March 7, 1967 A. W. SCRIBNER 3,307,228

CONTINUOUS CASTING CONTROL METHOD AND APPARATUS

Filed Nov. 1, 1963

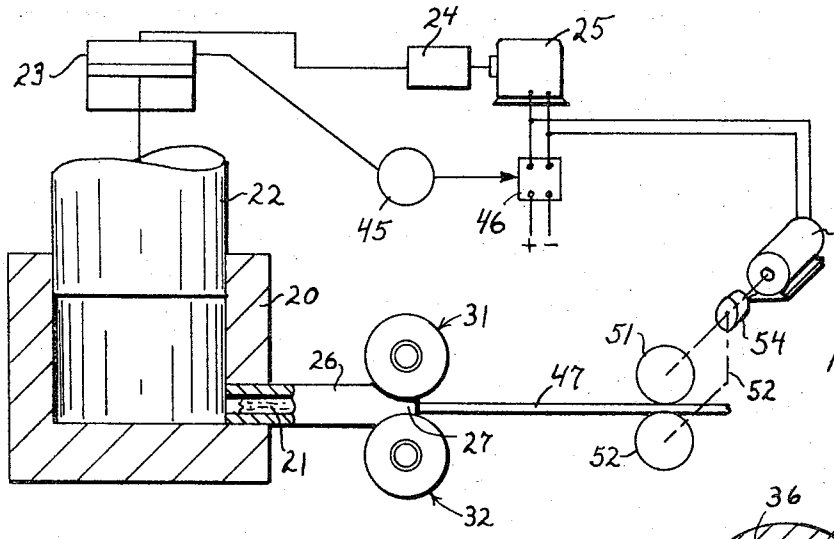


Fig. 1

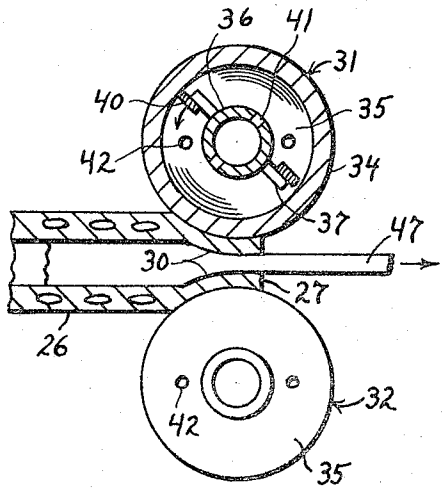


Fig. 2

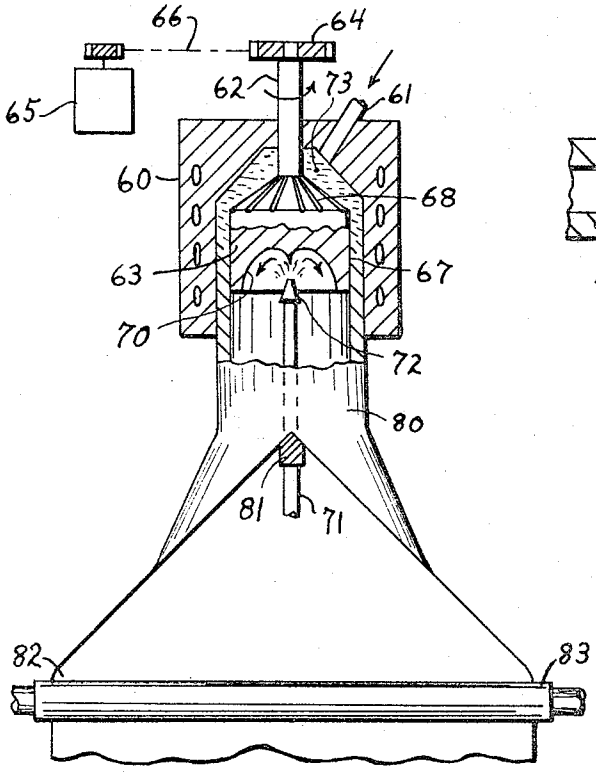


Fig. 3

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3,307,228

Patented Mar. 7, 1967

3,307,228

CONTINUOUS CASTING CONTROL METHOD AND APPARATUS

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Filed Nov. 1, 1963, Ser. No. 320,760
4 Claims. (Cl. 22—57.2)

This application is a continuation-in-part of my copending application Serial Number 149,378 filed Nov. 1, 1961, now Patent No. 3,120,037.

This invention relates to a novel method and apparatus for continuously casting metal and the like.

One object of the invention is to provide a novel method and apparatus for casting metal whereby work metal is pumped into an open ended casting passage at controlled mass flow rates that are correlated with the resistance to movement of the work metal through said passage.

Another object of the invention is to provide a novel method and apparatus for progressively moving work metal through an open ended casting passage whereby controlled and correlated pumping and withdrawing force actions are simultaneously applied to the work metal in said passage so that simultaneous changes in the said pumping and withdrawing actions tend to induce normally equal changes in the mass rate of flow of work material into and out of said casting passage.

Other objects of the invention will become apparent as the disclosure progresses.

In the drawings:

FIG. 1 is a side elevation view in partial section of the instant apparatus.

FIG. 2 is a detailed sectional elevational view of the cooling portion of the apparatus of FIG. 1.

FIG. 3 is a diametral sectional view of an apparatus constituting a modified embodiment of the instant invention.

Referring to FIG. 1 there is shown a container 20 which is adapted to receive and hold a body of molten metal 21 and which has slidably mounted at one end thereof a work metal pumping ram 22 that is power operated by means of a hydraulic motor 23. The motor 23 is operated by a pressure source or positive action pump 24 that is driven by variable speed electric motor 25. The inner surfaces of the container and ram may be covered with a layer of heat insulating material. A casting tube 26 communicates with the inside of container 20 and has a casting nozzle 27 secured to the outer end thereof. Nozzle 27 is formed with slightly tapering inner end surfaces 30, FIG. 2, and with cooling means 31 and 32 which are capable of rapidly extracting large amounts of heat from the work metal. In that each of the cooling units 31 and 32 is similar a detailed discussion of one thereof will suffice here. The unit 31 comprises a tube 34 that is integral with or fixed to one side of the outer end of the casting tube 26. To each end of tube 34 there is sealingly secured a plate such as 35 in which is centrally rotatably mounted a tubular shaft 36. Fixed to shaft 36 is a radially disposed pair of arms such as 37 to and between the outer ends of which are secured paddles such as 40. Shaft 36 is formed with apertures 41 so that liquid coolant may be introduced from the inside of shaft 36 through said apertures 41 and into the inner portion of tube 34. The shaft 36 is rapidly rotated and the coolant rapidly spins around the inner wall surfaces of said tube 34 and will thereby rapidly extract large quantities of heat from the work metal passing through the casting passage defined by said nozzle 27 and casting tube 26. The tube end plates 35 are formed with openings such as 42 to permit the escape of coolant vapor.

The ram drive means between motors 23 and 25 has a positive action and when the resistance to the passage of the metal through the nozzle orifice varies due to the variation in the rate of freezing of the work metal then a corresponding variation in the pressure in the hydraulic motor 23 will occur. Thus the hydraulic pressure in motor 23 reflects the degree of solidification of the work metal that is then passing through the casting passage. A conventional type pressure transducer 45 is adapted to continually sense the fluid pressures in the hydraulic motor 23 and the output from this transducer is connected so as to control the speed control means 46 for the motor 25 whereby the working pressure in the hydraulic motor 23 may be controllably varied and corrected by the error signal from unit 45. If for a given speed of motor 25 and a given rate of cooling produced by the cooling means the work metal progressing through the casting passage begins to freeze too fast then the rate of advance of the ram 22 should be increased so that the mass rate of flow of the work metal through the nozzle is correspondingly increased. Conversely if the work metal is not being cooled fast enough then the speed of advance of the ram 22 should be decreased so that the mass rate of flow through the casting passage is correspondingly decreased. The pressure transducer 45 is set so that when the metal freezing occurs too rapidly in the casting passage and the hydraulic pressure in motor 23 thereby goes up the speed of motor 25 will increase to speed up the flow of metal through the nozzle orifice or casting passage. Conversely when the said freezing is not occurring fast enough and the pressure in motor 23 thereby goes down the speed of motor 25 will be decreased so as to slow down the flow of metal through the nozzle. In this way the continuously cast strip or product 47 will be produced at a varying rate depending on the servo-action of the transducer 45. As the work metal progressively freezes and is die expressed through the casting passage serial casting and slight reducing actions occur.

The tapered surfaces 30 at the nozzle end of the casting passage have been exaggerated in the drawings for the purpose of clarity. The actual tapering or reduction in cross sectional area of the passage is relatively small, such reduction serving to promote compacting and good tool surface contacting pressures by the solidifying work metal. The terminal cross sectional profile of said casting passage here is rectangular so that a strip type product 47 may be produced.

A pair of cooperating pinch rolls 50, 51 are provided for applying a drawing force to the work metal leaving the casting passage. These pinch rolls are rotatably coupled by suitable gearing diagrammatically illustrated at 52 and are adapted to be driven by a motor 53 through a slip clutch 54; the latter being set to permit only a predetermined maximum torque to be applied to rolls 50, 51. Motor 53 like motor 25 is connected so as to be controlled by said speed control means 46 in the manner to be described. The operational speeds of motors 25 and 53 are correlated so that for a given error signal from transducer 45 any resultant change in the mass rate of flow of work metal produced by the pumping means 22, etc., is substantially equal to that tending to be simultaneously induced by the action of the drawing rolls 50, 51. In other words both push and pull forces acting always exists on the solidifying work metal in the casting passage and these actions at any given time each produce the same mass rate of flow, thereby avoiding any tendency for the pinch rolls to withdraw metal at a faster or slower mass rate than it is being supplied to the casting passage by the pumping ram 22. The slip clutch 54 is set to slip whenever a predetermined maximum permissible ten-

ion has been applied to the cast strip 47; this preventing ny serious elongation of the cast material. In this type of control arrangement the pumping force and withdrawng force are both simultaneously increased when the reistance to flow of work metal through the casting passage ncreases, and both forces are simultaneously decreased vhen said resistance decreases.

The modified embodiment of the invention shown in FIG. 3 comprises an open ended casting mold 60 having a casting passage formed therein which has an open lower end and an upper end that communicates with a source of molten metal through a supply tube 61. A shaft 62 exends through a central aperture in the upper end of the casting mold and is attached at its lower end to a rotor 63 that is centrally disposed in the upper end of said casting passage. Secured to the upper end of shaft 62 is a gear 64 which is rotatably driven by a motor 65 through a suitable linkage 66. The lower cylindrical surfaces 67 of rotor 63 cooperate with the adjacent inner cylindrical side walls of the mold cavity so as to define an annular terminal sectional profile for the casting passage. The upper conical portion of the rotor 63 is formed with slight radial ribs 68 and the lower central portion of the rotor is formed with a symmetrical cavity having a diametral sectional profile as shown at 70. A coolant conduit 71 extends upwardly towards the bottom of the rotor and is provided with a nozzle 72 whereby coolant may be symmetrically sprayed over the surfaces defined by said profile 70.

In operation the rotor 63 is rapidly rotated and molten metal 73 is continuously supplied through supply tube 61 to the upper end of the casting passage. The rotating rotor 63 will cause the work metal to spin about the axis of the casting passage and the centrifugal pressure built up in the spinning work metal will tend to force it down through the annular portion of the casting passage. The coolant sprayed on the lower end of the turning rotor will cause heat to be progressively extracted from the molten work material passing through the casting passage thus forming a tubular cast product 80 that is longitudinally slit by a suitable severing blade or cutter means 81 so that the tubular product may be flattened out to strip form 82 and fed through a pair of pinch rolls such as 83 which are driven so as to apply a substantially constant tension to the work metal leaving the casting passage. The work metal 73 when first introduced into the upper end of the casting passage experiences an angular acceleration due to the action of the rotor 63 and thereafter spins in the passage until it progressively hardens and thus slows down and finally stops spinning when cooled sufficiently to be out of the liquid or viscous phase. The non-rotating cooled work metal thereafter continues to move axially out through the discharge end of the casting passage. The passage sizes and the speed and configuration of the rotor are adjusted so as to produce as close to a laminar type of flow as possible in the spinning and angularly decelerating work metal as the latter progressively moves toward the annular portion of the casting passage. The lower portion of the rotor walls will be rotating relative to the adjacent portion of the non-rotating hardened work metal and this will assist in the extraction of heat from the work metal. All of the coolant spray (such as water) will be vaporized in rapidly moving over the profile surfaces 70 and the vapor will escape by flowing downwardly as seen in FIG. 3. The apparatus of FIG. 3 may be used to cast a solid bar where the elements 71, 72, 81 and 83 are removed along with the lower end of the rotor 63 whereby the rotor is entirely above the hardening portion of the work metal that is progressively disposed in the lower part of the casting passage.

While several embodiments of the invention have been shown and described, it will be apparent to those skilled in the art that numerous variations and modifications may be made in the particular construction without departing from the underlying principles of the invention. It is therefore desired by the following claims to include within the scope of the invention all such variations and modifications whereby substantially the results of the invention may be obtained by the use of substantially the same or equivalent means.

The invention claimed is:

1. A method of continuously casting work metal and the like: comprising the steps of

providing a source of work metal;

providing an open ended casting passage through which said work metal may flow and be progressively hardened;

applying a pumping force to the work metal so as to progressively force the same into said casting passage;

simultaneously applying a drawing force to the hardened work metal leaving the casting passage; and

increasing both of the said forces when the resistance to metal flow through said casting passage increases, and decreasing both of said forces when said resistance decreases.

2. The method defined by claim 1: additionally comprising controlling the application of said pumping and drawing forces so as to tend to induce at any given time substantially equal changes in the mass rate of flow of work material into and out of said casting passage.

3. In a continuous casting device:

mold means defining an open ended casting passage that is adapted to progressively receive molten work material that is to be cast in passing therethrough;

cooling means for extracting heat from the work material in said casting passage;

withdrawing means disposed downstream from said mold passage for pulling cast work material from said mold passage at variable rates;

pumping means for forcing work material into and along said casting passage;

sensing means for sensing the resistance to the sliding movement of the work material along the mold surfaces defining said casting passage; and

control means operated by said sensing means for controlling the operation of said withdrawing means and said pumping means so as to thereby control the rate of entry and withdrawal of cast work material into and from said casting passage.

4. Apparatus as defined by claim 3 wherein said control means operates to tend to induce substantially equal changes in the mass rate of flow of work material into and out of said casting passage.

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