ANSYS

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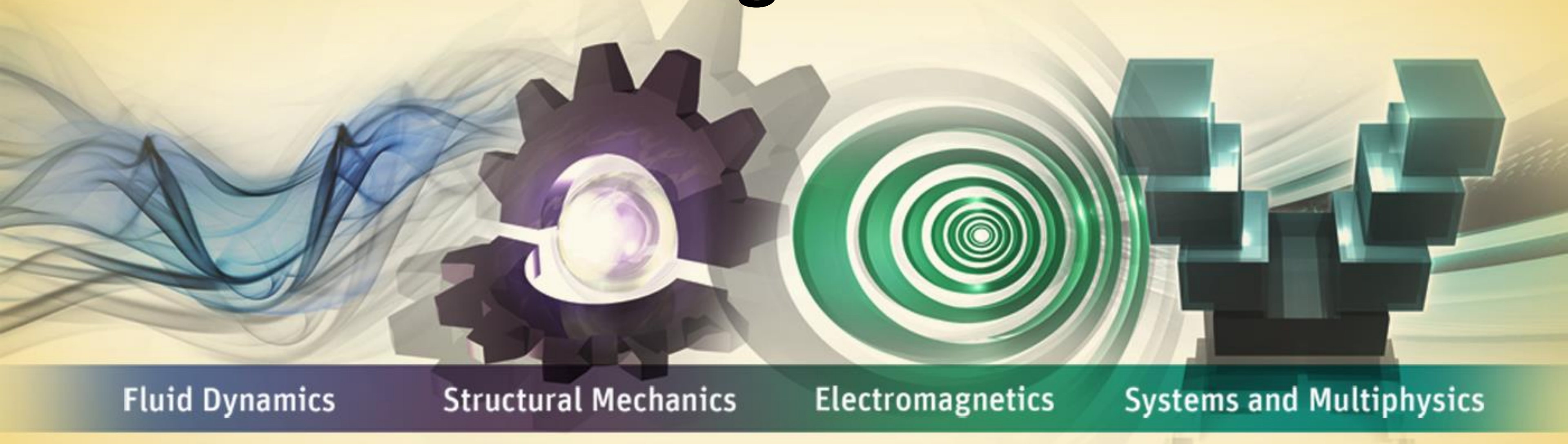
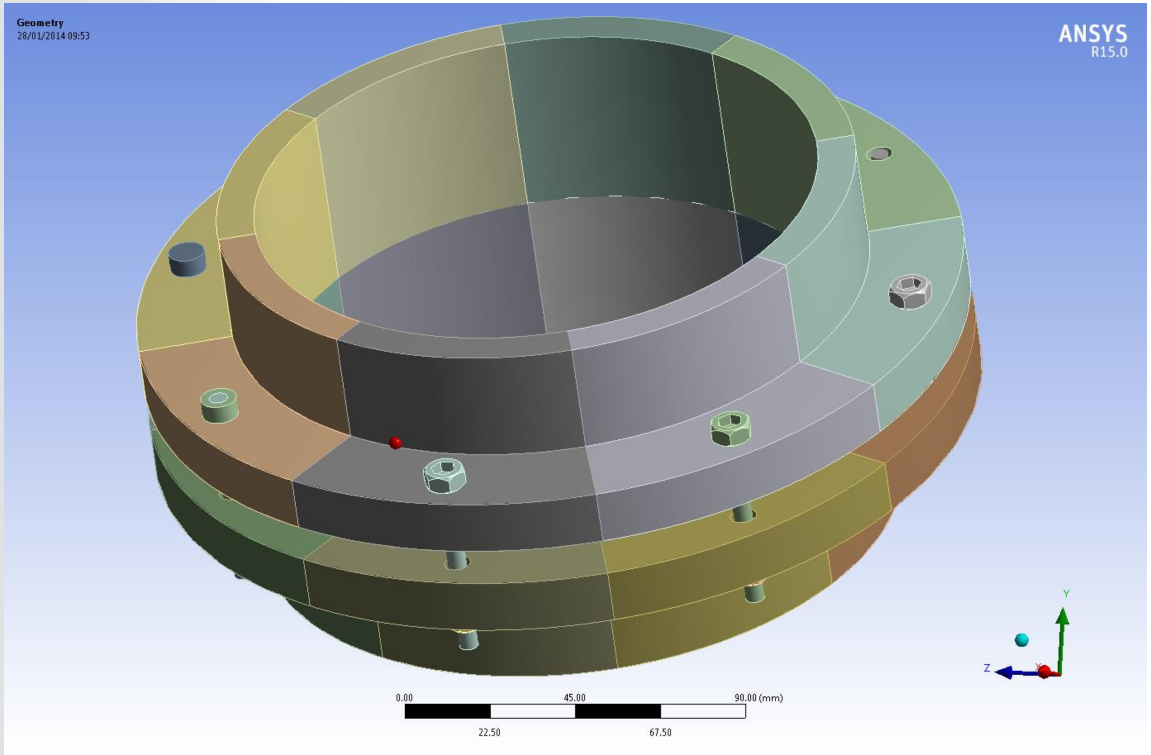
An overview of methods for modelling bolts in ANSYS V15



Bolt modelling

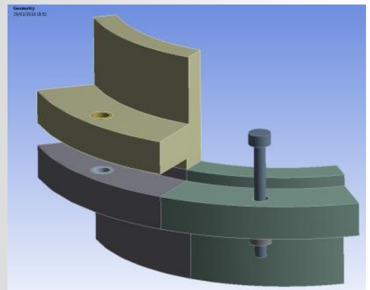
A simple eight bolt flange model for assessment of different methods of modelling bolts, aspects to consider:

- **Geometry**
- **Meshing**
- **Contact**
- **Pre-tension loading**
- **Post processing**

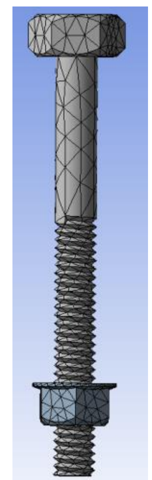


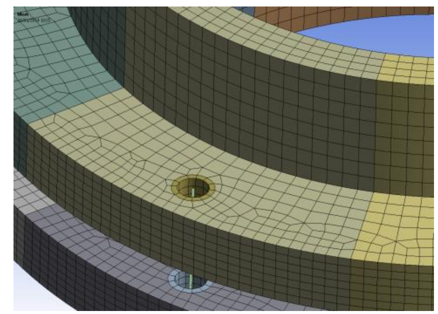
Model and analysis considerations

Approach to modelling the bolts will usually involve making engineering decisions about the following:



- **Prepare geometry**
  - **Bolt and flange**

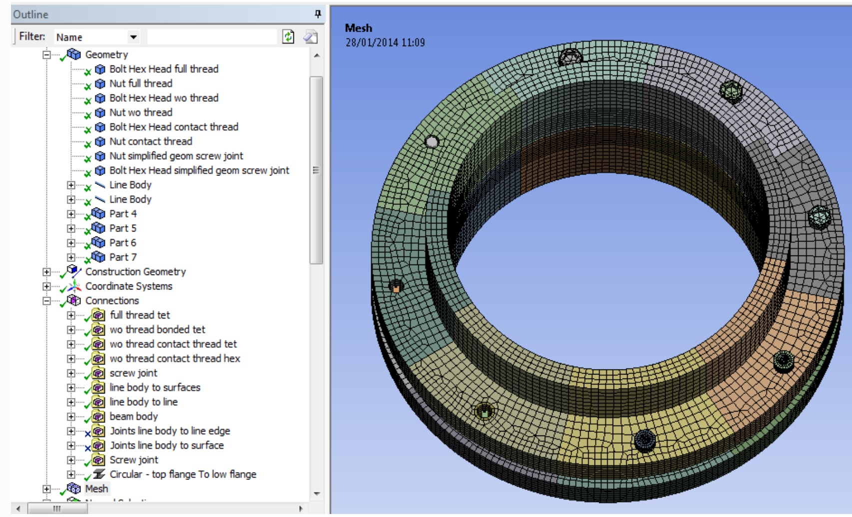


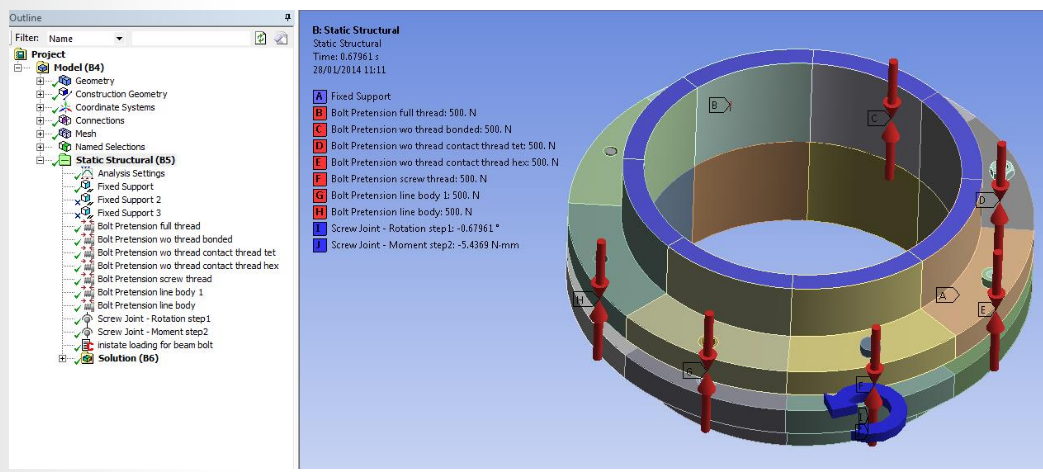


- **Mesh**
  - **Minimum DOF for best representation**
  - **Consider contact areas for load transfer/stress**
  - **Hex / tet**
- **Three step analysis:**
  - **Step 1: preload by load or adjustment, possibly need to temporarily hold all free floating bolts if frictional contact is being relied on to prevent rigid body motion**
  - **Step 2: fix the pretension, release any temporary restraining boundary conditions**
  - **Step 3: Apply in-service loads**

Overview of model

- **Eight sectors, each has a different method of modelling the bolt**
- **Upper / lower flanges are multi-body, sweep-able parts**
- **All contacts are asymmetric & bonded**
- **Analysis settings:**
  - **Upper / lower flanges fixed at pipe OD**
  - **2 step (load/lock), linear analysis**
  - **500N pre-load to all bolts**

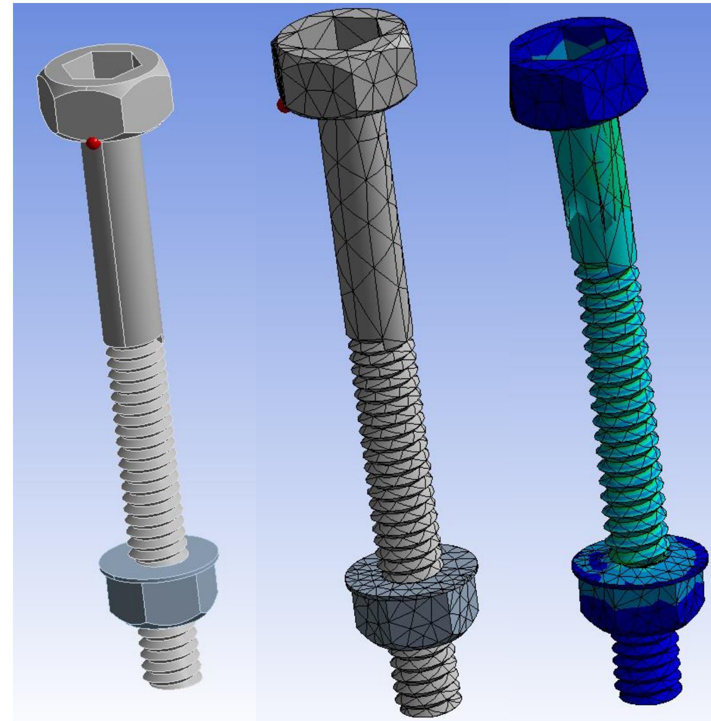


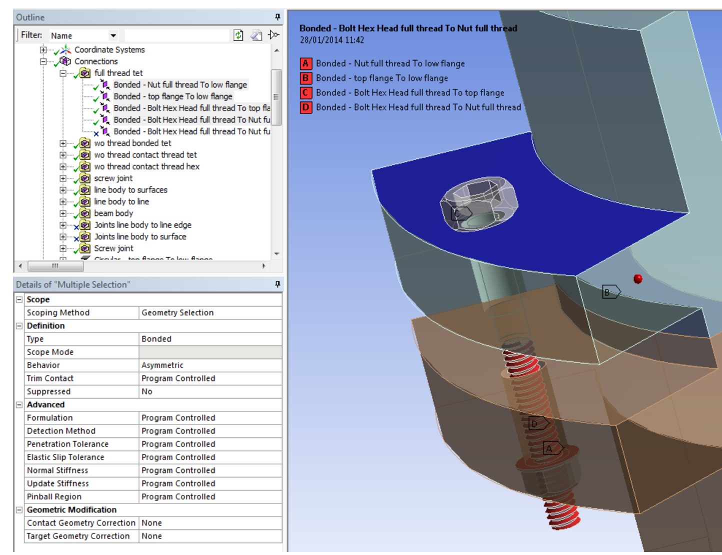


Bolt model 1:

Key features of this approach:

- **No/very little geometry preparation**
- **Full thread on bolt and nut, in this case the nut thread on the nut was created using a boolean operation with the bolt as tool geometry**
- **Good geometric representation of stiffness of bolt/nut will be captured if mesh is dense enough**
- **Slave contact areas give accurate representation of bolt head and nut contact area to flange**
- **Most cases will produce a tetrahedral mesh, check element quality, density can vary dramatically depending on mesh controls particularly on threads**

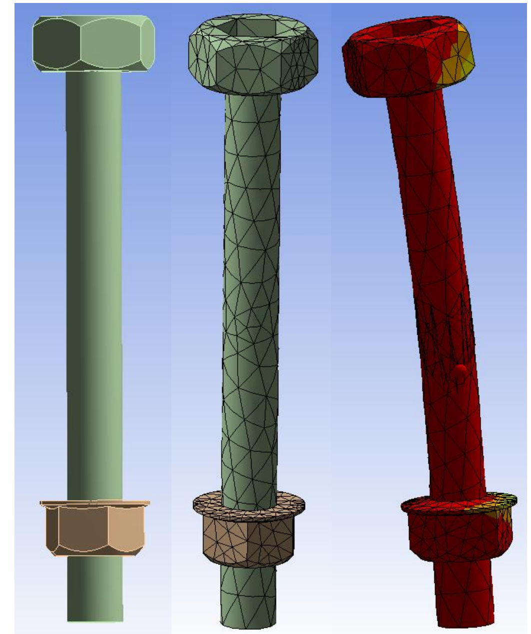


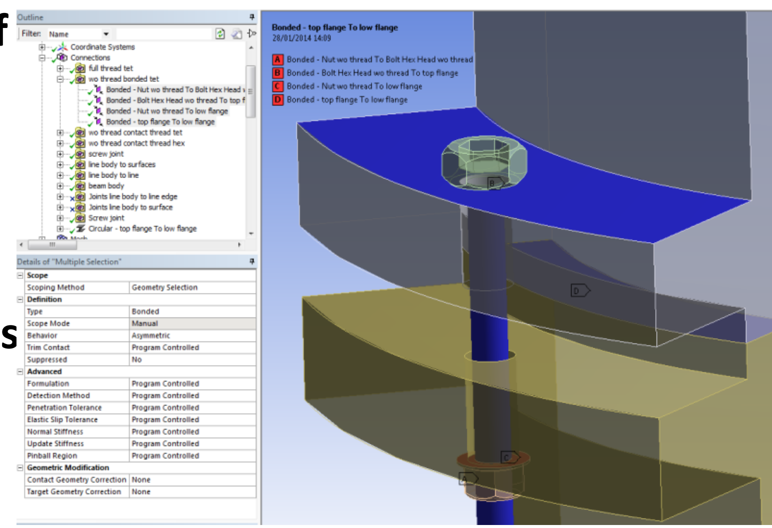


Bolt model 2:

Key features of this approach:

- **Some geometry preparation, threads removed on bolt and nut, could increase preparation by including cross section variations at thread and neck sections**
- **Care should be taken not to alter bolt shank stiffness as this will affect bolt deflection and load transfer in the system during pre-tension and in-service loading**
- **Slave contact areas give accurate representation of bolt head and nut contact area to flange**
- **Most cases will produce a tetrahedral mesh, check element quality, density can vary dramatically depending on mesh controls particularly on threads but generally should be able to producer smaller mesh without the threads**

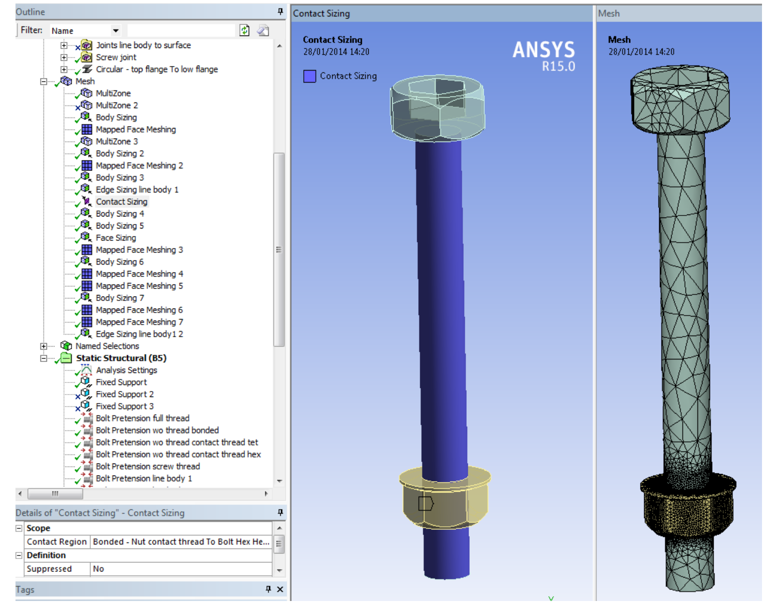


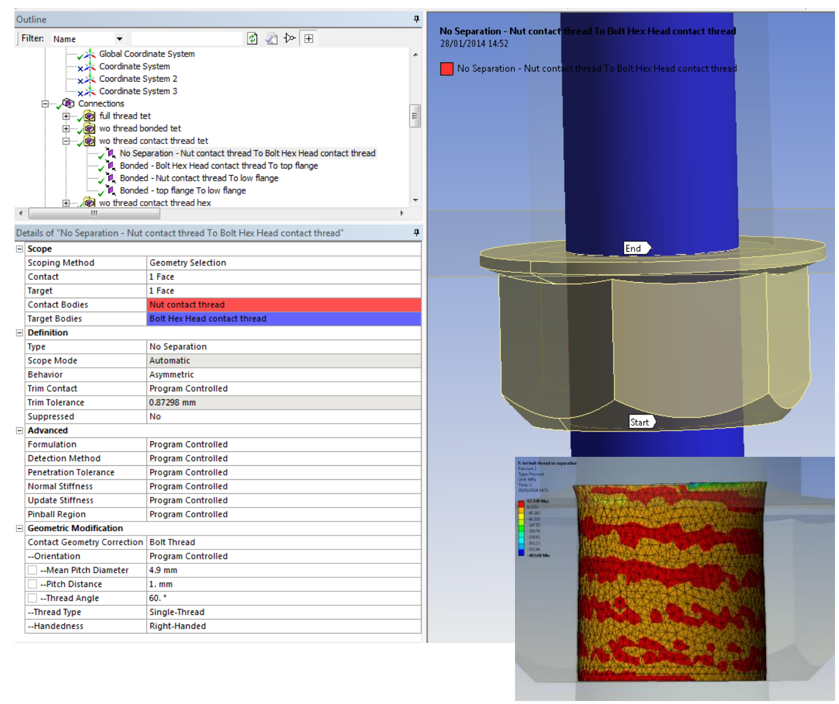


Bolt model 3:

Key features of this approach:

- **Geometry as bolt model 2**
- **New V15 bolt thread contact applied (recommended 4 elements span 1 thread width)**
- **Contact sizing option to increase number of elements in thread area**
- **Contact results show helical load transfer at threads (bonded contact)**

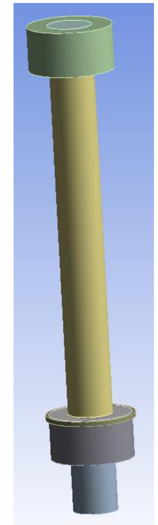


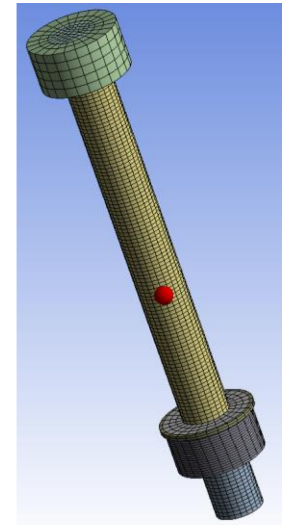


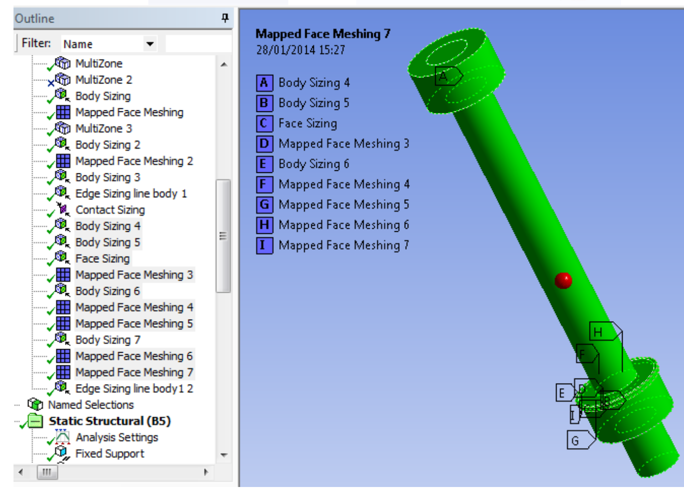
Bolt model 4:

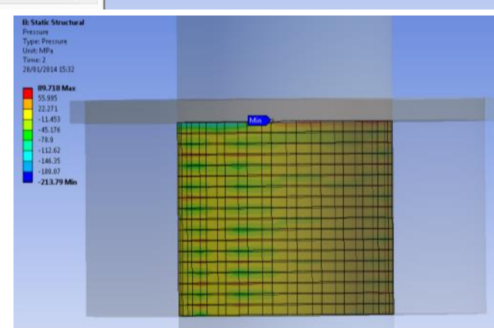
Key features of this approach:

- **Significant amount of geometry preparation on bolt and nut**
  - **De-feature, respecting size of contact area under bolt head/nut and bolt shank diameter**
  - **Decompose to sweep-able bodies**
  - **Multi-body back together**
  - **Prepare 1 fastener and use pattern to replace others**
- **Can take quite a few mesh controls to get a good quality mesh, mesh density can be quite high due to structured mesh continuation from dense thread region, may also benefit from ordered meshing via worksheet**
- **New V15 bolt thread contact applied (recommended 4 elements span 1 thread width)**







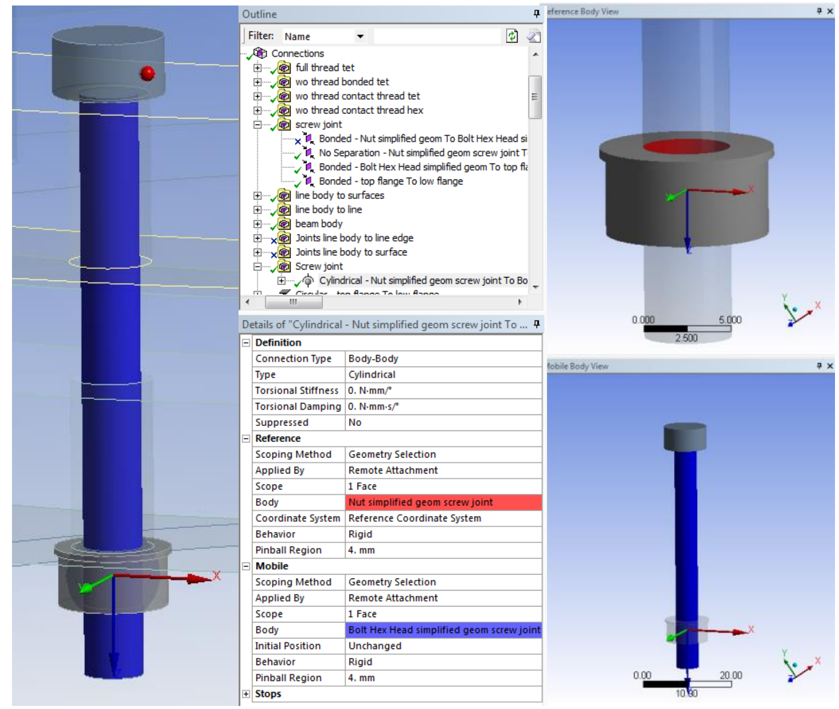


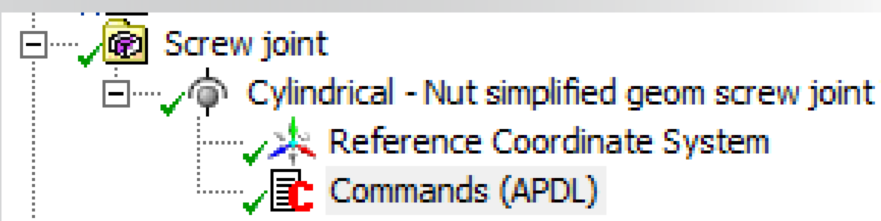
  July 17, 2015

Bolt model 5:

Key features of this approach:

- **Geometry and mesh same as bolt 4**
- **Bolt thread contact replaced with a cylindrical joint**
- **APDL commands to redefine joint as a screw joint**






```
keyo,_jid,1,17
sectype,_jid,joint,screw,_wbjoint
pi=acos(-1)
secjoin,,12
pas=1
secjoin,pitch,(pas/2/pi)
```

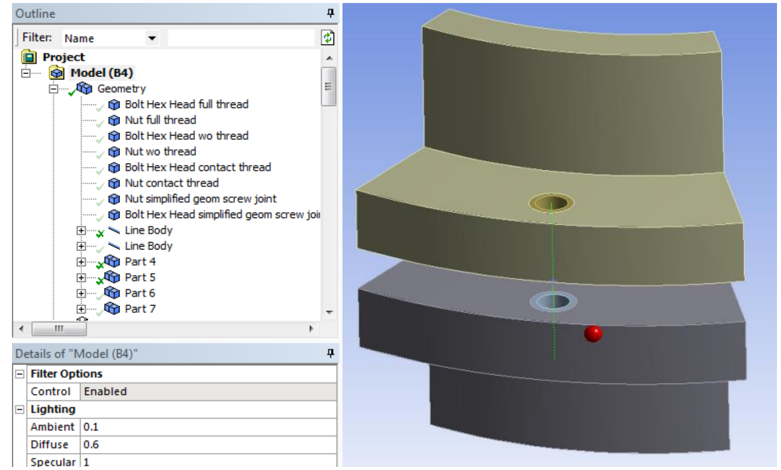

Bolt model 6:

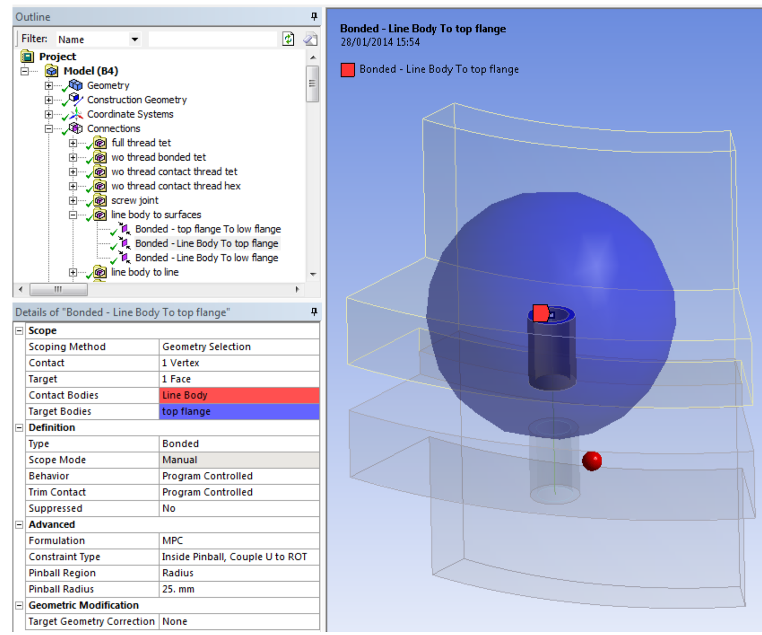
Key features of this approach:

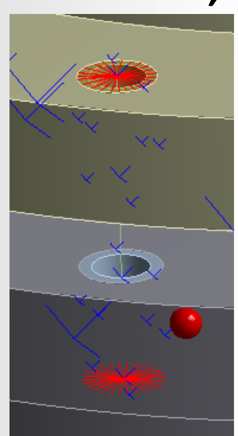
- Geometry preparation
  - Bolt/nut geometry replaced with a line body
  - Upper/lower flanges have been split and mutli-bodied back together to give a contact area to attach the beam ends to.

- Line body meshed as beam elements, model size significantly reduced

- Contact, end of bolt to flange cylindrical face, MPC couple U-Rot inside pinball



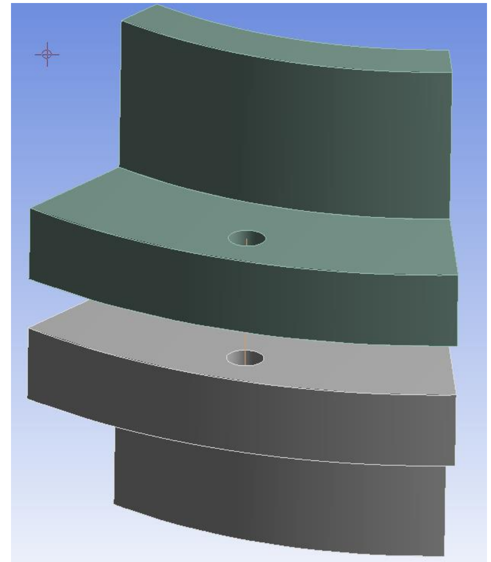


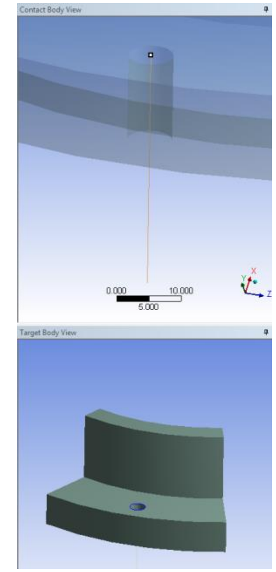


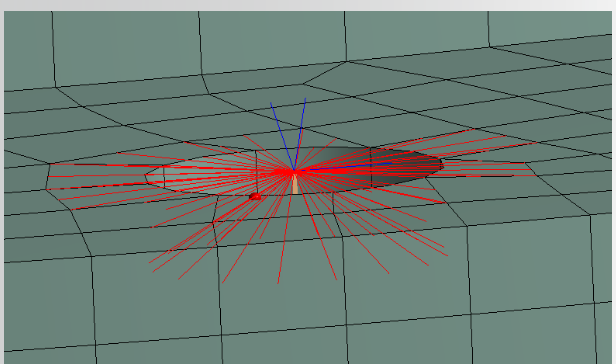
Bolt model 7:

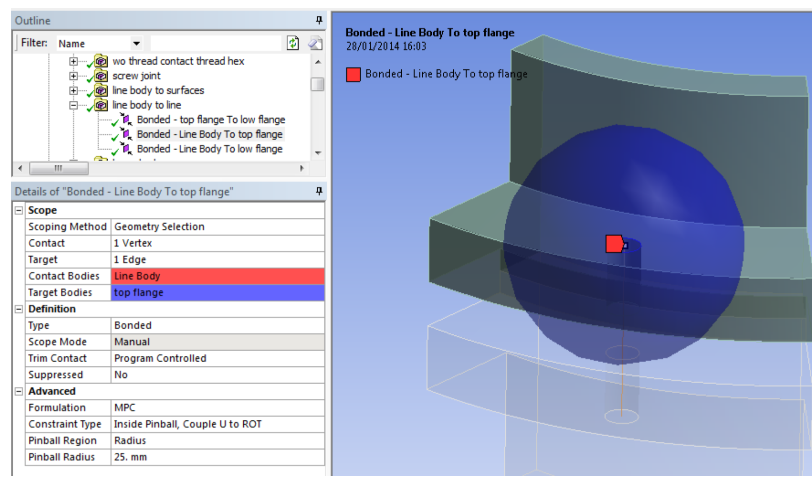
Key features of this approach:

- **Geometry preparation**
  - **Bolt/nut geometry replaced with a line body**
- **Line body meshed as beam elements, model size significantly reduced**
- **Contact, end of bolt to cylindrical edge of bolt hole, MPC couple U-Rot inside pinball, note: for edge contacts WB automatically extends spider out 1 element for load transfer**





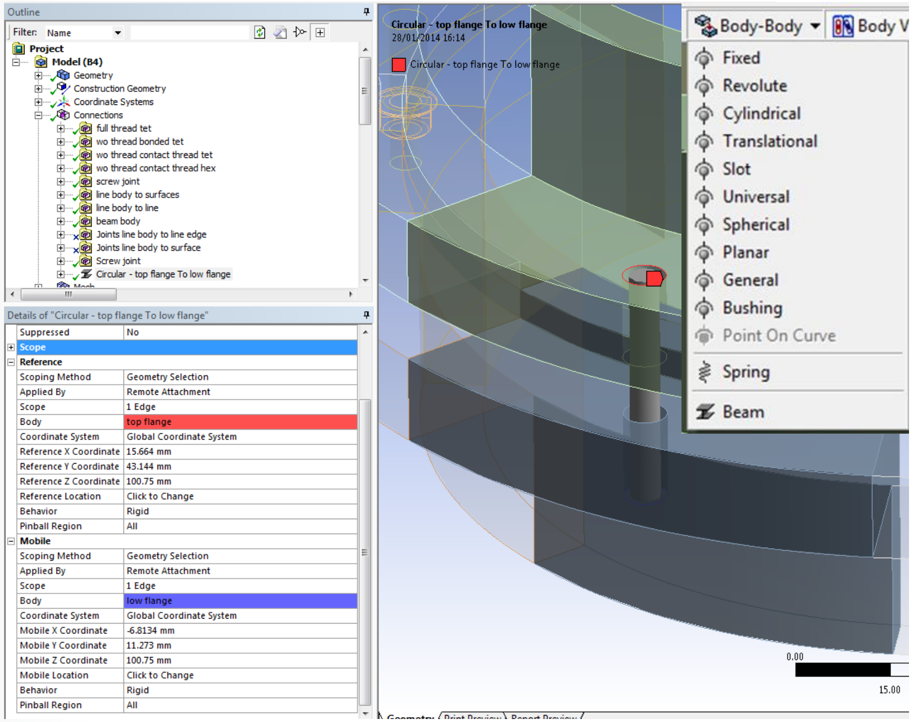




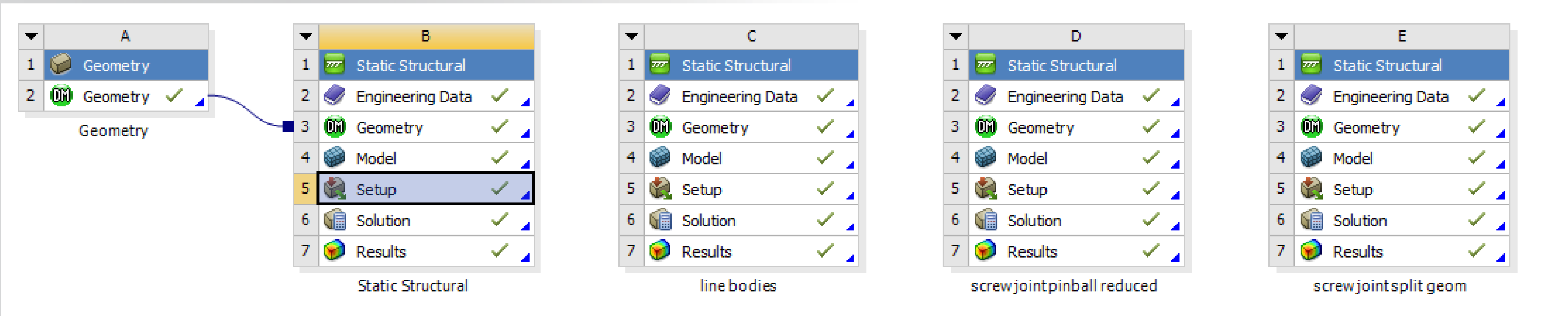
Bolt model 8:

Key features of this approach:

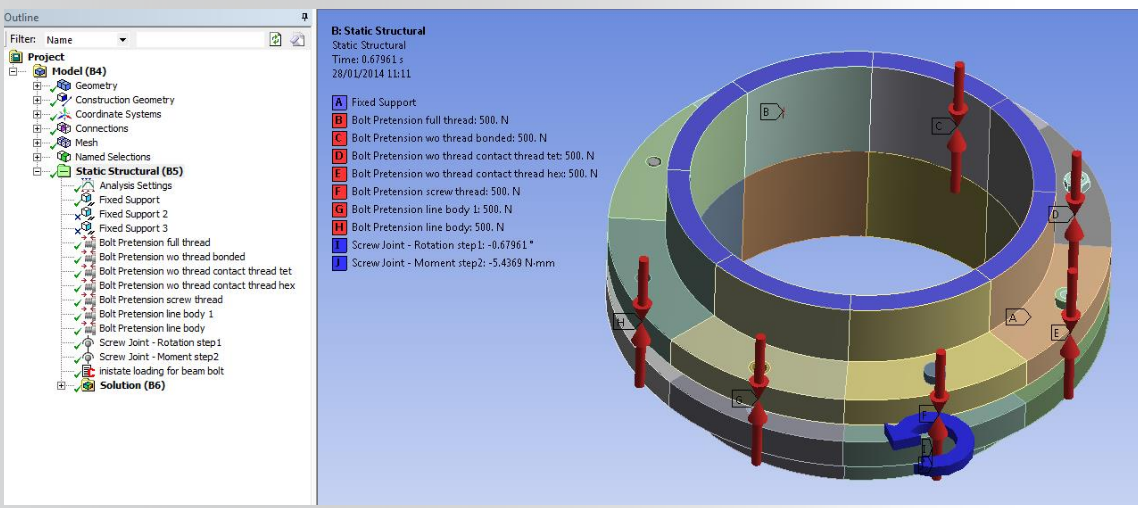
- No bolt/nut geometry
- Use “Body-Body > Beam”
  - Single beam188 element between mobile/reference geometry
  - Scope to edge or surface of bolt holes on flanges
  - Radius of beam = bolt shank diameter
- Recommend use of named selections (flange edge/surface geometry) and object generator to copy a master “body-body beam”
- This method cannot use a bolt pre-tension load directly, need to apply load via APDL inistate commands

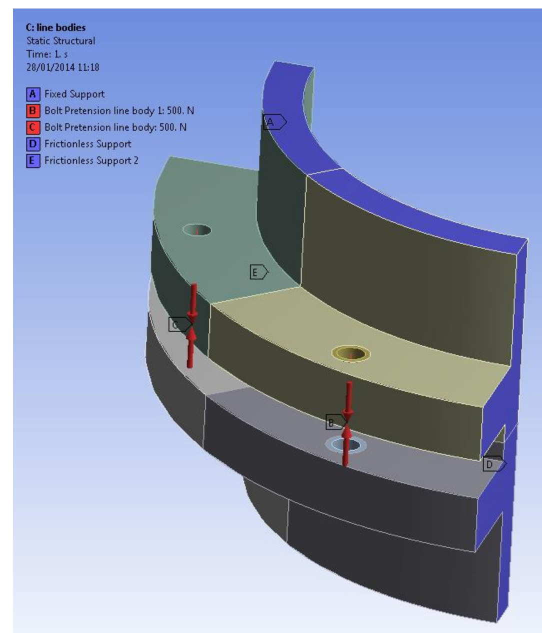


Overview of workflow



Module “B” is the original 8 bolt flange, this can be duplicated to investigate bolt modelling further, i.e. frictional contact, mesh sizing, etc.





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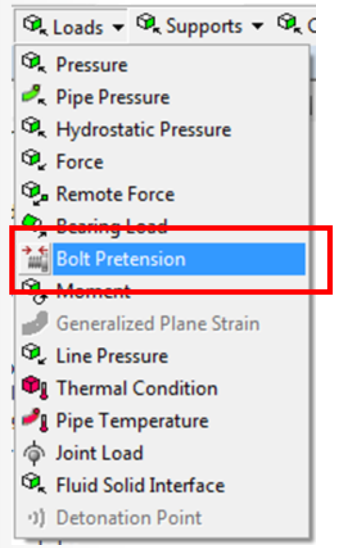
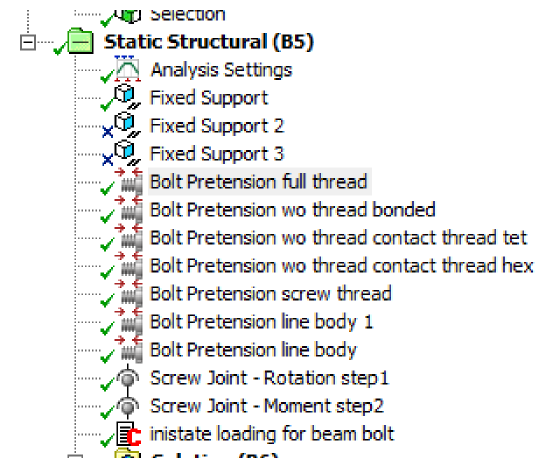
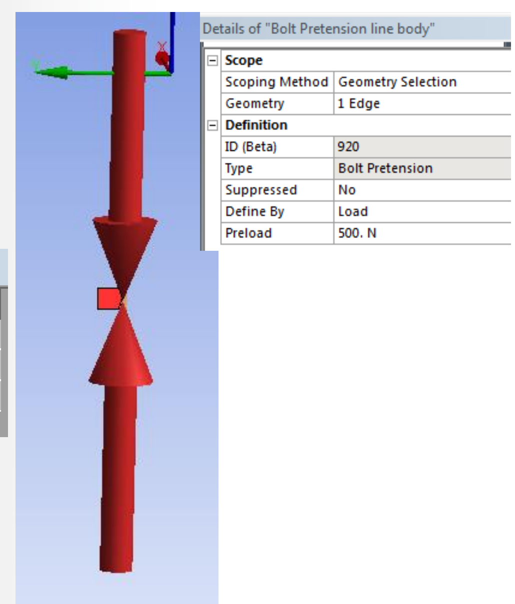
Bolt Pretension

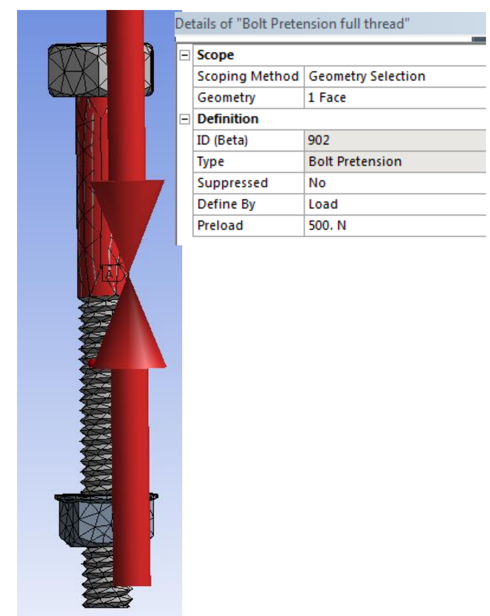
How to apply bolt pretension

- **Insert Bolt Pretension load**
- **Select geometry to apply load to**
  - Solid body > select body or face
  - Line body > select edge
- **Define load**
  - Load / lock / magnitude etc









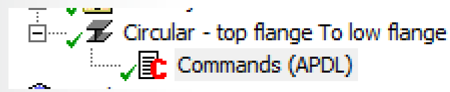
Tabular Data

	Steps	Define By	Preload [N]	Preadjustment [mm]	Increment [mm]
1	1.	Load	500.	N/A	N/A
2	2.	Lock	N/A	N/A	N/A
*					

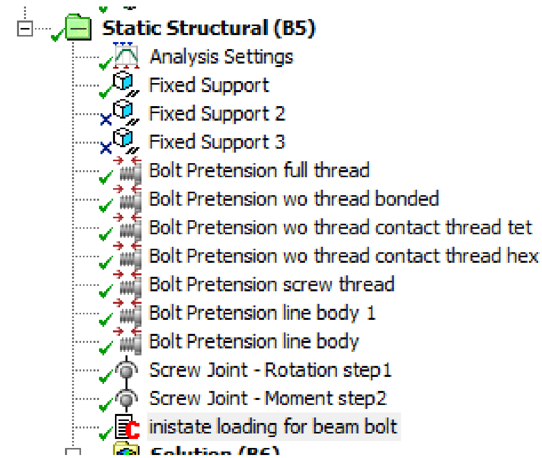
Bolt Pretension

How to apply bolt pretension to a "body-body beam"

- **Inistate stress to beam188 element**
  - **Command snippet**
  - **Define bolt geometry and load**
  - **Calculate initial bolt stress required to "result" in desired bolt load, ie needs to be factored to account for load taken to deform the flange**
  - **If model contains beam elements elsewhere then you will likely need additional APDL commands to isolate these bolt beams to apply inistate commands to**



Identify beams for loading purposes:
beam_bolt_id = _bid

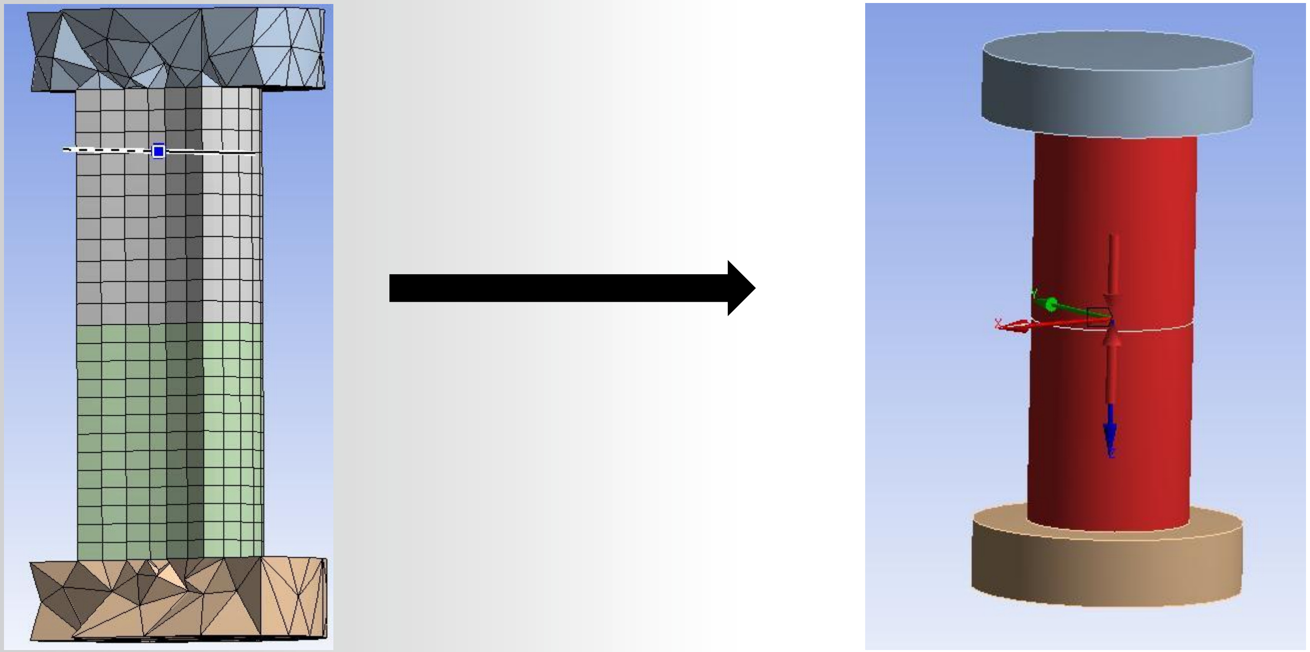



```
bolt_rad  = 2.5    ! bolt shank radius mm
bolt_load = 500    ! bolt pretension load N

bolt_area  = (22/7)*(bolt_rad*bolt_rad)
bolt_stress = 1.5*bolt_load/bolt_area

esel,s,ename,,188                ! select all beam elements in model
esel,r,real,,beam_bolt_id        ! select bolts defined as beams only
nsle                             ! select nodes on beam bolt element
/solu                            ! enter solution to define bolt load
inistate,set,csys,-2             ! select element coordinate system
inistate,set,dtyp,stre           ! set to initial stress definition
inistate,define,,,,,bolt_stress  ! define bolt stress
alls                             ! reselect all entities
```


Bolt Pretension

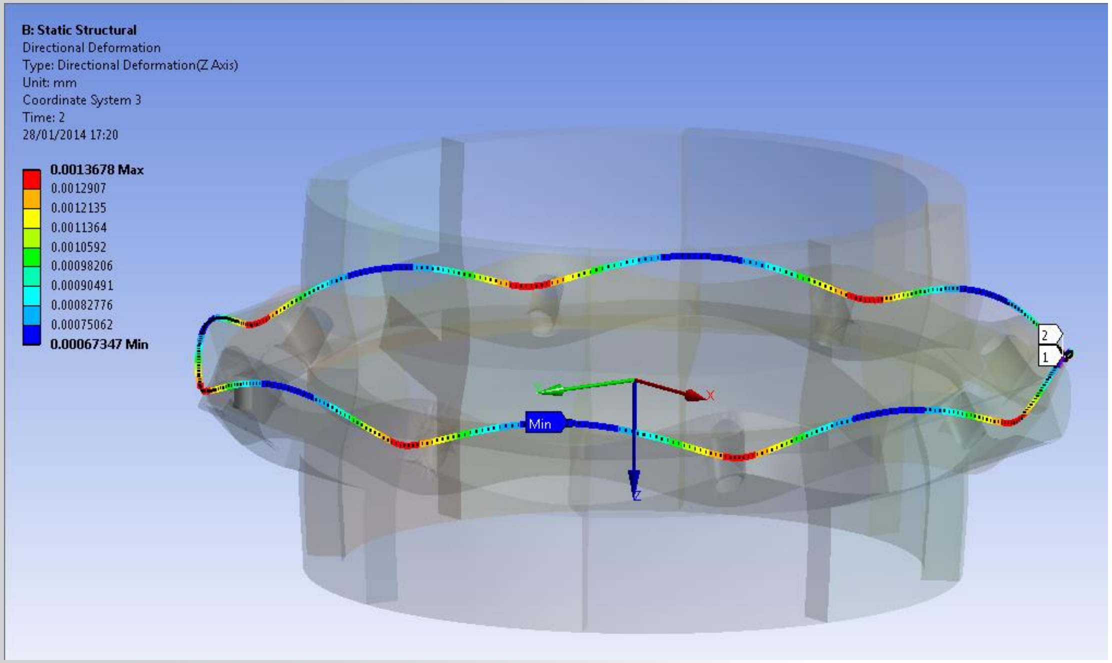
A word on meshing … ensure there is at least 2 elements (hex, tet, beam) along the shank of the bolt

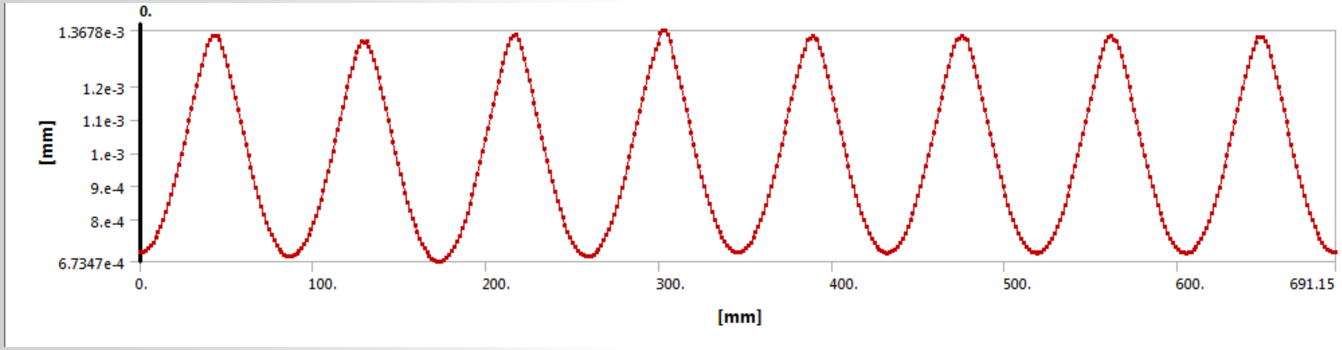
Why … because ANSYS “bolt-pretension” load splits the bolt shank and connects the resulting faces (solid) / vertices(beam) to a pilot node, the load is then applied via the pilot nodes



Results comparison

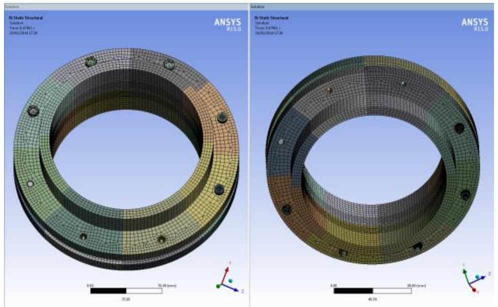
Flange deflection - consistent irrespective of how bolt has been modelled

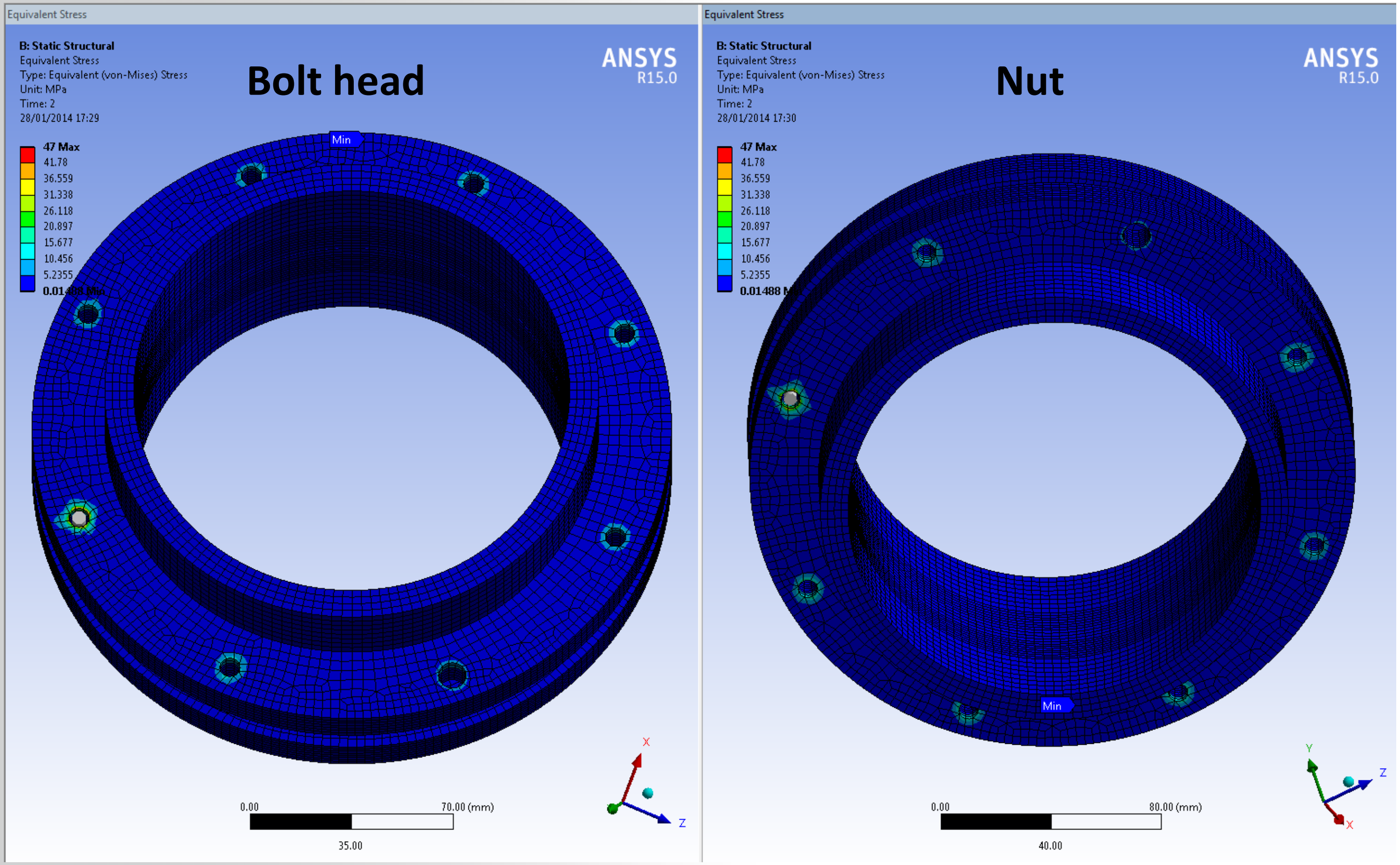




Results comparison

Stress in flange - some differences between "line" and "area" contacts, biggest difference is with beam connector where spider extends out 1 element depth

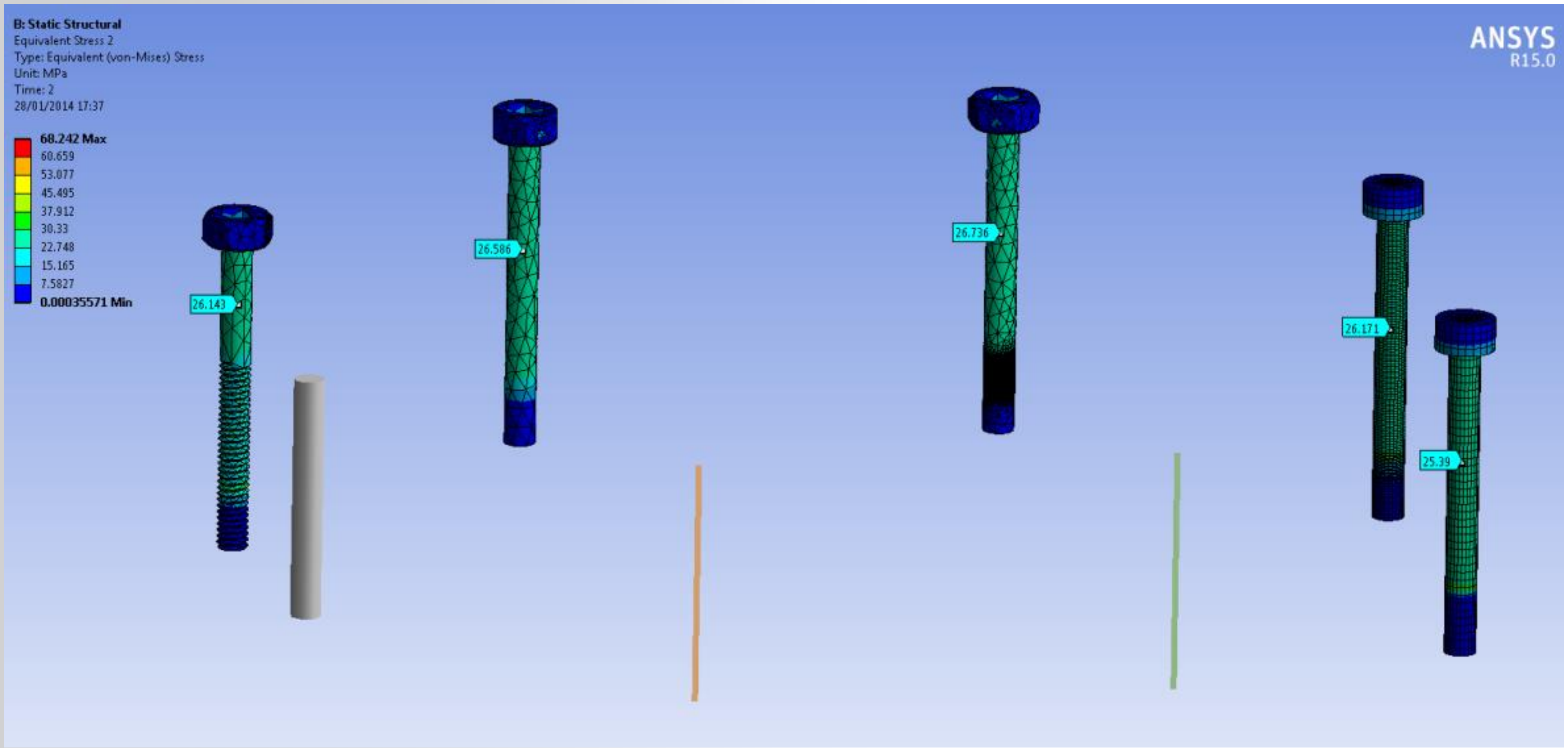




Results comparison

Stress in bolt shank:

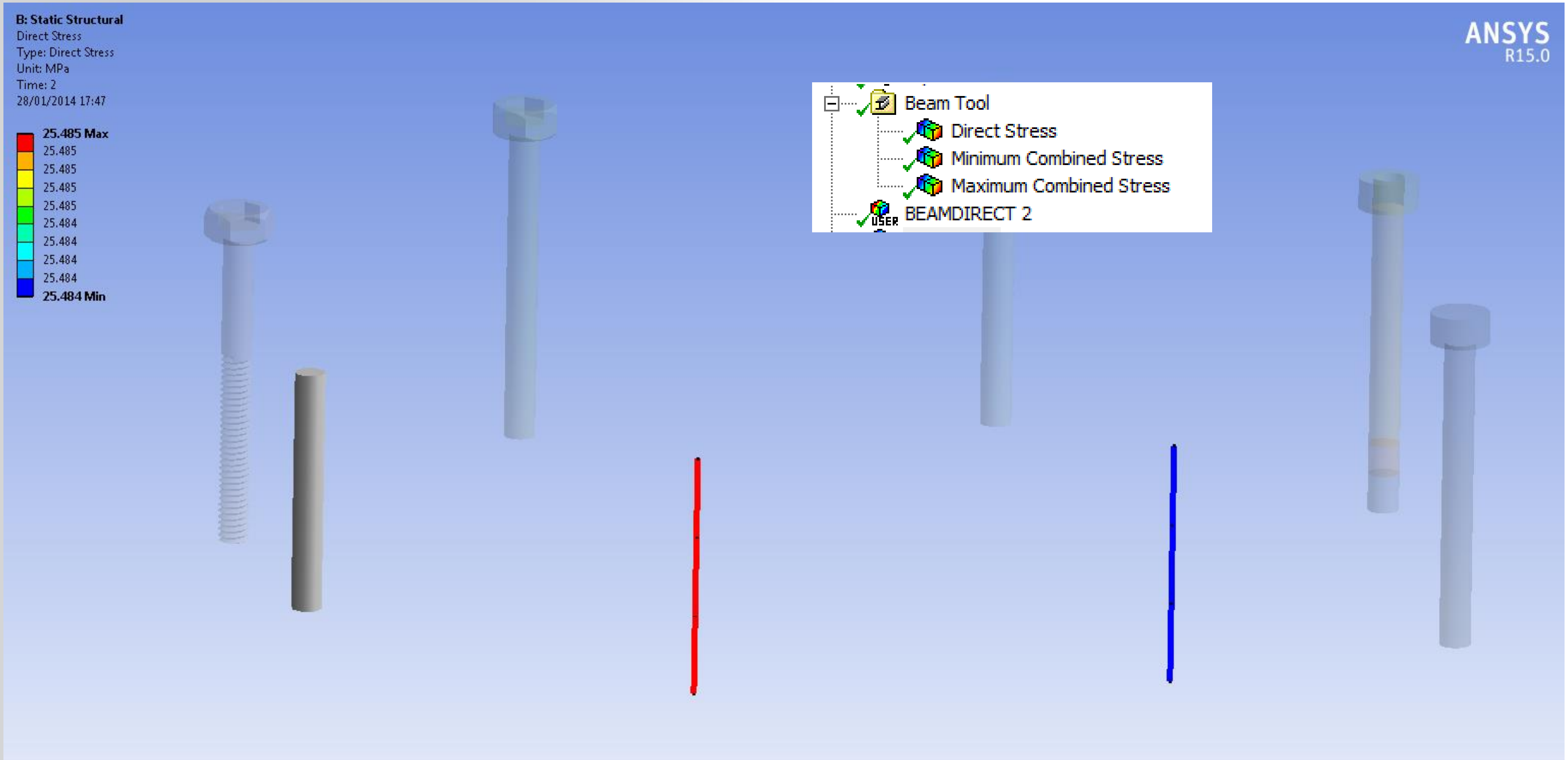
- **Solid body bolts > scope stress to bolt body**
  - **Results fairly consistent irrespective of method used to model bolt**
- **Line body bolts > Post process using “Beam Tool” or “User Result > Beamdirect”**
- **Body-body beam connector > APDL commands to post process**



Results comparison

Stress in bolt shank:

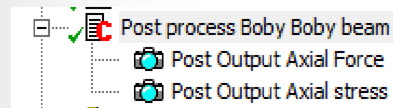
- **Line body bolts > Post process using "Beam Tool" or "User Result > Beamdirect"**
  - **25.5 MPa vs Solid 25.4 to 26.7 MPa**

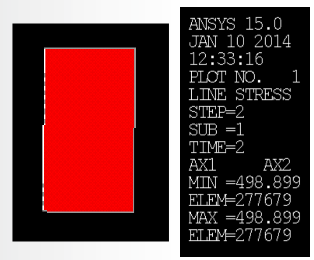


Results comparison

Stress in bolt shank:

- **Body-body beam connector > APDL commands to post process**
- **Axial bolt force = 498.9 N**
- **Bolt shank stress = 25.4 MPa**
- **Bolt shank stress comparison**
  - **Beam connector 25.4 MPa**
  - **Line body 25.5 MPa**
  - **Solid 25.4 to 26.7 Mpa**






```
set,last
esel,s,type,,beam_bolt_id

!Length unit for the following data is MM
/FOC,  1,  62.9820904842815  ,-13.5452039539814
,171.46091721952
/VIEW,  1,  -623.383469365249  ,773.613482745931
,113.645190993093
/ANG,  1,  5.37623044565048
/DIST,  1,  136.558237213941

ETABLE,ax1,smisc,1
ETABLE,ax2,smisc,14
/title, Axial Force Diagram
/SHOW,png
PLLS,ax1,ax2

! Direct Stress Axial
ETABLE,sdir1,smisc,31
ETABLE,sdir2,smisc,36
/title,Direct Stress Axial
/SHOW,png
PLLS,sdir1,sdir2
```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Summary

	Beam Connector	Line body	Solid body
+	• Easy to setup • No geometry required for bolt • Low computation time • Good simplification of bolt/flange stiffness	• Easy to setup • Low computation time • Good simplification of bolt/flange stiffness • Some post-processing tools available	• Most accurate/realistic representation of joint • Stresses available for all parts depending on how modelled • All contact details available, depending on how modelled • Post-processing tools available
-	• No contact detail between fastener and flange • No stress detail in flange • Need to know correct initial stress to achieve required pretension • APDL post-processing	• Requires line bodies in model • No contact detail between fastener and flange • No stress detail in flange	• Some geometry preparation liklely to be required • Mesh controls will be required • Large model / high computational time