

1

3,409,068

METHOD OF CONTINUOUSLY CASTING TUBES USING A ROTATING MANDREL

Douglas C. Yearley, Westfield, and Harry H. Stout, Jr., Plainfield, N.J., assignors to Phelps Dodge Copper Products Corporation, New York, N.Y., a corporation of Delaware

Continuation-in-part of application Ser. No. 468,771, July 1, 1965. This application Mar. 1, 1966, Ser. No. 530,869

4 Claims. (Cl. 164—85)

ABSTRACT OF THE DISCLOSURE

Tubing is continuously cast by solidifying molten material as it is withdrawn from a casting zone defined by a rotating central mandrel and a surrounding mold.

DISCLOSURE OF INVENTION

This application is a continuation-in-part of an application by Douglas C. Yearley, Ser. No. 468,771 filed July 1, 1965.

This invention relates to a method and apparatus for the continuous casting of hollow metal tubes. It has particular reference to apparatus for such casting which includes a rotatable mandrel and to the related method.

Continuous casting of tubes comprises the uninterrupted flow of molten metal to one end of a casting mold, uninterrupted withdrawal of solid metal from the other end of the casting mold and the removal of heat from the metal to solidify it as it is formed into the desired sectional shape during passage of the metal through the mold. Tubing is cast continuously by the use of an inner core or mandrel positioned within a cylindrical mold or die. The molten metal is supplied under pressure or by gravity feed to the annular space between the mandrel and the cylindrical mold. The mold is cooled to solidify the metal, and cast tube is drawn from the mold by rollers or the like which grip the outer surfaces of the tubing.

In general, the relatively slow rates of continuously casting tubing in prior apparatus and the poor quality of such tubing are serious problems which heretofore have made it economically impractical to continuously cast tubing for direct fabrication into commercial tubing. Those problems are due in part to adhesion of the metal to the surfaces of the mold and the mandrel and to shrinking of the metal on the mandrel during the cooling and solidifying phase of the process. These difficulties have persisted despite various counteracting measures which have been attempted, such as vibrating the mold and providing the mandrel with a taper in the direction of the metal movement through the mold.

Other factors which have precluded extensive use of continuous tube casting for direct fabrication to commercial tubing include the difficulty in starting the tube casting process, the tendency for the cast tube to have an intolerable degree of eccentricity and lack of control over the solidification process in the mold during the casting operation.

Control over the solidification process is important since the process of solidification, including the rate of solidification and the position and stability of the solid/liquid interface, determines the properties of the resulting tubing such as surface quality, tensile strength, elongation, grain size, etc.; and lack of control of that process will, of course, give poor properties in the tubing.

2

This invention provides an improved apparatus for the continuous casting of tubes and a new method for such casting, which will allow for the manufacture of high quality tubes on a commercial and economical basis. It eliminates start-up difficulties, provides a concentric tubing of good quality which may be rapidly and economically fabricated into commercial tubing. Another important aspect of this invention is that it permits the molten metal used to form the tubing to be fed to the casting mold by gravity without any need for metering that flow or the use of a feed spout to deliver and position the metal in the mold.

According to the present invention, the mandrel is mounted for vertical movement relative to a mold which is fed from a molten pool of metal maintained in a reservoir above the mold. The mandrel is adapted to permit rotation relative to the mold. In starting the tube casting operation, molten metal is first fed to the mold from the overlying reservoir while the mandrel is in a withdrawn position whereby solid rod is drawn initially from the exit or lower end of the mold; and then, as the feed of molten metal is continued, the mandrel is lowered through the reservoir so that the tapered lower end of the mandrel enters the mold to a depth sufficient to effect transition from rod to tube casting. The mandrel is guided in its vertical movement by guide means adjustable laterally to effect accurate centering of the mandrel relative to the mold.

According to our method, rotation of the mandrel with respect to the mold, either in a clockwise or counterclockwise direction or with rotational oscillation, has been found to improve substantially the metal grain and thus the ductility of the inner surface of cast tubes. We believe that any such mandrel rotation, within limits as to the rotational rates, will improve the ductility of the inner surface of a tube cast according to our method. When castings are made without any form of mandrel rotation, the inner surface of the tube lacks ductility and may crack when subjected to plastic elongation (i.e. an internal bend test or a standard tensile test). These cracks also develop as laps on the internal diameter of the tubing during cold drawing, causing the resultant finished tube to be rejected as defective. When tubes are made with a rotating mandrel, no cracking occurs in the internal diameter when elongated and the casting can be successfully fabricated.

The direction of rotation of the mandrel according to our method may be clockwise or counterclockwise or it may be oscillatory wherein the direction is reversed periodically. Such reversal may occur after less than a complete revolution, at the end of each revolution, or at the end of several revolutions. Satisfactory castings have been obtained over a wide range of rotational speeds up to 900 r.p.m. The preferred range appears to be between 10 and 100 r.p.m.

As stated, mandrel rotation according to our method will improve the ductility of the inner surface of the cast tubing. However, the manner of rotation of the mandrel may induce or reinforce an adverse swirl effect upon the outer surface of the tubing, which also must be considered to determine the optimum manner of rotation of the mandrel.

While mandrel rotation above a minimum rate and not at excessive rates will improve the ductility of the inner surface of a tube cast according to our method, if the rotation of the mandrel reinforces the swirl which would otherwise exist, cracking may occur in the outer surface of the tube. Mandrel rotation which minimizes the swirl is therefore generally preferred.