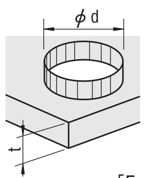
[PRODUCTS DATA] CALCULATION OF PUNCH STRENGTH①

There are cases where trouble, such as punch tip breakage and flange fractures, occurs during the punching operation.
Often the cause of this trouble is a lack of technical data concerning standard parts, or an error in the selection of the punching tool material or shape. In order to reduce the incidence of this kind of trouble, standards for correct punch use, with consideration for factors such as the fatigue strength of tool steel and concentration of stress at flanges, are presented here.

■1. Calculation of punching force

• Punching force P [kgf]

$P = \ell t \tau$ .... (1)



ℓ : Punching profile length [mm]
(For a round punch, $\ell = \pi d$)
t : Material thickness [mm]
τ : Material shearing resistance [kgf/mm^2]
($\tau \fallingdotseq 0.8 \times$ Tensile strength σ_B)

[Example 1] The maximum punching force P when punching a round hole of diameter 2.8 mm in a high-tensile steel sheet of thickness 1.2 mm (tensile strength 80 kgf/mm^2), is the following. When $P = \ell t \tau$,
Shearing resistance $\tau = 0.8 \times 80$
$= 64$ [kgf/mm^2]
$P = 3.14 \times 2.8 \times 1.2 \times 64 = 675$ kgf

[Table 1] Shearing resistance and tensile strengths of various materials

M	Shearing resistance τ (kgf/mm²) Soft	Shearing resistance τ (kgf/mm²) Hard	Tensile strength σB (kgf/mm²) Soft	Tensile strength σB (kgf/mm²) Hard
Lead	2～ 3	—	2.5～4	—
Tin	3～ 4	—	4～ 5	—
Aluminum	7～11	13～16	8～12	17～22
Duralumin	22	38	26	48
Zinc	12	20	15	25
Copper	18～22	25～30	22～28	30～40
Brass	22～30	35～40	28～35	40～60
Bronze	32～40	40～60	40～50	50～75
Nickel silver	28～36	45～56	35～45	55～70
Silver	19	—	26	—
Hot rolled steel sheet (SPH1～8)	26 or more		28 or more	
Cold rolled steel sheet (SPC1～3)	26 or more		28 or more	
Steel sheet for deep drawing	30～35		28～32	
Steel sheet for building structures (SS330)	27～36		33～44	
Steel sheet for building structure (SS400)	33～42		41～52	
Steel 0.1% C	25	32	32	40
〃 0.2% C	32	40	40	50
〃 0.3% C	36	48	45	60
〃 0.4% C	45	56	56	72
〃 0.6% C	56	72	72	90
Steel 0.8% C	72	90	90	110
〃 1.0% C	80	105	100	130
Silicon steel sheet	45	56	55	65
Stainless steel sheet	52	56	66～70	—
Nickel	25	—	44～50	57～63
Leather	0.6～0.8		—	
Mica 0.5 mm thick	8		—	
〃 2 mm thick	5		—	
Fiber	9～18		—	
Birch wood	2		—	

＊{N} = kgf × 9.80665 (Schuler, Bliss)

■2. Fracture of punch tip

• Stress applied to punch tip σ [kgf/mm^2]

$\sigma = P/A$

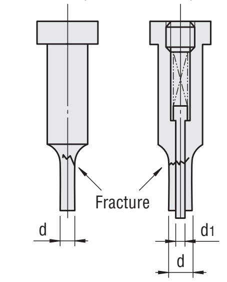
P : Punching force, A : Cross-section area of punch tip

(a) For shoulder punch

$\sigma_S = 4 t \tau / d$ .... (2)

(b) For jector punch

$\sigma_J = 4 d t \tau / (d^2 - d_1^2)$ .... (3)



[Fig. 1] Fracture of punch tip

[Example 2] Find the possibility of punch tip fracture when shoulder punch SPAS6—50—P2.8 and Jector punch SJAS6—50—P2.8 (d_1 dimension = 0.7, as shown on P. 186) are used. (Punching conditions are the same as in Example 1.)

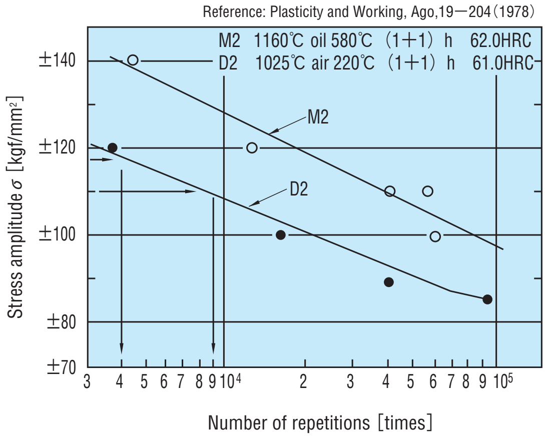
(a) For the shoulder punch, from Formula (2):
$\sigma_S = 4 \times 1.2 \times 64 / 2.8 = 110$ kgf/mm^2

(b) For the jector punch, from Formula (3):
$\sigma_J = 4 \times 2.8 \times 1.2 \times 64 / (2.8^2 - 0.7^2)$
$= 117$ kgf/mm^2

From Fig. 2, we see that when σ_S is 110 kgf/mm^2, there is the possibility of fracture occurring with an D2 punch at approximately 9,000 shots.
When the material is changed to M2, this increases to approximately 40,000 shots.
The possibility for the jector punch is found in the same way. Because the cross-section area is smaller, the punch tip will fracture at approximately 5,000 shots.
Fracture will not occur if the stress applied to the punch during use is less than the maximum allowable stress for that punch material.
(Consider this to be only a guide however, because the actual value varies depending on variations in the the die accuracy, die structure, and punched material, as well as the surface roughness, heat treatment, and other conditions of the punch.)

[Fig. 2] Fatigue characteristics of tool steel

Reference: Plasticity and Working, Ago, 19—204 (1978)



■3. Minimum punching diameter

• Minimum punching diameter: dmin.

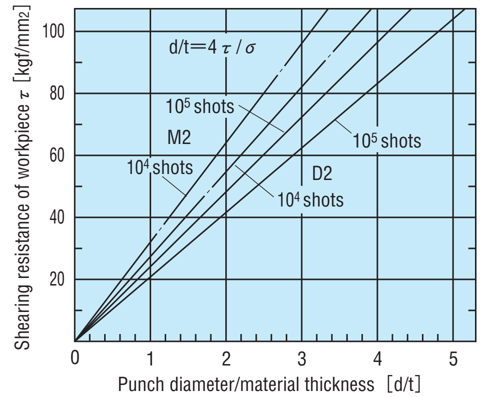
$dmin = 4t\tau / \sigma$

σ : Fatigue strength of tool steel [kgf/mm^2]

[Example 3] The minimum punching diameter that is possible when punching 100,000 shots or more in SPCC of thickness 2 mm with an M2 punch is the following.

$dmin = 4t\tau/\sigma$ .... (4)
$= 4 \times 2 \times 26/97$
$\fallingdotseq 2.1$ mm Fatigue strength for M2 at 100,000 shots:
$\sigma = 97$ kgf/mm^2 (from Fig. 2) τ
$= 26$ kgf/mm^2 (from Table 1)

[Fig. 3] Punching limit



■4. Fracture due to buckling

• Buckling load P [kgf]

$P = n\pi^2 EI/\ell^2$ .... (5)

$\ell = \sqrt{n\pi^2 EI/P}$ .... (6)

n : Coefficient n=1 : Without stripper guide
n=2 : With stripper guide
I : Second moment of inertia [mm^4]
For a round punch, $I = \pi d^4/64$
ℓ : Punch tip length [mm]

E : Young's modulus [kgf/mm^2]
D2 : 21000
M2 : 22000
HAP40 : 23000
V30 : 56000

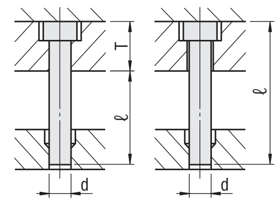
As indicated by Euler's formula, steps which can be take to improve buckling strength P include the use of a stripper guide, the use of a material with a larger Young s modulus (SKD→SKH→HAP), and reducing the punch tip length.
The buckling load P indicates the load at the time when a punch buckles and fractures. When selecting a punch, it is therefore necessary to consider a safety factor of 3～5.
When selecting a punch for punching small holes, special attention must be paid to the buckling load and to the stress which is applied to the punch.

[Example 4] Calculate the full length of the punch which will not produce buckling when a φ8 hole is punched in stainless steel 304 (sheet thickness 1 mm, tensile strength $\sigma_b = 60$ kgf/mm^2) with a straight punch (D2).

From Formula (6): $\ell = \sqrt{n\pi^2 EI/P}$
$= \sqrt{2 \times \pi^2 \times 21000 \times 201/1206}$
$= 262$ mm
If the safety factor is 3, then
$\ell = 262/3 = 87$ mm

Punching force $P = \pi d t \tau$
$= \pi \times 8 \times 1 \times 0.8 \times 60$
$= 1206$ kgf
Second moment of inertia $I = \frac{\pi d^4}{64} = \frac{\pi 8^4}{64}$
$= 201 mm^4$
With stripper guide : n=2

If the punch plate sheet thickness t is 20 mm, then buckling can be prevented by using a punch of total length 107 mm or less. For a punch based on the stripper plate (punch plate tip is guided by the clearance), the full length should be 87 mm or less.

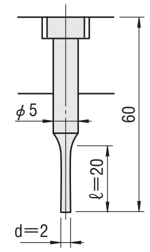


Based on punch plate Based on stripper

[Example 5] The buckling load P when a SHAL5—60—P2.00—BC20 punch is used without a stripper guide is the following.

$P = n\pi^2 EI/\ell^2$
$= 1 \times \pi^2 \times 22000 \times 0.785/20^2$
$= 426$ kgf
If the safety factor is 3, then
$P = 426/3 = 142$ kgf
∴ Buckling will not occur at a punching force of 142 kgf or less.

Punch material : M2
$E = 22000$ kgf/mm^2
$I = \frac{\pi d^4}{64} = \frac{\pi 2^4}{64}$
$= 0.785$ mm^4
Without stripper guide : n=1



[Fig.4] Buckling of punch