Bolt Representation

Modeling the Bolt and Preload

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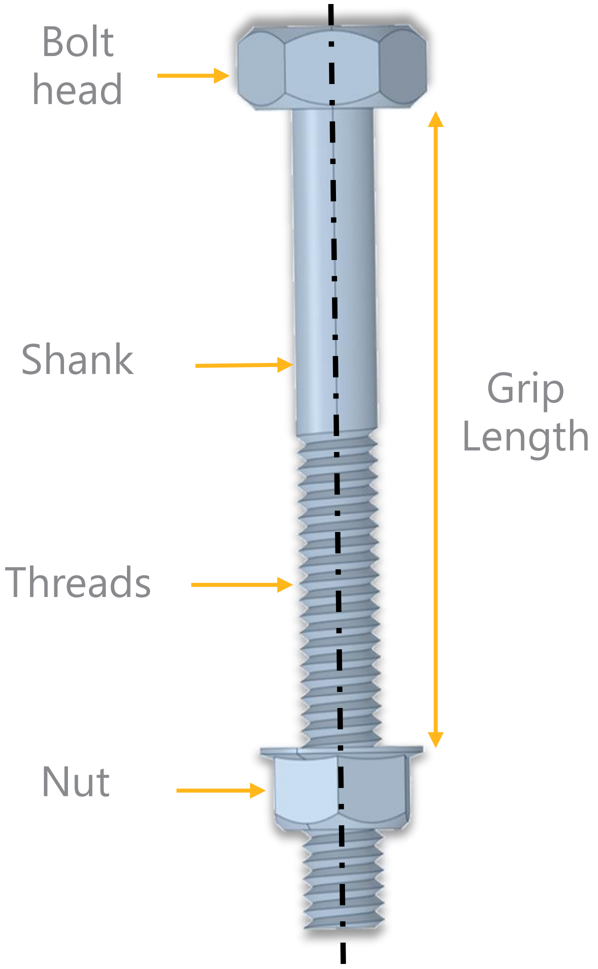
Structure of Bolt and Nut Assembly

- Let’s revisit the structure of bolt and nut Assembly.
  - The bolt head is the flat portion of the bolt which transfers forces to the clamped plates.
  - The nut and the bolt engage via threads which are cut into them. The nut holds the assembly and prevents slippage.
  - Threads are helical groves cut in the shape of V or square. This is where thenut and bolt transfer forces between them.
  - The portion of the bolt between the nut and the bolt head is the grip length.
  - The threadless portion of the bolt is called the shank.
- Some simulation requires modeling the bolt with all details to study the effects of bolt head area, bolt diameter, thread pitch and angle, etc.
- Not all simulations require these details, as bolts are standardized components in many mechanical applications.
- Some simulations can be run with a simplified representation of the bolt as a line body.



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Solid Body Versus Line Body

- When to use a solid body or a line body
  - A solid body can provide detailed results regarding the threads, bolt head area, frictional effects in the bolt and clamped plates, or stress modeling in the compressed area.
  - In cases where these results are not a concern, a simplified bolt representation can be used to save solution time as well as computational resources.
  - When hundreds of bolts are to be modeled, it becomes computationally expensive.
  - In such cases, a line body representation will be more computationally efficient.
  - Efficient solution can reduce the solution time and computational resources, thus saving costs.
  - A little approximation such as using a line body (beam theory) doesn't decrease the accuracy but provides faster solution.

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Solid Body

- The solid bolt parts are discretized using 3D shapes like tetrahedral, prism and hexahedral solid elements.
- Each node has 3 DOFs, resulting in a huge number of equations to be solved.
- A solid body requires less preprocessing time as meshing and contacts can be automated.
- Each element face has multiple integration points; nodal displacements are interpolated to the integration points.
- Stresses are calculated at integration points and extrapolated to the nodes. Further averaged stresses are calculated at the node for the connected elements.
- Solid models are computationally expensive as they require solving a large number of DOFs.
- Solid body simulation results are more accurate. A solid model can capture local effects of stress, strain at a sharp corner, fillet radius, etc.

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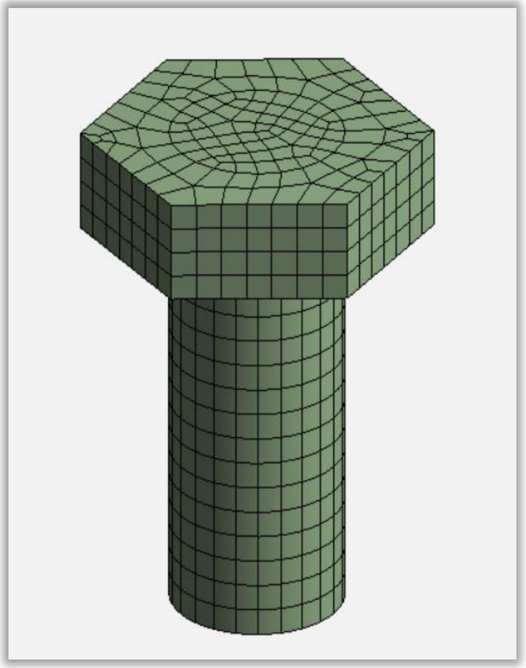
Solid Body (cont.)

- Let's see an example of bolt meshing with solid elements in Ansys Mesher
- A bolt is meshed with hexahedral mesh. With an element size of 3 mm, the total node count is 12610
- Each node has 3 DOFs. Thus the total number of DOFs= 12610 x 3 = 37830
- It is necessary to use solid element
  - To capture the stress and strain in bolt heads, nuts, local stress in threads, etc.
  - To model the friction between the bolt head and clamped plates
  - To model the effects of the threads under the applied loads



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Line Body

- Line body bolts are discretized using 1D 2-node or 3-node beam elements.
- Each node has 3 translational and 3 rotational DOFs.
- Stresses are calculated from section integration points and extrapolated to the nodes. But beam elements cannot calculate averaged stresses.
- We get a reduced state of stress with the line bodies. The solver provides 3 stress components SXX, SXY and SXZ for the line bodies instead of 6 stress components with a solid body..
- Due to low node count, beam models can solve faster and are computationally efficient.
- Line bodies require additional preprocessing work to extract beams, create connections, etc.
- Beam elements can give good estimates of axial and bending stress, but are poor in making shear estimates.

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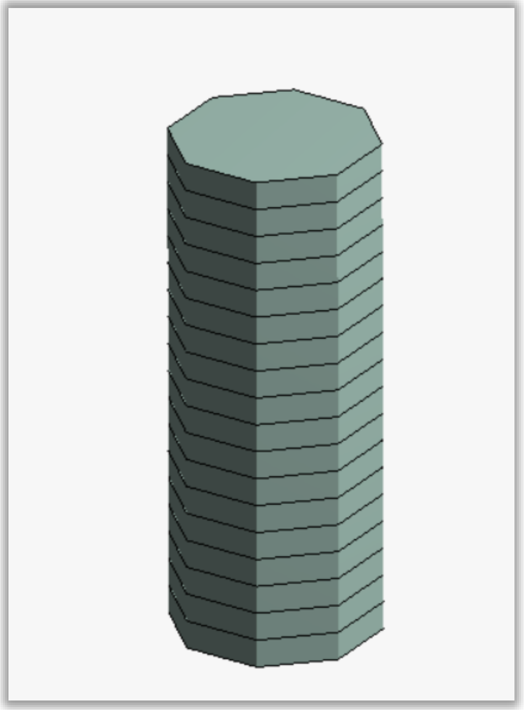
Beam Elements

- Let's see an example of bolt meshing with beam elements in Ansys Mesher
- With the element size of 3mm , the total node count is 39
- Each node has 6 DOFs, so the total number of DOFs= 39 x 6= 234
- Beam elements can be used when
  - Faster solution time is needed
  - There is no need of study stress/strain in bolt heads, nuts or threads
  - The role of bolt is limited to generate preload and interest is in the clamped plate's pressure cone or contact pressure, etc.
  - Bolts are least affected under the loads



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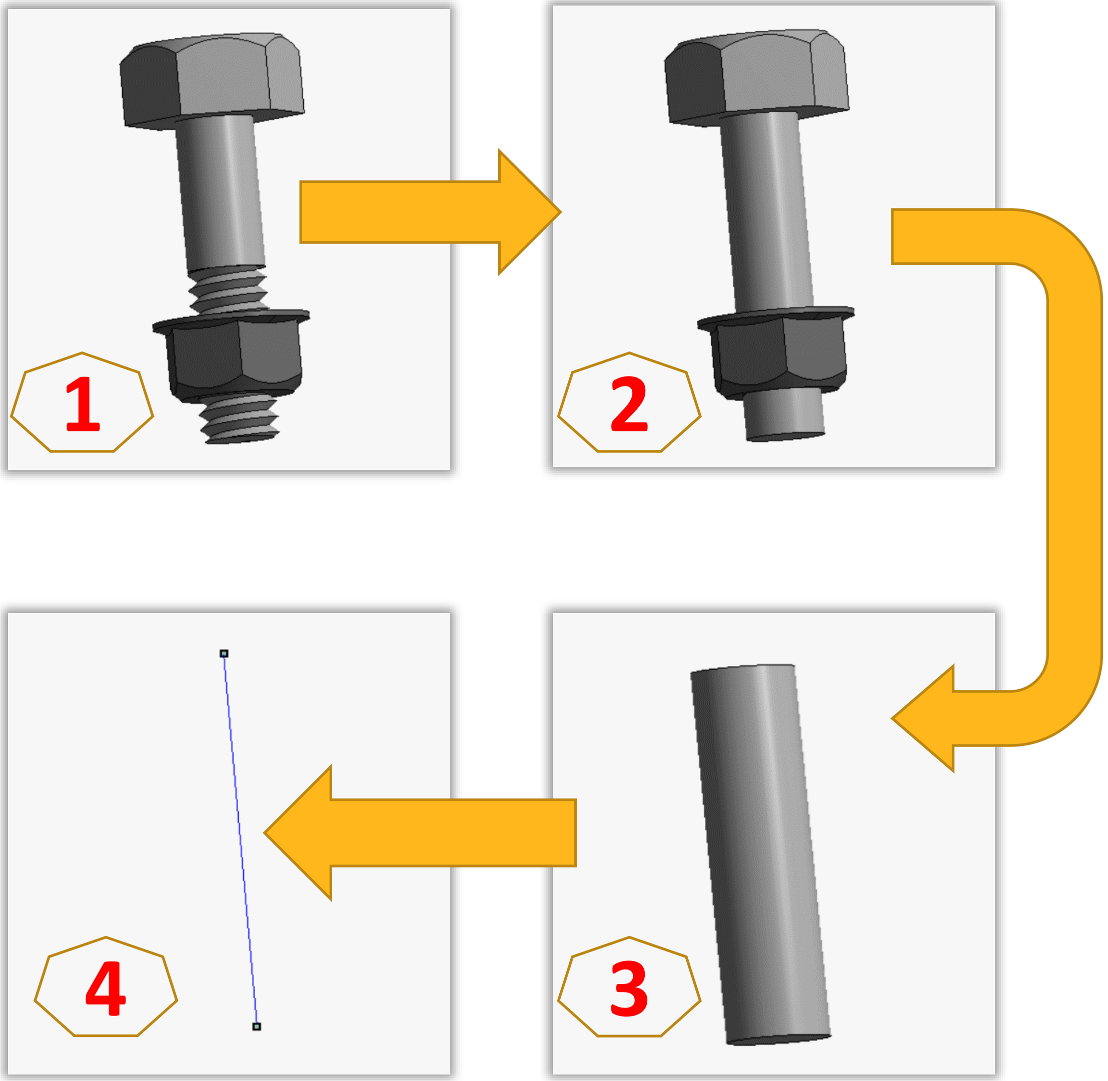
Abstract Modeling of a Bolt

- Consider bolts that are modeled with all the details to study the different features.
- Assume threads have enough strength for load carrying and thus can be ignored for the simulation.
  - The threaded portion is replaced with a cylinder
  - A bonded contact is used between the nut and bolt
- If the simulation requires the bolt to generate the preload or support shear load only, the bolt head and the nut can be removed from modeling.
  - Bolt head, nut and the extra length of the bolt is sliced off from the model
  - Bonded or MPC contact is used between the bolt shank and plate holes
- To further simplify the model, the solid cylinder body is replaced with a line body.



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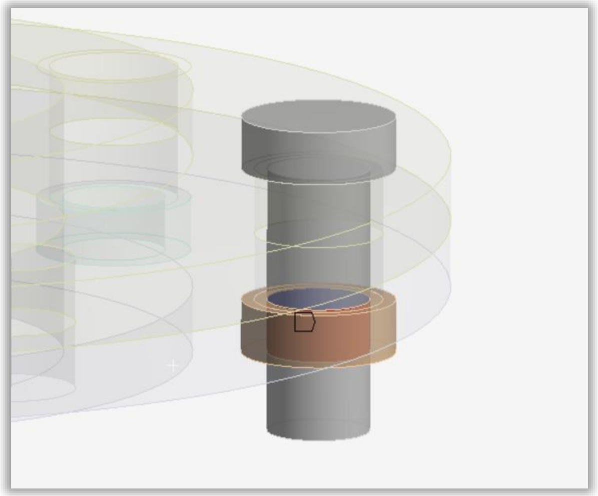
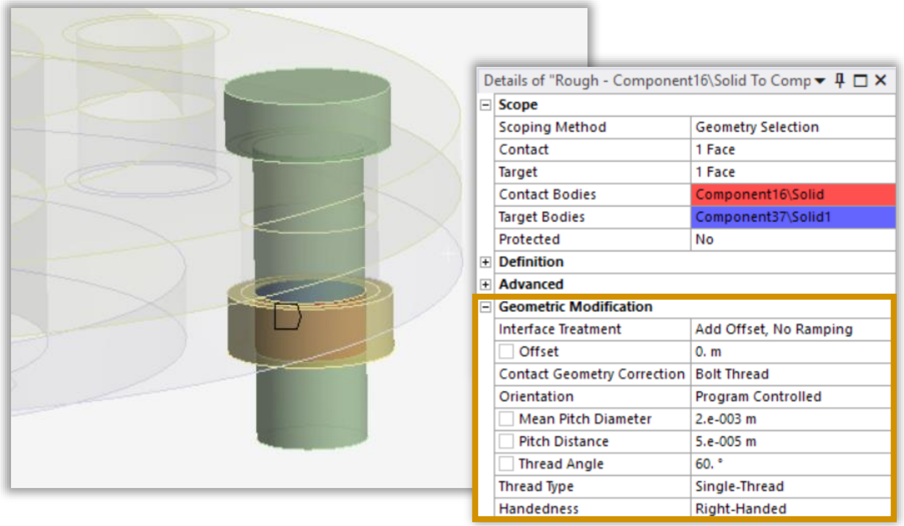
Different Types of Bolt Representation

- Let's see different types of bolt representation



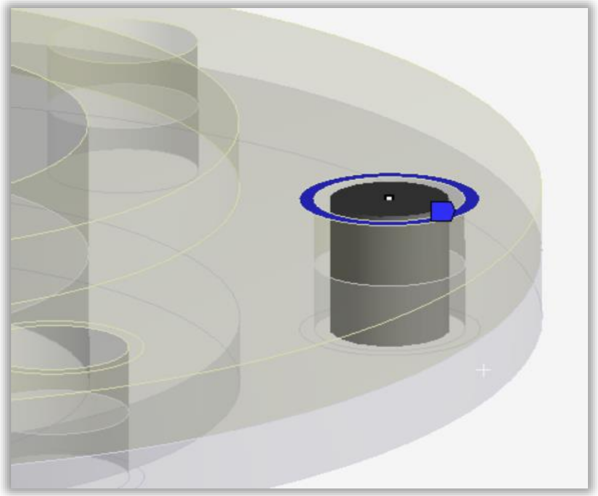
Bolt-nut using solid elements

- Threaded portion is replaced with cylinder
- Bonded contact is used between nut and bolt



Bolt-nut using solid elements

- Threaded portion is replaced with cylinder
- Frictional contact with geometry correction is used between nut and bolt



Line body using imprint for bolt head

- A line body is used to represent the bolt shank
- The bolt head is imprinted on the plate
- Bonded contact is used between the end point and bolt head imprint

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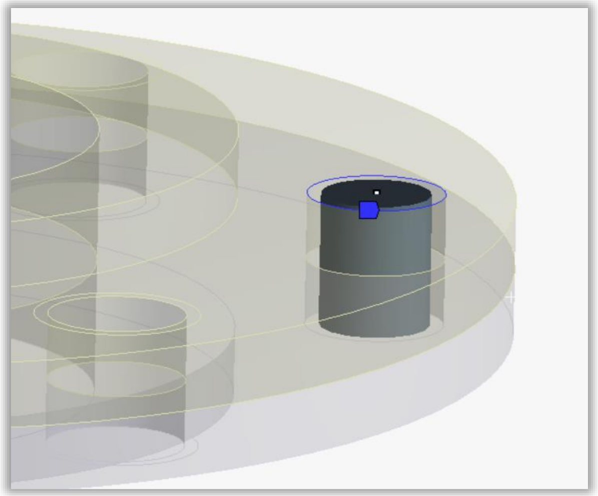
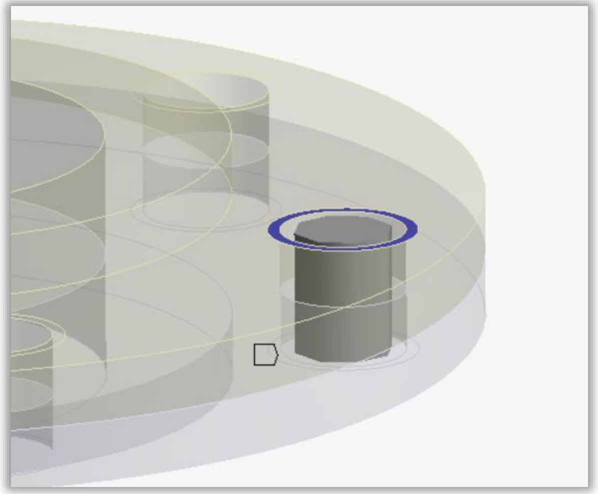
Different Types of Bolt Representation (cont.)



Line body using MPC with plate hole

- A line body is used to represent the bolt shank
- An MPC bonded contact is used between the end point and the plate hole edge



Beam connection (without using geometry)

- Internally creates a beam connecting to two surfaces
- Internally uses remote points to connect the beam to plate surfaces

Details of "Circular - Flange\Flange1 To Flange\Fl...

Graphics Properties	
Definition	
Material	Structural Steel
Cross Section	Circular
Radius	2.e-003 m
Suppressed	No
Beam Length	5.e-003 m
Element APDL Name	
Scope	
Scope	Body-Body
Reference	
Scoping Method	Geometry Selection
Applied By	Remote Attachment
Scope	1 Face
Body	Flange\Flange1
Coordinate System	Global Coordinate System
Reference X Coordinate	1.7321e-002 m
Reference Y Coordinate	0. m
Reference Z Coordinate	1.e-002 m
Reference Location	Click to Change
Behavior	Rigid
Pinball Region	All
Mobile	
Scoping Method	Geometry Selection
Applied By	Remote Attachment
Scope	1 Face
Body	Flange\Flange2
Coordinate System	Global Coordinate System
Mobile X Coordinate	1.7321e-002 m
Mobile Y Coordinate	5.e-003 m

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