Theory of hole punching

The Theory

Punching is a metal forming process that uses a press to force a tool, called a punch, through the workpiece to create a hole via a shearing process. The punch passes through the workpiece and into a die. The slug from the new hole is deposited into or completely pushed through the die in the process.

The sheared edge exhibits some distinctive features; they include: rollover, burnish, fracture, and burrs. Rollover occurs as the material engages the die and distorts as the material is forced into the die.

The process by which a hole is punched involves three phases:

*Diagram showing three phases: Plastic Deformation, Penetration and Fracture*

Phase one: Plastic deformation

*Plastic deformation* occurs as the punch tip begins to push against the material.

Increasing pressure causes the punch tip to push into the material until the material reaches its elastic limit.

Beyond this point the punch tip begins to penetrate into the material itself by fracturing the surfaces. From that point the material will no longer be able to return to its original shape if the punch tip were to be pulled back from the material surface, figure 1.

Phase Two: Penetration

*Penetration* begins with cutting of the material by the tool set until fracture lines (cracks) first appear in the material.

Penetration is occurring at the punch tip while the die is penetrating the material from the bottom, figure 2.

Phase Three: The Fracture

As the fracture lines from both sides of the material meet, the material slug will be pushed free of the blank. Figure 3 shows a cutaway view with the results of the different phases.

Note, the roll-over on the slug is seen on the bottom surface of the slug the top surface of the material.
Die clearance and Angle of fracture

The effects of clearance on the fracture angle are profound. Clearance is described as the difference between the outside measurement of the punch and the inside measurement of the die. The angle of the fracture is not a function of clearance alone. The angle of fracture can also be a function of the material type. It is for that reason hot or cold rolled steel, aluminum, or stainless steel all require different die clearance.

Figure 4 shows an example of how the angle of fracture can affect the hole quality. The center graphic labeled “optimum” displays a cut-away view of the fracture using the correct clearance; note how the fractures lay on a common plane through the material. If this clearance is maintained, the feature will be produced with the least amount of machine effort.

On the other hand, where the clearance is too tight and the fractures are not on a common plane, the resulting hole or feature will have two distinct “fractures”. When the punch must force itself past the overlapping material, the machine needs extra effort to produce a feature of lesser quality. As the die clearance decreases, an equal amount of increase in the “shear” or “burnish” will occur. The shear is the portion of the punching event where the material is in physical contact with the punch. This “shear” or “burnish” runs from the first fracturing through to the “breakout” or “fracture” point.

The third graphic in figure 4 show the fracturing with too much clearance. The edges tend to be rolled (roll over) more than shearing (burnish), and again the angles of the fractures are not on the same plane.

The Slug

Compare the edge condition of the Slug to quickly see if you clearance is adequate; note the burnish, fracture and burr; this check will help ensure proper die clearance, figure 5.

Tooling ware and clearance

Normal tooling wear is set by the number of hits and the material type being punched. Paying attention to the burr and observing the changes in height are some of the best indicators of proper tool clearance and wear.

With the dulling of the cutting edge, an increase of burr height and the size of the plastic deformation (roll over) is increased. This is caused by the friction between the punch, die and material.

Tooling may also dull quickly from a notching or nibbling process. Nibbling causes a lateral force or “side thrust” to be produced during the punching process.

This lateral force causes a decrease in the clearance on one side of the die.

It is conceivable the punch tip could shave the edges of the die on the opposite edge, resulting in a rapid dulling of the tooling, both the punch and the die, figure 6.

It is recommended that you never nibble less than 2-1/2 times the material thickness (Mt). When the cut gets too thin...
the material will “roll” or “bend down” into the die space, making a clean shear almost impossible. It is also a good idea to stagger the nibbling process; this keep the tool loading correctly. Figure 7 shows the slug from a staggered pattern: 1,3,2,5,4….

Punches that are narrower or have a smaller diameter as the material thickness (Mt) are extremely susceptible to that lateral force; the punch tip is likely to bend and/or break. This lateral force side thrust will cause a tightening of the clearance on one side. It is again possible for the punch tip to shear the die body because of the lateral forces. In general, it is best practice never to attempt punching a feature at less than material thickness.

Die Clearance by material type

A gradual increase in the amount of clearance should be observed as the thickness surpasses .250-inches. When the clearance is excessive, burring will occur. Burring is caused by the “fracture” not meeting with the edge of the die. As this happens, stress points are created in the material resulting in premature fracturing.

Too little clearance has more compression error; therefore, exerting a larger stretching force within the material also results in a burr. With a proper clearance, less stress fracturing occurs resulting in less burr being created.

Burnish percentages

Shear “burnish” size is expressed as a percentage of material type.

This desired shear burnish is not the same for all materials. The list in table 2 gives the percentages of shear (measured) as a percentage of the material type. Again, shear is the distance covered by the punch when in contact with the material and before the breakout. The following video, The Theory of Hole Punching, covers materials from this chapter and the chapter on Punch Press Tooling.

<table>
<thead>
<tr>
<th>Material type</th>
<th>minimum</th>
<th>optimum</th>
<th>maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>cold rolled steel</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
</tr>
<tr>
<td>Carbon steel</td>
<td>12%</td>
<td>18%</td>
<td>24%</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>15%</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>E.G. mild steel</td>
<td>12%</td>
<td>18%</td>
<td>24%</td>
</tr>
<tr>
<td>5052 H32 aluminum</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>T4 aluminum</td>
<td>12%</td>
<td>18%</td>
<td>24%</td>
</tr>
<tr>
<td>T6 aluminum</td>
<td>15%</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>Brass</td>
<td>6%</td>
<td>12%</td>
<td>16%</td>
</tr>
<tr>
<td>1/2 hard copper</td>
<td>8%</td>
<td>12%</td>
<td>16%</td>
</tr>
</tbody>
</table>

Table 1
## Burnish Percentages by Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Burnish Percentage</th>
</tr>
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<tbody>
<tr>
<td>Mild cold rolled steel</td>
<td>30%</td>
</tr>
<tr>
<td>5052 H32 Aluminum</td>
<td>60%</td>
</tr>
<tr>
<td>304 Stainless</td>
<td>15%</td>
</tr>
<tr>
<td>Brass or Copper</td>
<td>55</td>
</tr>
</tbody>
</table>

**Table 2**

## Theory of hole punching

The Theory of Hole Punching

Courtesy of Asma LLC