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(54) Long slab rolling process and apparatus

(57) A long slab rolling process and apparatus for producing a plurality of coils from a single slab, comprises at least one continuous caster producing a cast metal slab, means to cut the slab into discrete lengths for rolling, a reheat furnace, a slab welder, an edger, rough and finish rolling mills to produce hot rolled metal strip, a runout cooling table to cool the hot rolled strip, a pair of pinch rolls and a pair of strip deflector tables to deflect the rolled strip downwardly from the rolling line and, in conjunction with a slowing of the speed of the second pinch roll, to form a loop of strip, a flying shear disposed downstream of the loop and adapted to cut the strip, a part of which is directed onto a first coiler and a remaining portion of which is directed onto a second coiler. In one embodiment of the invention, a second caster and cutter produces second cut slab lengths which are transferred to the reheating furnace after a slab length from the first caster has exited the furnace, and the head end of the second slab length is welded to the tail end of the first slab length.

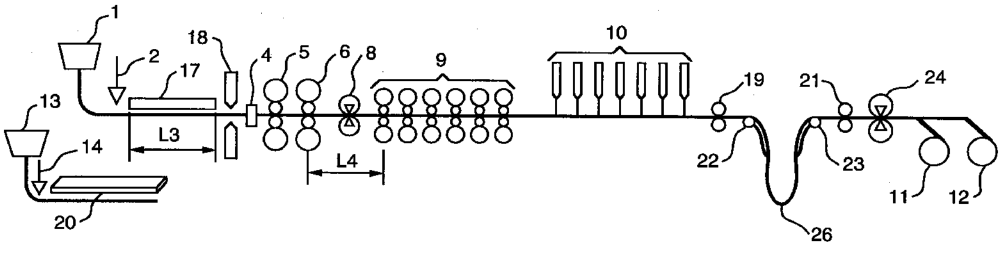

FIG. 2

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to improved hot strip rolling mills and, more particularly, to such improved mills which have an ability to continuously produce a plurality of rolled coils from a single slab continuously cast from one or a number of heats of molten metal, e.g. steel.

2. Description of the Prior Art

Presently, in a hot strip rolling mill, each slab is sized to produce only one coil from that slab. This creates the following problems:

1. Because, during strip threading and tailing out, a portion of the strip is rolled without interstand strip tension, the quality of this part of the strip is inferior to the quality of the remaining part of the strip that is rolled with a controlled interstand strip tension.
2. A probability of strip cobbling during threading and tail out also increases.
3. When rolling thin gage strip, e.g. 2 mm thick and thinner, the threading speed must be reduced to avoid air-lifting of the strip after it exits the mill.
4. It is necessary to cut the head and tail ends of each transfer bar, thus increasing yield losses.
5. A long length of reheat tunnel furnaces is required.

A typical present mill arrangement comprises a continuous caster coupled to a rolling line comprising a shear to cut the continuously cast slab into lengths to produce a single coil, a first tunnel reheat furnace, an edger, one or more roughing stands, a second tunnel reheat furnace, a flying shear, finish rolling stands, a runout cooling table, and one or more coilers.

More recently, a continuous or endless hot rolling system has been developed. "Outline of Newly Built Chiba No. 3 Hot Strip Mill," Kawasaki Steel Technical Report No. 34, March 1996; "Endless Rolling Begins in Japan," New Steel, May 1996, pages 54-55; "Endless Hot Strip Rolling at Kawasaki Steel Chiba Works," Iron and Steel Engineer, February 1997, pages 41-47. In this process, slabs are reheated and rough rolled to sheet bars which, after holding in a coil box, then are joined head-to-tail by induction heating, finish rolled, cooled, sheared and coiled. Accordingly, every transfer bar, each corresponding to one coil, must be welded or otherwise joined. Moreover, the high speed at which down coiling is effected provides an inherently unreliable process.

SUMMARY OF THE INVENTION

In accordance with the present invention, the prior art mill arrangement is modified to increase the length of the first tunnel reheat furnace so as to accommodate all the slabs that can be produced from one heat of molten metal, and a movable welding machine for welding successive slabs together is introduced into the mill line after the first tunnel reheat furnace. The second tunnel reheat furnace is eliminated and a pair of pinch rolls and a pair of deflecting roller tables are installed after the runout cooling table, and a second flying shear is installed after the second pinch roll. By means of such modification, continuous (uninterrupted) rolling can be performed with the production of a plurality of coils from a single slab or from a plurality of slabs from a single heat or a plurality of heats and with a minimum requirement for welding or otherwise joining successive coils. By forming a loop of finish rolled strip by means of the deflecting roller tables, cutting and coiling the finished coils can be done at lower speed, thus minimizing or eliminating the disadvantages of high speed cutting and coiling.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sketch, in side elevation, of a continuous casting/rolling mill arrangement of the prior art, and
Fig. 2 is a similar sketch of a modified continuous casting/rolling mill arrangement in accordance with the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 shows a typical present continuous casting/rolling mill arrangement. In that arrangement, slab is continuously cast with one or two continuous casters 1 and 13, e.g. in a thickness range of from about 50 to about 100 mm. Typical reductions in thickness are shown in Table 1.

Table 1

Typical Mill Reductions Schedule and Speeds										
Slab Thickness mm	Slab Thickness After Rolling Pass, mm								Mill Train Speed,m/min	
	1	2	3	4	5	6	7	8	Entry	Exit
90	52	25	10.6	5.38	3.04	2.03	1.46	1.2	10	740
90	51	27	12.8	7.1	4.37	3.12	2.4	2.0	14.6	650
90	55	30	17.0	10.6	7.6	6.22	5.35	5.0	25.8	460
90	57	32	22.0	16.0	12.9	11.5	10.5	10.0	26.9	240

The continuously cast slab then is cut, by shear 2 (which can be either a crank-type shear or a torch cutter) into lengths to produce one coil from a cut slab. For example, to produce a coil of 1000 mm wide with a specific weight of 20 kg/mm from a 100 mm thick slab, the slab length will be approximately 26 meters. The cut slab then is introduced into the first tunnel reheat furnace 3 where its temperature is raised to about 1100-1200°C. The length of the first reheat tunnel furnace L1 is determined by a required buffer time, i.e. a time during which the casting process can continue while the rolling mill is not operating. The length L1 usually is selected to accommodate three or four cut slabs.

After reheating in furnace 3, the slab enters edger 4. Then, after rolling by the first roughing stand 5 and the second roughing stand 6, the slab is reduced in thickness to about 20-50 mm. The thus-obtained long transfer bar then enters the second reheat furnace 7 where its temperature is raised to about 1050-1100°C. The length L2 of the furnace 7 is selected to accommodate the longest transfer bar. For example, for a coil with a specific weight of 20 kg/mm, the length of the 20 mm thick transfer bar would be approximately 130 meters. After shearing with the flying shear 8, the transfer bar is threaded through the finishing train 9 where it is reduced in thickness to about 1.0 to 12 mm.

When rolling thin gauges, the threading speed of the last stand does not exceed about 10-11 meters/sec in order to prevent air-borning of the strip exiting this stand.

After the head end of the strip is directed to and engaged on the coiler 11 or 12 by any suitable known strip guiding means such as a belt wrapper as disclosed in U.S. Patent No. 3,315,510 or a slotted coiler drum as disclosed in U.S. Patent No. 3,122,337, both of which patents are incorporated herein by this reference. Thereafter strip tension is established between the finishing mill and the coiler, the rolling line can be accelerated to either control the strip temperature or to increase the production rate, or to do both. After rolling and before coiling, the strip is water cooled by the runout table cooling system 10.

If the second caster is used, the second cast slab is cut with a shearing machine 14 into the slab lengths from which only one coil is rolled. Each cut slab then is reheated in the tunnel furnace 15 and transferred to the rolling line by a transfer ferry 16.

To achieve the main objective of the invention--provision for continuous rolling as long as it is practically needed--the following principal modifications were made to the prior art arrangement as above-described:

1. A first tunnel furnace 17 is extended so that its length L3 is sufficient to accommodate all the slabs that can be produced by using one heat size. For example, if the heat weight is 160 tons and coil weight is 20 tons, then the first tunnel reheat furnace must have a capacity sufficient to accommodate the slabs for eight coils. For coils with a specific weight of 20 kg/mm, the length L3 will be approximately 210 meters.
2. The second tunnel furnace 7 (Fig. 1) is completely eliminated, and the distance L4 between the roughing mills 5 and 6 and the finishing mill 9 is reduced to about 12-15 meters.
3. A movable welding machine 18 is installed at the end of the first tunnel reheat furnace 17.
4. Two pinch roll machines 19, 21 are installed after the runout table cooling system 10.
5. Two deflecting roller tables 22, 23 are installed between the pinch roll machines 19 and 21.
6. A second flying shear 24 is installed after the second pinch roll machine 21.
7. In the second caster line, the reheat furnace 15 and the short transfer ferry 16 (Fig. 1) are replaced with a long transfer ferry 20 that also serves as a reheat furnace and can accommodate the entire slab length corresponding to one heat size.

In operation, the process and apparatus of the invention can function in any one of three different modes.

In a first mode, the invention can operate in accordance with the above-described and illustrated conventional casting by cutting the slab into lengths and rolling only one coil per cut slab length.

In a second mode, the invention operates as a continuous casting and rolling process in which cast slabs are cut into lengths to roll more than one coil per cut slab length and up to an entire heat size. Since casting speed is in the range or about 3 to 4.5 m/min, that is, slower than the entry speed of the rolling mill which is within the range of about 10 to 30 m/min (see Table 1), the casting cycle for one caster will be longer than the rolling cycle. After casting and cutting a required slab length (if the entire heat is not used), the slab is preheated in the tunnel furnace 17 and subsequently is rolled by the edger 4 and the horizontal mill stands 5, 6 and 9. The flying shear 8 generally will be used for shearing the head and tail ends of the bar rolled from each cut slab. At the beginning of rolling of each coil, both pinch roll machines 19 and 21 are disengaged from the strip and the deflecting tables 22 and 23 are maintained in a horizontal position, i.e. in line with the runout table 10. After arrival of the head end of the coil, the pinch roll machines are engaged with the strip and the deflecting roller tables 22 and 23 are lowered, as illustrated in Fig. 2. The speeds of both the pinch roll machine 21 and coiler 11 or 12 (whichever is used at that time in the coiling process) are slowed to the speed optimum for shearing (approximately 1 to 5 m/min). As a result of the difference in speed of the pinch roll machines 19 and 21, a temporary loop 26 (Fig. 2) is formed between those machines. At a predetermined time, the flying shear 24 will make a cut of the strip. Then the head end of the remaining portion of the strip is guided toward the previously unused coiler. As soon as a new portion of the strip enters the latter coiler, and the strip tension between the pinch roll machine 21 and that coiler is established, the speeds of both the pinch roll machine 21 and the newly used coiler is increased to mill exit speed. After the strip loop 26 is eliminated, the deflecting tables 22 and 23 are again raised to the mill pass lie and the pinch roll machines are disengaged from the strip.

A third mode of operation comprises operating the inventive process and apparatus by continuous casting in two casters and rolling the slab length corresponding to more than one heat. In this operative embodiment, the second caster 13 casts a slab, with cutting, if necessary, by the cutting machine 14. After a slab, produced by the first caster 1, leaves the reheat tunnel furnace 17, the cut slab length, produced by the second caster 13, is transferred by the transfer ferry 20 to the rolling mill line. This portion of the slab then is accelerated so that its head end gets in touch with the tail end of the slab, produced by the first caster 1, that is being rolled. After establishing such contact of the ends of the respective slabs, the speeds of both slabs are synchronized with each other. At the same time, the welding machine 18 starts moving along the mill line with the same speed as the slabs and performs a stick welding operation. After the welding procedure is completed, the welding machine returns to its initial position. Thereafter the operation can continue as in the second mode of operation to produce a plurality of coils of rolled metal strip.

Practice of the invention provides a means for producing multiple coils from longer slabs than possible with use of the prior art. It consequently reduces the number of times threading of the mill has to be done, thereby reducing yield losses in the form of scrapped lower quality strip rolled without interstand strip tension, reducing the risk of strip cobbling and reducing productivity losses due to the need to slow down the strip to avoid air-lifting during threading. The invention also reduces yield losses incident to the necessity of cutting out lower quality transfer bar head and tail portions.

Claims

1. A long slab rolling process comprising:

a) in a first continuous caster, continuously casting a first heat of molten metal;
b) forming the cast metal into one or more cut first slab lengths;
c) simultaneously reheating all of the first slab lengths in a reheating zone;
d) rolling each first slab length into strip;
e) cutting the strip rolled from each first slab length into a plurality of desired coil lengths, and
f) forming each coil length into a coil.

2. A process according to claim 1, wherein the rolling step comprises:

a) edge rolling each of the reheated slab lengths;
b) rough rolling each of the slab lengths into a transfer bar, and
c) finish rolling the transfer bar into strip of a desired final thickness.

3. A process according to claim 2, further comprising cooling the finish rolled strip.

4. A process according to claim 3, comprising directing a first portion of the finish rolled strip onto a first coiler to form a first coil of strip and a second portion of the strip onto a second coiler to form a second coil of strip.

5. A process according to claim 4, wherein the strip cutting step comprises:

a) passing the uncut strip through a pair of spaced-apart pinch roll machines disposed in a rolling line;
b) slowing the speed of a downstream pinch roll machine and, with use of a pair of deflecting tables, downwardly deflecting the strip out of the rolling line, thereby forming a temporary loop in the uncut strip;
c) with use of a flying shear, cutting the strip downstream from the loop to form a tail end of the first coil, and
d) directing a head end of a remaining portion of the strip onto a second coiler to form a second coil of strip from the same slab length.

6. A process according to claim 5, further comprising:

a) in a second continuous caster, continuously casting a second heat of molten metal;
b) forming the cast metal from the second heat into the form of cut second slab lengths;
c) after a first slab length has been reheated, transferring a second slab length into the reheating zone and reheating it therein, and
d) moving a head end of the reheated second slab length into contact with a tail end of the first slab length and welding it thereto.

7. A long slab rolling system comprising:

a) a first continuous caster to continuously cast a first heat of molten metal into slab form;
b) means to cut the cast slab into one or more cut first slab lengths;
c) a reheating furnace to reheat the first slab lengths;
d) means in a rolling line to roll each first slab length into strip;
e) means to cut the strip rolled from each first slab length into a plurality of desired coil lengths, and
f) means to form each coil length into a coil.

8. A system according to claim 7, further comprising:

a) welding means disposed in the rolling line adjacent and downstream of the reheating furnace;
b) edge rolling means disposed adjacent and downstream of the welding means to edge roll each of the reheated slab lengths;
c) at least one rough rolling mill disposed in the rolling line downstream of the edge rolling means to rough roll each of the slab lengths into a transfer bar, and
d) at least one finish rolling mill disposed in the rolling line downstream of the rough rolling mill to finish roll the transfer bar into strip of a desired final thickness.

9. A system according to claim 8, further comprising means disposed downstream of the finishing mill to cool the finish rolled strip.

10. A system according to claim 9, further comprising first and second coilers, and means to direct a first portion of the finish rolled strip onto the first coiler to form a first coil of strip and a second portion of the strip onto the second coiler to form a second coil of strip.

11. A system according to claim 10, further comprising:

a) a pair of spaced-apart pinch roll machines disposed in the rolling line downstream of the finish rolling mill;
b) a pair of deflecting tables disposed in the rolling line between the pinch roll machines and adapted to downwardly deflect the strip out of the rolling line and, in conjunction with a slowing of the speed of a downstream pinch roll machine, thereby to form a temporary loop in the uncut strip, and
c) a flying shear disposed in the rolling line downstream from the loop and adapted to cut the strip into separate lengths for coiling.

12. A system according to claim 11, further comprising a second continuous caster for producing second cut slab lengths, a transfer ferry for transferring a second cut slab length to the reheating furnace after a first cut slab length has exited the reheating furnace.

13. A system according to claim 11, wherein the tunnel reheat furnace has a length sufficient to accommodate all the

cut slab lengths that can be continuously cast from one heat of molten metal.

14. A system according to claim 12, wherein the transfer ferry also serves as a reheat furnace and has a length sufficient to accommodate all the cut slab lengths that can be continuously cast by the second caster from one heat of molten metal.

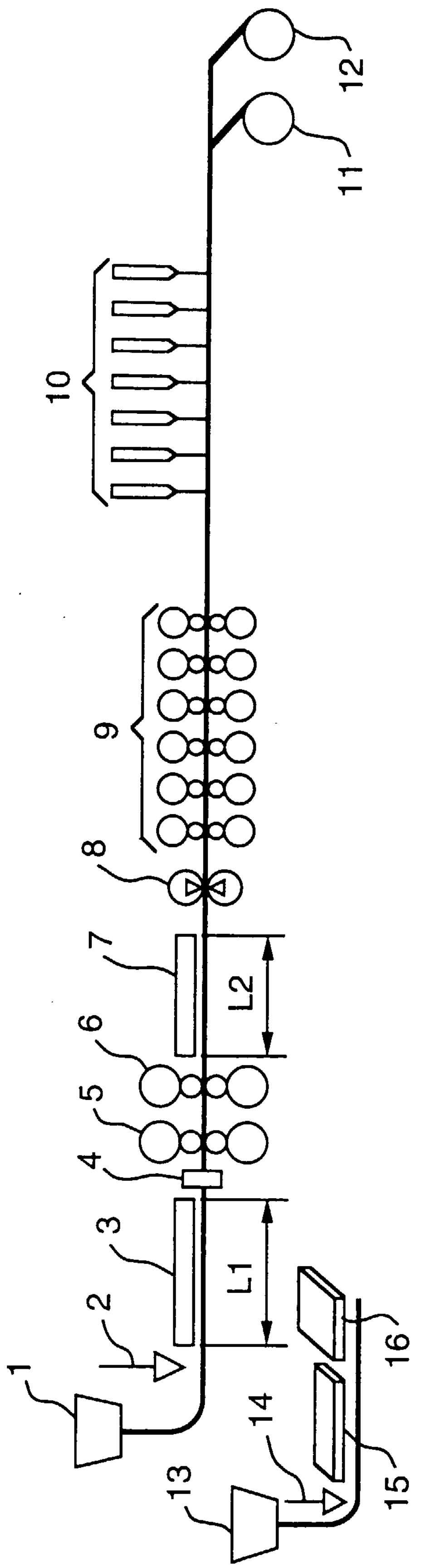

FIG. 1 Prior Art

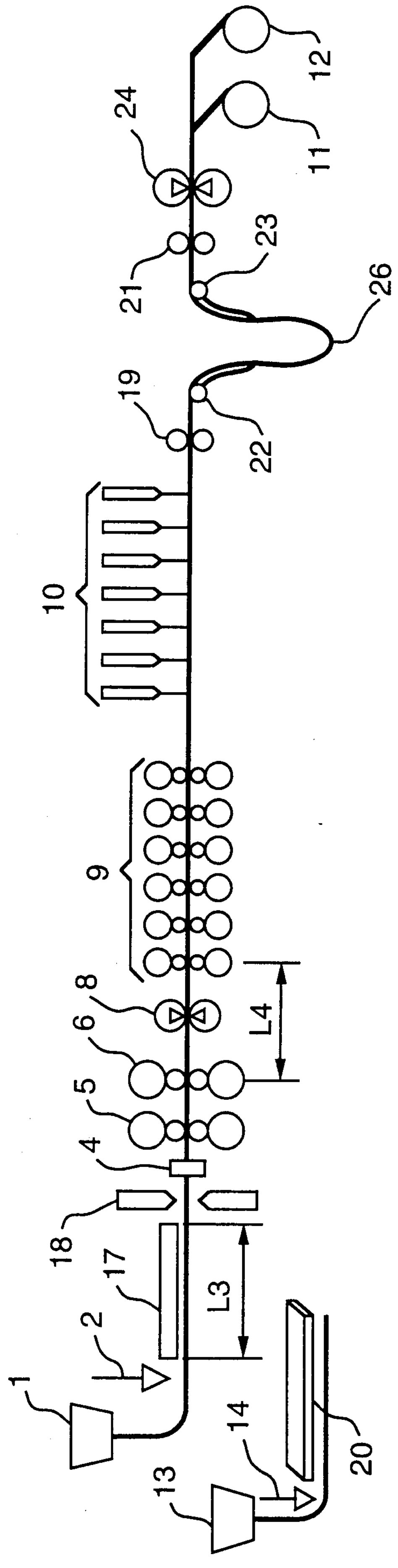

FIG. 2