

# BENDING AND FORMING OF TUBING

THE PRINCIPLES for bending tubing are much the same as for bending bars. Two important additional features in bending of tubes are that internal support is often needed, and sometimes support is needed on the inner side of a tube bend.

Wall thickness of the tubing affects the distribution of tensile and compressive stresses in bending; a thick-wall tube will usually bend more readily to a small radius than a thin-wall tube.

Table 2 gives the minimum practical inside radii for cold draw bending of round steel or copper tubing, with and without various supports against flattening and wrinkling.

## SELECTION OF BENDING METHOD

The four most common methods of bending tubing are basically the same as those used in the bending of bars; compression bending, stretch bending, draw bending, and roll bending. The method selected for a particular application depends on the equipment available, number of parts required, the size and wall thickness of the tubing, the work metal, the bend radius, the number of bends in the workpiece, the accuracy required, and the amount of flattening that can be tolerated.

**Table 2. Minimum practical inside radii for cold draw bending of annealed steel or copper round tubing to 180°(a)**

Tubing OD, in.	Minimum practical inside radius, in.		Cylindrical bending block without mandrel; ratio, <30(b) (poor conditions)
	With mandrel; ratio, <15(b) (best conditions)	With mandrel or filler; ratio, <50(b) (normal conditions)	
1/8 . . . . .	1/16	1/4	1/2
1/4 . . . . .	1/8	5/16	1
3/8 . . . . .	3/16	3/8	2
1/2 . . . . .	1/4	7/16	3
5/8 . . . . .	5/16	9/16	4
3/4 . . . . .	7/16	11/16	6
7/8 . . . . .	1/2	3/4	8
1 . . . . .	9/16	7/8	10
1 1/4 . . . . .	1 1/16	1	15
1 1/2 . . . . .	1 3/16	1 1/8	20
1 3/4 . . . . .	1 5/16	1 1/4	27
2 . . . . .	1 7/16	1 3/8	35
2 1/2 . . . . .	1 3/8	1 5/8	...
3 . . . . .	1 5/8	1 7/8	...
3 1/2 . . . . .	1 7/8	2 1/8	...
4 . . . . .	2 1/8	2 3/8	...

(a) Radii can be slightly less for a 90° bend, but must be slightly larger for 360°. (b) Ratio of outside diameter to wall thickness of tubing.

## TOOLS

Tools used for the bending of tubes are similar to those used for the bending of bars. One important difference is that tools for tubes need carefully shaped guide grooves to support the sidewalls and preserve the cross section during the bend.

For round tubes, the depth of the groove in the

form block should be half the outside diameter of the tube, to provide sufficient sidewall support. The block becomes the template for holding the shape of the bend. Form blocks can be made of wood, plastic or hardboard; if they are to be used for an extensive production run, they can be made of tool steel and hardened.

## BENDING TUBING WITH A MANDREL

Mandrels are sometimes used in bending to prevent collapse of the tubing or uncontrolled flattening in the bend. A mandrel cannot correct failure in bending after the failure has begun, nor can it remove wrinkles.

Five types of mandrels used in the bending of tubing are shown in Fig. 3. The plug mandrel and the formed mandrel are rigid, but the three other types shown are flexible or jointed to reach farther into the bend.

The largest diameter of the rigid portion of the mandrel should reach a short distance into the bend, the distance that it extends (past the tangent straight portion) depending on the kind of mandrel and the size of tube, and usually being established by trial. If the mandrel extends too far, it can cause a bulge in the bend. Conversely, if the mandrel does not extend far enough, wrinkles may form or the outer tube surface may flatten in the bend area.

The need for a mandrel depends on the tube and bend ratios. The tube ratio is  $D/t$ , where  $D$  is outside diameter and  $t$  is wall thickness. The bend ratio is  $R/D$ , where  $R$  is the radius of bend measured to the centerline.

Table 3 can be used to determine whether or not a mandrel is needed for bending steel tubing.

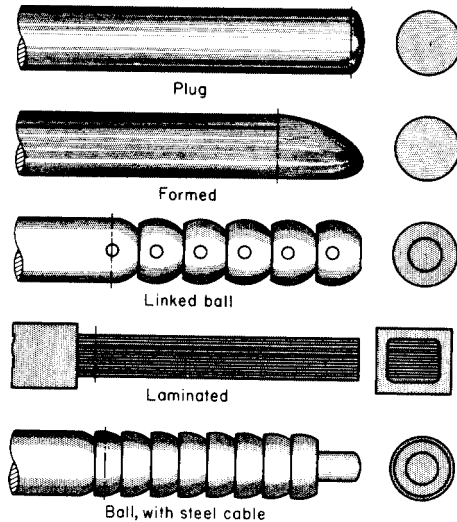
## BENDING TUBING WITHOUT A MANDREL

It is cheaper to bend tubing without a mandrel. Trial bending is generally necessary to find what bends

**Table 1. Typical lubricants for bending various metals**

Work metal	Lubricant
Low-carbon steel . . . . .	Water-soluble, vegetable-oil-base-drawing oil
Stainless steel and other high-alloy iron-base alloys . . . . .	Mineral-oil-base drawing oil
Aluminum alloys and copper alloys . . . . .	Mineral oil
Brass (severe bends) . . . . .	Soap solution
Hot bending of carbon, alloy and stainless steels . . . . .	Molybdenum disulfide

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**Fig. 3. Five types of mandrels used in bending of tubing. Broken vertical lines are points at which bends should be tangent to mandrel centerlines**

can be made. Tubing with thick walls is more likely to be bendable without a mandrel than thin-wall tubing. Bends with large radii are more likely to be formable without a mandrel than those with small radii. Slight bends are more feasible than acute bends. Wide tolerances on permissible flattening make a bend easier to form without a mandrel.

Springback is greater without a mandrel, but it can be compensated for by overbending, or lessened by increasing force on the pressure die.

## MACHINES

Powered rotary benders are commonly used to bend tubing as large as 8 in. OD. Capabilities exist for bending tubing as large as 12 in. OD with a 1/4 in.

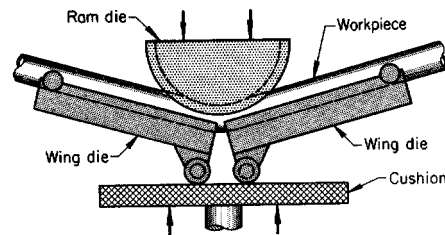
wall, and special power benders can bend 18 inch pipe.

Bending presses are hydraulic machines made

**Table 3. Minimum centerline radii for bending steel tubing without a mandrel**

Tubing OD. in.	Minimum centerline radius, in., for tubing with wall thickness, in., of:					
	0.035	0.049	0.065	0.083	0.093	0.120 <sup>1</sup>
3/16	5/16	1/4	3/16	...	...	...
1/4	1/2	3/8	5/16	...	...	...
5/16	7/8	3/4	5/8	...	...	...
3/8	1 1/2	1 1/4	1 1/8	1	...	...
1/2	2 1/4	2	1 3/4	1 1/2	...	...
3/4	4	3	2 1/2	2	...	...
1	8	6	4	3	2	2
1 1/2	...	...	12	10	8	6
2	...	...	...	24	20	16
2 1/2	...	...	...	...	24	20
3	...	...	...	...	...	25

especially for bending both bars and tubes, but most often for tubes. The ram of a bending press can be stopped at any point in the stroke. Wing dies and a cushioning device help to wrap the work around the ram die, as shown in Fig. 4. When the ram moves down, it causes the wing dies to pivot by a sort of camming action and wrap the workpiece around the



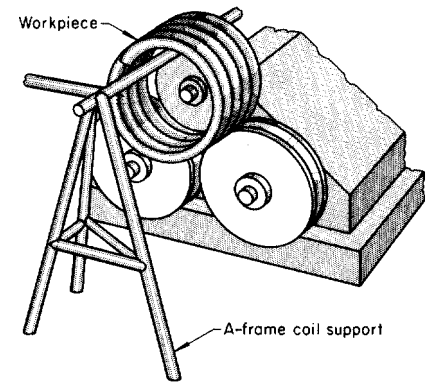
**Fig. 4. Essential components and mechanics of a bending press**

ram die. The wing dies wipe the work to control the flow of metal; a compression bend is made on each die of the ram die, without wrinkles or distortion.

Roll benders for bending tubes are similar to those used for bending bars, as described in the preceding article, but tolerances are more critical on the rolls and spacing. The contour of the rolls must match that of the tube to minimize wrinkling or flattening. Tubes of sizes up to 8-in. OD by 0.240 in. wall can be bent into arcs, circles or helices. An example of coiling a helix in a three roll bender is shown in Fig. 5.

## LUBRICATION FOR TUBE BENDING

Where a mandrel is used, both the mandrel and the interior of the tube are heavily coated with a thick lubricant. Pigmented lubricants are useful for adding body between the mandrel and the tube. Sometimes, thick lubricants are heated to 250 F and sprayed onto the inner surface of the tube. An oil hole in a mandrel can be used to lubricate the inside of a tube during bending.



**Fig. 5. Coiling a helix from round steel tubing by three-roll bending**