



Ringhals 4 Auxiliary feedwater system

Mitigation of vibration in branch connection using additive manufacturing

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Ringhals Nuclear Power Plant

Ringhals 1

Started: 1976

881 MW

Permanent shutdown
2020

Ringhals 2

Started: 1975

904 MW

Permanent shutdown
2019

Ringhals 3

Started: 1981

1063 MW

Operation to 2041
LTO* operation 2021

Ringhals 4

Started: 1983

1130 MW

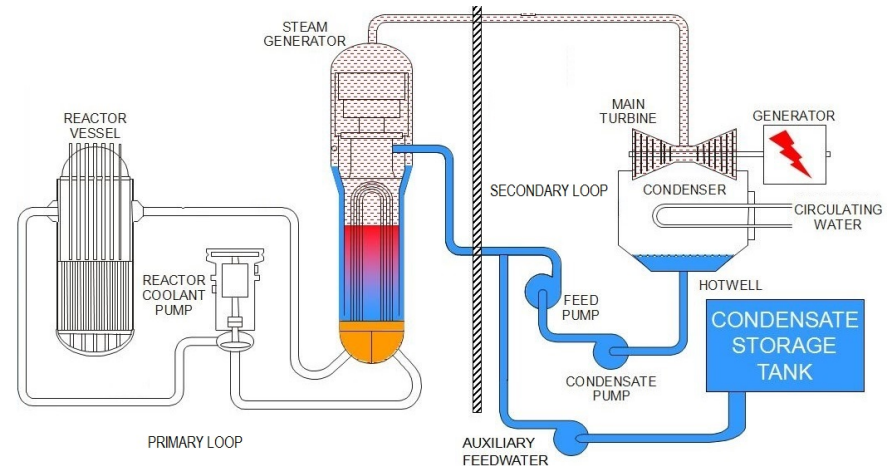
Operation to 2043
LTO operation 2023



* LTO = Long Term Operation

Description – Auxiliary feedwater system

- System 327 is auxiliary feed water system
- The function of the Auxiliary Feedwater System (AFWS) is to supply high pressure feedwater to the steam generators during plant startup, cool down, and emergency conditions when the normal feedwater supply is not available.
- The system consist of:
 - Two electric pumps
 - One steam powered pump



Auxiliary feedwater steam powered pump

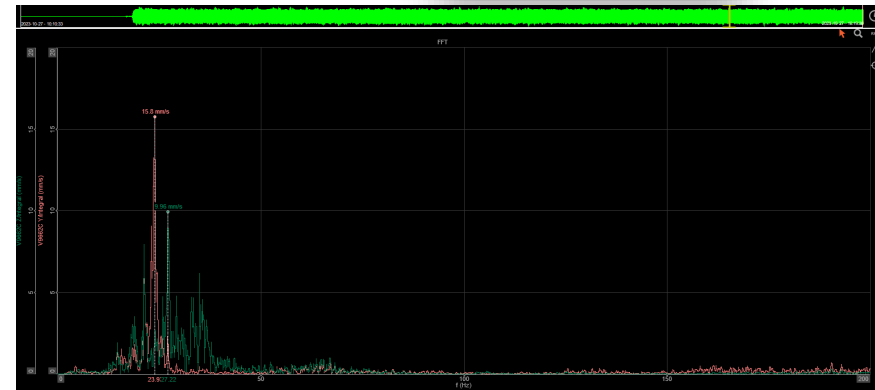
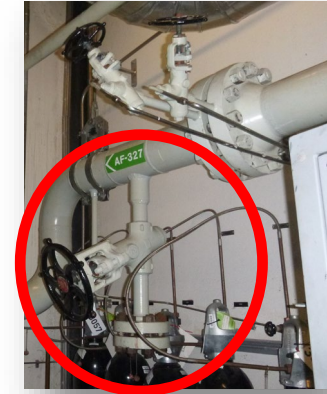
- Steam for the pump is taken from Steam Generator 2 and 3



Orifice at the outgoing line

Vibration in 2" branch pipe

- The 2" branch line after the orifice have vibrations above acceptance criterion
 - Vibration frequency : ~24 Hz
- How to increase robustness
 - ~~Replace/remove heavy flange and valve~~
 - Add support to increase stiffness
 - Decided to investigate the possibility to use additive manufactured support to be able to optimize the design



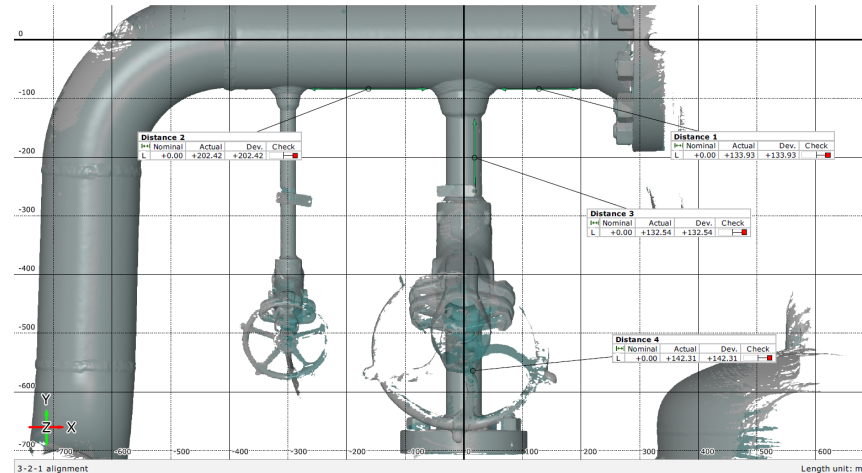
3D scanning

- The geometry of the run pipe and the branch pipe was measured using 3D scanning



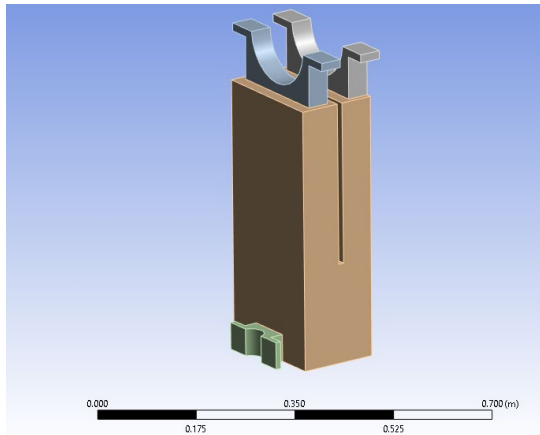
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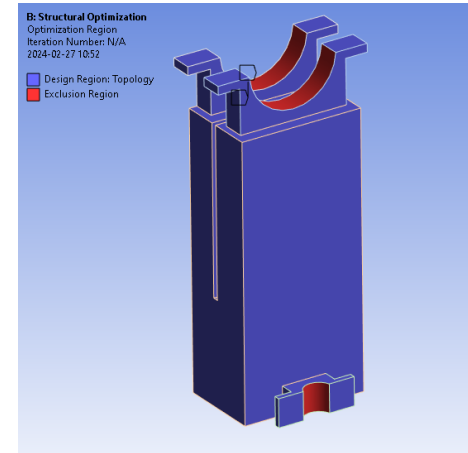
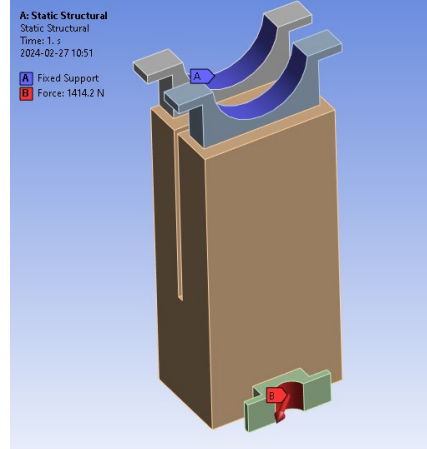


Design of 3D printed support

- The geometry for the 3D printed support was optimized using Ansys Workbench 2022 R1, with respect to mass & stress.
- Response criteria: change in moment of inertia of block
- Start geometry

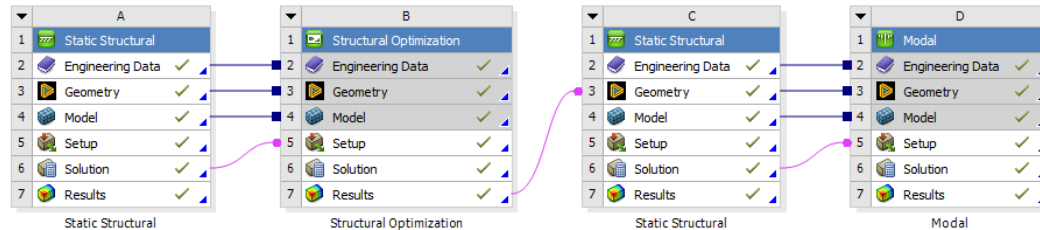
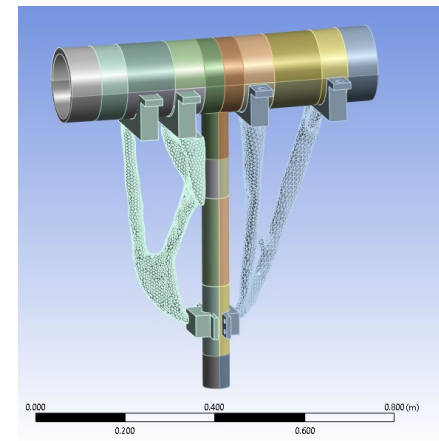
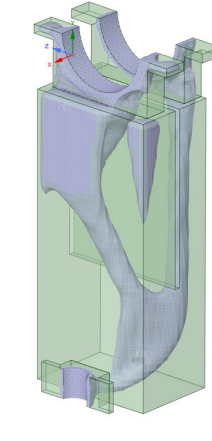
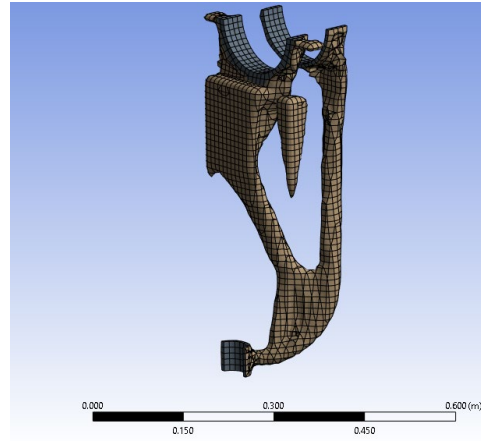
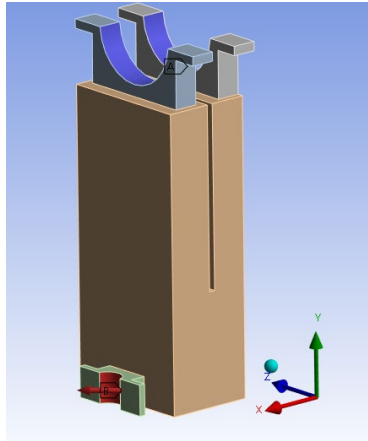


Topology Optimization



Design of 3D printed support

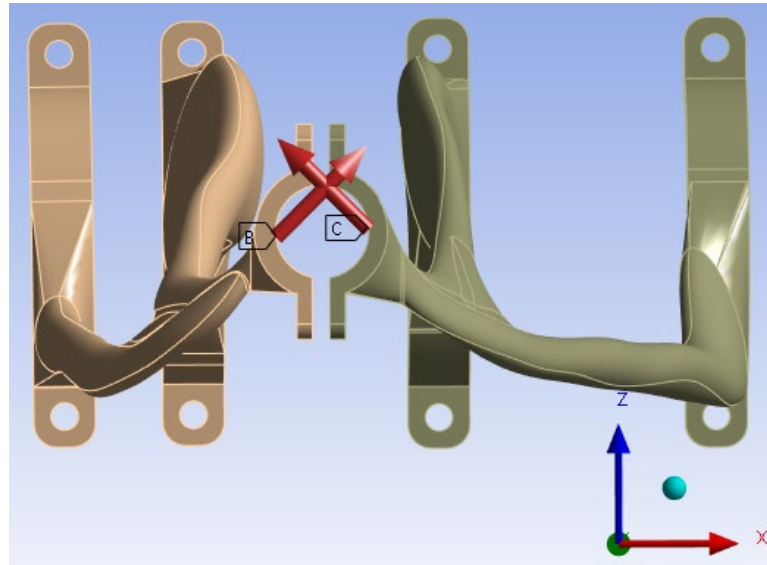
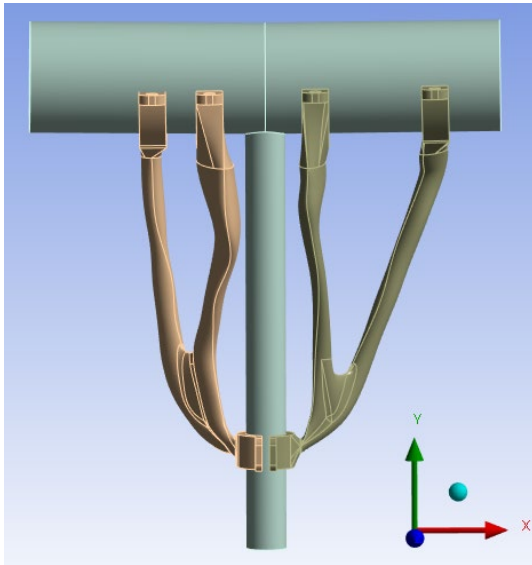
- Optimization process



Aim:
A frequency well above 50 Hz

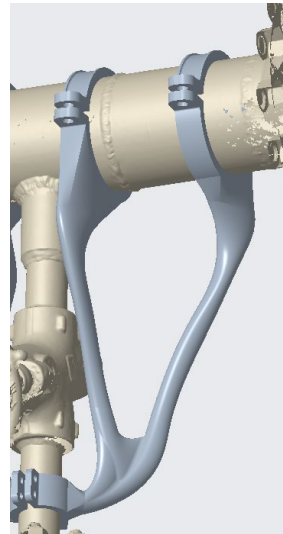
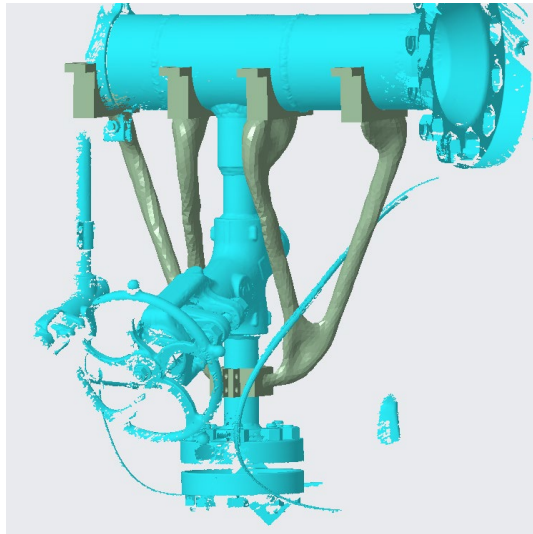
Loads for optimization

- Different loads are used to optimize the different sides



Export of geometry to CAD

- The optimized geometry was exported to CREO and smoothed
- The geometry was made hollow to reduce weight



Eigenfrequency without and with support

Without support (26 Hz)

C: No support
Total Deformation
Type: Total Deformation
Frequency: 26.770 Hz
Unit: m
2024-10-24 14:02

0.20711 Max
0.1941
0.16109
0.13087
0.11106
0.09101
0.06907
0.046015
0.023172
0 Min



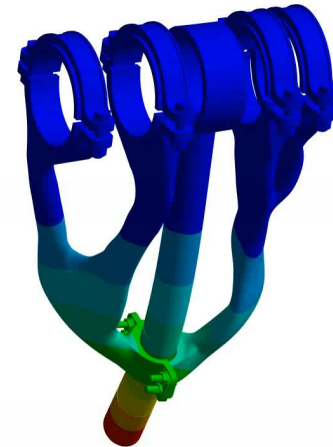
Valve and flange
modelled as
point mass

Measured eigenfrequency about 24 Hz

With support (76 Hz)

B: Model
Total Deformation
Type: Total Deformation
Frequency: 76.262 Hz
Unit: m
2024-10-24 13:40

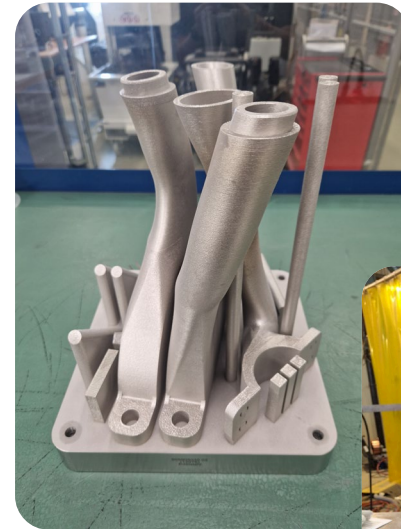
0.21173 Max
0.19318
0.16905
0.14609
0.12074
0.096991
0.073443
0.049295
0.024148
0 Min



F1 = 76 Hz, F2 = 110 Hz

Manufacturing of support

- The design was manufactured using additive manufacturing in a SLM280
 - 3D printer Additive Technology with selective laser melting of metal powders
- A weld was added to make it possible to use a smaller machine
- The material was tested with good results with respect to yield limit, fracture limit, fatigue etc.
- The tolerances was found to be well acceptable



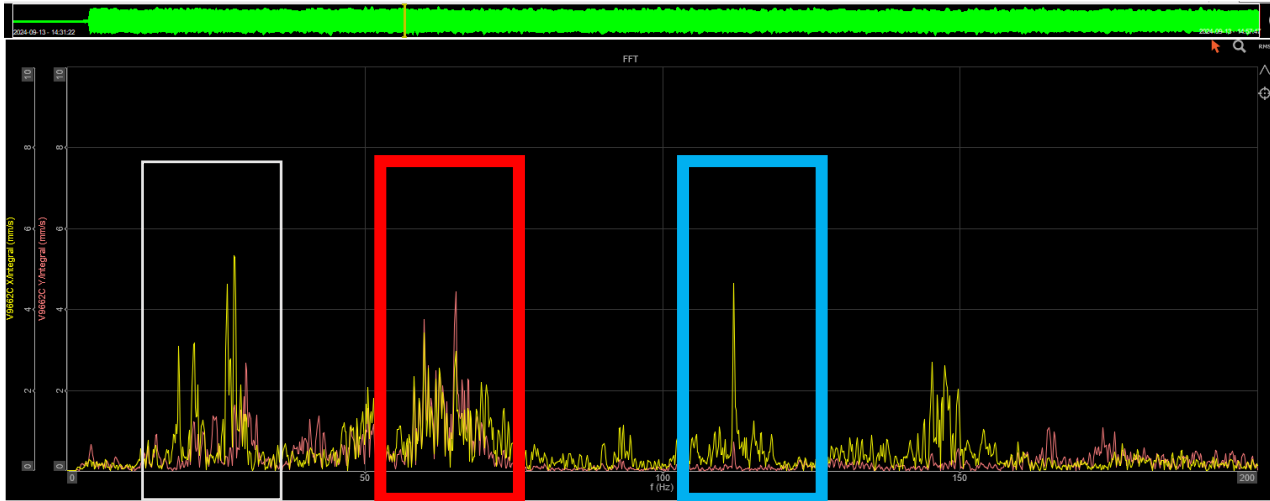
Additive manufactured support mounted

- The support fitted well on the piping

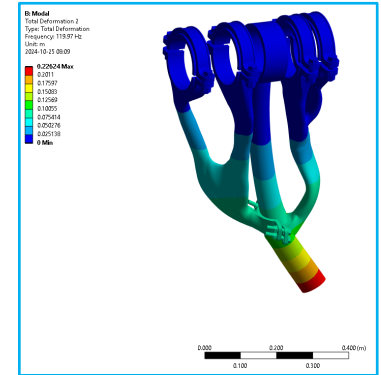
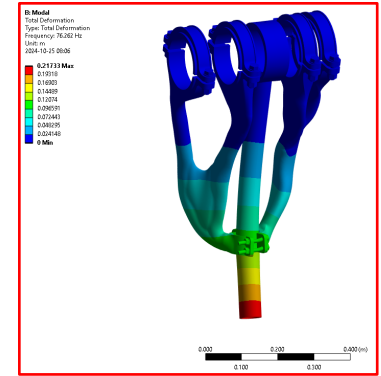


Measurement of frequency

- The measured frequency of the 2" branch with support is



Vibrations main pipe



Concluding remarks

- Vibration level at about 25 Hz reduces from about 15 mm/s to 5 mm/s (0-peak)
- The 2" branch line with the additive manufactured support will be more robust for vibration loads



VDI 3842:2004-6

