Is Frame Vibration Enough Protection? 
Early Detection of a Wrist Pin Failure Using Crosshead Vibration
Site Particulars

- **BP Refinery Rotterdam, Facts and Figures (2007)**

- Capacity
  - 400,000 barrels/day

- Primary units
  - 3 (2 x CDU - 1 x FCCU)

- Employees
  - 730

- Contractors
  - 500

- Vessels
  - 7,000 per year

- Tankers trucks at TTLR
  - 25,000 per year

- Storage tanks
  - 125
Compressor Application

- **Machine & Monitoring Info:**

  - Hydrogen, Suction 3.3 barg (47.5 psig)
    Discharge 34 barg (495 psig)
  - 4 throw – 3 cylinders – 3 stages (1 balance dummy throw)
  - 2 bearing motor - 1400 kW (1875 hp)
  - 2 compressors in parallel operation
  - 100%, 85% and 50% load possibility
  - Crosshead, Frame and Cylinder Vibration
  - Piston Rod Position (Y-axis)
  - Internal Cylinder Pressure (PV)
  - Motor Vibration
Compressor Photos at Commissioning
General Sequence of Events

What happened?

- During initial 24 hour full load test of this newly commissioned compressor, several load steps were executed.
- Machine ran at 100% load for 20 hrs, with no indications of problems.
- Load was changed to 50% load (using head end plug un-loaders).
- After 8 minutes at 50% load, the machinery protection system automatically stopped the compressor on high vibration of 1st stage crosshead (factory default safety limit was 6.5 g).
- High vibration and shut down was the result of a seized wrist pin caused by insufficient lubrication.
- At the time of submission, root cause of loss of lube condition was still under investigation by compressor OEM and the final RCFA results have yet to be published.
Failure Photos

Small end of connecting rod

Crosshead slipper
Failure Mechanism

- Due to the resistance at the wrist pin, the crosshead is forced to tilt in the guide. Loss of babbitt at both ends of the slippers confirms the mechanism.
- Piston rod position data clearly shows the movement which occurs due to bending of piston rod and vertical displacement of crosshead.
Crosshead Load (100% & 50%)
Online Data Plot at 100% Load (normal)

Rod load curve 100%
Online Data Plot at 50% Load (normal)

Rod load curve 50%
Compressor Loading / Trip Timeline

Sequence:
8:09:10 – load changed from 100 to 85%
9:10:34 – load changed from 85 to 50%
9:18:36 - trip activated on high crosshead vibration (RMS Acceleration)

Showing a lot of graphs would take too long… so let’s switch to the actual data recorded by the monitoring system

The following movie starts 2 minutes before compressor trip (6 minutes after switching to 50% load)
Ringbuffer Movie

Signal legend:

- Red signal is the *crosshead* vibration sensor
- Black signal is the *frame* vibration sensor (NDE)
- Orange signal is the *rod position* sensor

*Notice crosshead and rod position signals compared to frame*
2D Vibration Trend – All Crosshead Sensors

2 Hour Trend of Single Averaged RMS Acceleration – Blue curve is 1st stage

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<th>Measurement</th>
<th>Data Name</th>
<th>TAG-Name</th>
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2D Vibration Trend – Both Frame Sensors

2 Hour Trend of Single Averaged RMS Velocity – Blue curve is NDE

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3D Trend of Last 20 min. (Crosshead – Rod Position – Frame)

100% Load   85% Load   50% Load

Crosshead

Piston Rod

Frame
Default Trip Limit of 1000 µm (not active) reached approx. 1 min. earlier (24 – 118 Mils)
Conclusion

- Crank case vibration monitoring provides only limited protection for reciprocating compressors.
- Crosshead vibration monitoring reduces risk of loss of mechanical integrity (recommended as mandatory in new 5th Edition of API 670).
- Rod position can detect development of certain recip failure modes earlier than crosshead vibration and can greatly reduce consequential damages.
- By gaining a good understanding of a machine’s mechanical behavior and possible failure modes, and pre-determining acceptable damage levels, operators can implement a more sound shutdown philosophy.
THANK YOU FOR YOUR ATTENTION!

QUESTIONS?