Thermomechanicle examinations for the design of the radiation cooled positron target

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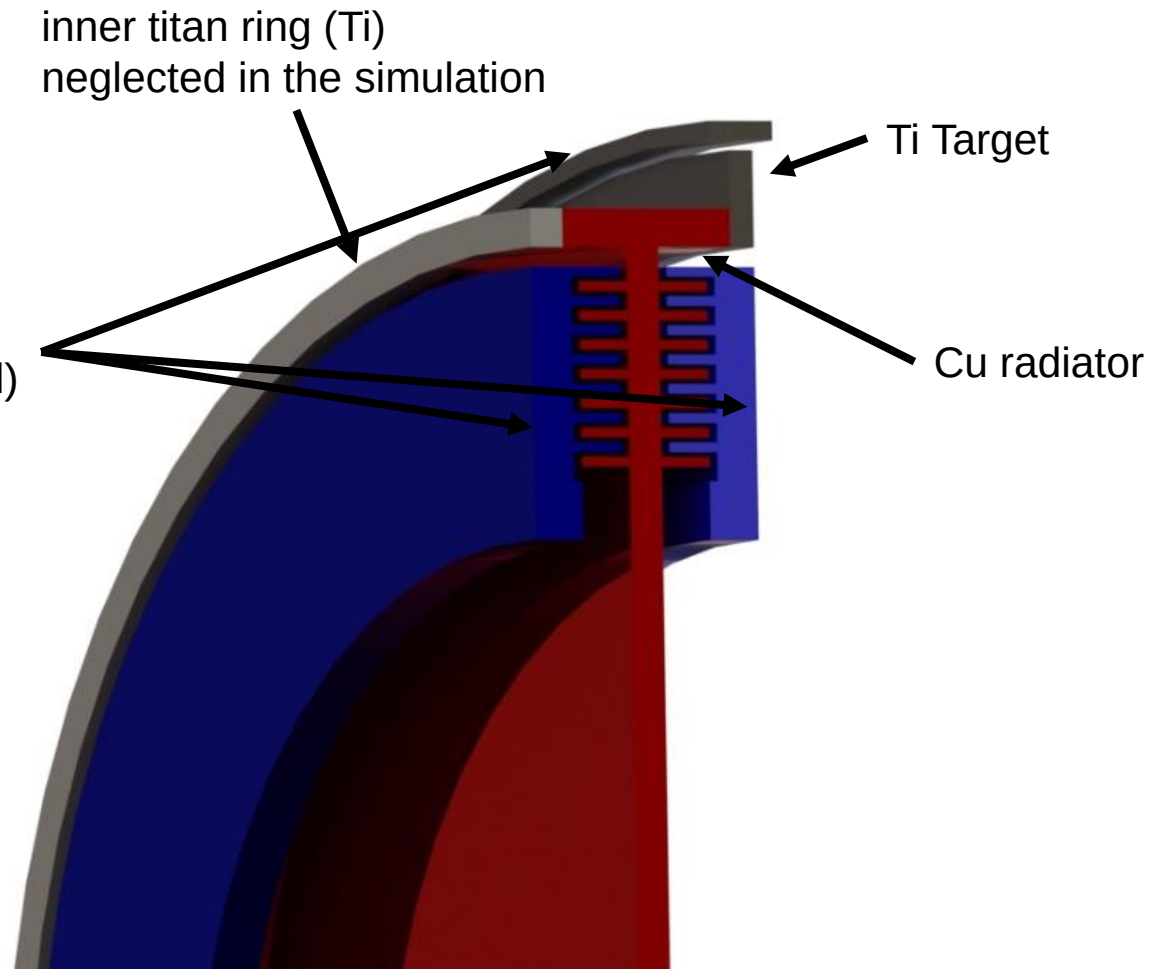
DESY

Outline

- The radiation cooled positron target
- Changes in the Models
- Firetree root
- Summary

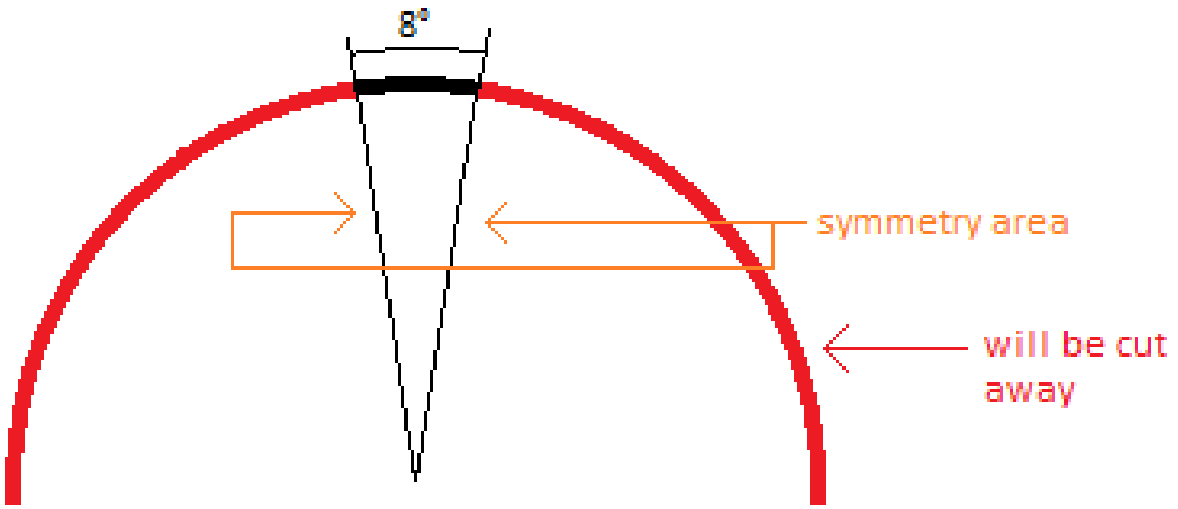
The radiation cooled positron target – used model

- Based on a proposal of Dr. Peter Sievers (CERN)
- Presented on last POSIPOL
- Titan ring is connected to a Copper disc
- Cooper disc radiates in to Fe-cool-bodies
- The titan ring has a thickness of 14.8mm



The radiation cooled positron target – the simulation set up

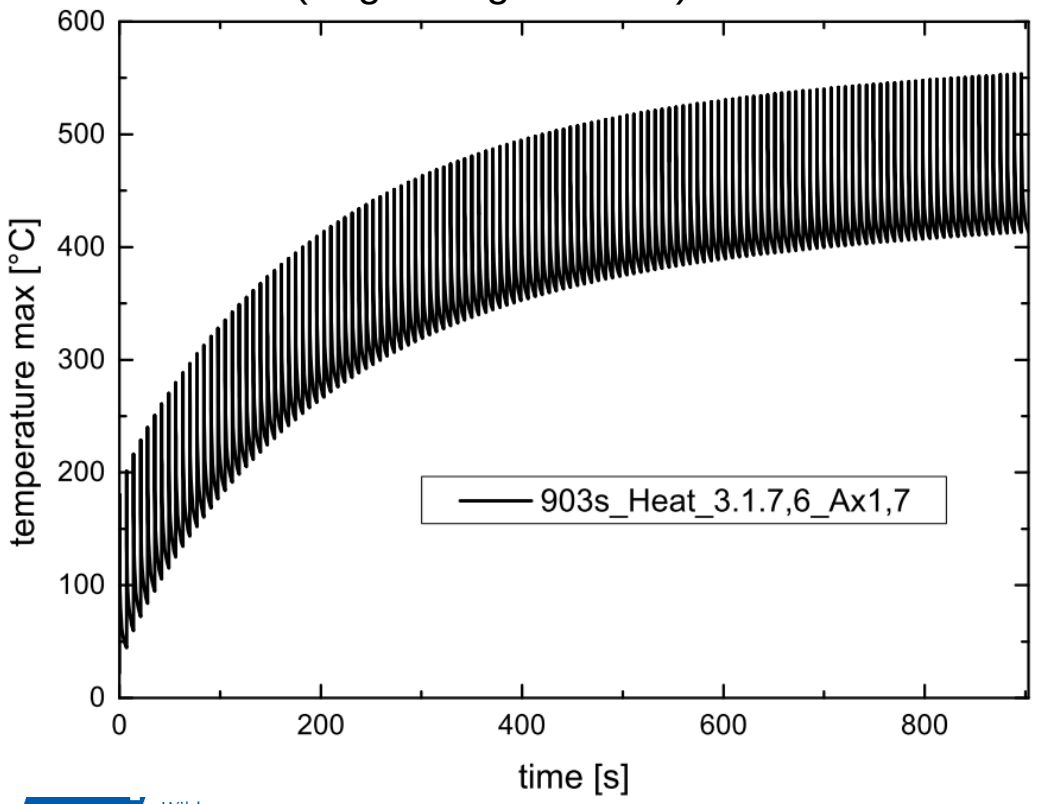
- only a „slice“ is simulated
  - The issue whether or not the target will be build sliced or not is not solved
  - the simulations can be assumed valid for both versions
- it has a length of 8°
  - hence 45 places can be hit
- the surfaces created by cutting are symmetry areas
  - results on that area will be „mirrored“
  - ANSYS will expect the same behaviour on the other side of the mirror
- Only the fins radiate (worst case)
- An FLUKA input is used for 2.3 kW
- **This applies to all simulations**



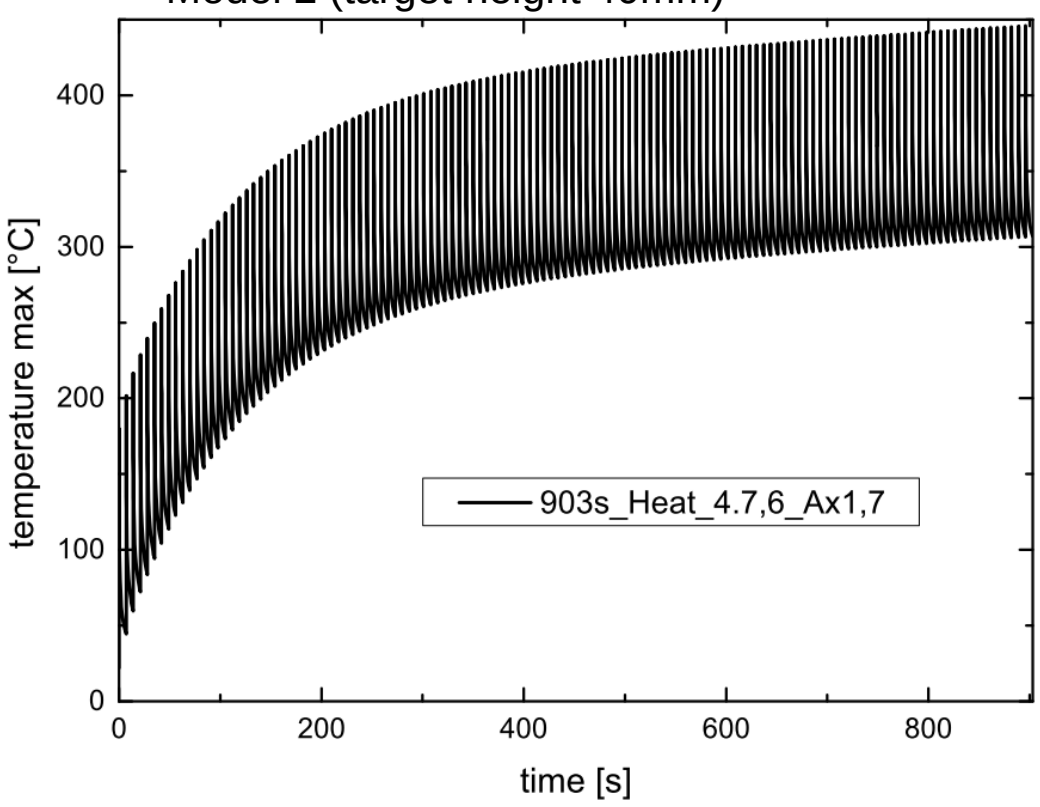
The radiation cooled positron target – Results from last year

- Results from last year
- Comparison of to different heights
- Result was that the height is crucial for the maximum temperature

Model 1 (target height 50mm)

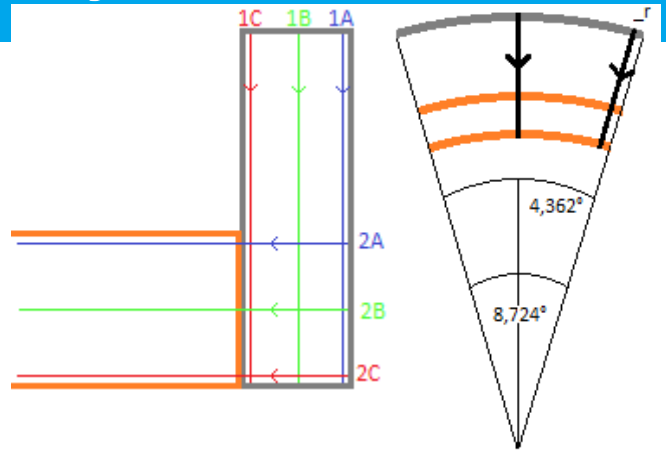


Model 2 (target height 40mm)

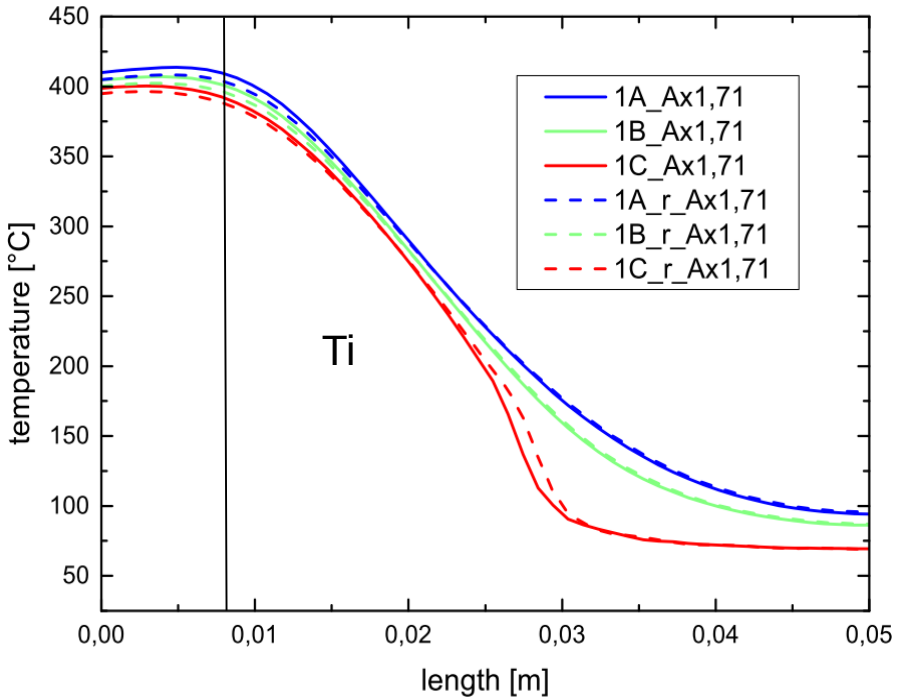


The radiation cooled positron target – Results from last year

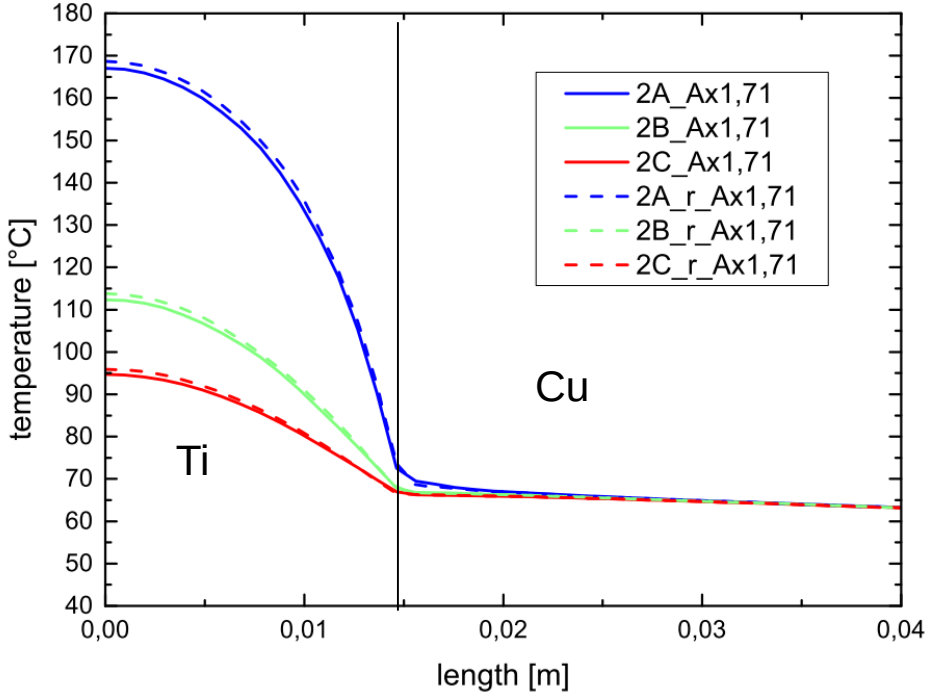
- Temperature in the Target along 6 path
- target height 50mm
- Time 895,58s (after 128th pulse short before 129th pulse)
- index r → same path but one the side of the target (4.362°)



vertical Temperature distribution



horizontal Temperature distribution



The radiation cooled positron target – Results from last year

- Temperature in the Target along 6 path
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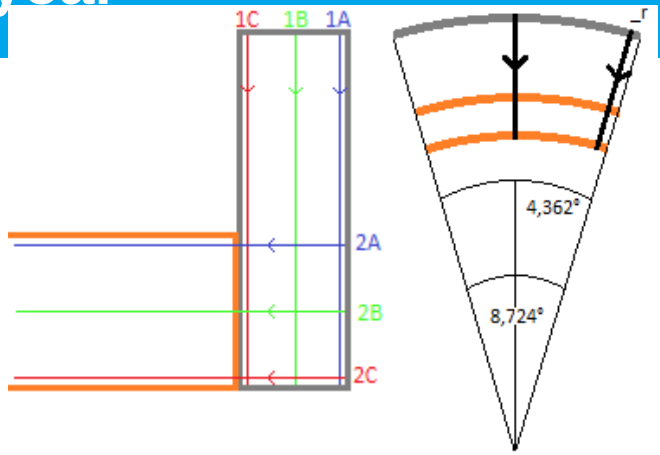
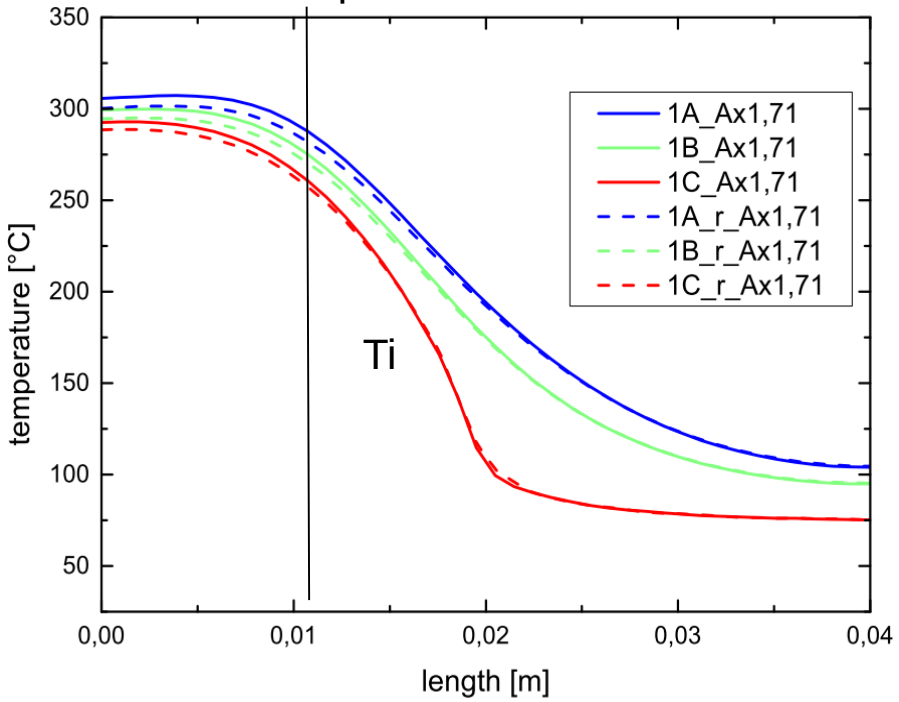
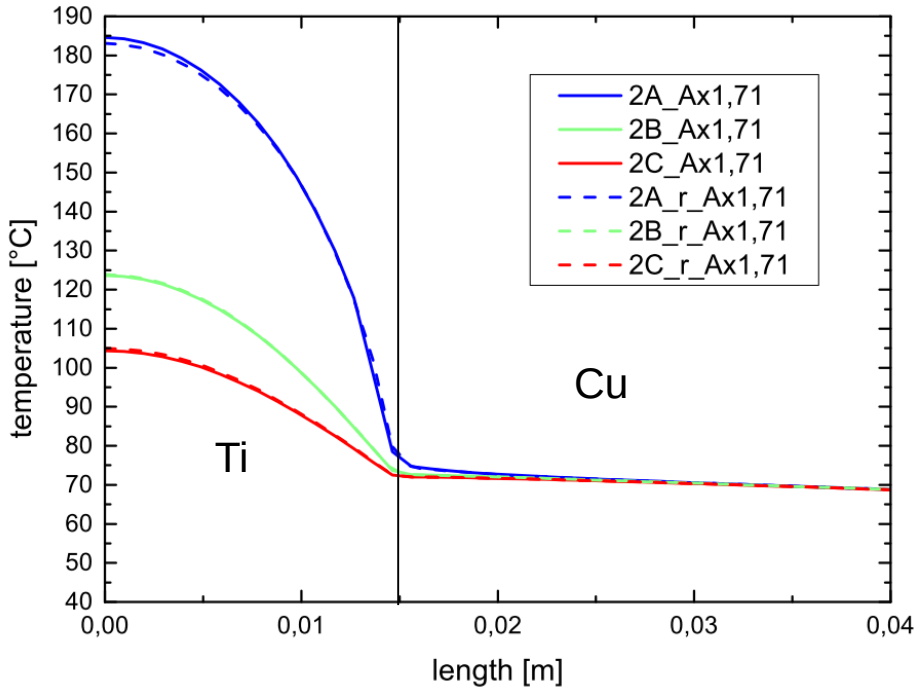


vertical Temperature distribution

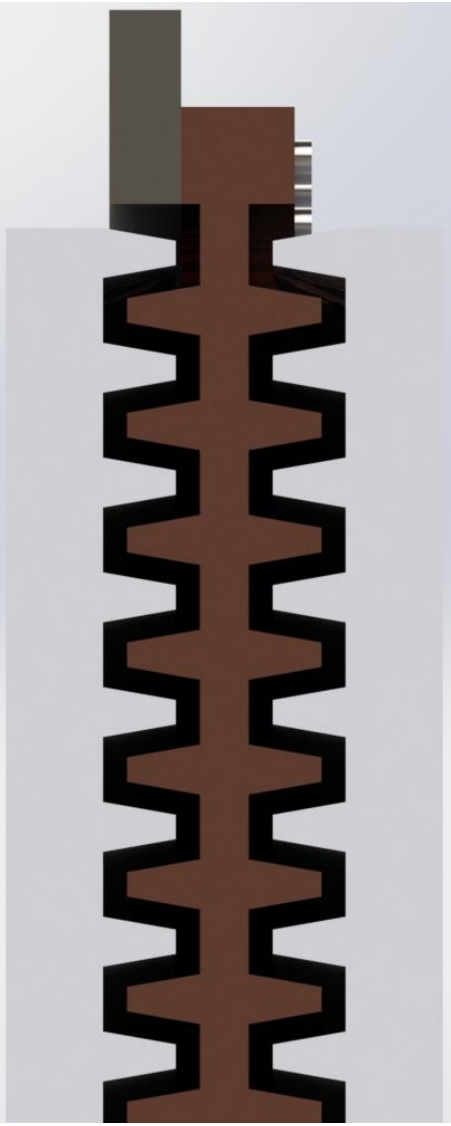


horizontal Temperature distribution



Changes in the Models

- Some small changes happened since then
- screws were added
- The „head“ was redesigned
  - the centre of mass is in the middle of the model
  - contact area height can be variated
- The thickness of the titan ring was reduced to11.1 mm for tests
- a new Finn form was created
  - Trapeze as basic form
  - Reduces deformation due to rotational forces
  - length is 15 mm (for now)
  - angel is 80°



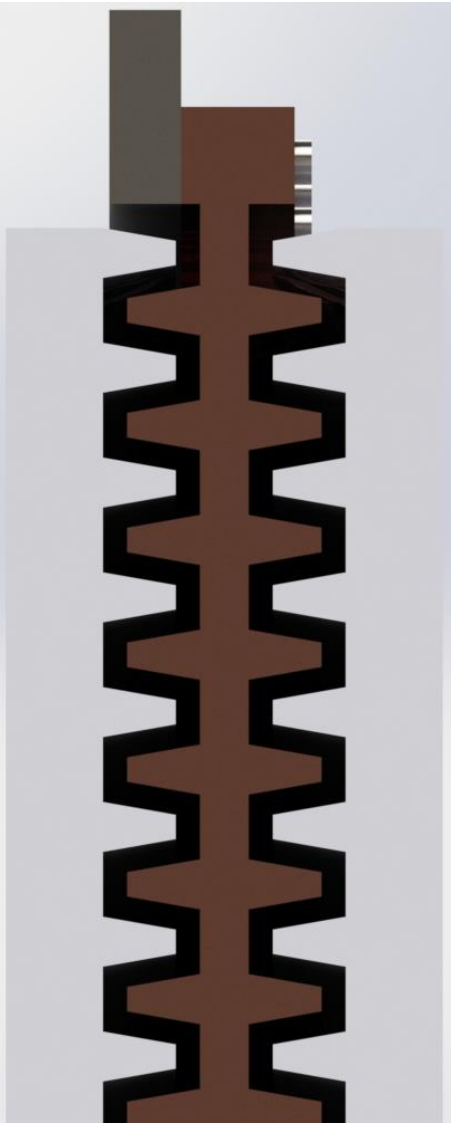
Changes in the Models – issues with the connection

- The titan ring is somehow connected to the cooper disc
- One option is to screw these to materials together
- To dimension the screws the following should be considerate
  - The screws have to be preloaded with a Force to hold the Target in Place bevor it is actual in action
  - This force is about 3 kN (this has to be beard by to 2 or more screws)
  - The stress in the screws is depended on the screw parameter

$$F_{Kl} = \frac{\left(m \cdot \frac{v^2}{r} + m \cdot g\right)}{\mu}$$

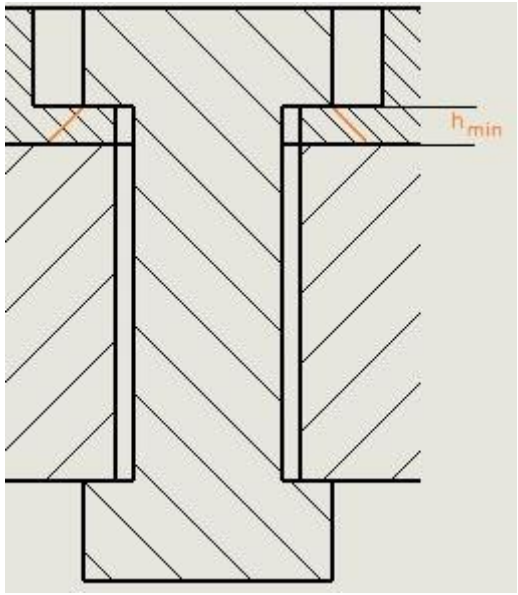
- It will be tested with an M5 and an M12
- The number of screws depends on the thickness of the clamped components and the diameter of the screws

$$F = \frac{-\alpha_S \cdot \Delta T_S + \alpha_{Cu} \cdot \Delta T_{Cu} + \alpha_{Ti} \cdot \Delta T_{Ti}}{\frac{1}{A_S \cdot E_S} + \frac{1}{A_{Cu} \cdot E_{Cu}} + \frac{1}{A_{Ti} \cdot E_{Ti}}}$$



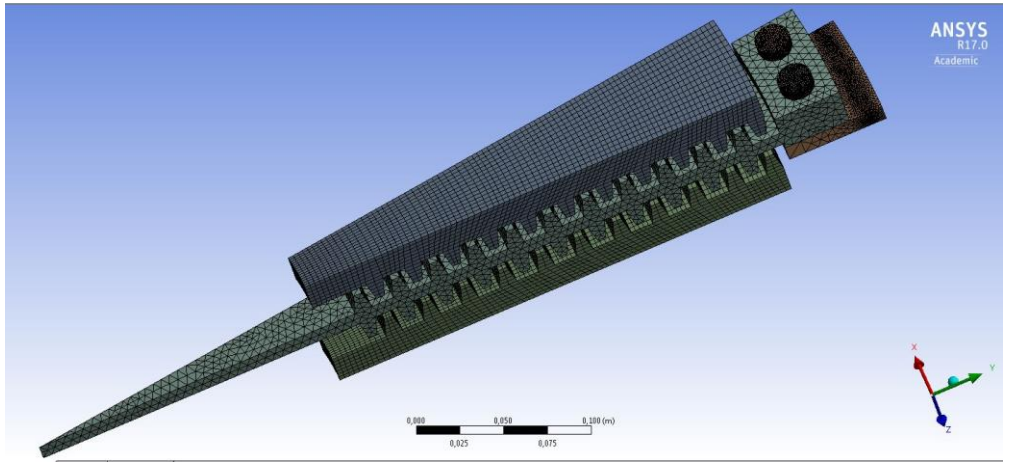
Changes in the Models – issues with the connection

- The count screws is set by a rule of thumb
  - basic idea is called pressure cone
  - $l = h_{min} + d_w$
  - l=Length between screws
  - h_{min}= smallest height
  - d_w=diameter of the screw head
- Result could be 23 mm
  - that means:
  - if the distance is less then l the cones will overlap
  - if it is greater then l the pressure cones will not overlap and the pressure may be not equally distributed



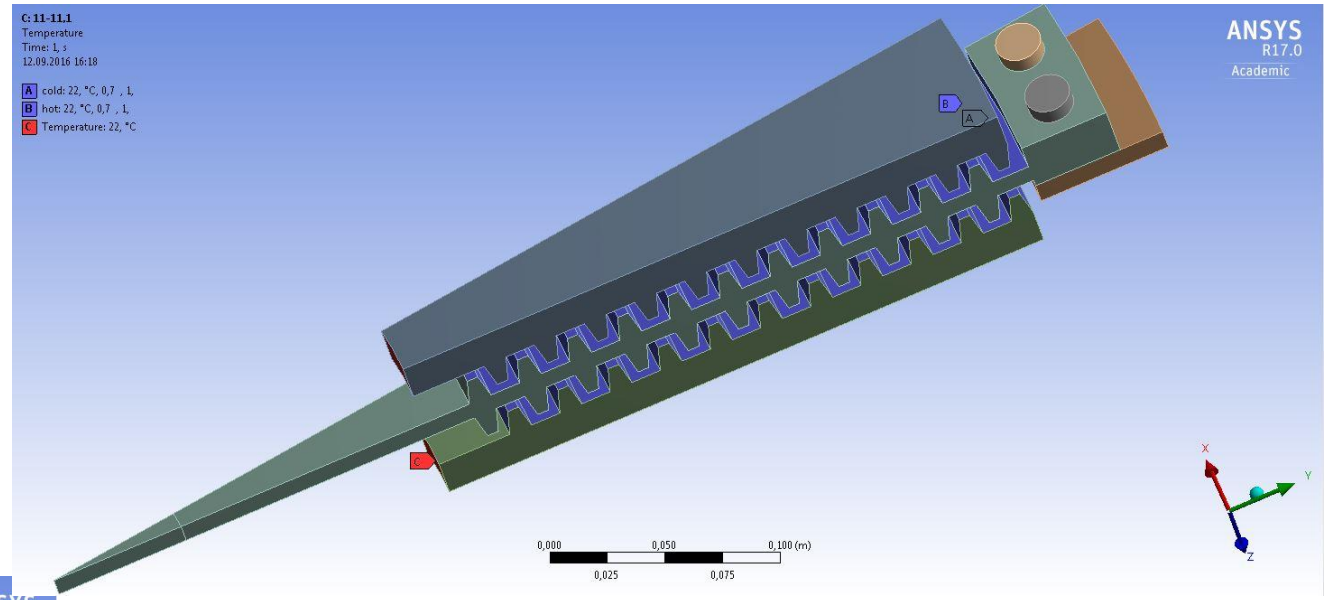
Modified Model – simulation set up

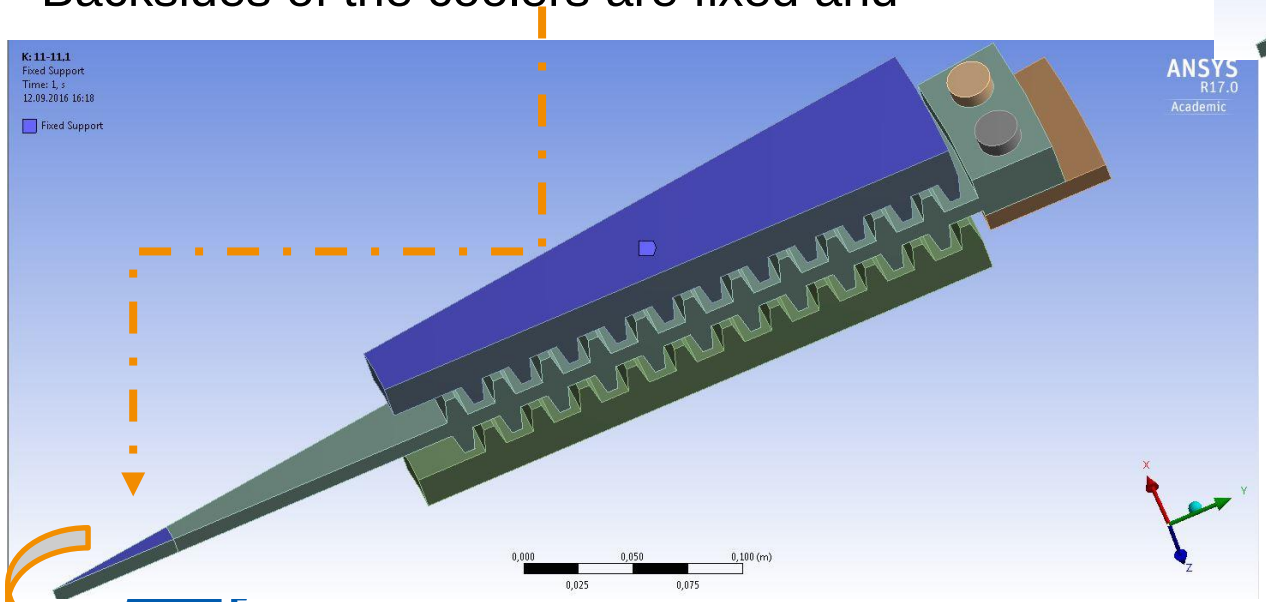
- the new Model is simulated with an energy deposition of 2.3 kW
- there is only a static thermal simulation
- there is now a static structural analysis
  - including a constant rotational force
  - the wheel has fixed faces under the fins
  - Screw were fixed with Bolt pretensions and frictional connections
- 3 Simulations were done
  - M12 with 11.1 mm thickness
  - M12 with 14.8 mm thickness
  - M5 with 14.8 mm Thickness



Modified Model – simulation set up

- Radiating surface ~ 0,079m^2 per slice
- 11 fins are used
- Bottom of the coolers is set to 22°C (it's a constrain to simulate a cooling)
- Rotational speed is 203 rad/s
- Only titan ring and copper disc is rationing
- Backsides of the coolers are fixed and





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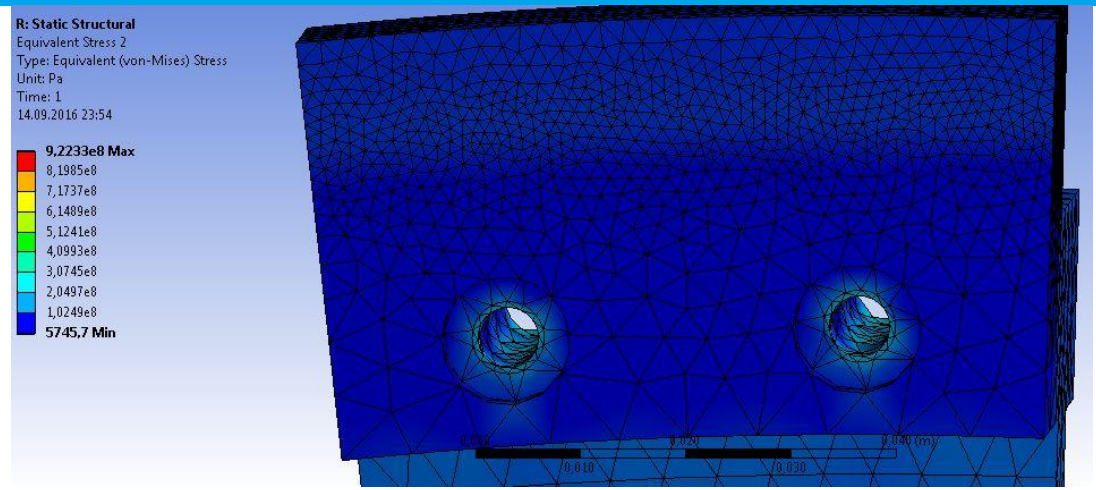
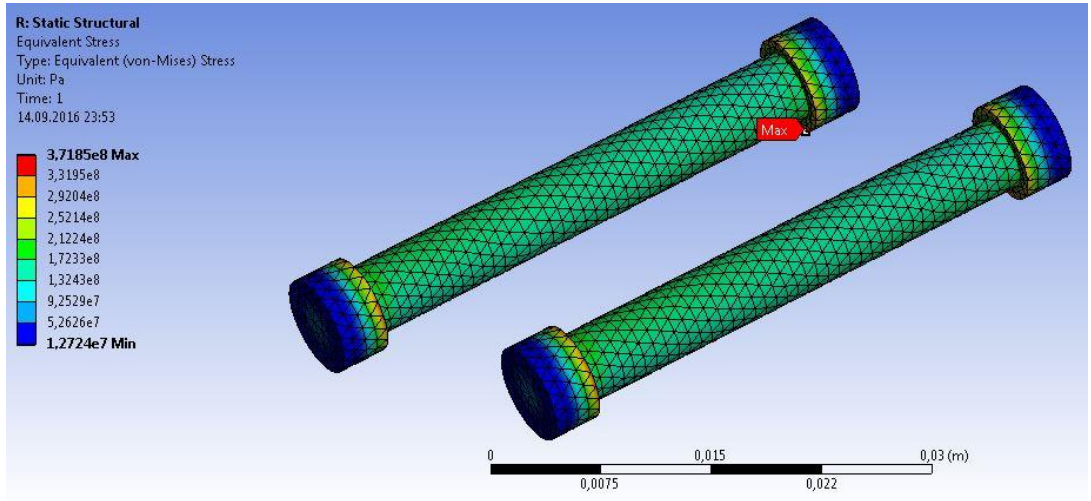
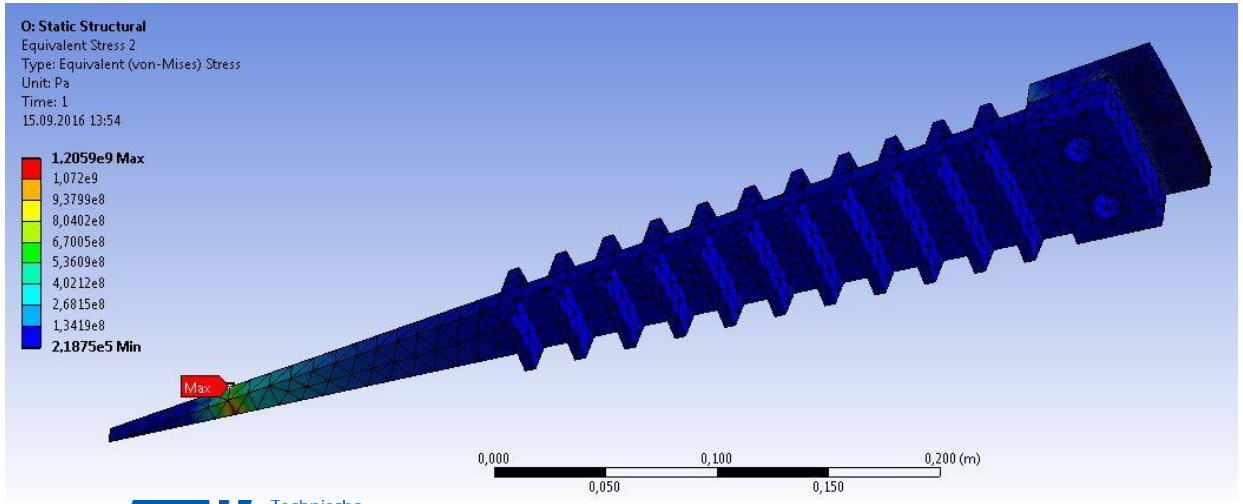
New Model – result

- Max. temperature: 430.32°C (703.47 K)
  - located in the middle of the beam spot
- Max von Mises stress: 922.33 MPa
  - at the fixed surface (maybe artificial)
- Max. von Mises stress at the screws 371.85MPa
- Max. von Mises stress at the contact surface is 167.85MPa

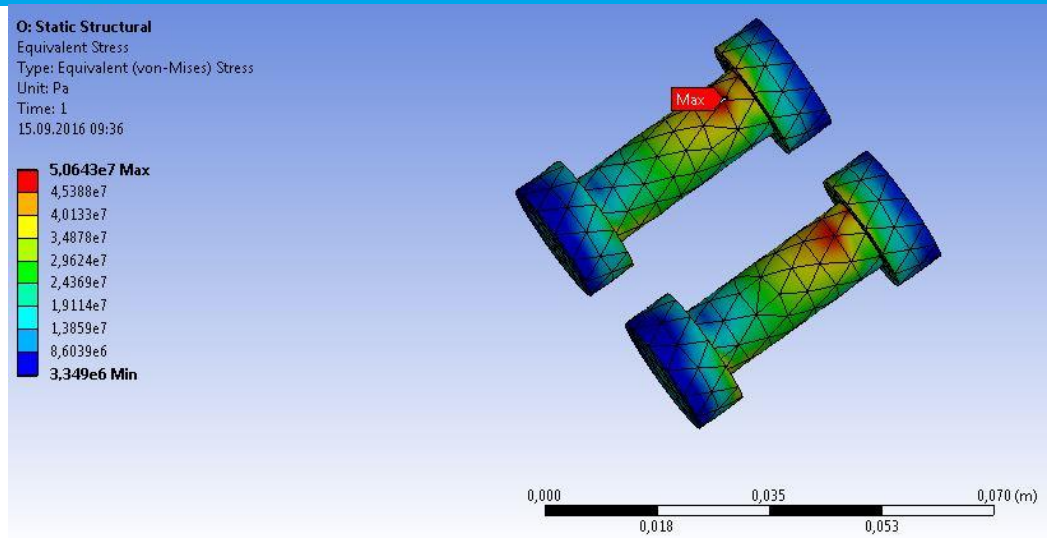


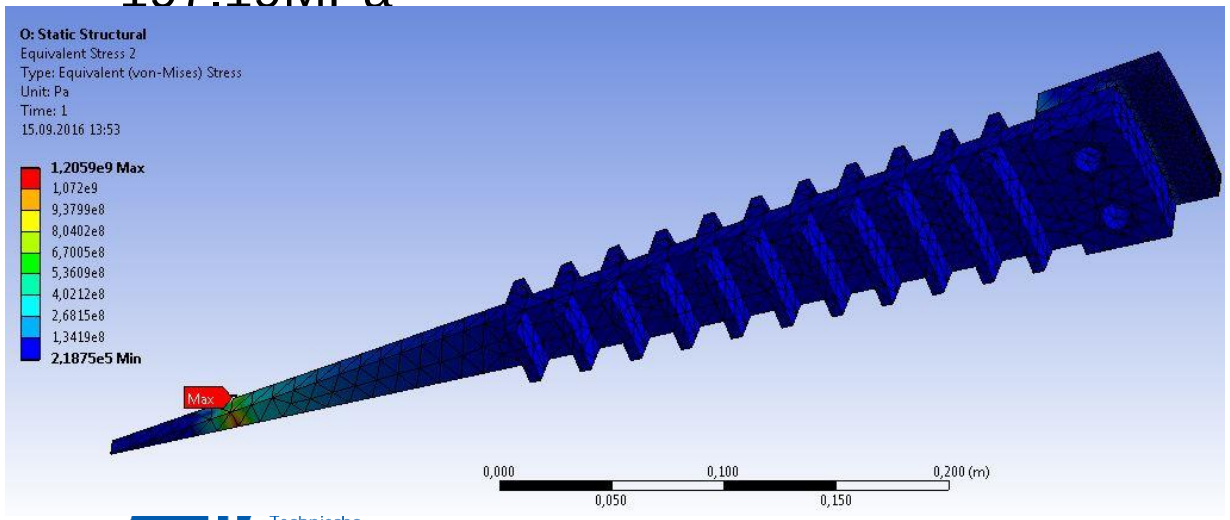


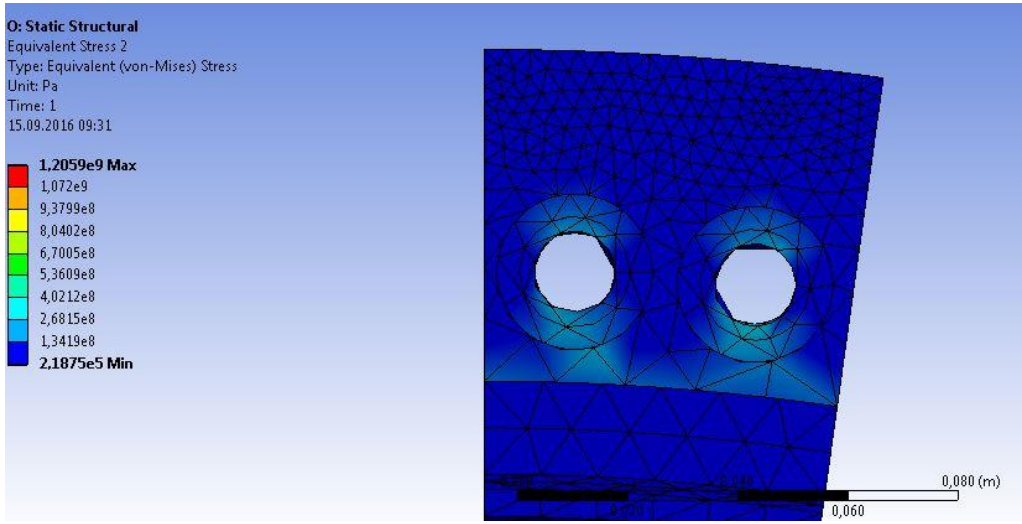


New Model – result

- Max. temperature: 447.13°C (720.28K)
  - located in the middle of the beam spot
- Max von Mises stress: 1.21GPa
  - at the fixed surface (maybe artificial)
- Max. von Mises stress at the screws 50.64MPa
- Max. von Mises stress at the contact surface is 197.19MPa







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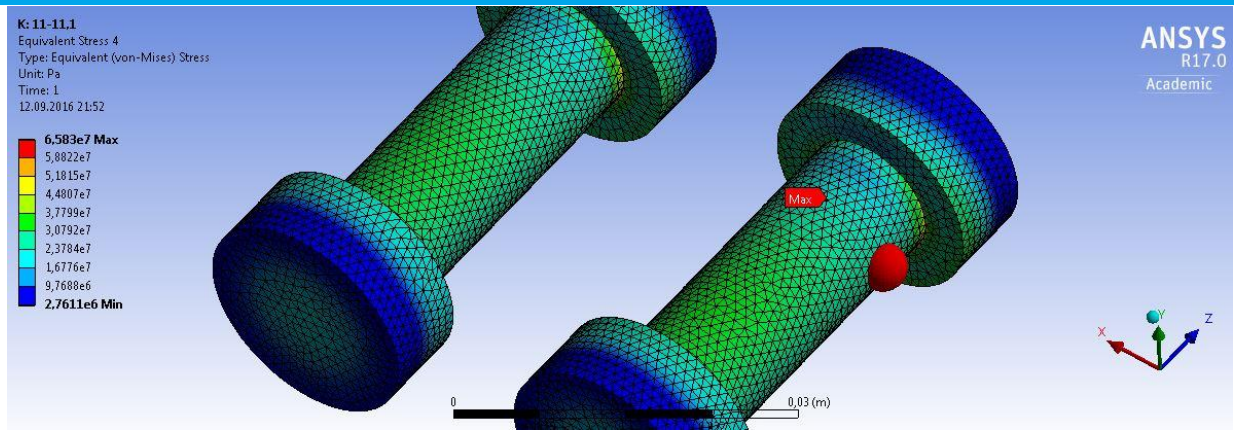
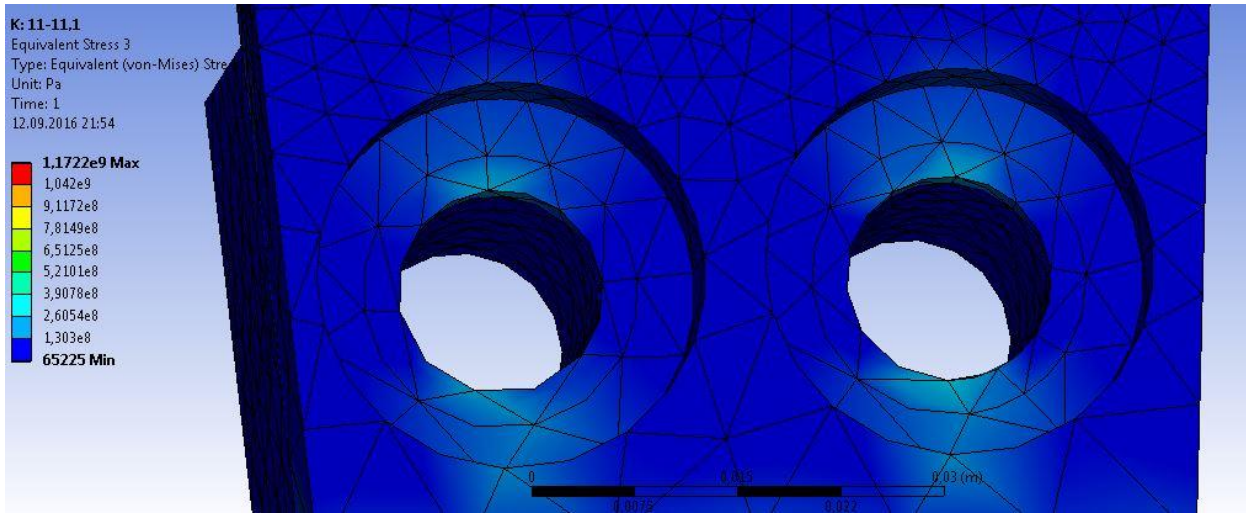
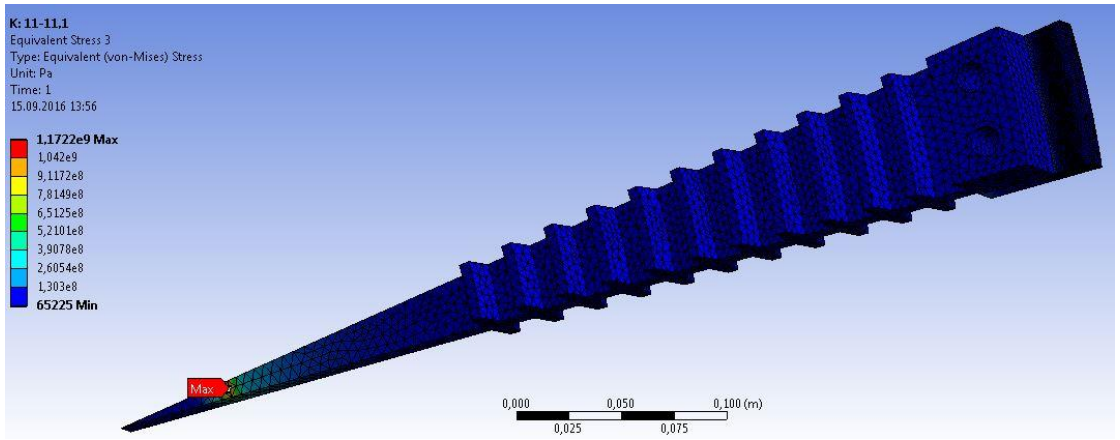
New Model – result

- Max. temperature: 282.71°C (555.86 K)
  - located in the middle of the beam spot
- Max von Mises stress: 1,17GPa
  - at the fixed surface (maybe artificial)
- Max. von Mises stress at the screws 65,83MPa
- Max. von Mises stress at the contact surface is 203,8MPa







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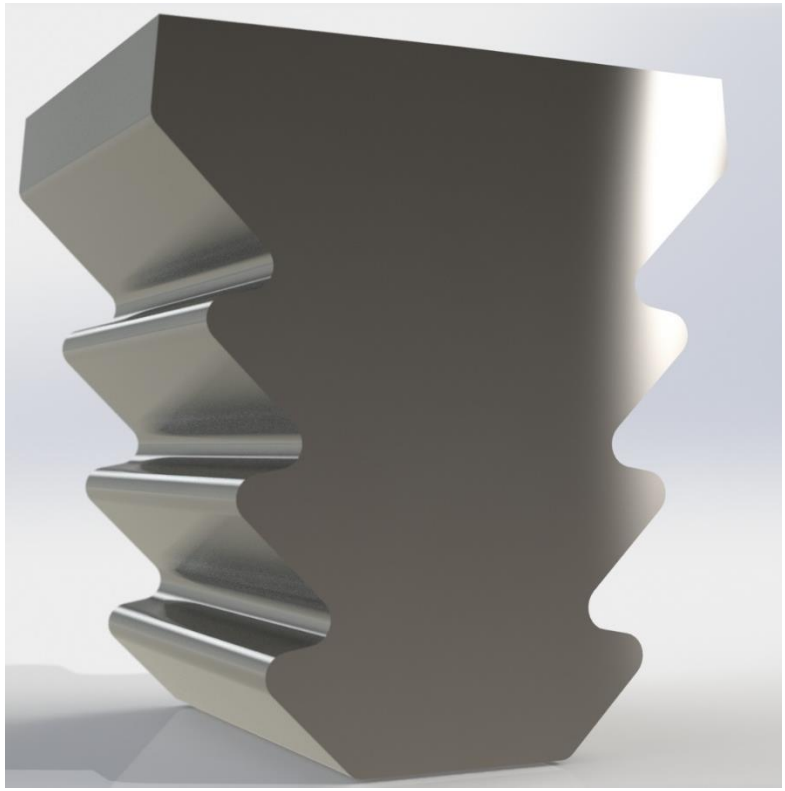
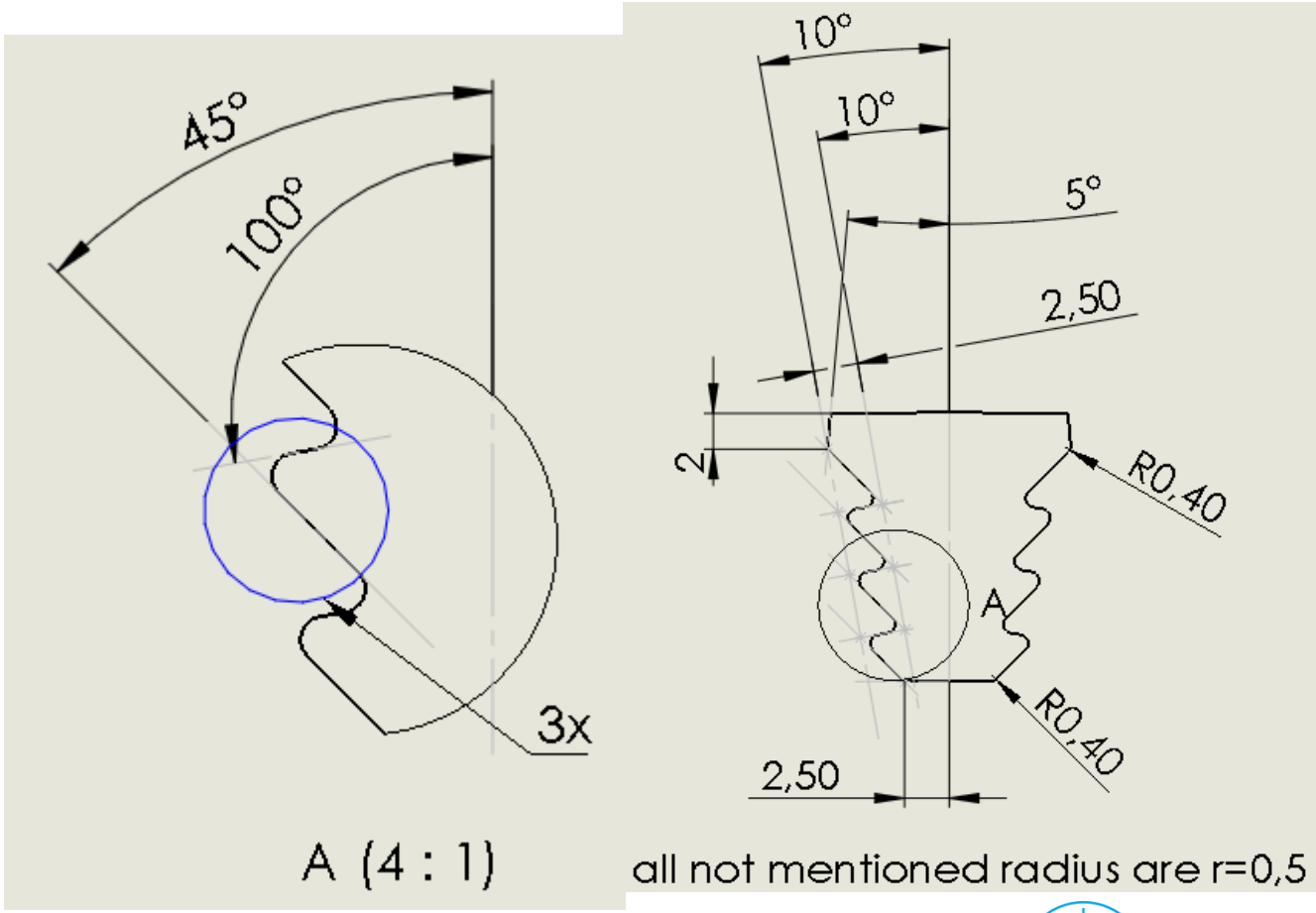
Fire-tree-root

- Is used in Turbine to connect wings to a carrier wheel
- Is used in extreme environments
- Experience in manufacturing exist
- Can be created by high speed milling (costume tools exist)



Fire-tree-root – model

- Basic plain is an isosceles Trapezoid with an angel of 10°
- To a parallel line the spokes are build
- the bottom face is 5mm long

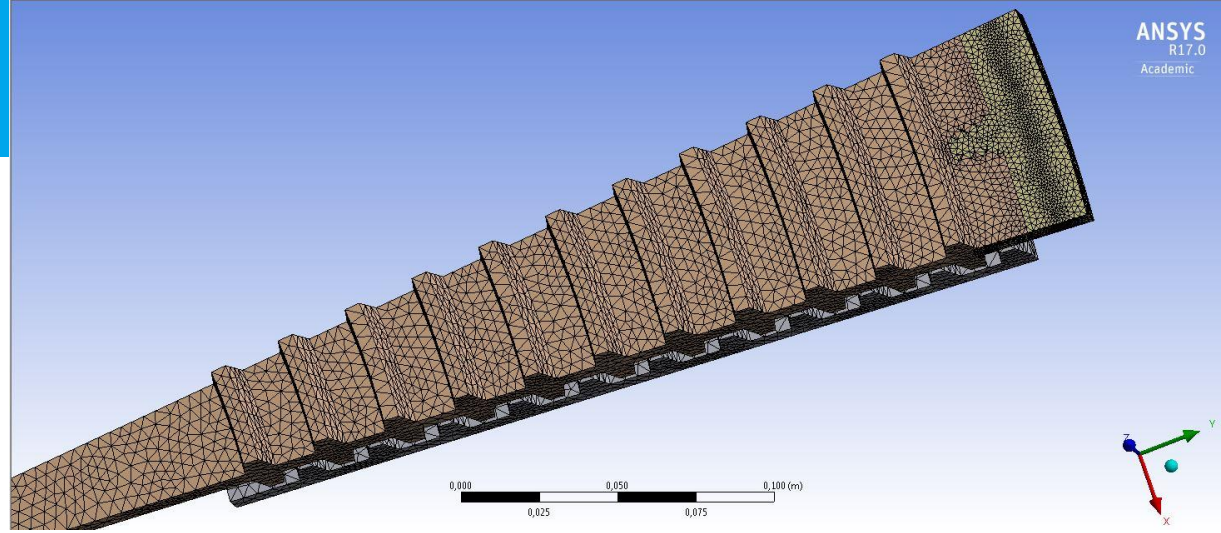


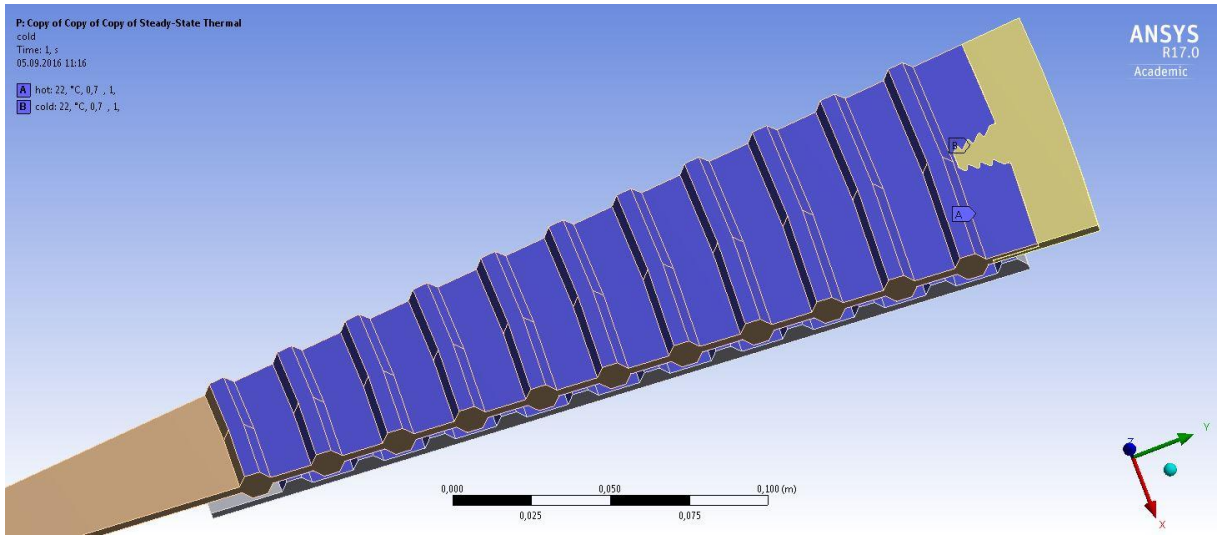
Fire-tree-root– simulation set up

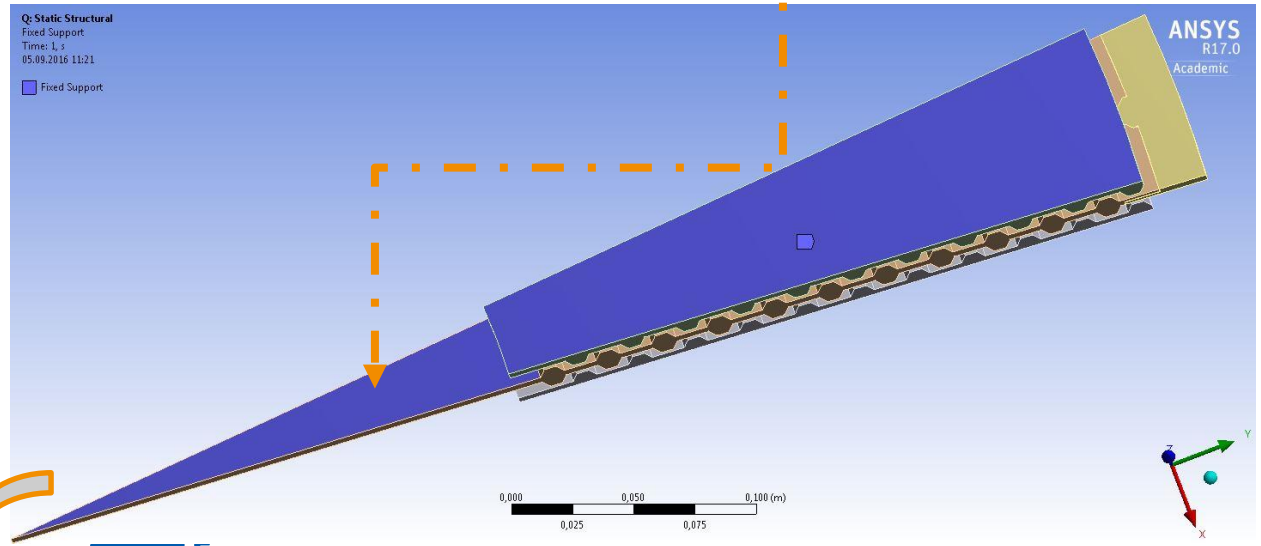
- there is only a static thermal simulation
- there is a static structural analysis
  - including a constant rotational force
  - the wheel has fixed faces under the fins
- Two Simultaions were done
  - 14.8 mm Thickness
  - 11.1 mm Thickness

Fire-tree-root – results

- Titan ring is bonded to copper disc at the fire tree
- Radiating surface ~ 0,079m^2 per slice
- 11 fins are used
- Bottom of the coolers is set to 22°C (it's a constrain to simulate a cooling)
- Rotational speed is 203 rad/s
- Only titan ring and copper disc is rationing
- Backsides of the coolers are fixed and







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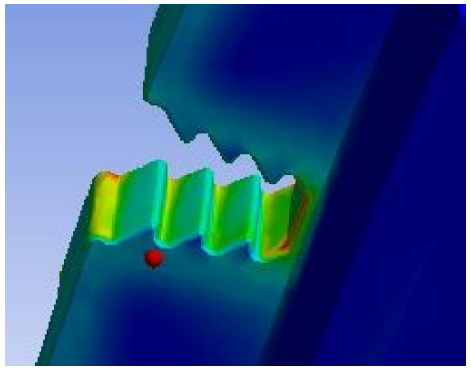
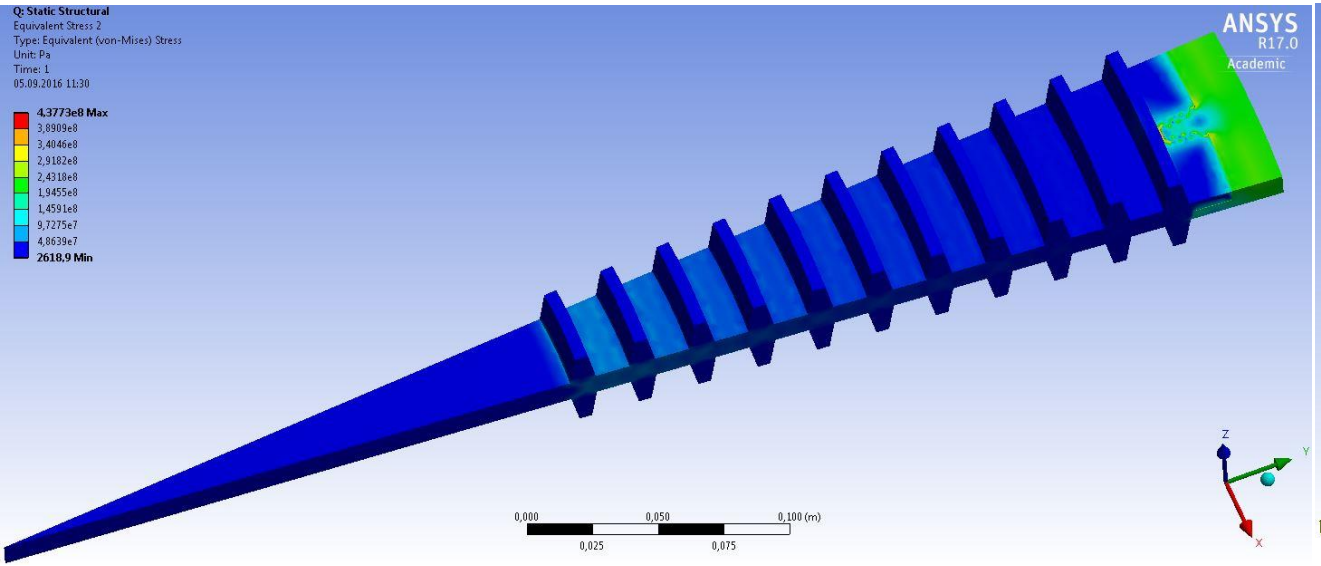
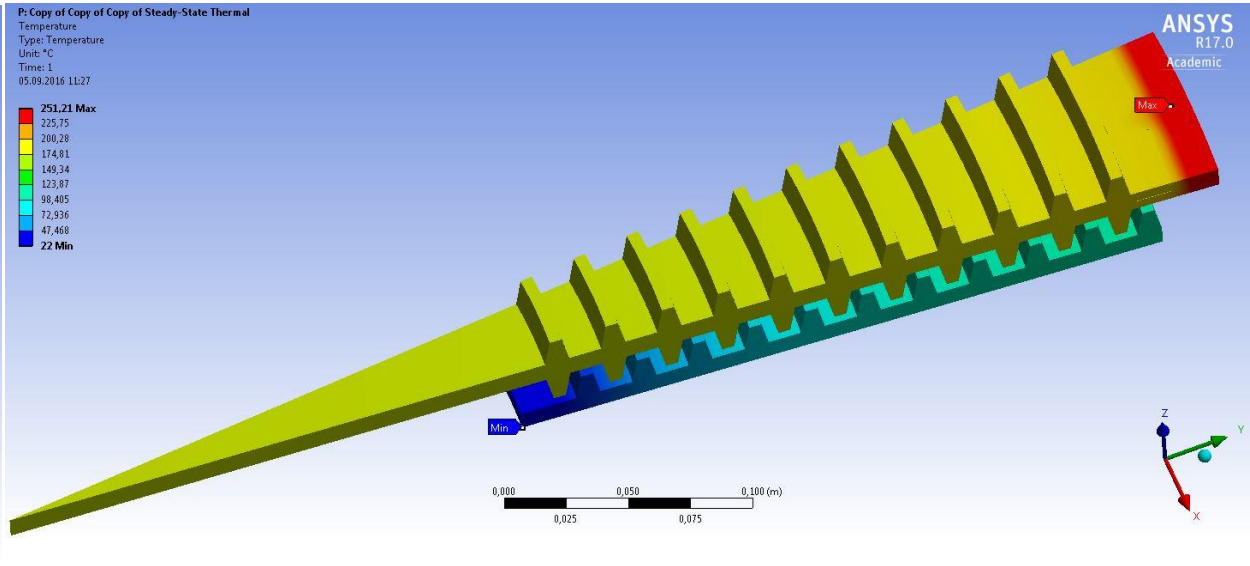
Fire-tree-root – results

- Max equilibrium temperature is 251.21 °C (524.36K)
  - located over the fire tree ,at the exit side, in the middle of the beam spot
- Static simulation shows max. von Mises Stress of 43.77 MPa
  - locates at the bottom of the fire-tree notch

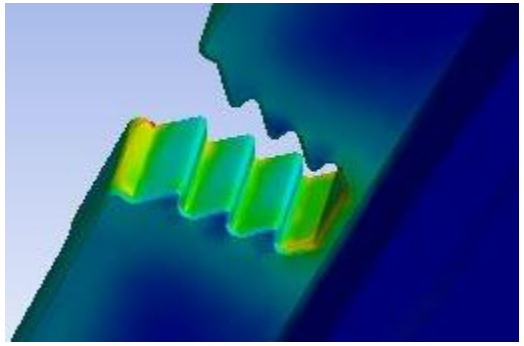


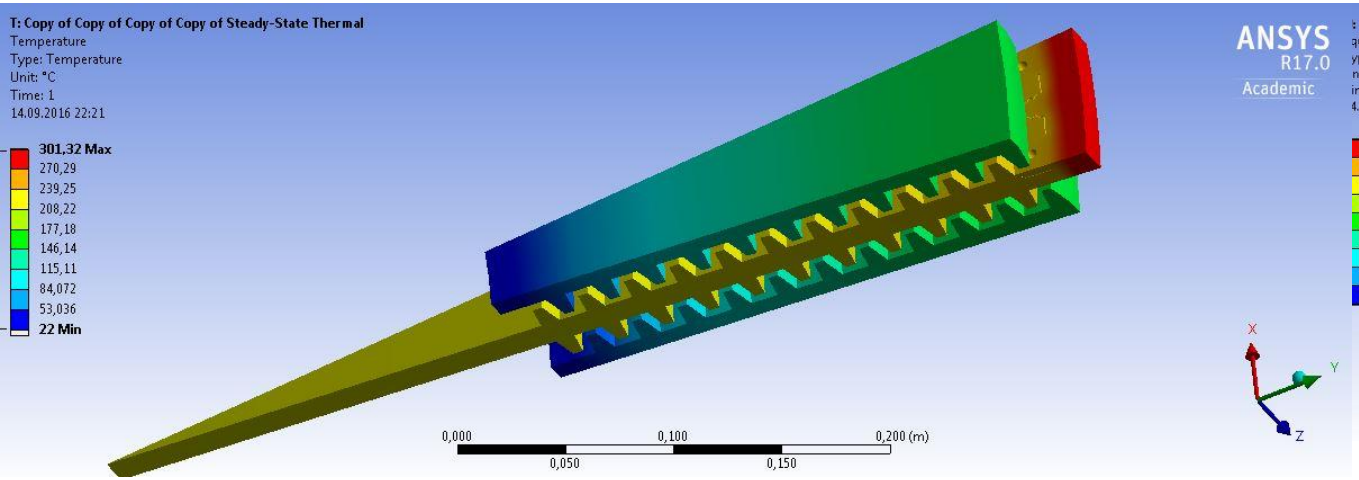


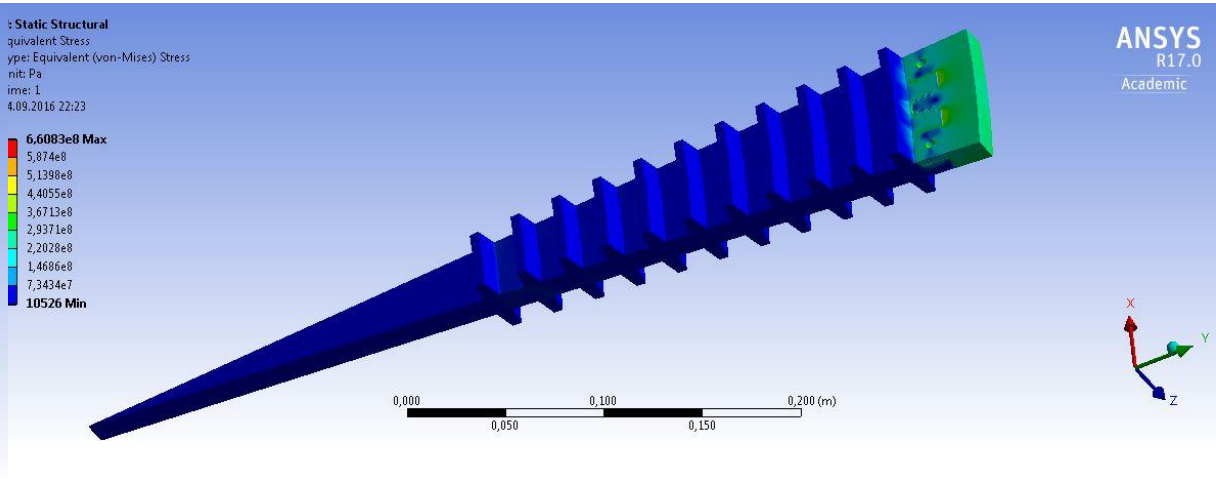


Fire-tree-root – results

- Max equilibrium temperature is 301.31 °C (574.46K)
  - located over the fire tree ,at the exit side, in the middle of the beam spot
- Static simulation shows max. von Mises Stress of 66,08 MPa
  - locates at the bottom of the fire-tree notch







Summary

- Connections between copper and Titan are still problematic
- Both connections shows advantages and disadvantages
- The fire-tree has lower temperature and lower weight but more stress (even too much)
  - has to be redesigned
  - bigger
  - or more trees
- the connection with screws has lower stress but higher weight
  - to high stress at the fixed surfaces