Training session
Pulsation & Vibration Control

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Delft, The Netherlands

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TNO innovation for life

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Newly commissioned reciprocating system showing vibration issues throughout, including shed

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Piping well supported and axial restrained throughout the system

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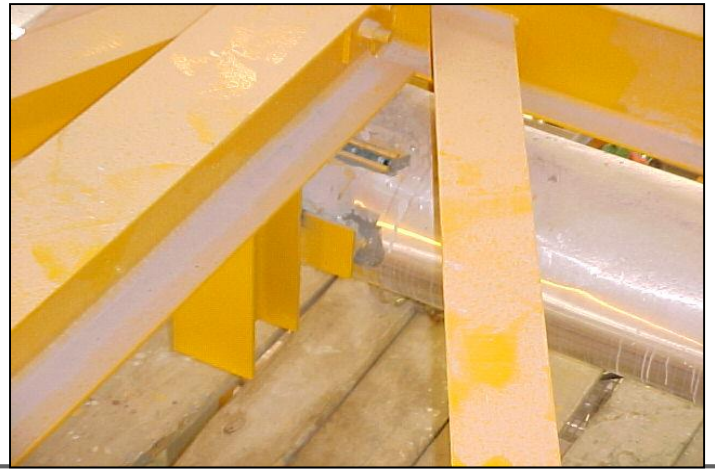
Piping supported on rack, steel was already added after commissioning (no success)



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Cylinders well supported (no significant vibrations)

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Background design

Fixed speed – 990 rpm (16.5Hz)

Two compressors in parallel, double acting, single stage, two cylinders.

API 618 DA1 study was conducted

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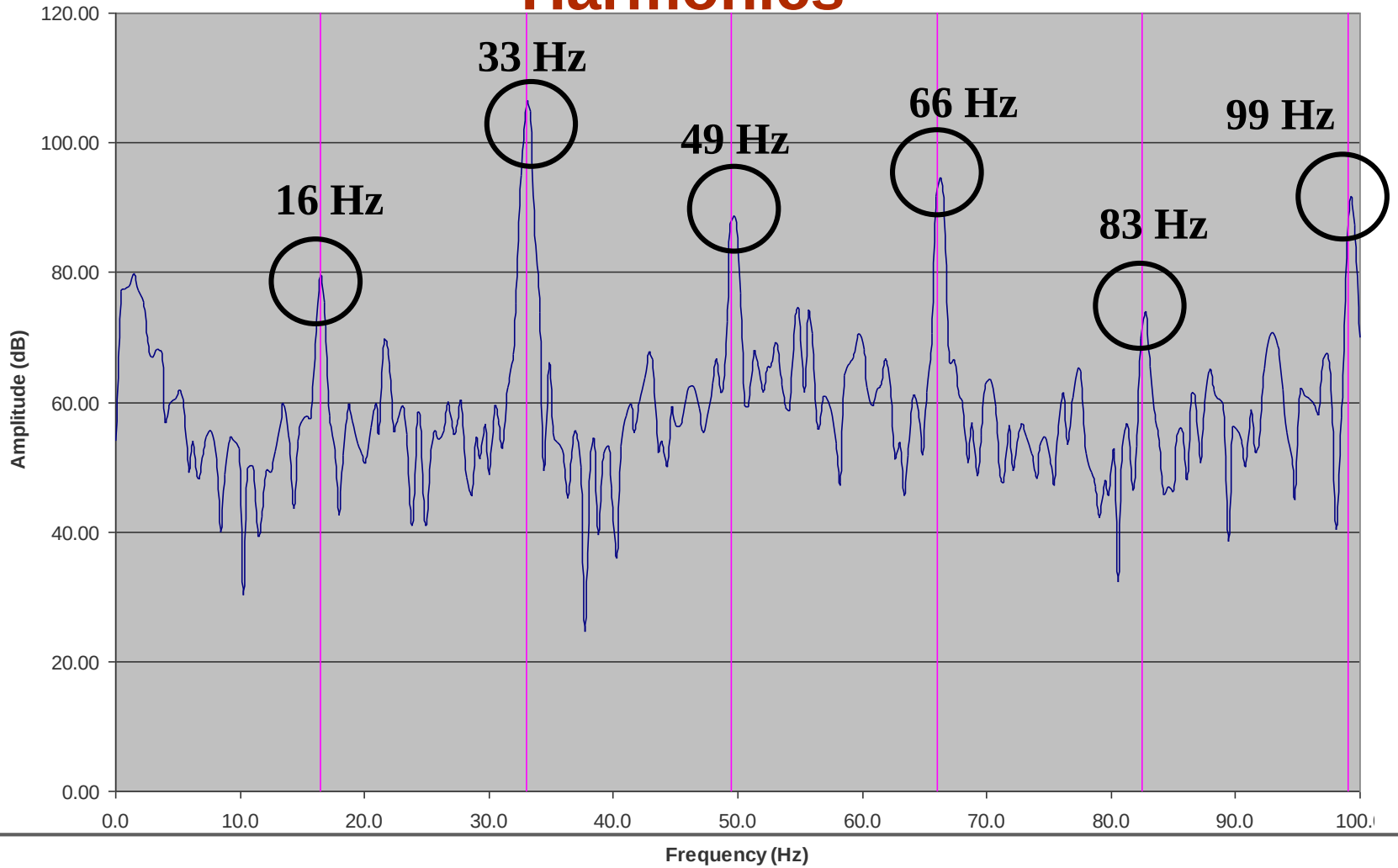
Root cause analysis

Started with vibration measurements to determine cause.

Trying to determine what cause (acoustic or mechanical) and how to best mitigate with minimum effort and high likelihood of success

Step 1. Vibration Measurements and Compressor Harmonics



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Intermediate conclusion from step 1

Vibrations are at compressor harmonics

Vibrations must be result of:

- Acoustical resonance

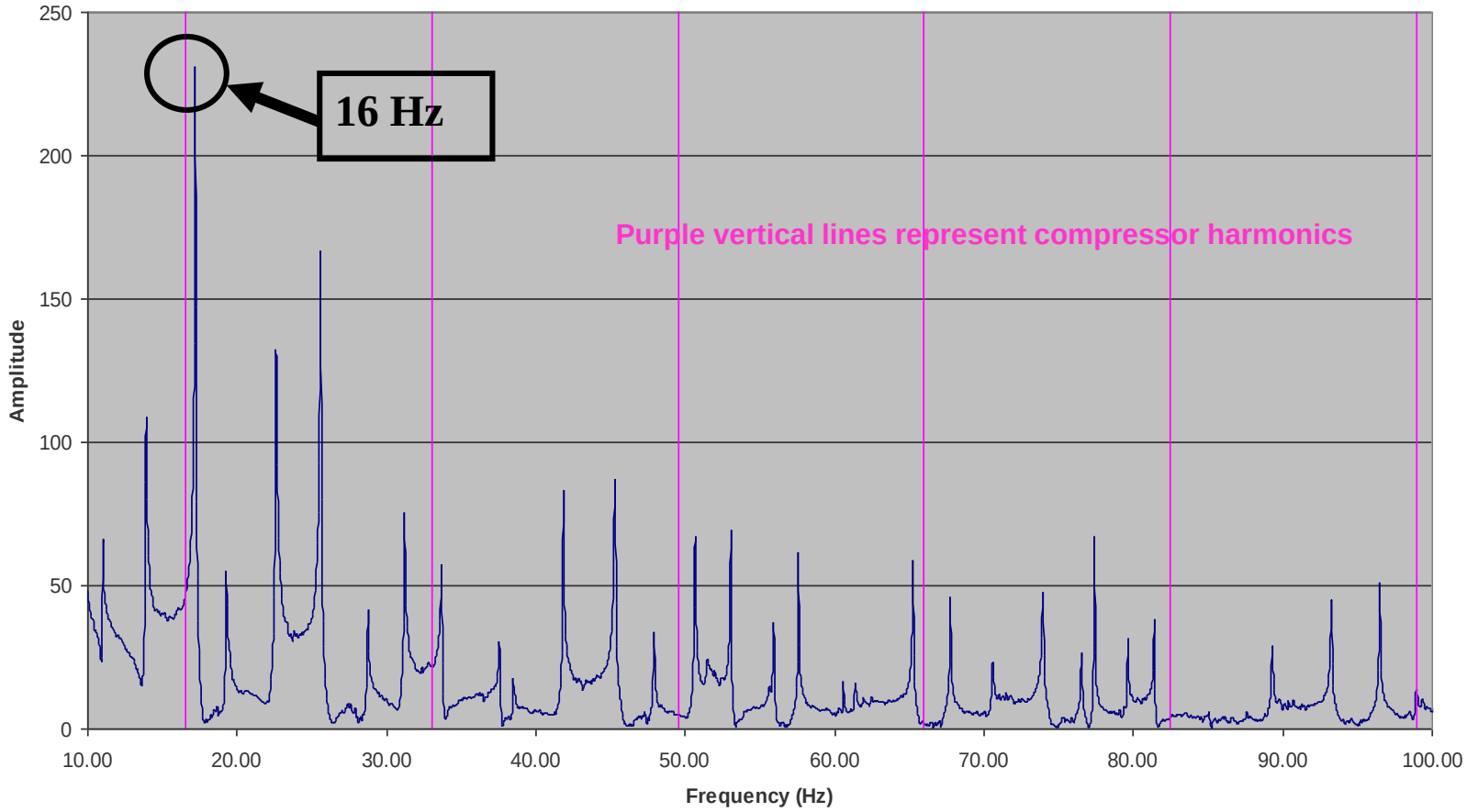
or

- Mechanical resonance

or

- High pulsation forces without resonance (compressor bottle sizing problem)

Step 2. Acoustical Natural Frequencies only show resonance mode around first harmonic (excluding bottle)



Intermediate conclusion from step 2

Most probably acoustic resonance condition at first compressor harmonic (16.5 Hz).

No further acoustical resonance likely

Vibration peak at 16.5 Hz, most probably is due high shaking forces as a result of near acoustic resonant condition.

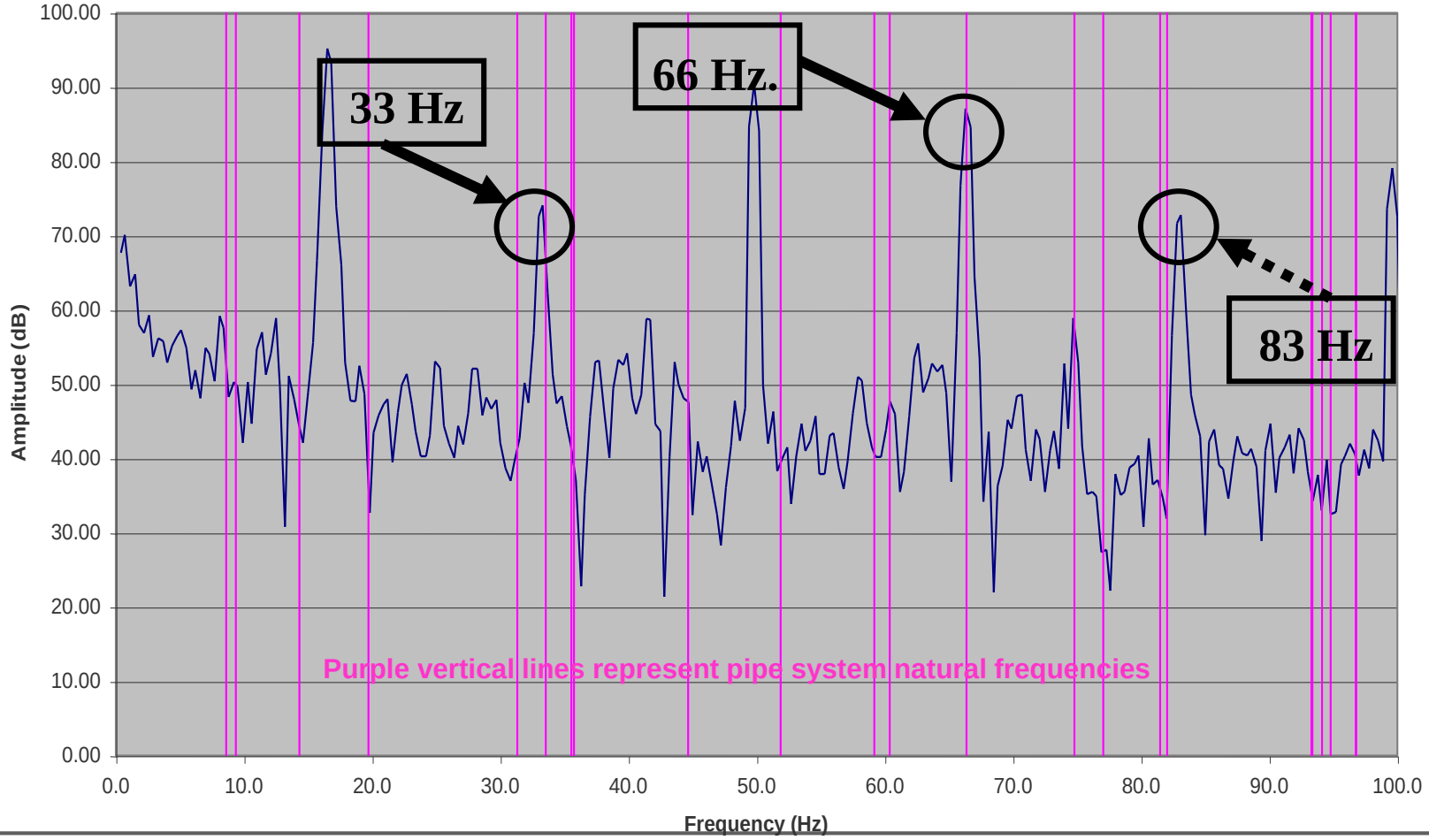
The other vibration peaks must be the result of:

- Mechanical resonance

or

- High pulsation forces without resonance (compressor bottle sizing problem)

Step 3. Vibration Measurements & Calculated Mech. Natural Frequencies (Search for Mechanical Resonance)



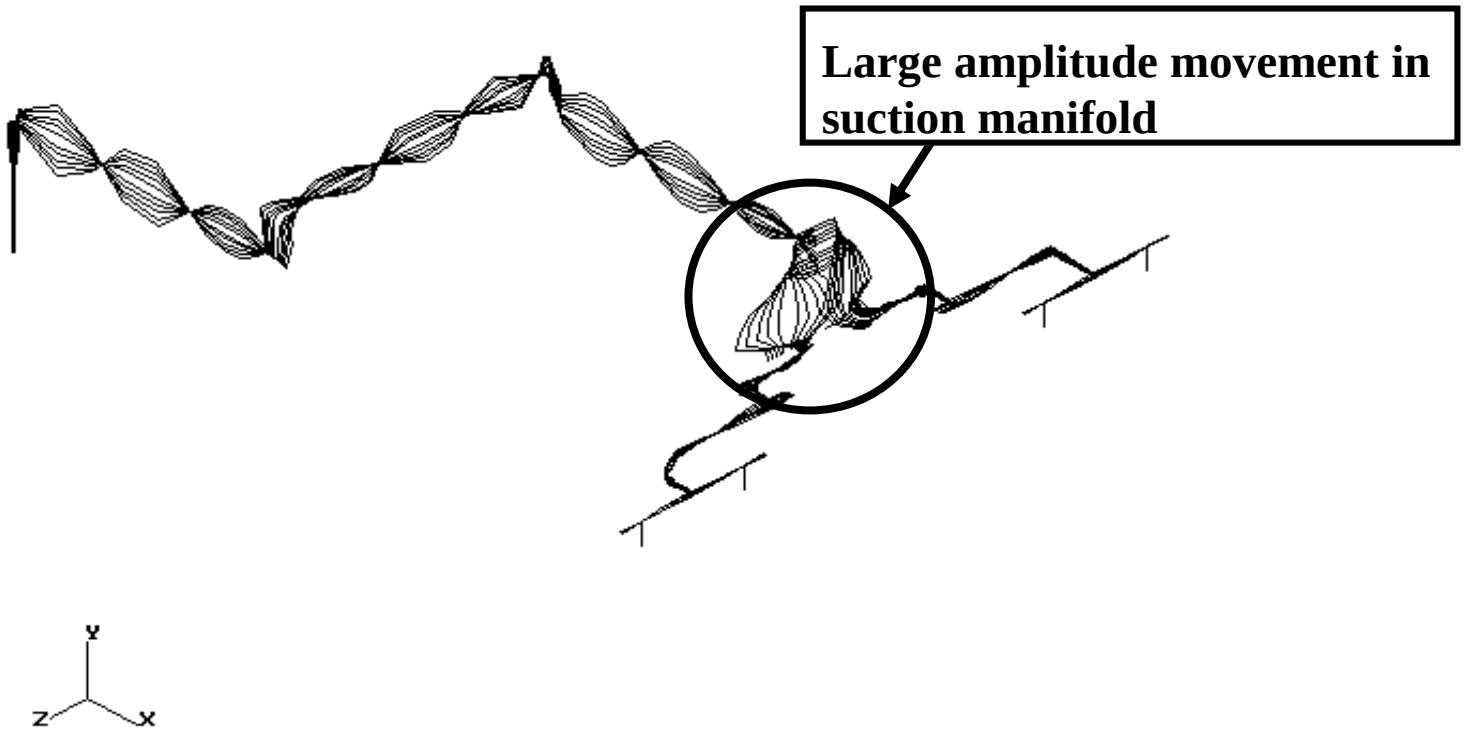
Conclusion from step 3 & Identification of cause of vibration problem

Mechanical resonance likely at 33 Hz, 66 Hz and 83 Hz.

No mechanical resonance condition at the first harmonic (16.5 Hz.) and at 49 Hz. and 99 Hz.

- Mechanical nature vibrations at 33 Hz, 66 Hz and 83 Hz.
- Acoustic resonance problem at 16.5 Hz
- High pulsations forces without acoustic of mechanical resonance at 49 Hz and 99 Hz (compressor bottle sizing problem)

Examination of mechanical behaviour
66 Hz. mode shape



Step 4.Modifications

Mechanical nature vibrations at 33 Hz, 66 Hz and 83 Hz need a mechanical solution:

- Better supporting
- Improved support stiffness

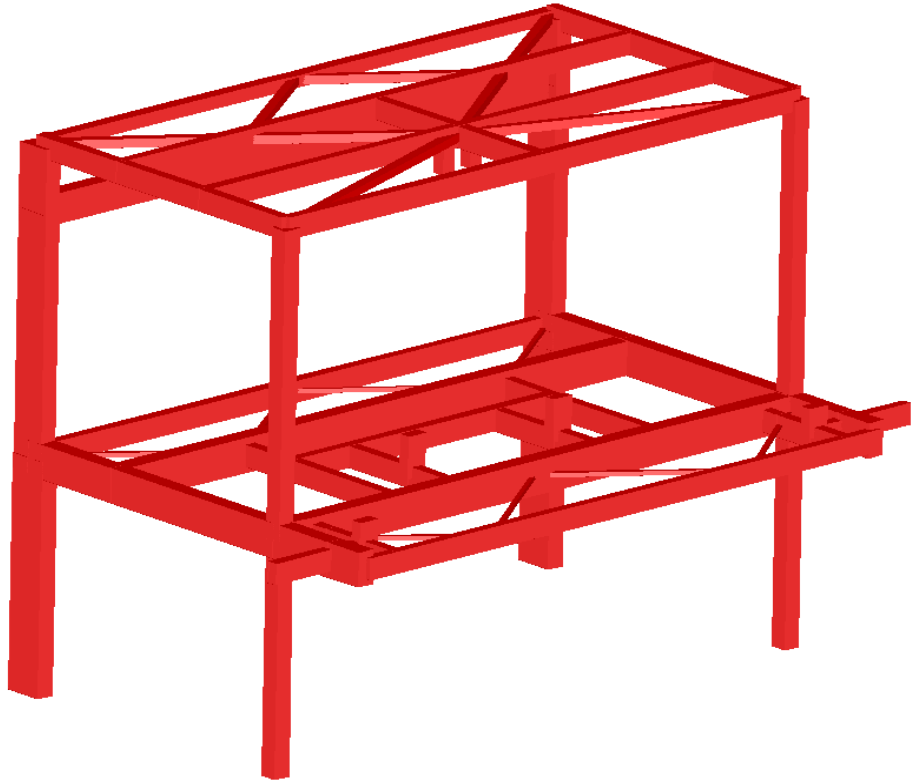
Acoustic resonance problem at 16.5 Hz needs an acoustical solution:

- I.e. different bottles and/or orifice plates to introduce more damping

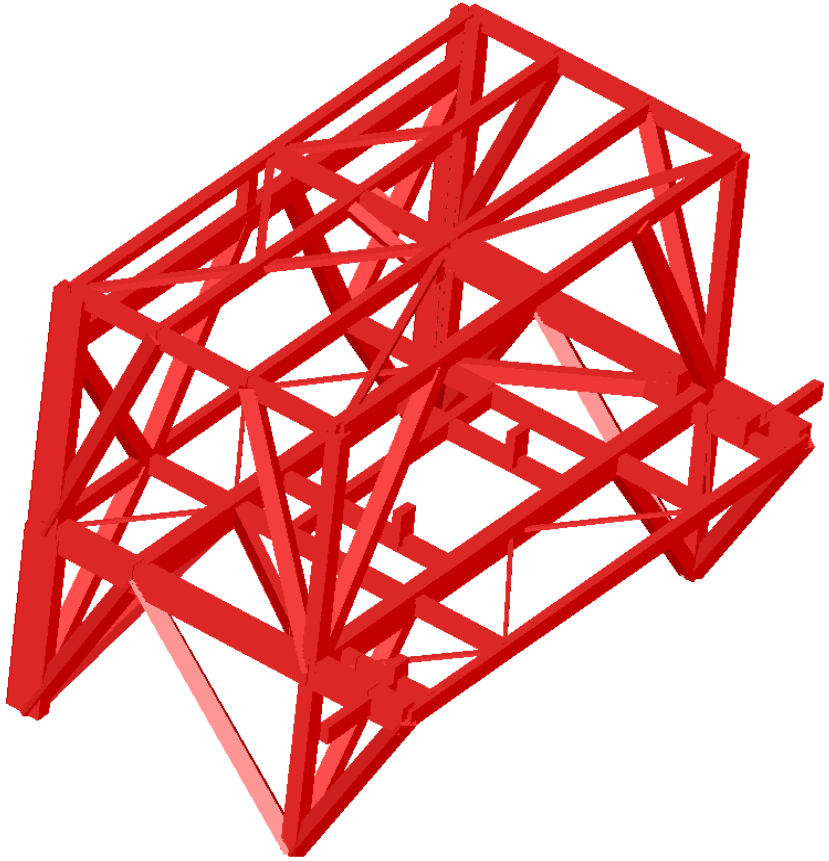
The high vibration level at 49 Hz and 99 Hz are the result of high pulsation forces without resonance and require redesign of compressor bottle.

Changed supporting structure

“As Built” supporting



Recommended supporting



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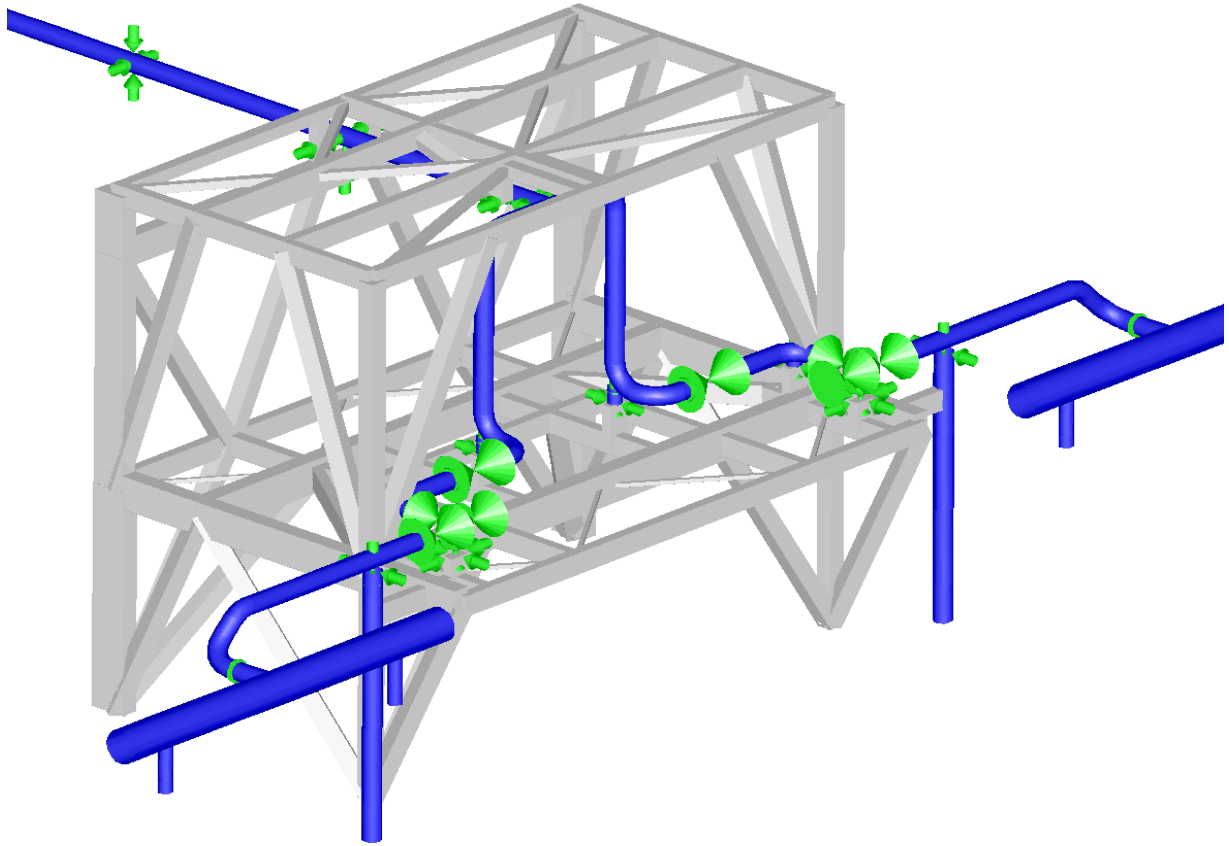
Modified Structure Implemented & Connected to Attached Piping



After implementation of structural changes, vibrations were drastically reduced.

Client decided not to pursue addition mitigations (pulsation damping/bottle redesign)

Conclusions from example

Compressor vibration problems many cases are of a mixed nature

- Part is mechanical
- Part is acoustical

Each category requires a different approach and result in different solutions.

Not all vibration problems can be solved by mechanical measures.

However, for as-built systems, mechanical mitigation is most likely cheapest.