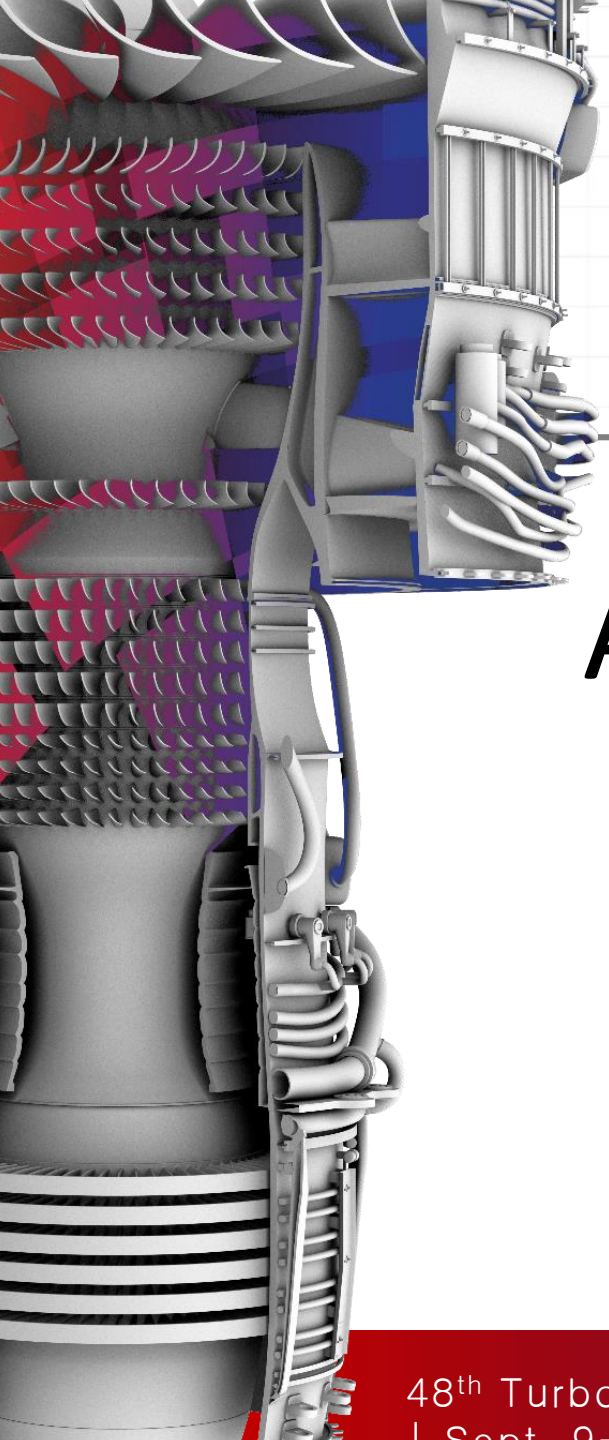

TURBOMACHINERY & PUMP SYMPOSIA

Analysis and troubleshooting of a piston rod failure of RC

Sanghun Lee / Jinseok Yang

DK. Cho

Presenter / Authors bios

Presenter, Mr. Sanghun Lee

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He is a key member of KRMEA(Korea Rotating Machinery Engineers Association).

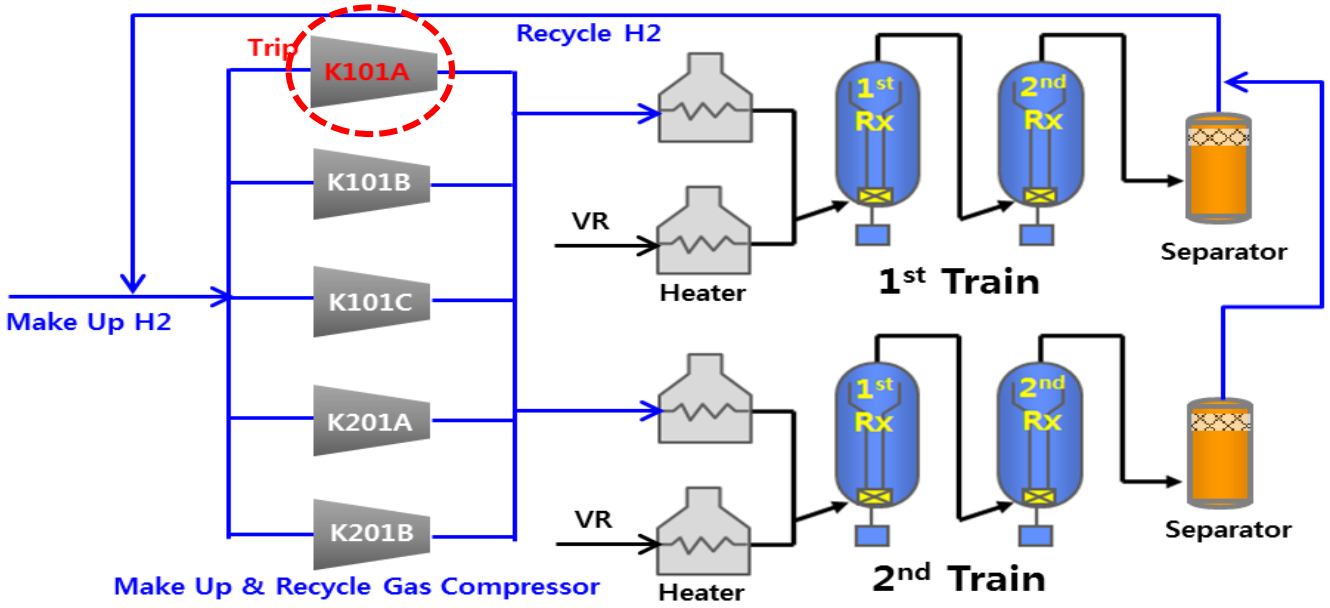
Contents

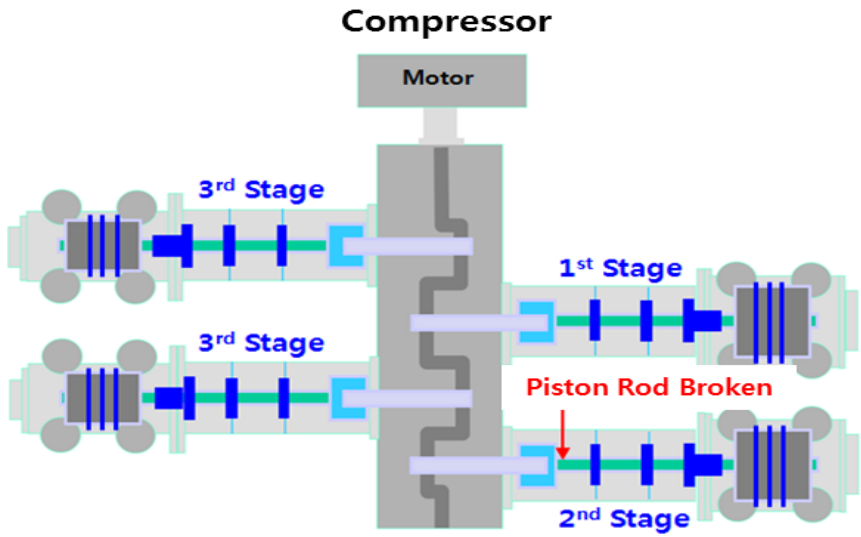
Abstract

Piston Rods are one of the most vulnerable components in reciprocating compressors and, if failing, one of the most important parts that can cause serious secondary damage. Based on an actual experience with a piston rod failure in a H2 recycle and make-up gas compressor of a Vacuum Residual Hydrocracker(VRHCR) plant, this presentation shows how to find out the root cause of the failure, to take a countermeasure, and to produce lessons learned for maintenance.

Introduction

Compressor is located on a make and recycle loop of reactor in VRHCR(Vacuum Residual Hydrocracker) plant and delivers a H2 rich recycle gas to reactor.

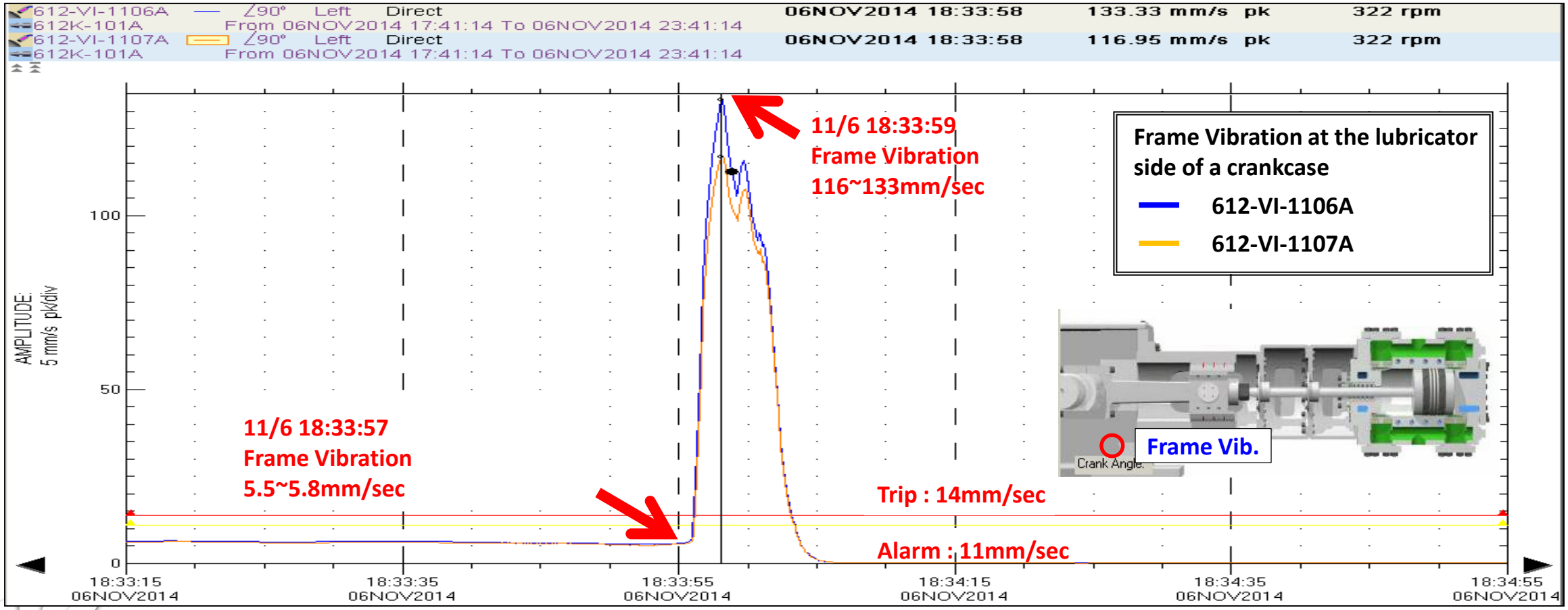




- 1st Stage Suction Pressure : 19.2 kg/cm2g(273psig)
- 2nd Stage Suction Pressure : 42.2 kg/cm2g(600psig)
- 3rd Stage Suction Pressure : 90.6 kg/cm2g(1,289psig)
- 3rd Stage Discharge Pressure : 200 kg/cm2g(2,844psig)
- Motor Rated Power : 12,020 kw(16,112.6hp)

Overview of the Problem

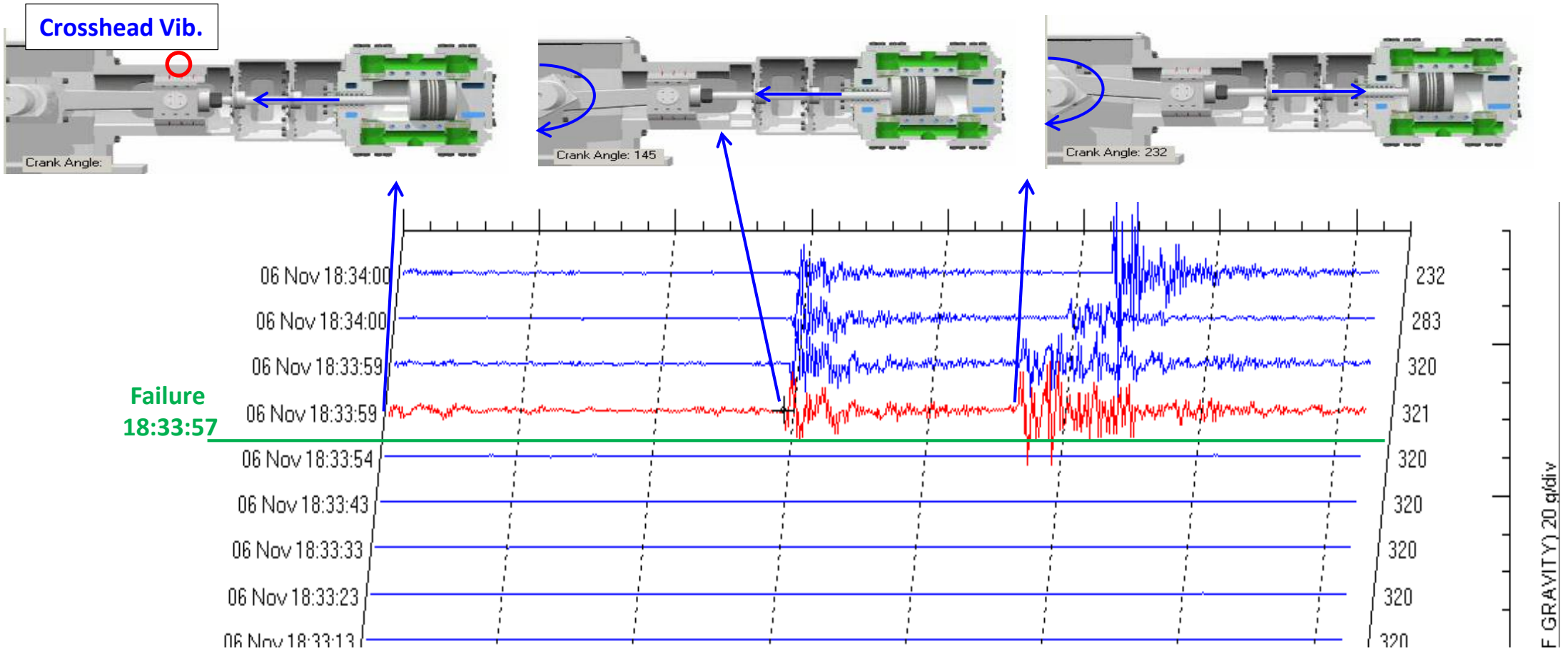
The compressor tripped due to high vibration(133mm/s) in 128 days after overhaul. It normally operated at about 5.5m/s of frame vibration and there was no indication just before the event. * Alarm : 11mm/s, Trip : 14mm/s



Overview of the Problem

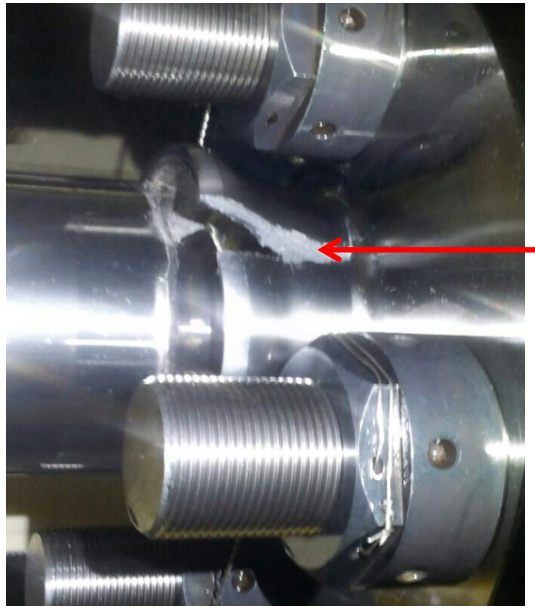
A crosshead vibration also increased suddenly from normal 0.5G to 56G after failure.

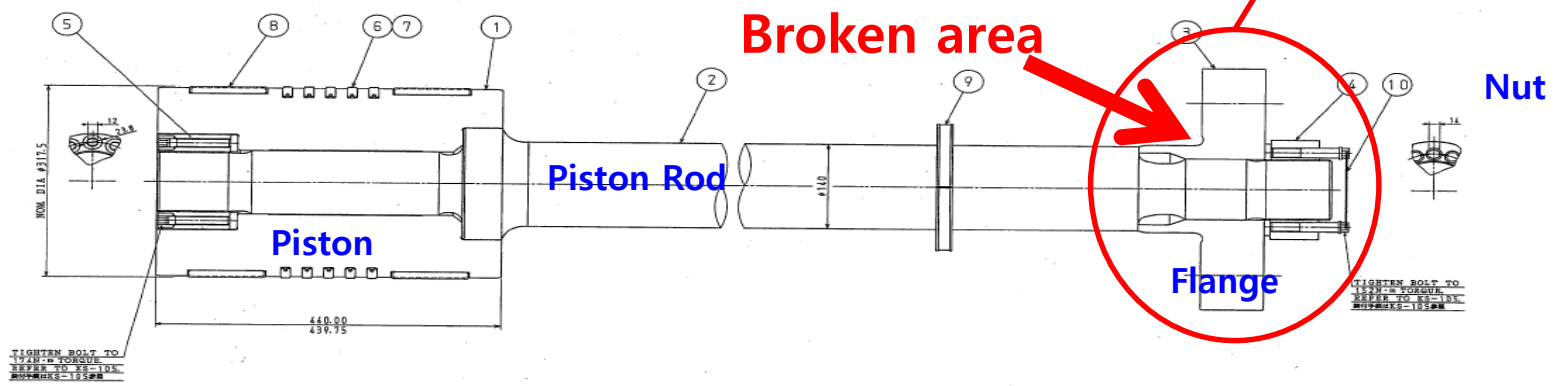
* Alarm : 1.5G, Trip : null



Inspection and findings

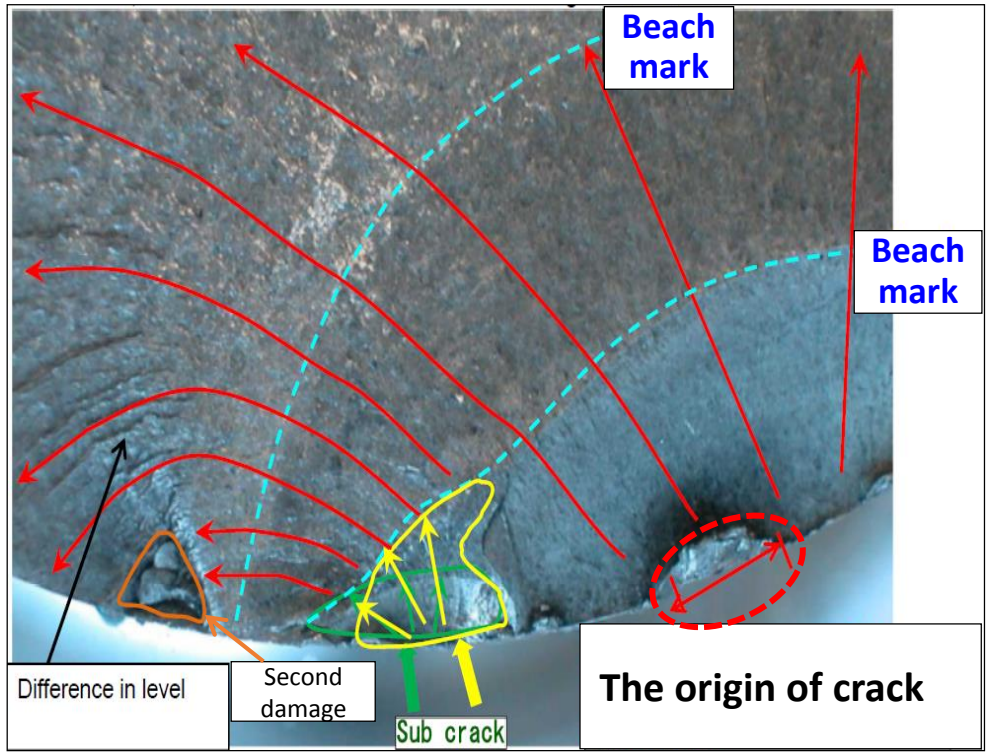
Severely damaged piston rod connecting flange





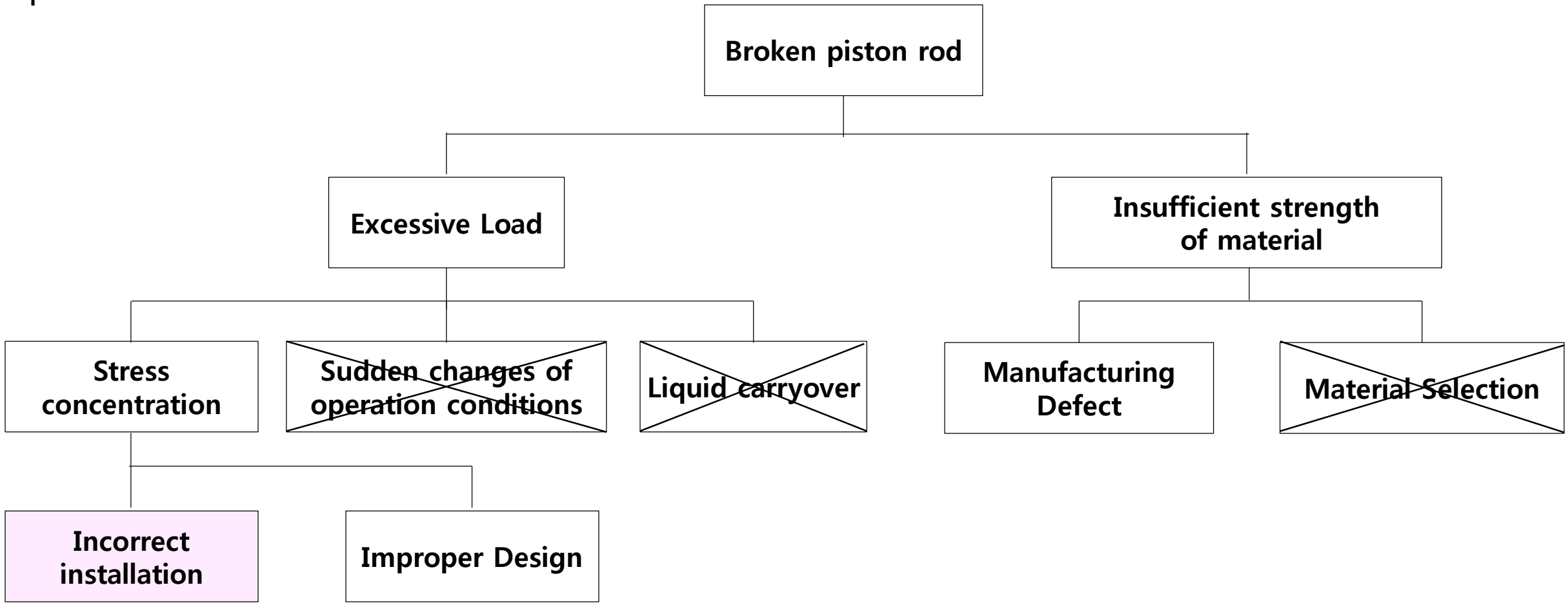
Inspection and findings

Piston rod broke due to excessive stress and fatigue. There is a beach mark which is the typical fatigue failure on fracture surface. The origin of the crack is located in the center of the arc.



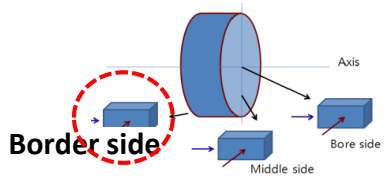
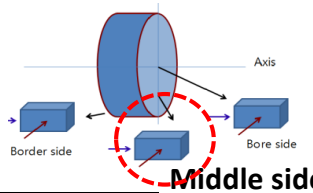
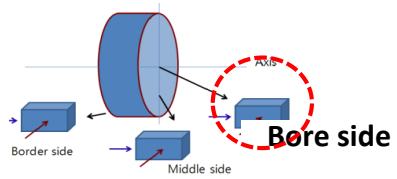
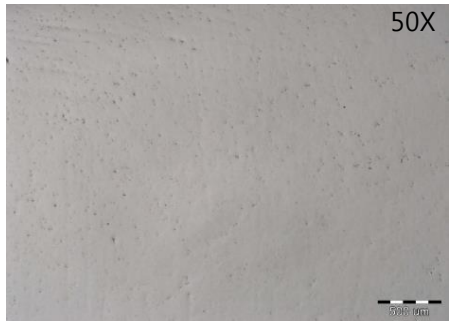
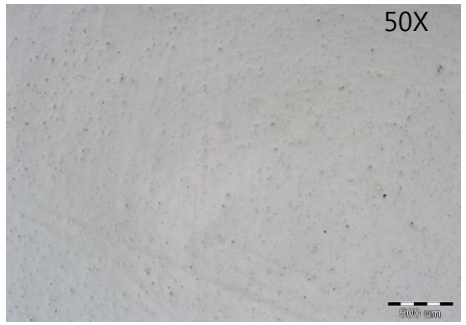
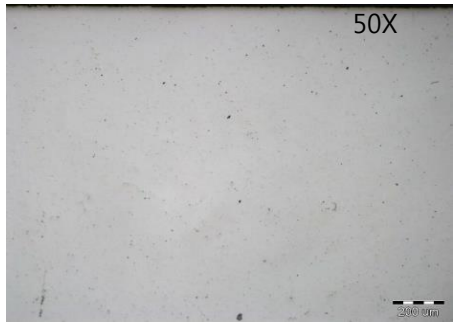
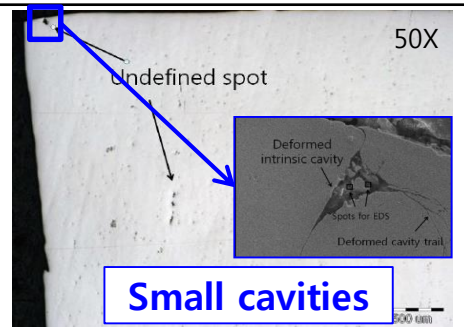
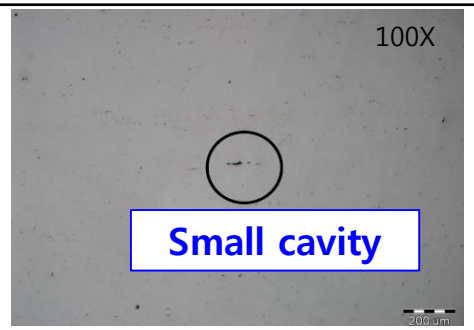
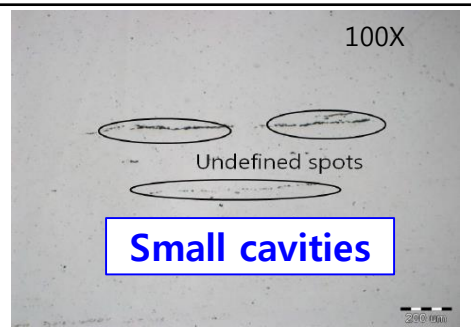
Root Cause Analysis

Performed RCA with OEM through "Why trees" and derived and validated all possible root causes



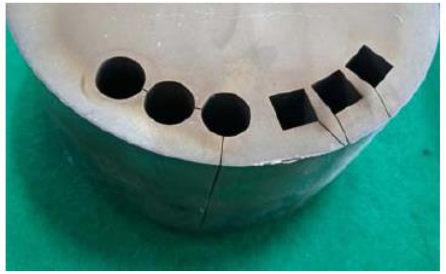
Root Cause Analysis

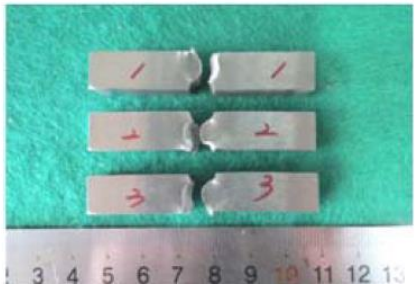
The research institute investigated material for defects. There were some small cavities at the microstructure. Additional verification required if these cavities had affected the material properties.

	Surface	Middle	Center
Sample point			
Radial Direction			
Axial Direction			

Root Cause Analysis

Destructive testing performed to verify the mechanical properties of the material, and to confirm that all samples met the ASTM standard.

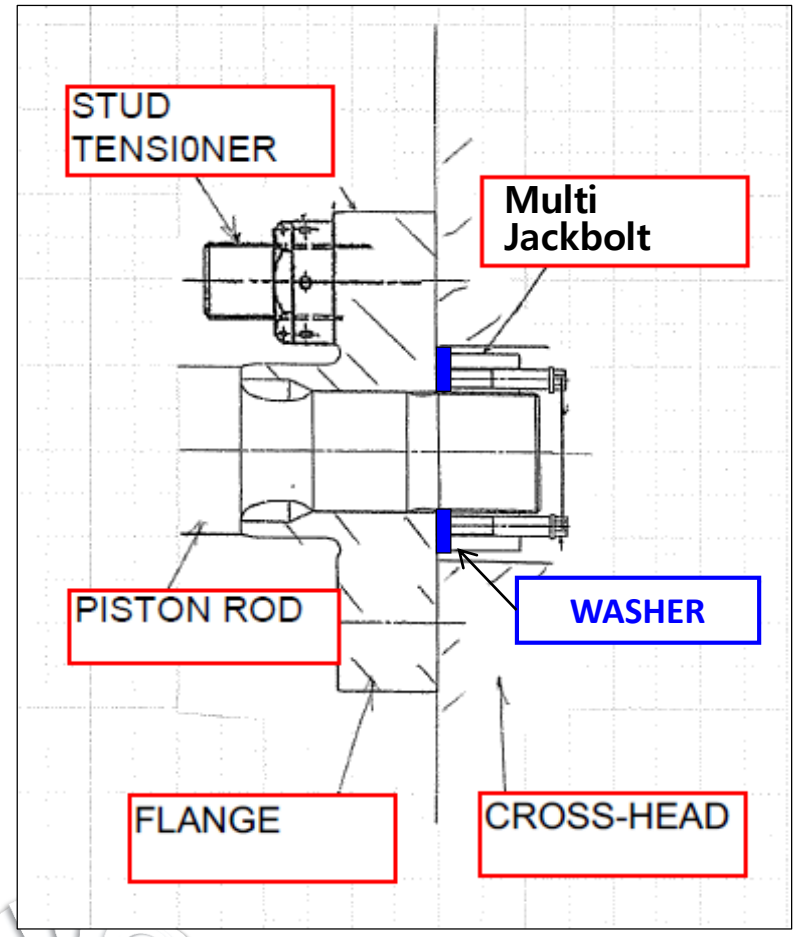


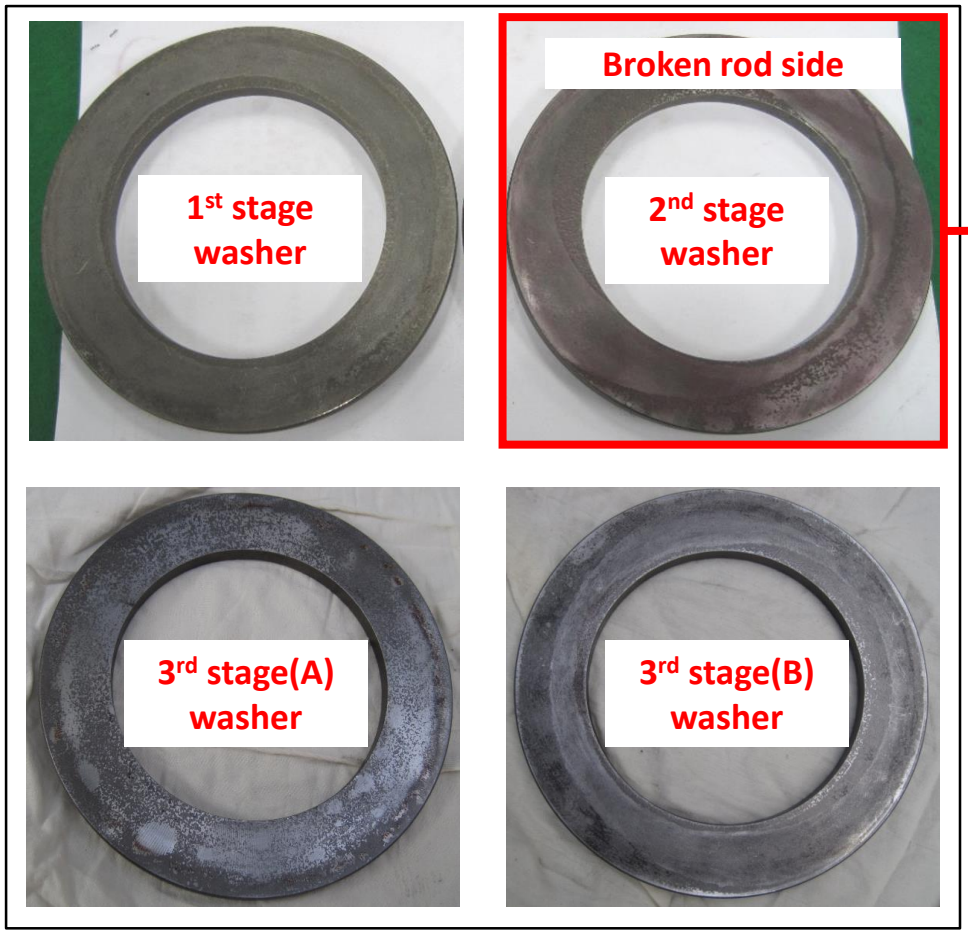


Specification \ Properties		Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)	Impact Test (Joule)	Hardness (0.5kg)	Result
ASTM A564 Type6310, H1150		min. 930	min. 725	min. 16	min. 41	min. 292	-
Mill Certificate		1,008	758	22	-	292	Acceptable
Test Result	①	1,016	871	23	111	① 322.1 ② 314.5	Acceptable
	②	1,017	871	23	110	① 322.1 ② 318.0	Acceptable
	③	1,017	871	23	112	① 320.3 ② 320.9	Acceptable

Root Cause Analysis

The investigation team found traces of non-uniform force applied to the washer of the 2nd cylinder. Fortunately, there were no traces in other cylinders except the broken one. Did further investigation to determine the cause of the non-uniform forces.





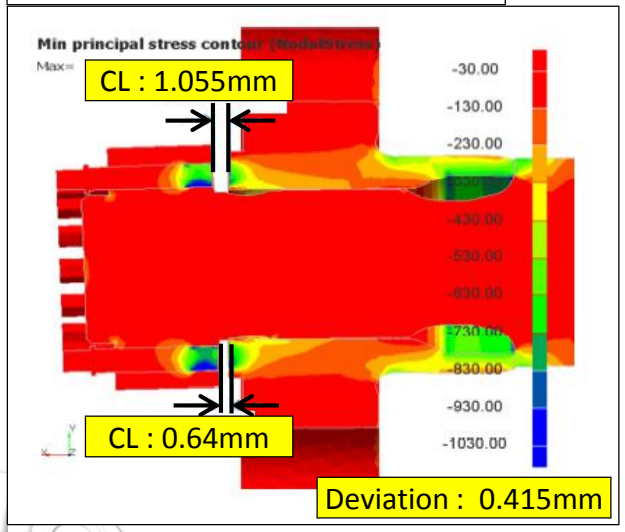
Root Cause Analysis

OEM's instruction manual omitted a procedure to check the inclination of the flange. We performed a test to assemble the piston rod according to OEM's instruction manual at the OEM's maintenance shop, and as a result, confirmed there was a 0.5mm of deviation.

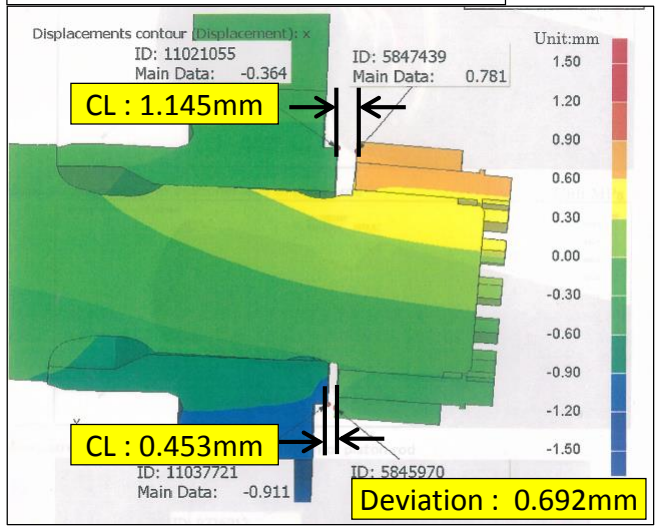
Since our workers assembled the piston rod according to the OEM's guide, it is highly likely that they made a similar mistake.

Therefore we performed a FEM analysis to find out how much inclination can cause failure of the piston rod.

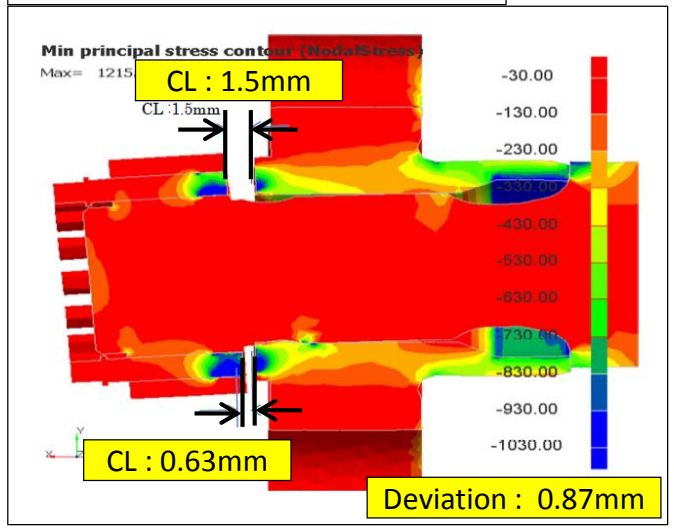
Case 1 : 0.4mm inclination



Case 2 : 0.7mm inclination



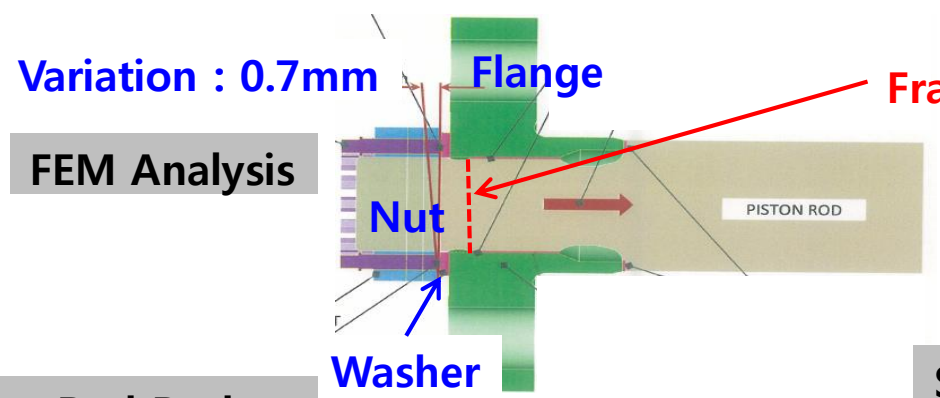
Case 3 : 0.9mm inclination

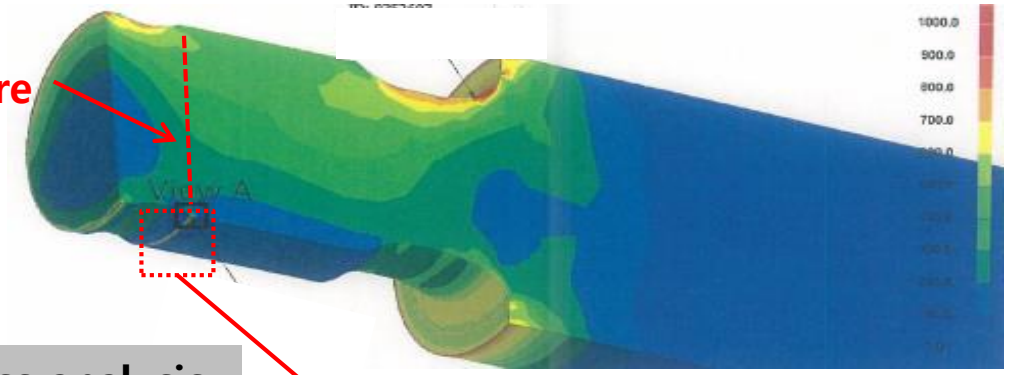


Root Cause Analysis

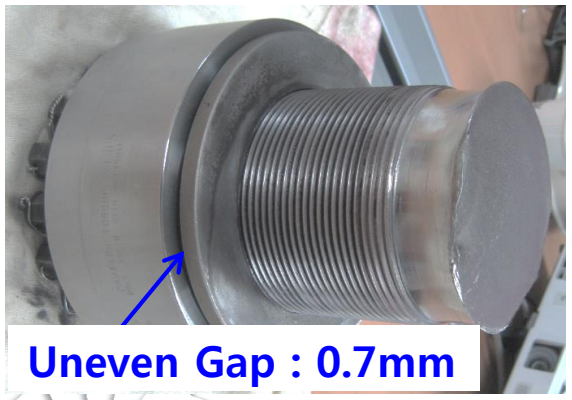
Confirmed through FEM analysis that if there is a 0.7mm of inclination between a flange and a washer, the stress concentration(68.3MPa) above the allowable stress occurs at the piston rod. (Maximum allowable stress: 68.1 MPa)

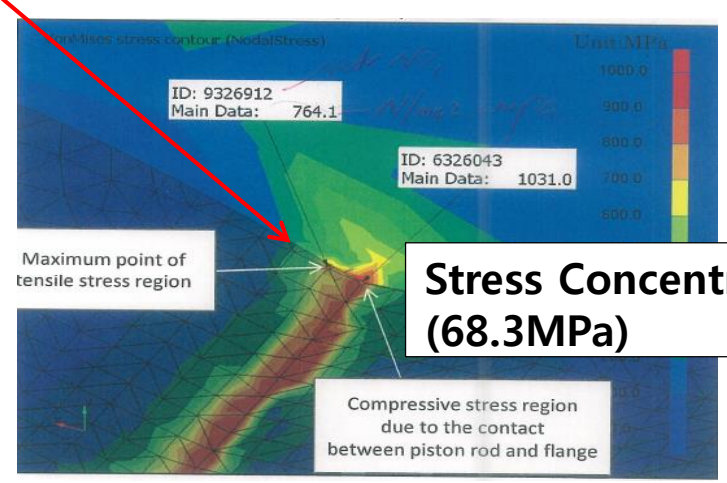
It means the rod may break if the inclination is greater than 0.7mm during assembly.





Piston Rod Broken





Solution

For assembling the piston nut with the same torque, the maintenance procedure improved as follows.

1) When assembling the piston rod nut, tighten the multi jackbolts 4 times by increasing the torque sequentially.(5%, 30%, 60%, 100%)

2) Check the clearance between flange and piston rod nut at every step, and adjust so that it is less than 0.1mm.

3) Train maintenance workers on the proper procedure to assemble the multi jackbolt tensioner.

Solution

The instruction manual supplemented in detail so that the method of operation can be easily understood.

	Before	After
Procedure		When tightening the multi jackbolts, it is very important to minimize the differential gap between the surface of the bolt body and the flange.
	1. Spin the tensioner onto the main thread until it sets against the washer. You have to back off the tensioner to provide 1mm to 3mm gap. If you can't see the gap, instead you may back off around 180˚.	1. Spin the tensioner onto the main thread until it sets against the washer. You have to back off the tensioner to provide 1mm to 1.5mm gap. If you can't see the gap, instead you may back off around 120~180˚
	2. Tighten (4) jack-bolts at 90˚ apart(12:00 6:00 9:00 and 3:00) with a partial torque(50%).	2. Tightening the jack-bolt by the hand, and then adjust the differential gap between the bolt body and the washer to become less than 0.1mm.
	3. At 100% target torque, tighten the same (4) jack-bolts.	3. Tighten the jack-bolts with 5% of the prescribed torque according to the sequiential order
	4. At 100% target torque, tighten all jack-bolts in a circular pattern.(1 round only)	(Note) Make sure the differential gap is less than 0.1mm. If the differential gap is bigger than 0.1mm, start over again.

Lessons learned

- Incorrect tightening of bolts can cause fatigue failure by stress concentration, even if there are no problems in design and operation.

- It is most important to assemble the piston rod nut in parallel, to avoid excessive stress.

- The proper procedures should be provided to prevent maintenance errors regardless of the worker's skill. And it is highly recommended to inspect and verify the critical points.

We checked all the other cylinders and compressors, and there was about 0.3mm of the inclination. We reassembled all of them according to the revised procedure and confirmed the inclination was less than 0.1mm. Since then, for about four years, the reciprocating compressors are operating well without any problem.

Thank you
&
Questions?

ACKNOWLEDGEMENTS

This work has been encouraged by the Korea Rotating Machinery Engineers Association, (KRMEA). The authors are grateful for the encouragement