17. Press Die Design
(Blanking and Punching Dies)

Blanking and Punching Dies

- Die block
  - a construction component that houses the opening and receives punches
  - die opening profile
    - depending on the purpose and required tolerance of the workpiece
Blanking and Punching Dies

- **Die block**
  - (a) the highest quality but the most expensive
  - \( h > \) thickness of the workpiece, \( \alpha = 3^\circ ~ 5^\circ \)
  - for blanking parts having complex contours with greater accuracy
  - \( \alpha \leq \tan^{-1} \frac{\Delta}{2H} \)
  - for making small parts with low accuracy
  - (c) the simplest cylindrical opening
  - for making relatively large parts
  - (d) two-cylinder die opening profile
  - to punch small-diameter holes (\( d \leq 5 \text{mm} \))
  - \( D = d + 3 \text{mm} \)

(table and formula for commonly used dimensions)

Blanking and Punching Dies

- **Die block**
  - fastening to the die shoe
    - socket head screws
    - dowels to prevent a shift in the position of the block
    - (sometimes) retainer with a bushing for the die opening

methods of inserting a bushing into a machined retainer
Blanking and Punching Dies

- **Die block**
  - sectioned die
    - if a workpiece is large, or if the die opening is complicated, and the contours are difficult to machine

![Diagram of die block sections](image)

- **Die block**
  - welded edges
    - to save very expensive tool steel, a die and punch with welded edges is often used, primarily for blanking parts of larger dimensions and material thickness up to \( T = 1.5 \text{mm} \)
Blanking and Punching Dies

- **Die block**
  - calculation of die block dimensions
  
  (simplified but practical) two empirical formulas calculating only the thickness of the die block \( H \), and the width of the wall \( e \)

\[
H = \left(10 + 5T + 0.7\sqrt{a + b}\right)c
\]

\( T \): material thickness
\( a, b \): die opening dimensions
\( c \): constant depending on the workpiece material

<table>
<thead>
<tr>
<th>UTS (MPa)</th>
<th>117</th>
<th>245</th>
<th>392</th>
<th>784</th>
</tr>
</thead>
<tbody>
<tr>
<td>( c )</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

\( e = (10 \sim 12) + 0.8H \)

If the die opening has a contour with angle less than 90°, the value of \( e \) needs to be increased from 15 to 20 percent

\[ M = \frac{1}{8}Fl \]

\[ W = \frac{(B - b)H^2}{6} \]

\[
\sigma_s = \frac{M}{W} = \frac{6Fl}{8(B - b)H^2} = 0.75 \frac{Fl}{(B - b)H^2} \]

\[
\Rightarrow \sigma_s = 0.75 \frac{Fl}{(B - b)H^2} \leq \sigma_{sd}
\]
Blanking and Punching Dies

- **Die block**
  - calculation of die block dimensions
    - (simplified but practical) two empirical formulas calculating only the thickness of the die block $H$, and the width of the wall $e$

\[
\sigma_s = \frac{2.5F}{H} \left(1 - \frac{2d}{3d_0}\right) \leq \sigma_{sd}
\]

- **Punch**
  - standard punches for a wide variety of round, oblong, and square holes
  - main considerations
    - designed so that they do not buckle
    - strong enough to withstand the stripping force
    - not be able to rotate as a result of the cutting action
Blanking and Punching Dies

- Punch
  - punch face geometry
    - it is possible to control the area being sheared at any moment by making the punch and die surface at an angle
      - flat face surface: rapid built-up of the punch force
      - concave face surface
      - bevel face surface
      - double bevel face surface

- Punch
  - assembly of punches
    - methods for assembling blanking and piercing punches on a punch holder

  - piercing punches
    - longer than blanking punches
    - designed to withstand shock and buckling and to be easily removed and replaced
Blanking and Punching Dies

- **Punch**
  - assembly of punches
    - (hardened) backing plate
      - between the head of the punch and the punch holder
      - if
        \[
        p = \frac{F}{A} = \frac{4F}{\pi d^2} \geq p_d = 245 [\text{MPa}]
        \]
      
      ![Diagram of punch assembly](image)

- Quick removal and replacement of the piercing punch
  - with a ball under spring pressure: used with complex dies
  - with a screw: for punching holes of d=20–60mm

  ![Diagram of ball and screw](image)
Blanking and Punching Dies

- Punch
  - calculation of punches
  - compression stress
    \[ \sigma_d = \frac{F}{A} \leq \sigma_{pd} \]
  - buckling (free end)
    - Euler formula
      \[ F_{cr} = \frac{\pi^2 E I_{min}}{4l^2} \]
      \[ \rightarrow l_{max} = \sqrt{\frac{\pi^2 E I_{min}}{4LT(0.8UTS)}} \]
      
      L: length of cut
      T: thickness of material

- Punch
  - calculation of punches
  - buckling (fixed end)
    \[ F_{cr} = \frac{2\pi^2 E I_{min}}{l^2} \]
    - maximum length: \( \sqrt{8} \) times larger

- for punching any material where the shearing stress is \( \tau \geq 295 \text{[MPa]} \), the punch diameter must be greater than the thickness of the workpiece
Blanking and Punching Dies

- **Stripper plate**
  - when a punch shears its way though a workpiece, the material contracts around the punch to the degree that it takes a substantial force to withdraw the punch from the material
  - efficient removal of the workpiece and scrap from the die increases productivity, quality, and workplace safety

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Blanking and Punching Dies

- **Stripper plate**
  - stripper force
    - force required to strip the material from the punch

\[ F_s = C_s F \]

<table>
<thead>
<tr>
<th>material thickness T [mm]</th>
<th>&lt;1.0</th>
<th>1.0~5.0</th>
<th>5.0~</th>
</tr>
</thead>
<tbody>
<tr>
<td>simple punching or blanking</td>
<td>0.02~0.06</td>
<td>0.06~0.08</td>
<td>0.08~0.10</td>
</tr>
<tr>
<td>compound punching or blanking</td>
<td>0.06~0.08</td>
<td>0.10~0.12</td>
<td>0.12~0.15</td>
</tr>
<tr>
<td>punching and blanking at same time</td>
<td>0.10~0.12</td>
<td>0.12~0.15</td>
<td>0.15~0.20</td>
</tr>
</tbody>
</table>
Blanking and Punching Dies

- Stripper plate
  - stripper design
    - solid stripper

  - elastic stripper
    - to hold the scrap strip in a flat position before the punch makes contact with the workpiece → very accurate punching of very thin materials, or with thin punches
    - compression spring or rubber pad
Blanking and Punching Dies

**Stripper plate**
- stripper design
  - elastic stripper
    - helical springs

maximum static force
\[ F_{\text{max}} = \frac{\pi d^3 \tau}{8D} \]
shearing stress, \( \tau = 490\sim 685\text{[MPa]} \)
total deflection
\[ f_{\text{max}} = \frac{8nD^3 F_{\text{max}}}{Gd^4} \]
shear modulus, \( G = 75\sim 83\text{[GPa]} \) for steel springs
\( n \): number of active coils
spring force
\[ F = cf = F_{\text{max}} \frac{f}{f_{\text{max}}} \]
→ during assembly, the springs need to be preloaded with a force of \((0.1\sim 0.2)F_{\text{max}}\)

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**Stripper plate**
- stripper design
  - elastic stripper
    - rubber pads
      (minimum hardness of 68Shore & cylindrical shape with a height-to-diameter ratio of 0.5\sim 1.5)

maximum deflection
\[ f_{\text{max}} = (0.35 \sim 0.40)h \]
stripper force
\[ F = pA \]
\( A \): cross-sectional area of rubber pad
\( p \): permitted specific pressure for rubber pad (3.5[MPa] for \( f_{\text{max}} = 0.40h \) & hardness of 68Shore)
Blanking and Punching Dies

- Guiding and stopping components
  - stock guide and guide rails
    - stock guide: in the entryway
    - guide rail: to guide the work strip through the die

**tunnel dimension**

\[ A = B + 2c \]

- \( B \): strip width
- \( c \): clearance (0.25~0.75mm for fixed guide rails & 2.5~4.0mm for elastic guide rails)

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### Blanking and Punching Dies

- Guiding and stopping components
  - stock guide and guide rails

<table>
<thead>
<tr>
<th>material thickness, ( T )(mm)</th>
<th>tunnel height, ( H )(mm)</th>
<th>stop pin height, ( h )(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>manual feed</td>
<td>automatic feed</td>
</tr>
<tr>
<td>0.3~2.0</td>
<td>6.0~8.0</td>
<td>4.0~6.0</td>
</tr>
<tr>
<td>2.0~3.0</td>
<td>8.0~10.0</td>
<td>6.0~8.0</td>
</tr>
<tr>
<td>3.0~4.0</td>
<td>10.0~12.0</td>
<td>6.0~8.0</td>
</tr>
<tr>
<td>4.0~6.0</td>
<td>12.0~15.0</td>
<td>8.0~10.0</td>
</tr>
<tr>
<td>6.0~10.0</td>
<td>15.0~25.0</td>
<td>10.0~15.0</td>
</tr>
</tbody>
</table>
Blanking and Punching Dies

- Guiding and stopping components
  - die stops and French notch punch
    - die stops
      - to stop the material strip after each feed movement is completed
      - solid pins should be lightly press-fitted into the die shoe and should extend above the die block face
    - French notch punch
      - for trimming away a length of work strip that is equal to the progression of the die
      - one of the best ways to control the problems of strip width tolerance, strip camber, and progression control

<table>
<thead>
<tr>
<th>material thickness, T (mm)</th>
<th>material</th>
<th>notch width, w</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.5</td>
<td>steel</td>
<td>(2–3)T</td>
</tr>
<tr>
<td></td>
<td>other softer ones</td>
<td>(2–3)T</td>
</tr>
<tr>
<td>&gt;1.5</td>
<td>1.5T</td>
<td>2T</td>
</tr>
</tbody>
</table>
Blanking and Punching Dies

- Guiding and stopping components
  - die stops and French notch punch
    - adjustable stop and finger stop

- Guiding and stopping components
  - positioning the individual blank
    - depending on the shape and dimension of the workpiece
      - three dowels
      - a ring
      - a combination of dowels and guide rails
Blanking and Punching Dies

- Guiding and stopping components
  - pilots
    - in progressive and compound dies to position the work strip so that the relationships between stations or previously punched holes and the outside blanked contours of workpieces may be maintained.
Blanking and Punching Dies

- Examples (I)
  - single blanking die

- Examples (II)
  - single punching die with a series of punches staggered
Blanking and Punching Dies

- Examples (III)
  compound die with parallel positions for punching and blanking operations

- Examples (IV)
  four-serial compound die