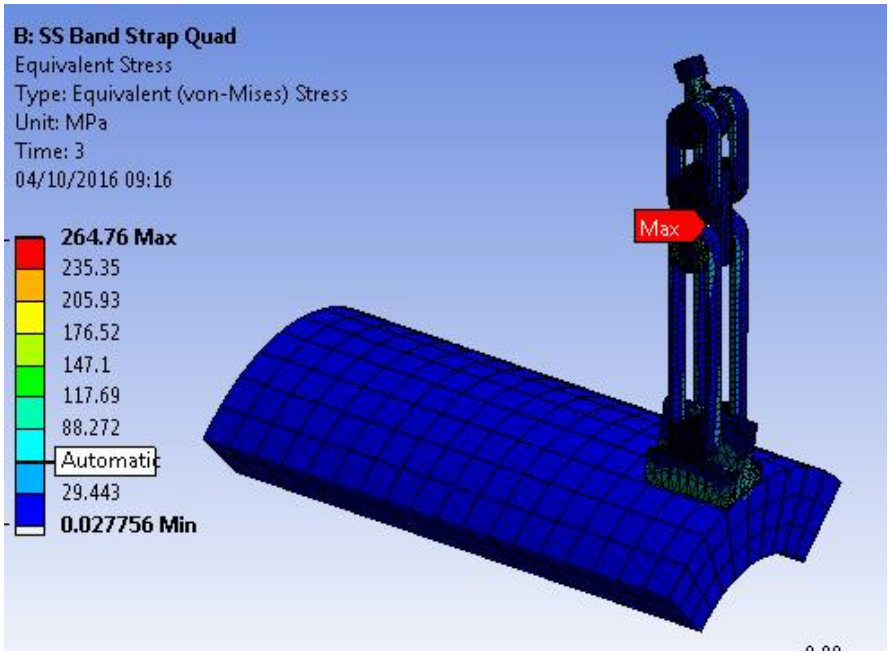
Step IV - Engineering

Jason Tarrant – Integration Engineering

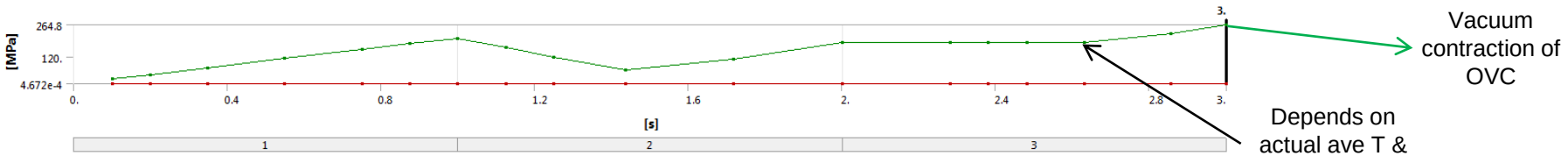
- Bobbin support & stiffness – for discussion at magnet meeting 05/10/2016

PRY SS Stand-Off

- Loads
  - Bobbin strap pre-tension / pre-load



6000 lb pre-load / strap warm, not change when cold (S Virostek)



Vacuum contraction of OVC

Depends on actual ave T & CTE

Preload to 6000 lb

Bobbin cool down to 4 K

Strap cool down to 170 K

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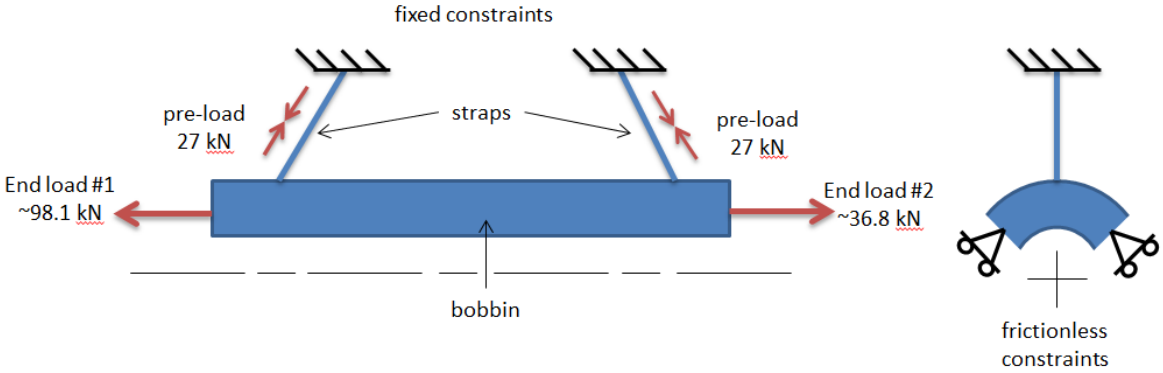
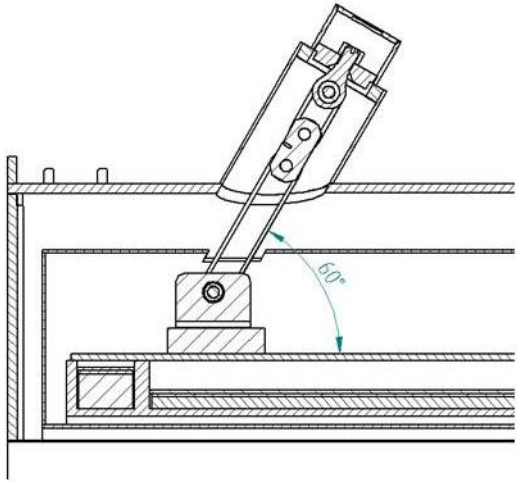
SS Bobbin

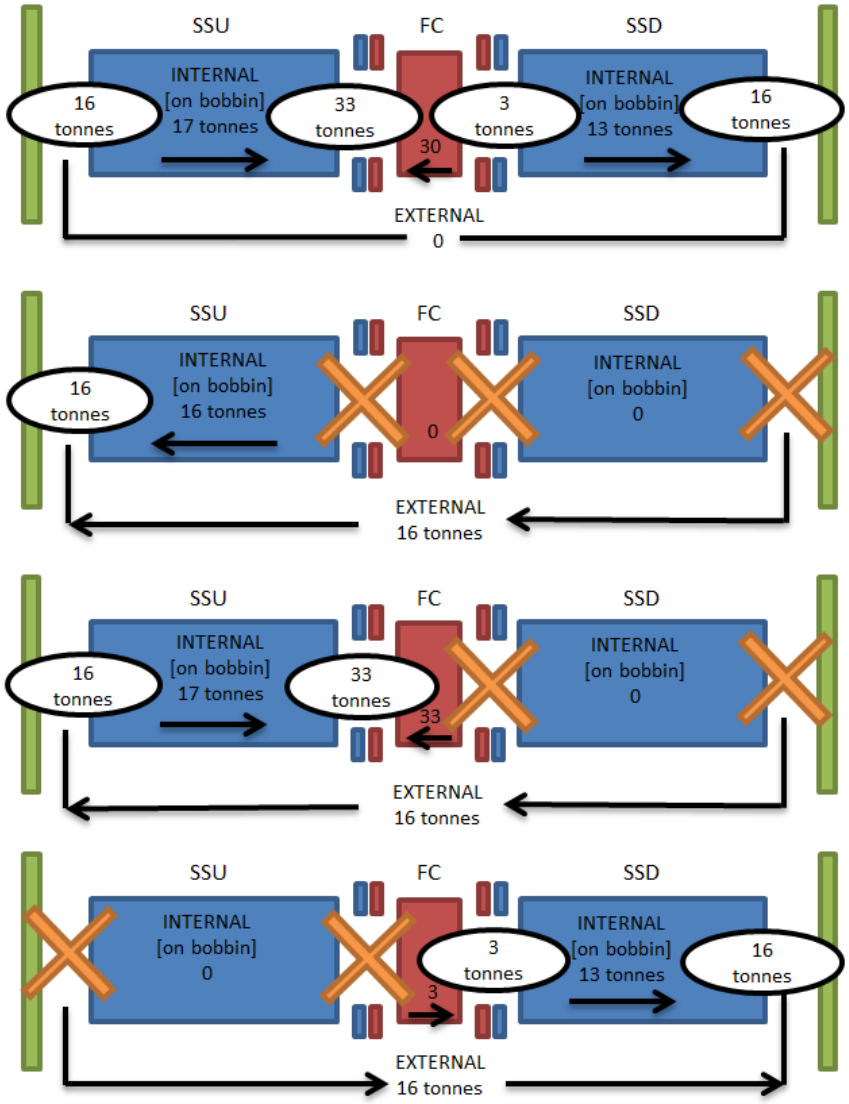
- **Strap properties**
  - Steve Virostek estimated 45 GPa tensile stiffness warm and up to +15 % when cold = ~ 52 Gpa
- **Model set-up**
  - ¼ model with fixed & frictionless constraints = radially flexible but ‘on rails’ axial movement, i.e. if the pins & bands disconnect the bobbin does not drop on slack end
  - ¼ model has ¼ load applied to end





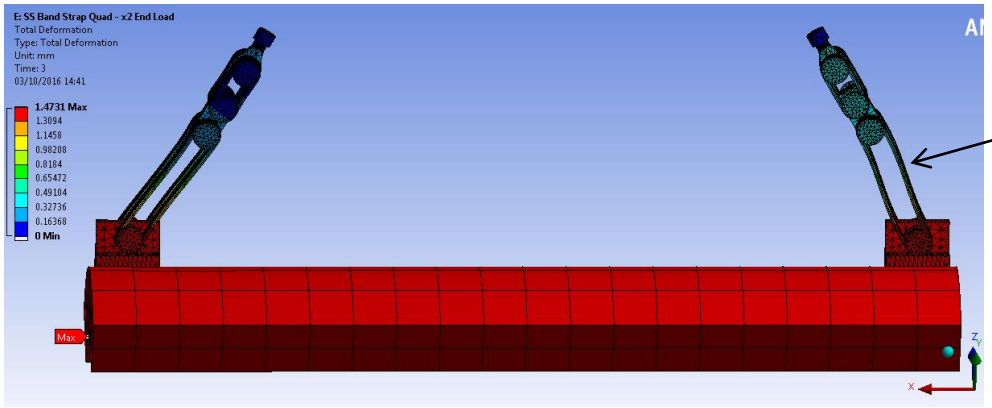
SS Bobbin

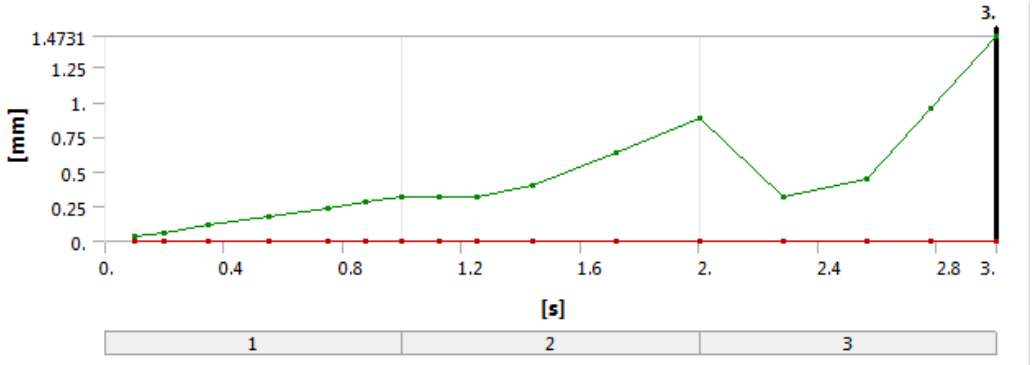
- ‘Final’ predicted loads (as of 05/10/16)



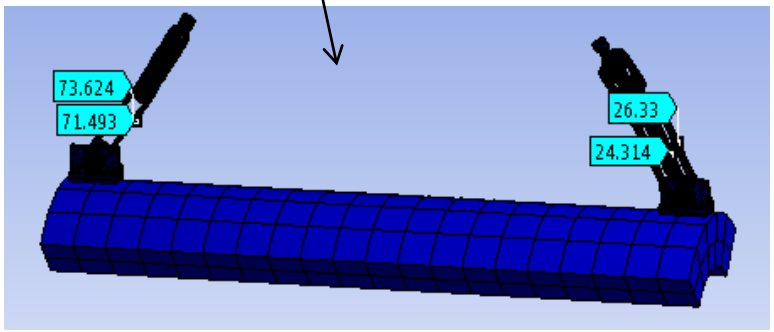
SS Bobbin

- Bobbin movement – <u>fixed straps</u> & **<u>15 - 40</u>** tonne loads
  - Straps & pins bonded
  - 6000 lb / 27 kN preload
  - Elastic modulus 40 GPa
  - 15 tonne / ~147 kN -ve X, then 40 tonnes / ~392 kN +ve X





Note 'S' bend
(from locked connections)



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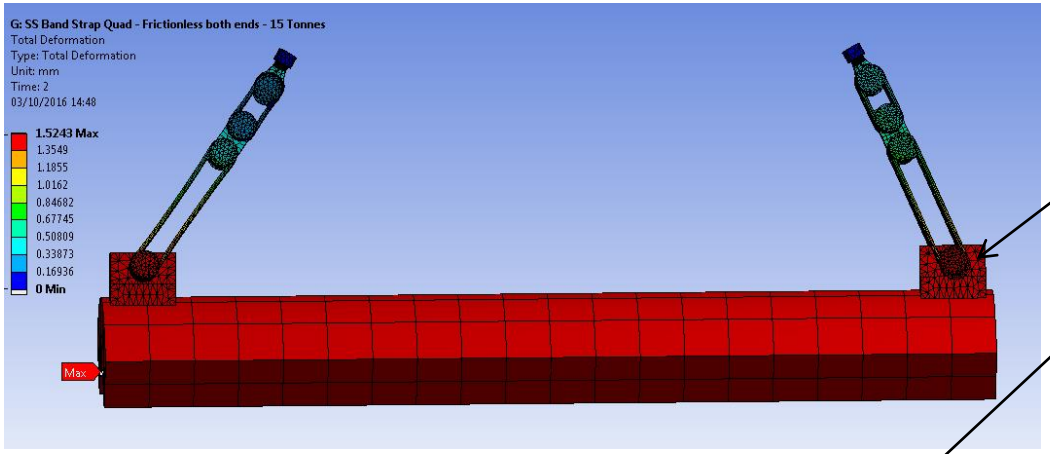
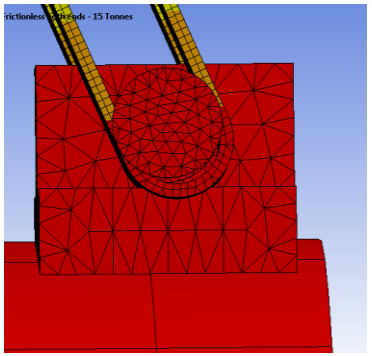
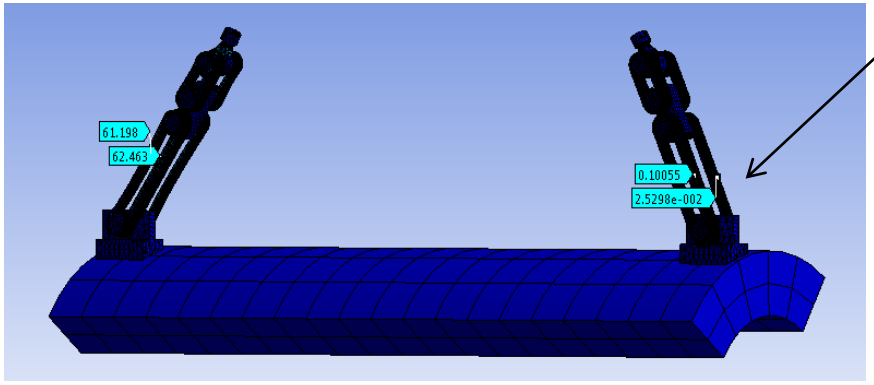
SS Bobbin

- Bobbin movement – flexible straps & **15** tonne load
  - Straps flexible around pins – frictionless connection
  - 6000 lb / 27 kN preload
  - Elastic modulus 52 GPa
  - 15 tonne / ~147 kN -ve X



Note band has
been lost from pin





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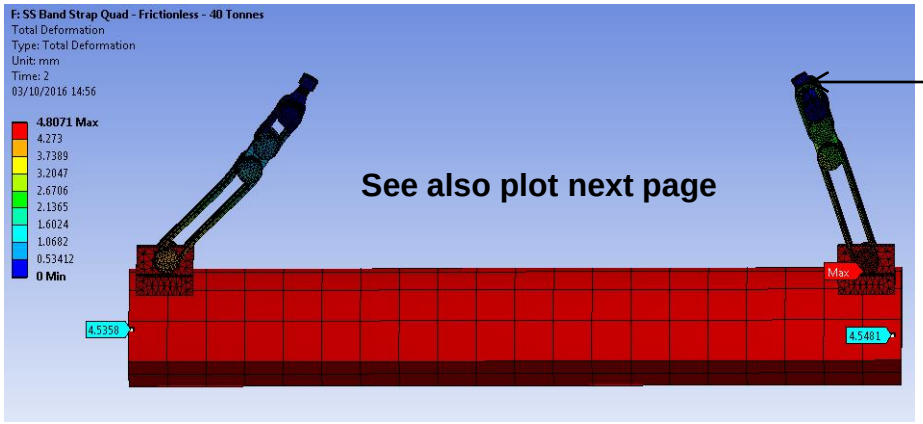
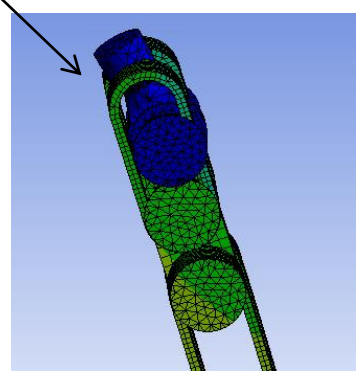
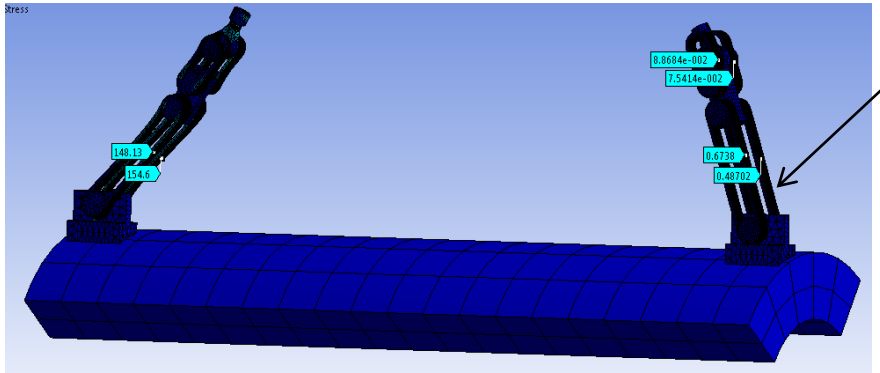
SS Bobbin

- Bobbin movement – flexible straps & **40** tonne load
  - Straps flexible around pins – frictionless connection
  - 6000 lb / 27 kN preload
  - Elastic modulus 52 GPa
  - 40 tonne / ~392 kN -ve X



Note band has been lost from pin





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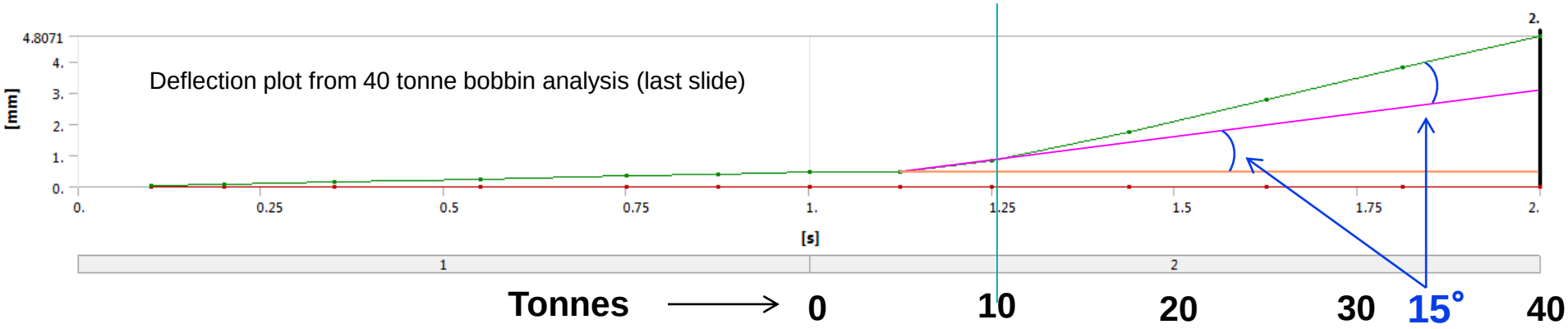
SS Bobbin

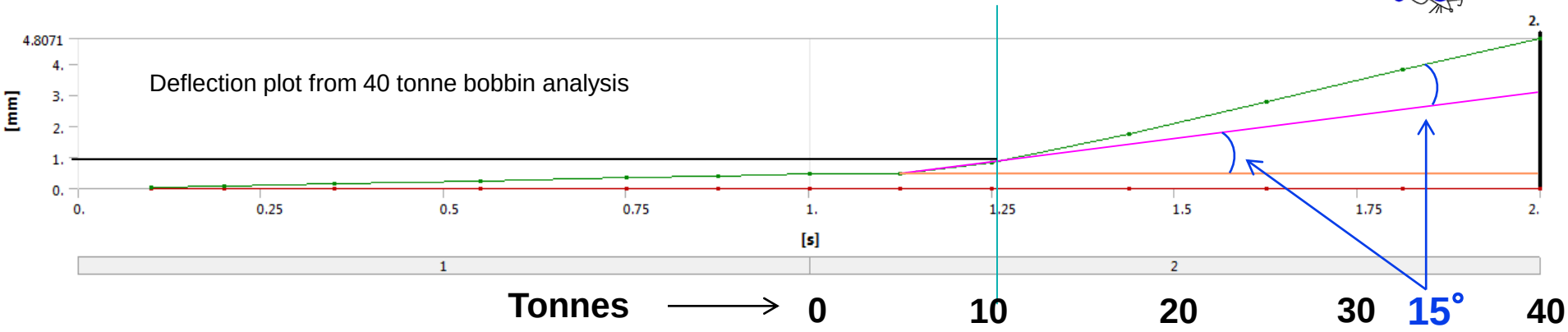
- Loss of pretension
  - With a preload of 6000 lb / 27 kN John Cobb estimated that with the 60 degree strap angle, strap preload would be lost around 11 tonnes.



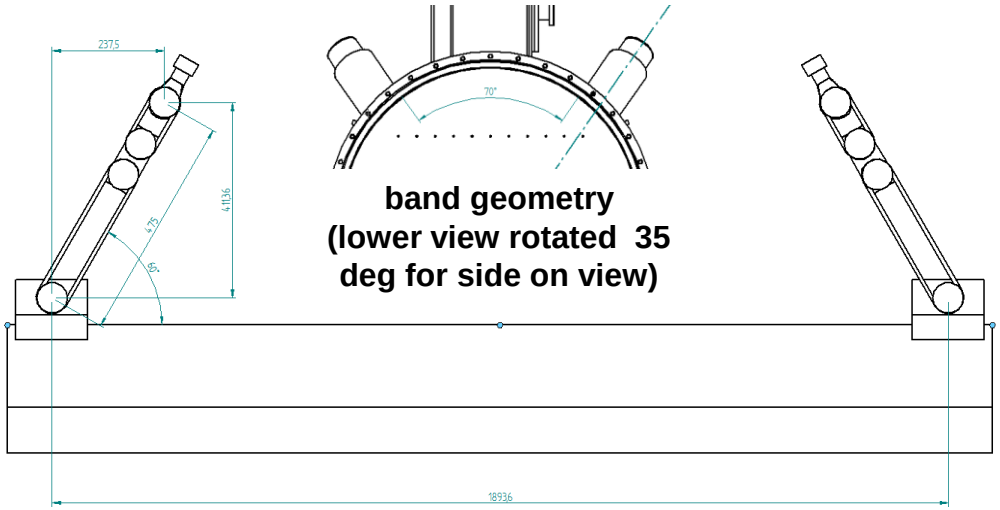
- Step 1 shows the deformation in the straps due to the 27 kN preload
- Step 2 the 40 tonne (392 kN) load is applied linearly, the bobbin starts to move…
- 0-5 tonnes the deformation is relatively flat as material in the bands is moving too
- 5-just over 10 tonnes the graph takes a steady linear angle of 15 deg from horizontal
- Just over 10 - 40 tonnes the graph rises by 15 deg to 30 deg from horizontal
- 15 deg + 15 deg is indicative of the stiffness halving from just over 10 tonnes, this appears to coincide with John's predicted loss of preload in one set of bands

SS Bobbin

- Possible off-axis bobbin movement



With this set-up @ 11 tonnes ~ 1 mm of axial bobbin movement occurs before the bands slip their pins*. The bands on the bottom would lose control of the bobbin at this point but those on top would still be in contact, however as the bobbin moves axially further the top bands would rotate between their anchor point on the OVC and their anchor point on the bobbin potentially changing the height of the bobbin on the slack band end



***Actual movement where bands slip & total drop in height is dependant on stiffness of bands + gravity effects, however assuming further ~ 4 mm of movement [from 1 mm to 4.81 mm] the drop in height of the end of the bobbin could be as shown in the adjacent table [based purely on geometric rotation from 60 degrees of bands then reduced for 35 degree angle]**

Length Change	Height Change
0.5	0.24
1	0.47
1.5	0.71
2	0.94
2.5	1.17
3	1.41
3.5	1.64
4	1.87

SS Bobbin

- Conclusion - **Strap Supports**
  - Model with frictionless strap-pin connections appears to behave as expected losing pre-load at just over 10 tonnes with 6000 preload
  - 15 tonnes = 1.5 mm bobbin axial movement (52 GPa / 6000 lb)
  - 40 tonnes = 4.5 mm bobbin axial movement (52 GPa / 6000 lb)
  - Analysis models ‘on rails’ constraints do not allow a vertical displacement / gravitational drop if band slips the pins, however ‘geometric’ estimates show that for 4 mm of movement after the bands lose contact, the bobbin may drop ~1.9 mm