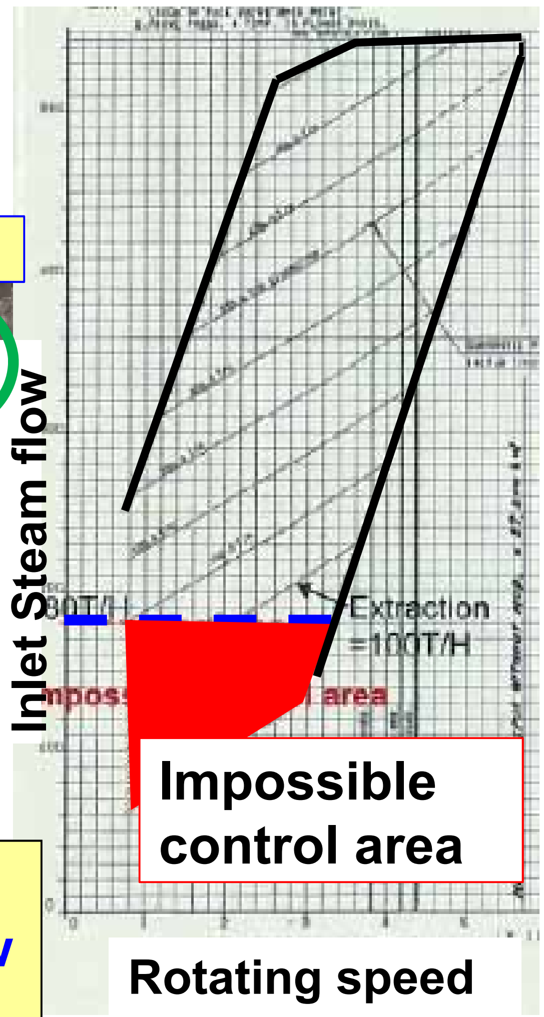
Pedestal vibration record from 2005 to 2012

2.2 Background



GV linkage damage condition

Steam flow map



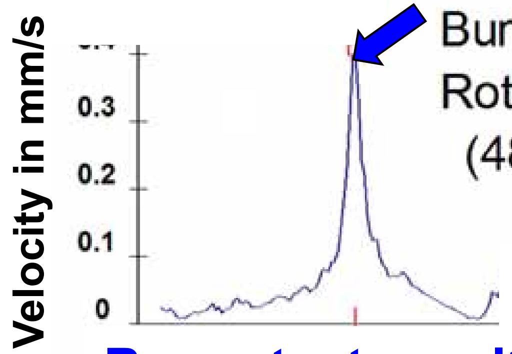
Operation condition ;

It was shifted actual inlet steam flow against E/H actuator signal.

Occurred Impossible control area.

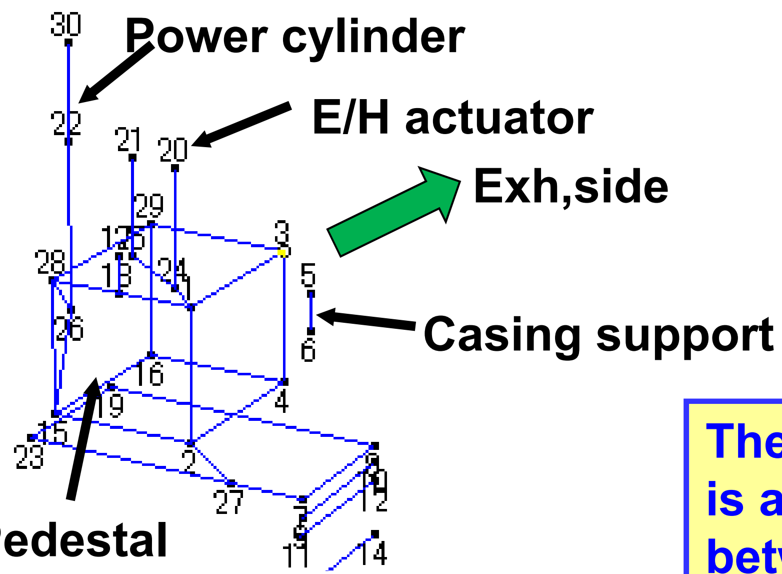
2.3 Background

Site vibration measurement record ;

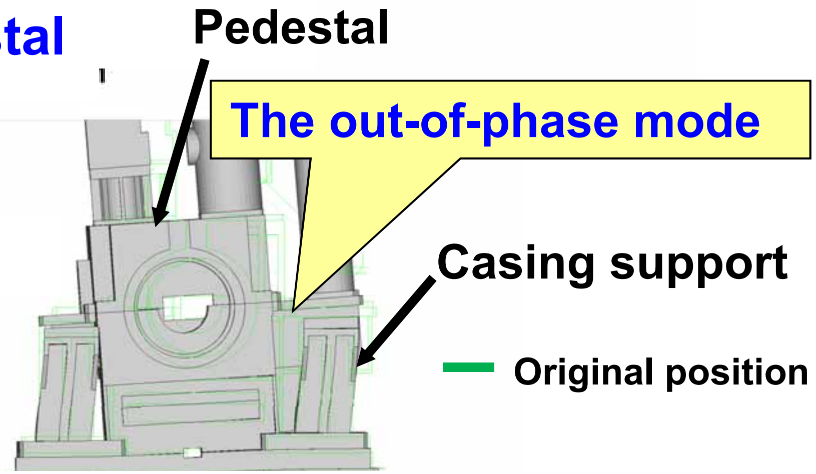


Bump test result ; 73 Hz(Natural frequency)
Rotating speed
(48.8 to 64Hz(2830 to 3845rpm))

Bump test result of pedestal



Site measurement points (No,30)



Measured vibration mode at 3555 rpm

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

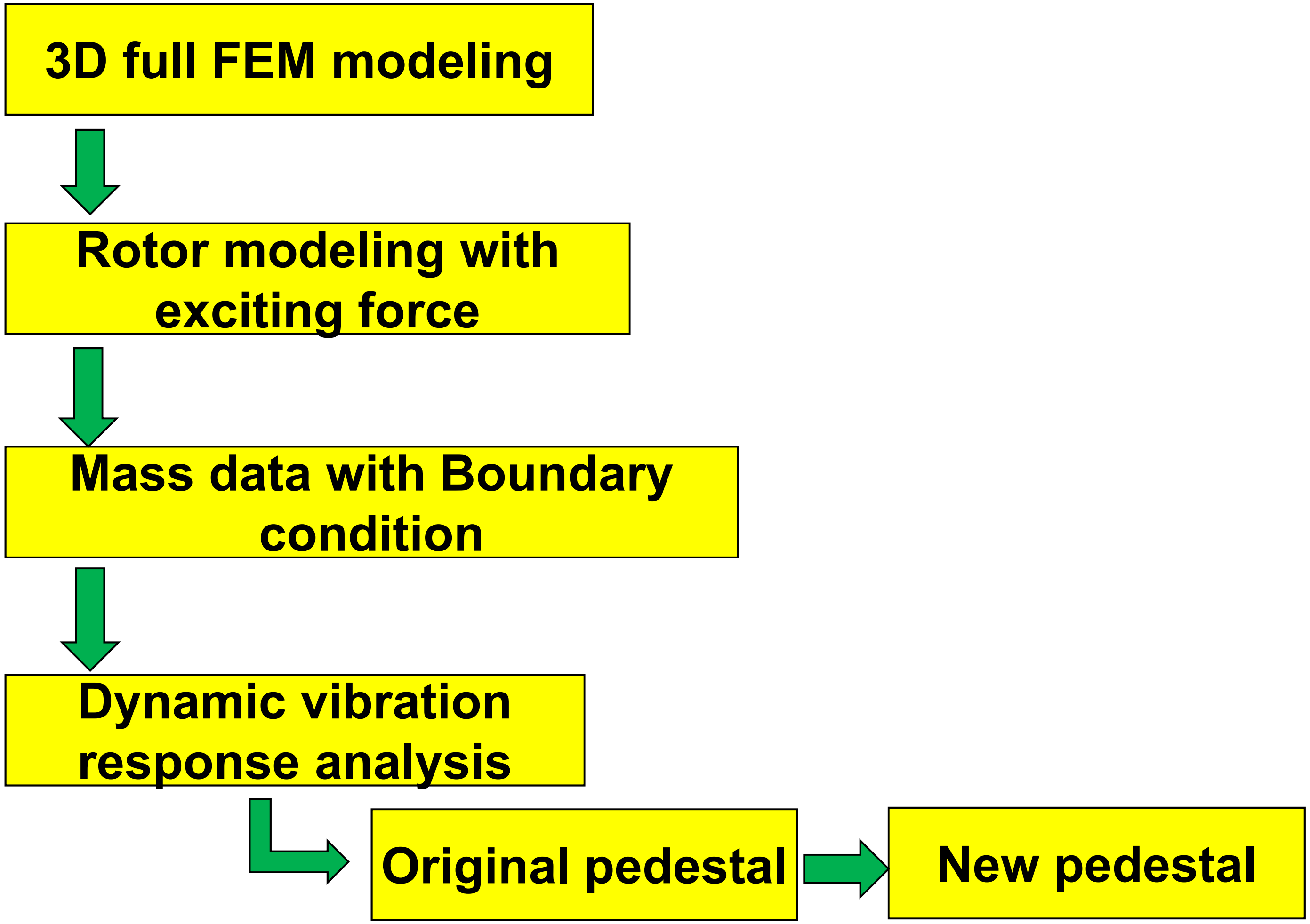
3, Decrease of dynamic stiffness

- **Foundation degradation**
- **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.

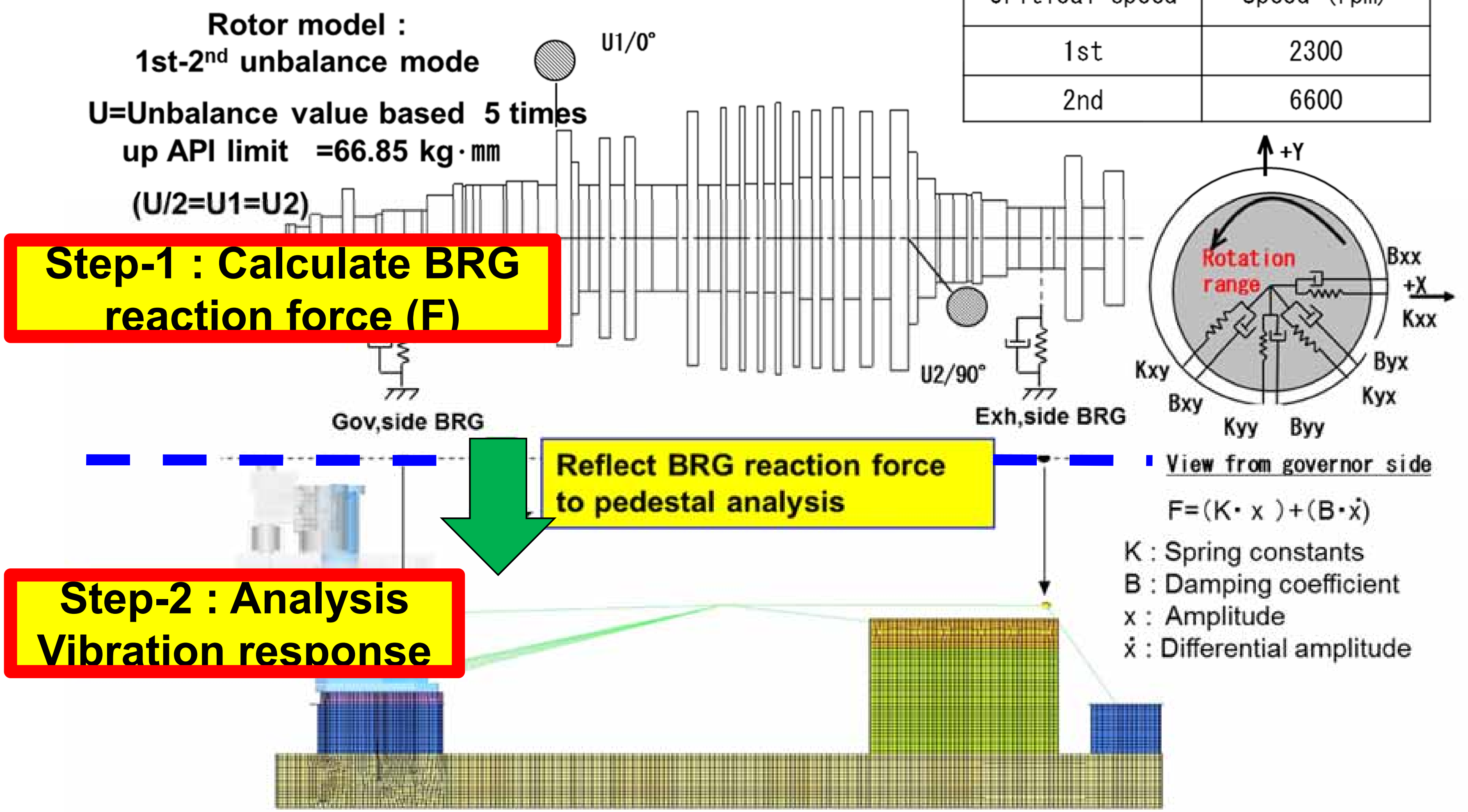


4.2 Response analysis of 3D Full modeling

Rotor modeling with excitation force calculation

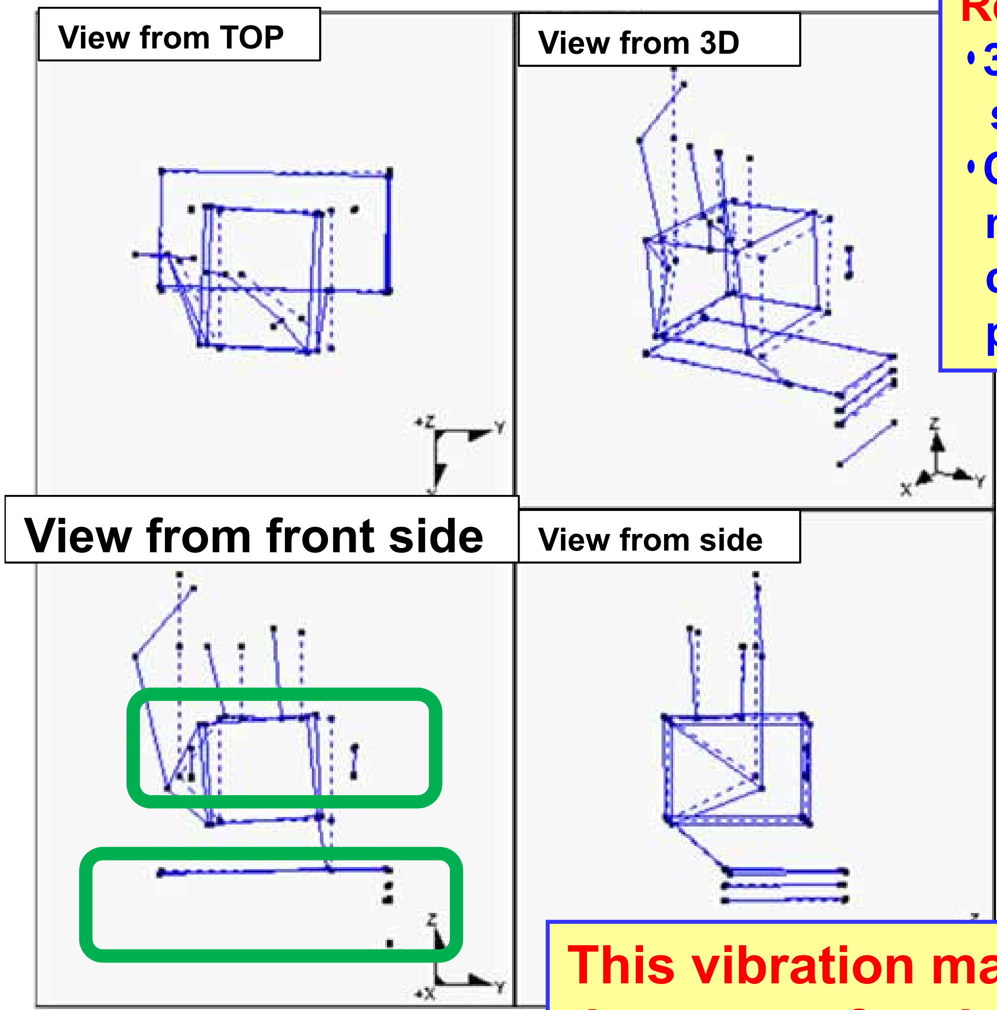
Calculation of BRG reaction force by rotor unbalance response (Code=ROT-CAE)

Critical speed	Speed (rpm)
1st	2300
2nd	6600



5.1 Analysis result of original pedestal in hot condition

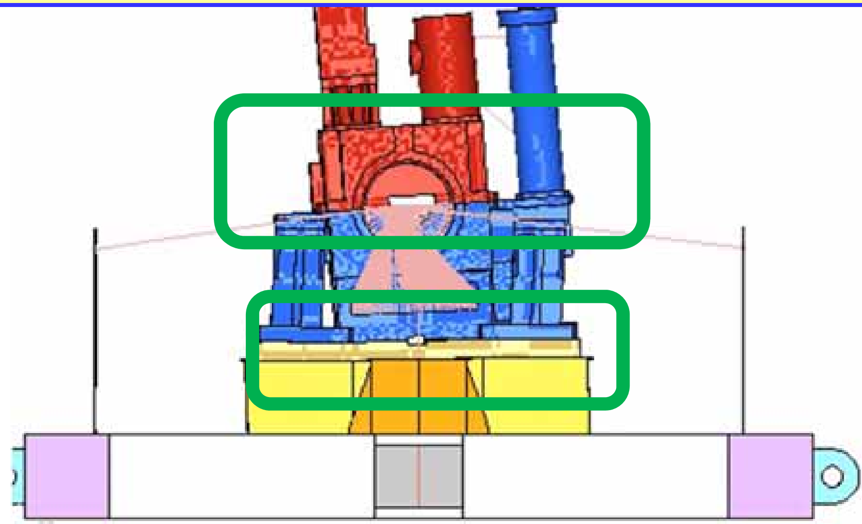
Comparison between Measurement data and Analysis result by animation mode.



Measured vibration mode at site

Result;

- 3D response analysis method is almost suitable for site operating condition.
- Confirm the out-of-phase(counter-motion) mode between main pedestal and upper casing support, and moving up for pedestal contact surface.



Analysis vibration mode result
(View from Exh, side)

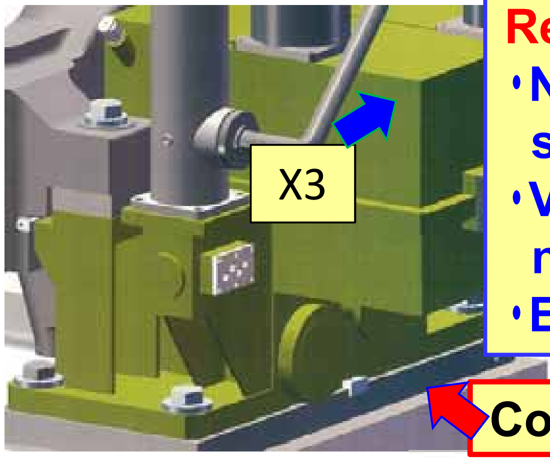
This vibration main cause is the decrease of pedestal stiffness

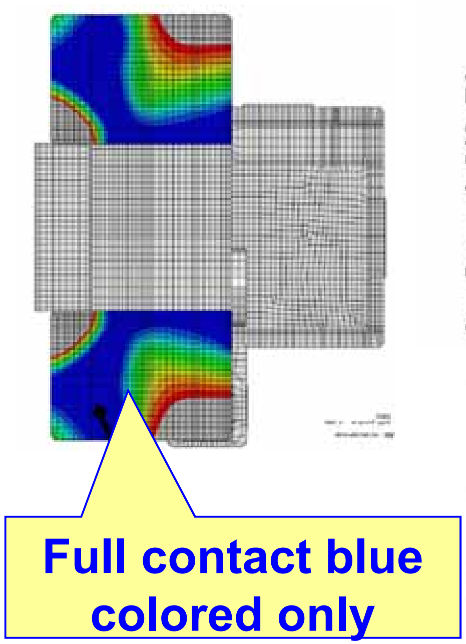
5.2 Analysis result of original pedestal in hot condition

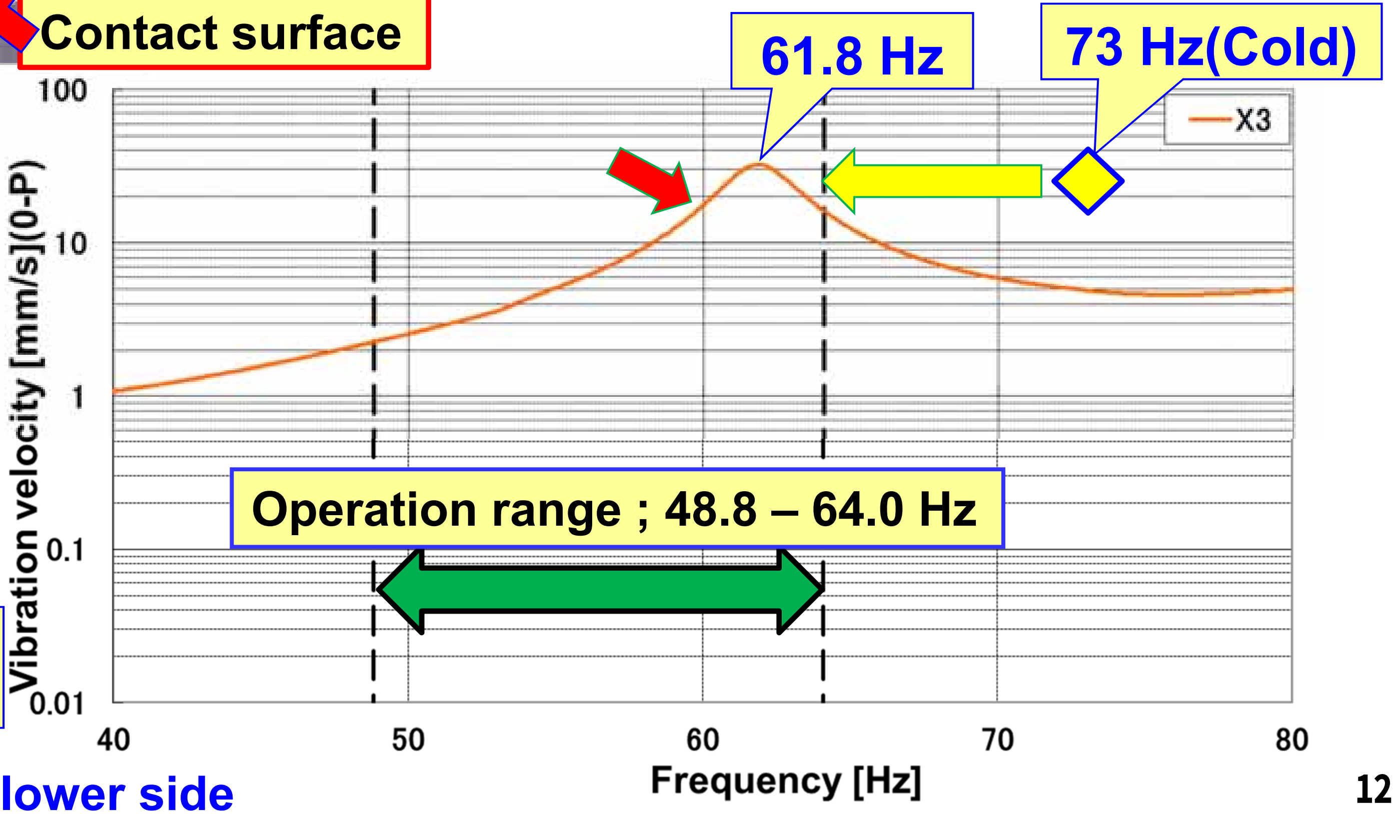
Final analysis results of fabricated pedestal type

Result;

- **Natural frequency 61.8Hz is in to the turbine operating speed range at hot condition, it shifted from cold condition.**
- **Vibration level in analysis is 10 to 30mm/s 0-P around normal to max speed as same as site vibration level.**
- **Equivalent to full contact area of pedestal to be reduced.**





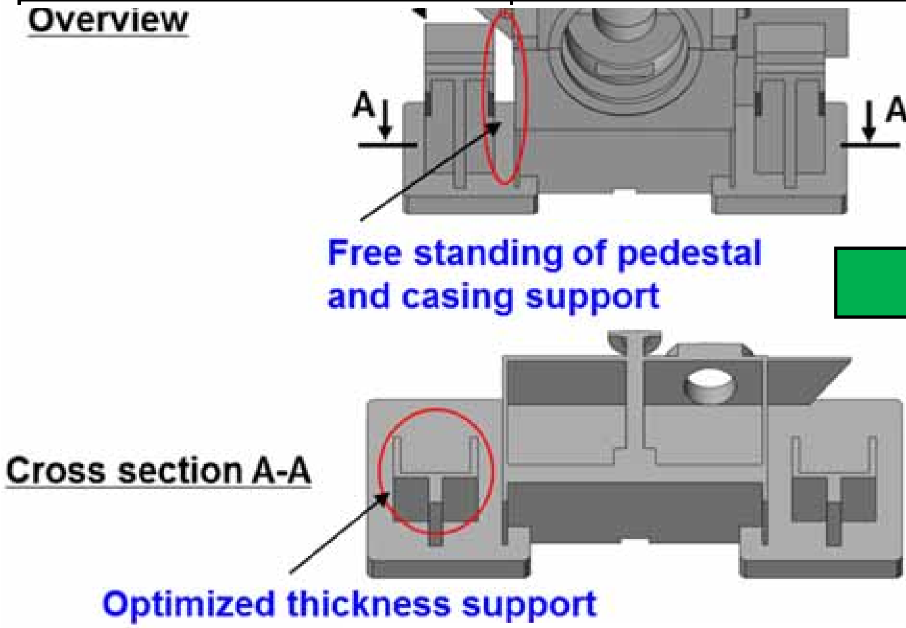


View from pedestal lower side

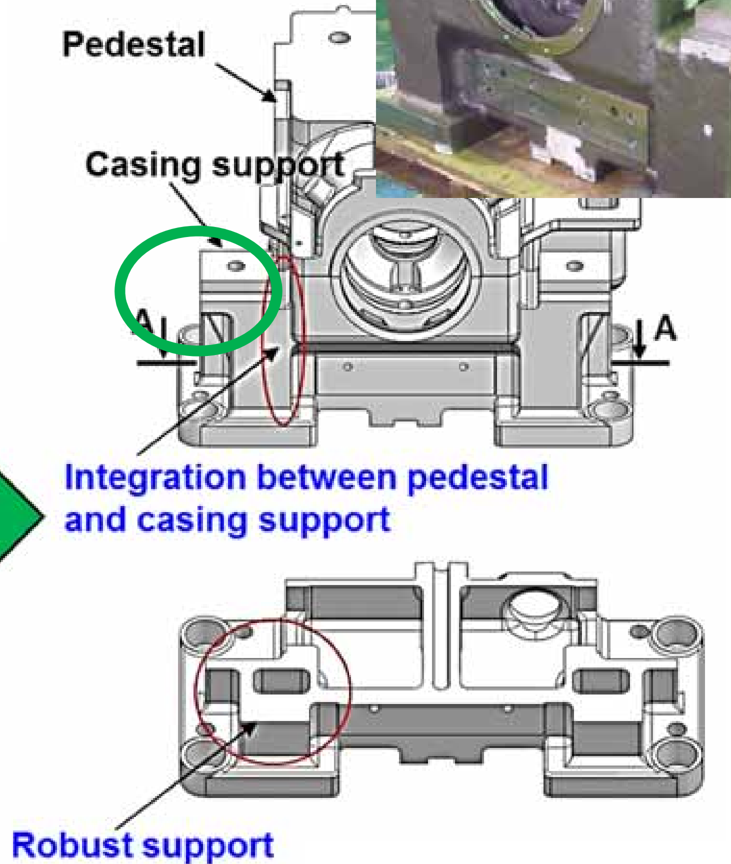
6. Comparison of original and improved pedestals

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



Old fabricated type

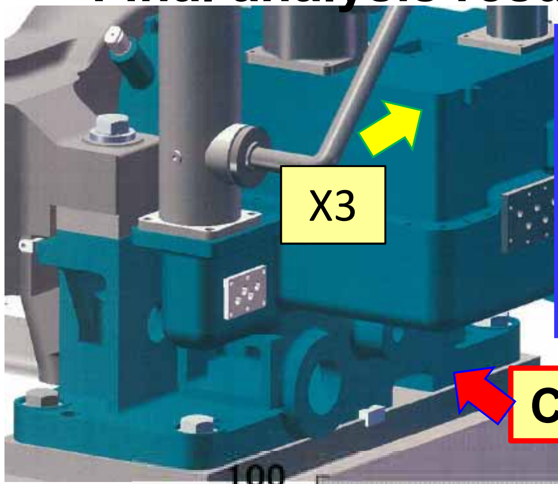


New casting type

Casting pedestal type has more high stiffness than original type

7.1 3D analysis result of improved pedestal in hot condition

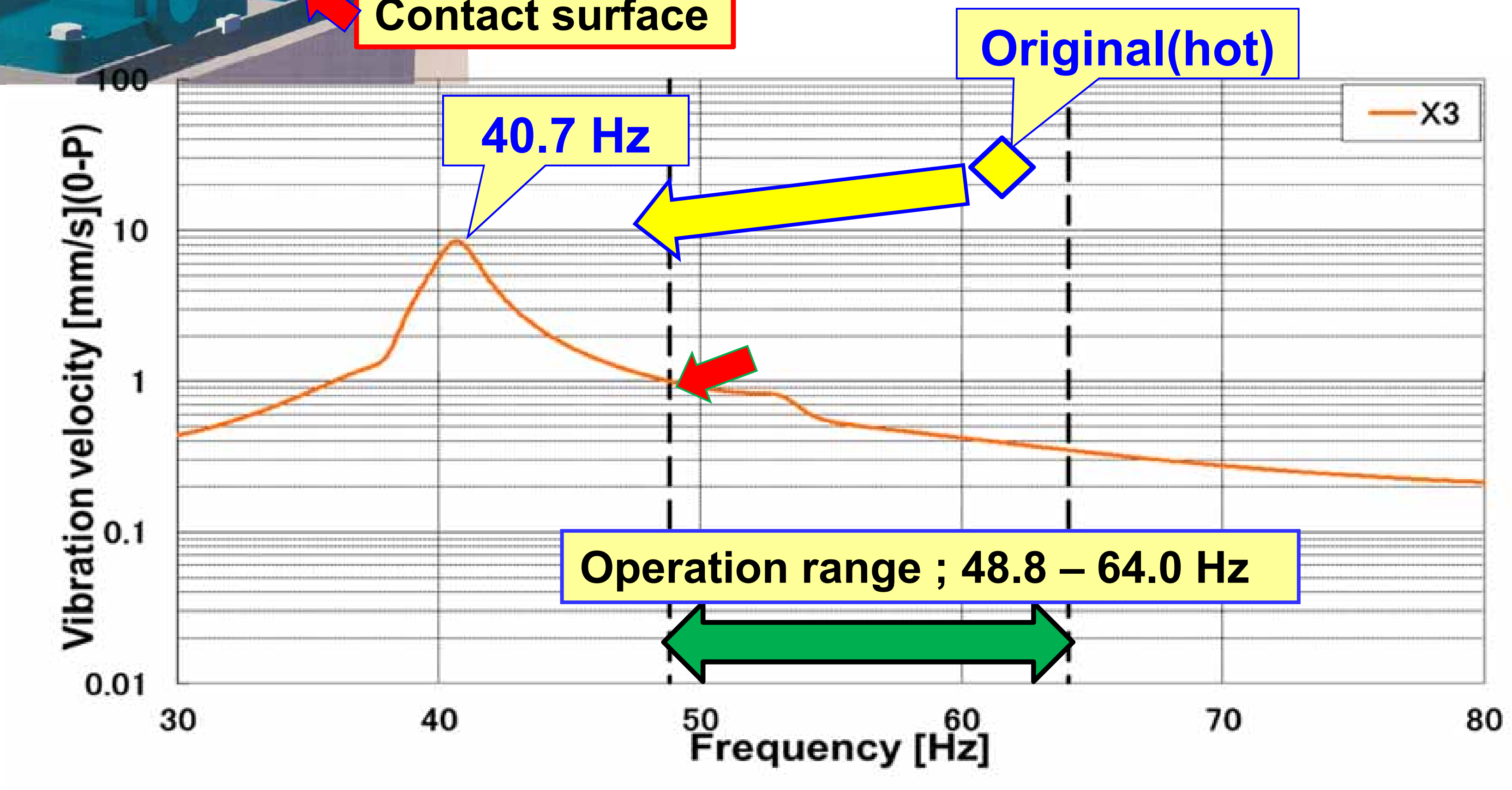
Final analysis results of Casting pedestal type



Result;

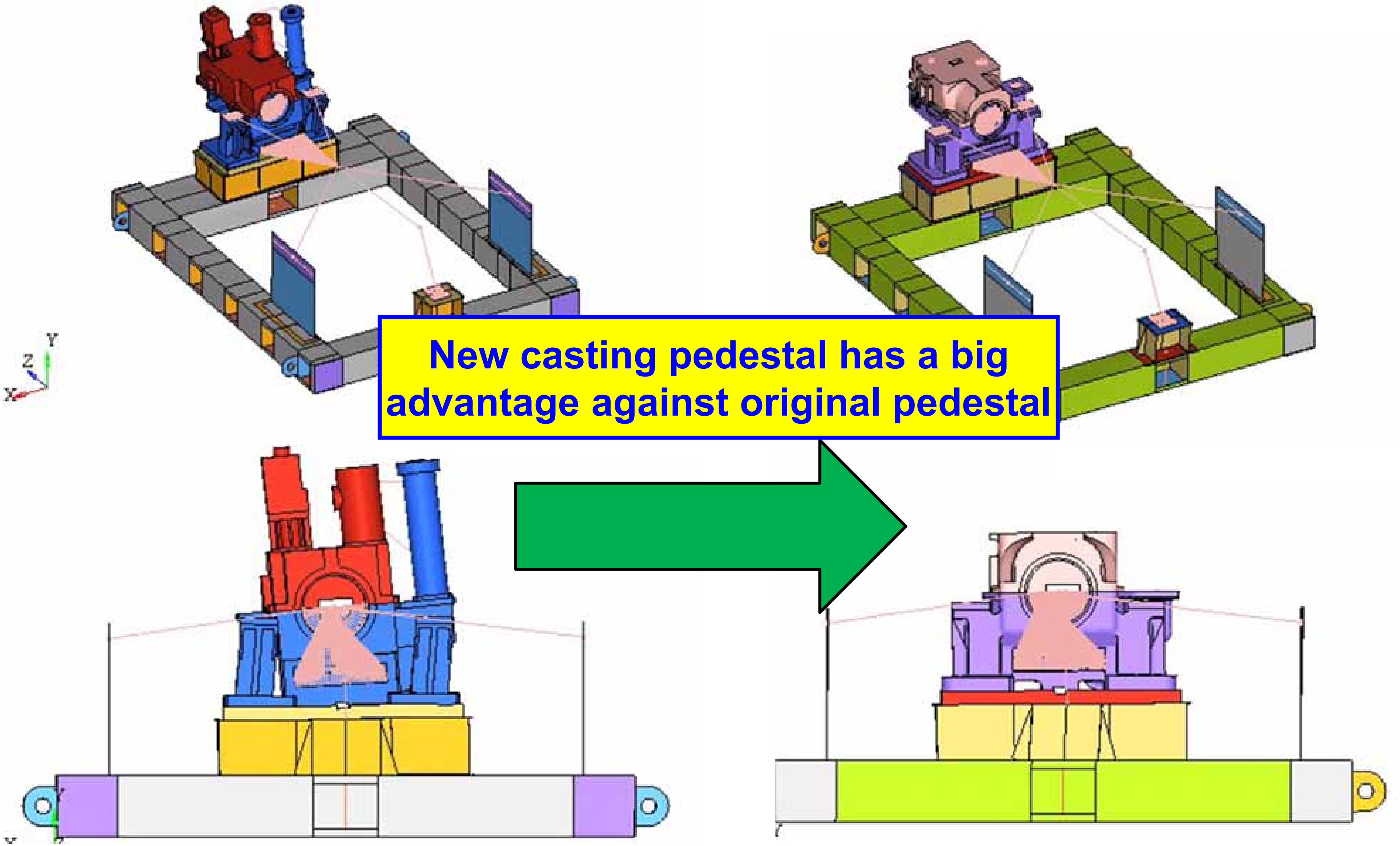
a) Natural frequency 40.7Hz to be out of operation range, and satisfied with API standard (less than 41Hz).

b) Vibration level in operation to be much lower at 0.3 to 1 mm/s 0-P even by 5-times of API unbalanced limit



7.2 3D analysis result of improved pedestal in hot condition

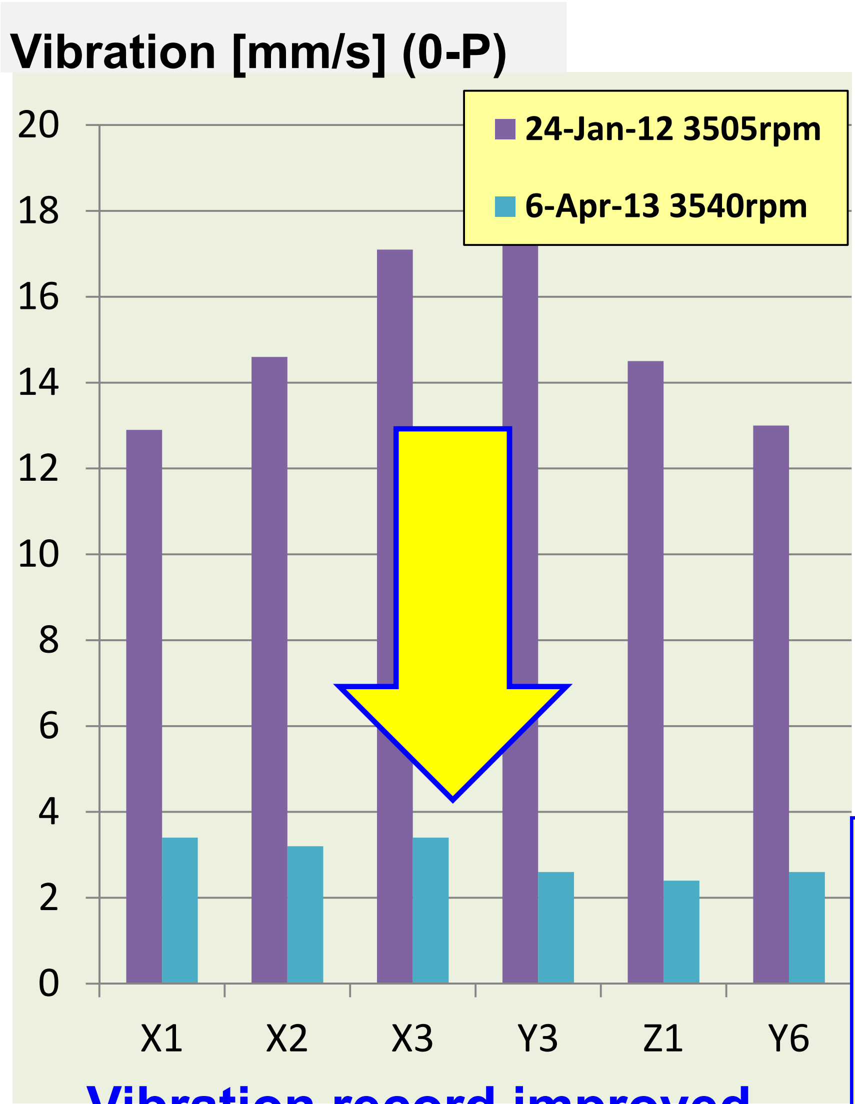
Following shows vibration mode of animation for original and improved pedestal .



Original pedestal **Improved pedestal**

8. Site verification result for permanent solution

Result for applying of new improved pedestal



Vibration record improved pedestal in 2013

Out view of similar turbine

Result ;
Vibration level in rotating speed to be much reduced to less than 3.0 mm /sec (0-P) , which means reduction of 80% 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)	61.8Hz (Hot condition)	Maximum 30mm/s 0-P (H-direction)	Almost same as site bump test (73Hz) with cold condition 69.2Hz.
Casting type (Improved design)	40.7Hz	Less than 1mm/s 0-P (H-direction)	17% separation margin against 48.8Hz (Min. speed) satisfied with API standard of more than 16%

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

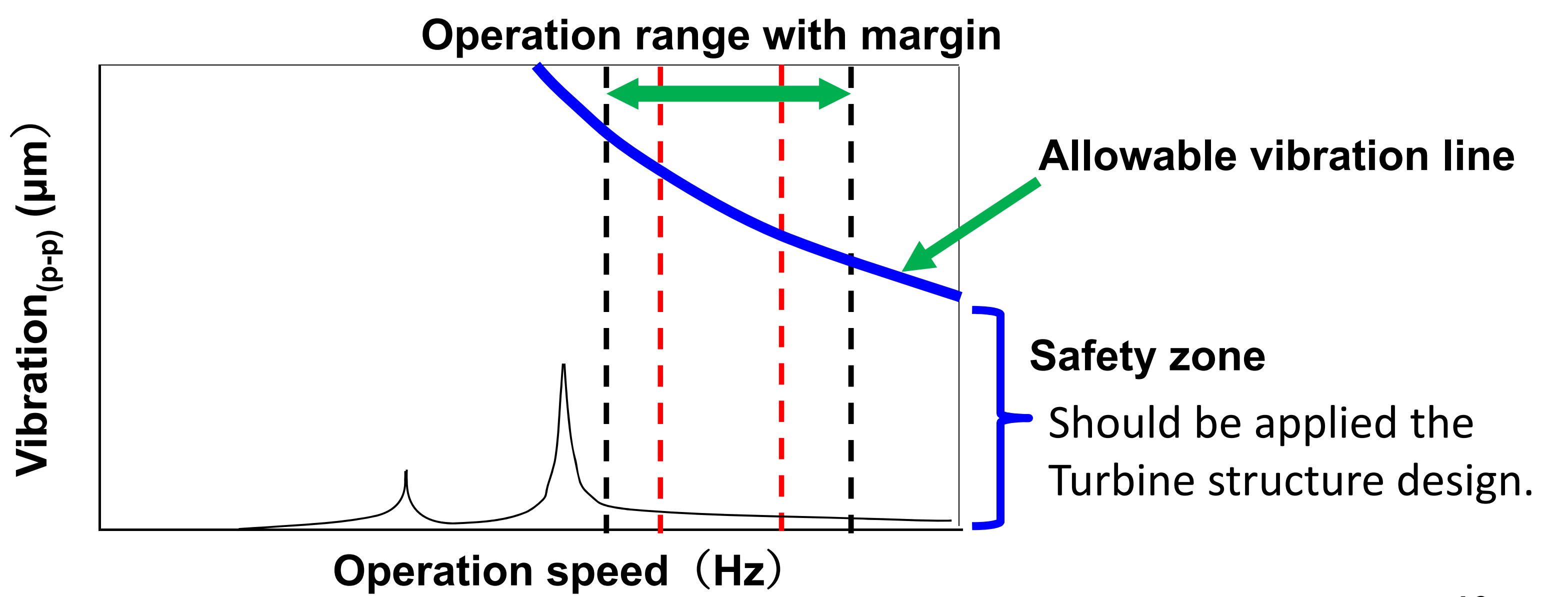
- Analysis was confirmed root cause of site pedestal vibration.
- Analysis model used to design new bearing pedestal, and confirmed the expected vibration include separation margin.
- Improved bearing pedestal retrofit to similar machines.
- Field record verified the improved vibration response analysis.

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