

[Technical Data]

Proper Bolt Axial Tightening Force and Proper Tightening Torque

■ Axial tightening force for bolt and fatigue limit

- The proper axial tightening force for a bolt should be calculated within an elasticity range up to 70% of the rated yield strength when the torque method is used.
- The fatigue strength of a bolt under repeated load should not exceed the specified tolerance.
- Do not let the seat of a bolt or nut dent the contact area.
- Do not break the tightened piece by tightening.

A bolt is tightened by torque, torque inclination, rotational angle, stretch measurement and other methods. The torque method is widely used due to its simplicity and convenience.

■ Calculation of Axial Tightening Force and Tightening Torque

The relation between the axial tightening force and Ff is represented by Equation (1) below:

$$Ff = 0.7 \times \sigma_y \times A_s \dots (1)$$

Tightening Torque, TfA, can be calculated using the equation (2) below:

$$TfA = 0.35k(1 + 1/Q) \sigma_y \cdot A_s \cdot d \dots (2)$$

- k : Torque Coefficient
- d : Nominal Diameter of Bolt [cm]
- Q : Tightening Coefficient
- σ_y : Proof Stress (112kgf/mm² when the strength class is 12.9)
- A_s : Effective Sectional Area of the Bolt [mm²]

■ Calculations Example

Proper torque and axial force for soft steel pieces tightened together by means of a bolt with a hexagonal hole, M6 (strength bracket 12.9), with the pieces lubricated with oil can be calculated.

- Proper Torque, by using Equation (2):
- Axial Force, by using Equation (1):

$$TfA = 0.35k(1 + 1/Q) \sigma_y \cdot A_s \cdot d$$

$$= 0.35 \cdot 0.17(1 + 1/1.4) 112 \cdot 20.1 \cdot 0.6$$

$$= 138 [\text{kgf} \cdot \text{cm}]$$

$$Ff = 0.7 \times \sigma_y \times A_s$$

$$= 0.7 \times 112 \times 20.1$$

$$= 1576 [\text{kgf}]$$

■ Surface treatment for bolt and torque coefficient dependent on the combination of material for area to be fastened and material of female thread

Surface Treatment for Bolt Lubrication	Torque coefficient k	Combination of material for area to be fastened (a) and material for female thread (b)
Steel Bolt Black Oxidized Film Lubricated with oil	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 Oxidized Film Not Lubricated	0.25	S10C-FC SCM-FC FC-FC
	0.35	S10C-SCM SCM-SCM FC-S10C FC-SCM AL-FC
	0.45	S10C-S10C SCM-S10C AL-S10C AL-SCM
	0.55	SCM-AL FC-AL AL-AL

S10C : Soft steel not thermally refined SCM : Thermally Refined Steel (35HRC) FC : Cast Iron (FC200) AL : Aluminum SUS : Stainless Steel (SUS304)

■ Standard value of tightening coefficient Q

Tightening Coefficient Q	Tightening Method	Surface Condition		Lubrication
		Bolt	Nut	
1.25	Torque Wrench	Manganese Phosphate		
1.4	Torque Wrench	Not treated or treated with phosphate.	Not treated or treated with phosphate.	Lubricated with oil or MoS2 paste.
	Limited-Torque Wrench			
1.6	Impact Wrench			
1.8	Torque Wrench	Not treated or treated with phosphate.	Not Treated	Not Lubricated
	Limited-Torque Wrench			

Strength Code

ex. 12.9

- Proof Stress (Yield Stress) : 90% of the minimum value of tensile strength
- Min. Tensile Strength : 1220N/mm² {124kgf/mm²}

10.9

- Proof Stress (Yield Stress) : 90% of the minimum value of tensile strength
- Min. Tensile Strength : 1040N/mm² {106kgf/mm²}

■ Initial Tightening Force and Tightening Torque

Nominal of Thread	Effective Sectional Area A _s mm ²	Strength Code								
		12.9			10.9			8.8		
		Yield Load kgf	Initial Tightening Force kgf	Tightening Torque kgf · cm	Yield Load kgf	Initial Tightening Force kgf	Tightening Torque kgf · cm	Yield Load kgf	Initial Tightening Force kgf	Tightening Torque kgf · cm
M 3×0.5	5.03	563	394	17	482	338	15	328	230	10
M 4×0.7	8.78	983	688	40	842	589	34	573	401	23
M 5×0.8	14.2	1590	1113	81	1362	953	69	927	649	47
M 6×1	20.1	2251	1576	138	1928	1349	118	1313	919	80
M 8×1.25	36.6	4099	2869	334	3510	2457	286	2390	1673	195
M10×1.5	58	6496	4547	663	5562	3894	567	3787	2651	386
M12×1.75	84.3	9442	6609	1160	8084	5659	990	5505	3853	674
M14×2	115	12880	9016	1840	11029	7720	1580	7510	5257	1070
M16×2	157	17584	12039	2870	15056	10539	2460	10252	7176	1670
M18×2.5	192	21504	15053	3950	18413	12889	3380	12922	9045	2370
M20×2.5	245	27440	19208	5600	23496	16447	4790	16489	11542	3360
M22×2.5	303	33936	23755	7620	29058	20340	6520	20392	14274	4580
M24×3	353	39536	27675	9680	33853	23697	8290	23757	16630	5820

(Note) Tightening Conditions : Use of a torque wrench (lubricated with oil / Torque coefficient k = 0.17/ Tightening coefficient Q = 1.4)

- The torque coefficient varies with the usage conditions. Values in this table should be used as rough referential values.
- The table is an excerpt from a catalog of Kyokuto Seisakusho Co., Ltd.

[Technical Data]

Strength of Bolts, Screw Plugs and Dowel Pins

■ Strength of Bolt

1) Tensile Load Bolt

$$Pt = \sigma_t \times A_s \dots (1)$$

$$= \pi d^2 \sigma_t / 4 \dots (2)$$

P_t : Tensile Load in the Axial Direction [kgf]
 σ_b : Yield Stress of the Bolt [kgf/mm²]
 σ_t : Allowable Stress of the Bolt [kgf/mm²]
 ($\sigma_t = \sigma_b / \text{safety factor } \alpha$)
 A_s : Effective Sectional Area of the Bolt [mm²]
 $A_s = \pi d^2 / 4$
 d : Effective Dia. of the Bolt (Core Dia.) [mm]

(Ex.) The proper size of a bolt with a hexagonal hole, which is to bear a repeated tensile load (pulsating) at P = 200 kgf, should be determined. (Bolt with a hexagonal hole, made of SCM435, 38 to 43 HRC, strength code 12.9)

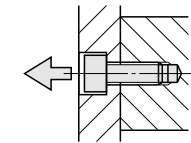
Using Equation (1)

$$A_s = Pt / \sigma_t$$

$$= 200 / 22.4$$

$$= 8.9 [\text{mm}^2]$$

∴ A larger effective sectional area should be found in the table at the right, and M5, 14.2 [mm²], should be selected. M6, tolerable load of 213 kgf, should be selected from the column for strength code 12.9, with the fatigue strength taken into account.



2) If the bolt, like a stripper bolt, is to bear a tensile impact load, the right size should be selected from the fatigue strength column. (Under a load of 200 kgf, Stripper bolt made of SCM435, 33 to 38 HRC, strength code 10.9)

If the tolerable load is 200 kgf or more, strength code 10.9, M8, 318 [kgf], should be selected from the table at the right. Hence, MSB10 with the M8 threaded portion and an axial diameter of 10 mm should be selected. If it is to bear a shearing load, a knock pin should also be used.

■ Strength of Screw Plug

Allowable Load P when screw plug MSW30 is to bear an impact load should be determined.

(MSW30 made of S45C, Tensile force σ_b , 34 to 43 HRC : 65 kgf/mm².)

If MWS is shown at a spot within the minor diameter section and is broken, allowable load P can be calculated as shown below.

$$\text{Allowable Load } P = \tau \times A$$

$$= 3.9 \times 107.4$$

$$= 4190 [\text{kgf}]$$

Find the allowable shearing force base on the core diameter of internal thread if tapping is made of soft material.

$$\text{Area } A = \text{Core Diameter } d_1 \times \pi \times L$$

(Core Diameter $d_1 = M - P$)

$$A = (M - P) \pi L = (30 - 1.5) \pi \times 12$$

$$= 1074 [\text{mm}^2]$$

$$\text{Yield Stress } \approx 0.9 \times \text{Tensile Strength } \sigma_b = 0.9 \times 65 = 58.2$$

$$\text{Shearing Stress } \approx 0.8 \times \text{Yield Stress}$$

$$= 46.6$$

$$\text{Allowable Shearing Stress } \tau = \text{Shearing Stress} / \text{Safety Factor } 12$$

$$= 46.6 / 12 = 3.9 [\text{kgf} / \text{mm}^2]$$

■ Strength of Dowel Pin

The proper size of a dowel pin under repeated shearing load of 800 kgf (one-way swing) should be determined. (Knock pin made of SUJ2, 58HRC or greater.)

$$P = A \times \tau$$

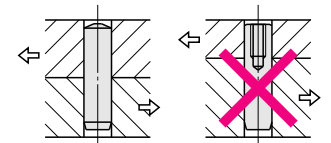
$$= \pi D^2 \tau / 4$$

$$D = \sqrt{(4P) / (\pi \tau)}$$

$$= \sqrt{(4 \times 800) / (3.14 \times 19.2)}$$

$$\approx 7.3$$

Yield Stress for SUJ2 $\sigma_b = 120 [\text{kgf} / \text{mm}^2]$
 Allowable Shearing Strength $\tau = \sigma_b \times 0.8 / \text{Safety Factor } \alpha$
 $= 120 \times 0.8 / 5$
 $= 19.2 [\text{kgf} / \text{mm}^2]$



The dowel pin must not be loaded.

Typical strength calculations are presented here. In a real-life situation, it will be necessary to take into account hole-to-hole pitch accuracy, hole perpendicularity, surface coarseness, true-circle accuracy, plate material, parallelism, quenching or non-quenching, accuracy of the press, product output, wear of tools, etc. Hence the values in these examples are referential (but not guaranteed) values.

■ Safety factor of Unwin based on tensile strength α

Material	Static Load	Repeated Load		Impact Load
		Pulsating	Reversed	
Steel	3	5	8	12
Cast Iron	4	6	10	15
Copper, Soft Metal	5	5	9	15

Stress = Reference Strength / Safety α Reference Strength : Yield Stress for Ductile Material / Stress for Fragile Material

The Yield Stress, Strength Code 12.9, is $\sigma_b = 112 [\text{kgf} / \text{mm}^2]$
 Allowable Stress $\sigma_t = \sigma_b / \text{Safety Factor } (5 \text{ in the above table})$
 $= 112 / 5$
 $= 22.4 [\text{kgf} / \text{mm}^2]$

■ Fatigue Strength of Bolt (Thread: Fatigue strength 2 million times)

Nominal of Thread	Effective Sectional Area A _s mm ²	Strength Code			
		12.9		10.9	
		Fatigue Strength* kgf/mm ²	Allowable Load kgf	Fatigue Strength* kgf/mm ²	Allowable Load kgf
M 4	8.78	13.1	114	9.1	79
M 5	14.2	11.3	160	7.8	111
M 6	20.1	10.6	213	7.4	149
M 8	36.6	8.9	326	8.7	318
M10	58	7.4	429	7.3	423
M12	84.3	6.7	565	6.5	548
M14	115	6.1	702	6	690
M16	157	5.8	911	5.7	895
M20	245	5.2	1274	5.1	1250
M24	353	4.7	1659	4.7	1659

Fatigue strength* is a revision of an excerpt from "Estimated Fatigue Limits of Machine Screws, Bolts and Metric Screws for Nuts" (Yamamoto).

