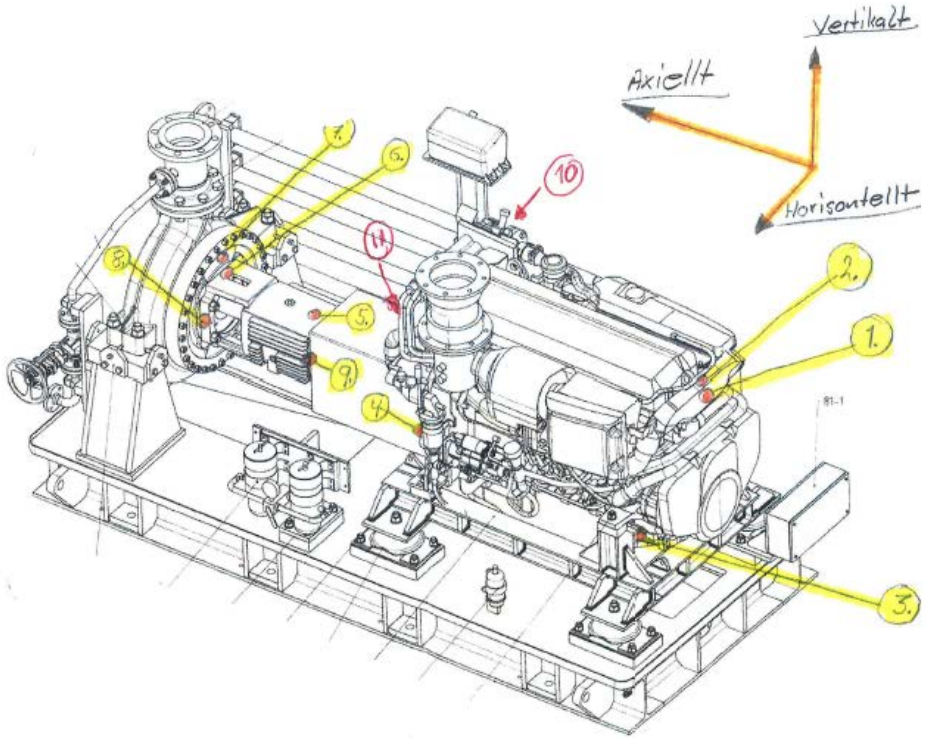

Resonance in diesel engine driven pump - ICC

Presentation Elforsk 2021-11-10

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Agenda

1 Definitions

2 Specifications

3 Verifications

4 Corrective actions

5 Final solution

Some definitions…

1. Eigen frequency or natural frequency

   is the frequency at which a system tends to oscillate in the absence of any driving or damping force (wiki definition..)

2. Firing frequency (excitation frequency)

   Each cylinder in a 4-stroke engine fire once every second revolution, so a firing takes place every crankshaft angle of 720°divided by the number of cylinders. The firing frequency for an engine is then given by:

$$f = \frac{N_{cyl}}{2} * \frac{n}{60}$$

   where N_{cyl} is the number of cylinders in one row and n is the running speed of the engine in rpm. For example in straight 6 engines the firing frequency then occurs at third order running speed frequency, f = 3*n/60 with multiples. This is the most severe excitation frequencies in engines.

3. Resonance

   describes the phenomenon of increased amplitude that occurs when the frequency of an excitation is equal or close to a natural frequency

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Basic specification (as it started..)

Diesel Pump Unit (ICC – Independent Core Cooling)

Consists of the diesel engine, pump, base frame, coupling, combustion air system, cooling water system, fuel tank and fuel supply system, lubricating oil system, starting energy sources, auto-start controls, manual controls etc. The unit shall generate the electrical power needed for starter, controller and I&C. The unit shall supply a flow between approximately 20-100 kg/s at given system curves.

KSB (with subsidiary Kagema) was chosen as supplier ~2017.

The diesel engine pump operates at two speeds:

head ~4 bar, flow ~20 kg/s @ 1220 rpm

head ~10 bar, flow ~100 kg/s @ 1643 rpm

Vibration requirements specified (as I wrote it)

The DP-set shall be proofed by analysis and test (Factory test and Site test) not to have any resonance frequencies (local or global) within ±20 % of the speed or flow range.

Vibration velocity limits on all steel pipes, components and auxiliary systems attached to the DP-set shall be below 20 mm/s within ±20 % of the speed or flow range. This requirement does not apply to process pipes attached to the pump.

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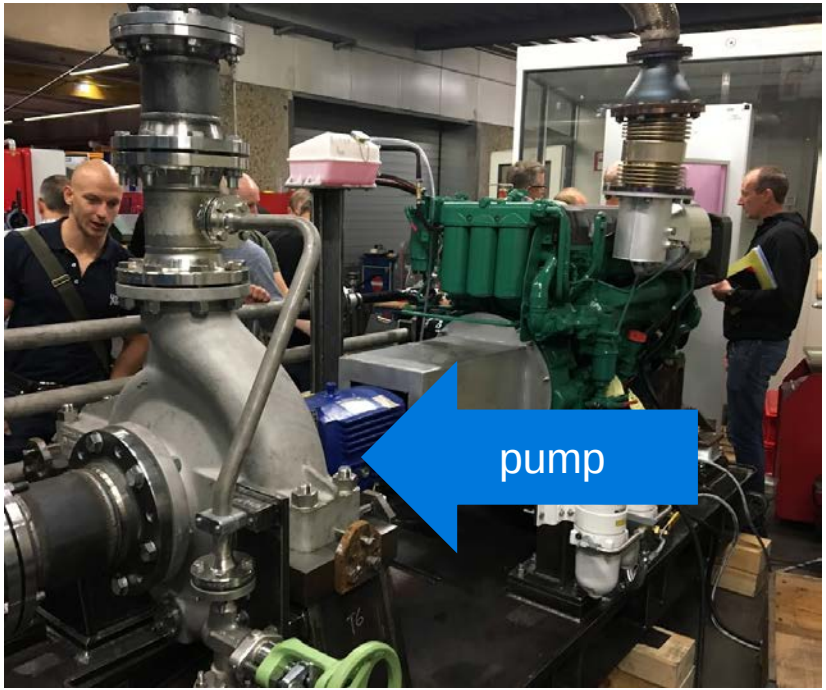
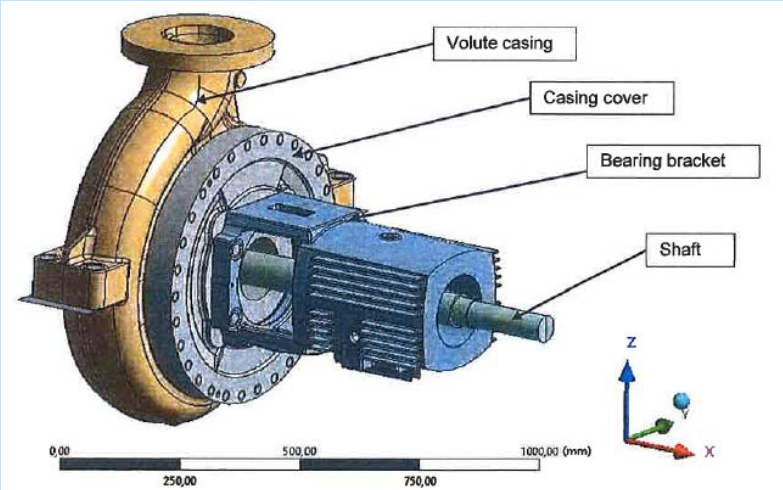
Major mechanical components (picture from FAT)
KSB RPH A8 150-501



Pump



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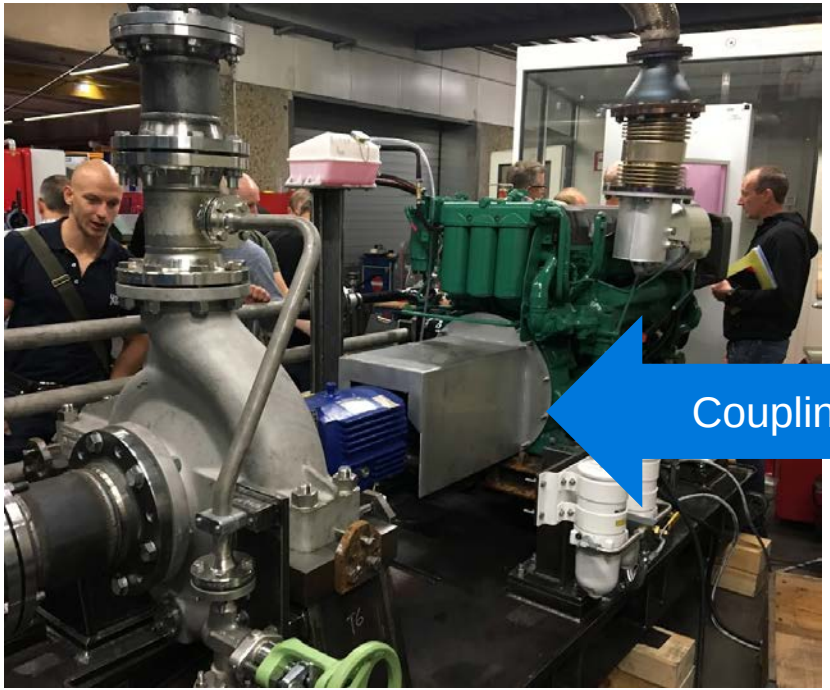
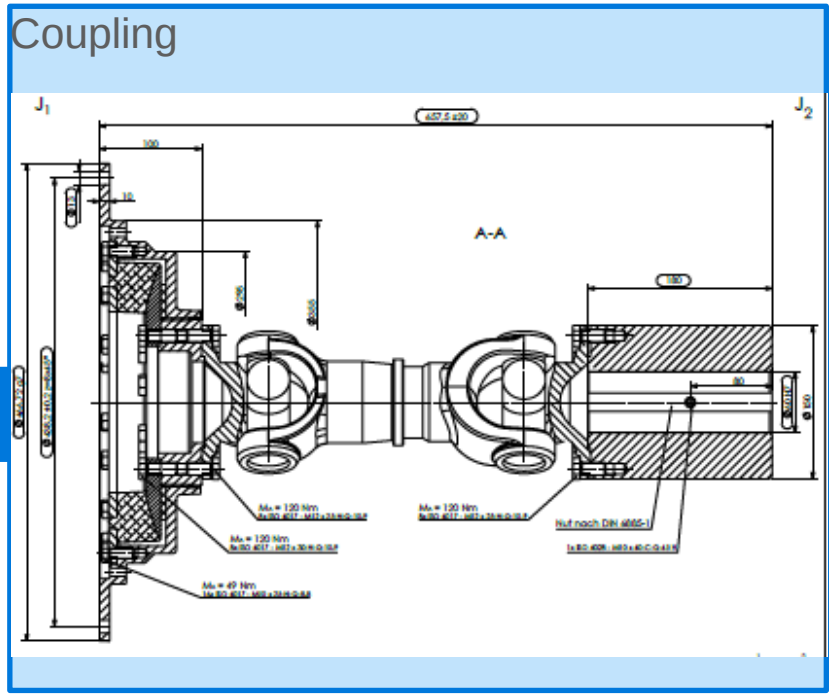
Major mechanical components (Coupling)





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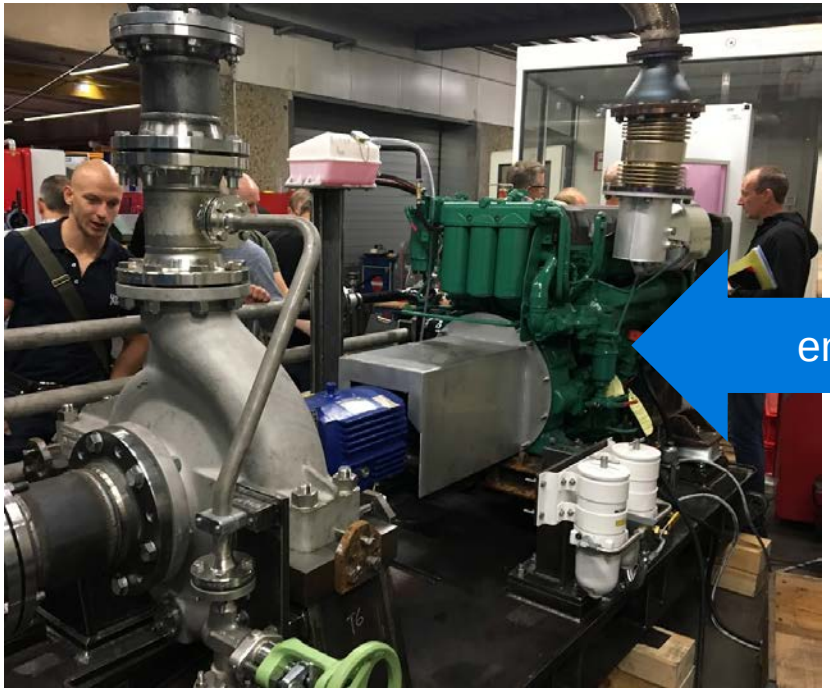
Major mechanical components (engine – Volvo D9)

4-stroke direct injected, turbocharged and aftercooled diesel engine, 6 cylinder



engine

engine

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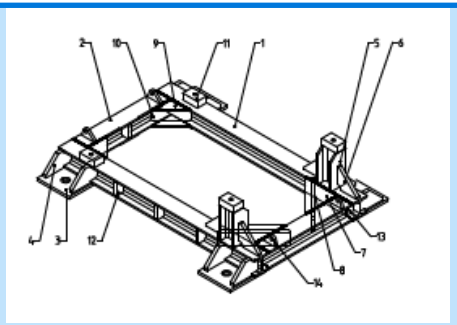
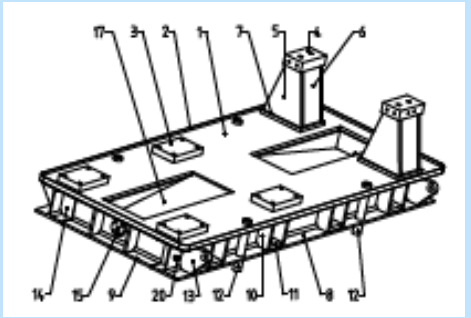
Major mechanical components (frame)

Base frame

Engine frame



Base frame



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Verification by analysis & FAT

Analysis actually shows resonance in pump at 3EO (firing frequency), was disregarded by manufacturer and passed review at OKG without notice.

Vibration speed measurement (no frequency spectra) was conducted during **FAT**, passed review since values were below 20 mm/s rms as required. No major verification with frequency analysis.

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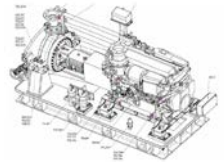
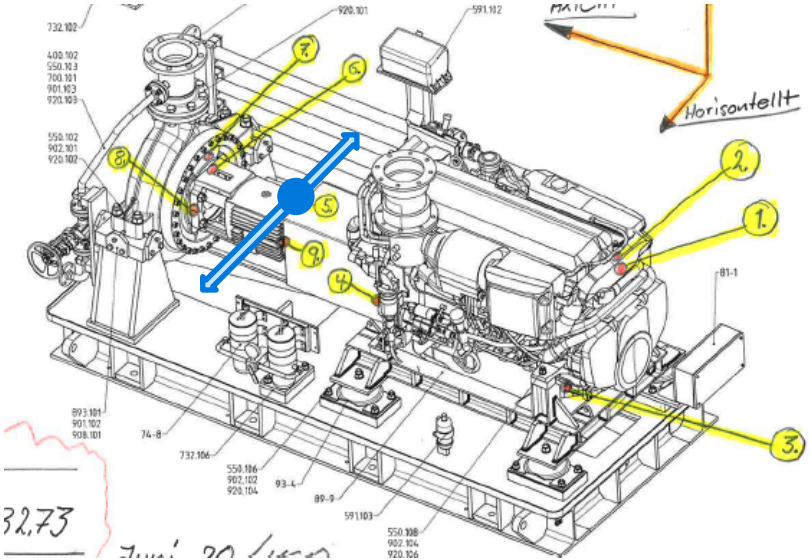
Verification at SAT & bump test



SAT

Higher vibration speeds were measured during SAT on pump, ~30 mm/s. Measurements with frequency spectra was conducted for the first time and evaluated.

Conclusion – likely resonance between engine firing speed (3N @ 1643 rpm) and pump horizontal eigen frequency @ 82 Hz



Bump test

Bump test verified eigen frequency for pump – resonance determined

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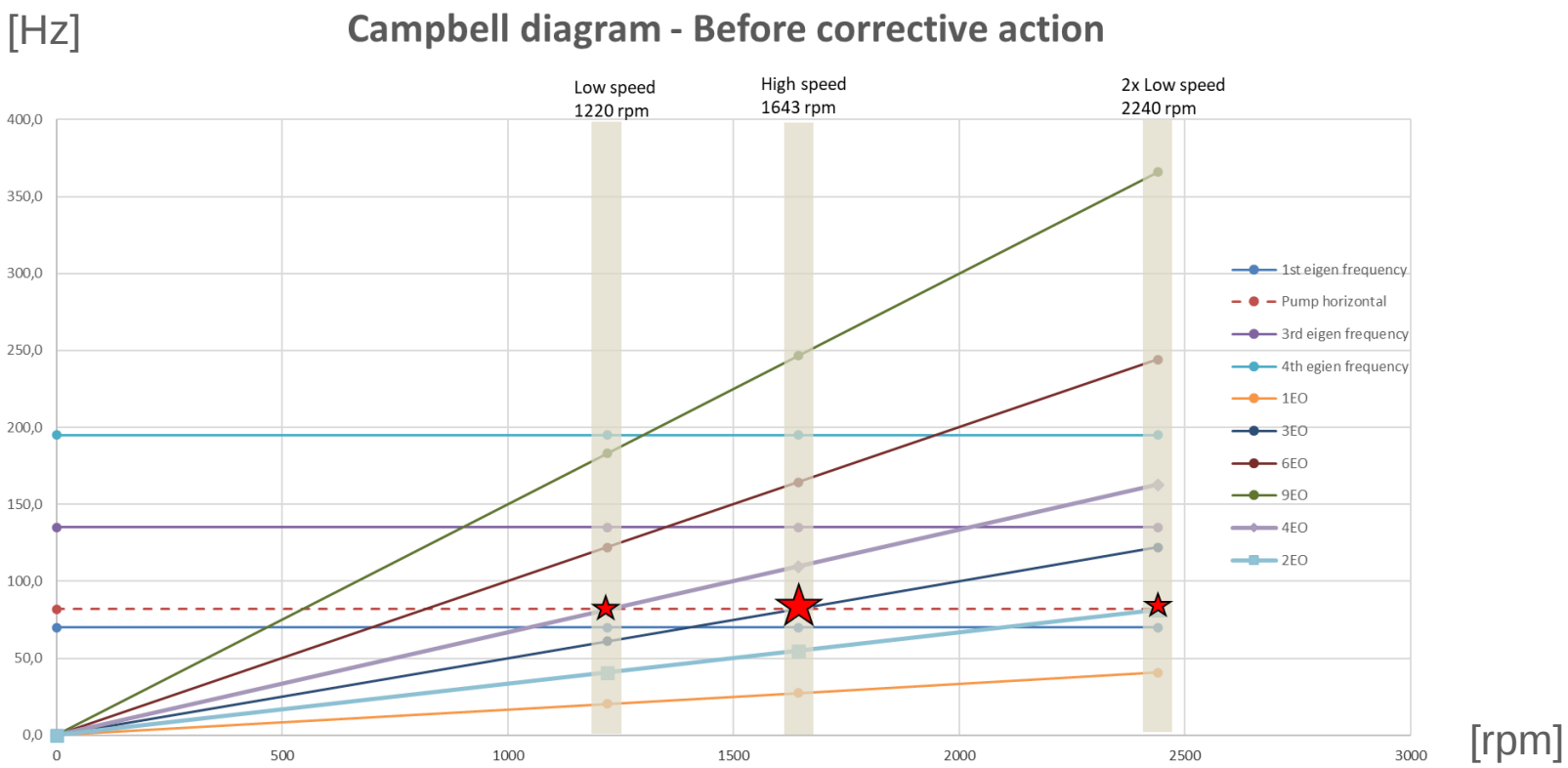
Campbell diagram



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Corrective actions

Three possibilities

1. Change excitation frequency (speed) or
2. Change the natural frequency of the pump according to $f = \sqrt{\frac{k}{m}}$
   - change mass on pump to change the natural frequency for pump and/or
   - change stiffness on pump to change the natural frequency for pump

Impossible to change the speed of the pump because it will not fulfill requirements on flow and head.

Both a change of mass and change of stiffness were examined during operation and a solution was concluded:

Corrective actions, continued..

- Short term corrective action ⟹ load the pump with lead sacks to increase mass (minor decrease of resonance condition)

- Final corrective action ⟹ design and install supports to the pump to increase the stiffness (and exchange pump bearing and sealing)

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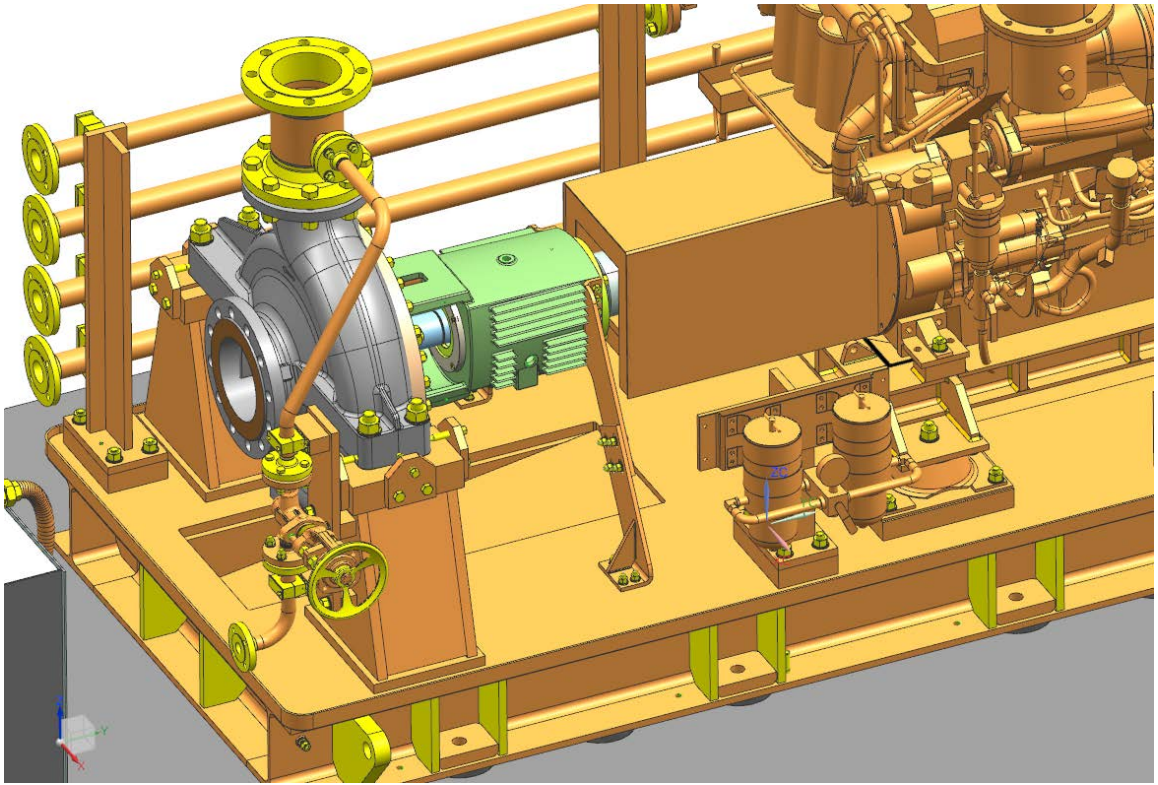
Final solution



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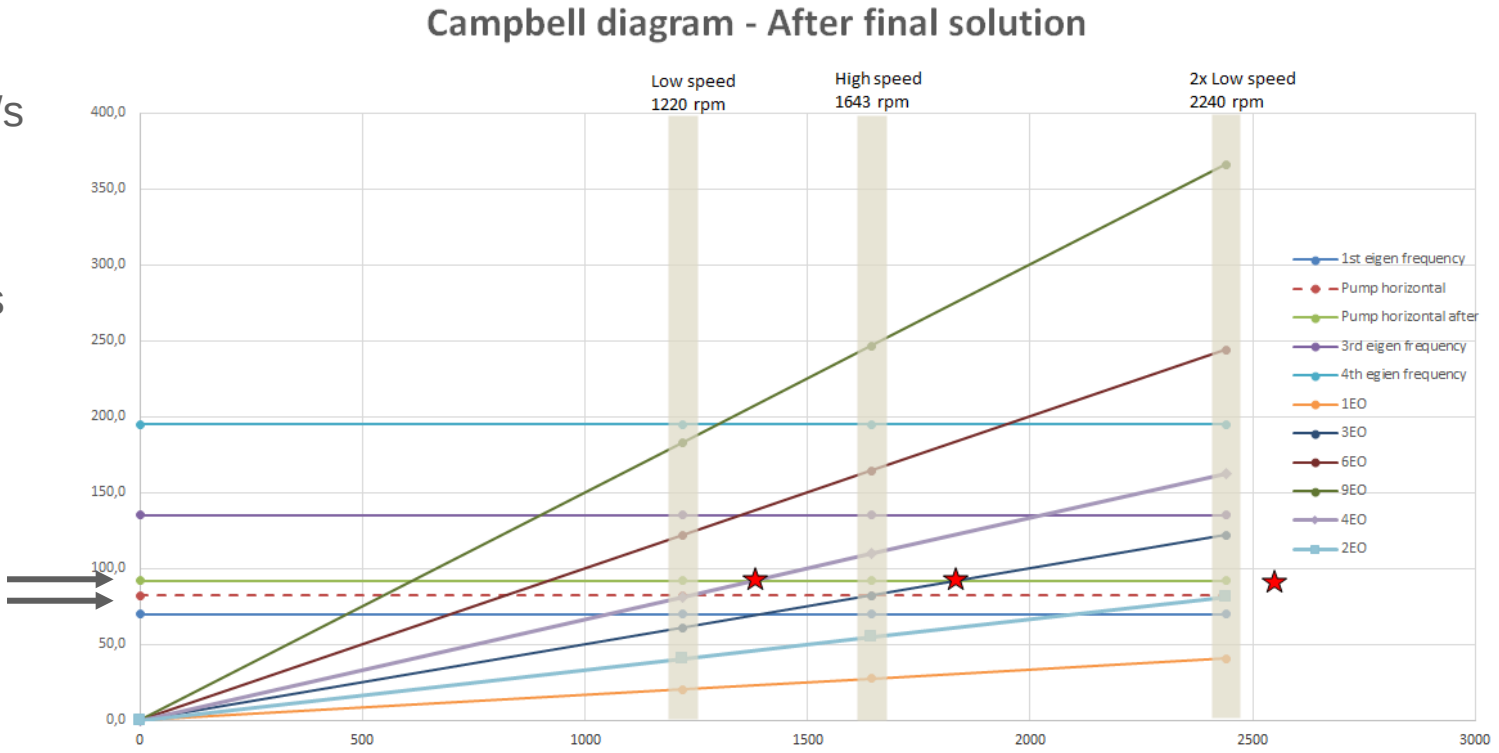
After final actions – pump horizontal eigen frequency moved from 82 to 92 Hz

~ 30 mm/s

~ 4 mm/s



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