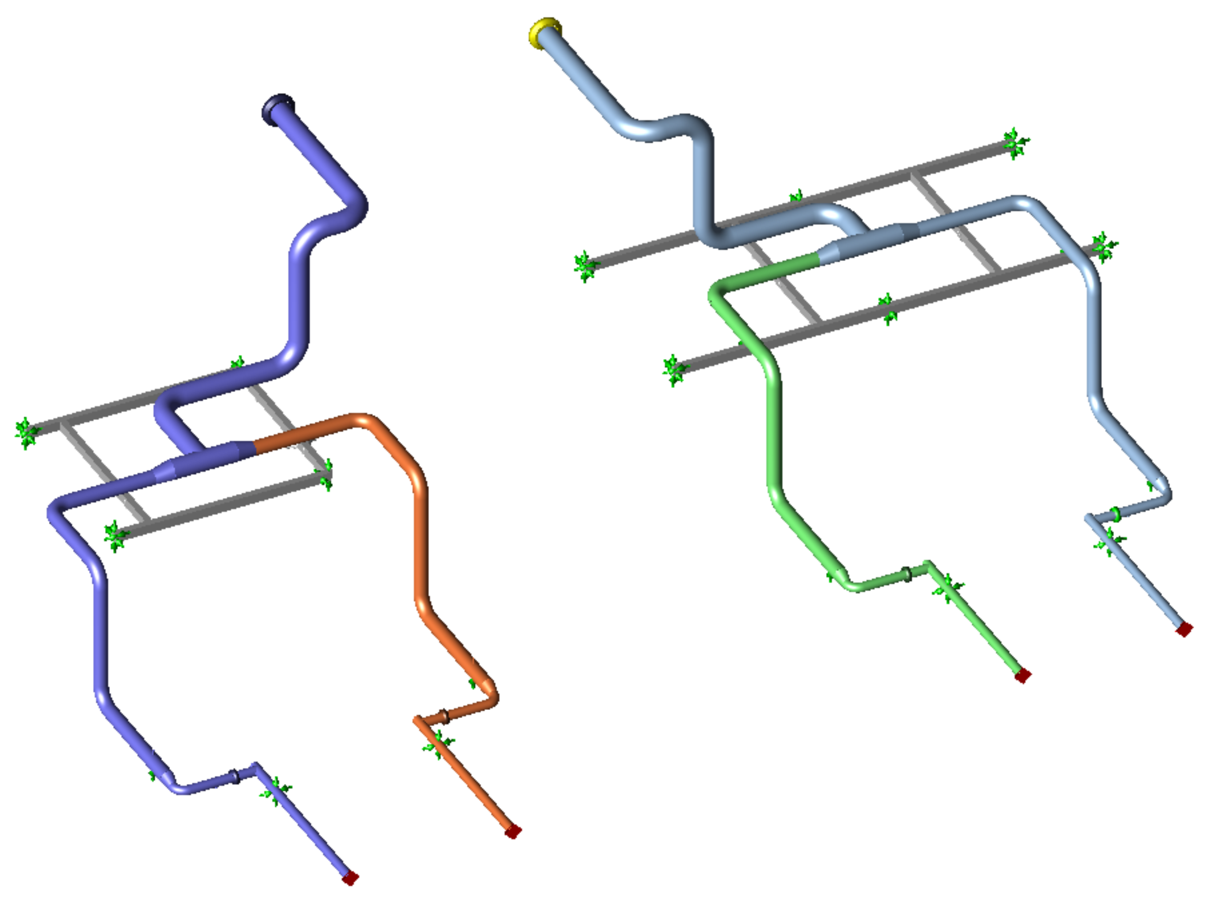
PIPING VIBRATIONS
MEASUREMENT, ANALYSIS, MITIGATION



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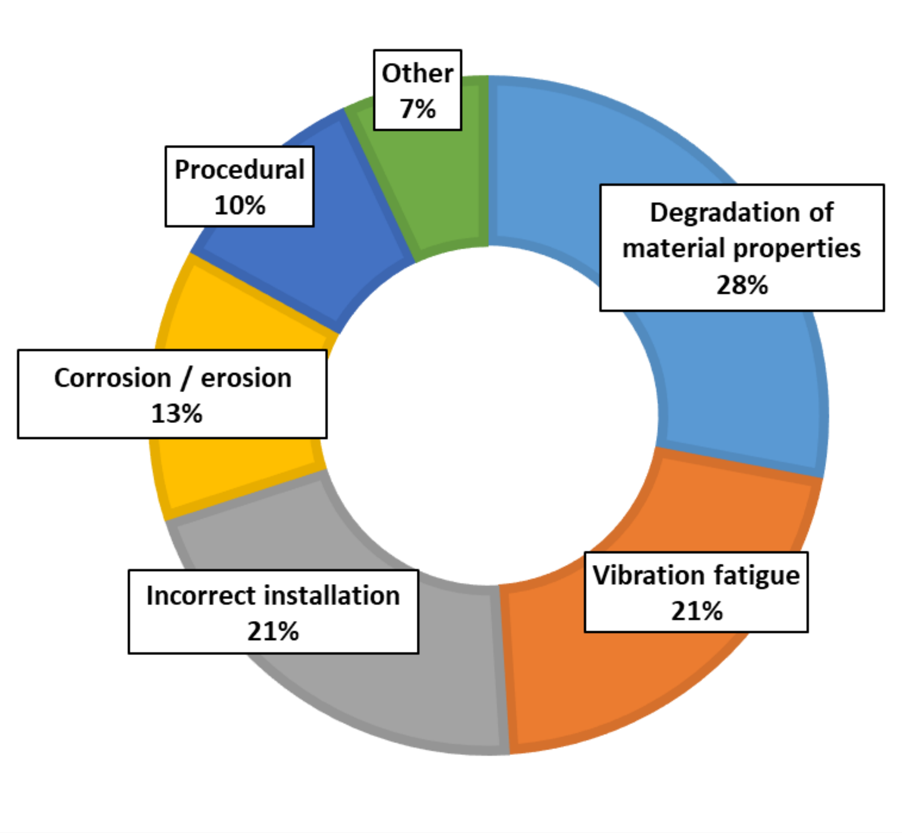
PIPING VIBRATIONS IN INDUSTRY

- Pipes are widely used in industry to convey water, gas, oil, or other fluid substances systems.
- The piping system is by far the **leading source of failures** in facilities. This is in part due to the sheer quantity of piping in facilities, but also due to inadequacies in integrity programs to consider vibration and fatigue. The commonly used **design codes do not consider vibration in detail**.
- Vibration induced fatigue has always been recognized as a potential failure mode of pipework.



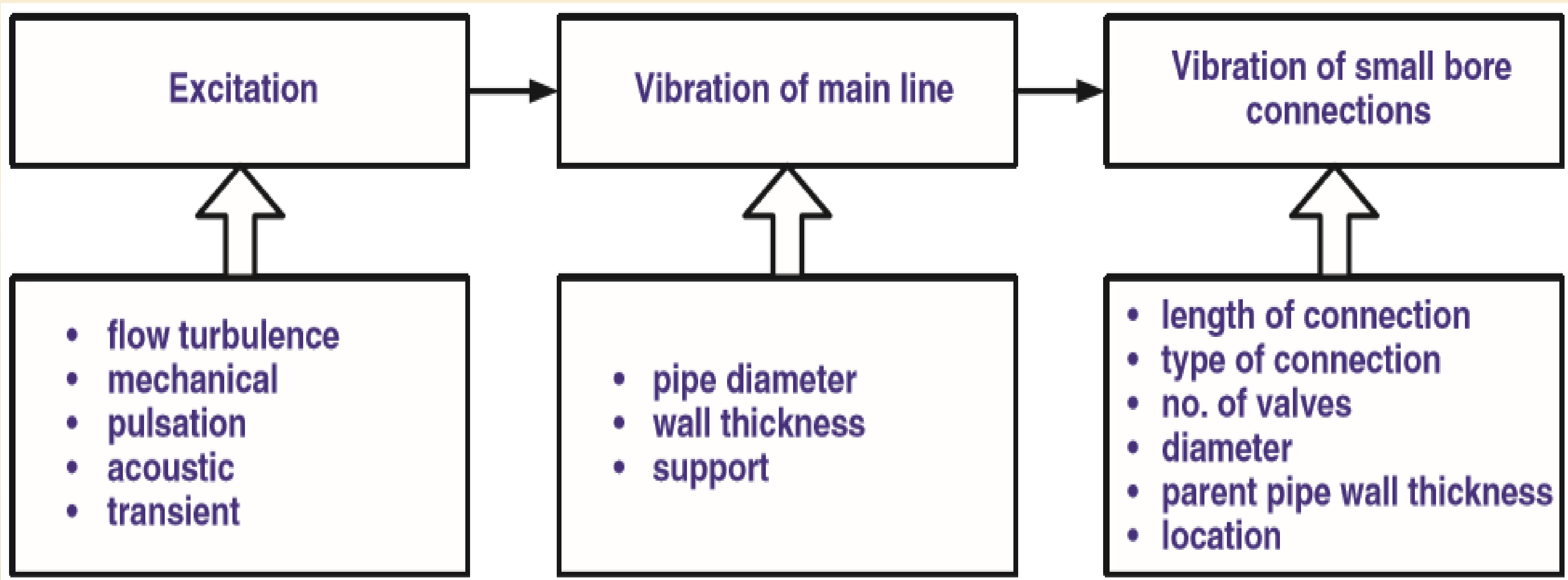
Causes of failure offshore
(from Health and Safety Executive 2002a

PIPING VIBRATIONS IN INDUSTRY

Usual questions about vibrating pipes:

- Is it dangerous or not? Are we within safe limits?
- If it is dangerous, how can we bring the pipework vibrations within safe limits?
- What are the causes?
- What has to change and how soon?
  - Structural modifications
  - Process modifications
- How can we extend the lifetime of the pipework?

PIPING VIBRATION CAUSES



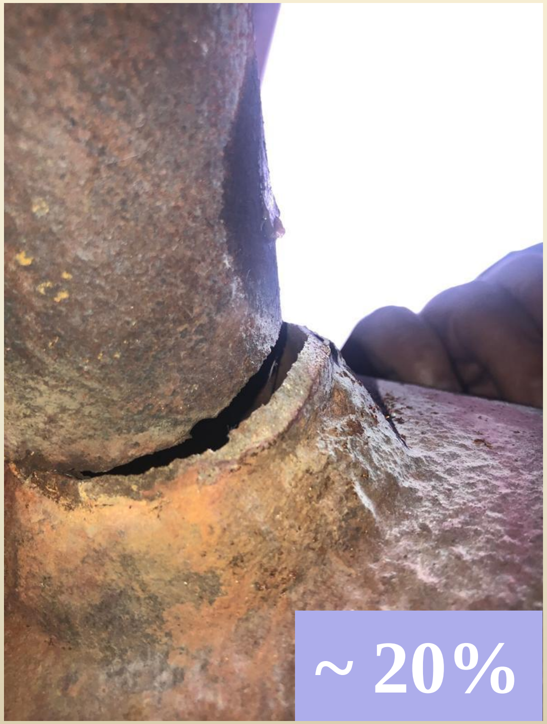
Vibration induced fatigue failure chain

VIBRATION INDUCED FAILURE

- Overall, only a small portion of piping is of high risk of failure, but identifying those high-risk locations is the challenge.
- Piping vibration risks can be identified at any stage of the asset lifecycle, but few companies have a systematic approach to evaluating these risks. Usually the vibration problem is addressed on a reactive basis.

Around 80% of vibration-induced failures are associated with small-bore connections (SBCs).

The remaining 20% are generally associated with main line (parent pipe) girth weld failure.



VIBRATION MEASUREMENT AND EVALUATION

- **Pipe vibration measurements**
  - In operation
  - In-situ measurements during maintenance outages
- **Piping vibration evaluation criteria**
  - ASME OM-2017 standard
  - VDI 3842 standard
- **Selection of vibration sensor**
  - **Accelerometers - for high frequencies (2÷1600 Hz or higher)**
  - **Velocity sensors - for medium frequencies (10÷1600 Hz or higher)**
    - ACC overloads compromise low amplitude and low frequency signal
    - VS has lower sensitivity to higher frequencies.
  - **Displacement - for low frequencies (< 25 Hz). Nuclear NDT uses a contactless laser system able to perform measurements on hot pipes.**

STRESS AND FATIGUE ASSESSMENT

○ Loading assessment

The fatigue loads acting on the piping circuit are extracted from the results of the vibration measurements. These loads are added to the design loads forming the fatigue load cases.

○ Vibration loads

- Displacement range
- Frequency

+

○ Design loads

- Pressure
- Temperature
- Weight
- Occasional loads

○ Stress and fatigue assessment

TOOLS: Piping circuit analysis – CAESAR II software
Detailed stress analysis – COMSOL software

HOT SPOTS: Branches, Supports, Circumferential welds, Miscellaneous attachments

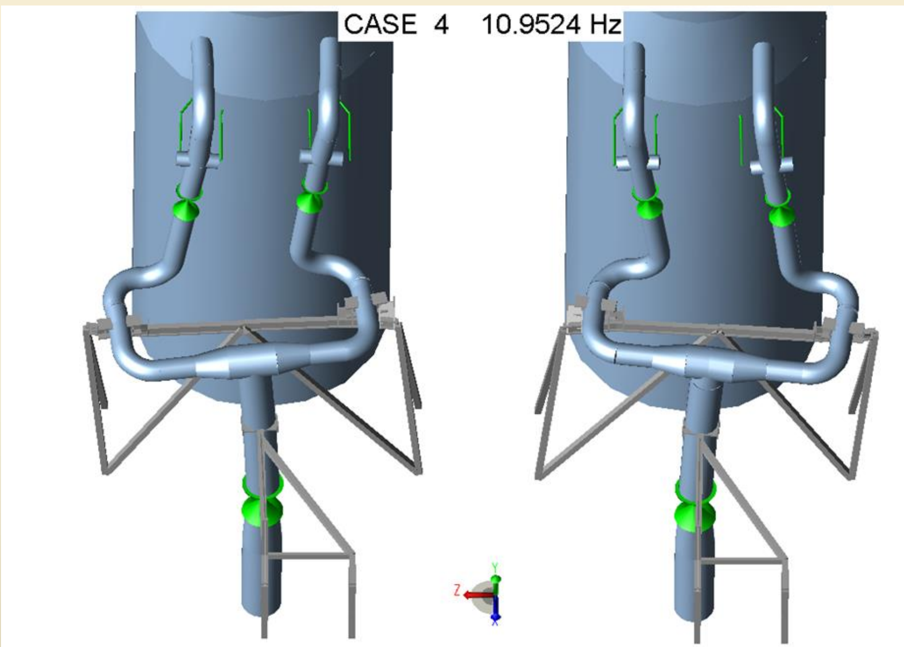
CASE STUDY

Crude oil pipes in a vacuum distillation unit

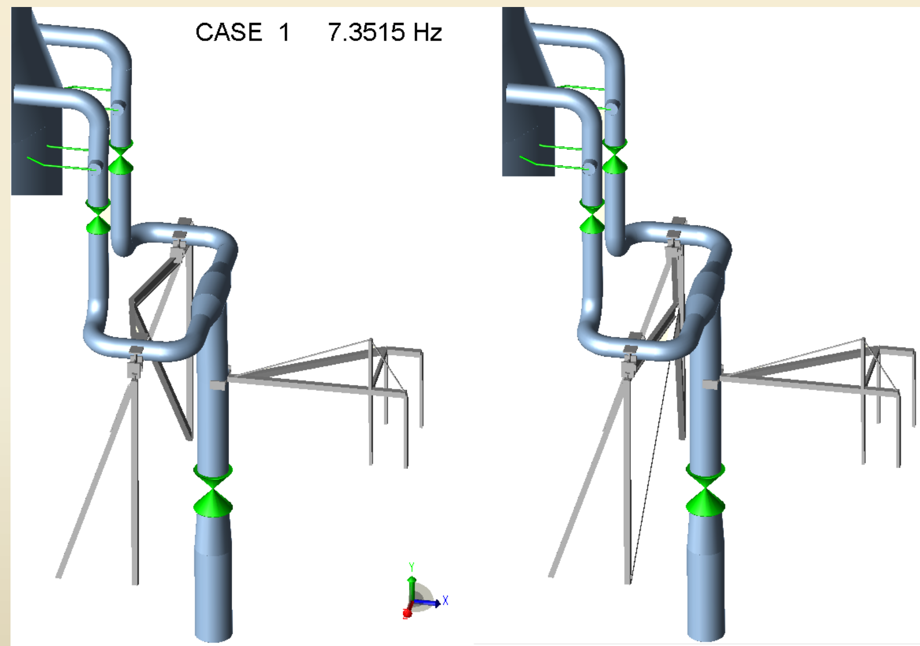
SUMMARY: When changing the operating conditions of the installation the vibration level of the piping increased considerably. The question was whether the additional load on the pipe would lead to a failure.

VIBRATION MEASUREMENT AND ANALYSIS: Vibration measurements were conducted on the pipe and on the anti-vibration steel constructions. The spectral analysis of the records singled out the highest vibration amplitude at the frequency of 11 Hz.
The vibration amplitude on the anti-vibration structure peaked at the frequency of 8 Hz.

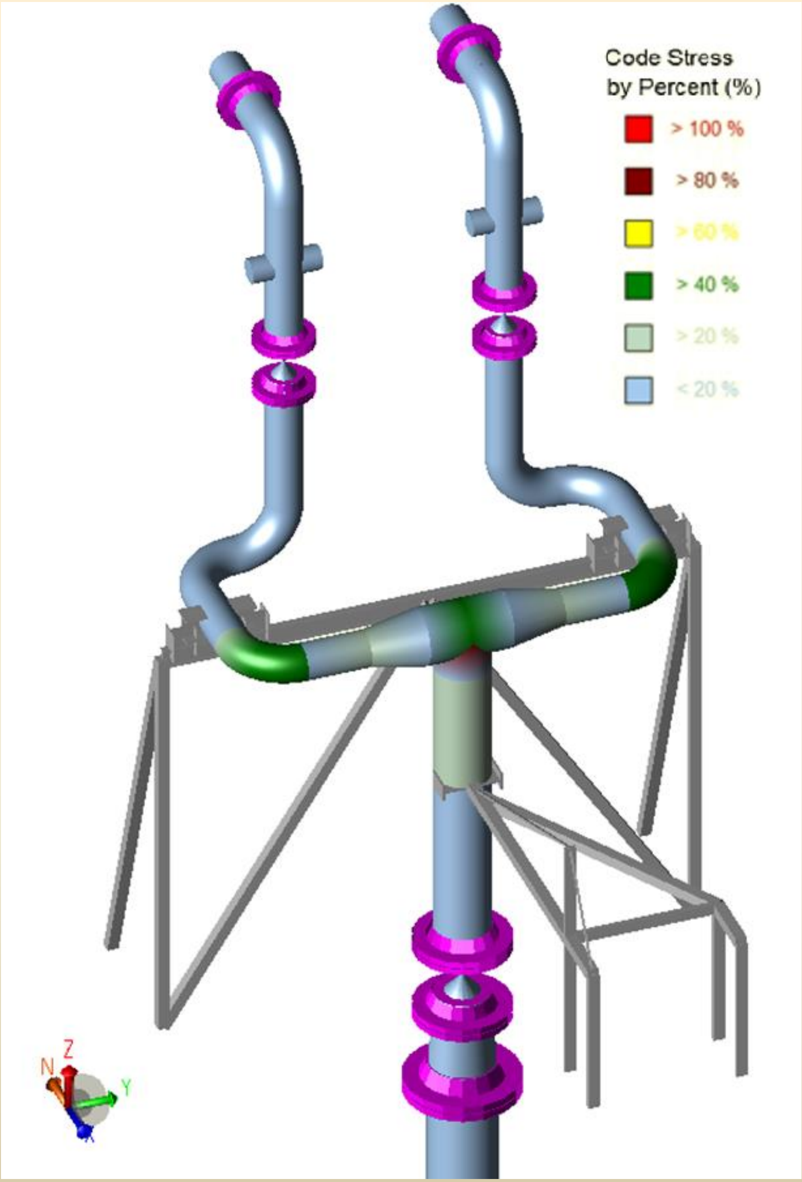
MODAL AND HARMONIC ANALYSIS: The results of the analysis performed with CAESAR II were in good agreement with the vibration measurements. See below the calculated vibration modes.



Vibration mode of the pipe together with the anti-vibration structure corresponding to the natural frequency of 10.95 Hz.



Vibration mode of the anti-vibration structure corresponding to the natural frequency of 7.35 Hz



FATIGUE ANALYSIS RESULTS

- This analysis was also performed using CAESAR II.
- Fatigue analysis results:
  - In the picture – calculated fatigue stress range on the crude-oil pipe with respect to the allowable fatigue stress range.
  - The highest values (in brown), are at the middle of the tee and in the two elbows closest to the tee. The maximum value is 93,2 % of the allowable fatigue stress range.

MITIGATION

- **Actions**
  - Eliminate the vibration cause
  - Reduce the vibration level within acceptable limits
  - Reinforce the piping circuit to keep the vibration stresses within acceptable limits

- **Means**
  - Change the flow parameters
  - Install vibration dampening devices
  - Modify the piping circuit
    - Shape of the circuit
    - Thickness of the sensitive elements
    - Supporting – type and position

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