METHODS USED FOR THE THREADED JOINT'S FORCE CONTROL

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Abstract: *Practice shows that it is necessary to control threaded joint's assembly tightness when mounting or due to the exploitation. If this condition is not provided in necessary quality and tightness is insufficient or too big, it may cause threaded joint's damage.*

The most popular methods for the threaded joint's assembly control in machine manufacturing are as following:

1) *measurement of the screw's prolongation;*
2) *control of the screw-nut's turning angle;*
3) *measurement of the screw-nut's torque;*
4) *control of the yield.*

Key words: screw joint's; force control methods; screws; tightness moment.

1. INTRODUCTION

Because a threaded joint is very common in assembly, it can be found in various units and devices. In order to guarantee necessary threaded joint's assembly tightness, different control methods are used and adapted depending on the various inner and outer factors.

2. MEASUREMENT OF THE SCREW'S PROLONGATION

The most exact results provide the measurement of the screw's prolongation. This method is widely used when controlling threaded joint's tightness for very responsible assembly units, for example, for pitman screw joints. This category includes the use of special load indicating bolts, load indicating washers and the use of methods which determine the length change of the fastener. There are a wide number of ways bolt tension can be indirectly measured.

When using long screw-bolts (threaded studs) it is possible to measure the changes of the distance between screw-bolt's end and the corpus. In this case different measurement indicators and samplers are used. Sometimes in order to determine the necessary tightness force when mounting and when exploiting, screws (taps) with central boring are used. In these borings special core is inserted and the length of this core is chosen in such a way that if the full tightness is made then the frontal surface of the core is on the same level as the screw's frontal surface.

Also special bolts have been designed which give an indication of the force in the bolt. One such fastener is the Rotabolt which measures bolt extension by the use of a central gauge pin which passes down a centrally drilled hole in the bolt. Underneath the head of the gauge pin, a rota is retained which is free to spin in a very accurately set gap. The fastener stretches elastically, whereas the gauge pin does not move since it experiences no load. As tightening continues, the bolt will stretch sufficiently to eliminate the gap and prevent the rota from being able to be rotated. This is the indication that the bolt is correctly loaded. Another proprietary fastener uses a similar method. The HiBolt

uses a pin located centrally down the bolt as does the Rotabolt except the pin is gripped by the slight contraction of the bolt diameter; the pin being locked when the correct preload is reached.

The extension which a bolt experiences can be measured either using a micrometer or by a more sophisticated means such as using ultrasonics. The extension can be related to preload either directly, by calibration, or indirectly, by calculation. If ultrasonic measurement is used then the end of the bolt shank and the head may require surface grinding to give a good acoustic reflector.

For measurement of the responsible threaded joints force also strand sensors are used which are fastened on the screw's smooth part or poured into the screw's central drillhole. These strand sensors may be left there during the exploitation. Also very effective is pneumosensormetric method which is based on the measurement of the changes of the air consumption between screw insert's gap.

The use of load indicating washers is widespread in structural engineering. Such washers have small raised pips on their surface which plastically deform under load. The correct preload is achieved when a predetermined gap is present between the washer and the underhead of the bolt. This is measured using feeler gauges. Generally they are not used in mechanical engineering, but are, extensively, in civil engineering.

If the threaded joint is used in very important place, it is possible to guarantee the necessary tightness parameters using special measurable shim and ring. These two elements are added to the joint in addition to two ordinary shims. The difference of height of measurable shim and the ring comprises the necessary play. The tightness force of the threaded joint is guaranteed when the ring is compressed until it cannot be turned around its axis using special thin device which is inserted in one of the ring's three holes.

The experimental results that were made in laboratories and during exploitation showed that the error of control method which is based on the measurement of screw's prolongation is ±10%.

3. MEASUREMENT OF THE SCREW-NUT'S TURNING ANGLE

When controlling threaded joints tightness using screw-nut's turning angle measurement method it is necessary to follow the technical documentation where all necessary information concerning proper turning angle for the concrete assembly unit is given. The method has been applied for use with power wrenches, the bolt being tightened to a predetermined angle beyond the elastic range and results in a small variation in the preload due, in part, to the yield stress tolerance. But using this control method we must take into account that during the tightness process the screw itself and some details have ductility characteristics. The advantage of this method is that it is not connected with friction forces and that is why is not dependent from the threaded joint's individual characteristics. The main disadvantages of this method lie in the necessity for precise, and, if possible, experimental determination of the angle; also the fastener can only sustain a limited number of re-applications before it fails. This method is rather simple but it cannot be used for short screws and it can provide the preciseness only in the limits of ±20%.

4. THREADED JOINT'S TORQUE CONTROL

In practice rather simple and in the same time effective is method which is based on the threaded joint's torque control using divided wrenches, for example, dynamometric wrenches or utmost limit

wrenches. Controlling the torque which a fastener is tightened to is the most popular means of controlling preload. The nominal torque necessary to tighten the bolt to a given preload can be determined either from tables, or, by calculation using a relationship between torque and the resulting bolt tension. When a bolt is tightened the shank sustains a direct stress, due to the elongation strain, together with a torsional stress, due to the torque acting on the threads. Most tables of bolt tightening torques ignore the torsional stress and assume a direct stress in the threads of some proportion of the bolts yield stress, usually 75%. For high frictional conditions the magnitude of the torsional stress can be such that when combined with the direct stress, an equivalent stress over yield can result, leading to failure. A more consistent approach is to determine the magnitude of the direct stress which, when combined with the torsional, will give an equivalent stress of some proportion of yield. The proportion commonly used with this approach is 90%. Torque prevailing fasteners (such as Nyloc, Cleveloc nuts etc.) are often used where there exists a risk of vibration loosening. The prevailing torque has the effect of increasing the torsional stress in the bolt shank during tightening. This affects the conversion of the tightening torque into bolt preload and should be allowed for when determining the correct torque value for this type of fastener. But there is one fundamental problem with torque tightening. The majority of the torque is used to overcome friction (usually between 85% and 95% of the applied torque), slight variations in the frictional conditions can lead to large changes in the bolt preload. This effect can be reduced by the use of so called friction stabilizers. These are substances which are coated onto the fasteners to reduce the frictional scatter.

There is a wide range of different torque control devices (mechanical and electrical) with the help of which the necessary torque moment can be measured in order to guarantee the necessary threaded joint's tightness.

Mechanical dynamometric wrenches are constructed in such a way that with the usage of the special devices (flexible elements) the screw joint's tightness moment is measured in each moment of the time. When the necessary tightness moment is reached the further movements are ended. Using utmost limit wrenches the tightness moment is limited with the help of special couplings or friction limiters. Utmost limit wrench turns off or special light or sound signal is provided when the necessary screw joint's tightness moment is reached.

The most accurate dc assembly systems use a torque transducer to continuously monitor the dynamic torque delivered to the fastener during the tightening process. The controller electronics monitor this dynamic torque signal to control the precise shut-off point. These systems usually include a method of data output to document joint quality. Documentation may not be required to error-proof the tightening process. Some lower cost options that do not require a torque transducer include:

Clutch Control: A mechanical clutch can be directly connected to a dc electric tool to control torque without the need for a torque transducer. This provides torque control comparable to pneumatic tools and can be calibrated to a reference torque control standard. However, a mechanical clutch adds weight and size to the tool that can decrease ergonomics. The wear of components requires periodic manual torque adjustment.

Basic Current Control: Another torque control method is to measure the power consumption of the motor. A controller monitors the electric current used by the motor, and when this current reaches a predetermined level, the motor is shut off to complete the tightening process. However, the flow of current into the motor is not directly related to the torque delivered to the

fastener. Many other factors can affect this current measurement. As the temperature of the motor increases, less torque is produced for a given amount of current. Shutting off the tool at a preset current level will produce less torque when the tool increases in temperature with use.

Advanced Current Control: A comprehensive software algorithm can integrate several other factors to arrive at a more accurate estimation of torque using current control. Sensing the motor temperature allows compensation for the difference in torque output with changing temperature. Operating the system in a "learn mode" on a specific test joint while sensing the joint rate, and then reducing the tool's speed to a level where the torque overshoot produced by the rotating inertia becomes negligible, can help reduce the effects of inertia and can reduce torque overshoot. But this is only effective on production joints that are consistently similar to the sample joint. When these systems are used on production joints of varying torque rates, they fail to meet expectations. And when used on multiple joints of different torque rates, they require a joint type selector, which adds cost and complexity to the fastening system.

One of the basic requirements of the ISO 5393 test method for torque capability over a wide range of joints is that tools be tested on both hard and soft joints without any adjustment to the control system. Systems that must "re-learn" or have control parameters changed for either type of joint will violate this basic requirement of this industry-standard performance test.

Data to document process control capability from current control systems usually is not accepted. Current control data is merely a target, or a calculation based on a number of measured properties, not the actual dynamic torque delivered to the fastener. When compared to a reference master torque transducer, the indicated torque can differ substantially from the actual torque.

Transducer Control: The simplest, most direct, and most accurate torque control method measures dynamic torque using a torque transducer. Not including networked data collection can simplify the system: a simplified system confirms tightening to within the specified torque limits.

5. YIELD CONTROL METHOD

This yield control method is also known under the proprietary name "Joint Control Method". Very accurate preloads can be achieved by this method by minimizing the influence of friction and its scatter. The method has its roots in a craftsman's "sense of feel" on the wrench which allowed him to detect the yield point of the fastener with reasonable precision. With the electronic equivalent of this method, a control system is used which is sensitive to the torque gradient of the bolt being tightened. Rapid detection of the change in slope of this gradient indicates the yield point has been reached and stops the tightening process. This is achieved by incorporating sensors to read torque and angle during the tightening process. Since angle of rotation and torque are both measured by the control system, permissible values can be used to detect fasteners which lie outside their specification (having too low a yield for example). A small degree of preload scatter still results from this method due to the influence of friction. The method detects the yield point of the fastener under the action of combined tension and torsion. The higher the thread friction, the higher the torsional stress, which, for a given yield value, results in a lower preload due to a lower direct stress. The method has been used in critical applications, such as cylinder head and conn-rod bolts, in order that consistently high preloads can be achieved (which can allow

smaller bolts to be used). However, because of the cost of the tools necessary to use this method (a hand wrench incorporating the control circuitry costs many times more than a conventional torque wrench), widespread adoption of this method is unlikely.

6. CONCLUSION

In conclusion it is necessary to stress the fact that the appropriate method used for the threaded joint's force control can lead to the cost decrease which are connected with manufacture and can save the necessary time that is used for the control process itself.

7. REFERENCES

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