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Examples of vibration problems and approaches from the oil and gas industry, focusing on vibration damping of vibration frequency range 30-300 Hz (TMD).

Even Lund
R&D Manager, Momentum Technologies

www.momentumtechnologies.com

Even Lund

R&D Manager, Momentum Technologies

MSc Mechanical Engineering, NTH/NTNU 2000

«Vibration guy»

- 21 years applied vibration measurement, analysis, mitigation
- Latest 11 years in Oil & Gas

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Speech content

- Our experiences of vibration problems within the oil & gas industry.
- Possible parallels to nuclear power industry.
- Case-study, Momentum high frequency Tuned Mass Damper
- Possible discussion points/topics

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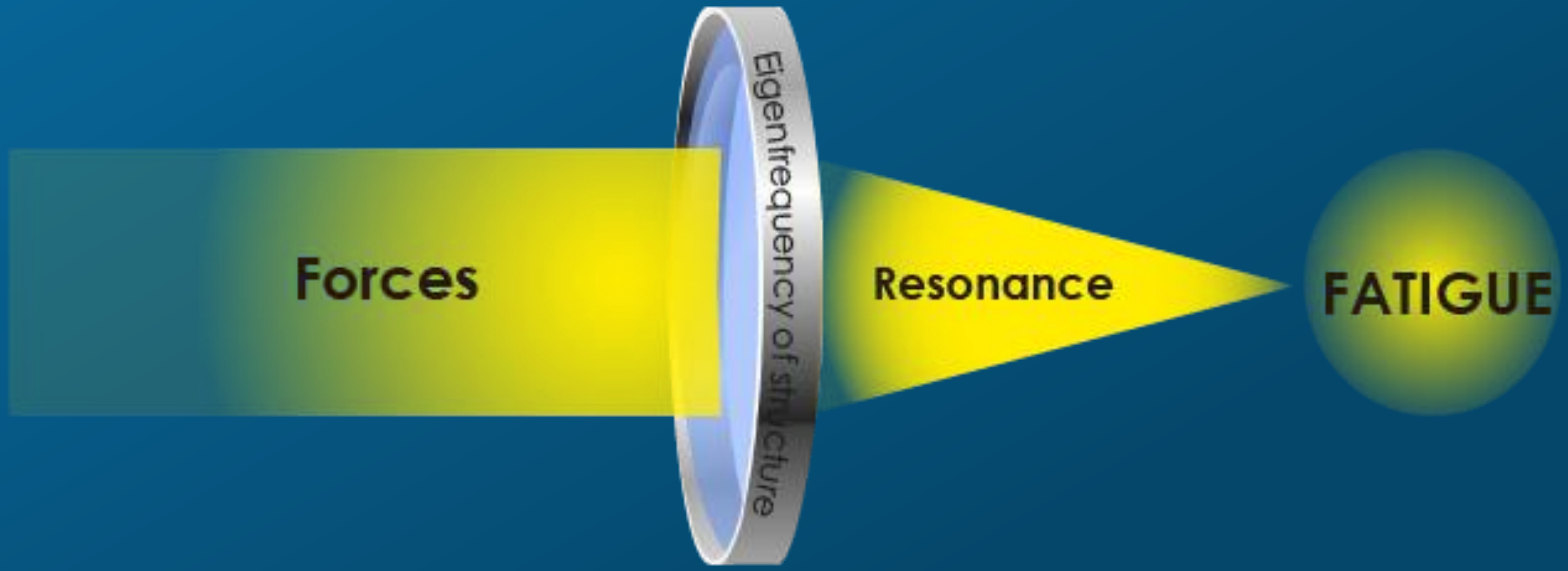
MOMENTUM TECHNOLOGIES

We are experts within vibration, dynamics and sound.
We prevent fatigue.



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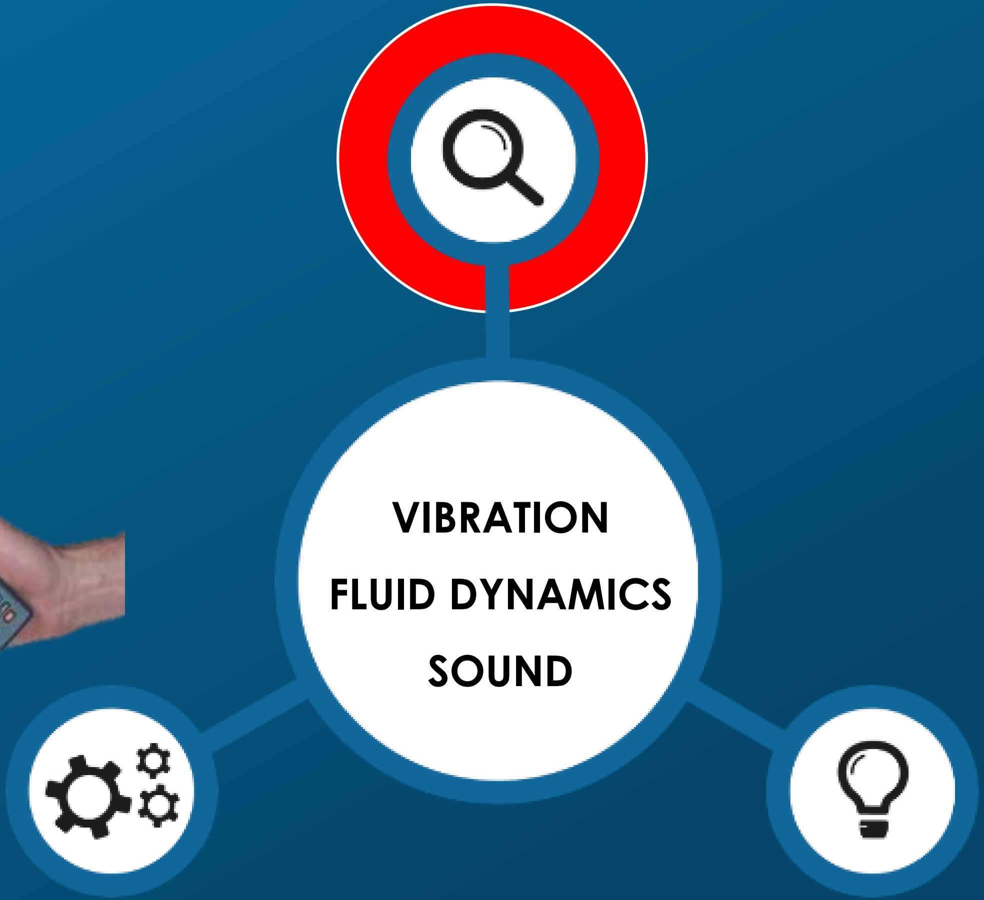
OUR MISSION

Prevent accidents caused by vibration and sound.

OUR APPROACH

- Measurement services



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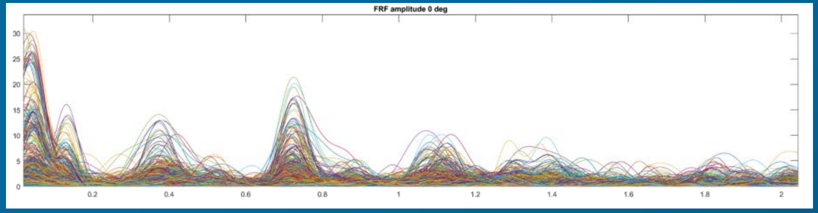
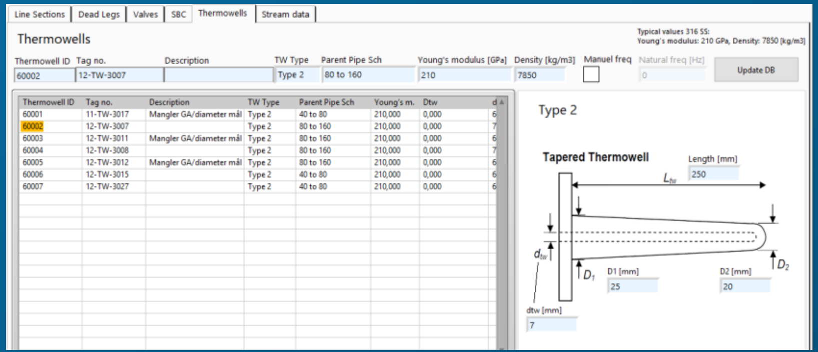
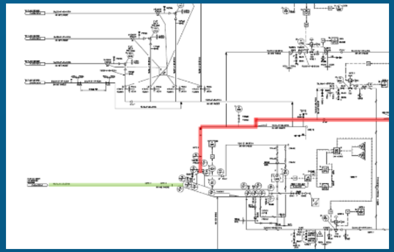
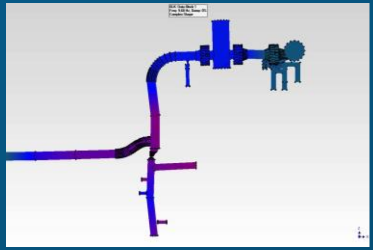
OUR APPROACH

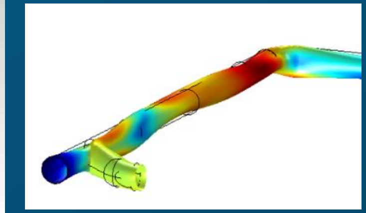
- Measurement services
- Vibration and noise assessments

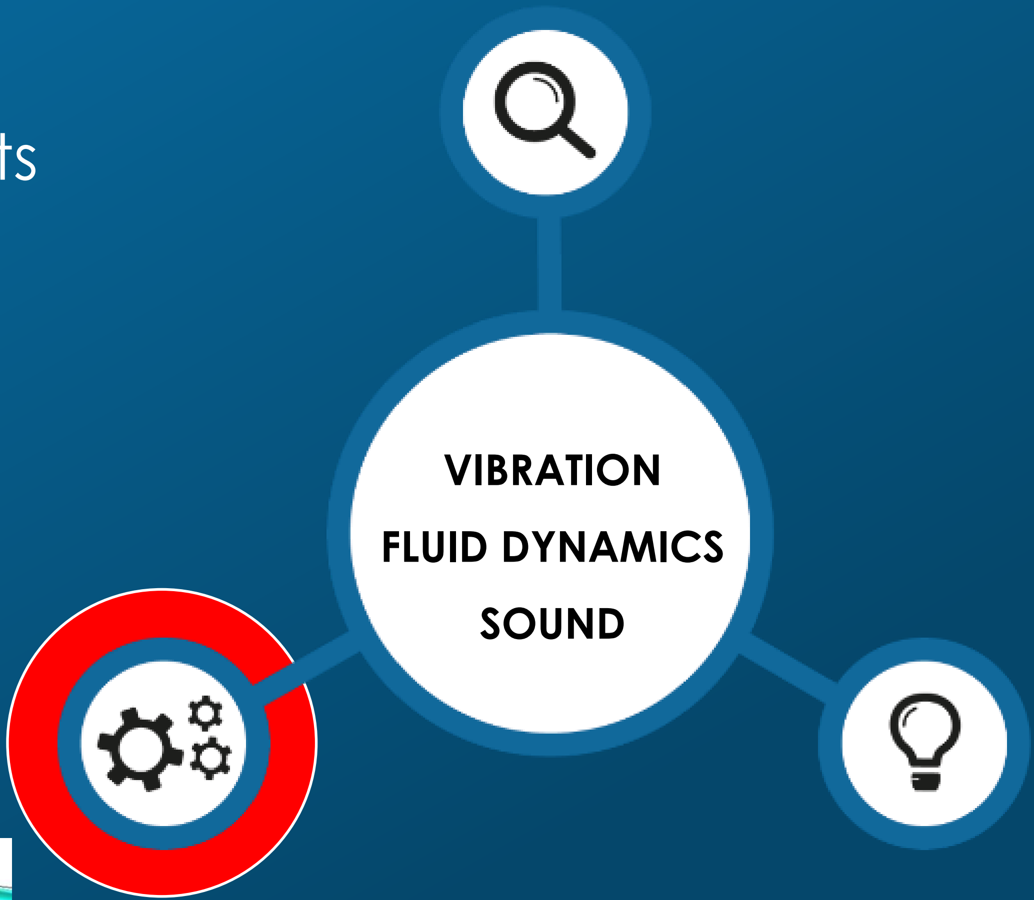












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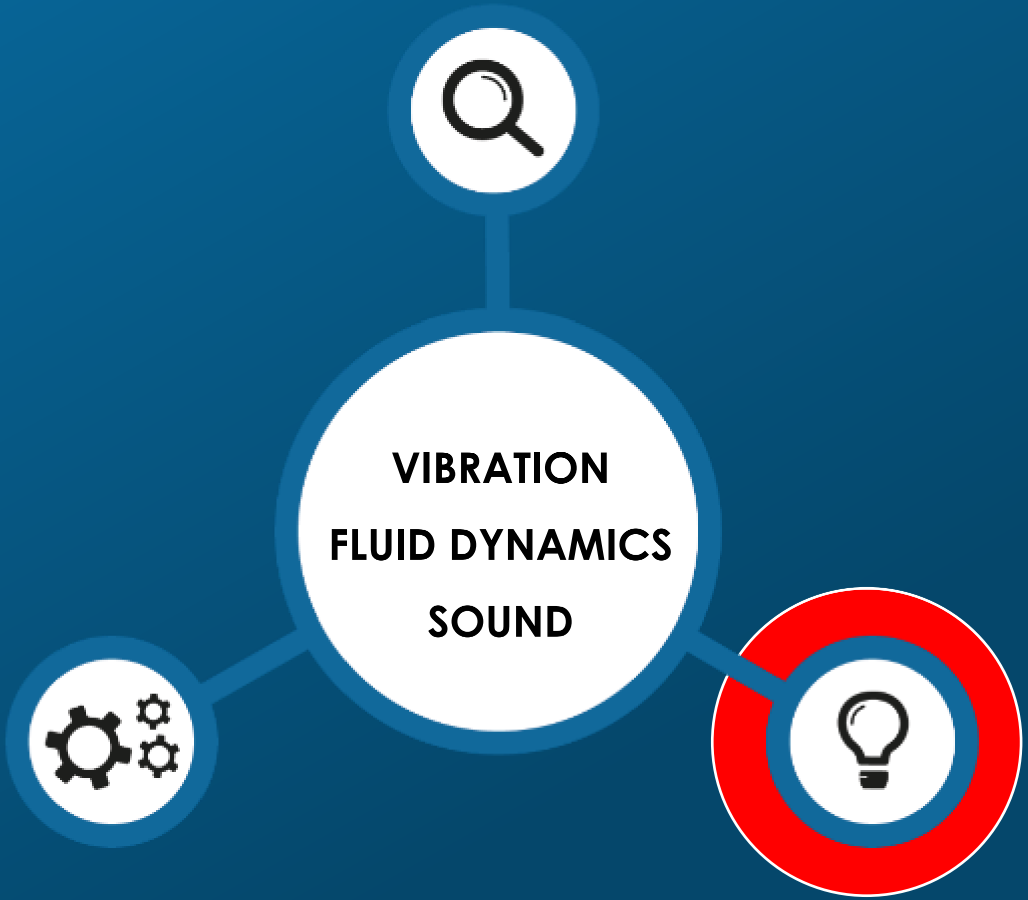
OUR APPROACH

- Measurement services
- Vibration and noise assessments
- Vibration damping solutions



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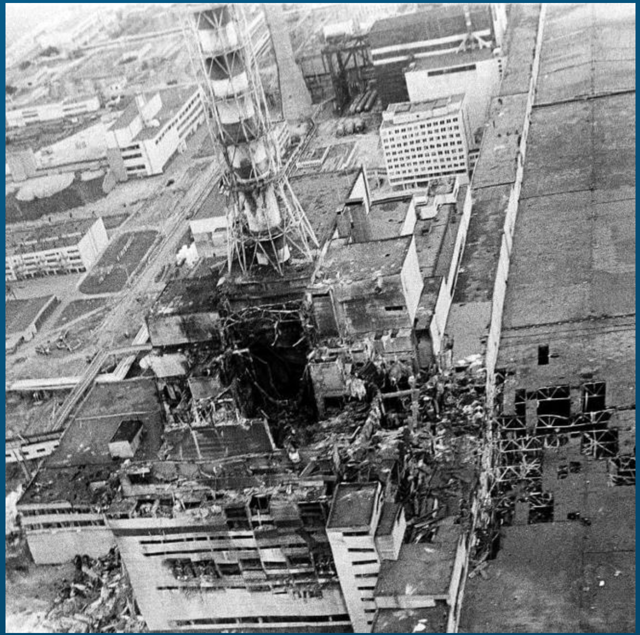
LARGE consequences

HSE - Loss of income - Bad reputation



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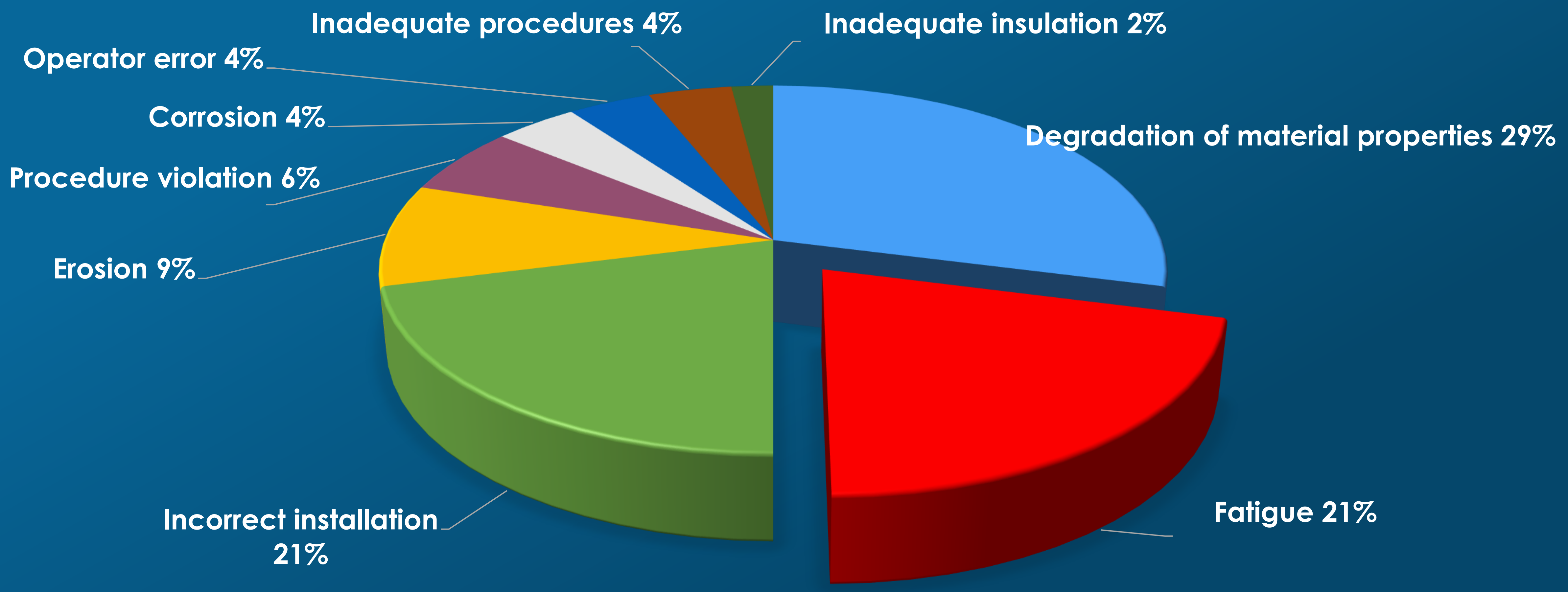
Cause of pipework failure



Source: UK-Health & Safety Executive

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PETROLEUMSTILSYNET

Oil & Gas vibration handling
Full disclosure principle

- All incidents, even unharmful ones, are tracked on the oil rigs.
- Petroleumstilsynet (ptil.no) disclose all information found through inspections and investigations.

Kårstø, 2016

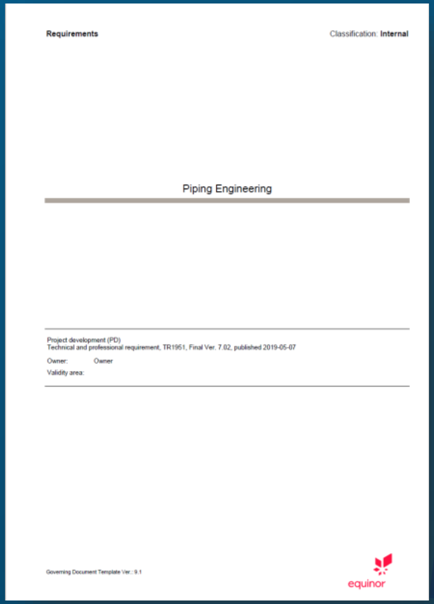
Statfjord A, 2016

Gudrun, 2016

Gjøa, 2017

Common vibration challenges in the oil & gas industry – organizational

- High competence within vibration/flow assurance available in the central organizations of the oil companies and contractors
- Limited competence of vibration and dynamic problems/challenges in engineering and operational organization and contractors



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How to find root cause of vibration

1. Talks with people with knowledge of the system
2. Walk-down to localize problem
3. Elimination of vibration mechanisms based on fluid phase and energy sources (flow, sound, vibration)
4. Further elimination with limited input (P&IDs, ISOs, fluid properties)
5. Measurement and analysis
6. Simulations
7. Experience
8. Documented history

How to find root cause of vibration?

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6. Simulations
7. **Experience**
8. Documented history

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3. Elimination by mechanism

Main categories **AVIFF**

«Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework», Energy Institute 2008

- High kinetic energy flow
  - FIT, flow induced turbulence (all fluids)
  - FLIP/FIP, flow induced pulsation (gas, side branches)
- Slug flow (multiphase flow)
- HF AIV, Choked flow (gas)
- Machinery (mechanical excitation, pulsation)
- FLIP from flexible pipes (gas)
- Surge/momentum changes (all fluids, Fast acting valves, bends & reducers)
- Cavitation & flashing (liquids/multi phase, restrictions)
- Intrusive elements (liquids & multiphase, thermowells)

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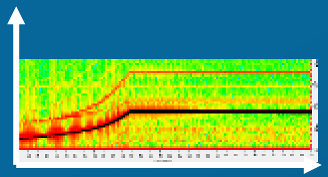
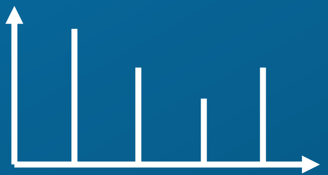
5. Measurement and analysis
Simplified identification of vibration problems from spectra

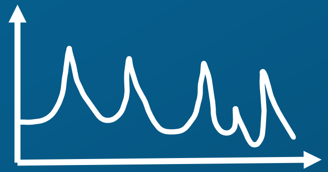
FIV → Random → Flow



AIV #1 → Varying tonal, harmonic → FLIP, Intrusive elements; Pressure drops (valves/restrictions)



AIV #2 → Stationary tonal, harmonic → Machinery; Acoustic resonance



Stationary tonal, non-harmonic → Mechanic resonance

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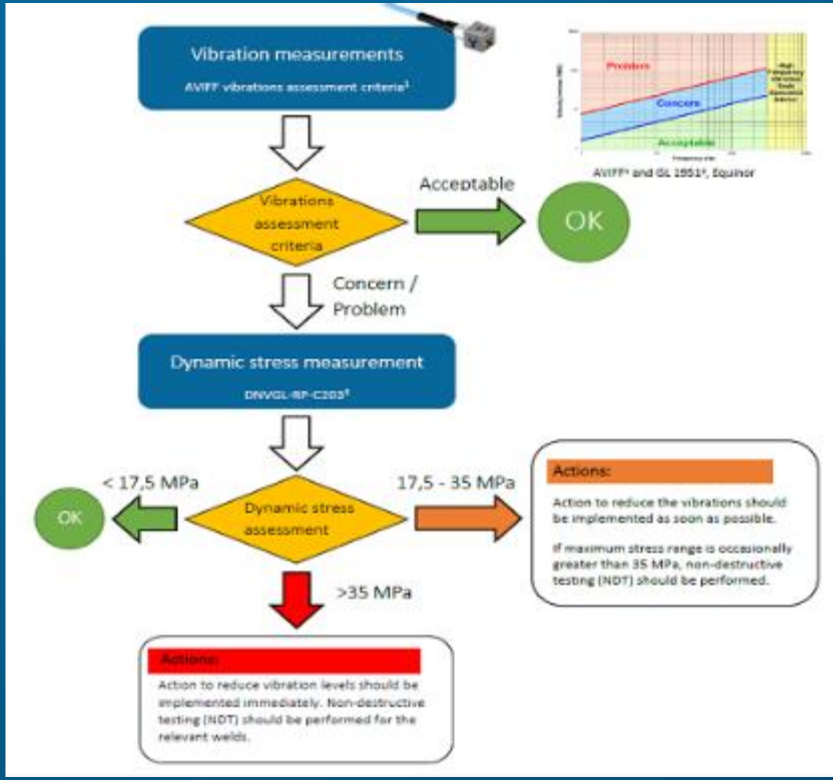
5. Measurement and analysis
Typical oil and gas pipe vibration criteria

Primary vibration pipe criteria
Frequency and stress based



Secondary
Time domain vibration criteria

- Allowable: <9 mm/s rms
- Concern: 9-18 mm/s rms
- Problem: >18 mm/s rms

Comparison:
Secondary limits are similar to the established limits for NPPs,
ref: "PIPE VIBRATIONS IN NUCLEAR APPLICATIONS, REPORT 2017:451"

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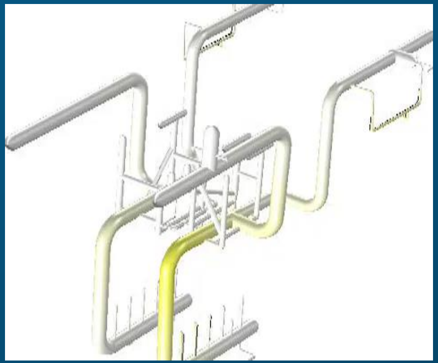
7. My experience: Common vibration problems oil and gas

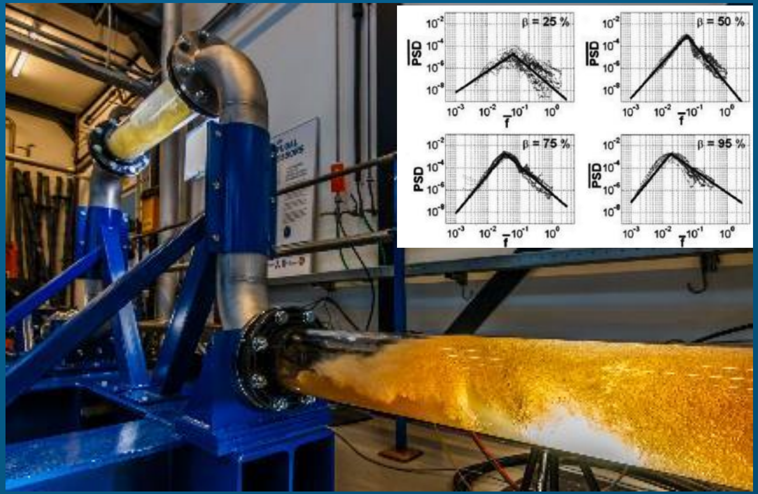
Flow induced vibration (FIV)
(low to medium frequency)

- Turbulent single phase flow (natural gas). Low pressure, high velocity tail production
- Multi phase well stream (oil/water/gas, varying flow types including slug flow)
- Water systems
  - Sea water intake
  - Produced water return
  - Fire water systems (titanium)

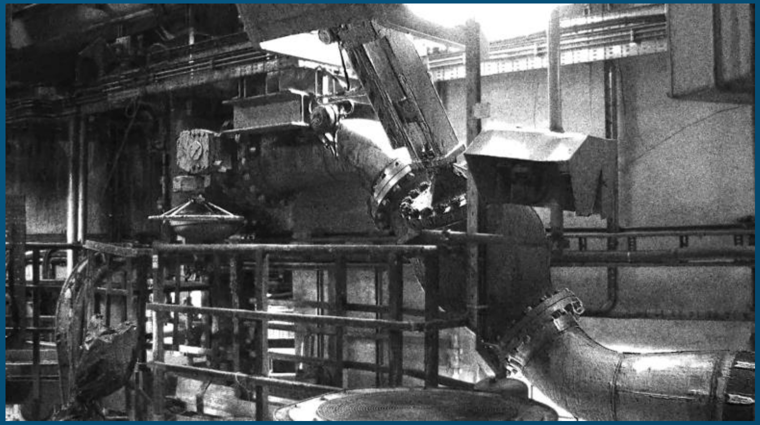
Produced water return



Well flow



Multiphase research



Sea water intake

Turbulent NG flow

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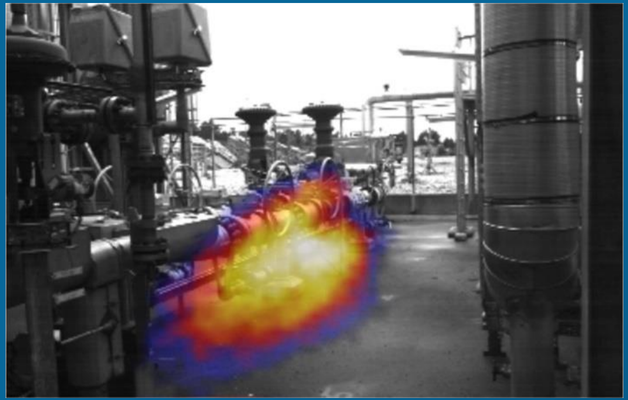
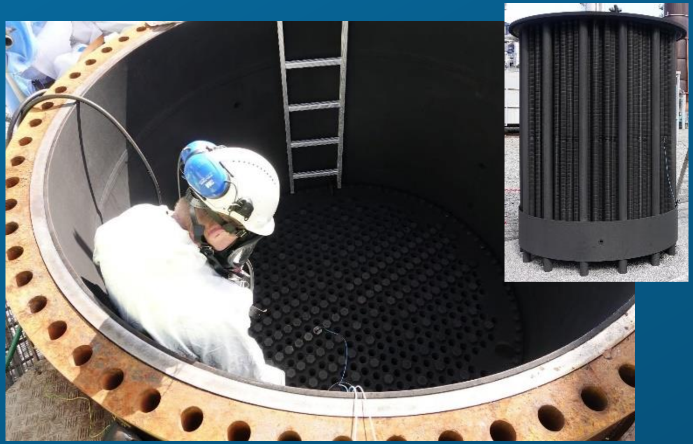
7. My experience:
Common vibration problems oil and gas



Letdown valves



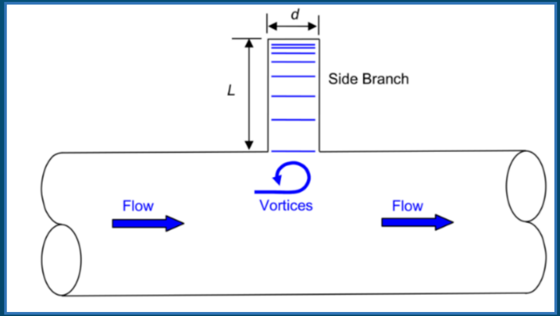
Pipe bundle in filter

Anti surge valve

Large side branch

__Acoustic induced vibration (AIV)__
(low to high frequency, can excite cross acoustic and mechanical shell modes)

- HF Sound generated at high pressure drops (pressure letdown valves, safety valves, anti surge).
- Sound generated when (dry) gases are transported past dead legs.
- Sound generated when transporting dry gas through corrugated pipes, «singing riser» (vortex shedding+acoustic lock in,mechanic resonance).



Dead leg example

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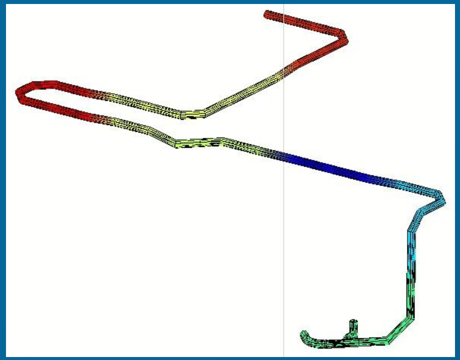
7. My experience: Common vibration problems oil and gas



LF sound from cementing pump

LF from compressor

Machinery
(low to high frequency)

- HF (sound) from turbo machinery (centrifugal compressors, turbines, transmitted through structure, pipes and fluid)
- LF from Pumps

LF sound from pump

HF sound compressor

LF sound compressor

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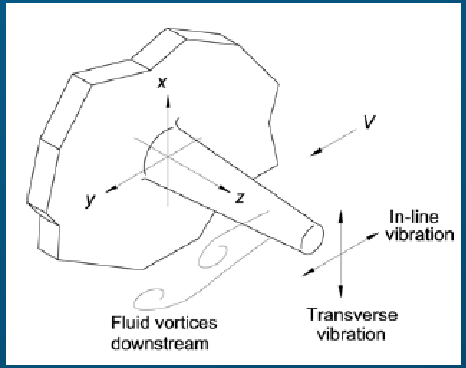
7. My experience: Common vibration problems oil and gas

Measurement of thermowell vibration



Thermowell with crack

General

- Thermo wells designed pre 2012 (ASME PTC 19.3 TW) – vortex shedding from intrusive elements.
- Unsupported slender pipes (helping systems)
- Large pressure drops -> flashing and cavitation
- Less common? Water hammer and rapid opening/closing of valves.

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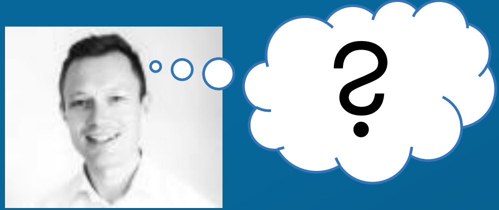
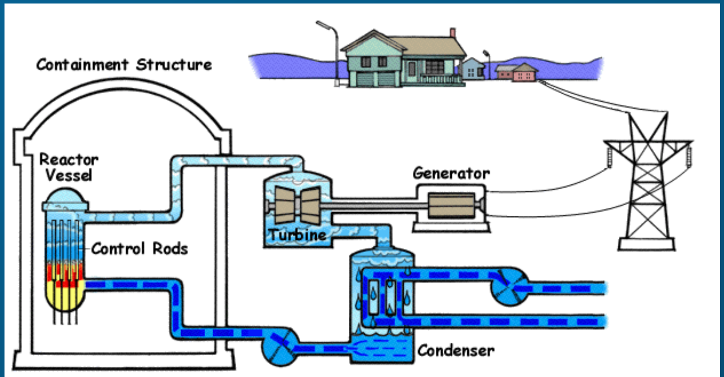
My first guess: Vibration mechanisms in NPPs?



Appologies for my inexperience…



https://energyeducation.ca/encyclopedia/Nuclear_power_plant

FIV

- Multi phase steam/water (Condenser)
- Water systems (Condenser, feed water)

AIV

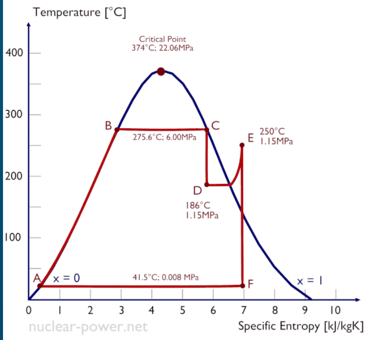
- Sound generated when steam is transported past dead legs (downstream reactor vessel, acoustic resonant lengths are similar in steam and natural gas (about 30% higher)).

Machinery

- HF sound from turbo machinery (turbine, generator)
- Pumps (Feed water)
- Anti surge (Turbine)

General

- Thermo wells designed pre 2012, (Everywhere, ASME PTC 19.3 TW revised due to nuclear accident)
- Unsupported slender pipes
- Large pressure drops -> flashing and cavitation (Letdown valves to turbine?)



Monju 1995

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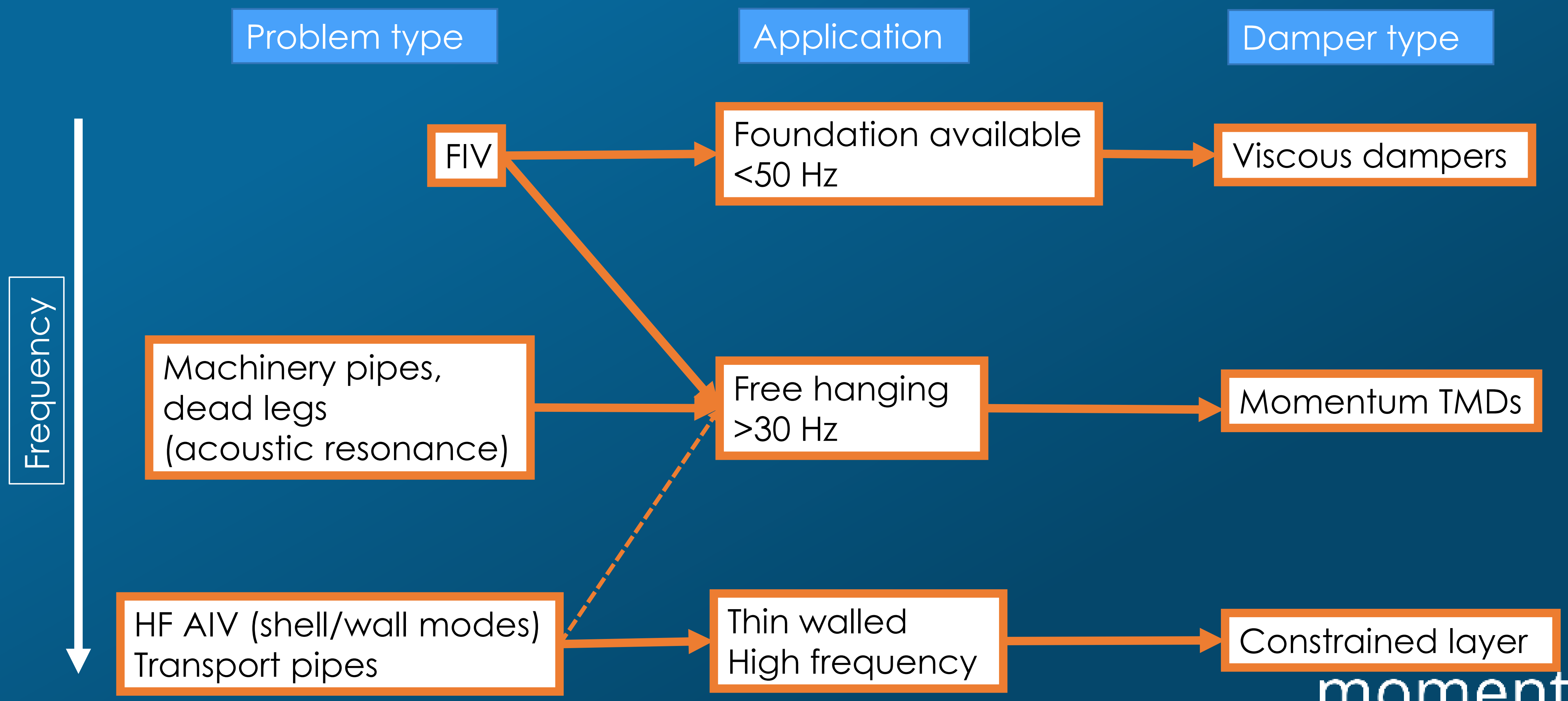
Momentum Technologies
Common vibration damper pairing for pipes



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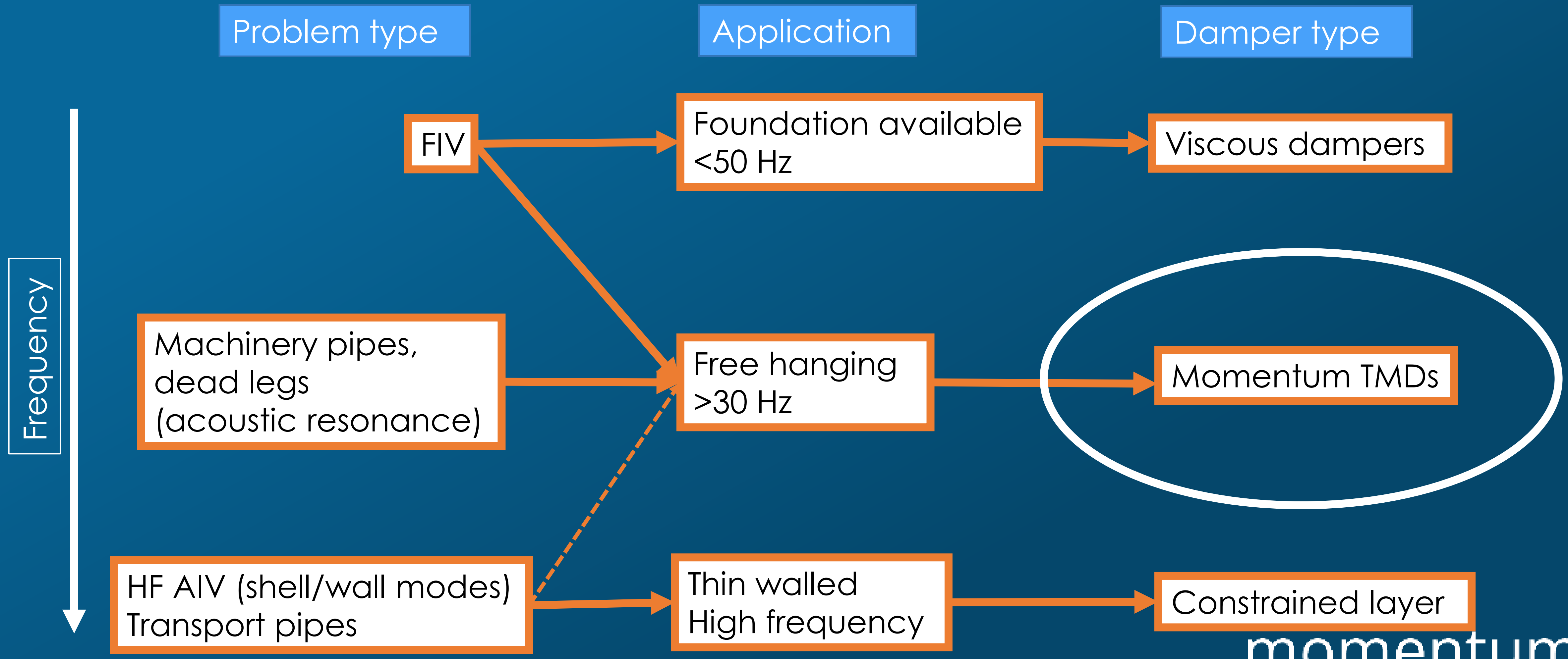
Momentum Technologies
Common vibration damper pairing for pipes



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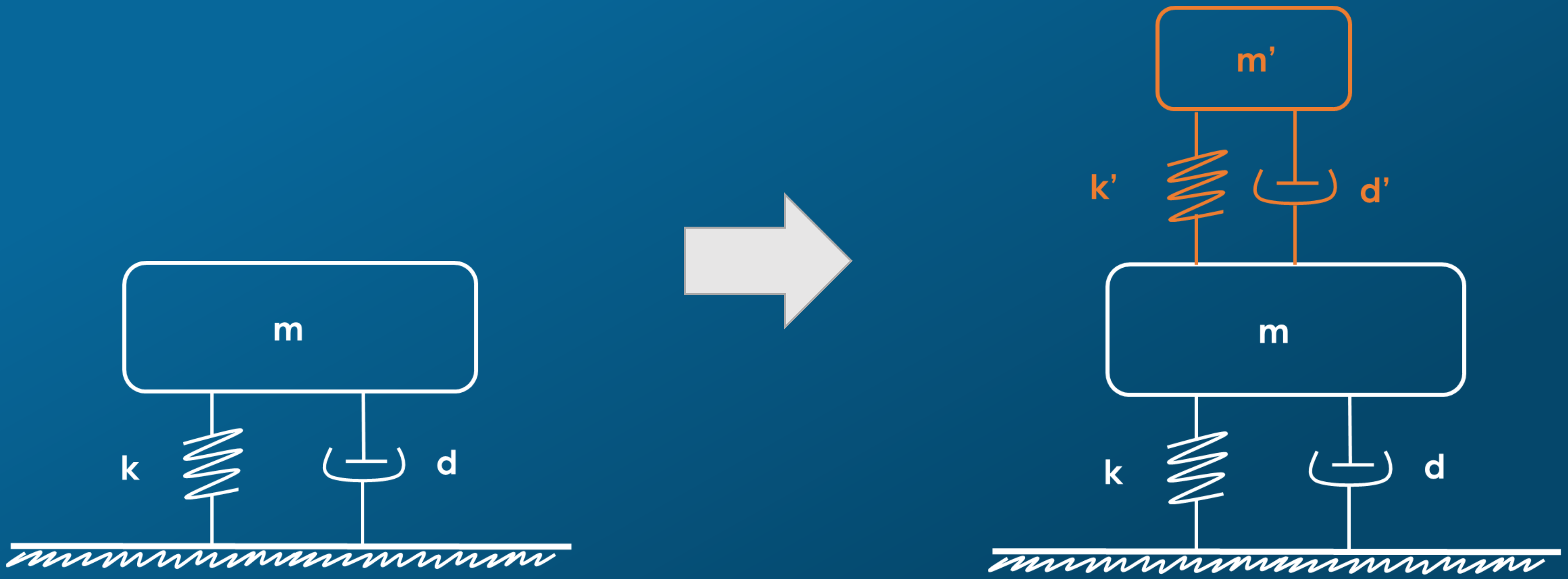
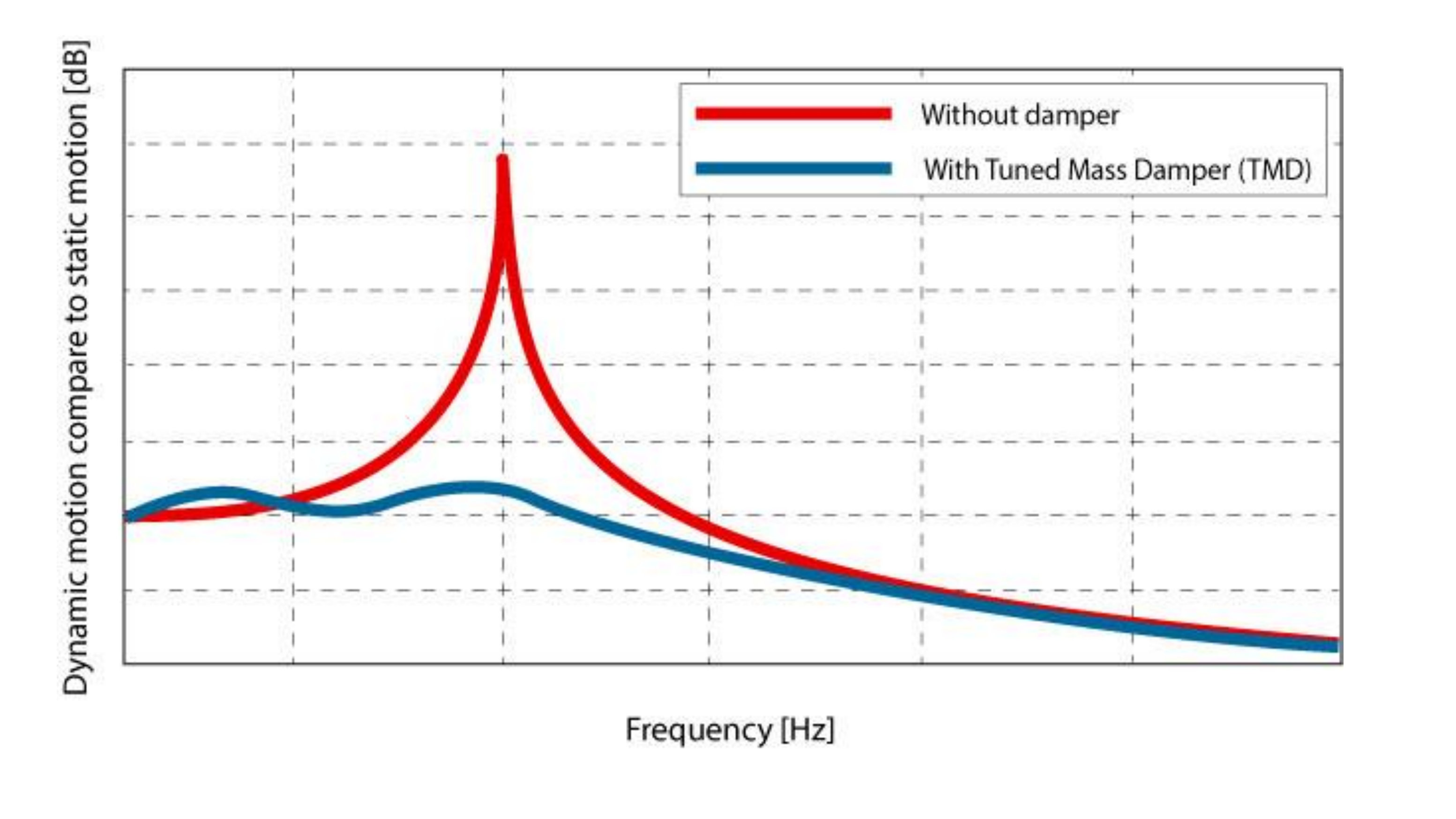
Momentum TMD
Simplified dynamic system overview

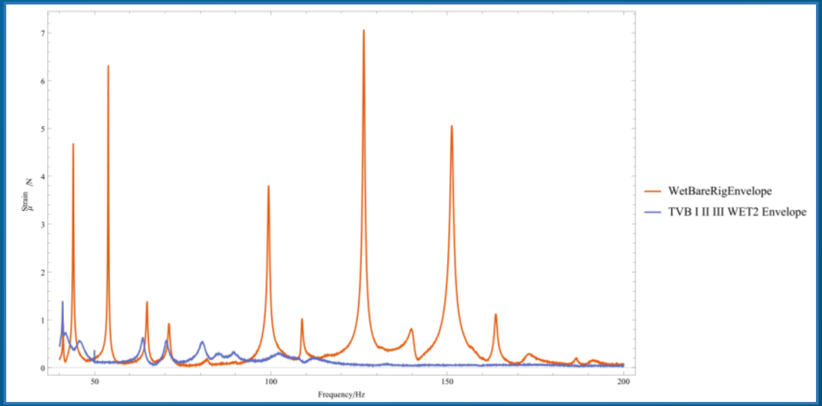


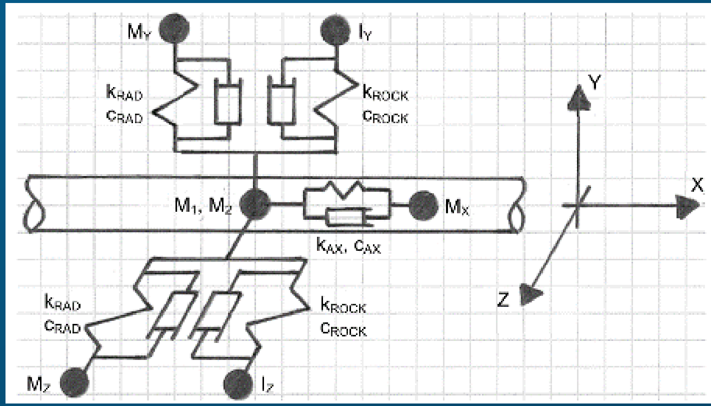
Momentum TMD
Response with and without damper



Momentum TMD Features

- Medium to high frequency TMD,
  standard tuning frequency range ≈30-300 Hz
- Clamp-on
- Broadband effect, acting on multiple modes.
- 6 degrees of freedom
- Qualified and used in tough environments
  (high temperatures and pressures)





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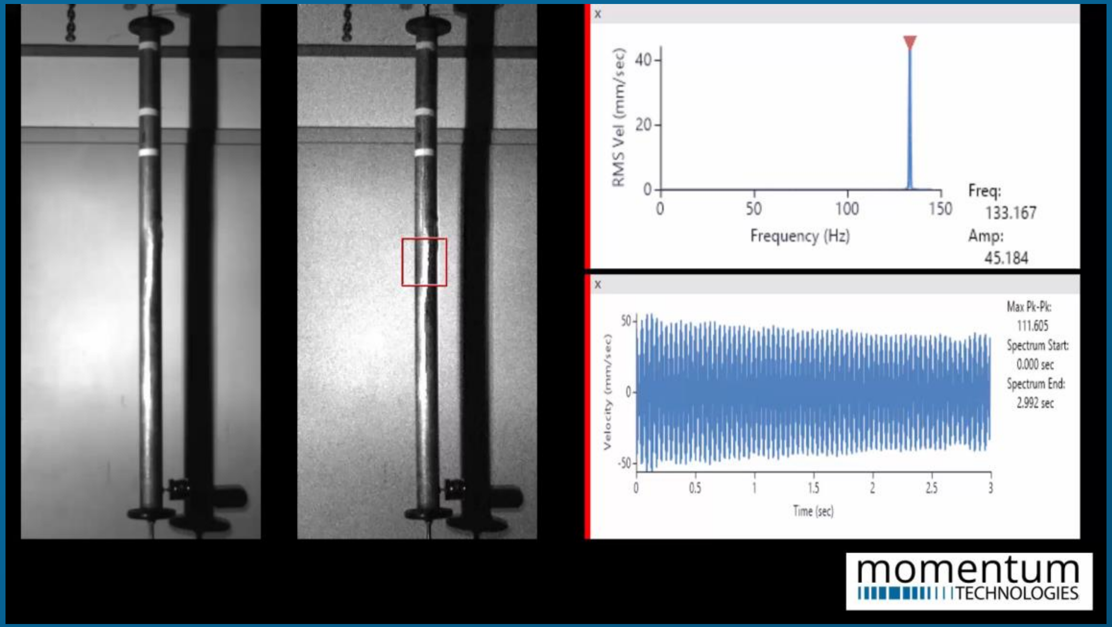
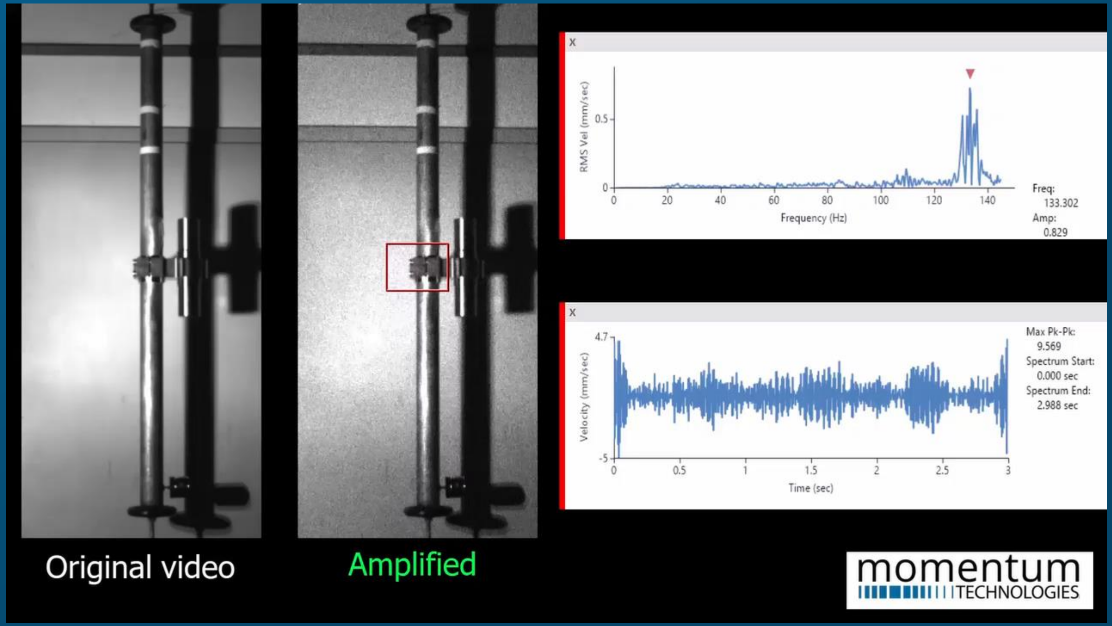
Momentum TMD
Demonstration of function





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World-wide collaboration platform for designing Momentum TMDs

PRINT DO	F NODAL	ION PER NODE				
NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
422	8,88E-04	3,87E-04	-2,33E-03	-2,08E-02	1,58E-03	-3,55E-03
432	4,04E-04	4,72E-03	2,95E-03	2,90E-02	2,40E-03	1,03E-03
442	2,60E-04	4,73E-03	6,28E-03	3,59E-02	3,09E-03	1,61E-03
448	1,31E-03	3,81E-04	-4,75E-03	-2,61E-02	2,59E-03	-4,98E-03
454	2,52E-03	-5,37E-03	-1,20E-02	-9,56E-02	8,48E-03	-2,51E-02
455	-5,93E-03	-0,1265	-1,21E-02	-0,12336	-3,83E-03	-0,12539
534	-5,19E-03	-0,12503	-1,31E-02	-0,109	-1,86E-02	-0,14478
637	1,82E-03	3,73E-04	-7,14E-03	-4,10E-02	5,76E-03	-9,99E-03
652	-4,91E-04	4,78E-03	2,13E-02	9,80E-02	9,93E-03	4,14E-03
670	-1,80E-03	1,57E-02	3,09E-02	0,16895	1,44E-02	4,75E-03
671	-9,36E-03	0,11362	3,09E-02	0,1968	1,20E-02	1,19E-03
714	-1,00E-02	0,12765	3,15E-02	0,17651	2,94E-03	7,78E-03
802	-5,24E-03	3,04E-02	-2,33E-02	-2,33E-02	3,01E-02	3,01E-02
822	-1,00E-02	8,06E-02	1,54E-02	3,65E-02	-2,85E-02	9,64E-02
838	-1,00E-02	3,05E-02	6,56E-04	3,46E-02	-2,73E-02	9,59E-02
842	-5,24E-03	1,46E-02	-7,65E-03	-2,24E-02	2,98E-02	3,17E-02
880	-9,94E-03	1,00E-02	-2,53E-03	4,37E-03	3,39E-03	9,92E-03
886	-5,27E-03	4,26E-03	-9,47E-04	-1,31E-02	1,11E-02	8,74E-03
918	-9,92E-03	6,02E-03	-1,66E-04	3,69E-03	4,20E-03	6,02E-03
924	-5,27E-03	2,23E-04	5,22E-03	-1,34E-02	9,65E-03	6,13E-03
964	-5,31E-03	6,83E-04	4,05E-03	-1,68E-02	-1,08E-02	-3,72E-03
986	-9,71E-03	6,30E-03	1,05E-03	-6,01E-03	1,24E-04	-4,90E-03
998	-6,21E-03	2,18E-03	2,67E-03	-1,71E-02	-1,42E-02	-2,66E-03
1034	-9,68E-03	6,82E-03	1,03E-03	-6,63E-03	-7,03E-04	-4,91E-03
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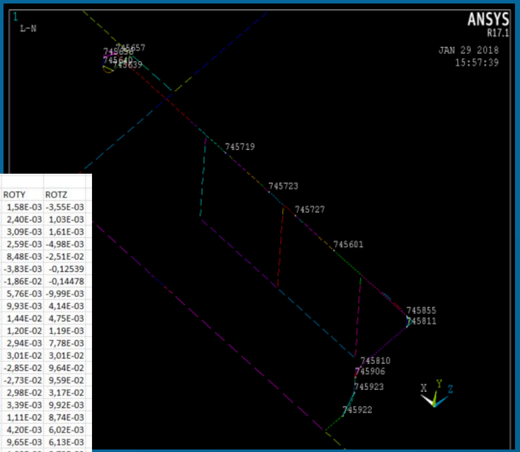
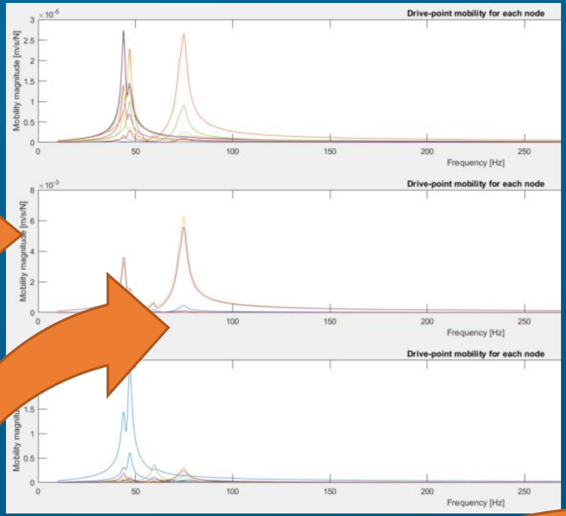
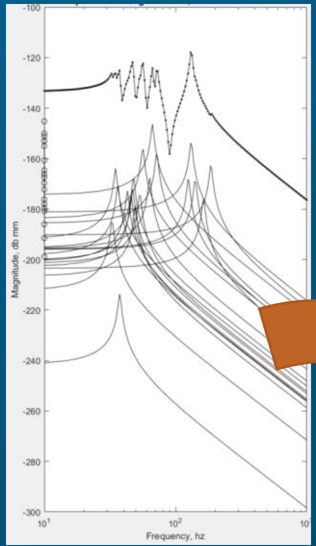
1061	-9,65E-03	7,68E-03	8,62E-04	-6,69E-03	-1,11E-03	-4,70E-03
1063	-9,40E-03	3,01E-03	-2,61E-04	-1,88E-03	-2,37E-04	1,49E-02
1127	-6,29E-03	1,77E-04	-1,12E-04	-7,91E-04	-3,81E-04	2,09E-02
1190	-2,11E-03	1,77E-04	1,50E-06	-2,96E-04	-2,67E-04	1,60E-02
MAXIMUM	ABSOLUTES					
NODE	714	714	714	671	802	534
VALUE	-1,00E-02	0,12765	3,15E-02	0,1968	3,01E-02	-0,14478



Finite element matrices or **measured FRFs**

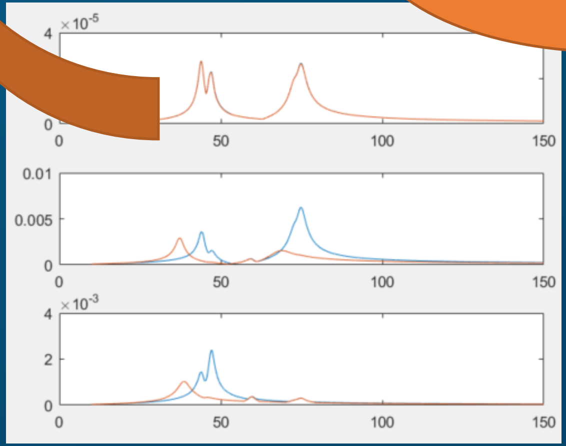


MDOF response

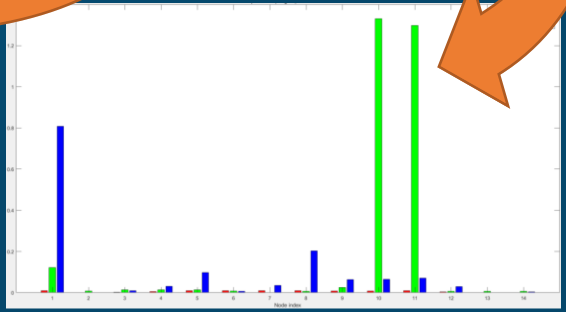


Modal importance

Optimization loop



MDOF automatic damper tuning



Selection of location and orientation of dampers

Optimized damper

equinor

AkerSolutions

TechnipFMC

OneSubsea
A Schlumberger Company

bp

wood.

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TMD CASE-STUDY:
Pressure let-down stations LNG facility, Australia

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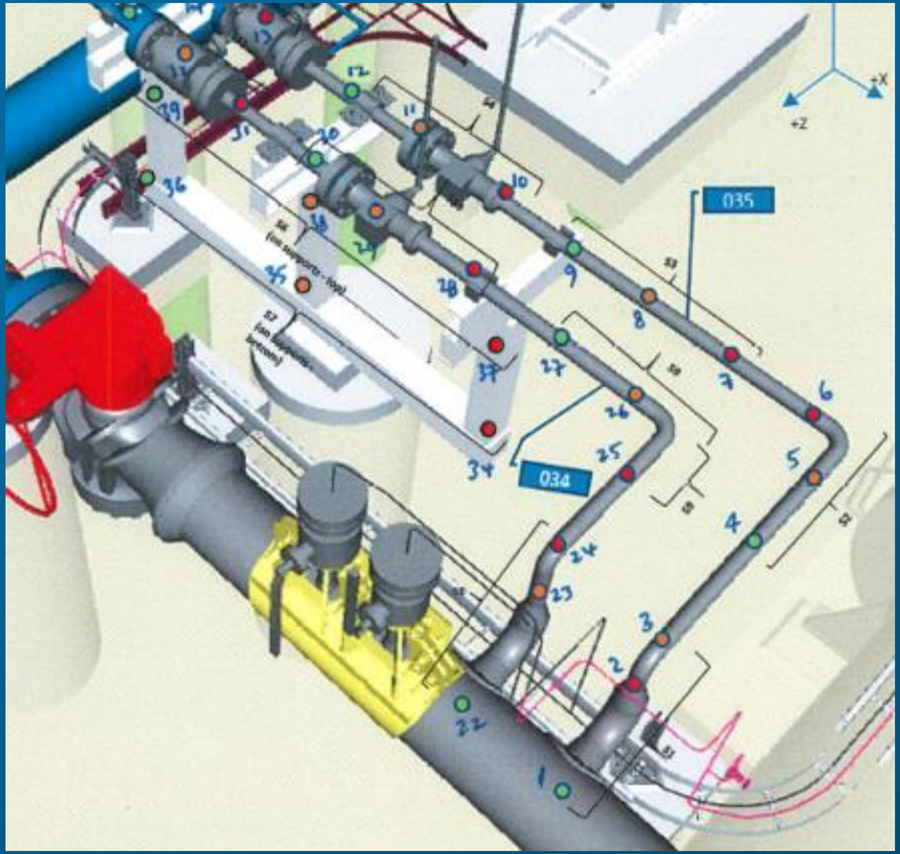
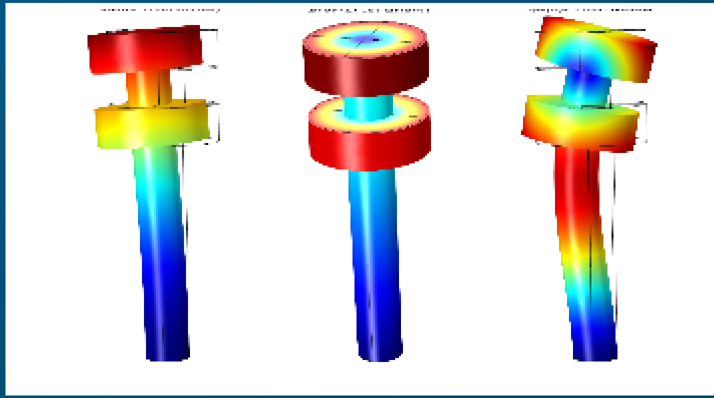
TMD CASE-STUDY

Systematic FRF measurements + Finite element modelling





Example of first mode shapes
Not from actual case

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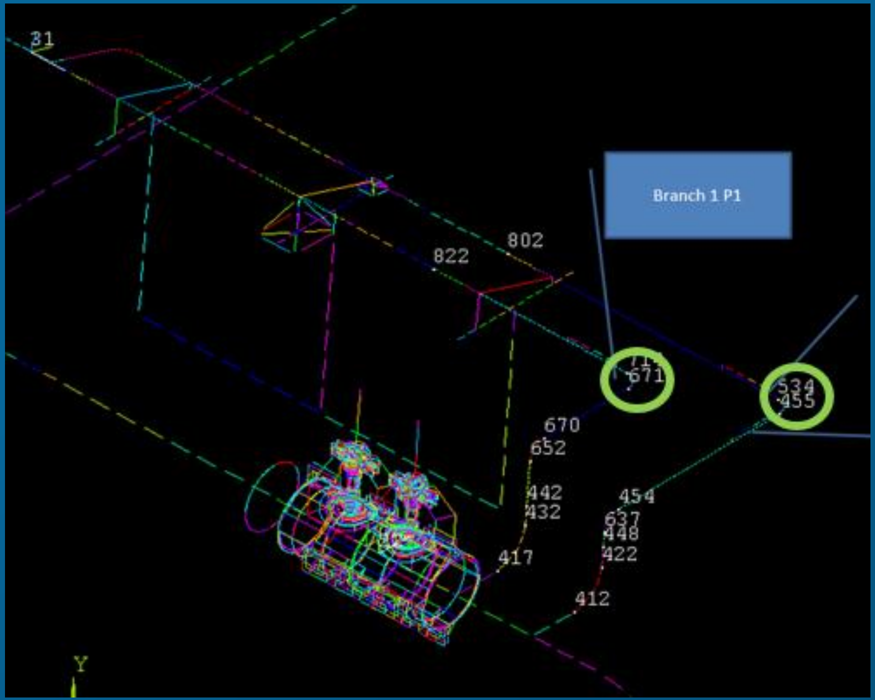
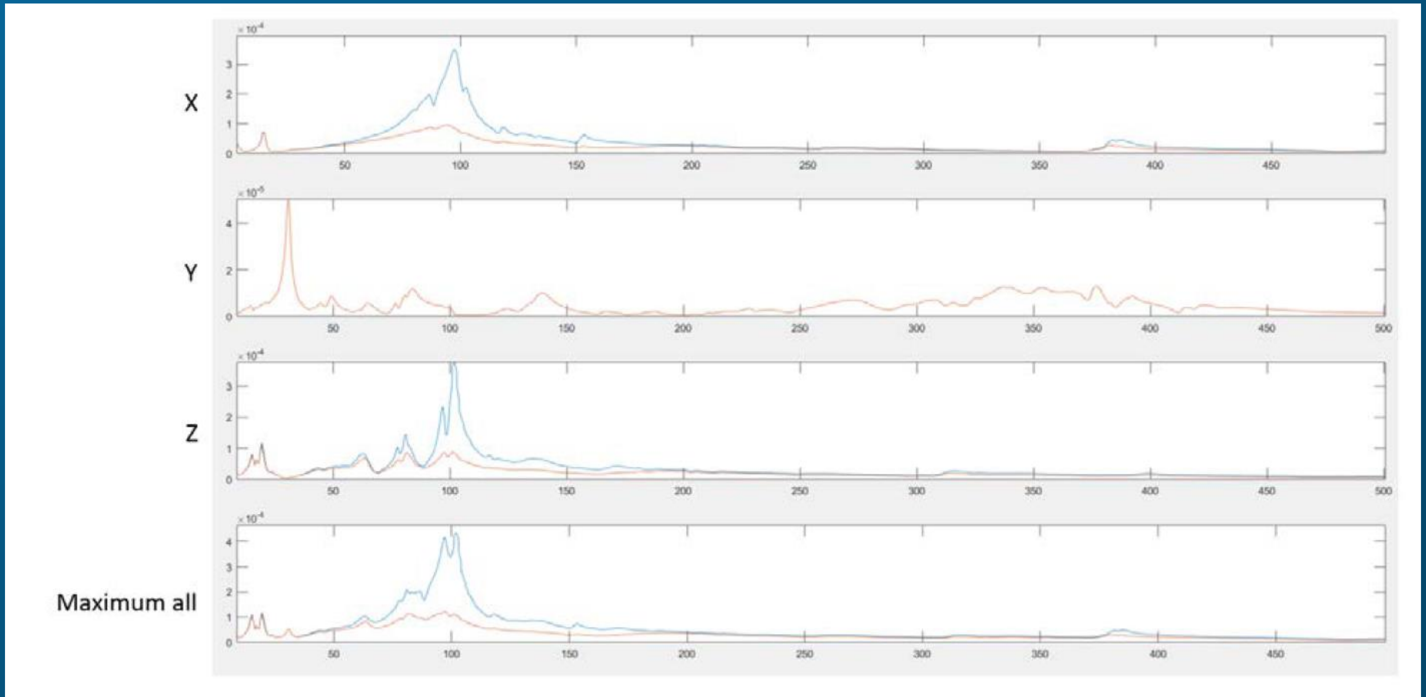
TMD CASE-STUDY

Calculated response from measurements





CASE-STUDY
Installation

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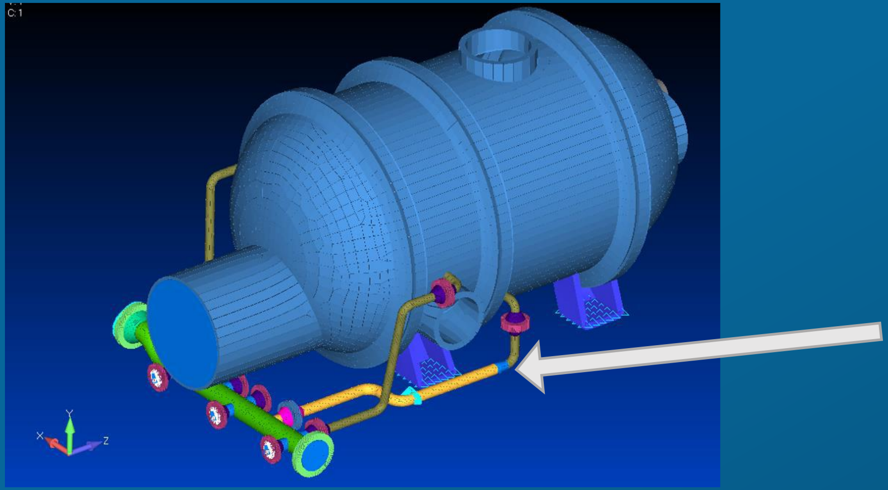
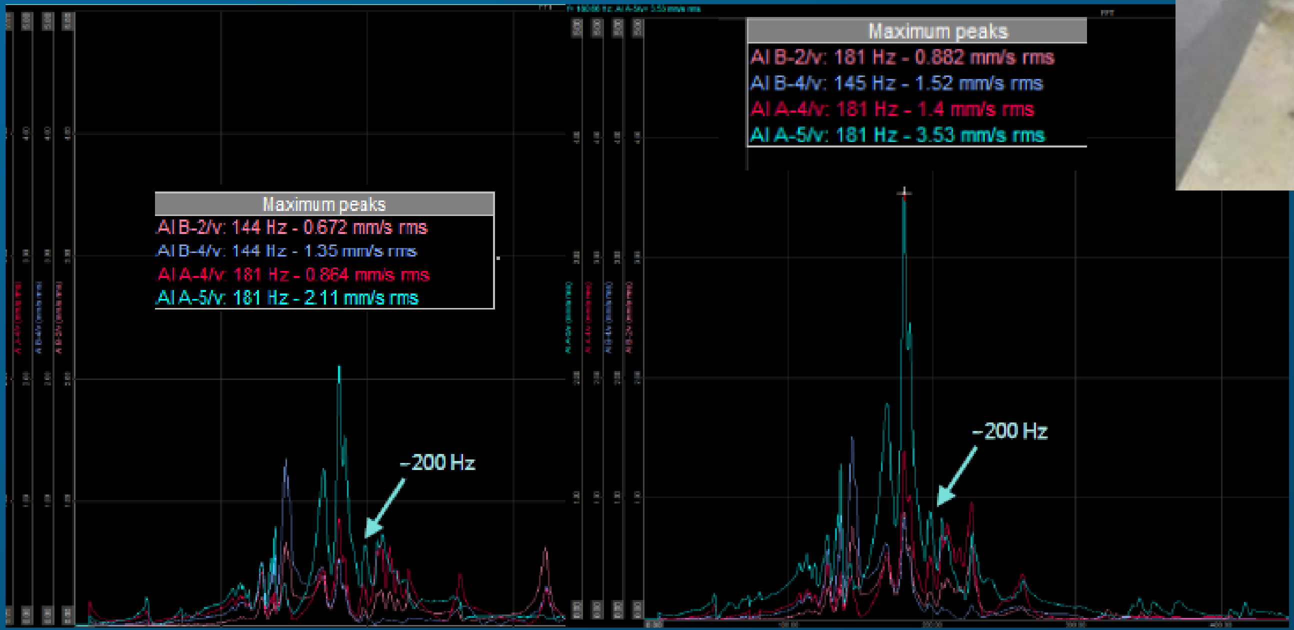
CASE-STUDY

Evaluation of TMD performance after installation

TMD Tag No.	Site	DN100/50 Bypass Line No./ DN50 PIT Valve No.	Specified Frequency Range	Reduction Required[1]	Reduction Achieved[1]
			100-200	1.53	3.2
			30-70	1.53	8.5
			120-155	1.53	2.5
			30-70	1.53	16.6
			100-200	1.4	4.5
			40-80	1.4	7.7
			100-200	1.4	2.2
			40-80	1.4	10.7
			30-60	1.45	4.3
			50-80	1.35	13.8
			200-300	1.7	11.7
			200-300	1.7	12.6
			140-200	2.0	2.9

Momentum TMD
Example from machinery piping





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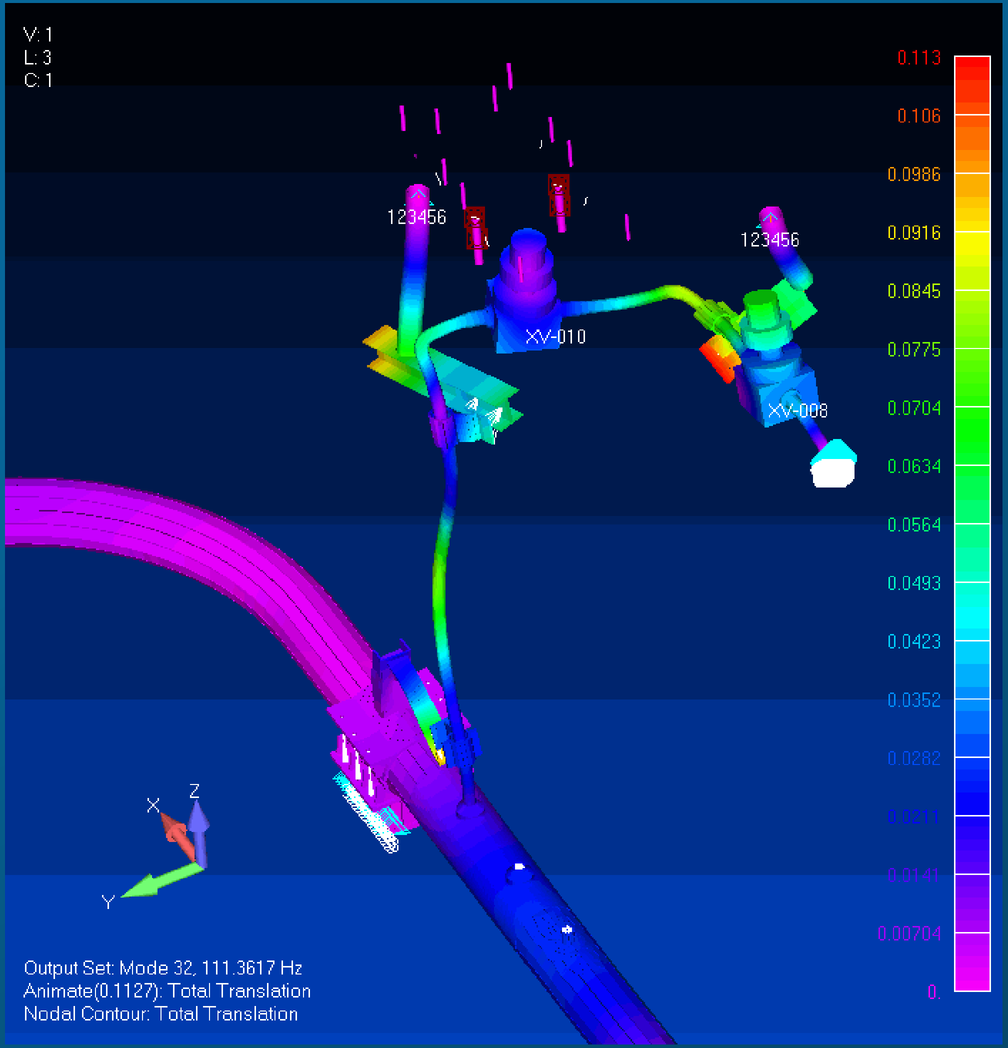
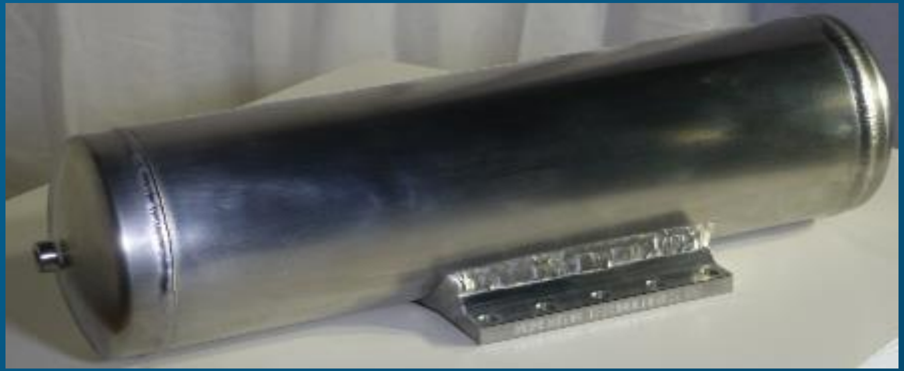
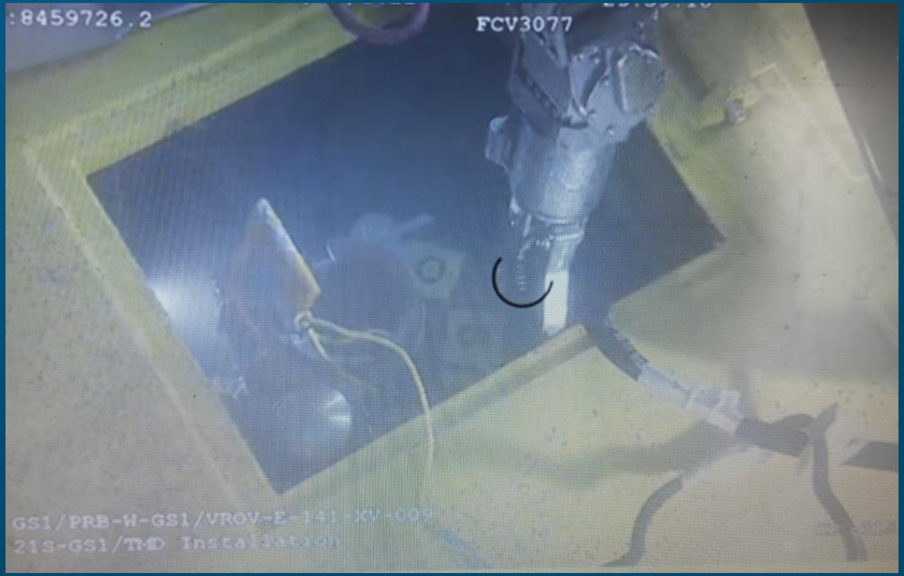
Momentum TMD

Example from subsea piping







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Proposed topics of discussion

- What can we learn from comparing oil&gas with nuclear industry? Main similarities and differences
    - How is vibration handled within NPPs (design, organizational, operational)?
    - What vibration mechanisms are not relevant in NPPs?
    - What does the statistics say about incidents due to fatigue in NPPs (21% in O&G)?

- Why are TMDs not very common in the nuclear industry?
    - Mainly low frequency problems?
    - Difficult to tune and get working?
    - Is the working frequency range considered too narrow for TMDs?
    - Difficulties of qualification?

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SIMPLE SOLUTIONS, COMPLEX PROBLEM

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