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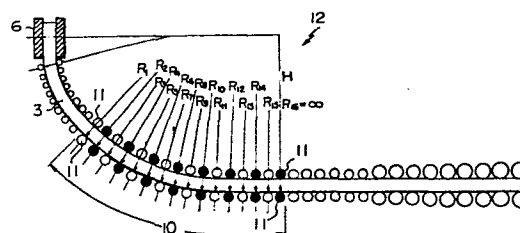
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⑥④ **A bow-type continuous-casting method and apparatus.**

⑥⑦ The apparatus has a low height, a curved mold (6), and a multi-point straightening zone (10).

The prior art involves a problem in that the straightening rolls (7) are not reliable due to a high load which is generated during a non-stationary casting period during which the top or bottom section of a strand (3) is conveyed through a multi-point straightening zone (10). One selected pair of straightening rolls (11) is shunted from the defined radius (Rn) of the curve by means of cone-shaped springs (28) or hydraulic cylinders so that the distance between the two pairs of straightening rolls (11) which are engaged in straightening during a non-stationary casting period is increased. The reliability of the straightening rolls (11) is so enhanced that high-speed and moderate-cooling casting in a low-head CCM can be directly combined with hot-rolling of the strands (3).



A BOW-TYPE CONTINUOUS-CASTING
METHOD AND APPARATUS

The present invention relates to a method for the continuous casting of a high-quality strand with a high production efficiency, as well as to an apparatus for carrying out the method mentioned above. More particularly, the present invention relates to a bow-type continuous-casting method and apparatus in which a strand is straightened in a multi-point straightening zone by means of a plurality of pairs of straightening rolls which define curves having successively increasing radii. Furthermore, particularly, the present invention relates to an improvement in the bow-type continuous-casting method and in the apparatus, the apparatus having a low height and comprising a multi-point straightening zone, in which pairs of the straightening rolls are successively arranged, the aim of the above method and apparatus being to realize a directly combined continuous-casting and rolling process (hereinafter referred to as the CD process).

Recently, the CD process has attracted attention because of a reduction in the amount of thermal energy required to produce hot-rolled products according to this process and because the CD process enables strands formed in a continuous-casting machine and having a high sensible heat to be directly supplied to a hot-rolling mill without being subjected to cooling, conditioning and reheating, and thereby predetermined hot-rolled products are obtained. In order to realize the CD process, the following must be reliably and simultaneously achieved in continuous casting: (1) the temperature of the strands must be high enough to allow direct hot-rolling; (2) the quality of the strands must be high enough to allow the production of hot-rolled products having desired qualities regardless of whether or not the strands are conditioned; and (3) the strand productivity must be higher than that of conventional casting

so as to compete with the high productivity of a hot-rolling mill.

The present applicant has already proposed new continuous-casting methods and apparatuses so that the
5 above-mentioned (1), (2), and (3) can be effectively achieved. The basic concept of the applicant's proposals involves high-speed and moderate-cooling casting carried out in a bow-type continuous-casting machine having a low height and comprising a multi-point straightening zone.
10 More in detail, in the continuous-casting machine according to the applicant's proposals, casting is carried out at a higher speed and more moderate cooling than in the conventional, widely used, bow-type continuous-casting machine, in which machine the machine height is 12 m or more, the
15 radius of the curve is from 10 to 13 m, and the straightening of a strand is carried out by means of single unbending or one-point straightening. The casting conditions according to the applicant's proposals enable surface defects in strands to be prevented and, further, enable high-temperature
20 strands to be produced with a high productivity. The bow-type continuous-casting machine is hereinafter referred to as a bow-type CCM. Bow-type CCMs having high and low machine heights are hereinafter referred to as high-head and low-head CCMs, respectively. The conventional bow-type
25 continuous-casting machine mentioned above is hereinafter referred to as the conventional bow-type CCM.

The problems involved in a high-head CCM are now specifically described.

If casting is carried out in the high-head CCM at a
30 high speed and moderate cooling, the solidified shell of a strand has such a small thickness that its rigidity is decreased, with the result that a thin solidified shell is subjected to a high ferrostatic pressure due to the high machine height of the high-head CCM. Consequently, the
35 bulging strain, which can cause inner defects in a strand, is increased. If the diameter of the rolls which support a strand is made small and if the distance between these

rolls is decreased, an increase in the bulging strain can be prevented. However, such a method for preventing an increase in the bulging strain cannot be employed in the case of the high-head CCM because it is difficult to

5 support by means of small-diameter rolls a strand to which a high ferrostatic pressure due to a high machine height is applied.

In an attempt to reduce the ferrostatic pressure, such a high machine height as that provided in the conventional
10 bow-type CCM is reduced by one half or less than one half and simultaneously the conventional radius of the curve is decreased by, for example, one half or less than one half, according to the applicant's proposals. In this case, the unbending of a strand is carried out at a plurality of
15 straightening points since, if conventional single-point straightening were carried out in the case of a strand having a small radius, the straightening strain, which can cause inner defects in the strand, would be increased and thus inner defects would frequently occur. In other words,
20 concentration of the straightening strain on one point of the strand is avoided and instead the straightening strain is distributed to a plurality of straightening points in the strand where the straightening strain is made lower than the permissible value.

25 In addition to the present applicant, Sumitomo Metals Co., Ltd. has recently proposed a low-head CCM in which strands having a high material quality can be efficiently produced due to a low machine height.

The prior art is now described with reference to
30 Fig. 1.

In the drawings:

Figure 1 is a schematic view of a known low-head CCM comprising a five-point straightening zone;

Figs. 2 through 5 are schematic views of a low-head CCM
35 comprising a fifteen-point straightening zone according to the present invention;

Figs. 6 and 7 are views of straightening-roll assemblies

according to the present invention;

Fig. 8 is a graph showing a load by one pair of the straightening rolls applied to a strand during straightening in the three successive continuous casting (CC) operations;
5 and

Fig. 9 is a graph showing the S-N curve in a multi-point straightening zone.

In Fig. 1, the low-head CCM produced by Sumitomo Metals Co., Ltd. (TRANS. IRON & STEEL INSTITUTE OF JAPAN
10 Vol 20. NO. 12.1980 page B-565) and described in Japanese Laid-open Patent Application Nos. 56-14062 through 14065 (1981) is schematically illustrated. The machine height H of this low-head CCM, which is collectively denoted by 1, is a little less than 6 m, and in the five-point straight-
15 ening zone 2, six straightening rolls 7 are successively arranged in this zone 2 and define curves having successively increasing radii R_1 through R_5 , respectively, R_1 is the basic radius of the curve and is 5800 mm and R_2 is 7100 mm. A curved mold is denoted by 6. In such a low-head
20 CCM, low-speed (from 0.7 to 0.85 m/min) and moderate-cooling casting is carried out. Also, in the five-point straightening zone 2 in which six straightening rolls 7 are successively arranged, a section of the strand 3, in which the molten steel has not yet been solidified and the thickness
25 of the high-temperature solidified shell is thin, is subjected to straightening at all five straightening points P_n ($n=1 \sim 5$), so that the straightening strain is 0.35% or less. The percentage of solidification of the molten steel in said section being straightened in the five-point
30 straightening zone 2 is from 40 to 70%, the ferrostatic pressure applied to said section is low, and the surface temperature of said section is from 900 to 1000°C. Allegedly, the temperature of the strand is high, and the quality of the strand is not inferior to but instead is
35 improved over that of a strand obtained by means of a high-head CCM.

The low-head CCM illustrated in Fig. 1 and described

above is practically operated according to the information given in the above-mentioned technical report and has a machine height of a little less than 6 m, the basic radius (R_1) of the curve being 5.8 m, and comprises a five-point
5 straightening zone in which six straightening rolls 7 are successively arranged. This low-head CCM is hereinafter referred to as the SH-CCM.

When the applicant's proposed CCM described hereinabove is compared with the SH-CCM, the former is distinct from
10 the latter in respect to the following: (a) high-speed and moderate-cooling casting is carried out in a low-head CCM in which the machine height and the basic radius of the curve are as small as possible and in which the straightening points are increased; (b) with a decrease in the
15 machine height and the basic radius of the curve, as well as an increase in the straightening points, the straightening strain can be better distributed in the strand and therefore can be decreased more; and (c) consequently, the above mentioned (1), (2), and (3) required for realizing
20 the CD process can be reliably and simultaneously achieved.

On the other hand, the SH-CCM is distinct from the applicant's proposed CCM in respect to the following: (a) the SH-CCM is constructed so as to continuously cast steels of a special size or small lots while the continuous casting
25 of mass produced steels is carried out in an existing continuous-casting machine in which the radius (R) of the curve is 12.5 m; (b) the machine height of the SH-CCM is such that it can be installed in a steel-refining mill without the necessity of creating additional space, the
30 reason for the production of the SH-CCM being that previously the ingot-making yard and the ladle cranes of the steel-refining mill of the SH-CCM producer were idle due to an increase in the percentage of continuously cast steels; (c) as a result of (b), the costs of the SH-CCM, including
35 the installation and construction costs are very low; and (d) strands are charged, as a rule, into a heating furnace in a rolling-mill with a hot charge.

It is an object of the present invention to improve the conventional bow-type continuous-casting method and apparatus so that the CD process can be realized.

It is another object of the present invention to
5 improve the low-head CCM and continuous casting in the low-head CCM so that the above mentioned (1), (2), and (3) can be reliably and simultaneously achieved.

In accordance with the objects of the present invention, there is provided a bow-type continuous-casting
10 method, wherein a strand is straightened, at a plurality of straightening points, by means of a plurality of pairs of straightening rolls which are successively arranged in a multi-point straightening zone and which define the radii of the curves, said radii successively increasing in the
15 multi-point straightening zone, characterized in that during a non-stationary casting period in which the top section or bottom section of said strand is conveyed through said multi-point straightening zone, at least one selected pair of said straightening rolls is shunted from
20 the defined radius of the curve, thereby increasing the distance between the pairs of straightening rolls, which pairs exert a straightening effect on said strand, and decreasing the straightening points of said multi-point straightening zone. Said distance is hereinafter referred
25 to as the straightening roll pitch.

In accordance with the objects of the present invention, there is also provided a bow-type continuous-casting apparatus having a low height and comprising a multi-point straightening zone in which a plurality of
30 pairs of straightening rolls for straightening a strand are stationarily arranged and define curves having successively increasing radii, characterized in that at least one selected pair of said straightening rolls is operably connected to an elastic means for automatically shunting
35 said at least one selected pair of the straightening rolls from the defined radius of the curve during a non-stationary casting period in which the top section or the bottom

section of said strand is conveyed through said multi-point straightening zone.

In an embodiment of the bow-type continuous-casting method according to the present invention, the basic radius of the curve of the strand is from 3 to 5 m and the number of straightening points is from five to fifteen. So that the continuous-casting machine of the present invention has a low machine height, the basic radius of the curve of the strand, i.e., the radius of the curved mold, must be small or is preferably 5 m at the maximum. The basic radius of the curve is, however, desirably at least 3 m according to the results of a study of the relationship between the basic radius of the curve, the casting speed, the thickness of the strand, and the technique of pouring molten steel into a curved mold. A basic radius of the curve of the strand of at least 3 m is deemed to be necessary for eliminating any restrictions on the pouring of the molten steel into a curved mold, which is curved, when a strand having a thickness of 200 mm or more, particularly from 200 to 300 mm, is to be formed at a high casting speed of 1.2 m/min or more, particularly approximately 1.7 m/minute.

When the basic radius of the curve of the strand is 3 m and is formed by means of high-speed and moderate-cooling casting, particularly in a case in which the casting speed is 1.7 m/minute, the section of the strand subjected to straightening has a surface temperature of 900°C or more and also has a solidified shell 60 mm thick or less at each side of the strand. The number of straightening points for successively straightening said section must be three or more so as to keep the straightening strain below the permissible value at all the straightening points.

In the low-head CCM of the present invention, the casting of a strand includes a stationary casting period and a non-stationary casting period. In the stationary casting period, a section of the strand, or the so-called middle section, is conveyed through the multi-point

straightening zone in which the straightening rolls are successively arranged, the section having a high temperature and a thin solidified shell, containing a considerable amount of molten metal, and being subjected to a low
5 ferrostatic pressure. A load, hereinafter referred to as the stationary roll load, is applied to each of the straightening rolls, all of which are successively arranged in the multi-point straightening zone, and the stationary roll load is the sum of the reaction force due to straight-
10 ening P_{uB} (M) and the reaction force due to bulging P_B (M) (P_{uB} (M) + P_B (M)). In a non-stationary casting period, a section of the strand, or the so-called top or bottom section, in which virtually complete solidification of the
15 molten metal is achieved, is subjected to multi-point straightening in a multi-point straightening zone in which the straightening rolls are successively arranged. Since the reaction force due to bulging during a non-stationary casting period is very low, the load applied to the top or bottom section, hereinafter referred to as the non-stationary
20 roll load, essentially consists of the reaction force due to straightening P_{uB} (T) or P_{uB} (B).

The present inventors tentatively calculated the stationary and non-stationary roll loads in a low-head CCM under conditions in which: the basic radius of the curve
25 of the strand was from 3 to 5 m; the number of straightening points in the multi-point straightening zone in which the straightening rolls are successively arranged was from 5 to 15; the cross section of the strand was from 200 to 300 mm in thickness and approximately 2000 mm in width;
30 and high-speed and moderate-cooling casting was carried out. The stationary roll load was from 30 to 45 tons (the reaction force due to bulging was from 10 to 15 tons and the reaction force due to straightening was from 20 to 30 tons). The non-stationary roll load was from 200 to
35 240 tons, being from five to seven times as great as the stationary roll load. Contrary to this, in the conventional bow-type CCM, the non-stationary roll load is only

approximately three times as great as the stationary roll load. Namely, when low-speed and strong-cooling casting is carried out in the conventional bow-type CCM in which the basic radius (R_1) of the curve is 10.5 m, the stationary and non-stationary roll loads applied to a 200-300 mm thick and approximately 2000 mm wide strand during its conveyance through a single-point straightening zone are from 60 to 70 tons and from 200 to 240 tons, respectively.

Accordingly, in the low-head CCM that the straightening rolls of the multi-point straightening zone, which rolls are successively arranged, must tolerate a considerably high load during the non-stationary period, which period is a very minor part of the entire casting period.

Before completing the present invention, the inventors considered whether or not it would be possible for a multi-point straightening zone, in which the straightening rolls are successively arranged, particularly comprising from five to fifteen straightening points to have a straightening roll pitch enabling the bulging strain to be satisfactorily suppressed and a roll diameter capable of tolerating the non-stationary roll load. This was found to be possible but is not reliable enough to realize the CD process. More specifically, when straightening in a multi-point straightening zone in which the straightening rolls are successively arranged is carried out, the straightening rolls are periodically subjected to stationary and non-stationary roll loads, the non-stationary roll load being from five to seven times as great as the stationary roll load. As a result of the difference in loads, the life of the straightening rolls is shortened, and therefore the straightening rolls must be replaced frequently. In addition, since the number of straightening points is large, the CD process cannot be reliably realized.

A multi-point straightening zone in which a plurality of straightening rolls are successively arranged must simultaneously satisfy two requirements which are contradictory. One of the requirements is that the straightening rolls be

unlikely to undergo destruction. The other requirement is that the straightening rolls be reliable. When the number of straightening points is small, the number of repeated applications of permissible stress (σ_a), shown
5 in the ordinate of Fig. 8, is small, which number is represented in the abscissa of Fig. 9 by "Na". The destruction stress at which a material undergoes destruction after a given number (Na) of repeated applications of
10 permissible stress (σ_a) is determined by the well-known S-N curve or Wöhler curve. Therefore, when stress applied to the straightening rolls is low, the permissible number of repeated application of stress, which number is permissible in the light of life of the straightening rolls, is great. In addition, when the number of straightening points is
15 small, the permissible stress (σ_a) is high. Contrary to this, in a multi-point straightening zone in which the straightening rolls are successively arranged, a reduction in the number of straightening points leads to an increase in the amplitude of stress (σ), shown in the ordinate of
20 Fig. 8, with the result that the difference in the stationary and non-stationary roll loads is drastically increased. This in turn leads to a reduction in the reliability of the straightening rolls. Accordingly, the number of straightening points which can makes possible fulfillment of one of
25 the above-mentioned requirements does not make possible fulfillment of the other requirement. These two requirements can be fulfilled in accordance with a concept of the present invention in which the middle section and the top or bottom section of a strand are straightened at different
30 straightening strains, the straightening strain of the middle section being such that specifically the quality of the strand is ensured, and in which the straightening strain in the top or bottom section may be higher than the permissible value in the light of the quality of the strand
35 since a part of the top or bottom section becomes a crop, and the reliability of the low-head CCM is specifically ensured and enhanced by decreasing the non-stationary roll

load. The present inventors discovered that the shunting of at least one pair of straightening rolls, hereinafter simply referred to as the shunting method, can increase the straightening strain and can decrease the non-stationary roll load, thereby increasing the number of repeated application of a permissible stress (σ_a) applied to the straightening rolls. Since the non-stationary roll load can be decreased by means of the shunting method and, further, since the number of straightening points in the multi-point straightening zone of the present invention is large, the reliability of the bow-type CCM according to the present invention is enhanced.

In an embodiment of the shunting method according to the present invention, said at least one selected pair of straightening rolls shunted from the defined radius of the curve is either an even or an uneven numbered pair of straightening rolls as seen in the withdrawal direction of the strand. In this embodiment, the straightening roll pitch and the non-stationary roll load can be decreased by approximately one half.

In another embodiment of the shunting method according to the present invention, a plurality of pairs of straightening rolls comprises a plurality of groups, each group comprising at least three pairs of straightening rolls, and said at least one selected pair of straightening rolls is either the second or a subsequent pair of straightening rolls of said groups as seen in the withdrawal direction of the strand. In this embodiment, the straightening roll pitch in each group and the non-stationary roll load can be decreased approximately $1/(n+1)$ times, wherein n indicates the number of pairs straightening rolls shunted in each group.

In Fig. 2, an embodiment of a low-head CCM according to the present invention is schematically illustrated. Namely, the multi-point straightening zone 10 comprises sixteen pairs of straightening rolls 11 successively arranged. The radii of the curves R_n defined by the sixteen pairs of

straightening rolls 11 successively increase from R_1 to $R_{16}=\infty$ in the withdrawal direction of the strand 3. Since the radius R_1 is the basic radius of the curve defined by the curved mold, the number of straightening points is
5 fifteen. The machine height H is preferably from 3.4 to 5.2 m, and the basic radius R_1 of the curve defined by the curved mold is from 3 to 5 m. When a top or bottom section (not shown) having a length of from 500 to 1000 mm from
10 either of the ends of the strand and a low temperature due to virtually complete solidification of the molten metal is conveyed through the multi-point straightening zone 10, the even numbered pairs of straightening rolls defining the radii $R_2, R_4, R_6, R_8, R_{10}, R_{12}, R_{14}$, and R_{16} are shunted from the defined radii so that the straightening roll pitch
15 is approximately doubled. The length of the section of a strand being unbent between adjacent pairs of straightening rolls is also approximately doubled. This length is hereinafter referred to as the unbending-arm length.

In Fig. 3, when a top or bottom section (not shown)
20 having a length of from 500 to 1000 mm from either of the ends of the strand 3 and having a low temperature due to virtually complete solidification of the molten metal is conveyed through the multi-point straightening zone 10, the uneven numbered pairs of straightening rolls defining the
25 radii $R_1, R_3, R_5, R_7, R_9, R_{11}, R_{13}$, and R_{15} are shunted straightening rolls and the bending-arm length is approximately doubled.

In Fig. 4, an embodiment of the shunting method, which embodiment is appropriate for a low-head CCM having a
30 machine height of, for example, 3 m, is schematically illustrated. In this embodiment, every three pairs of straightening rolls 11 as calculated in the withdrawal direction of the strand constitute one group, and therefore the multi-point straightening zone 10 has five groups of
35 straightening rolls, the three pairs of straightening rolls 11 in each group being successively arranged. The second and third pairs of straightening rolls 11 in the

five groups are shunted from the defined radii R_2 , R_3 , R_5 , R_6 , R_8 , R_9 , R_{11} , R_{12} , R_{14} , and R_{15} . In this embodiment, the basic radius R_1 of the curve may be 3 m, and the straightening roll pitch and the unbending-arm length are approximately tripled.

In Fig. 5, an embodiment of the shunting method, which embodiment is appropriate for a low-head CCM having a height of, for example, 3 m, is schematically illustrated. In this embodiment, every four pairs of straightening rolls 11 as calculated in the withdrawal direction of the strand constitute one group, and therefore the multi-point straightening zone 10 has four groups, the four pairs of straightening rolls 11 each in group being successively arranged. The second, third, and fourth pairs of straightening rolls 11 in the four groups are shunted from the defined radii R_2 , R_3 , R_4 , R_6 , R_7 , R_8 , R_{10} , R_{11} , R_{12} , R_{14} , R_{15} , and R_{16} ($=\infty$). In this embodiment, the basic radius R_1 of the curve may be 3 m, and the straightening roll pitch and the unbending-arm length are approximately quadrupled.

As stated above, shunting is carried out during a period when the top or bottom section of a strand, where virtually complete solidification of the molten metal is attained, is conveyed through a multi-point straightening zone in which the straightening rolls are successively arranged. Shunting during this period is achieved by of tracking a section of the strand being conveyed through the multi-point straightening zone mentioned above and then, upon detecting the border between the middle section and the top or bottom section of the strand, successively shunting pairs of the straightening rolls as seen in the withdrawal direction of the strand.

In Fig. 6, straightening-roll assemblies which are capable of realizing the shunting method are illustrated. The two straightening-roll assemblies at either the inner or outer side of the strand are shown while the two straightening-roll assemblies at the other side of the strand are not shown. One straightening-roll assembly,

which is not shunted during a non-stationary casting period, is collectively denoted by 11s while the other straightening-roll assembly, which is shunted during a non-stationary casting period, is collectively denoted by 11m. The
5 straightening-roll assembly 11s is hereinafter referred to as the stationary straightening-roll assembly 11s. The straightening roll 11 of the stationary straightening-roll assembly 11s is mounted on a bearing box 16 which is rigidly secured to a supporting frame 17. The supporting frame 17
10 is rigidly secured by means of bolts and nuts 18 to the top surface of a supporting base 15, which is in turn secured to a stationary frame 14 of a low-head CCM by means of bolts and nuts 13. Therefore, the stationary straightening-roll assembly 11s is stationarily arranged in the multi-
15 -point straightening zone during both the stationary and non-stationary casting periods.

In the straightening-roll assembly 11m, hereinafter referred to as the movable straightening-roll assembly 11m, it is now described how one straightening roll in each pair
20 of straightening rolls is automatically moved so as to decrease the number of straightening rolls. Generally speaking, the movable straightening-roll assembly 11m comprises an elastic means which is operably connected to the straightening roll 11 so that the straightening roll 11
25 rotatably engages with the strand (not shown) and which is responsive to the stationary and non-stationary roll loads as a rigid body and an elastic body, respectively. The elastic means preferably comprises cone-shaped springs 28 or a hydraulic cylinder (not shown). The cone-shaped
30 springs 28 are secured between the supporting frame 17 and the supporting base 15. The supporting frame 17 is preferably slidably mounted on the supporting base 15 so that the supporting frame 17 is slidably retracted towards a space 24 within the supporting base 15 during a non-
35 -stationary casting period. To accomplish this slidable retraction, the supporting base 15 has a large-diameter base part 20, which defines the space 24 therein, and a

medium-diameter cylindrical part 21, which defines a vertical slot 23 therein. In addition, the supporting frame 17 has a frame 25 for supporting the bearing box 16 and a flange 26, which comprises a downwardly protruding rod 27. The downwardly protruding rod 27 is inserted in and is vertically slidable along the vertical slot 23.

The cone-shaped springs 28 are preferably surrounded by the inner wall of a cylindrical sleeve 29 which is secured to the flange 26 but which is slidably displaced along the outer periphery of the medium-diameter cylindrical part 21 until the cylindrical sleeve 29 engages with the top surface of the large-diameter base part 20. The length of the cylindrical sleeve 29 is determined so that the maximum stroke during slidable retraction of the supporting frame 17 is restricted by the distance between the top surface of the medium-diameter cylindrical part 21 and the lower end of the cylindrical sleeve 29 during the stationary casting period.

Due to the spring action of the cone-shaped springs 28, the supporting frame 17 is capable of slidably retracting due to the force of the strand (not shown) during a non-stationary casting period. A slidable advancing of the supporting frame 17 is preferably restricted by a stopper disc 30 which is secured to the lower end of the rod 27 by means of a bolt 31 and which can engage with the lower end of the medium-diameter cylindrical part 21. The vertical position of the supporting frame 17 relative to the supporting base 15 can therefore be maintained within a predetermined range due to the cylindrical sleeve 29 and the stopper disc 30, the stopper disc 30 preventing the supporting frame 17 from moving away from the supporting base 15.

The straightening roll 11 of the movable straightening-roll assembly 11m can be automatically retracted or displaced in a downward direction, as shown in the drawing; when the strand (not shown) exerts on said roll a critical force which is greater than the value predetermined by the

cone-shaped springs 28. This critical force is one half of the non-stationary roll load due to shunting of at least one selected pair of straightening rolls.

Shunting is now described in regard to how the radius
5 of the curve defined by one pair of straightening rolls varies.

Although in the following description shunting of only one pair of straightening rolls is described, it is evident that shunting of a plurality of pairs of straightening rolls
10 can be carried out accordingly. In the above-mentioned pair of straightening rolls, the straightening roll located on the inner side of a strand is retracted or displaced toward the interior of the strand or in an upward direction during shunting. In addition to or instead of this dis-
15 placement or retraction, the corresponding straightening roll located on the outer side of the strand is displaced toward the exterior of the strand or in a downward direction during shunting. These two straightening rolls are herein-
after simply referred to as the inner roll and the outer
20 roll, respectively. The inner roll displaced as described above tends to decrease the radius of the curve of the strand as compared with the radius (R_n) of the curve defined by the pair of straightening rolls before shunting or during the stationary casting period. This radius is
25 simply referred to as the theoretical radius (R_n). The outer roll displaced as described above tends to increase regarding the radius of the curve of the strand as compared with the theoretical radius (R_n).

When the inner and outer rolls are connected to the
30 two hydraulic cylinders, respectively, a decrease in the radius of the curve and an increase in the radius of the curve as compared with the theoretical radius (R_n) simultaneously result so that the inner and outer rolls can no longer exert a straightening force on a strand or engage in
35 the straightening of a strand. On the other hand, when the inner and outer rolls are operably connected to two cone-shaped springs, respectively, either a decrease in the

radius of the curve defined by the inner roll or an increase in the radius of the curve defined by the outer roll results so that either the inner roll or the outer roll can essentially no longer engage in the straightening of the strand.

5 I. Shunting in which the elastic means is a cone-shaped spring and in which an increase in the radius of the curve defined by the outer roll takes place is now described. In this type of shunting, the first and third pairs of rolls are not shunted but the second pair of rolls
10 is shunted during a non-stationary casting period.

A. Conveyance of the Top Section of a Strand Through the Multi-point Straightening Zone

When the top end of a strand arrives at the second pair of inner and outer rolls, the top section is
15 between the second and third pairs of rolls. The outer roll of the second pair of rolls is retracted and is subjected to a load which is determined by the cone-shaped spring operably connected to the outer roll. The outer roll presumably still engages in the straightening of the
20 strand since the outer roll exerts on the strand a force which is determined by the cone-shaped spring and which is less than the straightening force during the stationary casting period. However, since the degree of engagement of the outer roll in straightening is very small as compared
25 with that of the inner roll, straightening is carried out essentially by the inner roll of the second pair of rolls. An increase in the straightening roll pitch and in the unbending-arm length therefore results since the pairs of rolls which engage in the straightening of the strand,
30 i.e., the inner and outer rolls, are the first and third pairs of rolls.

B. Conveyance of the Bottom Section of a Strand Through the Multi-Point Straightening Zone

When the bottom section of a strand arrives
35 at the second pair of inner and outer rolls, the bottom end of the strand is between the first and second pairs of rolls. The outer roll of the second pair of rolls is

retracted and is subjected to a load which is determined by the cone-shaped spring operably connected to the outer roll. An increase in the straightening roll pitch and in the unbending-arm length results since, as in A above, the
5 outer roll exerts on the strand a force which is determined by the cone-shaped spring and which is less than the straightening force during the stationary casting period.

II. Shunting in which the elastic means is a hydraulic cylinder and in which the first and third pairs of rolls
10 are not shunted but the second pair of rolls is shunted during a non-stationary casting period is now described.

A. Conveyance of the Top Section of a Strand

When the border between the top and middle sections of a strand is detected by means of tracking as
15 having arrived at the first pair of rolls, both the inner and outer rolls of the second pair of rolls are retracted. After the top end of the strand has passed through the second pair of rolls, the inner and outer rolls of the second pair of rolls are reverted to their original
20 positions. As a result of retraction, the force to which the inner and outer rolls of the second pair of rolls are subjected during a non-stationary casting period is the stationary roll load. In addition, the force to which the non-shunted first and third pairs of rolls are subjected
25 during a non-stationary casting period is only approximately one half the non-stationary roll load according to the conventional straightening process.

An increase in the straightening roll pitch and in the unbending-arm length results due to both a
30 decrease in and an increase in the radii of the curves defined by the inner and outer rolls, respectively.

B. Conveyance of the Bottom Section of a Strand

When the bottom end of a strand is determined by means of tracking as having arrived at the first
35 pair of rolls, the inner and outer rolls of the second pair of rolls are retracted. When the border between the bottom and middle sections is detected by means of tracking as

having arrived at the third pair of rolls, the inner and outer rolls of the second pair of rolls are reverted to their original positions. As a result of retraction, the force to which the second pair of rolls is subjected during a non-stationary casting period is the stationary roll load. In addition, the force to which the non-shunted first and third pairs of rolls are subjected during a non-stationary casting period is only approximately one half the non-stationary roll load according to the conventional straightening process. An increase in the straightening roll pitch and in the unbending-arm length results due to, as in A above, both a decrease in and an increase in the radii of the curves defined by the inner and outer rolls, respectively.

In the above description of the two types of shunting, it is presumed that both the top and bottom sections are longer than the straightening roll pitch.

Bow-type continuous casting methods according to the present invention and a conventional method are now described with reference to the example and the comparative example.

Example

The essential parts of the low-head CCM of the example according to the present invention are schematically shown in Fig. 2. The continuous casting method of the present invention was carried out by means of a low-head CCM under the casting parameters given below. The parameters of the low-head CCM were as follows:

- A. Basic radius (R_1) of the curve: 3 m
- B. Multi-point straightening zone 10:
 - (1) Straightening points: 15
 - (2) Radii of pairs of stationary straightening rolls 11:

- 5 R_2 : 3100 mm
 R_4 : 3650 mm
 R_6 : 4400 mm
 R_8 : 5500 mm
 R_{10} : 7500 mm
 R_{12} : 11650 mm
 R_{14} : 26000 mm
- 10 (3) Theoretic radii of pairs of straightening
 rolls 11 to be shunted during non-stationary
 casting
 period:
 R_1 : 3000 mm
 R_3 : 3350 mm
 R_5 : 4000 mm
15 R_7 : 4900 mm
 R_9 : 6400 mm
 R_{11} : 9150 mm
 R_{13} : 16100 mm
 R_{15} : 67100 mm
- 20 (4) Diameter (r) of straightening rolls 11
 and straightening roll pitch (p):
 r = 230 mm
 p = 300 mm
- 25 (5) Construction of stationary straightening-
 -roll assemblies: shown in Fig. 6.
- (6) Construction of movable straightening-roll
 assemblies:
 (a) As shown in Fig. 7.
 (b) Characteristic of cone-shaped
30 springs 28: deflection of the
 springs 28 was zero under a load of
 up to 70 tons, enabling the springs 28
 to behave as a rigid body under a load
 of up to 70 tons; deflection was 1 mm
35 under a load of 100 tons.

C. Machine height H: 3.5 m

The casting parameters during a normal continuous-casting period were as follows:

A. Casting speed: 1.7 m/min.

(high casting speed)

5 B. Cooling condition: moderate cooling so that the surface temperature and the thickness of the solidified shell of the strand in the multi-point cooling zone were 900°C or more and 60 mm or less (at each side of the
10 strand), respectively.

The stationary and non-stationary roll loads were from 28 to 33 tons and from 55 to 116 tons, respectively.

Produced strands having a cross section 250 mm thick and 2000 mm wide were free of internal and external defects
15 and had a high temperature. The life of the straightening rolls, which was calculated on the basis of the non-stationary roll load, was such that the rolls could withstand repeated applications of the non-stationary roll load of 1.5×10^6 times.

20 Comparative Example

Continuous casting in accordance with the method described in the above example was repeated except that all of the straightening rolls were stationary during the stationary and non-stationary casting periods. The
25 stationary and non-stationary roll loads were from 28 to 33 tons and from 108 to 231 tons, respectively. Strands produced were free of internal and external defects, but the non-stationary roll load was, on the average, twice as high as that of the above example. According to the
30 calculated life of the straightening rolls, the straightening rolls could withstand repeated applications of the non-stationary roll load of 2×10^4 times. This value was approximately 1/75 times as low as that of the above example. That is, according to the shunting method, the
35 life of the straightening rolls could be prolonged approximately 75 times as long as in the case of conventional continuous casting.

CLAIMS

1. A bow-type continuous-casting method, wherein a strand is straightened, at a plurality of straightening points, by means of a plurality of pairs of straightening rolls which are successively arranged in a multi-point
5 straightening zone and, define the radii of the curves, said radii successively increasing in the multi-point straightening zone, characterized in that during a non-stationary casting period in which the top section or bottom section of said strand is conveyed through said
10 multi-point straightening zone (10), at least one selected pair of said straightening rolls (11) is shunted from the defined radius (R_n) of the curve, thereby increasing the distance between the pairs of straightening rolls (10), which pairs exert a straightening effect on said strand (3),
15 and decreasing the straightening points of said multi-point straightening zone (10).

2. A bow-type continuous-casting method according to claim 1, wherein the basic radius of the curve of said strand (3) is from 3 to 5 m and the number of straightening
20 points is from five to fifteen.

3. A bow-type continuous-casting method according to claim 1 or 2, wherein said at least one selected pair of the straightening rolls (11) shunted from the defined radius (R_n) of the curve is either an even or an uneven
25 numbered pair or pairs of straightening rolls (11) as seen in the withdrawal direction of said strand (3).

4. A bow-type continuous-casting method according to any one of claims 1 through 3, wherein said at least one pair of straightening rolls (11) comprise a plurality of
30 groups, each group comprising at least three pairs of straightening rolls (11), and said at least one selected pair of straightening rolls is either the second or a subsequent pair of straightening rolls of said groups as seen in the withdrawal direction of the strand (3).

35 5. A bow-type continuous-casting method according to any one of claims 1 through 4, wherein said strand (3) has

a temperature of at least 900°C at the completion of multi-point straightening.

6. A bow-type continuous-casting apparatus having a low height and comprising a multi-point straightening zone in which a plurality of pairs of straightening rolls for straightening a strand are stationarily and successively arranged and define curves having successively increasing radii, characterized in that at least one selected pair of said straightening rolls (11) is operably connected to an elastic means for automatically shunting said at least one selected pair of straightening rolls (11) from the defined radius (R_n) of the curve during a non-stationary casting period in which the top section or the bottom section of said strand (3) is conveyed through said multi-point straightening zone.

7. A bow-type continuous-casting apparatus according to claim 6, wherein said elastic means comprises a hydraulic cylinder.

8. A bow-type continuous-casting apparatus according to claim 7, wherein said elastic means comprises a cone-shaped spring (28).

9. A bow-type continuous-casting apparatus according to claim 8, wherein said cone-shaped spring (28) is secured between a supporting base (15) and supporting frame (17) which is slidably mounted on said supporting base (15) so that said supporting frame is slidably retracted towards a space (24) within said supporting base (15).

10. A bow-type continuous-casting apparatus according to claim 9, wherein said supporting base (15) has a large-diameter base part (20) which defines said space (24) therein and medium-diameter cylindrical part (21) which defines a vertical slot therein; further, said supporting frame supports a bearing of one of the straightening rolls and has a flange (26) which comprises a downwardly protruding rod (27) inserted in and vertically slidable along said vertical slot.

11. A bow-type continuous-casting apparatus according

to claim 10, wherein said cone-shaped spring (28) is surrounded by the inner wall of a cylindrical sleeve (29) which is secured to the flange of said supporting frame (17) but is slidably displaced along the outer periphery of said
5 medium-diameter cylindrical part (21) until said cylindrical sleeve (29) engages with the top surface of said large-diameter base part (20), the length of said cylindrical sleeve being determined so that the maximum stroke during the slidable retraction of said supporting frame (17) is
10 restricted by the distance between the top surface of said medium-diameter cylindrical part (21) and the lower end of said cylindrical sleeve (29) during a stationary casting period.

Fig. 1

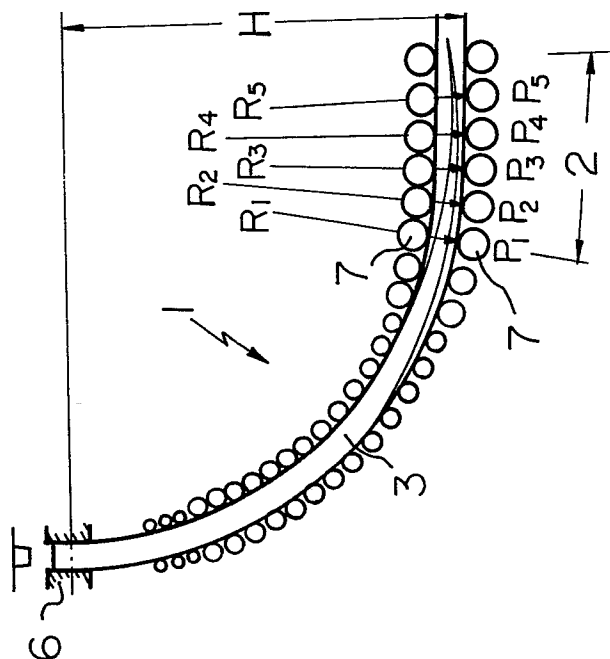


Fig. 2

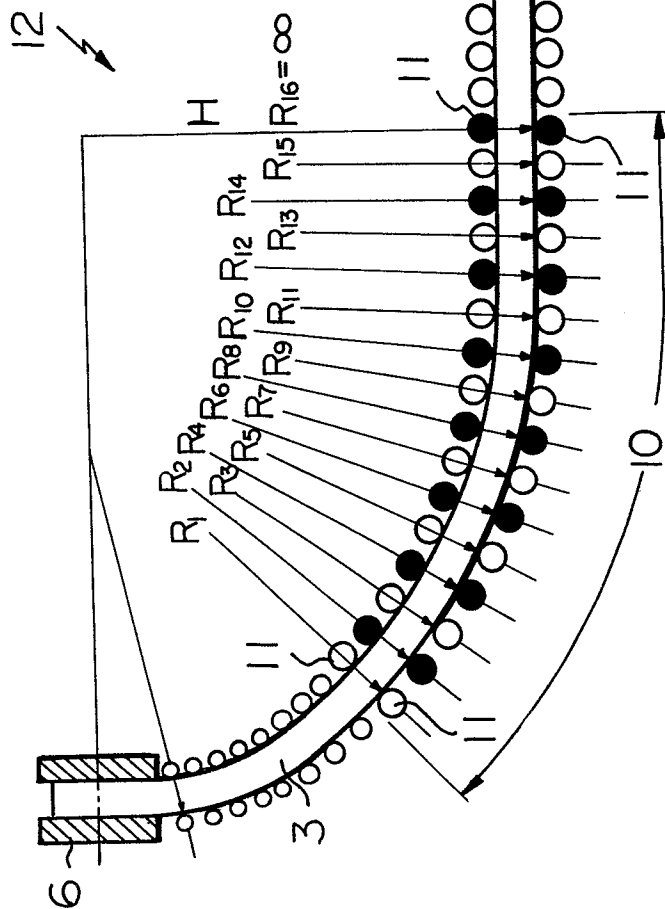


Fig. 3

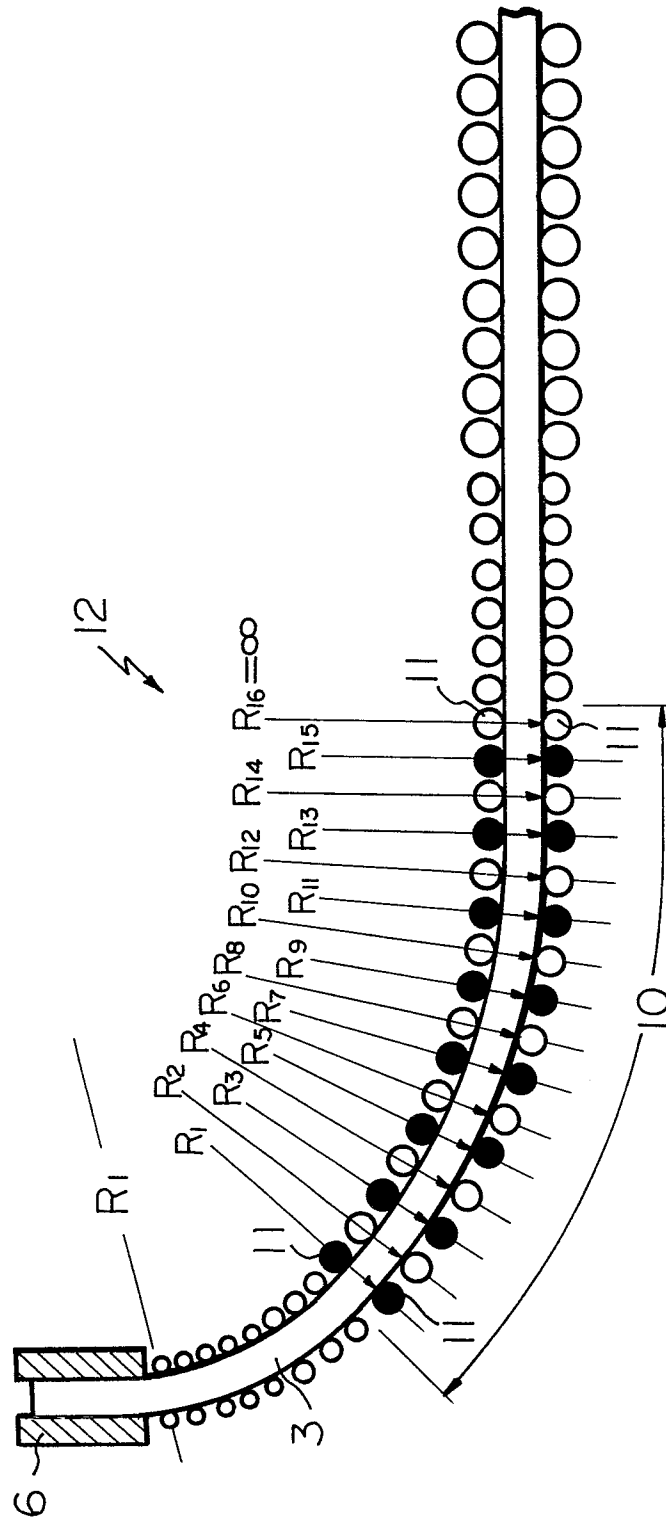


Fig. 4

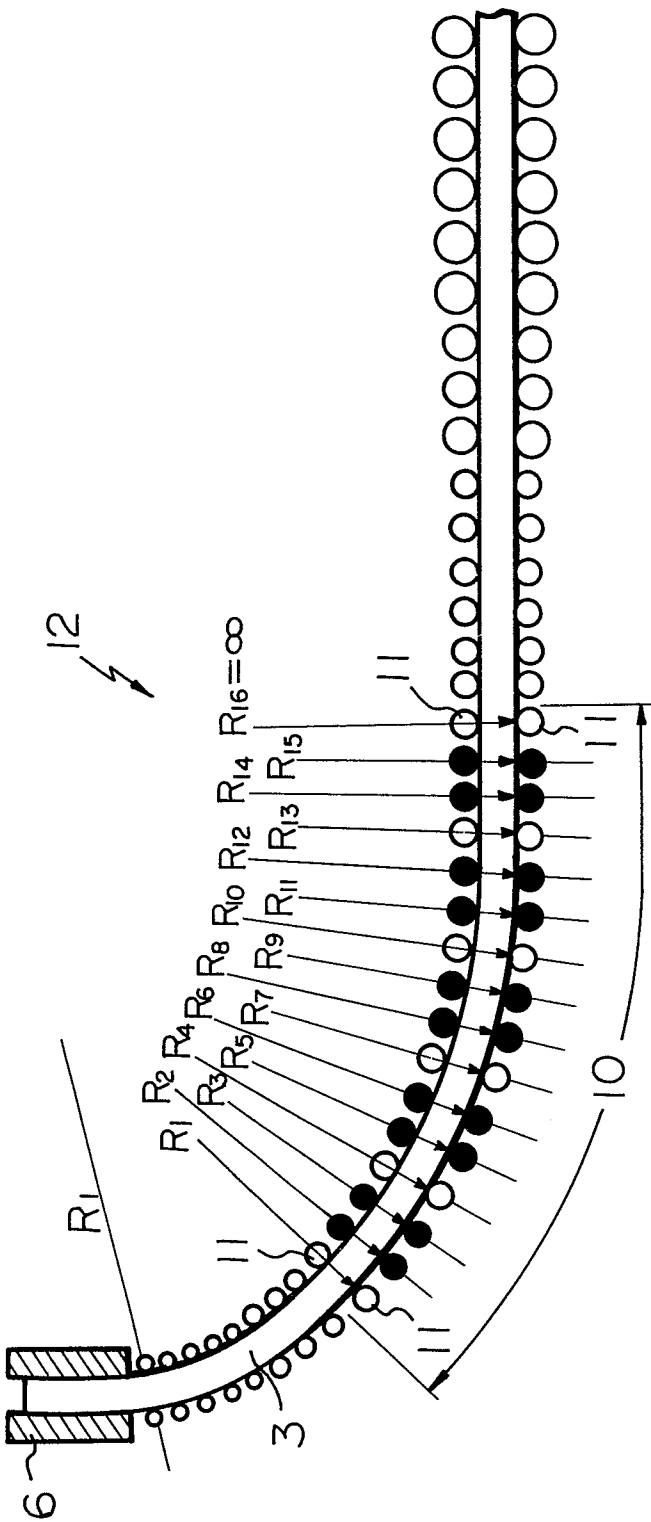


Fig. 5

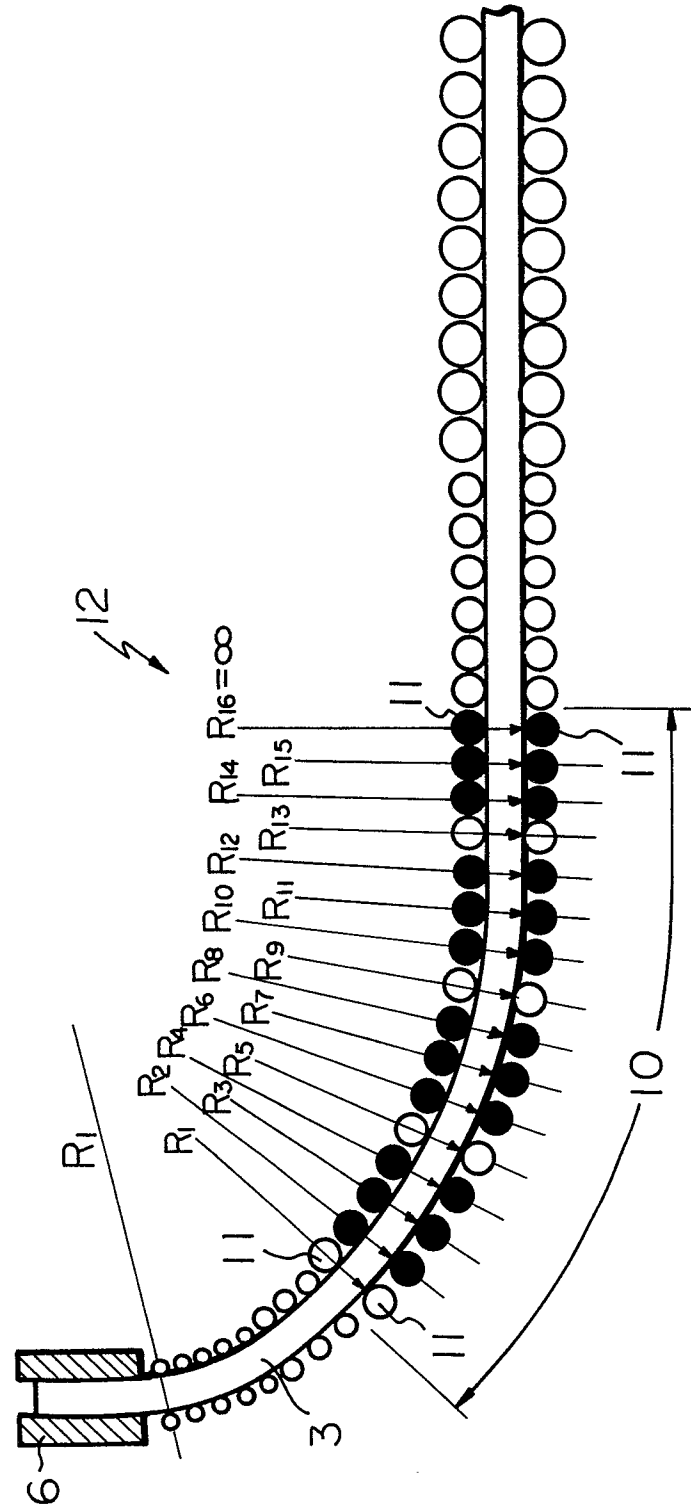


Fig. 6

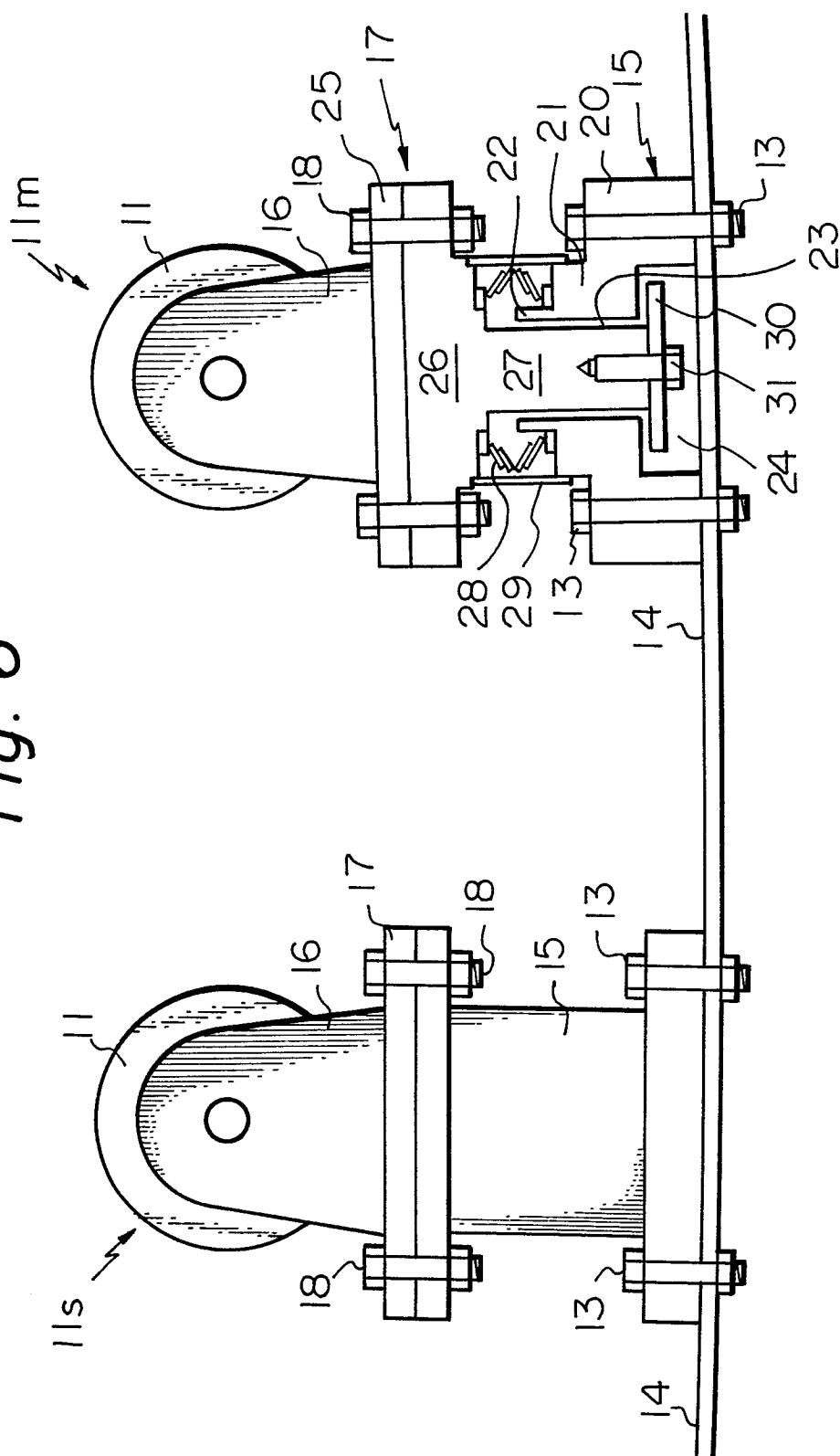


Fig. 7

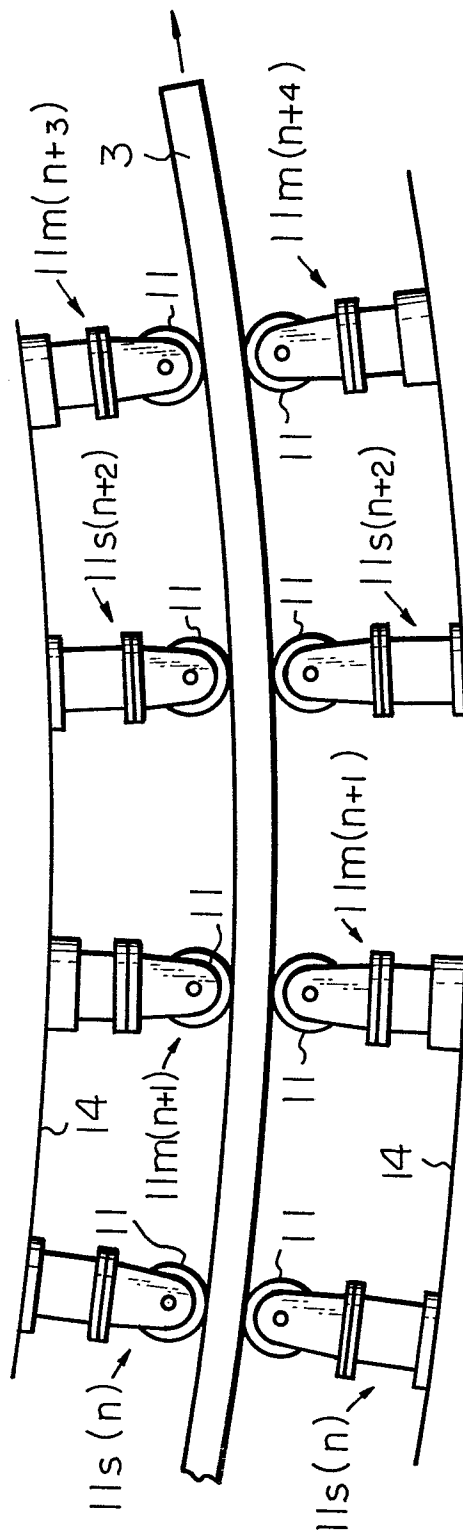
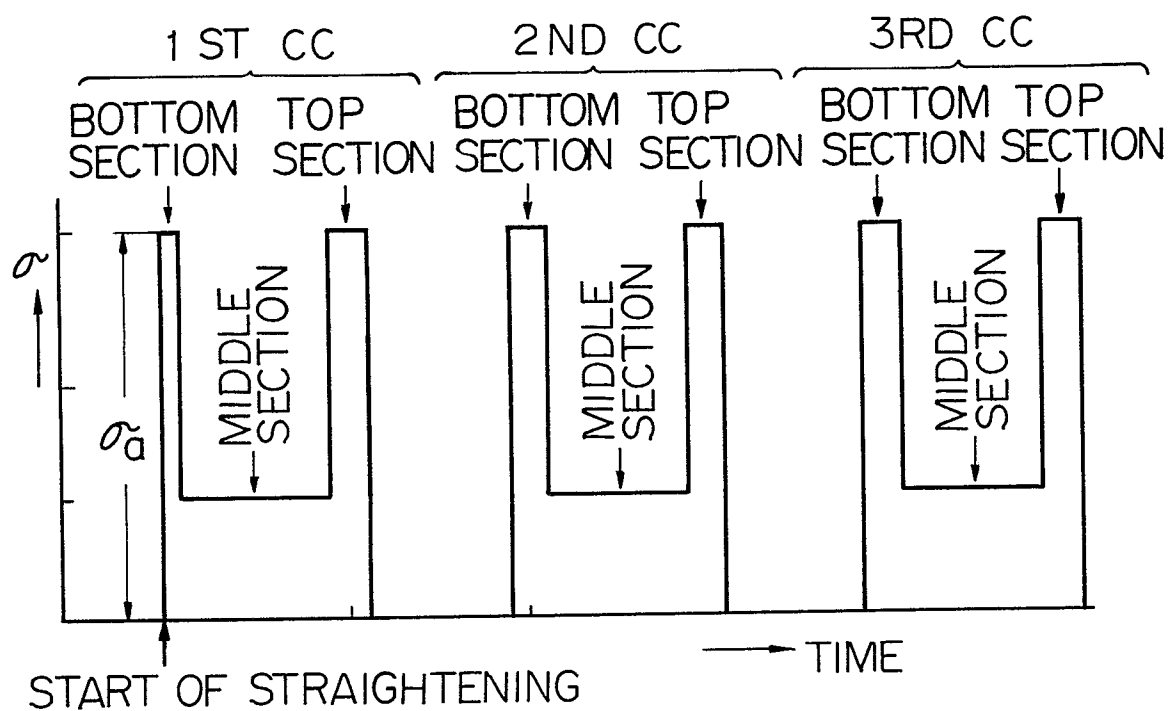
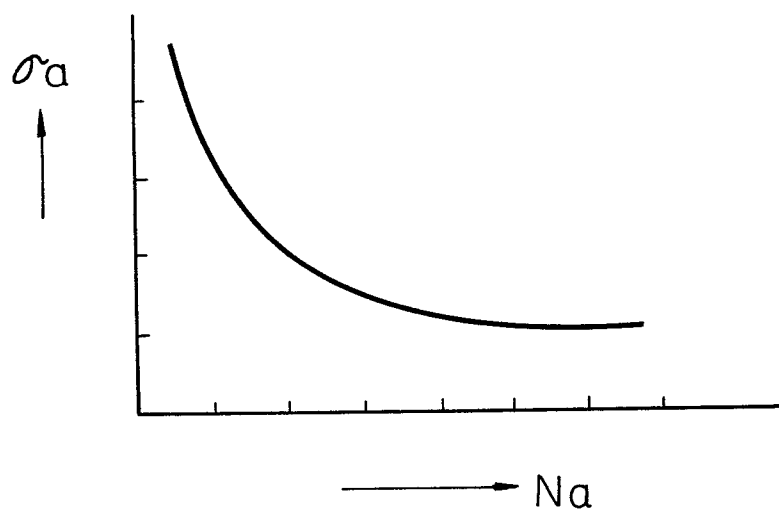


Fig. 8*Fig. 9*



European Patent
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EUROPEAN SEARCH REPORT

0068814

Application number

EP 82 30 3283.4

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	DE - A1 - 2 559 038 (NIPPON KOKAN K.K.) * claims 1, 3 * & US - A - 4 043 382 --	1,2	B 22 D 11/128 B 22 D 11/12 B 22 D 11/16
A	DE - B2 - 2 544 556 (DEMAG AG) * claim 1 * & US - A - 4 227 636 --	1	
A	US - A - 3 776 298 (VOGT) * claims 1 to 3 * --	1	TECHNICAL FIELDS SEARCHED (Int.Cl. 3)
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A	Patent Abstracts of Japan Vol. 5, No. 61, 24 April 1981	1	
D	& JP - A - 56 - 14064 ----		
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☒ The present search report has been drawn up for all claims			&: member of the same patent family, corresponding document
Place of search Berlin		Date of completion of the search 17-09-1982	Examiner GOLDSCHMIDT