〔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
σ_y : Tensile stress ($112 kgf/mm^2$ when the strength class is 12.9)
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.

- Proper Torque, by using Equation (2)
  $T_{fA} = 0.35k(1 + 1/Q)\, \sigma_y . As . d$
  $= 0.35 . 0.17 (1 + 1/1.4)\, 112 . 20.1 . 0.6$
  $= 138$ [kgf・cm]
- Axial Force Ff, by using Equation (1)
  $Ff = 0.7 \times \sigma_y \times As$
  $0.7 \times 112 \times 20.1$
  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
- .9 — Tensile Strength (Yield Stress) : 90% of the minimum value of tensile strength
- 12 — The minimum value of tensile strength is $1220 N/mm^2$ {$124 kgf/mm^2$}

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

■Initial Tightening Force and Tightening Torque

Nominal of Thread	Effective Sectional Area As mm^2	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
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 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

$Pt = \sigma_t \times As$ …… (1)
$= \pi d^2 \sigma_t / 4$ … (2)

Pt : Tensile Load in the Axial Direction [kgf]
σ_b : Yield Stress of the Bolt [kgf/mm^2]
σ_t : Allowable Stress of the Bolt [kgf/mm^2]
($\sigma_t = \sigma_b$ / Safety Factor α)
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

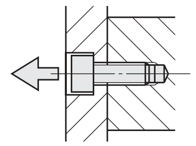
Allowable Stress = Reference Strength / Safety Factor α

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

(Ex.) The proper size of a hexagon socket head cap screws, which is to bear a repeated tensile load (pulsating) at P=200 kgf, should be determined. (The hexagon socket head cap screws are 4137 Alloy Steel, 38 to 43 HRC, strength class 12.9)

(1) Using Equation

$As = Pt / \sigma_t$
$= 200 / 22.4$
$= 8.9$ [mm^2]



The yield stress, strength class 12.9, is $\sigma_b = 112$ [kgf/mm^2].
Allowable Stress $\sigma_t = \sigma_b$ / Safety Factor (from the above table Safety Factor 5)
$= 112 / 5$
$= 22.4$ [kgf/mm^2]

∴ By finding a value greater than the result of the equation in the Effective Sectional Area column in the table on right, M5, 14.2 [mm^2], should be selected.
M6, allowable load of 213 kgf, should be selected from the column for strength class 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 200kgf, stripper bolt made of 4137 Alloy Steel, 33 to 38 HRC, strength class 10.9)

By finding a value greater than the allowable load of 200 kgf in the Strength Class 10.9 column in the table on right, M8, 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* kgf/mm^2	12.9 Allowable Load kgf	10.9 Fatigue Strength* kgf/mm^2	10.9 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 Small Screws, Bolts and Metric Screws for Nuts」 (Yamamoto).

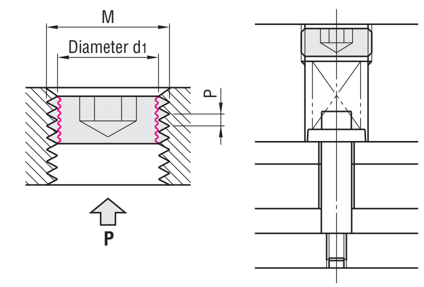
■Strength of Screw Plug

When screw plug MSW30 is to bear an impact load, allowable load P should be determined.
(The materials of MSW30 are 1045 Carbon Steel, 34 to 43 HRC, tensile strength σ_b $65 kgf/mm^2$.)

If M S W is shorn at a spot within the minor diameter section and is broken, allowable load P can be calculated as shown below. $P = \tau_t \times A$
$= 3.9 \times 107.4$
$= 4190$ [kgf]

Area A = Diameter $d1 \times \pi \times L$
(Diameter $d_1 \fallingdotseq M - P$)
$A = (M - P)\, \pi L = (30 - 1.5)\, \pi \times 12$
$= 1074$ [mm^2]
Yield Stress $\fallingdotseq 0.9 \times$ Tensile Strength $\sigma_b = 0.9 \times 65 = 58.2$
Shearing Stress $\fallingdotseq 0.8 \times$ Yield Stress
$= 46.6$
Allowable Shearing Stress τ_t = Shearing Stress/Safety Factor12
$= 46.6/12 = 3.9$ [kgf/mm^2]

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



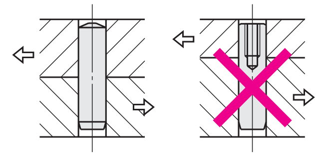
■Strength of Dowel Pins

The proper size of a dowel pin under repeated shearing load of 800 kgf (Pulsating) should be determined. (The material of Dowel Pins is 52100 Bearing Steel. Hardness 58HRC〜)

$P = A \times \tau$
$= \pi D^2 \tau / 4$
$D = \sqrt{(4P) / (\pi\tau)}$
$= \sqrt{(4 \times 800) / (3.14 \times 19.2)}$
$\fallingdotseq 7.3$

Yield Stress for 52100 Bearing Steel σ_b $= 120$ [kgf/mm^2]
Allowable Shearing Strength $\tau = \sigma_b \times 0.8$ / Safety Factor α
$= 120 \times 0.8/5$
$= 19.2$ [kgf/mm^2]

∴ 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.



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. (Not guaranteed values)