Pipe vibration measurements

Energiforsk - KK50427

2016-10-04
Åsa Collet, ÅF

asa.collet@afconsult.com

Governance

Steering group consists of:

- Forsmark: Magnus Adolfsson and Ylva Vidhög
- Fortum: Heikki Haapaniemi and Jari Tenhunen
- OKG: Tobias Törnström(chairman), Carl Möller and Kent Andersson
- Ringhals: Stefan Melby and Lena Skoglund
- Energiföretagen Sverige: Inge Pierre
- TVO: Paul Smeekes and Petri Lemettinen

Objective

- Assemble knowledge and experience in the area of piping vibration measurements.
- Study in some depth what are the best practices to perform the measurements
- Assemble list of available measurement equipment (own \ available via consultants) for the pipe vibration measurements at the four participating nuclear power plants (NPP) (FKA, OKG, RAB, and TVO).

Background

- Pipe vibration problems are often complex and cause long periods of shut down
  - Pipes that contain media under pressure (e.g. steam, water), which during a pipe break or leakage can cause fire or other damage or trip of the machine shall be judged
  - Modifications of pipes ALSO influence machinery dynamics
- Reduced power leading to large losses of income. Especially during power uprate projects there have been large vibration problems at the nuclear power plants.
- The current situation with low electricity prices has led to a new situation where the NPPs are down regulated.
  - This might lead to increased wear, tear and vibration levels.
- The vibration experts at the nuclear power plants have expressed a desire to increase the in-house knowledge on measurement, analysis and mitigation of vibrations in different components.
  - There are only a few experts within the field and many expert are close to retirement.

Pipe vibration sources

Ex. Where does pipe vibrations come from?

1. Mechanical Induced Sources –
   - Machinery Unbalanced Forces and Moments

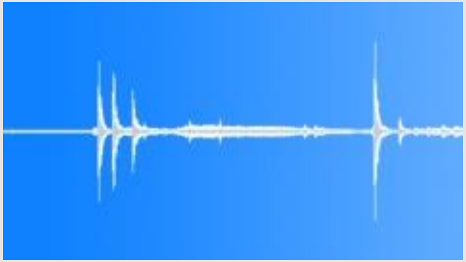
2. Pulsation Induced Sources –
   - Reciprocating/Centrifugal Compressor and Pumps, Turbine Flow through, Valves, Orifice plates

3. Cavitation and flashing

4. Vortex shedding

5. Acoustical resonance

6. Water- and Steamhammer



Sometimes, a scary subjective feeling!

Purchase requirement

Utilized purchase requirements on pipes and valves.

- Vibration criteria for connecting pipes from machinary:

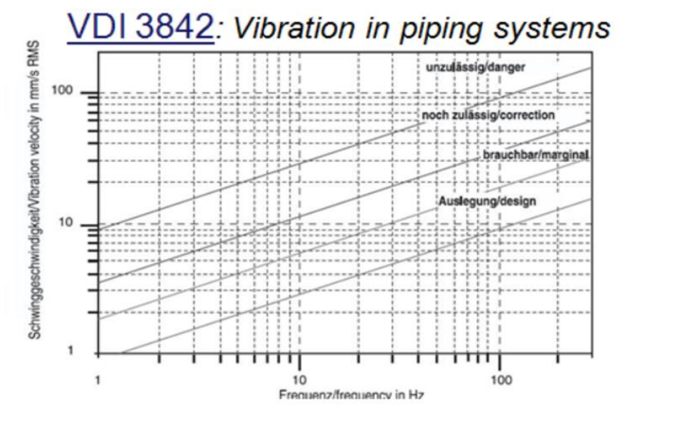
  The overall vibration level in the frequency range 1-1000 Hz shall be measured using vibration velocity in mm/s rms and vibration displacement in microns peak.

  If the vibration level is above 7 mm/s rms or above 150 microns peak, steps shall be taken by the Contractor to reduce the vibrations.

- Requirements are generally not set on pipes but on on valves and then in terms of max. acceleration which has been determined by calculation.

Piping vibration evaluation criteria – Vibration requirements

- ASEA STAAL standard, rule of thumb levels are presented > 20 mm/s danger <8 mm/s OK
- VDI 3842 (as function of frequency)
- ASME OM-SG-2007, 12.7mm/s 0-peak

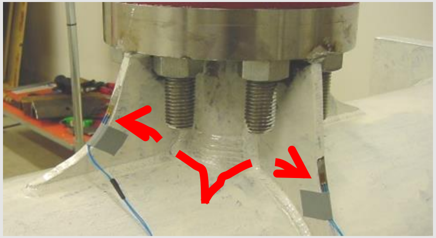


Note: Number of measurement points and locations are in most cases to be decided by each specific project or vibration specialist

Best Practice – Vibration requirements

Use standards together with your own ”common sense”

- Acceptable stress and vibration levels depend on many factors, a few of which are:
  - Material (composition, strength, endurance, etc.)
  - Geometry (size, quality of manufacturing, stress concentrations such as tee-intersections and cutouts, etc.)
  - Number of stress cycles
  - Amount of residual static stress.



Example of stress concentration

What to look for – describe the symptom – prepare for *measurement?*

1. Frequency of vibration. Is it low frequency below 10 Hz, medium up to 300 Hz or high frequency?
   - Select appropriate vibration sensor -s?
2. Amplitude of vibration
   - severe vibration - validated against requirement?
3. Location of highest vibration
   - On a pipe, pipe support, valve etc?
   - Decide if other complementary sensors are necessary strain, pressure etc.
4. Identify which kind of vibrations it is, steady state, transient or random vibrations
   - Select time domain for transient vibration
   - Select frequency for steady state
5. Identify mode shape or vibration pattern of local pipe component and global pipe system This step may require a deeper understanding of vibration methods.
   - ODS measurement and FE calculations

Selection of vibration sensor

Best Practice

- Often depends on frequency bandwidth
  - Acceleration: accelerometers 2-1600 Hz or higher (use piezo resistive accelerometer for strong shock measurements to avoid overload at higher frequencies)
  - Velocity (mechanical): velocity sensors 10-1600 Hz or higher(=no electronic linearization)
  - Displacement: LVDT sensors Dc-30 Hz

Upper frequency range is depending on vibration requirements (often up to 1000Hz) but in practice up to some hundred Hz. However depending on equipment (pumps, compressors, motors, valves, orifices, bellows) it could be wise if possible to choose 2 kHz and sometimes even higher but seldom over 4-5 kHz.

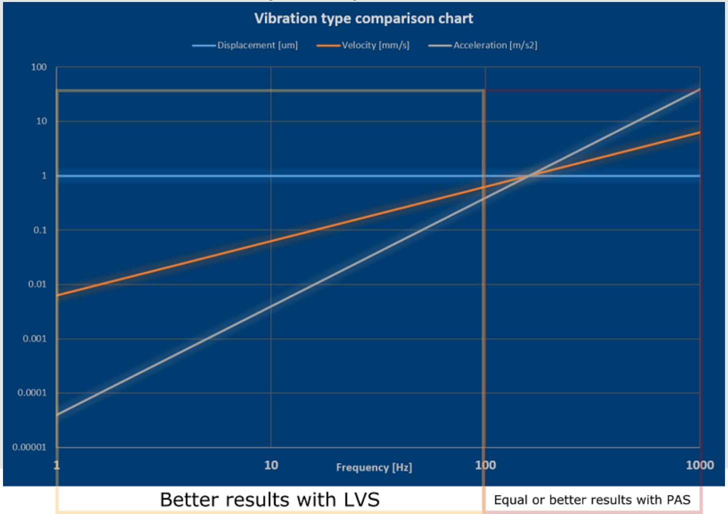
Pro and Cons – Velocity Sensor (VS) and Accelerometer (ACC)

\+ For frequencies below 100Hz, VS provides a much larger signal than a conventional PACC (Piezoelectric Accelerometer Sensor)

- \- ACC overloads compromise low amplitude and low frequency signal
- \- VS has lower sensitivity to higher frequencies.

\+ ACC with additional LP filters might be better (however not so straight farward)

\- VS are heavy compared to ACC



The resonant frequencies of the **velocity sensors** are at 8 Hz or 15 Hz depending upon their different constructional features.
Through electronic linearization of the respective frequency range it is possible to also measure vibrations that lie well below these resonant frequencies with high accuracy.

How to select measurement points

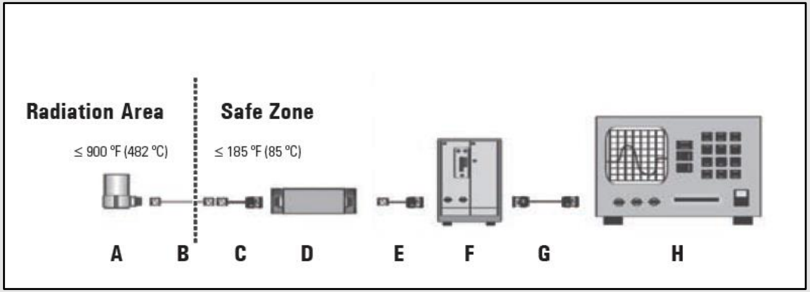
Best Practice

- Pipe measurement points are selected from an ISOMETRI drawing and not so often by subjected walkdowns. The selected measurement points from the ISOMETRI have preferable connection to a fatigue pipe design calculation model where fatigue hot spots have been determined.
- Alternative pipe measurement points are selected from know-hows experiences i.e. similar experiences from sister blocks
- Limited by accessibility of the measurement location and areas
- CFD calculations – Thermohydraulic simulation

Safe for Heat and Radiation

Best Practice: Long term measurements

- Example



A: Piezoelectric charge sensor (no electronics inside sensor)

B: Raychem cable or any other radiation harded cable (expensive, kept as short as possible)

D: Charge Converter/Amplifier (convert the high impedance output of a charge mode piezoelectric transducer to a low-impedance voltage output. This allows a long cables to minimize noise.)

E: Low noise cable i.e. good twisted pair shielded coax. cable (may be long)

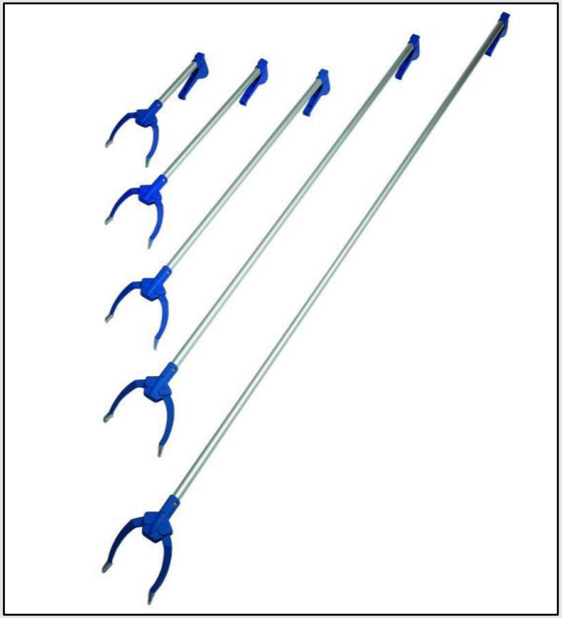
F: ICP converter

H: Measurement system

- PVC material is not accepted in hot environments and fixed cable installations due to risk of fire which may spread particles. Use glass fiber armed cable instead.
- Teflon is not allowed in radiation area.

Short term vibration measurements

Ex. Inside containment



Long trash stick

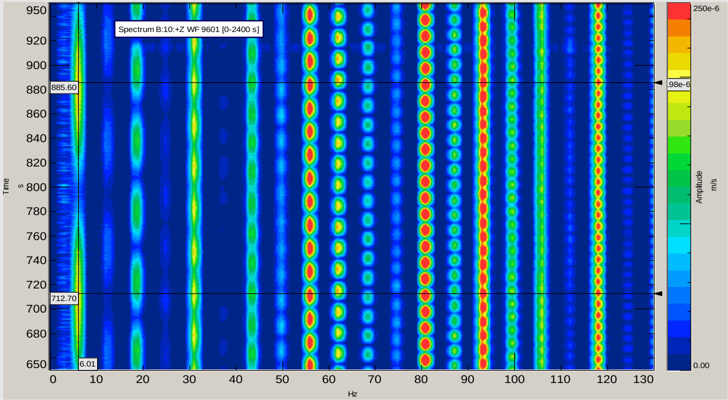
accelerometer

+

Magnetic mounting Neodymium magnets are the strongest type of permanent magnet commercially available.

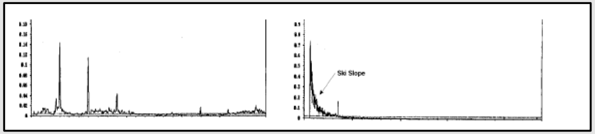
Checking consistency of the collected data

- Measurement performed in correct time slot?



Ex. Can ~5 s measurement always reveal correct levels?

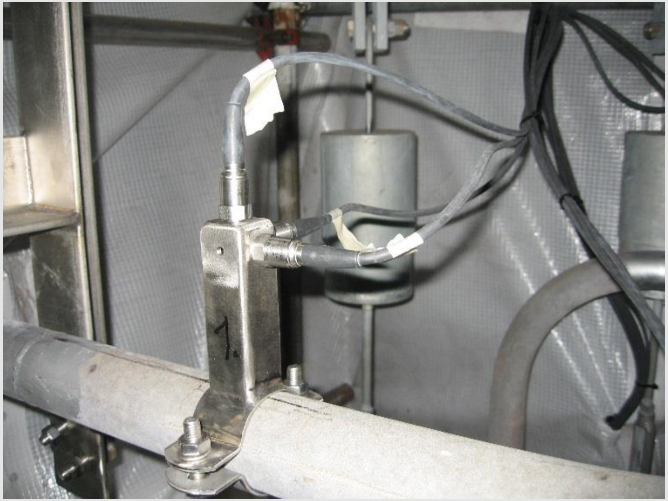
- Are there signal disturbances, noise, ski-slope=overload etc?

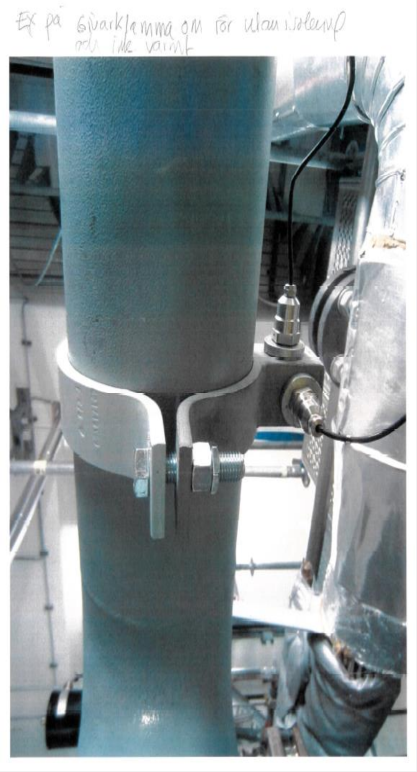


- It’s prudent to keep track of loading condition, flow, speed of adjacent machinary and other system parameters which can give influence to pipe vibration before you can evaluate the reliability etc?

Sensor mounting Accelerometer

Ex. Accelerometers on pipe (no isolation)





U-clamps

Sensor mounting Velocity sensor

Ex. Velocity sensor on pipe with isolation

Sensor mounting LVDT sensor

Ex. Displacement LVDT < 30 Hz

Note: LVDT sensor has short sensor distance ~10 cm

Instrumentation

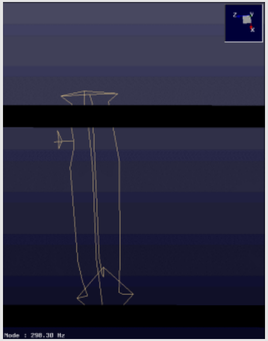
Available instruments at NPP sites

- Handheld: CSI (1-2 ch), VibXpert (1-2 ch), Svantek (4-ch), SKF Microlog, Percon logger (Noiden)
- Multichannel systems: CSI2600, Oros OR-38 multichannel, Oros OF -24 multichannel, BERAN 766 , LMS Scadas
- Analysis ODS+Modal: ME-Scope, LMS TestLab

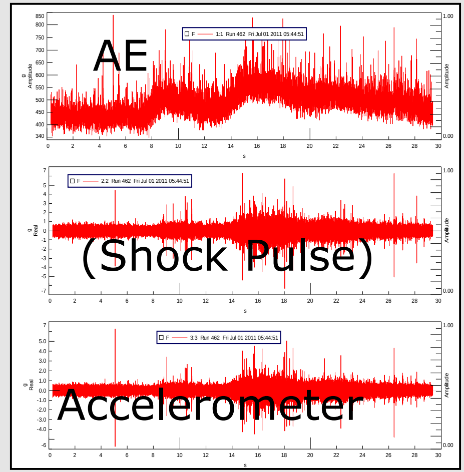
Measurements for Trouble shooting –

ODS Operational Deflection Shapes

- In this case it was very difficult to know if the main pipe itself had global modes which affected the SBC vibrations or if the high detected vibrations at the flanges of the SBC were local. The most efficient way to find out was to perform a multichannel ODS where you can easy determine the vibrations relative phase behavior for bending, torsion, shell modes and how the main pipe modes affects the SBC.



Measurement for trouble shooting – Acoustic emission (AE)



The AE-envelope sensor is DC coupled which means that it both capture the slow and fast varying trends in the steam pipe, for instance slowly increase/decrease of air flow, along with the sudden impacts of pulsation hitting the probe.

AE is a good complement to ODS measurement to determine the measured load case in the ODS measurements

Thank you all!!

Questions?