Considerations for Tool Selection and Installation of Fastening Bolts for Flanges with Large Nominal Diameters

1. Introduction

Various tightening tools are used for fastening bolts. Correctly selecting the optimal tools depending on the usage environment and required fastening precision and properly using such tools reduces the workload and improves fastening precision, work efficiency, and safety.

Bolt fastening is required not only during plant construction but also maintenance and inspection. However, bolt fastening is difficult to control and so even now it still depends on the operator's instincts and experiences. In addition, as the number of skilled operators decreases, bolt fastening is becoming a major cause of leakage accidents and fires at plants. Despite this situation, training on bolt tightening, including the systematic selection of fastening tools and their usage, is rarely provided. In recent years, a certification system for a flange-fastening qualification[1)] has been introduced in other countries, and has helped to reduce leakage. However, especially in Japan, efforts to prevent leakage are left to the discretion of facility owners and engineering companies.

Regarding large bolts, which are difficult to fasten by manpower alone, we sell and rent out tools for such bolts. We also offer on-site supervision on shop floors where fastening skills vary among the different operators who perform fastening.

We have accumulated useful knowledge and information about fastening from on-site experience, and would like to share tips on fastening regarding tool selection and considerations for installation.

2. Selection of optimal tools

Firstly, using tools offers the following benefits:

Benefits associated with installation quality:

- Correct fastening force can be applied to bolts.
- Gaskets, flanges, and bolts are not overloaded.
- Tightening will be consistent if it can be managed based on torque values and axial force values.

Benefits associated with operation:

- Work time can be decreased by reducing staff number and operation time.
- Heavy manual work can be eliminated, reducing the burden on operators.
- Tightening can be executed even in narrow areas where there is little space around equipment.

To obtain such benefits, it is crucial to select tools that meet the on-site conditions. Below, we explain the important factors for selection.

① Fastening-torque value or axial-tension value

When the fastening torque is known, select a tool which can apply that torque at no more than 70% of its maximum output.

【Point】 Consider the tool's fastening performance.

As a guide, a tool should be selected from tools which have maximum torque output equal to 1.5 times the target torque. If the axial-tension value (bolt elongation) is the target value, the tightening is managed by using a bolt tensioner or a hydraulic torque wrench & ultrasonic axial force meter as shown in Figure1.

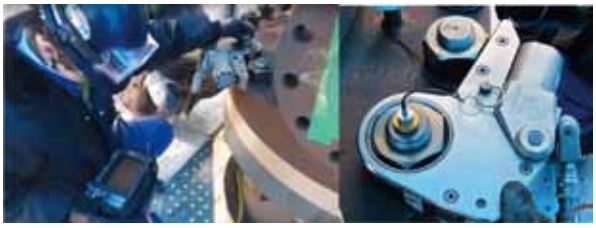

Figure1 Measurement of bolt elongation value using an ultrasonic axial force meter

② Shape and number of bolts and nuts

Since the types of tools that can be used are limited depending on the shapes of bolts and nuts, such as all-screw bolts, tap-end bolts, hexagon headed bolts, and cap nuts, select tools which match such bolts and nuts.

【Tip】Check whether the selected tool matches the shapes of bolts and nuts.

When the long part of a bolt protrudes from the nut's top face, the bolt cannot be fitted with a hexagonal socket. Therefore, center-hole tools and center-hole bolt tensioners should be selected.

【Tip】Consider the tool's operational speed.

Since the operation time per bolt should be shortened, consider selecting a tool with a high fastening speed, fastening bolts concurrently using several tools, and other strategies.

③ Clearance around the target bolt and equipment environment

Check the clearance around bolts to be tightened and the equipment environment.

【Tip】Check whether there is space in the axial direction of bolts.

Large spaces in the axial direction are required for pistol-type tools including air torque wrenches. On the other hand, hydraulic torque wrenches

Table1 Characteristics and evaluation of each tool

	Booster wrench	Battery-type torque wrench	Air torque wrench	Hydraulic torque wrench	Bolt tensioner
Applicable bolt	M16–36	M20–48	M20–56	M30–76	M30 to over M100
Torque range	300–2,000 N・m	500–4,000 N・m	500–6,000 N・m	1,000–30,000 N・m	Managed using axial tension (kN)
Major characteristics	Very strong torque can be applied with light force.	Easy cordless operation using a pistol-type tool	Easy operation using a pistol-type tool	Smallest and lightest among tools with the same torque	No scoring on screws Several screws can be fastened concurrently.
Advantages	No need for power source	Handy for anyone High speed	Handy for anyone High speed	Highly precise torque Wide torque range	Highly-precise fastening No co-rotation
Disadvantages	Takes time in fastening.	Regular charging is required.	Need for stable air supply	Need for pumps and hydraulic hoses	Troublesome setting Heavy tool
Power source	Unnecessary (Manpower)	Rechargeable battery	Compressed air 500 kPa -	Compressed air 500 kPa -, Power supply 100 V, 200 V	Compressed air 500 kPa -
Explosion-proof	○	×	○	○ Depends on pump's function	○
Condition for application 1	Space of at least 250 mm is required in the axial direction of a bolt.	Space of at least 500 mm is required in the axial direction of a bolt.	Space of at least 500 mm is required in the axial direction of a bolt.	Space can be minimal in the axial direction of a bolt.	Space of at least 300 mm is required in the axial direction of a bolt.
Condition for application 2	A reaction-force point should be secured on the neighboring bolt or other area.	←	←	←	Bolt's head should protrude from nut's top face by at least 1d (d: diameter) .
Management method	Input torque wrench	Digital pre-setting	Air pressure	Hydraulic power up to 70 MPa	Hydraulic power up to 150 MPa
Concurrent fastening	N/A	N/A	N/A	Available (up to 4 bolts)	Best (2 bolts to half the total number of bolts)
Operator No.	1 operator/tool	1 operator/tool	1 operator/tool	1–2 operators/tool	0.5–1 operator/tool
Nut fitting	Socket	Socket	Socket	Socket or direct fitting	Prybar
Speed	☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆	☆☆
Precision	☆☆	☆☆☆	☆☆☆	☆☆☆☆	☆☆☆☆☆
Operability	☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆	☆☆
Lightness	☆☆☆	☆☆☆☆	☆☆☆	☆☆☆☆☆	☆
Concurrent multiple-bolt fastening	☆	☆☆☆	☆☆☆	☆☆☆	☆☆
Applicability to various sizes	☆☆☆	☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆
Introduction cost	☆☆☆☆☆	☆☆☆	☆☆☆	☆☆	☆☆☆

are compact and can be widely used. Care should be taken, if space is tight, such as under piping elbows.

【Tip】Check the orientation in which tools are applied.

When tools are heavy, especially when used from underneath, workability is greatly affected by the tool's weight, so the tool's weight is an important factor. When a tool weighing over 10 kg is used upwardly from underneath, some measure to support the tool or prevent it from falling is necessary.

④ Available power source

Check the type of power source available.

【Tip】Secure a power supply of 200 V or stable compressed air.

If there is no power supply, a booster wrench or a battery-type torque wrench should be selected (the wrench should be charged). Also, bolt tensioners can be pressurized using a hand pump. By considering the above factors and comparing them with each tool's characteristics as shown in Table1, the candidate tool types can be identified. Especially, the bolt tensioner uses a different fastening mechanism from the torque method: the bolt tensioner applies axial force to a bolt by directly pulling the bolt. Therefore, the bolt tensioner is rarely affected by the friction coefficient of the contact surface, and so offers highly accurate fastening and does not scratch the flange's surface. However, many devices are designed without assuming that the bolts are fastened using a bolt tensioner; in some cases, part of the device must be remodeled, including changing the bolts, in order to use a bolt tensioner in existing facilities.

3. Considerations of assembly

3-1) Maintenance of bolts and nuts

The next important factor is maintenance of bolts and nuts. Especially, in the case of torque fastening, the axial tension applied to bolts varies depending on the maintenance condition, so maintenance is very important, which includes the following:

① Removing rust and scale
② Repairing damaged screw threads
③ Applying lubricant to the nut seat and threaded portion
④ Smoothing the flange's surface (when impossible, use a washer)

We have checked the maintenance conditions at many sites and found that although 1) and 2) are conducted properly, 3) is often inadequate. In the case of torque control, the axial-tension value of the nut seat surface, which is greatly affected by friction, varies significantly when a lubricant is applied to the surface. When the surface condition of a flange is poor, inserting a washer may improve the condition. We have seen many such cases.

In the case of the all-screw bolt, when lubricant is not applied to the fastening side and opposite side of the nut seat surface, co-rotation is less likely to occur.

3-2) Fastening procedures

When fastening a flange's bolts while uniformly compressing the gasket, fastening should be conducted in a stepwise fashion, as described in JIS B2251[2] and JPI-8R-15.[3]

In practice, these standards are rarely observed, and they show procedures only when using one tool for fastening. The proper procedures vary depending on the number of tools used, so it is desirable to set

Figure2 Parallel fastening using two hydraulic torque wrenches

efficient procedures which are tailored to the number of tools used.

Among the proper procedures, we especially recommend parallel fastening as shown in Figure2. In parallel fastening, at least two tools are placed diagonally for fastening.

This requires less work for one bolt until fastening is completed in a shorter time period, and the gasket is compressed evenly. Therefore, this fastening method can prevent malfunctions resulting from uneven fastening. Valqua's Seal Training Center[4] has facilities where you can experience parallel fastening of flanges with large nominal diameters, so we encourage you to take advantage of these facilities.

3-3) Considerations on reaction-force point

In torque fastening, in principle tools should apply force from a reaction-force point. Securing a stable reaction-force point directly results in accurate fastening force and safety. Therefore, the following procedures are important when fastening nuts: 1) Draw a horizontal line extended from the center of the nut to be fastened. 2) On the horizontal extended line, set a position where a reaction-force arm is fixed. 3) Tightly secure the reaction-point arms on the position in such a manner that the arm is securely fixed to the position when force is applied to the arm. Regarding common flanges, reaction-force points can usually be secured by using the neighboring nut. However, in other cases, it is necessary to carefully check in advance whether a reaction-force point can be correctly secured.

3-4) Efficient operation

After tool selection, the actual work will start; a little preparation in advance can reduce the working time, so we recommend preparing the following items.

① Backup wrench

Figure3 shows some backup wrenches. A backup wrench is set on the nuts on the fastening side and on the opposite side to prevent co-rotation. In addition, backup wrenches can be removed easily. If backup wrenches are not used, co-rotation must be prevented by using slogging wrenches and chisels, but it takes longer to remove the wrenches than when fastening nuts.

Figure3 Backup wrench

② Hydraulic pump with large discharge volume

The speed of the hydraulic torque wrench and bolt tensioner depends on the pump's discharge volume; the discharge volume makes a significant difference especially when a large tool is used. However, large tools are less portable. Therefore, take on-site conditions into account when selecting appropriate tools.

③ Not-too-long hydraulic hose

If the hydraulic hose is too long, it is obstructive on the scaffold, and makes tools not only cumbersome but also slower. The standard length is 5m.

④ Nut splitter

Figure4 shows a hydraulic nut splitter. Although this phenomenon occurs only when a nut is

Figure4 Nut splitter

loosened, if the nut adheres to a bolt too strongly the nut does not rotate. In this case, hydraulic power can be used to cut a nut quickly to remove a bolt.

4. Conclusion

This article introduced considerations for tool selection and installation when fastening the bolts of flanges with large nominal diameters.

Our first priority is to resolve on-site problems and challenges in bolt-fastening operations. To achieve this goal, we have developed products which are useful on shop floors; selected tools which meet the requirements of each shop floor and promptly procured these tools; created on-site guidance on handling; and performed fastening management using an ultrasonic axial force meter.

Through these experiences, we have encountered many cases in which ignoring small details resulted in problems. Two decades ago, there were many skilled workers and we witnessed their excellent hammering works. However, when an ultrasonic axial force meter was used to measure the fastening conditions of the bolts which they had fastened, the meter showed that the bolts had been fastened too strongly. Over-fastening was probably performed because the gaskets of many flanges did not function as intended.

Valqua offers various services at its Seal Training Center, to provide proper knowledge and significantly reduce the risks stemming from users' ignorance.

Leakage at the bolted flange joint is mainly due to poor assembly, which may be due to bolt-tightening problems. We offer products and services for bolt-tightening, to accumulate on-site experience which cannot be gained from studying theories, and provide useful information for those who need it, ranging from designers to operators. To achieve this goal, we are establishing a system and offering support for all procedures ranging from seal selection to bolt tightening.

5. References

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3) Management Standard for Fastening Flanges/Bolts, JPI-8R-15-2013.
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