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# Influence of Thread Root Radius on Maximum Local Stresses at Large Diameter Bolts under Axial Loading

*In the thread root area of the threaded bolts submitted to axial loading occur local stresses, higher that nominal stresses calculated for the bolts. These local stresses can generate failure and can reduce the fatigue life of the parts. The paper is focused on the study of the influence of the thread root radius on the maximum local stresses. A large diameter trapezoidal bolt was subjected to a static analysis (axial loading) using finite element simulation.*

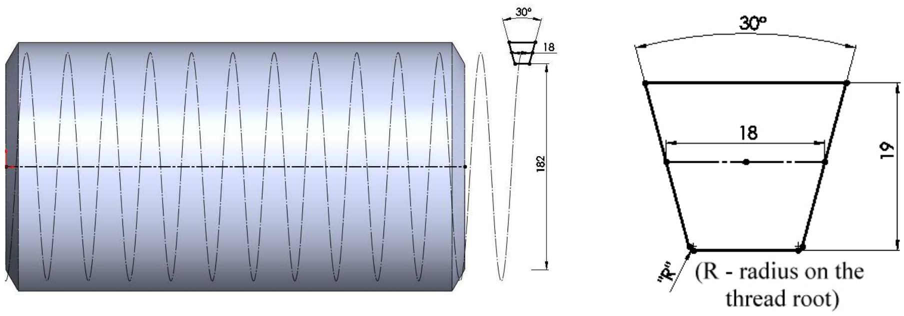
***Keywords***: *threaded bolts, local stress, FEM analysis, 2D simplification*

## 1. Introduction

Threaded connections are components widely used on the mechanical systems. Due the geometric features and the manufacturing processes [3], [5], [8], in the thread area of these elements occur high local stresses that exceed the nominal values obtained by calculus [6], [7], [9]. These local stresses, highlighted by experimental methods and by finite element simulations can lead to part failure [3], [10].

The research is focused on the large diameter threaded bolts (nominal diameter over 200 mm) used at the positioning systems of heavy duty mechanical equipment. Previous researches revealed that the bolts with trapezoidal thread have a superior behaviour for these applications, compared to the bolts with square thread [2]. Also the stress distributions revealed that the maximum local stresses occur in the root area of the trapezoidal thread. These maximum local stresses vary on the thread turns, the maximum values being located on the first turn from the contact bolt – nut [2].

A bolt with trapezoidal thread Tr220x36 (figure 1) was subjected to axial loading. The static FEM (finite element method) analysis was made using the Solid Works Simulation. A 2D planar simplification was used in order to enable the increase of the mesh quality in the area of the thread root. This simplification does not have a significant influence on the results accuracy and decrease the simulation time, compared to a 3D study [1,3,4].




a) b)

**Figure 1.** Main parameters of threaded bolt

### 2. FEM Study Definition

The material used in simulation was the carbon steel grade 1.0577, with the yield strength $Rp_{0.2}$≈275 MPa, tensile strength $R_m$≈480 MPa, Young's modulus E=2.1e5 MPa and Poisson's ratio $\upsilon$=0.28. The model was considered linear elastic isotropic and the default failure criterion was the maximum von Mises Stress.

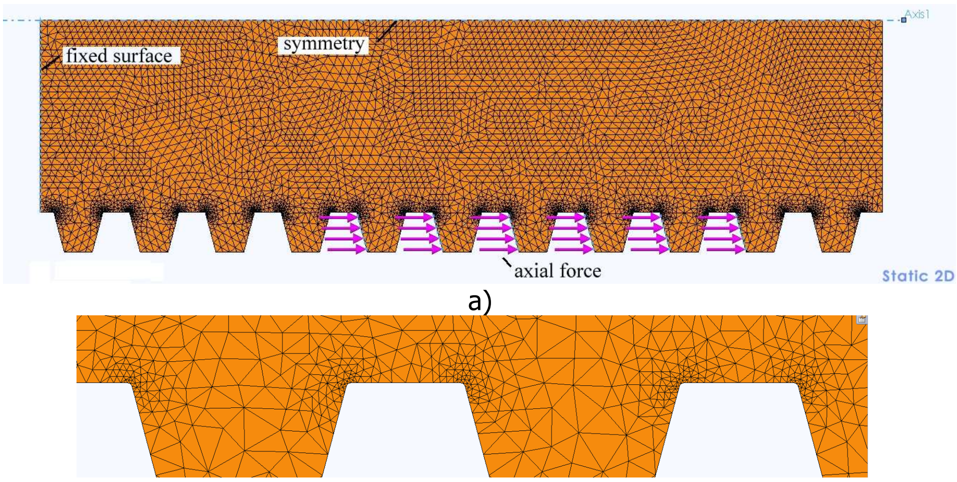
The mesh was generated at a maximum element size of 4 mm with a refinement in the fillet area from the thread root (maximum element size of 1 mm). The mesh details are presented in table 1 and figure 1.

**Table 1.** Mesh properties

| | |
|---|---|
| Mesh type | Planar 2D Mesh |
| Mesher used | Curvature based mesh |
| Maximum element size | 4.010 mm |
| Maximum element size on thread root | 1.007 mm |
| Total nodes | 33741 |
| Total elements | 16426 |

The fixture (0 DOF) was applied on the end surface of the bolt (figure 2, a). The axial force (F=260 kN) was applied on six thread turns, on the surface in contact between the bolt and the nut threads (the thread surface between the minor diameter of the bolt - 182 mm and the minor diameter of the nut – 184 mm, was not loaded). The bolt was designed with a total length corresponding to 11 thread turns. The end turns were not summited to loading, in order to remove the influence of their geometric features on the stress state.

At the trapezoidal turns the edge of intersection between the thread turns and the minor diameter cylinder represents the main stress concentrator of the thread [8], [11], [12]. A fillet radius (R – figure 1) was applied on this edge in order to decrease the maximum local stresses. The radius was varied between 0.1 mm and 0.6 mm, values lower than the gap between the bolt and the nut. This filet can be manufactured at in thread turning process, using a cutting insert with tip radius.




a)

b)

**Figure 2.** FEM study definition: a) planar mesh with the force and the fixtures applied and b) detail on mesh refinement at thread root

### 3. Results

The stresses (von Mises and axial stresses) obtained for the bolts with the six values of radius are presented in table 2. The von Mises stress variation $\Delta\sigma_{vonMises} =(\sigma_{vMi} - \sigma_{vM0})\cdot100/\sigma_{vM0}$, was referenced to the von Mises stress $\sigma_{vM0,}$ obtained at the bolts with R=0.1 mm.

**Table 2.** Stress variation at various thread root radius

| Crt. No. | R [mm] | $\sigma_{vonMises}$ [MPa] | $\sigma_x$ [MPa] | $\sigma_y$ [MPa] | $\sigma_z$ [MPa] | $\Delta\sigma_{vonMises}$ [%] |
|---|---|---|---|---|---|---|
| 1 | 0.1 | 114.8 | 80.3 | 45 | 109.4 | reference |
| 2 | 0.2 | 94.7 | 71.3 | 33.2 | 98.7 | -17.51 |
| 3 | 0.3 | 75.3 | 58.5 | 28.1 | 82.1 | -34.41 |
| 4 | 0.4 | 68.8 | 50.3 | 25.4 | 71.9 | -40.07 |
| 5 | 0.5 | 66 | 45.4 | 22.5 | 69.1 | -42.51 |
| 6 | 0.6 | 63.9 | 40.2 | 20.8 | 59.9 | -44.34 |

The variation of stresses indicates a significant decrease for the bolts with R=0.6 mm (44.34% lower than for R=0.1). This decrease occurs on all principal directions (figure 3).

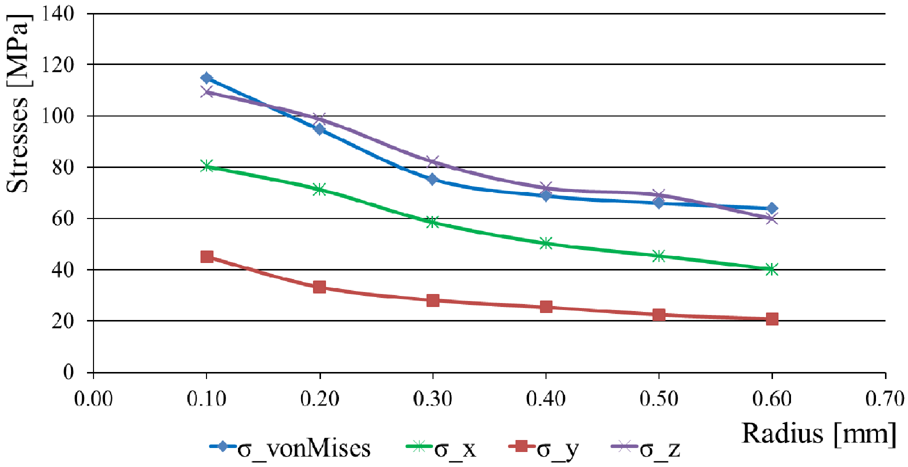



**Figure 3.** Stresses vs. thread root radius variation

The Von Mises stress distribution for the bolt with R=0.6 mm (figure 4) highlights the occurrence of the maximum stress in the thread root area. This distribution is similar for all six studies.

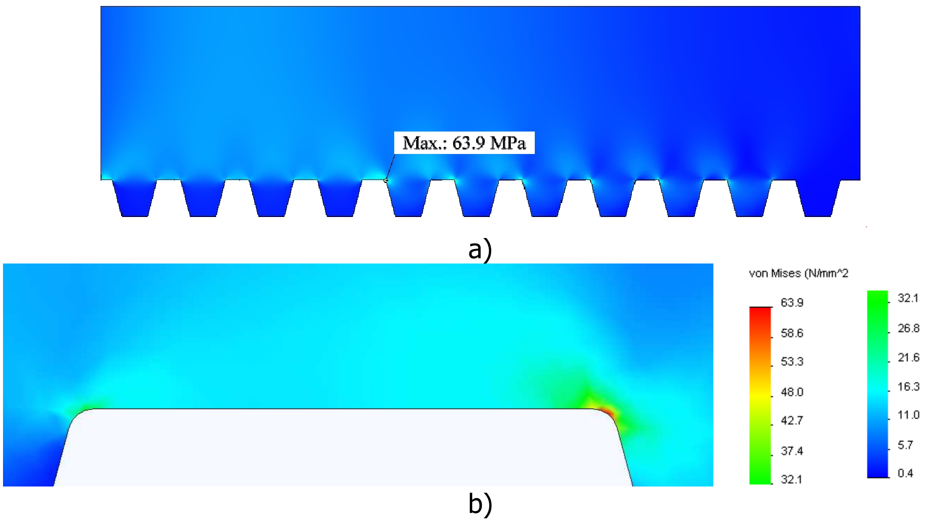



**Figure 4.** Von Mises stress variation for the bolt with R=0.6 mm: a) overview and b) details on the root area of the first thread turn of bolt – nut interface

## 4. Conclusion

The paper points out the influence of the thread root radius on the maximum local stresses at a large diameter bolt under axial loading. The analyses were made using static planar 2D FEM studies. For the bolt with the trapezoidal thread Tr220x36, the variation of the radius from 0.1 mm to 0.6 mm lead to a decrease of the maximum local stresses with approximately 44 %. This decrease can improve the fatigue behaviour of the part.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