Torque Tightening Process Qualification

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Abstract: In order to achieve quality products, certification of production processes is currently required in companies. It is possible to mention the procedure of screw tightening. To obtain a certificate, it is necessary to check in the company the technological assembly procedure and the equipment of the workplace with jigs and tools. It is necessary to check whether all provisions of regulations and standards are observed during the assembly of the product. In the case of screw connections, it is necessary to carry out experiments to verify the correctness of the tightening torque and to determine the Torque-angle curve. It is often required to assess the quality of threaded surfaces after disassembly of the product on a metallographic cut. This paper describes the certification procedure of tightening the main screw connection of a selected product. Without the granting of the certificate, it would not be possible to proceed with further assembly.

Keywords: prestressed screw connection; screw tightening; Torque-angle curve; process certification.

1 Introduction

The strength calculation of prestressed screw connections is usually performed according to *VDI 2230* [1]. The size of the *tightening factor* α_A is selected according to the selected method of mounting the screw connection and for the considered scattering of the coefficients of friction, the required range of tightening torque $M_{k\,\mathrm{min}}$ to $M_{k\,\mathrm{max}}$ is then calculated. The *Torque-angle curve* is an indicator of the correct tightening process of the screw connection. Certification of the screw connection assembly process is performed according to the standard *EN 14831: 2005 - Fasteners - Tightening performance - Torque/Angle simplified test method* [2].

The whole certification process was implemented in the following steps [3]:

- visual inspection of the tightened connection,
- check of the technological process of tightening the screw connection,
- verification of the correctness of the tightening torque determination,
- check the equipment of the workplace with jigs and tools,
- testing of untightening torque values and statistic evaluation,
- experimental determination of the Torque-angle curve,
- inspection of threaded surfaces after disassembly of a screw connection from a metallographic cut.

2 Certification of the screw tightening process

In the following subchapters, a brief description of all implemented activities performed within the certification of the tightening process of the screw connection is given. Used screws M6×16 are made of stainless steel A2-80. A threaded hole is made in the aluminum alloy.

2.1 Visual inspection of the tightened connection

To perform the measurements tightening and untightening torque were delivered 5 pieces assembled products (cover and housing). Tested samples meet the requirements according to the standard EN 14831: 2005. During and after the tests there were not found any visible damages or wrongly performed tightening.

2.2 Check of the technological process of tightening the screw connection

The cover of Pulse Generator assembled according to the specified technological procedure (assembly instruction). The prescribed tightening torque (10–11) Nm corresponds to the EN 14831: 2005 standard.

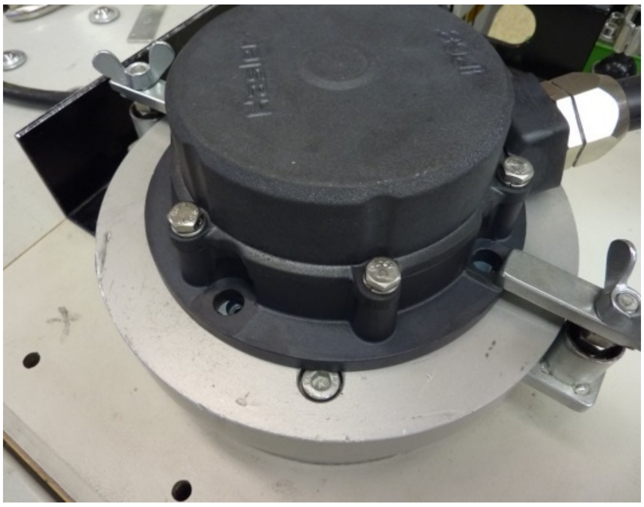

Fig. 1: Assessed product with screwed cover.

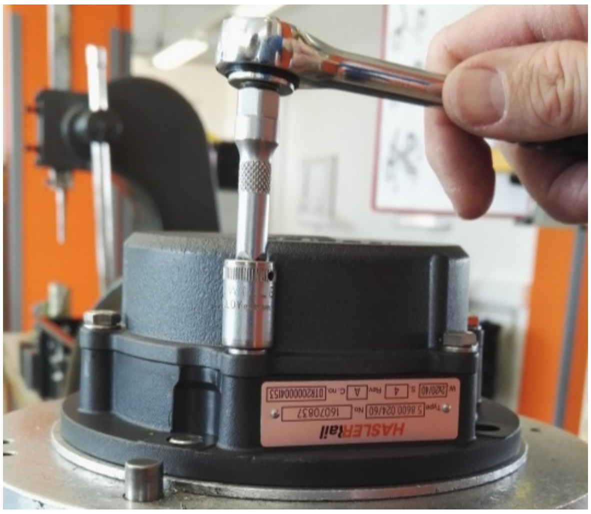

Fig. 2: Tightening the screw with a torque wrench.

The following assembly procedure is available at the workplace (see Fig. 1 and Fig. 2), prepared in the form of a clear table. Below are the individual operations for assembling the cover:

- insert the O-ring to the groove on the cover,
- before you mounted both parts again together after the EOL-Test, check that O-ring is still in the correct position and that the both parts are clean,
- apply a slight layer of grease Klüber Petamo GHY 133N inside the thread of the housing,
- fixing the two parts cover and housing with screws M6×16, sealing screws M6×16 and high tension spring rings together,
- tight them with a torque of (10–11) Nm according the assembly drawing,
- insert the sealing wire through the hole of the screw and twist it clockwise with using the special pliers,
- put the label and insert the wire through the hole of the second screw,
- twist counter clockwise the sealing wire with special pliers,
- when it's twisted, insert the seal through the wires and pull the wires far apart as its shown on picture below,
- when the seal is prepared, then use sealing pliers to press it. Cut the exceeded wires after seal pressing,
- bend the sealing wire towards the cover.

2.3 Verification of the correctness of the tightening torque determination

Tab. 1: Tightening torques for screws according to EN ISO 4014 and EN ISO 4017 depending on the coefficients of friction.

Diameter nominal Md [mm]	Thread pitch P [mm]	0.06	0.08	0.10	0.12	0.14	0.16	0.18
M6	1.00	6.23	7.02	7.80	8.6	9.4	10.1	10.9
M8	1.25	13.96	15.92	17.88	19.8	21.8	23.8	25.7
M10	1.50	30.75	34.00	38.57	42.5	46.4	50.3	54.2
M12	1.75	52.16	58.94	65.72	72.5	79.3	86.0	92.8
M14	2.00	78.26	89.11	99.96	110.8	121.7	132.5	143.4
M16	2.00	127.06	144.43	161.81	179.2	196.6	214.0	231.3

As an example, the following table shows the values of the tightening torques for the coefficients of friction 0.06 to 0.18. These tightening torque values have been calculated according to EN 14831: 2005 for bolts according to EN ISO 4014 [4] and EN ISO 4017 [5] (see Tab. 1). See 1st row – diameter nominal M6 and coefficients of friction 0.16 and 0.18. The specified tightening torque is determined correctly.

2.4 Check the equipment of the workplace with jigs and tools

Tightening of the screws crosswise is always performed with a calibrated Torque wrench 10.5 Nm.

Fig. 3: Calibrated Torque wrench 10.5 Nm (side view).

Fig. 4: Calibrated Torque wrench 10.5 Nm.

The mounting fixture used is shown in Fig. 1.

2.5 Testing of untightening torque values and statistic evaluation

A simple test stand was designed to verify the tightening torque. Tightening and untightening torque were measured using a calibrated torque sensor HBM T20WN/20 Nm (see Fig. 5 and Fig. 6).

Fig. 5: A simple test stand for tightening and untightening torque measurement of the bolts were realized.

Fig. 6: Calibrated Torque wrench 10.5 Nm.

The experimentally determined values of tightening and loosening torques of the bolts were statistically evaluated (30 measurements were performed). Selection average value of the experimentally determined untightening torque of bolt joints is 9.289 Nm and selection standard deviation of the experimentally determined untightening torque of bolt joints is 1.533 Nm.

2.6 Experimental determination of the Torque-angle curve

Maximum and minimum values of tightening torques and axial forces in the M6 screw connection were calculated according to the standard EN 14831: 2005 (Fasteners – Tightening performance – Torque/Angle simplified test method) (see Tab. 2).

Tab. 2: Maximum and minimum values of tightening torques and clamping forces in the M6 screw connection according to the Standard EN 14831: 2005.

Thread parameters of the M6 screw		
Basic major diameter	d [mm]	6.000
Thread pitch	P [mm]	1.000
Minor diameter	d_3 [mm]	4.773
Pitch diameter	d_2[mm]	5.350
Minimum outer diameter of the seating face	$d_{w\,\mathrm{min}}$ [mm]	8.880
Minimum hole diameter	$d_{n\,\mathrm{min}}$ [mm]	6.400
Minimum friction coefficient in threads	μ_{min} [1]	0.120
Maximum friction coefficient in threads	μ_{max} [1]	0.180
Calculated values of tightening torques and clamping forces		
Preliminary torque	T_p [Nm]	3.000
Minimum clamping force	$F_{p,\mathrm{min}}$ [kN]	2.135
Maximum clamping force	$F_{p,\mathrm{max}}$ [kN]	3.031
Testing force	F_{test} [kN]	8.000
Minimum testing force	$F_{test,\mathrm{min}}$ [kN]	7.756
Maximum testing force	$F_{test,\mathrm{max}}$ [kN]	8.631
Minimum torque	T_{min} [Nm]	8.544
Maximum torque	T_{max} [Nm]	10.870

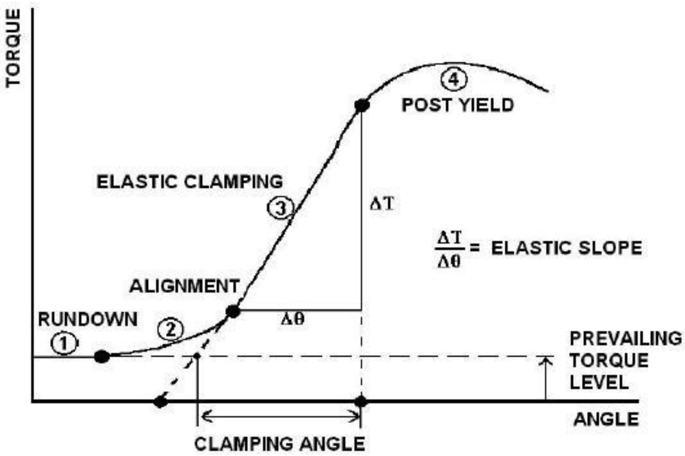

Fig. 7: Torque-angle curve [6].

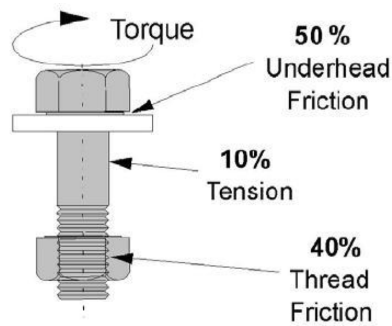

Fig. 8: Energy distribution when tightening the screw joint (standard thread pitch) [6].

The Torque-angle curve is a reliable indicator of the correct tightening of the screw connection (see Fig. 7 and Fig. 8). The implementation of the experiments was controlled by a PC, the collection and evaluation of measured data was carried out by a control program created using the software "LabVIEW FDS" from the company "National Instruments". Experimental determination of Torque-angle curves was measured on six M6 screw joints on the sample No. 3.

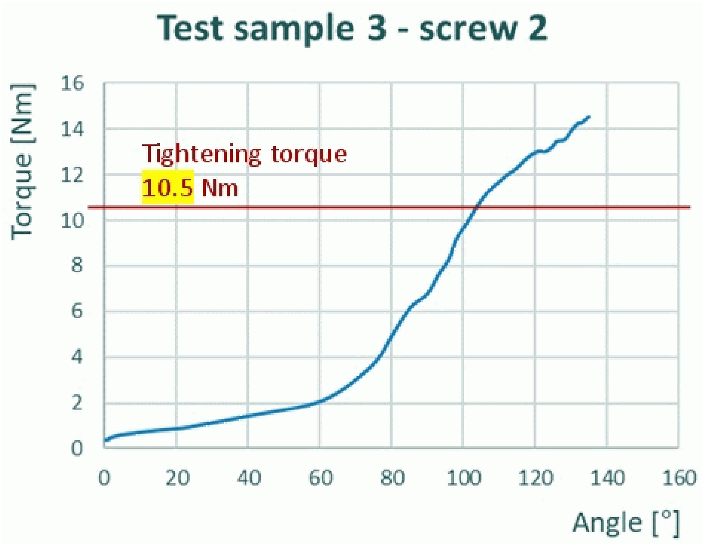

Fig. 9: Experimentally determined Torque-angle curves (for test sample 3, screw 2).

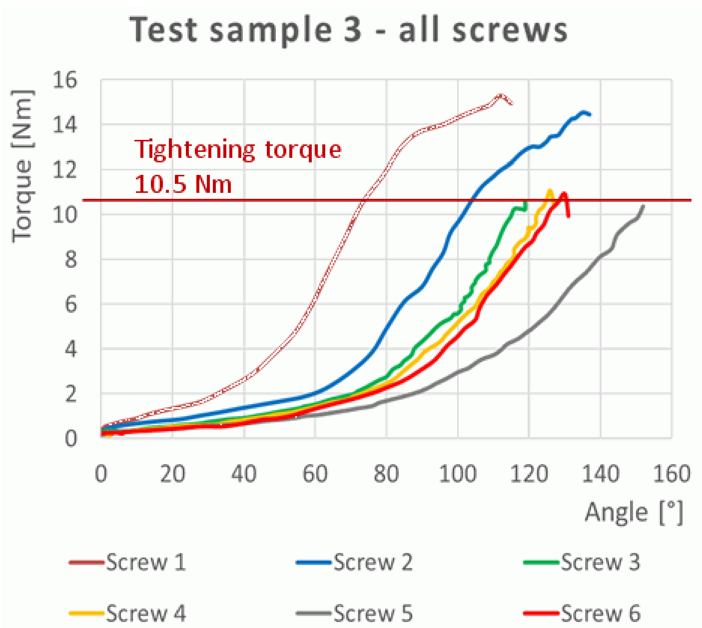

Fig. 10: Experimentally determined Torque-angle curves (for test sample 3, all screws).

From the experimentally determined Torque-angle curves, it is evident that from the torque of about 3 Nm, the Torque-angle curve dependence is steeper linear in accordance with the theory of tightening bolted joints assembly up to a tightening torque of 10.5 Nm (see Fig. 9). In the case of lower tightening torques, the contact surfaces of the joint are seated and the lock washer is compressed.

The measured curves show a mutual displacement in the direction of the horizontal axis, which was probably caused by a different angle of rotation before started the actual process of the screw joint tightening when turning by hand with a torque sensor HBM T20WN/20 Nm (see Fig. 10). This fact must always be taken into account when evaluating the measured Torque-angle curves.

There are presented the linear parts of all measured Torque-angle curves after adjusting the source data in Fig. 11. For each line (shown by the dashed line), its equation in parametric form and the reliability value R^2 are given in Fig. 11.

Experimentally evaluated values of untightening and tightening torques of the assessed bolted joints prove that the bolted joints are tightened with the correct specified tightening torque and that is used very good thread locking system (washer) too.

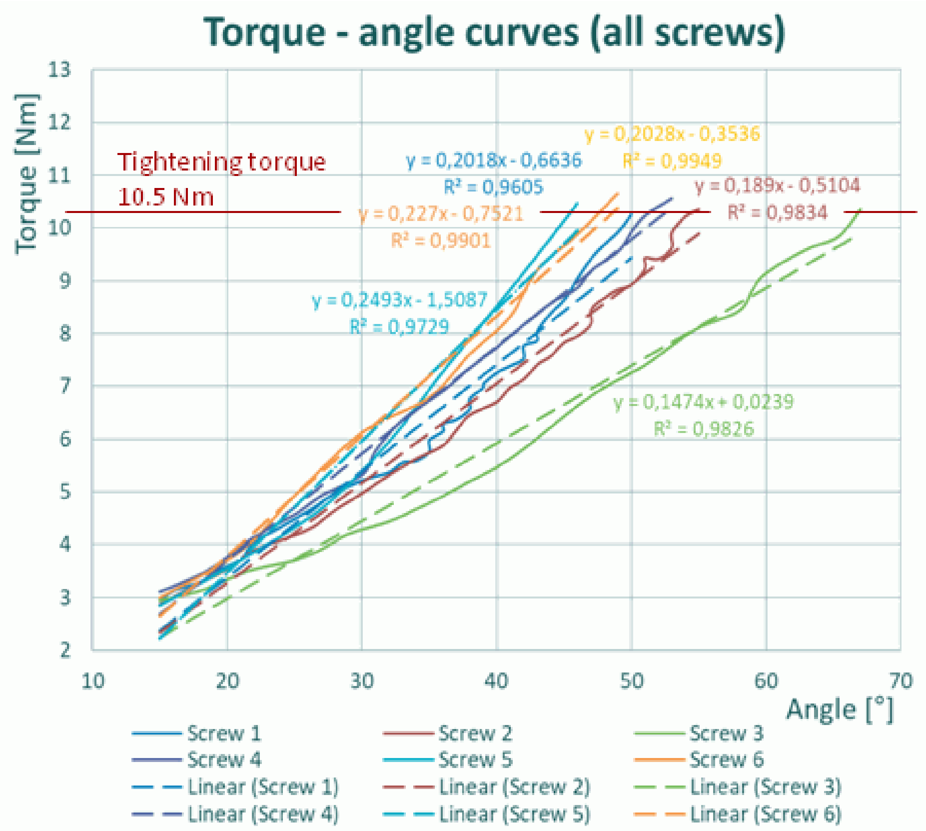

Fig. 11: Experimentally determined Torque-angle curves after adjusting the source data (for test sample 3, all screws).

2.7 Inspection of threaded surfaces after disassembly of a screw connection from a metallographic cut

After disassembly of the screw joints, metallographic samples of the screw and internal thread in aluminum alloy were made in order to assess the state of the threaded surfaces.

For the purpose of metallographic analysis, delivered part was cross-sectioned in the area of screw joint using LECO MSX255 sectioning machine. The samples of screw and threaded hole were mounted into fenol resin using LECO MX400 mounting press. Obtained metallographic specimens (see Fig. 12) were grinded up to grit P4000 and polished by 0.08 μm colloidal silica suspension (threaded hole) and 0.05 μm Al_2O_3 polishing suspension (screw) using LECO GPX300 grinding and polishing machine. Due to the etching nature of colloidal silica suspension, the microstructure of cross-sectioned threaded hole was revealed.

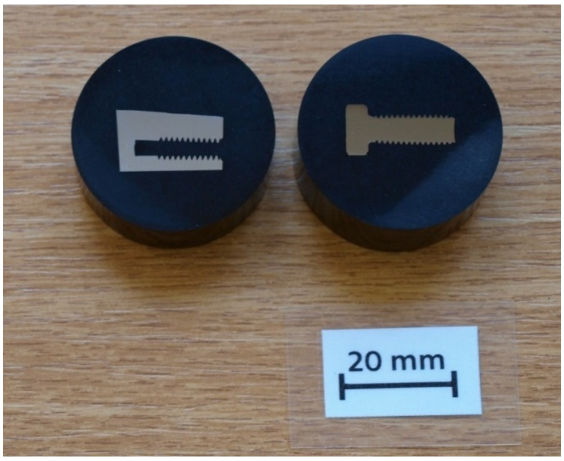

Fig. 12: Metallographic specimens, threaded hole and screw.

Fig. 13: Digital high-resolution light microscope OLYMPUS DSX 1000.

Metallographic analysis was performed using high-resolution light microscope OLYMPUS DSX 1000 (see Fig. 13). The brightfield illumination method (BF) was used for documentation of thread profiles of both specimens (threaded hole and screw).

There are presented details of photographs of the external thread of the M6 screw and the internal thread of the M6 hole after disassembly of the screw connection in Fig. 14 to Fig. 15.

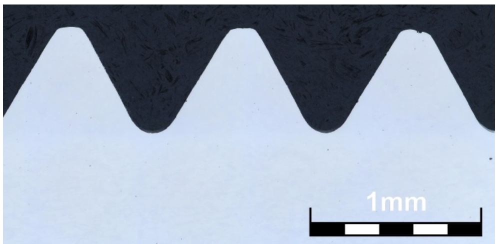

Fig. 14: Part of the external thread of the M6 screw, detail.

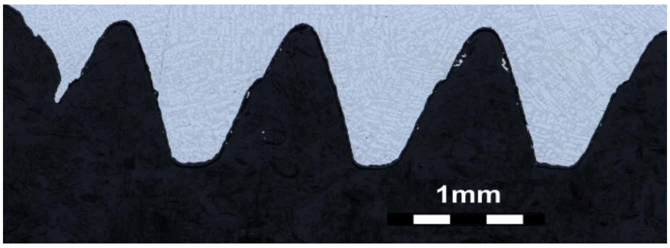

Fig. 15: Part of the internal thread of the M6 threaded hole, detail.

There are visible small deformations of the threaded surface of the internal thread M6 in the aluminum alloy in the Fig. 15, while the external thread of the steel screw M6 shows no changes (see Fig. 14).

3 Conclusion

To perform the measurements untightening torque were delivered 5 pieces assembled products. Tested samples meet the requirements according to the standard EN 14831: 2005. During and after the tests there were not found any visible damages or wrongly performed tightening.

The cover of product assembled according to the specified technological procedure (assembly instruction). The prescribed tightening torque (10–11) Nm corresponds to the EN 14831: 2005 standard. A simple test stand was designed to verify the tightening torque. Tightening and untightening torque were measured using a calibrated torque sensor HBM T20WN/20 Nm. A simple test stand was designed for experimental determination of the Torque-angle curve. Tightening torques and wrench rotation angles were measured using a calibrated torque sensor HBM T20WN/20 Nm.

The experimentally determined values of tightening and loosening torques of the bolts were statistically evaluated. Selection average value of the experimentally determined untightening torque of bolt joints is 9.289 Nm and selection standard deviation of the experimentally determined untightening torque of bolt joints is 1.533 Nm.

Checking the tightening torque of bolt joints by the "untightening and tightening method":

1. untightening torque 9.56 Nm / tightening torque 10.66 Nm (row was O.K.) / untightening torque 6.71 Nm;
2. untightening torque 9.50 Nm / tightening torque 10.67 Nm (row was O.K.) / untightening torque 6.92 Nm.

From the experimentally determined Torque-angle curves, it is evident that from the torque of about 3 Nm, the Torque-angle curve dependence is steeper linear in accordance with the theory of tightening bolted joints assembly up to a tightening torque of 10.5 Nm.

The measured curves show a mutual displacement in the direction of the horizontal axis, which was probably caused by a different angle of rotation before started the actual process of the screw joint tightening when turning by hand with a torque sensor HBM T20WN/20 Nm. This fact must always be taken into account when evaluating the measured Torque-angle curves. In the case of lower tightening torques, the contact surfaces of the joint are seated and the lock washer is compressed.

Experimentally evaluated values of untightening and tightening torques of the assessed bolted joints prove that the bolted joints are tightened with the correct specified tightening torque and that is used very good thread locking system (washer).

There are visible small deformations of the threaded surface of the internal thread M6 in the aluminum alloy, while the external thread of the steel screw M6 shows no changes. Based on all performed analyzes, the process of tightening screw joints was certified.

Acknowledgement

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References

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