Possibilities of modelling the bolts in program ANSYS

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Abstract. In this paper, the techniques of modelling bolts in program ANSYS are investigated. Several types of the bolt models are proposed and compared. The finite element models with solid bolt with and without thread, and no-solid model. The pretension effect is applied for all types of bolts. Different types of connections and finite elements are used for modelling. In addition, the assembled mechanical structure is loaded by pretension effect and the field of stress and displacement of points around holes for bolts are investigated. Moreover, the stresses in the bolts computed by three-dimensional finite elements are investigated.

1. Introduction
The bolts are used for connection of two or more parts together. For good connection every joint have to be very tied and loaded by pretension load applied to the bolt. A lot of studies are dedicated to study the behaviour of bolts. Kim et al. [1] investigated a modelling technique of the bolted joints. They stated, that the solid bolt model provided the best accurate responses compared with the experimental results. In addition, the coupled bolt model showed the smaller computational time and memory usage. Zhang and Poirier [2] used an analytical model of bolted joints and took into account the compression deformation caused by external force. This analytical model cannot be used to bolted assemblies when the members are of different geometry or when the external forces are not symmetric. Maggi et al. [3] showed using the ANSYS how changes of geometric shapes in bolted plate could change the connection behaviour. Other application can be found in papers [4–8].

The bolts are assembled from parts with small edges and shapes. So, if the real bolts are modelled in the finite element software, then the simulation need a lot effort for computation of analysis. In this work, the possibilities of modelling of bolts are investigated and compared in program ANSYS. The bolts are modelled as 3D and line bodies with different definition of contacts behaviour.

2. The finite element modelling of bolts
The modelling methods of bolts are described in this chapter. The model consists of two flanges with holes for bolts and different types of modelled bolts (figure 1). In this model is taken into account the pretension effect (500 N) and a contact behaviour between bodies. All created holes have bigger diameter as diameter of considered bolts. The bottom face of the flange is fixed.

2.1. Bolt model with real thread
The bolt is modelled as solid body with thread (figure 2). On its body, the finite element mesh is created by three-dimensional elements. For better results, the mesh has to be very fine. The pretension is applied
by the option pretension load in ANSYS. The contacts between all parts are defined as frictional with coefficient equal 0.15.

**Figure 1.** Model of assembly.  
**Figure 2.** Real bolt model with thread.

### 2.2. Bolt model with thread defined in options of contact
The modelled bolt is shown in figure 3, it is simpler than the above model, because the thread is deleted. The same types of pretension effect and contacts are used. However, the frictional contact between nut and the body of bolt is modified by option “Contact correction” where the bolt thread is defined using the real parameters of thread.

**Figure 3.** Bolt model with thread defined in options of contact.  
**Figure 4.** Bolt model without thread.

### 2.3. Bolt model without thread
The modelled bolt is shown in figure 4. It is almost the same as the above model, the thread is deleted and the contact behaviour does not use option “Contact correction”. The same type of pretension effect is used. The frictional contacts between bolt and flanges are used and bonded contact between nut and head of bolt is used.
2.4. **Bolt model with cylindrical head and nut**

The next model (figure 5) is modelled as solid body but the small faces on head and nut are removed. The bonded contact is used between nut and body of bolt. Other contacts are defined as frictional.

![Figure 5. Bolt model with cylindrical head and nut.](image1)

![Figure 6. Bolt model with cylindrical head and nut, and cylindrical joint contact.](image2)

2.5. **Bolt model with cylindrical head and nut, and cylindrical joint contact**

The solid model is shown in figure 6 and it is the same as mentioned above. The bonded contact between nut and bolt is replaced by cylindrical joint with defined thread parameters. The thread parameters have to be defined by using the “Commands”.

2.6. **Bolt model as line body with bonded contact and imprint faces**

The 3D solid body is replaced by line body (figure 7) whose diameter is the same as diameter of the bolt. The line body is meshed by beam elements BEAM188. The bonded contact is used for the connection between the line body and the flanges. One end of the line is connected with the upper imprint face on the flange and the other end is connected with the lower imprint face of the flange. However, the multi point constraint is defined in the contact formulation. The end of the link body with flange is connected by rigid links.

2.7. **Bolt model as line body with bonded contact**

The 3D solid body is replaced too by line body (figure 8) whose diameter is the same as diameter of the bolt. The line body is meshed again by beam elements BEAM188. This model is simplified because it does need the imprint faces. The bonded contact is used for the connection between the line body and the flanges. The one end of the line is connected with the upper flange and the other end is connected with the lower flange. The pinball radius must be defined in the contact options. The one should be big enough to include the cylindrical edges of real structure. However, the multi point constraint is defined in the contact formulation. The end of the link body with flange is connected by rigid links.
2.8. Bolt model without solid and line body
The bolt is not modelled in geometry, only the beam connector is used (figure 9). In the ANSYS Workbench Connection menu, the beam connect is created from body to body. The same procedure for the connection is used as is mentioned above.

3. Results and discussion
The model with defined contacts, pretension effects and boundary conditions is computed by ANSYS software. At first, the reaction forces for all modelled bolts are checked to ensure they are the same. The computed stresses on the whole body of the bolts can be compared for the whole 3D solid body models (figure 10). The computed stresses of the line bodies are the same for the whole cross-section. To view results on the body to body beam connector is required to use the ANSYS parametric design language commands. The displacement of the points of model are shown in the figure 11. It can be stated that the
displacements are axially symmetric. For the solid bodies can be concluded that the stresses are available for all parts, the best representation or real bolt, the mesh must be fine, the high computational time. For the line body can be stated that the low computational time is required, simple geometry but no contact results. The geometry and the contact results are unavailable for the beam connector. The APDL commands are needed to know for the post-processing.

The behaviour of the flanges is affected by definition of contacts. The biggest effect can be seen for body to body beam connector, because bonded contact is defined only between edges.

Figure 10. Computed stresses in the solid bolts (MPa).

Figure 11. Computed displacements in the model (mm).

4. Conclusion
In this paper, the possibilities of modelling of the bolts in ANSYS software were investigated. The solid models were compared with line models and with beam connector without body. The basic advantages and disadvantages were summarized. If it is necessary to know the behaviour of bolts, then the best
option is to use the 3D solid bolts in the models. If they only represent the stiffness of the joint, then it is possible to use the line bodies. The body to body beam connector is suitable for the structures where do not have to modelled the bolts.

5. References
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