Impact of process engineering factors on stabilization of screw joint

ALEKSANDER NIEOCZYN
ZBIGNIEW KRZYSIAK
SŁAWOMIR TARKOWSKI
ANNA SKIC
BARTŁOMIEJ RACHWAŁ
KRZYSZTOF PLIZGA
FRANTISEK BRUMERCIK

Aleksander Nieoczym (a.nieoczym@pollub.pl), Lublin University of Technology, Lublin, Poland; Zbigniew Krzysiak (zbigniew.krzysiak@wp.pl), University of Life Sciences, Lublin, Poland; Sławomir Tarkowski (s.tarkowski@pollub.pl), Lublin University of Technology, Lublin, Poland; Anna Skic (anna.skic@up.lublin.pl), University of Life Sciences, Lublin, Poland; Bartłomiej Rachwał (bkrachwal@gmail.com), University of Life Sciences, Lublin, Poland; Krzysztof Plizga (krzysztof.plizga@up.lublin.pl), University of Life Sciences, Lublin, Poland; Frantisek Brumercik (frantisek.brumercikf@fstroj.uniza.sk), University of Zilina, Zilina, Slovakia

How to cite: A. Nieoczyn, Z. Krzysiak, S. Tarkowski, A. Skic, B. Rachwał, K. Plizga, F. Brumercik.
Impact of process engineering factors on stabilization of screw joint.
Advanced Technologies in Mechanics, Vol 3, No 1(6) 2016, p. 12-18
DOI: http://dx.doi.org/10.17814/atim.2016.1(6).35

Abstract

The stabilization of screw joint and influence of factors protecting against loosening of the joint have been discussed in the present article. The results of experimental examinations associated with the impact of the type of protective coat on threaded section and lubrication on the value of tightening torque have been also presented.

KEYWORDS: **screw joint, protective coats, lubrication, friction moment, moment of torque, fatigue stress**

Additional clamping force shall be maintained in the correctly designed joint in order to prevent the loss of clamping force in result of external load to the extent exceeding the initial value. Usually the joint is designed in manner preventing the fastener load exceeding the yield point Re_1 (R_{02}) with consideration of preliminary clamping force and external load. Any load exceeding this limit value will result in permanent elongation of the fastener and in consequential reduction of clamping force or joint breaking. Another essential phenomenon is the friction affecting the tightening process and the value of axial clamping force. Its importance is reflected in the fact that only 10% of energy used for the rotation of the fastener will be transformed into clamping force. Remaining 90% of energy is lost in overcoming friction [3-5].

In screw joint under static loading and insignificant load oscillations, the screw joint is protected against loosening by means of friction forces occurring on thread surface and on mating surface of the elements being connected together. In order to ensure sufficient friction forces in the elements being connected together, adequate tightening of each threaded fastener is required. In case of variable loads affecting the screw joint, the application of additional protections encompassing the following four (4) groups is necessary:

- The generation of additional friction forces – an insert characterized by significant friction factor, lock – nut.
- Positioning of the following parts to each other:
  - bolt and nut
  - bolt head or the nut in relation to the housing
  - positioning of specified number of bolts incorporated in the joint to each other.
- Locking of the joint by means of local plastic strain.
- Permanent locking.

The threaded fastener is tensioned by means of pre-clamping force Q_w in the course of tightening process. The value of a/m force should be sufficient in order to prevent any clearance between the elements being connected after the applying of working load Q_r.

The screw joint is protected against loosening by means of friction forces occurring on thread surface and on mating surface of the elements being connected together. In order to ensure sufficient friction forces in the elements being connected together, appropriate tightening of each threaded fastener is required. The reduction of safety factor in strength calculations is possible in result of proper selection of the fastener in screw joint design process.

Refer to Figure 1 for diagrams of the torques M_g, M_t and force Q in course of tightening process.

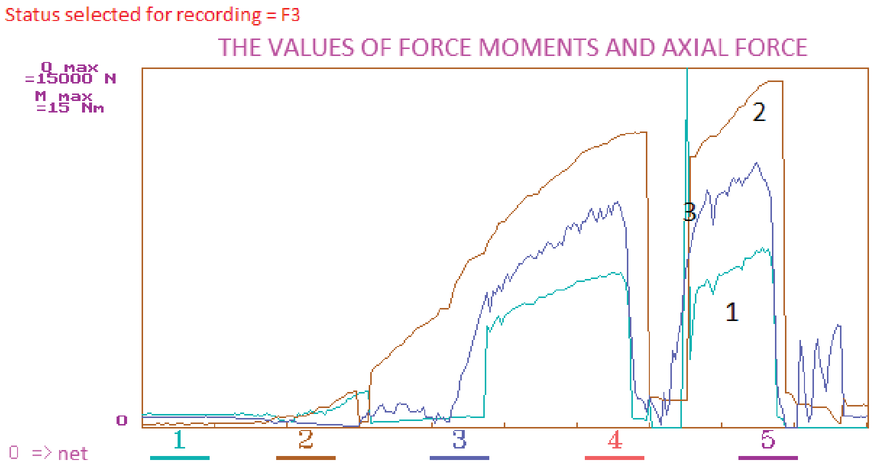

Fig. 1. The curve illustrating the screwing – in sequence for M8 B 6.8 bolt. Two – phase screwing – in by means of an impact head [6], in-screwing parameters measurement on the device [7]. 1 – friction moment under the bolt head, 2 – moment on the thread, 3 – axial force in the bolt

The value of the torque required to tighten the threaded fastener in order to achieve required pre-tension, is not constant and depends on many factors, mainly the following: lubrication of thread surface, kind of protective coat, number of tightening sequences. The results obtained from tests carried out at the test stand [1, 3] for the bolts M6×30 B6.8 in course of their screwing into the mandrel made of steel, are presented below. The tests encompassed the following:

1. The determination of the value of tightening torque required to achieve the specified value of axial force in the bolt considering the influence of lubrication (Fig. 2). The following average increase of the value of tightening torque resulting from the lack of lubrication has been found for the bolts with protective coats:

a. oxides coat - 8%,
b. nickel and copper – and – nickel coat - 22%,
c. zinc coat - 21%,
d. copper – nickel – and – chromate coat - 20%,
e. cadmium – and – chromium coat - 24%,
f. zinc – and – chromate coat - 25%,
g. steel bolt (without coat) - 15%.

The determination of the value of tightening torque required in generate the specific axial force in the bolt in course of single tightening step and in course of several (n) successive tightening steps.

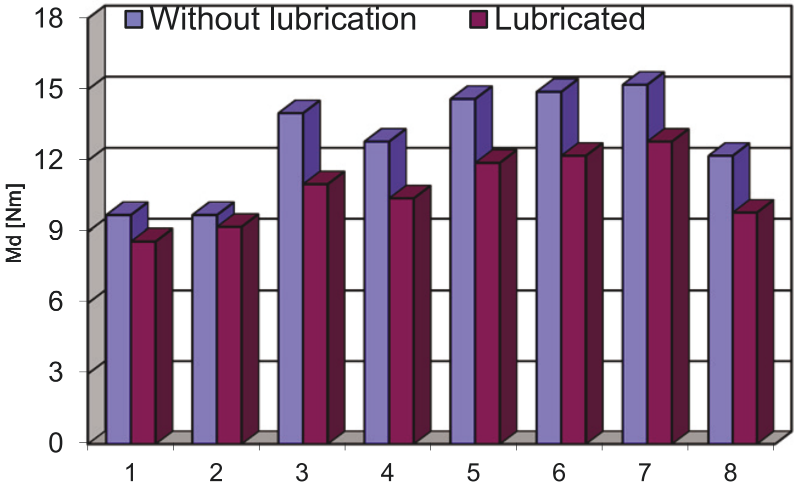

Fig. 2. Impact of lubrication on change of tightening torque for M6 bolts with various protective coats. 1 – Steel (without coat), 2 – Oxides coat, 3 – Zinc - and - chromate coat, 4 – Zinc coat, 5 – Copper - and -nickel coat, 6 – Nickel coat, 7 – Copper - nickel - and -chromate coat, 8 – Cadmium - and - chromate coat

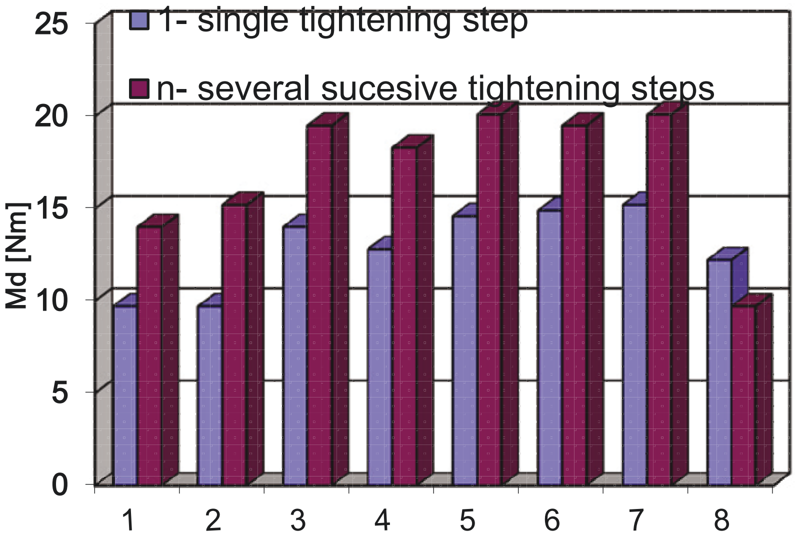

Fig. 3. *Impact of quantity tightening steps on change of tightening torque for M6 bolt (without lubrication); 1 – Steel (without coat), 2 – Oxides coat, 3 – Zinc - and - chromate coat, 4 – Zinc coat, 5 – Copper - and - nickel coat, 6 – Nickel coat, 7 – Copper - nickel - and - chromate coat, 8 – Cadmium - and - chromate coat. M_d-moment of torque*

The phrase "several (n) successive tightening steps" corresponds to the situation consisting in the tightening until the required value of axial force in achieved and the joint is released there after. A/m sequence is continued until the maximum value of tightening torque is recorded. In the course of tests, tightening torque required in generate the specific axial force in the bolt *Q= 8682,48 N* (PN 81/M-82056) has been recorded in course of tightening step and in course of several (n) successive tightening steps. The results obtained from the testes are illustrated in the diagrams – Figure 3 and Figure 4.

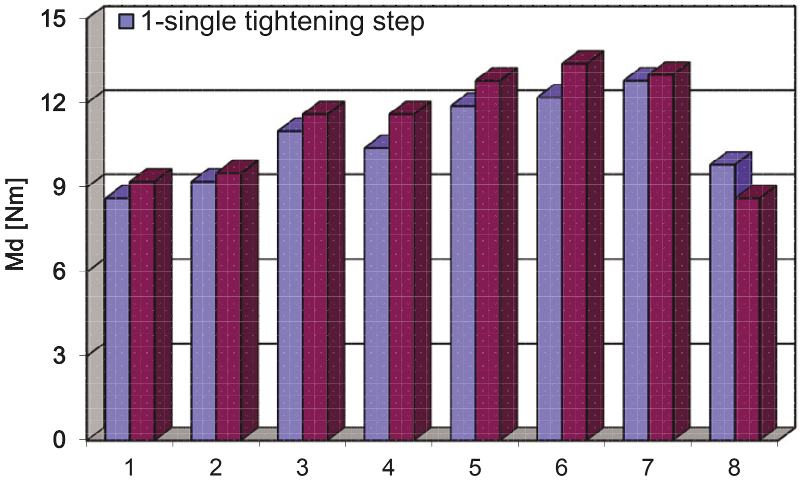

Fig. 4. *Impact of quantity tightening steps on change of tightening torque for M6 bolt (with lubrication) 1 – Steel (without coat), 2 – Oxides coat, 3 – Zinc - and - chromate coat, 4 – Zinc coat, 5 – Copper - and - nickel coat, 6 – Nickel coat, 7 – Copper - nickel - and - chromate coat, 8 - Cadmium - and - chromate coat*

The values of tightening torques obtained in course of testing are specified in Table 1.

Table 1. *Average values of tightening torques in course of testing without lubrication and quantity of tightening steps (1- single tightening step, n- several successive tightening steps)*

Item	Test pieces	Tightening torque [Nm]			
		without lubrication		with lubrication	
		1	n	1	n
1	Steel (without coat)	9,7	14,0	8,6	9,2
2	Oxides coat	9,7	15,2	9,2	9,5
3	Zinc - and - chromate coat	14,0	19,5	11,0	11,6
4	Zinc coat	12,8	18,3	10,4	11,6
5	Copper - and - nickel coat	14,6	20,1	11,9	12,8
6	Nickel coat	14,9	19,5	12,2	13,4
7	Copper - nickel - and -chromate coat	15,2	20,1	12,8	13,0
8	Cadmium - and - chromate coat	12,2	9,7	9,8	8,6

The selected results of the tests can be used for drawing of the diagrams (Fig. 5, 6) to enable the determination of the value of tightening torque vs. axial clamping force and type of lubrication and to enable the superposition of straight lines constituting the limit values of friction coefficients µ [4, 5].

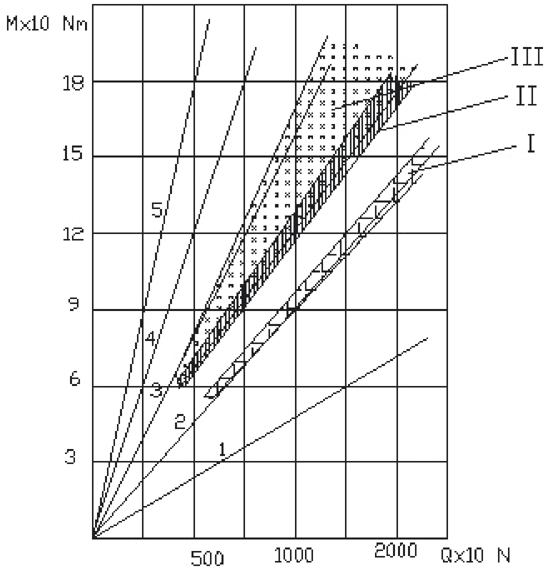

Fig. 5. *Tightening torque M vs. axial force in the bolt Q for various values of friction factor on the thread. Steel bolt with nickel and copper - and - nickel coat, nut without coat, several (n) successive tightening steps; I – grease, II – oil, III – without lubrication; 1-µ=0,05, 2-µ=0,1, 3-µ=0,2, 4-µ=0,3, 5-µ=0,5*

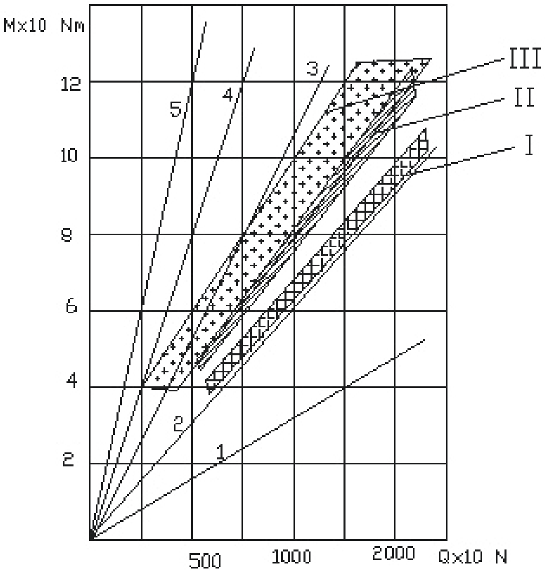

__Fig. 6.__ Tightening torque M vs. axial force in the bolt Q for various values of friction factor on the thread. Steel bolt and nut without coat, several (n) successive tightening steps; I – grease, II – oil, III – without lubrication; 1-μ=0,05; 2-μ=0,1; 3-μ=0,2; 4-μ=0,3; 5-μ=0,5

Bolts fatigue tests (in from of repeated load cycles). The fatigue tests have been carried out for the bolts M16×1,5 for asymmetrical load cycle for the three following values: σ_m=200, 400, 600 MPa. A/m stress values were associated with the stresses generated in course of tightening by means of torques M_s=50, 100, 130 MPa correspondingly. The basic number of cycles in course of tests was equal to $N \geq 10^7$.

The conditions of and results obtained from the tests of bolts manufactured in accordance with various processes [2, 4, 5] have been presented in table 2.

Table 2. *Impact of various process manufactured bolts for fatigue strength*

	σm [MPa]		
	200	400	600
	Amplitude of stress σa [MPa]		
Thermic processing + scarification	-	60	50
Thermic processing + scarification+ hardening treatment	-	60	50
Rolling process + thermic process	60	50	40
Rolling process + thermic process + hardening treatment	50	45	40

On the basic of a/m data, it appears that the value of fatigue strength limit for the bolts with machined thread is higher than for those with rolled thread. Such phenomenon is caused by elimination (in course of heat treatment) of internal hardening caused by plastic deformation of surface thread layer resulting from thread rolling process, partial oxidizing of thread surface and relaxation of internal stresses generated in the course of thread rolling process.

Simultaneously no increase of fatigue strength limit has been caused by thread hardening by micro-ball peening. It is mainly the result of non-optimal selection of hardening method and forming conditions. Refer to table 3 for the data referring to fatigue strength limit for the bolts vs. average value of stresses σ_m for fatigue life N=(10^6, 10^7) cycles.

Table 3. *Impact of various process manufactured bolts and average value of stress σ_m for amplitude value of stress*

	σm [MPa]	Amplitude of stress σa [MPa]	
		N = 106 cycles	N = 107 cycles
Scarification	400 600	80 75	60 55
Rolling process	200 400 600	77 68 57	60 50 40
Rolling process + hardening treatment	200 400 600	70 62 60	48 45 40

Conclusions:

- The highest influence of increased load asymmetry on fatigue strength limit has been found for threads obtained from thread rolling process. The fatigue strength of the bolts with thread obtained from thread rolling process was lower than in case of bolts with machined threads. The hardening treatment of the bolts with rolled thread in reduction of fatigue strength.
- The area of destruction in bolts occurred on the thread only, most often on its first turn from the face of the nut. In case of bolts with machined thread, the centers of fatigue cracks overlapped with machining profiles situated in the grooves of the thread.

Acknowledgement

This paper presents results of work supported by the Slovak Scientific Grant Agency of the Slovak republic under the project No. VEGA 1/0077/15.

References:

[1] Nieoczym A., Gardyński L., Wierzbicki S., Machrowska A.: *„Projekt stanowiska do badań zmęczeniowych śrub”*. Logistyka, str. 7806-7810, nr 6, 2014.

[2] Nieoczym A., Krzywonos L., Machrowska A., Lukac M.: *„Warunki pracy układów śrubowych poddanych napięciu wstępnemu i oddziaływaniu pola temperatur”*. Logistyka, str. 7811-7815 nr 6, 2014.

[3] Nieoczym A., Gardyński L.: *„Badania stanowiskowe jakości połączeń gwintowych”*. Postępy Nauki i Techniki, nr 7, 2011, str. 120-127.

[4] Nieoczym A.: *„Wybrane zagadnienia wytrzymałościowe połączeń gwintowych”.* Monografia, wyd. Lubelskie Towarzystwo Naukowe, Lublin, 2003.

[5] Nieoczym A., Szabajkowicz W.: *„Montażowe połączenia gwintowe”*, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2009.

[6] Nieoczym A., Wituszyński K.: *„Impulsowa głowica wkręcająca”*. Patent nr 329139.

[7] Nieoczym A., Kisiel J.: *„Stanowisko do pomiaru momentu dokręcającego i siły osiowej”.* Wzór użytkowy nr W 105608.