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INFLUENCE OF THE TOLERANCES OF THE THREADED JOINTS ON PRELOADED BOLTED CONNECTION

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Abstract: On the base of experimental results we can conclude that the mini bolt and large internal threads as well as large bolt and mini internal thread combination leads to developing of not satisfied preload. It means that the combination of marginal values of the tolerance field could cause “loose” or “forced” fittings. If we consider the presence of lubricant it could effect the overloading of the bolt connection.

KEYWORDS: bolt connection, tolerance, preload

1 Introduction into the problem

Bolted connections subjected to a fluctuating load are usually created as preloaded connections. The design of a preloaded connection is initiated by force-elongation diagram of the connection. Analysis of the assembly and properly created model enables definition of the recommended preload as well as the tightening torque. The application of the tightening torque calculation concept can result case of not satisfied clamping force in the joint or the overloading of the bolt. The contribution analyses interaction between the tolerances and fittings respectively of threaded connection and the resulting clamping force of the connection.

2 Basics of preloaded bolt connection dimensioning, tightening methods

The preload is very desirable in bolted connection, we must consider means of ensuring that the preload is actually developed when the parts are assembled.

In case if the overall length of the bolt can actually be measured when it is assembled, the bolt elongation due to the preload can be computed using appropriate formula. Then the nut is tightened until the bolt elongates through the calculated value. But the elongation of a screw cannot usually be measured, because the end of bolt or stud is in a blind hole. It is also impractical especially in serial production to measure bolt elongation. In such cases the wrench torque required to develop the specified preload must be estimated. Then the torque wrenching method may be used.

The turn of the nut method requires first to define the meaning of snug tight. The snug tight condition is the tightness attained by a partial wrench torque. When the snug tight condition is attained, all additional turning develops useful tension in the bolt. The method requires computing the fractional number of turns necessary to develop the required preload from the initial snug tight condition.

Although the coefficient of friction may vary widely, a good estimate of the torque required to produce a given preload can be obtained by computing based on data characterising the connection members, friction conditions, material properties. The greatest influence on the required wrenching

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torque has the friction between the members of connection. The coefficient of friction depends upon the surface roughness, accuracy and presence of lubricant.

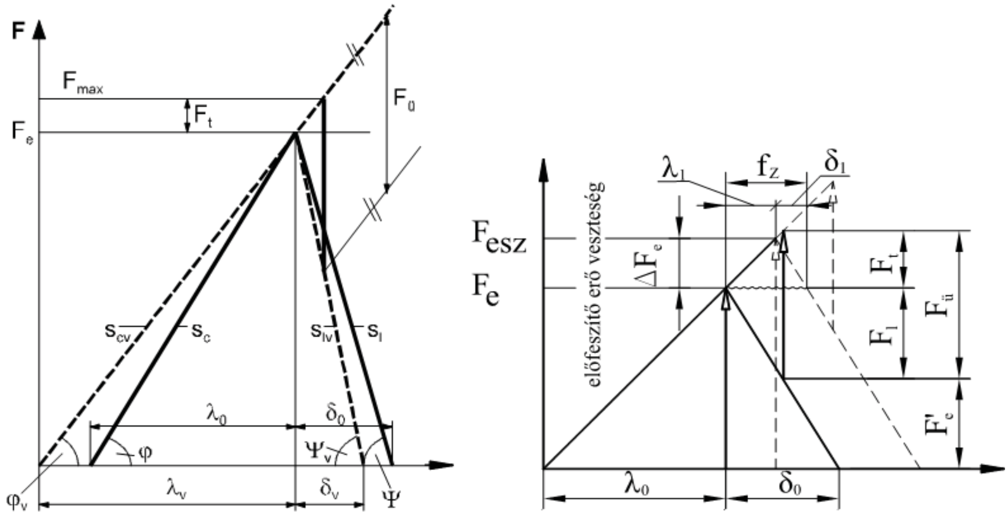

Fig. 1 The force – elongation diagram

Figure 1 illustrates the force – elongation diagram of a preloaded bolt connection. By the designing such a connection it have to be analysed the diagram and it have to be taken in account all properties the members of the connection. The diagram shows that the external tensile load increases the resultant bolt load and decreases the clamping force. Next, the lower is the stiffness of the bolt and higher of tightened members the smaller is the proportion of the external load taken by the bolt. The stiffness corresponds with tangents of angles φ and ψ in the diagram. It is to be assumed that the preload has been correctly applied by tightening the some clamping load must remain in the members.

The major problem of the tightening methods is to proceed and to identify the snug tight condition.

Attaining of this condition depends on more influence.

In case of wrenching torque method the determining of the torque properly causes difficulties. The distribution of the wrenching torque based on experiments is the follows:

- friction in the thread: 40…67%
- friction under the nut: 16…50%
- preload: 10…17%

So, the main factor is the friction influenced by following:

- quality of materials
- surface roughness
- surface treatment
- lubrication
- geometrical tolerances

If we suppose the relatively constant material quality, surface roughness and treatment in the mass production, the lubrication can be controlled, so the resulting friction depends on the geometrical tolerances.

3 The research program

- Determining of the geometrical dimensions of bolt and nut threads.
- Estimation of tightening torque based on relating standards.

- To form classes of external and internal threads based on dimension, creation of FEM models of connection.
- Examination of bolt connection from the tightening torque and provided preload point of view.

3.1 The prescribed dimensions of the threaded connection:

Connecting rod bolt: M9x1,25-4h/5H	M9x1.25-4h M9x1.25-5H
Nominal size (dmax) = 9.000 mm	Nominal size (dmax) = ---
Nominal size (dmin) = 8.868 mm	Nominal size (dmin) = 9.000 mm
Pitch diameter ($d_2$max) = 8.188 mm	Pitch diameter ($d_2$max) = 8.313 mm
Pitch diameter ($d_2$min) = 8.113 mm	Pitch diameter ($d_2$min) = 8.188 mm
Minor diameter ($d_3$min) = 7.466 mm	Minor diameter ($d_3$min) = 7.859 mm
Minor diameter ($d_3$max) = 7.343 mm	Minor diameter ($d_3$max) = 7.647 mm

3.2 Definition of the tightening torque:

The tightening torque of connecting rod bolt: 47.22 Nm (theoretical: 40 Nm)

3.3 Classes:

The tolerance field of the bolt and nut threads are divided into 6 equal classes, the same dividing was realised on bolts and “nuts”:

1. mini bolt (1)
2. small bolt (2)
3. small middle bolt (3)
4. middle bolt (4)
5. large middle bolt (5)
6. large bolt (6)

The internal threads of rod where similar divided:

1. mini internal thread (S1)
2. small internal thread (S2)
3. small internal thread (S3)
4. middle internal thread (S4)
5. large middle internal thread (S5)
6. large internal thread (S6)

It was created model of connection of the piston rod and cover of crankshaft bearing with six-six different bolt and internal thread. The model consists of three various members, the bolt, rod and cover (Fig. 2). The contact conditions are supposed between the threads, under the head of the bolt and between the clamed members as well. In the model were applied properties of real materials.

Material properties of the bolt:

Yield stress ($R_{P0,2}$)	990 MPa
Tensile strength (R_m)	1150 MPa

Elastic modulus (E)	206000 MPa
Poisson ratio (n)	0.3

Material properties of the piston rod and cover:

Yield stress ($R_{P0,2}$)	960 MPa
Tensile strength (R_m)	1050 MPa
Elastic modulus (E)	205000 MPa
Poisson ratio (n)	0.3

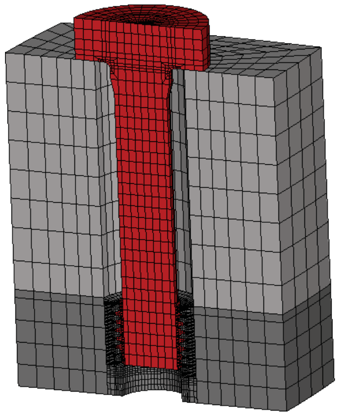

Fig. 2 The model of the connection prepared for FEM

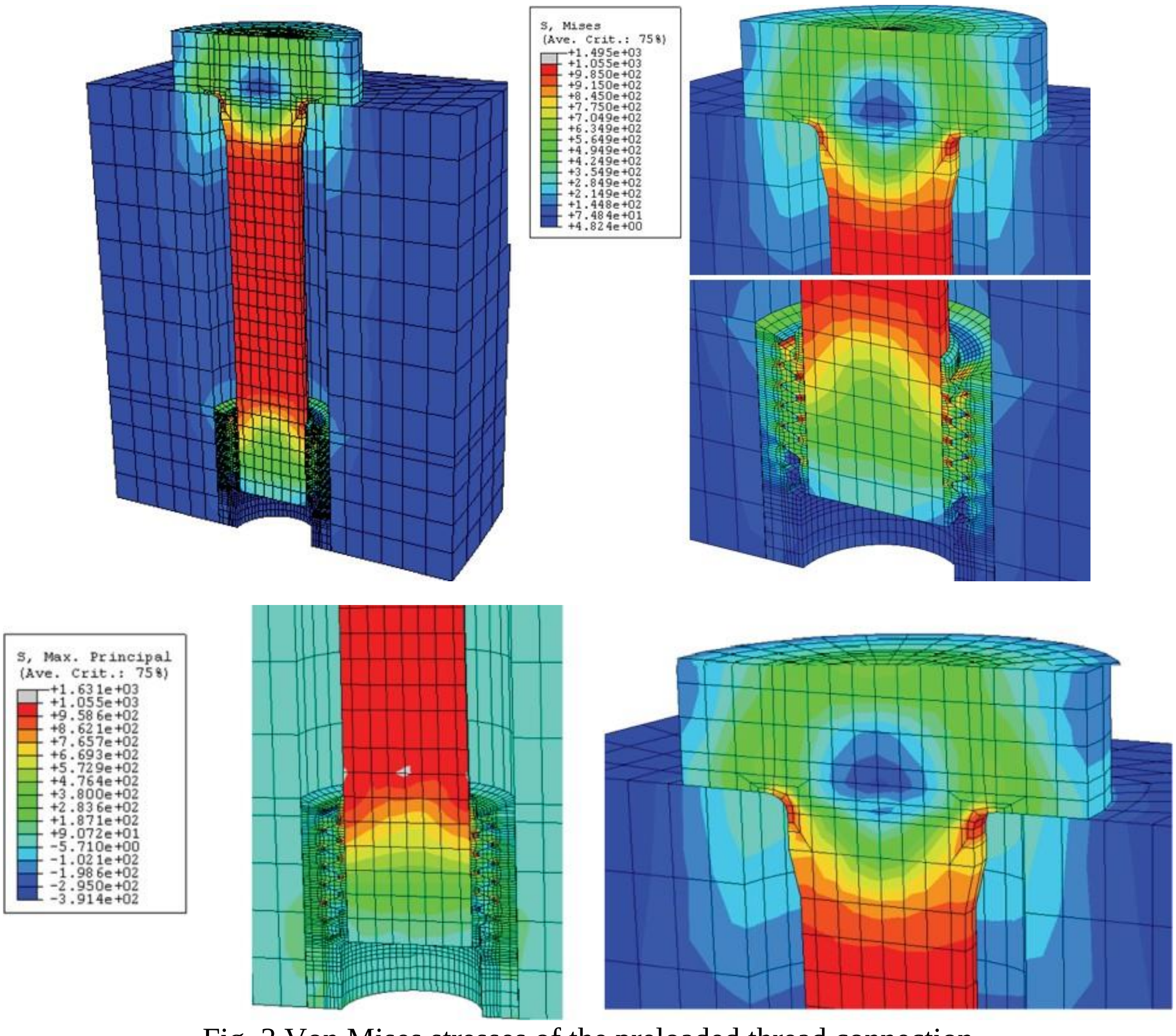

Fig. 3 Von Mises stresses of the preloaded thread connection

3.4 The FEM analysis of the bolted connection

The piston rod model (Fig. 2) examination was provided by revised tightening torque and different combinations of bolt threads and internal threads in rod. Applied software was the ABAQUS, nonlinear statics procedure (Fig. 3).

4 The loading analysis of the bolted connection under different thread coupling

The following diagrams show the results of the FEM analysis of the marginal cases. It can be learned, comparing the diagrams, the different combinations of external and internal threads and assembling conditions develops different loading of the bolted connection.

4.1 Tightening by dry surfaces:

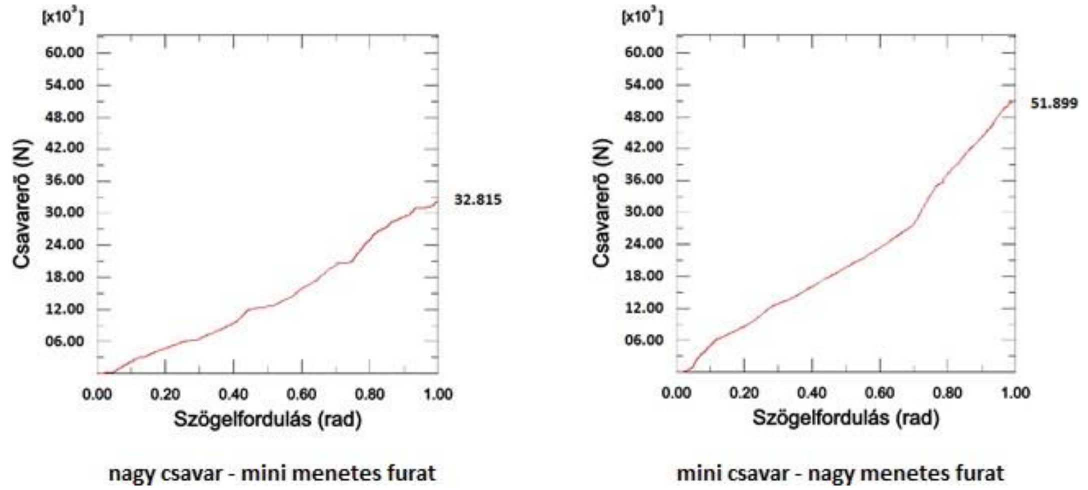

Fig. 4 Diagram of preload (dry surfaces)

The diagrams show the load of the bolt as function of turning in case of coupling large bolt and mini internal thread and mini bolt thread and large internal thread respectively. In first case is the clearance in threads the smallest, the friction is large, so the tightening portion of the wrenching torque is less then in the opposite case and the prescribed preloading condition is not satisfied.

4.2 Tightening by oil lubricated surfaces

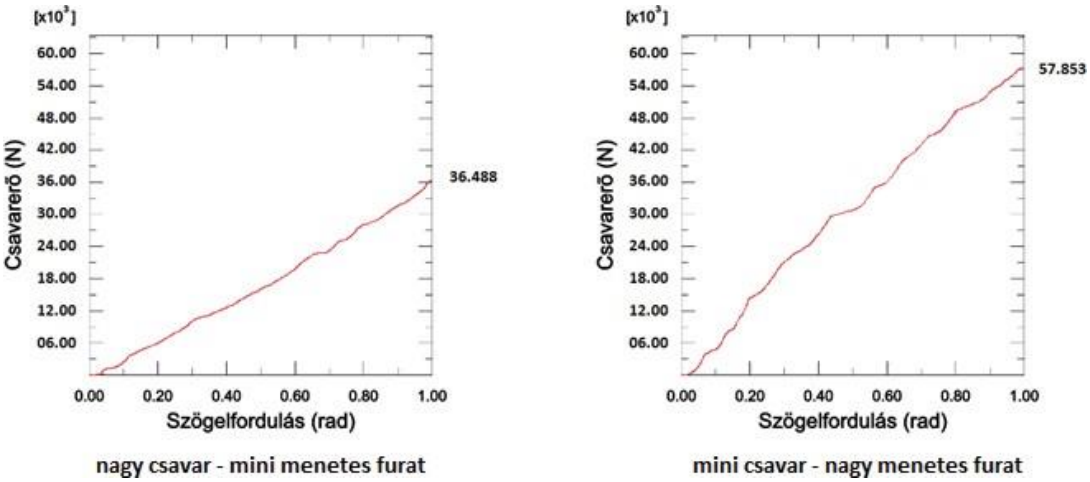

Fig. 5 Diagram of preload (lubricated surfaces)

The diagrams are similar to previous. In case of coupling large bolt and mini internal thread is due to lubrication the friction reduced, so the prescribed preload is developed but in the opposite case is the tightening portion of the wrenching torque to large and the preload is too high. The bolt could be overloaded.

CONCLUSION

The measurement results indicate that the combination of a small screw with a large hole and a large screw with a small hole can lead to the development of an insufficient preload force. Therefore, it can be stated that the combination of extreme values of components within their tolerance ranges can cause "loose" or "tight" joints. In these cases, applying the specified torque can lead to overtightening of the joint or the creation of an inadequate preload force. Furthermore, considering the effects of oil and cleaning agents, it can be established that their presence increases the risk of overtightening the joint.

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