[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 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, rotating 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:

$Ff=0.7\times\sigma y\times As$……(1)

Tightening torque TfA can be obtained by using the following formula (2).

$T_{fA}=0.35k(1+1/Q)\sigma y\cdot As\cdot d$……(2)

k : Torque Coefficient
d : Nominal Diameter of Bolt[cm]
Q : Tightening Coefficient
σy : Tensile strength (When the strength class is 12.9, it is 112kgf/mm^2)
As : Effective Sectional Area of the Bolt [mm^2]

■Calculation Example

Proper torque and axial force for Mild steel pieces tightened together by means of a hexagon socket head cap screw, M6 (strength class 12.9), with the pieces lubricated with oil, can be calculated as follows.

- Proper Torque, by using Equation(2)

$T_{fA}=0.35k\ (1+1/Q)\ \sigma y\cdot As\cdot d$
$=0.35\times0.17\ (1+1/1.4)\ 1098\times20.1\times0.6$
$=1351$[N · cm] {138[kgf · cm]}

- Axial Force Ff, by using Equation(1)

$Ff=0.7\times\sigma y\times As$
$=0.7\times1098\times20.1$
$=15449$[N] {1576[kgf]}

■Surface Treatment for Bolt and Torque Coefficient Dependent on the Combination of Material for Area to be Fastened and Material of Female Thread

Bolt Surface Treatment Lubrication	Torque Coefficient k	Combination of material for area to be fastened and material for female thread (a) (b)
Steel Bolt Black Oxided Film Oil Lubrication	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 Oxided Film Unlubricated	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: Mild steel not thermally refined SCM:Thermally Refined Steel(35HRC) FC:Cast Iron(FC200)AL:Aluminum SUS:Stainless Steel

■Standard Value of Tightening Coefficient Q

Tightening Coefficient Q	Tightening Method	Surface Condition: Bolts	Surface Condition: Nuts	Lubrication
1.25	Torque Wrench	Manganese Phosphate	Not treated or Treated with Phosphate.	Lubricated with oil or MoS2 paste
1.4	Torque Wrench	Not treated or Treated with Phosphate.		
	Limited-Torque Wrench			
1.6	Impact Wrench			
1.8	Torque Wrench	Not treated or Treated with Phosphate.	No Treatment	Unlubricated
	Limited-Torque Wrench			

Strength Class
Ex. 12.9
- Tensile Strength (Yield Stress): 90% of the minimum value of tensile strength
- The minimum value of tensile strength is 1220N/mm^2 { 124kgf/mm^2 }

10.9
- Tensile Strength (Yield Stress): 90% of the minimum value of tensile strength
- The minimum value of tensile strength is 1040N/mm^2 { 106kgf/mm^2 }

■Initial Tightening Force and Tightening Torque

Nominal of Thread	Effective Sectional Area As mm^2	12.9 Yield Load N {kgf}	12.9 Initial Tightening Force N {kgf}	12.9 Tightening Torque N · cm {kgf · cm}	10.9 Yield Load N {kgf}	10.9 Initial Tightening Force N {kgf}	10.9 Tightening Torque N · cm {kgf · cm}	8.8 Yield Load N {kgf}	8.8 Initial Tightening Force N {kgf}	8.8 Tightening Torque N · cm {kgf · cm}
M 3×0.5	5.03	5517{ 563}	3861{ 394}	167{ 17}	4724{ 482}	3312{ 338}	147{ 15}	3214{ 328}	2254{ 230}	98{ 10}
M 4×0.7	8.78	9633{ 983}	6742{ 688}	392{ 40}	8252{ 842}	5772{ 589}	333{ 34}	5615{ 573}	3930{ 401}	225{ 23}
M 5×0.8	14.2	15582{ 1590}	10907{ 1113}	794{ 81}	13348{ 1362}	9339{ 953}	676{ 69}	9085{ 927}	6360{ 649}	461{ 47}
M 6×1	20.1	22060{ 2251}	15445{ 1576}	1352{ 138}	18894{ 1928}	13220{ 1349}	1156{ 118}	12867{ 1313}	9006{ 919}	784{ 80}
M 8×1.25	36.6	40170{ 4099}	28116{ 2869}	3273{ 334}	34398{ 3510}	24079{ 2457}	2803{ 286}	23422{ 2390}	16395{ 1673}	1911{ 195}
M10×1.5	58	63661{ 6496}	44561{ 4547}	6497{ 663}	54508{ 5562}	38161{ 3894}	5557{ 567}	37113{ 3787}	25980{ 2651}	3783{ 386}
M12×1.75	84.3	92532{ 9442}	64768{ 6609}	11368{ 1160}	79223{ 8084}	55458{ 5659}	9702{ 990}	53949{ 5505}	37759{ 3853}	6605{ 674}
M14×2	115	126224{ 12880}	88357{ 9016}	18032{ 1840}	108084{ 11029}	75656{ 7720}	15484{ 1580}	73598{ 7510}	51519{ 5257}	10486{ 1070}
M16×2	157	172323{ 17584}	117982{ 12039}	28126{ 2870}	147549{ 15056}	103282{ 10539}	24108{ 2460}	100470{ 10252}	70325{ 7176}	16366{ 1670}
M18×2.5	192	210739{ 21504}	147519{ 15053}	38710{ 3950}	180447{ 18413}	126312{ 12889}	33124{ 3380}	126636{ 12922}	88641{ 9045}	23226{ 2370}
M20×2.5	245	268912{ 27440}	188238{ 19208}	54880{ 5600}	230261{ 23496}	161181{ 16447}	46942{ 4790}	161592{ 16489}	113112{ 11542}	32928{ 3360}
M22×2.5	303	332573{ 33936}	232799{ 23755}	74676{ 7620}	284768{ 29058}	199332{ 20340}	63896{ 6520}	199842{ 20392}	139885{ 14274}	44884{ 4580}
M24×3	353	387453{ 39536}	271215{ 27675}	94864{ 9680}	331759{ 33853}	232231{ 23697}	81242{ 8290}	232819{ 23757}	162974{ 16630}	57036{ 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 conditions of use. 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

$P=\sigma t\times As$ ·······(1)
$=\pi d^2\sigma t/4$ ·····(2)

Pt : Tensile Load in the Axial Direction [N]
σb : Yield Stress of the Bolt [N/mm^2]
σt : Allowable Stress of the Bolt [N/mm^2] ($\sigma t=\sigma b$/Safety Factorα)
As : Effective Sectional Area of the Bolt [mm^2] $As=\pi d^2/4$
d : Effective Dia. of the Bolt (Core Dia.) [mm]

■Safety Factor α of Unwin Based on Tensile Strength

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

Reference Strength: Yield Stress for Ductile Material
Fracture Stress for Fragile Material

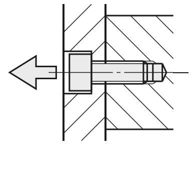
$$\text{Allowable Stress}=\frac{\text{Reference Strength}}{\text{Safety Factor}\alpha}$$

(Ex.)The proper size of a hexagon socket head cap screws, which is to bear a repeated tensile load (pulsating) at P=1960N {200 kgf} , should be determined. (The hexagon socket head cap screws are SCM435, 38 to 43 HRC, strength class 12.9)

(1) Using Equation

$As=Pt/\sigma t$
$=1960/219.6$
$=8.9$ [mm^2]

∴By finding a value greater than the result of the equation in the Effective Sectional Area column in the table on the right, M5, 14.2 [mm^2], should be selected.



M6, allowable load of 2087N {213 kgf} , should be selected from the column for strength class 12.9, if the fatigue strength is considered.

The yield stress, strength class 12.9, is $\sigma b=1098$[N/mm^2] {112[kgf/mm^2]}.
Allowable Stress $\sigma t=\sigma b$/Safety Factor(from the above table Safety Factor 5)
$=1098/5$
$=219.6$[N/mm^2] {22.4[kgf/mm^2]}

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 1960N {200kgf}, stripper bolt made of SCM435, 33 to 38 HRC, strength class 10.9)
By finding a value greater than the allowable load of 1960N {200 kgf} in the Strength Class 10.9 column in the table on right, M8, 3116[N] {318[kgf]} , should be selected. 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 dowel pin should also be used.

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

Nominal of Thread	Effective Sectional Area As mm^2	12.9 Fatigue Strength† N/mm^2 [kgf/mm^2]	12.9 Allowable Load N {kgf}	10.9 Fatigue Strength† N/mm^2 [kgf/mm^2]	10.9 Allowable Load N {kgf}
M 4	8.78	128{ 13.1}	1117{ 114}	89{ 9.1}	774{ 79}
M 5	14.2	111{ 11.3}	1568{ 160}	76{ 7.8}	1088{ 111}
M 6	20.1	104{ 10.6}	2087{ 213}	73{ 7.4}	1460{ 149}
M 8	36.6	87{ 8.9}	3195{ 326}	85{ 8.7}	3116{ 318}
M10	58	73{ 7.4}	4204{ 429}	72{ 7.3}	4145{ 423}
M12	84.3	66{ 6.7}	5537{ 565}	64{ 6.5}	5370{ 548}
M14	115	60{ 6.1}	6880{ 702}	59{ 6}	6762{ 690}
M16	157	57{ 5.8}	8928{ 911}	56{ 5.7}	8771{ 895}
M20	245	51{ 5.2}	12485{ 1274}	50{ 5.1}	12250{ 1250}
M24	353	46{ 4.7}	16258{ 1659}	46{ 4.7}	16258{ 1659}

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

■Strength of Screw Plug

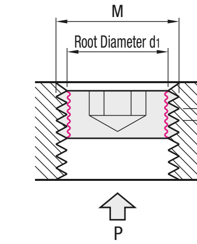
When screw plug MSW30 is to bear an impact load, allowable load P should be determined.
(The materials of MSW30 are S45C, 34 to 43 HRC, tensile strength σt 637N/mm^2 {65kgf/mm^2.})

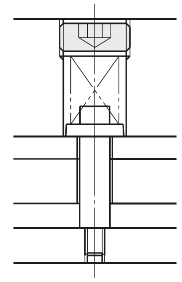
If M S W is shorn at a spot within the root diameter section and is broken, allowable load P can be calculated as shown below.

Allowable Load $P=\tau t\times A$
$=3.9\times107.4$
$=40812$[N] {4164[kgf]}

Find the allowable shearing force base on the core diameter of female thread if a tap is made of soft material.

Area A=Root Diameter $d_1\times\pi\times L$
(Root Diameter $d_1\approx M-P$)
$A=(M-P)\pi L=(30-1.5)\pi\times12$
$=1074$ [mm^2]
Yield Stress≈0.9×Tensile Strength $\sigma b=0.9\times637=573$[N/$mm^2$]
Shearing Stress≈0.8×Yield Stress
$=459$ [N/mm^2]
Allowable Shearing Stress τt=Shearing Stress/Safety Factor 12
$=459/12=38$ [N/mm^2] {3.9 [kgf/mm^2]}





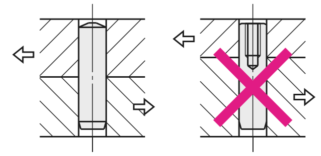
■Strength of Dowel Pins

The proper size of a dowel pin under repeated shearing load of 7840N {800 kgf} (Pulsating) should be determined as follows. (The material of Dowel Pins is SUJ2. Hardness 58HRC~)

$P=A\times\tau$
$=\pi D^2\tau/4$
$D=\sqrt{(4P)/(\pi\tau)}$
$=\sqrt{(4\times7840)/(3.14\times188)}$
≈7.3

∴D8 or a larger size should be selected for MS.
If the dowel pins are of a roughly uniform size, the number of the necessary tools and extra pins can be reduced.

Yield Stress for SUJ2 $\sigma b=1176$ [N/mm^2] {120 [kgf/mm^2]}
Allowable Shearing Strength $\tau=\sigma b\times0.8$/Safety Factor α
$=1176\times0.8/5$
$=188$ [N/mm^2] {19.2 [kgf/mm^2]}



The dowel pin must not be loaded.

Typical strength calculations are presented here. In practice, further conditions including hole-to-hole pitch precision, hole perpendicularity, surface roughness, circularity, plate material, parallelism, quenching or non-quenching, precision of the press, product output, wear of tools should be considered. Hence the values in these examples are typical but not guaranteed values.