Reference of Nut Factors and Friction Coefficients in Bolt Tightening for Bolted Flange Connections[1]

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1. SCOPE

When a torque control method is applied for tightening a lot of bolts in a bolted flange connection, a target torque should be determined by using appropriate nut factors or friction coefficients for threads and for bearing surfaces in order to achieve the axial bolt force desired. This study shows examples of nut factors and friction coefficients obtained by the experimental bolt tightening tests for single bolt connections and bolted flange connections. Since the nut factors or the friction coefficients depend on those conditions such as material, lubrication, tolerance of threads, tightening tool, craftsmanship and so on, it can vary in case by case. Thus, the examples provided here do not specify nor limit the range of variation. Note that it may happen the case beyond the range shown here.

2. NOMENCLATURE

d : Nominal Diameter of Bolt mm

d_2 : Effective Diameter of Bolt mm

d_h : Bolthole Diameter mm

d_w : Diameter of Bearing Surface of Nut mm

D_w : Equivalent diameter of torque on bearing surfaces $\left(= \frac{2}{3} \cdot \frac{d_w^3 - d_h^3}{d_w^2 - d_h^2}\right)$ mm

F_f : Bolt preload kN

K : Nut factors

P : Pitch of threads mm

T_f : Tightening torque N·m

T_w : Torque on bearing surfaces N·m

T_s : Torque on fitted portion of threads N·m

μ_s : Friction coefficient of between threads

μ_w : Friction coefficient between bearing surfaces

β_p : Lead angle of threads at the effective diameter, $\tan\beta_p = P/(\pi d_2)$

3. RELATIONSHIP BETWEEN TIGHTENING TORQUE AND AXIAL BOLT FORCE IN TORQUE METHOD

A tightening torque is given by the equation (1), when a axial bolt force is controlled by the torque method.

$$T_{\mathrm{f}} = T_{\mathrm{w}} + T_{\mathrm{s}} = K \cdot F_{\mathrm{f}} \cdot d \qquad \cdots\cdots (1)$$

The tightening torque can also be written by the equation (2) using the friction coefficients between threads and between bearing surfaces.

$$T_{\mathrm{f}} = \frac{d_2}{2} \cdot F_{\mathrm{f}} \cdot \left(\tan \beta_{\mathrm{p}} + 1.155\ \mu_{\mathrm{s}}\right) + \frac{D_{\mathrm{w}}}{2} \cdot F_{\mathrm{f}} \cdot \mu_{\mathrm{w}} \qquad \cdots\cdots (2)$$

Properties related to the tightening characteristics such as the nut factors and the friction coefficients depend on the conditions of threads tolerance manufactured, surface roughness, lubrication and so on. The tightening characteristics can be obtained or estimated by the experiments representing those conditions in the actual bolted joint. Or predefined figures are also available. A standard procedure of bolt tightening test is specified in **JIS B 1084** “Method of Tightening Test for Threaded Fasteners” [2].

4. IDENTIFICATION OF TIGHTENING CHARACTERISTICS BY BOLT TIGHTENING TEST

Figures 1, 2 and **3** show the nut factors, the friction coefficient on the thread surface and the friction coefficient on the bearing surface obtained by experimental bolt tightening tests for single bolt connection, respectively. In the bolt tightening tests, M20 stud bolts and heavy nuts are used. The bolts are made of SNB7 equivalent to A193 Gr. B7 and the nuts are made of S45C equivalent to A194 Gr. 2H. The clamped plates are made of SFVC2A equivalent to A105.

The threads of bolt and nut and the bearing surface are lubricated by dry coat of MoS_2 sprayed. Bolt tightening is performed repeatedly 10 times for one set of bolt and nut to examine the effects of reuse of bolt and nut provided that the lubricant is sprayed in every time before tightening.

In cases of 4 inch flange connections assembled according to ASME PCC-1 “Guidelines for Pressure Boundary Bolted Flange Joint Assembly” [3], it is examined that nut factors and friction coefficient supposing $\mu_{\mathrm{s}} = \mu_{\mathrm{w}}$. The mean values of them for all the bolts in the Round 5 are 0.098 and 0.056, respectively.

The friction coefficient obtained by the present tests generally shows lower value than 0.08

known as the conventional value for MoS_2 lubricant. In the single bolt tightening tests, it shows the tendency that the highest nut factors and friction coefficient are obtained at the first time in the repeated tightening and the values decrease as increasing the number of repeat, though the coefficients somehow depend on the tightening torque in some cases. In addition, the results obtained by the flange connections do not consist exactly with those by the single bolt connections.

Variation or inconsistency in the tightening characteristics shown here is not a special case but general facts in tightening bolts by the torque control method.

REFERENCE

[1] **HPIS Z103 TR** “Bolt Tightening Guidelines for Pressure Boundary Flanged Joint Assembly”, High Pressure Institute of Japan, 2004

[2] **JIS B 1084** “Method of Tightening Test for Threaded Fasteners”, Japanese Standards Association, 1990

[3] **ASME PCC-1** “Guidelines for Pressure Boundary Bolted Flange Joint Assembly”, ASME, 2000

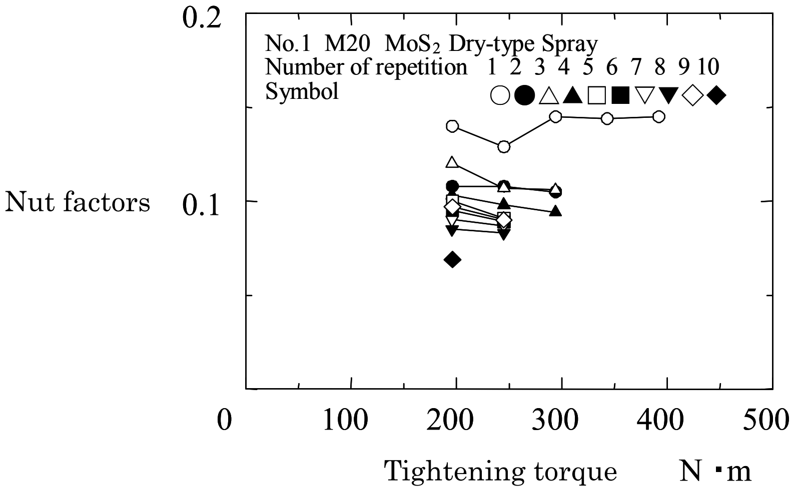

Fig.1 Nut factors vs Tightening torque

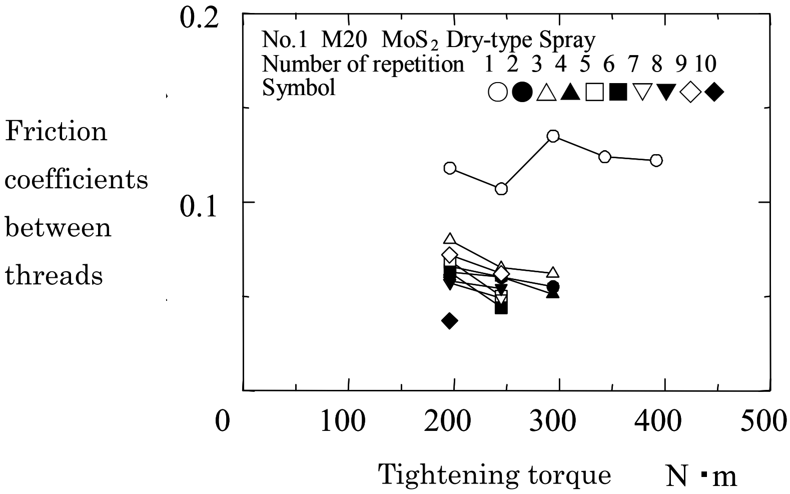

Fig.2 Friction coefficients between threads vs Tightening torque

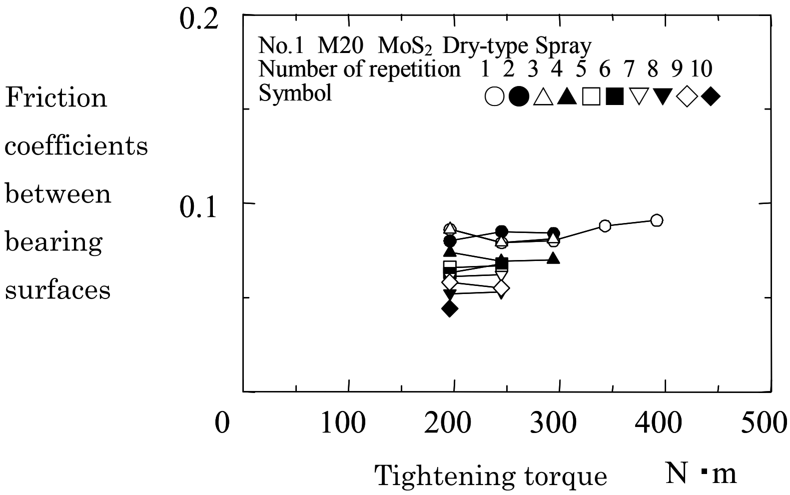

Fig.3 Friction coefficient between bearing surfaces vs Tightening torque