FORMING

SHEARING AND SLITTING STEEL SHEET AND STRIP

TECHNICAL BULLETIN TB-F2

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1 SHEARING AND SLITTING PROCESSES

Most steel sheet fabricating processes require blanks of suitable sizes to be cut from steel strip or sheet by straight blade shearing, rotary shearing or slitting. In these processes, two blades are forced in opposite directions against the steel workpiece, the two opposing forces being greater than the shear strength of the workpiece material.

Although a sheared or slit edge is inferior to a machined edge, good practices will produce an edge which is adequate for a wide range of end uses.

2 STRAIGHT BLADE SHEARING

Straight blade shearing or guillotining utilises a stationary lower blade and moveable upper blade. The workpiece is held securely in position between the blades by holddown feet which prevent any movement of the sheet during the cut. Shears are either mechanically or hydraulically operated, mechanical shears being more widely used. Details of the features and relative advantages of the two methods may be obtained from equipment manufacturers or agents.

To obtain optimum shearing performance the shears used should be of adequate capacity *(refer Section 2.1)* and maintained in good condition. The blades should be kept sharp to minimise burr, and the clearance between the blades set to give good edge quality. Some shears have an adjustable clearance feature. For shears which do not allow rapid clearance changes it is important to set the blades to a suitable clearance for the range of thicknesses to be sheared *(refer 2.3)*. If the thickness range to be sheared is wide it may be necessary to adjust clearance for groups of very thick to very thin steels.

When shearing BlueScope AQUAPLATE® steel sheet or strip, cutting blades must be sharp and clearance adjusted at 5% of the steel base thickness to give a clean shear of the polymer coating with acceptable burring of the metal substrate. This would also apply for shearing COLORBOND® prepainted steel with CORSTRIP® film applied.

2.1 Capacity of Shears

The capacity of shears is usually expressed in terms of the maximum thickness of annealed low carbon steel which can be cut. Steels with tensile strengths significantly higher than low carbon steel *(that is, above 450 MPa)* reduce the capacity of the machine. Table 1 shows the relative thicknesses of steel which can be cut for tensile strengths from 450 to 750 MPa compared to the thickness of annealed low carbon steel *(300-450 MPa)*.

Table 1 – Recommended maximum sheet steel thickness for shearing

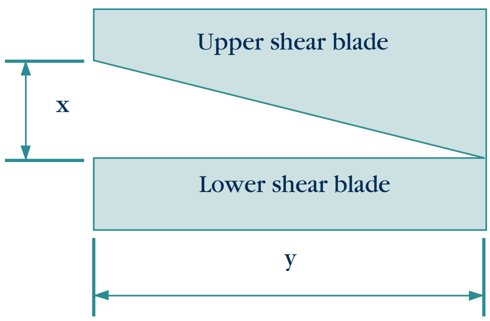
Steel tensile strength MPa	Maximum thickness for shearing mm						
	1.0	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	
Up to 450	1.0	1.5	2.0	2.5	3.0	3.5	**Shearing machine rate capacity maximum thickness mm**
450-550	0.9	1.3	1.7	2.1	2.5	2.9	
550-650	0.8	1.2	1.5	1.9	2.3	2.7	
650-750	0.7	1.1	1.4	1.8	2.1	2.5	

Shearing machine capacity is normally rated for annealed low carbon steel. Capacity reduces as steel strength increases.

2.2 Rake or Shear Angle

The maximum thickness which can be cut by a given shear can be increased by setting the upper shear blade at an angle to the lower shear blade *(Figure 1)*.

Figure 1 – Shear angle



The angle known as shear angle, or as rake, is defined as the ratio x/y. Where shear is used, the workpiece is sheared progressively a little at a time, rather than instantaneously, as is the case with parallel blades. Rake, therefore, reduces the shearing force required to cut a sheet of a given thickness. The maximum rake in common use is 1/8. As rake is increased further, distortion of the workpiece increases, and the holddown forces necessary to avoid slippage increase.

It is usual that high rake shears are less expensive than low rake shears of the same capacity, since the frame of the high rake shear can be made lighter. However, in selecting shears it is necessary to consider both capital cost and the levels of distortion which are acceptable in the sheared parts.

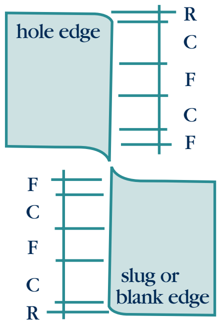
2.3 Shear Blade Clearance

The clearance between upper and lower shear blades determines the quality of the cut edge, and can influence shearing force.

Excessive clearance results in heavy burr, and where soft steels are being sheared, increased distortion of the cut edge. In extreme cases the workpiece can be pulled between the blades, causing overloading or blade damage.

Insufficient clearance results in secondary shearing and what is referred to as a Type 5

Figure 2 – Total Clearance 2-5% of steel thickness



KEY
Minimum rollover *(2-5% of thickness)* and a large burr.
Cut depth is 50-70% of thickness in two portions, alternating with fracture. Fracture depth is 25-45% of thickness in two portions.
Useful where edges must have a maximum straight-wall depth without secondary operations. Blade life can be extremely short.

edge *(Figure 2)*.

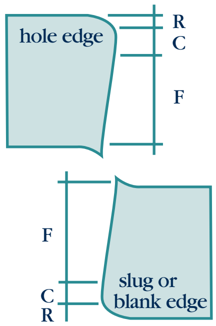
The optimum clearance results in a Type 3 edge *(Figure 3)*. Optimum clearance varies with both the mechanical properties and thickness of the workpiece but since most shears are used to shear a range of steels, a compromise clearance setting is usually required. Note that other sheared edge types are discussed in TB-F3.

It is common practice to set blade clearances at 10% of workpiece thickness. Where a range of thicknesses is sheared on the one machine, clearance is set at 10% of the mean thickness. However, there is a limit to the thickness range which can be accommodated by a single clearance setting.

Examples of clearance settings used are:

- Clearance is set at 0.05 to 0.07 mm for shears used for a number of products ranging from 0.40 to 0.80 mm thickness.
- Shears used for thicker products *(1.0 to 2.0 mm)* use clearance settings of 0.15 mm.

Figure 3 – Total Clearance 15-20% of steel thickness



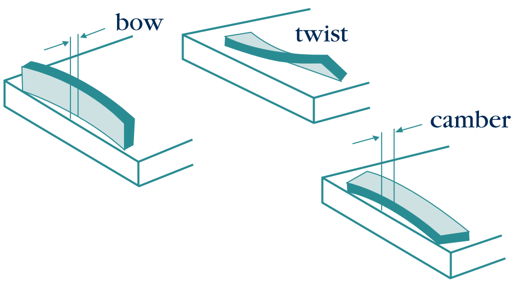
KEY
Small rollover (6-8% of thickness) and a small burr.
Cut depth 25-40% of thickness. Fracture depth is about 50% of the steel thickness and fracture angle is small (7-11°).
Radial stress is low, making the edge particularly suitable for use in parts made from work-hardenable material that will undergo severe forming. The clean, stress-free edge reduces the possibility of edge cracking during forming.

2.4 Distortion

During shearing, the part of the workpiece supported on the shear table remains flat but the part extending beyond the blades shows some distortion. This part is often scrap, but where it is the part to be used the degree of distortion becomes important. Distortion usually increases as the width of the sheared piece decreases, and is usually only a problem when shearing narrow strips.

Distortion takes three forms: bow, twist and camber as shown in Figure 4.

Figure 4 – Distortion of sheared strips



2.4.1 BOW

Bow is related to the blade rake angle, and can be minimised by reducing rake angle. However, depending on the capacity of the shear, it may not be possible to reduce the rake angle sufficiently to eliminate bowing completely.

2.4.2 TWIST

The factors affecting twisting are given in Table 2.

Table 2 – Factors affecting twist in sheared product

Factor	More Twist	Less Twist
Material thickness	Thicker	Thinner
Material hardness	Softer	Harder
Width of piece sheared off	Narrower	Wider
Length of material	Longer	Shorter
Material stresses	More stresses	Stress-free
Rake angle	Higher	Lower
Speed of knife	Lower	Higher

2.4.3 CAMBER

The tendency to camber increases as the width of the sheared strip decreases. However, in the thickness range below 3 mm, camber is minimal.

2.5 Shear Blades

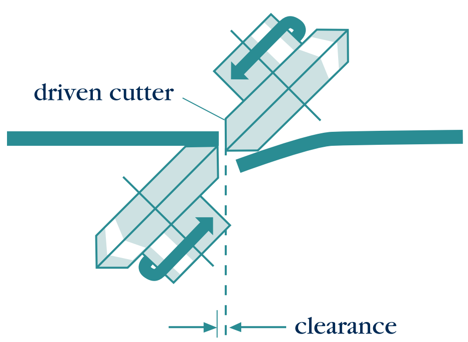
Shear blades are usually made from tool steel grades which exhibit good wear resistance combined with sufficient toughness to avoid breakage under impact loading.

The hardness of the blade is selected as a compromise between rate of wear and resistance to chipping or breakage. In general, the higher the hardness the better the wear resistance, but as hardness is increased there is an increase in the tendency for chipping or breakage. Blades made from air hardening high carbon/high chromium steel with hardness HRC 58-60 give satisfactory results when shearing low carbon steel over a wide range of thicknesses.

3 ROTARY SHEARING

Rotary shearing uses two revolving cutters as shown in Figure 5. This method is more often used for circle cutting but can also be used to cut other contours and straight lines.

Figure 5 – Cutter arrangement for rotary shearing



As with straight blade shearing, selection of correct clearance is necessary to obtain optimum edge quality and cutter life. Negative clearance, or overlap, can be used to produce a bevelled or partly bevelled edge if required. Penetration must be sufficient to give complete separation of the cut edge. Excess penetration, however, can increase cutter wear.

4 SHEAR LINES

Shear lines *(also called cut-up lines or cut-to-length lines)* produce accurately cut-to-length sheets from coil stock. A shearline generally consists of an uncoiler, a roller leveller to remove coil set, followed by a feeding and measuring system, shears and finally a stacking device for the cut sheets. The two basic types of shear line are those using stationary shears and those using flying shears.

In a stationary-shear line the strip is stopped and then cut by straight shears. Feeding is by hump table (*accumulates strip prior to shearing to length*) and gauge table, or alternatively by measuring feed rolls. This type of line is lower in cost and slower than flying-shear lines.

Flying-shear lines use moving shears to cut the strip as it moves continuously through the shear line. The shears are of two main types; guillotine shear and rotary drum shear. The guillotine shear is mounted on a moveable housing which moves forward with the strip while cutting and then returns to its starting position. The rotary drum shear utilises shear blades mounted on rotary drums above and below the strip. The shear blades are brought together as the drums rotate. Rotary drum shears operate at very high speeds.

Information on the relative merits of each type of line for a given range of products may be obtained from equipment manufacturers or their agents.

5 SLITTING

Slitting is the operation of cutting a wide strip into a number of narrow strips by passing the strip between circular cutters or blades, as shown in Figure 6.

Figure 6 – Cutter arrangement for slitting

5.1 Slitting Line Configurations

Slitting lines consist of an uncoiler for holding the wide coil, one or more slitters, and a coiler for simultaneous recoiling of all the slit strips. Slitting lines can be of two main types, pull-through or driven.

In pull-through slitting all the power for slitting and coiling comes from the coiler drive system. In driven slitters the power for slitting comes from the slitting machines, while uncoiler and coiler are separately driven.

The choice between the two types depends on steel sheet strength and thickness and on the quality of slit strip required. Driven slitters are often used where the strip to be slit:

a) has a low strength and is, therefore, likely to be locally stretched, or

b) is thinner than 0.40 mm and likely to tear in the pull-through.

While the lower cost pull-through system is the more commonly used method for the general range of steel products, the versatility of the driven system is a definite advantage in the slitting of products where optimum edge condition, minimum surface damage and a freedom from camber, distortion and residual stresses are required. Residual stresses can be present in strip slit by a pull-through unit and may cause problems where a high degree of flatness from edge to edge is necessary.

Combination pull-through and driven slitters are sometimes used where the versatility to slit a wide range of material types and thicknesses is required.

In many slitting lines the material forms a free hanging loop either before *(preloop)*, after *(postloop)* or before and after *(double loop)* the slitting head. Double loop slitting, using a driven slitter, is preferable for slitting electrical steels, since the stresses induced in pull-through slitters can be harmful to the magnetic properties of the steel. Residual or locked-in stresses are generally the cause of bowing in narrow sections formed in a press brake from pull-through slit strip, the thickness/width range of 1.6-2.0 mm/150-250 mm in low carbon steel being more prone to this effect.

5.2 Cutters

Cutters are arranged on parallel arbors. The distance between cutters is set by spacers.

They are usually made from similar material to shear blades *(see 2.5)*.

The clearance between cutters needs to be closely controlled to achieve optimum width accuracy and edge condition. Recommended clearances vary from 10% of material thickness to 7 - 8% of thickness where minimum burr is required. Suggested clearance conditions based on experience and published information are shown in Table 3.

Vertical overlap or penetration must be sufficient to give complete separation of the slit strips. However, excess penetration can increase cutter wear and increase burr height *(Table 3)*.

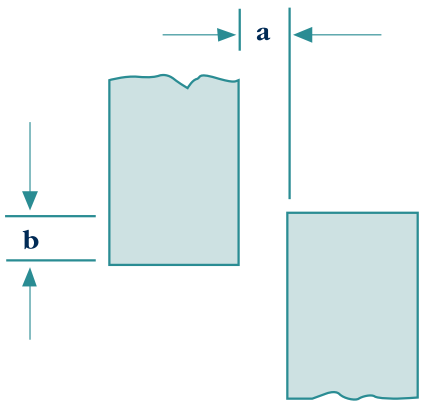
In general, optimum horizontal clearance will result in a Type 3 edge with minimum burr. Insufficient clearance will result in a Type 5 edge and excessive burr or edge crimping. Excessively tight clearance can result in damaged cutters or machine overload. Excessive clearance will result in a distorted, rolled edge with high burr.

The properties of the steel workpiece influence the horizontal clearance. Fully annealed low carbon steels usually require less clearance than high strength steels.

As with other sheared edges, a slit edge always exhibits a burr which increases in height as the cutters wear. Burr height can usually be minimised by close attention to rigidity of slitter head design, setting of vertical and horizontal clearances, and cutter resharpening practice.

Table 3 – Vertical and horizontal cutter clearances for slitting[1]

Steel sheet thickness mm	(a) Horizontal clearance mm	(b) Vertical overlap mm
0.25	0.018-0.020	0.10
0.50	0.038-0.050	0.20
0.75	0.055-0.075	0.25
1.00	0.080-0.10	0.35
1.25	0.10-0.12	0.45
1.50	0.12-0.15	0.55
1.75	0.14-0.18	0.50
2.00	0.16-0.20	0.45



5.3 Stripping

The shearing action between the cutters tends to separate the slit strips. To maintain the strip in a horizontal plane requires the use of strippers. Two commonly used stripping methods are:

a) timber or metal fingers inserted between the cutters

b) rubber or Neoprene rings fitted over the spacers that occupy the space between the cutters.

Clearance between cutters and strippers should be minimal. Excessive clearance between the stripper and cutter results in a rolled edge on the workpiece.

The use of rubber or Neoprene strippers for thin, soft steel sheet can cause surface indentations. For these applications timber fingers, with protective covering where necessary, are preferred. Tallowood fingers can be used for uncoated steels or for coated electrical steel where the insulating coating *(Coreplate)* has lubricant properties and is resistant to scratching. However, for most coated products timber fingers can cause surface scratching or scuffing, and therefore a protective covering is beneficial. Light felt and vinyl have been used to avoid damage to zinc-coated, ZINCALUME® zinc/aluminium alloy-coated and COLORBOND® prepainted steels.

5.4 Coiling

After passing through the cutters the multiple strands from the slitter are wound onto a mandrel. There are a number of alternative mandrel designs all of which must meet the following requirements:

a) The mandrel surface must be sufficiently smooth and free from irregularities to prevent marking of the wound slit coils

b) It must hold the end of the slit strip securely, and in such a manner that there is no marking of subsequent wraps

c) It must provide a reliable expanding and collapsing mechanism to allow trouble-free removal of the slit coils.

Two aspects of coiling which require special consideration are strip tension control and separation of the slit coils.

Both hot-rolling and cold-rolling produce strip which is characteristically slightly thinner near the edges than in the centre. As a result, on coiling the slit strips, the thicker slits are wound more tightly than the thinner slits. Uniform tension can be achieved by inserting a drag pad or bridle arrangement between the slitting head and coiler. However, the diameter of the coils from thin slits will then be less than those of thicker slits, with the result that excess length will accumulate between slitting head and tensioning device of the thinner slits. The excess length is usually accommodated by provision of a postloop pit.

With both drag pad and bridle rolls, care needs to be taken to avoid marking of products with critical surface finish, particularly prepainted products. Drag pads are covered with industrial felt or rubber-backed carpet to minimise damage to zinc-coated, ZINCALUME® steel or COLORBOND® steel.

Where provision for uniform coiling tension is not made, operators have developed the practice of inserting cardboard fillers between the wraps of loose coils. However, extreme caution is needed to avoid damage to soft, thin products when using this method.

Slit coils are separated on the coiler mandrel *(as shown in Figure 7)* either by large separator discs which fit between each slit coil on the mandrel, or more commonly by overarm separators, using tapered steel separator discs. In either case damaged separators must not be used as they can cause damage to the edges of the slit strip.

The distance between slitting head and coiler is important as it determines the angular displacement of outside slits relative to the centre line. Excessive angular displacement can cause camber in the slit coils.

Figure 7 – Coiling slit strip with separators

5.5 Lubricant

The use of lubricant, even sparingly, reduces cutter wear, improves stripping and enhances the effectiveness of drag pads in controlling uniform coiling tension. Lubrication can also reduce any tendency for drag pads to damage prepainted coatings. Do not use lubricants for COLORBOND® steel surfaces unless absolutely necessary. If it is absolutely necessary, use SHELLSOL T or an equivalent.

6 SLIT-SHEARING

There is an increasing demand for sheet or blanks with dimensions within the width range 350-600 mm and length in excess of 1200 mm. It is uneconomical to produce the master coil at these narrow widths, so the master coil width must represent two or three multiples. The blanks can be produced by shearing the master coil to the required length and then separately guillotining to separate the width multiples. Alternatively, the master coil can be slit and the slit strip then sheared on a normal shear line. However, there is another system available which combines slitting and shearing on the one unit by having a slitting head in-line ahead of the length shear.

Slitting and shearing in the one operation is often referred to as slit-shearing or slearing and has several advantages over the other two systems. As compared with shearing and guillotining, there is less labour involved and the slit width is more consistent than can be normally achieved by manual shearing.

Compared with slitting and shearing as two separate operations, the process cost is obviously lower and the quality hazards arising from the extra handling associated with the two separate operations are avoided.

Specially designed slit-shear lines are commercially available or in some instances, existing shear lines can be adapted to carry out the additional slitting function.

REFERENCES AND FURTHER READING

1. ASM Metals Handbook 9th Edition - Volume 14 - "Forging and Forming".

2. R. Usinger "Principles of Shearing" Modern Machine Shop, 64 - 73, Jan 1973.

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