Shear – the cut

Fabricating with sheet or plate metal of any kind will require a blank, sheared to a suitable size. To produce sheets, blanks or strips of a specific size, a squaring shear is employed. The material is cut by two knives being forced through the material in opposing directions. Assuming the shear is of the correct capacity, the force of the knives will be greater than the shear strength of the material; this allows the cut to be made.

The shear utilizes a stationary lower knife with a moveable and adjustable upper knife. Workpiece hold downs located across the length of the worktable clamp the material and keeps it from moving during the cutting process.

There are two basic types of shears: the Hydraulic and Mechanical. These shears; vary in many ways in addition to the obvious one.

They can be further sub-grouped as “fixed rake” and “variable rake” machines.

There are some distinct differences in the designs. The list below describes the drive systems:

- The average mechanical shear is capable of approximately 60 strokes per minute compared to the 20 to 25 strokes of the average hydraulic machine.
- The mechanical machine produces a cleaner edge than the hydraulic machine due to the speed of operation.
- The hydraulic shear has a much slower action; there is more time for bow, twist and camber to develop in the drop.
- The slower action of the hydraulic machine also requires you to gap the machine to a nominal blade gap setting for each material type and thickness in much the same way a punch clearance is selected.
- The faster speed of the mechanical shears, on the other hand, allow for a wider range of materials and material thickness with a single blade gap setting.

Shear Capacities

Shear Capacity is usually expressed in terms of the maximum thickness of low carbon, annealed steel that can be sheared. The higher the tensile strength of the material, the lower the thickness capacity of the shear.

Shears must be of an appropriate size and of sufficient strength for the materials they are to cut. Because each machine is different, review the operator’s manual for the specific machine and note its capacity; there should also be a plaque on the shear stating the various material type capacities.

Knife Rake

The capacity of a squaring shear can be varied and sometime increased by adjusting the rake. The rake is the incline of the top knife from the bottom knife is rated as inches of rise per foot. On a fixed rake machine the rake remains the same throughout the cut. While the rake remains the same throughout the cut; while variable rake machines start with one rake and ends with another, figure 2.
The workpiece is sheared progressively across the length of the cut a small amount at a time. Without the rake the knives would require huge amounts of force, to cut the sheet with two parallel knives all at once. The opposite is also true; increasing the rake will lower the required shear force.

It should also be noted that as the rake increases distortions in the drop will also increase. The drop being defined as the portion of the workpiece that drops behind the shear.

A **fixed rake** shear will produce a better quality in a short cut length. A fixed rake machine produces better quality in long cuts. **Variable rake** machines are common with thicker materials; one-half inch and up. Changing the rake allows the shear to make better cuts on a wide range of thicknesses and materials. A lower rake equals a better quality and a larger shear load.

The rake makes the blades interact in a similar fashion as a pair of scissors, with only a small portion of the material being cut at any one time by the blades.

Because of the scissor action, a full sheet of material can be cut with the shear force remaining constant as the blade moves through the cutting or downward portion of the machine’s stroke. How far the shear blades penetrate into the material before the fracturing begins is determined by the hardness and shear strength of the material. The shear strength can be expressed as a the penetration factor or Burnish of the cut.

For example: a material with a penetration factor of 35% allows the blades to penetrate 35% of the material with the cut before the fracture occurs.

**Shear Burnish**

The shear “burnish” size is expressed as a percentage of material and defined as the distance penetrated by the knives before the fracture occurs, figure 3.

Note, the desired shear burnish is not the same for all material types. The following table gives the percentage of shear as a percentage of the material type.

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Rolled Steel</td>
<td>30%</td>
</tr>
<tr>
<td>H-series 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 1**

To achieve the proper burnish requires the knifes to be gapped a small amount.
Shear Knife Clearance

The clearance between the upper and lower knives determines the quality of the cut, the burnish and the amount of shear force required. But it is much more than just having some clearance. Too much clearance causes heavy burring and increased distortions; bow, twist and camber.

If the clearance is allowed to become too extreme, overloading can become an issue which causes damage the knives. Too much clearance is defined as clearances greater than 20% of the thickness.

If the clearance is too tight, 5% of the thickness or less, a secondary shear occurs. The burnish increases as much as 70% of the thickness in total, alternating burnish/fracture/burnish. Tight clearances can also increase tonnages dramatically.

It is best practice to set the shear gap at 10% of the material thickness. This should give the proper amount of burnish based on material type, table 1.

Proper clearance:

Below is a list of rules and extenuating circumstances for proper clearance.

- Rule 1) The thicker the material, the greater the amount of clearance that is required.
- Rule 2) The higher the tensile strength, the greater the amount of required clearance.
- Rule 3) Tool condition. Dull knives will have the same effect on shearing as having too tight a clearance.

Distortion

The parent sheet or plate is clamped in position by the hold downs and remains flat, while the portion extending beyond the knives, the drop, may show some form of distortion. If the drop is a trim piece, the distortion is irrelevant; but if the drop is a part, it becomes an issue. Note that when it comes to distortion, the narrower the width of the drop, the greater the chance for distortion, especially when shearing strips.

The three forms of distortion are Bow, Twist and Camber. Two are normally a function of the shear and one camber, is a function of the material.

Bow

Bow is described as the tendency for material to curl downward during the shearing process and is most prevalent when shearing long, narrow strips. It is caused by flaws or stresses in the material and by shearing at higher rake angles. Bow is a function of the Rake and can be reduced by lowering the angle of rake, figure 5.

If the shear is of the fixed rake variety, there’s not much you can do eliminate the bow.

It is also worth noting that the slower the beam moves, the longer the time that gravity has to create bow in the drop. Bow and twist are caused by the blade pushing the material down during the cutting process; this creates a “bending force” at the shear point.
Slower hydraulic shears allow the strip to hang during the cut. That hang is caused by gravity, and it has a tendency to increase the amount of bow and twist.

**Twist**

**Twist** is the shearing condition described as the tendency for the drop to attempt to curl into a spiral or corkscrew, figure 6. Twist can be caused by internal stresses and sometimes because of dull knives. A steep rake angle will increase the twisting action during the shearing process.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Increased twist</th>
<th>Reduced twist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material thickness</td>
<td>Thicker material</td>
<td>Thinner material</td>
</tr>
<tr>
<td>Hardness (tensile)</td>
<td>Soft material</td>
<td>Harder materials</td>
</tr>
<tr>
<td>Internal stress (material)</td>
<td>Greater stress</td>
<td>Reduced stress</td>
</tr>
<tr>
<td>Length of cut</td>
<td>Longer</td>
<td>Shorter</td>
</tr>
<tr>
<td>Width of drop</td>
<td>Narrower</td>
<td>Wider</td>
</tr>
<tr>
<td>Rake angle</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Beam speed</td>
<td>Slower</td>
<td>Faster</td>
</tr>
</tbody>
</table>

**Table 2**

**Camber**

**Camber**, unlike bow and twist, is a function of internal stress within the material. Shearing releases this natural stress which causes the material to deform slightly at the point of shear.

When the material being sheared moves away from the sheet horizontally, it is almost entirely the result of internal stresses within the material. Nonetheless, ram speed, **grain direction** and knife clearance can also have an affect on the amount of camber.

If you are shearing strips of highly stressed or inferior material these factors can also amplify the amount of camber. Only good quality, stress relieved or low-stress material can reduce camber in a cut.

**Run Out**

**Run out** occurs at the end of the cut as the knife blades “break” through the end of the material, just before the cut piece drops. It is the beveled area caused by the downward bending force created by the weight of the part.

Run out can be reduced or alleviated by using some kind of supporting structure or by increasing the rake angle, figure 8.

**Shear Load**

The load required to shear a piece of material is dependant on three basic factors: material thickness, shear stress, and the rake of the blade.
The square of the material thickness is equal to the load required to shear after factoring for the shear stress. The third factor comes from the machine itself and is the rake of the blade.

Shear Load (force) can be expressed in the following way:

$$\text{Shear force} = \frac{(S \times P \times Mt^2)}{(R / 12)}$$

$Mt = \text{material thickness}$  
$S = \text{Shear strength}$  
$P = \text{Penetration factor}$  
$R = \text{Rake of the top blade in inches per foot}$

In applying the formula to a given situation, notice the shear load increases rapidly as the material thickness increases. To go from a material thickness of $0.250$ to $0.375$ is a physical increase of $50\%$. However, the shear load will increase to $225\%$ should you try to shear material gauges greater than the rated capacity of the shear. Even if you try shearing short lengths, the resulting shear load could do a great amount of damage to the shear and the knives.

Some materials, such as soft aluminum alloys, have a greater shear load due to the increased penetration factor: the softer the material, the greater the distance the blade must penetrate into the material before the fracture occurs. Harder aluminums require less shear load because the blade doesn't need to penetrate as far for fracture to happen.

**Sag, Spudding and Supports**

The backgauge does not account for the sag in the workpiece from the knife edge to the backstop. This sagging can leave the sheared piece longer than the backgauge dimension. The problem is common when shearing light gauge material where the sheet does not have the strength to support itself. If this is the case, a sheet support system may be necessary to ensure good accuracy.

There are two ways of supporting the sheet; “Spudding”, or a sheet “support system”.

Spudding is a historical way of supporting the sheet. This is done by wedging a $2\times4$ wood beam between the underside of the sheet and the backgauge arm.

This method uses leverage to support the sheet. It is a very dangerous way to support the sheet because the operator is so close to the drop. Between the weight of the material and the sharp edges involved, injuries are likely, figure 9.

The other form of sheet support is much safer; it is a “Sheet Support System”.

**Sheet Supports**

This system supports the drop with a framework that rises up parallel to the lower knife (table) and moves in direct relationship with the shears movements. Once the cut has been made, the support system will set the material gently onto a pallet; no “dropping” is really involved.

This does not mean that all the danger has been eliminated. If caution is not used, cuts and crushed feet can still happen.

**Shearing Non-metals**

It is possible to shear some plastics, but if the blade passes through the material at too high of a rake angle, the
material will tend to fracture or crack ahead of the cut. To keep this cracking from happening, relieve (lessen) the angle of the rake. Doing so should cause the cracking to decrease or stop, but it will increase the shear load because more material is in contact with the blades. This also has the effect of lowering the capacity of the shear.

It should also be noted that shearing materials such as cardboard, paper or sandpaper will quickly dull your knives! Do not do it!