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Damaged Compressor Stator Parts — Resulting from Operation in Deep Choke



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Damaged Compressor Stator Parts

Resulting from Operation in Deep Choke

The internal stationary parts of a high-speed, oil-free, integrated motor compressor used in gas storage service were found severely damaged. The analysis of the operational trend data suggested prolonged operation in deep choke condition. Additional CFD calculations for these operating points confirmed that severe flow separations and flow reversals (at exactly the damaged stages) had to be expected.

Concluding from the RCA the following measures were taken:

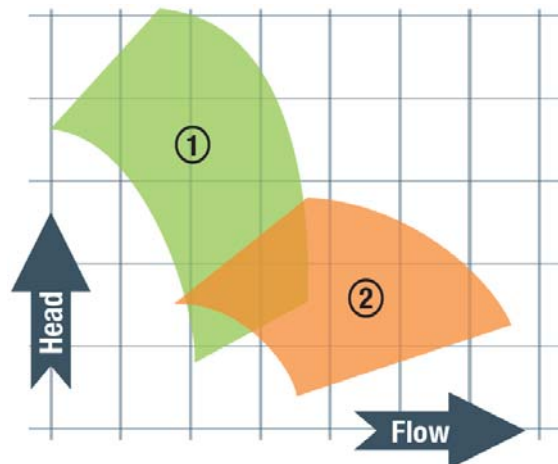
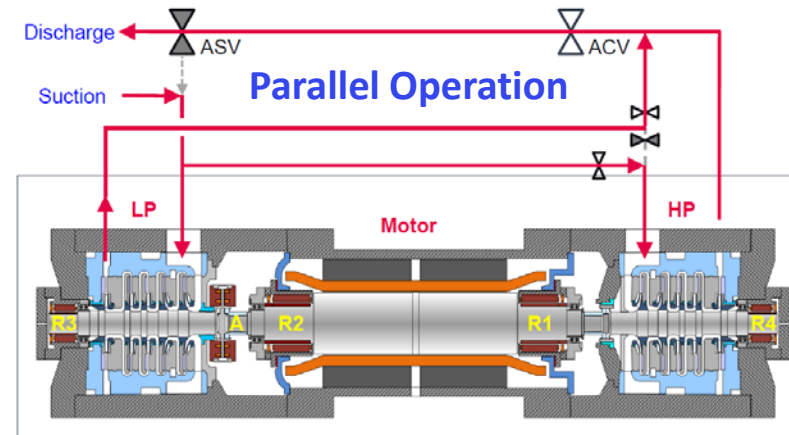
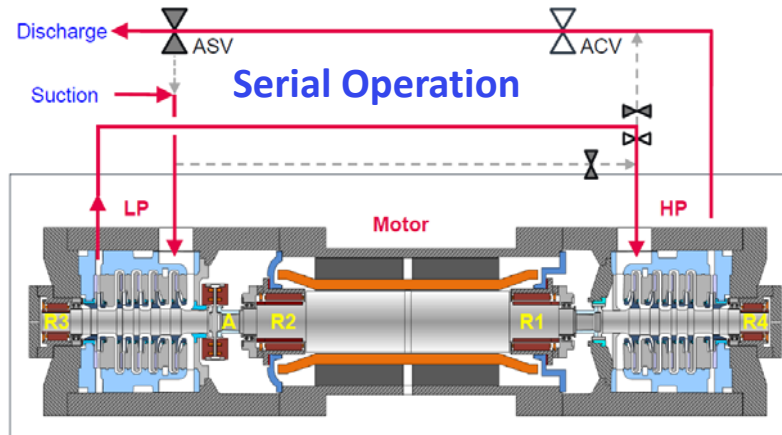
- Recalibration of the anti-choke control to move the response line to higher pressure ratios
- Instruction to the operators to switch from serial mode to parallel mode operation if the compressor is operated beyond the response line of the anti-choke controller.

After repair (no design changes) the machine is now in service for more than one year without any problems.



Description of the System

Tandem HOFIM™ – Operating Modes



The machine is able to operate in

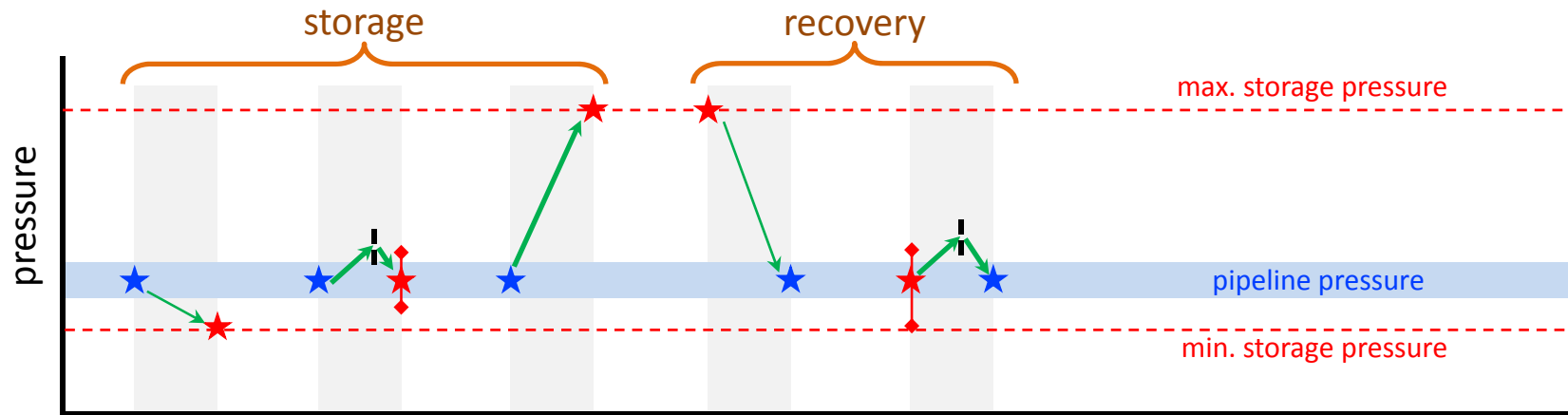
- serial ①
- parallel ②

modes, according to the requirements of the process



Gas Storage Application

Operating Conditions



empty cavern
free flow into cavern

empty cavern
very low pr.ratio
parallel operation

full cavern
highest pr.ratio
serial operation

full cavern
free flow from cavern into pipeline

empty cavern
very low pr.ratio
parallel operation

backpressure throttling

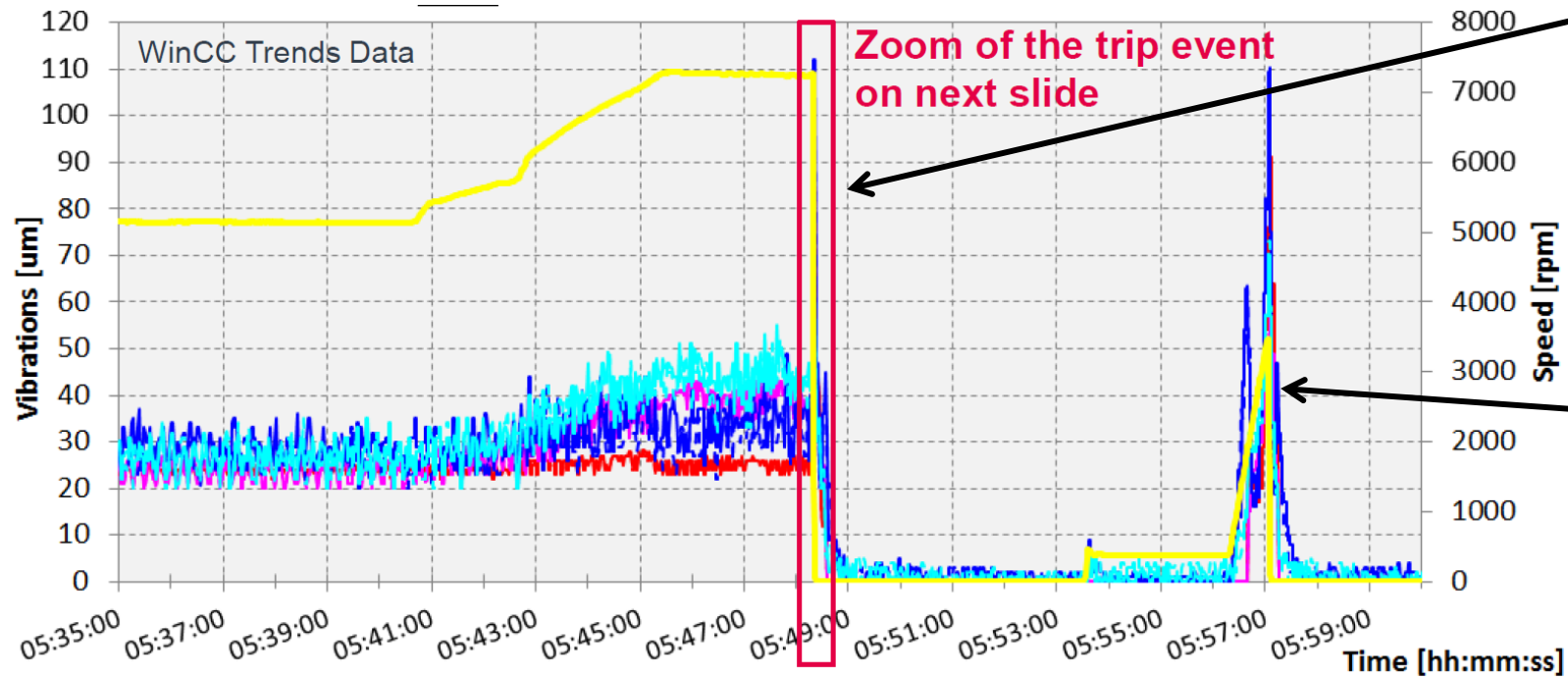
backpressure throttling

The backpressure throttle ensures that the minimum pressure ratio of the compressor is always maintained.



RCA

Vibration Data Analysis

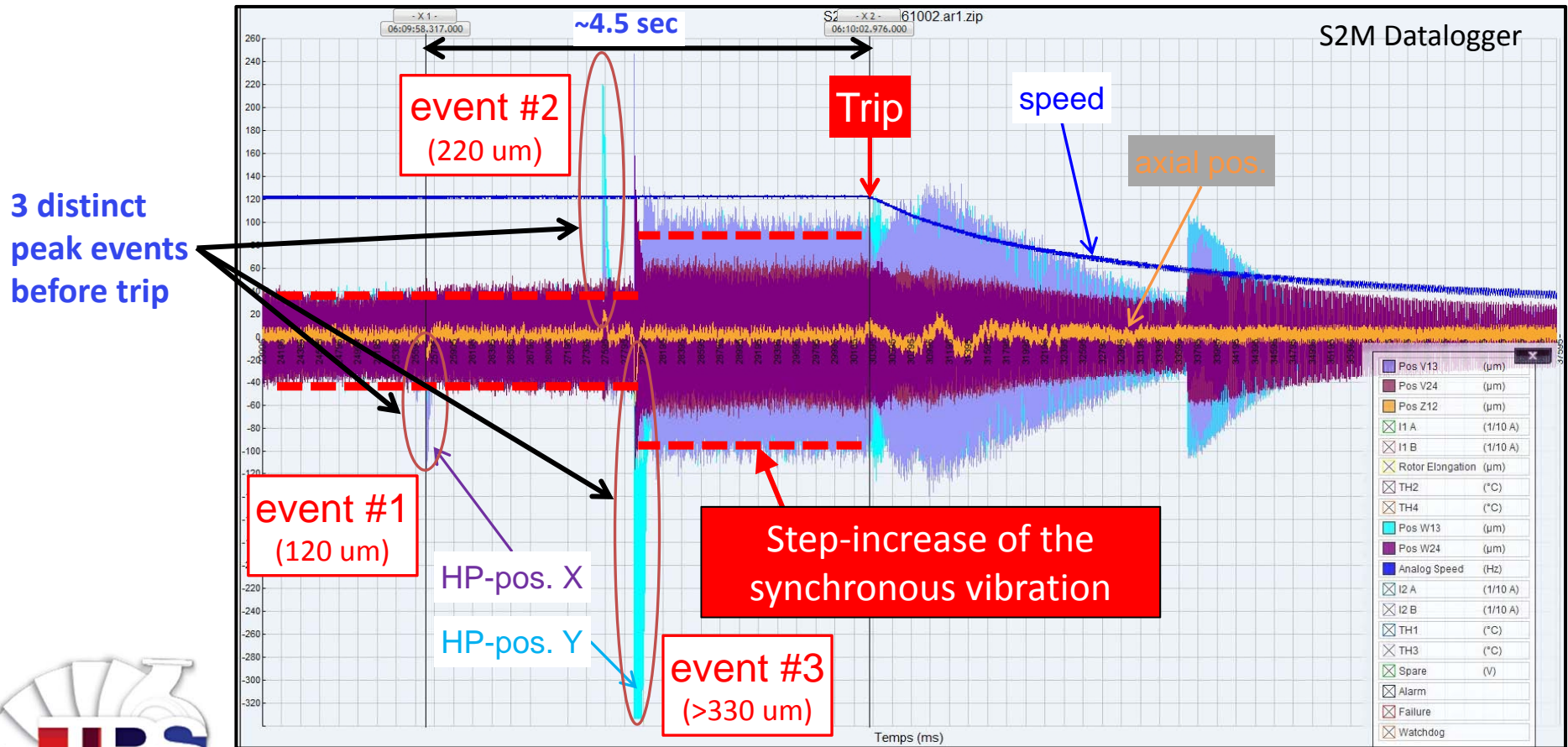


— VI 15204 A Unbalance R4 (UV13) [μm]	- - - VI 15204 B Unbalance R4 (UW13) [μm]
— VI 15203 A Unbalance R3 (UV24) [μm]	- - - VI 15203 B Unbalance R3 (UW24) [μm]
— GI 15246 A Radial Position R4 (PV13) [μm]	- - - GI 15246 B Radial Position R4 (PW13) [μm]
— GI 15245 A Radial Position R3 (PV24) [μm]	- - - GI 15245 B Radial Position R3 (PW24) [μm]
— SI 15201 Speed (VFD) [rpm]	



RCA

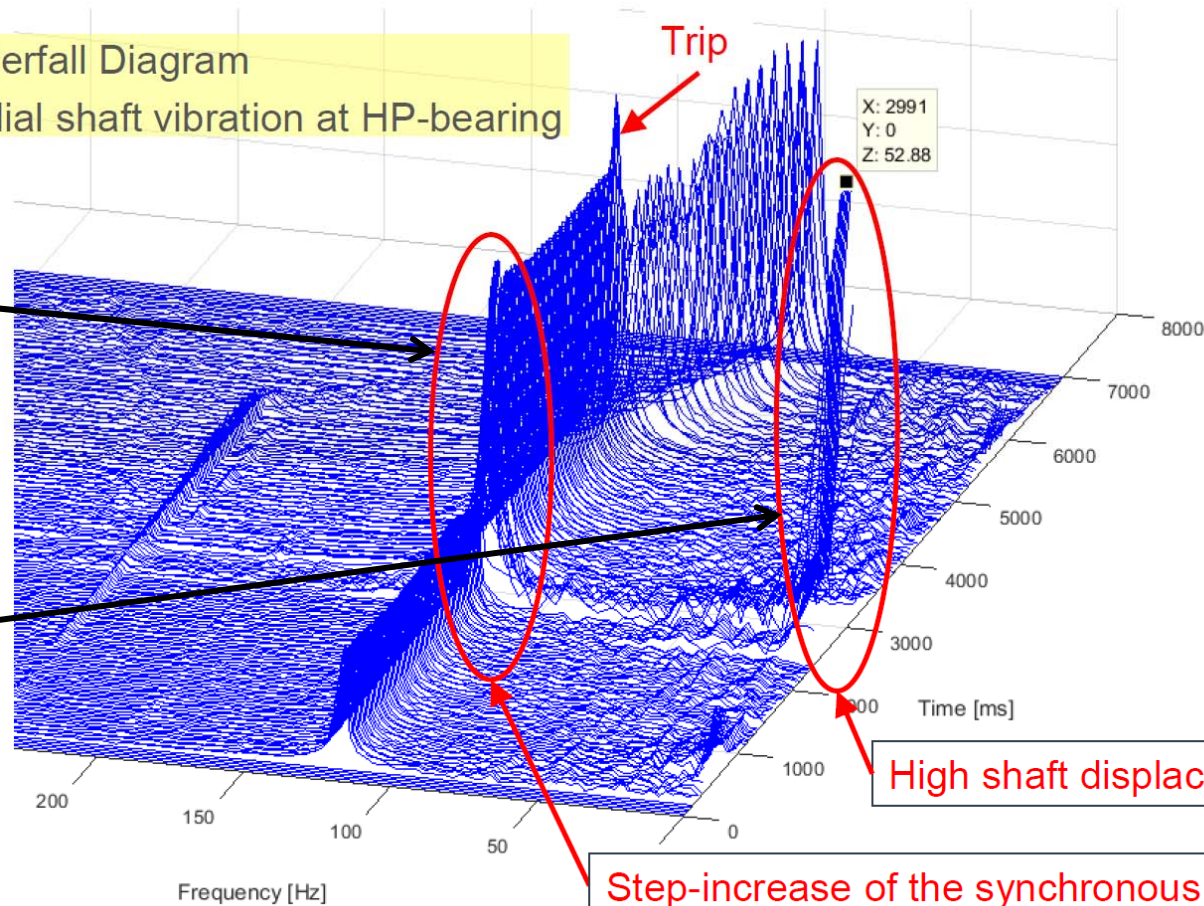
Vibration Data Analysis



RCA

Vibration Data Analysis

Waterfall Diagram
Radial shaft vibration at HP-bearing



the waterfall plot reveals a step increase of the unbalance (1x)

and

an excessive shaft displacement (impact or the like)

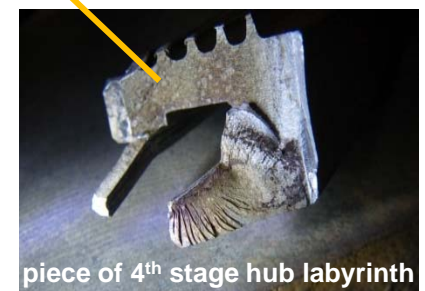
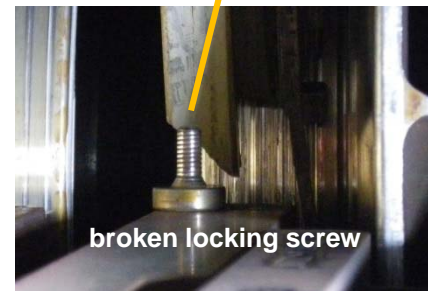
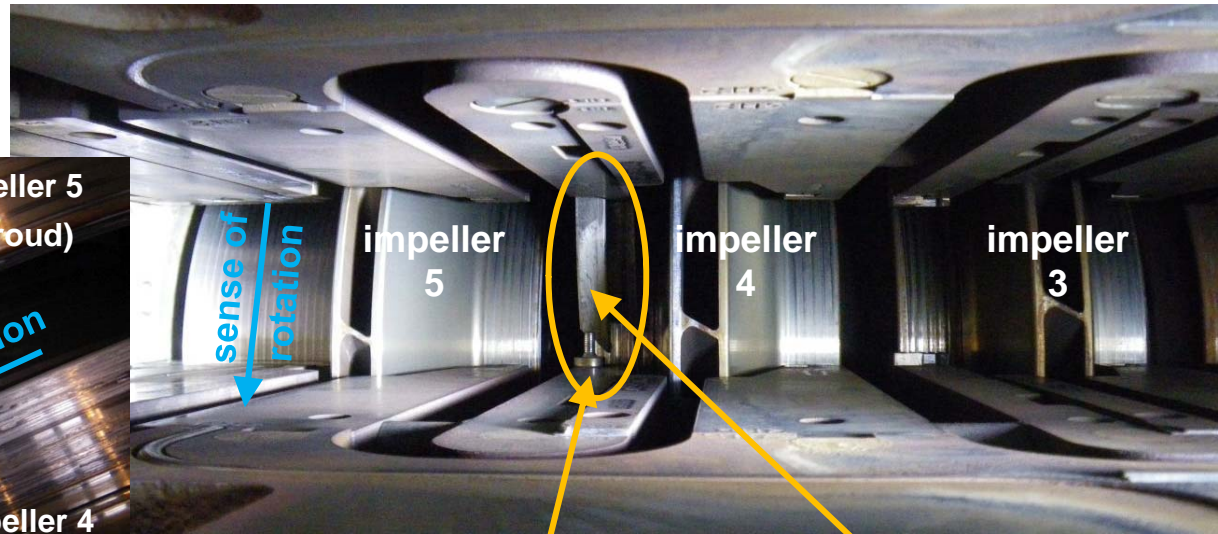
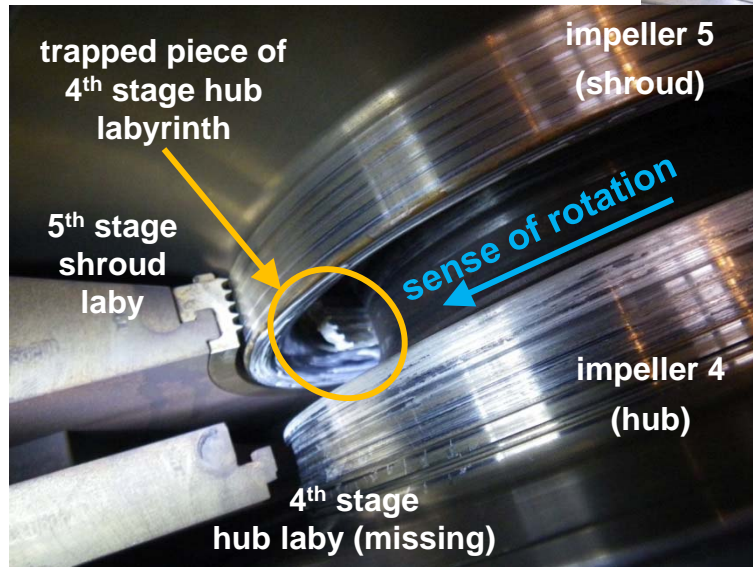
High shaft displacement

Step-increase of the synchronous vibration

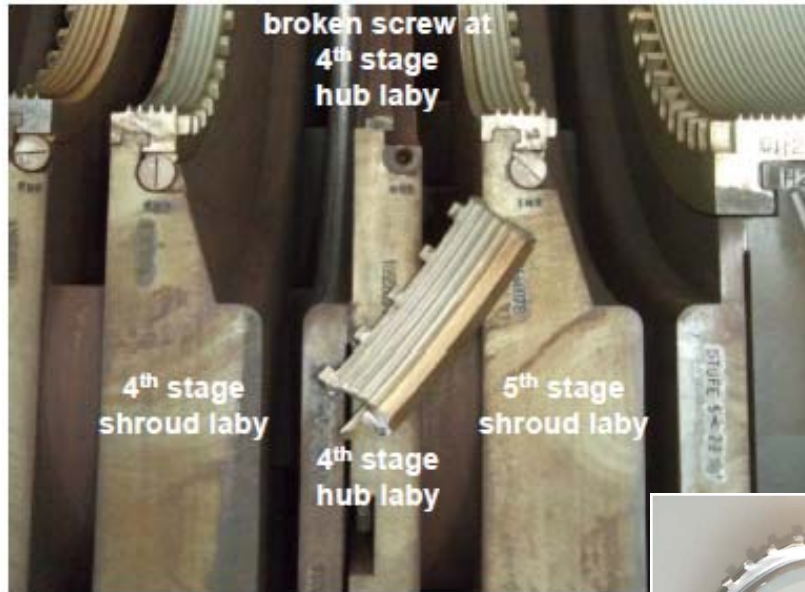


Investigation

Visual Inspection on Site



Investigation

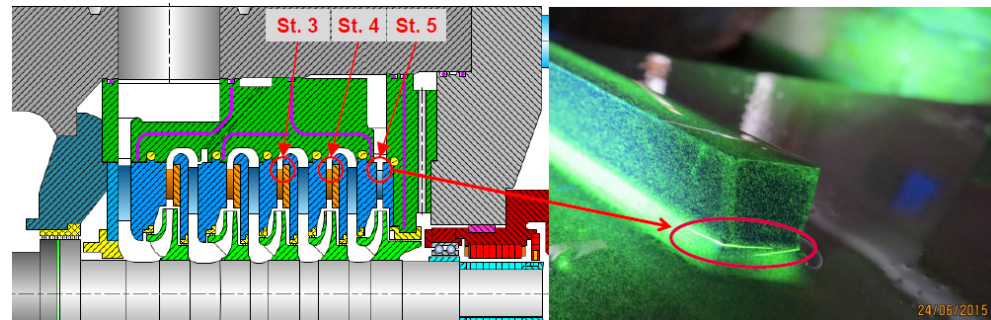


damaged hub labyrinths found in stages 3, 4 & 5 only



Inspection at OEM's Facility

damages found in HP compressor only

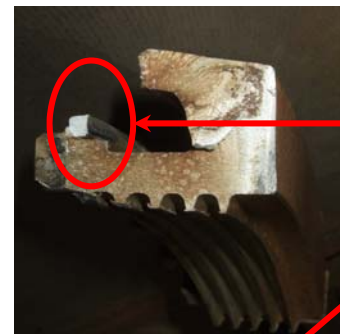
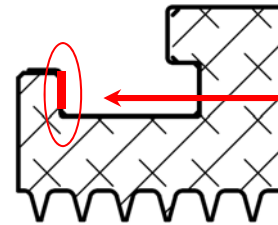
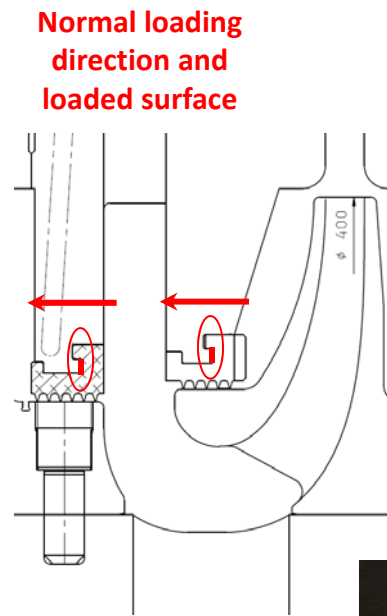
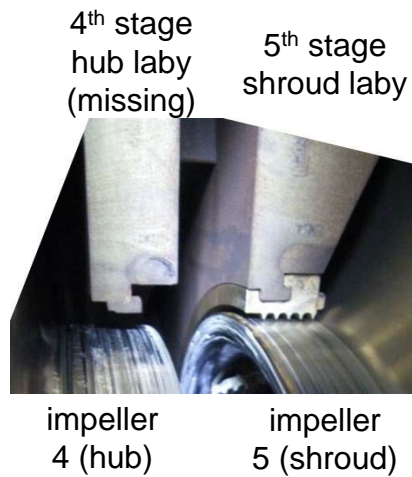


damaged diffuser vanes found in stages 3, 4 & 5 only



RCA

Interpretation of Damaged Laby's



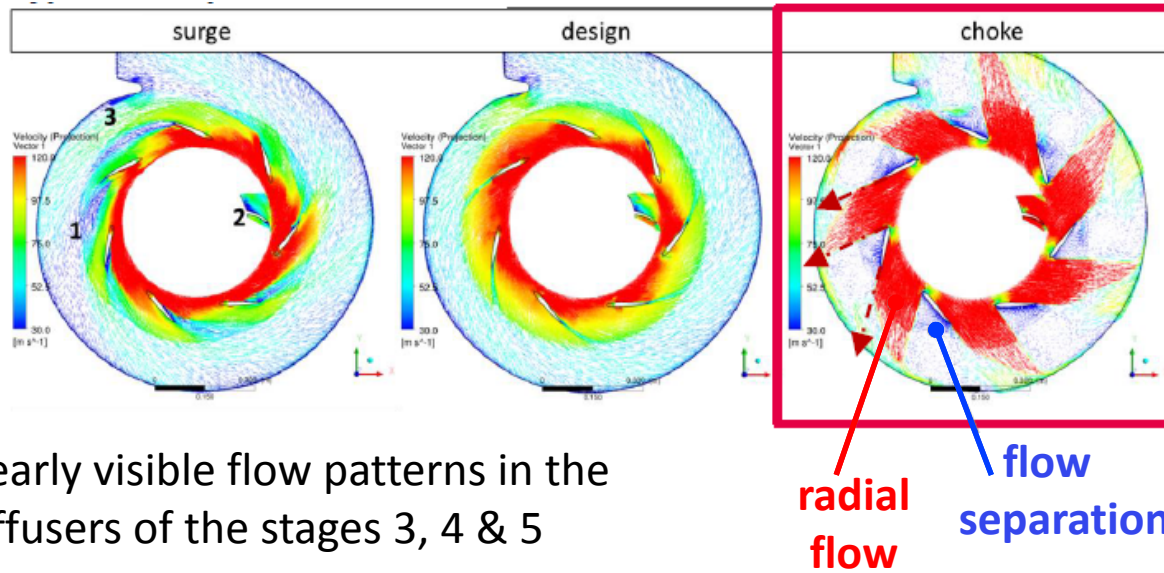
Conclusion:
Reversing flow direction causing alternating load on both faces



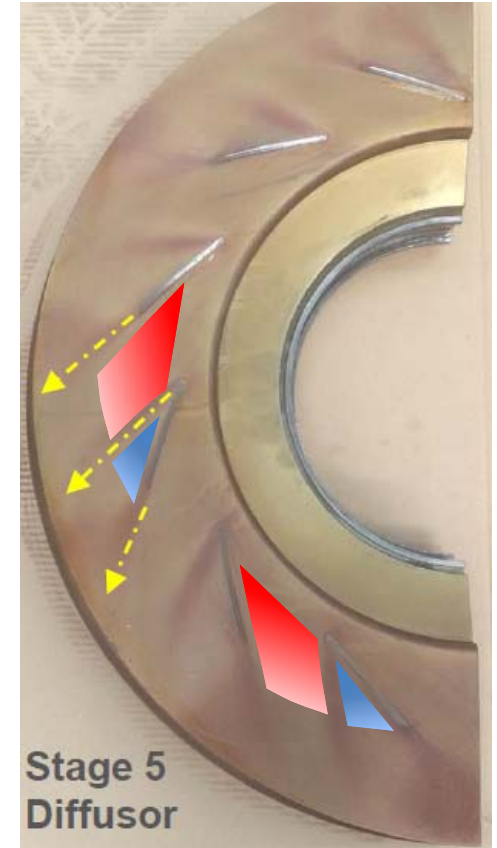
RCA

Evidence for Operation at Choke

Calculated Flow Patterns Typical for Operation at:

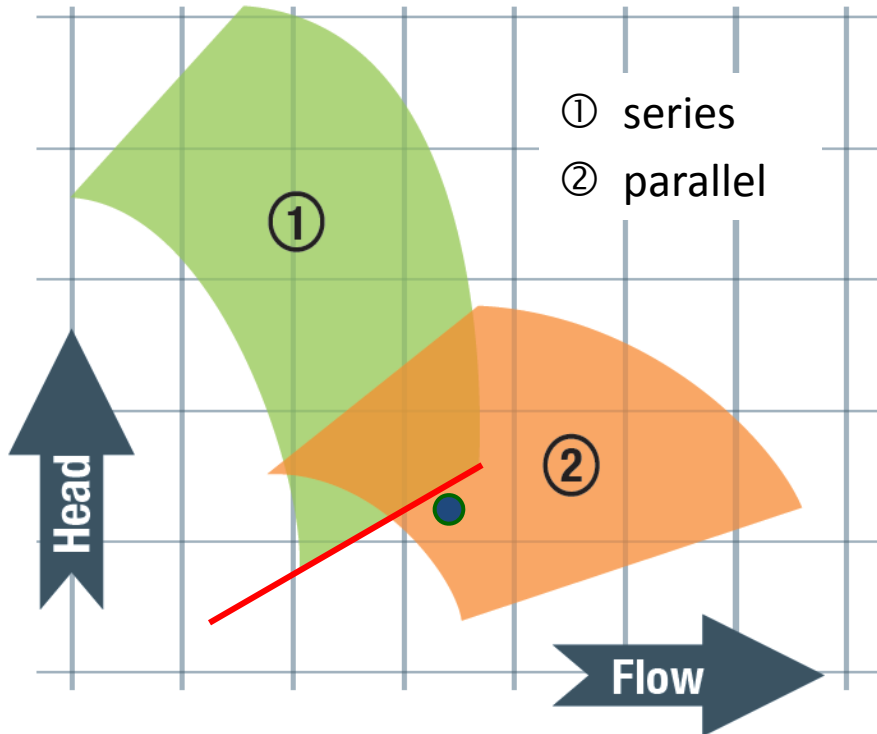


- clearly visible flow patterns in the diffusers of the stages 3, 4 & 5
- the comparison with CFD simulations of typical operating conditions evidences repeated or continuous operation at choke.



RCA

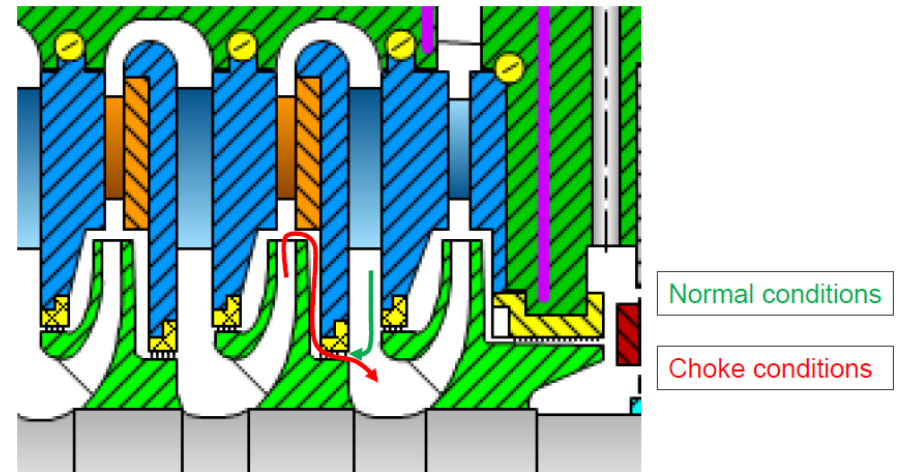
Repeated or Continuous Operation at Choke



- ① series
- ② parallel

- Operating point in serial operation
- Effective choke line

In choke conditions the diffuser of the last stage(s) do not increase pressure. Therefore the hub labyrinth has a reversed flow.



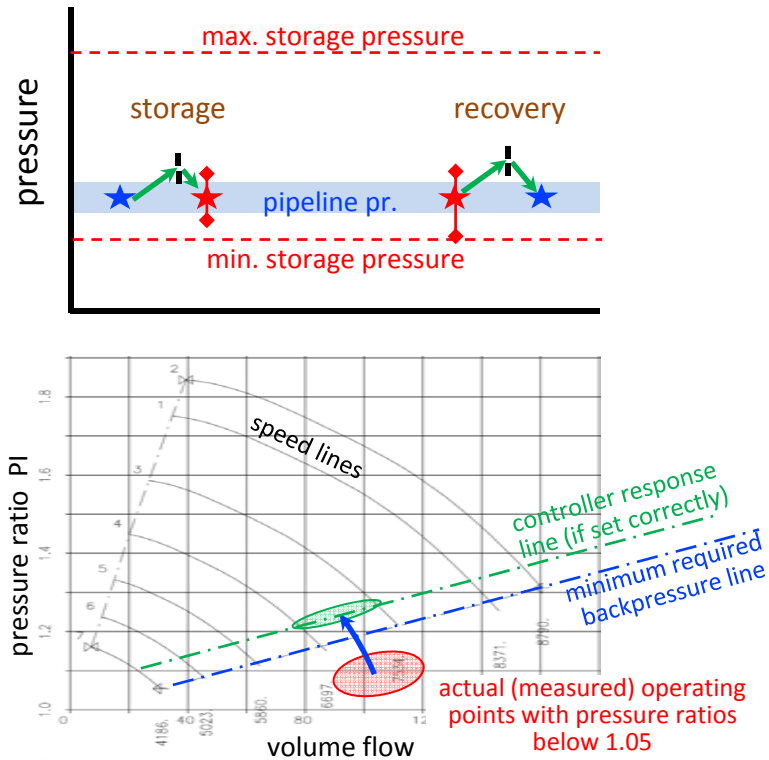
Normal conditions

Choke conditions

Dynamic flow and pressure fluctuations during choke operation caused the damages in the last stages of the HP compressor.



Conclusion

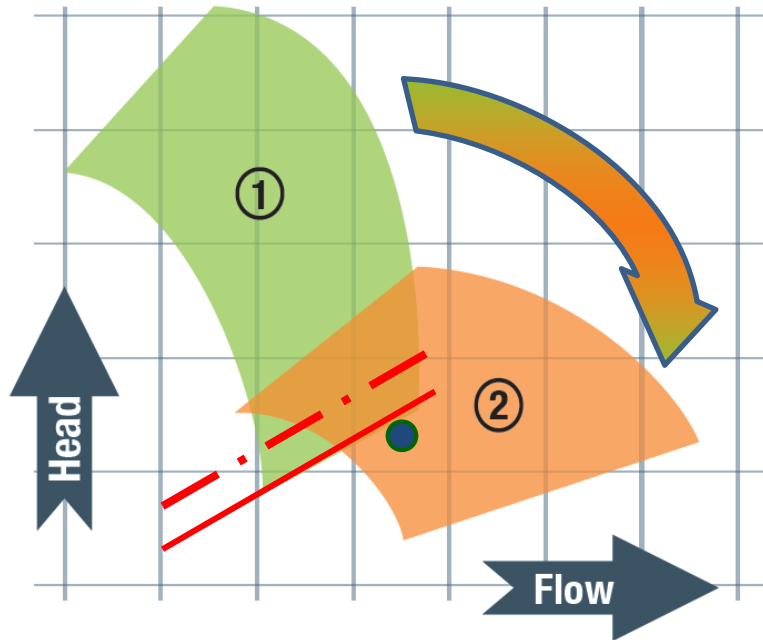


- According to the production profile prolonged operation at very low pressure ratios was a fact ($p_i \text{ HP} < 1.05$, or even below 1.00).
- The choke controller should have prevented the machine from running in this condition.
- The choke controller response line was not set properly. Therefore the machine was running in deep choke.
- The two compression sections were always running in serial mode. With these low pressure ratios parallel mode would have been appropriate.



Measures

Correct Implementation of the Choke Controller Response Line



- Operating point in serial operation
- - - Choke controller response line
- Effective choke line

- Prevent machine from operating in deep choke.
- Implementation of a correct choke controller response line.
- Encourage the operator to switch from serial to parallel operation if the choke response line is reached.
- In this case the efficiency will be significantly higher than in serial operation.



Thank You

for your kind attention

Questions ?



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