■Axial tightening force and fatigue limit when fastening with bolts

- When calculating the suitable axial tightening force for bolt tightening, the maximum force shall be 70% of the standard proof strength using the torque control method, and the force shall be within the elastic range.
- Bolt fatigue strength under repeated load must not exceed the maximum allowable value.
- The bolt and nut seat must not cause any depression in the fastened part.
- Tightening must not cause any damage to the fastened part.

Methods of bolt tightening include the torque control method, torque gradient control method, rotation angle control method, and extension measurement method. The torque control method is most commonly used, due to its simplicity.

■Calculation of axial tightening force and tightening torque

The relationship of axial tightening force Ff is shown by Formula (1).

$Ff = 0.7 \times \sigma y \times As$ ····· (1)

Tightening torque T_A is found from Formula (2).

$T_A = 0.35k(1+1/Q)\,\sigma y \cdot As \cdot d$ ····· (2)

k : Torque coefficient
d : Bolt nominal diameter [cm]
Q : Tightening coefficient
σy : Proof strength (112 kgf/mm² for strength class 12.9)
As : Bolt effective cross-section area [mm²]

■Sample calculation

Find the suitable torque and axial force when using an M6 hexagon socket head cap screw (strength class 12.9) to fasten soft steel to soft steel, and tightening with oil lubrication.

- The suitable torque is found by Formula (2), as shown below.

$T_A = 0.35k(1+1/Q)\,\sigma y \cdot As \cdot d$
$= 0.35 \cdot 0.17(1+1/1.4)\,112 \cdot 20.1 \cdot 0.6$
$= 138$ [kgf·cm]

- Axial force Ff is found from Formula (1), as shown below.

$Ff = 0.7 \times \sigma y \times As$
$0.7 \times 112 \times 20.1$
1576 [kgf]

■Torque coefficient based on the combination of bolt surface treatment, tightened parts, and internal thread material

Bolt Surface treatment Lubrication	Torque coefficient k	Combination Tightened part material—Female screw material (a) (b)
Steel bolt Black oxide coating Not lubricated	0.145	SCM—FC FC—FC SUS—FC
	0.155	S10C—FC SCM—S10C SCM—SCM FC—S10C FC—SCM
	0.165	SCM—SUS FC—SUS AL—FC SUS—S10C SUS—SCM SUS—SUS
	0.175	S10C—S10C S10C—SCM S10C—SUS AL—S10C AL—SCM
	0.185	SCM—AL FC—AL AL—SUS
	0.195	S10C—AL SUS—AL
	0.215	AL—AL
Steel bolt Black oxide coating Not lubricated	0.25	S10C—FC SCM—FC FC—FC
	0.35	S10C—FC SCM—S10C SCM—SCM FC—S10C FC—SCM
	0.45	S10C—S10C SCM—S10C AL—S10C AL—SCM
	0.55	SCM—AL FC—AL AL—AL

S10C: Non-heat-treated soft steel SCM: Heat treated steel (36HRC) FC: Cast iron (FC200) AL: Aluminum SUS: Stainless steel (sus304)

■Standard value for tightening coefficient Q

Tightening coefficient Q	Tightening method	Surface condition Bolt	Surface condition Nut	Lubrication
1.25	Torque wrench	Manganese phosphate	Untreated or phosphate	Not lubricated or MoS_2 paste
1.4	Torque wrench	Untreated or phosphate		
	Torque wrench with torque limiter			
1.6	Impact wrench			
1.8	Torque wrench	Untreated or phosphate	Untreated	Not lubricated
	Torque wrench with torque limiter			

Indicating the strength class
Example: 12.9
- Proof strength (yield stress): 90% of minimum tensile strength
- Minimum tensile strength is 1220 N/mm² {124kgf/mm²}

10.9
- Proof strength (yield stress): 90% of minimum tensile strength
- Minimum tensile strength is 1040 N/mm² {106kgf/mm²}

■Initial tightening force and tightening torque

Nominal thread size	Effective cross-section area As mm²	Strength class 12.9 Yield load kgf	12.9 Initial tightening force kgf	12.9 Tightening torque kgf·cm	10.9 Yield load kgf	10.9 Initial tightening force kgf	10.9 Tightening torque kgf·cm	8.8 Yield load kgf	8.8 Initial tightening force kgf	8.8 Tightening torque kgf·cm	4.8 Yield load kgf	4.8 Initial tightening force kgf	4.8 Tightening torque kgf·cm
M 3×0.5	5.03	563	394	17	482	338	15	328	230	10	175	122	5
M 4×0.7	8.78	983	688	40	842	589	34	573	401	23	305	213	12
M 5×0.8	14.2	1590	1113	81	1362	953	69	927	649	47	493	345	25
M 6×1	20.1	2251	1576	138	1928	1349	118	1313	919	80	697	488	43
M 8×1.25	36.6	4099	2869	334	3510	2457	286	2390	1673	195	1270	889	104
M10×1.5	58	6496	4547	663	5562	3894	567	3787	2651	386	2013	1409	205
M12×1.75	84.3	9442	6609	1160	8084	5659	990	5505	3853	674	2925	2048	358
M14×2	115	12880	9016	1840	11029	7720	1580	7510	5257	1070	3991	2793	570
M16×2	157	17584	12039	2870	15056	10539	2460	10252	7176	1670	5448	3814	889
M18×2.5	192	21504	15053	3950	18413	12889	3380	12922	9045	2370	6662	4664	1220
M20×2.5	245	27440	19208	5600	23496	16447	4790	16489	11542	3360	8502	5951	1730
M22×2.5	303	33936	23755	7620	29058	20340	6520	20392	14274	4580	10514	7360	2360
M24×3	353	39536	27675	9680	33853	23697	8290	23757	16630	5820	12249	8574	3000

Note: • Tightening condition: Tightened by torque wrench. (Surface oil lubrication Torque coefficient k=0.17 Tightening coefficient Q=1.4)
• Because the torque coefficient varies depending on the conditions of use, use this table only as an approximate guide.
• This table consists of edited excerpts from the Catalog of Kyokuto MFG Co Ltd.