Title: PRODUCTION OF THIN STEEL STRIP

Abstract: A twin roll caster (11) produces thin steel strip (12) which passes in a transit path (10) across guide table (13) to a pinch roll stand (14). After exiting pinch roll stand (14) the strip passes through rolling mill (15) comprising two roll stands (16) in which it is hot rolled to reduce its thickness. The rolled strip passes to run-out table (17) on which it may be force cooled by water jets (18). The already rolled strip is then descaled in a descaler (19) comprising upper and lower water jet nozzles (61,62) which removes scale from both the upper and lower surfaces of the strip. The descaled strip is passed through a pinch roll stand (20) to a coiler (50).
PRODUCTION OF THIN STEEL STRIP

TECHNICAL FIELD

This invention relates to the production of thin steel strip. It has particular application to the production of steel strip by continuous casting and inline hot rolling of the strip to a final gauge or thickness.

Steel strip produced by continuous thin slab casting or by twin roll strip casting may be subjected to inline hot rolling to reduce the strip to the final gauge.

In a twin roll caster molten metal is introduced between a pair of contra-rotated horizontal casting rolls which are cooled so that metal shells solidify on the moving roll surfaces and are brought together at the nip between them to produce a solidified strip product delivered downwardly from the nip between the rolls. The term "nip" is used herein to refer to the general region at which the rolls are closest together. The molten metal may be poured from a ladle into a smaller vessel from which it flows through a metal delivery nozzle located above the nip so as to direct it into the nip between the rolls, so forming a casting pool of molten metal supported on the casting surfaces of the rolls immediately above the nip and extending along the length of the nip. This casting pool is usually confined between side plates or dams held in sliding engagement with end surfaces of the rolls so as to dam the two ends of the casting pool against outflow, although alternative means such as electromagnetic barriers have also been proposed.

When casting steel strip in a twin roll caster the strip leaves the nip at very high temperatures of the order of 1400°C and if exposed to air, it suffers very rapid scaling due to oxidation at such high temperatures. It has therefore previously been proposed to install descaling equipment to descale the strip immediately before it enters the inline rolling mill. On the other hand, there have been proposals to shroud the newly cast strip
within an enclosure containing a non-oxidising atmosphere up to the time that it enters the inline rolling mill so as to reduce scaling and avoid the need to descale prior to hot rolling. One such proposal is described in United States Patent 5,762,126 according to which the cast strip is passed through a sealed enclosure from which oxygen is extracted by initial oxidation of the strip passing through it thereafter the oxygen content in the sealed enclosure is maintained at less than the surrounding atmosphere by continuing oxidation of the strip passing through it so as to control the thickness of the scale on the strip emerging from the enclosure. By this means it is possible to allow the strip to exit the enclosure and be presented to the hot rolling mill with scale thickness no more than 10 microns.

According to the previous proposal as described in United States Patent 5,762,126 the strip leaving the hot rolling mill was subjected to water cooling and then coiled. With this procedure, the strip may need to be subsequently descaled or pickled prior to some end uses.

We have now determined that if the hot rolled strip is subjected to descaling prior to coiling at temperatures in the range 900°C to 600°C the rate of rescaling will be very low. The strip can be coiled with very low scale of the order of only 1 to 2 micron thick and there will be no further appreciable scale development. The resulting coils can be sent directly to end users for many applications such as in the production of drums and any painted strip products. In other applications, they will allow much faster pickling than the material not subjected to descaling immediately prior to coiling.

DISCLOSURE OF THE INVENTION

According to the present invention, there is provided a method of producing steel strip comprising:

continuously casting a steel strip;

guiding the strip through an enclosure containing an atmosphere which inhibits oxidation of the strip surface
and consequent scale formation;

feeding the strip through a rolling mill in which it is rolled as it is produced;

passing the rolled strip through a descaler so as to remove scale therefrom as it leaves the rolling mill;

and passing the rolled and descaled strip to a coiler.

The strip may be passed out of said enclosure prior to passing through the rolling mill.

Alternatively, the rolling mill may be disposed within the enclosure so that the strip passes through the rolling mill before leaving the enclosure.

Preferably, the strip is continuously cast by supporting a casting pool of molten steel on a pair of chilled casting rolls forming a nip between them and the solidified strip is produced by rotating the rolls in mutually opposite directions such that the solidified strip moves downwardly from the nip.

The atmosphere in said enclosure may be formed of inert or reducing gases or it may be an atmosphere containing oxygen at a level lower than the atmosphere surrounding the enclosure.

Preferably, the atmosphere in the enclosure is formed by sealing the enclosure to restrict ingress of oxygen containing atmosphere, causing oxidation of the strip within the enclosure during an initial phase of casting thereby to extract oxygen from the sealed enclosure and to cause the enclosure to have an oxygen content less than the atmosphere surrounding the enclosure, and thereafter maintaining the oxygen content in the sealed enclosure at less than that of the surrounding atmosphere by continuous oxidation of the strip passing through the sealed enclosure thereby to control the thickness of the resulting scale on the strip.

Preferably, the rolling mill hot rolls the strip at a temperature in the range of 750 to 1250°C.
The invention further provides apparatus for producing steel strip comprising:

a continuous caster for continuously casting steel strip;

strip guide means to guide the strip through a transit path away from the caster;

an oxidation inhibiting enclosure to confine the strip throughout said transit path to control formation of scale on the strip;

a rolling mill operable to roll the strip as it is produced;

a descaler operable to descale the strip as it leaves the rolling mill; and

a coiler to receive the rolled and descaled strip.

Preferably, the continuous caster includes:

a pair of generally horizontal casting rolls forming a nip between them;

metal delivery means to deliver molten steel into the nip between the casting rolls to form a casting pool of molten steel supported on the rolls;

means to chill the casting rolls; and means to rotate the casting rolls in mutually opposite directions whereby to cast said strip and to deliver it downwardly from the nip.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more fully explained one particular embodiment will be described in detail with reference to the accompanying drawings in which:

Figure 1 is a vertical cross-section through a steel strip casting and rolling installation constructed and operated in accordance with the present invention;

Figure 2 illustrates essential components of a twin roll caster incorporated in the installation;

Figure 3 is a vertical cross-section through part
of the twin roll caster;

Figure 4 is a cross-section through end parts of
the caster.

Figure 5 is a cross-section on the line 5-5 in
Figure 4;

Figure 6 is a view on the line 6-6 in Figure 4;
and

Figure 7 is a diagrammatic view of part of a
modified installation constructed and operated in
accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The illustrated casting and rolling installation
comprises a twin roll caster denoted generally as 11 which
produces a cast steel strip 12 which passes in a transit
path 10 across a guide table 13 to a pinch roll stand 14.
Immediately after exiting the pinch roll stand 14, the
strip passes into a hot rolling mill 15 comprising roll
stands 16 in which it is hot rolled to reduce its
thickness. The thus rolled strip exits the rolling mill
and passes to a run out table 17 on which it may be force
cooled by water jets 18. In accordance with the present
invention the strip is then passed through a descaler 19
before passing between pinch rolls 20A of a pinch roll
stand 20 to a coiler 50.

Twin roll caster 11 comprises a main machine
frame 21 which supports a pair of parallel casting rolls 22
having casting surfaces 22A. Molten metal is supplied
during a casting operation from a ladle 23 through a
refractory ladle outlet shroud 24 to a tundish 25 and
thence through a metal delivery nozzle 26 into the nip 27
between the casting rolls 22. Hot metal thus delivered to
the nip 27 forms a pool 30 above the nip and this pool is
confined at the ends of the rolls by a pair of side closure
dams or plates 28 which are applied to stepped ends of the
rolls by a pair of thrusters 31 comprising hydraulic
cylinder units 32 connected to side plate holders 28A. The
upper surface of pool 30 (generally referred to as the "meniscus" level) may rise above the lower end of the delivery nozzle so that the lower end of the delivery nozzle is immersed within this pool.

Casting rolls 22 are water cooled so that shells solidify on the moving roller surfaces and are brought together at the nip 27 between them to produce the solidified strip 12 which is delivered downwardly from the nip between the rolls.

At the start of a casting operation a short length of imperfect strip is produced as the casting conditions stabilise. After continuous casting is established, the casting rolls are moved apart slightly and then brought together again to cause this leading end of the strip to break away in the manner described in Australian Patent Application 27036/92 so as to form a clean head end of the following cast strip. The imperfect material drops into a scrap box 33 located beneath caster 11 and at this time a swinging apron 34 which normally hangs downwardly from a pivot 35 to one side of the caster outlet is swung across the caster outlet to guide the clean end of the cast strip onto the guide table 13 which feeds it to the pinch roll stand 14. Apron 34 is then retracted back to its hanging position to allow the strip 12 to hang in a loop beneath the caster before it passes to the guide table 13 where it engages a succession of guide rollers 36.

The twin roll caster may be of the kind which is illustrated and described in some detail in granted Australian Patents 631728 and 637548 and United States Patents 5,184,668 and 5,277,243 and reference may be made to those patents for appropriate constructional details which form no part of the present invention.

The installation is manufactured and assembled to form a single very large scale enclosure denoted generally as 37 defining a sealed space 38 within which the steel strip 12 is confined throughout a transit path from the nip between the casting rolls to the entry nip 39 of the pinch
roll stand 14.

Enclosure 37 is formed by a number of separate wall sections which fit together at various seal connections to form a continuous enclosure wall. These comprise a wall section 41 which is formed at the twin roll caster to enclose the casting rolls and a wall section 42 which extends downwardly beneath wall section 41 to engage the upper edges of scrap box 33 when the scrap box is in its operative position so that the scrap box becomes part of the enclosure. The scrap box and enclosure wall section 42 may be connected by a seal 43 formed by a ceramic fibre rope fitted into a groove in the upper edge of the scrap box and engaging flat sealing gasket 44 fitted to the lower end of wall section 42. Scrap box 33 may be mounted on a carriage 45 fitted with wheels 46 which run on rails 47 whereby the scrap box can be moved after a casting operation to a scrap discharge position. Cylinder units 40 are operable to lift the scrap box from carriage 45 when it is in the operative position so that it is pushed upwardly against the enclosure wall section 42 and compresses the seal 43. After a casting operation the cylinder units 40 are released to lower the scrap box onto carriage 45 to enable it to be moved to scrap discharge position.

Enclosure 37 further comprises a wall section 48 disposed about the guide table 13 and connected to the frame 49 of pinch roll stand 14 which includes a pair of pinch rolls 14A against which the enclosure is sealed by sliding seals 60. Accordingly, the strip exits the enclosure 38 by passing between the pair of pinch rolls 14A and it passes immediately into the hot rolling mill 15. The spacing between pinch rolls 14 and the entry to the rolling mill should be as small as possible so as to control the formation of scale prior to entry into the rolling mill.

Most of the enclosure wall sections may be lined with fire brick and the scrap box 33 may be lined either with fire brick or with a castable refractory lining.
The enclosure wall section 41 which surrounds the casting rolls is formed with side plates 51 provided with notches 52 shaped to snugly receive the side dam plate holders 28A when the side dam plates 28 are pressed against the ends of the rolls by the cylinder units 32. The interfaces between the side plate holders 28A and the enclosure side wall sections 51 are sealed by sliding seals 53 to maintain sealing of the enclosure. Seals 53 may be formed of ceramic fibre rope.

The cylinder units 32 extend outwardly through the enclosure wall section 41 and at these locations the enclosure is sealed by sealing plates 54 fitted to the cylinder units so as to engage with the enclosure wall section 41 when the cylinder units are actuated to press the side plates against the ends of the rolls. Thrusters 31 also move refractory slides 55 which are moved by the actuation of the cylinder units 32 to close slots 56 in the top of the enclosure through which the side plates are initially inserted into the enclosure and into the holders 28A for application to the rolls. The top of the enclosure is closed by the tundish, the side plate holders 28A and the slides 55 when the cylinder units are actuated to apply the side dam plates against the rolls. In this way the complete enclosure 37 is sealed prior to a casting operation to establish the sealed space 38 whereby to limit the supply of oxygen to the strip 12 as it passes from the casting rolls to the pinch roll stand 14. Initially the strip will take up all of the oxygen from the enclosure space 38 to form heavy scale on the strip. However, the sealing of space 38 controls the ingress of oxygen containing atmosphere below the amount of oxygen that could be taken up by the strip. Thus, after an initial start up period the oxygen content in the enclosure space 38 will remain depleted so limiting the availability of oxygen for oxidation of the strip. In this way, the formation of scale is controlled without the need to continuously feed a reducing or non-oxidising gas into the enclosure space 38.
In order to avoid the heavy scaling during the start-up period, the enclosure space can be purged immediately prior to the commencement of casting so as to reduce the initial oxygen level within the enclosure and so reduce the time for the oxygen level to be stabilised as a result of the interaction of oxygen from the scaled enclosure due to oxidation of the strip passing through it. The enclosure may conveniently be purged with nitrogen gas. It has been found that reduction of the initial oxygen content to levels of between 5% to 10% will limit the scaling of the strip at the exit from the enclosure to about 10 microns to 17 microns even during the initial start-up phase.

In a typical caster installation the temperature of the strip passing from the caster will be of the order of 1400°C and the temperature of the strip presented to the mill may be about 1200°C. The strip may have a width in the range 0.9 m to 2.0 m and a thickness in the range 0.7 mm to 2.0 mm. The strip speed may be of the order of 1.0 m/s. It has been found that with strip produced under these conditions it is quite possible to control the leakage of air into the enclosure space 38 to such a degree as to limit the growth of scale on the strip to a thickness of less than 5 microns at the exit from the enclosure space 38, which equates to an average oxygen level of 2% with that enclosure space. The volume of the enclosure space 38 is not particularly critical since all of the oxygen will rapidly be taken up by the strip during the initial start-up phase of a casting operation and the subsequent formation of scale is determined solely by the rate of leakage of atmosphere into the enclosure space though the seals. It is preferred to control this leakage rate so that the thickness of the scale at the mill entry is in the range 1 micron to 5 microns. Experimental work has shown that the strip needs some scale on its surface to prevent welding and sticking during hot rolling. Specifically, this work suggests that a minimum thickness of the order of 0.5 to 1 micron is necessary to ensure satisfactory
rolling. An upper limit of about 8 microns and preferably 5 microns is desirable to avoid "rolled-in scale" defects in the strip surface after rolling and to ensure that scale thickness on the final product is no greater than on conventionally hot rolled strip.

After leaving the hot rolling mill the strip passes to run out table 17 on which it may be forced cooled by water jets 18. In accordance with the present invention, it then passes through a descaler 19 before being coiled on coiler 20. Descaler 19 may be of conventional construction. It may typically comprise upper and lower water jet nozzles 61, 62 supplied with water from a pressure pump through respective water jet manifolds 63, 64 so as to produce water jets 65, 66 directed against the upper and lower surfaces of the strip to remove the scale from both surfaces.

In a typical installation producing steel strip to widths of the order of 1300 mm to 1700 mm there may be an array of 15 to 20 upper nozzles 61 and a similar array of 15 to 20 lower nozzles 62 spaced across the strip. Typically the nozzles may each have a spray angle of the order of 50° to 55° and be spaced to produce fanned jets which overlap by about 10 mm. They may sit at a stand off distance of 60 to 70 mm and be operated to produce a nozzle flow rate of about 60 L/min at a pressure of 7 MPa to 10MPa.

The water jets of the descaler further reduce the temperature of the strip prior to coiling. Typically, the strip may be descaled at a temperature of 750°C and coiled at a temperature of around 600°C. In these circumstances the strip in the coil will typically have scale of only 1 to 2 microns thick and there will be no appreciable further scaling as the strip cools to ambient temperature. This is a significant development and results in a commercially valuable product in that for many applications such as manufacture of drums or production of painted products the lightly scaled strip can be used directly as a feed
material without further treatment, thus eliminating the cost of pickling or pre-treatment normally required with strip formed by conventional processes. For more demanding applications the lightly scaled strip can be pickled much more rapidly than the strip which has not been descaled immediately prior to coiling.

Figure 7 illustrates a modification by which the enclosure 37 is extended to enclose the rolling mill 15 so that the strip is rolled before it leaves the enclosure space 38. In this case, the strip exits the enclosure through the last of the mill stands 16 the rolls of which serve also to seal the enclosure so that separate sealing pinch rolls are not required.

It has been found that in order to avoid excessive scale formation, the strip should preferably leave enclosure 37 at a temperature of no more than 925°C. Accordingly, with the arrangement illustrated in Figures 1 to 6, the strip may be hot rolled at a temperature in the range 750 to 925°C whereas in an installation arranged as illustrated in Figure 7 the strip may be hot rolled at temperatures in the full range of 750° to 1250°C.

Although the preferred embodiment of the invention employs a twin roll strip caster, this is not essential in invention in its broadest aspect and the twin roll caster could be replaced by a conventional continuous thin slab caster producing an initial slab or strip with a thickness of the order of 120 to 50 mm which may then be rolled in the hot rolling mill down to a final thickness of the order of 16.0 to 0.7 mm.
CLAIMS:
1. A method of producing steel strip comprising:
   continuously casting a steel strip;
   guiding the strip through an enclosure containing
   an atmosphere which inhibits oxidation of the strip surface
   and consequent scale formation;
   feeding the strip through a rolling mill in which
   it is rolled as it is produced;
   passing the rolled strip through a descaler so as
   to remove scale therefrom as it leaves the rolling mill;
   and
   passing the rolled and descaled strip to a
   coiler.
2. A method as claimed in claim 1, wherein the
   rolling mill hot rolls the strip at a temperature in the
   range of 750 to 1250°C.
3. A method as claimed in claim 1 or claim 2,
   wherein the strip is passed out of said enclosure prior to
   passing through the rolling mill.
4. A method as claimed in claim 1 or claim 2,
   wherein the rolling mill is disposed within the enclosure
   so that the strip passes through the rolling mill before
   leaving the enclosure.
5. A method as claimed in any one of claims 1 to 4,
   wherein the strip is continuously cast by supporting a
   casting pool of molten steel on a pair of chilled casting
   rolls forming a nip between them and the solidified strip
   is produced by rotating the rolls in mutually opposite
   directions such that the solidified strip moves downwardly
   from the nip.
6. A method as claimed in any one of claims 1 to 5,
   wherein the atmosphere in said enclosure is formed of inert
   or reducing gases.
7. A method as claimed in any one of claims 1 to 5,
   wherein the atmosphere in said enclosure is an atmosphere
   containing oxygen at a level lower than the atmosphere
   surrounding the enclosure.
8. A method as claimed in claim 7, wherein the atmosphere in the enclosure is formed by sealing the enclosure to restrict ingress of oxygen containing atmosphere, causing oxidation of the strip within the enclosure during an initial phase of casting thereby to extract oxygen from the sealed enclosure and to cause the enclosure to have an oxygen content less than the atmosphere surrounding the enclosure, and thereafter maintaining the oxygen content in the sealed enclosure at less than that of the surrounding atmosphere by continuous oxidation of the strip passing through the sealed enclosure thereby to control the thickness of the resulting scale on the strip.

9. A method as claimed in any one of claims 1 to 8, wherein the strip leaves said enclosure at a temperature less than 925°C.

10. A method as claimed in any one of claims 1 to 9, wherein the strip is passed generally horizontally through the descaler and scale is removed therein by water jets directed against the upper and lower face of the strip to remove scale from both surfaces.

11. Apparatus for producing steel strip comprising:

- a continuous caster for continuously casting steel strip;
- strip guide means to guide the strip through a transit path away from the caster;
- an oxidation inhibiting enclosure to confine the strip throughout said transit path to control formation of scale on the strip;
- a rolling mill operable to roll the strip as it is produced;
- a descaler operable to descale the strip as it leaves the rolling mill; and
- a coiler to receive the rolled and descaled strip.
12. Apparatus as claimed in claim 11, wherein the rolling mill is located outside said enclosure so as to receive the strip after it exits the enclosure.

13. Apparatus as claimed in claim 12, wherein the rolling mill is located within the enclosure so as to roll the strip before it exits the enclosure.

14. Apparatus as claimed in any one of claims 11 to 13, wherein the continuous caster includes:
   - a pair of generally horizontal casting rolls forming a nip between them;
   - metal delivery means to deliver molten steel into the nip between the casting rolls to form a casting pool of molten steel supported on the rolls;
   - means to chill the casting rolls; and means to rotate the casting rolls in mutually opposite directions whereby to cast said strip and to deliver it downwardly from the nip.
# INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

Int Cl?: B22D 11/14

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC: B22D 11/14, 11/06, 11/041, 11/04, B21B 1/46

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

AU: IPC AS ABOVE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>AU, 42235/96, A (BHP Steel (JLA) Pty Ltd et al) 22 August 1996</td>
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* Further documents are listed in the continuation of Box C

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**Date of the actual completion of the international search**

23 November 2000

**Date of mailing of the international search report**

5 - DEC 2000

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