US 20020029865A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2002/0029865 A1

Kneppe et al. (43) Pub. Date: Mar. 14, 2002

(54) METHOD OF AND APPARATUS FOR CONTINUOUS CASTING OF STEEL STRIP

(75) Inventors: **Gunter Kneppe**, Hilchenbach (DE); **Hans Streubel**, Erkrath (DE); **Volker Loth**, Freudenberg (DE)

Correspondence Address:
THE FIRM OF KARL F ROSS
5676 RIVERDALE AVENUE
PO BOX 900
RIVERDALE (BRONX), NY 10471-0900 (US)

(73) Assignee: **SMS DEMAG AKTIENGESELLSCHAFT**

(21) Appl. No.: **09/938,867**

(22) Filed: **Aug. 24, 2001**

(30) **Foreign Application Priority Data**

Aug. 26, 2000 (DE)..... 10042078.8

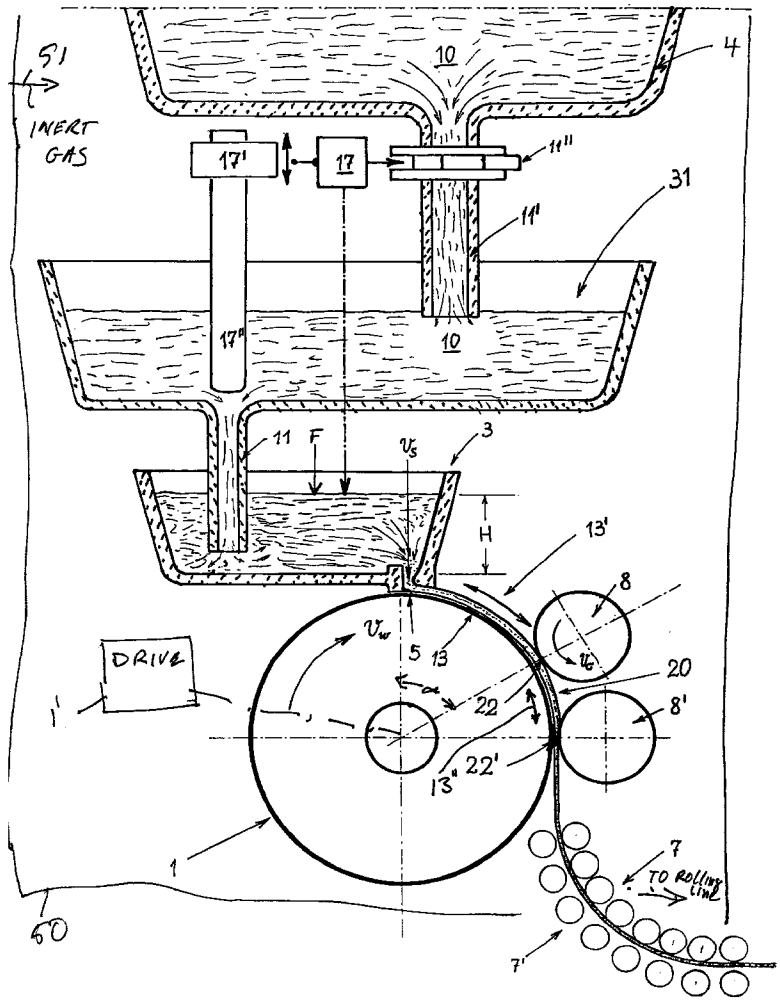
Publication Classification

(51) **Int. Cl.**[7] **B22D 11/06**; B22D 11/18; B22D 11/20

(52) **U.S. Cl.** **164/453**; 164/476; 164/479

(57) **ABSTRACT**

A continuous casting method and apparatus in which a distributor deposits a strand of molten steel upon a cooled surface of casting roll to a thickness of **1.0** to **6.0** mm, the cooling strand passes through the nip or gap between a fist counterroll and the casting roll and hardening strip is then passed through at least a first further nip between one or more further counterrolls and the surface of the casting roll. The height of the molten metal in the distributor is controlled to be constant by detecting the surface of the melt and regulating the outflow from an intermediate receptacle into the distributor and/or from the casting ladle into the intermediate receptacle so that the peripheral speed of the casting roll is matched to the speed with which the strand emerges from the distributor onto the casting roll.



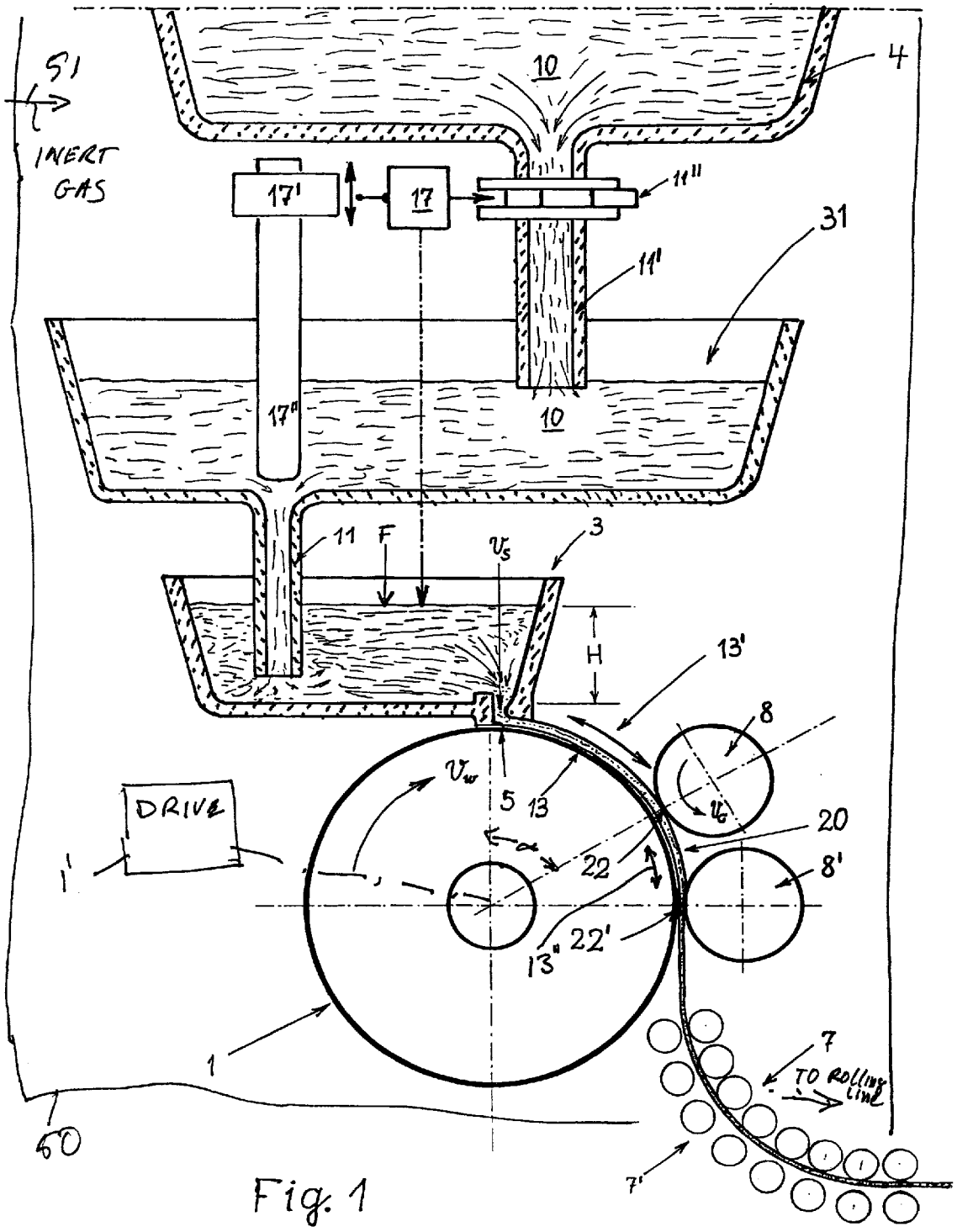

51
INERT GAS
10
4
17'
17
11''
31
11'
17''
10
11
F
v_s
3
H
13'
8
v_w
5
13
DRIVE
1'
20
22
8'
13''
22'
1
7
TO Rolling line
7'
60

Fig. 1

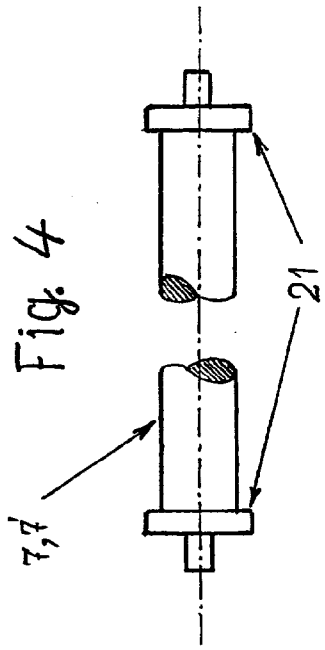


Fig. 4

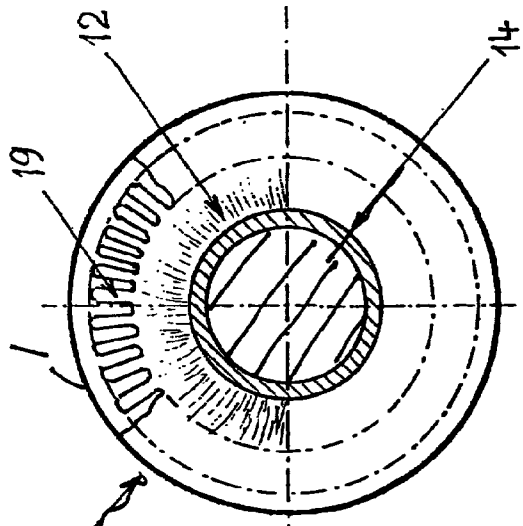


Fig. 3

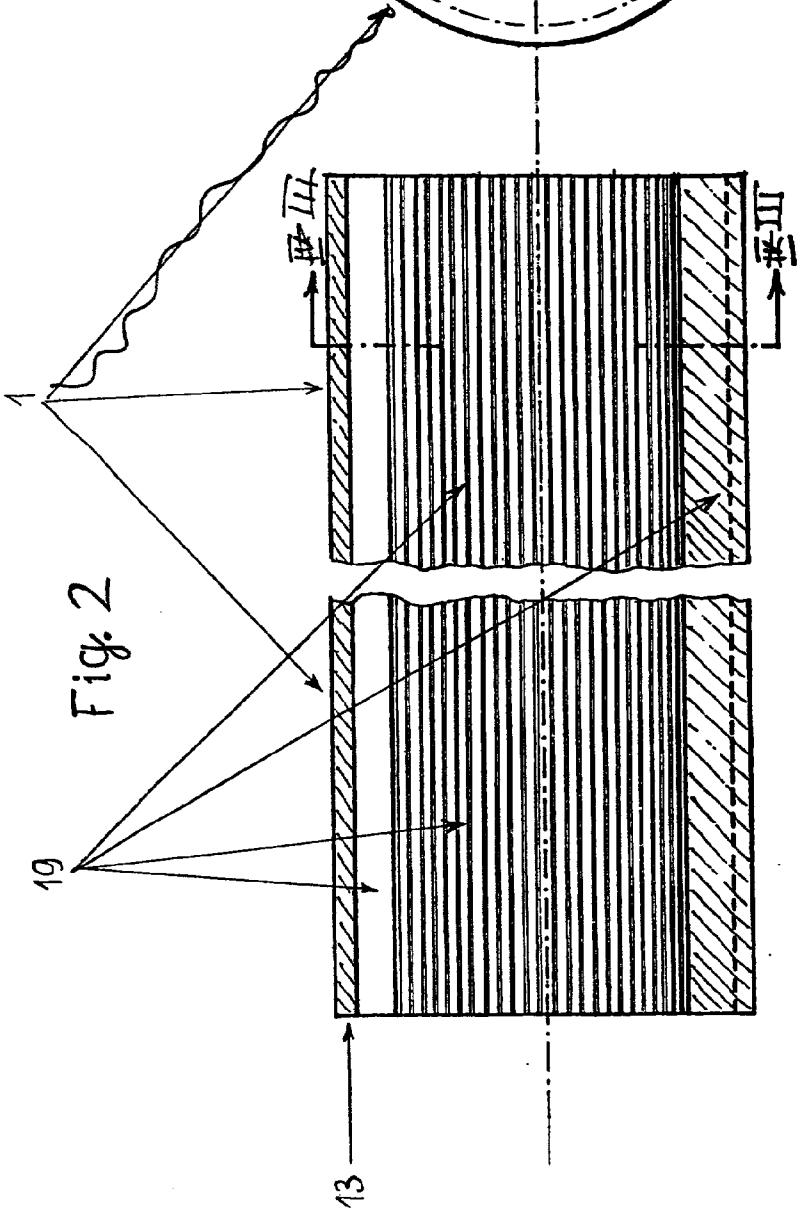


Fig. 2

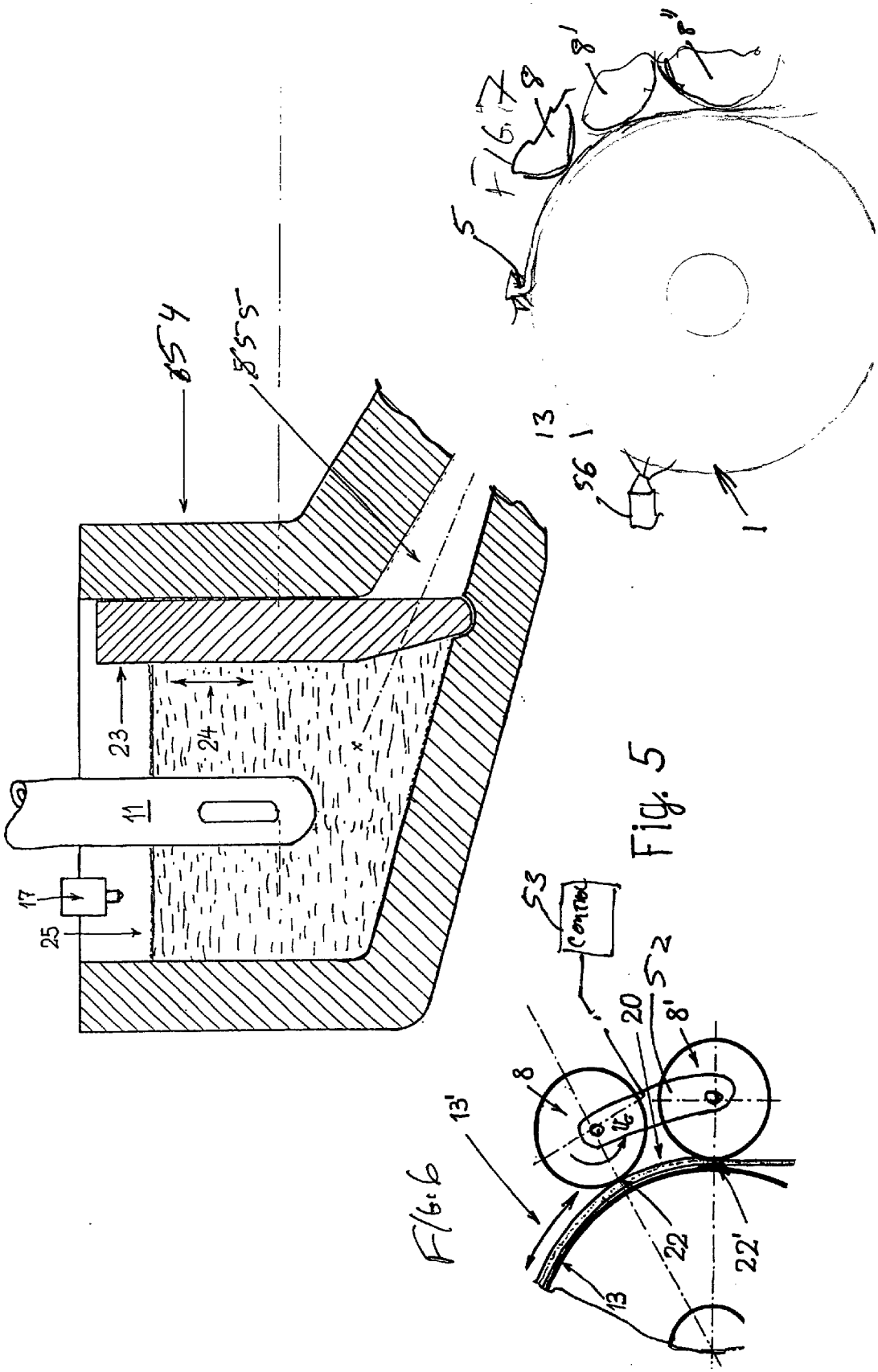


Fig. 4

Fig. 5

Fig. 6

METHOD OF AND APPARATUS FOR CONTINUOUS CASTING OF STEEL STRIP

FIELD OF THE INVENTION

[0001] Our present invention relates to a method of and to an apparatus for the continuous casting of steel strip. More particularly, the invention relates to the continuous casting of strands having a thickness between about 1.0 mm and 6.0 mm from a steel melt utilizing the deposition of the steel melt on the cooled surface of a casting roll and the solidification of the resulting strand on this roll.

BACKGROUND OF THE INVENTION

[0002] Continuous casting of molten metal on the chilled surface of a casting roll is known from the copious literature dealing with the casting of steel strip as well as of other metals.

[0003] In Hartmann, page 174, **FIG. 814**, aluminum strip with a thickness of 0.25 mm or less and with a ratio of width to thickness of at least 500:1 is continuously cast from a bath of aluminum by contact with a rising cooled surface drawing the cast strand from the bath of molten metal using an endless band or drum.

[0004] On page **25** of this publication, a method used by the Cleveland Graphite Bronze Company for the production of alloy strip over a wide hardening range has been described. The metal passes between rolls juxtaposed with one another such that the molten metal layer is at least partially hardened before it passes through the nip between the rolls. Utilizing this technique, cadmium lead alloy strip with good characteristics can be produced.

[0005] At still another point in this publication (see page **230**) a method of and an apparatus for the continuous casting of steel strip is described. Cast iron from a cupola furnace is refined together with scrap in an electrical furnace to steel and then is cast in a mold formed by a pair of horizontal rolls to strip. The endless strip is wound up, annealed and after unrolling is subdivided into lengths which are rolled into pipes.

[0006] In the aforementioned publication, moreover, a process practiced by Creusot-Loire is described whereby the steel melt flows upwardly into a gap between two cooled cylinder with the mold being introduced under a hydrostatic pressure and the cast strip lying along the periphery of a cylinder until it has been fully solidified.

OBJECTS OF THE INVENTION

[0007] It is the principal object of the present invention to provide an improved continuous casting method for the production of steel strip, especially in a thickness range between about 1.0 mm and about 6.0 mm, whereby the cast steel strip is of especially uniform constant thickness.

[0008] Another object of this invention is to provide a method of producing such steel strip which is particularly simple, easily controlled and compact.

[0009] It is also an object of the invention to provide an improved method of making steel strip whereby drawbacks of earlier systems and methods can be avoided.

[0010] Still another object is to provide an improved continuous casting system, apparatus or device which is simple, compact, easily controlled and adapted to produce particularly uniform steel strip, especially in the thickness range of 1.0 to 6.0 mm.

SUMMARY OF THE INVENTION

[0011] These objects and others which will become apparent hereinafter are attained, in accordance with the invention by a combination of feeding the steel melt from a distributor supplied by a tundish uniformly across the length of a casting roll having a cooled surface and such that the casting strand will harden at least partially through its thickness on the surface and that roll is in the nip formed by that roll with a first counterroll, passing the strand which can be in the form of a shell whose opposite sides flank a steel molten portion of the strand, along the surface of that casting roll so further solidification occurs therein and into the nip formed by a second counterroll with that surface to compress the resulting layer so that it is solid all across its thickness upon emerging from between the second counterroll and that surface, i.e. is solidified through and the thickness has been reduced from the thickness imparted to the layer in the first nip, i.e. between the first counterroll and the casting roll.

[0012] According to the invention, the method of continuously casting steel strip comprises the steps of:

[0013] (a) feeding a continuous stream of molten steel from a distributor across a length of a cooled casting roll and upstream of a first counter roll, thereby forming a hardening layer of a thickness of about 1.0 to 6.0 mm of the molten steel on a surface of the casting roll;

[0014] (b) controlling a speed with which the molten steel is fed onto the surface by regulating a ferrostatic height of molten steel in the distributor, the layer partially hardening on the surface to form a shell;

[0015] (c) compressing the shell between the surface of the casting roll and the counter roll in a first nip between the casting roll and the counter roll to impart a first cross sectional contour to the hardening layer; and

[0016] (d) thereafter compressing the hardening layer in a second nip between the casting roll and a further counter roll downstream of the first counter roll to reduce the thickness of the layer on the surface thereby imparting a cross sectional contour to the layer to form the steel strip.

[0017] The steel melt is delivered to the chilled surface of the casting roll with a velocity V_S which is determined by its ferrostatic height H and is controlled so that this velocity (and hence the height) are constant. The contact of the melt with the surface of the roll results in a partial hardening. The partially hardened strip or layer is usually solidified except for a central portion so that the solidified part can be termed a shell which passes through the first nip with a counterroll and then, usually still in the partially solidified state, through a second nip in which the thickness is reduced and a new contour imparted to the strip whereby the strip, at least upon leaving the second nip, is hardened through its thickness.

This in part can be due to a compression of the partially hardened strip so the strip leaving the nip is hardened through its thickness.

[0018] According to a feature of the invention, the strip downstream of the second shaping nip is bent into a horizontal orientation, between guide rollers and counterrollers. The thickness reduction in the first gap of a plurality of nips or gaps following the first counterroll can be between 5% and 20% and the thickness reduction in a second nip or gap can be between 10% and 50%. The peripheral speed V_W of the casting roll should be matched to the output velocity V_S of the melt from the distributor. The peripheral speed V_G is 0.5% to 1.5% greater than the peripheral speed V_W.

[0019] According to another feature of the invention the counterrolls themselves are cooled.

[0020] The ferrostatic height H of the melt in the distributor is continuously measured and by control of the supply of the melt to the distributor from a casting ladle and an intervening receptacle, e.g. a tundish, the height H is held constant in the distributor.

[0021] The delivery of the melt form the tundish to the distributor can be effected via a downcomer immersed in the melt in the distributor.

[0022] The outflow velocity from the distributor can also be set by pressure control and such that a controllable subatmospheric pressure is applied to the surface of the liquid melt in the distributor. It has been found to be advantageous to apply a blanket of an inert gas to the melt at least in the region in which the melt flows from the distributor and thereby prevent reoxidation of the melt and the avoidance of slag formation. The melt in the distributor and in the tundish can also be blanketed by the inert gas which can protect the cast steel preferably until the cast steel reaches a rolling line downstream of the casting unit.

[0023] The cooling of the casting roll and the counterrolls can be effected by passing coolants through internal bores or grooves thereof, thereby ensuring intensive cooling and the guide rolls along which the strip is bent to the horizontal can also be internally cooled. The casting can additionally be cooled or cleaned by water spray jets applied from the exterior.

[0024] The invention also comprises an apparatus for the continuous casting of steel strip, preferably in a thickness range of 1.0 mm to 6.0 mm from a steel melt and which comprises a distributor for the steel melt having a slit-like outlet opening at a bottom portion thereof, means for metering the melt from a ladle, and an intermediate distributor or receptacle (tundish) receiving the melt from the casting ladle and a means for controlling the flow of the melt from the intermediate receptacle into the distributor. According to the invention, a sensor is provided for controlling the height of the level of the melt in the distributor and regulating the flow through a dip tube or downcomer connecting the intermediate receptacle with the distributor.

[0025] The outlet slot of the distributor opens onto a cooled surface of a roller which is driven with a peripheral speed matched to the outflow speed of the melt from the outlet opening of the distributor. The surface of the casting roller is juxtaposed with a plurality of counterrolls or shaping rolls, such that at least one of the nips or gaps between the surface of the counterroll is adjustable. Downstream of the casting roll the strip can be guided into a horizontal orientation between guide rolls and counterrolls.

[0026] According to a feature of the invention, the apparatus is maintained in an inert gas atmosphere from at least the outlet of the distributor to the guide rolls.

[0027] The coolable gas roll and the counterrolls can be composed of a CuNiBe alloy and the guide rolls can be solid and can be of relatively small diameter, i.e. a diameter less than that of the casting roll and its counterroll, and also can be fabricated from a CuNiBe alloy. Such an alloy has been found to be especially temperature and wear-resistant particularly when they may come into contact with molten steel.

[0028] According to a further feature of the invention, a plurality of counterrolls may be joined together in a segment which can be adjustable as a unit and can be provided with common setting means, e.g. for adjusting the respective gap width. The casting roll, counterrolls and guide rollers can be provided at least in part with guide edges or flanges of a height or thickness corresponding to the thickness of the cast product or can be made concave when, for example, a bulge in the profile or cross section of the strip of about 1% is to be provided.

BRIEF DESCRIPTION OF THE DRAWING

[0029] The above and other objects, features, and advantages will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

[0030] **FIG. 1** is a diagrammatic cross sectional view of an apparatus for the continuous casting of steel strip from a steel melt according to the invention;

[0031] **FIG. 2** is an axial cross section through the casting roll of the apparatus of **FIG. 1**;

[0032] **FIG. 3** is section taken along the lime III-III of **FIG. 2**;

[0033] **FIG. 4** is an elevational view, partly broken away of one of the guide or counterrolls of the system of **FIG. 1** illustrating a feature of those rolls and o the casting and counterroll if desired;

[0034] **FIG. 5** is a cross sectional view showing another embodiment of the distributor according to the invention;

[0035] **FIG. 6** shows the connection of counterrolls to form a segment according to the invention; and

[0036] **FIG. 7** is a detail view showing another feature of the invention.

SPECIFIC DESCRIPTION

[0037] The apparatus shown in **FIG. 1** comprises a casting ladle **4** having a casting tube **11'** from which a steel melt **10** is delivered to an intermediate receptacle **31**, i.e. a tundish from which a dip tube or downcomer **11** delivers that melt to the distributor **3**.

[0038] In the upper region of the outlet **11'**, a controllable throttle valve **11"**, e.g. a slider, is provided which is controlled by a sensor **17** which detects the liquid level S in the distributor **3** and thus regulates the height H so that the latter is constant and determines the velocity V_S of the molten

steel flow out of the slot-like outlet opening **5** and onto the chilled surface of a casting roll or drum **1**.

[**0039**] The valve **11**" opens further with a drop in the level F or closes further upon an increase in that level.

[**0040**] In addition the outlet **11** may have a stopper **17**" with a control **17**'for the height of that stopper operated by the level controller **17** to reduce the flow through the outlet **11** upon an increase in the level height F or, conversely, to increase the flow should the liquid level drop. In this manner, the height H of the molten metal within the distributor can be maintained constant with a high degree of accuracy.

[**0041**] The roll **1** may be provided with a controlled drive **1**' which maintains the peripheral speed of the drum V_W equal to the speed V_S of the molten steel for a thickness of the strip formed on the surface of the drum between 1.0 and 6.0 mm. Over an angle a, corresponding to the stretch **13**' of the surface **13** of the roller, such a thickness is maintained by the control of the drive **1**'. The molten steel contacting the surface **13** spontaneously begins to solidify and forms a shell which passes through a nip or gap **22** between the surface and a counterroll **8** which can be driven with a peripheral speed V_G which is slightly higher than the peripheral speed V_W. Further solidification takes place in the region **13**" of the travel of the strip which is not fully solidified at the gap **22**. In the latter, however, a thickness reduction is carried out in an amount between 5% and 20% of the cast thickness.

[**0042**] In the region **13**" the solidification of the strip **20** continues until at the outlet from the gap **22**', the strip is fully solidified. The full solidification of the strip can occur upstream of the gap **22**' formed between the surface **13** of the roll **1** and the surface of a counterroll **8**' which also can be rotated at a peripheral speed slightly higher than that of the surface **13** of roll **1**. In the gap **22**', a further thickness reduction between 10 and 50% is effected.

[**0043**] The fully solidified strip **20** is then guided away from the surface **13** of the roll **1** by guide rolls and counterrolls **7**, **7**' and delivered to a rolling line.

[**0044**] The entire apparatus from at least the distributor **3** to the last of a plurality of counterrolls **8**, **8**' . . . can be increased in a housing **50** supplied with an inert gas at **51**. The inert gas can be argon.

[**0045**] For especially good heat conductive contact between the steel strip and the cooled surface of the roll **1**, the peripheral speed V_G should be 0.5% to 1.5% more than the peripheral speed V_W. At least the surface of the casting roll **1** in contact with the molten steel should be composed of CuNiBe alloy and it has been found that the surfaces of the rolls **8**, **8**' etc. at least should also be composed of such an alloy. This alloy has been found to have effective heat-conductive and wear-resistance properties.

[**0046**] The casting roll **1** (see **FIGS. 2 and 3**) can be formed with cooling channels **19** which can lie close to the surface **13** of the cooling roll and can be provided on a shell mounted on a hub **12** receiving a shaft **14**. A liquid coolant can be forced through the channels **19**. The channels can be cooling bores or cooling grooves.

[**0047**] The guide rolls **7**, **7**'can be of comparatively small diameter and can be solid, e.g. composed of a CuNiBe alloy (FIG. **3**) and may have rims, flanges or raised edges as shown at **21** of radial heights equal to the thickness of the strip in these regions. The casting roll **13** and the counterrolls **8**, **8**', etc. can also be provided with flanges **21** of the full height of the strip thickness or half that height where the counterrolls and the casting roll have such flanges juxtaposed with one another.

[**0048**] The rolls **8**, **8**', etc. may be mounted to form a segment on a common support **52** (**FIG. 6**) which can have a control **53** for the widths of the gaps **22** and **22**'.

[**0049**] In **FIG. 5** there is shown a different configuration for a distributor **54** whose outlet **55** can be blocked by a slider **23** which can be raised and lowered as represented at **24** at least partially to control the outflow velocity. A level sensor **17** is here responsive to the molten metal level **25** and controls the flow of the outlet tube **11** from the intermediate receptacle.

[**0050**] **FIG. 7** shows that more than two counterrolls **8**, **8**', **8**" can be provided in juxtaposition with the casting roll **1** and that the latter may be additionally cooled by spray nozzles **56** directing jets of water against the surface **13** before it reaches the outlet **5** or **55** from a distributor **3** or **54**. The apparatus of **FIG. 1** can preferably be operated at a temperature in the range of 1100° to 1400° C.

We claim:

1. A method of continuously casting steel strip comprising the steps of:

(a) feeding a continuous stream of molten steel from a distributor across a length of a cooled casting roll and upstream of a first counter roll, thereby forming a hardening layer of a thickness of about 1.0 to 6.0 mm of said molten steel on a surface of said casting roll;

(b) controlling a speed with which said molten steel is fed onto said surface by regulating a ferrostatic height of molten steel in said distributor, said layer partially hardening on said surface to form a shell;

(c) compressing said shell between said surface of said casting roll and said counter roll in a first nip between said casting roll and said counter roll to impart a first cross sectional contour to said hardening layer; and

(d) thereafter compressing said hardening layer in a second nip between said casting roll and a further counter roll downstream of said first counter roll to reduce the thickness of the layer on said surface thereby imparting a cross sectional contour to said layer to form said steel strip.

2. The method defined in claim 1 wherein said steel strip is hardened throughout its thickness upon emerging from said second nip.

3. The method defined in claim 2 wherein said steel strip is guided between guide and counterrolls into a horizontal orientation following the last of the counterrolls juxtaposed with said surface.

4. The method defined in claim 2 wherein a thickness reduction in said first nip is effected of about 5% to 20%.

5. The method defined in claim 2 wherein a thickness reduction is effected in said second nip by about 10 to 50%.

6. The method defined in claim 2, further comprising the step of controlling a peripheral speed of said casting roll to match a speed with which said molten steel is fed onto said surface.

7. The method defined in claim 2 wherein said counterrolls are driven with peripheral speeds 0.5 to 1.5% higher than a peripheral speed of said casting roll.

8. The method defined in claim 2, further comprising the steps of cooling said counterrolls.

9. The method defined in claim 2 wherein a perspective height of the melt in said distributor is continuously measured and supply of melt to said distributor is controlled to maintain said height constant.

10. The method defined in claim 9 wherein said melt is delivered by an intermediate receptacle receiving said melt from a casting ladle to said distributor by a tube dipping into the melt in said distributor.

11. The method defined in claim 2 wherein a speed of said melt discharged from said distributor is controlled at least in part by controlling a subatmospheric pressure applied to said distributor.

12. The method defined in claim 2, further comprising the step of blanketing said melt at least from said distributor to a last of said counterrolls with an inert gas to prevent oxidation of said melt and slag formation.

13. The method defined in claim 12 wherein said melt is fed to said distributor from a tundish and the melt in said tundish is also blanketed with said inert gas.

14. The method defined in claim 2, further comprising the step of internally cooling said casting roll and counterroll by passing coolant through cooling bores or grooves in said casting roll and said cooling rolls.

15. The method defined in claim 14, further comprising the step of additionally cooling or cleaning said casting roll by directing water spray jets thereagainst.

16. The method defined in claim 3, further comprising the steps of cooling the guide and counterrolls with which said strip is guided into said horizontal orientation.

17. The method defined in claim 2 wherein said strip is at a temperature in a range between 1100° and 1400° C. upon casting onto said casting roll.

18. An apparatus for continuously casting steel strip comprising:

a casting roll having a cooled peripheral surface;

a distributor having a slot-shaped outlet extending along said surface for depositing a molten steel strand on said surface whereby said strand cools on said surface to form a shell and hardening into a steel strip;

a first counterroll juxtaposed with said surface for compressing said shell and thereby reducing a thickness of said strip in a first nip;

at least one second counterroll juxtaposed with said surface downstream of said first nip and defining with said surface a second nip for compressing said strip whereby said strip is solidified through a thickness thereof upon emergence from said second nip;

a tundish receiving molten metal from a casting metal and delivering said molten metal to said distributor through a tube immersed in molten metal in said distributor; and

a sensor responsive to a height of molten metal in said distributor for controlling delivery of a molten metal from said tundish to said separator to maintain said height substantially constant, said casting roll being driven with a peripheral speed matched to a speed with which molten steel is delivered by said distributor to said surface.

19. The apparatus defined in claim 18, further comprising guide and counterrollers downstream of said casting roll, receiving said strip and bending said strip into a horizontal orientation, said guide and counterrollers being of smaller diameter than said rolls, composed of solid material and constituted of a CuNiBe alloy.

20. The apparatus defined in claim 18 wherein at least one of said rolls is composed of CuNiBe alloy.

21. The apparatus defined in claim 18 wherein a plurality of said counterrolls are interconnected to form a segment having a common control for positioning the counterrolls of said segment.

22. The apparatus defined in claim 18, further comprising means for blanketing the molten steel at least in said distributor and along said casting roll with an inert gas.

* * * * *