4. Tubular Structures

Tubular structures are used for rigid frames in a number of situations. The applications range from elevated walkways, lightweight roof trusses and space frames with large spans to offshore oilrig support structures (jackets). They include flare towers, bridges and crane booms. Rigid frames for motorcycles, racing cars and light aircraft are built using similar principles. This publication will however concentrate on structures such as those designed to AS 4100 or AS 4600, and including offshore structures. Tubes usually have circular, square or rectangular sections, although other shaped sections are possible. Section sizes (diameter or width) may be from 20mm to several metres.

The main reason for the selection of a tube rather than a solid section is that weight-for-weight, tubes are inherently rigid. The disadvantage is that connections between tubes are more difficult to make than for plate or hot-rolled sections.

4.1. Tubular Material

The material used for tubular structures includes circular hollow sections (CHS), rectangular hollow sections (RHS) and square hollow sections (SHS). These materials are available as cold-formed steel, to AS 1163 [Reference 1] with specified minimum yield stresses up to 450 MPa. Tubular structures may also be manufactured using rolled plate, stainless steels, high strength quenched and tempered steels and non-ferrous alloys.

Circular hollow sections are commonly available in sizes from 21.3 mm OD to 610mm OD. The standard tube diameters and wall thicknesses are not in exact metric units, because they are largely based on standard API (American Petroleum Institute) pipe sizes, which were determined using imperial measurements. This enables the manufacturer to make pressure piping to the same dimensions, and allows the substitution of pressure piping for CHS in some circumstances. The manufacture of small diameter tube to non-standard dimensions is possible, but is expensive and largely unwarranted.

Stock circular hollow sections can be formed as seamless tube by a process of billet piercing and tube drawing. Tubes made in this way have a limited length (12m) without butt-welding. The wall thickness may vary round the section because of eccentricity during the manufacturing process, which affects section properties.

Bending flat sheet or plate to the required shape and welding the edges together is used to make stock circular, rectangular or square hollow sections. These tubes therefore have a longitudinal weld seam, but apart from this irregularity have a more uniform wall thickness than seamless tube. Cold forming may be used during manufacture of carbon steel tube to AS 1163. This affects strength, toughness and ductility, but the steel has to meet minimum standards for these properties.

Unusual shapes are available as stock material, such as hollow rail (oval section) and trapezoidal sections. The ovals may find uses such as for ballustrading and handrails. The trapezoidal sections are produced to match the contours of silos with sloped sides, but may find uses elsewhere.

If the tube diameter exceeds that available in stock sizes, the fabricator can form tube from plate and weld the longitudinal seam.

4.2. Bend-forming of CHS, SHS and RHS

The bending of hollow sections to form curved components is complicated, yet is commonly undertaken on sections up to 410mm deep. The bending radius of a hollow section is usually expressed as the ratio of the centreline bend radius, to the depth (D) of the section in the plane of bending. The minimum bend radius is dependent on the following factors:

- The depth of the section in the plane of bending,
- The section thickness,
- The section shape,
- The material strength and ductility, which depends on the amount of cold work used to fabricate the hollow section,
- The bending equipment: surface shape and profile of formers and clamps, speed of bending, lubrication, whether a mandrel or packing are used,
- The desired appearance of the bend, and on the required sectional properties over the bent portion.

If the desired amount of bend is high, then trials should be undertaken using the intended material and bending equipment to determine feasibility and optimise technique. Suppliers of pipe material can provide much useful information. Tubes may suffer the following faults because of over-bending:

- Buckling or puckering on the compression side of the bend. This is unsightly and may adversely affect stiffness.
- Collapse and distortion of the section shape, such as round sections becoming oval, and rectangular sections becoming trapezoidal. The section will crush flat if the radius is tight and the sidewalls buckle.
- Cracking on the outside surface of the bend, particularly if the longitudinal weld is at this location.

Roll bending is used to cold-form gentle curves of radius 30D or greater. SHS and RHS can be formed using rolls to these gentle curves using flat three-point bending rolls. This technique can be used to bend to radii down to 10D if the rolls are profiled to suit the tube section shape. The profile of the rolls has to match the section profile to prevent distortion and collapse.

A draw bending or wiper forming machine is used to cold form tighter bends in CHS, RHS or SHS. In this machine, one end of the tube is clamped in a grip that is shaped to suit the section. The other end is free. A contoured forming roller is used to wrap the tube round a contoured former. This generates tensile stress along the length of the tube to prevent puckering. Further details of the arrangement are shown in Volume 1 of this publication. Bending radii as small as 4D are possible with this equipment if there is no internal mandrel or 2D if a mandrel is used to help support the tube during bending. These limits are dependent on the material being drawn.

An Engineer's Guide to Fabricating Steel Structures

Volume 2
Successful Welding of Steel Structures

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ISBN 0-909945-92-6
9 780909 945923

Contents