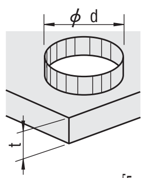
CALCULATION OF PUNCH STRENGTH①

There are cases where trouble, such as punch tip breakage and flange fractures, occurs during the punching operation.
Many of these problems are caused by a lack of technical data on standard components or improper material or the shape of the selected punching tools. To reduce the number of these problems, standards for proper use of punches are described below, taking into account the fatigue strength of tool steel, stress concentration on flanges, and so on.

■1. Calculation of punching force

● **Maximum punching force Pmax.〔kgf〕**



$P= \ell t \tau$ ······ (1)

ℓ : Punching profile length〔mm〕
(For a round punch $\ell = \pi d$)
t : Material thickness〔mm〕
τ : Shearing resistance of material〔kgf/mm²〕
($\tau \fallingdotseq 0.8 \times$ Tensile strength σ_B)

〔Example 1〕To calculate the maximum punching force P when a round hole with a diameter of 2.8mm is to be punched in a high tensile strength steel plate (tensile strength : 80kgf/mm²) with a thickness of 1.2mm:

In Pmax.$= \ell t \tau$
Shearing resistance $\tau = 0.8 \times 80$
$= 64$〔kgf/mm²〕
$P = 3.14 \times 2.8 \times 1.2 \times 64 = 675$kgf

Table 1. Shearing resistance and tensile strength of various materials

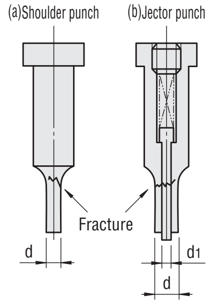
Material	Shearing resistance τ (kgf／mm²) Soft	Shearing resistance τ (kgf／mm²) Hard	Tensile strength σB (kgf／mm²) Soft	Tensile strength σB (kgf／mm²) Hard
Lead	2～ 3	—	2.5～4	—
Tin	3～ 4	—	4～ 5	—
Aluminum	7～11	13～16	8～12	17～22
Duralumin	22	38	26	48
Zinc	12	20	15	25
Lead	18～22	25～30	22～28	30～40
Brass	22～30	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 plate (SPH1～8)	26 or more		28 or more	
Cold rolled steel plate (SPC1～3)	26 or more		28 or more	
Steel plate for deep drawing	30～35		28～32	
Steel plate for structural use (SS330)	27～36		33～44	
Steel plate for structural use (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 plate	45	56	55	65
Stainless steel plate	52	56	66～70	—
Nickel	25	—	44～50	57～63
Leather	0.6～0.8		—	
Mica 0.5mm in thick	8		—	
〃 2mm in thick	5		—	
Fiber	9～18		—	
Birch material	2		—	

＊{N} ＝kgf×9.80665 (Schuler, Bliss)

■2. Fracture of punch tip

● **Stress σ exerted on punch tip〔kgf／mm²〕**

$\sigma = P/A$
P : Punching force, A : Cross-sectional area of punch tip
(a) For shoulder punch
$\sigma_S = 4t\tau / d$ ················· (2)
(b) For jector punch
$\sigma_J = 4dt\tau / (d^2 - d_1^2)$ ········ (3)



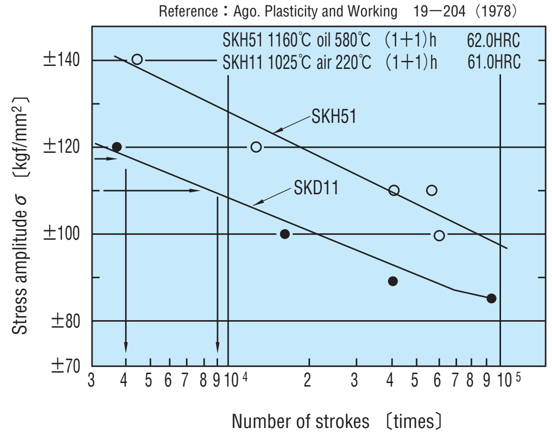
〔Fig.1〕Fracture of punch tip

〔Example 2〕Probability of punch tip fracture is calculated using shoulder punch SPAS6-50-P2.8 and jector punch SJAS6-50-P2.8 (the d_1 dimension is 0.7 from P.160).
(Punching conditions are the same as in Example 1.)
(a) For the houlder punch, from equation (2)
$\sigma_S = 4 \times 1.2 \times 64 / 2.8 = 110$kgf/mm²
(b) For the jector punch, from equation (3)
$\sigma_J = 4 \times 2.8 \times 1.2 \times 64 / (2.8^2 - 0.7^2)$
$= 117$kgf／mm²

From Fig. 2, when σ_S is 110kgf/mm², the punch tip of SDK11 punch will break after 9,000 punching shots. Use of the SKH51 material instead will increase this value to 40,000 shots or so.
The probability on the jector punch can be found in the same way. Its punch tip will break after about 5,000 punching shots because it has a smaller sectional area.
Where the stress σ exerted on punches is controlled to a value equal to or below the allowable stress of the specific punch materials, they will not fracture.
(This is only for reference; the maximum allowable stress depends on conditions, including die accuracy, die structure, variations in workpieces, the surface roughness of punches, heat treatment, and so on.)

〔Fig.2〕 Fatigue characteristics of tool steel

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



■3. Minimum punching diameter

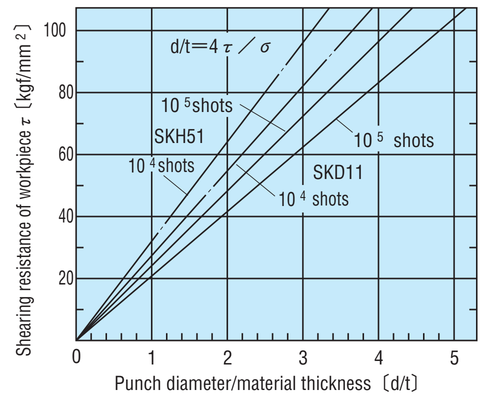
● **Minimum punching diameter : dmin.**

$d_{min} = 4t\tau / \sigma$
σ : Fatigue strength of tool steel〔kgf/mm²〕

〔Example 3〕To obtain the minimum punching diameter that makes it possible to punch SPCC plates with a thickness of 2mm 100,000 shots or more using a SKH51 punch :

$d_{min} = 4t\tau / \sigma$ ············· (3)
$= 4 \times 2 \times 26 / 97$
$\fallingdotseq 2.1$mm The fatigue strength σ of SKH51, subjected to 100,000 shots of punching;
σ is 97kgf/mm² from Fig 2.
τ is 26kgf/mm² from Table 1.

〔Fig.3〕Punching limit



■4. Fracture due to buckling

● **Buckling load P〔kgf〕**

$P = n\pi^2 EI / \ell^2$ ··········· (4)
$\ell = \sqrt{n\pi^2 EI / P}$ ··········· (5)

n : Coefficient n=1 : Without stripper guide
n=2 : With stripper guide
I : Secondary moment of inertia〔mm⁴〕
For a round punch $I = \pi d^4 / 64$
ℓ : Punch tip length〔mm〕

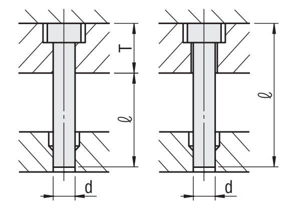
E : Young's modulus〔kgf/mm²〕
SKD11 : 21000
SKH51 : 22000
HAP40 : 23000
V30 : 56000

As expected from Euler's formula, to improve buckling strength P, it is recommended that a stripper guide and a material with a higher Young's modulus (SKD, SKH, and HAP in increasing order of Young's modulus) be used, and that the punch tip length be reduced.
The buckling load P represents the value of the load when a buckled punch fractures. When selecting a punch, therefore, safety factor 3 to 5 should be taken into account.
When selecting a punch for small holes, special attention should be paid to buckling load and stress exerted on the punch.

〔Example 4〕Calculating the full length of punch when a ϕ hole is punched in stainless steel SUS304 (thickness 1mm, tensile strength $\sigma b = 60$kgf/mm²) using a straight punch (SKD11) without buckling:

Punching force $P = \pi dt\tau$
$= \pi \times 8 \times 1 \times 0.8 \times 60$
$= 1206$kgf
Secondary moment of inertia $I = \frac{\pi d^4}{64} = \frac{\pi 8^4}{64}$
$= 201$mm⁴
With stripper guide : n=2

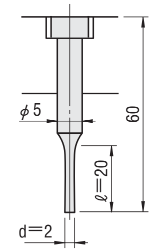
From equation (5) $\ell = \sqrt{n\pi^2 EI/P}$
$= \sqrt{2 \times \pi^2 \times 21000 \times 201 / 1206}$
$= 262$mm
If the safety factor is 3
$\ell = 262/3 = 87$mm
If punch plate thickness T=20mm, buckling can be prevented by using a punch having a full length of 107mm or less. The full length is 87mm or less for the punches relative to stripper (the punch plate guides the tip in the clearance).



〔Example 5〕To obtain the buckling load P for SHAL5−60−P2.00−BC20, the punch is used without a stripper guide:

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

Punch material : SKH51
E=22000kgf/mm²
$I = \frac{\pi d^4}{64} = \frac{\pi 2^4}{64}$
=0.785mm⁴
Without stripper guide : n=1



〔Fig.4〕Buckling of punch

〔PRODUCTS DATA〕

CALCULATION OF PUNCH STRENGTH②

■5. Flange fractures

As shown in Products Information of punches for heavy load on page 1131, it is said that the cause of flange fractures is tensile force due to elastic waves that are produced during the punching operation（the tensile force corresponding to the punching load applies to the punch at the time of breaking through）and the concentration of stress.

There are various methods for the prevention of flange fractures including：

1. Increase the radius under the flange to ease the concentration of stress.（use a punch for thick plates）
2. Increase the strength of the flange of a punch to a value higher than that of its tip.

Let us use method 2 above to find the optimum shank diameter that will not cause flanges to fracture.

● Calculations for the optimum shank diameter

The punching load P exerted on a punch tip is as follows：

$P = \pi d t \tau$

The allowable stress σ_w on the flange is

（a）For shoulder punch

$\sigma_w = P\alpha / A_t$

$= 4P\alpha / \pi D^2$

（b）For jector punch

$\sigma_{wJ} = 4P\alpha / \pi (D^2 - M^2)$

Find the strength of the flange when the punching conditions are the same as in Example 1.

A_t：Cross-sectional area flange ［mm^2］

（a）For shoulder punch

$A_t = \pi D^2 / 4$

（b）For jector punch

$A_t = \pi (D^2 - M^2) / 4$

D：Shank diameter

α：Coefficient of stress concentration

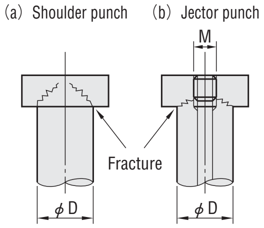
（a）For shoulder punch, $\alpha \fallingdotseq 3$

Punch for punching plate thickness $\alpha \fallingdotseq 2$

For taper head punch, $\alpha \fallingdotseq 1.6$

（b）For jector punch, $\alpha \fallingdotseq 5$

〔Fig.5〕Flange fractures



［Example 6］（a）For shoulder punch SPAS6—50—P2.8

$\sigma_w = 4 \times 675 \times 3 / \pi \cdot 6^2 = 71.6 kgf/mm^2$ ········Fractures starting from the flange will not occur because the stress applied to the punch tip in Example 2 is smaller than $110 kgf/mm^2$

（b）For jector punch SJAS6—50—P2.8

$\sigma_{wJ} = 4 \times 675 \times 5 / \pi (6^2 - 3^2) = 159 kgf/mm^2$ ····Fractures starting from the flange will occur because the stress applied to the punch tip in Example 2 is greater than $117 kgf/mm^2$.

When the shank diameter is 8mm, $\sigma_{wJ} = 90 kgf/mm^2$, which does not cause flange fractures.（Considering from the figure showing the fatigue strength of tool steel, the flange will break after about 50,000 shots.

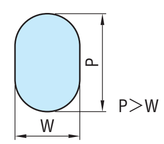
● Selection table for the optimum shank diameter

Punching conditions：Punch tip to convert P=12.8, W=10.6 into punch diameter ϕd, use the following equation：

$\phi d = [2(P - W) + W\pi] / \pi$

$= [2(12.8 - 10.6) + 10.6\pi] / \pi$

$= 12mm$



When material thickness is t=4mm, shearing resistance is $\tau = 50 kgf/mm^2$, and total number of shot times is 10^4 shots, to find the shank diameter, follow the steps described below：

Durability of punch tip（Fracture）［Fig. 6］

a）Obtain point a where material thickness t and shearing resistance τ intersect.

b）Obtain point b by extending a line from point a to the left or right until it intersects the diameter of the punch tip.

・Since the point b is below the line for the total number of shot times of 10^5, it is interpreted that both SKH and SKD have the durability for 10^5 shots or more.

Selection of shank diameter［Fig. 7］

c）Extend a line from point a to the right and obtain point c where it intersects the tip diameter.

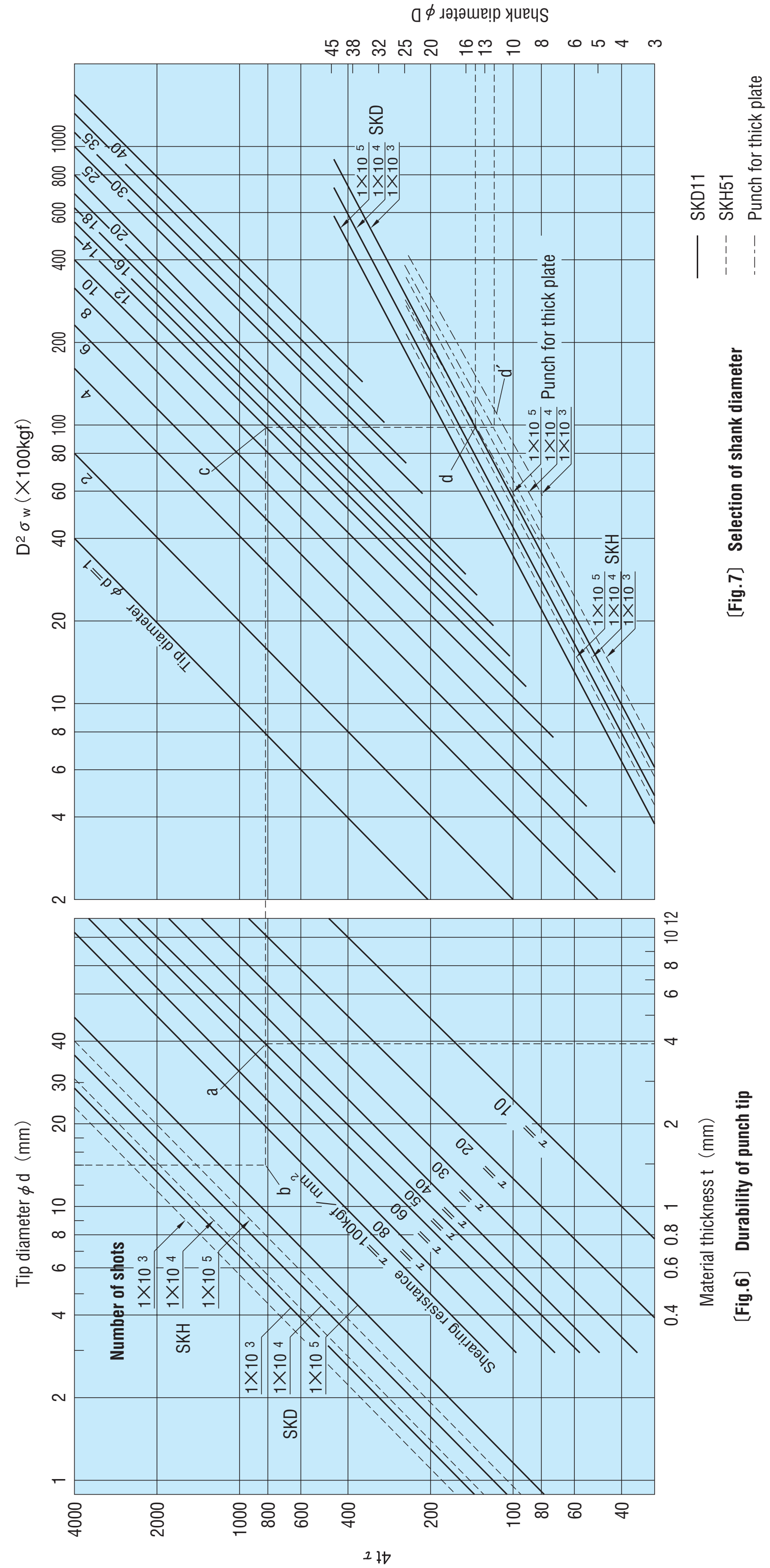
d）Extend a line from point c downward and obtain points d and d' where they intersect the line for total shot times of 10^4（for standard and thick material）.

e）Obtain the shank diameter by extending a line from points d and d' to the right.

・Since 14.0 is indicated for standard punches（SKH）, select $\phi 16$ for the shank.

・Since 11.8 is indicated for punches for thick material（SKH）, select $\phi 13$ for the shank.

Note：This selection table was prepared based on the results of tensile／compressive fatigue tests. The data may differ slightly from actual punching conditions.



〔Fig.7〕 Selection of shank diameter

〔Fig.6〕 Durability of punch tip