Adjustable support for the accelerating structure

CLIC Module working group
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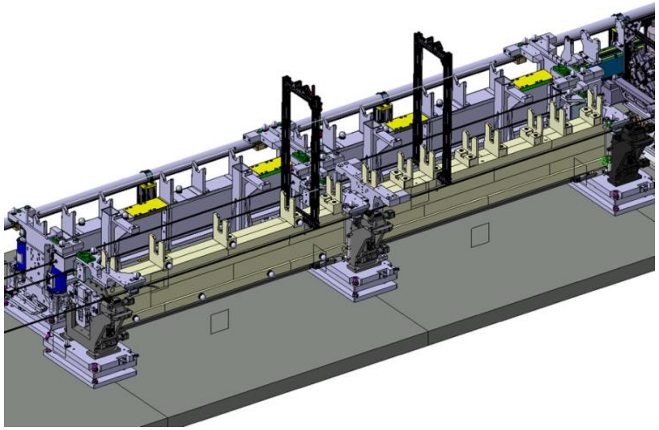
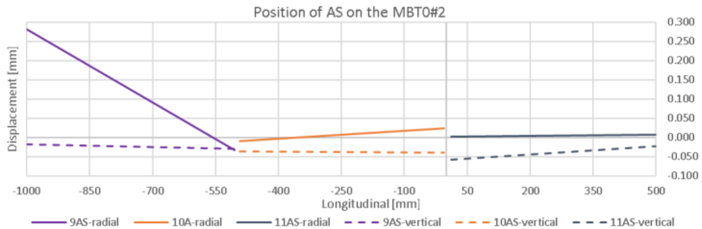
Motivation

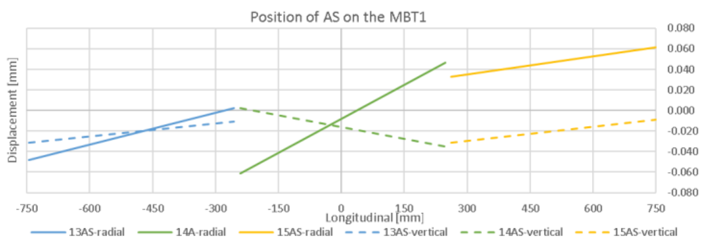
- Current (lab and CDR) design based on V-supports
  - High manufacturing tolerances for girder and supports → high cost
  - AS/SAS manufacturing tolerances,
    - all differnet
    - only 3 points supporting AS from outer surface of core

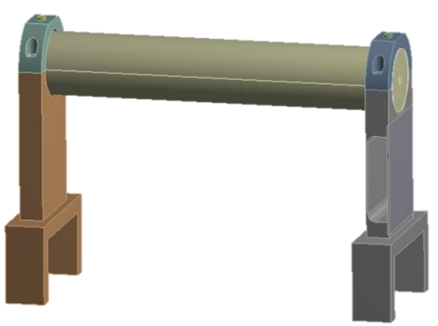
    -> High manufacturing requirements for AS outer surface
  - Installation/thermal expansion → scratches, missmatching, missing accuracy, missalginment

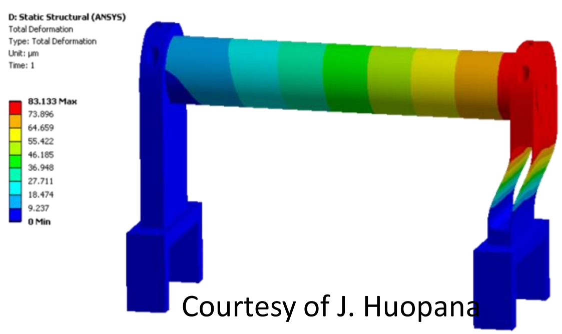


Position of the structures







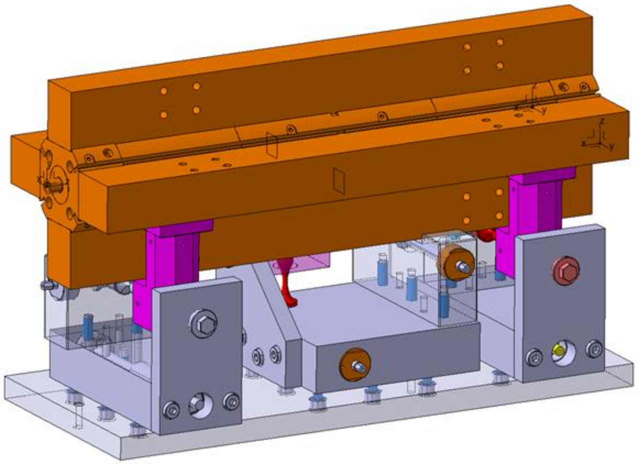


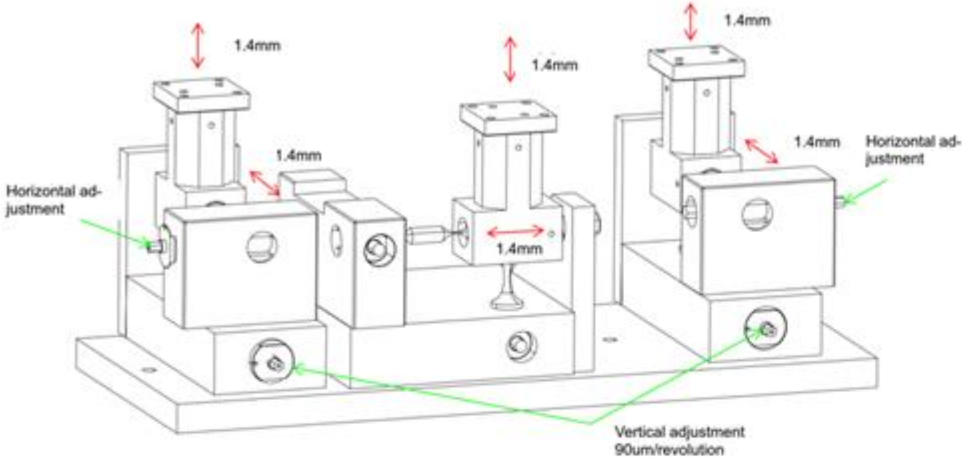
Courtesy of J. Huopana

Courtesy of Anna Zemanek

First prototype design

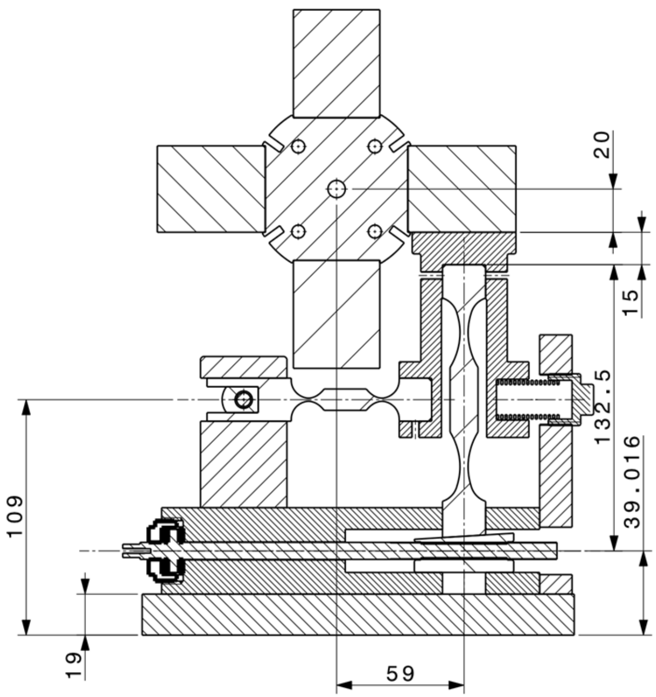
- 3 supporting points
- 6 DOF
- 1µm accuracy
- ~2 mm range
- Current girder
- Standard ”milking machine” interface (Mateusz Sosin DBQ support interface, UAP)

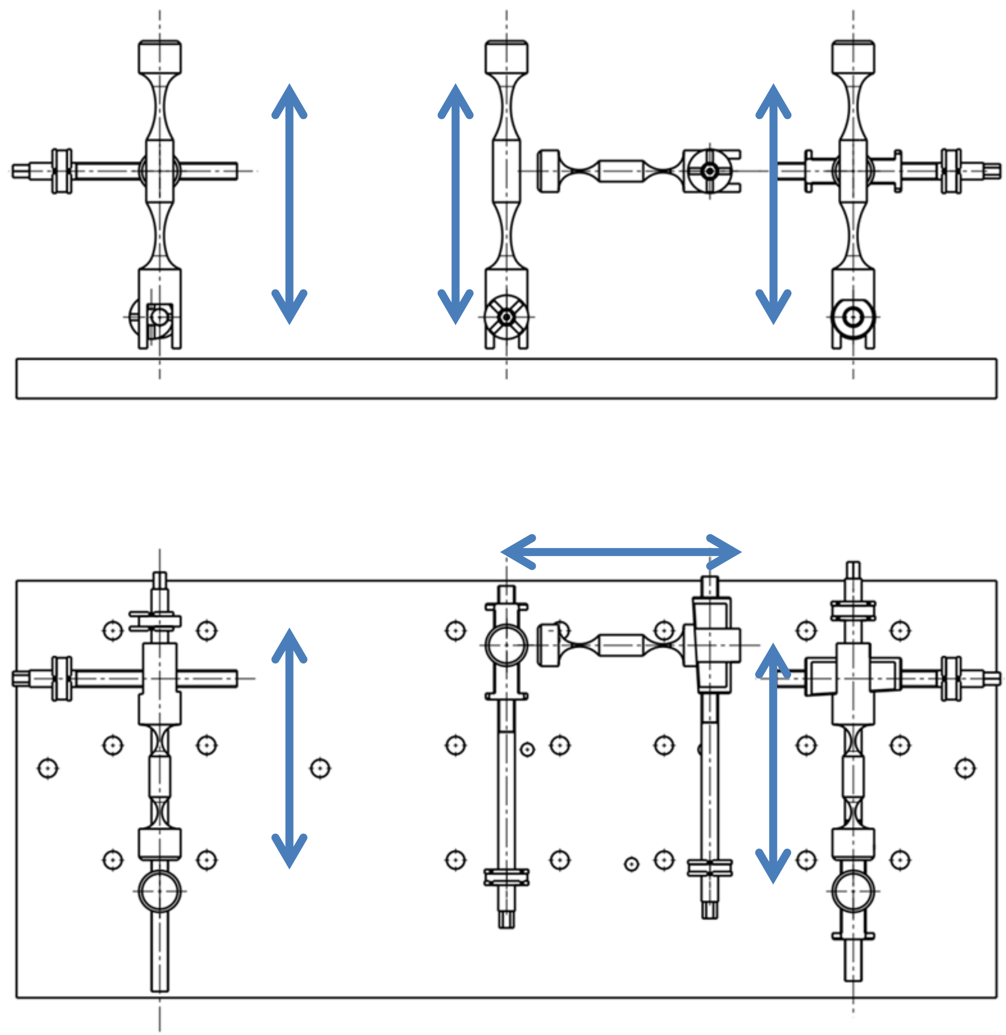




First prototype

- 3 x 2DOF
- Wedge driven
- Standard interface
- Limitied space between AS and girder

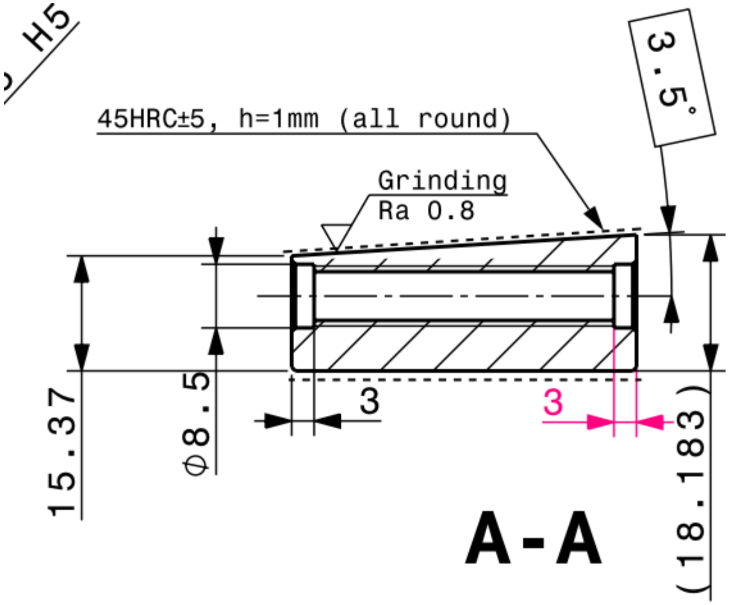




Operational conditions

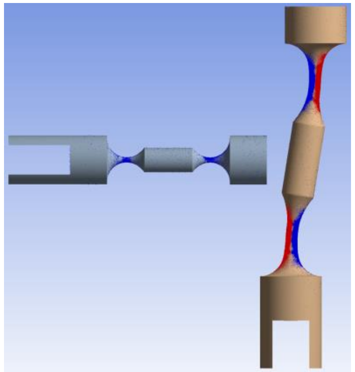
Wedge-rod

- Thread Tr.8 1.5
- Wedge length 46mm
- Wedge angle 3.5°
- 1 revolution→1.5 mm→90µm
- Range ~1.4 mm (±0.7)



Simulation results by Ed Lam

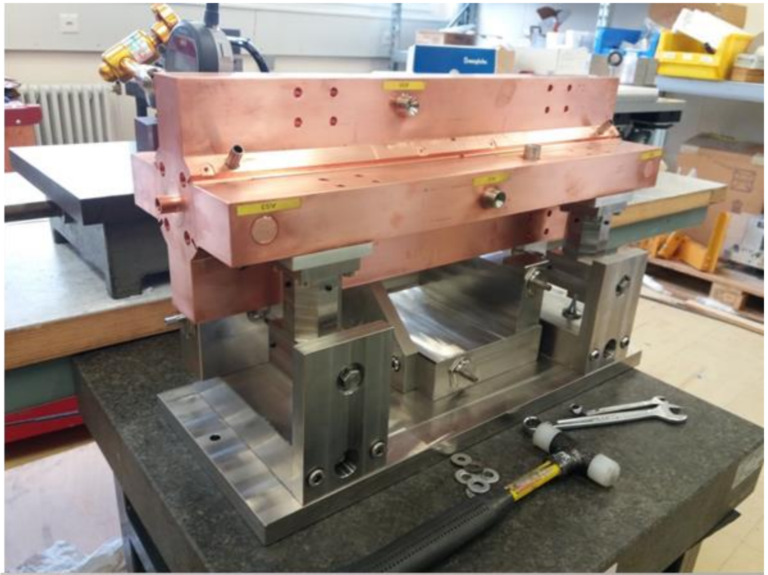
Vertical Bar	Displacement range of the horizontal bar (only horizontal adjustment)	Displacement range of the vertical bar (only vertical adjustment)	Displacement range of both bars (simultaneous adjustment)
0.5 mm thicker	Up to 1.82521 mm	Up to 1.40390 mm	Up to 1.35708 mm
Original	Up to 1.95669 mm	Up to 1.58024 mm	Up to 1.41851 mm
0.5 mm thinner	Up to 2.10496 mm	Up to 1.78631 mm	Up to 1.48287 mm
1 mm thinner	Up to 2.30213 mm	Up to 1.98169 mm	Up to 1.59089 mm

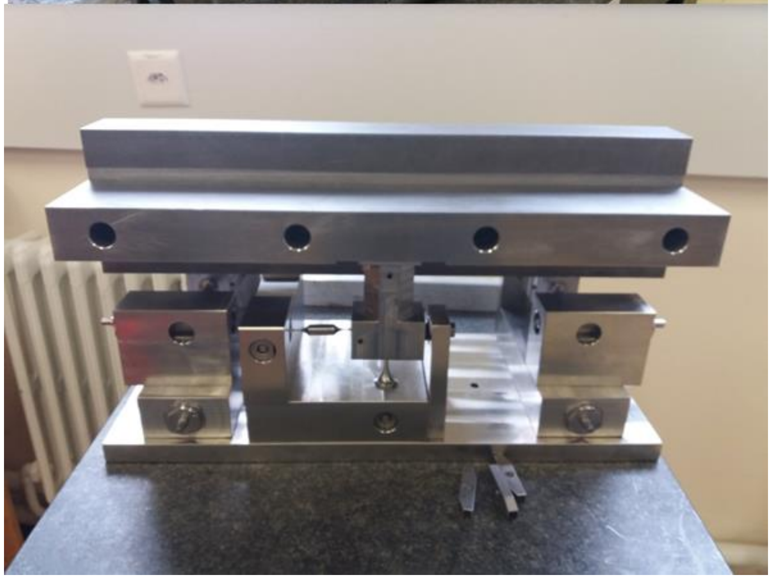


Material: 30CrNiMo8
Yield strength: 1.034E+09 Pa
Ultimate strength: 1.158E+09 Pa

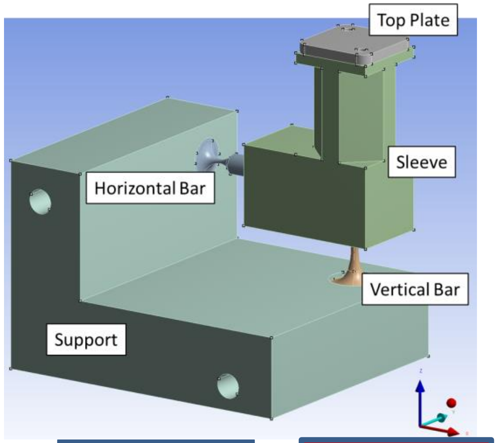
First prototype, manufacturing

- Two sets of components manufactured by 2 companies
  - Metsi Oy (FI) Stainless steel components
  - Mectalent Oy (FI) high strength steel+ heat treated (subcontracted) components
    - Bars, rods, wedges
- Assembled at CERN/S.Lebet
- Some fitting problems-one manufacturer could verify the fitting in house before delivery
- First assembly, transportation test AS used as AS, Second assembly additional steel mockup manufactured at CERN workshop (equal weight)

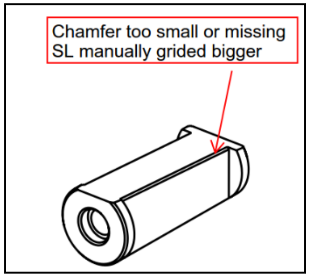


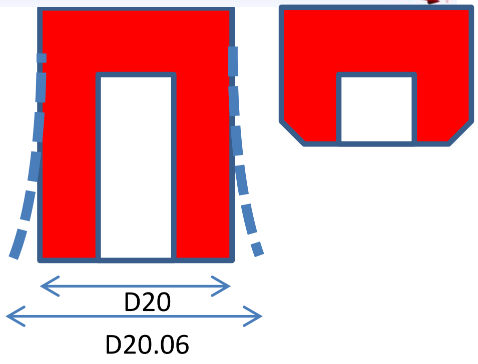


Fitting errors in assembly



- **During the installation some fitting errors were observed**
- **Bars-holes tolerances**
  - Reason: Tolerance definition perhaps too optimistic and tight
    - (but same tolerances in top end of the bar without problems)
  - Reason: Bars lower end, (fork) deformed in heat treatment
    - Estimated/measured deformation 0.05-0.06 mm, (measurement S.L)
      - -> holes machined bigger (D20.1mm, S.Lebet)
      - -> fork shape shortened, corner chamfered (manually, S.Lebet)
- **Wedge-bar contact surface**
  - Chamfers (0.5mm) missing/too small wedge
    - Reason: Unclear drawing interpretation?
      - -> Chamfers grinded manually to wedge



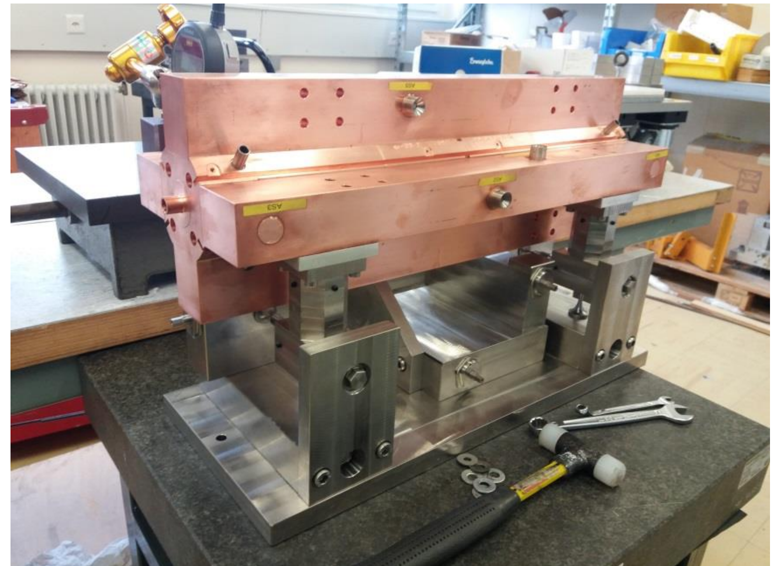


- **Burs -> deburring** (some corners and threads)
  - Nuts, threads, holes
  - → Holes drilled bigger, deburring and girnding manually (S.Lebet)
- 2 operation thread bars were missing, (missing from order confirmation), new rods manufactured at CERN workshop with lower tolerances from ICONEL

- **Other improvements for next version:**
  - Installation quidance for wedge/bar
  - Placement indicators (0-position etc.)

Verification, measurements

- Preliminary funcitonality test
  - 1 µm accuracy achieved
  - Nominal movement according to design (90um/r), except longitudinal
  - Measurements performed with Mitytoyo dial indicator with arm in 169 lab
  - Good response, reverse first ½ round only 20 um, then ok
  - Difficulties to find the 0-position
  - Counter forces with springs, adjusting right spring force (not optimised for transportation yet)



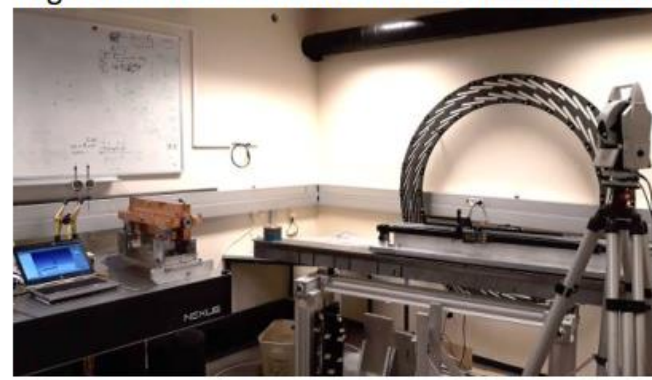
Verification, survey team report

- Same tests than for Universal Adjustement Platform (UAP)
  - Single translation test
    - 5 iterations, mostly within precision of AT401
  - Spatial translations test
    - 5 iterations, mostly within the precision of AT401
  - Single rotations test
    - 3 iterations/rotation, under 100urad
  - Spatioal translations and rotations test
    - 3 itrearions/motion, results within the procision of AT401 (les tan +-20µm, +-50 µrad
  - Stability in transport test
    - Measurement→100m transportation in corridor-remeasurement
    - Repeated 5 times, displacement under 50 µm
- Equipment
  - Lasertracker AT401
  - Precicion in 1m 10.3 um, 2m 14.4um

Resolution test

axis	resolution [mm]
X	0.001
Y	0.001
Z	0.001

Alignment of the UAP with AT and watch window



Range test

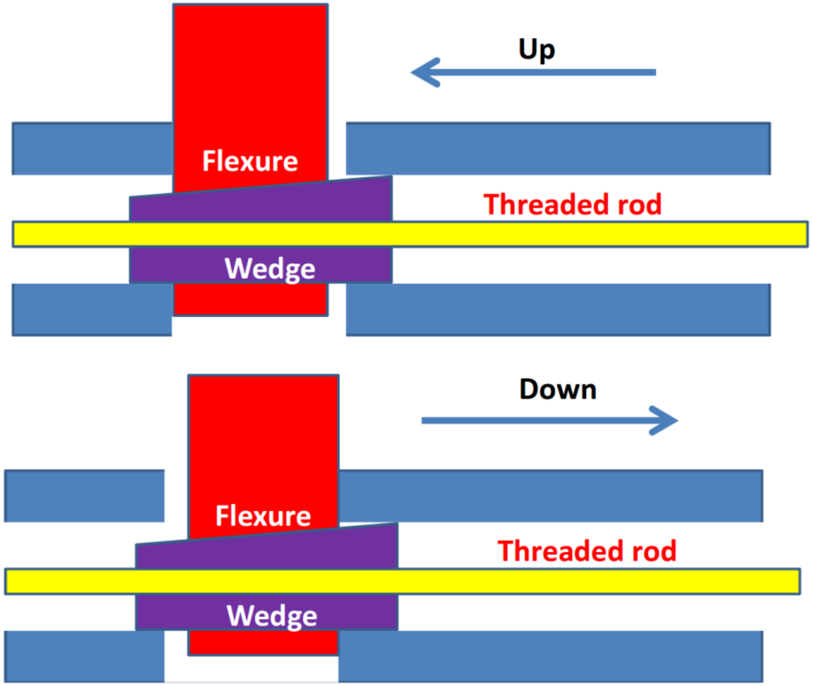
axis	no. rotations	range [mm]	app. centre [mm]
X	15-15.5	1.173 1.344	0.629
Y	15.5 (5.5)	0.867	0.434
Z	15.5-16	1.426 1.435 1.409	0.712

4 SUMMARY

- The resolution of movement along each axis is 1µm.
- The range of movement depends on the axis. For the the longitudinal it was 0.867mm instead of 1.225mm. The range on this axis after adjusting the wedge pushing spring was changing throughout the time. Possibly the spring is not strong enough to counteract the AS weight.
- The 3D precision of the AS platform alignment is below AT401 precision on 2m distance – 15µm. Rotation precision below 50µrad.
- The 3D alignment of the platform in typical conditions would take around 15 - 20min.
- Placing the knobs at all sides of the platform increased the time of alignment and made it more uncomfortable. It could also mean a decrease in precision if the Platform is touched while trying to reach the knobs.
- Stability of the platform was satisfying (displacements below 50µm), except for the Y axis. Possibly caused by the spring on the Y axis jig.
- The jig responsible for the vertical axis near fiducial number 3 and 4 blocked couple of times during rotations. After applying some force it moved with the whole platform to the designated position.

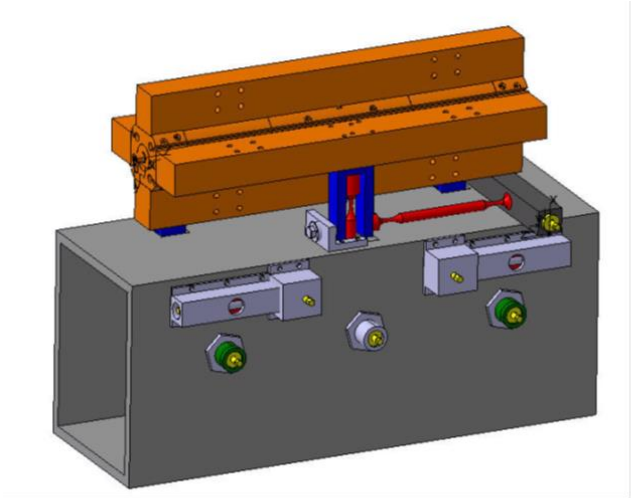
Results

- Despite of all tolerance releases and manual modification work, accuracy of 1 µm was achieved
- Longitudinal operation not working as it is supposed to, due to thinner and shorter bar, spring forces or what?
- Changing direction -> some delay in movement (only 20um for first 0.5-rotation)
  - Due to backlash in thread and holes?
- Operational order - approaching target position always from same positive direction would give more reliable results
- Stability- not optimal- influence of spring forces-not optimised for transportation

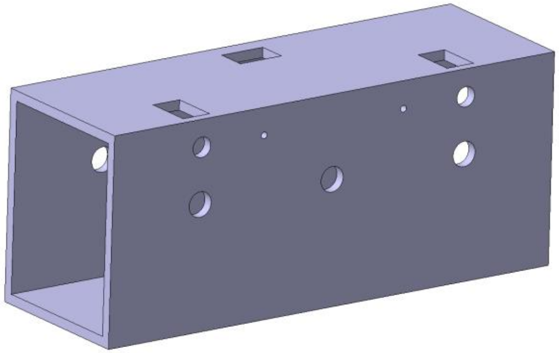


Second prototype

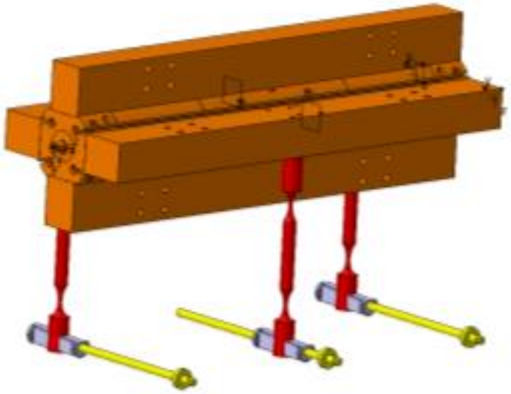
- High precision girder + V- or adjustable support
  → low precision girder + adjustable support
- Adjustable support integrated to girder
  - More space to flexueres+systems
  - Less/simplier components?
- Low/normal manufacturing tolerances for girder
  - Hollow steel profile (200*300*10)
    (see Alex's simulations for profile 150*300*10)
- Improvements to first prototype
  - integrated design
  - lower material and manufacturing cost
  - longer flexures - larger range
  - all operations from same side
  - compatibility with the "milking machine"
  - assembly features
  - position indicators



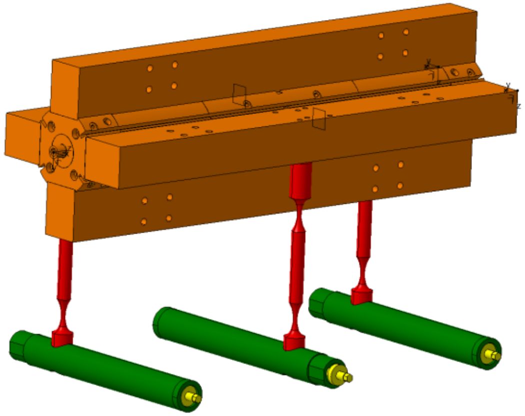
Prototype design V2, vertical



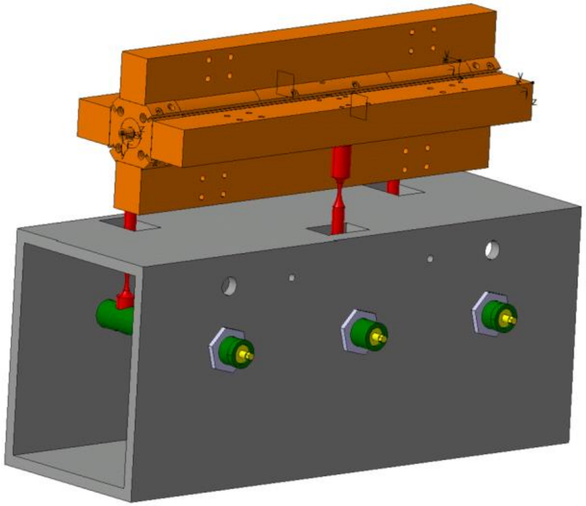
Steel girder 200x250x10
Standard machining for holes



Longer flexures, more range
Limiting component middle wedge

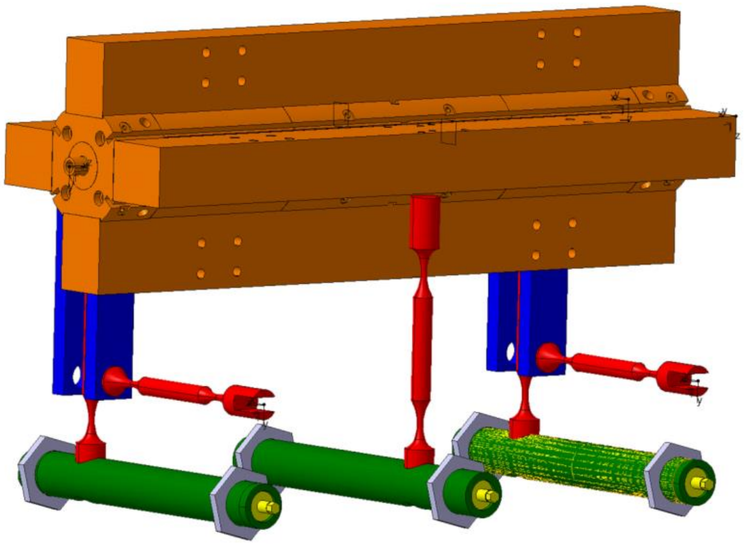


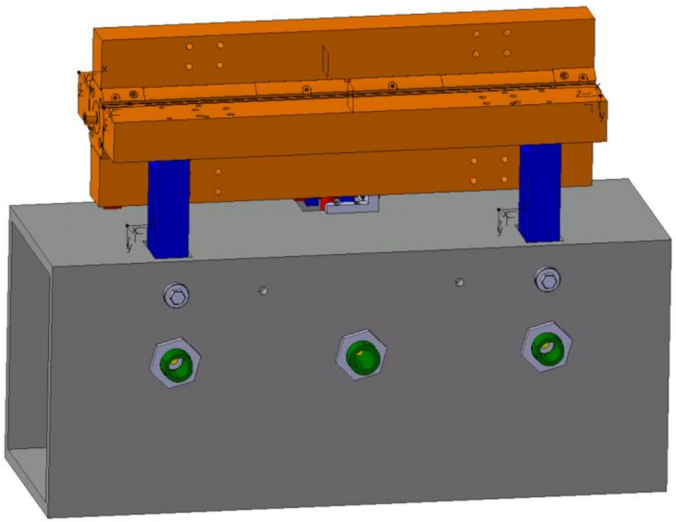
Rods+ wedges to sylinders

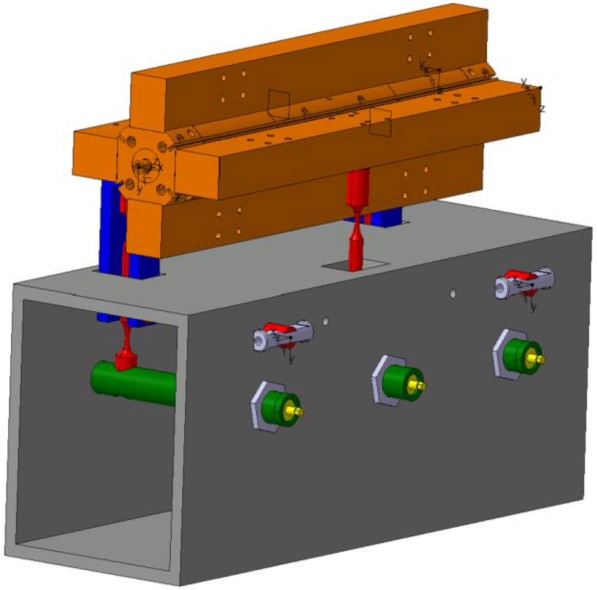


Cylinders mounted to girder with nuts
(prealigning)

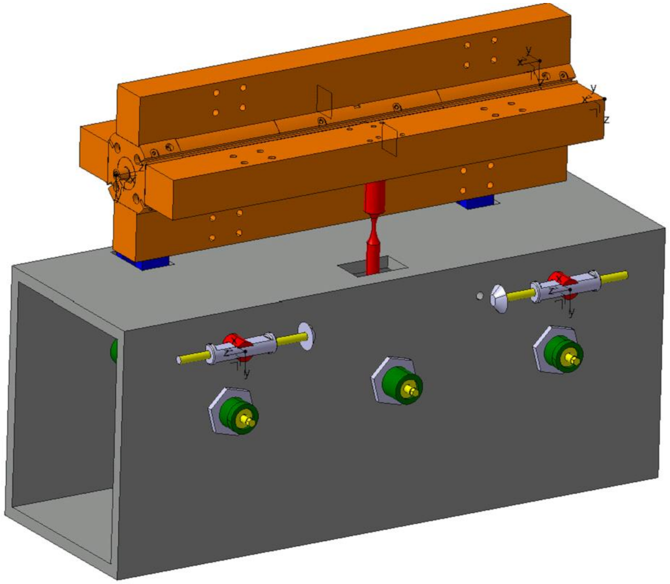
Prototype design V2, lateral

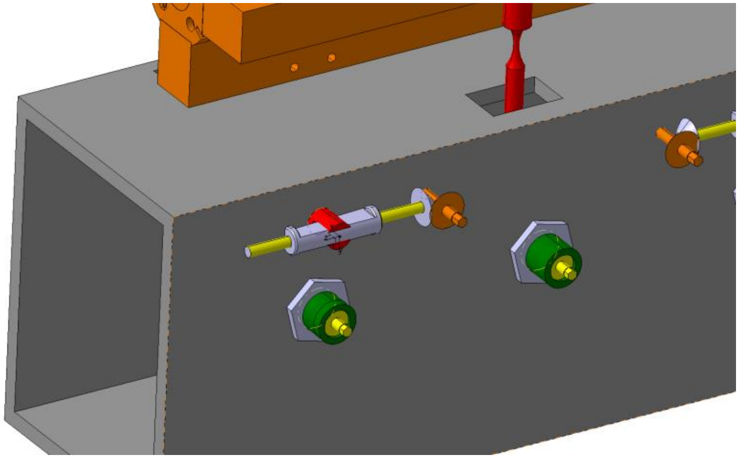


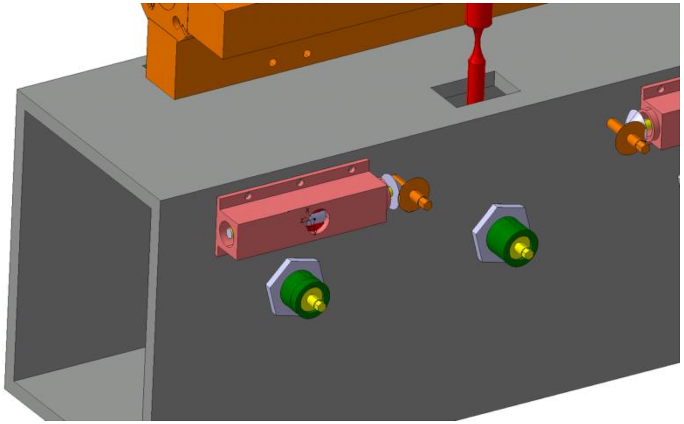


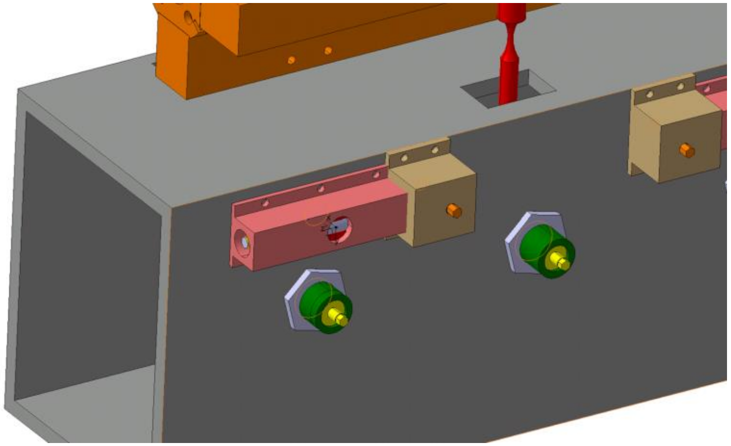


Prototype design V2, lateral

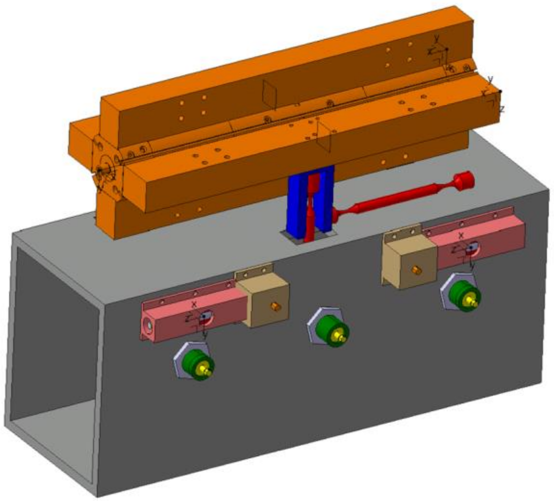


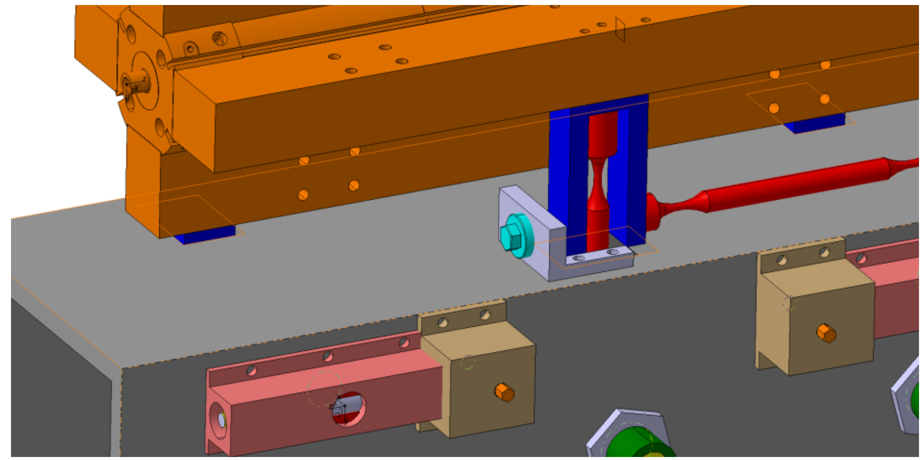


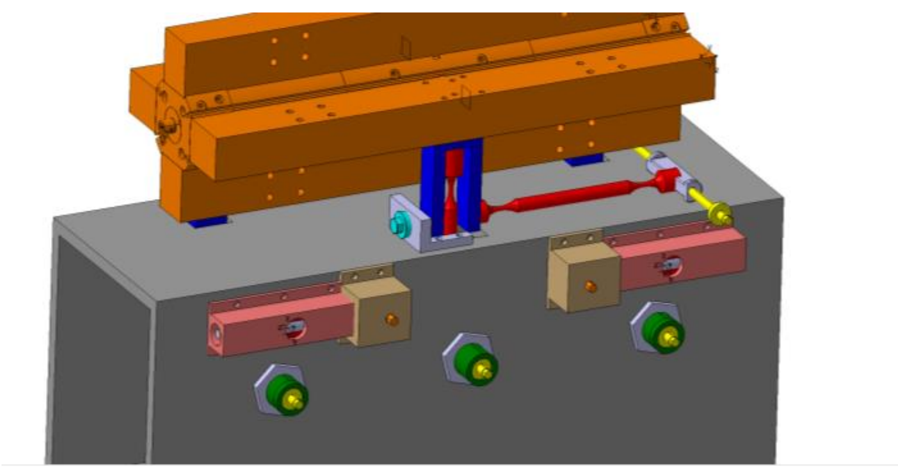


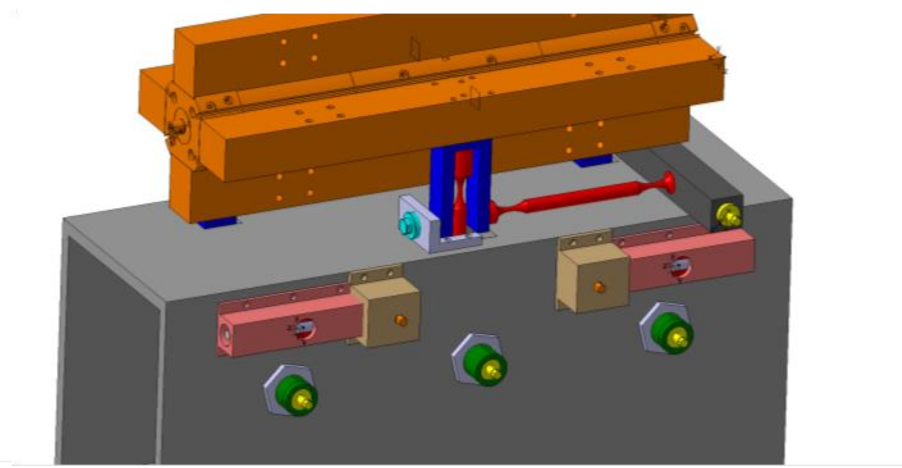


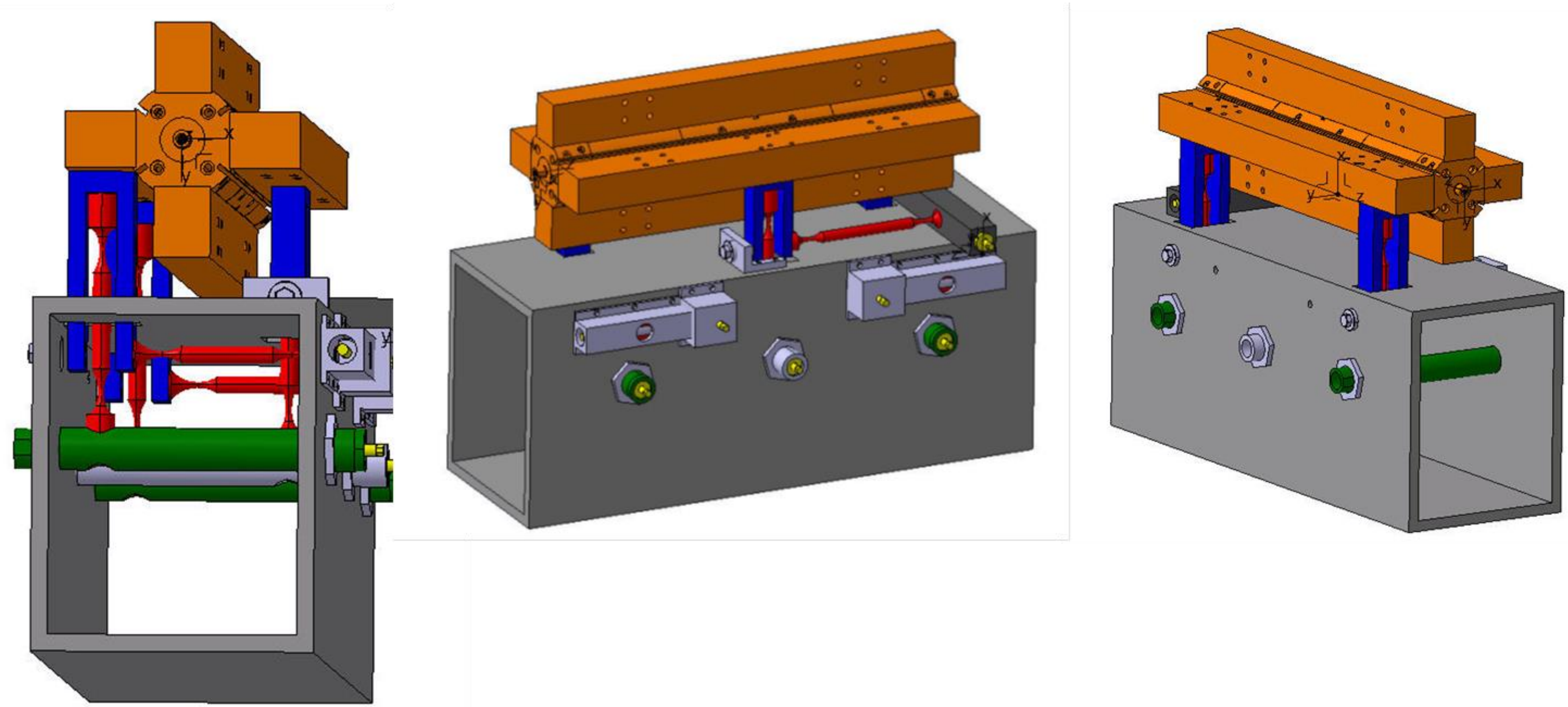
Prototype design V2, longitudinal







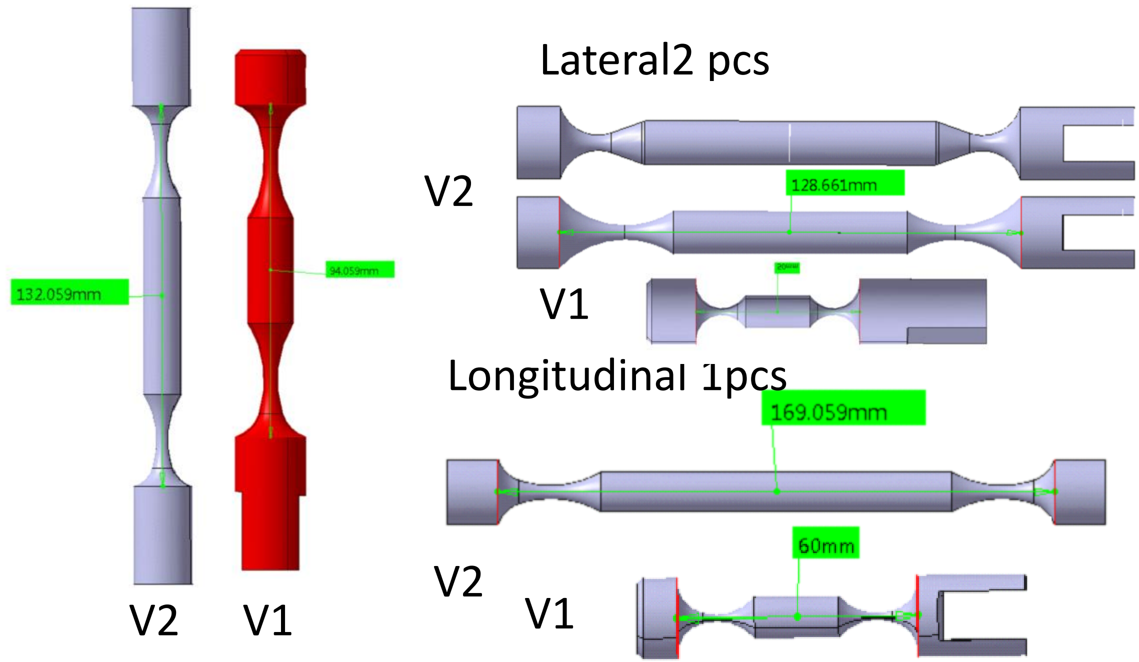




Operation bar comparison

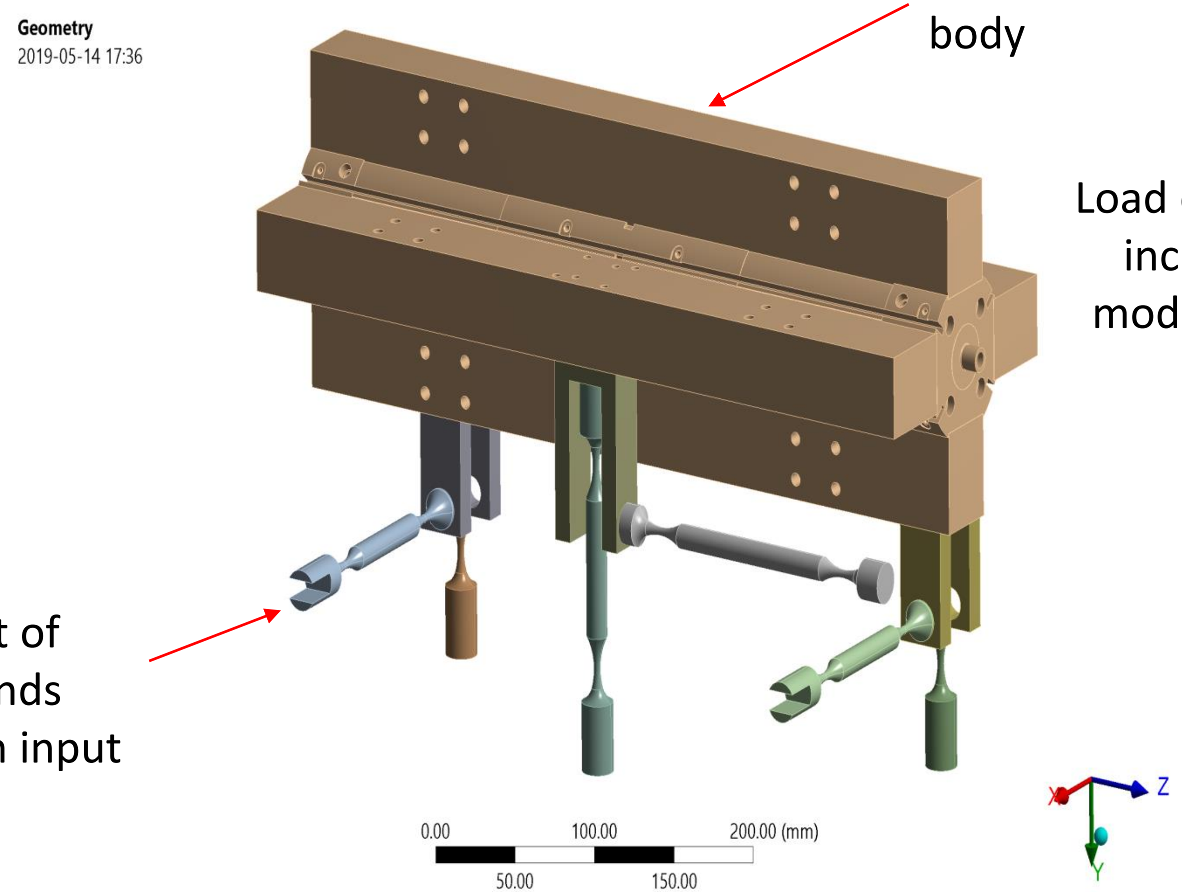
- Bar geometry
  - Length
  - Cross section geometry

➔operation range



Single bar range for V2 app. ±2mm
Combined range worst case ~0.5
➔ optimisation

Full System Analysis Set-up

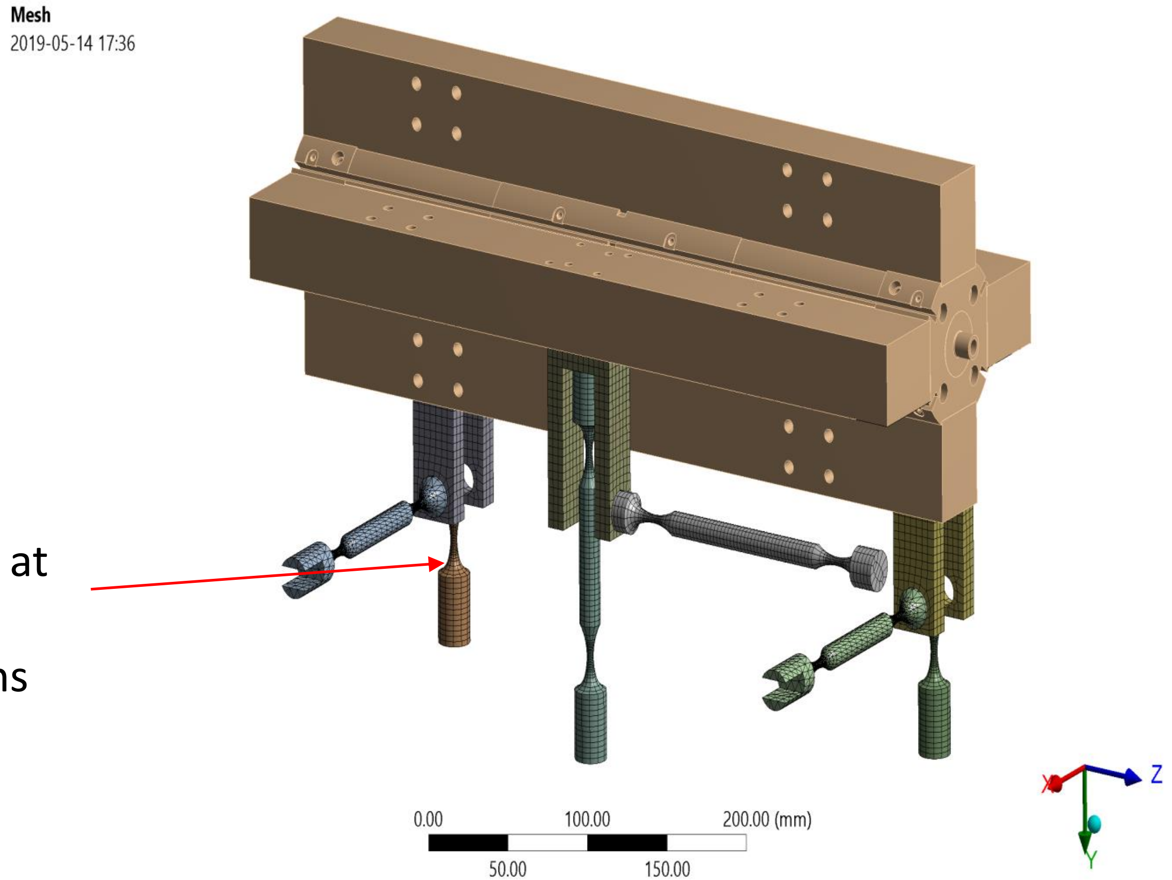


AS treated as rigid body

Load due to gravity included (only modelled bodies)

Linear displacement of the flexure ends defined as an input

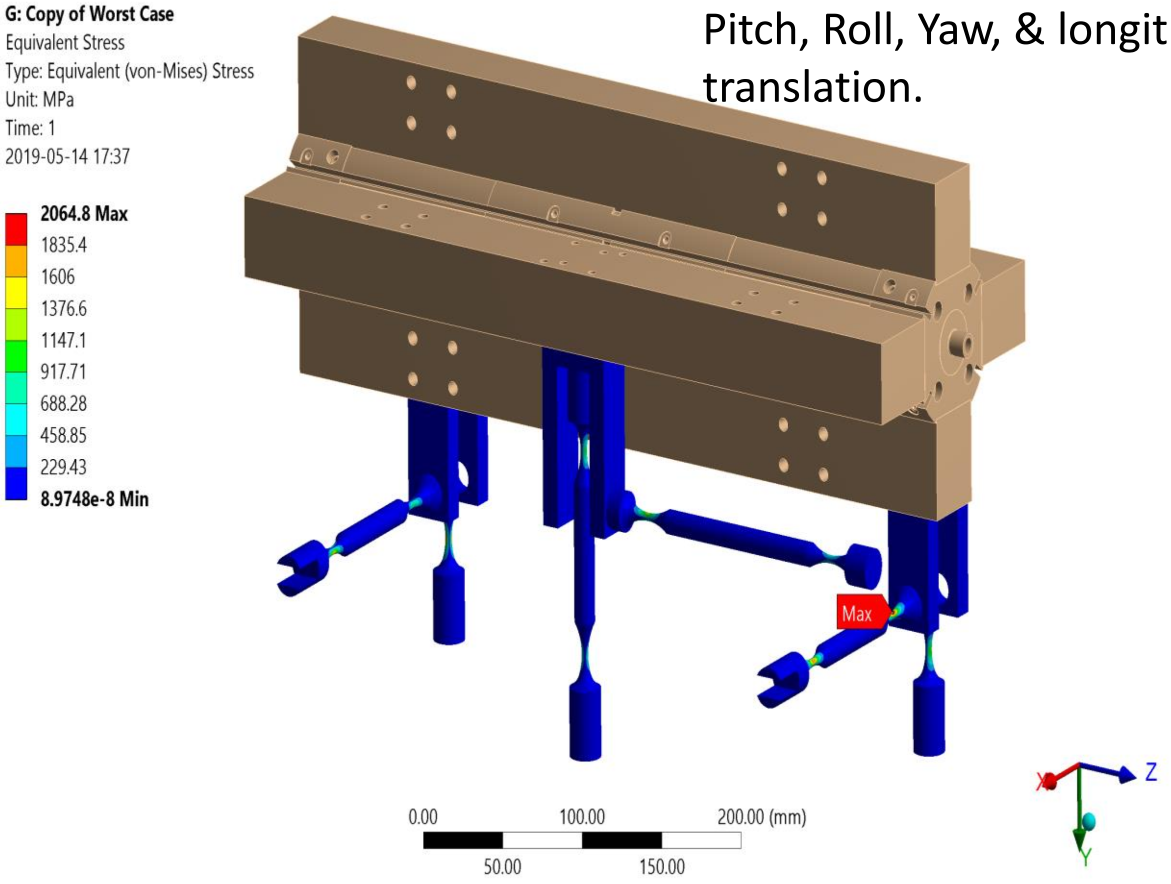
Full System Analysis Mesh



Mesh refined at flexure stress concentrations

‘Worst Case’ Max Stress

‘Worst Case’ encountered when the during a combination of maximum Pitch, Roll, Yaw, & longitudinal translation.

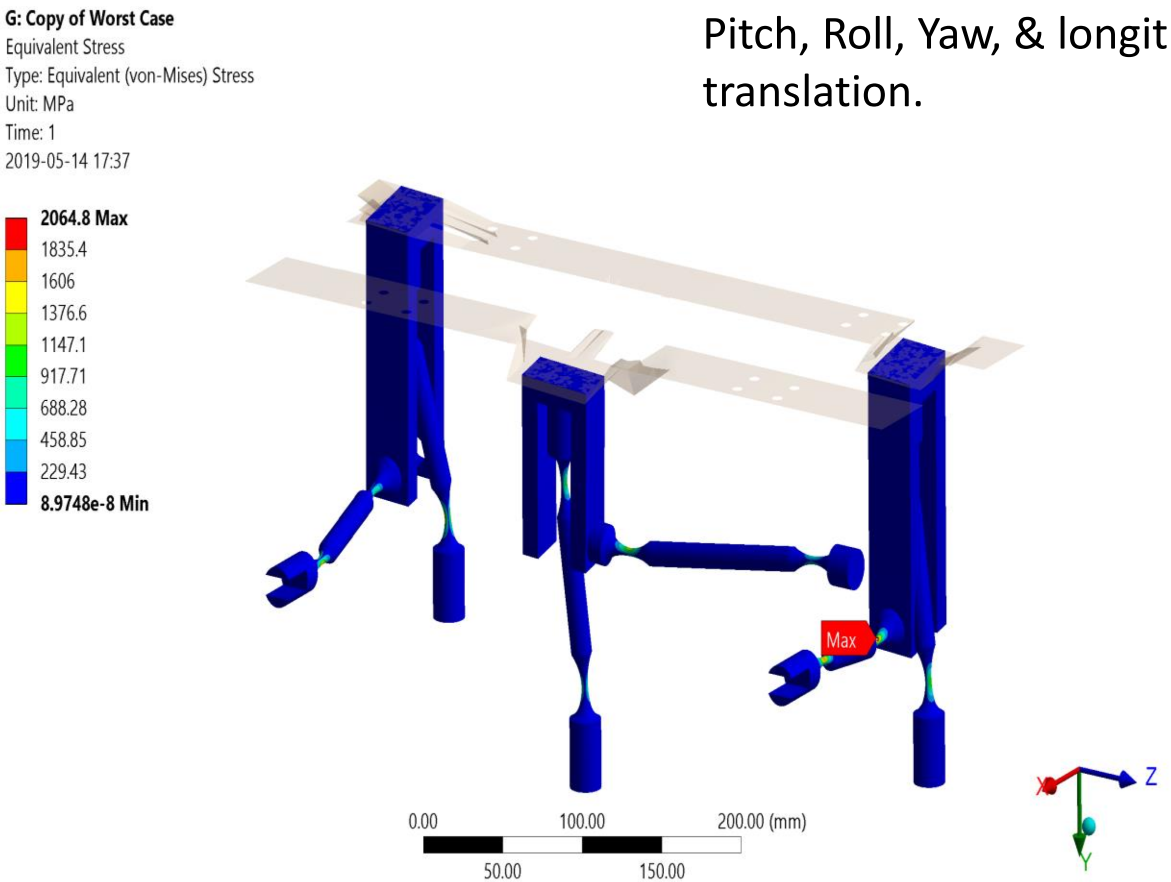


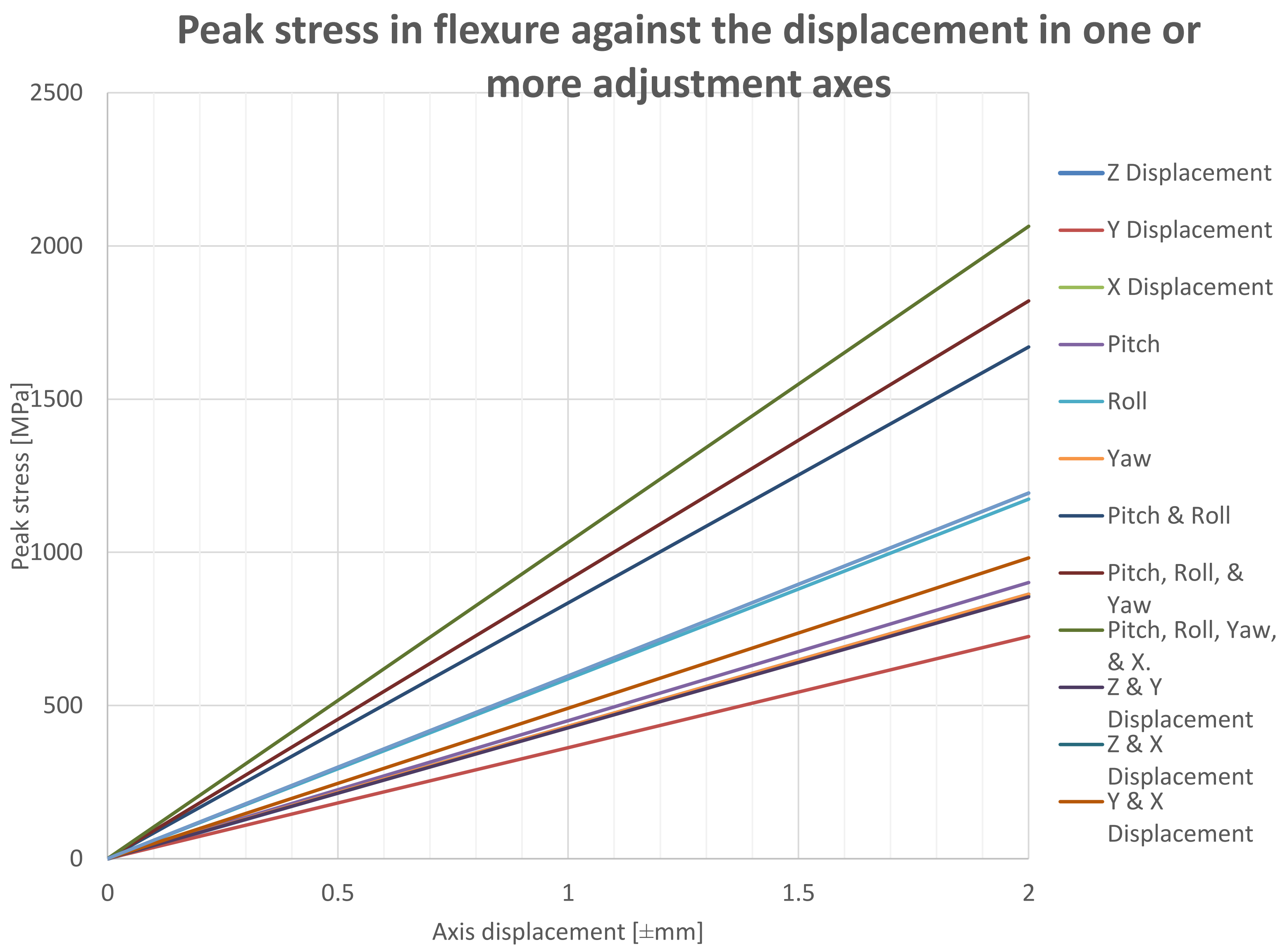
Stress due to 2mm deflection shown here, due the substeps were also calculated: results were linear

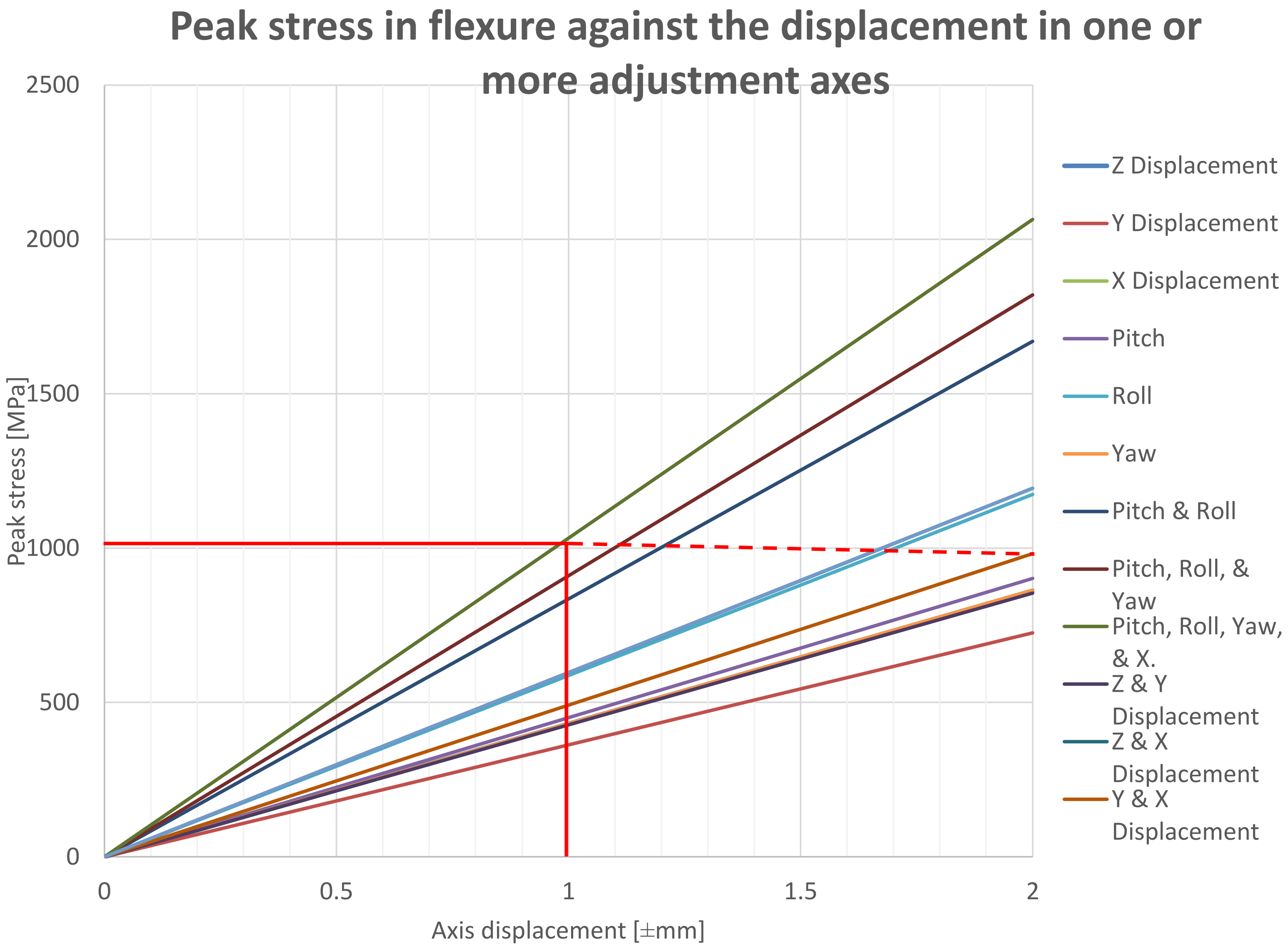
‘Worst Case’ Max Stress (Exaggerated)

‘Worst Case’ encountered when the during a combination of maximum Pitch, Roll, Yaw, & longitudinal translation.

Stress due to 2mm deflection shown here, due the substeps were also calculated: results were linear

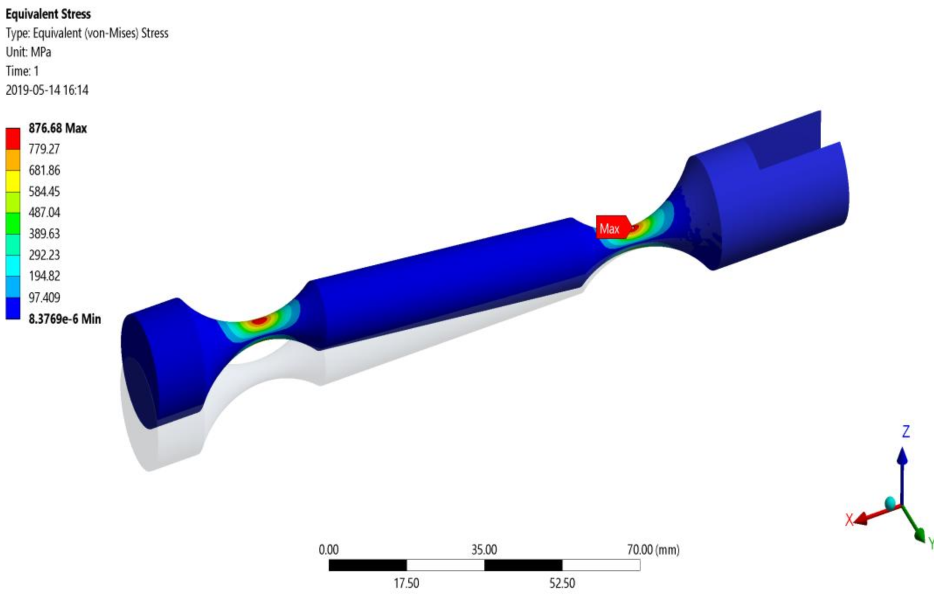


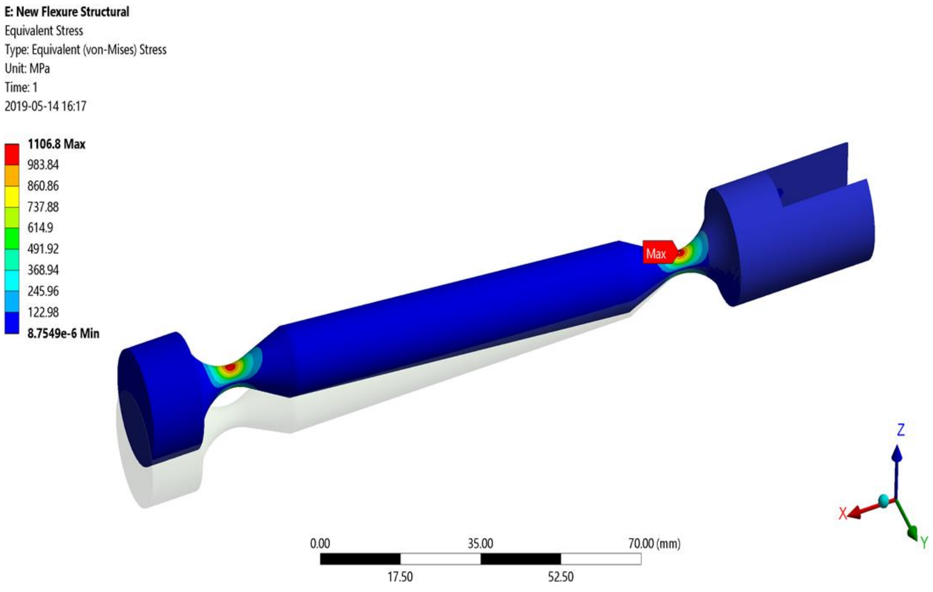

Peak stress in flexure against the displacement in one or more adjustment axes
Peak stress [MPa]
2500
2000
1500
1000
500
0
0
0.5
1
1.5
2
Axis displacement [±mm]
Z Displacement
Y Displacement
X Displacement
Pitch
Roll
Yaw
Pitch & Roll
Pitch, Roll, & Yaw
Pitch, Roll, Yaw, & X.
Z & Y Displacement
Z & X Displacement
Y & X Displacement



Peak stress in flexure against the displacement in one or more adjustment axes
Peak stress [MPa]
2500
2000
1500
1000
500
0
0
0.5
1
1.5
2
Axis displacement [±mm]
Z Displacement
Y Displacement
X Displacement
Pitch
Roll
Yaw
Pitch & Roll
Pitch, Roll, & Yaw
Pitch, Roll, Yaw, & X.
Z & Y Displacement
Z & X Displacement
Y & X Displacement

Lateral Flexure Investigation

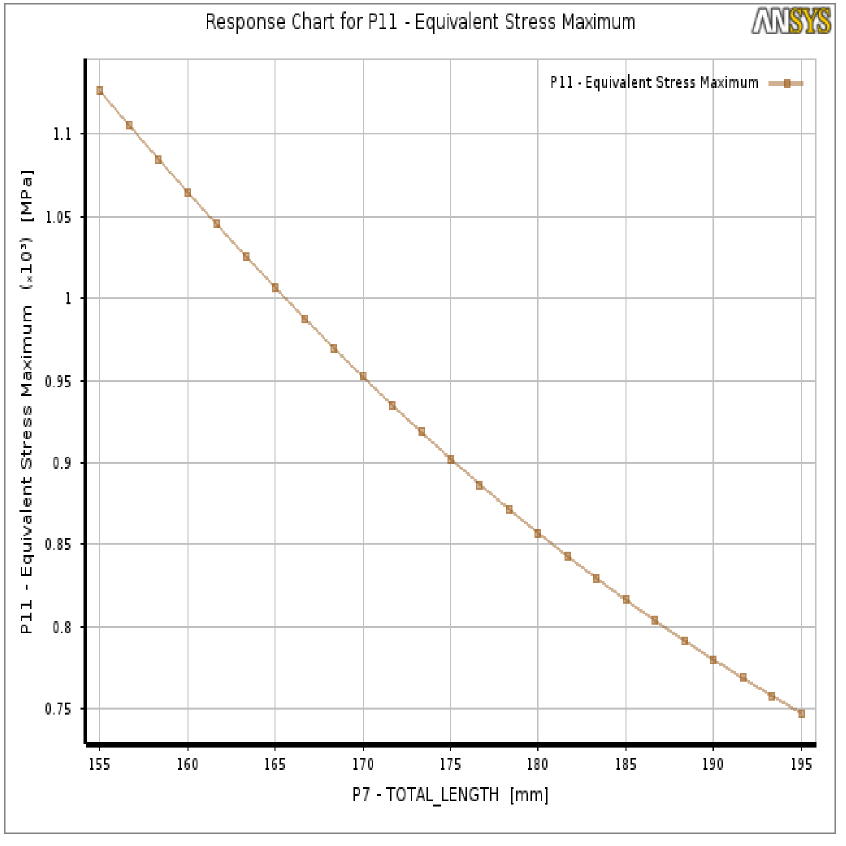


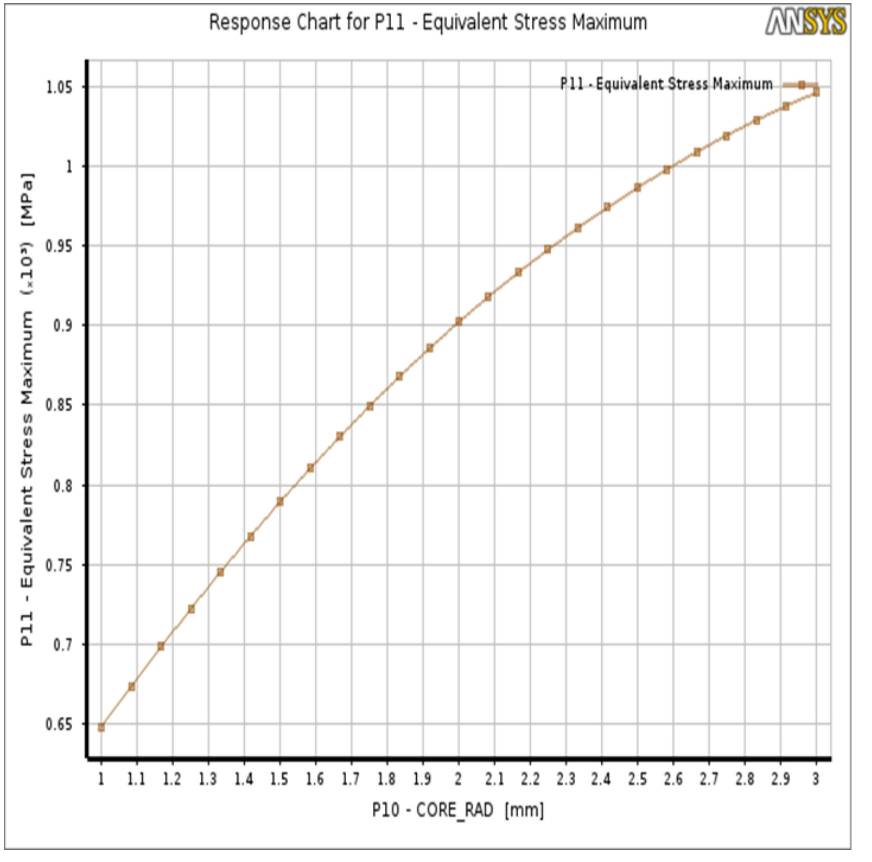


Initial design

Modified design

Design Optimisation

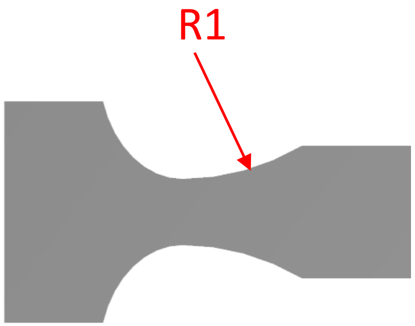


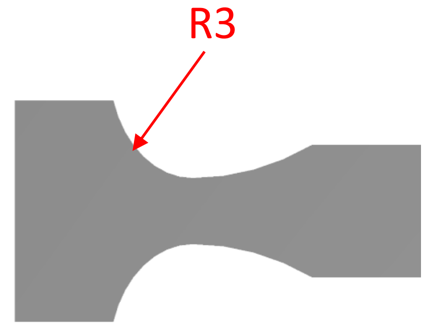


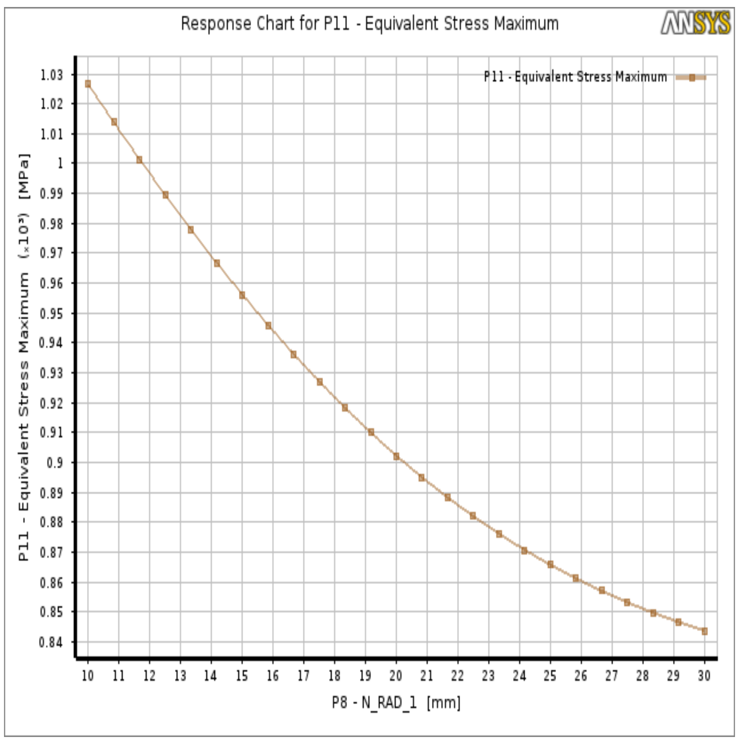
Length optimisation:
+5mm = -50MPa

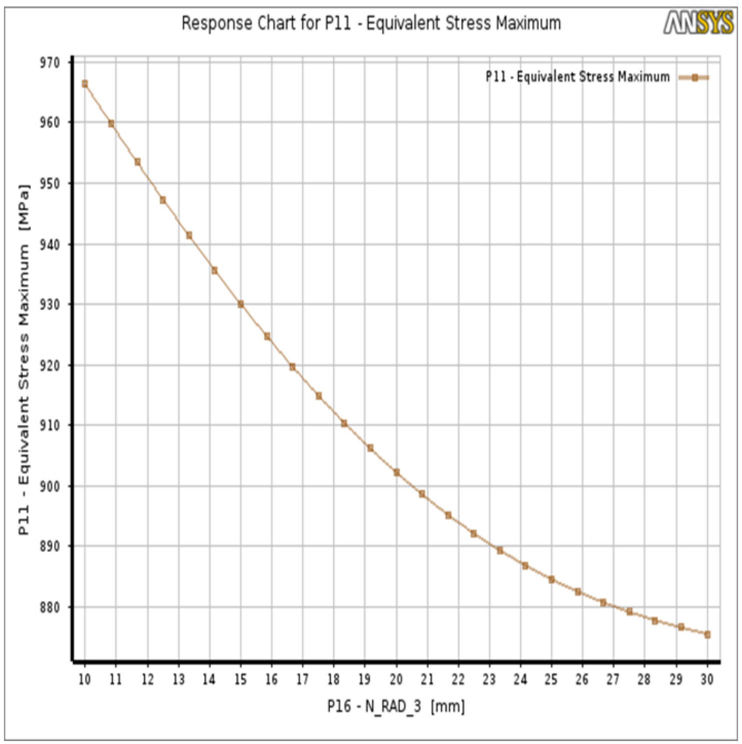
Core diameter optimisation:
-0.5mm = -100MPa

Design Optimisation







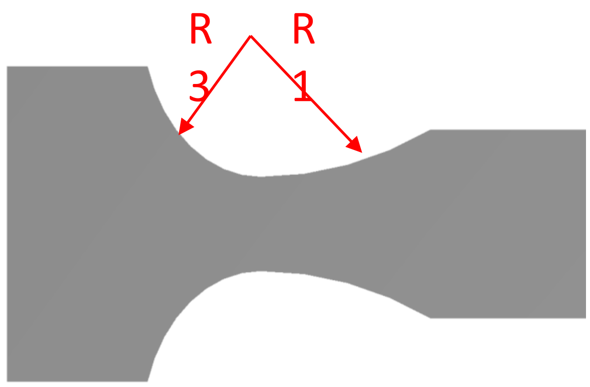


R1 optimisation:
+5mm = -50MPa

R3 optimisation:
+5mm = -30MPa

Combined Radial Optimisation

- If R3 is reduced and R1 is increased by the same amount the net affect is a reduction in max stress
  - Controlling all other factors
  - The narrowest point is moved further apart, effectively increasing the flexure length
- Effect is very small, probably not worth considering compared to the other factors



Conclusion

- First prototype: principle is working
- Limited range due to the availabe space especially if design based on worst case scenario
- Cost saving potential

Next steps

- Design optimisation
  - Range, operation, manufacturability
  - Availability of components
- Detailed drawings

Lateral Flexure Alternative Design