1. Torque

1-1 Torque

(1) Torque

Torque=Force×Length (T=F×L)

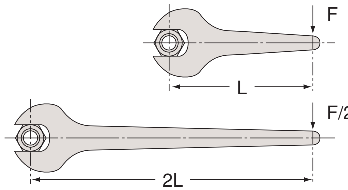
T=F×L

=2F×L/2

(If force will be double, half length will develop same torque)

=F/2×2L

(if force will be half, double length will develop same torque)



(2) Weight and mass

- Force unit … [N] (newton) SI unit
  A mass of 1kg is accelerated at 1m/s²
  [kgf] Metric unit (old JIS unit)
- Mass unit … [kg] (kilogram)
- Length unit … [m] (meter)

[N] (newton) is the new standard unit of "force". We used to call "mass" of the object as weight and used [kg] for "mass", [kgf] for "weight". We use both [kg], so the term of "mass" and "force" was used incorrectly for a long time. We say "mass" for a particular measure that will not change anywhere on the earth, even under non-gravity conditions. But "weight" is a force that is felt by addition of acceleration. So in a non gravity condition "we don't feel weight" or "no weight". On earth weight acceleration produced by the difference of latitude or height is different and "weight" will change.

For example if we compare weight of 1[kg] at sea level and at the top of a mountain, about 1[g] differences on mass unit will happen. Because top of a mountain is so high against sea level, centrifugal will be bigger by rotation of earth and gravity acceleration will be smaller.

MASS

WEIGHT (felt by hand)

Table 1-1 Acceleration of gravity

The name of the places	Latitude	Height above sea level [m]	Acceleration of gravity [m/s²]	Difference between international standard [%]
International standard			9.80665	0
Tohnichi (Tokyo Omori)	35°38'	15	9.79782	-0.090
Yamanashi (Kofu plant)	35°39'	138	9.79785	-0.090
Sapporo	43°04'	15	9.80596	-0.007
Naha	26°12'	25	9.79095	-0.160
Matsumoto	36°14'	611	9.79774	-0.091
Nagoya	35°09'	46	9.79705	-0.098
Osaka (Itami)	34°47'	15	9.79707	-0.098
Hiroshima	34°22'	1	9.79658	-0.103
Mexico City	19°20'	2269	9.77927	-0.279
Singapore	1°18'	8	9.78066	-0.265
Helsinki	60°10'	21	9.81901	+0.126

Your Torque Partner TOHNICHI

1-2 Torque Units

SI unit … [N·m]

1000 [mN·m] =100 [cN·m] =1 [N·m] =0.001 [kN·m]

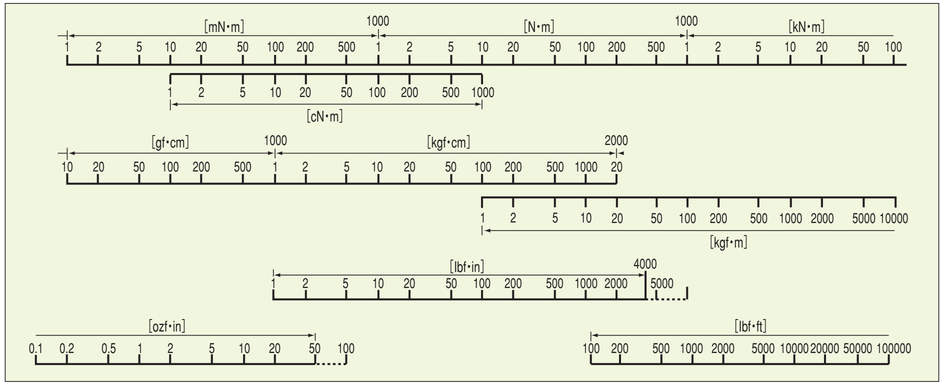
Gravity unit … [kgf·cm]

1000 [gf·cm] =1 [kgf·cm] =0.01 [kgf·m]

American unit … [lbf·in]

16 [ozf·in] =1 [lbf·in] =0.0833 [lbf·ft]

Figure 1-1 Main application range of torque unit



(1) Unit of torque and conversion value

Table 1-2 Unit of torque and conversion value

	S.I. unit system			Metric unit system			American unit system		
	[mN·m]	[cN·m]	[N·m]	[gf·cm]	[kgf·cm]	[kgf·m]	[ozf·in]	[lbf·in]	[lbf·ft]
1 [mN·m] =	1	0.1	0.001	10.2	0.0102	0.000102	0.142	0.00885	0.000738
1 [cN·m] =	10	1	0.01	102	0.102	0.00102	1.42	0.0885	0.00738
1 [N·m] =	1000	100	1	10200	10.2	0.102	142	8.85	0.738
1 [gf·cm] =	0.0981	0.00981	0.0000981	1	0.001	0.00001	0.0139	0.000868	0.0000723
1 [kgf·cm] =	98.1	9.81	0.0981	1000	1	0.01	13.9	0.868	0.0723
1 [kgf·m] =	9810	981	9.81	100000	100	1	1390	86.8	7.23
1 [ozf·in] =	7.06	0.706	0.00706	72.0	0.072	0.00072	1	0.0625	0.00521
1 [lbf·in] =	113	11.3	0.113	1150	1.15	0.0115	16	1	0.0833
1 [lbf·ft] =	1360	136	1.36	13800	13.8	0.138	192	12	1
Country	Japan, China, Europe			Asia			U.S.A., Aircraft industry		

1 [N·m] =10.1972 [kgf·cm] ≒10.20 [kgf.cm]
1 [kgf·cm] =0.0980665 [N·m] ≒0.0981 [N·m]

Example) T=25.0 [kgf·cm]
=25.0×0.0980665
=2.4516625 [N·m]
≒2.45 [N·m]

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

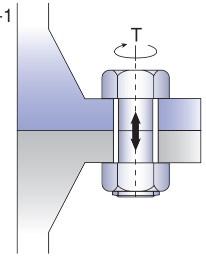
Why do we tighten screws?

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.

Figure 2-1



2-2 Torque and Screw

(1) Relation formula between screw and torque

Formula of screw ①

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

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

From Table 8-1 $d_2=7.188$ [mm]
$dn_1=11.27$ [mm] (1 class nut)
$\tan\beta=0.0554$

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

$$T=8000\left\{\frac{7.188}{2}\left(\frac{0.15}{\cos30^\circ}+0.0554\right)+0.15\left(\frac{11.27}{2}\right)\right\}\div1000$$

$=13.4$ [N･m]

Figure 2-2 Detail drawing

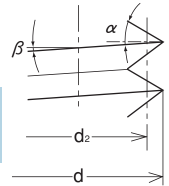
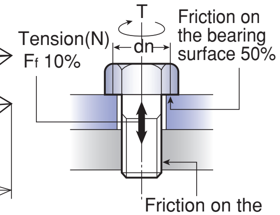


Figure 2-3 Relation drawing



- T : Torque .... [N･m]
- F_f : Axial tension .... [N]
- d_2 : Pitch diameter .... [mm] (See table 8-1)
- dn : Pitch diameter of bearing surface .... [mm] (See table 8-1)
- μ : Friction coefficient of threaded portion .... (See table 2-4)
- μn : Friction coefficient of bearing portion .... (See table 2-4)
- α : Half angle of screw thread .... (ISO screw 30°)
- β : Lead angle [degree] .... $\tan\beta$: (See Figure 2-2) (See table 8-1)

■Formula of pitch diameter of bearing surface (dn_1、dn)

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

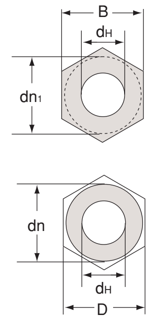
$$d_{n1}=\frac{0.608B^3-0.524d_H^3}{0.866B^2-0.785d_H^2}$$

B : Hexagon width across flats [mm]
d_H : Bearing surface inside diameter [mm]

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

$$d_n=\frac{2}{3}\cdot\frac{D^3-d_H^3}{D^2-d_H^2}$$

D : Hexagon width across flats [mm]
d_H : Bearing surface inside diameter [mm]



Formula of screw ②

$$T=K\cdot d\cdot F_f \quad \text{or} \quad F_f=\frac{T}{K\cdot d}$$

K : Torque coefficient (See table2-4)
d : Nominal size of screw [mm]

Example) Axial tension M20 screw to tighten T=400 [N.m]

d=20 [mm] K=0.2(See P28 table 2-4) $F_f=\dfrac{400}{0.2\times20\div1000}=100000$ [N]