Tube Bending

Training Objective

After watching the program and reviewing this printed material, the viewer will be aware of the essentials of tube bending technology, methods employed, and the machinery involved.

- Types of tubing are shown
- Bending dynamics are illustrated
- Tube bending methods are demonstrated
- Tooling and machinery are highlighted

Tube Materials and Types

Metal tubing is used for a wide variety of industrial and commercial products. Tube materials include steels, aluminum, copper, and brass. Tubing shapes include round, square, rectangular, oval, and special shapes. Tubing may be produced by roll forming, drawing, and extrusion and they have a variety of seam configurations. Seams may be welded, open, lock-seams, or tubes may be seamless.

Tube stock is cut to length by either sawing, shearing, disc cutting, lathe cutting, or laser cutting methods. Once cut to size, tubes are processed into components by bending and/or tube end forming operations.

Tube Bending Basics

When tubing is bent to a specific shape or geometry, force must be applied so as to exceed the materials 'yield point', which is the material's capability to resist permanent deformation, while staying below the material's 'ultimate tensile strength', which is the limit of the material's ability to resist tearing. As the tube is bent over a specific radius the outside wall will stretch in tension while the inside wall bends under compressive forces. The boundary line through the center of the tube, between the tension and compressed zones is called the 'neutral axis'. The 'neutral axis' is the location from which all dimensional calculations are made.

Bending Operations

Tube bending can be done manually, semi-automatically, with CNC equipment, or with dedicated machines.

Manual bending involves minimum costs but is not reliable in regards to accuracy and repeatability. Manual bending is usually applied to tubing less than one inch in diameter or cross section. Semi-automatic bending uses machines with either hydraulic or electric motors providing the bending force. Typically the tube must be manually repositioned before each subsequent bend. Thus repeatability and accuracy may still be an issue. In contrast, CNC or computer numerically controlled machines incorporating servo-drives can accurately control the degree of bend, distances between bends, as well as the plane of the bend. Dedicated bending machines are designed for specific parts or families of parts.

During some bending operations an internal mandrel might be required to prevent excessive distortion on the tube wall. There are several types of mandrels including the plug mandrel, the form mandrel, the single-ball mandrel, and the multi-ball mandrel.

The mandrel is placed inside the workpiece at a position tangent to the actual beginning of the bend radius. The extraction of the mandrel after bending is facilitated by some form of extraction mechanism.

There are several different bending methods, the use of which depends upon the tube diameter, wall thickness, minimum bend radius required, and part complexity. These bending methods include:

- Rotary draw bending
- Compression bending
- Ram bending
- Roll bending

Rotary draw bending uses a movable bending form or die, along with a clamping die, a pressure die, and a wiper die, and is the most common tube bending method. Rotary draw bending can produce bends up to 180 degrees with standard tooling.

Compression bending is similar to rotary bending except that the bending form remains stationary rather than rotating with the workpiece. This method is used where there is minimum clamping space between bends.

Ram bending uses either a horizontal or vertical press to force a die or forming shoe to against a workpiece supported by supporting dies. These dies are also contoured like the die or forming shoe to match the profile of the tube. As force is applied the supporting dies rotate or swivel, following and supporting the workpiece during the forming cycle.

Roll bending is used to produce large radius bends on heavy walled tubing. Roll bending is not typically used to bend thin wall tubing due to the high degree of wall stretching and thinning that occurs with the process. Roll bending uses three forming rolls arranged in a pyramid configuration, either in a horizontal or vertical position. Each roll has approximately the same diameter and all are contoured to match the cross-sectional shape of the workpiece. Two of the rolls are fixed while the third is adjusted to determine the finished bend radius. Roll bending can produce a multiple radius part, full circles, and helixes on tube, pipe, solid, as well as extruded material.

Tube End Forming

Tube end forming methods are used to alter a tube at its end. Tube end forms are required for many applications, such as creating a connection to another component, such as a tube or fitting, or to achieve a close-tolerance fit for certain fluid-handling systems. There are many basic forms that can be applied to the end of a tube, including:

- Reduction
- Expansion
- Flaring
- Beading

In tube end reduction, the tube is typically held stationary on a ram-forming machine while a reduction punch is forced axially over the end of the tube to reduce the diameter. This reduction in diameter places the tube end section under predominately compressive stresses. Additionally, there is an increase in tube wall thickness and tube end length.

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In tube end expansion, the expanded tubular diameter is placed under predominately tensile stresses, resulting in a decrease in tube wall thickness and tube end length.

Tube end flaring is the opening, or expanding outward, of the end of a tube. There are several types of tube end flares, including single flares, which can be performed in a single set-up, and inside double flares, which use a two-flare punch operation within the same tooling.

Beading is a projection or projections used around a tube end to provide strength. Beading is commonly used for close-tolerance connections. Beads can be generated using a variety of methods, with bead rolling being one of the most common. Beads produced are of two types, external tube beads, and internal tube beads, which are also referred to as 'grooves'.

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Review Questions

1. The material's capability to resist permanent deformation is called:
   a. yield point
   b. ultimate tensile strength
   c. elasticity
   d. compression

2. The 'neutral axis' of the tube workpiece:
   a. follows along the outer tube wall
   b. follows along the inner tube wall
   c. is the boundary line between the tension and compression zones
   d. is at the point of tangency

3. The location of the 'neutral axis' determines:
   a. the maximum bend radius
   b. the minimum bend radius
   c. dimensional calculations
   d. the plane of the bend

4. Specific parts or families of parts, are often formed on:
   a. rotary bending machines
   b. roll benders
   c. ram benders
   d. dedicated machines

5. The purpose of a mandrel is to:
   a. set the basic bend radius
   b. prevent outer wall stretching
   c. increase tensile yield points
   d. control tube distortion

6. With standard tooling, rotary bending can produce bends up to:
   a. 120 degrees
   b. 90 degrees
   c. 180 degrees
   d. 270 degrees

7. Roll bending uses:
   a. 2 adjustable rollers
   b. 3 adjustable rollers
   c. 1 adjustable and 2 fixed rollers
   d. 2 adjustable and 1 fixed roller

8. The largest bend radii are accomplished by:
   a. compression bending
   b. roll bending
   c. ram bending
   d. a dedicated bending machine

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Answer Key

1. a
2. c
3. c
4. d
5. d
6. c
7. c
8. b