Cavity support scheme options

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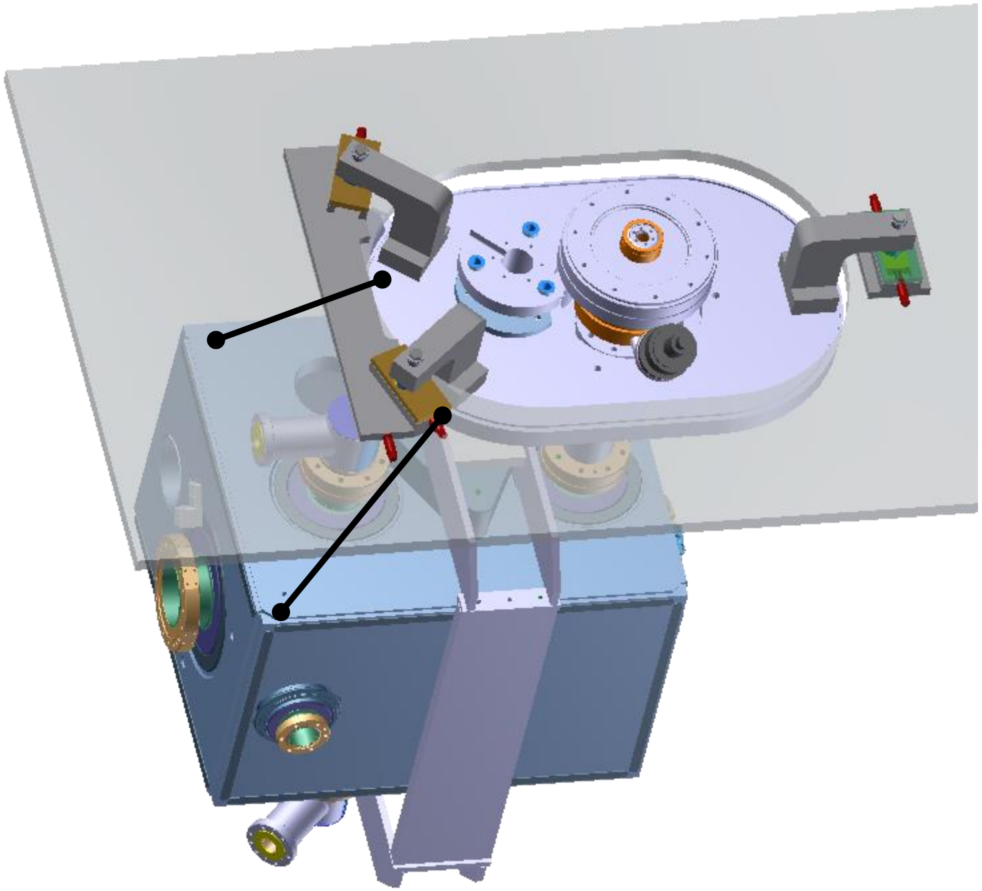
Cavity support



- The cavities will be rigidly supported by the input coupler.
- Additional supports are required that will be attached to a common adjustable alignment plate.
- The current design utilises rods, however, the following analysis proposes the use of ‘blade’ type flexures to increase stiffness in the required directions and therefore reduce low order vibrations.

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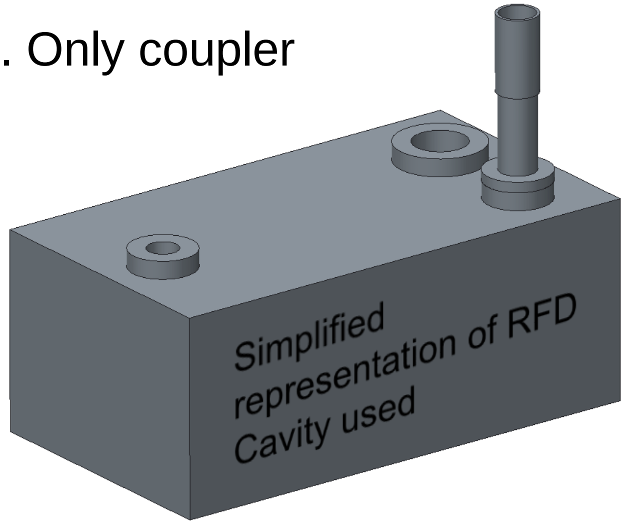
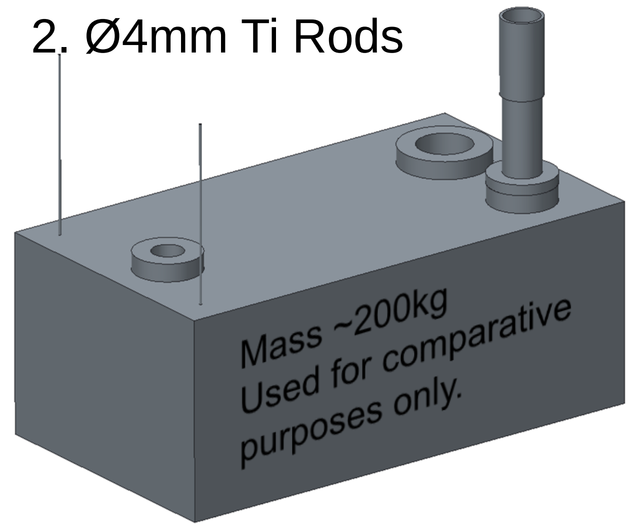
Analysis models

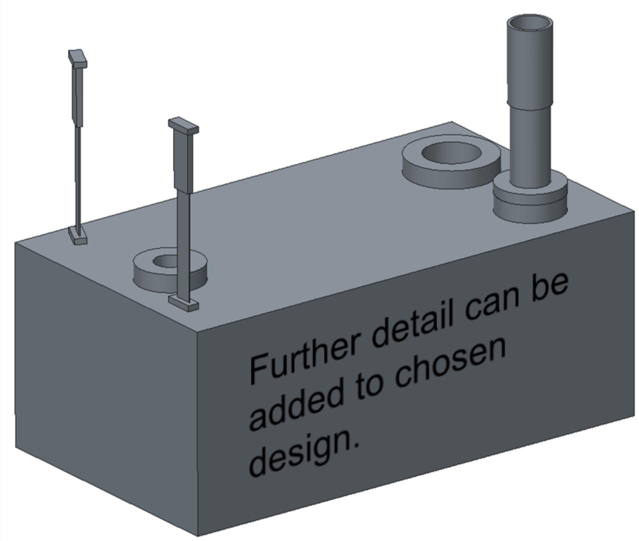
1. Only coupler



2. Ø4mm Ti Rods

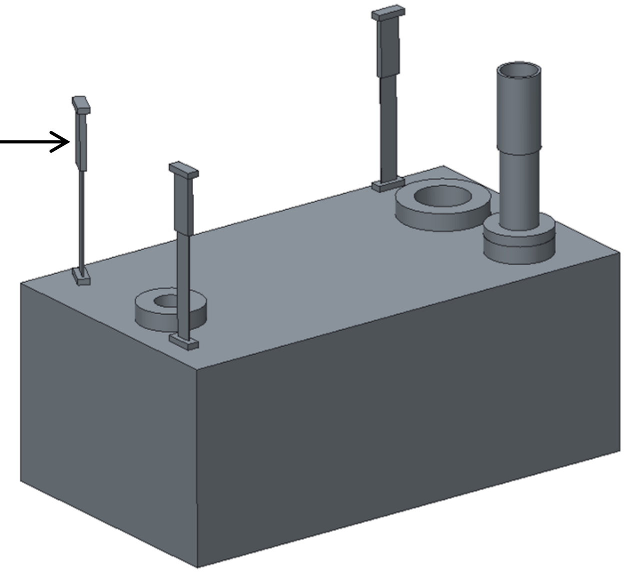


3. Stainless Steel flexures (2mm thick)



Thickness to give similar thermal conduction and therefore similar temperature profile and contraction as the input coupler

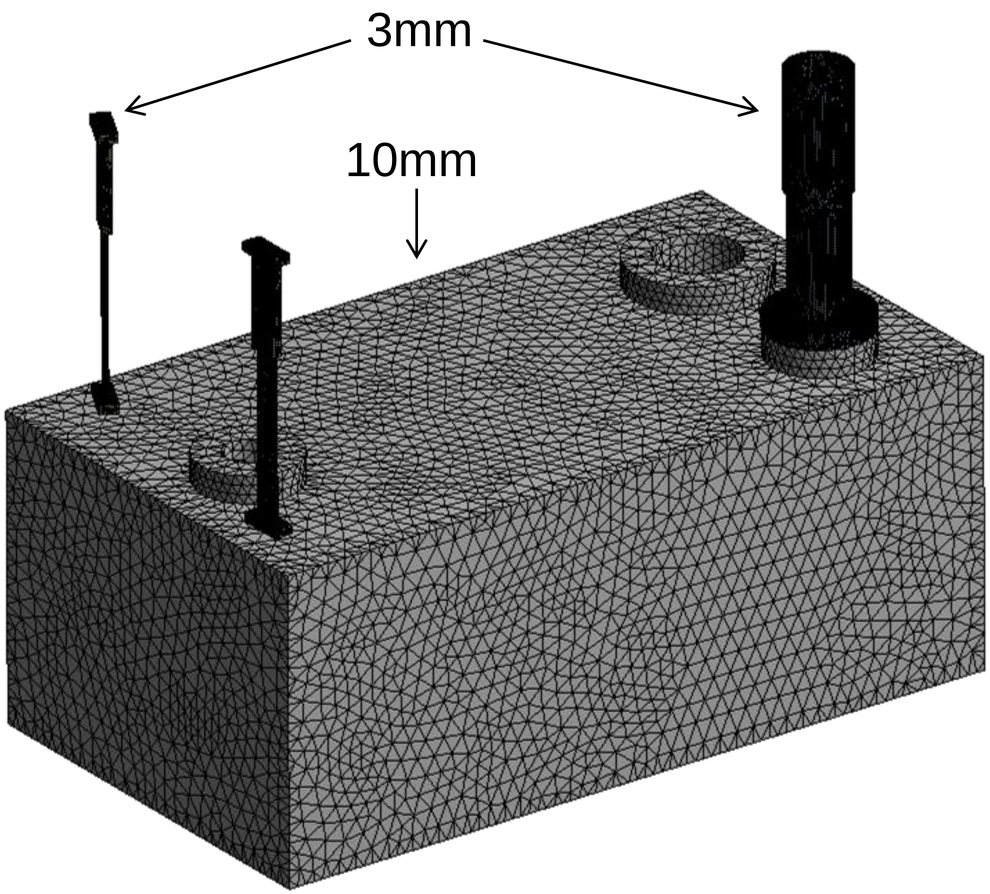
4. Additional flexure

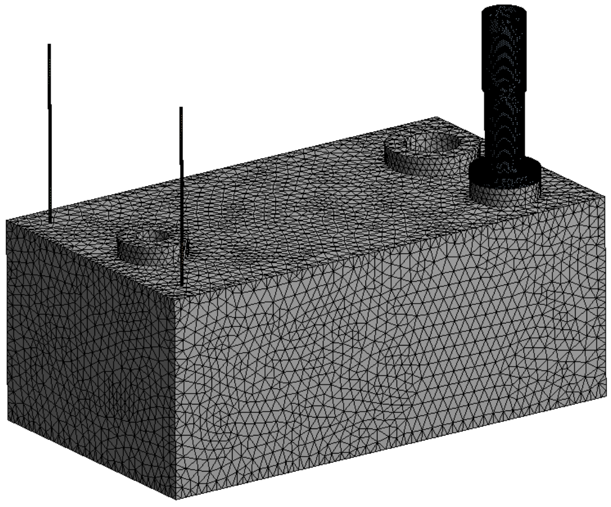


Analysis setup

- RFD cavity represents the 'worst case' as it is the most cantilevered support.
- The mass is approximate, but is valid for these comparative purposes.
- Standard earth gravity applied.
- Coupler, rods and flexures fixed at common support plate.
- Static total deformation, Max von-Mises Stress and first 4 modes were found.
- No mesh convergence check performed, but same meshing used for each analysis (see next).
- Material properties measured by FermiLab from 300K to 2K used.

Meshing





Analysis Result

Analysis	Max Deformation (mm)	Max von-Mises stress (MPa)	Mode 1 Frequency (Hz)	Mode 2 Frequency (Hz)	Mode 3 Frequency (Hz)	Mode 4 Frequency (Hz)
1	3.9	183	7.7	8.3	16.1	61.1
2	0.24	65.2	8.5	25.3	38.3	70.9
3	0.025	15.3	25.1	48.3	56.5	122
4	0.010	10.5	27.2	50.15	66.9	174

- Performance is significantly improved using blade type flexures.
- The 3 flexure design is best, however, need to consider increased heat load.
- Analysis 3, i.e. with only 2 blades was then analysed for thermal deformation/stress.

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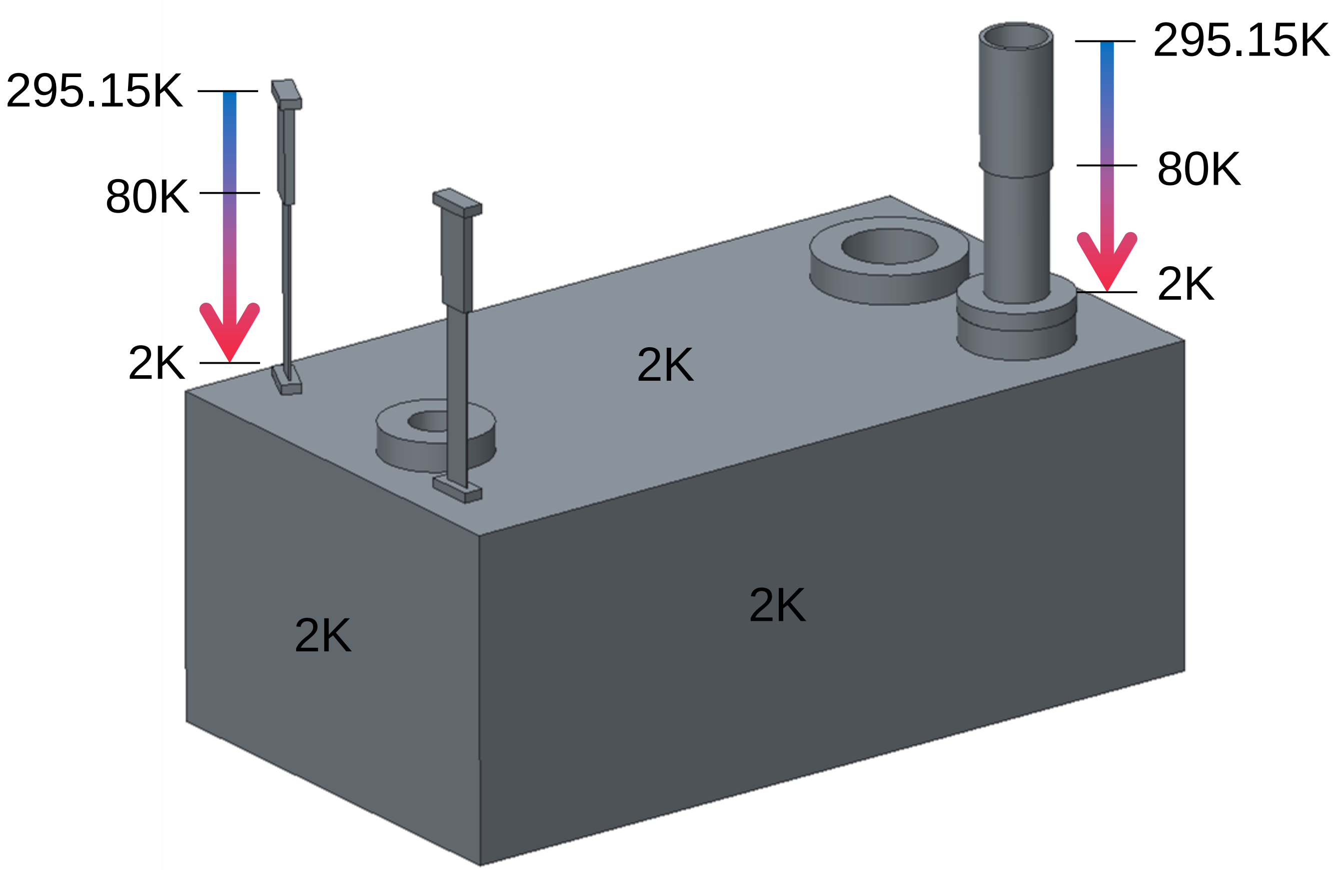
Thermal analysis



Flexures will ideally be thermalised the same as the coupler to minimise heat leak, however, optimisation to be completed.

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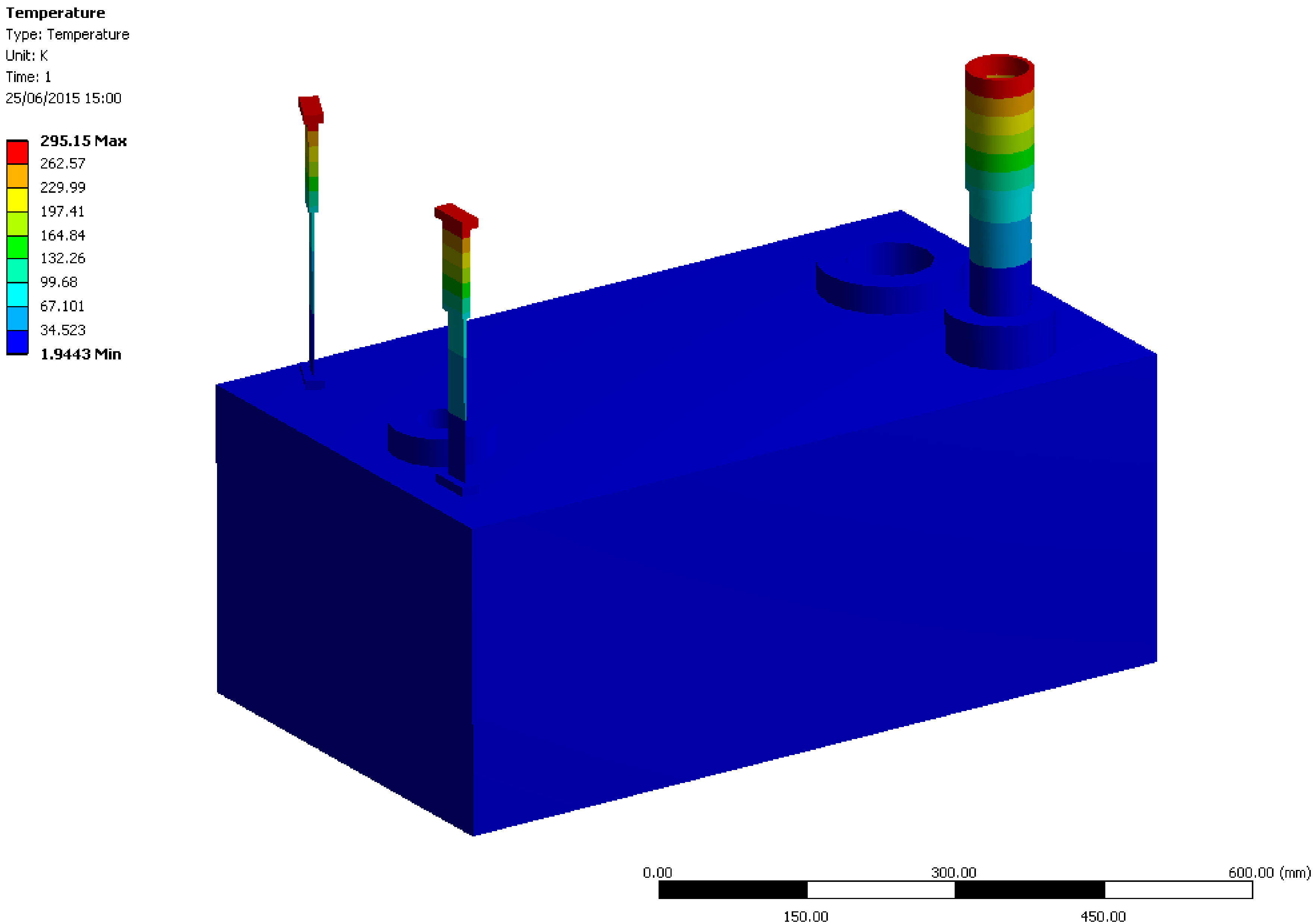
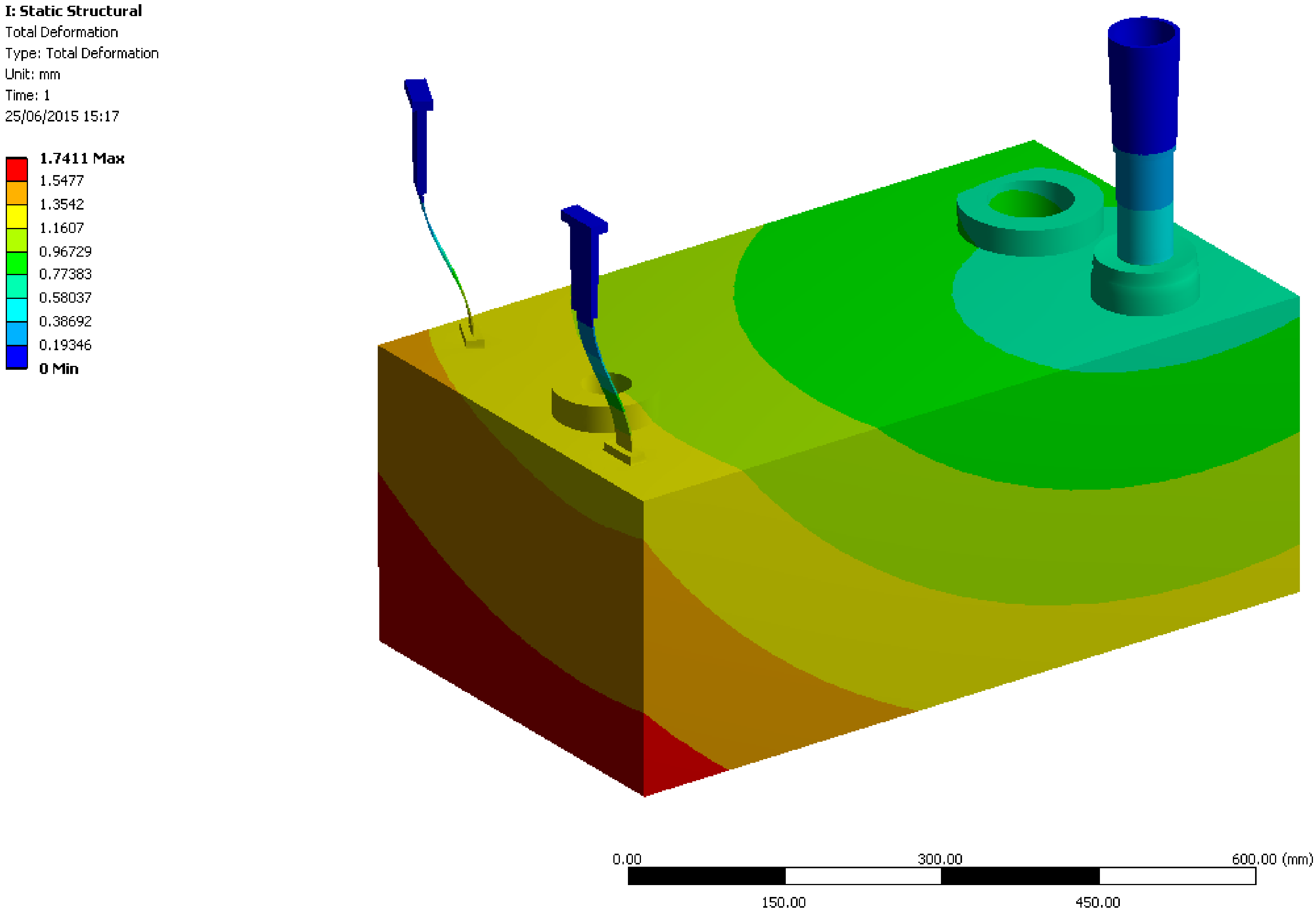
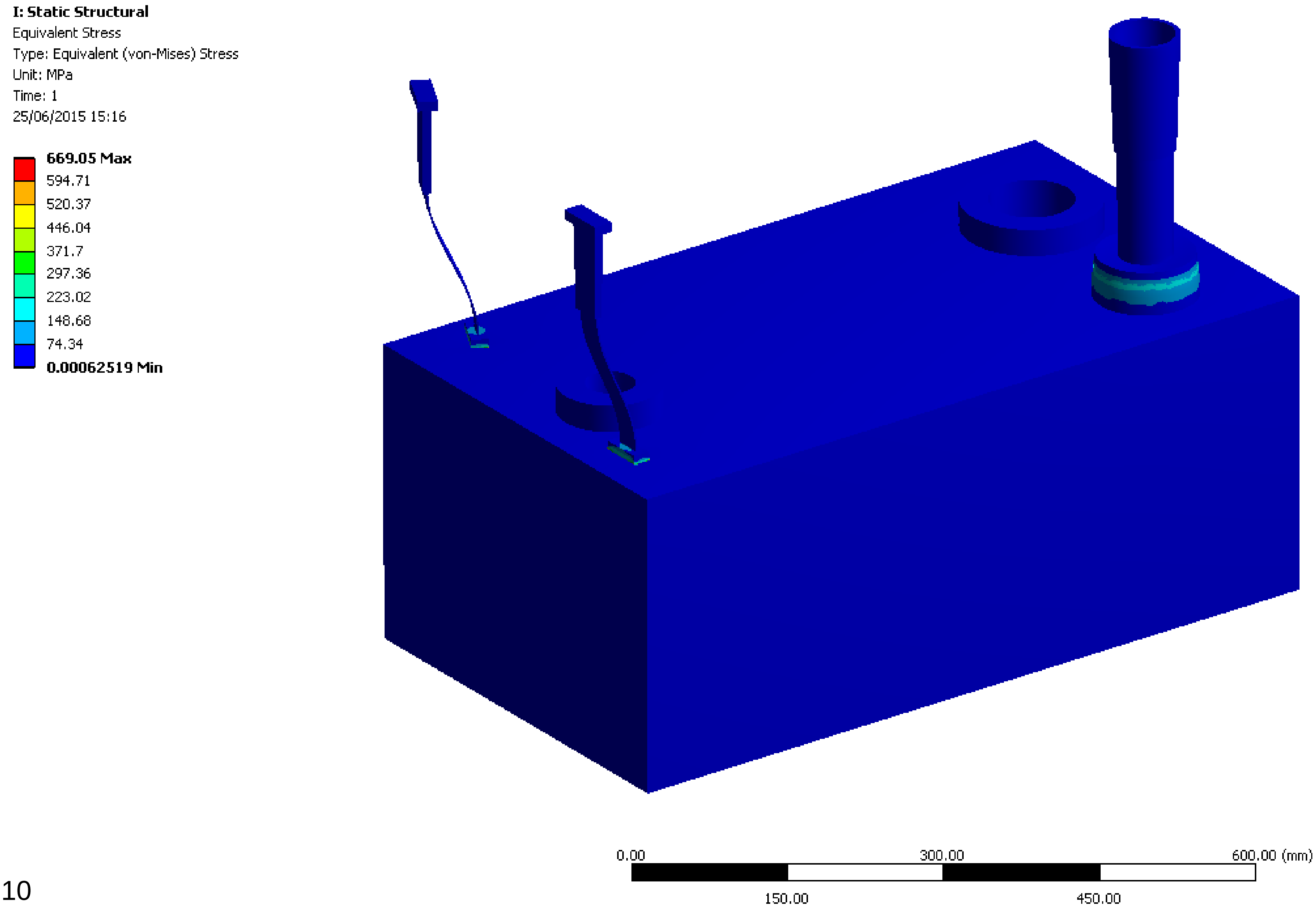
Thermal results



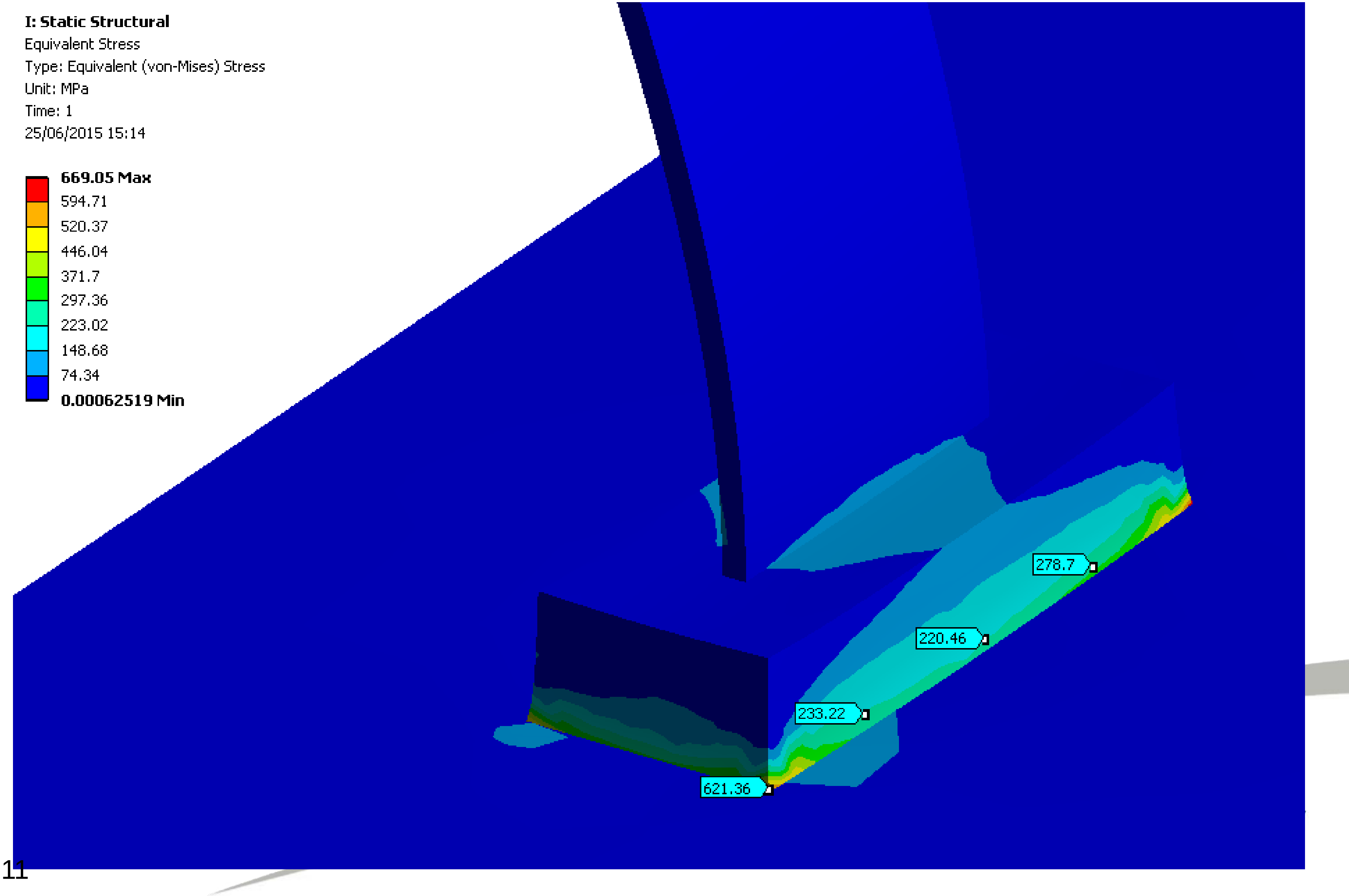
Thermal results



Thermal results



Thermal results



Result comment

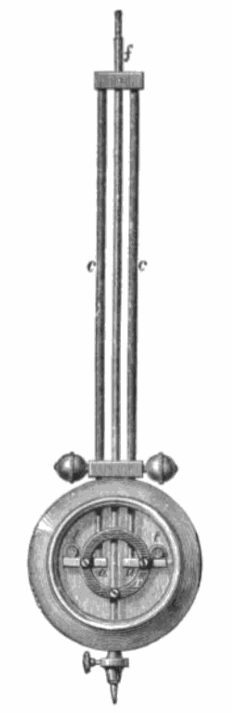
- Stresses are well within acceptable limits.
- There are no detrimental stresses in the helium vessel and therefore there will be no additional deformation of the cavity due to the flexures.
- The elevated stressed are found in the interface between materials and are highly localised (see previous).
- The method of mounting can be optimised to reduce stress even further if required. This could be for example a Grade 2 Ti block, which the Stainless blade is then clamped into.
- The high stresses will be ofound anyway in the coupler were we have 316LN to Grade 2 Ti connections.
- It has been observed through experience with these joints that the stresses are below allowable for the material properties at 2K.
- i.e. CERN have brazed 316LN flanges to Nb and they do not fail.

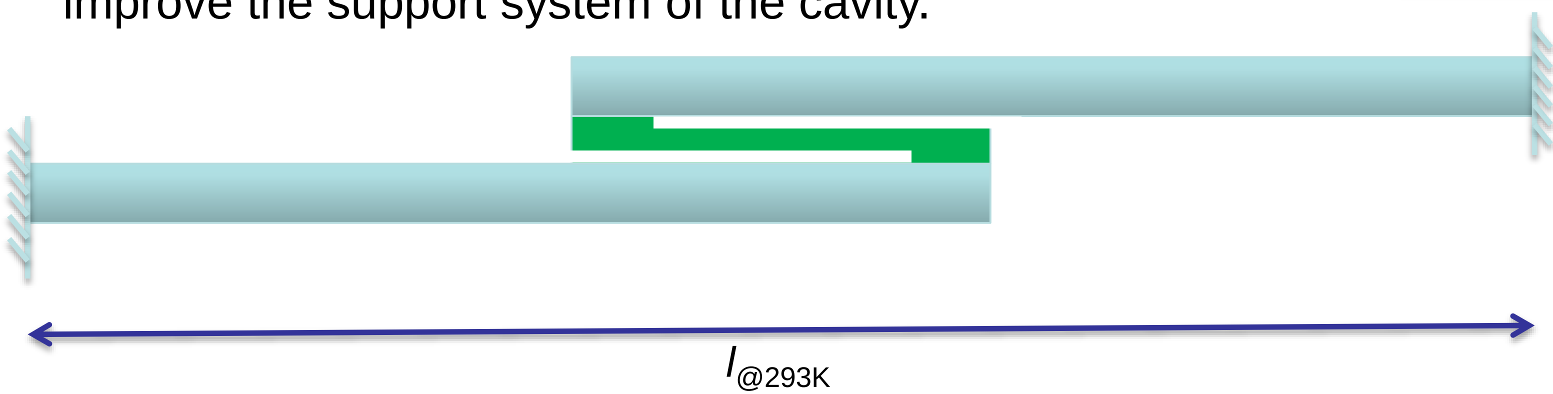
Recommendations

- STFC recommend that first order frequencies in the system be above 25Hz to avoid unwanted high amplitude vibration.
- Blade flexures have been shown to increase stiffness, reduce deformation, reduce stress and raise the first order vibration mode above 25Hz.
- The current flexure geometry can be optimised to give minimised heat leak and/or increased stiffness. Flexure design currently used is a first order approximation.
- The use of the common adjustable support flange is compatible with the flexure system.
- The flexures require no penetration through the Outer Vacuum Chamber, simplifying the design and reducing the risk of leaks.
- They also take up no space externally on the module where space is at a premium.
- Flexures will require no adjustment after cooldown and can be thermalised using copper shunts to ensure the heat leak is minimal.

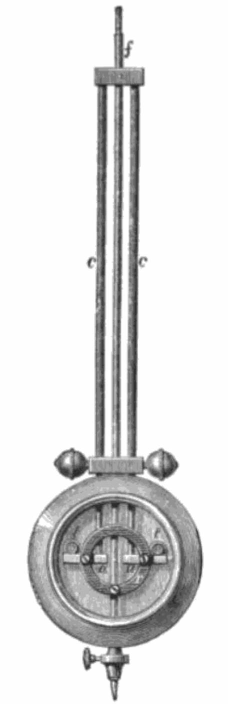
Inter-cavity supports

- A thermally neutral support system was developed for the UK4ROD.
- This relied on differences in thermal contraction of materials to maintain the same length after cooled down to 2K.
- It was shown to increase the stiffness and low frequency modes of the system.
- However, this was compared to a ‘coupler only’ type support.
- Also the UK4ROD had much more balanced forces, i.e. the coupler was in the centre of the cavity. This was by design, to improve the support system of the cavity.





Inter-cavity supports



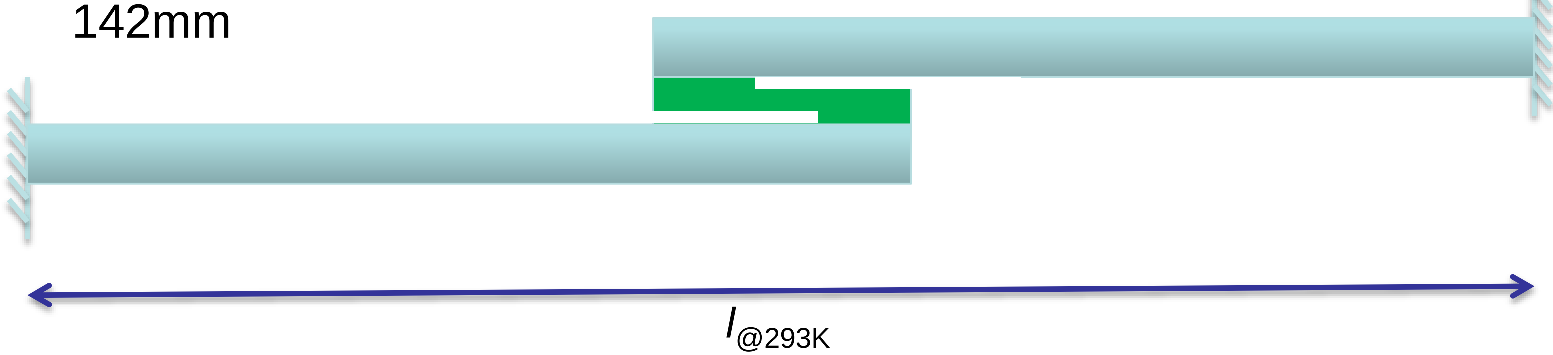
- Invar integrated contraction from room temperature to 2K is L_i x (0.037/100)
- 304 Stainless steel contraction from room temperature to 2K is L_{ss} x (0.306/100)
- Therefore;

$$2L_i \times (0.037/100) = L_{ss} \times (0.306/100)$$

AND

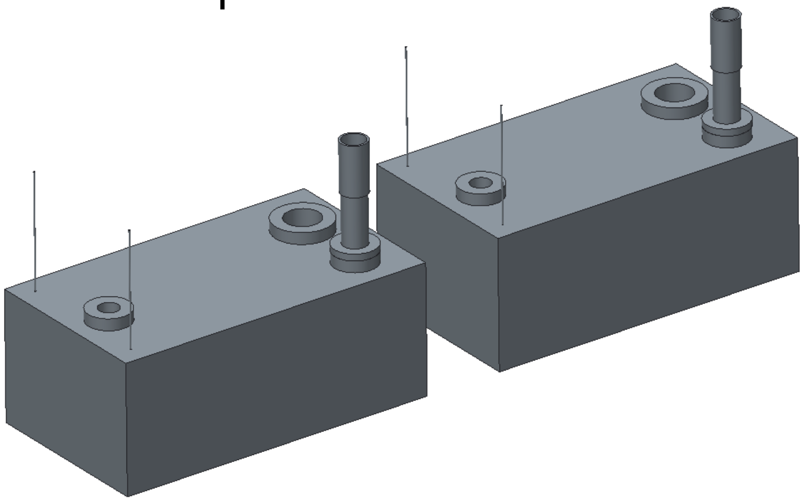
$$2L_i - L_{ss} = 1032\text{mm (distance between fixed points)}$$

- So, 2Li x (0.037/100) = (2Li – 1032) x (0.306/100)
- Solving the simultaneous equation gives L_i = 587mm and Lss = 142mm

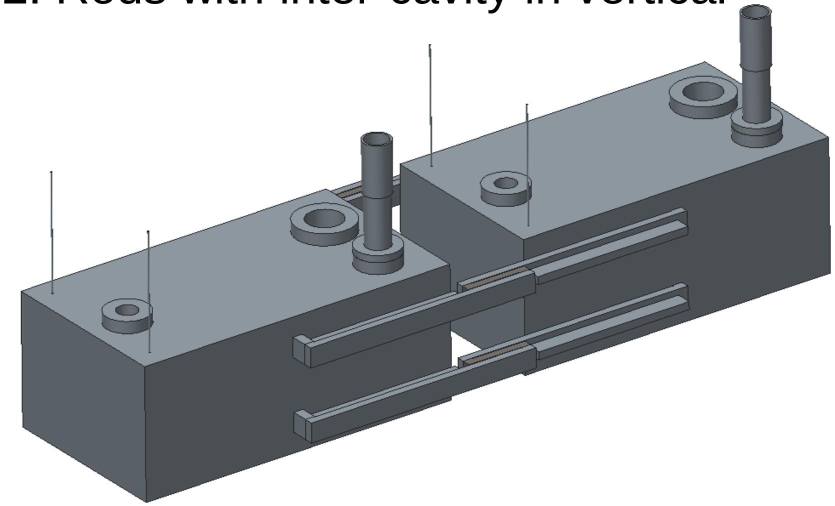


Analysis Models

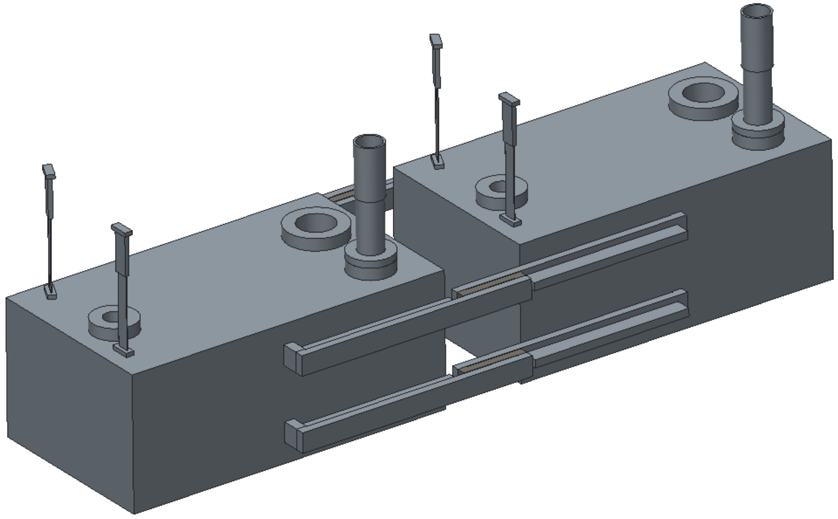
1. 2 independent cavities on rods



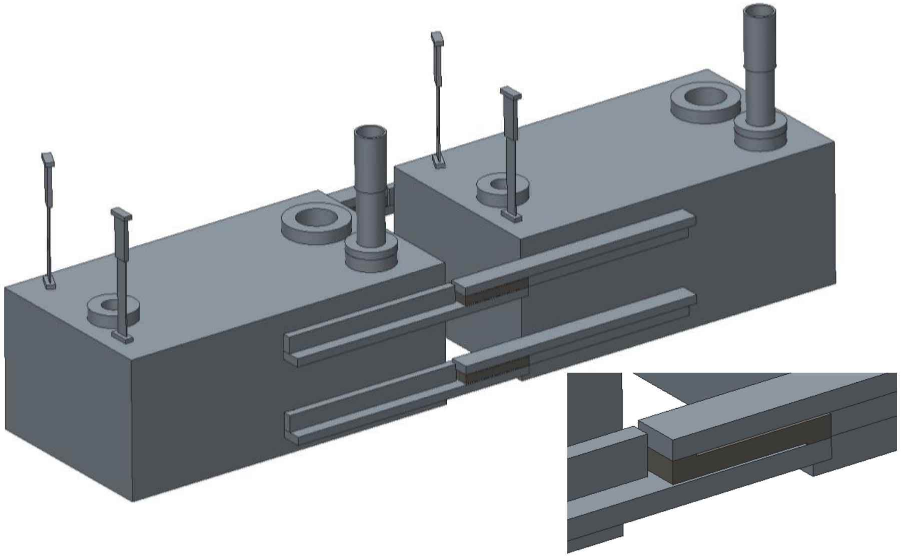
2. Rods with inter-cavity in vertical



3. Blades with inter-cavity in vertical



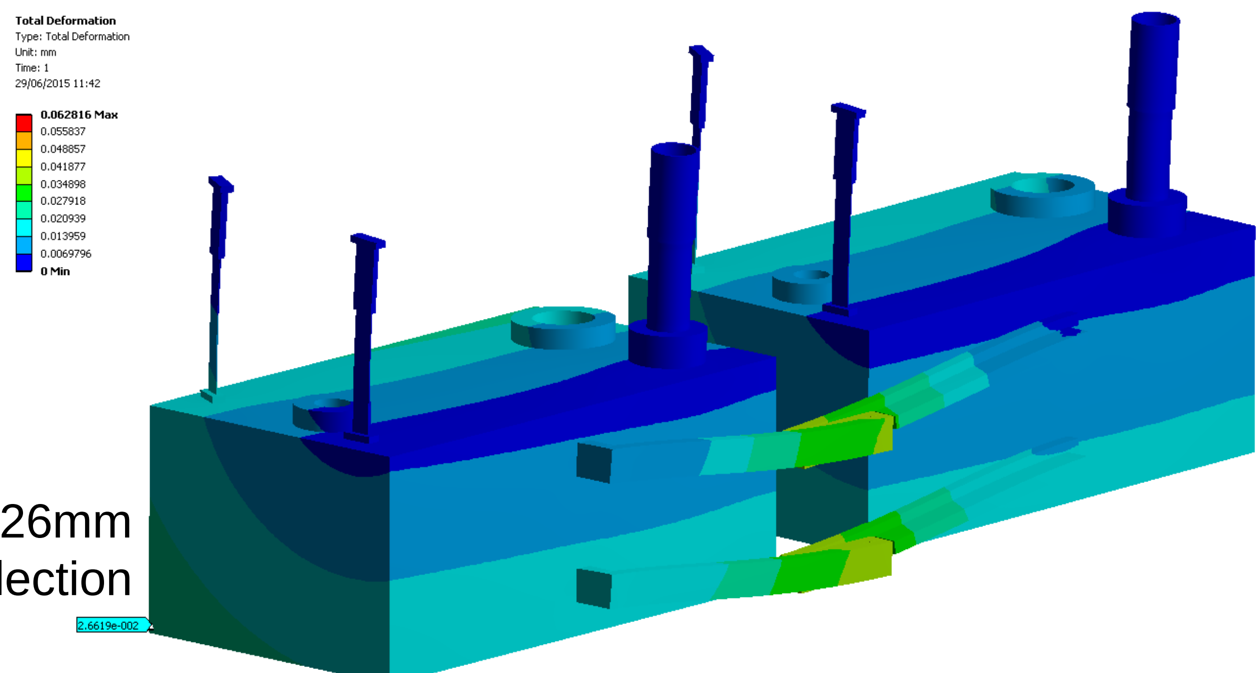
4. Blades with inter-cavity in horizontal



Result summary

Analysis	Max Deformation (mm)	Max von-Mises stress (MPa)	Mode 1 Frequency (Hz)	Mode 2 Frequency (Hz)	Mode 3 Frequency (Hz)	Mode 4 Frequency (Hz)
1	0.24	65.2	8.5	25.3	38.3	70.9
2	0.43	61.8	12.6	20.0	27.5	34.3
3	0.063*	18.2	26.4	40.5	44.7	55.0
4	0.068*	24.0	26.1	40.9	44.9	55.1

*deformation of the inter-cavity supports.



0.026mm
Cavity deflection

Recommendations

- The use of the inter-cavity support in conjunction with the blade flexure supports offers no significant improvement.
- Some modes are actually lowered, due to the increased mass.
- Despite the inter-cavity supports adding rigidity the cold mass still ‘sways’ as one unit.
- The inter-cavity supports use invar which is a strongly magnetic material.
- Simulations have shown this not to be an issue, however, it seems in this instance that it is not worth the increased risk in using them for little to no gain.
- Using blades only also gives the ability to move the cavities freely independent of each other.
- If a ‘Plan B’ is required I suggest we investigate other options.

Conclusion

- RFD used as this is the more difficult of the two cavities to support and therefore represents the worst case.

- Blade type flexures will perform significantly better than supporting rods.

- Maximum deformation is reduced by 10x. Stress reduced by 4x.

- The fundamental vibration mode with thin rods and coupler for this cavity may be as low as 8.5Hz, this would certainly be a risk. The blades increase the fundamental mode above 25Hz.

- With the blades there would be no need for any inter-cavity support therefore allowing independent movement of the cavities.

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