# STRENGTH OF BOLTS, SCREW PLUGS AND DOWEL PINS

## ■Strength of bolts

1) When tensile load is applied to the bolt

Pt＝σt×As……… (1)

＝πd²σt／4…… (2)

Pt：Tensile load in the axial direction [kgf]
σb：Yield stress of bolt [kgf/mm²]
σt：Allowable stress of bolt [kgf/mm²]
(σt＝σb/safety factor α)
As：Effective sectional area of bolt [mm²]
As＝πd²/4
d：Effectiveness of bolt (core diameter) [mm]

■Safety factor α of Unwin based on tensile strength

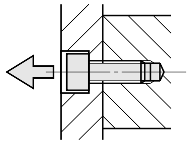
| Material | Static load | Repeated load | | Impact load |
|---|---|---|---|---|
| | | Pulsating | Reversed | |
| Steel | 3 | 5 | 8 | 12 |
| Cast iron | 4 | 6 | 10 | 15 |
| Copper, soft metal | 5 | 5 | 9 | 15 |

Allowable stress＝Reference strength / Safety factor α　Reference strength：Yield stress for ductile materials
Fracture stress for brittle materials

(Example) Find a suitable size when a socket head cap screw receives tensile load of P＝200kgf repeatedly (pulsating).
(Socket head cap screw material：SCM435, 38～43HRC, strength class：12.9)

From equation (1)

As＝Pt／σt
＝200／22.4
＝8.9 [mm²]



∴ Find an effective sectional area greater than this value from the table at the right.
M4 of 14.2 [mm²] will be the selection.
If fatigue strength is taken into account, M6 of allowable load 213kgf in 12.9 should be selected.

Yield stress in strength class 12.9 is σb=112 [kgf/mm²].
Allowable stress σt＝σb/safety factor (safety factor is 5 from the above table)
＝112／5
＝22.4 [kgf／mm²]

2) Selection must be based on fatigue strength for the bolts such as the stripper bolt which receives impact load from tension. (As the above example, 200kgf load is applied. Stripper bolt material：SCM435, 33～38HRC, strength class 10.9)

From the table at the right, M8 of 318 [kgf] is found when allowable load of strength class 10.9 is over 200kgf. Accordingly, MSB10 having M8 screw and axial diameter of 10mm is the selection. Use dowel pins when shearing load is applied.

■Fatigue strength of bolts (In case of screws：Fatigue strength is 2 million times)

| Nominal diameter of thread | Effective sectional area As mm² | Strength rank 12.9 Fatigue strength* kgf／mm² | 12.9 Allowable load kgf | 10.9 Fatigue strength* kgf／mm² | 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 corrected excerpt from "Estimated values of fatigue limit of metric screw threads for machine screws, bolts and nuts" (Yamamoto).

## ■Strength of screw plugs

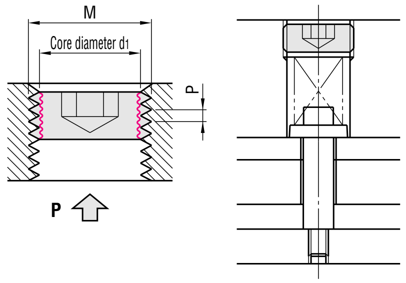
Find allowable load P when screw plug MSW30 receives impact load.
(MSW30 material：S45C, tensile strength σb for 34～43HRC is 65kgf／mm².)

If MSW breaks by shearing force applied to the core diameter part, allowable load

P＝τt×A.
＝3.9×107.4
＝4190 [kgf]

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

Shearing sectional area A＝Core diameter d1×π×L
(Core diameter d1≒M−P)
A＝(M−P)πL＝(30−1.5)π×12
＝1074 [mm²]
Yield stress≒0.9×Tensile strength σb＝0.9×65＝58.2
Shearing stress≒0.8×Yield stress
＝46.6
Allowable shearing stress πt＝Shearing stress/safety factor 12
＝46.6／12＝3.9 [kgf／mm²]



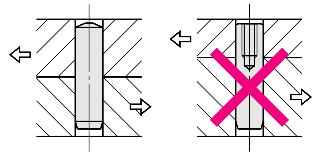

## ■Strength of dowel pins

Find a suitable size when a dowel pin receives 800kgf repetitive (pulsating) shearing load. (Dowel pin material：SUJ2・Hardness 58HRC or more)

P＝A×τ
＝πD²τ／4
D＝√((4P)／(πτ))
＝√((4×800)／(3.14×19.2))
≒7.3

σb for yield stress of SUJ2＝120 [kgf／mm²]
Allowable shearing strength τ＝σb×0.8／safety factor α
＝120×0.8／5
＝19.2 [kgf／mm²]

∴ For MS dowel pin, select D8 or larger size.
When larger size dowel pins are used, tools and stocks can be reduced.



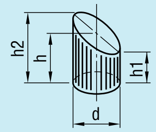
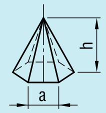
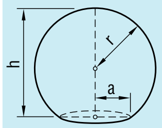
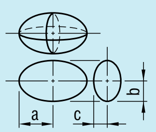
Avoid using the dowel pins in such a way as load is applied to the screw part.

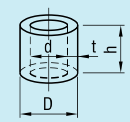
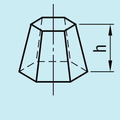
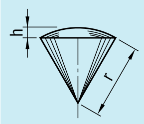
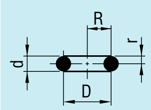
The calculations shown above are only examples of finding strength. For actual calculation, various conditions, such as accuracy of inter-hole pitch, perpendicularity of holes, surface roughness, circularity, plate materials, parallelism, quenching, precision of press machine, quantity of production, and wear of tools, should be taken into account. Use these examples as a reference for calculating strength. (They are not guaranteed values.)

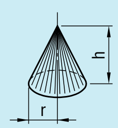
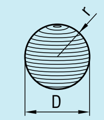
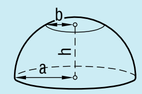
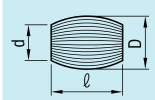




# CALCULATION OF CUBIC VOLUME

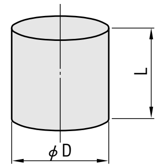
| Solid | Volume V |
|---|---|
| Truncated cylinder  | $V=\frac{\pi}{4}d^2h$ $=\frac{\pi}{4}d^2\left(\frac{h_1+h_2}{2}\right)$ |
| Pyramid  | $V=\frac{h}{3}A=\frac{h}{6}arn$ A＝Area of base; r＝Radius of inscribed circle; a＝Length of a side of a regular polygon; n＝Number of the sides of a regular polygon |
| Spherical crown  | $V=\frac{\pi h^2}{3}(3r-h)$ $=\frac{\pi h}{6}(3a^2+h^2)$ a is the radius. |
| Ellipsoid  | $V=\frac{4}{3}\pi abc$ In case of a spheroid (b＝c) $V=\frac{4}{3}\pi ab^2$ |

| Solid | Volume V |
|---|---|
| Hollow cylinder  | $V=\frac{\pi}{4}h(D^2-d^2)$ $=\pi th(D-t)$ $=\pi th(d+t)$ |
| Truncated pyramid  | $V=\frac{h}{3}(A+a+\sqrt{Aa})$ A,a＝Area of both ends |
| Spherical segment  | $V=\frac{2}{3}\pi r^2h$ $=2.0944r^2h$ |
| Torus  | $V=2\pi^2Rr^2$ $=19.739Rr^2$ $=\frac{\pi^2}{4}Dd^2$ $=2.4674Dd^2$ |

| Solid | Volume V |
|---|---|
| Circular cone  | $V=\frac{\pi}{3}r^2h$ $=1.0472r^2h$ |
| Sphere  | $V=\frac{4}{3}\pi r^3=4.1888r^3$ $=\frac{\pi}{6}d^3=0.5236d^3$ |
| Spherical belt  | $V=\frac{\pi h}{6}(3a^2+3b^2+h^2)$ |
| Barrel  | When circumference makes a curve equal to the circular arc, $V=\frac{\pi\ell}{12}(2D^2+d^2)$ When its periphery makes a curve equal to a parabolic line, $V=0.209\ell(2D^2Dd+1/4d^2)$ |

## ■How to calculate the weight

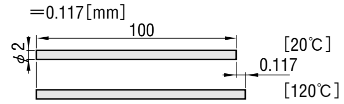
Weight [g]＝Volume [cm³]×Density



Example：Soft steel
φD＝16　L＝50mm, the weight is：
$W=\frac{\pi}{4}D^2\times L\times Density$
$=\frac{\pi}{4}\times1.6^2\times5\times7.85$
≒79 [g]

## ■Method for finding changes dimensions due to thermal expansion

Example：SKD11
φD＝2　The volume of dimension change δ
when a pin of L＝100mm is heated to 2℃ is
δ＝Coefficient of thermal expansion×Total length×Change in temperature
＝11.7×10−⁶×100mm×100℃
＝0.117 [mm]

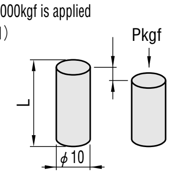



## ■Finding strain with Young's modulus E

〔Example〕 Find amount of strain when load P＝1000kgf is applied to φ10×L60 pin. (Material：SKD11)

$E=\frac{PL}{A}$
$=\frac{PL}{AE}=\frac{1000\times60}{78.5\times21000}$
≒0.036mm

Sectional area $A=\frac{\pi}{4}D^2$




## ■Characteristics of Metals

| Material | Density [g/cm³] | Young's modulusE [Kgf/mm²] | Thermal expansion coefficient [×10⁻⁶/℃] |
|---|---|---|---|
| Soft steel | 7.85 | 21000 | 11.7 |
| SKD11 | 7.85 | 21000 | 11.7 |
| Powdered high-speed steel (HAP40) | 8.07 | 23300 | 10.1 |
| Cemented carbide V30 | 14.1 | 56000 | 6.0 |
| Cast iron | 7.3 | 7500～10500 | 9.2～11.8 |
| SUS304 | 8.0 | 19700 | 17.3 |
| Oxygen free copper C1020 | 8.9 | 11700 | 17.6 |
| 6/4 Brass C2801 | 8.4 | 10300 | 20.8 |
| Aluminum A1100 | 2.7 | 6900 | 23.6 |
| Duralumin A7075 | 2.8 | 7200 | 23.6 |
| Titanium | 4.5 | 10600 | 8.4 |

$1Kgf/mm^2=9.80665\times10^6Pa$