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

(11) **EP 3 981 522 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
13.04.2022 Bulletin 2022/15

(21) Application number: **19949862.7**

(22) Date of filing: **25.10.2019**

(51) International Patent Classification (IPC):
B21B 31/18 *(2006.01)* ***B21B 29/00*** *(2006.01)*
B21B 37/42 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B21B 29/00; B21B 31/18; B21B 37/42

(86) International application number:
PCT/JP2019/041943

(87) International publication number:
WO 2021/079498 (29.04.2021 Gazette 2021/17)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **Primetals Technologies Japan, Ltd.**
Hiroshima-shi, Hiroshima 733-8553 (JP)

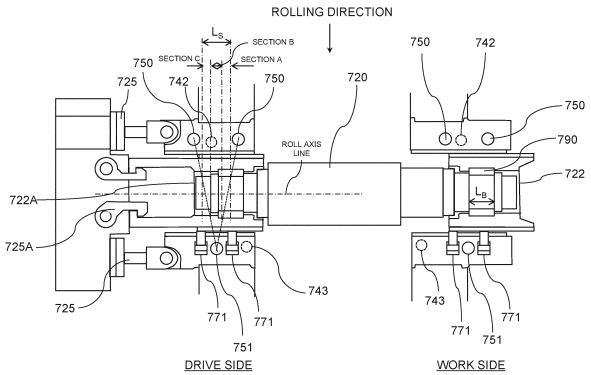
(72) Inventors:
- **HORII Kenji**
  Hiroshima-shi, Hiroshima 733-8553 (JP)
- **SUGIMOTO Tatsunori**
  Hiroshima-shi, Hiroshima 733-8553 (JP)
- **OWADA Takao**
  Hiroshima-shi, Hiroshima 733-8553 (JP)
- **SAKO Akira**
  Hiroshima-shi, Hiroshima 733-8553 (JP)
- **WATANABE Hiroaki**
  Hiroshima-shi, Hiroshima 733-8553 (JP)

(74) Representative: **Strehl Schübel-Hopf & Partner**
Maximilianstrasse 54
80538 München (DE)

(54) ROLLING MILL

(57) A rolling mill including: a roll that is shifted in an axial direction; a bearing that is shifted in a roll-axis direction along with the roll, and receives a load from the roll; and three or more first cylinders that apply bending force vertically to the bearing to cause the roll to perform bending, in which the bearing and the first cylinders are provided on each a drive side and an work side of the roll, two first cylinders among the first cylinders are provided in the roll-axis direction on a rolled material 5 entry side or exit side, one first cylinder among the first cylinders is provided on a side that is one of the rolled material 5 exit side and entry side, and that is opposite to a side provided with the two first cylinders, and the first cylinder on the opposite side is positioned between the two first cylinders when viewed in a rolling direction.

Fig 5



EP 3 981 522 A1

Description

Technical Field

[0001] The present invention relates to a rolling mill.

Background Art

[0002] Patent Document 1 describes one example of rolling mills that can prevent occurrence of extreme offset loads on bearings, and make it possible to attempt to extend the service life of the bearings, increase the roll shift amount, and in turn improve the capability of correcting the shape of a rolled material. In this document, in order for the resultant force of bending force that acts on a bearing of a rolling roll to always act on the lengthwise center position of the bearing, each pressure of a plurality of bending cylinders arranged along the roll-axis direction is made adjustable. That is, for example, the hydraulic pressure of a cylinder proximate to the lengthwise center of the bearing is set high, and the hydraulic pressure of a cylinder not proximate to the lengthwise center of the bearing is set low. Thereby, the resultant force of the bending force is caused to act on the bearing at the lengthwise center of the bearing even if the acting positions of the bending force are different.

Prior Art Document

Patent Document

[0003] Patent Document 1: JP-1988-055369-B

Summary of the Invention

Problem to be Solved by the Invention

[0004] There is a known rolling mill that has a shift functionality of moving rolling rolls in the roll-axis directions, and a bending functionality of causing pressurizing force to act on bearings of the rolls in a direction perpendicular to the axes, and controls the shape of a rolled material by controlling related action between movements of the rolls and bending force of the rolls.

[0005] In such a rolling mill, if an offset load acts on a bearing as a result of changes in the positions of the bearing and a bending cylinder depending on the position of a shifted roll, the lifetime of the bearing becomes shorter in some cases, and this is particularly noticeable when the shift amount of the roll is large.

[0006] Patent Document 1 describes one example of a technology for suppressing offset loads to act on bearings, and extending the lifetime of the bearings. In Patent Document 1, each cylinder pressure can be adjusted such that the resultant force of bending force acting on a bearing acts on a middle portion of the bearing in the roll-axis direction.

[0007] The rolling mill requires a large number of bending cylinders according to shifting of rolls, and furthermore requires a large number of mechanisms for adjusting pressing force of the cylinders. For example, in Patent Document 1, eight cylinders and at least four adjustment mechanisms are required per bearing. Since the number of components of such a rolling mill increases, there is room for improvement in terms of simplification of the structure.

[0008] An object of the present invention is to provide a rolling mill having a structure that can reduce offset loads on bearings even with a simple structure as compared to conventional rolling mills.

Means for Solving the Problem

[0009] The present invention includes plurality of means for solving the problem described above, and one example thereof is a rolling mill including: a roll that is shifted in an axial direction; a bearing that is shifted in a roll-axis direction along with the roll and receives a load from the roll; and three or more first cylinders that apply bending force vertically to the bearing to cause the roll to perform bending, in which the bearing and the first cylinders are provided on each a drive side and an work side of the roll, two first cylinders among the first cylinders are provided in the roll-axis direction on the exit side or entry side in a rolling direction, one first cylinder among the first cylinders is provided on a side that is one of the exit side and the entry side in the rolling direction, and that is opposite to a side provided with the two first cylinders, and the first cylinder on the opposite side is positioned between the two first cylinders when viewed from the exit side or entry side in the rolling direction.

Advantages of the Invention

[0010] According to the present invention, offset loads on bearings can be reduced even with a simple structure as compared to conventional rolling mills. Problems, configurations, and advantages other than those described above become apparent from the following explanation of embodiments.

Brief Description of the Drawings

[0011]

FIG. 1 is a figure illustrating an overview of a rolling facility including a rolling mill according to a first embodiment of the present invention.
FIG. 2 is a front view for explaining an overview of the rolling mill according to the first embodiment.
FIG. 3 is a figure illustrating part of a cross-sectional view taken along A-A' in FIG. 2.
FIG. 4 is a figure illustrating part of a cross-sectional view taken along B-B' in FIG. 2.
FIG. 5 is a plan view for explaining details of an intermediate-roll portion of the rolling mill according to the first embodiment.
FIG. 6 is a figure for explaining the pressing force of a second cylinder in a case where only an axially-inner upper-intermediate-roll bearing-housing backlash elimination cylinder on the drive side of the rolling mill according to the first embodiment is driven.
FIG. 7 is a figure for explaining the pressing force of a second cylinder in a case where only an axially-outer upper-intermediate-roll bearing-housing backlash elimination cylinder on the drive side of the rolling mill according to the first embodiment is driven.
FIG. 8 is a plan view for explaining details of an intermediate-roll portion of the rolling mill according to a second embodiment of the present invention.
FIG. 9 is a plan view for explaining details of an intermediate-roll portion of the rolling mill according to a third embodiment of the present invention.
FIG. 10 is a plan view for explaining details of an intermediate-roll portion of the rolling mill according to a fourth embodiment of the present invention.
FIG. 11 is a plan view for explaining details of an intermediate-roll portion of the rolling mill according to a fifth embodiment of the present invention.

Modes for Carrying Out the Invention

[0012] Hereinafter, embodiments of a rolling mill according to the present invention are explained by using the figures.

<First Embodiment

[0013] A first embodiment of a rolling mill according to the present invention is explained by using FIG. 1 to FIG. 5. FIG. 1 is a figure illustrating an overview of a rolling facility including a rolling mill according to the present first embodiment. FIG. 2 is a front view for explaining an overview of the rolling mill. FIG. 3 is a figure illustrating part of a cross-sectional view taken along A-A' in FIG. 2. FIG. 4 is a figure illustrating part of a cross-sectional view taken along B-B' in FIG. 2. FIG. 5 is a plan view for explaining details of an intermediate-roll portion.

[0014] First, the overview of the rolling facility including the rolling mill according to the present embodiment is explained by using FIG. 1.

[0015] As illustrated in FIG. 1, a rolling facility 1 has: a plurality of rolling mills that perform hot rolling of a rolled material 5 into a strip; and a controller 80. The rolling mills include seven stands, which are a first stand 10, a second stand 20, a third stand 30, a fourth stand 40, a fifth stand 50, a sixth stand 60 and a seventh stand 70, from the rolled material 5 entry side. Each the first stand 10, the second stand 20, the third stand 30, the fourth stand 40, the fifth stand 50, the sixth stand 60 and the seventh stand 70 in the stands, and a portion of the controller 80 that controls the stands correspond to what is called a rolling mill in the present invention.

[0016] Note that the rolling facility 1 is not limited to a facility including seven stands like the one illustrated in FIG. 1, and can be a facility including at least two stands.

[0017] Next, part of the overview of the rolling mill according to the present invention is explained by using FIG. 2. Note that whereas the seventh stand 70 illustrated in FIG. 1 is explained as an example in FIG. 2, the rolling mill according to the present invention can be applied to any stand of the first stand 10, the second stand 20, the third stand 30, the fourth stand 40, the fifth stand 50, and the sixth stand 60 illustrated in FIG. 1.

[0018] In FIG. 2, the seventh stand 70, which is a rolling mill according to the present embodiment, is a rolling mill

including six rolls that roll the rolled material 5, and has housings 700, the controller 80, and a hydraulic device (illustration omitted).

[0019] The housings 700 include: an upper work roll 710 and a lower work roll 711; and an upper intermediate roll 720 and a lower intermediate roll 721 that support the upper work roll 710 and the lower work roll 711 by contacting the upper work roll 710 and the lower work roll 711, respectively. Furthermore, the housings 700 include an upper backup roll 730 and a lower backup roll 731 that support the upper intermediate roll 720 and the lower intermediate roll 721 by contacting the upper intermediate roll 720 and the lower intermediate roll 721, respectively.

[0020] The upper work roll 710 in the rolls has, at its axial end portions and on both the drive side and the work side, bearings (omitted for the convenience of illustration) that are shifted in the roll-axis direction together with the upper work roll 710, and receive loads from the roll, and these bearings are supported by upper-work-roll bearing housings 712. Similarly, the lower work roll 711 also has bearings (illustration omitted) at its axial end portions and on both the drive side and the work side, and these bearings are supported by lower-work-roll bearing housings 713.

[0021] In the present embodiment, the upper work roll 710 is configured to be shifted in the roll-axis direction by a shift cylinder 715 like the one illustrated in FIG. 3 via a work-side upper-work-roll bearing housing 712. Similarly, the lower work roll 711 also is configured to be shifted in the roll-axis direction by a shift cylinder 716 like the one illustrated in FIG. 3 via a work-side lower-work-roll bearing housing 713.

[0022] The upper intermediate roll 720 has bearings 790 (see FIG. 5) at its axial end portions and on both the drive side and the work side, and these bearings 790 are supported by upper-intermediate-roll bearing housings 722A and 722, respectively. The lower intermediate roll 721 also has bearings (illustration omitted) at its axial end portions and on both the drive side and the work side, and these bearings are supported by lower-intermediate-roll bearing housings 723A and 723, respectively.

[0023] In addition, the upper intermediate roll 720 is configured to be shifted in the roll-axis direction by a shift cylinder 725 like the one illustrated in FIG. 3 via the drive-side upper-intermediate-roll bearing housing 722A. Similarly, the lower intermediate roll 721 also is configured to be shifted in the roll-axis direction by a shift cylinder 726 like the one illustrated in FIG. 3 via the drive-side lower-intermediate-roll bearing housing 723A.

[0024] Returning to FIG. 2, an entry-side fixation member 702 is fixed to the rolled material 5 entry-side housing 700, and on the rolled material 5 exit side, an exit-side fixation member 703 is fixed to the exit-side housing 700 such that the exit-side fixation member 703 becomes opposite to the entry-side fixation member 702.

[0025] In the seventh stand 70, as illustrated in FIG. 2 and FIG. 4, on each the work side and the drive side, upper-work-roll bending cylinders 740 provided to a work-roll bending block part 714 of the entry-side fixation member 702, an upper-work-roll bending cylinder 742 provided to an upper-intermediate-roll bending block part 727, and upper-work-roll bending cylinders 741 and 743 provided to the exit-side fixation member 703 support the upper-work-roll bearing housing 712, and, by driving these cylinders as appropriate, it is possible to apply bending force vertically to the bearing of the upper work roll 710 to cause the upper work roll 710 to perform bending.

[0026] Similarly, as illustrated in FIG. 2 and FIG. 4, on each the work side and the drive side, lower-work-roll bending cylinders 744 and 746 provided to the entry-side fixation member 702, and lower-work-roll bending cylinders 745 and 747 provided to the exit-side fixation member 703 support the lower-work-roll bearing housing 713, and, by driving these cylinders as appropriate, it is possible to apply bending force vertically to the bearing of the lower work roll 711 to cause the lower work roll 711 to perform bending.

[0027] Regarding the upper intermediate roll 720, on each the work side and the drive side, upper-intermediate-roll bending cylinders 750 provided to the upper-intermediate-roll bending block part 727 of the entry-side fixation member 702, and an upper-intermediate-roll bending cylinder 751 provided to the upper-intermediate-roll bending block part 727 of the exit-side fixation member 703 support the upper-intermediate-roll bearing housing 722 or 722A, and, by driving these cylinders as appropriate, it is possible to apply bending force vertically to the bearing 790 to cause the upper intermediate roll 720 to perform bending. In addition, the upper-intermediate-roll bending block part 727 is provided with the upper-work-roll bending cylinders 742 and 743 on the entry side and the exit side, and, by driving these cylinders as appropriate, it is possible to cause the upper work roll 710 to perform bending.

[0028] Regarding the lower intermediate roll 721 also, on each the work side and the drive side, lower-intermediate-roll bending cylinders 752 provided to a lower-intermediate-roll bending block part 728 of the entry-side fixation member 702, and a lower-intermediate-roll bending cylinder 753 provided to the lower-intermediate-roll bending block part 728 of the exit-side fixation member 703 support the lower-intermediate-roll bearing housing 723 or 723A, and, by driving these cylinders as appropriate, it is possible to apply bending force vertically to the bearing 790 to cause the lower intermediate roll 721 to perform bending. In addition, the lower-intermediate-roll bending block part 728 is provided with the lower-work-roll bending cylinders 746 and 747 on the entry side and the exit side, and, by driving these cylinders as appropriate, it is possible to cause the lower work roll 711 to perform bending.

[0029] The upper-work-roll bending cylinders 740 and 741 (first cylinders) in these cylinders are arranged such that bending force is applied to the bearings of the upper work roll 710, which contacts the rolled material 5, toward the vertical increase side (away from the rolled material), to thereby cause the upper work roll 710 to perform bending. In

addition, the upper-work-roll bending cylinders 742 and 743 (fifth cylinders) are arranged such that bending force is applied to the bearings toward the vertical decrease side (in the direction toward the rolled material), which is a direction opposite to the bending force applied by the upper-work-roll bending cylinders 740 and 741, to thereby cause the upper work roll 710 to perform bending.

[0030] Similarly, the lower-work-roll bending cylinders 744 and 745 (first cylinders) are arranged such that bending force is applied to the bearings of the lower work roll 711 that contacts the rolled material 5 toward the vertical increase side, to thereby cause the lower work roll 711 to perform bending. In addition, the lower-work-roll bending cylinders 746 and 747 (fifth cylinders) are arranged such that bending force is applied to the bearings toward the decrease side, which is a direction opposite to the bending force applied by the lower-work-roll bending cylinders 744 and 745, to thereby cause the lower work roll 711 to perform bending.

[0031] The upper-intermediate-roll bending cylinders 750 and 751 (first cylinders) are arranged such that bending force is applied to the bearings 790 of the upper intermediate roll 720 toward the vertical increase side, to thereby cause the roll to perform bending.

[0032] The lower-intermediate-roll bending cylinders 752 and 753 (first cylinder) are arranged such that bending force is applied to the bearings 790 of the lower intermediate roll 721 toward the vertical increase side, to thereby cause the roll to perform bending.

[0033] As illustrated in FIG. 2, FIG. 3, and FIG. 4, for the purpose of preventing backlashes, the entry-side fixation member 702 on the rolled material 5 entry side is provided with upper-work-roll bearing-housing backlash elimination cylinders 760 (second cylinders) such that horizontal force, specifically pressing force in the rolling direction, is applied to the upper work roll 710 via liners (illustration omitted) of the upper-work-roll bearing housings 712. Similarly, the entry-side fixation member 702 is provided with lower-work-roll bearing-housing backlash elimination cylinders 762 (second cylinders) such that pressing force is applied to the lower work roll 711 in the rolling direction via liners of the lower-work-roll bearing housings 713. Thereby, desired force can be applied to the work roll or the like in a direction orthogonal to the roll-axis direction.

[0034] In addition, as illustrated in FIG. 2, FIG. 3, and FIG. 4, for the purpose of preventing backlashes, the exit-side fixation member 703 on the rolled material 5 exit side is provided with upper-intermediate-roll bearing-housing backlash elimination cylinders 771 (second cylinders) such that horizontal force, that is, pressing force in a direction opposite to the rolling direction, is applied to the upper intermediate roll 720 via liners of the upper-intermediate-roll bearing housings 722A and 722. Similarly, the exit-side fixation member 703 is provided with lower-intermediate-roll bearing-housing backlash elimination cylinders 773 (second cylinders) such that pressing force is applied to the lower intermediate roll 721 in a direction opposite to the rolling direction via liners of the lower-intermediate-roll bearing housings 723A and 723.

[0035] Returning to FIG. 2, the upper backup roll 730 has bearings (illustration omitted) at its axial end portions and on both the drive side and the work side, and these bearing are supported by upper-backup roll bearing housings 732. Similarly, the lower backup roll 731 also has bearings (illustration omitted) at its axial end portions and on both the drive side and the work side, and these bearings are supported by lower-backup roll bearing housings 733.

[0036] In addition, as illustrated in FIG. 2, the entry-side housing 700 is provided with upper-backup roll bearing-housing backlash elimination cylinders 780 such that horizontal force is applied to the upper backup roll 730 via the upper-backup roll bearing housings 732. Similarly, the entry-side housing 700 is provided with lower-backup roll bearing-housing backlash elimination cylinders 782 such that horizontal force is applied to the lower backup roll 731 via the lower-backup roll bearing housings 733.

[0037] The hydraulic device is connected to hydraulic cylinders such as the bending cylinders, backlash elimination cylinders, or shift cylinders that are mentioned above, or rolling cylinders (illustration omitted) that apply rolling force for rolling the rolled material 5 to the upper work roll 710 and the lower work roll 711. This hydraulic device is connected to the controller 80.

[0038] The controller 80 performs actuation control of the hydraulic device, and supplies and discharges a hydraulic fluid to the bending cylinders and the like mentioned above, to thereby perform drive control of those cylinders.

[0039] Next, configurations related to the upper intermediate roll 720 in the rolls are explained by using FIG. 5. Note that the upper work roll 710, the lower work roll 711, and the lower intermediate roll 721 also can have configurations equivalent to those of the upper intermediate roll 720. Their configurational details are approximately the same as those of the upper intermediate roll 720, and therefore explanations thereof are omitted.

[0040] The present invention is suitably applied to the upper intermediate roll 720 like the one illustrated in FIG. 5 or the lower intermediate roll 721.

[0041] As illustrated in FIG. 5, in the present embodiment, on the rolled material 5 entry side, and on each the drive side and the work side of the upper intermediate roll 720, two upper-intermediate-roll bending cylinders 750 are provided in the roll-axis direction. In addition, on the rolled material 5 exit side, one upper-intermediate-roll bending cylinder 751 is provided. The upper-intermediate-roll bending cylinder 751 provided on the rolled material 5 exit side in the cylinders is arranged such that it is positioned between the two upper-intermediate-roll bending cylinders 750 provided on the opposite entry side when viewed in the rolling direction.

[0042] Furthermore, the axially-outer upper-intermediate-roll bending cylinder 750 in the two upper-intermediate-roll bending cylinders 750 provided on the entry side on each the drive side and the work side is arranged outside an area within which the center of the bearing 790 is shifted when the upper intermediate roll 720 is shifted in the axial direction by the shift cylinder 725 via a shift mechanism 725A.

[0043] In addition, in the present embodiment, the upper-intermediate-roll bearing-housing backlash elimination cylinders 771 arranged on the rolled material 5 exit side are arranged on both axial sides of the one upper-intermediate-roll bending cylinder 751 provided on the same exit side when viewed in the rolling direction.

[0044] Particularly, desirably, an acting position of the output force of the three upper-intermediate-roll bending cylinders 750 and 751, and an acting position of the output force of the two upper-intermediate-roll bearing-housing backlash elimination cylinders 771 are arranged such that each of them is kept within $L_B/4$ on the axially-outer side of the axial center of the bearing 790, and within $L_B/4$ on the axially-inner side of the axial center of the bearing 790, that is, within $L_B/2$ from the axial center of the bearing 790, when the axial length of the bearing 790 is defined as L_B, or the output force is controlled in such a manner.

[0045] More desirably, the intermediate position of the two entry-side upper-intermediate-roll bending cylinders 750, and the intermediate position of the two exit-side upper-intermediate-roll bearing-housing backlash elimination cylinders 771 are the same with each other or proximate to each other desirably. In this case, more desirably, the axial position of the exit-side upper-intermediate-roll bending cylinder 751 is positioned at the intermediate position of the axial positions of the two entry-side upper-intermediate-roll bending cylinders 750, that is, at the intermediate position between the two upper-intermediate-roll bearing-housing backlash elimination cylinders 771.

[0046] In the present embodiment, on each the drive side and the work side, the upper-work-roll bending cylinder 742 arranged on the rolled material 5 entry side is provided at an axial position between the two upper-intermediate-roll bending cylinders 750 that are provided in the axial direction.

[0047] In contrast to this, on each the drive side and the work side, the upper-work-roll bending cylinder 743 arranged on the rolled material 5 exit side is provided at a position on the axially-inner side of the upper-intermediate-roll bending cylinder 751.

[0048] Next, details of drive control of the upper-intermediate-roll bending cylinders 750 and 751, and the upper-intermediate-roll bearing-housing backlash elimination cylinders 771 according to the present embodiment are explained with reference to FIG. 5 and TABLE 1. The drive control of these is executed by the controller 80 that performs drive control of the hydraulic device.

[0049] First, the controller 80 is configured to perform control such that when bending of the roll is performed, the difference between the total output force of the two first cylinders, and the output force of the first cylinder provided on the opposite side is within a predetermined range. Preferably, the resultant force of the roll bending cylinders is caused to act on the roll-axis line. In addition, the controller 80 is configured to drive any one of or both of the two upper-intermediate-roll bending cylinders 750 arranged on the entry side, and drive the first cylinder provided on the opposite side, according to the shift position of the upper intermediate roll 720.

[0050] Here, the shift amount of the upper intermediate roll 720, that is, the shift amount of the axial center of the bearing 790, is defined as Ls (the shift amount toward the drive direction is defined as a positive amount).

[TABLE 1]

section / actuation target	C	B	A
drive-side entry-side bending cylinder (inner)	OFF	ON×1/2	ON
drive-side entry-side bending cylinder (outer)	ON	ON×1/2	OFF
drive-side exit-side bending cylinder	ON	ON	ON
work-side entry-side bending cylinder (inner)	ON	ON×1/2	OFF
work-side entry-side bending cylinder (outer)	OFF	ON×1/2	ON
work-side exit-side bending cylinder	ON	ON	ON
drive-side backlash elimination cylinder (inner)	OFF	ON×1/2	ON
drive-side backlash elimination cylinder (outer)	ON	ON×1/2	OFF
work-side backlash elimination cylinder (inner)	ON	ON×1/2	OFF
work-side backlash elimination cylinder (outer)	OFF	ON×1/2	ON

[0051] When the intermediate roll shifts within Ls, the bearing center exists in any of sections A, B, and C illustrated in FIG. 5. When the bearing center exists in the section C, on the drive side, the axially-inner cylinder in the entry-side upper-intermediate-roll bending cylinders 750 is not driven, but the axially-outer upper-intermediate-roll bending cylinder 750 and the exit-side upper-intermediate-roll bending cylinder 751 are driven.

[0052] The total output force of the driven cylinders on the entry side and the exit side acts on a position near the intersection of the roll-axis line and a line linking the driven cylinders. The acting position of the total output force of the cylinders is arranged such that it is kept within $L_B/4$ on the axially-outer side of the axial center of the bearing 790, and within $L_B/4$ on the axially-inner side of the axial center of the bearing 790, that is, within $L_B/2$ from the axial center of the bearing 790.

[0053] Accordingly, the boundary between the section A and the section B exists at a position within $L_B/4$ on the axially-outer side of the intersection of the roll-axis line and a straight line linking the axially-inner entry-side upper-intermediate-roll bending cylinder 750 and the exit-side upper-intermediate-roll bending cylinder 751.

[0054] In addition, the boundary between the section B and the section C exists at a position within $L_B/4$ on the axially-inner side of the intersection of the roll-axis line and a straight line linking the axially-outer entry-side upper-intermediate-roll bending cylinder 750 and the exit-side upper-intermediate-roll bending cylinder 751.

[0055] On the work side, the axially-outer cylinder in the entry-side upper-intermediate-roll bending cylinders 750 is not driven, but the axially-inner upper-intermediate-roll bending cylinder 750 and the exit-side upper-intermediate-roll bending cylinder 751 are driven.

[0056] When the bearing center exists in the section A, on the drive side, the axially-outer cylinder in the entry-side upper-intermediate-roll bending cylinders 750 is not driven, but the axially-inner upper-intermediate-roll bending cylinder 750 and the exit-side upper-intermediate-roll bending cylinder 751 are driven.

[0057] On the work side, the axially-inner cylinder in the entry-side upper-intermediate-roll bending cylinders 750 is not driven, but the axially-outer upper-intermediate-roll bending cylinder 750 and the exit-side upper-intermediate-roll bending cylinder 751 are driven.

[0058] When the bearing center exists in the section B, on each the drive side and the work side, the output force of both of the entry-side upper-intermediate-roll bending cylinders 750 is made 1/2 such that the total becomes the same as the output force of the exit-side upper-intermediate-roll bending cylinder, and the exit-side upper-intermediate-roll bending cylinder 751 is driven similarly to the cases of the sections A and C.

[0059] Regarding the upper-intermediate-roll bearing-housing backlash elimination cylinders 771, in the case of the section C in TABLE 1, on the drive side, the axially-inner cylinder is not driven, but only the axially-outer cylinder is

driven. On the work side, the axially-outer cylinder is not driven, but the axially-inner cylinder is driven.

[0060] In addition, in the case of the section A in TABLE 1, on the drive side, the axially-outer cylinder is not driven, but only the axially-inner cylinder is driven. On the work side, the axially-inner cylinder is not driven, but the axially-outer cylinder is driven.

[0061] In the case of the section B in TABLE 1, on each the drive side and the work side, both of the two cylinders are driven at output force which is 1/2 of required output force.

[0062] Whereas the output force of the upper-intermediate-roll bending cylinders 750 and 751, and the output force of the upper-intermediate-roll bearing-housing backlash elimination cylinders 771 have three states, which are the ON state, 1/2 ON state and OFF state, in the case explained in the example described above, by separately and more finely adjusting the output force of each upper-intermediate-roll bending cylinder 750 or 751 and the output force of each upper-intermediate-roll bearing-housing backlash elimination cylinder 771, it is possible to cause the bending force to be applied onto the axial center of the bearing 790 more accurately. Hereinafter, one example of different output control is explained.

[0063] Hereinafter, only the drive side is explained as an example. It is possible to deal with the work side by reversing the positional relation in the axial direction, and details thereof are omitted.

[0064] When the bearing center exists in the section C, the axially-outer upper-intermediate-roll bending cylinder 750 is driven at output force obtained by multiplying total output force of the two upper-intermediate-roll bending cylinders 750 by $\alpha 1$, the axially-inner upper-intermediate-roll bending cylinder 750 is driven at output force obtained by multiplying the total output force by $\alpha 2$, the total of $\alpha 1$ and $\alpha 2$ is 1, and $\alpha 1$ and $\alpha 2$ are adjusted such that the acting position of the total output force is almost at the bearing center. The two upper-intermediate-roll bending cylinders 750 are driven along with the upper-intermediate-roll bending cylinder 751 in this manner. Alternatively, $\alpha 1$ is set to 1, $\alpha 2$ is set to 0, and the axially-outer upper-intermediate-roll bending cylinder 750 and the upper-intermediate-roll bending cylinder 751 are driven.

[0065] In addition, the axially-outer upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven at output force obtained by multiplying required output force by a predetermined coefficient $\gamma 1$, and the axially-inner upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven at output force obtained by multiplying the required output force by a predetermined coefficient $\gamma 2$. Here, the total of $\gamma 1$ and $\gamma 2$ is 1, and $\gamma 1$ and $\gamma 2$ are adjusted such that the acting position of the total output force is almost at the bearing center. Alternatively, only the axially-outer upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven.

[0066] When the bearing center exists in the section A, the axially-outer upper-intermediate-roll bending cylinder 750 is driven at output force obtained by multiplying total output force of the two upper-intermediate-roll bending cylinders 750 by $\alpha 1$, the axially-inner upper-intermediate-roll bending cylinder 750 is driven at output force obtained by multiplying the total output force by $\alpha 2$, the total of $\alpha 1$ and $\alpha 2$ is 1, and $\alpha 1$ and $\alpha 2$ are adjusted such that the acting position of the total output force is almost at the bearing center. The two upper-intermediate-roll bending cylinders 750 are driven along with the upper-intermediate-roll bending cylinder 751 in this manner. Alternatively, $\alpha 1$ is set to 0, $\alpha 2$ is set to 1, and the axially-inner upper-intermediate-roll bending cylinder 750 and the upper-intermediate-roll bending cylinder 751 are driven.

[0067] In addition, the axially-outer upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven at output force obtained by multiplying required output force by the predetermined coefficient $\gamma 1$, and the axially-inner upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven at output force obtained by multiplying the required output force by the predetermined coefficient $\gamma 2$. Here, the total of $\gamma 1$ and $\gamma 2$ is 1, and $\gamma 1$ and $\gamma 2$ are adjusted such that the acting position of the total output force is almost at the bearing center. Alternatively, only the axially-inner upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven.

[0068] When the bearing center exists in the section B, the axially-outer upper-intermediate-roll bending cylinder 750 is driven at output force obtained by multiplying total output force of the two upper-intermediate-roll bending cylinders 750 by $\alpha 1$, the axially-inner upper-intermediate-roll bending cylinder 750 is driven at output force obtained by multiplying the total output force by $\alpha 2$, the total of $\alpha 1$ and $\alpha 2$ is 1, and $\alpha 1$ and $\alpha 2$ are adjusted such that the acting position of the total output force is almost at the bearing center. The two upper-intermediate-roll bending cylinders 750 are driven along with the upper-intermediate-roll bending cylinder 751 in this manner.

[0069] In addition, the axially-outer upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven at output force obtained by multiplying required output force by the predetermined coefficient $\gamma 1$, and the axially-inner upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven at output force obtained by multiplying the required output force by the predetermined coefficient $\gamma 2$. Here, the total of $\gamma 1$ and $\gamma 2$ is 1, and $\gamma 1$ and $\gamma 2$ are adjusted such that the acting position of the total output force is almost at the bearing center.

[0070] When the two upper-intermediate-roll bearing-housing backlash elimination cylinders 771 are actuated as in TABLE 1, the actuation position can be kept within $L_B/2$ from the axial center of the bearing 790 when the bearing center exists in the section B, but the actuation position cannot be kept within $L_B/2$ from the axial center of the bearing 790 when the bearing center exists in the section C or the section A in some cases. In contrast to this, by adjusting $\gamma 1$ and $\gamma 2$, it becomes possible to keep the actuation position within $L_B/2$ from the axial center of the bearing 790 in each of the cases of the sections A, B, and C.

[0071] Note that the values of $\alpha 1$ and $\alpha 2$ for each area need not be the same values, and can be set to different values as appropriate for each area such that the acting position of the total of the output force of the two upper-intermediate-roll bending cylinders 750 and the output force of the upper-intermediate-roll bending cylinder 751 approximately matches the center position of the bearing 790.

[0072] In addition, the values of $\gamma 1$ and $\gamma 2$ for each area need not be the same values, and can be set to different values as appropriate for each area such that the acting position of the output force of the two upper-intermediate-roll bearing-housing backlash elimination cylinders 771 approximately matches the center position of the bearing 790.

[0073] Next, advantages of the present embodiment are explained.

[0074] The rolling mill according to the first embodiment of the present invention mentioned above includes: a roll that is shifted in the axial direction; a bearing that is shifted in the roll-axis direction along with the roll, and receives a load from the roll; and three or more first cylinders that apply bending force vertically to the bearing to cause the roll to perform bending, and the bearing and the first cylinders are provided on each the drive side and the work side. Two first cylinders in the first cylinders are provided in the roll-axis direction on the rolled material 5 entry side or exit side, one first cylinder in the first cylinders is provided on a side which is one of the rolled material 5 exit side and entry side, and is opposite to a side provided with the two first cylinders, and the first cylinder on the opposite side is positioned between the two first cylinders when viewed in the rolling direction.

[0075] In this manner, by arranging the three first cylinders in total in a staggered manner on the rolled material 5 entry side and exit side, it is possible to change first cylinders to be driven as appropriate according to the shift position of the roll, and it is thereby possible to realize a structure that can cause the resultant bending force to act on a position near the lengthwise middle portion of the bearing even with a simple structure as compared to conventional rolling mills. Accordingly, offset loads on the bearing can be reduced even with a simple structure.

[0076] In addition, since one or more first cylinders in the two first cylinders are arranged outside an area within which the center of the bearing is shifted, it is possible to cause the resultant force of the bending force of the first cylinders to act on a position near the lengthwise middle portion of the bearing more accurately and surely, and it is possible to reduce offset loads on the bearing more surely.

[0077] Furthermore, since second cylinders that apply pressing force to the bearing 790 in the rolling direction or in a direction opposite to the rolling direction are further included in one of the entry-side fixation member 702 and the exit-side fixation member 703 that are fixed to the housings 700 at least on either the rolled material 5 entry-side or exit-side, and are provided with the first cylinders. Thereby, it is possible to prevent the bearings and the first cylinders from moved in the rolling direction at the time of biting of the top of the rolled material 5. Thereby, an advantage of preventing the bending acting position from moved can be attained. That is, it is possible to suppress the movement of the bearings in the rolling direction in a state in which the bending force is acting thereon. Accordingly, a slip does not occur at portions that are pressed by the first cylinders, and it is possible to suppress damages to the first cylinders and wear on the pressed side, and to keep the bending precision high.

[0078] In addition, since the second cylinders that apply pressing force to the bearing in a rolling direction or in a direction opposite to the rolling direction are further included on either the entry side or the exit side, and the second cylinders are arranged on both of axial sides of the first cylinder when the rolling mill is viewed in the rolling direction, it becomes easier to cause the pressing force of the second cylinders to act on a position near the lengthwise middle portion of the bearing, and it is possible to make it more difficult for the bearings and the first cylinders to shift in the rolling direction at the time of biting of the rolled material. Accordingly, the bending precision can be kept higher.

[0079] An advantage attained by causing the pressing force of the second cylinders to act on a position near the lengthwise middle portion of the bearing is as follows. FIG. 6 illustrates a case where the pressing force of a second cylinder acts on a position near the lengthwise middle portion of the bearing in a case where only the drive-side axially-inner upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven.

[0080] As illustrated in FIG. 6, if it is defined that the force in the rolling direction that acts on the bearing from the roll is Fd, the pressing force of the second cylinder is Fg2, and the outer reaction force and inner reaction force generated to liners of the upper-intermediate-roll bearing housing 722A and the upper-intermediate-roll bending block part 727 are F1 and F2, respectively, there is a relation of Fg2 = Fd + F1 + F2. If any of F1 and F2 becomes 0, the liners are out of contact, and this is not preferable. Here, Fg2 is generated near the Fd-acting position, and therefore, Fg2 can be made a relatively small value. That is, the pressing force of the second cylinder can be reduced.

[0081] In contrast to this, FIG. 7 illustrates a case where the pressing force of a second cylinder acts on a position away from a position near the lengthwise middle part of the bearing in a case where only the drive-side axially-outer upper-intermediate-roll bearing-housing backlash elimination cylinder 771 is driven.

[0082] The pressing force Fg1 of the second cylinder has a relation of Fg1 = Fd + F1 + F2, similarly. In order for F2 to be not 0, Fg1 inevitably becomes a large value for the balance of moments. This makes it necessary to use larger second cylinders, and it becomes structurally difficult to house such large cylinders in the upper-intermediate-roll bending block part 727. However, as in FIG. 6, by causing the pressing force of the second cylinders to act on a position near the lengthwise middle portion of the bearing, the output force required of the second cylinders can be reduced, and the

size of the cylinders can be reduced. Thereby, they can be housed in the upper-intermediate-roll bending block part 727.

[0083] Furthermore, the controller 80 that drives the first cylinders is further included, and the controller 80 is configured to drive any one first cylinder in the two first cylinders and drive the first cylinder provided on the opposite side when bending of the roll is performed and also the center of the bearing is arranged on the outer side of X, which is defined as an intersection of the roll-axis line and a straight line linking the outer first cylinder and the first cylinder provided on the opposite side, or is arranged on the inner side of Y, which is defined as an intersection of the roll-axis line and a straight line linking the inner first cylinder and the first cylinder provided on the opposite side. Thereby, it is possible to cause the resultant bending force to act on a position near the lengthwise middle portion of the bearing by two first cylinders per bearing more accurately, and it is possible to suppress application of offset loads onto the bearing more surely.

[0084] In addition, the controller 80 that drives the first cylinders is further included, and the controller 80 is configured to perform control such that when bending of the roll is performed, the difference between the total output force of the two first cylinders and the output force of the first cylinder provided on the opposite side is within a predetermined range. Thereby, it is possible to cause almost the same bending force to act on the entry side and the exit side of the bearing, and it is possible to keep the roll stably.

[0085] Furthermore, the upper intermediate roll 720 and the lower intermediate roll 721 typically have large shift amounts. In view of this, the upper work roll 710 and the lower work roll 711 that contact the rolled material 5, and the upper intermediate roll 720 and the lower intermediate roll 721 that contact the upper work roll 710 and the lower work roll 711 are included, and the roll is used as the upper intermediate roll 720 and the lower intermediate roll 721. Thereby, it is possible to realize a structure that can cause the resultant bending force to act on a position near the lengthwise middle portion of the bearing by a simple structure even in a case where the shift amounts are large.

[0086] In addition, the entry-side fixation member 702 and the exit-side fixation member 703 that are fixed to the housings 700 at least on either the rolled material 5 entry-side or exit-side and are provided with the first cylinders, and the fifth cylinders that apply, to the bearings of the upper work roll 710 and the lower work roll 711 that contact the rolled material 5, bending force in a direction opposite to the bending force applied by the first cylinders to cause the upper work roll 710 and the lower work roll 711 to perform bending are further included. Thereby, it is possible to provide the fifth cylinders also to the same members as the first cylinders, and it is possible to attempt to save spaces.

<Second Embodiment

[0087] The rolling mill according to a second embodiment of the present invention is explained by using FIG. 8. The same configurations as the first embodiment are denoted with the same reference characters, and explanations thereof are omitted. The same applies also to the following embodiments.

[0088] As illustrated in FIG. 8, in the rolling mill according to the present embodiment, in a manner opposite to that of the rolling mill according to the first embodiment, one upper-intermediate-roll bending cylinder 750A (first cylinder) is provided in the roll-axis direction on the rolled material 5 entry side, and two upper-intermediate-roll bending cylinders 751A (first cylinders) are provided on the rolled material 5 exit side.

[0089] The upper-intermediate-roll bending cylinder 750A provided on the rolled material 5 entry side in the upper-intermediate-roll bending cylinders is arranged such that it is positioned between the two upper-intermediate-roll bending cylinders 751A provided on the opposite exit side when viewed in the rolling direction.

[0090] In addition, in the present embodiment, an upper-intermediate-roll bearing-housing backlash elimination cylinder 771A arranged on the rolled material 5 exit side is arranged, in the axial direction, between the two upper-intermediate-roll bending cylinder 751A provided on the same exit side when viewed in the rolling direction.

[0091] In the present embodiment, the axial positions of the upper-intermediate-roll bending cylinder 750A provided on the entry side and the exit-side upper-intermediate-roll bearing-housing backlash elimination cylinder 771A are desirably the same.

[0092] Next, details of drive control of the upper-intermediate-roll bending cylinders 750A and 751A, and the upper-intermediate-roll bearing-housing backlash elimination cylinder 771A according to the present embodiment are explained with reference to FIG. 8 and TABLE 2.

[TABLE 2]

section / actuation target	C	B	A
drive-side entry-side bending cylinder	ON	ON	ON
drive-side exit-side bending cylinder (inner)	OFF	ON×1/2	ON
drive-side exit-side bending cylinder (outer)	ON	ON×1/2	OFF
work-side entry-side bending cylinder	ON	ON	ON
work-side exit-side bending cylinder (inner)	ON	ON×1/2	OFF
work-side exit-side bending cylinder (outer)	OFF	ON×1/2	ON
drive-side backlash elimination cylinder	ON	ON	ON
work-side backlash elimination cylinder	ON	ON	ON

[0093] The boundary between the section B and the section C exists at a position within $L_B/4$ on the axially-inner side of the intersection of the entry-side upper-intermediate-roll bending cylinder 750A and the axially-outer exit-side upper-intermediate-roll bending cylinder 751A. When the bearing center exists in the section C, on the drive side, the entry-side upper-intermediate-roll bending cylinder 750A is driven, and the axially-inner cylinder in the exit-side upper-intermediate-roll bending cylinders 751A is not driven, but the axially-outer cylinder is driven. On the work side, the entry-side upper-intermediate-roll bending cylinder 750A is driven, and the axially-outer cylinder in the exit-side upper-intermediate-roll bending cylinders 751A is not driven, but the axially-inner cylinder is driven.

[0094] The boundary between the section A and the section B exists at a position within $L_B/4$ on the axially-outer side of the intersection of the entry-side upper-intermediate-roll bending cylinder 750A and the axially-inner exit-side upper-intermediate-roll bending cylinder 751A. When the bearing center exists in the section A, on the drive side, the entry-side upper-intermediate-roll bending cylinder 750A is driven, and the axially-outer cylinder in the exit-side upper-intermediate-roll bending cylinders 751A is not driven, but the axially-inner cylinder is driven. On the work side, the entry-side upper-intermediate-roll bending cylinder 750A is driven, and the axially-inner cylinder is not driven, but the axially-outer cylinder is driven.

[0095] When the bearing center exists in the section B, on each the drive side and the work side, the entry-side upper-intermediate-roll bending cylinder 750A is driven similarly to the cases of the sections A and C, and the output force of both of the exit-side upper-intermediate-roll bending cylinders 751A is made 1/2 such that the total thereof becomes the same as the output force of the entry-side upper-intermediate-roll bending cylinder.

[0096] The upper-intermediate-roll bearing-housing backlash elimination cylinder 771A is driven no matter which of the sections A, B, and C in TABLE 2 the bearing center exists in.

[0097] In other respects, the configuration/action is approximately the same as the configuration/action of the rolling mill according to the first embodiment mentioned before, and details thereof are omitted.

[0098] In the second embodiment of the present invention also in which a second cylinder that applies pressing force to the bearing 790 in the rolling direction or in a direction opposite to the rolling direction is further included on either the entry side or the exit side, and the second cylinder is arranged between the two first cylinders when the rolling mill is viewed in the rolling direction. Also because of this, advantages almost similar to those of the rolling mill according to the first embodiment mentioned before can be attained.

[0099] When the intermediate roll shifts within Ls, the bearing center exists in any of sections A, B, and C illustrated in FIG. 8. By arranging the second cylinder between the first cylinders in the axial direction when the rolling mill is viewed in the rolling direction, the second cylinder is positioned almost at the intermediate position of Ls. Accordingly, it becomes easier to cause the pressing force of the second cylinder to act on a position near the lengthwise middle portion of the shifted bearing, the output force required of the second cylinder can be reduced, and the size of the cylinder can be reduced. Thereby, it can be housed in the upper-intermediate-roll bending block part 727. Thereby, it becomes possible to make it difficult for the bearing and the first cylinders to shift in the rolling direction at the time of biting of the rolled

material, and thus the bending precision can be kept higher.

[0100] Similarly to the first embodiment, the axially-outer upper-intermediate-roll bending cylinder 751A is driven at output force obtained by multiplying total output force of the two upper-intermediate-roll bending cylinders 751A by $\alpha 1$, the axially-inner upper-intermediate-roll bending cylinder 751A is driven at output force obtained by multiplying the total output force by $\alpha 2$, the total of $\alpha 1$ and $\alpha 2$ is 1, and $\alpha 1$ and $\alpha 2$ are adjusted such that the acting position of the total output force is almost at the bearing center. The two upper-intermediate-roll bending cylinders 751A can be driven along with the upper-intermediate-roll bending cylinder 750A in this manner also.

[0101] Note that the form illustrated on the drive side in FIG. 5 can be adopted for the drive side, and also the form illustrated on the work side in FIG. 8 can be adopted for the work side. In addition, conversely, the form illustrated on the drive side in FIG. 8 can be adopted for the drive side, and also the form illustrated on the work side in FIG. 5 can be adopted for the work side.

<Third Embodiment

[0102] The rolling mill according to a third embodiment in the present invention is explained by using FIG. 9 and TABLE 3.

[0103] The rolling mill according to the present embodiment illustrated in FIG. 9 corresponds to the rolling mill according to the first embodiment, but is different in that it includes, between the two rolled material 5 entry-side upper-intermediate-roll bending cylinders 750, an upper-intermediate-roll bending cylinder 750B (third cylinder) that further applies bending force vertically to the bearing 790 to cause the roll to perform bending. Similarly to the upper-intermediate-roll bending cylinders 750, the upper-intermediate-roll bending cylinder 750B is arranged so as to apply bending force toward the increase side.

[0104] Next, details of drive control of the upper-intermediate-roll bending cylinders 750, 750B, and 751, and the upper-intermediate-roll bearing-housing backlash elimination cylinders 771 according to the present embodiment are explained.

[0105] In the present embodiment also, the shift amount of the bearing 790 is defined as L_s, and L_s is divided into sections A, B, C, and D. TABLE 3 illustrates a relation between the bearing-center position and the state of driving of each cylinder. The intersection position of the roll-axis line and a line linking e1 and d1 is the boundary between the section D and the section C. The intersection position of the roll-axis line and a line linking e3 and d1 is the boundary between the section B and the section A.

[TABLE 3]

type	position		acting force	section where bearing-center position exists			
				D	C	B	A
bending force	entry side	e1	Pe1	1xPbe	$\alpha 1\times$Pbe	0×Pbe	0×Pbe
		e2	Pe2	0×Pbe	$\alpha 2\times$Pbe	$\alpha 2\times$Pbe	0×Pbe
		e3	Pe3	0×Pbe	0×Pbe	$\alpha 3\times$Pbe	1xPbe
		Total =Pe1+Pe2+Pe 3		Pbe	Pbe	Pbe	Pbe
	exit side	d1	Pd1	1×Pbd	1×Pbd	1×Pbd	1×Pbd
	total			Pbe+Pbd	Pbe+Pbd	Pbe+Pbd	Pbe+Pbd
backlash elimination pressing force	axial direction	g1	Pg1	$\gamma 1\times$Pg	$\gamma 1\times$Pg	$\gamma 1\times$Pg	$\gamma 1\times$Pg
		g2	Pg2	$\gamma 2\times$Pg	y2xPg	y2xPg	$\gamma 2\times$Pg
	total output force =Pg1+Pg2			Pg	Pg	Pg	Pg

[0106] When the axial center of the bearing exists in the section D, an axially-outer upper-intermediate-roll bending cylinder 750,e1 and an upper-intermediate-roll bending cylinder 751,d1 are driven.

[0107] When the axial center of the bearing exists in the section C, the axially-outer upper-intermediate-roll bending cylinder 750,e1 is driven at output force obtained by multiplying required entry-side bending force Pbe by a predetermined coefficient $\alpha 1$, an upper-intermediate-roll bending cylinder 750B,e2 is driven at output force obtained by multiplying the required entry-side bending force Pbe by a predetermined coefficient $\alpha 2$, and the upper-intermediate-roll bending cylinder 751,d1 is driven.

[0108] When the axial center of the bearing exists in the section B, the upper-intermediate-roll bending cylinder 750B, e2 is driven at output force obtained by multiplying the required entry-side bending force Pbe by the predetermined coefficient $\alpha 2$, and an axially-inner upper-intermediate-roll bending cylinder 750,e3 is driven at output force obtained by

multiplying the required entry-side bending force Pbe by a predetermined coefficient $\alpha 3$, and the upper-intermediate-roll bending cylinder 751,d1 is driven.

[0109] When the axial center of the bearing exists in the section A, the axially-inner upper-intermediate-roll bending cylinder 750,e3 and the upper-intermediate-roll bending cylinder 751,d1 are driven.

[0110] No matter which area the axial center of the bearing exists in, the resultant force of the entry-side bending force Pbe and the exit-side bending force Pbd is adjusted such that it becomes bending force required for the roll, and the resultant force is adjusted such that it acts on a position near the axial center of the roll.

[0111] Regarding the output force of the upper-intermediate-roll bearing-housing backlash elimination cylinders 771, at any location, an axially-outer upper-intermediate-roll bearing-housing backlash elimination cylinder 771,g1 is driven at output force obtained by multiplying required backlash elimination pressing force Pg by the predetermined coefficient $\gamma 1$, and an axially-inner upper-intermediate-roll bearing-housing backlash elimination cylinder 771,g2 is driven at output force obtained by multiplying the required backlash elimination pressing force Pg by the predetermined coefficient $\gamma 2$.

[0112] Note that similarly to $\gamma 1$ and $\gamma 2$, the values of $\alpha 1$, $\alpha 2$, and $\alpha 3$ for each area need not be the same values, and can be set to different values as appropriate for each area such that the acting position of the output force of the four upper-intermediate-roll bending cylinders 750, 750B, and 751, and the acting position of the output force of the two upper-intermediate-roll bearing-housing backlash elimination cylinders 771 approximately match the center position of the bearing 790. In addition, it is also possible to use not only e1, but to use e1 and e2 on the entry side in the case of the section D to cause bending force to act on a position near the lengthwise center position of the bearing, and allocation of the output force can be set as appropriate by setting $\alpha 1$, $\alpha 2$, and $\alpha 3$ for each section.

[0113] In other respects, the configuration/action is approximately the same as the configuration/action of the rolling mill according to the first embodiment mentioned before, and details thereof are omitted.

[0114] With the rolling mill according to the third embodiment of the present invention also, advantages almost similar to those of the rolling mill according to the first embodiment mentioned before can be attained.

[0115] In addition, since a third cylinder that further applies bending force vertically to the bearing 790 to cause the roll to perform bending is included between the two first cylinders, an area within which the bending force can be caused to act widens in the axial direction. Accordingly, the shift amount can be increased, and it is possible to cause a load to be applied at the lengthwise center position of the bearing more accurately when the shift amount is small.

[0116] Furthermore, the output force of the upper-intermediate-roll bending cylinders 750, 750B, and 751 is caused to act on an upper-intermediate-roll bearing-housing flange part 822AB in FIG. 9 as roll bending force. The length of the upper-intermediate-roll bearing-housing flange part 822AB is defined as L_{CB}. When the intermediate roll shifts, the bearing also shifts along with its bearing housing. In order to cause roll bending force to act at a position to which the bearing has shifted, the upper-intermediate-roll bearing-housing flange part 822AB is needed for bending cylinders that are driven at the position to which the bearing has shifted. Since bending cylinders to be used are chosen according to the shift position, this gives an advantage of not requiring long L_{CB} even in a case where the shift amount is large, and of not complicating the bearing housing. Problems that a bearing housing becomes long in the axial direction, and large in size, and the structure becomes complicated occur in a case where long L_{CB} is required, but these problems can be avoided.

[0117] Note that whereas the one upper-intermediate-roll bending cylinder 750B is provided in the case explained in the present embodiment, two or more upper-intermediate-roll bending cylinders 750B can be provided. At this time, the axial positions of the second and subsequent upper-intermediate-roll bending cylinders 750B are not particularly limited. One or more second and subsequent upper-intermediate-roll bending cylinders 750B can be arranged on the axially-outer side of the axially-outer upper-intermediate-roll bending cylinder 750, one or more second and subsequent upper-intermediate-roll bending cylinders 750B can be arranged on the axially-inner side of the axially-inner upper-intermediate-roll bending cylinder 750, and so on.

[0118] In addition, like the relation between the first embodiment and the second embodiment, the entry side and the exit side in FIG. 9 can be reversed, and the upper-intermediate-roll bending cylinders 750 and the upper-intermediate-roll bending cylinder 750B can be arranged on the exit side. In this case also, the number of upper-intermediate-roll bending cylinders 750B is not particularly limited, and one or more upper-intermediate-roll bending cylinders 750B can be provided.

[0119] Furthermore, one or more cylinders with specifications similar to those of the upper-intermediate-roll bending cylinder 750B can be added on the entry side and the exit side.

<Fourth Embodiment>

[0120] The rolling mill according to a fourth embodiment of the present invention is explained by using FIG. 10 and TABLE 4.

[0121] The rolling mill according to the present embodiment illustrated in FIG. 10 corresponds to the rolling mill according to the first embodiment, but is different in that it further includes, on the rolled material 5 exit side, upper-intermediate-

roll bending cylinders 751C (fourth cylinders) each of which is, on the drive side, at a position on an axially-outer side of, and is, on the work side, at a position on an axially-inner side of the two rolled material 5 entry-side upper-intermediate-roll bending cylinders 750 when viewed in the rolling direction. Similarly to the upper-intermediate-roll bending cylinders 750, the upper-intermediate-roll bending cylinders 751C are arranged to apply bending force toward the increase side.

[0122] Next, details of drive control of the upper-intermediate-roll bending cylinders 750, 751, and 751C, and the upper-intermediate-roll bearing-housing backlash elimination cylinders 771 according to the present embodiment are explained.

[0123] In the present embodiment also, the shift amount of the bearing 790 is defined as L_s, and L_s is divided into sections A and B. TABLE 4 illustrates a relation between the bearing-center position and the state of driving of each cylinder. The intersection position of the roll-axis line and a line linking e1 and d2 is the boundary between the section B and the section A.

[TABLE 4]

type	position		acting force	section where bearing-center position exists	
				B	A
bending force	entry side	e1	Pe1	1×Pbe	αe1×Pbe
		e2	Pe2	0×Pbe	αe2×Pbe
		total=Pe1+Pe2		Pbe	Pbe
	exit side	d1	Pd1	αd1×Pbd	0×Pbd
		d2	Pd2	αd2×Pbd	1×Pbd
		total=Pd1+Pd2		Pbd	Pbd
	total			Pbe+Pbd	Pbe+Pbd
backlash elimination pressing force	axial direction	g1	Pg1	γ1×Pg	γ1×Pg
		g2	Pg2	γ2×Pg	y2xPg
	total output force=Pg1+Pg2			Pg	Pg

[0124] When the axial center of the bearing 790 exists in the section B, the axially-outer upper-intermediate-roll bending cylinder 750,e1 and upper-intermediate-roll bending cylinder 751C,d1 are driven at output force obtained by multiplying the required exit-side bending force Pbd by a predetermined coefficient αd1, and the upper-intermediate-roll bending cylinder 751,d2 is driven at output force obtained by multiplying the required exit-side bending force Pbd by a predetermined coefficient αd2.

[0125] Regarding the backlash elimination cylinders, in any section, the axially-outer upper-intermediate-roll bearing-housing backlash elimination cylinder 771,g1 is driven at output force obtained by multiplying the required backlash elimination pressing force Pg by the predetermined coefficient γ1, and the axially-inner upper-intermediate-roll bearing-housing backlash elimination cylinder 771,g2 is driven at output force obtained by multiplying the required backlash elimination pressing force Pg by the predetermined coefficient γ2.

[0126] When the axial center of the bearing 790 exists in the section A, the upper-intermediate-roll bending cylinder 750,e1 is driven at output force obtained by multiplying the required entry-side bending force Pbe by a predetermined coefficient αe1, an upper-intermediate-roll bending cylinder 750,e2 is driven at output force obtained by multiplying the required entry-side bending force Pbe by a predetermined coefficient αe2, and the upper-intermediate-roll bending cylinder 751,d2 is driven.

[0127] Note that the coefficients αe1, αe2, αd1, and αd2 for each section need not be the same values, but are set to different values as appropriate for each section such that the acting position of the output force of the four upper-intermediate-roll bending cylinders 750,e1, 750,e2, 751C,d1, and 751,d2 approximately matches the center position of the bearing 790.

[0128] In addition, the coefficients γ1 and γ2 for each section of the upper-intermediate-roll bearing-housing backlash elimination cylinders 771,g1 and 771,g2 need not be the same values, but are set to different values as appropriates for each section such that the acting position of the output force of the upper-intermediate-roll bearing-housing backlash elimination cylinders 771,g1 and 771,g2 approximately matches the center position of the bearing 790 or becomes as close to the center position of the bearing 790 as possible.

[0129] In other respects, the configuration/action is approximately the same as the configuration/action of the rolling

mill according to the first embodiment mentioned before, and details thereof are omitted.

[0130] With the rolling mill according to the fourth embodiment of the present invention also, advantages almost similar to those of the rolling mill according to the first embodiment mentioned before can be attained.

[0131] In addition, one or more fourth cylinders that further apply bending force vertically to the bearing 790 to cause the roll to perform bending are further included at positions on an axially-outer side of the one first cylinder provided on the opposite exit side, and one of the two entry-side first cylinders is arranged between the first cylinder and the fourth cylinders that are provided on the opposite side when the rolling mill is viewed in the rolling direction. Also because of this, the area within which the bending force can be caused to act can be widened in the axial direction, and the shift amount can be increased.

[0132] Note that whereas the one upper-intermediate-roll bending cylinder 751C is provided in the case explained in the present embodiment, two or more upper-intermediate-roll bending cylinders 751C can be provided. At this time, the axial positions of the second and subsequent upper-intermediate-roll bending cylinders 751C are not particularly limited. One or more upper-intermediate-roll bending cylinders 751C can be arranged between the upper-intermediate-roll bending cylinder 751C and the upper-intermediate-roll bending cylinder 751, one or more upper-intermediate-roll bending cylinders 751C can be arranged on the axially-inner side of the upper-intermediate-roll bending cylinder 751, and so on.

[0133] In addition, the entry side and the exit side in FIG. 10 can be reversed, and the upper-intermediate-roll bending cylinders 750 and the upper-intermediate-roll bending cylinder 751C can be arranged on the entry side. In this case also, the number of the upper-intermediate-roll bending cylinders 751C is not particularly limited, and one or more upper-intermediate-roll bending cylinders 751C can be provided.

[0134] Furthermore, the upper-intermediate-roll bending cylinders 751C can be added on the entry side and the exit side.

<Fifth Embodiment>

[0135] The rolling mill according to a fifth embodiment of the present invention is explained by using FIG. 11.

[0136] The rolling mill according to the present embodiment illustrated in FIG. 11 corresponds to the rolling mill according to the first embodiment illustrated in FIG. 5, but is different in that the upper-work-roll bending cylinders 742 and 743 and the lower-work-roll bending cylinders 746 and 747 that apply pressing force toward the decrease side are omitted. In other respects, the configuration/action is approximately the same as the configuration/action of the rolling mill according to the first embodiment mentioned before, and details thereof are omitted.

[0137] With the rolling mill according to the fifth embodiment of the present invention also, advantages almost similar to those of the rolling mill according to the first embodiment mentioned before can be attained.

[0138] Note that similarly to the present embodiment, it is possible to omit decrease-side bending cylinders in the third embodiment and the fourth embodiment also. In addition, it is also possible to add decrease-side bending cylinders in the second embodiment.

<Others>

[0139] Note that the present invention is not limited to the embodiments described above, and includes various modification examples. The embodiments described above are explained in detail in order to explain the present invention in an easy-to-understand manner, and the present invention is not necessarily limited to those including all the configurations explained. Whereas portions around intermediate rolls are explained, the same principles can be used effectively for portions around shifted work rolls.

[0140] In addition, it is also possible to replace some of the configurations of an embodiment with configurations of another embodiment, and it is also possible to add a configuration of an embodiment to the configurations of another embodiment. In addition, also, some of the configurations of each embodiment can additionally have another configuration, can be deleted and can be replaced with other configurations.

Description of Reference Characters

[0141]

1: Rolling facility
5: Rolled material
10: First stand (rolling mill)
20: Second stand (rolling mill)
30: Third stand (rolling mill)
40: Fourth stand (rolling mill)

50: Fifth stand (rolling mill)
60: Sixth stand (rolling mill)
70: Seventh stand (rolling mill)
80: Controller
700: Housing
702: Entry-side fixation member
703: Exit-side fixation member
710: Upper work roll (roll)
711: Lower work roll (roll)
712: Upper-work-roll bearing housing
713: Lower-work-roll bearing housing
714: Work-roll bending block part
715, 716, 725, 726: Shift cylinder
720: Upper intermediate roll (roll)
721: Lower intermediate roll (roll)
722, 722A: Upper-intermediate-roll bearing housing
723, 723A: Lower-intermediate-roll bearing housing
725A: Shift mechanism
727: Upper-intermediate-roll bending block part
728: Lower-intermediate-roll bending block part
730: Upper backup roll
731: Lower backup roll
732: Upper-backup roll bearing housing
733: Lower-backup roll bearing housing
740, 741: Upper-work-roll bending cylinder (first cylinder)
742, 743: Upper-work-roll bending cylinder (fifth cylinder)
744, 745: Lower-work-roll bending cylinder (first cylinder)
746, 747: Lower-work-roll bending cylinder (fifth cylinder)
750, 750A, 751, 751A: Upper-intermediate-roll bending cylinder (first cylinder)
750B: Upper-intermediate-roll bending cylinder (third cylinder)
751C: Upper-intermediate-roll bending cylinder (fourth cylinder)
752, 753: Lower-intermediate-roll bending cylinder (first cylinder)
760: Upper-work-roll bearing-housing backlash elimination cylinder (second cylinder)
762: Lower-work-roll bearing-housing backlash elimination cylinder (second cylinder)
771, 771A: Upper-intermediate-roll bearing-housing backlash elimination cylinder (second cylinder)
773: Lower-intermediate-roll bearing-housing backlash elimination cylinder (second cylinder)
780: Upper-backup roll bearing-housing backlash elimination cylinder
782: Lower-backup roll bearing-housing backlash elimination cylinder
790: Bearing
822AB: Upper-intermediate-roll bearing-housing flange part

Claims

1. A rolling mill comprising:

a roll that is shifted in an axial direction;
a bearing that is shifted in a roll-axis direction along with the roll, and receives a load from the roll; and
three or more first cylinders that apply bending force vertically to the bearing to cause the roll to perform bending,
wherein
the bearing and the first cylinders are provided on each a drive side and an work side of the roll,
two first cylinders among the first cylinders are provided in the roll-axis direction on the exit side or entry side in a rolling direction,
one first cylinder among the first cylinders is provided on a side that is one of the entry side and the exit side in the rolling direction, and that is opposite to a side provided with the two first cylinders, and
the first cylinder on the opposite side is positioned between the two first cylinders when viewed from the exit side or entry side in the rolling direction.

2. The rolling mill according to claim 1, wherein
one or more of first cylinders in the two first cylinders are arranged outside an area within which a center of the bearing is shifted.

3. The rolling mill according to claim 1 or 2, further comprising:

a fixation member that is fixed to a housing of the rolling mill at least on either the exit side or entry side in the rolling direction, and that is provided with the first cylinders; and
a second cylinder that is disposed on either the entry side or the exit side of the fixation member, and applies pressing force to the bearing in a rolling direction or in a direction opposite to the rolling direction.

4. The rolling mill according to any one of claims 1 to 3, further comprising:

on either the entry side or the exit side, a second cylinder that applies pressing force to the bearing in a rolling direction or in a direction opposite to the rolling direction, wherein
the second cylinder, when the rolling mill is viewed from the exit side or entry side in the rolling direction, is arranged between the two first cylinders or is arranged on both of axial sides of the one first cylinder.

5. The rolling mill according to any one of claims 1 to 4, further comprising:

a controller that drives the first cylinders, wherein
the controller is configured to drive any one first cylinder of the two first cylinders and drive the first cylinder provided on the opposite side when bending of the roll is performed and when a center of the bearing is arranged on either an axially-outer side of an intersection of an axis line of the roll and a straight line linking the one first cylinder and a first cylinder, the first cylinder being one first cylinder of the two first cylinders and being provided on an axially-outer side, or an axially-inner side of an intersection of the axis line of the roll and a straight line linking the one first cylinder and a first cylinder, the first cylinder being one first cylinder of the two first cylinders and being provided on an axially-inner side.

6. The rolling mill according to any one of claims 1 to 5, further comprising:

a controller that drives the first cylinders, wherein
the controller is configured to perform control such that when bending of the roll is performed, a difference between total output force of the two first cylinders and output force of the first cylinder provided on the opposite side is within a predetermined range.

7. The rolling mill according to any one of claims 1 to 6, further comprising:
between the two first cylinders, a third cylinder that further applies bending force vertically to the bearing to cause the roll to perform bending.

8. The rolling mill according to any one of claims 1 to 6, further comprising:

at a position on an axially-outer side of the one first cylinder provided on the opposite side, one or more fourth cylinders that apply bending force vertically to the bearing to cause the roll to perform bending, wherein,
when the rolling mill is viewed from the exit side or entry side in the rolling direction, one first cylinder of the two first cylinders is arranged between the first cylinder and the fourth cylinder that are provided on the opposite side.

9. The rolling mill according to any one of claims 1 to 8, comprising:

a work roll that contacts a rolled material; and
an intermediate roll that contacts the work roll, wherein
the roll is the intermediate roll.

10. The rolling mill according to any one of claims 1 to 9, further comprising:

a fixation member that is fixed to a housing of the rolling mill at least either entry-side or exit-side in the rolling direction, and is provided with the first cylinders; and
a fifth cylinder that applies, to a bearing of a work roll that contacts a rolled material, bending force in a direction

opposite to the bending force applied by the first cylinders to cause the work roll to perform bending.

Fig 1

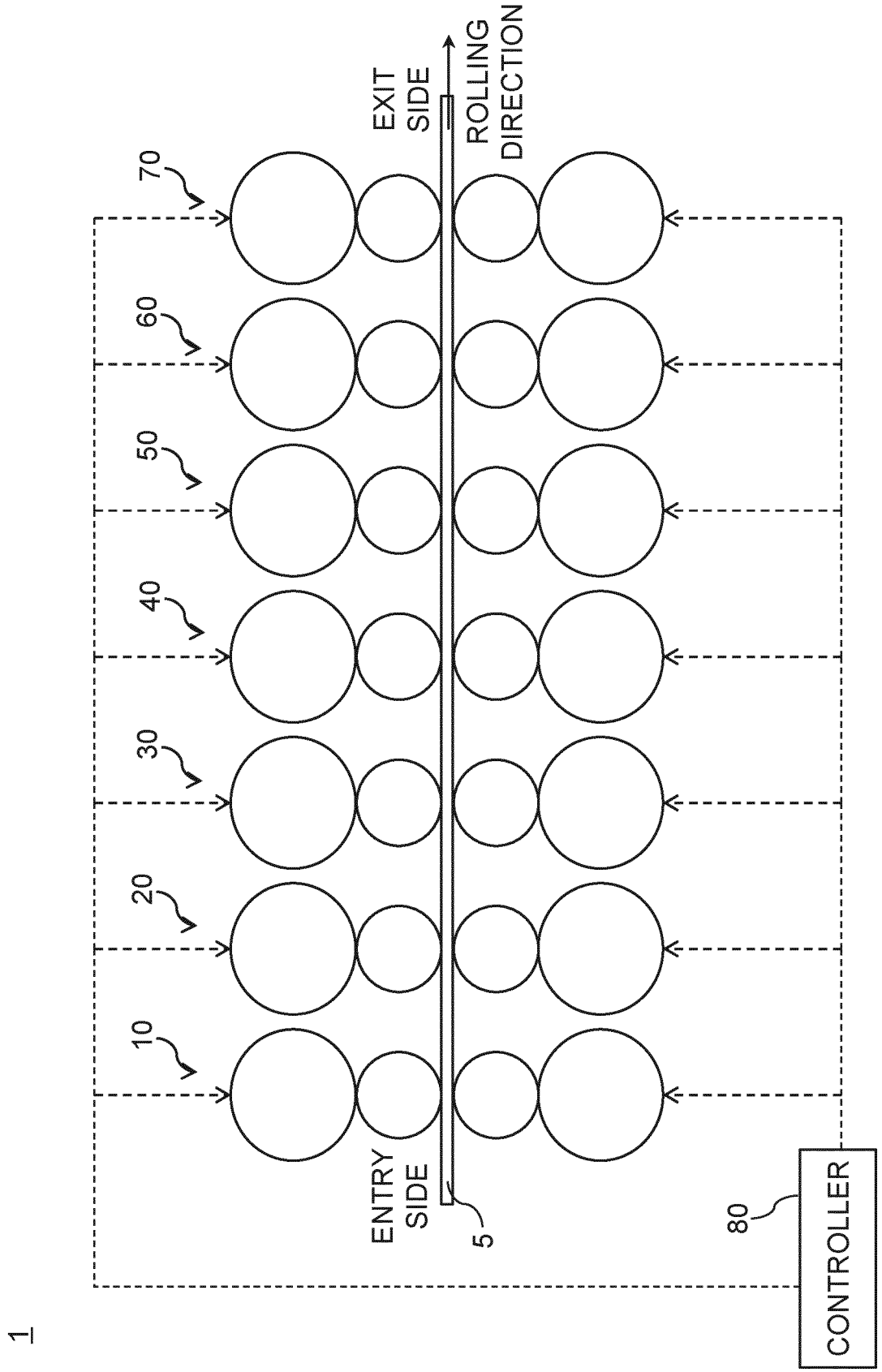

1
10
20
30
40
50
60
70
ENTRY SIDE
EXIT SIDE
ROLLING DIRECTION
5
80
CONTROLLER

Fig 2

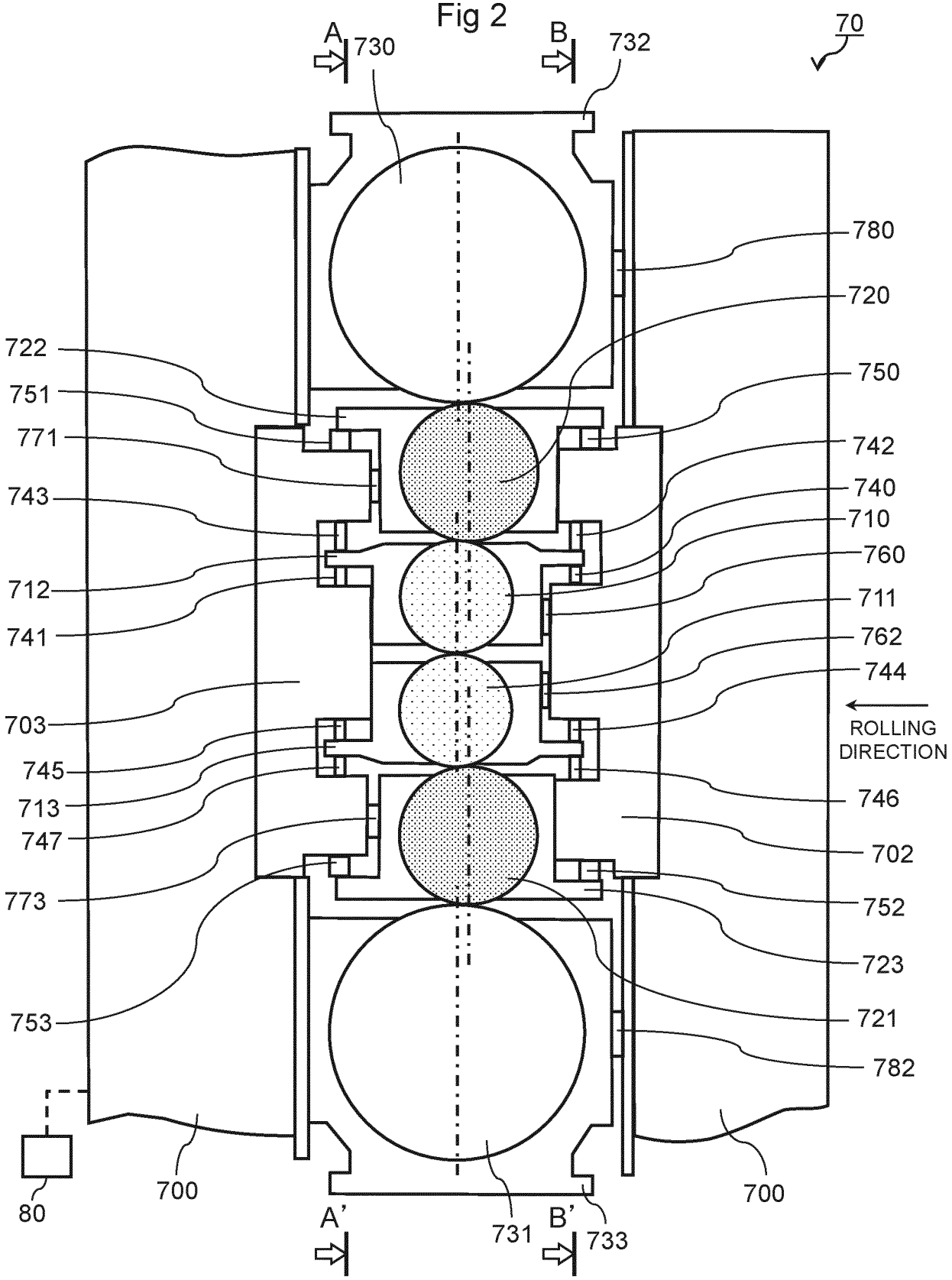

A
730
B
732
70
780
720
722
750
751
771
742
743
740
710
712
760
741
711
762
744
703
ROLLING DIRECTION
745
746
713
747
702
773
752
723
753
721
782
80
700
700
A'
731
B'
733

Fig 3

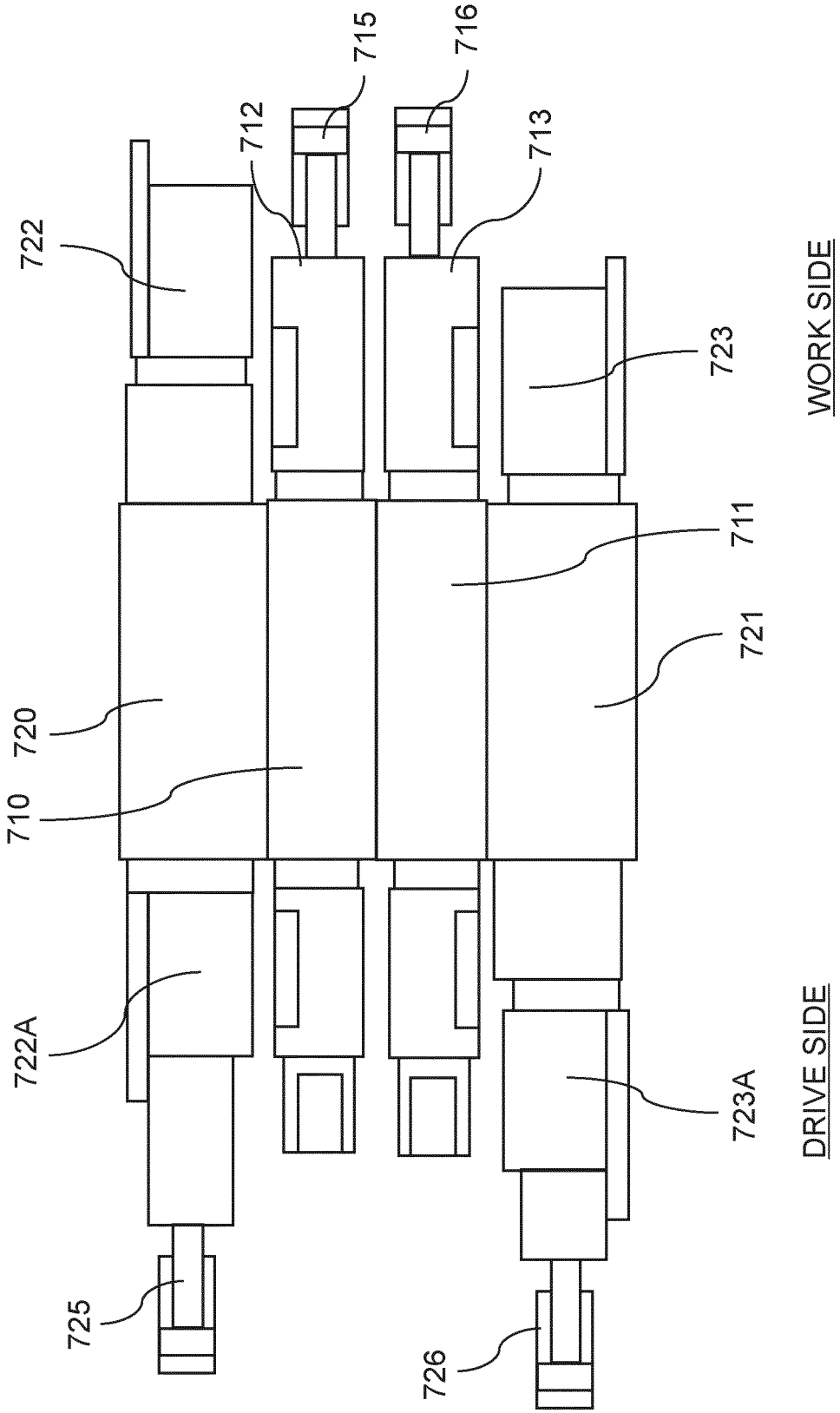

715
716
712
713
722
723
WORK SIDE
711
721
720
710
722A
723A
DRIVE SIDE
725
726

Fig 4

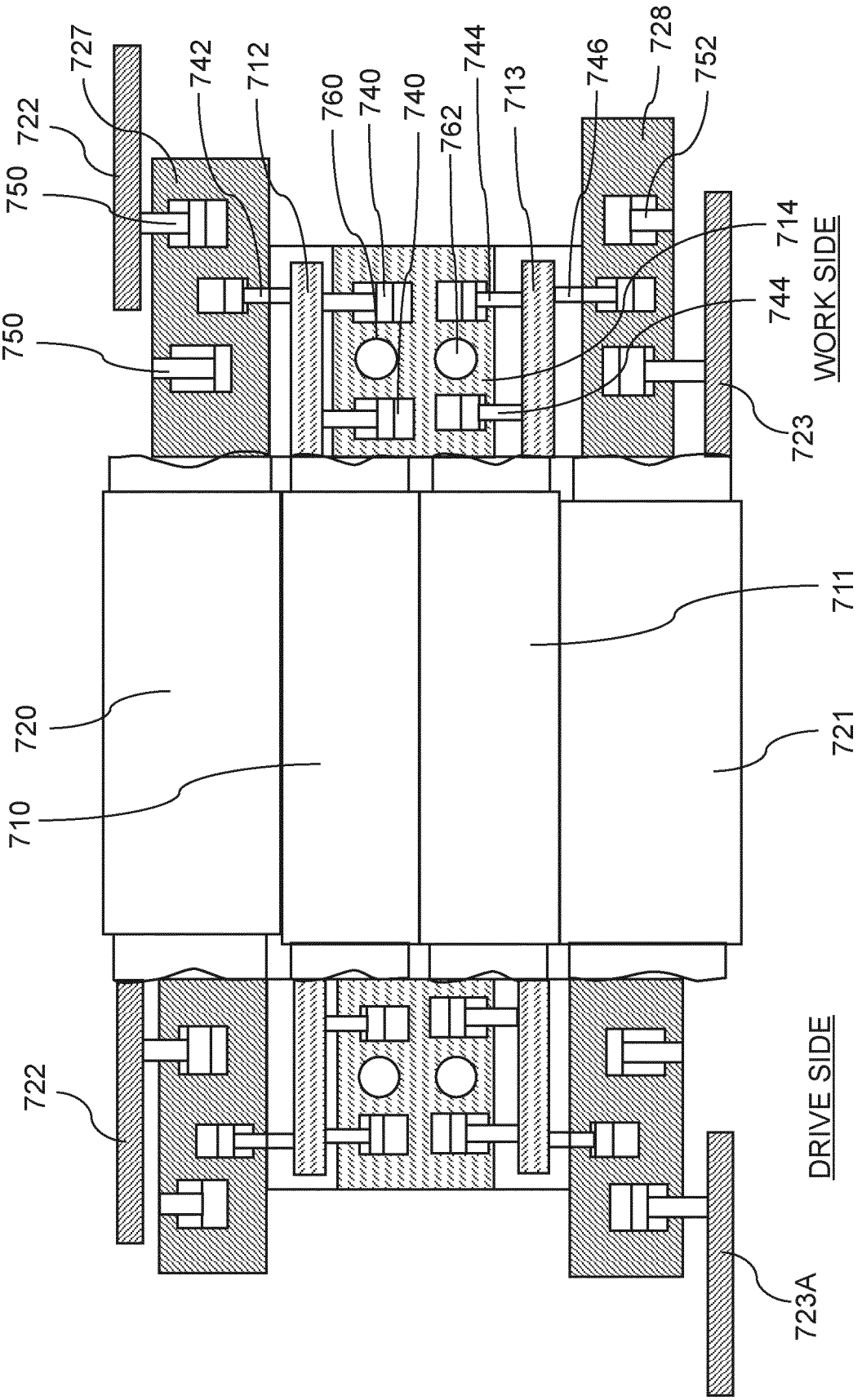

727
722
750
742
712
760
740
740
762
744
713
746
728
752
714
744
WORK SIDE
723
750
711
720
721
710
722
DRIVE SIDE
723A

Fig 5

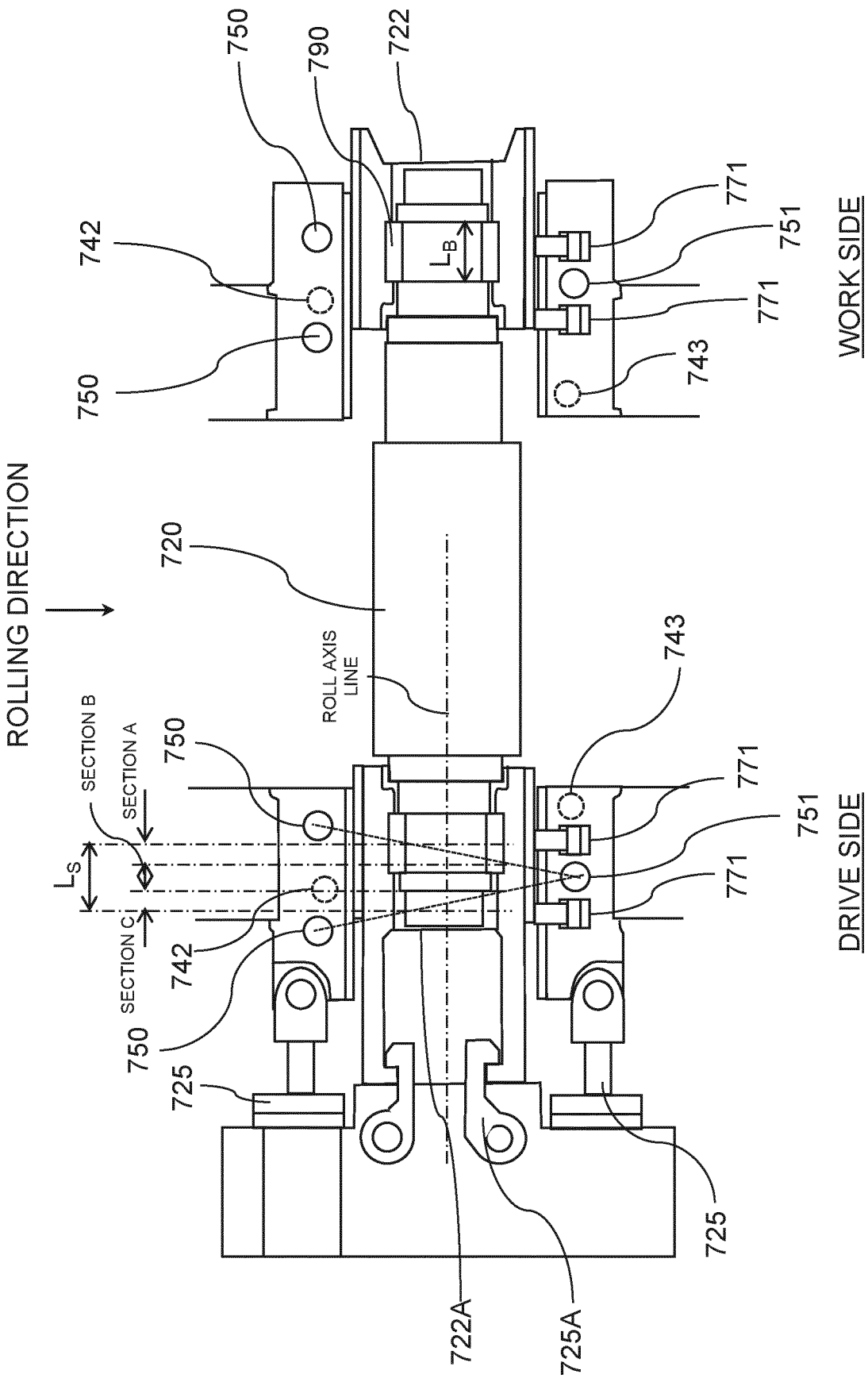

ROLLING DIRECTION
SECTION B
SECTION A
SECTION C
L_S
L_B
ROLL AXIS LINE
WORK SIDE
DRIVE SIDE
720
722
722A
725
725A
742
743
750
751
771
790

Fig 6

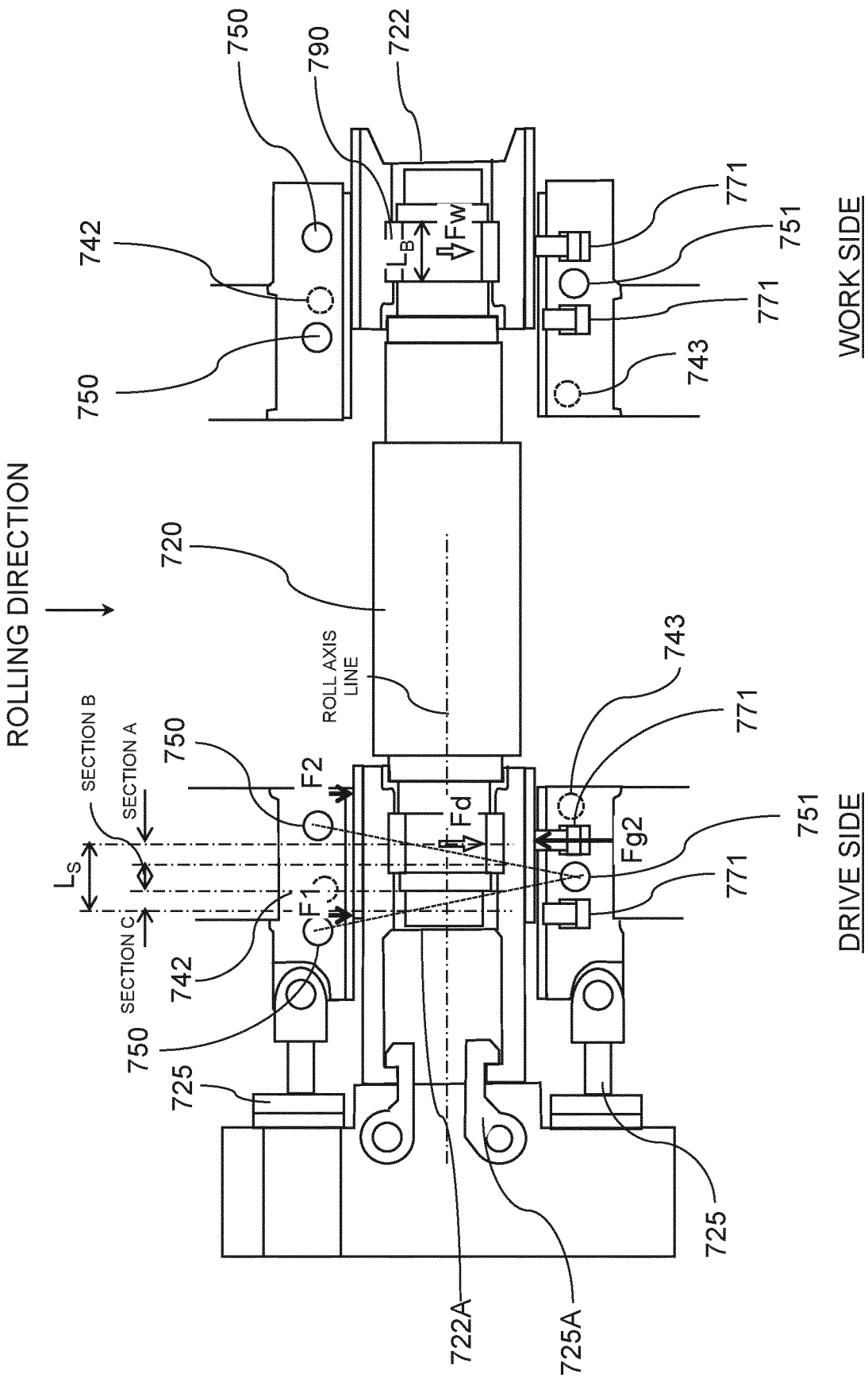

ROLLING DIRECTION
SECTION B
SECTION A
SECTION C
L_S
ROLL AXIS LINE
720
722
750
790
742
743
771
751
725
722A
725A
F1
F2
Fd
Fg2
L_B
Fw
WORK SIDE
DRIVE SIDE

Fig 7

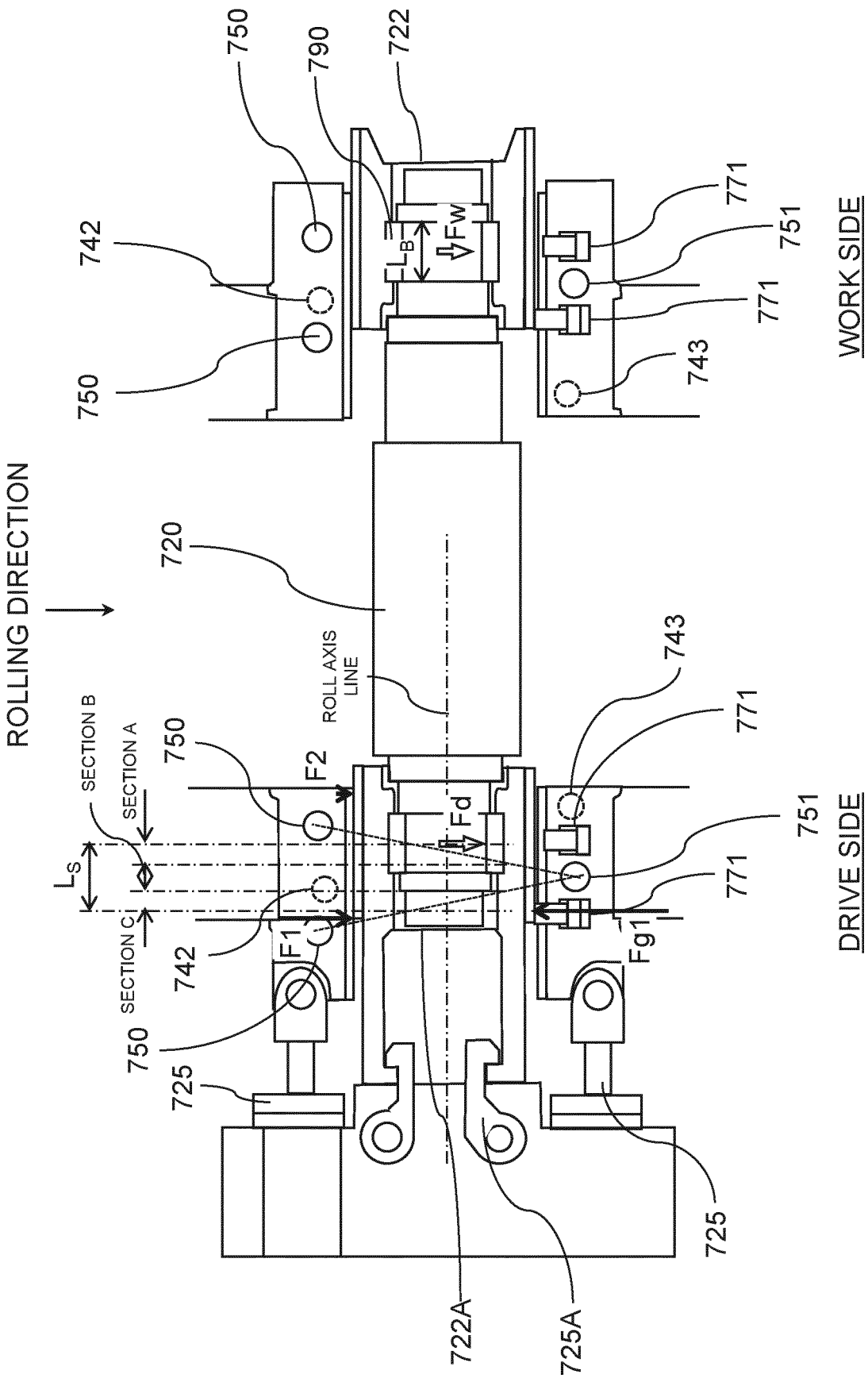

ROLLING DIRECTION
SECTION B
SECTION A
SECTION C
L_S
ROLL AXIS LINE
720
722
750
790
742
743
771
751
L_B
Fw
F2
Fd
F1
Fg1
725
722A
725A
WORK SIDE
DRIVE SIDE

Fig 8

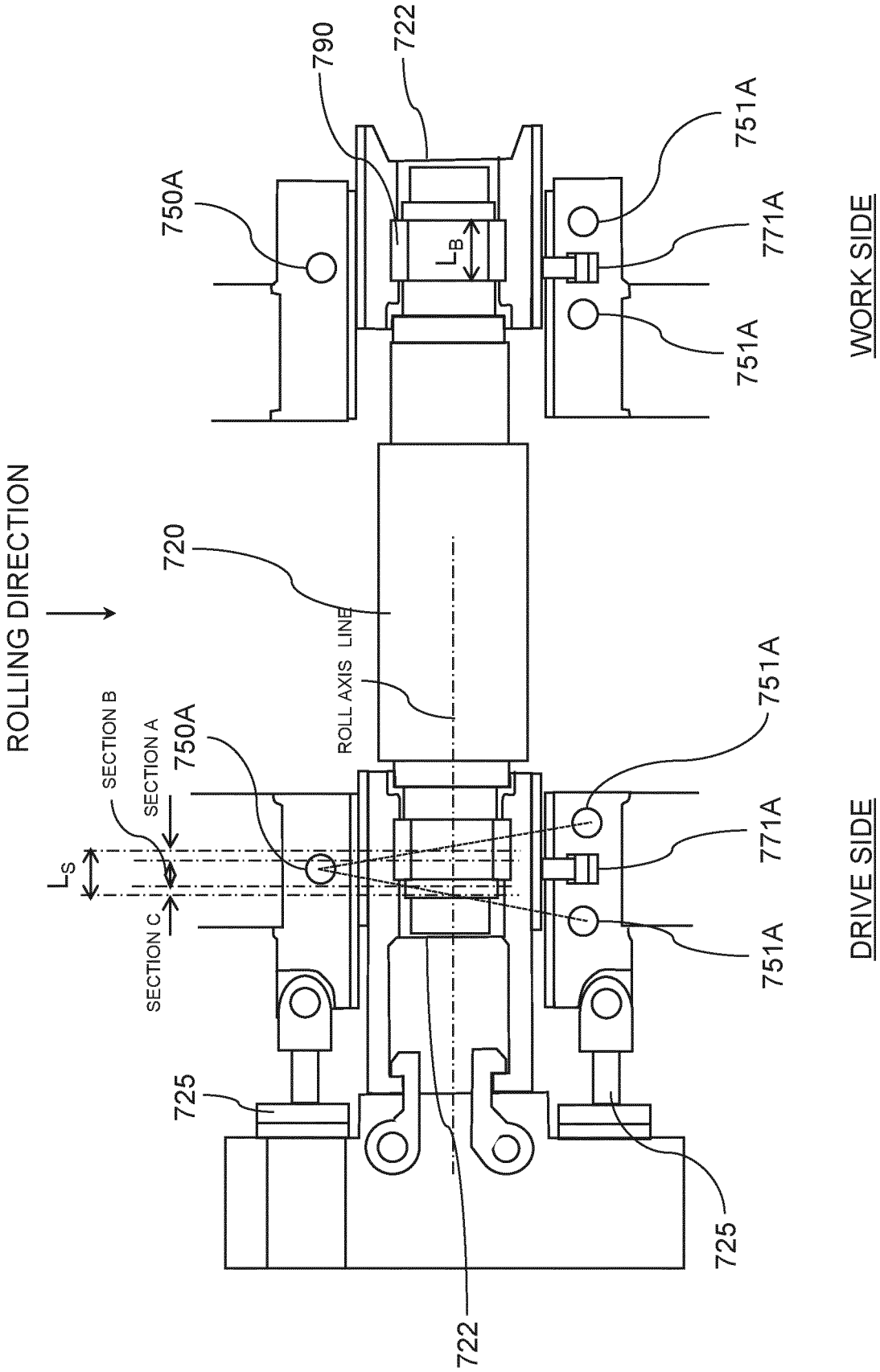

ROLLING DIRECTION
790
722
751A
750A
771A
L_B
751A
WORK SIDE
720
ROLL AXIS LINE
751A
SECTION B
SECTION A
750A
771A
L_S
SECTION C
751A
DRIVE SIDE
725
725
722

Fig 9

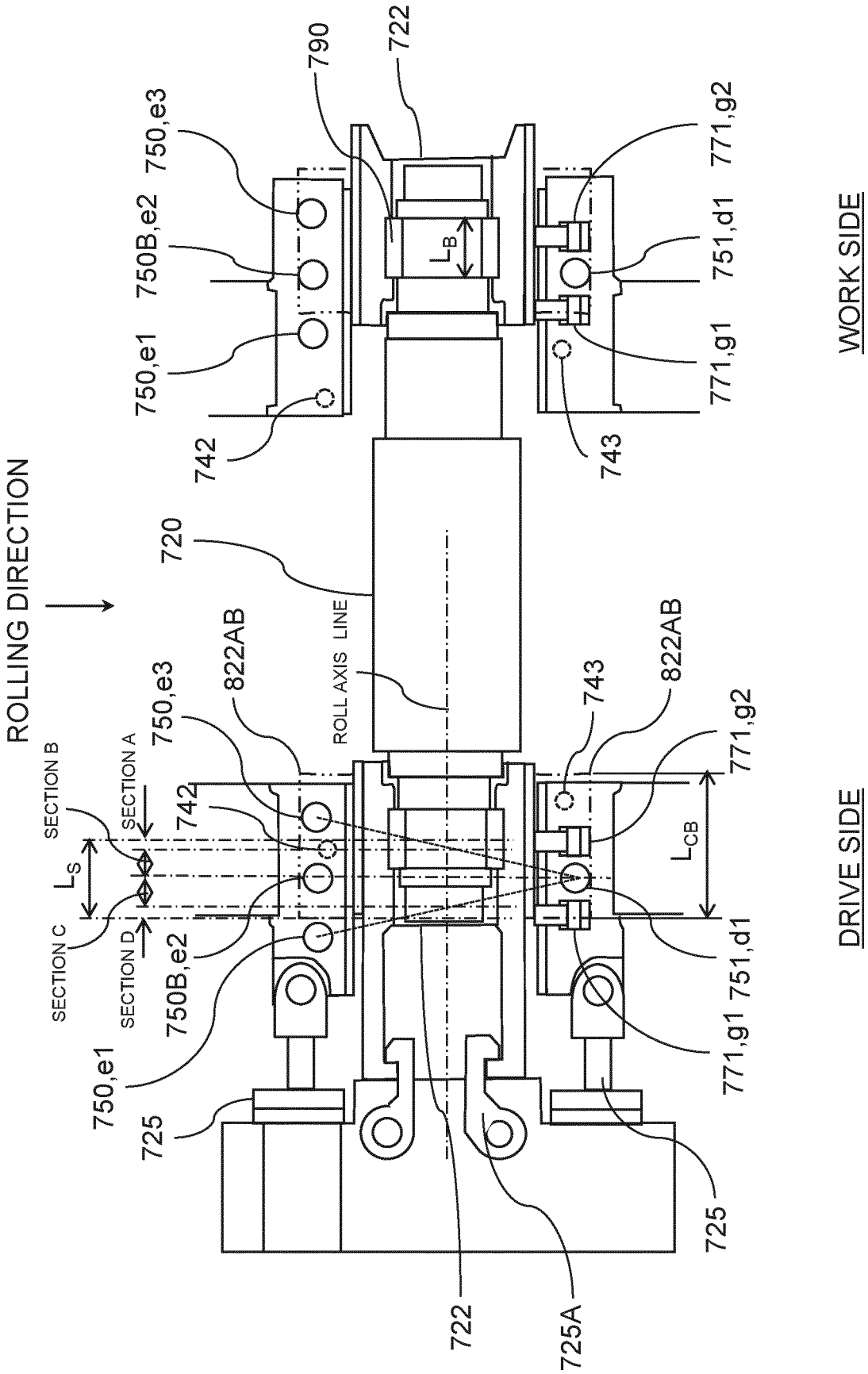

ROLLING DIRECTION
SECTION B
SECTION A
SECTION C
SECTION D
L_S
ROLL AXIS LINE
720
790
722
750,e3
750B,e2
750,e1
742
743
725
725A
822AB
771,g2
771,g1
751,d1
L_B
L_{CB}
WORK SIDE
DRIVE SIDE

Fig 10

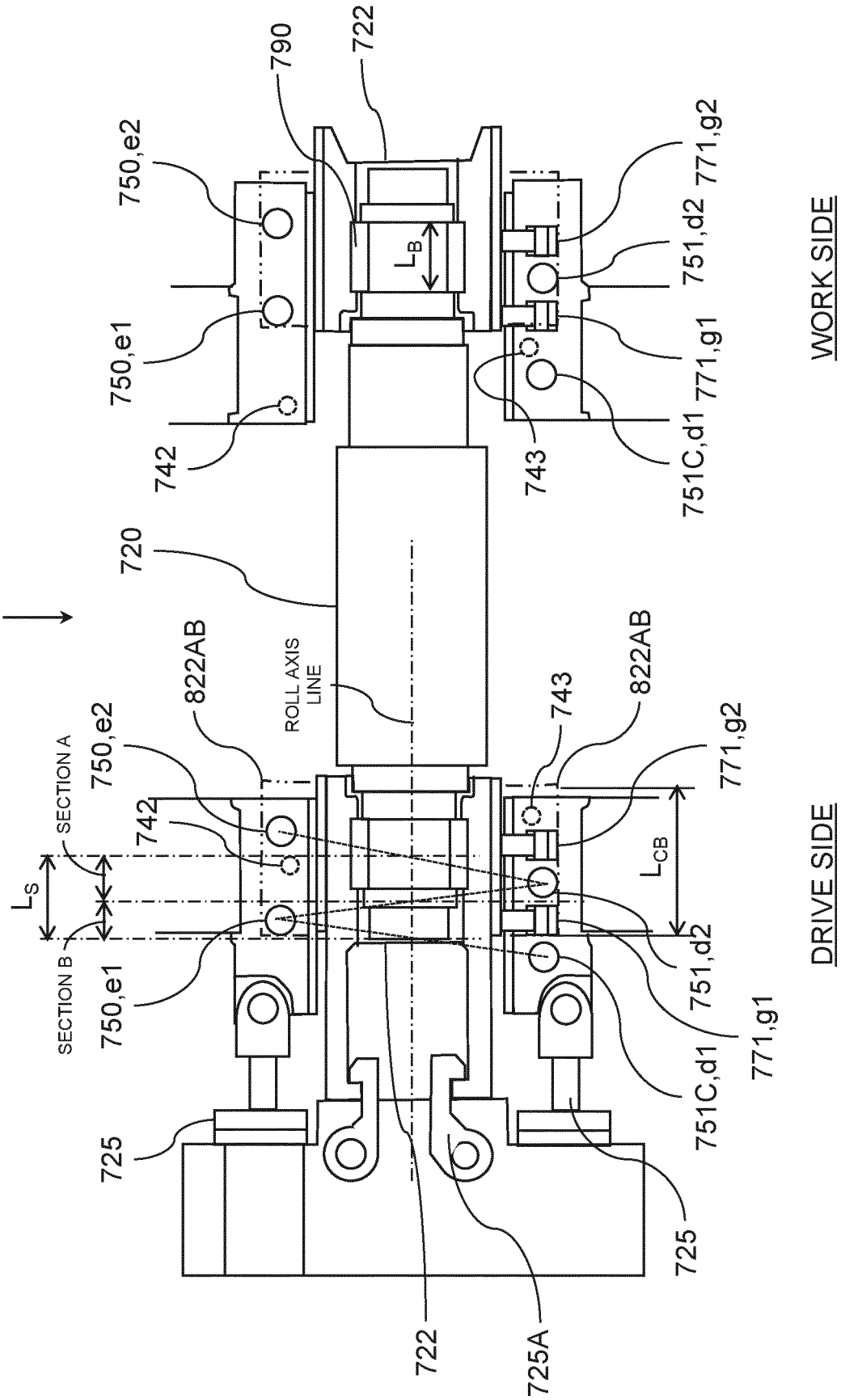
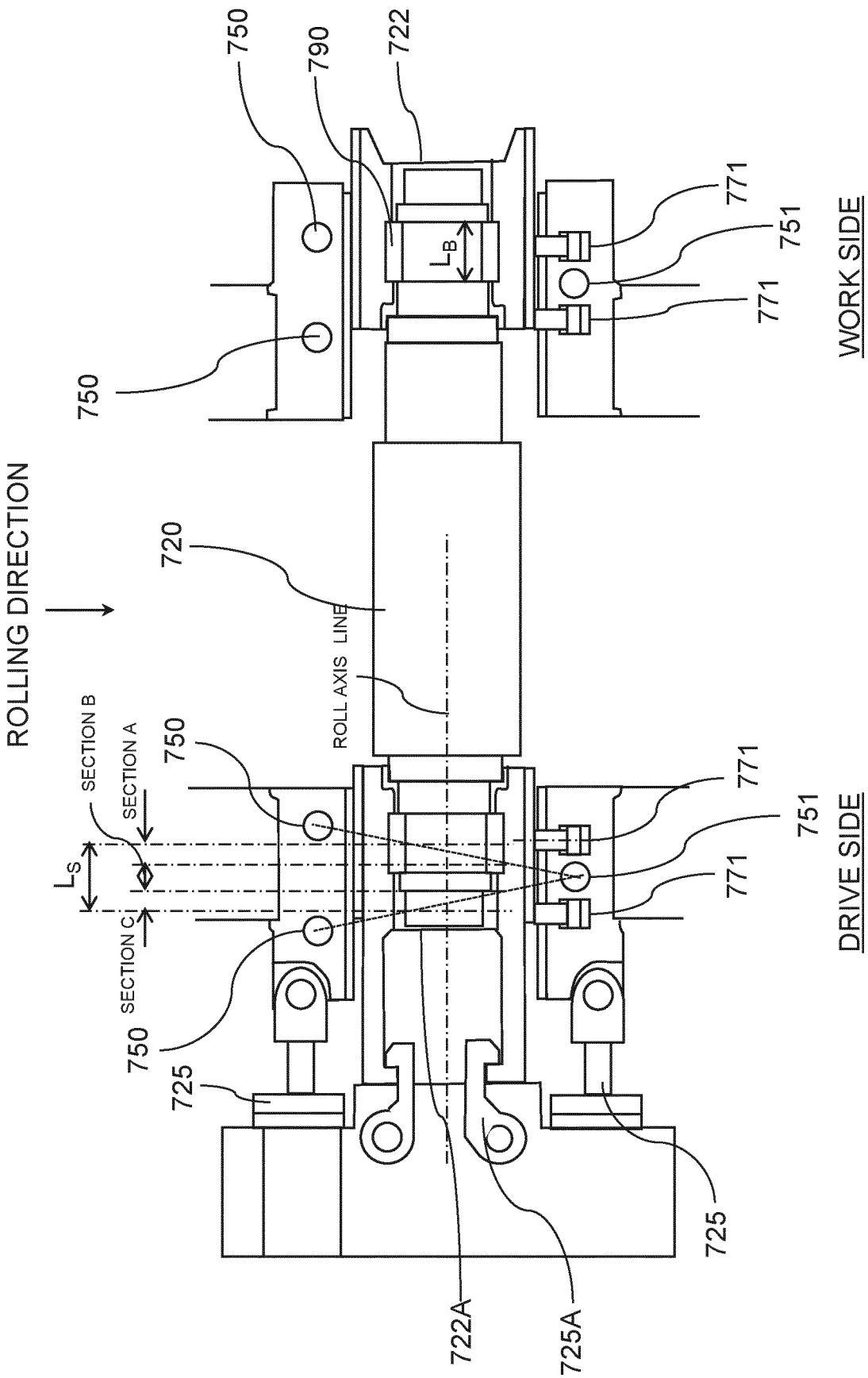

ROLLING DIRECTION
SECTION A
SECTION B
L_S
L_B
L_{CB}
ROLL AXIS LINE
790
722
750,e2
750,e1
742
720
822AB
743
771,g2
751,d2
771,g1
751C,d1
725
725A
WORK SIDE
DRIVE SIDE

Fig 11


ROLLING DIRECTION
SECTION B
SECTION A
SECTION C
L_S
L_B
ROLL AXIS LINE
750
790
722
771
751
720
725
722A
725A
WORK SIDE
DRIVE SIDE

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/041943

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. B21B31/18(2006.01)i, B21B29/00(2006.01)i, B21B37/42(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. B21B31/18, B21B29/00, B21B37/42

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2019
Registered utility model specifications of Japan 1996-2019
Published registered utility model applications of Japan 1994-2019

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 63-55369 B2 (HITACHI, LTD.) 02 November 1988, claim 1, fig. 2 (Family: none)	1-10
A	JP 2000-015310 A (DANIELI UNITED A DIVISION OF DANIELI CORP.) 18 January 2000, claim 1, paragraph [0013], fig. 1-5 & US 5924319 A, claim 1, column 3, lines 33-43, fig. 1-3 & EP 09970761 A2	1-10
A	JP 02-070311 A (HITACHI, LTD.) 09 March 1990, claim 1, fig. 1 (Family: none)	1-10

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07.11.2019	19.11.2019
Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/041943

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2011/122069 A1 (NIPPON STEEL CORP.) 06 October 2011, paragraphs [0032], [0033], fig. 1-3 & EP 2554282 A1, paragraphs [0033], [0034], fig. 1-3 & CN 102821881 A	1-10

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 63055369 B **[0003]**