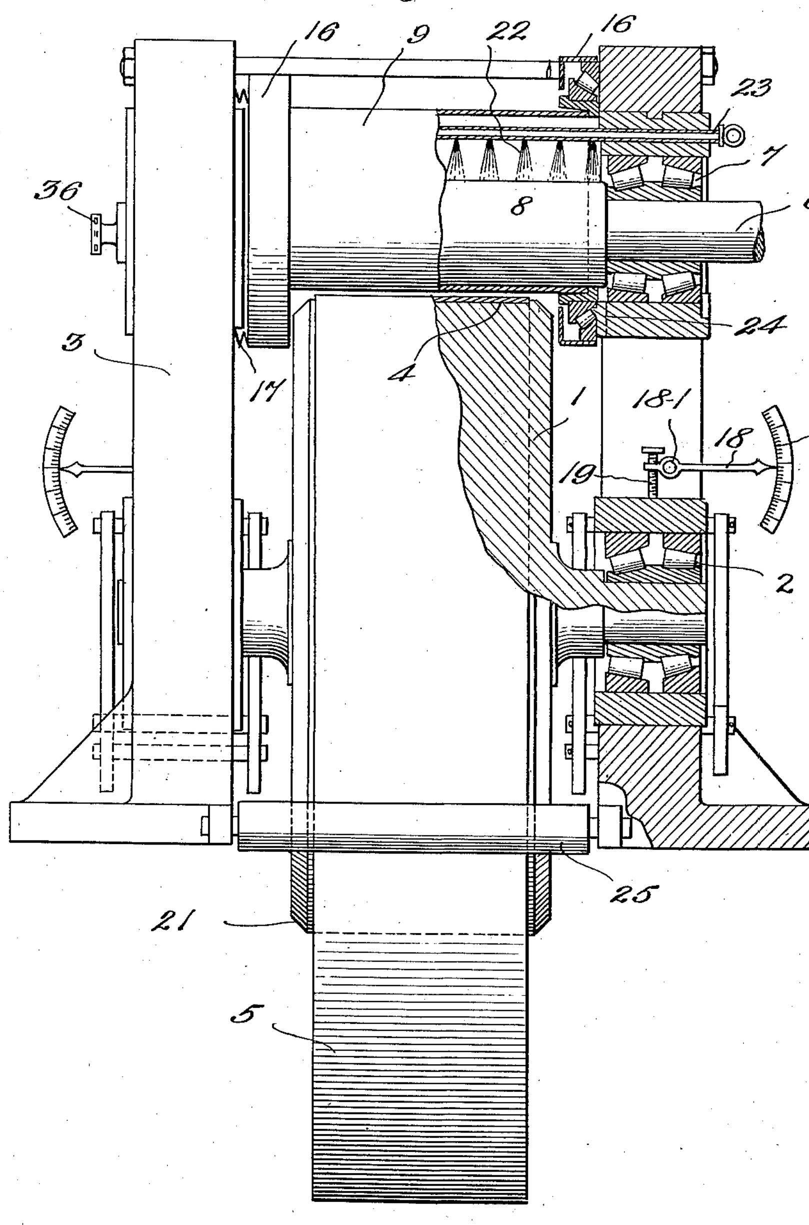
CONTINUOUS CASTING APPARATUS AND PROCESS

Filed March 16, 1939 4 Sheets-Sheet 1

Fig. 1.



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CONTINUOUS CASTING APPARATUS AND PROCESS

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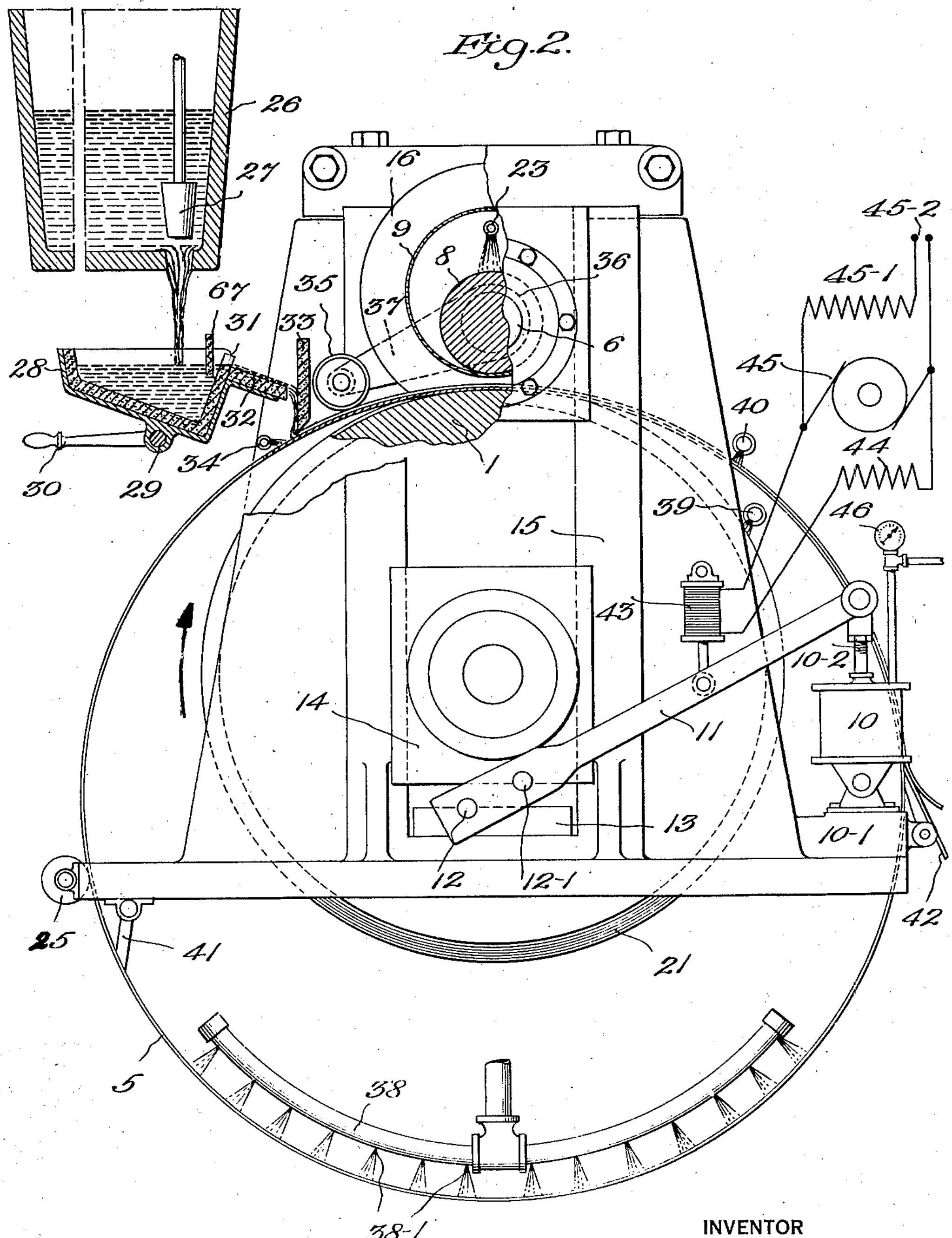
Fig. 2.



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CONTINUOUS CASTING APPARATUS AND PROCESS

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Fig. 3.

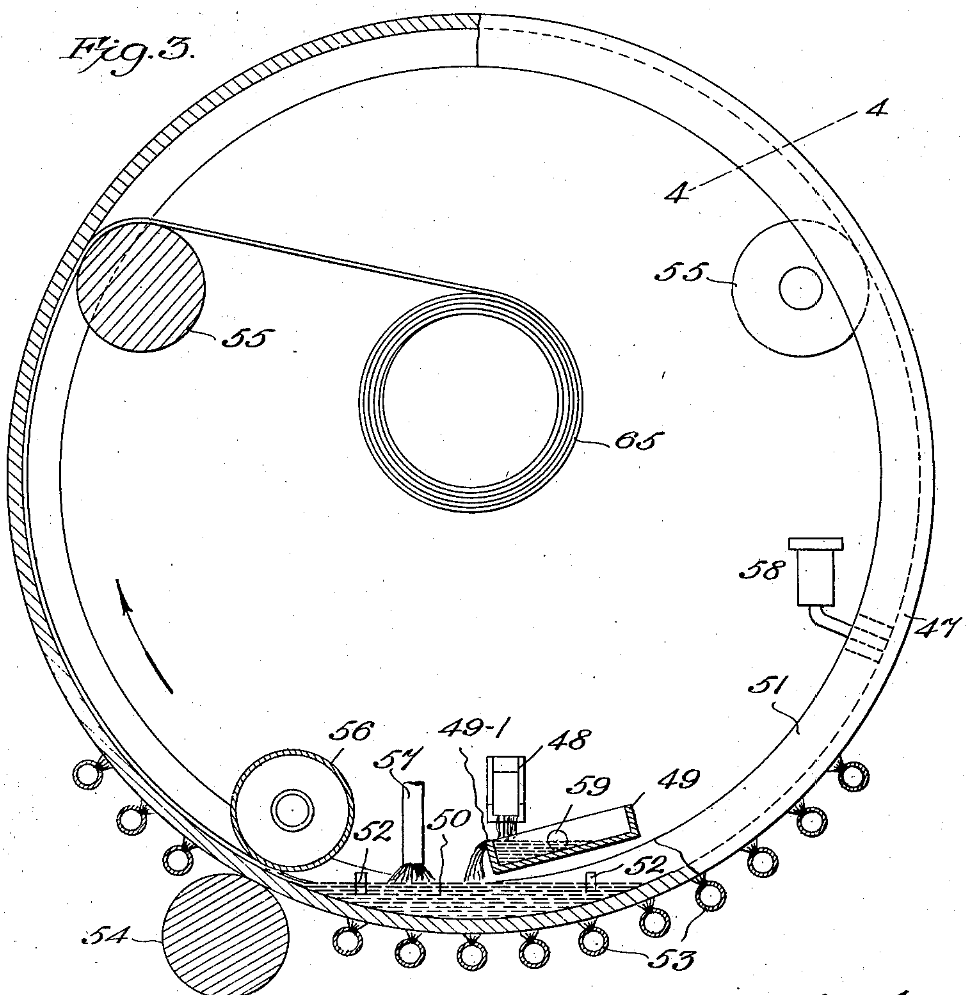


Fig. 4.

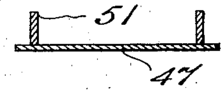
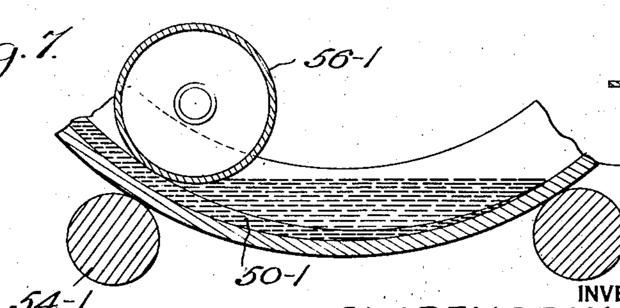


Fig. 7.



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CONTINUOUS CASTING APPARATUS AND PROCESS

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Fig. 5.

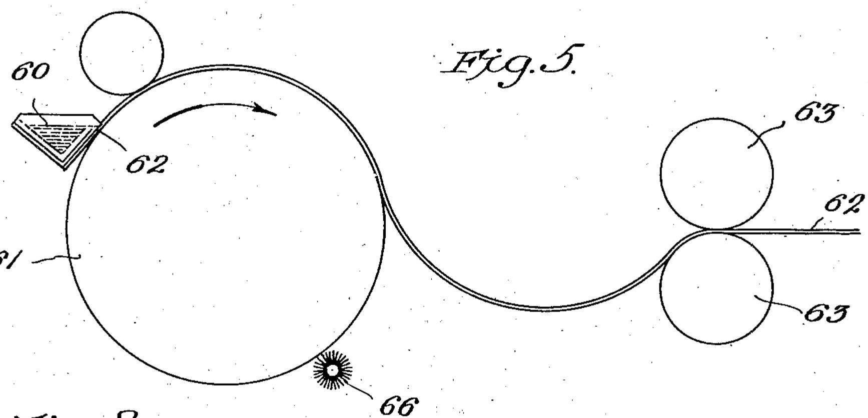


Fig. 8.

Fig. 6.

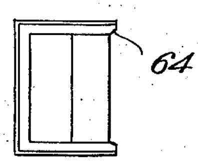
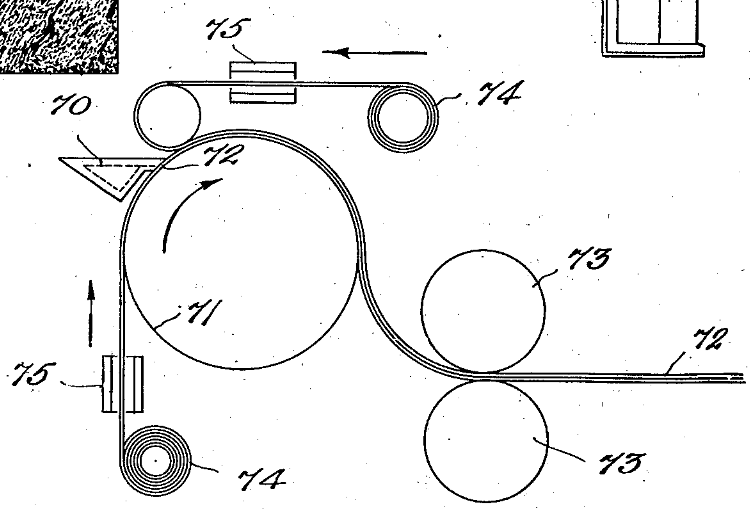


Fig. 9.



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Patented Aug. 21, 1945

2,383,310

UNITED STATES PATENT OFFICE

2,383,310

CONTINUOUS CASTING APPARATUS AND PROCESS

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Application March 16, 1939, Serial No. 262,223

6 Claims. (Cl. 22—57.2)

The present invention relates to the art of metal casting and working and, more particularly, to a novel process of producing metallic shapes or strips directly from molten metal and to an apparatus therefor and to the product thereof.

It is an object of the present invention to provide a process of producing metallic shapes or strips directly from molten metal which eliminates the disadvantages of conventional processes.

It is another object of the present invention to provide a novel and improved process of producing metallic bodies of elongated character directly from molten metal which may be applied to the production of sheets, strips, and the like, constituted of high melting point metals including steel.

It is a further object of the present invention to provide a high speed process for producing metallic shapes directly from molten metal which involves pouring molten metal on to a cooling member in the form of a ring or roll rotated at high speeds.

Still another object of the invention is to provide an apparatus for carrying the process of the invention into practice.

The invention also contemplates the provision of an apparatus for the continuous production of metallic bodies of constant cross section directly from molten metal including a main cooling member preferably of a ring or shell-like character onto the outer or inner surface of which the molten metal is poured and is carried upwards by the rotation of said member.

Other and further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawings, in which—

Fig. 1 illustrates an end view having parts in section of a mill embodying the principles of the present invention;

Fig. 2 depicts a side elevational view having parts in section of the mill illustrated in Fig. 1;

Fig. 3 shows a modified embodiment of the invention into a mill in which the molten metal is poured in the interior of a ring-shaped cooling member;

Fig. 4 is a sectional detail view of the cooling ring shown in Fig. 3;

Fig. 5 illustrates a side elevational view somewhat fragmentary and diagrammatic in character, of another modified embodiment of the invention into a mill;

Fig. 6 depicts a top elevational view of the metal feeding distributor shown in Fig. 5;

Fig. 7 shows a fragmentary vertical sectional view of a modification of the mill illustrated in Fig. 3 which is especially adapted to the production of metallic bodies having accentuated cross sections;

Fig. 8 is a photomicrograph of a cross section of the product of the invention; and

Fig. 9 is a diagrammatic view of a further modified embodiment of the invention.

Broadly stated, according to the principles of my invention, I provide a main cooling member in the form of a roll or preferably in the form of a hollow shell or ring, and provide driving means for causing displacement of the outer surface of said cooling member along a circular path. Onto the surface of said cooling member I feed a molten metal which will solidify and will be moved upwards up to a point where it is again removed and separated from the surface of the cooling member. I have found that a mill of the described type can be operated at extremely high speeds so that very large quantities of metal may be fed to the cooling member. This greatly simplifies the problem of preventing excessive cooling or irregular feeding of the molten metal. I have also discovered that when the operating speed of the cooling member exceeds a predetermined limit the metal will not run backwards and downwards, provided the angle between the radius drawn to the point where the stream of molten metal strikes the ring or roll and the vertical is not more than 40 degrees. To make this angle the largest possible, compressed gas preferably of a reducing nature may be blown against the stream of molten metal in a substantially tangential direction in order to prevent running of the metal backwards. Likewise, a back dam of suitable character may be employed preferably in combination with the stream of compressed gas.

The main cooling member cooperates with one or more auxiliary cooling members generally provided in the form of a roll or shell. The auxiliary cooling member or members exert a cooling effect and in most cases some rolling pressure upon the surface of the solidified metal. It is generally preferred to employ rings for both the main and the auxiliary cooling members. The advantage of the ring type structure is that cooling members of very great circumference may be employed without making the weight or the cost of the structure excessive. Backing rolls of suitable dimensions are provided within the rings in proximity to the point of tangency thereof in order to take up the pressure at these points. Another important advantage of the ring-like cooling members is that they may be constituted of relatively expensive, high strength and high melting metals which will not scale at the temperatures necessary for "degassing," whereas the inner or backing rolls may be made of cheap steel. The relatively thin and shell-like construction of the main and auxiliary members also makes possible efficient inner or both inner and outer cooling thereof which would be unobtainable with solid rolls. Of vital importance is the circumstance that a ring may be readily preheated and "degassed," while this would be impracticable with a roll.

According to a modification of my process which is especially adaptable to the production of sheets or slabs of accentuated thickness, a ring is used as main cooling member and molten metal is fed into a bath established within the ring and supported by the bottom portion of the inner surface and by laterally arranged flanges of the ring. The ring is supported by a plurality of back up rolls at least one of which cooperates with a surfacing roll arranged within the inner space of the ring and exerts a pressure upon the surface of the solidified metal. Rotation of the ring is obtained by rotating the surfacing roll and the backing roll cooperating therewith. I found it advantageous to provide a reducing gas atmosphere above the bath. Bone black or some other facing material may be applied to the inner surface of the circular dams or flanges of the ring to decrease the amount of chilling by these members and to facilitate the removal of the product.

In another modification of the process of the invention, one or a plurality of strips of metal produced by the present process or by a conventional process are fed over a ring or roll, after having been passed through heating furnaces. Molten metal is subsequently poured much in the same manner as in the other embodiments of the invention, except that one or both of the cooling surfaces will be formed by said strips. The pressure present in the surface of contact and the high temperature of the molten metal causes welding of the molten metal to the solid strip or strips. The product may be further improved by immediate re-rolling.

Referring now more particularly to Figs. 1 and 2 of the drawing, a preferred embodiment of the invention is illustrated. The mill essentially comprises a lower roll 1 mounted in roller bearings 2 in a housing 3. Roll 1 is provided with a groove 4 in which travels a ring 5 constituting the main cooling member of the mill. Ring 5 is driven in the following manner: A suitable motor (not shown) is attached to an upper roll shaft 6 and drives the same in roller bearings 7. Shaft 6 supports upper roll 8 carrying a surfacing ring 9. When the mill is running idle, lower roll 1 is pressed against ring 5, ring 5 pressing against surfacing ring 9, which in turn is pressed against the driven roll 8. It is to be noted that in this construction it is desirable to provide anti-friction bearings on roll 1 in order to prevent slippage of the same in operation.

The pressure between the rolls is provided by means of air or hydraulic cylinders 10. As it will be best observed in Fig. 2, fluid pressure cylinders 10 are pivotally mounted on a base or support 10—1 and are provided with an upwardly extending connecting rod 10—2. Connecting rod 10—2 is jointedly connected to one of the ends of a lever 11 having its other end fulcrumed in 12 and acting on sliding plates 13. Levers 11 are provided with a pin or similar protruding member 12—1 engaging lower bearing housing 14 slidably mounted in ways 15 so that by actuation of cylinders 10, bearing housing 14 and thereby lower roll 1 may be raised to any desired extent.

Upper or surfacing ring 9 is provided with radial thrust bearings having fittings to the ends of ring 9 to take up the end thrust thereof so that when the ring is worn out merely a plain ring 9 has to be replaced. The right hand thrust bearing 16 presses against the right hand housing, whereas the left hand one is held against the end of the top ring by spring means 17 to allow for expansion of the ring. A pointer 18 pivoted in a pin 18—1 and cooperating with a scale 20 is provided for indicating position of the lower roll and is equipped with a zero adjustment screw 19. Roll 1 is chamfered at 21 to cause any water accumulating at this point to run off easily as otherwise explosions could be caused by molten metal reaching this point. Surfacing ring 9 is internally cooled by means of water sprayed against the inner surface thereof through the apertures 22 of pipe 23. Suitable channels 24 are provided through which the water may run off. It is important that ring 9 shall be wider than the width of lower roll 1 so that the cooling water is discharged beyond said roll to prevent explosions when an excess of metal is poured on ring 5.

Ring 5 may be of any suitable diameter and in practical and industrial operation may be from about 10 to about 50 feet in diameter. This ring may be omitted in the production of shapes constituted of low melting point metals, such as lead or tin, but large diameter rings are particularly suitable for the production of brass, copper, and steel strips directly from molten metal. As large diameter rings of the described character and traveling at the very high speeds possible in this mill may "whip," for the prevention of this, one or more rollers 25 bearing against the outer surface of the ring may be provided.

The metal feeding means (Fig. 2) include a conventional ladle 26, such as is used for pouring steel, having a stopper 27 for regulating the flow of metal to a pouring box or distributor 28 pivoted at 29 and provided with a handle 30 or other suitable means for tilting the same. A baffle 67 of refractory material prevents the overflow of slag into the mill. Due to the extremely great operating speed of this mill compared to any one heretofore built, it is possible and is preferred to pour the metal over a weir or straight edge 31. This was impossible in prior direct casting and rolling processes as uniform pouring over a weir cannot be obtained unless much larger quantities of metal are poured in a given time than heretofore. When small quantities of metal are poured, due to surface tension phenomena, the metal runs irregularly and in individual streams, giving entirely unsatisfactory results. After passing over weir 31, the metal pours over shelf 32 against baffle 33 which carries the metal close to the surface of ring 5. At the operating speeds contemplated by the present invention, the metal will not run backwards and downwards, provided the angle between the radius to the point where the stream of molten metal strikes the ring or roll and the vertical does not exceed 40 degrees. To make this angle as large as possible, a pipe 34 is provided through which compressed gas, preferably of a reducing nature, is blown against the molten metal tangentially and in the direction of the rotation of the main cooling member or ring 5. This is accomplished by providing a large number of holes or nozzles in pipe 34 through which the gas under pressure is blown in the direction of the molten metal and positively prevents its flowing backwards by cooling it and by exerting pressure upon the same. Additional advantages may be obtained by supplying pipe 34 with a combustible gas which may be used for preheating the surface of ring 5. At a small distance from the point of contact of the molten metal with ring 5 and in the direction of movement of the ring, a cooling roll 35 may be provided. This is a thin-walled, internally cooled roll, which merely cools the upper surface of the molten metal, but does not exert any actual pressure thereon, nor does it solidify the molten metal except on the immediate surface. Cooling roll 35 may be driven by a sprocket wheel 36 through a chain 37. The provision of cooling roll 35 permits a still further increase in the speed of production as well as an increase in the thickness of the product. Surfacing ring 5 is water cooled by means of a pipe 38 having a large number of discharge openings or nozzles 38—1 therein and preferably supplied with water at very high pressures. Similar water cooling means (not shown) may be provided for externally cooling the ring. Lower back-up roll 1 may be additionally cooled by means of a water pipe 39, and in some cases the strip produced may be cooled by spraying high pressure water thereon by means of a pipe 40. The interior of ring 5 is scraped clean by means of a scraper 41 and another scraper 42 is provided for removing the produced strip from ring 5. A similar scraper (not shown) serving the same purpose of maintaining the surface of top ring or roll 9 clean may be provided.

Fig. 2 also illustrates the method and means of controlling the gauge of the finished product by varying the speed and the pressure. Increase in the thickness of the product will cause downward displacement of ring 5 and of roll 1 rotatably mounted in bearing housing 14, which is slidably mounted in ways 15 and is yieldingly supported by means of levers 11 associated with fluid pressure cylinders 10. Reference character 43 denotes a carbon pile rheostat inserted in series with shunt field winding 44 of mill driving motor 45 having a series field winding 45—1 and being connected to a source of current 45—2. Rheostat 43 is so connected with lever 11 that an increase in the thickness of the product, which results in the lower bearing 14 dropping downward, decreases the pressure on the rheostat and increases its resistance. This in turn will decrease the current in the shunt field winding of the motor causing speeding up of motor 45, and bringing the hot metal in contact with surfacing ring 9 in a shorter period of time, thereby causing the sheet to be made thinner. The air or liquid pressure supplied to cylinder 10 may also be varied, and such pressure is indicated by a pressure gauge 46. An increase in this pressure will decrease the thickness of the product and will also increase the amount of work done on it and the degree of refinement imparted to the structure thereof. It will be understood that provision is made for varying the pressure on the cylinder 10 on only one side of the mill to correct slight inequalities of the product across its width.

From the preceding description, the operation of the mill embodying the invention will be readily understood by those skilled in the art. Shaft 6 of top backing roll 8 is driven by motor 45 at a predetermined high speed. Stopper 27 in ladle 26 is lifted permitting metal to flow into distributor or pouring box 28 wherefrom it may be poured at a manually or automatically controlled rate over weir 31 and along shelf 32 against baffle 33 which carries the metal close to the surface of ring 5. Fluid pressure is applied to cylinders 10 thus causing pressure on the metal solidified on ring 5 by the adjustable and yielding pressure means. Of course, the velocity of the main and auxiliary cooling members or rings 5 and 9, the amount of metal fed against the main cooling member in the unit of time, the period of compression of the solidified metal on the cooling members have to be critically controlled in accordance with the principles of my invention, as it will be explained more fully hereinafter. The finished strip is removed by means of scraper 42 and may be subjected to re-rolling on its initial heat or may be cooled and rolled up or cut to individual lengths. To prevent damage to the rolls due to the cold drops of metal, it is highly desirable to turn on the air pressure after the molten metal has started through the mill and to release it before the pour is finished. It has been also found that compressed air moves rapidly enough through orifices and pipes to accomplish the desired result.

Figs. 3 and 4 illustrate a modified apparatus for carrying the process of the invention into practice, which is especially adaptable to the production of sheets and slabs of relatively thick cross section. This modified apparatus and modified process are especially advantageous and practical when rings of very large diameter are employed. Reference character 47 denotes a ring of large dimensions which is employed as main cooling member. Molten metal obtained from any suitable source is poured into a chute 48 at a point outside of the ring and then falls into a distributor box 49. From the distributor box, the metal flows over a weir 49-1 into bath 50 which is supported by ring 47 and the end flanges or circular dams 51. Skimming baffles 52 extend into bath 50 to collect the slag on the upper surface thereof. High pressure water is sprayed onto the outer surface of ring 47 directly beneath the bath and elsewhere, if desired, through pipes 53. Ring 47 is supported by a back up roll 54 and a surfacing roll 56 which in this case is shown as a thin-walled, internally cooled, cylindrical shell. Of course, surfacing roll 56 may be of the same construction as ring 9 and backing roll 8 shown in Fig. 1. A reducing gas atmosphere is provided over the bath through a pipe 57. Power is supplied through surfacing roll 56 which is connected to a motor, (not shown). A container 58 is provided to apply bone black or some other suitable facing material to the inner surface of circular dams 51 to decrease the amount of chilling by these members and to facilitate the removal of the product. The distributor box 49 may be tilted on pivot 59 to control the pouring more accurately, much in the same manner as this is shown in Fig. 2. Fig. 4 depicts a sectional view of ring 47 and of circular dams 51 which may either be integral with ring 47 or may be adjustable in order to vary the width of the product. As it will be readily understood from Figs. 3 and 4, when ring 47 is rotated by applying power to surfacing ring 56, metal will solidify in the form of a layer on the inner surface of ring 47 as it emerges from bath 50, due to the cooling action of ring 47. The finished strip is passed around supporting roll 55 and is wound up into a coil 65 or is otherwise removed from the cooling member.

Fig. 5 illustrates diagrammatically and by way of example a further modified type of mill embodying the principles of the invention in which a pouring box 60 having a solid barrier or shoe 62 is provided in contact with a roll or ring 61 to prevent the molten metal from running backwards and downwards thereon. This construction can be used only where the speed of the mill exceeds a definite and predetermined amount. Since any material in contact with ring or roll 61 will be cooled by it, molten metal will freeze to it at the coldest point, to wit: at the line of contact with the ring or roll. I have discovered that this can be avoided by so constructing the mill and by providing such spaced relations between its parts that speeds in excess of 120 feet per minute are obtained, and by so arranging the pour that the maximum possible amount of incoming metal flows by this junction point between the stationary dam 62 and the moving roll or ring 61. By either of these means freezing of the metal at these critical points, which may make the mill entirely inoperative, may be avoided. For high melting point metals, I prefer to use a refractory lining to the box 60 and a shoe made of copper or nickel sheet between the refractory and the roll. This sheet wears much longer than any refractory material and does not spall off, causing defects in the product from the inclusions. Moreover, by the production of strips at such high speeds, the strip may be re-rolled on its initial heat, as this is indicated by rolls 63 in Fig. 5. Of course, this was altogether impossible with the speeds heretofore obtained in direct fabrication. As it appears from Fig. 6, which depicts a top view of box 60, that part of the dam which extends beyond the line of contact of the dam and the ring or roll and in the direction of motion thereof, is flared out, as indicated by reference character 64. The effect of this type of construction is to continuously pull away from the vertical surface of this side dam any metal freezing thereto. It is to be noted that the freezing at any point is always cumulative and progresses until a large body has formed, which may then be released and may get between the main cooling means and the surfacing roll and do great damage to the mill.

Fig. 7 illustrates a modification of the apparatus shown in Fig. 3, in which ring 47—1 is driven by means other than the cooling and surfacing roll, such as the two supporting rolls 54—1. Surfacing roll 56—1 exerts practically no compression on the product but cools the top surface of the product after the major portion thereof has been solidified by ring 47—1. This apparatus and method are particularly useful in producing thick slabs with good surfaces on both sides. It is to be noted that no shrinkage can take place, any shrinkage being fed by the molten bath continuously supplying the metal in the center of the slab. The method of cooling and the distribution of the cooling effect of the ring is shown by the shaded portion in Fig. 7, denoted by reference character 50—1.

The principal advantage of pouring on the inside of a ring is that no back dam or barrier is required. This permits slow speed operation for the production of thicker sections, which cannot be attained with pouring on the exterior of a ring or roll. As to the removal of the finished product, the sheets are coiled on a coiler within the ring, such as is denoted by reference character 65 in Fig. 3, or, if narrow, they may be spiralled outside of the ring on the side thereof.

In the operation of the mill, molten metal is supplied directly from a furnace or a ladle into a distributor box extending lengthwise of the mill, such as 28 in Fig. 2, 49 in Fig. 3, or 60 in Fig. 5. The supply of molten metal may be more closely regulated than is possible by tilting a furnace or operating a stopper by tilting the distributor box manually or automatically. From the distributor box, the molten metal flows in contact with a relatively large main cooling member which may be a roll for small quantities of metal or for low melting point metal, but should be a ring for the production of large quantities of high melting point strip. The relation of the parts of the mill and their operation should be such as to permit the production of strip in excess of 120 feet per minute when the metal is poured on the outside of the ring. This is necessary for two basic reasons; first, to get uniform and open distribution of high melting point metals, it is necessary to pour at least 700 cubic inches of metal per minute for each foot in width of the mill; and second, to prevent freezing of the metal to the back dam or barrier at the point of contact with said main cooling means. Furthermore, I have discovered that when metal is poured on the exterior of a cylindrical surface, it is necessary to compress it within a period less than one half of a second after the time it strikes the main cooling means, if the temperature of said cooling means is within the practical operating range of metals suitable for this purpose. If the temperature of the cooling means is above a certain point, the ring itself will be rolled and lengthened by the pressure means of the mill. I have also found that when the time of contact of the metal with the cooling means exceeds the critical limit referred to in the foregoing, the lower solidified surface has cooled beyond the point where the same can be satisfactorily smoothed by compression. For example, I find that when in the production of steel or brass strip by the process of the invention, the molten metal makes contact with the cooling member for one eighth of a second to one-fiftieth of a second before rolling and the cooling member is maintained at a temperature of about 500 to 700 degrees Fahrenheit, a high quality surface can be produced on the bottom of the strip. It is also to be noted that preferably the period for which the upper face of the partly solidified metal is subjected to compression and to cooling by the secondary cooling member should not exceed fifty per cent of the period of contact with the main cooling member. I have found that the quality of the upper surface depends upon entirely different factors than that of the lower. If the metal fed on to the ring or roll is traveling tangentially in the direction of its motion, it may be carried upwards, causing a substantial accumulation of molten metal just back of the surfacing roll. In the process of the invention, the molten metal is carried to the surfacing roll by its friction or cohesion with the metal solidified on the lower cooling means. I have further found that in order to produce a satisfactory top surface with moderate pressures, the metal accumulating behind the surfacing roll should not have a greater height above the lower ring than three quarters of an inch. A large accumulation causes irregular cooling and folding, spoiling the product. To avoid this, it is essential to either operate the mill with the molten metal being fed against gravity, as shown in Fig. 5; to feed the metal with no appreciable velocity tangential to the direction of motion, as shown in Fig. 2; or to pour the metal in such a manner that it is free to flow sidewise, which occurs under the conditions shown in Fig. 5 where the effect of gravity prevents building up of a bath of metal on the roll. I have found that the angle between the radius extending to the point of contact of the molten metal and the vertical center line of the lower cooling ring or roll must not exceed 40 degrees. If this angle exceeds 40 degrees, the metal flows sidewise too much when a back dam is used and backwards too much when no back dam is used.

I have also discovered that further important advantages are obtained by employing shoes with feeding slots for feeding the molten metal onto the circumferential surface of the cooling member in order to produce a plurality of individual streams which merge on the cooling member or ring to form a stream. This has the advantage of providing very uniform distribution of the flow and at the same time the high velocities of the flow prevent skulling and oxidation of the molten metal. Moreover, heat is conserved by the reduction in radiating surface.

Preferably, cooling means constituted of heat-resisting materials are used having substantial chromium nickel or molybdenum contents, as ordinary steels will scale non-uniformly producing non-uniform cooling and cast spots unless continuously brushed, as this is shown at 66, in Fig. 5. Another advantage of using heat-resisting metals is that metals discharge occluded gases when heated until the heating is continued for a substantial length of time. This degassing process has to be carried out at temperatures at which ordinary steels tend to oxidize, whereas the heat-resisting materials contemplated by the present invention such as 18–8 stainless steel, nichrome, and the like, do not oxidize. Likewise, I have found that materials having a lower heat conductivity, such as the above heat resisting materials, do not fire-crack as readily as other materials. It will be readily understood that in my process the under-surface of the product is first solidified, and only a molten surface is carried upward to the surfacing roll and that the lower surface has not yet chilled sufficiently at this point to prevent the consolidation of any imperfections in its surface when it is compressed by the surfacing roll. The immediate surface of the metal striking the surfacing roll is molten.

It has been found that the practical advantages of employing a ring as a main cooling member over a roll are of vital importance. Thus, a ring is much cheaper to build and to replace than a roll. The expansion at the two sides of the ring is but little different, which greatly reduces or almost completely eliminates fire cracking so frequently experienced on rolls. In view of the relatively low weight of the ring as compared to that of a roll of similar dimensions, expensive and heat resisting alloys may be used for the ring and cheap steels for the backing rolls. Rings can be readily cooled both on the outer and on the inner surface thereof and thus facilitate the production of large quantities of finished products. Since the back-up rolls used with the rings may be operated with water sprays directed thereon, they maintain their low temperatures and shape better than hot rolls, providing in a hot rolling process gauges as accurate as obtainable by cold rolling. Rings of extremely large diameter may be used, whereas the weight and cost of rolls providing cooling surfaces of the same order would be prohibitive. Strips of accentuated width can be produced on the mills embodying the present invention in view of the very low horse power required compared even to previous direct rolling mills. High tonnage production is necessary in the production of steel because of the enormous size of the standard ladles used for open hearth steels and due to the necessity of emptying them before they freeze. It is also to be observed that the enormous speeds of operation of which the mills of the invention are capable, permit open and weir type pouring, which were never practically accomplished heretofore and which are critically important in pouring high melting point metals such as steel, nickel, Monel metal, and the like, because of the great difficulty in keeping holes or closed pouring devices from freezing. Continuous re-rolling on the initial heat is only possible because of the great speed of this type of mill and particularly with very thin sheets. In the mill embodying the principles of the invention it is possible to produce steel and non-ferrous sheets of good quality as low as 0.01" in thickness at speeds of from about 200 to about 2000 feet per minute. High speeds are effected merely by increasing the distance of contact of the molten metal before it is compressed. Many metals must be re-worked before they fall to the "short" range. This can be readily accomplished with the process of the invention because of its speed and without any re-heating being necessary.

The structure of the product of the mill and of the process embodying the invention is to a great extent determined by the operating pressures. Thus, when employing high pressures and a surfacing roll of smaller diameter than that of the lower cooling member, the product is substantially cast on the lower side and shows substantial work or extrusion on the top side. This will be readily observed from Fig. 8 depicting a photomicrograph of the cross section of the finished product which is an aluminum strip, magnified 100 times. This product has the ductility due to the working on the top surface thereof and the resistance to corrosion due to the very slightly worked structure on the bottom surface thereof. This can be shown by the fact that the distance between roll marks on the upper surface of the sheet is greater than the circumference of the upper ring or roll and the distance between roll marks on the lower surface of the sheet is smaller than the circumference of the lower ring or roll, due to the actual shrinkage of the product. It has been found that the metal in contact with the surfacing roll shows an extrusion on the top surface of the strip of about 10% but no extrusion whatsoever on the bottom. In other words, the product is a compressed casting on the bottom and substantially a worked metal on the upper surface. A perfect strip is obtained when this extrusion on the top exceeds 10%. On the other hand, when operating under extremely low pressures, as low as 125 pounds per inch width of the strip being rolled, purely cast products are obtained which are uniform on both sides.

Fig. 9 illustrates somewhat diagrammatically a further modified embodiment of the invention. It will be noted at the outset that this mill is much similar in general appearance and operation to the one described in connection with Fig. 5 in that a main cooling member 71, and a pouring box 70 having a solid barrier or shoe 72 in contact with the cooling member are provided. Reference character 74 denotes coils of strip metal of any type produced by the process of the present invention or by some conventional process. One or both of these strips are fed over ring or roll 71 first passing through heating furnaces 75 which may be provided with reducing atmospheres, if desired, in order to avoid oxidation, and then through the mill. Molten metal from the distributing box 70 is poured much in the same manner as in the apparatus shown in Fig. 5, except that one or both of the cooling surfaces will be formed by the strip coming from coils 74. A combination of the pressure and of the high temperature of the molten metal will cause welding of the molten metal to the solid strip or strips. The resulting product may be further improved by immediate re-rolling by rolls 73.

It is to be observed that the process of the invention is capable of producing metallic strips from various metals and alloys. Thus, metals such as lead, aluminum, zinc, copper, steel, and the like, have been rolled as well as alloys, such as brass, silicon-steel, etc. Gauges as thin as 0.010 inch and as thick as 0.050 inch have been produced at speeds of about 150 to 600 lineal feet per minute. Strips having varying widths, for instance having widths from about 2 to about 8 inches, have been produced on the same mill by varying the width of the pouring member and the quantity of metal poured. Due to the low power requirements of the mill embodying the invention, the width of the strips produced can be increased considerably above the widths obtainable with ordinary mills. For instance, widths up to about ten feet, or more, can be obtained without difficulty.

Although the present invention has been described in connection with a few preferred embodiments thereof, variations and modifications may be resorted to by those skilled in the art without departing from the principles of the present invention. I consider all of these variations and modifications as within the true spirit and scope of the present invention, as disclosed in the present description and defined by the appended claims.

I claim:

1. The process of producing metallic shapes of substantially constant cross section throughout their length directly from molten metal which comprises pouring molten metal onto the exterior surface of a continuously moving cylindrical cooling member at a point located not more than 40 degrees from the vertical center line of said member without forming an appreciable bath thereon to cause upward displacement of metal partly solidified thereon, and directing a stream of compressed gas against said partly solidified metal to reduce sidewise and downward flow thereof.

2. In a combination of the class described, a pair of moving surfaces, pressure means yieldingly pressing one of said surfaces toward the other along a predetermined line, means for supplying molten metal to said surfaces at one side of said line, said metal then passing between said surfaces and under the influence of said pressure means, and means actuated through the separation of said surfaces against said pressure means by the metal passing between said surfaces, for changing the ratio of the speed of movement of said surfaces to the rate of supplying of said metal whereby to control the thickness of the metal to be formed by said surfaces.

3. In a combination of the class described, a pair of moving surfaces, pressure means yieldingly pressing one of said surfaces toward the other along a predetermined line, means for depositing molten metal on one of said surfaces to one side of said line, said metal then passing between said surfaces and under the influence of said pressure means, driving means for moving said surfaces at variable speeds, and means whereby the separation of said surfaces against said pressure means by the metal passing between said surface controls said driving means for varying the speed of movement of said surfaces whereby to control the thickness of the metal to be formed by said surfaces.

4. In a combination of the class described, a pair of moving flangeless surfaces, pressure means yieldingly pressing one of said surfaces toward the other along a predetermined line, means for depositing molten metal on one of said surfaces to one side of said line for free lateral spreading thereon, said metal passing between said surfaces and under the influence of said pressure means, driving means for moving said surfaces at variable speeds, and means whereby the separation of said surfaces against said pressure means by the metal passing between said surfaces controls the driving means for varying the speed of movement of said surfaces whereby to control the thickness of the metal to be formed by said surfaces.

5. In a combination of the class described, a pair of moving flangeless surfaces, pressure means yieldingly pressing one of said surfaces toward the other along a predetermined line, means for depositing molten metal on one of said surfaces to one side of said line for free lateral spreading thereon, said metal passing between said surfaces and under the influence of said pressure means, and means actuated through the separation against said pressure means of said surfaces by the metal passing between said surfaces, for changing the ratio of movement of said surfaces to the deposit rate of said metal whereby to control the thickness of the metal to be formed by said surfaces.

6. In a combination of the class described, a pair of rotating flangeless rings, pressure means yieldingly pressing one of said rings toward the other, means for depositing molten metal on one of said rings to one side of their line of nearest approach, said metal passing between said rings and under the influence of said pressure means, and means whereby the separation of said rings by the metal passing between said rings against said pressure means controls the rate of rotation of said rings relatively to the deposit rate of said metal whereby to control the thickness of the metal to be formed by said rings.

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