

1. Torque

(2) [kgf·cm] ([kgf·m]) to [N·m] conversion value

Conversion value 1 [kgf·cm] = 0.0980665 [N·m]
1 [kgf·m] = 9.80665 [N·m]

Table 1-3

[kgf·cm]	0	1	2	3	4	5	6	7	8	9
10	0.981	1.08	1.18	1.27	1.37	1.47	1.57	1.67	1.77	1.86
20	1.96	2.06	2.16	2.26	2.35	2.45	2.55	2.65	2.75	2.84
30	2.94	3.04	3.14	3.24	3.33	3.43	3.53	3.63	3.73	3.82
40	3.92	4.02	4.12	4.22	4.31	4.41	4.51	4.61	4.71	4.81
50	4.90	5.00	5.10	5.20	5.30	5.39	5.49	5.59	5.69	5.79
60	5.88	5.98	6.08	6.18	6.28	6.37	6.47	6.57	6.67	6.77
70	6.86	6.96	7.06	7.16	7.26	7.35	7.45	7.55	7.65	7.75
80	7.85	7.94	8.04	8.14	8.24	8.34	8.43	8.53	8.63	8.73
90	8.83	8.92	9.02	9.12	9.22	9.32	9.41	9.51	9.61	9.71
100	9.81	9.90	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7

Table 1-4

[kgf·cm]	0	10	20	30	40	50	60	70	80	90
100	9.81	10.8	11.8	12.7	13.7	14.7	15.7	16.7	17.7	18.6
200	19.6	20.6	21.6	22.6	23.5	24.5	25.5	26.5	27.5	28.4
300	29.4	30.4	31.4	32.4	33.3	34.3	35.3	36.3	37.3	38.2
400	39.2	40.2	41.2	42.2	43.1	44.1	45.1	46.1	47.1	48.1
500	49.0	50.0	51.0	52.0	53.0	53.9	54.9	55.9	56.9	57.9
600	58.8	59.8	60.8	61.8	62.8	63.7	64.7	65.7	66.7	67.7
700	68.6	69.6	70.6	71.6	72.6	73.5	74.5	75.5	76.5	77.5
800	78.5	79.4	80.4	81.4	82.4	83.4	84.3	85.3	86.3	87.3
900	88.3	89.2	90.2	91.2	92.2	93.2	94.1	95.1	96.1	97.1
1000	98.1	99.0	100	101	102	103	104	105	106	107

Table 1-5

[kgf·m]	0	1	2	3	4	5	6	7	8	9
10	98.1	108	118	127	137	147	157	167	177	186
20	196	206	216	226	235	245	255	265	275	284
30	294	304	314	324	333	343	353	363	373	382
40	392	402	412	422	431	441	451	461	471	481
50	490	500	510	520	530	539	549	559	569	579
60	588	598	608	618	628	637	647	657	667	677
70	686	696	706	716	726	735	745	755	765	775
80	785	794	804	814	824	834	843	853	863	873
90	883	892	902	912	922	932	941	951	961	971
100	981	990	1000	1010	1020	1030	1040	1050	1060	1070

2. Bolt Tightening

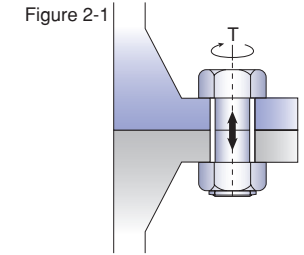
2-1 Torque and Tension

Why do we tighten screws?

The purpose of tightening screws is to fix one object to another object. We call this force to fix axial tension.

Apply suitable axial tension

It is best to do axial tension control for tightening screw, but actually it is difficult to measure axial tension. Torque control is done as a substitute characteristic.



2-2 Torque and Screw

(1) Relation formula between screw and torque

Formula of screw ①

$$T = F_r \left\{ \frac{d_2}{2} \left(\frac{\mu}{\cos \alpha} + \tan \beta \right) + \mu_n \frac{d_n}{2} \right\}$$

Example) If M8, Ft=8000 [N], tightening torque is

From Table 8-1 $d_2=7.188$ [mm]
 $d_{n1}=11.27$ [mm] (1 class nut)
 $\tan \beta=0.0554$

From Table 2-5 $\mu=\mu_n=0.15$ $\alpha=30^\circ$

$$T = 8000 \left\{ \frac{7.188}{2} \left(\frac{0.15}{\cos 30^\circ} + 0.0554 \right) + 0.15 \left(\frac{11.27}{2} \right) \right\} \div 1000 = 13.4 \text{ [N}\cdot\text{m]}$$

Formula of pitch diameter of bearing surface (d_{n1} , d_n)

a: Hexagon bearing surface (first type nut, bolt)

$$d_{n1} = \frac{0.608B^3 - 0.524d_H^3}{0.866B^2 - 0.785d_H^2} \quad \begin{array}{l} B : \text{Hexagon width across flats [mm]} \\ d_H : \text{Bearing surface inside diameter [mm]} \end{array}$$

b: Round shape bearing surface (second, third type nut)

$$d_n = \frac{2}{3} \cdot \frac{D^3 - d_H^3}{D^2 - d_H^2} \quad \begin{array}{l} D : \text{Hexagon width across flats [mm]} \\ d_H : \text{Bearing surface inside diameter [mm]} \end{array}$$

Formula of screw ②

$$T = K \cdot d \cdot F_r \quad \text{or} \quad F_r = \frac{T}{K \cdot d} \quad \begin{array}{l} K : \text{Torque coefficient (See table 2-4)} \\ d : \text{Nominal size of screw [mm]} \end{array}$$

Example) Axial tension M20 screw to tighten $T=400$ [N·m]
 $d=20$ [mm] $K=0.2$ (See P28 table 2-4) $F_r = \frac{400}{0.2 \times 20} = 100000$ [N]

Figure 2-2 Detail drawing

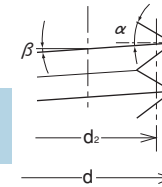
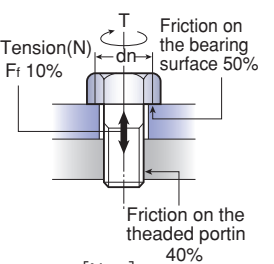
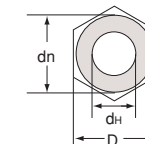
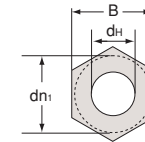


Figure 2-3 Relation drawing



- T : Torque [N·m]
- Fr : Axial tension [N]
- d2 : Pitch diameter [mm] (See table 8-1)
- dn : Pitch diameter of [mm] (See table 8-1)
- bearing surface
- μ : Friction coefficient of (See table 2-4)
- threaded portion
- μn : Friction coefficient of (See table 2-4)
- bearing portion
- α : Half angle of screw thread (ISO screw 30°)
- β : Lead angle [degree] tan β; (See Figure 2-2)
- (See table 8-1)



(2) Relation figure between screw and torque (Torque coefficient K=0.2)

2. Bolt Tightening

2-3 Standard Torque

(1) Standard torque

Table 2-1 Standard torque [N·m] (Ref. data)

Nominal diameter	T [N·m]	0.5 series [N·m]	1.8 series [N·m]	2.4 series [N·m]
M1	0.0195	0.0098	0.035	0.047
(M1.1)	0.027	0.0135	0.049	0.065
M1.2	0.037	0.0185	0.066	0.088
(M1.4)	0.058	0.029	0.104	0.140
M1.6	0.086	0.043	0.156	0.206
(M1.8)	0.128	0.064	0.23	0.305
M2	0.176	0.088	0.315	0.42
(M2.2)	0.23	0.116	0.41	0.55
M2.5	0.36	0.18	0.65	0.86
M3	0.63	0.315	1.14	1.50
(M3.5)	1	0.5	1.8	2.40
M4	1.5	0.75	2.7	3.6
(M4.5)	2.15	1.08	3.9	5.2
M5	3	1.5	5.4	7.2
M6	5.2	2.6	9.2	12.2
(M7)	8.4	4.2	15	20.0
M8	12.5	6.2	22	29.5
M10	24.5	12.5	44	59
M12	42	21	76	100
(M14)	68	34	122	166
M16	106	53	190	255
(M18)	146	73	270	350
M20	204	102	370	490
(M22)	282	140	500	670
M24	360	180	650	860
(M27)	520	260	940	1240
M30	700	350	1260	1700
(M33)	960	480	1750	2300
M36	1240	620	2250	3000
(M39)	1600	800	2900	3800
M42	2000	1000	3600	4800
(M45)	2500	1260	4500	6000
M48	2950	1500	5300	7000
(M52)	3800	1900	6800	9200
M56	4800	2400	8600	11600
(M60)	5900	2950	10600	14000
M64	7200	3600	13000	17500
(M68)	8800	4400	16000	21000

Table 2-2 Standard torque [kgf·cm] (Ref. data)

Nomina diameter	T [kgf·cm]	0.5T series [kgf·cm]	1.8T series [kgf·cm]	2.4T series [kgf·cm]
M1	0.199	0.100	0.357	0.479
(M1.1)	0.275	0.138	0.500	0.663
M1.2	0.377	0.189	0.673	0.897
(M1.4)	0.591	0.296	1.06	1.43
M1.6	0.877	0.438	1.59	2.10
(M1.8)	1.31	0.653	2.35	3.11
M2	1.79	0.897	3.21	4.28
(M2.2)	2.35	1.17	4.18	5.61
M2.5	3.67	1.84	6.63	8.77
M3	6.42	3.21	11.6	15.3
(M3.5)	10.2	5.1	18.4	24.5
M4	15.3	7.6	27.5	36.7
(M4.5)	21.9	11.0	39.8	53.0
M5	29.4	14.7	53.0	70.6
M6	53.0	26.5	93.8	124
(M7)	85.7	42.8	153	204
M8	127	63.2	224	301
M10	250	127	449	602
M12	428	214	775	1020
(M14)	693	347	1240	1690
M16	1080	540	1940	2600
(M18)	1490	744	2750	3570
M20	2080	1040	3770	5000
(M22)	2880	1430	5100	6830
M24	3670	1840	6630	8770
(M27)	5300	2650	9590	12600
M30	7140	3570	12800	17300
(M33)	9790	4890	17800	23500
M36	12600	6320	22900	30600
(M39)	16300	8160	29600	38700
M42	20400	10200	36700	48900
(M45)	25500	12800	45900	61200
M48	30100	15300	54000	71400
(M52)	38700	19400	69300	93800
M56	48900	24500	87700	118000
(M60)	60200	30100	108000	143000
M64	73400	36700	133000	178000
(M68)	89700	44900	163000	214000

Standard bolt stress : 210 [N/mm²]

Pitch of cross section of bolt (JIS B1082)

Note: conversion value modified 3 effective figures

(2) Screw and applicable T series

Table 2-3 Screw and applicable T series

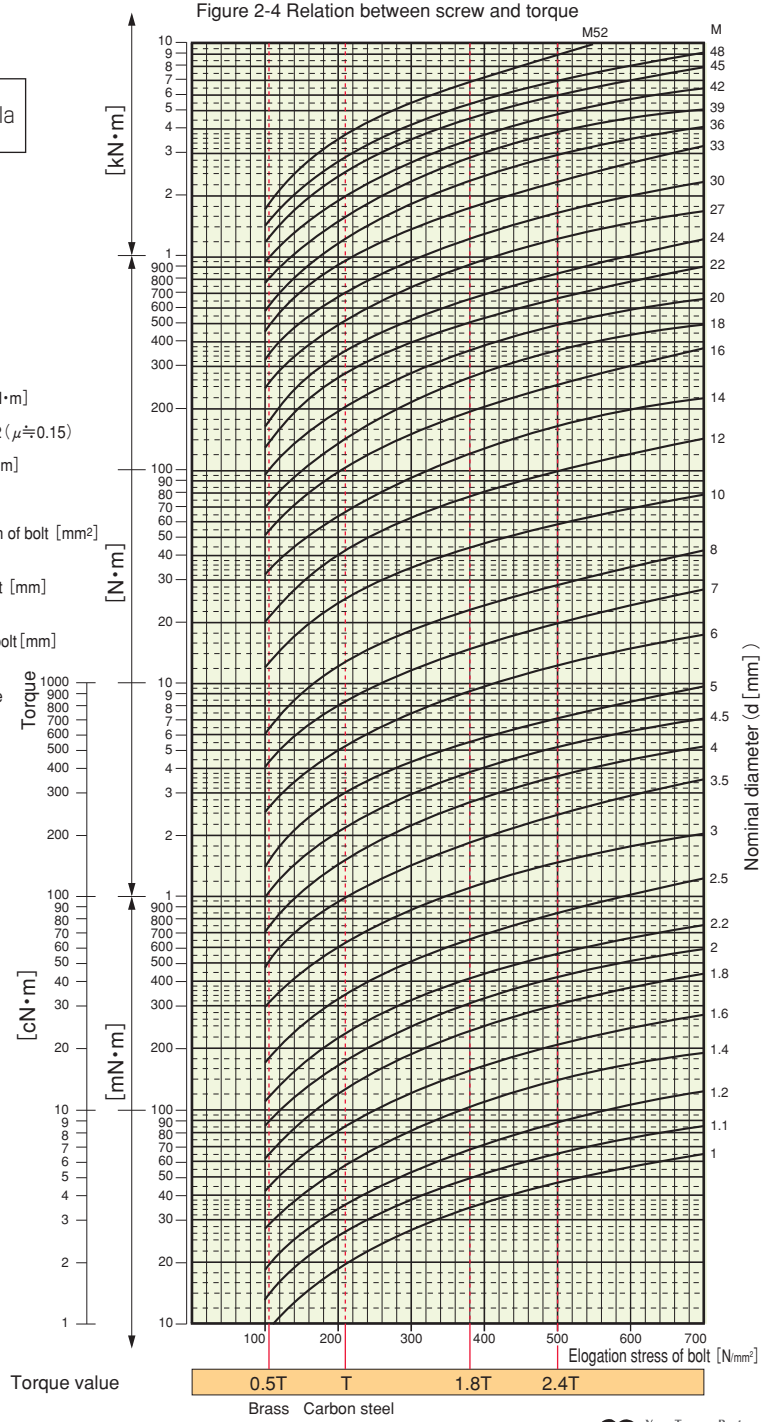
	T series	0.5 series	1.8 series	2.4 series
Screws (Strengths) (Material)	4.6~6.8 SS,SC,SUS	—	8.8~12.9 SCr,SNC,SCM	10.9~12.9 SCr,SNC,SCM,SNM
Axial tension Standard value [N/mm ²] Min~Max	210 300~160	105 150~80	380 540~290	500 710~380
Application	To be applied to ordinary screws, unless otherwise specified	Male and female screws with copper, aluminum or plastic, for die-cast plastic products	Durable screw joints made of special steel including those affected by additional dynamic loads (Friction clamping)	
Application products	Ordinary products	Electronic products	Vehicles, Engines	Construction products

* From Max. to Min. of axial stress is considered about dispersion of torque coefficient.

Example) $\sigma_{max} = 210 \times (0.2 \div 0.14) = 300$ [N/mm²]

Torque coefficient : 0.14 (minimum)~0.2 (average)~0.26 (maximum)

Figure 2-4 Relation between screw and torque



Calculation formula

$$T = K \cdot d \cdot F_f$$

$$A_s = \frac{\pi}{4} \left(\frac{d_2 + d_3}{2} \right)^2$$

$$d_3 = d_1 - \frac{H}{6}$$

$$H = 0.866025P$$

$$\sigma = \frac{F_f}{A_s}$$

T : Tightening torque [N·m]

K : Torque coefficient 0.2 ($\mu \neq 0.15$)

d : Nominal diameter [mm]

Ff : Axial tension [N]

As : Pitch of cross section of bolt [mm²]
(JIS B 1082)

d2 : Pitch diameter of bolt [mm]
(JIS B 0205)

d1 : Bottom diameter of bolt [mm]
(JIS B 0205)

H : Fundamental triangle height [mm]

P : Pitch [mm]

σ : Elongation stress of bolt [N/mm²]

Technical Data

Technical Data

2. Bolt Tightening

2-4 Torque Coefficient

(1) Formula of torque coefficient

$$K = \frac{1}{2d} \left[d_2 \left(\frac{\mu}{\cos \alpha} + \tan \beta \right) + \mu_n \cdot d_n \right]$$

d is Nominal diameter [mm]

(2) Torque coefficient is not stable

Table 2-4 Torque coefficient and friction coefficient

Lubrication	Torque coefficient K min~average~max	Friction coefficient $\mu (= \mu_n)$ min~average~max
General machine oil [Spindle oil, machine oil, turbine oil, cylinder oil]	0.14~0.20~0.26	0.10~0.15~0.20
Low friction oil [Double sulfurous molybdenum, wax based oil]	0.10~0.15~0.20	0.067~0.10~0.14
Fcon (Bolt tension stabilization: See P328)	0.16~0.18~0.20	0.12~0.135~0.15

Note: The value on this table is for standard screw joint. This is not applicable for special condition. $K \approx 1.3\mu + 0.025$
Min and max mean width of dispersion. Variation width will be smaller if the condition is limited (lubrication oil, shape etc.)

(3) Even torque is stable axial tension may vary

Factors of defects in torque coefficient

- Lubrication
- Machine factor of body tightened
- Environment
- Tightening speed
- Reutilization screw

Example: Tightening is stable, how axial tension will change if torque coefficient will change?

$$F_f = T / (K \cdot d)$$

Nominal diameter: $d=10$ [mm]

Tightening torque: $T=24$ [N·m]

Torque coefficient: $K_{min}=0.14, K=0.2, K_{max}=0.26$

$K_{min}=0.14$

$$F_{fmax} = 24 / (0.14 \times 0.01) = 17140 \text{ [N]}$$

$K_{max}=0.26$

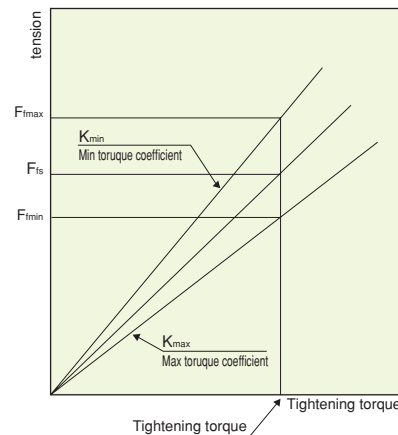
$$F_{fmin} = 24 / (0.26 \times 0.01) = 9230 \text{ [N]}$$

$K=0.2$

$$F_f = 24 / (0.2 \times 0.01) = 12000 \text{ [N]}$$

Axial tension will change around double on K_{min}, K_{max} .

Figure 2-5 Relation between tightening torque and tightening axial tension



(4) Standard torque and bolt axial tension

Table 2-5 Standard torque and bolt axial tension

Nominal diameter	Pitch of cross section of bolt [mm]	T series				0.5T series				1.8T series				2.4T series			
		Standard torque [N·m]	Standard axial tension F_{Ts} [N]	Maximum axial tension F_{Tmax} [N]	Minimum axial tension F_{Tmin} [N]	Standard torque [N·m]	Standard axial tension F_{Ts} [N]	Maximum axial tension F_{Tmax} [N]	Minimum axial tension F_{Tmin} [N]	Standard torque [N·m]	Standard axial tension F_{Ts} [N]	Maximum axial tension F_{Tmax} [N]	Minimum axial tension F_{Tmin} [N]	Standard torque [N·m]	Standard axial tension F_{Ts} [N]	Maximum axial tension F_{Tmax} [N]	Minimum axial tension F_{Tmin} [N]
M1	0.46	0.0195	96	139.50	75.0	0.0098	49.0	70.0	37.7	0.035	175.0	250.0	134.5	0.047	235.0	336.0	181.0
(M1.1)	0.588	0.027	122.8	175.5	94.4	0.0135	61.4	87.6	47.2	0.049	222.5	318	171.5	0.065	295.5	422	227.5
(M1.2)	0.732	0.037	154	220	118.6	0.0185	77	110.2	59.3	0.066	275	393	211.5	0.088	367	524	282
(M1.4)	0.983	0.058	207	296	159.6	0.029	103.6	148	79.6	0.104	371	531	285.5	0.14	500	714	385
M1.6	1.27	0.086	268.5	384	206.5	0.043	134.5	192	103.4	0.156	487	696	375	0.206	644	920	495
(M1.8)	1.7	0.128	356	508	273.5	0.064	178	254	137	0.230	639	912	491	0.305	848	1210	652
M2	2.07	0.176	440	629	338	0.088	220	314.5	169	0.315	788	1126	606	0.42	1050	1500	808
(M2.2)	2.48	0.23	523	746	402	0.116	263.5	377	203	0.41	932	1332	716	0.55	1250	1785	962
M2.5	3.39	0.36	720	1028	554	0.18	360	514	277	0.65	1300	1850	1000	0.86	1720	2455	1324
M3	5.03	0.63	1050	1500	808	0.315	525	750	404	1.14	1900	2715	1460	1.5	2500	3570	1925
(M3.5)	6.78	1.00	1430	2040	1098	0.50	714	1020	549	1.80	2570	3670	1980	2.4	3430	4900	2635
M4	8.78	1.50	1875	2680	1440	0.75	950	1355	730	2.7	3380	4820	2595	3.6	4500	6430	3460
(M4.5)	11.3	2.15	2390	3410	1840	1.08	1200	1715	924	3.9	4330	6190	3330	5.2	5780	8260	4440
M5	14.2	3.00	3000	4290	2310	1.50	1500	2145	1154	5.4	5400	7720	4150	7.2	7200	10280	5540
M6	20.1	5.2	4330	6190	3330	2.6	2165	3095	1665	9	7660	10960	5900	12.2	10160	14500	7820
(M7)	28.9	8.4	6000	8580	4620	4.2	3000	4290	2310	15	10720	15300	8240	20.0	14300	20400	10980
M8	36.6	12.5	7820	11160	6010	6.3	3910	5540	3000	22	13750	19650	10580	29.5	18450	26350	14200
M10	58	24.5	12260	17500	9420	12.3	6130	8920	4720	44	22000	31450	16900	59.0	29500	42100	22700
M12	84.3	42	17500	25000	13450	21.0	8750	12500	6730	76	31650	45200	24350	100.0	41700	59500	32050
(M14)	115	68	24300	34700	18700	34.0	12150	17350	9350	122	43600	62200	32500	166.0	58300	84600	45600
M16	157	106	33150	47300	25500	53	16580	23650	12750	190	59400	84800	45700	255.0	79600	113800	61300
(M18)	192	146	40600	57900	31200	73	20300	29000	15600	270	75000	107200	57700	350.0	97200	139000	74800
M20	245	204	51000	72800	39200	102	25500	36400	19600	370	92600	132200	71200	490.0	122600	175000	94200
(M22)	303	282	64100	91600	49300	141	32000	45700	24600	500	113600	162500	87400	670.0	152500	217500	117200
M24	353	360	75000	107200	57700	180	37500	53600	28850	650	135500	193500	104200	860.0	179000	256000	138000
(M27)	459	520	96200	137500	74000	260	48100	68800	37000	940	174000	248500	134000	1240	229500	328000	176500
M30	561	700	116600	166500	89800	350	58300	83300	44800	1260	210000	300000	162500	1700	283500	405000	218000
(M33)	694	960	145500	208000	111800	480	72800	104000	56000	1750	265000	379000	204000	2300	348000	498000	268000
M36	817	1240	172000	246000	132400	620	86000	123000	66200	2250	312500	446000	240500	3000	417000	595000	320500
(M39)	976	1600	205000	293000	158000	800	102500	146500	78800	2900	372000	531000	286000	3800	487000	696000	375000
M42	1120	2000	238000	340000	183000	1000	119000	170000	91500	3600	429000	612000	329500	4800	571000	816000	440000
(M45)	1310	2500	278000	397000	213500	1250	139000	200000	107000	4500	500000	714000	385000	6000	668000	952000	513000
M48	1470	2950	307500	439000	236500	1475	154000	220000	118500	5300	552000	788000	425000	7000	730000	1042000	561000
(M52)	1760	3800	365000	522000	281000	1900	182500	261000	140400	6800	654000	934000	503000	9200	884000	1264000	680000
M56	2030	4800	429000	612000	329500	2400	214500	306000	165000	8600	768000	1096000	591000	11600	1036000	1480000	796000
(M60)	2360	5900	492000	702000	378000	2950	246000	351000	189000	10600	884000	1262000	680000	14000	1166000	1665000	898000
M64	2680	7200	563000	804000	433000	3600	281500	402000	216500	13000	1016000	1450000	782000	17000	1365000	1955000	1052000
(M68)	3060	8800	647000	924000	498000	4400	323500	462000	249000	16000	1176000	1680000	904000	21000	1545000	2205000	1188000

2. Bolt Tightening

2-5 Method for Determining Tightening Torque

(1) To apply appropriate bolt tension

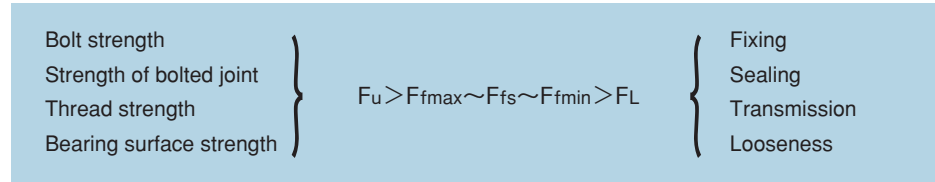
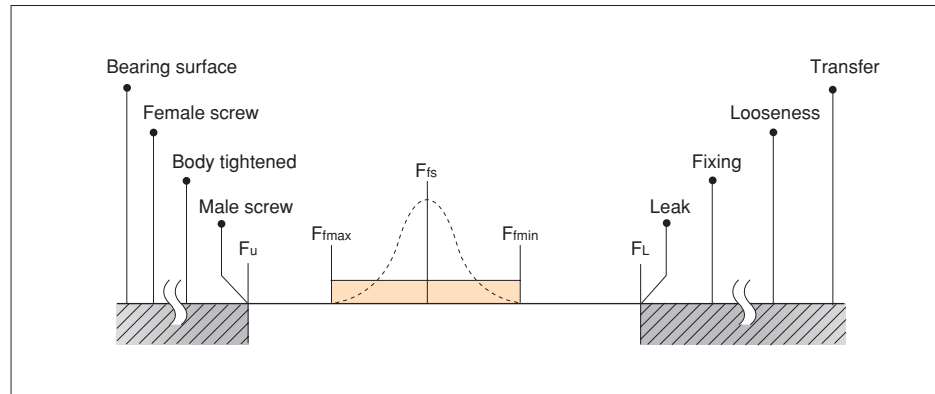
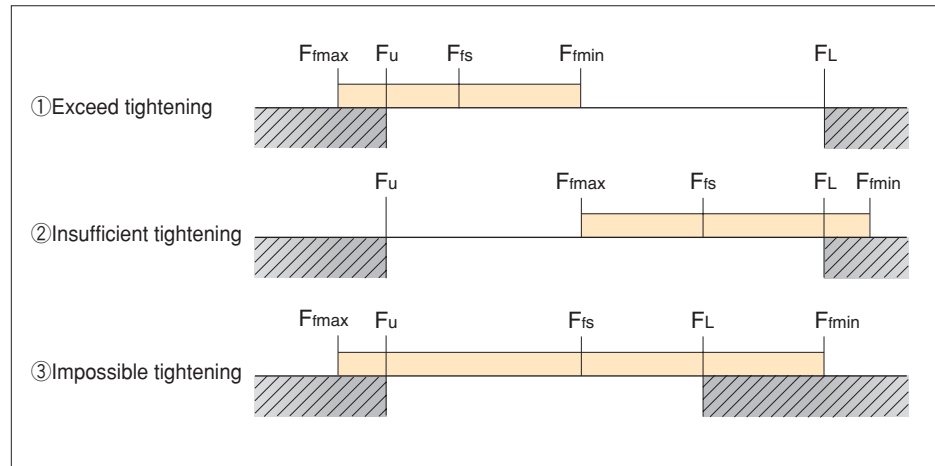


Figure 2-6 To apply appropriate bolt tension



(2) Various defective joint

Figure 2-7 Various defective joint

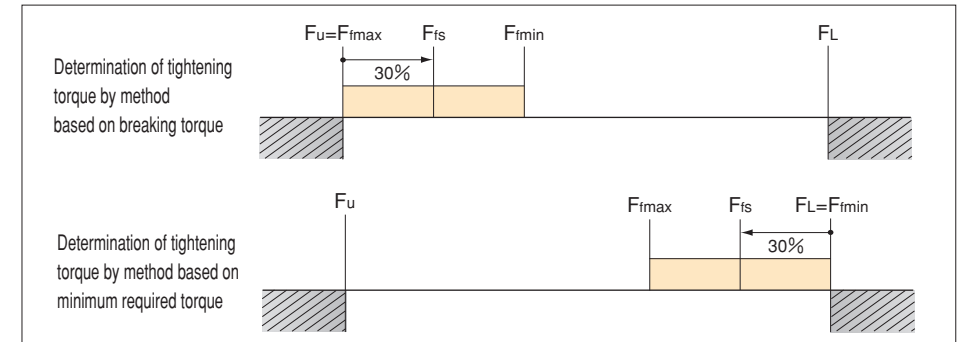


(3) Methods for determining tightening torque

Table 2-6 Methods for determining tightening torque

1 Standardization	To establish company standard of tightening torque. (See Figure 2-4)
2 Confirmation of the present tightening torque	To establish present tightening torque and confirm it.
3 Method based on breaking torque (Determination of lower limit)	To adopt 70% of the breaking torque as the tightening torque for screw joints. ($F_{max}=F_U$)
4 Method based on axial tension (Determination of lower limit)	To adopt 130% of the minimum required tightening torque, the level that prevent loosening, as the tightening torque. ($F_{min}=F_L$)
5 Method based on axial tension measurement	To specify the tightening torque as the optimal axial tension by measuring with an axial tension meter.

Figure 2-8 Methods for determining tightening torque



2-6 Tolerance of Tightening Torque

For threaded joints, sometimes more definite tightening control is necessary, and sometimes relatively rough control is enough just so that it will not loosen.

Table 2-7

Class	Tightening torque		Torque coefficient		Axial tension	
	Torque	Tolerance	Coefficient	Tolerance	Variation width	Upper lower limit (Ratio)
Special	Measured value	±5%	Measured value	±15%	±15%	0.75
					115~85%	
1st class	Standard torque (measured value)	±10%	Measured value	±20%	±20%	0.65
					120~80%	
2nd class	Standard torque (measured value)	±20%	0.14~0.26 (0.10~0.20)	±30%	±35%	0.50
					135~65%	
3rd class	Standard torque	±30%	0.12~0.28 (0.09~0.20)	±40%	±50%	0.35
					150~50%	

() Value is for using disulfide molybdenum, wax as lubrication.

2. Bolt Tightening

When you need strict bolt management, the following formulas express the relationships using the standard deviation of dispersion of tightening torque and the torque coefficient.

Dispersion in axial tension (σ_n), a torque coefficient (σ_k), and tightening torque (σ_t) relation

$$\sigma_n = \sqrt{\sigma_k^2 + \sigma_t^2}$$

In order to make σ_n smaller, it is necessary to make σ_k and σ_t smaller, respectively. Since it is easy to manage tightening torque, it will be set to $\sigma_k \approx \frac{1}{3} \sigma_t$ grade.

Example)

$$K = 0.2 \pm 0.06 (3\sigma)$$

$$\sigma_k = \frac{0.06}{3 \times 0.2} \times 100 (\%) = 10 (\%)$$

$$\sigma_t = 3\%$$

$$\sigma_n = \sqrt{10^2 + 3^2} = 10.4\%$$

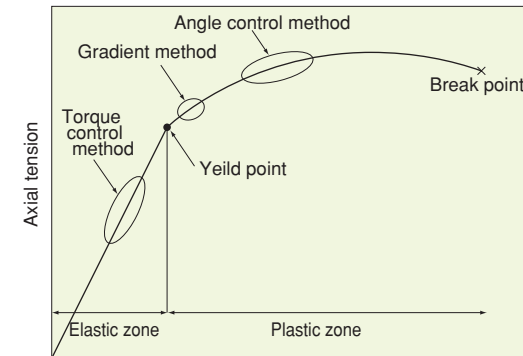
$$(3\sigma_n = 31.2\%)$$

2-7 Various Tightening Methods

Table 2-8 Various tightening methods

Tightening method	Description	Advantage and disadvantage
Torque control method	Bolt tightening is controlled by torque value. Widely used	Control and operation is easy in tightening. Since torque value does not change because of bolt length, standardization is easy. Dispersion band of axial tension is wide and bolt efficiency is low.
Angle control method	Bolt tightening is controlled by angle. The bolt is tightened to a defined angle from snug torque	When bolts are tightened within the plastic zone, dispersion of axial tension is small and operation is easy. Since it will be tightened over yield point, there is a limitation on the threaded joint with additive load or retightening, and it is difficult to define the tightening angle.
Gradient method	Bolt is tightened from proportional point until the yield point is reached. Electronic circuit makes arithmetic processing of angle, torque, etc	Since dispersion width of the axial tension is small, efficiency of bolted joint is large. Inspection of bolt itself is possible. Tightening will go over yield point. Tightening device is expensive. In the service field, the tightening method is not available.
Elongation measurement method	Bolt tightening is controlled by elongation of bolt, generated by bolt tightened. Elongation is measured by micrometer, ultrasonic or mandrel.	Dispersion of bolt is very small. Tightening within elastic zone is available. Efficiency of bolted joint is large. Additive loading and a second time tightening are possible. End face finish of bolt is required. Tightening cost is high.
Loading method	While defined tensile load is applied to bolt, tightening is controlled by the given load to the bolt.	Axial tension can directly be controlled. Torsion stress of bolt does not generate. Tightening device and bolts are special made. High cost.
Heating method	Bolt is heated to generate elongation. Tightening is controlled temperature.	Space and force are not required for tightening. There is no clear relation between heat and axial tension. Temperature setting control is difficult.

Figure 2-9 Tightening methods



2-8 Tightening of Tension Stability

Various tightening methods for stability of initial axial tension are invented. Following are some of examples.

(1) Zigzag tightening

It is recommended to tighten by diagonal sequence as the drawing.

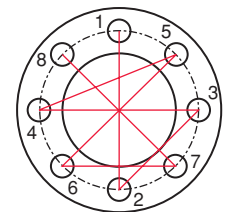
First time... To tighten around 50% of the specified torque by turn.

Second time... To tighten around 75% of the specified torque by turn.

Third time... To tighten 100% of specified torque by turn.

It is recommended to tighten all bolts equally, and to avoid applying torque on one or several bolts in one side.

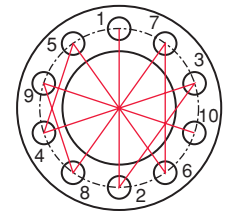
Zigzag tightening



(2) Two steps tightening

The tightening sequence will not follow, as this drawing if tightening will be done by multiple automatic nutrunners. Then in the first step it will be tightened provisionally. (50% of the tightening torque)

Next the final tightening will be done by 100% torque. The method to tighten on two steps.



(3) Two times tightening

There's a delay for axial tension transmission and adequate initial axial tension will not be obtained because there's an existing soft part such as packing or rubber in the flap tightened. This method is a kind of tightening to get initial axial tension. First it will be tightened with 100% torque and once more tightened with 100% torque.

(4) Stabilized tightening

This is a kind of tightening method to prevent initial axial tension drop by doing tightening with 100% torque, loosening the screw and doing tightening one more, when bearing surface will be deformed (including bur and surface roughness) by tightening.

2-9 Joint coefficient

When statistical characteristics of torque tools are discussed, just tightening torque is considered and rotation of screws is neglected. But when dynamic characteristics (overtorque measure of multiple units) are discussed, how the tightening torque will increase with rotation of screws should be considered. Generally speaking, it is called a "soft joint" or a "hard joint", but it is necessary to express quantitatively.

Joint coefficient (e) is identified and written as follows.

(1) Definition of joint coefficient (e)

The relation between tightening torque and rotation for a screw, joint is shown on Figure 2-10.

Joint coefficient (e) on $T=T_0$ for this joint is defined as

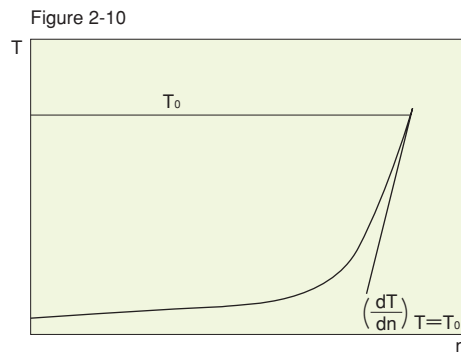
$$e = \frac{1}{T_0} \left(\frac{dT}{dn} \right)_{T=T_0} \quad \dots \text{formula (1)}$$

n : turns of rotation
 T_0 : Tightening torque

Use rotation angle (θ), and get formula (2).

$$e = \frac{360}{T_0} \left(\frac{dT}{d\theta} \right)_{T=T_0} \quad \dots \text{formula (2)}$$

θ : rotation angle of the screw (°)



(2) Meaning of joint coefficient

① To make it easier, relation of torque and rotation angle(θ) is shown by straight line in Figure 2-11.

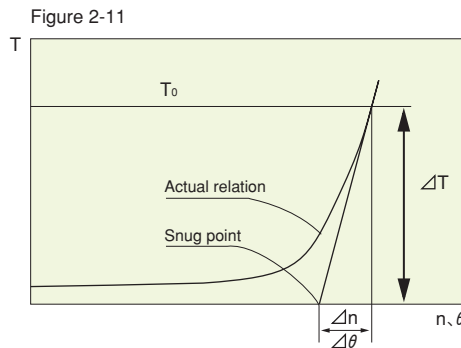
$$e = \frac{1}{T} \cdot \frac{\Delta T}{\Delta n} \quad \Delta T = T_0$$

$$e = \frac{1}{\Delta n} \quad \text{or} \quad e = \frac{360}{\Delta \theta}$$

$$\Delta n = \frac{1}{e} \quad \Delta \theta = \frac{360}{e}$$

That is $e=10$ means $\Delta n = \frac{1}{10}$ rotation or it is reached from snug torque to tightening torque by $\Delta \theta = 36^\circ$.

② As joint coefficient (e) is non-dimension figure, it is not changed by size of screw.



(3) How to get joint coefficient?

① Method by drawing

It is measured from actual screw joint for tightening rotation turn (angle).

(For this case original point of rotation - angle can be neglected.)

As shown Figure 2-12 plot on the drawing, and get Δn or $\Delta \theta$ from tangent on prescribed tightening torque T_0 . e is available from formula (3), (4).

$$e = \frac{1}{\Delta n} \quad \dots \text{formula (3)}$$

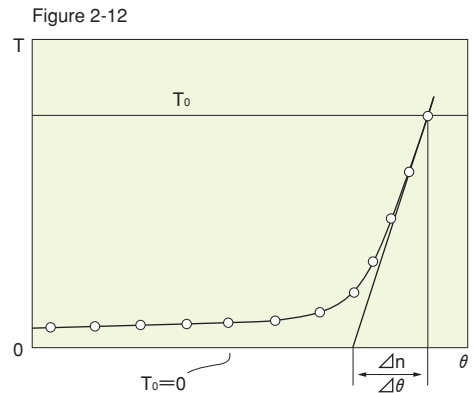
$$e = \frac{360}{\Delta \theta} \quad \dots \text{formula (4)}$$

② Simple method

(e) is available from rotation angle ($\Delta \theta'$) when tighten up to $0.8T_0$ and tighten up to T_0 once more.

$$e = \frac{72}{\Delta \theta'} \quad \dots \text{formula (5)}$$

$$e = \frac{360}{T_0} \cdot \frac{T_0 - 0.8T_0}{\Delta \theta'}$$



Sample of actual joint coefficient measurement. *By ② simple method above
Bolt: M8

Tightening torque (T_0): For 13.4 [N.m] $0.8T_0$ is 10.7 [N.m]

① Preparation

Put protractor on outside of measuring bolt (The protractor should have a hole as bolt will be center.)
Set the line to be needle on outside of the socket

② Measurement

Tighten up to $0.8T_0$ (10.7 [N.m]) first.
Next, set the protractor "0" to fit with the needle.
Tighten up to T_0 (13.4 [N.m]) and read the angle (7.2°).

③ Calculation

From simple method

$$e = \frac{72}{\Delta \theta} = \frac{72}{7.2} = 10$$

Medium joint is available from this formula.

