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Journal of Materials Processing Technology 179 (2006) 5–10

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Aspects of tube and pipe manufacturing processes: Meter to nanometer diameter

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Abstract

The use of tubes and pipes has a long history in different industrial applications. New methods for manufacturing tubes and pipes are developing and improvement of the existing manufacturing methods is continuing. Broadly speaking, the manufacturing methods of metal tubes and pipes can be divided as seamless and welded. Tubes and pipes manufactured through different routes have their specific advantages and disadvantages. Depending on the application requirements, tubes and pipes are manufactured in different sizes and shapes. The outside diameter of tubes and pipes could be several meters to even few nanometers. The tube and pipe industries face many challenges to produce high quality tubing in a cost effective and productive way in today's marketplace. Some of these challenges are requests for tube products in a wider variety of shapes and sizes by the end users, applications that require special materials, and demand for improved product quality from manufacturer. In this paper, different aspects of manufacturing, processing, design, utilization, quality control, handling, cost and safety in tube and pipe production are briefly reviewed to offer a general idea relating to these issues.
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Keywords: Tube; Pipe; Seamless; Welded; Manufacturing; Nanotube; Finite element

1. Introduction

Tubes refer to any shape of hollow material of uniform wall thickness and defined by the outside diameter and wall thickness dimensions. On the other hand, a pipe is one type of tube with the specific circular shape. Tubes can be of different shapes in cross-section like square, rectangular, oval, circular, conical or any special shape (e.g., hexagonal). In general, tubes and pipes refer to hollow sections with smaller and larger outer diameter, respectively. The outer diameter of tubes and pipes could be as large as several meters and as small as few nanometers. In today's technology tubes and pipes play an important role in many applications primarily for conveying of fluids and are made of diverse materials and dimensions according to the purpose for which they are intended, metal pipes being of the greatest consequence. Tubes and pipes have also found their way as structural elements in buildings, bridges, and automotive and aerospace industries. Modern materials for constructing tubes and pipes are principally divided into metallic and non-metallic. Metallic materials can also be divided as ferrous (e.g., cast iron, wrought iron and steel) and non-ferrous (e.g., copper, aluminum, brass, lead or alloys of copper, aluminum, titanium and magnesium). Whereas non-metallic materials include plastic, concrete, clay, wood, glass, paper and many others.

The tube and pipe industry faces many challenges in today's marketplace. Firstly, the end users are demanding tube products in a wider variety of shapes and sizes. The manufacturers of tubes and pipes face the complexity when the shapes required are other than regular ones and sizes become either very small or very large. Secondly, applications that require special materials such as titanium alloy are becoming more common and special techniques are needed to process them. Finally, improved product quality with reasonable cost is being demanded from every manufacturer. To meet these challenges, it is necessary to use optimized tooling and advanced manufacturing and quality control techniques. This paper briefly outlines different aspects of manufacturing tubes and pipes.

2. Tube and pipe manufacturing processes

Promising developments have been made over the past decades to master the manufacturing processes in terms of product quality, process quality, automation, etc. Various methods of manufacturing tubes and pipes from different materials are briefly described in the following sections.

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doi:10.1016/j.jmatprotec.2006.03.104

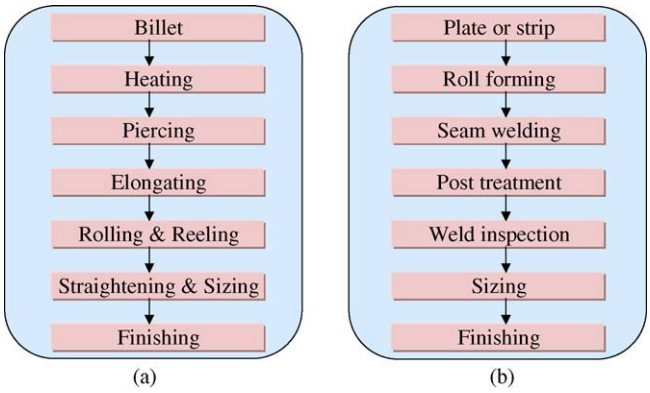

Fig. 1. Basic steps in manufacturing (a) seamless and (b) welded tubes and pipes.

2.1. Metallic tubes and pipes

The manufacturing processes for metal tubes and pipes can be divided into welded (seamed) and seamless.

2.1.1. Seamless tubes and pipes

The production process for seamless pipe begins by heating a metal billet at high temperature. The red-hot billet is rotated and drawn by rolls over a piercing rod or mandrel. The action of the rolls causes the metal to flow over and about the mandrel to create a hollow pipe shell. The shell is then moved forward over a support bar and is hot-rolled or cold-rolled in several reducing/sizing stands to obtain the desired wall thickness and diameter (Fig. 1(a)).

Seamless tubes are produced mainly for the applications where the ranges of wall thickness extend from small to large with the diameter range up to approximately 650 mm [1]. Hot extrusion process is also used for producing seamless tubes of approximately up to 230 mm outside diameter. Another method of manufacturing seamless tubes is casting, centrifugal casting being the most common method used to manufacture tubes and pipes from cast iron either grey or ductile [2]. Seamless pipe has outstanding homogeneity in the circumferential direction and is thus highly resistant to internal pressure and torsion. In the seamless tube manufacturing process, the life of mandrels is an important factor for producing quality tube consistently. While the advances in optimization of the mandrel position, roll geometry, rolling speed, etc. is continuing to reduce the wear of mandrels, deposition of advanced hard coatings on the mandrel also have significant effect on the extension of mandrel life.

2.1.2. Welded tubes and pipes

Welded pipe is made by bending metal strips (skelp) or plate into the form of a tube by roll forming and welding the seam by various welding processes (Fig. 1(b)). The diameter of welded tubular product ranges from approximately 6–2500 mm with a wall thickness from 0.5 mm to approximately 40 mm [1]. Currently around two thirds of the steel tube production in the world are accounted for by welding processes. Depending on the forming method, the manufacturing of welded tubes and pipes are classified as longitudinal and spiral (helical) seam. In contrast to longitudinally welded pipe production where each pipe diameter requires a certain plate width, spiral pipe production is characterised by the fact that various pipe diameters can be manufactured from a single strip or plate width with a ratio of pipe diameter to width of between 1:2 and 1:2.2. Large diameter pipe ranging from approximately 500–2500 mm is the current state-of-art in spiral welded pipe production [1]. Welding methods are improving for faster operation and controlled quality welding with laser-based vision and guidance systems and automated welding machines. Optimisation of edge shape is required to obtain a sound welding zone without any deformation and thickness reduction at the edge during the roll forming of thick plates [3].

After manufacturing tubes and pipes are processed through several operations such as annealing, coating deposition, cutting, bending, straightening, forming, etc. to make it suitable for any particular end applications. Tubes and pipes are cut into required sizes using sawing, lathe cutting, rotary cutting, etc. Laser cutting is becoming popular where high precision and smaller cutting width is necessary. Tube hydroforming [6] is achieving increasing acceptance in the automotive industry for making a wide variety of components including suspension frame, body structure, power-train components and exhaust pipes (Fig. 2(a)). Laser forming [7] have also been developed to make a precise and complex shape of tube by a controllable laser beam without pre-processing. Computer numerical control (CNC) bending is being used for automatic operation with precise control of shape and size (Fig. 2(b)).

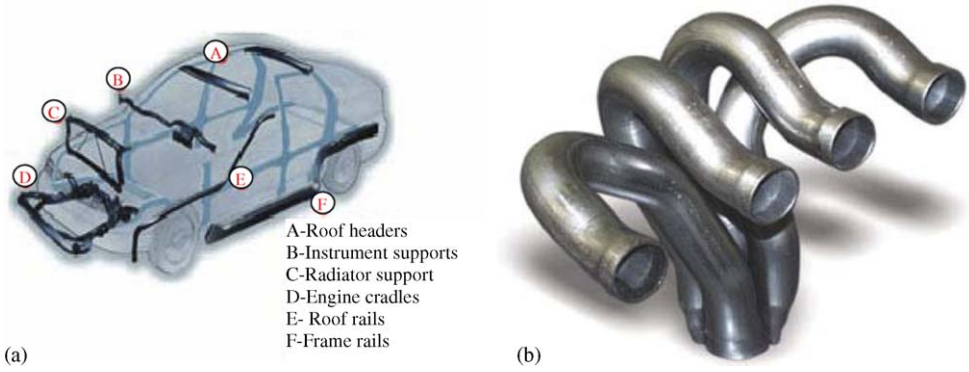

Fig. 2. (a) Hydroformed tubular parts for automotive applications [4] and (b) rotary draw bent tube [5].

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