UDC 624.078.2

High-strength bolts control-stretch methods improvement

Raber L.M.

D. Sc. In engineering
National Metallurgical Academy of Ukraine

Chervinskiy A.E.

National Metallurgical Academy of Ukraine

Abstract
Reasonability of high-strength bolts control-stretch existing methods improvement is shown. One of this problem solving promising directions is using of the method developed by authors, which does not depend on applied power hand or hand-held tools.
Key words: HIGH-STRENGTH BOLTS, STRETCH, TESTING, NUT ROTATION ANGLE

State of the art

At metallurgical plants, the high-strength bolts are usually used for the slip-critical design, where the effective force in joint and attaching elements are totally transmitted by friction force over the mating surfaces of connected elements under the action of high-strength bolts control stretch. It is evident that bolts must have planned stretching force for required load capacity of compound ensuring. However, the tightening can be ensured by several methods. Initially, the semi-mechanical processing technique with the force control by twisting moment value gained widespread occurrence. At that, the bolts are firstly tightened to 80…90% from calculated twisting moment by mechanical hand tools, and then final tightening is carried out by hand torque wrench. This processing technique is characterized by the high labour intensity and the use of hard manual labour.

In the modern period, the fully-mechanized technologies implemented by high or low speed impact wrench are rated among the most efficient. The high or low speed impact wrenches tightening is carried out by nut rotation angle force control.

The various approaches to fixation of nut rotation angle value, when the bolts work in elastic or elastic-plastic stage, are known. The first approach [1] involves the angle fixation depending on thickness of components pack compressed by bolts. In the case of the great amount of components packs typical sizes when bolts of various diameters and lengths using, this method is inefficient and low-tech.

The field experience shows that the second approach is more inefficient [2], e.g. the method when the bolts are tightened to transit them to the elastic-plastic range. In accordance with this method, the nut is rotated by 180 ^{O} (±30^{O}) from conventional initial position, which conforms to leakages elimination between the components of pack tightened with bolt. At that, bolts stretching force are close to breaking stretch, which is determined by ultimate tensile strength of material. This method limitation is the absence of clear criteria, which could allow bolts strength margin evaluation when stretching and construction operating depending on pack thickness, bolts diameter and strength. The scientists from different countries pay their attention on this circumstance. Significant step in creation of regulatory framework, on the base of which execution technique of fitters and erecting work by nut rotation angle force control can be improved, is European standard establishing in 2005 [3], where nut rotation limit angle testing for bolts is provided in common with another testing types. The laboratory tests, which are not connected with production technique of fitters and erecting work and design connection features, are regulated by this standard. As is well-known, the high-strength bolts are widely used while various structural steel (ore-grab cranes, blast furnaces hoist inclines, bin and train trestles, overhead traveling cranes, industrial buildings, bridges etc.) erection. The bolts number varies from 20 to 500 ths. The 3-8 bolts typical sizes by diameters and lengths are used depending on design features. Individual attention to tightening of every bolt group is impossible due to great variety of sizes.

Promising direction

The new control-stretch method of high-strength bolts, which are free from above-noted limitation [4], has been developed by authors due to conducted researches. The method is that bolts are divided into groups according to normalized stretching force with maximum spread of 25% in the group. After that, two samples are selected from each group. The bolts of the smallest diameters and lengths are selected for the first sample, and the biggest bolts - for the second sample. After this selection the first sample bolts are tightened to destruction and the second one are tightened to transit them to the elastic-plastic working range.

The minimum value of nut rotation angle ($\alpha_{min.1}$), at which the bolt is destroyed, is accepted as estimated and quantitative figure for the first sample bolts.

The maximum value of nut rotation angle ($\alpha_{max.2}$), at which the bolt is transited to the elastic-plastic range, is accepted as estimated and quantitative figure for the second sample bolts.

The assurance factor *m* is calculated as ratio of minimum value of nut rotation angle for the first sample bolts to maximum value of nut rotation angle for the second sample bolts. The value of this factor must be greater or equal to the value of normalized assurance factor.

The ability of bolts dividing to groups is illustrated in the Table of normalized stretching force for high-strength bolts various diameters.

Threaded diameter, mm	16	18	20	22	24	27	30	36	42	48
Normalized stretching force, kN	121	147	188	233	271	355	372	430	508	618

As the Table shows that normalized force for related diameters differs by no more than 25%. This difference is even less for the most widespread bolts groups (M22 – M24) and (M27 – M30). This spread makes it possible to divide the most used bolts into groups and also ensures the minimum bolts assurance factor difference within the group after tightening. The sample bolts number is determined by assumed confidence probability and confidence valuation of nut rotation angle accuracy measurement. At that, the limit state obtention (bolts distraction) is evident when the first sample bolts tightening while the second sample bolts transition to the elastic-plastic range require proper evaluation. The establishment of the elastic-plastic range obtaining is possible by any known method. The most effective is the method, in which while tightening after each nut rotation angle step (e. g. each 30^{o}, h. e. half-flat of hex nut), the rotational moment, by which the nut is tightened, is measured by hand torque wrench. The differential torque and differential torque of the last step to the previous one ratio are calculated. For the elastic-plastic range this ratio is 0,7…0,9.

All the bolts are tightened after such testing and therefore the nut rotation angle establishment for the bolts group, from which two samples are selected. For this purpose any known bolts control-stretch method with the nut rotation angle force control, where the bolts are tightened to transit them to the elastic-plastic range. However, as experience shows, the fully-mechanized method is the most perfect. It can be realized by calibrated wrenches with pneumatic, hydraulic, or electric drive. Such wrenches calibration consists in regulation of corresponding power parameters. For example, air wrench calibration consists in the selection of pressure and compressed air output, which is necessary for nut rotation by the preset angle.

Example. The bolts of M22-M24 group tightening. The normalized assurance factor ***m*=3**.

Experiments proved that the bolts M22 of the smallest length (the first sample) are destroyed when nut rotation angle 720^{O}…780^{O} ($\alpha_{min1}=720^{O}$) obtaining.

The second sample (bolts M24 of the biggest length) is tightened to the elastic-plastic working range by nut rotation by the angle of 150^{O}…210^{O} ($\alpha_{max2}=210^{O}$).

The assurance factor

$$\mathbf{m} = \frac{\alpha_{\min 1}}{\alpha_{\max 2}} = \frac{720^{o}}{210^{o}} = \mathbf{3.43} > 3.$$

The bolts tightening of whole group is carried out by nut rotation by the angle of $\alpha_{max2}=210^{O}$.

Conclusion

As can be seen from the above, the suggested method allows nut tightening before transiting them to the elastic-plastic range independent from the applied tool (mostly mechanized).

The method has passed laboratory and industrial testing of steel structures erection for various purposes.

References

1. Chesnokov A.S., Knyazhev A.F. *Sdvigoustoychivye soedineniya na vysokoprochnykh boltakh*.[Friction-type joint in high-strength bolts]. Moscow, Stroyizdat, 1974. 121 p.
2. Raber L.M. *Soedineniya na vysokoprochnykh boltakh. Diagnostika. Remont. Povyshenie nadezhnosti konstruktsiy*.[Compounds of high-strength bolts. Diagnostics. Repairing. Improving of designs reliability]. Dnepropetrovsk, Sistemnye tekhnologii, 2008. 124 p.
3. NF EN14399-2. European standard. High-strength structural bolting assemblies for preloading. Part 2. Suitability test for preloading. (Classificstion index: E25-801-2). AFNOR2005 – p. 13.
4. Patent №93136. UKRAINE, AIC V25V21 / 2 (2006.01). The method of threaded joints tightening. Patent owner - National Metallurgical Academy of Ukraine - №201401794; (appl. 02.24.2014, publ. 25.09.2014, bul. No 18)