(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 506 138 A1**

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **92105463.1**

(22) Date of filing: **30.03.92**

(51) Int. Cl.[5]: **B21B 13/02**, B21B 27/10, B21B 37/00, B21B 28/04

(30) Priority: **29.03.91 JP 66007/91**
06.02.92 JP 20956/92

(43) Date of publication of application:
30.09.92 Bulletin 92/40

(84) Designated Contracting States:
DE FR GB IT

(71) Applicant: **HITACHI, LTD.**
6, Kanda Surugadai 4-chome
Chiyoda-ku, Tokyo 101(JP)

(72) Inventor: **Kajiwara, Toshiyuki**
Wako Manshon 201, 14-13,
Higashimizumoto-3-chome
Katsushika-ku, Tokyo(JP)
Inventor: **Sugiyama, Tokuji**
2644-15, Ishi, Juomachi
Taga-gun, Ibaraki-ken(JP)
Inventor: **Takakura, Yoshio**
37-4, Nishinarusawacho-4-chome
Hitachi-shi(JP)
Inventor: **Sakanaka, Takao**
17-1, Hanayamacho-2-chome
Hitachi-shi(JP)
Inventor: **Yoshimura, Yasutsugu**
26-7, Nakanarusawacho-2-chome
Hitachi-shi(JP)
Inventor: **Yasuda, Ken-ichi**
1181-80, Higashiishikawa
Katsuta-shi(JP)
Inventor: **Kaga, Shinichi**
4-1-604, Nakanarusawacho-2-chome
Hitachi-shi(JP)

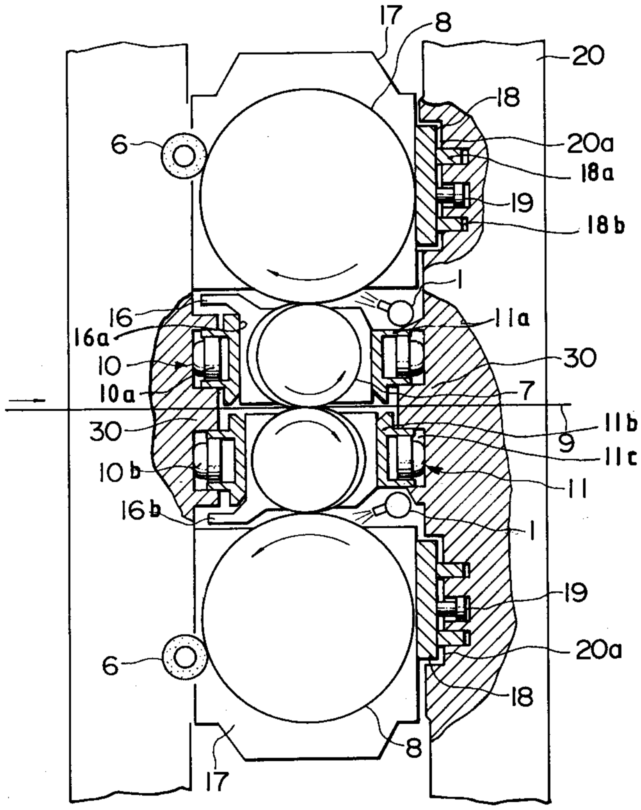
(74) Representative: **Patentanwälte Beetz sen. - Beetz jun. Timpe - Siegfried - Schmitt-Fumian**
Steinsdorfstrasse 10
W-8000 München 22(DE)

(54) **Rolling mill, hot rolling system, rolling method and rolling mill revamping method.**

(57) A work roll crossing type rolling mill has back-up rolls (8) arranged in such a manner that their axes are not inclined in a horizontal plane. Work rolls (7) are constructed in such a manner that their axes can be inclined in a horizontal plane relative to the back-up rolls such that the axes of the work rolls cross the axes of the back-up rolls and such that the axes of the work rolls cross each other. A lubricant supply device (1) is provided for supplying a lubricant between each work roll and each back-up roll to greatly reduce the thrust exerted to the work rolls, whereby the rolling mill is given an excellent ability of controlling the crown of the material to be rolled.

EP 0 506 138 A1

FIG. 1


17
8
20
18
20a
18a
19
18b
6
1
16
11a
16a
10
30
10a
7
30
9
11b
11c
10b
11
16b
1
19
6
20a
18
8
17

The present invention relates to a crossing type sheet rolling mill which shows an excellent ability with which it controls the crown of materials to be rolled, a hot rolling system, a rolling method and a rolling mill revamping method.

This type of rolling mill, which has already been known for some time (see, for instance, JP-A-47-27159), differs from conventional four-high rolling mills in that at least one set of rolls, normally the two work rolls, are with their longitudinal axes inclined relative to one another in the horizontal rolling plane by predetermined small angles to the rolling direction so that their longitudinal axes cross each other in the central portion of the material being rolled. This roll arrangement is particularly intended to improve the thickness control of the material being rolled across the width thereof because the offset of the ends of the work rolls with respect to the ends of the back-up rolls results in some compensation of the roll bending caused, in a known way, by the rolling force. However, this oppositely directed inclination of the work rolls has led to serious technical problems, for instance, excessive loads on the roll bearings and excessive wear of the roll barrels so that this type of rolling mill has not yet been put into practical use.

The rolling mill in which crossing of only the work rolls is performed cannot be put into practical use for the following two reasons.

First, when the work rolls cross the back-up rolls, an enourmous amount of thrust is exerted to both the work rolls and the back-up rolls in two directions along the axis of the rolls, as described in "Research of Machines, Vol. 42, No. 10 (1990)" from page 71 to page 72. This thrust, which changes depending on the cross angle, is about 30 % of the rolling loads. The thrust bearing of the large diameter back-up roll may sustain this thrust. However, it is very difficult for the work roll whose diameter is one half or less than that of the back-up roll to do that.

The second reason is roll wear caused by relative slip between the back-up roll and the work roll. Since the work rolls are changed with new ones every 2 or 3 hours due to wear caused by the material to be rolled which is greater than wear caused by relative slip, changing of the work rolls causes no problem. However, changing of the back-up roll takes place every 10 or 20 days and requires a long time. Therefore, frequent changing of the back-up rolls due to rapid wear greatly reduces productivity.

In the publication Technical Report, Vol. 21, No. 6 (1984), pp. 61 to 67 of Mitsubishi Heavy Industrial Co., Ltd. a practically used rolling mill is disclosed in which a roll pair consisting of an upper work roll and an upper back-up roll and a roll pair consisting of a lower work roll and a lower back-up roll are moved such that the axes of the two roll pairs cross each other on a horizontal plane.

In said pair cross type rolling mill the generation of extreme thrust between the back-up roll and the work roll is suppressed. Since the centers of the metal chocks of the back-up rolls which are directly subjected to the rolling load shifts from the center of the reduction screw, a rotational moment is exerted to the metal chock, generating a local load to the mill stand. Consequently, smooth rolling operation is prohibited and wear of the metal chock and of the bearing is accelerated. To prevent these drawbacks, a very rigid beam may be provided to balance the driving side and the operating side of the rolling mill. However, provision of such a rigid beam increases the overall size of the rolling mill.

Whereas the thrust exerted to the work rolls which do not cross each other is generally 1 to 2 % of the rolling loads in the case of the hot rolling, the thrust exerted to the work rolls which cross each other is 5 % of the rolling load, which is twice or three times that of the work rolls which do not cross each other.

Adjustment of the cross angle during rolling is necessary, because it enables changes in the rolling load or the crown of the material to be rolled to be coped with during rolling or because it enables the incorrectly set cross angle to be corrected. These would not be achieved by the bender alone, and changes in the cross angle in a state wherein a large rolling load is being exerted, are thus necessitated. In the continuous rolling operation, the metal chock of the back-up roll must be moved during rolling, i.e., under enormous rolling loads, thus necessitating a special bearing. This makes the structure of the rolling mill more complicated. Also, a troublesome maintenance is necessary due to scales entering the lower portion of the rolling mill stand, and productivity greatly reduces.

A generally known possibility of reducing wear of the rolls caused by friction as well as the excessive axial thrust is to reduce the friction between the respective pairs of surfaces by supplying a lubricant. So far, the use of a lubricant in a hot rolling mill has been found unsuited because the cooling water supplied in large amounts and at high pressure for cooling the rolls will largely or completely wash the lubricant of the roll surfaces so that their lubricating effect will be negligible. Further, some of the lubricant will either directly or via the barrel surfaces of the work roll reach the hot material being rolled and burn either partly or entirely. The solid residues of combustion may form deposits on the surfaces of the material being rolled, said deposits impairing the rolling properties of said material, in particular the bite, i.e. the drawing of the material to be rolled into the roll gap. This applies in particular to the drawing-in of a fresh or succeeding material after the work roll has for a short time revolved without contact with a hot material. It is true that the consequences of this effect could be reduced by maintaining the supply of the lubricant only during each rolling operation and by interrupting the supply before the respective material leaves the roll gap. However, such measures would require a highly complex lubricating system and could not eliminate the risk of the lubricant being washed off the roll barrels by the cooling water.

The object of the invention is to provide a method and a rolling mill for cross-rolling flat materials, wherein excessive axial thrust of the rolls as well as high wear of the roll barrels and of the further components are prevented.

According to the invention this object is solved in that a rolling mill is provided in which a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls are provided on a rolling stand, wherein the backup rolls are constructed in such a manner that axes thereof are not inclined in a horizontal plane while the work rolls are constructed in such a manner that axes thereof can be inclined in a horizontal plane relative to the back-up rolls such that the axes of the work rolls cross the axes of the back-up rolls and such that the axes of the work rolls cross each other, and a lubricant supply device is provided for supplying a lubricant between each work roll and each back-up roll.

An essential aspect of the invention is based on the discovery that owing to the inclination of only the two work rolls a dual compensating effect for compensating the undesirable roll bending of the work rolls caused by the rolling force is achieved so that an effective flatness control of the material being rolled across the entire width thereof is possible already with small angles of inclination in the order of 1°. Further, this results in a considerable reduction of the thrust acting on the work rolls because the thrust generated in the contact portion between the back-up roll aligned transversely to the direction of passage and the inclined work roll counter-acts the thrust generated between the work roll and the material being rolled so that these thrust forces cancel each other out at least partly. A further essential aspect of the invention is the controlled introduction of a lubricant into the contact portion between the respective work roll and the back-up roll, wherein special technical means provide for the lubricating effect being restricted to this contact portion only and for the lubrication being ineffective in the draw-in zone of the roll gap so that sufficient friction between the barrel surface of the work roll and the material being rolled will be retained. The combined action of the above-mentioned criteria has the effect that excessive axial thrust loads on the rolls and their bearings are reduced right to the limits of conventional 4-high rolling mills while wear of the roll surfaces is reduced effectively.

The rolling mill according to the invention comprises two back-up rolls which are disposed as usual transversely to the direction of passage of the material being rolled, the roll chocks of said back-up rolls each being guided for vertical displacement in a window of each stand and cooperating with the hydraulic or mechanical adjusting means for generating the controllable rolling force. The work rolls of the rolling mill according to the invention are inclined in the horizontal plane relative to each other and to the longitudinal axes of the back-up rolls by small angles of 1-3°, resulting also in inclined contact portions between the back-up roll, the work roll and the material being rolled. According to the invention lubricant supply means are provided for controlledly injecting a suitable lubricant, merely at the inlet side, into the gap area formed between the work roll and the back-up roll along the entire length of said gap area so as to reduce the coefficient of friction in this contact portion only, wherein provisions are made to prevent the occurrence of a lubricating effect in the vicinity of the roll gap in order not adversely to influence the draw-in effect of the work rolls, in particular when the leading edge of a material to be rolled enters the roll gap or when the rolling speed is changed.

Further advantages of the invention are the relatively simple structure, the allowance of schedule free rolling and the possibility of changing or adjusting the crown of the rolled material during the rolling operation by controlling the inclination of the axes of the work rolls.

The inventors have discovered that also in the case of hot rolling the draw-in properties in the roll gap are not impaired when certain lubricants are used. Even if after passage through the contact portion between work roll and back-up roll some of the lubricant adheres to the surface of the hot work roll and burns, a corresponding amount of lubricant will adhere to the surface of the relatively cooler back-up roll, even if a coolant is applied to the roll surface. In addition or alternatively measures may be provided for preventing the coolant for the work rolls to reach the respective roll surfaces of the back-up rolls. In certain cases lubricant supply may take place only during the actual rolling operation and be shut off in the periods between successive materials to be rolled. Further advantages, in particular in respect of a schedule free rolling operation, result from an additional axial displacement of the inclined work rolls during the rolling operation, which results in an improved distribution of the barrel wear and accordingly in a longer service life. This adjustment of the work rolls in the axial direction and the adjustment of their crossing inclined positions is suitably effected by means of hydraulic cylinders which require only relatively little space and can produce high actuating forces.

The invention can be used in cold rolling mills and in hot rolling mills, in the latter case in particular as a final stand in the finish rolling set. It is also possible and does not cause any difficulties to retrofit existing rolling mills with the measures and components according to the invention at a later time.

The above and other objects, features and advantages of the present invention will be made more apparent by the following description with reference to the accompanying drawings.

Fig. 1 is a schematic view of an embodiment of a work roll cross type four-high rolling mill according to the present invention, as seen in the direction of an axis of a roll;

Fig. 2 illustrates a device for moving a work roll in the axial direction thereof in the work roll crossing type four-high rolling mill shown in Fig. 1;

Fig. 3 is a graph showing the results of the experiments conducted to examine how the crown changes as a result of changes in the cross angle during rolling;

Fig. 4 illustrates a roll grinder for the back-up roll incorporated in the work roll crossing type four-high rolling mill shown in Fig. 1;

Fig. 5 illustrates how a roll lubricant and a coolant are supplied in the work roll crossing type four-high rolling mill shown in Fig. 1;

Fig. 6 is a graph showing the relation between the cross angle of the work roll in the work roll crossing type four high rolling mill, the thrust coefficient between the work roll and the back-up roll, and the thrust coefficient between the work roll and the material being rolled;

Fig. 7 is a graph obtained under a circumstance in which a roll lubricant is supplied between the rolls and showing the relation between the cross angle of the work roll in the work roll crossing type four high mill of the present invention, the thrust coefficient between the work roll and the back-up roll, and the thrust coefficient between the work roll and the material being rolled;

Fig. 8 is a view as seen when looking the rolls from above, illustrating the direction of the thrust generated by crossing the work rolls in the work roll crossing type four high rolling mill;

Fig. 9 is a view as seen when looking the rolls in the axial direction thereof, illustrating the direction of the thrust generated by crossing the work rolls in the work roll crossing type four high rolling mill;

Fig. 10 is a graph showing the relation between the cross angles of the work rolls which differ depending on the type of roll lubricant supplied between the rolls in the work roll crossing type four high rolling mill, which is the embodiment of the present invention, and the wear of back-up roll;

Fig. 11 is a graph showing the results of the experiments conducted to examine now the lubricating property (frictional coefficient) changes by the temperature of the lubricant;

Fig. 12 is a view as seen when looking in the axial direction of the roll, illustrating the experiments shown in Fig. 11;

Fig. 13 schematically illustrates how a lubricant and a coolant are supplied to a work roll and a back-up roll;

Fig. 14 is a graph showing the results of experiments conducted to show that the lubricating property can be maintained after supply of the lubricant is suspended.

Fig. 15 is a schematic view of the roll axis as seen when looking from above, illustrating an influence of the shift of the axis of a back-up roll which is generated by crossing the work roll in the work roll crossing type four high rolling mill;

Fig. 16 is a schematic view of roll axes as seen when looking in the axial direction thereof, illustrating an influence of the deviation of the axis of the back-up roll which is generated by crossing the work roll in the work roll crossing type four high rolling mill;

Fig. 17 is a schematic view explaining a difference in the forces applied to the hydraulic jacks on the operating and driven sides of the rolling mill, which are generated on the basis of the thrust generated by crossing the work roll in the work roll crossing type four high rolling mill; and

Fig. 18 is a schematic view of a hot rolling system which employs, as the finish rolling mill, the embodiment of the work roll crossing type four high rolling mill according to the present invention.

Referring to Figs. 1 and 2, a cross type for high rolling mill includes upper and lower work rolls 7 and upper and lower back-up rolls 8 which support the work rolls. Work roll chocks 16 are provided at the roll ends of each of the work rolls 7 so as to rotatably support the work roll 7. Each of said work roll chocks 16 has two vertical side surfaces 16a and lateral projections 16b on its upper and lower end of said side surfaces. A hydraulic cylinder means or jack 11 acts on each of said side surfaces 16a in the horizontal direction. Said jacks 11 comprise a cylinder member 11a and a piston 10 having a piston head 10a and a spherical press portion 10b. The cylinder member 11a is provided on its inner side with an enlarged end plate 11b which presses against the vertical side surfaces 16a of the work roll chocks 16. Each of said cylinder means 11 is slidably disposed in a separate housing chamber 11c. The cylinder means 11 of each work roll chock act against another symmetrical axis to its horizontal axis to avoid lateral moments and displacements. Further the contact-faces of said cylinder end plates 11b are large enough for uniformly transmitting a strong pressure force to the work roll chocks 16. The cylinder means 11 are securely guided in the chambers 11c, so that they can compensate and withstand the transverse forces produced by vertical movements of the work rolls 8 and its roll chocks 16. The free end portions of the end plates 11b of the cylinder member 11a can act as stopper means for limiting the movement of said cylinder member 11a in said chamber 11c. As shown in Fig. 2 each of said work roll chocks 16 is provided on its outer end with two parallel axial projections 16c having outer transverse end portions 16d.

The two back-up rolls 8 of the rolling mill are rotatably supported by back-up roll chocks 17. The rolling load will be transmitted through said roll chocks 17 to the back-up rolls 8. As shown in Fig. 1, on the lateral sides of said back-up roll chocks 17 are provided members 18 in form of a pressing plate, which are disposed in cutout 20a of the housing 20. Each pressing plate 18 acts at least on hydraulic jack 19 in the horizontal direction transvers to the length axis of the back-up roll 8. On the outer sides of said pressing plates 18 there are secured guiding members 18a, which are displaceably engaged in slots 18b formed in the housing in parallel to said jack 19.

The work roll chocks 16 and the back-up roll chocks 17 are disposed such that they oppose window surfaces 20a of a pair of stands 20 provided erect in spaced relation in the roll axial direction of the rolling mill. Rolling loads are exerted to the individual rolls by means of jacks (not shown) provided in an upper or lower portion of the stands 20 to roll a material to be rolled 9.

To incline the axes of the upper and lower work rolls 7 relative to the axes of the back-up rolls 8 on a horizontal plane and to make the axes of the upper and lower work rolls 7 cross each other, the hydraulic jacks 11 are provided on project blocks 30 of the stands 20 which oppose the two side surfaces of each of the work roll chocks 16 provided at the two ends of each of the upper and lower work rolls 7. The upper and lower work rolls 7 can be made to cross each other by operating both of the hydraulic jack 11. Namely, the hydraulic jacks 10 and 11 have pistons and cylinders. The pistons of the jacks have piston heads disposed in engagement with the project blocks 30, while the cylinders of the jacks are engaged with the upper and lower work rolls chocks 16. Accordingly, the hydraulic jacks 10 and 11 can be operated to move the cylinders of the jacks so that the upper and lower work roll chocks 16 are relatively moved to cross the upper and lower work rolls. A hydraulic oil is supplied to the hydraulic jack 10 through a switch-over valve 14. To detect the movement of a ram of the hydraulic jack 10, a sensor 13 detects a displacement of a rod 12 mounted on the ram. The hydraulic jack 10 is driven by a work roll cross angle controller 40 which adjusts the switch-over valve 14 on the basis of a signal corresponding to the rolling conditions. The work roll cross angle controller 40 also performs feedback control of the hydraulic jack 10 using the signal from the sensor 13 to obtain a desired cross angle of the upper and lower work rolls 7.

The cross angle can be changed during rolling, i.e., under enormous rolling loads.

Fig. 3 illustrates the results of the experiments conducted to examine how the crown of the material being rolled changes by a change in the cross angle during rolling. It can be seen that a change in the cross angle from 0.5 degree to 0.9 degree can change a flat material to one having a concaved crown.

A hydraulic oil is supplied to the hydraulic jack 11 through a pressure reduction valve 15 so that the hydraulic jack 11 can press against the work roll chock 16 with a required force.

Two hydraulic cylinders 22 for driving the work roll along the axis thereof are provided on the stand 20 on the two sides of each of the work roll chocks 16 to move the work roll 7 in the axial direction thereof. A hydraulic oil is sealed in the hydraulic cylinders 22 by means of a pilot check valve 31 so as to allow the position of the hydraulic cylinders 22 to be maintained. The rods of the hydraulic cylinders 22 are coupled to a common movable block 21. Locking portions 21a provided detachably on the common movable block 21 engage with projecting portions 16a formed at the end portion of the work roll chock 16, by which the driving force of the hydraulic cylinders 22 are transmitted to the work roll chock 16 and the work roll 7 can thereby be moved in the axial direction thereof.

Although not shown, the operation of moving the work roll 7 in the axial direction is controlled according to the rolling conditions by a movement control device.

As shown in Figs. 1 and 2, lubricant supply nozzles 1 are respectively disposed along the roll axes to supply a lubricant between the upper work roll 7 and the upper back-up roll 8 and between the lower work roll 7 and the lower back-up roll 8. The position of the lubricant supply nozzle 1 is not limited to that illustrated in Figs. 1 and 2 but the nozzle 1 can be located at any position where it can supply a lubricant, which is a lubricating agent, to between the two rolls. As will be seen in Fig. 2, the nozzle 1 has a plurality of nozzle orifices disposed in a row extending in the axial direction of the rolls 7 and 8 so that these rolls can be uniformly supplied with the lubricant.

Since a large amount of coolant is supplied to the work roll 7 from a nozzle 2, provision of a scraper 32 for preventing washing away of the lubricant is desired.

To prevent generation of backlash in the upper and lower back-up rolls 8 during rolling, a hydraulic jacks 19 is provided on the window surface 20a of the stand 20 which opposes the side surface of the back-up roll chock 17 provided at each of the roll ends of each of the upper and lower back-up rolls 8. A pressing plate 18 for transmitting the driving force of the hydraulic jack 19 is slidably mounted on the stand 20. The hydraulic pressure of the hydraulic jack 19 is exerted to the back-up roll chock 17 through the pressing plate 18 so as to eliminate backlash of the upper or lower back-up roll 8.

A roll grinder 6 is provided near the roll surface of each of the upper and lower back-up rolls 8 so as to grind the roll surface during rolling. The roll grinder 6 is moved in the axial direction of the back-up roll 8 by means of a driving motor 24, as shown in Fig. 4. The degree at which the roll is ground is adjusted by means of a grinding quantity operator 6a.

As shown in Fig. 5, in the work roll cross type four high rolling mill, the lubricant reserved in a tank 26 is supplied from the lubricant supply nozzle 1 in a spray to between the work roll 7 and the back-up roll 8 by means of a pump 27 through a change-over valve 28. When the material being rolled 9 is present between the rolls to or leaves the roll, spraying of the lubricant must be suspended. Hence, when a lubricant controller 50 receives a signal representing the rolling conditions, such as ending or beginning of supply of the material to be rolled, it changes over the change-over valve 28 and thereby suspends spraying of the lubricant onto the roll surface from the lubricant supply nozzle 1.

Roll cooling nozzles 2 and 3 are used to cool the work roll and the back-up roll.

In the aforementioned work roll cross type four high rolling mill, whereas the back-up rolls 8 are not moved in the horizontal direction, the work rolls 7 are moved in opposite directions and are thereby made to cross each other. This cross type mill is suitable for use in the hot strip mill in which a large crown must be set in the material to be rolled 9, particularly, suitable for use as the front stand of the finish mill. In the hot rolling, a cooling water is mainly ejected to the upper and lower work rolls 7 from the roll cooling nozzles 2 and 3 due to the biting property of the materials to be rolled 9. In the work roll crossing type rolling, the utmost requirement is concerned with how the thrust exerted to the work rolls can be coped with.

Fig. 6 are graphs respectively showing the cross angle of the work rolls in the work roll crossing type four high rolling mill, the thrust coefficient between the work roll and the back-up roll, and the thrust coefficient between the work roll and the material being rolled. In Fig. 6, the abscissa axis represents the cross angle of a single work roll relative to a line perpendicular to the direction of rolling. The ordinate axis represents the thrust coefficient. μ_{Tm} is a percentage obtained by dividing a thrust exerted to a single work roll 7 from the material being rolled 9 by the rolling load. μ_{Tm} is a function of the cross angle θ and other conditions, such as the draft. In general, the larger the draft, the lesser μ_{Tm}. In the case of the pair cross rolling, since the cross angle between the work rolls and the back-up rolls does not exist, no thrust is theoretically generated, and the thrust exerted to the single work roll is obtained by multiplying μ_{Tm} by the rolling load. In the case in which crossing of only the upper and lower work rolls 7 is performed, the thrust generated between the back-up roll 8 and the work roll 7 differs depending on the rolling conditions. In Fig. 6, three examples of such thrusts are given as μ_{TR1}, μ_{TR2} and μ_{TR3}. μ_{TR1} indicates the results of the experiments in which only water was supplied between the back-up roll 8 and the work roll 7. μ_{TR2} indicates the results of the experiments in which the concentration of the lubricanting oil present in the water supplied to the two rolls was low. μ_{TR3} indicates the results of the experiments in which the concentration of the lubricanting oil in the water was higher than that in μ_{TR2}. As can be seen from Fig. 6, the thrust μ_{TR} can be greatly reduced by the supply of the lubricanting oil between the rolls. The thrust μ_{TR} can be selected by selecting the concentration of the lubricanting oil. In the aforementioned experiments, the concentration was changed. However, the amount of emulsion of lubricanting oil and water may be changed to change the thrust.

Fig. 7 shows the thrust coefficient μ_{WT} exerted to the work roll 7 when the axes of the work rolls are made to cross the material being rolled 9 and back-up rolls 8 while the back-up rolls 8 are fixed in the horizontal direction, i.e., the value obtained by dividing the thrust by the rolling load. The thrust coefficient μ_{WT} is a percentage representing the sum of the thrust exerted from the back-up roll and that exerted from the material being rolled.

In the conventional pair cross type rolling mill, μ_{WT} is the same as μ_{Tm} shown in Fig. 6. It is to be noted that the direction of the thrust exerted to the work roll 7 from the material being rolled 9 and that of the thrust exerted from the back-up roll 8 oppose each other.

This will be discussed in detail with reference to Figs. 8 and 9.

Fig. 8 shows the relation between the speed at a contact portion A between the work roll 7 and the material being rolled 9 and that at a contact portion B between the work roll 7 and the back-up roll 8 shown in Fig. 9. V_M indicates the speed of the material being rolled at the contact portion, V_W indicates the peripheral speed of the work roll, and V_B indicates the peripheral speed of the back-up roll.

The work roll 7 is subjected to both the thrust in a direction of a relative speed ΔV_A between the work roll 7 and the material being rolled 9 and the thrust in a direction of a relative speed ΔV_B between the work roll 7 and the back-up roll 8. Since the directions of these relative speeds are opposite to each other, these thrusts cancel each other.

At the contact portion A, the material 9 is rolled and the thrust thereby reduces, that is, μ_{Tm} shown in Fig. 6 reduces. In spite of that, in the case of water spray, direction of μ_{WT1} is opposite to that of μ_{Tm}, that is, since the thrust exerted from the back-up roll 8 is large, μ_{WT1} is about 25%. In a practical rolling mill, the thrust must be 5% or less due to the designing of the thrust bearing. In this method, such a thrust therefore cannot be achieved. Also, wear of the back-up roll and that of the work roll are great. In the case of the supply of the lubricanting oil having a low concentration, μ_{WT2} is 2% or less, which is almost the same as that obtained in the normal rolling. When the concentration of the lubricanting oil is increased, although the direction of μ_{WT3} is the same as that of μ_{Tm}, the value is reduced to half of μ_{Tm}. Thus, it is possible to reduce the thrust to values obtained in the normal type of rolling mill in which the work rolls do not cross each other by adequately setting the concentration of the lubricanting oil.

Although $\mu_{TR} = \mu_{Tm}$ is the most desirable from the viewpoint of reduction in the thrust exerted to the work roll, $\mu_{TR} < \mu_{Tm}$ is desirable from the viewpoint of elimination of wear of the roll.

Fig. 10 shows the results of the experiments in which wear of the back-up roll 8 was greatly reduced by lubrication between the work roll 7 and the back-up roll 8 from the lubricant supply nozzle 1. The material of the back-up rolls 8 was a special steel having a hardness of HS60°, while that of the work rolls 7 was high chrome of HS75°. The contact stress P_0 between the rolls was 180 kg/mm. The total number of rotations was 250,000. The cross angle between the rolls was 0, 0.6° and 1.2°. In the hot strip mill, when the back-up roll used in the finish front stage mill has been rotated 200,000 times, it is replaced with a new one. The back-up roll in the finish rear stage is rotated 200,000 times before it is replaced with a new one. As can be seen from Fig. 10, when the lubricant is supplied, wear of the back-up roll can be reduced to 1/5th through 1/10th of that obtained when water is supplied. In the normal four high rolling mill in which the rolls do not cross each other, several tens of μm of wear occurs on the back-up roll due to the scale which flies from the material being rolled or the like by the time the roll has been rotated 250,000 times. The wear which occurs when the work rolls cross each other may also be considered the sum of the wear which occurs in the conventional case and that shown in Fig. 10. However, lubrication is effective to reduced the conventional wear as well.

By adapting the aforementioned lubrication method, all the problems of the conventional cross mill can be solved. Furthermore, the structure therefore is simple. In other words, the knowledge about lubrication between the rolls has turned crossing of the rolls, which is conventionally a negative, into a positive.

In the conventional pair cross mill, since the relation between the back-up roll and the work roll is not affected by crossing, distribution of contact pressure between the rolls remains the same. In the rolling mill in which only the work rolls 7 cross each other, it may be considered that an equivalent cross will occur between the rolls, increasing the pressure at the central portion. However, it does not happen for the following reason. When the roll surface length is 2000 mm, the diameter of the work roll 7 is 700 mm, the diameter of the back-up roll 8 is 1500 mm, and the cross angle θ of the work roll 7 is 1.2°, gap C_R of the end portions of the two rolls is expressed as follows:

[Equation 1]

$$C_R = \frac{\delta^2}{2(R_1 + R_2)}$$

$$\delta = \theta\frac{L}{2} = \frac{1.2}{57} \times \frac{2000}{2} = 21 \text{ (mm)}$$

$$C_R = \frac{21^2}{2(350 + 750)} = \frac{441}{700 + 1500} = 0.200 \text{ mm}$$

... Equation 1

where R_1 R_2 are respectively the radius of the work roll 7 and that of the back-up roll 8.

This gap corresponds to that obtained when 0.40 mm of crown is grounded on to the back-up roll 8. In a practically employed mill, a safe operation is assured even when a crown of 1 mm or more is provided.

A cross angle of 1.2° is enough to assure the sufficient control ability. Moreover, it can assure the advantage resulting from a change in the crown of the back-up roll 8 (it has been estimated that a cross angle of 1.2° is 10 to 20% more advantageous). Therefore, the cross angle θ can be less than that in the pair cross mill.

The second requirement of the work roll crossing type rolling mill is lubrication between the rolls.

The results of the experiments conducted to examine the effect of the lubricanting oil will be described below. In recent years, a so-called hot rolling oil (at a concentration of 1% or less) has been used in the hot rolling for the purpose of reducing wear of the work rolls and rolling load and rolling power. This hot rolling oil is characterized in that it can maintain its lubricating effect on a high-temperature material present in the roll bite of 700°C or above, and contains a large amount of fatty oil, such as beef tallow. A lubricanting oil mainly composed of a mineral oil, which may be a soluble oil containing an emulsifier, greatly degrades or loses the lubricating effect at high temperatures, and thus has no adverse effect on biting.

This will be discussed in detail using the results of the experiments shown in Fig. 11. In Fig. 11, (A portion) and (B portion) respectively correspond to (A portion) and (B portion) in Fig. 12. That is, a mineral oil type lubricant oil (including soluble oils) has a very low lubricating performance which ensures a frictional coefficient as high as that obtained when lubrication is not provided at (B portion) at which it is in contact with the material being hot rolled, but shows a good lubricating performance which ensures a low frictional coefficient at (A portion) of low temperatures. An example of the lubricant oil is "Daphne Roll Oil SL-2" (trade name) manufactured by IDEMITSU KOSAN, Japan. The lubricant is based on mineral oil, includes a special emulsifier, an oilness-improving material and an anti-corrosion material and has following physical properties:

Specific Gravity	15/4°C	0.9295
Color Order	(ASTM)	20
Flash Point	(COC)°C	164
Coefficient of Viscosity cSt		
	@ 40°C	22.94
	@100°C	4.11
Viscosity Index		58
Fluidizing point	°C	-175
Total Acid Value	mgKOH/g	3.58
Residual Carbon	wt %	0.5
Ash	wt %	0.17
Saponification Value	mgKOH/g	12.30
Copper Plate Corrosion (100°C x 3 h)		1

A fatty oil type lubricating oil, such as beef tallow, has a lubricating performance not only at (A portion) but also at (B portion) of high temperatures. Hence, presence of this type of lubricating oil when biting of the material to be rolled begins may generate biting failure.

Therefore, the use of the fatty oil type lubricanting oil causes no problem in the continuous hot strip mill. However, in the hot strip mill in which the materials to be rolled are supplied in sequence, the lubricant attached to the work roll 7 may cause bite failure. Furthermore, when acceleration or deceleration is performed after the material has left the roll, since the rolling load has been reduced to zero, small coefficient of friction between the rolls may cause slip between the rolls due to inertia of the reinforcing roll 8. Hence, the coefficient of friction of the roll surface must be increased immediately before the material leaves the roll, and supply of lubricant must thus be suspended before the material leaves the roll. In that case, it is desired that supply of lubricant be continued as long as possible until immediately before the rolled material leaves the roll.

When supply of the lubricant from the lubricant supply nozzle 1 shown in Fig. 13 is suspended, the lubricating effect does not disappear immediately after suspension, as shown in Fig. 14. Although the thrust coefficient (thrust) starts increasing in about one minute after suspension, the degree of increase is small and the amount of increase is only 0.025 in five minutes after suspension. Generally, it takes about one to three minutes for bite of a subsequent material to be rolled to be started after the trailing end of the previous material has left the roll, and the lubricant effect can thus be maintained sufficiently long.

The method of suspending supply of the lubricant will be described with reference to Fig. 5 which illustrates a control system.

First, a signal representing the rolling conditions is input to a lubricant controller 50 before the length l of the trailing end of the material being rolled 9 is $\pi/2D_W$, by which the lubricant controller 50 outputs an operation signal to the change-over valve 28 to close the lubricant supply nozzle 1. At that time, the lubricant already attached to half of the circumference $\pi/2D_W$ of the work roll 7 by that time is carbonized by the hot rolled material 9 and thereby loses its lubricating ability. However, the lubricant attached to the back-up roll 8 is not brought into direct contact with the rolled material 9 and thus remains on the back-up roll. Therefore, the lubricant effect between the work roll 7 and the back-up roll; 8 can be maintained, and lubrication can thus be provided between the rolls during rolling and non-rolling.

If a lubricant of the type which can be washed by the cooling water supplied from the roll cooling nozzles 2 and 3 is selected, the aforementioned arrangement is not necessary and application of lubricant can be performed throughout the rolling. That is, when acceleration or deceleration is performed after the rolled material leaves the roll, lubricant supply is suspended, the work rolls are retracted to a position where the cross angle is 0, and then roll balancing force is increased. Because of crossing of only the work rolls 7, crossing resistance is less and crossing operation can be quickly performed during rotation of the rolls. Therefore, reduction of the cross angle to zero after the rolled material 9 has left the roll is desired.

When the mineral type lubricant is used, supply thereof can be continued, as mentioned above. Alternatively, both the fatty oil type hot rolling oil and the mineral lubricanting oil can be used. That is, it can be arranged such that only the hot rolling lubricanting oil is supplied when the material being rolled is present in the rolling mill while only the mineral type lubricanting oil is supplied when the material is absent. In this way, lubrication between the rolls can be maintained throughout the operation without deteriorating biting of the materials to be rolled.

Lubrication performed in the hot rolling process has been described. In the cold rolling process, however, the lubricant is kept supplied, and the problem involving bite does not occur. Hence, the objective of the lubrication can be achieved by supplying an adequate type of lubricant between the back-up roll 8 and the work roll 7.

Wear of rolls, which would be caused by a great degree due to slippage of rolls when only water is supplied between the rolls, can be greatly reduced by supply of the lubricant in the manner mentioned above. However, this increases the degree at which the central portion of the roll wears. Hence, the on-line grinder 6 shown in Fig. 5 is used to grind the outer surface of the back-up roll 8 such that it is straight or has a predetermined crown.

On-line grinders for grinding the work roll 7 which is frequently replaced with a new one have been proposed. However, maintenance of the work roll 7 is very difficult, because the work roll 7 is very hard, because high quality is required for the finish of the surface, and because the space is not enough due to provision of guide or cooling water. In the case of the back-up roll 8, polishing is not so a hard work, because space is enough, because the roll is not so hard as the work roll, and because a surface quality as high as that for the work roll is not required. Even when correction of roll profile is not necessary, the back-up roll 8 is replaced for polishing because a fatigue layer generated by the contact of two rolls due to Hertz's stress must be removed. Therefore, if profile correction and removal of the fatigue layer can be performed at the same time, the roll exchange pitch of the back-up roll 8 can be greatly increased. Changing of the back-up roll 8 is so a hard work that it is generally conducted at the periodic repair. In an practical operation, changing of the back-up roll is conducted periodically. The use of the aforementioned method, however, allows the polishing work of the back-up roll 8 conducted by the rolling plate to be eliminated. In that case, the rolling plant performs polishing of the back-up roll 8 using the on-line grinder without using an expensive large back-up roll grinder. The back-up roll grinder can be employed for the back-up roll not only in the aforementioned work roll cross type four high mill but also in all types of mills, such as four, five or six high mill. Regarding shift of the cross point due to backlash of the roll bearing, the largest backlash occurs in a gap between the metal chock of the roll and the stand 20 or project block 30. The crossing mechanism for the work rolls 7 may be provided with a mechanism for reducing backlash. In the case of the back-up roll 8, since the gap thereof is normally fixed, it is set to a small value during rolling and to a large value during roll changing in this invention. Alternatively, the chock of the back-up, roll 8 may be pressed against the stand on one direction under a fixed hydraulic pressure during rolling while pressing is released during roll changing.

The nead for such a structure will be discussed with reference to Figs. 15 and 16.

Inclination of the back-up roll 8 about the crossing center of the work roll 7 due to the backlash between the bearing of the back-up roll 8 and the stand 20 may cause slight displacement of the cross angle of the work roll 7 but causes no serious problem. However, displacement of the axis of the back-up roll 8 by e in the direction of rolling shifts the cross point of the two rolls in the axial direction by $a = e/\theta$, generating a difference in the gaps of the upper and lower work rolls 7 which leads to zigzagging of the material being rolled 9. To eliminate this, the reduction level must be corrected by S_{df}. Where R_1 is the radius of the work roll 7, R_2 is the radius of the back-up roll 8, and L is the distance between the reduction screws, offset of the center of the two rolls by c, shown in Fig. 16, increases the roll pass g to $c^2/2\ (R_1 + R_2)$, thus increasing the difference G in the gaps at the right and left reduction positions as follows:

[Equation 2]

$$G = \frac{1}{2(R_1+R_2)} [\{(\frac{L}{2} + a)\ \theta\}^2 - \{(\frac{L}{2} - a)\ \theta\}^2]$$

$$= \frac{La\theta^2}{R_1+R_2} = \frac{Le\theta}{R_1+R_2} \quad \text{... (Equation 2)}$$

A reduction screw difference S_{df} corresponding to G is obtained by the following equation.

[Equation 3]

$$S_{df} = \frac{L}{R_1 + R_2} \cdot e\theta \quad \text{... (Equation 3)}$$

In a large hot strip mill, if $R_1 = 700/2 = 350$ mm, $R_2 = 1500/2 = 750$ mm, L = 3000 mm and θ = 1.20, S_{df} is obtained by the following equation in which the unit of e is mm.

[Equation 4]

$S_{df} = 0.05$ e (Equation 4)

Since it is practically impossible to correct S_{df}, i.e., the reduction level, according to e, e must be reduced to a value which can be neglected in a practical operation. From the experiences, in the case of the hot strip finish mill which rolls thick strips, S_{df} in the front stage mill stand is 0.05 mm, and that in the rear stage mill stand is about 0.025 mm. At that time, the allowable displacement e of the center of the back-up roll in the front stage mill stand is ±1 mm, and that in the rear stage mill stand is ±0.5 mm. However, the smaller, the better.

In the presently practiced hot strip mill, schedule free rolling is the important element, and shift of the work rolls in the axial direction is essential in order to disperse wear thereof. Therefore, crown control capability and wear dispersion function are the requirements of the hot strip mill. In this embodiment, since the force exerted to the work roll 7 in the axial direction can be reduced, the work roll shifting mechanism can be made simple.

Difference of the force applied to the jack by the thrust will be explained. In Fig. 17, when thrust F_1 is applied from the material being rolled while thrust F_2 is generated between the rolls, a load difference ΔQ occurs between the right and left jacks. ΔQ is obtained in Fig. 17 as follows:

[Equation 5]

$\Delta Q = \frac{1}{l} \{\frac{1}{2} (F_1 + F_2)\ D_W + \frac{1}{2} F_2 D_B\}$ Equation 5

If L = 3000 mm, D_W = 700 mm, D_B = 1500 mm,
$F_1 = F_2 = 0.05 \times P$, i.e., if thrust is 5%,

[Equation 6]

$\Delta Q = 0.024P$ Equation 6

That is, 2.4% of the rolling load is generated. If the thrust is 10%, ΔQ reaches 4.8%.

Hence, reduction in the thrusts F_1 and F_2, particularly, thrust F_2 between the rolls, is advantageous.

Difference in the reduction forces adversely affects correction of zigzagging, because in the correction a difference in the loads is detected and reduction forces are adjusted such that difference is reduced to zero. Although it is possible to perform correction of zigzagging using load difference ΔQ obtained from the thrust and stored beforehand, variations in the thrust causes disturbance of zigzaging correction, and reduction in the thrust as must as possible is thus desired.

The operation of the aforementioned embodiment, which is the work roll cross type four high rolling mill, will be described below.

Referring to Figs. 1 through 2, the upper and lower work rolls 7 which roll the material to be rolled 9 are pressed from two sides thereof by means of the hydraulic jacks 10 and 11 such that the axes thereof are respectively inclined by θ in the opposite directions. During rolling, the work rolls 7 are maintained at that position. Cross angle of the work roll 7 will be set in the manner described below. The sensor 13 provided on the hydraulic jack 10 through the rod 12 detects stroke of the jack, i.e., the position of the work roll chock 16. The other hydraulic jack 11 presses the work roll chock 16 by a pressing force which is adjusted by the pressure reduction valve 15. After the cross angle of the work roll is set with the change-over valve 14 opened, the change-over valve 14 is closed to maintain the set cross angle.

The chocks 17 of the back-up rolls 8 which hold the work rolls 7 are pressed against the window surfaces 20a of the stand 20 which are remote from the hydraulic jacks 19 by means of the hydraulic jacks 19 through the pressing plates 18 during rolling so that the back-up rolls 8 can be held in a fixed state. A work roll 7 shifting device will be described in detail below. The chock 16 of the work roll 7 is held by the movable block 21. The chock 16 can be shifted, together with the movable block 21, in the axial direction of the work roll 7 while being guided by a fixing frame 23 by means of the hydraulic cylinders 22 incorporated in the movable block 21. Since the chock 16 of the work roll 7 is shifted toward the direction of rolling as a result of crossing, the movable block 21 must be rotated according to the position of the chock 16. Hence, the guiding portion of the fixed frame 23 is made cylindrical so that it can follow the roll crossing operation.

To compensate for wear of the back-up roll 8 caused by relative slide speed ΔV_B (Fig. 9) generated between the rolls by making the work rolls 7 cross each other, the roll grinder 6 shown in Fig. 3 is provided. The grinder 6 moves together with the drive motor 24 in the axial direction of the back-up roll 8 while polishing the surface of the back-up roll 8, by which the roll surface is polished in a straight or curved fashion. Lubrication of the roll surface will be described below with reference to Fig. 5. Coolant is supplied to the work roll from the roll cooling nozzles 2 and 3 to cool the work roll. A lubricant of an adequate concentration is supplied to the vicinity of the entrance of the pass between the work roll 7 and the back-up roll 8 from the lubricant supply nozzle 1 in order to reduce the thrust between the rolls. The lubricant is supplied to the lubricant supply nozzle 1 from the tank 26 by the pump 27 through the change-over valve 28. Thus, supply of the lubricant can be suspended at suitable times, e.g., when the material being rolled leaves the roll or when the material to be rolled is supplied to the roll, by closing the change-over valve 28.

The most desirable position to which the lubricant is supplied from the lubricant supply nozzle 1 is shown in Fig. 5. However, a lubricant may also be supplied to other positions, e.g., to the circumference of the back-up roll 8, so that it can be finally supplied between the rolls therefrom.

As will be understood from the foregoing description, the work roll cross type four high rolling mill according to the present embodiment is capable of overcoming the drawbacks caused by making only the work rolls cross each other and can thus be put into practical use.

The mechanisms and structures which are necessary to accomplish the necessary functions have been described. It is, however, to be noted that the object of the present invention can also be achieved by other similar mechanisms. For example, a worm jack or a wedge mechanism may be used in place of the hydraulic jack to achieve crossing of the work rolls 7.

The aforementioned work roll cross type four high rolling mill can be provided by revamping the existing four high rolling mill without providing a new stand by reusing the stand 20 of the existing rolling mill. The existing four high rolling mill in which the pair of work rolls 7 and the pair of back-up rolls 8 for respectively supporting the work rolls 7 are provided on the rolling stand 20 will be revamped into the work roll cross type four high rolling mill in the manner described below: the hydraulic jacks 10 and 11, which are the hydraulic device that can be operated in the direction in which the material to be rolled 9 is fed, are provided at the positions on the rolling stand 20 which oppose the roll chocks 16 of the work rolls 7 so that the work rolls 7 can be inclined relative to the back-up rolls 8 on the horizontal plane in such a manner that the axes of the work rolls 7 cross the axes of the back-up rolls 8 and such that the axes of the work rolls 7 cross each other. Also, the hydraulic cylinders 22, which are the hydraulic devices that can be operated in the axial direction of the work roll 7, are provided so that the engagement of the hydraulic cylinders 22 with the roll chock 16 of the work roll 7 enables the work roll 7 to be moved in the axial direction thereof. The lubricant supply device 1 for supplying a lubricant is provided between the work roll 7 and the back-up roll

8.

Thus, a rolling mill in which crossing of only the work rolls 7 is provided can be obtained by utilizing the stand 20 of the existing rolling mill. IN this rolling mill, since the work rolls 7 can be moved in the axial direction thereof during rolling, schedule free rolling is allowed for. Furthermore, since the thrust exerted to the work roll 7 can be reduced to a degree which does not cause problems even when the work rolls 7 cross each other by the action of the lubricant supplied from the lubricant supply device 1 between the work roll 7 and the back-up roll 8, the rolling roll can show an excellent ability with which it controls crown of the materials to be rolled 9.

An example of application of the aforementioned work roll cross type four high rolling mill to the hot rolling system will be described below with reference to Fig. 18.

Fig. 18 shows a hot rolling system in which a joining device 63 is provided between rough rolling mills 61 and finish rolling mills 62 for sequentially joining the materials being rolled 9, and in which after the materials which have been rolled by the rough rolling mills 61 are joined to each other by the joining device 63, the joined materials are continuously rolled by the finish rolling mills 62. At least one of the finish rolling mills 62 is constituted by the aforementioned rolling mill which includes the pair of work rolls 7 and the pair of back-up rolls 8 for respectively supporting the work rolls 7, in which the axes of the back-up rolls 8 are not inclined on the horizontal plane while the work rolls 7 can be inclined relative to the back-up rolls 8 on the horizontal plane such that the axes of the work rolls 7 cross the axes of the back-up rolls 8 and such that the work rolls 7 cross each other, in which the work rolls 7 are movable in the axial direction thereof, and in which the lubricant supply device 1 for supplying a lubricant between the work roll 7 and the back-up roll 8 is provided.

Thus, it is possible to provide a rolling mill in which crossing of only the work rolls 7 is provided.

Furthermore, since the work rolls 7 are movable in the axial direction thereof, they can be moved in the axial direction during rolling, thus making schedule free rolling possible.

Furthermore, since the lubricant supply device 1 for supplying a lubricant between the work roll 7 and the back-up roll 8 is provided, the thrust exerted to the work roll 7 can be reduced to a degree which causes no problem in a practical operation even when the work rolls are made to cross each other by the action of the lubricant supplied between the work roll 7 and the back-up roll 8. It is therefore possible to provide a work roll cross type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled 9.

Thus, the work roll cross type rolling mill can be used as the finish rolling mill of the hot rolling system in which the materials rolled by the rough rolling mills are continuously rolled by the finish rolling mills.

The aforementioned rolling mill according to the present embodiment has a simpler structure than the conventional pair cross type four stage mill but is capable of controlling crown of the sheet more effectively. The aforementioned rolling mill has another advantage in that it can greatly reduce the thrust exerted to the work roll, which is the utmost requirement of the cross type mill. Consequently, the thrust bearing can be made simple, reduction in the diameter of the work roll is made possible, and shift of the work roll is facilitated. The last one is essential in the continuous rolling operation in which the work roll must be shifted during rolling. In the pair cross type rolling mill, changes in the cross angle during rolling require relative movement between the reduction device and the bearing of the back-up roll, and a more complicated structure is thus required. However, in the present embodiment, changes in the cross angle can be easily and quickly performed because they are the changes in the cross angle of the rotating rolls. Therefore, the present embodiment is suited to continuous rolling. Also, wear of the rolls, which would be caused by the slip of the rolls, can be greatly reduced by the use of an adequate lubricant. The use of the on-line grinder improves the problem involving the wear and allows for removal of the fatigue layer, and hence greatly increases the pitch of the back-up roll changing operation which is a troublesome task.

It is possible according to the first aspect of the present invention to provide a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, and which achieves reduction in the thrust exerted to the work roll with a simple structure.

It is also possible according to the second aspect of the present invention to provide a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, which achieves reduction in the thrust exerted to the work roll with a simple structure, and which allows for schedule free rolling.

It is also possible according to the third aspect of the present invention to provide a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, which achieves reduction in the thrust exerted to the work roll with a simple structure, and which is capable of preventing generation of excessive thrust between the work roll and the back-up roll.

It is also possible according to the fourth aspect of the present invention to provide a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, which achieves reduction in the thrust exerted to the work roll with a simple structure, which allows for schedule free rolling, and which is capable of preventing generation of excessive thrust between the work roll and the back-up roll.

It is also possible according to the fifth aspect of the present invention to provide a hot rolling system including a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, which achieves reduction in the thrust exerted to the work roll by a simple structure, and which allows for schedule free rolling.

It is also possible according to the sixth aspect of the present invention to provide a rolling method for a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, and which achieves reduction in the thrust exerted to the work roll with a simple structure.

It is also possible according to the seventh aspect of the present invention to provide a rolling method for a work roll crossing type rolling mill which shows an excellent ability with which is controls crown of the material to be rolled, which achieves reduction in the thrust exerted to the work roll with a simple structure, and which allows for schedule free rolling.

It is also possible according to the eighth aspect of the present invention to provide a rolling method for a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, which achieves reduction in the thrust exerted to the work roll with a simple structure, and which enables the crown to be changed during rolling.

It is also possible according to the ninth aspect of the present invention to provide a rolling method for a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, which achieves reduction in the thrust exerted to the work roll with a simple structure, which allows for schedule free rolling, and which enables the crown to be changed during rolling.

It is also possible according to the tenth aspect of the present invention to provide a revamping method of a work roll crossing type rolling mill which shows an excellent ability with which it controls crown of the material to be rolled, and which achieves reduction in the thrust exerted to the work roll with a simple structure.

Claims

1. A rolling mill in which a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls are provided on a rolling stand, wherein the backup rolls are constructed in such a manner that axes thereof are not inclined in a horizontal plane while the work rolls are constructed in such a manner that axes thereof can be inclined in a horizontal plane relative to the back-up rolls such that the axes of the work rolls cross the axes of the back-up rolls and such that the axes of the work rolls cross each other, and a lubricant supply device is provided for supplying a lubricant between each work roll and each back-up roll.

2. A rolling mill in which a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls are provided on a rolling stand, wherein the back-up rolls are constructed in such a manner that axes thereof are not inclined in a horizontal plane while the work rolls are constructed in such a manner that axes thereof can be inclined in a horizontal plane relative to the back-up rolls such that the axes of the work rolls cross the axes of the back-up rolls and such that the axes of the work rolls cross each other, the work rolls are movable in the axial direction thereof, and a lubricant supply device is provided for supplying a lubricant between each work roll and each back-up roll.

3. A rolling mill in which a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls are provided on a rolling stand, wherein the back-up rolls are constructed in such a manner that axes thereof are not inclined in a horizontal plane while the work rolls are constructed in such a manner that axes thereof can be inclined in a horizontal plane relative to the back-up rolls such that the axes of the work rolls cross the axes of the back-up rolls and such that the axes of the work rolls cross each other, a lubricant supply device is provided for supplying a lubricant between the work roll and the back-up roll, and a member for preventing a cooling water for the work roll from entering the rolls is provided in the vicinity of each work roll.

4. A rolling mill in which a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls are provided on a rolling stand, wherein the back-up rolls are constructed in such a manner

that axes thereof are not inclined in a horizontal plane while the work rolls are constructed in such a manner that axes thereof can be inclined in a horizontal plane relative to the back-up rolls such that the axes of the work rolls cross the axes of the back-up rolls and such that the axes of the work rolls cross each other, the work rolls are movable in the axial direction thereof, a lubricant supply device is provided for supplying a lubricant between the work roll and the back-up roll, and a member for preventing a cooling water for the work roll from entering the rolls is provided in the vicinity of each work roll.

5. A rolling mill according to claim 1, wherein said back-up rolls are constructed in such a manner that a force generated by a hydraulic device provided on one of side surfaces of a window of the rolling stand is applied to a roll chock of the back-up roll through a pressing plate member and the roll choke can thereby be pressed against the other side surface of the window.

6. A rolling mill according to any one of claims 1 to 4, wherein the lubricant is mainly based on a mineral lubricant.

7. A rolling mill according to claim 1, further including a grinding device for grinding a surface of the back-up rolls, said grinding device being provided in such a manner as to be movable in the axial direction of the back-up rolls.

8. A rolling mill according to claim 1, further including a control device for controlling supply of the lubricant from said lubricant supply device according to rolling conditions.

9. A hot rolling system in which a joining device for joining materials being rolled is provided between a rough rolling mill and a finish rolling mill and in which the materials which have been rolled by said rough rolling mill are rolled continuously by said finish rolling mill, wherein said finish rolling mill comprises a rolling mill which includes a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls, the back-up rolls are constructed in such a manner that axes thereof are not inclined in a horizontal plane while the work rolls are constructed in such a manner that axes thereof can be inclined in a horizontal plane relative to the back-up rolls such that the axes of the work rolls cross the axes of the back-up rolls and such that the axes of the work rolls cross each other, the work rolls are movable in the axial direction thereof, and a lubricant supply device is provided for supplying a lubricant between the work roll and the back-up roll.

10. A rolling method by use of a rolling mill including a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls, wherein a crown of the material being rolled is controlled by controlling, during rolling, an inclination of axes of the work rolls relative to the back-up rolls in a horizontal plane such that the axes of the work rolls cross axes of the back-up rolls and such that the axes of the work rolls cross each other in a state wherein a lubricant is supplied between each work roll and each back-up roll.

11. A rolling method by use of a rolling mill including a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls, wherein a crown of the material being rolled is adjusted by controlling, during rolling, an inclination of axes of the work rolls relative to the back-up rolls in a horizontal plane such that the axes of the work rolls cross axes of the back-up rolls and such that the axes of the work rolls cross each other in a state wherein a lubricant is supplied between each work roll and each back-up roll, and by controlling a movement of the work rolls in the axial direction.

12. A rolling method by use of a rolling mill including a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls, wherein a crown of the material being rolled is adjusted by controlling, during rolling, an inclination of axes of the work rolls relative to the back-up rolls in a horizontal plane such that the axes of the work rolls cross axes of the back-up rolls and such that the axes of the work rolls cross each other in a state wherein a lubricant is supplied between each work roll and each back-up roll, and by changing a cross angle of each work roll during rolling.

13. A rolling method by use of a rolling mill including a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls, wherein a crown of the material being rolled is adjusted by controlling, during rolling, an inclination of axes of the work rolls relative to the back-up rolls in a horizontal plane such that the axes of the work rolls cross axes of the back-up rolls and such that the axes of the work rolls cross each other in a state wherein a lubricant is supplied between each work roll and each back-up roll, by controlling a movement of the work roll in an axial direction thereof, and by changing a cross angle of each work roll during rolling.

14. A rolling method according to claim 10, wherein supply of the lubricant is suspended when the material being rolled leaves the roll.

15. A method of revamping a rolling mill in which a pair of work rolls and a pair of back-up rolls for respectively supporting the work rolls are provided on a rolling stand, the method comprising the steps of:

providing a hydraulic device on a position on the rolling stand which opposes a roll chock of each work roll in such a manner that said device can be operated in a direction in which a material being rolled proceeds, so that said device can incline axes of the work rolls relative to the back-up rolls in a horizontal plane such that the axes of the work rolls cross axes of the back-up rolls and such that the axes of the work rolls cross each other,

providing another hydraulic device on the rolling stand in such a manner that the other device can be operated in an axial direction of each work roll, so that the other device can engage with the roll chock of the work roll to thereby move the work roll in the axial direction thereof, and

providing a lubricant supply device for supplying a lubricant between the work roll and the back-up roll.

FIG. 1

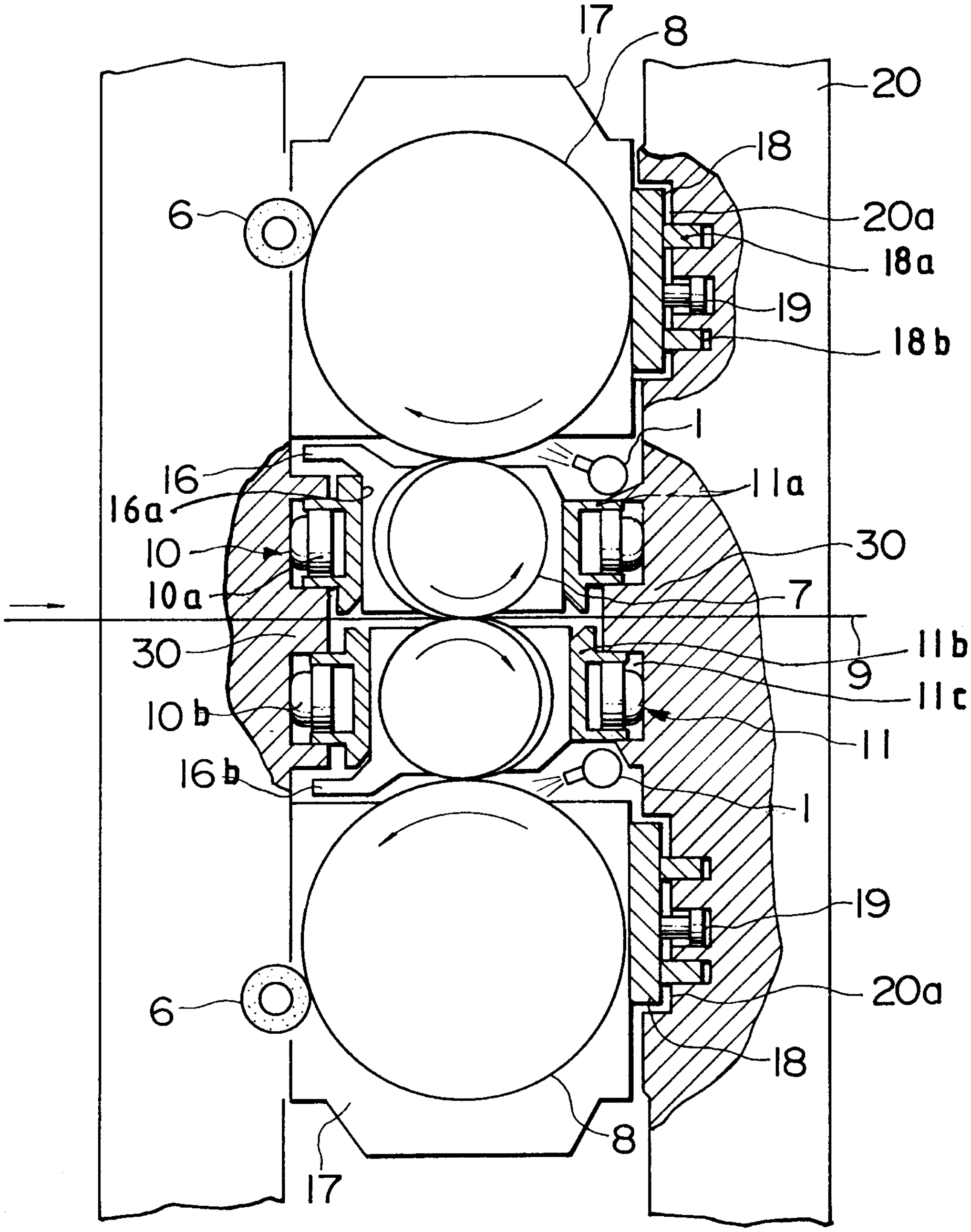

17
8
20
18
6
20a
18a
19
18b
1
16
11a
16a
10
30
10a
7
30
11b
9
11c
10b
11
16b
1
19
6
20a
18
8
17

FIG. 2

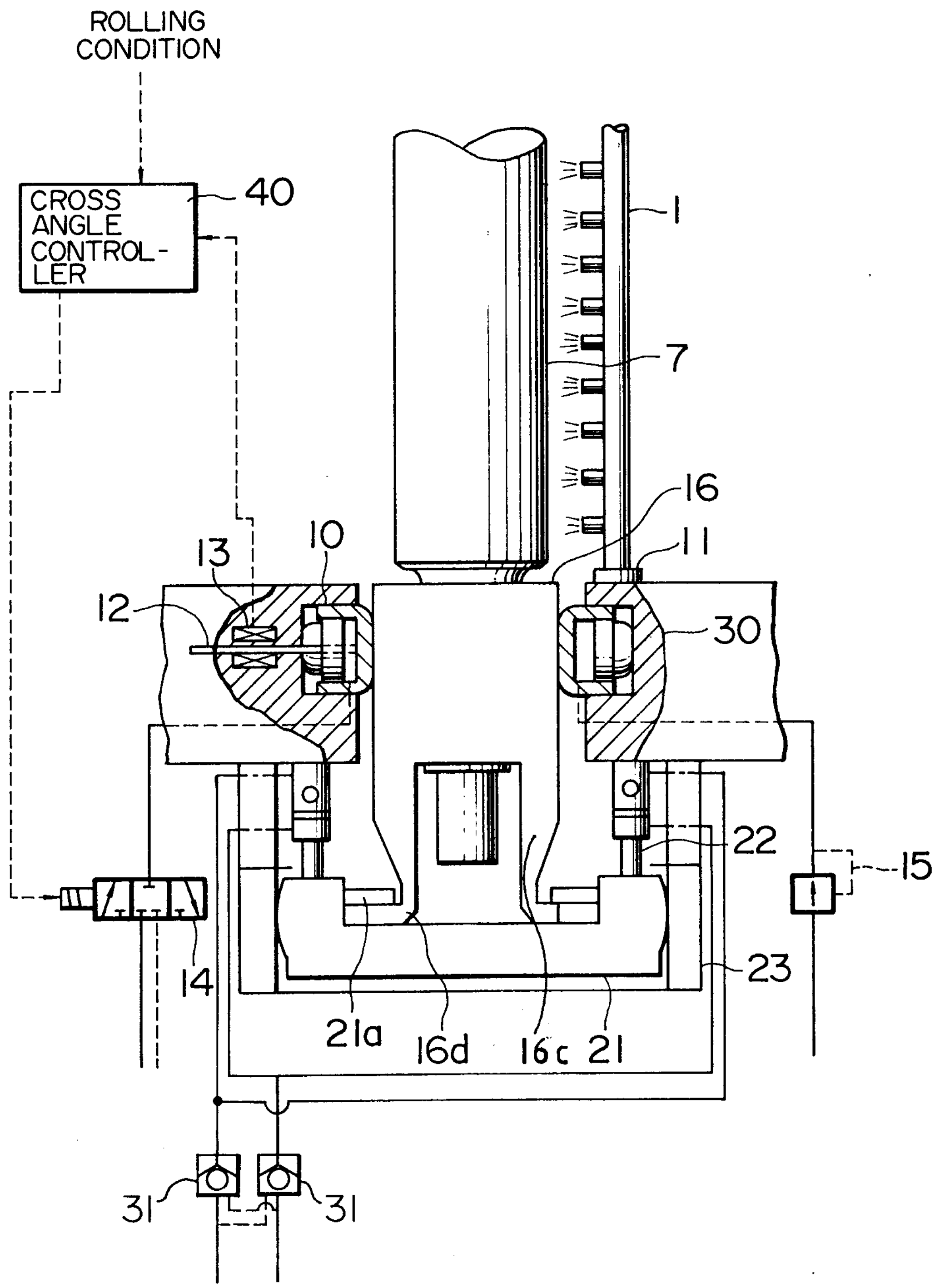

ROLLING CONDITION
CROSS ANGLE CONTROL- LER
40
1
7
16
11
10
13
12
30
22
15
14
23
21a
16d
16c
21
31
31

FIG. 3

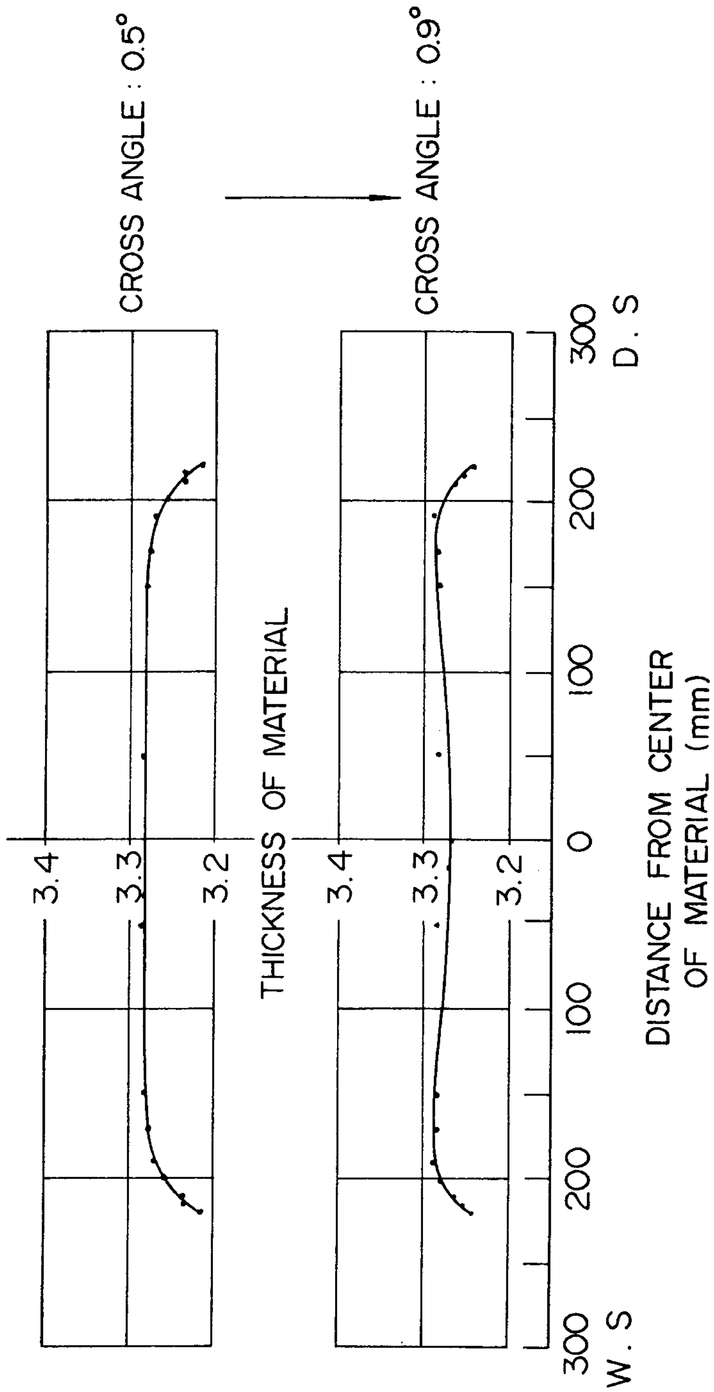

CROSS ANGLE : 0.5°
CROSS ANGLE : 0.9°
THICKNESS OF MATERIAL
3.4
3.3
3.2
3.4
3.3
3.2
300
200
100
0
100
200
300
D. S
W. S
DISTANCE FROM CENTER
OF MATERIAL (mm)

FIG. 4

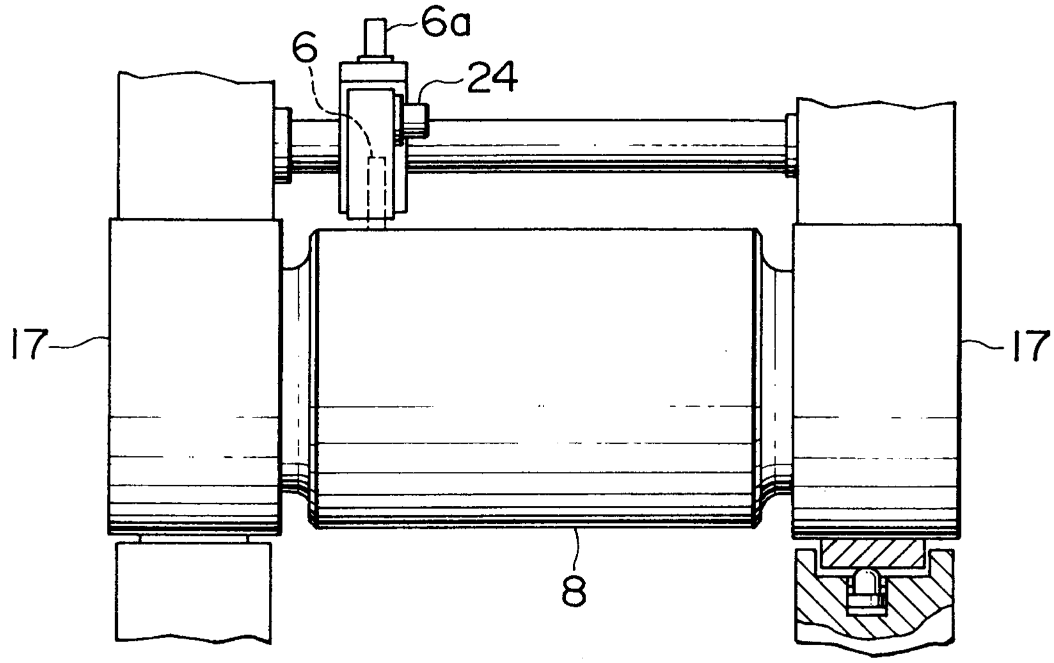


FIG. 5

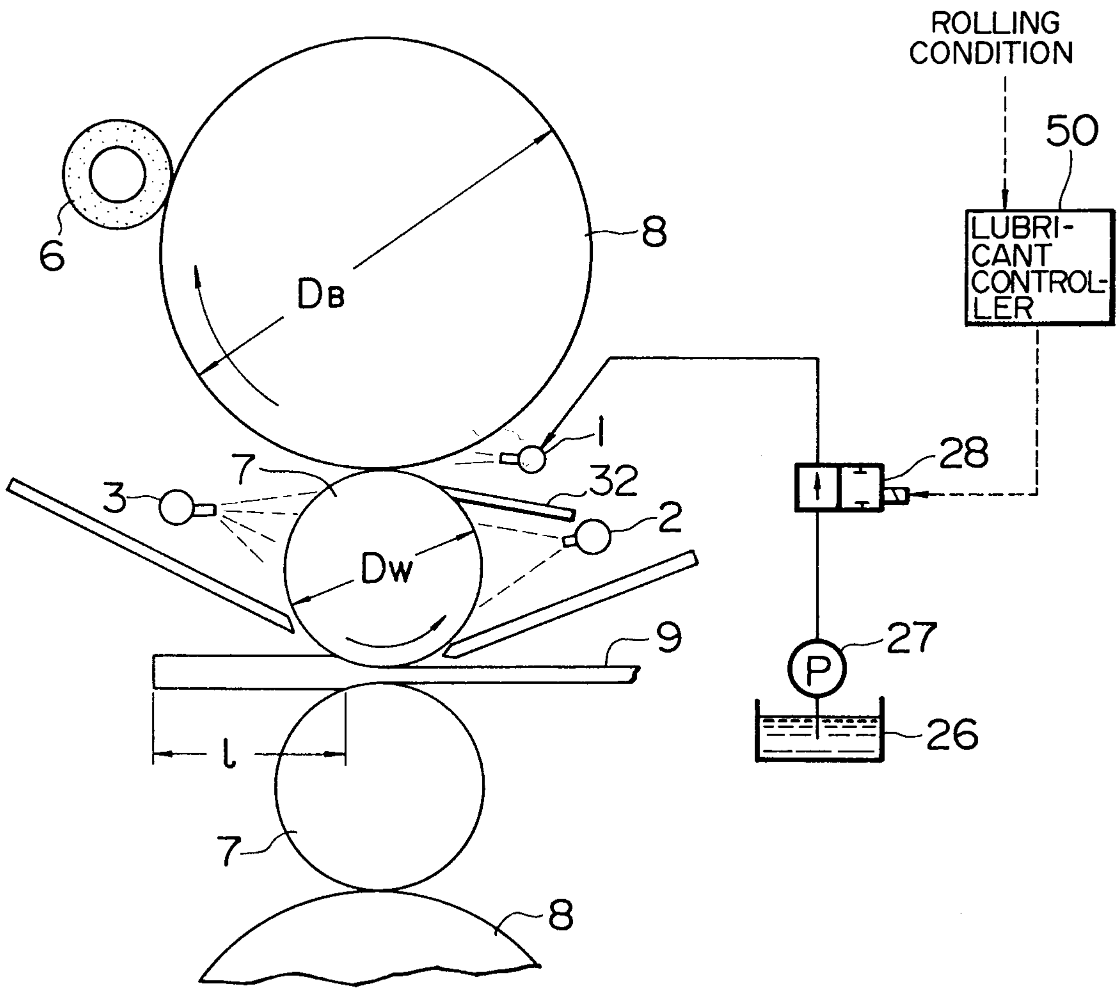

ROLLING
CONDITION
50
LUBRI-
CANT
CONTROL-
LER
8
6
DB
1
28
7
32
3
2
DW
9
27
P
26
l
7
8

FIG. 6

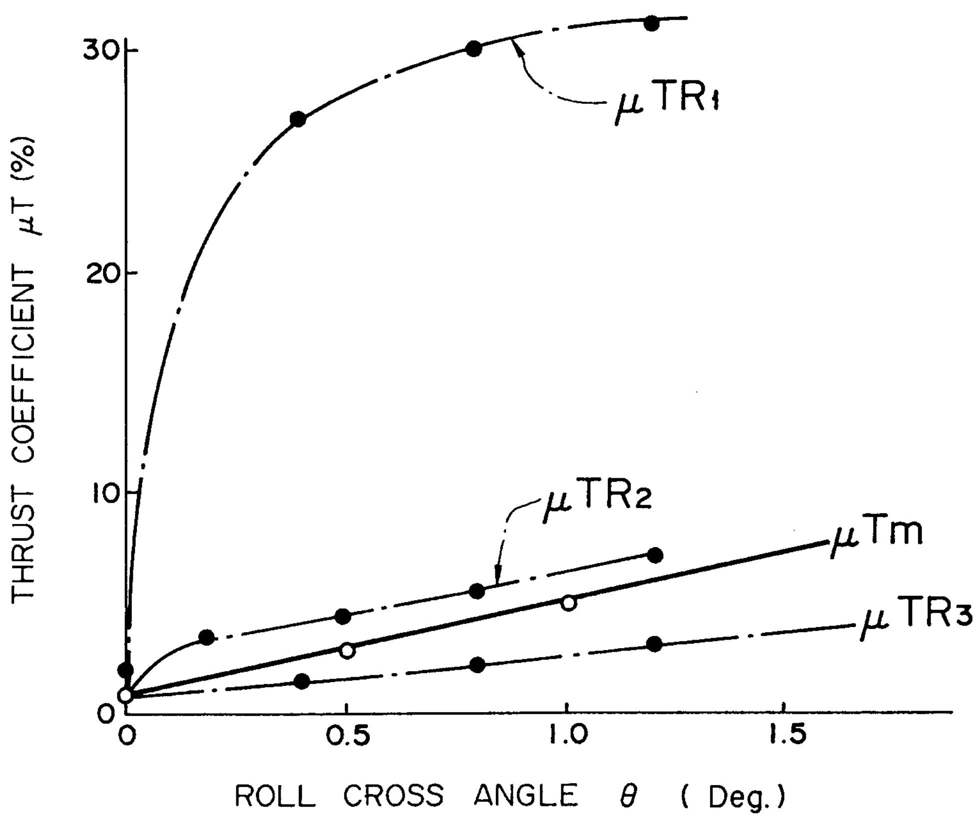

μ TR1
μ TR2
μ Tm
μ TR3
30
20
10
0
0
0.5
1.0
1.5
THRUST COEFFICIENT μT (%)
ROLL CROSS ANGLE θ (Deg.)

FIG. 7

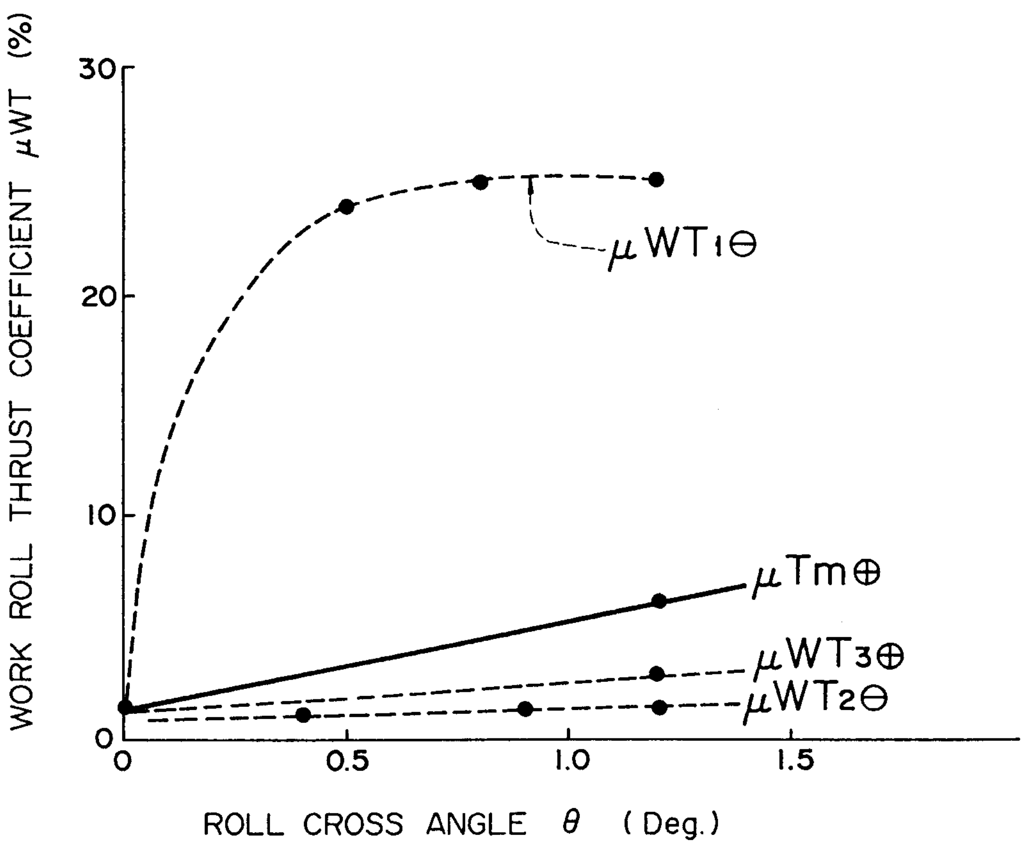

WORK ROLL THRUST COEFFICIENT μWT (%)
30
20
10
0
0
0.5
1.0
1.5
ROLL CROSS ANGLE θ (Deg.)
μWT1⊖
μTm⊕
μWT3⊕
μWT2⊖

FIG. 8

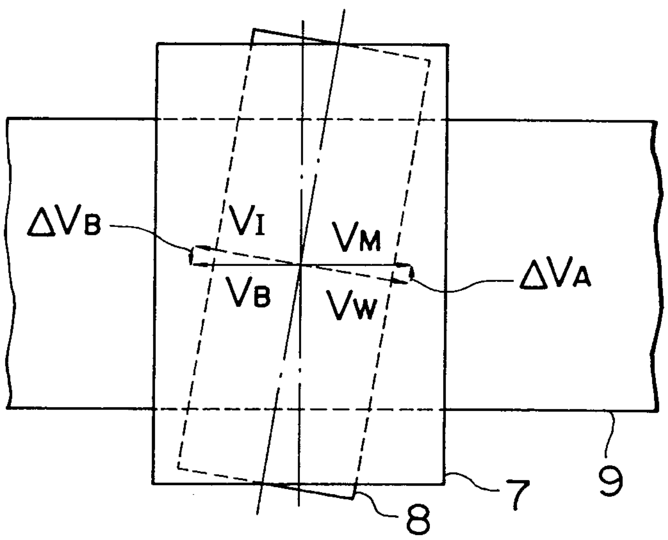


FIG. 9

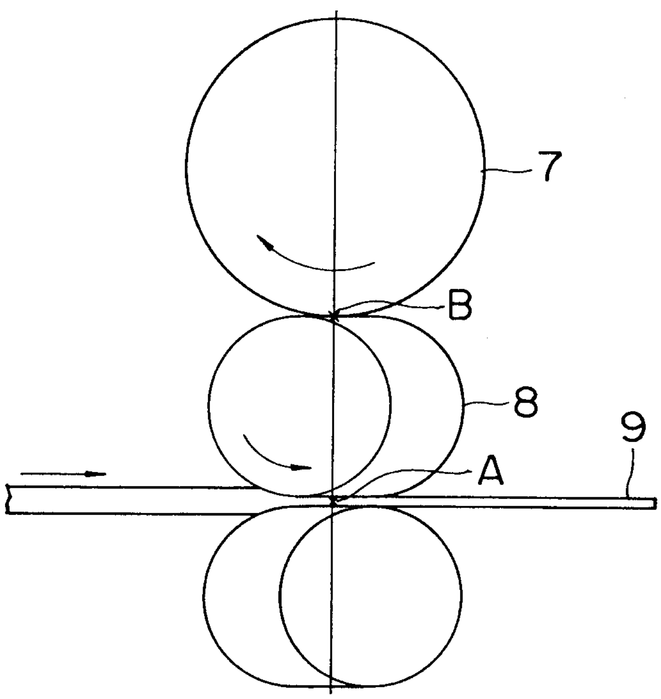


FIG. 10

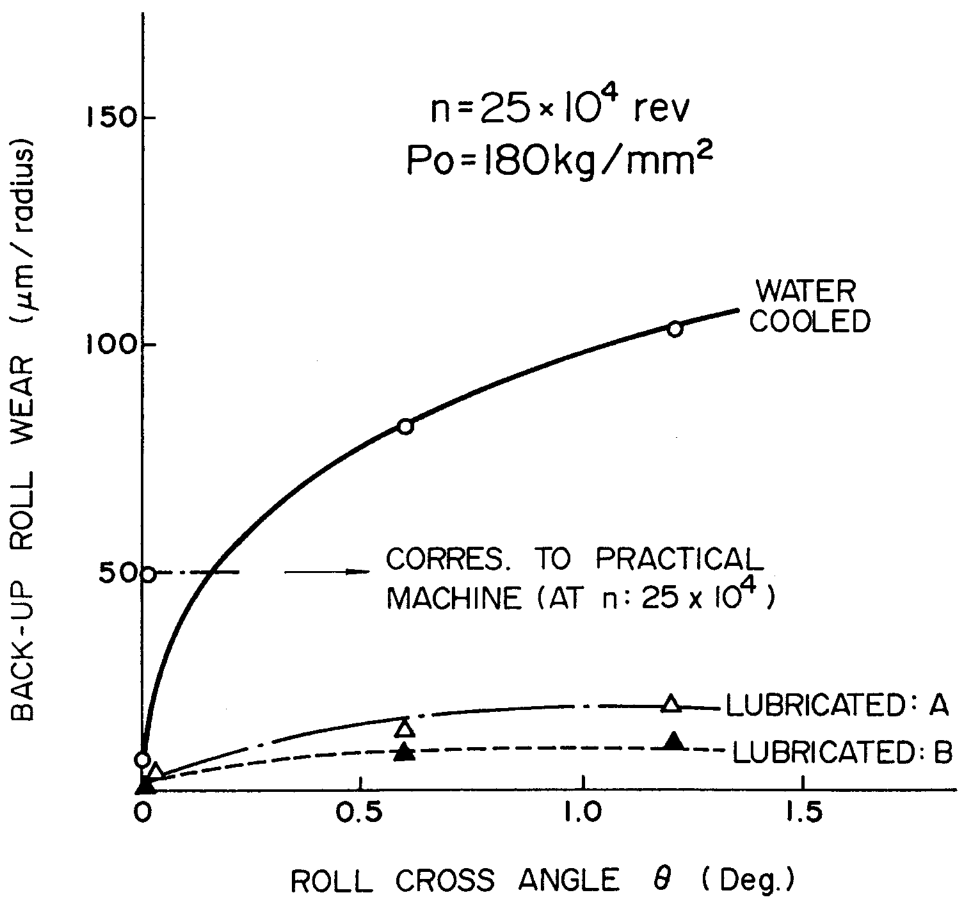

n=25×10⁴ rev
Po=180kg/mm²
150
100
50
0
0.5
1.0
1.5
BACK-UP ROLL WEAR (μm / radius)
WATER COOLED
CORRES. TO PRACTICAL MACHINE (AT n: 25 x 10⁴)
LUBRICATED: A
LUBRICATED: B
ROLL CROSS ANGLE θ (Deg.)

FIG. 11

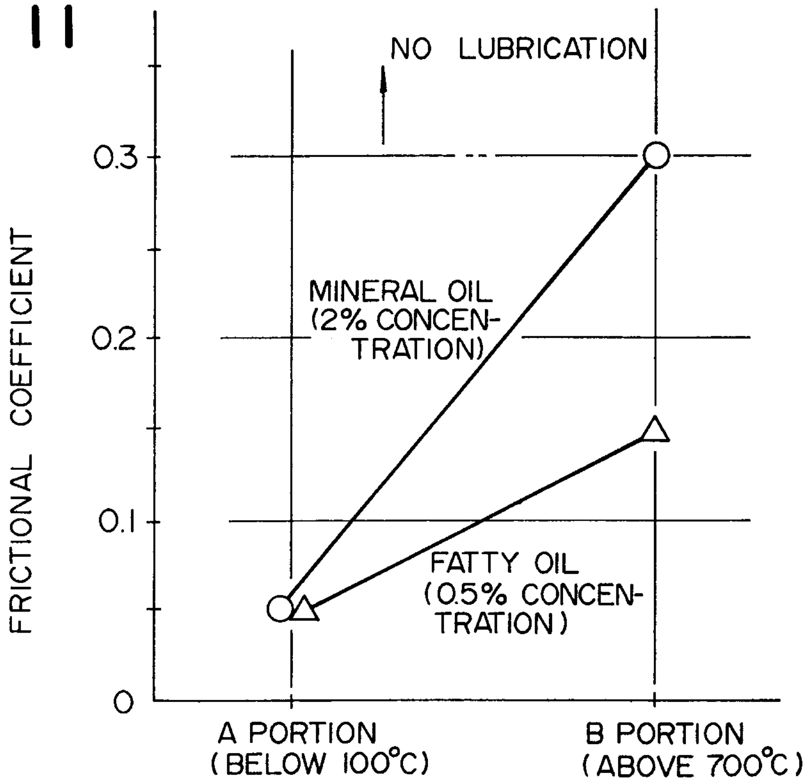

NO LUBRICATION
0.3
0.2
0.1
0
FRICTIONAL COEFFICIENT
MINERAL OIL
(2% CONCEN-
TRATION)
FATTY OIL
(0.5% CONCEN-
TRATION)
A PORTION
(BELOW 100°C)
B PORTION
(ABOVE 700°C)

FIG. 12

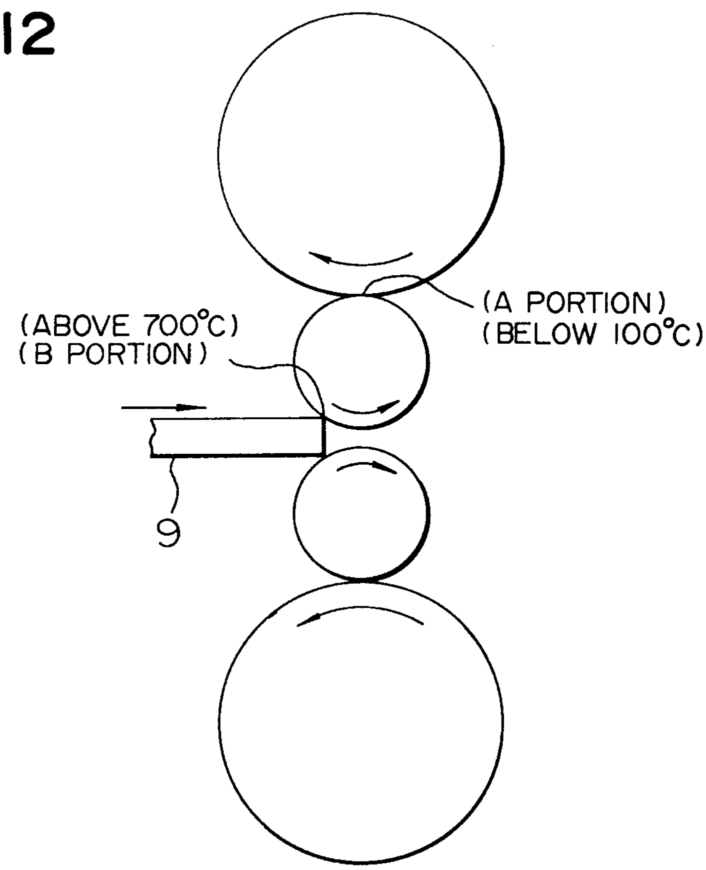

(A PORTION)
(BELOW 100°C)
(ABOVE 700°C)
(B PORTION)
9

FIG. 13

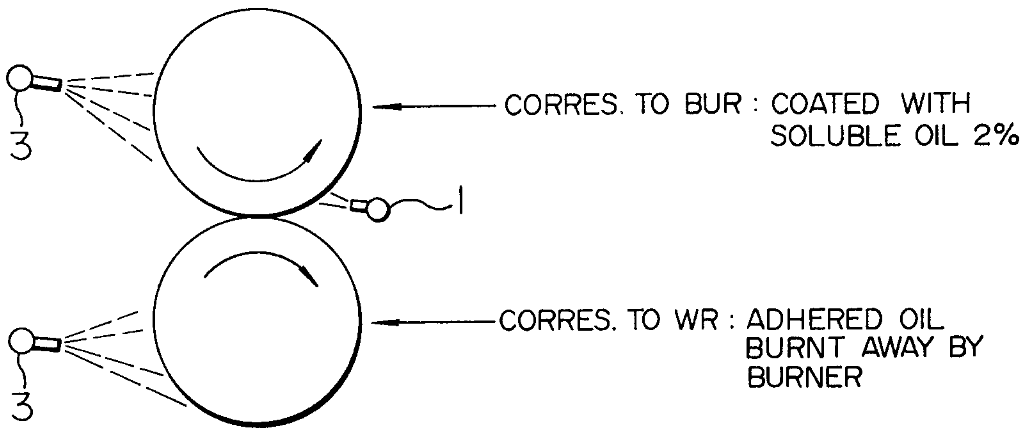

3
1
3
CORRES. TO BUR : COATED WITH SOLUBLE OIL 2%
CORRES. TO WR : ADHERED OIL BURNT AWAY BY BURNER

FIG. 14

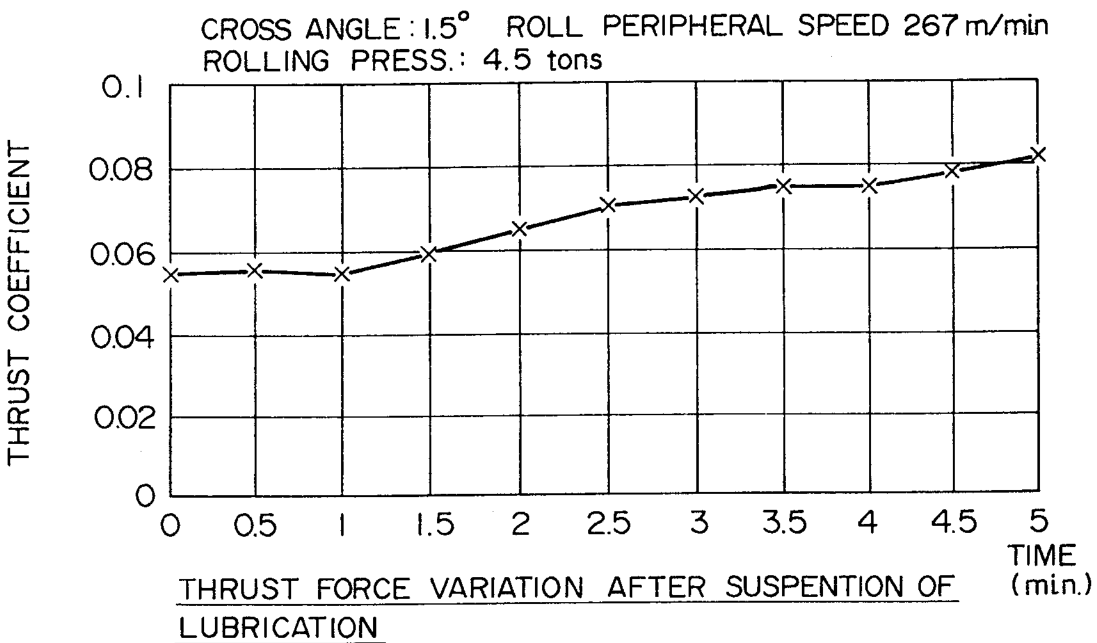

CROSS ANGLE : 1.5° ROLL PERIPHERAL SPEED 267 m/min
ROLLING PRESS. : 4.5 tons
THRUST COEFFICIENT
0.1
0.08
0.06
0.04
0.02
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
TIME (min.)
THRUST FORCE VARIATION AFTER SUSPENTION OF LUBRICATION

FIG. 15

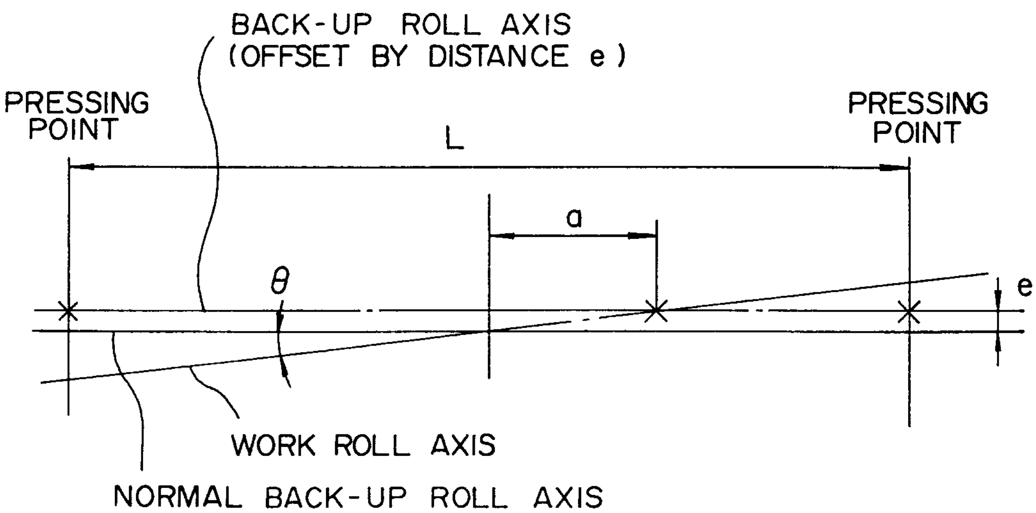

BACK-UP ROLL AXIS
(OFFSET BY DISTANCE e)
PRESSING POINT
L
PRESSING POINT
a
θ
e
WORK ROLL AXIS
NORMAL BACK-UP ROLL AXIS

FIG. 16

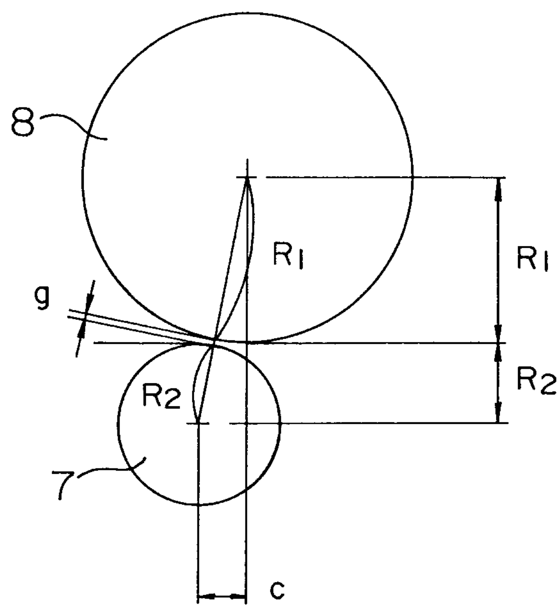

8
R1
R1
g
R2
R2
7
c

FIG. 17

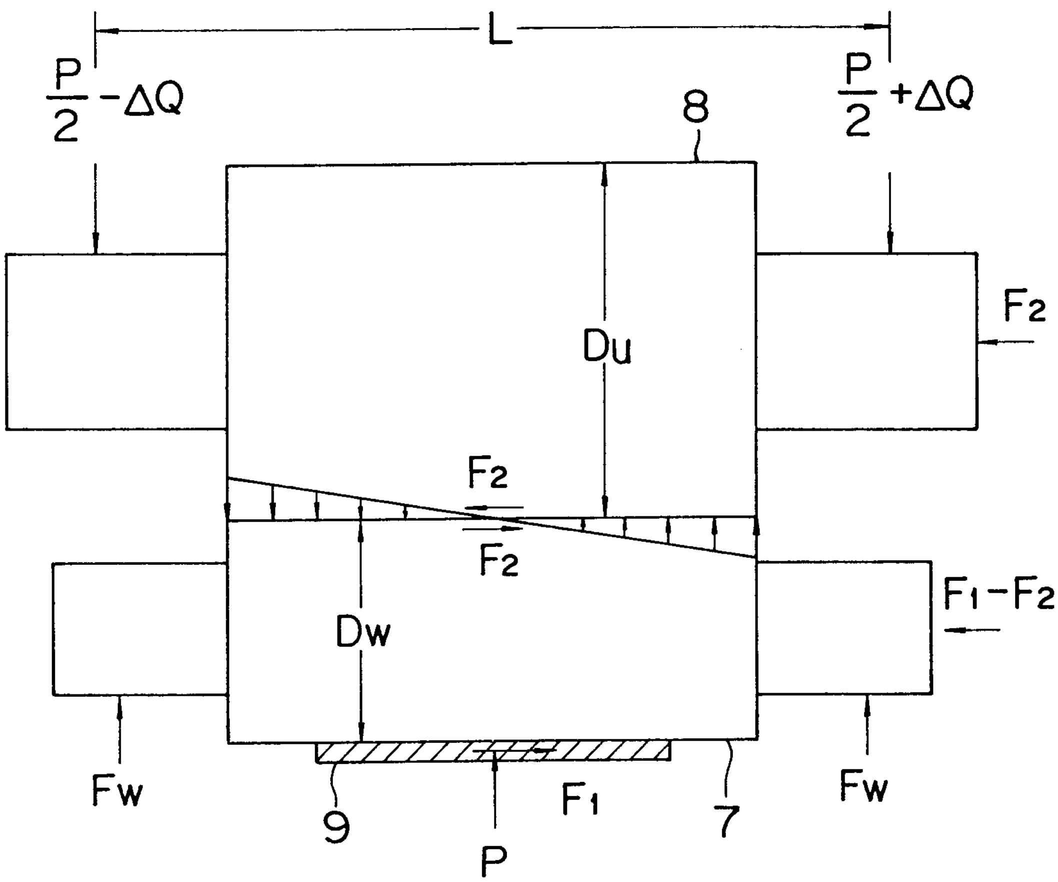
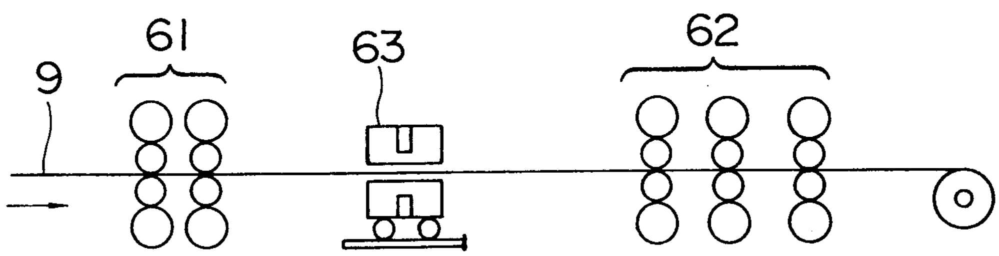


FIG. 18



European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 10 5463
Page 1

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	JP-A-61 279 305 (ISHIKAWAJIMA HARIMA HEAVY IND.) 10 December 1986 * figure 8 * & PATENT ABSTRACTS OF JAPAN vol. 11, no. 140 (M-586)(2587) 8 May 1987 * abstract * ---	1-4,8-15	B21B13/02 B21B27/10 B21B37/00 B21B28/04
Y	US-A-3 208 253 (ROBERTS) * the whole document * ---	1-4,8-15	
A	IRON AND STEEL April 1971, GUILDFORD GB pages 103 - 104; G. NEPORT: 'Application of a working lubricant on a wide hot strip rolling mill' * page 103; figure 1 * ---	1-4,6, 8-15	
A	JP-A-57 199 501 (KAWASAKI SEITETSU) 7 December 1982 * figures * & PATENT ABSTRACTS OF JAPAN vol. 7, no. 50 (M-197)(1195) 26 February 1983 * abstract * ---	1-4,8-15	**TECHNICAL FIELDS SEARCHED (Int. Cl.5)**
A	JP-A-59 039 408 (SHIN NIPPON SEITETSU) 3 March 1984 * figures * & PATENT ABSTRACTS OF JAPAN vol. 8, no. 140 (M-305)(1577) 29 June 1984 * abstract * ---	1-4,8-15	B21B
A	JP-B-52 017 515 (NIPPON STEEL) 16 May 1977 * figure 1 * & WORLD PATENTS INDEX Section PQ, Week 7723, Derwent Publications Ltd., London, GB; Class P51, AN 77-41042Y (23) * abstract * ---	1-4, 9-13,15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	06 JULY 1992	ROSENBAUM H.F.J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P0401)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 10 5463

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	IRON AND STEEL ENGINEER. vol. 61, no. 10, October 1984, PITTSBURGH US pages 26 - 33; HIDEHIKO TSUKAMOTO ET AL.: 'Shape and crown control mill - Crossed roll system' * pages 26, 32, 33; figures 1, 21 *	1-5, 9-13,15	
A	EP-A-0 184 481 (USINOR) * pages 4 - 6, 9; figures 1 - 3 *	1-4, 9-13,15	
A	JP-A-57 137 011 (NIPPON KOKAN) 24 August 1982 * figures * & PATENT ABSTRACTS OF JAPAN vol. 6, no. 236 (M-173)(1114) 25 November 1982 * abstract *	7	
A	JP-A-62 263 802 (MITSUBISHI HEAVY IND.) 16 November 1987 * figures 1-3 * & PATENT ABSTRACTS OF JAPAN vol. 12, no. 142 (M-692)(2989) 30 April 1988 * abstract *	7	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	JP-A-62 134 102 (ISHIKAWAJIMA HARIMA HEAVY IND.) 17 June 1987 * figures * & PATENT ABSTRACTS OF JAPAN vol. 11, no. 356 (M-644)(2803) 20 November 1987 * abstract *	9	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	06 JULY 1992	ROSENBAUM H.F.J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P0401)