

TURBOMACHINERY
& PUMP SYMPOSIA



RCA report on governing valve seat failure for ERC Turbine

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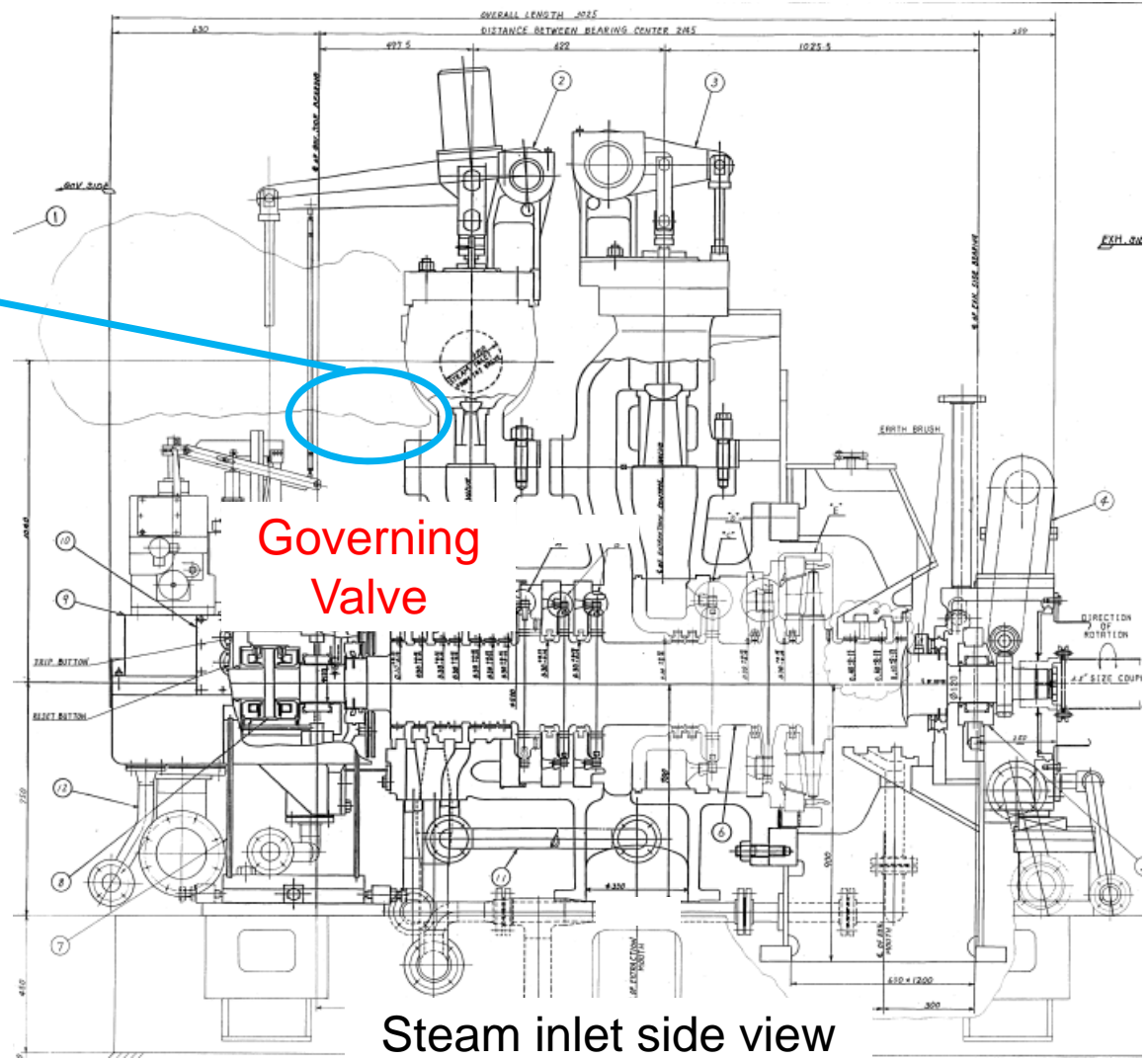
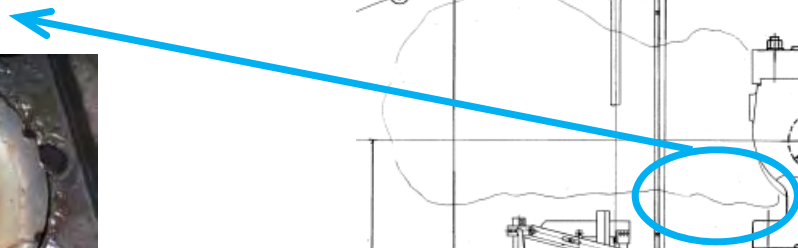
Engineer, Turbine Engineering & Design Section, Mitsubishi Heavy Industries Compressor Corporation, Hiroshima, Japan. He has 10 years of experience as a turbine engineer. Mr. Oishi graduated from Tokuyama College of Technology (Mechanical & Electrical Engineering).

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1. Site observation of valve seat failure in Governing valve

2nd valve seat (out of 3 valve seats) broke in the valve box of Governing valve.



Turbine spec.

Model : 5EL-6

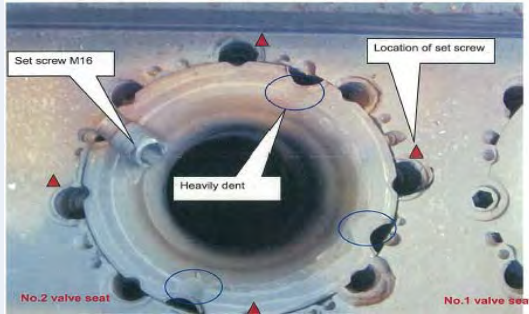

Max. speed : 9509 rpm

Max. power : 8988 kW

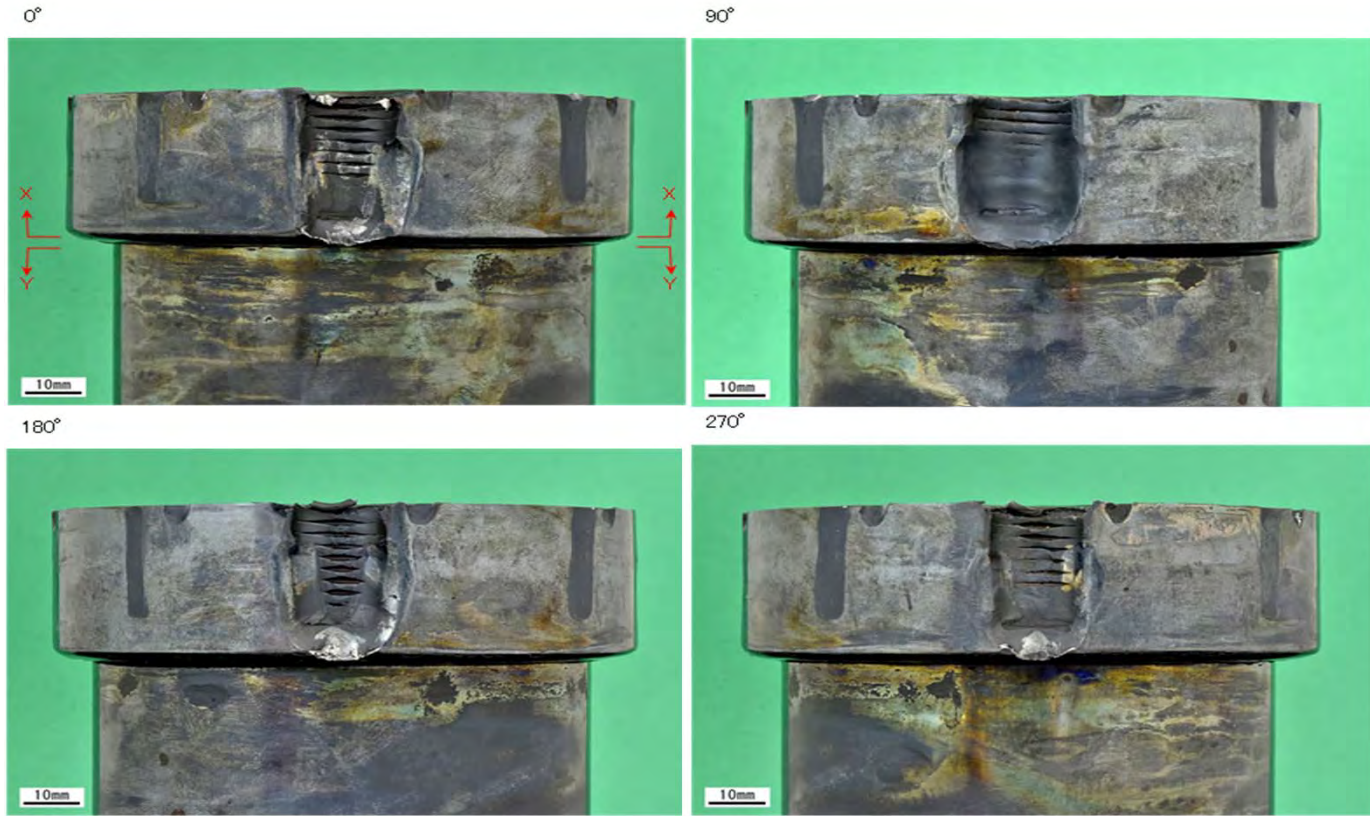
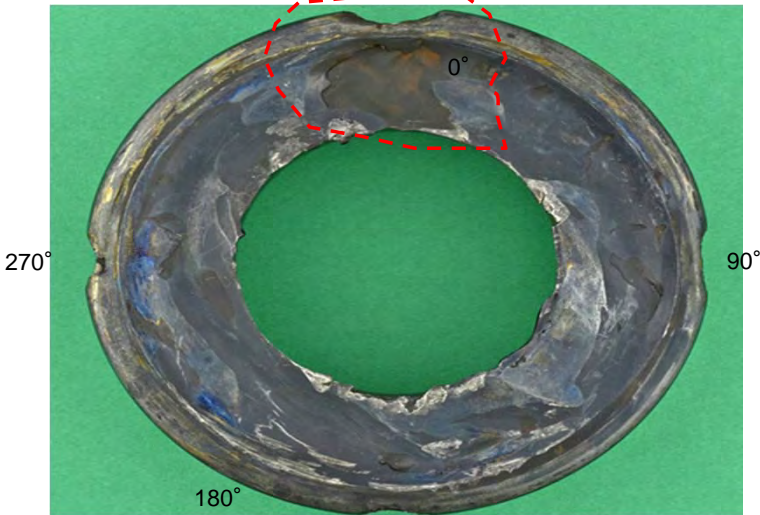
Steam inlet side view

2. Background(History)

Turbine history

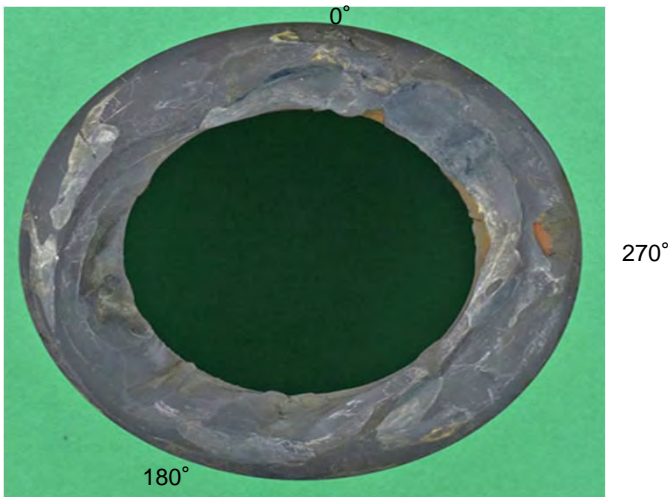
Year	1998	2005 TA	2011 TA	2018 TA
Action	Shipment of Turbine	Valve seat was replaced from $\phi 55$ to $\phi 60$	1) Install set screw with M20 2) Additional machining to install new set screw.	1) Install set screw M24 2) Install L-spacer 3) Additional machining to install L- Spacer
Bolt size Bolt Number	4xM16	4xM16 Same with original	4xM20 (After)	4xM24 (After)
Note	None	No major issue was reported for this.	All holding screw with M16 for 2nd valve were loosened 	Lower part of valve seat broke away from the main body. 

3. Fracture analysis for Valve seat (1)

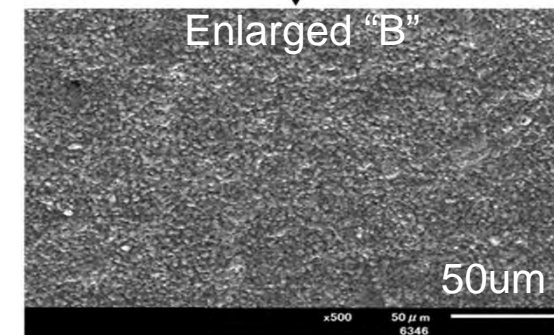
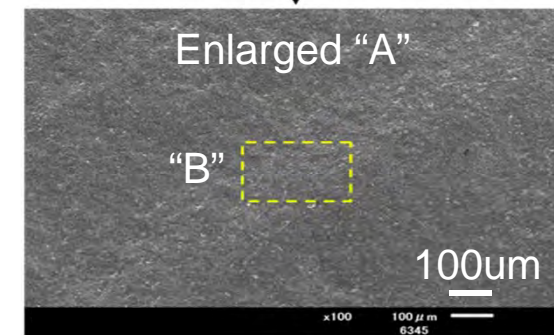
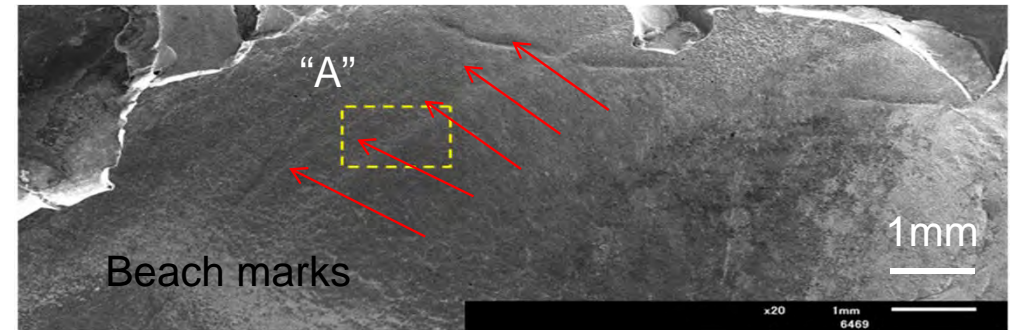
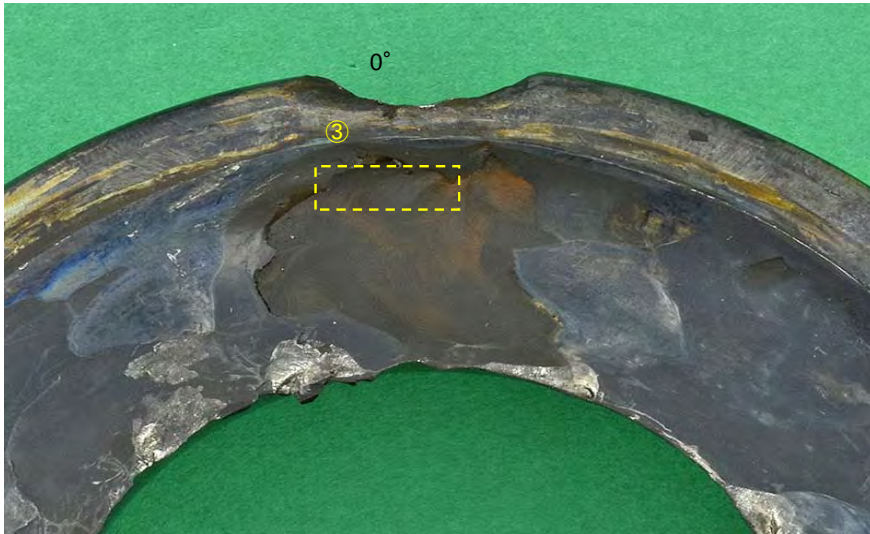


Findings

- 1) All thread screws were severely worn out.
- 2) Except for red boxed area, the surface was eroded and not confirmed as a typical fracture surface.



3. Fracture analysis for Valve seat (2)



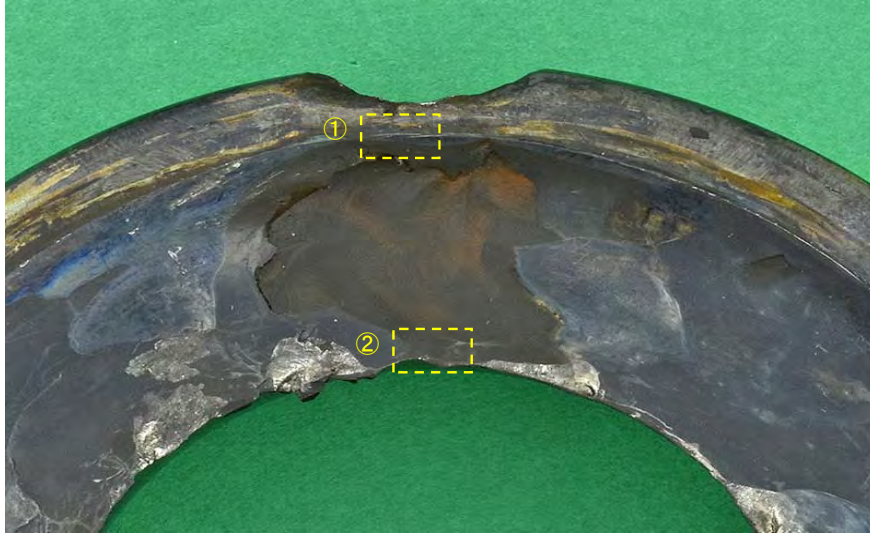
Findings

Fatigue fracture pattern like beach mark can be seen on the surface without erosion.

(In micro analysis for more detail, no striation pattern was observed due to oxide scale under high temperature.)

-> This shows a possibility of fatigue fracture.

3. Fracture analysis for Valve seat (3)

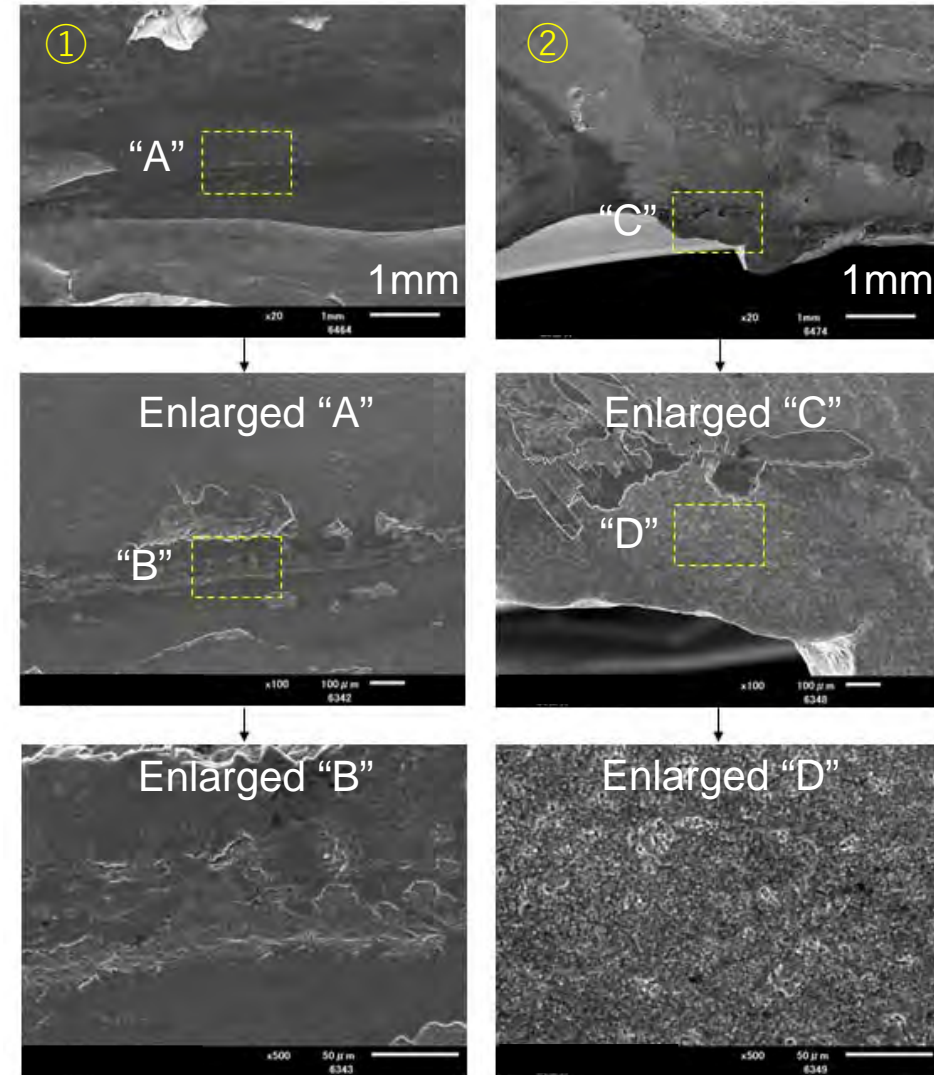


Findings

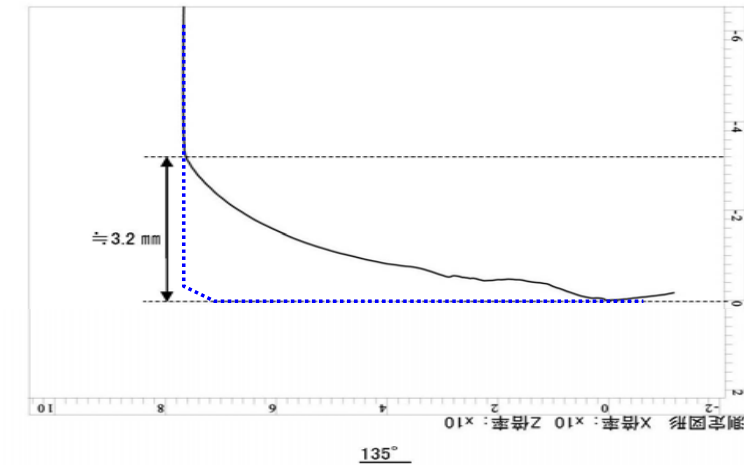
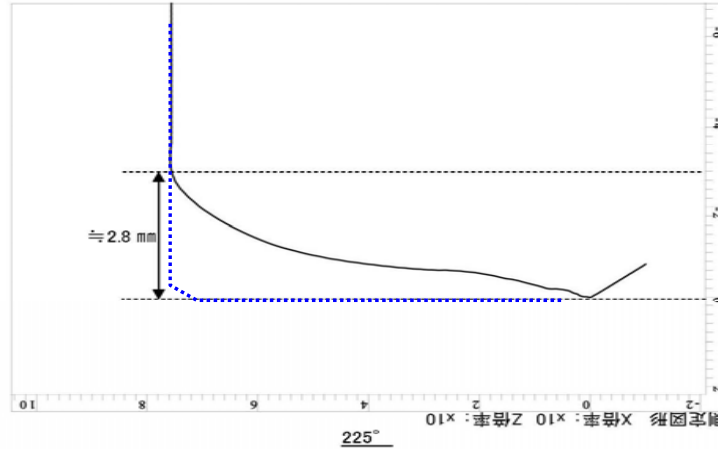
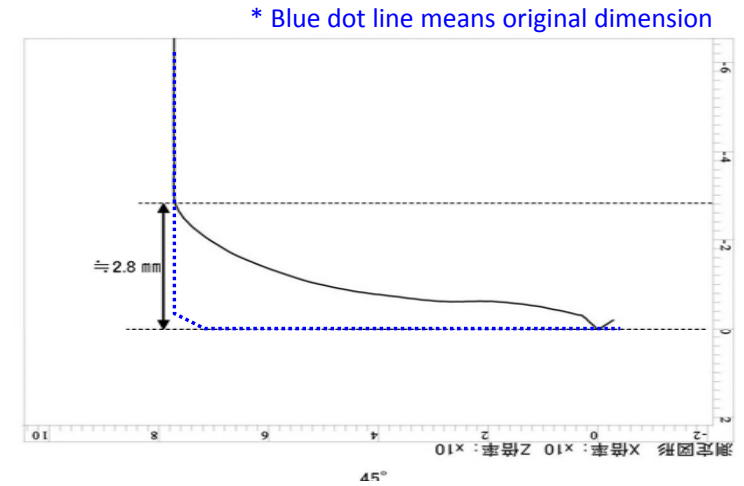
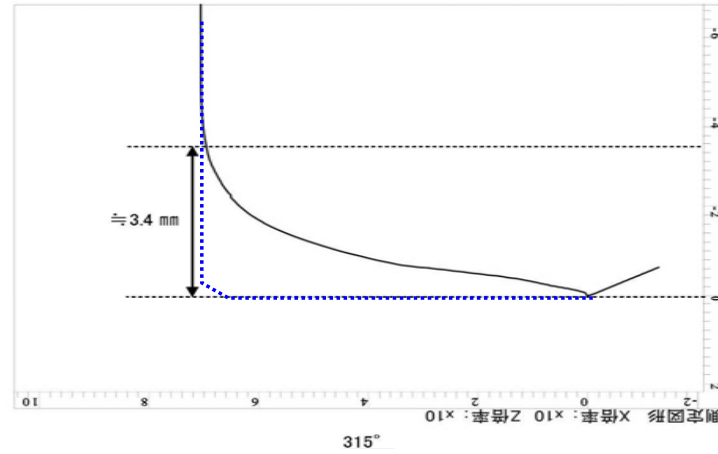
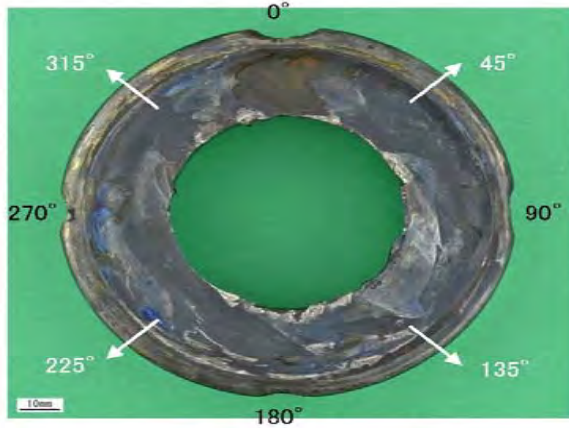
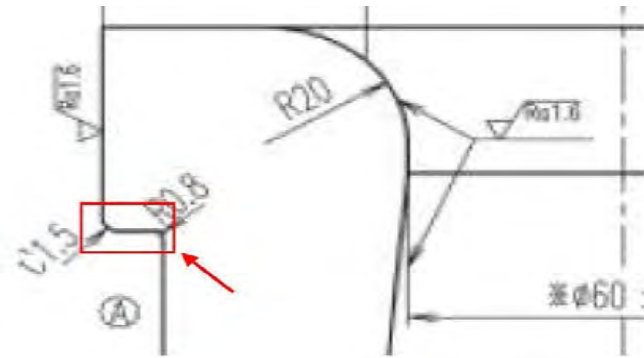
To check the validity of fatigue fracture, fracture marks are needed on the valve seat surface.

However, since most the valve seat surface was destroyed either by erosion or by oxidation of steam, it is very difficult to find the fracture marks on the broken surface of valve seat.

->No typical fracture marks were observed.



3. Fracture analysis for Valve seat (4)



Findings

-> Contact surface of valve seat was worn out.

3. Fracture analysis for Valve seat (5)

Material check

	C	Si	Mn	P	S	Ni	Cr	Mo	V	W
Result (%)	0.22	0.46	0.72	0.01	0.003	0.68	12	0.98	0.26	0.95
Requirement (%)	0.20~0.25	≤ 0.50	≤ 1.00	≤ 0.040	≤ 0.030	0.50~1.00	11.00~13.00	0.75~1.25	0.20~0.30	0.75~1.25

Table Chemical composition analysis result

Result ; A422-5

All chemical compositions were within the specification.

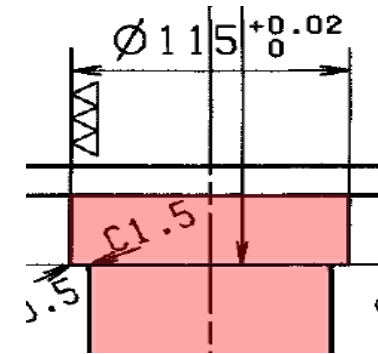
4. Root cause analysis of valve seat failure - Step1 -

Root cause of screw looseness

In 2011, the clearance between valve seat and valve box was increased according to the service report. (No record was remained in 2011.) In 2018, this got even bigger as per table.

Existing measurement of GV second valve seat

	0°	45°	90°	135°
Dia on Loc.1	115.51mm	116.16mm	116.17mm	115.80mm



Due to too large clearance, the setting bolts were not installed properly, which leads to an incomplete fixing. Then, excessive wear occurred on screw portion after long term operation by vibration or steam flow etc.



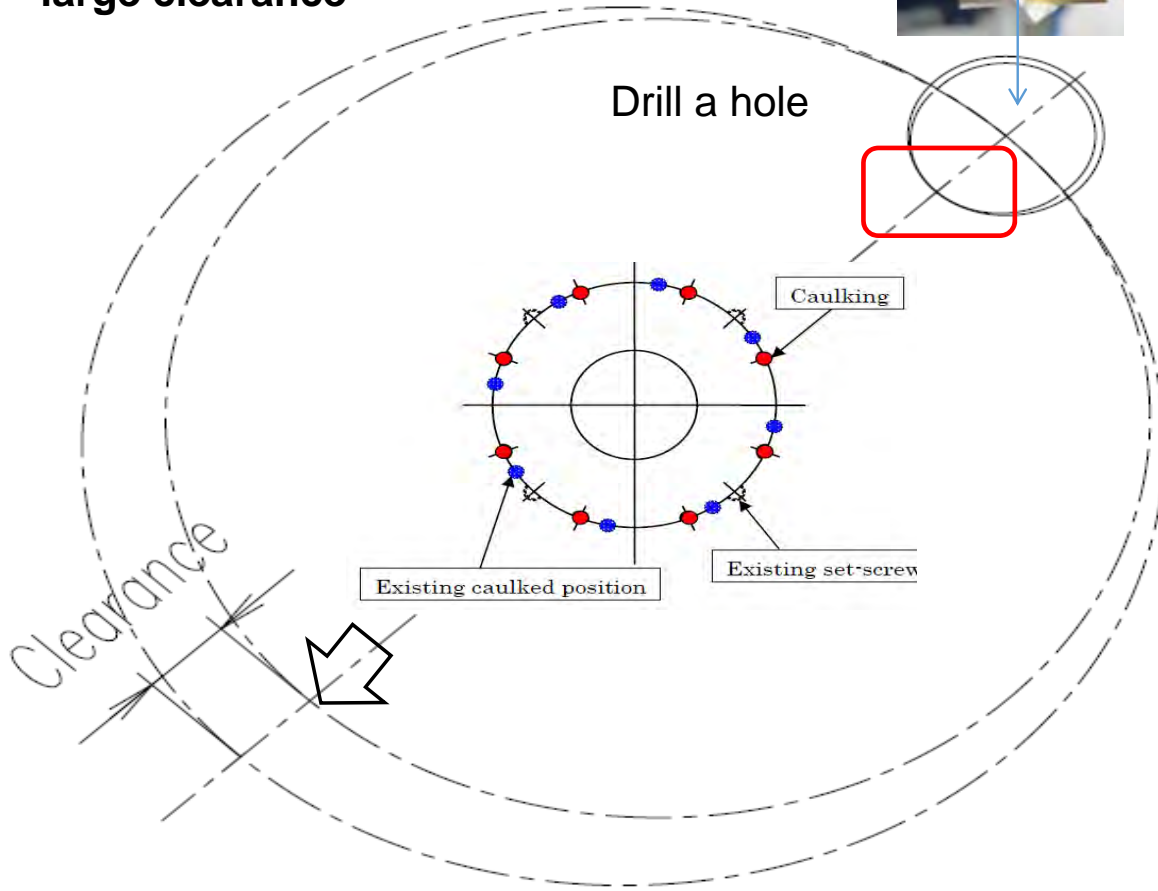
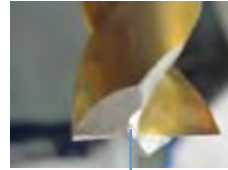
Wear



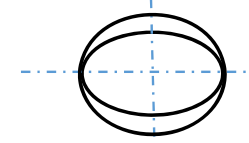
4. Root cause analysis of valve seat failure - Step1 -

Root cause of screw looseness

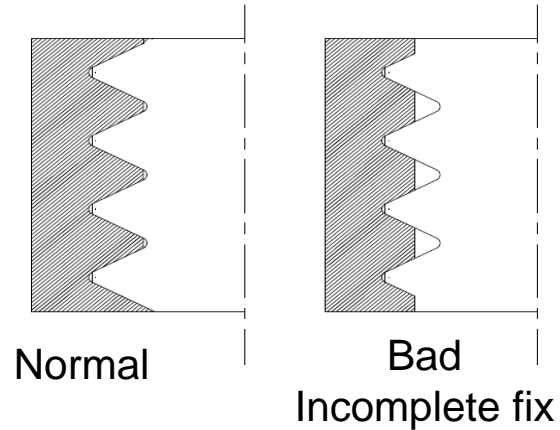
Detail explanation of impact by large clearance



If clearance is large, it is a high risk to process the pilot hole improperly to be shape of an ellipse .



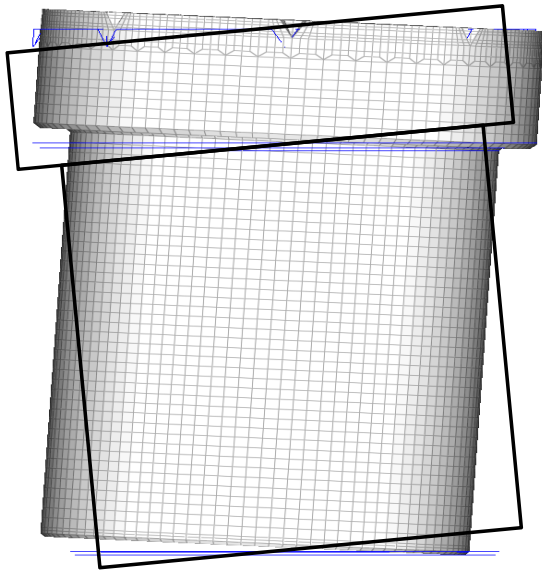
Then, screw engaged area decreases to be incomplete fixing like below Figure.



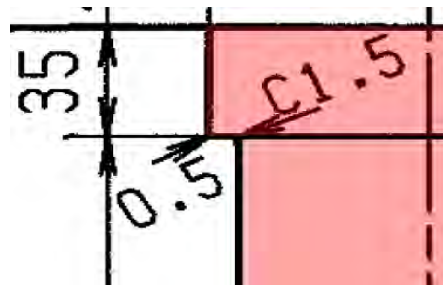
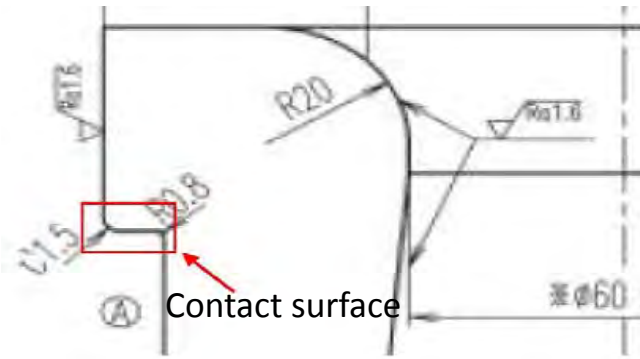
4. Root cause analysis of valve seat failure – Step2 -

Possibility check of wear on contact surface

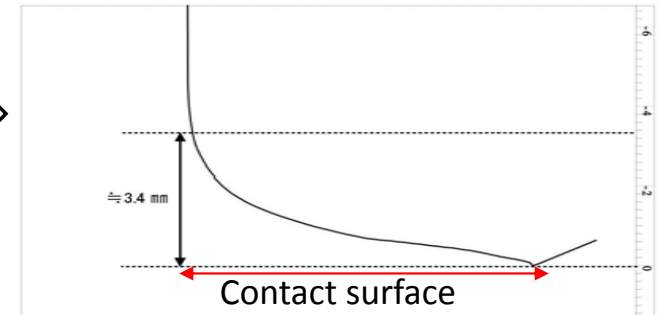
After loosening or wearing screw, valve seat was excited by steam flow or vibration, then unusual wear occurred on contact surface between valve seat and valve box.



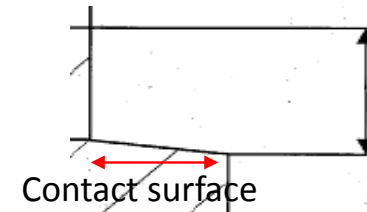
Valve seat excited by vibration Or steam flow.



Valve seat



Valve box



Existing measurement for depth

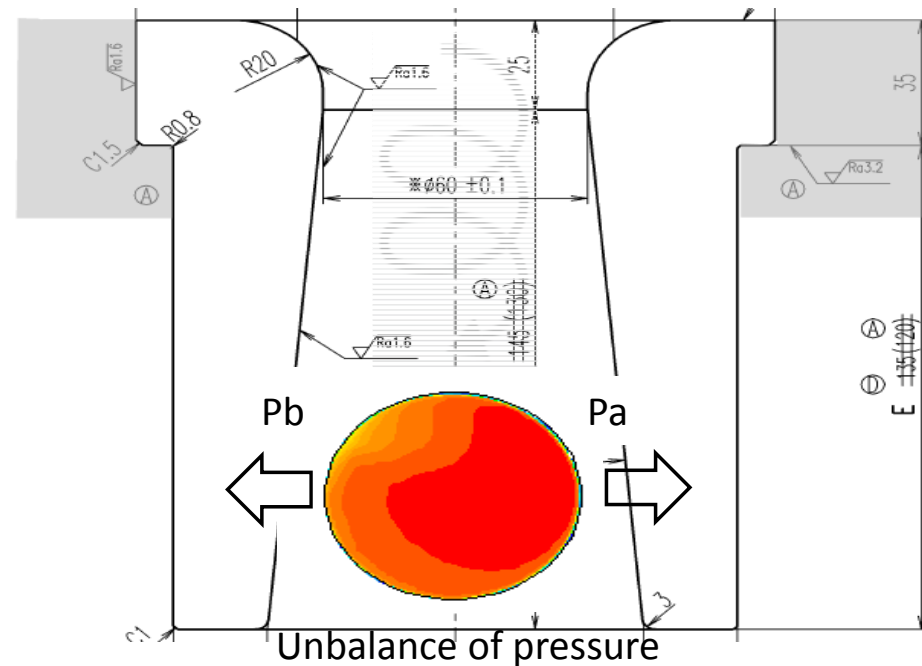
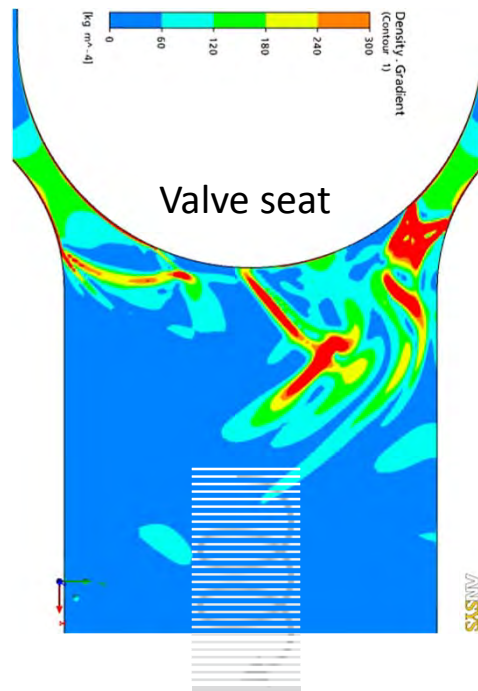
Depth	0°	45°	90°	135°	180°	225°	270°	315°
	37.56	37.86	37.95	37.86	37.17	38.46	37.37	38.69

Note : The reference surface is no even for this the depth is varying for each location

4. Root cause analysis of valve seat failure – Step2 -

Possibility check of wear on contact surface

If there is a unstable pressure distribution circumferentially, it's possible to slip valve seat without fixing by screw



Finding;

Unstable pressure distribution (about 0.2% of static pressure) causes a valve slip if there is not set screw. This unstable pressure is a realistic level due to its small value. Then, unusual wear is high possible in long time operation.

Review of past operation

Steam quantity and turbine speed

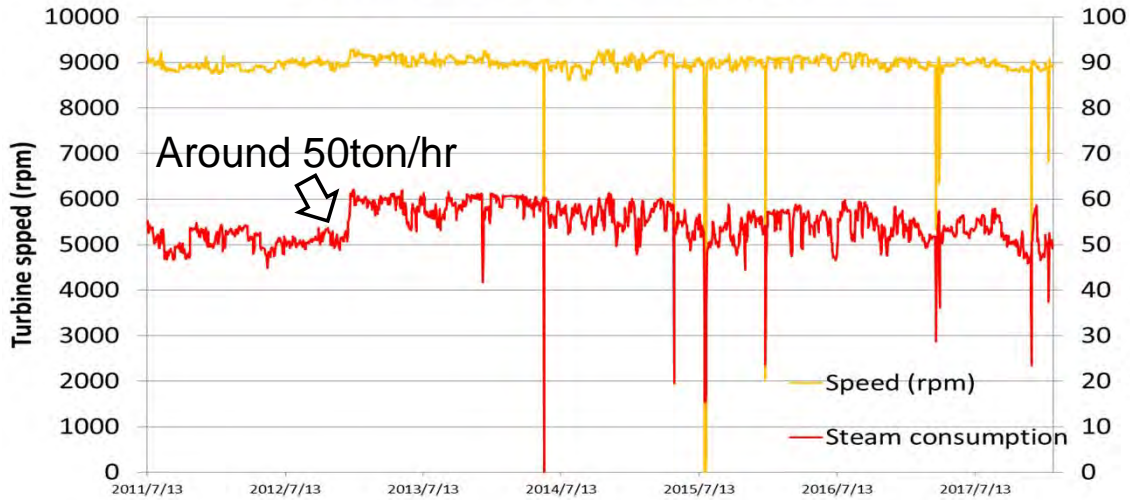


Fig Operation data

According to operation data from customer, the valve lift for 2nd valve was almost fully opened.



Abnormal operation is not confirmed.

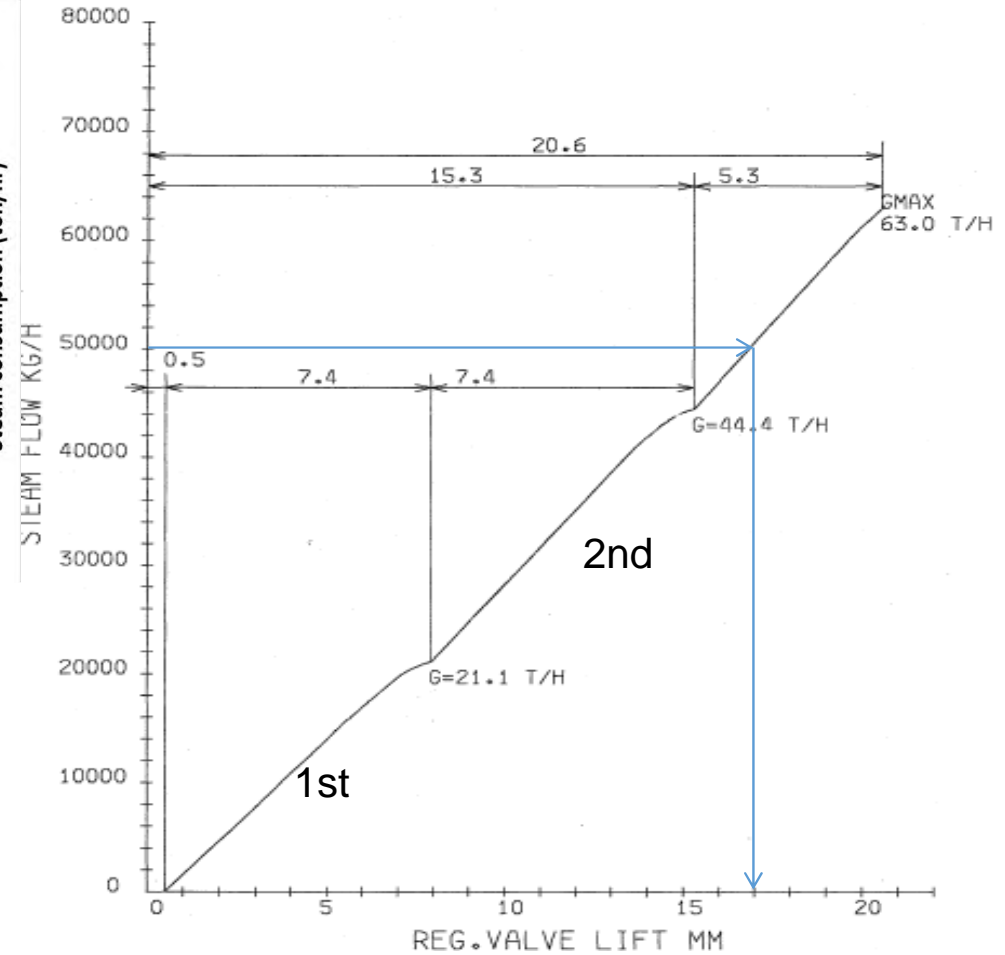


Figure. Valve lift curve

4. Root cause analysis of valve seat failure – Step3 -

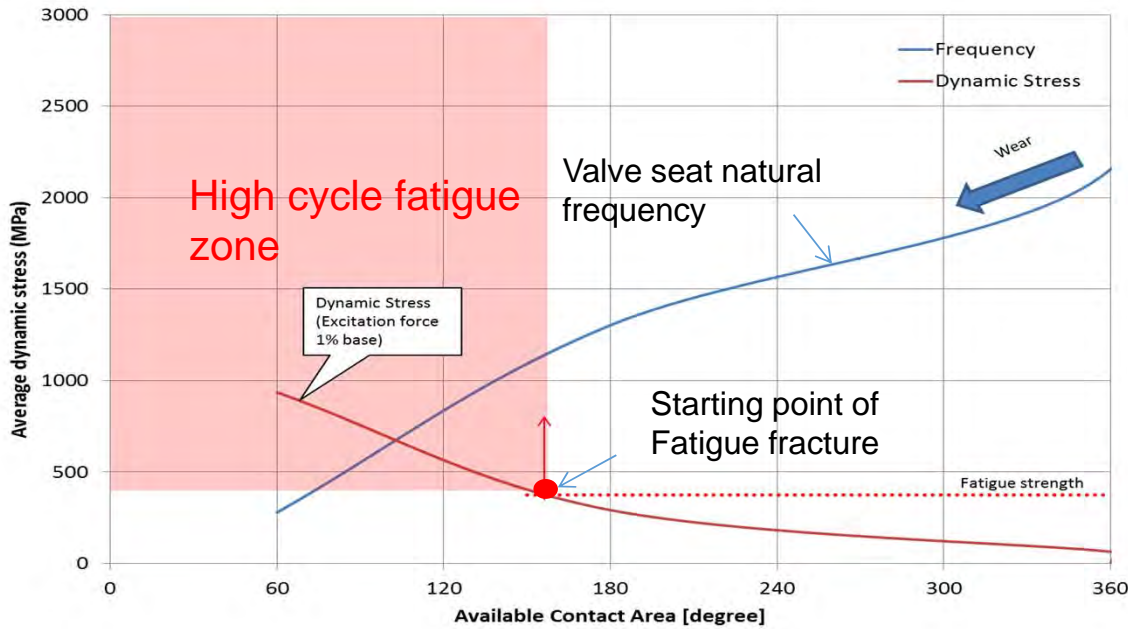


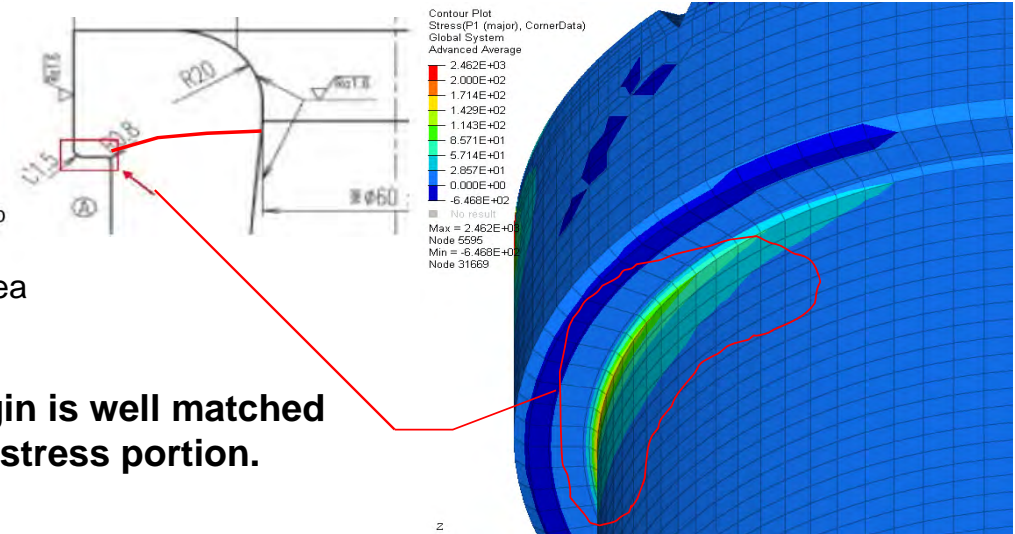
Fig. Relation of Valve seat natural frequency, dynamic stress VS Contact area
(Assumed excitation force = 1% fluctuation of static pressure)

Possible failure scenario

1. Valve seat was not fixed by set screw looseness
2. Usual pressure fluctuation caused valve seat slip which leads to wear damage on contact surface.
3. Valve seat natural frequency is decreased by contact area reduction. Also, dynamic stress is increased.
4. Valve seat was failed by high cycle fatigue.

Note;

Valve seat natural frequency is 3700Hz in proper fixing, which is far from this abnormal condition.



Crack origin is well matched with peak stress portion.

Finding

In abnormal situation of valve seat slip and wear on contact surface, dynamic stress rapidly increases and exceeds to material fatigue limit as contact area is reduced.

4. Summary of valve seat failure scenario

Looseness of screw

Step.1

Wear on contact surface

Step.2

High cycle fatigue

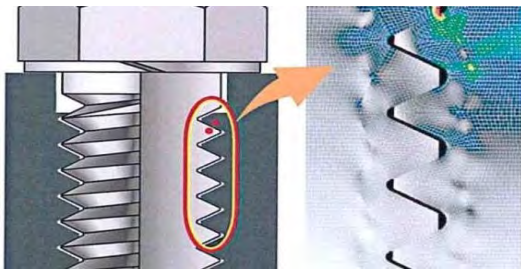
Step.3

Incomplete fixing due to large clearance

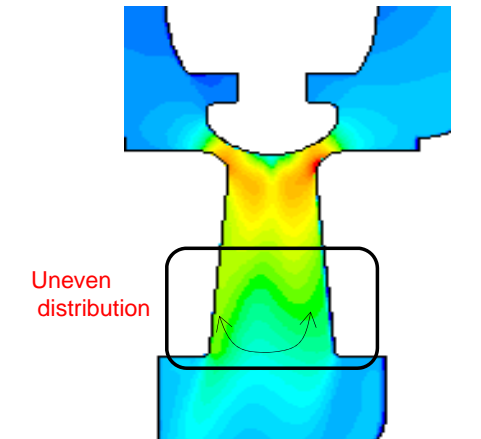
Worn out a screw

Worn out the contact surface by uneven steam pressure distribution

Dynamic stress of valve seat 1st bending mode exceeded to material fatigue limit through reduction of contact area by heavy wear

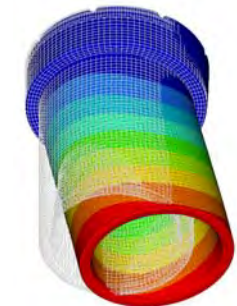
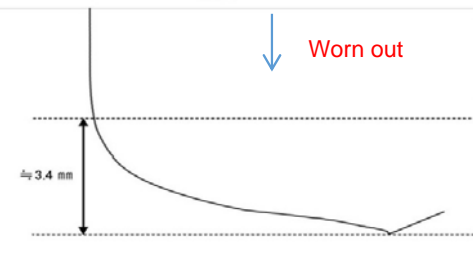


2nd valve

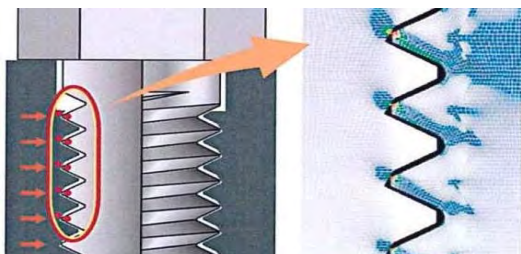
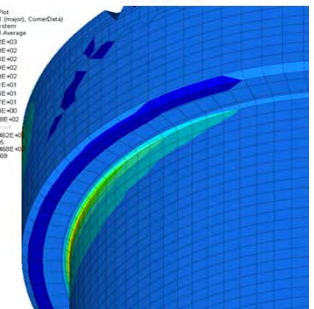


Uneven distribution

Worn out



Control Plot
Stress(P1) (Mpa), CornerData
Global System
Advanced Average
-2.000E+02
-1.714E+02
-1.429E+02
-1.143E+02
-8.571E+01
-5.714E+01
-2.857E+01
-1.000E+01
-6.486E+00
Max = 2.462E+02
Min = 0.000E+00
Nodes 21000



1st, 3rd valve


6. RCA summary for valve seat failure

Description ; FTA (Fault Tree Analysis) of GV valve seat set screw loose out with damage

○ ; Root cause

△ ; Possible cause

✕ ; Not cause

Phenomenon	Analysis of failure phenomenon	How to verification	Result	Conclusion	
2nd valve seat (out of 3 valve seats) broke in the valve box of Governing valve. 	Excessive exciting force by steam flow	Out of operation limit of inlet steam condition	Review of operation data	No observe abnormal condition	✕
		Damage by foreign material	Checking of valve box with casing internal	No observe abnormal condition for other valve seats	✕
	Error of valve seat installation work at site in 2005TA	Misalignment of set screw position	Observation of valve box	(No inspection record in 2005) The hole was enlarged a size, then installed the screw again.	△
		Large clearance in valve seat and body Original design ; 0.02 - 0.05mm /dia,	Inspection of valve box internal	Large gap according to inspection record in 2018)	○
		Shortage of tightening force of set screw	Checking of last valve seat installation work procedure	(No inspection record in 2005)	△
		Improper condition of first caulking to hold the valve position and final caulking on set screw	Checking of last valve seat installation work procedure	(No inspection record in 2005)	△
	Aged deterioration	Corrosion or erosion damage on set screw	Checking of valve box with casing internal	No observe abnormal condition for other valve seats	✕

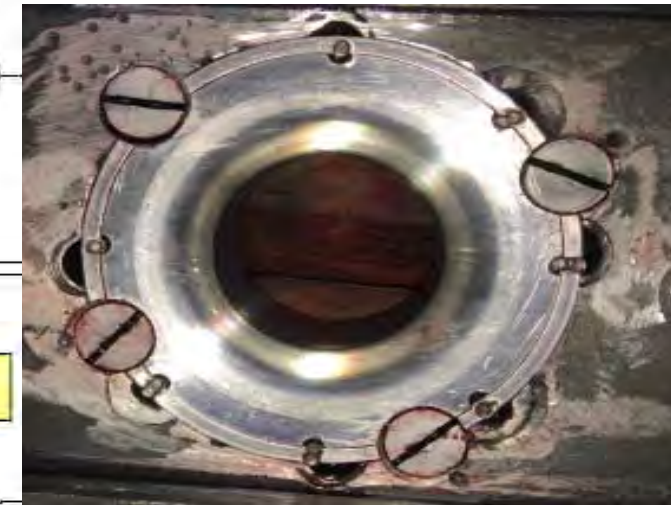
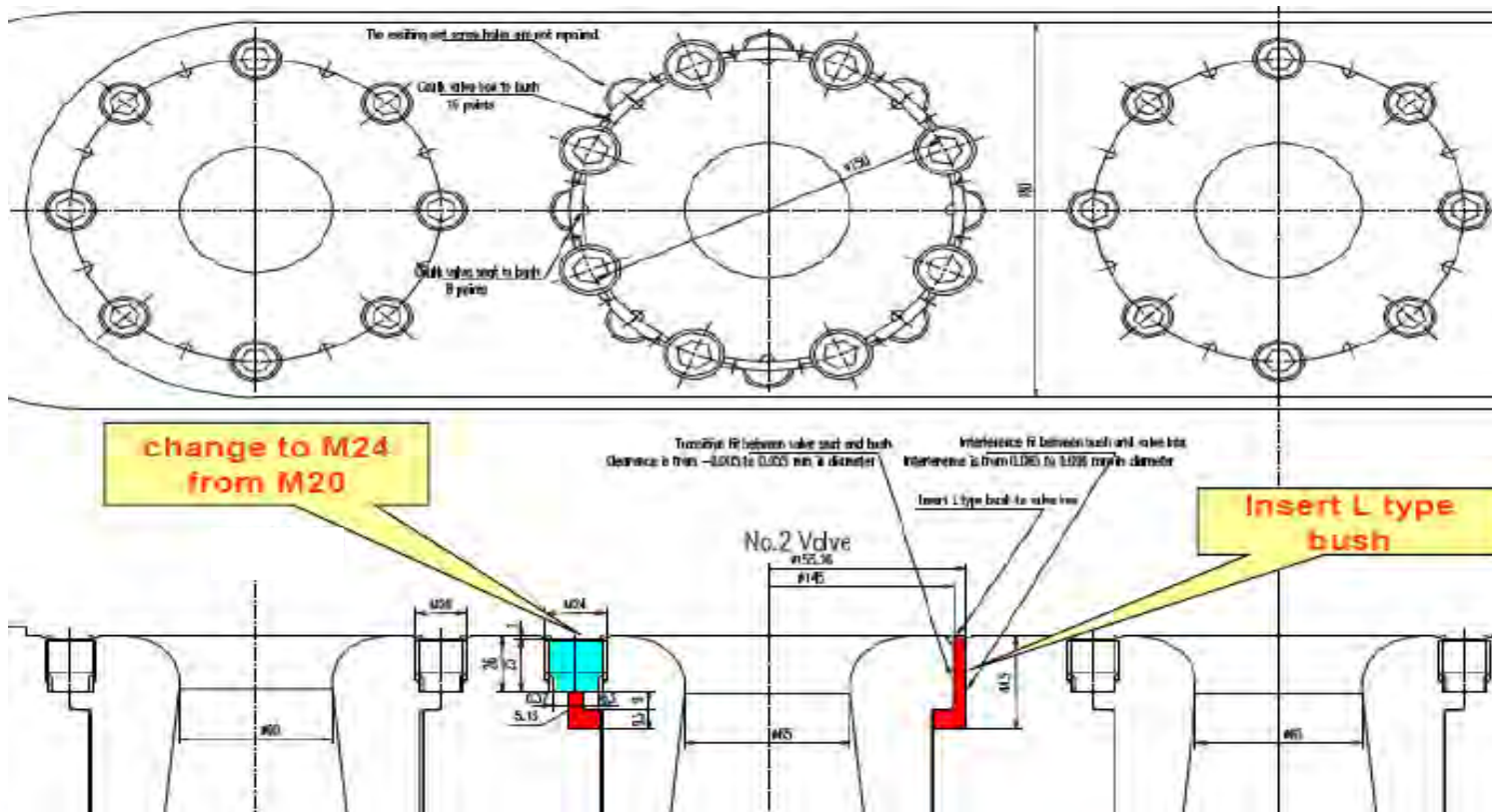
Findings:

- 1) Incomplete valve seat fixing due to large clearance is a root cause of this failure
- 2) Direct failure cause is a high cycle fatigue by excess dynamic stress due to reduction of valve seat natural frequency with decreasing contact surface by wear.

7. Site countermeasure

In order to enhance fixing quality of valve seat, the following countermeasure was conducted at our local repair shop.

- 1) Installation of size-up set screw M24 from M20 (Partial welding applied for set screw)
- 2) Install L-bush-spacer (Tight fitting)



8. Lesson and Learned.

1) Ensuring a contact between casing and valve seat is a prominent to avoid this matter. Therefore, the welding type is the best solution for this.

Fixing method	Advantage	Disadvantage
Welding	Never slip due to vibration or steam flow (Guarantee of holding the valve seat)	Difficult installation technique (require welding skill), especially at site.
Hex. Socket Screw	Easy to install the valve seat even at site	Bolt might get loosened due to difference of thermal expansion between valve seat and casing, resulting in valve slip.

2) Installation method should be considered the tolerance of site work and chose the best solution.

Than you for attention !!!