APPARATUS FOR THE PRODUCTION OF TUBULAR METALLIC OBJECTS

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This invention relates to the production of hollow or tubular metallic objects by a continuous process, and more particularly to means for directly producing such objects from molten metal. The resulting hollow metallic objects obtained according to the invention may serve best directly as finished tubular articles or they may serve as blanks to be eventually subjected to additional machining or other finishing operations.

The production of steel tubing by conventional methods involves a complex sequence of steps requiring the use of extensive and expensive equipment. Such conventional steps may by way of example be summarized as follows:

a. The metal is first melted and refined in a furnace or a converter;
b. The molten metal is then cast in ingot molds;
c. The ingots are rolled in a blooming mill;
d. Top and bottom ends are lopped off for removing bloom portions showing pipes, segregation, cracks, blowholes and similar defects all resulting from the discontinuous manner in which the ingots were cast;
e. In some cases the blooms are re-heated;
f. The blooms are then rolled into round bars and cut to length;
g. The lengths of round bars are heated;
h. The heated bars are rolled in a drilling mill; and
i. The resulting tubular blanks are passed in a finishing mill.

The resulting over-all cost of the tube is very high, especially owing to the following factors involved in the above described operations:

1. High depreciation and maintenance costs of the plants;
2. Considerable man-power, energy and fuel requirements;
3. Considerable loss of material incurred in the respective stages of manufacture: For example, as stated, the end portions of the ingots must be lopped off; also the ends of the round bars must be saved off; further losses are incurred by oxidation during the successive reheating treatments. The overall weight ratio from the molten metal required to the completed blank may be put at about 1500/1000.

It is an object of this invention to overcome the above objectionable features of conventional tube making processes and more particularly to produce blanks directly from the molten metal, thereby eliminating all the above-noted steps (a) through (i).

Another object is to produce directly and without delay finished metallic objects of tubular or hollow form. According to the invention, molten metal is directly poured into one end of a revolving mold open at both ends in which the metal is allowed to solidify; the solidified metal casting is continuously withdrawn from the mold through the other end thereof, the rate of withdrawal being regulated in correlation with the rate at which the molten metal is fed into the revolving mold. With the arrangement described, the metal fed into the mold in liquid state is immediately and forcibly applied against the inner walls of the mold by centrifugal force and is thus caused to assume, as it solidifies, a shape conforming to that of the internal wall of the mold while retaining an axial recess. Force is exerted at the outlet of the mold on the solidified portion thereby to extract the resulting hollow blank in a continuous way, thus at the same time clearing the top of the mold a free space which will receive the fresh molten metal continuously fed to it in order to provide a continuous tubular body. A tube of unlimited length is thus produced which as a practical matter is of course cut off into sections of any desired length without requiring discontinuation of the process. An important advantage is the possibility of thus producing tube sections having any desired length whatever. Another important advantage is that substantially no loss of metal is incurred throughout the process.

In addition to the economical advantages of the method of this invention, there is the further valuable feature that products of improved characteristics are obtained as a result thereof. Owing to the centrifugal effect, the resulting blanks are uniform in thickness and are highly homogeneous in structure and composition.

The invention is applicable to all metals, both ferrous and non-ferrous. In this respect, its use is especially advantageous in connection with metals unsuitable for rolling, such as very high-carbon steel, grades of alloy steel having a high nickel content, a high chromium content, and the like, cast iron, unforgeable grades of bronze or brass, etc. Thus the invention provides a new technique for producing tubular objects from all such materials from which it was hitherto difficult or impractical to produce such objects by the conventional processes owing to the poor working characteristics of the materials.

According to an important further object and feature of the invention, in contradistinction with the known methods of tube manufacture involving a series of successive, discrete steps or operations, the present process comprises but a single integral operation comprising a series of simultaneous phases correlated with one another in a harmonious manner, viz.: feeding molten metal to the rotating mold, centrifugal action within the mold, molding, solidification and discharge out of the mold.

The mold is preferably provided with an auxiliary adjustable cooling means for adequately cooling the tubular blank being formed by centrifuging. This cooling results in a contraction which separates the solidified tube from the inner mold wall and facilitates withdrawal thereof in a continuous and smooth manner.

Owing to the continuous solidification and extraction, the phase of feeding metal to the mold may be performed in a smooth and continuous way, and the semi-solid or solid metal serves as a support for the liquid metal delivered into the mold and forced against the wall thereof during the rotation imparted to it.

It has heretofore been suggested to produce tubes by so-called continuous casting processes where by a tubular blank or finished tube may be produced from molten metal in an appropriately constructed suitably cooled mold. In these old methods, however, no rotary mold was provided, and the use of an internal core or mandrel was therefore indispensable. It is an object and a feature of the present invention to provide a revolving mold which owing to the centrifugal effect developed will promote easy, positive and reliable formation of a hollow tubular body.

I am also aware that the use of centrifuging has been proposed for the production of hollow or tubular articles from liquid metal. However, conventional methods of this character and the devices used in carrying them into
practice have only made it possible to produce blanks or tubes of very restricted length, by a discontinuous and intermittent process, resulting in a considerable proportion of scrap, shut-downs and idle periods, leading to a low overall efficiency ratio and high cost.

Furthermore, an object and a feature of the invention reside in the use, in conjunction with conventional centrifuging pipes making processes of the discontinuous or batch type, a continuous discharge of the formed pipe correlated with the continuous feed of the molten metal. When, therefore, a centrifuging process was applied in discrete alternating steps, according to the invention centrifuging is applied in combination with a continuous pouring phase and a simultaneous continuous discharge or extraction phase, whereby a tubular casting of unlimited length is produced which can be cut to desired lengths independently of its production in a subsequent step or phase of operation, as dictated by requirements of shipping or of service.

The invention will now be described in greater detail with reference to some specific embodiments of apparatus usable in carrying it into practice, it being understood that said embodiments are given by way of illustrative examples and are in no way restrictive of the invention's scope. In the accompanying drawings:

Fig. 1 is a general diagrammatic view of one form of embodiment;

Fig. 2 is a more in detail the construction of a modified form of rotary mold used in the embodiment of Fig. 1, as seen in section;

Fig. 3 depicts the continuous feeding phase of molten metal into the mold;

Fig. 4 shows an alternative system in which the said continuous feeding phase may be embodied;

Fig. 5 relates to the discharge phase for continuously extracting the tubular casting from the mold; and

Fig. 6 illustrates one form of cutting means.

As shown in Fig. 1, the invention comprises in combination, means for continuously feeding molten metal, a rotary mold and a continuous extracting or discharge device for extracting the solidified blank formed in the mold.

The continuous feed means comprises a pocket supplied with molten metal from any suitable melting apparatus or furnace not shown. The pocket may have re-heating means associated with it, such as heating resistors, high frequency induction heating coils or the like.

Such means are well-known in the art and have not been illustrated. Formed in the bottom of the pocket 14 is an outlet delivering into the top inlet of a funnel, chute or runner 16 terminating in a jet outlet 17 adapted to discharge the liquid metal at a point adjacent to the inner wall of the rotary mold 12 in the form of a generally circular jet or sheet. A suitable control member 18 is provided for regulating the discharge of liquid metal delivered into the mold.

The rotary mold 12 essentially comprises a shell generally of cylindrical form. Integralely connected with the shell is a gear annulus 20 meshing with a drive pinion 21 driven from any suitable drive means, not shown. Surrounding the cylindrical surface of the mold shell 19 are a plurality of jet pipes 22 from which a coolant fluid may be discharged on the periphery of the shell.

The continuous extraction assembly 13 may assume any of various forms. As shown by way of example in Fig. 1, it comprises a set of rollers 23 rotated on inclined axes. The angle of inclination of the roller axes is adjustable as is also the spacing between the peripheries of the rollers. The angular rate at which the rollers are simultaneously rotated is also adjustable so that, for any given diameter of piping being made, the linear tangential speed of each of the rollers 26 can be made equal to the tangential speed of the inner wall of the rotary mold 19.

It will be seen that with the above described arrangement, molten metal discharged from the feeder 11 into the mold 12 which is revolving at a constant speed, is forcibly applied against the inner wall of shell 19 and quickly solidifies thereon under the cooling effect of the surrounding air and/or the coolant fluid delivered from 22. A tubular blank or cast blank A is thus continuously formed. This blank A is continuously fed out of the mold progressively as it forms and solidifies on the walls of the mold, under the action of the rollers 23. The blank as it is fed out of the mold continuously clears a free space at the top of the shell 19 adapted to receive a fresh supply of molten metal from the jet 17. Although description of the process necessitates the recitation of discrete steps, the cycle will of course be understood to be continuous, involving the simultaneous correlated phases of feeding centrifuging, molding, solidification, and discharge. A continuous tubular casting is thus produced.

This continuously cast blank A is of course cut to desired lengths by any suitable means, as by sawing, blow-pipe or the like.

By acting on the angle of the axes of rollers 23 with respect to the axis of rotation of the mold, the rate at which the blank A is extracted from the mold 12 may be controlled in correlation with the rate at which molten metal is fed into the top of shell 19. The adjustment of this rate of feed is further completed by means of the control member 18 cooperating with outlet 15. The resulting tubular blank A is then cut into lengths of suitable size for treatment by the usual rolling, drawing and other working steps for converting the blanks into pipes of the requisite dimensions.

In one form of embodiment (Fig. 2), the rotary mold comprises a shell 24 supported by an upper taper bearing surface in a corrected relationship to a rotary member 26 and by a lower cylindrical bearing surface 27 with respect to a second rotary member 28. This arrangement makes it possible readily to remove the shell 24 by pulling it upwards for replacement or other purposes, without having to dismantle its drive mechanism or other accessory parts.

The shell 24 is connected for rotation with the rotary members 26 and 28 through suitable cooperating stops or projections. The members 26 and 28 are driven in rotation through gear annuli 29, 30 meshing respectively with pinions 31, 32 secured on a shaft 33. Shaft 33 is driven through pulley 34 from a suitable source of motive power. The rotary members 26, 28 are supported from a frame comprising the frame elements 35-36 and top element 37, through suitable ball, roller or needle bearings 38. A cover plate 39 is provided for sealing the central aperture in top frame element 37.

Within the rotary member 26 separate circular conduits 49, 41, 42, 43 are provided, supplied with a suitable cooling fluid such as water which is delivered on to the outer surface of shell 24 through suitable nozzles directed inwardly from the circular conduits. The circular cooling pipes are preferably each provided with its control valve, not shown. The cooling liquid impinging on the outer wall of mold shell 24, streams down the wall and flows down the drip-surface 44, collecting in an annular trough 45 whence it is discharged through drain pipe 46. The shell 24 is provided with an inclined drip-flange 47, and the surface 44 has an overlying drip-plate 48 thereon to allow discharge of the cooling fluid while preventing its ingress into the underporting portions of the mechanism. An additional circular cooling pipe 49 with discharge nozzles or apertures therein may be provided at the top of the shell above the cover plate 39. The mold assembly thus provided is secured to the general frame of the machine or to suitable supporting structure by means of a base flange 50.

It will be noted that according to the arrangement described the mold shell 24 is so mounted as to allow free
expansion thereof relative to its supports. To this end the necessary clearance is allowed for where required. As stated, the shell can readily be removed and replaced. For this purpose, it is only necessary to remove the protecting plate 39 and pull the shell upwards.

Partly shown on an enlarged scale one embodiment of the means for continuously feeding molten metal into the rotary mold. The pocket 14 serves for the liquid metal and supplies the mold through outlet 15, nozzle 56 and removable nozzle 17. Outlet 15 is provided with a sealing plug 18, supported from a shank 52, this plug assembly being adjustable in the up-and-down direction. The plug assembly serves to complete the fine adjustment of the rate of feed for accurate correlation thereof with the rate of discharge of the centrifuged and solidified blank A.

The pocket 14 is internally lined with refractory material or any other suitable lining composition 53 in which heating resistor or induction coil element 54 are shown as imbedded.

In the construction illustrated, the mold shell 24 is provided at its lower end with a circular metal casing 55 provided with a refractory lining 56 so as to define a circular chamber 57 into which the molten metal discharged from nozzle 17 is delivered. Owing to this arrangement, the molten metal as it impinges on the surface of shell 24 is retained, and forcibly applied by centrifugal force into the annular chamber or groove 57 which it first fills up and whence it then overflows in the form of an annular sheet into the mold proper 24. In this way a continuous and uniform supply of metal into the mold is obtained.

Inert or reducing gas may be admitted into or produced locally by incomplete combustion of hydrocarbons in the mold chamber adjacent to the groove 57 and the entire upper part of the inner space of the blank. This will assure that the feed of molten metal and the formation of the inner wall of the tubular blank being produced, will occur in a suitable nonoxidising atmosphere.

A smooth continuous feed is insured by maintaining a constant level of the molten metal in the pocket 14, and for this purpose the pocket 14 may be supplied from a further pocket or ladle filled from the melting furnace, the metal being poured from the ladle either directly or by means of a stopper-rod into the pocket 14, and the outflow section of the removable nozzle 17 being suitably predetermined.

In the modified form shown in Fig. 4, the pocket or crucible 14 is fixed and is formed in its bottom with an outflow surface 58. Secured within the rotary mold in the upper part thereof is a bushing member 59 sealed by an end wall 60 at its lower end and internally lined with refractory composition. Formed through the sides of the bushing member are ports 53 which open outwardly adjacent to the annular chamber 57 in which the molten metal first collects upon admission thereof into the mold 55-56.

The outer diameter of bushing member 59 is substantially equal to the inner diameter of the tubular blank A to be produced; in other words, between the bushing member 59 and the inner wall of mold 55 a space is defined which corresponds to the skin thickness of the blank A.

In this form of embodiment, the annular chamber 57 rather than being provided with straight walls, is preferably formed with a curved configuration in cross section. Thus, its upper wall section is shown as substantially being in the form of a paraboloid of revolution 84 having its focal point at 85 on the same level with the free surface of the molten metal in bushing 59. This paraboloidal section merges at 86 over an arcuate section 87 with the cylindrical inner wall section of mold 24.

As shown, the fixed crucible 14, fed with metal from the melting furnace through the shoot or runner 88 discharges through outlet 58 a vertical jet of molten metal 89 which drops down on to the bottom wall 60 of the bushing member 59 revolving at a high rate with the rotary mold 24. The section area of outlet 59 is so adjusted as to cause the incoming metal to collect on the lower end wall of bushing member 59 up to the level 85 before the steady operating condition of the system has been established. Under the combined effect of the load produced by the jet 89 and of centrifugal force, the molten metal is discharged outwards through the ports 83 and against the curved section 84 of annular chamber 57. Owing to the configuration of this section, the liquid jet is so to speak reflected downwardly in a vertical direction into and through the annular space defined between the inner wall of mold 24 and outer wall of bushing 59. There is in this way created an annular sheet of molten metal continuously supplying the mold 24, thus promoting a smooth regular flow of metal and formation of the blank A.

The blank A formed by centrifugal action on the molten metal thus supplied in the embodiment of Figs. 3 and 4, solidifies owing to the cooling effect of the wall, as shown in Fig. 2, and is extracted from the rotary mold in a continuous manner by suitable extracting means exemplified in Fig. 5. This figure shows only one (the right) half of the whole system in section, the other (left side) half being symmetrical with respect to the right side half shown in detail.

The means for extracting the blank A comprise rollers 61, provided in any suitable number, and mounted with their axes forming equal, adjustable angles with respect to the axis of the system. Each roller 61 is secured on a spindle 62 mounted in bearings 63, 64 in a cylindrical cage or bushing member 65. The member or bushing 65 is mounted for rotation about an axis 66 in a support 67. The bushing member 65 may be rotated relatively to the support 67 by suitable means such as the worm 68 operable from outside the assembly. In this way any desired angle of inclination may be imparted to the spindle 62 with respect to the axis of the blank A in order to impart a selected value to the rate of discharge of the blank from the mold.

The support 67 is mounted for sliding movement along the surface 69 with respect to the frame 70 in a direction parallel to the axis 66. The support can be thus displaced by means of a screw 71 operated by a hand-wheel 72 rotatable on a cover flange 73 secured on frame 70.

Rotation of the hand-wheel 72 produces a transverse displacement of the support 67 which carries the bushing 65 and roller 61 with it. In this way the spacing between the rollers 61 may be adjusted in relation to the diameter of the desired blank and thereby the clamping pressure exerted thereon may be controlled, this having the further advantage of regularizing the thickness dimension of the blank owing to the latter's malleable condition. Roller 61 may be driven in rotation by an individual motor, or as shown swivel shanks 74 may be used cooperating with gear cases of a type conventionally used in rolling mills, or by any other suitable drive means. The speed of rotation of the rollers is preferably made adjustable. By varying the speed of rotation of the rollers 61, it is possible to impart to the blank a rate of rotation slightly different from that imparted to the rotary mold, thereby facilitating the extraction of the blank from the mold.

The continuous tubular blank thus extracted by the rollers 61 is then cut into sections by any suitable means. In one desirable embodiment of the cutted sections, the blank is locally heated by suitable heating means such as gas burners, heater resistances or the like, and a jet of oxygen 80 is applied to the area thus heated to a suitable red-hot temperature. This fuses the metal at the point of impact of the oxygen jet and provides a clean cut at the desired point of the blank.

In the construction shown in Fig. 6, a flange 75 is slidable on guides 76 extending parallel to and spaced to either side of the discharge path of the blank out of the mold, the flange supporting an annular pipe 77 provided with burner outlets or nozzles 78 supplied for ex-
ample with acetylene and oxygen through the flexible hose connections 79, 80. Also attached to flange 75 is a jet-nozzle 81 supplied with oxygen the jet from which is effective to sever the metal preliminarily heated by means of the burners 78.

The assembly comprising flange 75, and arcuate pipe 77 and nozzle 81 attached thereto is slideable on guides 76 in order to be enabled to follow the feed displacement of the blank during the heating and cutting operation. The displacement of the assembly along the guides 76 is synchronized with the displacement of the blank A through any suitable automatic means, readily devised by those familiar with the art, as for instance by providing the flange 75 with sliding arms adjustable in length and provided with retractable hogs cooperating with abutting stops. The spacing between the stops and the arcuate heating pipe 77 will vary according to the length of the desired pipe sections into which the blank is to be cut.

The flange 75 with its associated attachments is preferably balanced by means of a counterweight acting to urge it to its initial (uppermost) position after the cutting operation has been completed and the severed pipe section has been discharged.

The details of the embodiments described and illustrated are in no way restrictive and may be widely modified within the scope of the claims. While the invention has been more particularly described as applied to the continuous production of tubular blanks, this term should be understood in its broadest sense as designating any recessed metallic body, whether tubular or otherwise.

In the drawings the set-up illustrated is one in which the blank is disposed vertically. However, such a disposition is not restrictive, and the invention may equally well be embodied in arrangements wherein the blank is arranged horizontally or at any angle to the horizontal plane.

What I claim is:

1. Apparatus for continuously producing metal tubular objects which comprises a container for receiving molten metal therein and having an outlet, a mold comprising a removable open-ended cylindrical shell, an annular groove formed internally of said shell adjacent the upper end thereof and adapted to receive molten metal from said outlet, an annular flange on said shell at the upper end thereof and an annular guide surface near the lower end of said shell, a cylindrical element surrounding the upper end of the shell and adapted to receive said flange thereon, a further cylindrical element surrounding the lower end of the shell and having aperture means therein for guidingly engaging said guide surface of the shell, means for rotating both said elements at a common speed, means for discharging a cooling fluid on the outer mold wall between said mold and said upper element, means for discharging the spent cooling fluid, means for extracting a solidified tubular object from the mold, means for adjusting said extracting means in transverse dimension in accordance with the diameter of a tubular object and means for controlling the longitudinal rate of extraction of said object by said extracting means.

2. Apparatus for the continuous production of metal tubular objects, comprising means for receiving molten metal and having a molten metal outlet, mold means comprising a removable open-ended cylindrical shell, an annular groove formed internally of said shell adjacent the upper end thereof adapted to be fed from said outlet, an annular flange adjacent the upper end, an annular guide surface adjacent the lower end of said shell, a cylindrical element surrounding the upper end of the shell and adapted to receive said flange thereon, a further cylindrical element surrounding the lower end of the shell and having aperture means for guidingly engaging said guide surface, means for rotating both elements at a common rate, a plurality of separate spaced cooling fluid discharge means in the interval between said mold and said upper element for discharging cooling fluid against the outer mold wall, individually adjustable means for separately supplying cooling fluid to said discharge means, means for evacuating the spent cooling fluid, rollers adapted to engage the solidified tubular object within the mold for extracting the object from the mold, said rollers mounted on axes angularly disposed with respect to the mold axis, rotatable and slidable caging supporting said rollers, and means for rotating said axes at an adjustable rate.

3. Apparatus for continuously producing metallic tubular objects, comprising means for receiving molten metal, mold means comprising a removable open-ended cylindrical shell, an annular groove formed internally of said shell adjacent the upper end thereof adapted to be supplied with metal from said outlet, a flange at the upper end, an annular projecting guide surface at the lower end of the mold, a cylindrical element surrounding the upper end of the shell and having a portion adapted to receive the said flange thereon, a further cylindrical element surrounding the lower end of the shell and having an aperture for guidingly engaging said annular surface, means for rotating said elements at a common rate, a plurality of separate spaced cooling fluid discharge means along the gap between said mold and said upper element for discharging cooling fluid onto the outer mold wall, individually adjustable fluid supply means for each of said discharge means, means for leading off the spent cooling fluid, rollers circumferentially engaging said tubular object within the mold for extracting the object from the mold, said rollers mounted on axes angularly disposed with respect to the mold axis, rotatable and slidable caging supporting said rollers, means for rotating said axes at an adjustable rate, and means for cutting off predetermined lengths of the solidified tubular object and comprising a support having a heating range thereon and an oxygen-discharge nozzle adjustable in position along said tubular object.

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