Cutting and Shearing die design

Cutting die design

A stamping die is a special, one-of-a-kind precision tool that cuts and forms sheet metal into a desired shape or profile. The die's cutting and forming sections typically are made from special types of hardenable steel called tool steel. Dies also can contain cutting and forming sections made from carbide or various other hard, wear-resistant materials.

Cutting is perhaps the most common operation performed in a stamping die. The metal is severed by placing it between two bypassing tool steel sections that have a small gap between them. This gap, or distance, is called the cutting clearance.

Cutting clearances change with respect to the type of cutting operation being performed, the metal's properties, and the desired edge condition of the piece part. The cutting clearance often is expressed as a percentage of the metal's thickness. The most common cutting clearance used is about 10 percent of the metal's thickness.

Very high force is needed to cut metal. The process often introduces substantial shock to the die and press. In most cutting operations, the metal is stressed to the point of failure, which produces a cut edge with a shiny portion referred to as the cut band, or shear, and a portion called the fracture zone, or break line (see Figure 1).

The material for the part is thin at 0.25mm) the material thickness will require very close cutting clearances. For this design we will use a cutting clearance between the die and punch of 0.0125mm) Also with our punches being small and pretty delicate we will want to use a guided stripper. The guided stripper will give the punches a lot of support right at the point of their entry into the material.

We will have a stripper to punch clearance of 0.006mm) (about half of the cutting clearance). This will ensure that the punches will enter the die and not hit the die cavities. This would cause shearing of the die. Shearing is not good in a die as it reduces the die life in the tool from having to re-sharpen the die and punches. Sheared dies will also produce poor cut edge quality.

Over the years, Auer has developed what we call Master Dies. These are modular die sets in which we mount the punch holder, stripper, die and punches, etc. into standard chases. The die shoes; die stripper and punch holder chases; along with the spring packs, etc., are standard for
that master die. This allows us to offer the customer stamped parts and not have to pay for an entire stand alone progressive or single hit die asm. We can also turn the design and build around quickly with the standard inserts we use in the tools. There are over 100 different master die designs in tool inventory. For this tool design we are going to use Master Die 103A (Fig.2). This is a four post die, with a 4 post sub-guide system for the guided stripper. The master die was designed and built back in 1997. It is a great tool for stamping these small, close tolerance parts.

![Master Die 103A](image)

**Fig. 2 Master Die 103A**

On inside corners it is not feasible to create sharp corners in the punch cavities. The punch cavities are typically cut with a Wire EDM process. The wire that we use in most all cases is (0.25mm) in diameter. Normally used R(0.25mm) minimum for corner radii. We can go smaller, but that will require a smaller wire diameter in the WEDM machine, which really drives up costs as the rate per inch of cutting slows down quite a bit with the smaller diameter wire.

**Die Design for flat parts:**

Flatness is one of the most difficult part characteristics to achieve in a conventional stamping die. Some of the factors controlling part flatness are:

1. The severity of the steel cutting deformation.
2. The mechanical properties of the sheet material.
3. The incoming flatness of the material or coil.
4. The metal's thickness.
5. The residual stress created in previous operations.
6. The strain levels at various areas within the part.

The first step to improving flatness problems is to look at your cutting or piercing operation. If your part flatness requirements include reasonable tolerances, they can be addressed with something as simple as changing the cutting clearance. Although this is not the best way to achieve critical part flatness, it is the most economical way.

The cutting and piercing clearance that is selected affects the amount of internal stress created. Depending on the metal type and clearance between the upper and lower cutting steels, this stress can be significant enough to promote part distortion. Increasing the cutting clearance during the piercing process reduces part stress, mainly because the compressive metal deformation around the pierce punch decreases. When the clearance between the piercing punch and the die button is insufficient, the metal is forced to deform plastically or hump up around the perimeter of the pierce punch. This creates stress in the part. Increasing the clearance reduces the severity of the deformation, thus reducing stress (see Figure 3).

Keep in mind that as you increase cutting clearance, more stress will be introduced to your slug. If the slug is to be saved, blanking operation clearance should be decreased.

Figure 3
Be sure to leave enough cutting clearance around a pierce punch - - it is critical in avoiding plastic deformation.

Cut and Carry
A very popular way of achieving part flatness in a progressive die is to use a cut-and-carry process (see Figure 4). A cut and carry process holds the part flat during the cutting process and later ejects it from the carrier strip. In a cut and carry process, the slug produced is the piece part.
During the cutting process, the metal is squeezed and held flat between the face of the cutting punch and a high-pressure pad. This pad is powered by a nitrogen cylinder, die-draulic unit, or hydraulic cushion.

In the cut-and-carry method, a piece is blanked about halfway through as metal is squeezed and held flat, then is pushed through with a punch smaller than the cutting punch.

Another method used to achieve flat parts is fineblanking. This type of operation requires a special fineblanking press, which requires a substantial investment but generally produces excellent part flatness characteristics.

This type of operation also allows the cut edge of the part to be burnished fully without fracture. This is highly desirable, especially when you are manufacturing stamped parts such as gears or other items that require full edge contact.

**Fig.4**

**PHASE #1 Cutting (Approx. 50% Thru)**
A fineblanking operation utilizes a special high-pressure pad containing a stinger ring. This stinger ring is a barblike projection that is impaled or coined into the sheet metal surrounding the cutting profile. Its function is to keep the metal from flowing outward plastically when the metal is cut.

Because fineblanking uses little or no cutting clearance, the amount of outward metal flow must be restricted and controlled. Only when the outward metal flow is reduced can a fully sheared cut line be achieved. Much like a cut-and-carry process, a fineblanking operation also holds the blank flat during cutting. However, unlike cut and carry, a fineblanking operation uses a very high-pressure ram pad to hold the metal flat. This ensures maximum blank holding and flatness pressure (see Figure 5).

Stippling the Blank

Let's say you have a part that needs to be flat, and the current die design does not incorporate a way of controlling part stress. Don't worry - just stipple the blank.

Stippling the blank - a process that addresses internal stress after it has already been created - utilizes a cross-hatched pattern that is coined into one or both surfaces of the part after all cutting and extensive metal deformation is done. The stipple pattern breaks up internal part stress and destroys the part memory, allowing it to be rehit flat.

The depth of the stipple is relative to metal thickness, the mechanical properties of the material, and the stress that was previously induced. Experimentation may be necessary to achieve the desired results.
Shearing die design

Tooling for shearing is divided as follows:

1. According to the type of guide device

1.1 Unguided shearing
   Shearing tooling with no additional guiding device.

1.2 Guided shearing
   1.2.1 Directly guided Pressure plate-guided shearing
       a) Steel pressure plate
       b) Pressure plate lined with plastic (Duroplast)
       c) Pressure plate lined with Zamak (a zinc alloy)

   1.2.2 Indirectly guided
       Pillar guide shearing
       Here, the pillar guide frame acts as a guide

2. According to how the tooling functions

2.1 Single-stage tooling
   Can carry out only one function; either only piercing or only blanking.

2.2 Progressive tooling
   In a certain order, the openings are first pierced in the part being stamped, and then the prepunched part is blanked.

2.3 Compound tooling
   With compound tooling, the part is both pierced and blanked in one ram down-stroke.

Structural design of shearing tooling

1.1 Unguided shearing

With unguided shearing, the punch is not guided in the die itself. This means a machine with good guides is required. A stationary stripper fixed to the bottom of the die is used to strip the stamped strip from the punch. When shearing soft materials with this tooling only the punch is hardened. In small-scale production, the die block, made of St 60 or C100, remains soft. Unguided shearing is mainly used for small-scale production (Figure1).
1.2 Guided shearing
1.2.1 Directly guided

Pressure plate-guided shearing (tooling with guided punch)
With this tooling, the punch is guided by a special guidance pressure plate above the die block. The guidance pressure plate has the same opening as the die block, but with no punch clearance. Between the die block and pressure plate there are spacers whose thickness depends upon the thickness of the material. The pressure plate also acts as the stripper plate (Figure 2). With this tooling, precise guidance is only possible up to a punch diameter of up to around 10 mm, as the guidance length is too short due to the limited thickness of the pressure plate.
This kind of plate-guided shearing is only used for medium- to large-scale production. Tooling of this kind can easily be installed in the machine because of the punch guidance.
Producing the pressure plate from steel is expensive, so with this guide system, three structural designs are used:
a) pressure plate made of steel
b) pressure plate with plastic-lined guide
c) pressure plate with Zamak-lined guide (Zamak is the acronym for a zinc alloy).
Pressure plate-guided shearing with plastic guide:

For tooling which does not require very high precision and for medium-scale production, the punch-guiding openings can be lined with plastic or a zinc alloy (Zamak). The openings in the metal pressure plate are then considerably larger than the punch to be guided, so it is less important how precisely they are arranged together. The punch shoe, with the punches precisely positioned, is put in the pressure plate with its enlarged openings (Figure 3).

![Figure 3 Plate-guided shearing with plastic lined guide. 1 punch holder, 2 top plate, 3 punch carrier plate, 4 plastic or Zamak, 5 pressure plate, 6 die block.](image)

Next, the punches in the pressure plate are lined with plastic, giving them their precise positioning. Epoxy is used as a plastic liner. Pressure plates produced in this way are considerably cheaper than solid steel plates; however, they also have a shorter lifetime and are therefore only used when the conditions described above make it possible.

1.2.2 Indirectly guided

Pillar guide shearing

With this tooling, the punch is guided directly, rather than indirectly as above. The tooling itself is an unguided shearing assembly. A pillar guide frame is installed (using screws and pins). The pillar guide frame guides extremely precisely, so no press guide is needed. The high guide precision lengthens the lifetime of the tooling (Figure 4).

This kind of guide device is made up of an upper and a lower part, the case-hardened pillars (St C 10.61; St C 16.61) and the sliding guide or ball bearing guide. When the tooling is installed, the guide can be on top or below, depending on the design of the tooling and the kind of guide. Pillar guide frames come in various structural designs.
2.1 Single-stage tooling
This can carry out only one function; either only punching or only blanking. It can be designed as a guided or unguided shearing assembly.

2.2 Progressive tooling
With progressive tooling, several operations are carried out with the same tooling in a certain order. When the workpiece has openings, for example, first the openings are pierced and then the contour is blanked (Figure 5).

2.3 Compound tooling
With compound tooling (Figure 6) the periphery and the cut-out are blanked and pierced simultaneously on one ram down-stroke.
For this reason, the accuracy of the comparative positioning of the contour and the openings in the workpiece can be extremely high with this tooling. When the strip is fed in irregularly this also has no effect on the preciseness of the workpiece positioning. Any positioning defects arise entirely from the accuracy with which the workpiece was manufactured.

In the compound assembly shown in Figure 6, the upper part of the frame 1 holds the die block 2 with the hole punch 3. The stripper 4 pushes the strip off the punch 3. The blanking punch 5, which blanks the contour, is in the lower part of the frame. The stripper 6 strips the scrap off the blanking punch 5. The piece punched out 3 falls out downwards. The blank is pressed back into the strip with the stripper 6 and carried out of the tooling along with the strip. This kind of tooling is used to manufacture workpieces produced in large numbers with very low tolerances (up to 0.02 mm). Compound tooling is expensive: this kind of tooling costs about twice as much as shearing with two edge cutters, so it must always be checked in advance whether or not compound tooling is the most economical choice for the case in hand.

**Figure 6** Compound tooling to manufacture a pierced disc

The edge cutter provides the most accurate feed control. It is an extra shearing punch which notches the edge of the strip of sheet. The sheet is pushed against the stopper in the tooling (Figure 7). When the ram moves downwards, the edge cutter notches a piece of stock of width $b$ and length $L$ at the edge of the strip. The sheet can now be pushed forwards by this length $L$ (strip feed measurement).

Depending on the precision of the feed and material use of the strip (how it is used), one or two edge cutters are employed; when there are two, these are installed on the left and on the right, offset lengthwise (Figure 7). Edge cutters are divided into:

**Figure 7** Edge cutter arrangement. $W$ width of the strip before, $W1$ width of the strip after being cut by the edge cutter, $L$ length of the feed step, $w$ width of notch
Table 1 Standard values for cone angle and the height of the cylindrical part of shearing dies

<table>
<thead>
<tr>
<th>Sheet thickness $s$ in mm</th>
<th>Design b</th>
<th>Design a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cone angle $\alpha$</td>
<td>Height of the cylindrical opening $h$ in mm</td>
</tr>
<tr>
<td>0.5 – 1</td>
<td>15° – 20°</td>
<td>5 – 10</td>
</tr>
<tr>
<td>1.1 – 2</td>
<td>20° – 30°</td>
<td></td>
</tr>
<tr>
<td>2.1 – 4</td>
<td>30° – 45°</td>
<td></td>
</tr>
<tr>
<td>4.1 – 8</td>
<td>45° – 1°</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Steels suitable for blanking punch and die blocks

<table>
<thead>
<tr>
<th>Material to be cut</th>
<th>Material no.</th>
<th>Assembly hardness in HRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of material</td>
<td>Material no.</td>
<td>Assembly hardness in HRC</td>
</tr>
<tr>
<td>Sheets and strips from austenitic steels</td>
<td>up to 4</td>
<td>1.2379, 1.3343</td>
</tr>
<tr>
<td></td>
<td>up to 6</td>
<td>1.2379, 1.3343</td>
</tr>
<tr>
<td></td>
<td>up to 12</td>
<td>1.2550</td>
</tr>
<tr>
<td></td>
<td>above 12</td>
<td>1.2767</td>
</tr>
<tr>
<td>Precision tooling for sheets and strips made of metallic materials</td>
<td>up to 4</td>
<td>1.2379, 1.3343</td>
</tr>
<tr>
<td></td>
<td>up to 6</td>
<td>1.2379, 1.3343</td>
</tr>
<tr>
<td></td>
<td>up to 12</td>
<td>1.2379, 1.3343</td>
</tr>
<tr>
<td>Plastics, wood, rubber, leather, textiles, paper</td>
<td>up to 2</td>
<td>1.2080, 1.2379, 1.2436, 1.2842</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2550</td>
</tr>
</tbody>
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<th>Material to be cut</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Type of material</td>
<td>Material no.</td>
<td>Assembly hardness in HRC</td>
</tr>
<tr>
<td>Sheets and strips of steel and nonferrous metal alloys</td>
<td>up to 4</td>
<td>1.2080, 1.2436</td>
</tr>
<tr>
<td></td>
<td>up to 6</td>
<td>1.2379, 1.2363, 1.2842</td>
</tr>
<tr>
<td></td>
<td>up to 12</td>
<td>1.2550</td>
</tr>
<tr>
<td></td>
<td>above 12</td>
<td>1.2767</td>
</tr>
<tr>
<td>Transformer sheet and silicon steel sheet and strips</td>
<td>up to 2</td>
<td>1.2379, 1.2436</td>
</tr>
<tr>
<td></td>
<td>up to 6</td>
<td>1.2379</td>
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Example
The aim is to stamp 2mm-thick discs with a diameter of 40mm made of St 1303 with $\tau_B = 240$ N/mm$^2$. Find the force and mechanical work.

$$F = C \cdot s \cdot \tau_B - d \cdot \pi \cdot s \cdot \tau_B - 40 \text{ mm} \cdot \pi \cdot 2 \text{ mm} \cdot 240 \text{ N/mm}^2 = 60288 \text{ N}$$

$$F = 60.3 \text{ kN}$$

$$W = F \cdot s \cdot x = 60.3 \text{ kN} \cdot 0.002 \text{ m} \cdot 0.6 = 0.072 \text{ kNm} = 72 \text{ N m}$$