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(54) **A method and an apparatus for manufacturing wire**

Verfahren und Vorrichtung zur Herstellung von Draht

Méthode et dispositif de fabrication de fil

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Description

[0001] This invention relates to a method and an apparatus for manufacturing wire, particularly for manufacturing wire with a diameter less than 5.5 mm

Background of Invention

[0002] As conventional methods for manufacturing metal wire, metal drawing process, metal rolling process and combinational process of said two ones have been known. The metal drawing method has been used mainly for manufacturing fine wire, wherein work material is successively drawn trough a plurality of drawing dies, wherein the sizing passes successively decreases. On the other hand, in the metal rolling process, work material is successively rolled by a plurality of roller-couples which are alternately arranged so that the angle between the roller axes of adjacent roller-couples is almost 90°. This process achieves a higher productivity in comparison with the metal drawing process.

[0003] In many cases of the metal rolling process, the two rollers of each roller-couple have grooves on their rolling surfaces, respectively, which form a sizing pass for determining the cross sectional shape of resulting wire. By using an oval shape of sizing pass for upstream roller-couple and a circular shape of sizing pass for downstream one in adjacent roller-couples, a high wire productivity is achieved since the reduction of area against the work material at each pass of rolling increases.

[0004] The metal rolling process, however, has a problem that work material (or wire) is sometimes twisted when it is introduced to the downstream roller-couple from the upstream one. The tendency of occurring such twisting is rather high in the case that the shapes of the sizing passes are different between upstream and downstream roller-couples, particularly in the case of a combination of oval-circular sizing passes. Anyway, the twisting of work material may lead to such trouble as irregular cross section of resulting wire or cutting off of the material.

[0005] One of effective methods for preventing the work material from twisting is using auxiliary roller guides for guiding the introduction of the work material to the roller-couple. However, the size of the roller guides becomes smaller with decreasing the diameter of resulting wire, and it becomes substantially impossible to use such roller guides when the diameter of the wire is less than 5.5 mm, so that it has been regarded very difficult to produce fine wire with a diameter less than 5.5 mm through the metal rolling process. Therefore, in the process of the prior art for manufacturing such fine wire, first the work material is rolled to the diameter around 5.5 mm, and next drawn by using drawing dies to a designated diameter less than 5.5 mm. This process, however, has a disadvantage that the high productivity of the metal rolling process is reduced because the metal drawing process, whose productivity is rather low, should be combined. Furthermore, the metal drawing process can be applied only for the cold working process, so that for producing wires of work-difficult materials such as high speed tool steel or high alloy steel, stress relief annealing should be performed every designated number of drawing passes, so that the productivity becomes further worse.

[0006] European Patent Application Publication No. 0 543 479 A1 the features of which constitute the preamble part of independent claim 1 discloses a rolling mill comprising a plurality of roll stands arranged along a mill pass line, each roll stand having at least a first pair of work rolls mounted thereon. An oval-round work sequence is performed by roller-couples being dislocated by 90° each other so that an oval-round working sequence is performed, each roller-couple being supported by a single roller stand. Any odd roller couple (R1, R3, R5, ...) works a round cross-section into an oval cross-section while any subsequent even roller-couple (R2, R4, R5, ...) works the oval cross-section of its preceding odd roller couple into a round cross-section. Any conventional odd roller stand having one (oval-rolling) roller couple might be replaced by a modified roller stand having two roller couples both working in the same direction. An interval "A" between the preceding even (round-rolling) roller-couple stand and the modified roller stand is decreased in order to address a twisting tendency of the wire.

[0007] Further information about the prior art may be found in European Patent Application Publication No. 0 519 470 A2 which discloses a method of and an apparatus for producing wire of 5 mm or smaller diameter, using a continuous rolling mill comprising a plurality of round-grooved four-roll stands arranged one after another, wherein the grooved four-roll is displaced between adjacent roller-quadruple stands by 45° relative to each other around the pass line and the center-to-center distance between adjacent rolling stands measured in the pass line direction is not greater than 50 times the diameter of the rod.

[0008] The object of this invention is to offer a method and an apparatus for manufacturing wire with a diameter less than 5.5 mm which achieves a high productivity and high quality of wire by further suppressing a twisting tendency of the work material.

Summary of the Invention

[0009] The object of the invention is achieved by the features of independent claims 1 and 27. Further advantageous developments and embodiments of the invention constitute the subject-matter of the claims dependent therefrom.

[0010] The invention of independent claims 1 and 27 provides a method and an apparatus for manufacturing wire by rolling work material successively with a first roller-couple and a second roller-couple being arranged

spaced apart in the feeding direction of the work material. An angular position of rotational axes of the first roller-couple is different from that of the second roller-couple so that the work material is rolled in different directions each other, and shapes and/or positional relations of respective rollers of the first and second roller-couples are formed such that the shape of the cross section of the rolled wire after the first roller-couple is different from that after the second roller-couple. The first and second roller-couples are arranged such that a ratio of L/D, where L.is the center distance between the first and second roller-couples, and D is the wire diameter obtained after rolling the second roller-couple, is less than 30. The shapes and/or positional relations of respective rollers of the first and second roller-couples are formed such that wire obtained after the second roller couple comprises a substantially round or square cross-section and a resulting diameter D of less than 5.5 mm.

[0011] By arranging the first and the second roller-couples to be spaced apart with L/D less than 30 the work material may be effectively protected from said twisting during rolling without using any roller guides, thereby enabling production of wire with a diameter less than 5.5 mm by a metal rolling process and achieving very high efficiency of production of such fine wire in comparison with conventional method such as metal drawing process.

[0012] Furthermore, the reduction of area of the work material achieved by each roller-couples is set in a range of 5 - 35%. The reduction of area less than 5% leads to a poor wire productivity, and that exceeding 35% causes excess degree of working which may lead to a generation of faults in the work material or damaging the rollers. The reduction of area is preferably set in a range of 10 - 30%.

[0013] The apparatus of this invention comprises said first and second roller-couples. At least one of the first and second roller-couples can be constructed so as to comprise two rollers each of which has a groove on the circumferential surface thereof for forming a sizing pass, which determines the cross sectional shape of the wire. According to this construction, the cross section of the wire may be precisely formed in a designated shape. The optimization for the shapes of the sizing passes of the first and the second roller-couples may improve the wire productivity with maintaining high accuracy of dimension and good working condition of the wire since high reduction of area may be achieved for each pass of rolling.

[0014] For achieving a wire diameter less than 5.5 mm, the width of the grooves is set to be less than 7 mm for the first roller-couple and less than 6 mm for the second roller-couple. On the other hand, the wire may by produced by using a roller-couple having flat rolling surfaces without grooves. In this case, the clearance formed between two rollers is less than 7 mm for the first roller-couple and less than 6 mm for the second roller-couple. In both of the constructions, the center distance between the first and the second roller-couples, L, is set to be less than 50 mm. An adjacent arrangement of the first and the second roller-couples with the center distance L less than 50 mm may effectively protect the work material from said twisting during rolling.

[0015] For preventing the work material from twisting, the center distance L is preferably set to be as short as possible with a range where no interference occurs between the adjacent roller-couples. Specifically, the center distance L can be determined according to the outer diameter of each roller. When the outer diameter, d, of the rollers of the first roller-couple is the same as that of the second roller-couple, the ratio L/d is preferably set to be less than 1.2, and more preferably less than 1.0.

[0016] The first and second roller-couples may be arranged alternatingly so that the angle between the rotation axes thereof is almost 90°. More specifically, the first roller-couple can be constructed so as to roll the work material so that the cross sectional dimension of the work material in a direction of rolling reduction, D1, becomes shorter than that in a direction perpendicular to the direction of rolling reduction, D2, and the second roller-couple rolls the work material so that the ratio of the dimensions, D2/D1, is decreased. According to this configuration, a high reduction of area may be achieved for each pass of rolling, whereby the wire productivity improves.

[0017] The sizing passes may be formed in different shapes between the first and the second roller-couples, whereby the wire productivity improves while a high dimensional accuracy and a good working condition are maintained. For example, the sizing pass may be formed in an oval shape for the first roller-couple and in a circular shape for the second roller-couple. Such configuration of sizing passes achieves high dimensional accuracy and productivity of wire having a circular cross section.

[0018] The apparatus can be constructed so that a plurality of roller-couple units each of which comprises the first and the second roller-couples can be arranged in the feeding direction of the work material, and the work material may be successively rolled by the roller-couple units. According to such configuration, the work material can be rolled successively, so that fine wire may be produced even from work material with a large cross section.

[0019] The final diameter of the wire produced is preferably set in a range of 1.30 - 5.40 mm for achieving high dimensional accuracy of wire and for suppressing the frequency of faults in the resulting wire, whereby the superiority in wire productivity against the conventional method, such as the metal drawing process, becomes very significant.

[0020] Although the variety of the work material is not limited to a particular one, this invention is particularly advantageous for producing wire of work-difficult iron-based materials, such as high speed tool steels, stainless steels and other high alloy steels, whose efficient

production has been regarded to be difficult. However, this invention can be applied also to any other iron-based material such as soft steels, cold-workable carbon steels, alloy tool steels, and non-iron based metals such as Ni alloy and Ti alloy (for example, Ni-Ti based shape memory alloy), and so on.

[0021] The rolling temperature of the work material can be chosen arbitrarily according to the variety thereof. For a material with a high deformation resistance at a room temperature, a high rolling temperature is preferable for improving wire productivity since the deformation resistance decreases thereby increasing the reduction of area. Furthermore, such high rolling temperature may suppress the increase in the work stress according to the recovery or the recrystarization of the work material during rolling, so that no process annealing for stress relief or for reducing hardness is needed, whereby the advantage in the productivity becomes more significant.

[0022] In the case of iron-based work material, the temperature of the material when it is introduced to the first roller-couple is preferably adjusted in a range of 400 - 1300°C. The temperature below 400°C makes the effect of decreasing the deformation resistance insufficient, and that over 1300°C causes oversoftening of the work material which leads to buckling or twisting thereof, so that normal rolling becomes impossible.

[0023] In the case of using a plurality of roller-couple units for successively rolling the work material, the temperature of the material can be maintained in the temperature range mentioned above when it is introduced into the first roller-couple of the first unit.

[0024] Several kinds of work material have further preferable temperature range for rolling. For example, high speed tool steels is preferably rolled in a range of 800 - 1150°C. Rolling temperature below 800°C deteriorates not only the deformation resistance of the material but also the ductility, toughness and post-quenching hardness of the material since micro-voids are formed in the texture of the material due to cracking of carbides. On the other hand, temperature over 1150°C causes coarsening of carbides in the texture of the material, which decreases the strength of the wire obtained.

[0025] The rolling process according to the method of this invention may comprise steps of continuously removing scale formed on work material in feeding by using a scale-removing device arranged on the passage of said work feeding, and heating the work material after the removal of the scale by using a heating device which comprises an electrode contacting with the work material allowing continuous feeding thereof and sending electric current into the work material through the electrode for resistance-heating of the work material. The heated work material is rolled by using a rolling mill so that resulting diameter of wire is less than 5.5 mm. Since the scale formed on the work material is preliminarily removed and then heated by a resistance heating method through the electrode, the contact between the work material and the electrode becomes reliable and stable, and spark generation is suppressed therebetween, so that high quality of fine wire can be produced with a large yield.

[0026] The heating step may be performed so that the work material in feeding is heated by a heating device which is arranged on the passage of said transportation and comprises an induction heating coil. This configuration comprises no electrode contacting with the work material, so that no spark occurs during heating whereby fine wire can be produced with high quality and a large yield.

[0027] The distance between the heating device and the rolling mill is preferably set to be less than 4 m. In the hot-rolling process for fine wire, the heated work material tends to be cooled quickly because of its small diameter. In this case, work-difficult materials, such as high speed tool steels, stainless steels, super alloys, Ti alloys (for example, Ti-Ni based shape memory alloys), and so on, have considerable narrow temperature range suitable for hot-rolling and apt to occur cracks or other faults during rolling if the material is cooled below the optimum temperature range. However, when said distance is set to be less than 4 m, the work material can be immediately introduced into the roller-couples, so that said cooling of the material and relating faults may be effectively prevented. The distance between the heating device and the rolling mill is more preferably set to be less than 3 m.

[0028] The apparatus for performing the rolling method mentioned above may comprise the aforementioned rolling mill and following elements:

(1) a scale-removing device which is arranged on the passage of feeding of the work material and continuously removes the scale formed on said work material in continuous feeding; and
(2) a heating device for heating the work material after the removal of the scale comprising an electrode contacting with the work material allowing the feeding thereof and sending electric current into the work material through the electrode for resistance-heating of the work material.

[0029] The scale-removing device may comprise a shot-blasting device which removes the scale by blasting a flow of abrasive particles onto the surface of the work material in continuous feeding. According to this construction, the scale on the surface of the work material can be effectively removed.

[0030] The heating device can be constructed so as to comprise a roller electrode which contacts with the work material and sends electric current into the work material for its resistance-heating and an urging mechanism which urges the roller electrode against the work material. According to this construction, the contact between the roller electrode and the work material becomes more reliable. In this case, a groove is preferably

formed on the circumferential surface of the roller electrode for guiding the feeding of the work material. The urging mechanism may be constructed as a spring mechanism or a pressure cylinder mechanism comprising an air or hydraulic cylinder. The pressure cylinder mechanism comprising an air cylinder is particularly preferable since the urging pressure of the roller electrode against the work material can be adjusted easily.

[0031] The heating device may be constructed so as to comprise an induction heating coil for heating said work material in continuous feeding which is arranged on the passage of the feeding.

[0032] The rolling reduction against the work material by each roller-couple can be varied according to the variety of the work material, and the ratio, R1/R2, where R1 and R2 are roller-rotation rates in the first and second roller-couple, respectively, can be adjusted according to the rolling reduction. In this case, the rolling reduction and the ratio R1/R2 can be varied according to the torsional rigidity of the work material. The function and effect of this configuration is as follows.

[0033] The probability of occurrence of the wire twisting specifically depends upon the torsional rigidity of the work material. For example, as is shown in Fig.30 (a), when the rolling reduction is increased for the first roller-couple, the work material (A1) is deformed largely in the direction of the compression (or rolling) between the rollers. The resulting shape of the cross section of the work material is to be elongated along the direction perpendicular to said compression and cause a significant twisting torque upon the work material when a secondary rolling is performed in the direction crossing to the primary one. This means that a work material having a low torsional rigidity is apt to be twisted when the rolling reduction is increased for the first roller-couple. Therefore, such twisting of wire may be effectively prevented by adjusting the rolling reduction according to the variety of the work material, particularly to the torsional rigidity thereof.

[0034] In this case, the change in the rolling reduction at the first roller-couple causes a change in the reduction of area achieved thereat, so that the feeding rate of the work material from the first roller-couple, i.e., the feeding rate to the second roller-couple should be also changed. Therefore, by changing the rotation rate of the second roller-couple corresponding to the change in the feeding rate of the work material, i.e., by changing the ratio R1/R2, the rolling may be performed smoothly upon the work material even if the rolling reduction is varied.

[0035] On the other hand, the resulting wire diameter can be varied in a designated range by changing the rolling reductions in the first and second roller-couples against the work material in a corresponding range. According to this construction, there is no need to substitute current rollers with other ones having different configuration of sizing pass for changing the wire diameter, whereby wires having various diameter can be produced efficiently.

[0036] In the case that the ratio of roller rotation rates R1/R2 is fixed in a designated value, the total rolling reduction against said work material by the first and second roller-couples can be varied so that resulting change in the reduction of area of the work material is within 10 %. Even if the rolling reduction is changed at a fixed value of R1/R2, the rolling can be maintained in a excellent condition. In other words, the wire diameter can be changed without changing the sizing pass of the roller-couple as long as the change in the reduction of area is within 10%. This contributes significantly for increasing productivity of wires having various diameters. In this case, the change in the rolling reduction is preferably maintained within 7%.

[0037] If the ratio R1/R2 is varied according to the value of the total rolling reduction against the work material, the total rolling reduction can be varied so that resulting change in the reduction of area of said work material is up to 40 %. When the rolling reduction exceeds certain upper limit, the reduction of area at the first roller-couple increases, whereby the increase in the feeding rate of the work material from the first roller-couple, i.e., to the second one becomes no longer negligible. However, if the roller-rotation ratio R1/R2 is changed corresponding to the change in said transportation rate, the rolling can be performed smoothly even the rolling reduction is changes in such wider range. In this case, the shapes and/or sizes of sizing passes of the first and the second roller-couples are preferably changed according to the value of said total rolling reduction against said work material for maintaining the cross sectional shape of the resulting wire in a good condition.

[0038] In the case of changing R1/R2, the first and the second roller-couples can be driven by a common driving means through a first and a second reduction gear systems, respectively, and the inter-stand reduction ratio, Q1/Q2, where Q1 is the reduction gear ratio of said first reduction gear system and Q2 is the reduction gear ratio of said second reduction gear system, may be varied for changing the ratio R1/R2. According to this configuration, a common driving means is used for the first and the second roller-couples, so that the construction of the apparatus becomes simple.

[0039] Furthermore, in a configuration wherein a plurality of roller-couple units each of which comprises the first and second roller-couples are arranged in the feeding direction of said work material and the work material is successively rolled in each roller-couple units, the inter-stand reduction ratios Q1/Q2 of the roller-couple units can be changed synchronously. In this construction, when the inter-stand reduction ratio is set in a designated value for one of roller-couple units, the inter-stand reduction ratios for other roller-couple units are also set in corresponding values synchronously. According to this construction, even in the case of using many roller-couple units, the roller reductions and inter-stand reduction ratios may be easily changed corresponding to the torsional rigidity of the work material,

and so on.

[0040] The clearances between two rollers of the first and second roller-couples can be changed by a roller-clearance adjusting mechanism which moves the two rollers of each roller-couple relatively to and from each other in the direction of rolling reduction. Such roller-clearance adjusting mechanism can be constructed so as to comprise bearing portions which rotatively support the shafts of the two rollers, respectively, and a bearing rotation mechanism which rotates each bearing portion around an eccentric axis deviated from a corresponding roller axis in opposite direction, respectively, thereby moving the two rollers relatively to and from each other. This configuration accomplishes a simple and compact mechanism for changing the roller spacing.

[0041] The bearing rotation mechanism for the first roller-couple can be arranged upstream of the first roller-couple, and that for the second roller-couple can be arranged downstream of the second roller-couple. This configuration is preferable for accomplishing the proximate arrangement of the first and the second roller-couples with a center distant L within 50 mm since no bearing rotation mechanism is located between these roller-couples, so that there is no need to prepare auxiliary roller guides for guiding the work material to the second roller-couple.

[0042] The bearing rotation mechanism can be constructed so as to comprise first gear portions which are formed on the circumferences of the bearing portions of the two rollers, respectively, second gear portions each of which engages with corresponding first gear portion, and a driving mechanism which rotates the second gear portions synchronously in opposite directions each other.

[0043] The second gear portions can be specifically constructed as worms which are axially formed on a worm rotating shaft at an designated intervals along the longitudinal direction thereof and whose threads are formed in opposite directions each other. The driving mechanism drives the worm rotating shaft for rotating said worms integrally. This configuration accomplishes a simple and compact construction of the bearing rotation mechanism.

[0044] In a further specified construction of the apparatus according to the invention, the bearing portion comprises bearing casings which are arranged corresponding to both end portions of each roller shaft and each of which has a bearing accommodating hole extending along said roller shaft, a bearing main body which is accommodated in each said bearing accommodating hole. In this construction, a bearing hole is formed in each bearing main body so that the center of said bearing hole is deviated from the rotation axis of the bearing main body. Each end portion of each roller shaft is rotatively supported in the bearing hole, and the bearing main body has the first gear portion on its circumference and is rotated by the worm engaged with the first gear portion around an eccentric axis deviated from the rotation axis of the roller.

[0045] The bearing hole of the first roller couple can be formed in the bearing main body deviated from its rotation axis in the downstream, and the bearing hole of said second roller couple can be formed in the bearing main body deviated from its rotation axis in the upstream. In addition, each corresponding worm rotating shaft van be arranged in the similar manner. This configuration is preferable for accomplishing the proximate arrangement of the first and the second roller-couples.

[0046] At least one of said first and second roller-couples can be equipped with a roller thrust adjusting mechanism which moves the two rollers relatively in the thrust direction thereof and hold these two rollers at an arbitrary positions in the thrust direction. As is shown in Fig. 19 (b), the thrust displacement between two rollers of the roller-couple is one of major factor of causing wire twisting during rolling. In this case, as shown in Fig.19 (a), if these two rollers (101a, 101b) are precisely positioned, the distance line (U1, U2) between the inner surfaces of the grooves (161a, 161b) of said two rollers trough the center (O) of the sizing pass (161c) becomes uniform, thereby providing uniform compression against the work material. Therefore; the twisting of the work material becomes to be difficult to occur since the twisting torque against the work material is suppressed.

[0047] Such adjustment of the two rollers in the trust direction can be performed by using said roller thrust adjusting mechanism, and the thrust displacement in these two rollers can be dissolved by an adjustment of the position of each roller (thrust adjustment, hereinafter). On the other hand, such roller displacement in the thrust direction may causes an irregularity of the cross sectional shape of the resulting wire. However, aforementioned thrust adjustment of the rollers can simultaneously dissolve such problem. Furthermore, even if the surface accuracy of the sizing pass is not very high, a designated revel of the dimensional accuracy of the wire can be secured by such thrust adjustment.

[0048] The roller thrust adjusting mechanism can be constructed so as to comprise a fixed bearing portion which is provided for at least one of the two rollers and holds the roller shaft rotatively and movably in its thrust direction, and a roller sliding mechanism which is connected to one end portion of the roller shaft and slides the roller shaft against the bearing portion in the thrust direction.

[0049] The roller sliding mechanism can comprise a shaft holder to which the end portion of the roller shaft is connected and which is movable integrally with the roller shaft in the thrust direction, adjusting screw mechanism which is connected to the shaft holder directly or indirectly with other member and moves the shaft holder in the thrust direction according to its screwing or unscrewing operation. According to the operation of such adjusting screw mechanism, said thrust adjustment of the rollers can be easily performed.

[0050] A further specified configuration can be con-

structed as follows. The bearing portion comprises a bearing main body which has a through hole as a bearing hole in the direction of the roller shaft and rotatively supports the one end portion of the roller shaft in the through hole. The shaft holder is movable in the through hole with the roller shaft in the thrust direction. The shaft holder has a shaft-like protruding portion which extends along the axial direction of the roller shaft in the through hole and the end portion of which protrudes outside from the corresponding opening of the through hole. On the inner side of the through hole, a female threaded portion is formed on the end portion thereof leading to the opening. A male screw member is screwed on the female threaded portion in a position corresponding to the intermediary part of the shaft-like protruding portion. A stopper is mounted on the shaft-like protruding portion for preventing the male screw member from its relative moving against the shaft-like protruding portion in the axial direction thereof. The adjusting screw mechanism moves the shaft holder and the roller shaft in the thrust direction along with the male screw member according to the rotation of the male screw member. The adjusting screw mechanism becomes compact according to this configuration.

Brief Description of Drawings

[0051] In the accompanying drawings:

Fig.1 is a perspective view presenting the main part of one embodiment of the apparatus of this invention;
Fig.2 is a schematic view presenting the cross sectional shape of the sizing passes of the first and the second roller couples;
Fig.3 is a top view presenting the main part of one embodiment of the apparatus of this invention;
Fig.4 is a cross sectional side view presenting one embodiment of the apparatus of this invention;
Fig.5 is a schematic top view presenting the bearing rotation mechanism in Fig.4;
Fig.6 is a cross sectional side view of the first roller stand;
Fig.7 is a front view presenting the arrangement of the bearing main body and the worm rotating shaft;
Fig.8 is a schematic side view of Fig.7;
Fig.9 is a schematic top view presenting the states of the first roller-couple for rolling wires with various diameters;
Fig.10 is a schematic view presenting several modifications of the shape of the sizing pass;
Fig.11 is a schematic view presenting other example of the change in the cross sectional profile of work material;
Fig.12 is a top view conceptually presenting an apparatus comprising a plurality of roller-couple units;
Fig.13 is a schematic view presenting several examples of the change in the cross sectional profile of work material according to a successive rolling by the plural roller-couple units;
Fig.14 is a perspective view presenting the main part of an embodiment of the apparatus having flat rollers;
Fig.15 is a figure explaining the function of the first and second roller-couples in Fig.14;
Fig.16 is a cross sectional side view of an apparatus equipped with a roller thrust adjusting mechanism;
Fig.17 is a figure explaining the function of the roller thrust adjusting mechanism;
Fig.18 is an another figure explaining the function of the roller thrust adjusting mechanism;
Fig.19 is a figure explaining the influence of thrust displacement of the rollers upon the work material;
Fig.20 is a sectional view conceptually presenting one embodiment of a hot-rolling line for wire production;
Fig.21 is a schematic view of a shot-blasting device;
Fig.22 is a figure presenting a main part of an example of resistance-heating device with along the function thereof;
Fig.23 is a schematic view presenting an example of a heating device comprising movable roller electrode
Fig.24 is a figure explaining the function of the heating device in Fig.23;
Fig.25 is a figure of an induction heating device;
Fig.26 is a side view conceptually presenting a rolling apparatus equipped with a distributor and a reduction gear mechanism;
Fig.27 is a schematic view presenting the reduction gear mechanism;
Fig.28 is a figure explaining the method to change the inter-stand reduction ratio;
Fig.29 is a figure presenting how the inter-stand reduction ratios of plural roller-couple units are changed synchronously;
Fig.30 is a figure explaining how the wire twisting occurs;
Fig.31 is a figure presenting how the wire diameter is varied by changing in the roller-spacing.

Detailed Description of the Preferable Embodiments

[0052] Several embodiments of this invention will now be described with reference to drawings.

[0053] Fig.1 presents the main part of one embodiment of the apparatus regarding this invention for manufacturing wire by metal rolling process ("rolling apparatus", hereinafter). In the rolling apparatus 1, a first roller stand (horizontal stand) 12 comprising a first roller-couple 101a,101b is arranged on an unillustrated mill floor so that the roller axes is almost vertical to the mill floor, and a second roller stand (vertical stand) 14 comprising a second roller-couple 102a,102b is arranged adjacently to the first roller stand 12 on the downstream thereof along the feeding passage of work material A1

so that the roller axes is almost horizontal. These roller stands 12 and 14 construct a roller-couple unit S1. The angle between the roller axes of adjacent roller-couples 101a,101b and 102a,102b is almost 90°.

[0054] As shown in Fig.2, the roller-couples 101a, 101b and 102a,102b have rolling surfaces 151a,151b and 152a,152b on respective circumferences, and grooves 161a,161b and 162a,162b for determining the cross sectional shape of resulting wire are formed on respective rolling surfaces 151a,151b and 152a,152b. The width W1 of the grooves 161a,161b is less than 7 mm, and the width W2 of the grooves 162a,162b is less than 6 mm. As is shown in Fig.2 (a), in the first roller-couple 101a,101b, an oval sizing pass 161c is formed as the combination of the grooves 161a,161b, and in the second roller-couple 102a,102b, a circular sizing pass 162c is formed as the combination of the grooves 162a, 162b.

[0055] As is shown in Fig.3, the center distance L between the first and the second stands 12 and 14 is less than 50 mm, and the ratio of L/d, where d is the outer diameter of the rollers 101a,101b and 102a,102b, is less than 1.2.

[0056] Fig.4 is a cross sectional side view of the first and the second roller stands 12 and 14. These two roller stands 12 and 14 have almost the same configurations except for the direction of the roller axes. Therefore, the detailed description is presented only for the first roller stand 12, and the same portions or the members of the second roller stand 14 are indexed with the same numerals as those for the first one.

[0057] In the first roller stand 12, a pair of bearing casings 24 are arranged on both sides of the feeding passage (or pass line) PL of the work material A1. Each bearing casing 24 has a bearing accomodating hole 24a formed along the direction intersecting with the pass line PL. Each bearing accomodating hole 24a rotatively accommodates a bearing main body 26 wherein a through hole 26a as a bearing hole is eccentrically formed. In these through hole 26a, both end portions of a roller shaft 28 are rotatively supported by a bearing 30, respectively. On the intermediary portion of the roller shaft 28, a roller 101a (or 101b: represented by 101a, hereinafter) is integrally mounted. As shown in Fig.5 (a), the axis C1 of the roller shaft 28 is located deviating from the axis C2 of the bearing main body 26 at a designated distance. The axes C1 for rollers 101a,101b in opposite direction are to be displaced by the rotation of the corresponding bearing main bodies 26 according to the mechanism described later on.

[0058] As shown in Fig.4, on the upstream of the roller shaft 28, a pair of worm rotating shaft 32 are arranged in a direction crossing over the roller shaft 28. The worm rotating shaft 32 is provided on each side with respect to the first roller-couple 101a,101b (Fig.1), and as shown in Fig.5, worms 34 are integrally mounted thereon corresponding to upper and lower bearing main bodies 26 and engage with the gear portions 26b formed on the circumferences of the corresponding bearing main bodies 26, respectively (see also Fig.8). As shown in Fig.5, the direction of threads of the two worms 34 on each worm rotating shaft 32 are opposite each other. On the other hand, as shown in Fig.7, the threads of worms 34 corresponding to both end portions of the same roller shaft 28 are formed in the same direction.

[0059] As shown in Fig.7 and Fig.8, on the corresponding end portions of two worm rotating shaft 32,32, gears 36,36 are secured so as to rotate integrally with corresponding worm rotating shafts 32, respectively. These gears 36 engage with an adjusting gear 38 which is rotatively mounted on the bearing casing 24. The adjusting gear 38 is rotated by an unillustrated driving means, such as a motor, whereby said two worm rotating shafts 32,32 rotate simultaneously in the same direction. Thus, as shown in Fig.5 (b), the bearing main bodies 26 rotate around the axis C2 through corresponding worms 34, and the upper and lower roller shafts 28,28 move to or form each other, whereby the clearance between the roller shafts 28,28 i.e, the clearance between the rollers 101a,101b is adjusted.

[0060] As shown in Fig.4, there is no worm rotating shaft 32 as a bearing rotating mechanism is located downstream of the bearing casing 24, where the roller shaft 28 is eccentrically arranged, so that the thickness of the first roller stand 12 is decreased on that side. The thickness of the second roller stand 14 located upstream of the bearing casing 24 is also decreased due to the same reason. Since these two stands 12 and 14 are adjacently arranged so that the small thickness sides thereof are facing to each other, the center distance L between the first and the second roller-couples 101a, 101b and 102a,102b becomes short.

[0061] Now, the operation of the rolling apparatus 1 is going to be explained in the following. As is shown in Fig.1, the work material A1 having a circular cross section with a diameter D0 is introduced to the first roller stand 12 and rolled in the sizing pass 161c so that the shape of the cross section becomes oval as shown in Fig.2 (a). After that, as shown in Fig.2 (b), work material A1 is fed to the second roller stand 14 (Fig.1) and rolled in the sizing pass 162c so that the shape of the cross section becomes circular. Thus, the cross section of the work material A1 successively decreases with alternately varying the shape thereof as circular - oval - circular as shown in Fig.2 (c). The work material A1 is rolled in the first roller stand 12 so that the cross sectional dimension thereof in a direction of rolling reduction, D1 (corresponding to the short axis of oval), becomes shorter than that in a direction perpendicular to the direction of rolling reduction, D2 (corresponding to the long axis of oval). Then, in the second roller stand 14, since the direction of rolling-compression is changed by 90°, the work material A1 is rolled so that the ratio of the dimensions, D2/D1, is decreased (i.e., (D2/D1) > (D2'/D1'), where D1' and D2' are corresponding dimensions after rolling).

[0062] Since the first and the second roller stand 12 and 14 are adjacently arranged so that the center distance L between the first and second roller-couples 101a,101b and 102a,102b is less than 50 mm as shown in Fig.3, the work material A1 from the first stand 12 can be precisely supplied to the second one 14 causing no twisting of itself without any aid of roller guides. The final diameter of produced wire W2 is preferably set in a range of 1.30 - 5.40 mm for achieving high dimensional accuracy of the wire and for suppressing the frequency of the faults in the resulting wire, whereby the superiority in wire productivity to the conventional method such as the metal drawing process becomes very significant. For this purpose, the width W1 of the grooves 161a, 161b (Fig.2) is preferably set to be less than 7 mm, and the width W2 of the grooves 162a,162b is preferably set to be less than 6 mm.

[0063] The roller spacing can be changed in such way as follows (explained according to an example for the first roller stand 12, representatively). As shown in Fig. 9, when the work material A1 is switched to that having a larger cross sectional dimension, A2, the roller-couple 101a,101b should be replaced with the ones 101a', 101b' with wider width of grooves 161a,161b and larger diameter. The distance between the shaft axes is also changed from G1 to G2. According to the construction described above, necessary adjustment can be performed in a very easy operation. That is to say, as shown in Fig.7, the worm rotating shafts 32,32 are rotated in the same direction forwardly or reversely by the driving means through the gears 36 and the adjusting gear 38. Then, as shown in Fig.5 (a) and (b), the bearing main bodies 26 rotate around the axis C2, the upper and the lower roller shafts 28,28 moves to or from each other according to the rotation direction of the bearing main bodies 26, whereby the roller clearance is adjusted. The roller-couples can be driven independently by corresponding motors for the adjustment of said clearance.

[0064] The combination of the sizing passes 161c and 162c is not limited to the oval-circular one. Fig.10 presents an example of combination of rhombic and square sizing passes 161c and 162c. The work material is to be rolled into wire A2 having a square cross section. Furthermore, according to the choice of combination of sizing passes 161c and 162c presented in Fig.11, the work material A2 can be rolled successively changing the cross section as square-oval-circular, and so on.

[0065] As shown in Fig.12, the wire A2 rolled in the first roller-couple unit S1 can be further rolled into wire A3 having a smaller diameter by using another similarly constructed roller-couple unit S2 which comprises roller stands 212 and 214 having smaller sizing passes and is arranged adjacently to the first one S1 on the downstream thereof. For performing further many steps of successive rolling, more than three roller-couple units can be arranged in a series along the work feeding direction. In this case, the plural roller-couples are alternately arranged so that the angle between the roller axes of adjacent roller-couples is almost 90°.

[0066] In the case of using a plurality of roller-couple units, although the same combination of the sizing passes can be used for all roller-couple units, different combinations can be also used for each roller-couple unit. Fig.13 presents several example of using two roller-couple units. Fig.13 (a) and (b) are examples of using the same combinations for each units, such as oval-circular or rhombic-rhombic. Fig.13 (c) presents an example of using different combinations such as rectangular-square for the upstream unit S1 and oval-circular for the downstream unit S2.

[0067] As is shown in Fig.14, the wire may by produced by using first and second roller-couples 101a, 101b and 102a,102b which have flat rolling surfaces 151a,151b and 152a,152b without grooves, respectively. In this case, as shown in Fig.15, the clearance W1 between two rollers 101a,101b (i.e., the clearance between the rolling surfaces 151a,151b) is less than 7 mm, and the clearance W2 between two rollers 102a,102b (i.e., the clearance between the rolling surfaces 152a, 152b) less than 6 mm.

[0068] In such construction of the apparatus, as shown in Fig.15, the work material A1 is deformed to be a rectangular cross sectional one due to the compression between the rollers 101a,101b, and then is deformed between the rollers 102a,102b in a direction perpendicular to the first compression, thereby running out therefrom as a wire A2. As shown in Fig.15 (c), the cross section of the work material A1 successively decreases with alternately varying the shape thereof as square - rectangular - square.

[0069] An example of roller thrust adjusting mechanism will now be explained according to an example for roller 101a in Fig.4. As shown in Fig.16, the roller thrust adjusting mechanism 170 is constructed so as to comprise a fixed bearing portion (or a bearing) 30 which holds the roller shaft 28 rotatively and movably in its thrust direction, and a roller sliding mechanism 171 which is connected to one end portion of the roller shaft 28 and slides the roller shaft 28 to the bearing portion 30 in the thrust direction.

[0070] The roller sliding 171 mechanism comprises a shaft holder 172 to which the end portion of the roller shaft 28 is connected and which is movable integrally with the roller shaft 28 in the thrust direction, and an adjusting screw mechanism 173 which is connected to the shaft holder 172 and moves the shaft holder 172 in the thrust direction according to its screwing or unscrewing operation. The shaft holder 172 comprises a bearing 174, a sleeve 175, a holder main body 176, and so on. The bearing 174 is engaged with an annular groove 28a which is formed on the circumferential surface of one end portion of the roller shaft 28, and held by the sleeve 175 from outside which is provided slidable in the through hole 26a in its axial direction. Furthermore, annular rib 175a is formed protruding from the inner surface of the sleeve 175 on one end portion thereof and

engages with the edge portion of the end surface of the bearing 174.

[0071] On the inner surface of the sleeve 175, a female threaded portion 175b is formed in opposition to the rib 175a with respect to the bearing 174. The holder main body 176 connected with the sleeve 175 from inside by means of the male threaded portion 176a which is formed on its circumferential surface and is screwed in said female threaded portion 175b. The bearing 174 is clumped between the rib 175a and the holder main body 176, thereby prevented from loosening in the thrust direction. The roller shaft 28 is slidable integrally with the shaft holder 172 comprising said portion and members 174 - 176 so as to be able to rotate by means of bearing 174.

[0072] A shaft-like protruding portion 177 is integrally formed on the end surface of the holder main body 176. This portion 177 extends along the axial direction of the roller shaft 28 in the through hole 26a, and the end portion thereof protrudes outside from the corresponding opening 26b of the through hole 26a. On the inner side of the through hole 26a, a female threaded portion 26c is formed on the end portion thereof leading to the opening 26b. A male screw member 178 is screwed on the female threaded portion 26c in a position corresponding to the intermediary part of the shaft-like protruding portion 177. The male screw member 178 has a through hole 178a wherein the shaft-like protruding portion 177 is extending in its axial direction, and is rotatably held around the portion 177. These female threaded portion 26c and the male screw member 178 constructs said adjusting screw mechanism 173.

[0073] The end surface of the male screw member 178 is contacting with the edge portion of corresponding end surface of the holder main body 176. On the other hand, the opposite end surface of the male screw member 178 is contacting with a nut 179 screwed on the male thread 177a formed on the outer surface of the protruding portion 177. These holder main body 176 and nut 179 function as a stopper for preventing the male screw member 178 from its relative movement to the shaft-like protruding portion 177 in the axial direction thereof. On the other hand, a lock nut 180 is screwed on the male screw member 178 and secured toward the bearing main body 26 for preventing the male screw member 178 from loosening. Furthermore, the nut 179 also functions as a lock nut for the male screw member 178.

[0074] The adjusting screw mechanism 173 is operated in the following manner for the thrust adjustment of the roller 101a. As shown in Fig.17 (a), for the roller needed to be adjusted (represented by the roller 101a), the lock nut 180 is loosened, and subsequently the nut 179 is loosened so as not to occur an excess loosening thereof in the axial direction. In the case of moving the roller 101a toward the adjusting screw mechanism 173 (right on the figure), the male screw member 178 is rotated so as to move to right on the figure as shown in Fig.17 (b). The male screw member 178 urges the shaft holder 172 and the roller shaft 28 through the nut 179 and moves them integrally to the right. When the new position of the roller 101a is determined, the lock nut 180 and the nut 179 are successively secured in this order, and the operation of the adjustment is to be finished. On the other hand, in the case of moving the roller 101a leaving from the adjusting screw mechanism 173 (left on the figure), the male screw member 178 is reversely rotated. As shown in Fig.18, the male screw member 178 urges the shaft holder 172 and the roller shaft 28 through the holder main body 176, and moves them integrally to the left. When the new position of the roller 101a is determined, the lock nut 180 and the nut 179 are successively secured in this order.

[0075] In the case of using work-difficult materials, such as high speed tool steels, stainless steels, high alloy steel or Ti-Ni based shape memory alloys, it is advantageous to elevate the rolling temperature for decreasing the deformation resistance, whereby improving the productivity of wire. Therefore, the work material can be heated rolling in the first roller stand 12. As is shown in Fig.3, the work material can be heated by a heating device which comprises electrodes 71a,71b contacting with the work material A1 allowing the feeding thereof. Electric current is sent into the work material A1 from the electric power unit 72 through the electrode 71a,71b. The work material is to be heated by its own resistance-heat generation.

[0076] Fig. 20 presents one of preferable embodiments of hot-rolling line 401 for the wire production. This line 401 comprises an uncoiler 2 for drawing the work material A1, such as of a high speed tool steel or a stainless steel, from the coil thereof. The work material A1 drawn off by the uncoiler 2 is fed to a scale removing device 4 via a roller leveling device 3.

[0077] The scale-removing device 4 is constructed as a shot-blasting device. As shown in Fig.21, this device 4 removes the scale from the work material A1 by blasting a flow of abrasive particles 114b from rotary nozzles 114a onto the surface of the work material A1. The abrasive particles 114b is collected at the bottom of the housing 114c, elevated by a bucket conveyor 114d, and then mixed with a gas flow from an unillustrated source, such as a blower, and then supplied to the rotary nozzles 114a again.

[0078] As shown in Fig.20, the work material A1 after the removal of the scale is fed to the heating device 5. As shown in Fig.22, the heating device 5 comprises first and second water cooled roller electrodes 51,52 and 53,54 which contact with the work material A1 and send electric current thereinto for the resistance-heating thereof, corresponding first and second air cylinders 55,56 and 57,58 as urging mechanism which urges said roller electrodes 51,52 and 53,54 against the work material A1, and an electric power unit 59 (Fig.20) as a source of said electric current for heating. On the circumferential surfaces of roller electrode 51-54, grooves 51a-54a are formed, respectively, for guiding the trans-

portation of the work material A1. The cross sections of grooves 51a-54a are formed in a shape corresponding to the shape of the work material A1, for example in a semicircular shape for a work material A1 having circular cross section.

[0079] As is shown in Fig.20, the work material A1 heated by the heating device 5 is rolled by the rolling mill 6 (or the rolling apparatus), cooled in a water-cooling device 7, and then wound in a coil by a coiler 8. In the rolling mill 6, a plurality of aforementioned roller-couple units S are arranged along the direction of material feeding. The distance K between the heating device 5 and the rolling mill 6 is set to be less than 4 m, where K is defined as the distance from the second roller electrodes 53,54 and the entrance of the first roller-couple unit S.

[0080] Now, the operation of the hot rolling line 40 is going to be explained in the following. After leaving the roller levering device 3, the work material A1 is removed the scale in the shot-blasting device 4, and resistance-heated between the first and the second roller electrodes 51,52 and 53,54 to a designated temperature. The material temperature can be controlled by the adjustment of the electric current between the electrodes 51,52 and 53,54.

[0081] Since the scale is preliminarily removed from the surface of the work material A1 by using the shot-blasting device 4, the contact between the work material A1 and the electrodes 51-54 becomes more reliable, whereby spark generation is suppressed therebetween. Furthermore, since the grooves 51a-54a is formed corresponding to the cross sectional shape of the work material A1, the spark generation due to imperfect contact is prevented more effectively. When the cross section of the work material A1 is circular with a diameter of D0, the radius R of the semicircular cross section of the grooves 51a-54a is preferably in the range of $1.05\times(D0/2) \leq R \leq 5.0\times(D0/2)$ for preventing the spark generation.

[0082] When the work material A1 is heated over 1000°C, the deformation resistance of the material becomes considerably low, so that the urging pressure from the second roller electrodes 53,54 is preferably set to be lower than that from the first roller electrodes 51,52 for preventing the work material A1 from undesirable deformation due to the friction from the electrodes, such as buckling. The urging pressure can be adjusted by changing the pressure of the air cylinders 55-58.

[0083] The heating device 5 can be constructed so that at least one of first and second electrodes 51,52 and 53,54 is provided movably in the transportation direction of the work material A1, whereby the interval between the electrodes 51,52 and 53,54 becomes variable during heating of at least one of the tip and the tale end portions of the work material A1. According to this construction, the material yield improves since insufficiently heated part is hardly formed in the tip or the tale end portion of the work material A1.

[0084] In the embodiment presented in Fig.23, the rollers 51,52 and the rollers 53,54 are rotatively mounted on electrode holders 121 and 131, and driven by motors 122 and 132, respectively. The electrode holders 121 and 131 are reciprocated by air cylinders 123 and 133, respectively, in the feeding direction of the work material A1, or in the reverse direction thereof.

[0085] The work material A1 from the scale removing device 4 (Fig.20) is fed to the heating device 5 at a rate v. As shown in Fig.24, electric current is started to be supplied to the work material A1 when the tip end portion thereof is protruded from the second roller electrodes 53,54 by a length 11. As shown in Fig.24 (c) through the state of (b), the air cylinder 133 (Fig.23) retracts a rod 133a thereby moving the roller electrodes 53,54 along with the work material A1 at a rate v', and stops the retraction of the rod 133a when the interval between the electrodes 51,52 and 53,54 ("electrode interval', hereinafter) reaches to a value lo, which is sufficient for accomplishing a designated heating efficiency. Then, as shown in Fig.24 (d), the electrode interval is fixed to 10, and the work material A1 is started to be resistance-heated being transported at the rate v. The tip portion of the work material A1 thus passes through the heating device 5, next the part of length 11 without being resistance-heated and following insufficiently heated part of length 12, i.e., l1+l2 in total, are cut off by an unillustrated cutting device, and then the rest of the work material is supplied to the rolling mill 6.

[0086] On the other hand, when the length of the rest of the work material A1 becomes said l1+l2, the air cylinder 123 starts to move the first roller electrodes 51,52 in the direction of work feeding at the rate v', and when the electrode interval reaches to 12, the cylinder 123 stops moving electrodes 51,52. Then, the electric current supply to the work material is interrupted, and the tale end portion of the work material A1 with a length l1+l2 is cut off by a cutting device. Although the cutting length of respective tip and tale portions of the work material A1 is l0+l1 if the electrode interval is fixed, the cutting length becomes l1+l2 which is much shorter than the aforementioned one according to the construction described above whereby improving the yield of the work material A1 improves.

[0087] Instead of resistance-heating device, the work material A1 can be heated by means of an induction heating device. In this case, the scale removing device 4 and resistance-heating device 5 in Fig.20 is substituted with an induction heating device 44 as shown in Fig. 25. The induction heating device 44 is formed in a tunnel-like configuration having an entrance 44a and an exit 44b, and comprises an induction heating coil 44c. The work material A1 entered therein from the entrance 44a is continuously heated by the induction heating coil 44c and runs out from the exit 44b. In this case, if the distance from the exit 44b to the rolling mill 6 is set to be less than 4 m, the cooling of the work material A1 can be effectively suppressed.

[0088] Now, an example of rolling apparatus whose roller-couples are driven by a common driving means will be conceptually described in the following. As shown in Fig.26, the roller couples 101,102 of the unit S1 and the roller-couples 201,202 of the stand S2 is driven by a motor 252 as said common driving means through a distributor 250 and reduction gear mechanisms 253-256 each of which corresponds to each said roller-couple. The rotation of the motor 252 is reduced at each reduction gear mechanism 253-256 according to a designated reduction ratio and transmitted to corresponding roller couple 101,102,201,202 through the distributor 250.

[0089] Fig.27 schematically presents the reduction gear mechanisms 253,254 for the upstream roller stand S1. The reduction gear mechanism 253 comprises plural gears J1-J3 (tooth numbers are N1-N3, respectively) which are secured on a driving shaft 300 driven by the motor 252, and plural gears K1-K3 (tooth numbers are M1-M3, respectively) which are secured on a transmitting shaft 301 for the roller-couple 101 and engage directly or indirectly through other gears with said gears J1-J3, respectively. According to a relative sliding between the driving shaft 300 and the transmitting shaft 301, one of the gears K1-K3 is to be engages with corresponding one of the gears J1-J3. The rotation of the motor 252 is thus reduced according to the reduction gear ratio Q1 which is determined as the tooth number ratio of the engaging. gears (N1/M1 in Fig.27), whereby the rotation rate R1 of the roller-couple 101 is to be determined to a corresponding value.

[0090] The reduction gear mechanism 254 comprises plural gears J4-J6 (tooth numbers are N4-N6, respectively) which are secured on a driving shaft 302 driven by the motor 252, and plural gears K4-K6 (tooth numbers are M4-M6, respectively) which are secured on a transmitting shaft 303 for the roller-couple 102 and engage directly or indirectly through other gears with said gears J4-J6, respectively. According to a relative sliding between the driving shaft 302 and transmitting shaft 303, one of the gears K4-K6 is to be engaged with corresponding one of the gears J4-J6. The rotation of the motor 252 is thus reduced according to the reduction gear ratio Q2 which is determined by the tooth number ratio of the engaging gears (N4/M4 in Fig.27), whereby the rotation rate R2 of the roller-couple 102 is to be determined to a corresponding value.

[0091] As is shown in Fig.29, the reduction mechanisms 255,256 has almost the same construction as those of said mechanisms 253,254, except for the reduction ratios. The former one 255 comprises gears J7-J9 on a driving shaft 304 and gears K7-K9 on a transmitting shaft 305, and the latter one 256 comprises gears J10-J12 on a driving shaft 306 and gears K10-K12 on a transmitting shaft 307.

[0092] For example, in the roller stands S1 and S2, the inter-stand reduction ratio Q1/Q2, i.e., the ratio of the roller rotation rate R1/R2 between the first and the second roller-couples 101 and 102 can be selected from designated plural values according to the torsional rigidity of the work material A1. The rotation rate is lower for the first roller-couple 101 than for the second one 102, so that Q1>Q2. Therefore, the inter-stand reduction ratio Q1/Q2 decreases with decreasing the rotation rate R2 of the second one 102. As shown in Fig.28, the inter-stand reduction ratio Q1/Q2 can be changed, for example, by changing the reduction gear ratio Q2 for the second roller-couple 102 (N4/M4 $\rightarrow$ N5/M5, for example) while fixing the reduction gear ratio Q1 for the first roller-couple 101 to a designated value (N1/M1, for example). Furthermore, as shown in Fig.29, when the inter-stand reduction ratio Q1/Q2 of the roller-couple unit S1 is changed to Q1'/Q2', the ratio Q3/Q4 of the roller-couple unit S2 is synchronously changed to Q3'/Q4'.

[0093] Now, the operation of the rolling apparatus described above is going to be explained in the following. First of all, as shown in Fig.29, the inter-stand reduction ratios are set to designated values for the first and the second roller-couple units S1 and S2, respectively. The probability of occurrence of wire twisting specifically depends upon the torsional rigidity of the work material. For example, as is shown in Fig.30 (a), when the rolling reduction is increased for the first roller-couple 101 and 201 of the units S1 and S2, the work material A1 is deformed largely in the direction of the rolling compression. The resulting shape of the cross section of the work material A1 is to be elongated along the direction perpendicular to said compression, so that a significant twisting torque is applied upon the work material A1 when a secondary rolling is performed by the second roller-couples 102 and 202 in the direction crossing to the primary one.

[0094] Such twisting can be effectively suppressed by decreasing the rolling reduction for the work material having a low torsional rigidity as shown in Fig.30 (b). In this case, the decrease in the rolling reduction at the first roller-couple causes a decrease in the reduction of area achieved thereat, so that the feeding rate of the work material A1 from the first roller-couple, i.e., that to the second roller-couple should be also decreased. Therefore, under an assumption that the rotation rate for the first roller couple is constant, the inter-stand reduction ratios Q1/Q2 and Q3/Q4 are to be set in a smaller values for a work material A1 having smaller torsional rigidity.

[0095] On the other hand, by using such construction of the rolling apparatus, the diameter of the wire produced can be easily changed. In the roller-couple units S1 and S2, the rolling reduction against the work material A1 varies according to the change in roller clearance. Fig.31 presents an example for the unit S1, where the roller clearance of the roller-couple 101a,101b of the first stand 12 increases in the order of (a), (b), (c). The rolling reduction P1 for the working material A1 decreases in this order with decreasing the axial ratio of the oval cross section of the work material A1 after rolling. Therefore, the rolling reduction P2 in the second stand 14 for rolling the work material A1 in a circular cross section

should be decreased in this order and the roller clearance of the roller-couple 102a,102b should be correspondingly increased in the order of (a), (b), (c), whereby the diameter D of the wire from the unit S1 increases in the order of (a), (b), (c). In other words, different size of wire diameter D is easily obtained by changing the rolling reduction of each roller-couple without changing the configuration of the sizing pass.

[0096] For example, when the rolling reduction P1 is increased for the first roller-couple 101 and 201 in the units S1 and S2, the work material A1 is deformed largely in the direction of the compression (or rolling) between the rollers, so that the transportation rate of the work material A1 from the first roller-couple, i.e., that to the second roller-couple should be also decreased. However, if the rolling reduction P1 (=(D0 - D1)/D0 for the first stand; =(D2 - D)/D2 for the second stand: i.e., dimensional changing ratio in the direction of rolling compression) is within 20%, or preferably within 10%, the rolling can be performed under a fixed rotation rate of second roller-couple. Furthermore, when the total rolling reduction achieved in each roller-couple units (i.e., sum of rolling reductions at the first and the second roller-couple) is within 10%, or preferably within 7%, the diameter D of the wire produced can be easily changed only by changing the roller clearance, i.e., by changing the rolling reduction at a fixed rotation rates of the first and the second roller-couples.

[0097] On the other hand, when the rolling reduction P1 exceeds 20%, the rotation rate of the second roller-couple can be increased with the increase in the feeding rate of the work material A1 for the second roller-couple for maintaining the rolling condition in a optimum state. Such change in the rotation rate of roller-couples can be performed by varying the inter-stand reduction ratios Q1/Q2 and Q3/Q4. For maintaining the optimum rolling condition, the configurations, i.e., the shapes and/or sizes of sizing passes of the first and the second roller-couples are preferably changed according to the value of said total rolling reduction against said work material A1. The total rolling reduction in each roller-couple unit can be varied so that resulting change in the reduction of area of said work material A1 is up to 40 %.

Claims

1. A method for manufacturing wire, comprising steps of:

rolling work material (A1) successively with a first roller-couple (12; 212; 101, 201) and a second roller-couple (14; 214; 102, 202) of a rolling mill (6), said first and second roller-couples being arranged to be spaced apart in a feeding direction of said work material and rolling said work material in different directions each other so that the shape of the cross section of the rolled wire after the first roller couple is different from that after the second roller couple; and

varying a resulting wire diameter D in a designated range by changing the rolling reductions in said first and second roller-couples against said work material in a corresponding range,

said method being **characterized by** a step of

setting a ratio of L/D to less than 30, where L is the center distance between said first and second roller-couples, and D is the wire diameter obtained after rolling by said second roller-couple; so that

wire obtained after said second roller couple comprises a resulting diameter D of less than 5.5 mm.

2. The method according to claim 1 which comprises, before said work material is rolled by using said rolling mill (6), the step of

heating said work material in continuous feeding by using a heating device (44) which is arranged on the passage of said feeding and comprises an induction heating coil for continuously heating said work material.

3. The method according to claim 1 which comprises, before said work material is rolled by using said rolling mill (6), the steps of

continuously removing scale formed on work material in continuous feeding by using a scale-removing device (4) arranged on the passage of said work feeding; and

heating said work material after the removal of said scale by using a heating device (71a, 71b, 72; 5) which comprises an electrode (71a, 71b; 51, 52, 53, 54) contacting with said work material allowing the continuous feeding thereof and sending electric current into said work material through said electrode for resistance-heating of said work material.

4. The method according to claim 2 or 3, further comprising a step of keeping the temperature at a desired value of said wire before rolling the same in said rolling mill (6) by setting a distance between said heating device (5; 44) and said rolling mill (6) to less than 4 m.

5. The method according to any one of claims 1 to 4 wherein rolling reduction against said work material by each roller-couple is varied according to the variety of said work material, and the ratio, R1/R2,

where R1 and R2 are roller-rotation rates of said first and second roller-couples, respectively, is adjusted according to said rolling reduction.

6. The method according to claim 5 wherein said rolling reduction and said ratio R1/R2 are varied according to the torsional rigidity of said work material.

7. The method according to any one of claims 1 to 6 wherein the ratio, R1/R2, where R1 and R2 are roller-rotation rates in said first and second roller-couples, respectively, is fixed in a designated value; and

wherein total rolling reduction against said work material by said first and second roller-couples are varied so that resulting change in the reduction of area of said work material is within 10 %.

8. The method according to any one of claims 1 to 7 wherein total rolling reduction against said work material by said first and second roller-couples are varied so that resulting change in the reduction of area of said work material is within 40 %; and

wherein the ratio, R1/R2, where R1 and R2 are roller-rotation rates of said first and second roller-couple, respectively, is varied according to the value of said total rolling reduction against said work material.

9. The method according to claim 8 wherein shapes and/or sizes of sizing pass of said first and second roller-couples are changed according to the value of said total rolling reduction against said work material.

10. The method according to any one of claims 1 to 9 ,

wherein each of said first and second roller-couples comprises two rollers (101a, 101b, 102a, 102b; 101a', 101b') having grooves (161a, 161b, 162a, 162b) on the circumferential surface thereof for forming a sizing pass (161c, 162c) which determines cross sectional shape of said wire; the method further comprising steps of :

setting the width of said grooves (161a, 161b) to less than 7 mm for said first roller-couple; ,

setting the width of said grooves (162a, 162b) to less than 6 mm for said second roller-couple; and

setting the center distance (L) between said first and second roller-couples to less than 50 mm.

11. The method according to any one of claims 1 to 9, further comprising steps of :

setting a clearance formed between two rollers (101a, 101b) to less than 7 mm for said first roller-couple;

setting a clearance formed between two rollers (102a, 102b) to less than 6 mm for said second roller-couple; and

setting the center distance (L) between said first and second roller-couples to less than 50 mm.

12. The method according to claim 10 or 11 wherein said first and second roller-couples for manufacturing wire are arranged alternatingly so that the angle between the rotation axes thereof are almost 90°;

wherein said work material is rolled by said first roller-couple (12; 212; 101, 201) so that the cross sectional dimension of said work material in a direction of rolling reduction, D1, becomes less than that in a direction perpendicular to said direction of rolling reduction, D2;

and wherein said work material is rolled by said second roller-couple (14; 214; 102, 202) so that the ratio of said dimensions, D2/D1, is decreased.

13. The method according to one of claims 10 to 12, further comprising a step of moving two rollers (101a, 101b, 102a, 102b) of each roller-couple (12, 14) relatively to and from each other in the direction of rolling reduction by respective roller-clearance adjusting mechanisms (26, 32, 34, 36, 38) accompagning each of said first and second roller-couples;

wherein each said roller-clearance adjusting mechanism comprises :

bearing portions (26) which rotatively support the shafts of said two rollers, respectively;

and a bearing rotation mechanism (32, 34, 36, 38) which rotates each said bearing portion (26) around an eccentric axis (C_2) deviated from a corresponding roller axis (C_1) in opposite direction, respectively, thereby moving said two rollers relatively to and from each other.

14. The method according to claim 13 wherein said bearing rotation mechanism (32, 34, 36, 38) for said first roller-couple (12) is arranged upstream of said first roller-couple, and said bearing rotation mechanism for said second roller-couple (14) is arranged downstream of said second roller-couple.

15. The method according to claim 14 wherein said bearing rotation mechanism (32, 34, 36, 38) comprises :

first gear portions (26b) which are formed on the circumferences of said bearing portions (26) of said two rollers, respectively;

second gear portions (34) each of which engages with corresponding said first gear portion (26b);

and wherein a driving mechanism (36, 38) rotates said second gear portions (34) synchronously in opposite directions each other.

16. The method according to claim 15 wherein said second gear portions are worms (34) which are axially arranged on a worm rotating shaft (32) at a designated interval along the longitudinal direction thereof and whose threads are formed in opposite directions each other;

and wherein said worms (34) are rotated integrally by driving said worm rotating shaft (32) by means of said driving mechanism (36,38).

17. The method according to claim 16 wherein said bearing portion comprises:

bearing casings (24) which are arranged corresponding to both end portions of a roller shaft (28) and each of which has a bearing accommodating hole (24a) extending along said roller shaft (28);

bearing main bodies (26) each of which is accommodated in each said bearing accommodating hole (24a);

wherein a bearing hole (26a) is formed in'each said bearing main body (26) so that the center of said bearing hole (26a) is deviated from the rotation axis (C_2) of said bearing main body (26), and each end portion of said roller shaft (28) is rotatively supported in said bearing hole (26a);

and wherein said bearing main body (26) has said first gear portion (26b) on its circumference and is rotated by said worm (32) engaged with said first gear portion (26b) around an eccentric axis (C_2) deviated from the rotation axis (C_1) of said roller.

18. The method according to claim 17 wherein said bearing hole (26a) of said first roller-couple (12) is formed in said bearing main body (26) deviated from its rotation axis in the downstream, and said bearing hole (26a) of said second roller-couple (14) is formed in said bearing main body (26) deviated from its rotation axis in the upstream.

19. The method according to one of claims 10-18, further comprising steps of moving said two rollers (101a, 101b, 102a, 102b) relatively in the thrust direction thereof and holding said two rollers at an arbitrary positions in said thrust direction by means of a roller thrust adjusting mechanism (170) which at least one of said first and second roller-couples (12, 14) is equipped with.

20. The method according to claim 19 wherein said roller thrust adjusting mechanism (170) comprises:

a fixed bearing portion (30) which is provided for at least one of said two rollers and hold the roller shaft (28) rotatively and movably in its thrust direction;

and a roller sliding mechanism (171) which is connected to one end portion of said roller shaft (28) and slides said roller shaft against said bearing portion (30) in said thrust direction.

21. The method according to claim 20 wherein said roller sliding mechanism (171) comprises:

a shaft holder (172) to which said end portion of said roller shaft (28) is connected and which is movable integrally with said roller shaft in said thrust direction;

adjusting screw mechanism (173) which is connected to said shaft holder directly or indirectly with other member and moves said shaft holder (172) in said thrust direction according to its screwing or unscrewing operation.

22. The method according to claim 21 wherein said bearing portion comprises a bearing main body (26) which has a through hole as a bearing hole (26a) in the direction of said roller shaft (28) and rotatively supports said one end portion of said roller shaft in said through hole;

wherein said shaft holder (172) is movable in said through hole (26a) with said roller shaft (28) in said thrust direction;

wherein said shaft holder (172) has a shaft-like protruding portion (177) which extends along the axial direction of said roller shaft (28) in said through hole (26a) and the end portion of which protrudes outside from the corresponding opening (26b) of said through hole;

wherein on the inner side of said through hole (26a), a female threaded portion (26c) is formed on the end portion thereof leading to said opening (26b);

wherein a male screw member (178) is screwed on said female threaded portion (26c) in a position corresponding to the intermediary part of said shaft-like protruding portion (177);

wherein a stopper (179) is mounted on said shaft-like protruding portion (177) for preventing

said male screw member (178) from its relative movement against said shaft-like protruding portion in the axial direction thereof;

and wherein said adjusting screw mechanism (173) moves said shaft holder (172) and said roller shaft (28) in said thrust direction along with said male screw member (178) according to the rotation of said male screw member.

23. The method according to any one of claims 3 to 22 wherein said step of continously removing scale formed on work material includes a step of blasting a flow of abrasive particles onto the surface of said work material in continuous feeding by means of a shot-blasting device (4).

24. The method according to any one of claims 3 to 23 wherein said step of heating said work material inclides steps of :

contacting said work material by a roller electrode (51-54) and sending electric current into said work material for its resistance-heating; and

urging said roller electrode against said work material by means of an urging mechanism (55-58).

25. The method according to any one of claims 5, 6, 8 and 9, further comprising a step of driving said first (12; 101, 102) and second (14; 201, 202) roller-couples by a common driving means (252) through a first (253, 255) and a second (254, 256) reduction gear systems, respectively;

wherein the inter-stand reduction ratio, Q1/Q2, where Q1 is the reduction gear ratio of said first reduction gear system and Q2 is the reduction gear ratio of said second reduction gear system, is varied for changing said ratio, R1/R2.

26. The method according to claim 25, further comprising steps of

successively rolling said work material by a plurality of roller-couple units (S) each of which comprises said first and second roller-couples, said roller-couple units being arranged in the feeding direction of said work material;

changing said inter-stand reduction ratios Q1/Q2 of said roller-couple units synchronously; and

when said inter-stand reduction ratio is set in a designated value for one of roller-couple unit, also setting the inter-stand reduction ratios for other roller-couple units in corresponding values synchronously.

27. An apparatus for manufacturing wire, comprising:

a f irst roller-couple (12; 212; 101, 201) and a second roller-couple (14; 214; 102, 202) of a rolling mill (6) for successively rolling work material (A_1), said first and second roller-couples being arranged spaced apart in a feeding direction of said work material, wherein an angular position of rotational axes of said first roller-couple is different from that of said second roller-couple and wherein shapes and/or positional relations of respective rollers of said first and second roller-couples are formed such that the shape of the cross section of the rolled wire after the first roller couple is different from that after the second roller couple; wherein

rolling reductions in said first and second roller-couples against said work material are changeable in a range corresponding to a variation of a resulting wire diameter D;

characterized in that

shapes and/or positional relations of respective rollers of said first and second roller-couples are formed such that wire obained after said second roller couple comprises a substantially round or square cross section and a resulting diameter D of less than 5.5 mm; and

said first and second roller-couples are arranged such that a ratio of L/D, where L is the center distance between said first and second roller-couples, and D is the wire diameter obtained after rolling by said second roller-couple, is less than 30.

28. The apparatus according to claim 27, further comprising a heating device (44) which is arranged before said rolling mill on the passage of said work feeding and comprises an induction heating coil for continuously heating said work material.

29. The apparatus according to claim 27, further comprising :

a scale-removing device (4) which is arranged before said rolling mill on the passage of said work feeding for continuously removing scale formed on work material in continuous feeding; and

a heating device (71a, 71b, 72; 5) which comprises an electrode (71a, 71b; 51, 52, 53, 54) contacting with said work material allowing the continuous feeding thereof and sending electric current into said work material through said electrode for resistance-heating of said work material, said heating device being arranged between said scale-removing device (4) and said rolling mill (6).

30. The apparatus according to claim 28 or 29 wherein the distance between said heating device (5; 44) and said rolling mill (6) is less than 4 m.

31. The apparatus according to any one of claims 27 to 30 wherein rolling reduction against said work material by each roller-couple is variable according to the variety of said work material, and the ratio, R1/R2, where R1 and R2 are roller-rotation rates of said first and second roller-couples, respectively, is adjustable according to said rolling reduction.

32. The apparatus according to claim 31 wherein said rolling reduction is variable and said ratio R1/R2 is adjustable according to the torsional rigidity of said work material.

33. The apparatus according to any one of claims 27 to 32 wherein the ratio R1/R2, where R1 and R2 are roller-rotation rates in said first and second roller-couples, respectively, is fixable in a designated value; and

wherein total rolling reduction against said work material by said first and second roller-couples are variable so that resulting change in the reduction of area of said work material is within 10 %.

34. The apparatus according to any one of claims 27 to 33 wherein total rolling reduction against said work material by said first and second roller-couples are variable so that resulting change in the reduction of area of said work material is within 40 %; and

wherein the ratio, R1/R2, where R1 and R2 are roller-rotation rates of said first and second roller-couple, respectively, is variable according to the value of said total rolling reduction against said work material.

35. The apparatus according to claim 34 wherein shapes and/or sizes of sizing pass of said first and second roller-couples are changeable according to the value of said total rolling reduction against said work material.

36. The apparatus according to any one of claims 27 to 35,

wherein each of said first and second roller-couples comprises two rollers (101a, 101b, 102a, 102b; 101a', 101b') having grooves (161a, 161b, 162a, 162b) on the circumferential surface thereof for forming a sizing pass (161c, 162c) which determines cross sectional shape of said wire;

wherein the width of said grooves (161a, 161b) are less than 7 mm for said first roller-couple;

wherein the width of said grooves (162a, 162b) are less than 6 mm for said second roller-couple;

and wherein the center distance (L) between said first and second roller-couples is less than 50 mm.

37. The apparatus according to any one of claims 27 to 35,

wherein a clearance formed between two rollers (101a, 101b) is less than 7 mm for said first roller-couple;

wherein a clearance formed between two rollers (102a, 102b) is less than 6 mm for said second roller-couple;

and wherein the center distance (L) between said first and second roller-couples is less than 50 mm.

38. The apparatus according to claim 36 or 37 wherein said first and second roller-couples for manufacturing wire are arranged alternatingly so that the angle between the rotation axes thereof are almost 90°;

wherein shapes and/or sizes of said first roller-couple (12; 212; 101, 201) are formed so that the cross sectional dimension of said work material in a direction of rolling reduction, D1, becomes less than that in a direction perpendicular to said direction of rolling reduction, D2;

and wherein shapes and/or sizes of said second roller-couple (14; 214; 102, 202) are formed so that the ratio of said dimensions, D2/D1, is decreased.

39. The apparatus according to one of claims 36 to 38 wherein each of said first and second roller-couples is accompanied with a roller-clearance adjusting mechanism (26, 32, 34, 36, 38) for moving two rollers (101a, 101b, 102a, 102b) of each roller-couple (12, 14) relatively to and from each other in the direction of rolling reduction;

and wherein each said roller-clearance adjusting mechanism comprises :

bearing portions (26) which rotatively support the shafts of said two rollers, respectively;

and a bearing rotation mechanism (32, 34, 36, 38) which rotates each said bearing portion (26) around an eccentric axis (C_2) deviated from a corresponding roller axis (C_1) in opposite direction, respectively, thereby moving said two rollers relatively to and from each other.

40. The apparatus according to claim 39 wherein said bearing rotation mechanism (32, 34, 36, 38) for said first roller-couple (12) is arranged upstream of said first roller-couple, and said bearing rotation mechanism for said second roller-couple (14) is arranged downstream of said second roller-couple.

41. The apparatus according to claim 40 wherein said

bearing rotation mechanism (32, 34, 36, 38) comprises :

first gear portions (26b) which are formed on the circumferences of said bearing portions (26) of said two rollers, respectively;

second gear portions (34) each of which engages with corresponding said first gear portion (26b);

and a driving mechanism (36, 38) which rotates said second gear portions (34) synchronously in opposite directions each other.

42. The apparatus according to claim 41 wherein said second gear portions are worms (34) which are axially arranged on a worm rotating shaft (32) at a designated interval along the longitudinal direction thereof and whose threads are formed in opposite directions each other;

and wherein said driving mechanism (36, 38) drives said worm rotating shaft (32) thereby rotating said worms (34) integrally.

43. The apparatus according to claim 42 wherein said bearing portion comprises:

bearing casings (24) which are arranged corresponding to both end portions of a roller shaft (28) and each of which has a bearing accommodating hole (24a) extending along said roller shaft (28);

bearing main bodies (26) each of which is accommodated in each said bearing accommodating hole (24a);

wherein a bearing hole (26a) is formed in each said bearing main body (26) so that the-center of said bearing hole (26a) is deviated from the rotation axis (C_2) of said bearing main body (26), and each end portion of said roller shaft (28) is rotatively supported in said bearing hole (26a);

and wherein said bearing main body (26) has said first gear portion (26b) on its circumference and is rotated by said worm (32) engaged with said first gear portion (26b) around an eccentric axis (C_2) deviated from the rotation axis (C_1) of said roller.

44. The apparatus according to claim 43 wherein said bearing hole (26a) of said first roller-couple (12) is formed in said bearing main body (26) deviated from its rotation axis in the downstream, and said bearing hole (26a) of said second roller-couple (14) is formed in said bearing main body (26) deviated from its rotation axis in the upstream.

45. The apparatus according to one of claims 36-44 wherein at least one of said first and second roller-couples (12, 14) is equipped with a roller thrust adjusting mechanism (170) which moves said two rollers (101a, 101b, 102a, 102b) relatively in the thrust direction thereof and hold said two rollers at an arbitrary positions in said thrust direction.

46. The apparatus according to claim 45 wherein said roller thrust adjusting mechanism (170) comprises:

a fixed bearing portion (30) which is provided for at least one of said two rollers and hold the roller shaft (28) rotatively and movably in its thrust direction;

and a roller sliding mechanism (171) which is connected to one end portion of said roller shaft (28) and slides said roller shaft against said bearing portion (30) in said thrust direction.

47. The apparatus according to claim 46 wherein said roller sliding mechanism (171) comprises:

a shaft holder (172) to which said end portion of said roller shaft (28) is connected and which is movable integrally with said roller shaft in said thrust direction;

adjusting screw mechanism (173) which is connected to said shaft holder directly or indirectly with other member and moves said shaft holder (172) in said thrust direction according to its screwing or unscrewing operation.

48. The apparatus according to claim 47 wherein said bearing portion comprises a bearing main body (26) which has a through hole as a bearing hole (26a) in the direction of said roller shaft (28) and rotatively supports said one end portion of said roller shaft in said through hole;

wherein said shaft holder (172) is movable in said through hole (26a) with said roller shaft (28) in said thrust direction;

wherein said shaft holder (172) has a shaft-like protruding portion (177) which extends along the axial direction of said roller shaft (28) in said through hole (26a) and the end portion of which protrudes outside from the corresponding opening (26b) of said through hole;

wherein on the inner side of said through hole (26a), a female threaded portion (26c) is formed on the end portion thereof leading to said opening (26b);

wherein a male screw member (178) is screwed on said female threaded portion (26c) in a position corresponding to the intermediary part of said shaft-like protruding portion (177);

wherein a stopper (179) is mounted on said

shaft-like protruding portion (177) for preventing said male screw member (178) from its relative movement against said shaft-like protruding portion in the axial direction thereof;

and wherein said adjusting screw mechanism (173) moves said shaft holder (172) and said roller shaft (28) in said thrust direction along with said male screw member (178) according to the rotation of said male screw member.

49. The apparatus according to any one of claims 29 to 48 wherein said scale-removing device comprises a shot-blasting device (4) for removing said scale by blasting a flow of abrasive particles onto the surface of said work material in continuous feeding.

50. The apparatus according to any one of claims 29 to 49 wherein said heating device (5) comprises:

a roller electrode (51-54) for providing contact with said work material and sending electric current into said work material for its resistance-heating;

and an urging mechanism (55-58) for urging said roller electrode against said work material.

51. The apparatus according to any one of claims 31, 32, 34 and 35 wherein said first (12; 101, 102) and second (14; 201, 202) roller-couples are driven by a common driving means (252) through a first (253, 255) and a second (254, 256) reduction gear systems, respectively;

and wherein the inter-stand reduction ratio, Q1/Q2, where Q1 is the reduction gear ratio of said first reduction gear system and Q2 is the reduction gear ratio of said second reduction gear system, is varied for changing said ratio, R1/R2.

52. The apparatus according to claim 51 wherein a plurality of roller-couple units (S_1, S_2; S) each of which comprises said first and second roller-couples are arranged in the feeding direction of said work material, and said work material is successively rolled by said roller-couple units;

wherein said inter-stand reduction ratios Q1/Q2 of said roller-couple units are changed synchronously;

and wherein when said inter-stand reduction ratio is set in a designated value for one of roller-couple unit, the inter-stand reduction ratios for other roller-couple units are also set in corresponding values synchronously.

Patentansprüche

1. Verfahren zum Herstellen von Draht, welches die Schritte aufweist:

Walzen eines Werkstücks (A1) nacheinander mit einem ersten Walzenpaar (12; 212; 101, 201) und einem zweiten Walzenpaar (14; 214; 102, 202) einer Walzstraße (6), wobei das erste und das zweite Walzenpaar so angeordnet sind, daß sie in einer Zuführungsrichtung des Werkstücks beabstandet sind und das Werkstück jeweils in unterschiedlichen Richtungen derart walzen, daß sich die Gestalt des Querschnitts des gewalzten Drahts nach dem ersten Walzenpaar von der nach dem zweiten Walzenpaar unterscheidet; und

Variieren eines resultierenden Drahtdurchmessers D in einem gewünschten Bereich durch Ändern der Walzreduktionen in dem ersten und dem zweiten Walzenpaar an dem Werkstück in einem entsprechenden Bereich,

wobei das Verfahren ***gekennzeichnet ist durch*** einen Schritt eines

Einstellens eines Verhältnisses von L/D auf weniger als 30, wobei L der Mittenabstand zwischen dem ersten und dem zweiten Walzenpaar ist und D der nach Walzen **durch** das zweite Walzenpaar erhaltene Drahtdurchmesser ist; so, daß

ein nach dem zweiten Walzenpaar erhaltener Draht einen resultierenden Durchmesser von weniger als 5,5 mm aufweist.

2. Verfahren gemäß Anspruch 1, welches, bevor das Werkstück durch Verwenden der Walzstraße (6) gewalzt wird, den Schritt aufweist eines

Erwärmens des Werkstücks in kontinuierlicher Zuführung durch Verwenden einer Heizvorrichtung (44), welche auf dem Weg der Zuführung angeordnet ist und eine Induktionsheizspule zum kontinuierlichen Erwärmen des Werkstücks aufweist.

3. Verfahren gemäß Anspruch 1, welches, bevor das Werkstück durch Verwenden der Walzstraße (6) gewalzt wird, die Schritte aufweist eines

kontinuierlichen Entfernens von auf dem Werkstück ausgebildetem Zunder in kontinuierlicher Zuführung durch Verwenden einer Entzunderungsvorrichtung (4), welche auf dem Weg der Zuführung des Werkstücks angeordnet ist; und

Erwärmens des Werkstücks nach dem Entfernen des Zunders durch Verwenden einer Heizvorrichtung (71a, 71b; 72; 5), welche eine das Werkstück berührende Elektrode (71a, 71b; 51, 52, 53, 54) aufweist, die eine kontinuierliche Zuführung hiervon erlaubt, und zum Widerstandsheizen des Werkstücks elektrischen Strom durch die Elektrode in das Werkstück schickt.

4. Verfahren gemäß Anspruch 2 oder 3, welches weiter einen Schritt eines Haltens der Temperatur des Drahts auf einem gewünschten Wert aufweist, bevor derselbe in der Walzstraße (6) gewalzt wird, indem ein Abstand zwischen der Heizvorrichtung (5; 44) und der Walzstraße (6) auf weniger als 4 m eingestellt wird.

5. Verfahren gemäß einem der Ansprüche 1 bis 4, wobei die Walzreduktion an dem Werkstück durch jedes Walzenpaar gemäß der Art des Werkstücks varriert wird und das Verhältnis R1/R2, wobei R1 und R2 Walzendrehzahlen des ersten bzw. des zweiten Walzenpaares sind, gemäß der Walzreduktion eingestellt wird.

6. Verfahren gemäß Anspruch 5, wobei die Walzreduktion und das Verhältnis R1/R2 gemäß dem Torsionswiderstand des Werkstücks variiert werden.

7. Verfahren gemäß einem der Ansprüche 1 bis 6, wobei das Verhältnis R1/R2, wobei R1 und R2 Walzendrehzahlen in dem ersten bzw. dem zweiten Walzenpaar sind, auf einem gewünschten Wert festgelegt wird; und

wobei die Gesamtwalzreduktion an dem Werkstück durch das erste und das zweite Walzenpaar so variiert wird, daß die resultierende Änderung in der Flächenreduktion des Werkstücks innerhalb von 10 % liegt.

8. Verfahren gemäß einem der Ansprüche 1 bis 7, wobei die Gesamtwalzreduktion an dem werkstück durch das erste und das zweite Walzenpaar so variiert wird, daß die resultierende Änderung in der Flächenreduktion des Werkstücks innerhalb von 40 % liegt; und

wobei das Verhältnis R1/R2, wobei R1 und R2 Walzendrehzahlen in dem ersten bzw. dem zweiten Walzenpaar sind, gemäß dem Wert der Gesamtwalzreduktion an dem Werkstück variiert wird.

9. Verfahren gemäß Anspruch 8, wobei Formen und/oder Größen eines Bemessungswegs des ersten und des zweiten Walzenpaares gemäß dem Wert der Gesamtwalzreduktion an dem Werkstück geändert werden.

10. Verfahren gemäß einem der Ansprüche 1 bis 9,

wobei jedes des ersten und des zweiten Walzenpaares zwei Walzen (101a, 101b, 102a, 102b; 101a', 101b') aufweist, welche Rillen (161a, 161b, 162a, 162b) auf der Umfangsoberfläche hiervon aufweisen, um einen Bemessungsweg (161c, 162c) auszubilden, welcher eine Querschnittsform des Drahts bestimmt; wobei das Verfahren weiter Schritte aufweist eines:

Festlegens der Breite der Rillen (161a, 161b) auf weniger als 7 mm für das erste Walzenpaar;

Festlegens der Breite der Rillen (162a, 162b) auf weniger als 6 mm für das zweite Walzenpaar; und

Festlegens des Mittenabstands (L) zwischen dem ersten und dem zweiten Walzenpaar auf weniger als 50 mm.

11. Verfahren gemäß einem der Ansprüche 1 bis 9, welches weiter Schritte aufweist eines:

Festlegens eines Zwischenraums zwischen zwei Walzen (101a, 101b) auf weniger als 7 mm für das erste Walzenpaar;

Festlegens eines Zwischenraums zwischen zwei Walzen (102a, 102b) auf weniger als 6 mm für das zweite Walzenpaar; und

Festlegens des Mittenabstands (L) zwischen dem ersten und dem zweiten Walzenpaar auf weniger als 50 mm.

12. Verfahren gemäß Anspruch 10 oder 11, wobei das erste und das zweite Walzenpaar zum Herstellen von Draht abwechselnd derart angeordnet sind, daß der Winkel zwischen den Rotationsachsen hiervon etwa 90° beträgt;

wobei das Werkstück durch das erste Walzenpaar (12; 212; 101, 102) derart gewalzt wird, daß die Querschnittsdimension D1 des Werkstücks in einer Richtung einer Walzreduktion geringer wird als in einer Richtung D2 senkrecht zu dieser Richtung der Walzreduktion;

und wobei das Werkstück durch das zweite Walzenpaar (14; 214; 102, 202) derart gewalzt wird, daß das Verhältnis der Dimensionen D2/D1 verringert wird.

13. Verfahren gemäß einem der Ansprüche 10 bis 12, welches weiter einen Schritt eines Bewegens zweier Walzen (101a, 101b, 102a, 102b) jedes Walzenpaares (12, 14) relativ aufeinander zu und voneinander weg in der Richtung einer Walzreduktion durch jeweilige Walzenzwischenraum-Einstellmechanismen (26, 32, 34, 36, 38), die sowohl das erste als auch das zweite Walzenpaar begleiten, aufweist;

wobei jeder Walzenzwischenraum-Einstellmechanismus aufweist:

Lagerabschnitte (26), welche die Wellen der zwei Walzen jeweils unterstützen;

und einen Lagerdrehmechanismus (32, 34, 36,

38), welcher jeden der Lagerabschnitte (26) um eine von einer entsprechenden Walzenachse (C_1) abweichende exzentrische Achse (C_2) jeweils in entgegengesetzte Richtung dreht, wodurch die zwei Walzen relativ aufeinander zu und voneinander weg bewegt werden.

14. Verfahren gemäß Anspruch 13, wobei der Lagerdrehmechanismus (32, 34, 36, 38) für das erste Walzenpaar (12) stromaufwärts des ersten Walzenpaares angeordnet ist und der Lagerdrehmechanismus für das zweite Walzenpaar (14) stromabwärts des zweiten Walzenpaares angeordnet ist.

15. Verfahren gemäß Anspruch 14, wobei der Lagerdrehmechanismus (32, 34, 36, 38) aufweist:

erste Zahnradabschnitte (26b), welche jeweils auf den Umfängen der Lagerabschnitte (26) der zwei Walzen angeordnet sind;

zweite Zahnradabschnitte (34), die jeweils in den entsprechenden ersten Zahnradabschnitt (26b) eingreifen;

und wobei ein Antriebsmechanismus (36, 38) die zweiten Zahnradabschnitte (34) synchron in einander entgegengesetzten Richtungen dreht.

16. Verfahren gemäß Anspruch 15, wobei die zweiten Zahnradabschnitte Schnecken (34) sind, welche axial auf einer Schneckendrehwelle (32) mit einem bestimmten Abstand entlang der Längsrichtung hiervon angeordnet sind und deren Windungen in einander entgegengesetzten Richtungen ausgebildet sind;

und wobei die Schnecken (34) durch Antreiben der Schneckendrehwelle (32) mittels des Antriebsmechanismus (36, 38) gemeinsam angetrieben werden.

17. Verfahren gemäß Anspruch 16, wobei der Lagerabschnitt aufweist:

Lagergehäuse (24), welche entsprechend beiden Endabschnitten einer Walzenwelle (28) angeordnet sind und von welchen jedes ein Lageraufnahmeloch (24a) aufweist, welches sich entlang der Walzenwelle (28) erstreckt;

Lagerhauptkörper (26), von welchen jeder in dem Lageraufnahmeloch (24a) aufgenommen wird;

wobei ein Lagerloch (26a) in jedem der Lagerhauptkörper (26) derart ausgebildet ist, daß die Mitte des Lagerlochs (26a) vom der Rotationsachse (C_2) des Lagerhauptkörpers (26) ausgerückt ist und jeder Endabschnitt der Walzenwelle (28) in dem Lagerloch (26a) drehbar unterstützt ist;

und wobei der Lagerhauptkörper (26) einen ersten Zahnradabschnitt (26a) auf seinem Umfang aufweist und durch die in den ersten Zahnradabschnitt (26a) eingreifenden Schnecke (32) um eine von der Rotationsachse (C_1) der Walze versetzte, exzentrische Achse (C_2) gedreht wird.

18. Verfahren gemäß Anspruch 17, wobei das Lagerloch (26a) des ersten Walzenpaares (12) in dem von seiner Rotationsachse abweichenden Lagerhauptkörper (26) stromabwärts ausgebildet ist und das Lagerloch (26a) des zweiten Walzenpaares (14) in dem von seiner Rotationsachse abweichenden Lagerhauptkörper (26) stromaufwärts ausgebildet ist.

19. Verfahren gemäß einem der Ansprüche 10-18, welches weiter Schritte eines Bewegens der zwei Walzen (101a, 101b, 102a, 102b) relativ in der Schubrichtung hiervon und eines Haltens der zwei Walzen in beliebigen Positionen in der Schubrichtung mittels eines Walzenschubeinstellmechanismus (170), mit welchem wenigstens eines des ersten und des zweiten Walzenpaares (12, 14) ausgerüstet ist, aufweist.

20. Verfahren gemäß Anspruch 19, wobei der Walzenschubeinstellmechanismus (170) aufweist:

einen feststehenden Lagerabschnitt (30), welcher für wenigstens eine der zwei Walzen vorgesehen ist und die Walzenwelle (28) drehbar und in ihrer Schubrichtung beweglich hält;

und einen Walzenschiebemechanismus (171), welcher mit einem Endabschnitt der Walzenwelle (28) verbunden ist und die Walzenwelle in der Schubrichtung gegen den Lagerabschnitt (30) schiebt.

21. Verfahren gemäß Anspruch 20, wobei der Walzenschiebemechanismus (171) aufweist:

einen Wellenhalter (172), mit welchem der Endabschnitt der Walzenwelle (28) verbunden ist und welcher zusammen mit der Walzenwelle in der Schubrichtung beweglich ist;

einen Einstellschraubmechanismus (173), welcher mit dem Wellenhalter direkt oder indirekt mit einem anderen Bauteil verbunden ist und den Wellenhalter (172) in der Schubrichtung gemäß seiner Tätigkeit eines Hinein- oder Herausdrehens bewegt.

22. Verfahren gemäß Anspruch 21, wobei der Lagerabschnitt einen Lagerhauptkörper (26) aufweist, welcher ein Durchgangsloch als ein Lagerloch (26a) in der Richtung der Walzenwelle (28) aufweist und den einen Endabschnitt der Walzenwelle in dem Durchgangsloch drehbar unterstützt;

wobei der Wellenhalter (172) in dem Durchgangsloch (26a) mit der Walzenwelle (28) in der Schubrichtung beweglich ist;

wobei der Wellenhalter (172) einen wellenartig hervorstehenden Abschnitt (177) aufweist, welcher sich entlang der axialen Richtung der Walzenwelle (28) in dem Durchgangsloch (26a) erstreckt und dessen Endabschnitt außerhalb von der entsprechenden Öffnung (26b) des Durchgangslochs aus hervorsteht;

wobei auf der Innenseite des Durchgangslochs (26a) ein Muttergewindeabschnitt (26c) auf dem Endabschnitt hiervon ausgebildet ist, welcher zu der Öffnung (26b) führt;

wobei ein Schraubengewindebauteil (178) in einer Position auf den Muttergewindeabschnitt (26c) geschraubt ist, die dem Teil des des wellenartig hervorstehenden Abschnitts (177) dazwischen entspricht;

wobei ein Stopper (179) auf dem wellenartig hervorstehenden Abschnitt (177) montiert ist, um eine Relativbewegung des Schraubengewindebauteils (178) gegenüber dem wellenartig hervorstehenden Abschnitt in der axialen Richtung hiervon zu verhindern;

und wobei der Einstellschraubmechanismus (173) den Wellenhalter (172) und die Walzenwelle (28) in der Schubrichtung zusammen mit dem Schraubengewindebauteil (178) gemäß der Drehung des Schraubengewindebauteils bewegt.

23. Verfahren gemäß einem der Ansprüche 3 bis 22, wobei der Schritt eines kontinuierlichen Entfernens von auf dem Werkstück ausgebildetem Zunder einen Schritt eines Aufstrahlens eines Stroms von abrasiven Teilchen auf die Oberfläche des Werkstücks in kontinuierlicher Zuführung mittels einer Abstrahlvorrichtung (4) beinhaltet.

24. Verfahren gemäß einem der Ansprüche 2 bis 23, wobei der Schritt eines Erwärmens des Werkstücks Schritte aufweist eines:

Berührens des Werkstücks mit einer Rollenelektrode (51-54) und Schickens von elektrischem Strom in das Werkstück zum Zwecke des Widerstandsheizens desselben; und

Drängens der Rollenelektrode gegen das Werkstück mittels eines Drängmechanismus (55-58).

25. Verfahren gemäß einem der Ansprüche 5, 6, 8 oder 9, welches weiter einen Schritt eines Antreibens des ersten (12; 101, 102) und des zweiten (14; 201, 202) Walzenpaares durch eine gemeinsame Antriebseinrichtung (252) durch ein erstes (253, 255) bzw. ein zweites (254, 256) Untersetzungsgetriebesystem aufweist;

wobei das Reduktionsverhältnis zwischen Ständern Q1/Q2, wobei Q1 das Untersetzungsverhältnis des ersten Untersetzungsgetriebesystems ist und Q2 das Untersetzungsverhältnis des zweiten Untersetzungsgetriebesystems ist, variiert wird, um das Verhältnis R1/R2 zu ändern.

26. Verfahren gemäß Anspruch 25, welches weiter Schritte aufweist eines

Walzens des Werkstücks nacheinander durch eine Mehrzahl von walzenpaareinheiten (S), von denen jede ein erstes und ein zweites Walzenpaar aufweist, wobei die Walzenpaareinheiten in der Zuführungsrichtung des Werkstücks angeordnet sind;

Änderns der Reduktionsverhältnisse zwischen Ständern Q1/Q2 der Walzenpaareinheiten in synchroner Weise; und

wenn das Reduktionsverhältnis zwischen Ständern für eine der Walzenpaareinheiten auf einen gewünschten Wert festgelegt ist, ebenfalls Einstellens der Reduktionsverhältnisse zwischen Ständern für andere Walzenpaareinheiten auf entsprechende Werte in synchroner Weise.

27. Vorrichtung zum Herstellen von Draht, welches aufweist:

ein erstes Walzenpaar (12; 212; 101, 201) und ein zweites Walzenpaar (14; 214; 102, 202) einer Walzstraße (6) zum Walzen eines Werkstücks (A1) nacheinander, wobei das erste und das zweite Walzenpaar in einer Zuführungrichtung des Werkstücks beabstandet angeordnet sind, wobei eine Winkellage von Rotationsachsen des ersten Walzenpaares sich von der des zweiten Walzenpaares unterscheidet und wobei Formen und/oder Lagebeziehungen der jeweiligen Walzen des ersten und des zweiten Walzenpaares derart ausgebildet sind, daß sich die Gestalt des Querschnitts des gewalzten Drahts nach dem ersten Walzenpaar von der nach dem zweiten Walzenpaar unterscheidet; wobei

Walzreduktionen in dem ersten und dem zweiten Walzenpaar an dem Werkstück in einem Bereich änderbar sind, der einer Variation eines resultierenden Drahtdurchmessers D entspricht;

dadurch gekennzeichnet, daß

Formen und/oder Lagebeziehungen jeweiliger Walzen des ersten und des zweiten Walzenpaares derart ausgebildet sind, daß ein nach dem zweiten Walzenpaar erhaltener Draht einen im Wesentlichen runden oder quadratischen Querschnitt und einen resultierenden Durchmesser von weniger als 5,5 mm aufweist; und

das erste und das zweite Walzenpaar derart angeordnet sind, daß ein Verhältnis von L/D, wobei L der Mittenabstand zwischen dem ersten und dem zweiten Walzenpaar ist und D der nach Walzen durch das zweite Walzenpaar erhaltene Drahtdurchmesser ist, weniger als 30 beträgt.

28. Vorrichtung gemäß Anspruch 27, welche weiter eine Heizvorrichtung (44) aufweist, welche vor der Walzstraße auf dem Weg der Zuführung des Werkstücks angeordnet ist und eine Induktionsheizspule zum kontinuierlichen Erwärmen des Werkstücks aufweist.

29. Vorrichtung gemäß Anspruch 27, welche weiter aufweist:

eine Entzunderungsvorrichtung (4), welche vor der Walzstraße auf dem Weg der Zuführung des Werkstücks zum kontinuierlichen Entfernen von auf dem Werkstück ausgebildetem Zunder in kontinuierlicher Zuführung angeordnet ist; und

eine Heizvorrichtung (71a, 71b; 72; 5), welche eine das Werkstück berührende Elektrode (71a, 71b; 51, 52, 53, 54) aufweist, die eine kontinuierliche Zuführung hiervon erlaubt und zum Widerstandsheizen des Werkstücks elektrischen Strom durch die Elektrode in das Werkstück schickt, wobei die Heizvorrichtung zwischen der Entzunderungsvorrichtung (4) und der Walzstraße (6) angeordnet ist.

30. Vorrichtung gemäß Anspruch 28 oder 29, wobei der Abstand zwischen der Heizvorrichtung (5; 44) und der Walzstraße (6) weniger als 4 m beträgt.

31. Vorrichtung gemäß einem der Ansprüche 27 bis 30, wobei eine Walzreduktion an dem Werkstück durch jedes Walzenpaar gemäß der Art des Werkstücks varrierbar ist und das Verhältnis R1/R2, wobei R1 und R2 Walzendrehzahlen des ersten bzw. des zweiten Walzenpaares sind, gemäß der Walzreduktion einstellbar ist.

32. Vorrichtung gemäß Anspruch 31, wobei die Walzreduktion und das Verhältnis R1/R2 gemäß dem Torsionswiderstand des Werkstücks variierbar bzw. einstellbar sind.

33. Vorrichtung gemäß einem der Ansprüche 27 bis 32, wobei das Verhältnis R1/R2, wobei R1 und R2 Walzendrehzahlen in dem ersten bzw. dem zweiten Walzenpaar sind, auf einem gewünschten Wert festgelegt ist; und

wobei die Gesamtwalzreduktion an dem Werkstück durch das erste und das zweite Walzenpaar so variierbar ist, daß die resultierende Änderung in der Flächenreduktion des Werkstücks innerhalb von 10 % liegt.

34. Vorrichtung gemäß einem der Ansprüche 27 bis 33, wobei die Gesamtwalzreduktion an dem Werkstück durch das erste und das zweite Walzenpaar so variierbar ist, daß die resultierende Änderung in der Flächenreduktion des Werkstücks innerhalb von 40 % liegt; und

wobei das Verhältnis R1/R2, wobei R1 und R2 Walzendrehzahlen in dem ersten bzw. dem zweiten Walzenpaares sind, gemäß dem Wert der Gesamtwalzreduktion an dem Werkstück variierbar ist.

35. Vorrichtung gemäß Anspruch 34, wobei Formen und/oder Größen eines Bemessungswegs des ersten und des zweiten Walzenpaares gemäß dem Wert der Gesamtwalzreduktion an dem Werkstück änderbar ist.

36. Vorrichtung gemäß einem der Ansprüche 27 bis 35,

wobei jedes des ersten und des zweiten Walzenpaares zwei Walzen (101a, 101b, 102a, 102b; 101a', 101b') aufweist, welche Rillen (161a, 161b, 162a, 162b) auf der Umfangsoberfläche hiervon aufweisen, um einen Bemessungsweg (161c, 162c) auszubilden, welcher eine Querschnittsform des Drahts bestimmt;

wobei die Breite der Rillen (161a, 161b) für das erste Walzenpaar weniger als 7 mm beträgt;

wobei die Breite der Rillen (162a, 162b) für das zweite Walzenpaar weniger als 6 mm beträgt; und

wobei der Mittenabstand (L) zwischen dem ersten und dem zweiten Walzenpaar weniger als 50 mm beträgt.

37. Vorrichtung gemäß einem der Ansprüche 27 bis 35,

wobei ein Zwischenraum zwischen zwei Walzen (101a, 101b) für das erste Walzenpaar weniger als 7 mm beträgt;

wobei ein Zwischenraum zwischen zwei Walzen (102a, 102b) für das zweite Walzenpaar weniger als 6 mm beträgt; und

und wobei der Mittenabstand (L) zwischen dem ersten und dem zweiten Walzenpaar weniger als 50 mm beträgt.

38. Vorrichtung gemäß Anspruch 36 oder 37, wobei das erste und das zweite Walzenpaar zum Herstellen von Draht abwechselnd derart angeordnet sind,

daß der Winkel zwischen den Rotationsachsen hiervon nahezu 90° beträgt;

wobei Formen und/oder Größen des ersten Walzenpaares (12; 212; 101, 102) derart ausgebildet sind, daß die Querschnittsdimension des Werkstücks in einer Richtung einer Walzreduktion D1 weniger wird als in einer Richtung D2 senkrecht zu dieser Richtung einer Walzreduktion;

und wobei Formen und/oder Größen des zweiten Walzenpaares (14; 214; 102, 202) derart ausgebildet sind, daß das Verhältnis der Dimensionen D2/D1 verringert wird.

39. Vorrichtung gemäß einem der Ansprüche 36 bis 38, wobei sowohl das erste als auch das zweite Walzenpaar von einem Walzenzwischenraum-Einstellmechanismus (26, 32, 34, 36, 38) zum Bewegen zweier Walzen (101a, 101b, 102a, 102b) jedes Walzenpaares (12, 14) relativ aufeinander zu und voneinander weg in der Richtung einer Walzreduktion begleitet wird;

und wobei jeder Walzenzwischenraum-Einstellmechanismus aufweist:

Lagerabschnitte (26), welche die Wellen der zwei Walzen jeweils unterstützen;

und einen Lagerdrehmechanismus (32, 34, 36, 38), welcher jeden der Lagerabschnitte (26) um eine von einer entsprechenden Walzenachse (C_1) abweichende exzentrische Achse (C_2) jeweils in entgegengesetzte Richtung dreht, wodurch die zwei Walzen relativ aufeinander zu und voneinander weg bewegt werden.

40. Vorrichtung gemäß Anspruch 39, wobei der Lagerdrehmechanismus (32, 34, 36, 38) für das erste Walzenpaar (12) stromaufwärts des ersten Walzenpaares angeordnet ist und der Lagerdrehmechanismus für das zweite Walzenpaar (14) stromabwärts des zweiten Walzenpaares angeordnet ist.

41. Vorrichtung gemäß Anspruch 40, wobei der Lagerdrehmechanismus (32, 34, 36, 38) aufweist:

erste Zahnradabschnitte (26b), welche jeweils auf den Umfängen der Lagerabschnitte (26) der zwei Walzen angeordnet sind;

zweite Zahnradabschnitte (34), die jeweils mit dem entsprechenden ersten Zahnradabschnitt (26b) eingreifen;

und einen Antriebsmechanismus (36, 38), welcher die zweiten Zahnradabschnitte (34) synchron in einander entgegengesetzten Richtungen dreht.

42. Vorrichtung gemäß Anspruch 41, wobei die zweiten Zahnradabschnitte Schnecken (34) sind, welche axial auf einer Schneckendrehwelle (32) mit einem bestimmten Abstand entlang der Längsrichtung hiervon angeordnet sind und deren Windungen in einander entgegengesetzten Richtungen ausgebildet sind;

und wobei der Antriebsmechanismus (36, 38) die Schneckendrehwelle (32) antreibt, wodurch die Schnecken (34) gemeinsam angetrieben werden.

43. Vorrichtung gemäß Anspruch 42, wobei der Lagerabschnitt aufweist:

Lagergehäuse (24), welche entsprechend beiden Endabschnitten einer Walzenwelle (28) angeordnet sind und von welchen jedes ein Lageraufnahmeloch (24a) aufweist, welches sich entlang der Walzenwelle (28) erstreckt;

Lagerhauptkörper (26), von welchen jeder in dem Lageraufnahmeloch (24a) aufgenommen ist;

wobei ein Lagerloch (26a) in jedem der Lagerhauptkörper (26) derart ausgebildet ist, daß die Mitte des Lagerlochs (26a) von der Rotationsachse (C_2) des Lagerhauptkörpers (26) ausgerückt ist und jeder Endabschnitt der Walzenwelle (28) in dem Lagerloch (26a) drehbar unterstützt ist;

und wobei der Lagerhauptkörper (26) einen ersten Zahnradabschnitt (26a) auf seinem Umfang aufweist und durch die in den ersten Zahnradabschnitt (26a) eingreifenden Schnecke (32) um eine von der Rotationsachse (C_1) der Rolle versetzte, exzentrische Achse (C_2) gedreht wird.

44. Vorrichtung gemäß Anspruch 43, wobei das Lagerloch (26a) des ersten Walzenpaares (12) in dem von seiner Rotationsachse abweichenden Lagerhauptkörper (26) stromabwärts ausgebildet ist und das Lagerloch (26a) des zweiten Walzenpaares (14) in dem von seiner Rotationsachse abweichenden Lagerhauptkörper (26) stromaufwärts ausgebildet ist.

45. Vorrichtung gemäß einem der Ansprüche 36 bis 44, wobei wenigstens eines des ersten und des zweiten Walzenpaares (12, 14) mit einem Walzenschubeinstellmechanismus (170) ausgerüstet ist, welcher die zwei Walzen (101a, 101b, 102a, 102b) relativ in der Schubrichtung hiervon bewegt und die zwei Walzen in beliebigen Positionen in der Schubrichtung hält.

46. Vorrichtung gemäß Anspruch 45, wobei der Walzenschubeinstellmechanismus (170) aufweist:

einen feststehenden Lagerabschnitt (30), welcher für wenigstens eine der zwei Walzen vorgesehen ist und die Walzenwelle (28) drehbar und beweglich in ihrer Schubrichtung hält;

und einen Walzenschiebemechanismus (171), welcher mit einem Endabschnitt der Walzenwelle (28) verbunden ist und die Walzenwelle in der Schubrichtung gegen den Lagerabschnitt (30) schiebt.

47. Vorrichtung gemäß Anspruch 46, wobei der Walzenschiebemechanismus (171) aufweist:

einen Wellenhalter (172), mit welchem der Endabschnitt der Walzenwelle (28) verbunden ist und welcher zusammen mit der Walzenwelle in der Schubrichtung beweglich ist;
einen Einstellschraubmechanismus (173), welcher . mit dem Wellenhalter direkt oder indirekt mit einem anderen Bauteil verbunden ist und den Wellenhalter (172) in der Schubrichtung gemäß seiner Tätigkeit eines Hinein- oder Herausdrehens bewegt.

48. Vorrichtung gemäß Anspruch 47, wobei der Lagerabschnitt einen Lagerhauptkörper (26) aufweist, welcher ein Durchgangsloch als ein Lagerloch (26a) in der Richtung der Walzenwelle (28) aufweist und den einen Endabschnitt der Walzenwelle in dem Durchgangsloch drehbar unterstützt;

wobei der Wellenhalter (172) in dem Durchgangsloch (26a) mit der Walzenwelle (28) in der Schubrichtung beweglich ist;

wobei der Wellenhalter (172) einen wellenartig hervorstehenden Abschnitt (177) aufweist, welcher sich entlang der axialen Richtung der Walzenwelle (28) in dem Durchgangsloch (26a) erstreckt und dessen Endabschnitt außerhalb von der entsprechenden Öffnung (26b) des Durchgangslochs hervorsteht;

wobei auf der Innenseite des Durchgangslochs (26a) ein Muttergewindeabschnitt (26c) auf dem Endabschnitt hiervon ausgebildet ist, welcher zu der Öffnung (26b) führt;

wobei ein Schraubengewindebauteil (178) in einer Position auf den Muttergewindeabschnitt (26c) geschraubt ist, die dem Teil des des wellenartig hervorstehenden Abschnitts (177) dazwischen entspricht;

wobei ein Stopper (179) auf dem wellenartig hervorstehenden Abschnitt (177) montiert ist, um eine Relativbewegung des Schraubengewindebauteils (178) gegenüber dem wellenartig hervorstehenden Abschnitt in der axialen Richtung hiervon zu verhindern;

und wobei der Einstellschraubmechanismus (173) den Wellenhalter (172) und die Walzenwelle (28) in der Schubrichtung zusammen mit dem Schraubengewindebauteil (178) gemäß der Drehung des Schraubengewindebauteils bewegt.

49. Vorrichtung gemäß einem der Ansprüche 29 bis 48, wobei die Entzunderungsvorrichtung eine Abstrahlvorrichtung (4) zum Entfernen des Zunders durch Aufstrahlen eines Stroms von abrasiven Teilchen auf die Oberfläche des Werkstücks in kontinuierlicher Zuführung aufweist.

50. Vorrichtung gemäß einem der Ansprüche 29 bis 49, wobei die Heizvorrichtung (5) aufweist:

eine Rollenelektrode (51-54) zum Vorsehen eines Kontakts mit dem Werkstück und Schicken von elektrischem Strom in das Werkstück zum Zwecke des Widerstandsheizens desselben; und

einen Drängmechanismus (55-58) zum Drängen der Rollenelektrode gegen das Werkstück.

51. Vorrichtung gemäß einem der Ansprüche 31, 32, 34 oder 35, wobei das erste (12; 101, 102) und das zweite (14; 201, 202) Walzenpaar durch eine gemeinsame Antriebseinrichtung (252) durch ein erstes (253, 255) bzw. ein zweites (254, 256) Untersetzungsgetriebesystem angetrieben werden;

und wobei das Reduktionsverhältnis zwischen Ständern Q1/Q2, wobei Q1 das Untersetzungsverhältnis des ersten Untersetzungsgetriebesystems ist und Q2 das Untersetzungsverhältnis des zweiten Untersetzungsgetriebesystems ist, variiert wird, um das Verhältnis R1/R2 zu ändern.

52. Vorrichtung gemäß Anspruch 51, wobei durch eine Mehrzahl von Walzenpaareinheiten (S), von denen jede ein erstes und ein zweites Walzenpaar aufweist, in der Zuführungsrichtung des Werkstücks angeordnet sind und das Werkstück nacheinander durch die Mehrzahl von Walzenpaareinheiten gewalzt wird;

wobei die Reduktionsverhältnisse zwischen Ständern Q1/Q2 der Walzenpaareinheiten in synchroner Weise geändert werden;

und wobei, wenn das Reduktionsverhältnis zwischen Ständern für eine der Walzenpaareinheiten auf einen gewünschten Wert festgelegt ist, die Reduktionsverhältnisse zwischen Ständern für andere Walzenpaareinheiten auf entsprechende Werte in synchroner Weise eingestellt werden.

Revendications

1. Procédé de fabrication d'un fil, comprenant les étapes consistant à :

laminer une matière première (A1) successivement avec une première paire de rouleaux lamineurs (12 ; 212 ; 101, 201) et une deuxième paire de rouleaux lamineurs (14 ; 214 ; 102, 202) d'un laminoir (6), lesdites première et deuxième paires de rouleaux lamineurs étant agencées de manière à se trouver espacées l'une par rapport à l'autre dans une direction de fourniture de ladite matière première ; et laminer ladite matière première dans des directions différentes l'une par rapport à l'autre de telle sorte que la forme de la section transversale du fil laminé après la première paire de rouleaux lamineurs est différente de celle après la deuxième paire de rouleaux lamineurs ; et

faire varier un diamètre D de fil laminé obtenu dans une plage déterminée en modifiant les réductions de laminage dans lesdites . première et deuxième paires de rouleaux lamineurs par rapport à ladite matière première dans une plage correspondante ;

ledit procédé étant **caractérisé par** une étape consistant à :

définir un rapport de L/D à moins de 30, dans lequel L est la distance centrale entre lesdites première et deuxième paires de rouleaux lamineurs, et D est le diamètre du fil métallique obtenu après laminage par ladite deuxième paire de rouleaux lamineurs ; de telle sorte que

le fil obtenu après ladite deuxième paire de rouleaux lamineurs ait un diamètre D résultant, de moins de 5,5 mm.

2. Procédé selon la revendication 1 qui comprend, avant que ladite matière première ne soit laminée en utilisant ledit laminoir (6), l'étape consistant à :

chauffer ladite matière première en continu pendant qu'elle est fournie, en utilisant un dispositif de réchauffage (44) qui est disposé sur le passage de ladite matière première fournie et qui comprend un serpentin de chauffage par induction prévu pour chauffer ladite matière première en continu.

3. Procédé selon la revendication 1 qui comprend, avant que ladite matière première ne soit laminée en utilisant ledit laminoir (6), les étapes consistant à :

éliminer en continu la calamine formée sur la matière première pendant qu'elle est fournie en continu, en utilisant un dispositif d'élimination de la calamine (4) disposé sur le passage de ladite matière première fournie ; et

chauffer ladite matière première après que la calamine a été éliminée, en utilisant un dispositif de réchauffage (71a, 71b, 72 ; 5) qui comprend une électrode (71a, 71b ; 51, 52, 53, 54) qui vient en contact avec ladite matière première, ce qui permet à celle-ci d'être fournie en continu, et qui envoie un courant électrique dans ladite matière première par l'intermédiaire de ladite électrode afin de réaliser le chauffage par résistance de ladite matière première.

4. Procédé selon la revendication 2 ou 3, comprenant en outre une étape consistant à maintenir la température à une valeur désirée dudit fil avant de laminer celui-ci dans ledit laminoir (6) en définissant une distance entre ledit dispositif de réchauffage (5 ; 44) et ledit laminoir (6) à moins de 4 m.

5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel la réduction de laminage par rapport à ladite matière première par chaque paire de rouleaux lamineurs est variée selon la variété de ladite matière première, et le rapport R1/R2, dans lequel R1 et R2 sont des vitesses de rotation des rouleaux desdites première et deuxième paires de rouleaux lamineurs, respectivement, est ajusté en fonction de ladite réduction de laminage.

6. Procédé selon la revendication 5, dans lequel ladite réduction de laminage et ledit rapport R1/R2 sont variés en fonction de la rigidité de torsion de ladite matière première.

7. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel le rapport R1/R2, dans lequel R1 et R2 sont des vitesses de rotation des rouleaux dans lesdites première et deuxième paires de rouleaux lamineurs, respectivement, est fixé à une valeur déterminée ; et
dans lequel la réduction de laminage totale par rapport à ladite matière première par lesdites première et deuxième paires de rouleaux lamineurs est variée de telle sorte que le changement obtenu dans la réduction de la surface de ladite matière première est compris dans les 10%

8. Procédé selon l'une quelconque des revendications 1 à 7, dans lequel la réduction de laminage totale par rapport à ladite matière première par lesdites première et deuxième paires de rouleaux lamineurs est variée de telle sorte que le changement obtenu dans la réduction de la surface de ladite matière première est compris dans les 40 % ; et
dans lequel le rapport R1/R2, dans lequel R1 et R2 sont des vitesses de rotation des rouleaux dans lesdites première et deuxième paires de rouleaux la-

mineurs, respectivement, est varié en fonction de la valeur de ladite réduction de laminage totale par rapport à ladite matière première.

9. Procédé selon la revendication 8, dans lequel les formes et/ou les dimensions d'un passage de calibration desdites première et deuxième paires de rouleaux lamineurs sont modifiées en fonction de la valeur de ladite réduction de laminage totale par rapport à ladite matière première.

10. Procédé selon l'une quelconque des revendications 1 à 9, dans lequel chacune desdites première et deuxième paires de rouleaux lamineurs comprend deux rouleaux (101a, 101b, 102a, 102b ; 101a', 101b') qui comportent des rainures (161a, 161b, 162a, 162b) sur la surface circonférentielle de ceux-ci prévues pour réaliser un passage de calibration (161c, 162c) qui détermine la forme de section transversale dudit fil ; le procédé comprenant en outre les étapes consistant à :

définir la largeur desdites rainures (161a, 161b) à moins de 7 mm pour ladite première paire de rouleaux lamineurs ;

définir la largeur desdites rainures (162a, 162b) à moins de 6 mm pour ladite deuxième paire de rouleaux lamineurs ; et

définir la distance centrale (L) entre lesdites première et deuxième paires de rouleaux lamineurs à moins de 50 mm.

11. Procédé selon l'une quelconque des revendications 1 à 9, comprenant en outre les étapes consistant à :

définir un jeu formé entre deux rouleaux (101a, 101 b) à moins de 7 mm pour ladite première paire de rouleaux lamineurs ;

définir un jeu formé entre deux rouleaux (102a, 102b) à moins de 6 mm pour ladite deuxième paire de rouleaux lamineurs ; et

définir la distance centrale (L) entre lesdites première et deuxième paires de rouleaux lamineurs à moins de 50 mm.

12. Procédé selon la revendication 10 ou 11, dans lequel lesdites première et deuxième paires de rouleaux lamineurs adaptées pour fabriquer un fil laminé sont agencées de façon alternée de telle sorte que l'angle formé entre les axes de rotation de celles-ci est de presque 90° ;
dans lequel ladite matière première est laminée par ladite première paire de rouleaux lamineurs (12 ; 212 ; 101, 201) de telle sorte que la dimension de section transversale de ladite matière première dans une direction de réduction de laminage, D1, devient moins importante que celle dans une direction perpendiculaire par rapport à ladite direction de réduction de laminage D2 ;
et dans lequel ladite matière première est laminée par ladite deuxième paire de rouleaux lamineurs (14 ; 214 ; 102, 202) de telle sorte que le rapport desdites dimensions, D2/D1, est réduit.

13. Procédé selon l'une quelconque des revendications 10 à 12, comprenant en outre une étape consistant à déplacer deux rouleaux (101a, 101b, 102a, 102b) de chacune des paires de rouleaux lamineurs (12, 14) en les rapprochant ou en les éloignant relativement l'un de l'autre dans la direction de réduction de laminage à l'aide de mécanismes d'ajustement du jeu respectif des rouleaux (26, 32, 34, 36, 38) accompagnant chacune desdites première et deuxième paires de rouleaux lamineurs ;
dans lequel chacun des mécanismes d'ajustement du jeu des rouleaux comprend :

des parties de roulement (26) qui supportent de façon rotative les arbres desdits deux rouleaux, respectivement ;

et un mécanisme de rotation de roulement (32, 34, 36, 38) qui fait tourner chacune desdites parties de roulement (26) autour d'un axe excentrique (C2) dévié par rapport à un axe de rouleau correspondant (C1) dans une direction opposée, respectivement, moyennant quoi lesdits deux rouleaux tournent en se rapprochant et en s'éloignant relativement l'un de l'autre.

14. Procédé selon la revendication 13, dans lequel ledit mécanisme de rotation de roulement (32, 34, 36, 38) pour ladite première paire de rouleaux lamineurs (12) est agencé en amont de ladite première paire de rouleaux lamineurs, et ledit mécanisme de rotation de roulement pour ladite deuxième paire de rouleaux lamineurs (14) est agencé en aval de ladite deuxième paire de rouleaux lamineurs.

15. Procédé selon la revendication 14, dans lequel ledit mécanisme de rotation de roulement (32, 34, 36, 38) comprend :

des premières parties d'engrenage (26b) qui sont formées sur les circonférences desdites parties de roulement (26) desdits deux rouleaux, respectivement ;

des deuxièmes parties d'engrenage (34) dont chacune se met en prise avec la première partie d'engrenage correspondante (26b) ;

et dans lequel un mécanisme d'entraînement (36, 38) fait tourner lesdites deuxièmes parties d'engrenage (34) de façon synchrone dans des directions opposées l'une par rapport à l'autre.

16. Procédé selon la revendication 15, dans lequel lesdites deuxièmes parties d'engrenage sont des vis sans fin (34) qui sont disposées axialement sur un arbre rotatif de commande de vis sans fin (32) à un intervalle déterminé le long de la direction longitudinale de celui-ci et dont les filets sont formés dans des directions opposées les uns par rapport aux autres ;
et dans lequel lesdites vis sans fin (34) sont tournées d'un seul tenant par l'entraînement dudit arbre rotatif de commande de vis sans fin (32) au moyen dudit mécanisme d'entraînement (36, 38).

17. Procédé selon la revendication 16, dans lequel ladite partie de roulement comprend :

des carters de roulement (24) qui sont agencés de part et d'autre des parties d'extrémité d'un arbre à rouleaux (28) et dont chacun comporte un orifice de réception de roulement (24a) s'étendant le long dudit arbre à rouleaux (28) ;

des corps principaux de roulements (28) dont chacun est logé dans chacun desdits orifices de logement de roulement (24a) ;

dans lequel un orifice de roulement (26a) est réalisé dans chacun desdits corps principaux de roulement (26) de telle sorte que le centre dudit orifice de roulement (26a) est dévié par rapport à l'axe de rotation (C2) dudit corps principal de roulement (26) et dont chaque partie d'extrémité dudit arbre à rouleaux (28) est supportée relativement dans ledit orifice de roulement (26a) ;
et dans lequel ledit corps principal de roulement (26) porte ladite première partie d'engrenage (26b) sur sa circonférence et il est tourné par ladite vis sans fin (32) en prise avec ladite première partie d'engrenage (26b) autour d'un axe excentrique (C2) dévié par rapport à l'axe de rotation (C1) dudit rouleau lamineur.

18. Procédé selon la revendication 17, dans lequel ledit orifice de roulement (26a) de ladite première paire de rouleaux lamineurs (12) est formé dans ledit corps principal de roulement (26) dévié par rapport à son axe de rotation dans la direction en aval, et ledit orifice de roulement (26a) de ladite deuxième paire de rouleaux lamineurs (14) est formé dans ledit corps principal de roulement (26) dévié par rapport à son axe de rotation dans la direction en amont.

19. Procédé selon l'une quelconque des revendications 10 à 18, comprenant en outre les étapes consistant à déplacer lesdits deux rouleaux (101a, 101b, 102a, 102b) relativement dans la direction de butée de ceux-ci et à maintenir lesdits deux rouleaux à une position arbitraire dans ladite direction de butée au moyen d'un mécanisme de réglage de butée de rouleau (170) dont au moins une desdites première et deuxième paires de rouleaux lamineurs (12, 14) est équipée.

20. Procédé selon la revendication 19, dans lequel ledit mécanisme de réglage de butée de rouleau (170) comprend :

une partie de roulement fixe (30) qui est fournie pour au moins un desdits deux rouleaux et qui maintient l'arbre à rouleaux (28) de telle sorte qu'il soit susceptible de tourner et de se déplacer dans sa direction de butée ;

et un mécanisme de coulissement de rouleau (171) qui est raccordé à une partie d'extrémité dudit arbre à rouleaux (29) et qui fait coulisser ledit arbre à rouleaux contre ladite partie de roulement (30) dans ladite direction de butée.

21. Procédé selon la revendication 20, dans lequel ledit mécanisme de coulissement de rouleau (171) comprend :

un support d'arbre (172) auquel ladite partie d'extrémité dudit arbre à rouleaux (28) est raccordée et qui est susceptible de se déplacer d'un seul tenant avec ledit arbre à rouleaux dans ladite direction de butée ;

un mécanisme de vis de réglage (173) qui est raccordé au dit support d'arbre directement ou indirectement avec un autre élément et qui déplace ledit support d'arbre (172) dans ladite direction de butée selon qu'il est vissé ou dévissé.

22. Procédé selon la revendication 21, dans lequel ladite partie de roulement comprend un corps principal de roulement (26) qui comporte un trou traversant agissant en tant qu'un orifice de roulement (26a) dans la direction dudit arbre à rouleaux (28) et qui supporte de façon rotative ladite une extrémité partie dudit arbre à rouleaux dans ledit trou traversant ;
dans lequel ledit support d'arbre (172) est susceptible de se déplacer dans ledit trou traversant (26a) avec ledit arbre à rouleaux (28) dans ladite direction de butée ;
dans lequel ledit support d'arbre (172) comporte une partie saillante semblable à une tige (177) qui

s'étend le long de la direction axiale dudit arbre à rouleaux (28) dans ledit trou traversant (26a) et dont la partie d'extrémité se projette en saillie à l'extérieur à partir de l'ouverture correspondante (26b) dudit trou traversant ;
dans lequel, sur le côté intérieur dudit trou traversant (26a), une partie de vissage femelle (26c) est réalisée sur la partie d'extrémité de celui-ci qui aboutit à ladite ouverture (26b) ;
dans lequel un élément de vissage mâle (178) est vissé sur ladite partie de vissage femelle (26c) dans une position correspondant à la partie intermédiaire de ladite partie saillante semblable à une tige (177) ;
dans lequel une butée (179) est montée sur ladite partie saillante semblable à une tige (177) afin d'empêcher ledit élément de vissage mâle (178) de se déplacer relativement contre ladite partie saillante semblable à une tige dans la direction axiale de celle-ci ;
et dans lequel ledit mécanisme de vis de réglage (173) déplace ledit support d'arbre (172) et ledit arbre à rouleaux (28) dans ladite direction de butée le long en même temps que ledit élément de vissage mâle (178) en fonction de la rotation dudit élément de vissage mâle.

23. Procédé selon l'une quelconque des revendications 3 à 22, dans lequel ladite étape consistant à éliminer en continu la calamine formée sur la matière première comprend une étape consistant à projeter un flux de particules abrasives sur la surface de ladite matière première pendant qu'elle est fournie en continu au moyen d'un dispositif de grenaillage (4).

24. Procédé selon l'une quelconque des revendications 3 à 23 dans lequel ladite étape consistant à chauffer ladite matière première comprend les étapes consistant à :

mettre ladite matière première en contact avec une électrode rouleau (51 À 54) et envoyer un courant électrique dans ladite matière première afin de réaliser son chauffage par résistance ; et

pousser ladite électrode rouleau contre ladite matière première au moyen d'un mécanisme de poussée (55 à 58).

25. Procédé selon l'une quelconque des revendications 5, 6, 8 et 9, comprenant en outre une étape consistant à entraîner lesdites première (12 ; 101, 102) et deuxième (14 ; 201, 202) paires de rouleaux lamineurs à l'aide de moyens d'entraînement communs (252) par l'intermédiaire d'un premier (253, 255) et d'un deuxième (254, 256) systèmes d'engrenages réducteurs, respectivement ;
dans lequel le rapport de réduction entre engrenages réducteurs Q1/Q2, dans lequel Q1 correspond au rapport de l'engrenage réducteur dudit premier système d'engrenage réducteur et Q2 correspond au rapport de l'engrenage réducteur dudit deuxième système d'engrenage réducteur, est varié de manière à modifier ledit rapport R1/R2.

26. Procédé selon la revendication 25 comprenant en outre les étapes consistant à :

laminer successivement ladite matière première par une pluralité d'unités de paires de rouleaux lamineurs (S) comprenant chacune lesdites première et deuxième paires de rouleaux lamineurs, lesdites unités de paires de rouleaux lamineurs étant agencées dans une direction de fourniture de ladite matière première ;

modifier ledit rapport de réduction entre engrenages réducteurs Q1/Q2 desdites unités de paires de rouleaux lamineurs de façon synchrone ; et

lorsque ledit rapport de réduction entre engrenages réducteurs est défini à une valeur déterminée pour l'une des unités de paires de rouleaux lamineurs, définir également les rapports de réduction entre engrenages réducteurs pour les autres unités de paires de rouleaux lamineurs selon des valeurs correspondantes de façon synchrone.

27. Appareil adapté pour fabriquer un fil, comprenant :

une première paire de rouleaux lamineurs (12 ; 212 ; 101, 201) et une deuxième paire de rouleaux lamineurs (14 ; 214 ; 102, 202) d'un laminoir (6) pour laminer successivement une matière première (A1), lesdites première et deuxième paires de rouleaux lamineurs étant agencées de manière à se trouver espacées l'une par rapport à l'autre dans une direction de fourniture de ladite matière première ; dans lequel une position angulaire des axes de rotation de ladite première paire de rouleaux lamineurs est différente de celle de ladite deuxième paire de rouleaux lamineurs ; et dans lequel les formes et/ou les relations de position des rouleaux respectifs desdites première et deuxième paires de rouleaux lamineurs sont réalisées de telle sorte que la forme de la section transversale du fil laminé après la première paire de rouleaux lamineurs est différente de celle après la deuxième paire de rouleaux lamineurs ; dans lequel :

les réductions de laminage dans lesdites première et deuxième paires de rouleaux lamineurs par rapport à ladite matière première peuvent être modifiées dans une plage correspondant à une variation d'un diamètre D de fil laminé obtenu ;

caractérisé en ce que

les formes et/ou les relations de position des rouleaux respectifs desdites première et deuxième paires de rouleaux lamineurs sont réalisées de telle sorte que le fil obtenu après ladite deuxième paire de rouleaux lamineurs comprenne une section transversale sensiblement ronde ou carrée et qu'il ait un diamètre D de moins de 5,5 mm ; et
lesdites première et deuxième paires de rouleaux lamineurs sont agencées de telle sorte qu'un rapport de L/D, dans lequel L est la distance centrale entre lesdites première et deuxième paires de rouleaux lamineurs, et D est le diamètre du fil métallique obtenu après laminage par ladite deuxième paire de rouleaux lamineurs, soit de moins de 30.

28. Appareil selon la revendication 27, comprenant en outre un dispositif de réchauffage (44) qui est disposé avant ledit laminoir sur le passage de ladite matière première fournie et comprend un serpentin de chauffage par induction de manière à chauffer ladite matière première en continu.

29. Appareil selon la revendication 27, comprenant en outre :

un dispositif d'élimination de la calamine (4) qui est disposé avant ledit laminoir sur le passage de ladite matière première fournie pour éliminer en continu la calamine formée sur la matière première lorsqu'elle fournie en continu ; et

un dispositif de réchauffage (71a, 71b, 72 ; 5) qui comprend une électrode (71a, 71b ; 51, 52, 53, 54) qui vient en contact avec ladite matière première, ce qui permet à celle-ci d'être fournie en continu, et qui envoie un courant électrique dans ladite matière première par l'intermédiaire de ladite électrode afin de réaliser le chauffage par résistance de ladite matière première, ledit dispositif de réchauffage étant disposé entre ledit dispositif d'élimination de la calamine (4) et ledit laminoir (6).

30. Appareil selon la revendication 28 ou 29, dans lequel la distance entre ledit dispositif de réchauffage (5 ; 44) et ledit laminoir (6) est de moins de 4 m.

31. Appareil selon l'une quelconque des revendications 27 à 30, dans lequel la réduction de laminage par rapport à ladite matière première par chaque paire de rouleaux lamineurs peut varier en fonction de la variabilité de ladite matière première, et le rapport R1/R2, dans lequel R1 et R2 sont des vitesses de rotation des rouleaux desdites première et deuxième paires de rouleaux lamineurs, respectivement, est ajustable en fonction de ladite réduction de laminage.

32. Appareil selon la revendication 31 dans lequel ladite réduction de laminage peut varier et ledit rapport R1/R2 peut être réglé en fonction de la rigidité de torsion de ladite matière première.

33. Appareil selon l'une quelconque des revendications 27 à 32 dans lequel le rapport R1/R2, dans lequel R1 et R2 sont des vitesses de rotation des rouleaux dans lesdites première et deuxième paires de rouleaux lamineurs, respectivement, peut être fixé à une valeur déterminée ; et
dans lequel la réduction de laminage totale par rapport à ladite matière première par lesdites première et deuxième paires de rouleaux lamineurs peut varier de telle sorte que le changement obtenu dans la réduction de la surface de ladite matière première est compris dans les 10 %.

34. Appareil selon l'une quelconque des revendications 27 à 33, dans lequel la réduction de laminage totale par rapport à ladite matière première par lesdites première et deuxième paires de rouleaux lamineurs peut varier de telle sorte que le changement obtenu dans la réduction de la surface de ladite matière première est compris dans les 40 % ; et
dans lequel le rapport R1/R2, dans lequel R1 et R2 sont des vitesses de rotation des rouleaux dans lesdites première et deuxième paires de rouleaux lamineurs, respectivement, peut varier en fonction de la valeur de ladite réduction de laminage totale par rapport à ladite matière première.

35. Appareil selon la revendication 34, dans lequel les formes et/ou les dimensions du passage de calibration desdites première et deuxième paires de rouleaux lamineurs peuvent être modifiées en fonction de la valeur de ladite réduction de laminage totale par rapport à ladite matière première.

36. Appareil selon l'une quelconque des revendications des revendications 27 à 35,
dans lequel chacune desdites première et deuxième paires de rouleaux lamineurs comprend deux rouleaux (101a, 101b, 102a, 102b ; 101a', 101b') qui comportent des rainures (161a, 161b, 162a, 162b) sur la surface circonférentielle de ceux-ci prévues pour réaliser un passage de calibration (161c, 162c) qui détermine la forme de section transversale dudit fil ;
dans lequel la largeur desdites rainures (161a,

161b) est de moins de 7 mm pour ladite première paire de rouleaux lamineurs ;
dans lequel la largeur desdites rainures (162a, 162b) est de moins de 6 mm pour ladite deuxième paire de rouleaux lamineurs ;
et dans lequel la distance centrale (L) entre lesdites première et deuxième paires de rouleaux lamineurs est de moins de 50 mm.

37. Appareil selon l'une quelconque des revendications des revendications 27 à 35,
dans lequel un jeu formé entre deux rouleaux (101a, 101b) est de moins de 7 mm pour ladite première paire de rouleaux lamineurs ;
dans lequel un jeu formé entre deux rouleaux (102a, 102b) est de moins de 6 mm pour ladite deuxième paire de rouleaux lamineurs ;
et dans lequel la distance centrale (L) entre lesdites première et deuxième paires de rouleaux lamineurs est de moins de 50 mm.

38. Appareil selon la revendication 36 ou 37, dans lequel lesdites première et deuxième paires de rouleaux lamineurs adaptées pour fabriquer un fil laminé sont agencées de façon alternée de telle sorte que l'angle formé entre les axes de rotation de celles-ci est de presque 90° ;
dans lequel les formes et/ou les dimensions de ladite première paire de rouleaux lamineurs (12 ; 212 ; 101, 201) sont réalisées de telle sorte que la dimension de section transversale de ladite matière première dans une direction de réduction de laminage, D1, devient moins importante que celle dans une direction perpendiculaire par rapport à ladite direction de réduction de laminage D2 ;
et dans lequel les formes et/ou les dimensions de ladite deuxième paire de rouleaux lamineurs (14 ; 214 ; 102, 202) sont réalisées de telle sorte que le rapport desdites dimensions, D2/D1, est réduit.

39. Appareil selon l'une quelconque des revendications 34 à 38 dans lequel chacune desdites première et deuxième paires de rouleaux lamineurs comprend deux rouleaux est accompagnée d'un mécanisme d'ajustement du jeu des rouleaux (26, 32, 34, 36, 38) adapté pour déplacer deux rouleaux (101a, 101b, 102a, 102b) de chaque paire de rouleaux lamineurs (12, 14) relativement en les rapprochant et en les éloignant l'un de l'autre dans la direction de réduction de laminage ;
et dans lequel chacun des mécanismes d'ajustement du jeu des rouleaux comprend :

des parties de roulement (26) qui supportent de façon rotative les arbres desdits deux rouleaux, respectivement ;

et un mécanisme de rotation de roulement (32, 34, 36, 38) qui fait tourner chacune desdites parties de roulement (26) autour d'un axe excentrique (C2) dévié par rapport à un axe de rouleau correspondant (C1) dans une direction opposée, respectivement, moyennant quoi lesdits deux rouleaux tournent en se rapprochant et en s'éloignant relativement l'un de l'autre.

40. Appareil selon la revendication 39, dans lequel ledit mécanisme de rotation de roulement (32, 34, 36, 38) pour ladite première paire de rouleaux lamineurs (12) est agencé en amont de ladite première paire de rouleaux lamineurs, et ledit mécanisme de rotation de roulement pour ladite deuxième paire de rouleaux lamineurs (74) est agencé en aval de ladite deuxième paire de rouleaux lamineurs.

41. Appareil selon la revendication 48, dans lequel ledit mécanisme de rotation de roulement (32, 34, 36, 38) comprend :

des premières parties d'engrenage (26b) qui sont formées sur les circonférences desdites parties de roulement (26) desdits deux rouleaux, respectivement ;

des deuxièmes parties d'engrenage (34) dont chacune se met en prise avec la première partie d'engrenage correspondante (26b) ;

et un mécanisme d'entraînement (36, 38) qui fait tourner lesdites deuxièmes parties d'engrenage (34) de façon synchrone dans des directions opposées l'une par rapport à l'autre.

42. Appareil selon la revendication 41, dans lequel lesdites deuxièmes parties d'engrenage sont des vis sans fin (34) qui sont disposées axialement sur un arbre rotatif de commande de vis sans fin (32) à un intervalle déterminé le long de la direction longitudinale de celui-ci et dont les filets sont formés dans des directions opposées les uns par rapport aux autres ;
et dans lequel ledit mécanisme d'entraînement (36, 38) entraîne ledit arbre rotatif de commande de vis sans fin (32), ladite vis sans fin (34) tournant d'un seul tenant.

43. Appareil selon la revendication 42, dans lequel ladite partie de roulement comprend :

des carters de roulement (24) qui sont agencés de part et d'autre des parties d'extrémité d'un arbre à rouleaux (28) et dont chacun comporte un orifice de réception de roulement (24a) s'étendant le long dudit arbre à rouleaux (28) ;

des corps principaux de roulements (26) dont

chacun est logé dans chacun desdits orifices de logement de roulement (24a) ;

dans lequel un orifice de roulement (26a) est réalisé dans chacun desdits corps principaux de roulement (26) de telle sorte que le centre dudit orifice de roulement (26a) est dévié par rapport à l'axe de rotation (C2) dudit corps principal de roulement (25) et dont chaque partie d'extrémité dudit arbre à rouleau (28) est supportée relativement dans ledit orifice de roulement (26a) ;
et dans lequel ledit corps principal de roulement (26) porte ladite première partie d'engrenage (26b) sur sa circonférence et il est tourné par ladite vis sans fin (32) en prise avec ladite première partie d'engrenage (26b) autour d'un axe excentrique (C2) dévié par rapport à l'axe de rotation (C1) dudit rouleau lamineur.

44. Appareil selon la revendication 43, dans lequel ledit orifice de roulement (26a) de ladite première paire de rouleaux lamineurs (12) est formé dans ledit corps principal de roulement (26) dévié par rapport à son axe de rotation dans la direction en aval, et ledit orifice de roulement (26a) de ladite deuxième paire de rouleaux lamineurs (14) est formé dans ledit corps principal de roulement (26) dévié par rapport à son axe de rotation dans la direction en amont.

45. Appareil selon l'une quelconque des revendications 36 à 44 dans lequel au moins chacune desdites première et deuxième paires de rouleaux lamineurs (12, 14) est équipée d'un mécanisme d'ajustement de butée des rouleaux (170) qui déplace lesdits deux rouleaux (101a, 101b, 102a, 102b) relativement dans la direction de butée de ceux-ci et qui maintient lesdits deux rouleaux à une position arbitraire dans ladite direction de butée.

46. Appareil selon la revendication 45, dans lequel ledit mécanisme de réglage de butée de rouleau (170) comprend :

une partie de roulement fixe (30) qui est fournie pour au moins un desdits deux rouleaux et qui maintient l'arbre à rouleaux (28) de telle sorte qu'il soit susceptible de tourner et de se déplacer dans sa direction de butée ;
et un mécanisme de coulissement de rouleau (171) qui est raccordé à une partie d'extrémité dudit arbre à rouleaux (28) et qui fait coulisser ledit arbre à rouleaux contre ladite partie de roulement (30) dans ladite direction de butée.

47. Appareil selon la revendication 46, dans lequel ledit mécanisme de coulissement de rouleau (171) comprend :

un support d'arbre (172) auquel ladite partie d'extrémité dudit arbre à rouleaux (28) est raccordée et qui est susceptible de se déplacer d'un seul tenant avec ledit arbre à rouleaux dans ladite direction de butée ;

un mécanisme de vis de réglage (173) qui est raccordé au dit support d'arbre directement ou indirectement avec un autre élément et qui déplace ledit support d'arbre (172) dans ladite direction de butée selon qu'il est vissé ou dévissé.

48. Appareil selon la revendication 21, dans lequel ladite partie de roulement comprend un corps principal de roulement (26) qui comporte un trou traversant agissant en tant qu'un orifice de roulement (26a) dans la direction dudit arbre à rouleaux (28) et qui supporte de façon rotative ladite une extrémité partie dudit arbre à rouleaux dans ledit trou traversant ;
dans lequel ledit support d'arbre (172) peut se déplacer dans ledit trou traversant (26a) avec ledit arbre à rouleaux (28) dans ladite direction de butée ;
dans lequel ledit support d'arbre (172) comporte une partie saillante semblable à une tige (177) qui s'étend le long de la direction axiale dudit arbre à rouleaux (28) dans ledit trou traversant (26a) et dont la partie d'extrémité se projette en saillie à l'extérieur à partir de l'ouverture correspondante (26b) dudit trou traversant ;
dans lequel, sur le côté intérieur dudit trou traversant (26a), une partie de vissage femelle (26c) est réalisée sur la partie d'extrémité de celui-ci qui aboutit à ladite ouverture (26b) ;
dans lequel un élément de vissage mâle (178) est vissé sur ladite partie de vissage femelle (26c) dans une position correspondant à la partie intermédiaire de ladite partie saillante semblable à une tige (177) ;
dans lequel une butée (179) est montée sur la partie saillante semblable à une tige (177) afin d'empêcher ledit élément de vissage mâle (178) de se déplacer relativement contre ladite partie saillante semblable à une tige dans la direction axiale de celle-ci ;
et dans lequel ledit mécanisme de vis de réglage (173) déplace ledit support d'arbre (172) et ledit arbre à rouleaux (28) dans ladite direction de butée le long en même temps que ledit élément de vissage mâle (178) en fonction de la rotation dudit élément de vissage mâle.

49. Appareil selon l'une quelconque des revendications 29 à 48 dans lequel ledit dispositif d'élimination de la calamine comprend un dispositif de grenaillage (4) pour éliminer ladite calamine en projetant un flux de particules abrasives sur la surface de ladite ma-

tière première pendant qu'elle est fournie en continu.

50. Appareil selon l'une quelconque des revendications 29 à 45 dans lequel ledit dispositif de réchauffage (5) comprend :

une électrode rouleau (51 À 54) pour fournir le contact avec ladite matière première et envoyer un courant électrique dans ladite matière première afin de réaliser son réchauffage par résistance ;

et un mécanisme de poussée (55 à 58) pour pousser ladite électrode rouleau contre ladite matière première.

51. Appareil selon l'une quelconque des revendications 31 et 32 dans lequel la première (12 ; 101, 102) et la deuxième (14 ; 201, 202) paires de rouleaux lamineurs sont entraînées à l'aide de moyens d'entraînement communs (252) par l'intermédiaire d'un premier (253, 255) et d'un deuxième (254, 256) systèmes d'engrenages réducteurs, respectivement ;
et dans lequel le rapport de réduction entre engrenages réducteurs Q1/Q2, dans lequel Q1 est le rapport d'engrenage réducteur dudit premier système d'engrenage réducteur et Q2 est le rapport d'engrenage réducteur dudit deuxième système d'engrenage réducteur, peut être varié de manière à modifier ledit rapport R1/A2.

52. Appareil selon la revendication 51 dans lequel une pluralité d'unités de paires de rouleaux lamineurs (S1, S2 ; S) comprenant chacune lesdites première et deuxième paires de rouleaux lamineurs, sont agencées dans une direction de fourniture de ladite matière première, et ladite matière première est successivement laminée par lesdites unités de paires de rouleaux lamineurs ;
dans lequel ledit rapport de réduction entre engrenages réducteurs Q1/Q2 desdites unités de paires de rouleaux lamineurs est modifié de façon synchrone ;
et dans lequel lorsque ledit rapport de réduction entre engrenages réducteurs est défini à une valeur déterminée pour l'une des unités de paires de rouleaux lamineurs, les rapports de réduction entre engrenages réducteurs pour les autres unités de paires de rouleaux lamineurs sont également définis à des valeurs correspondantes de façon synchrone.

FIG. 1

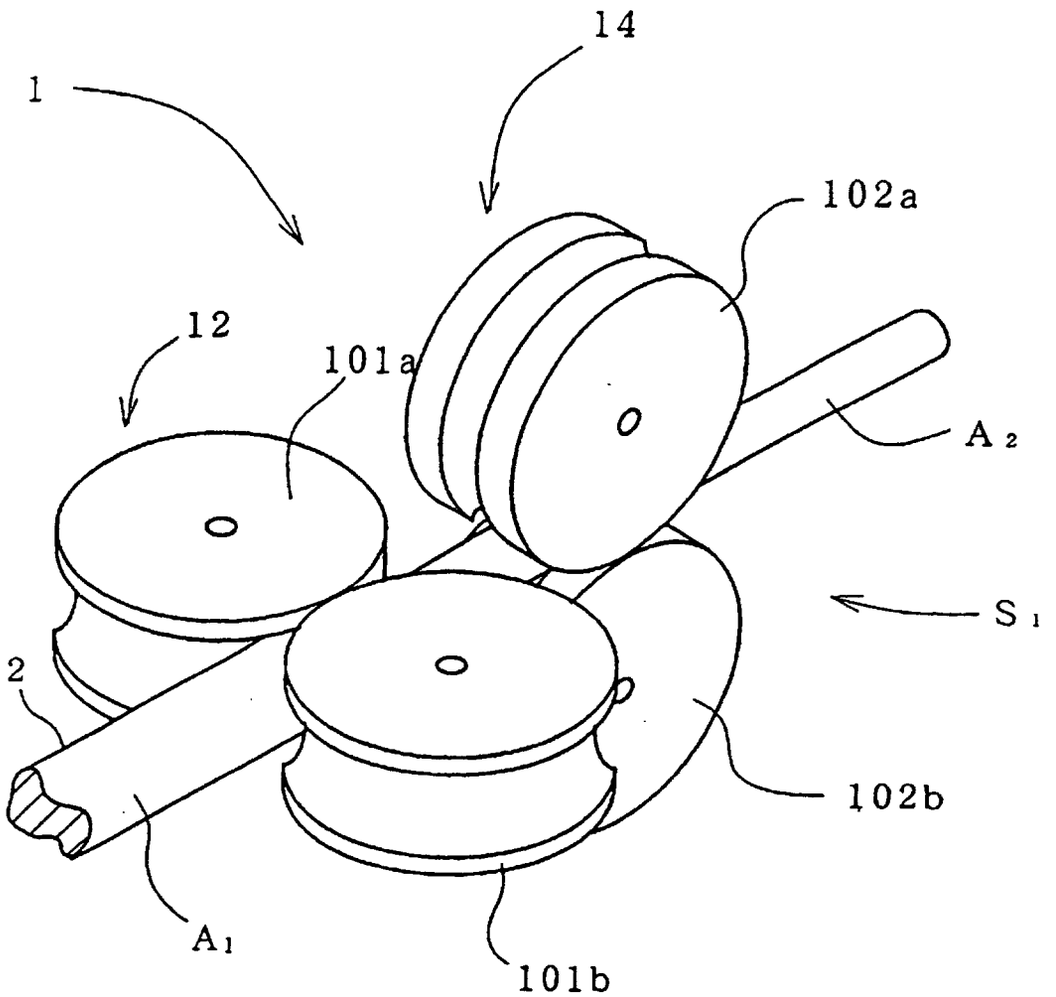
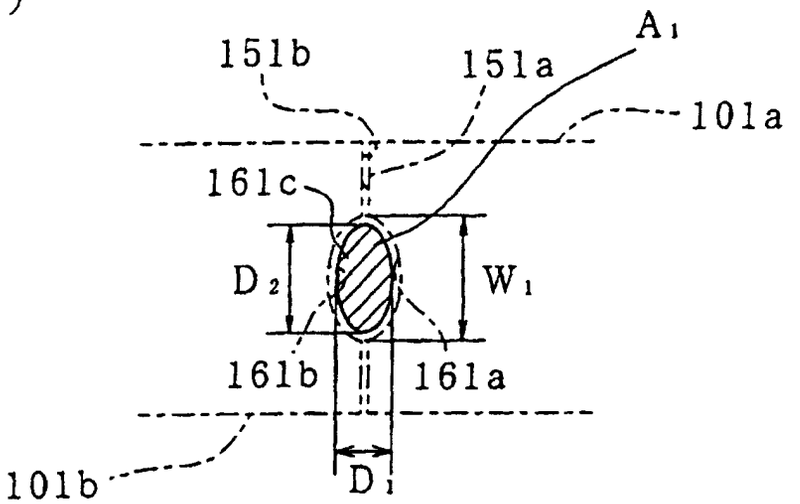
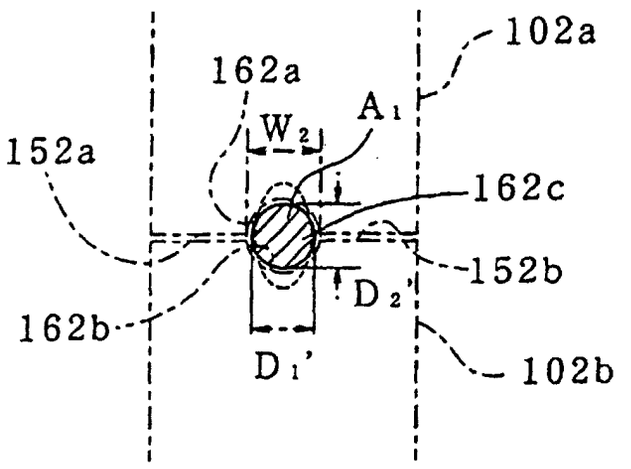


FIG. 2

(a)


151b
151a
A1
101a
161c
D2
W1
161b
161a
101b
D1

(b)


102a
162a
W2
A1
152a
162c
152b
D2'
162b
D1'
102b

(c)

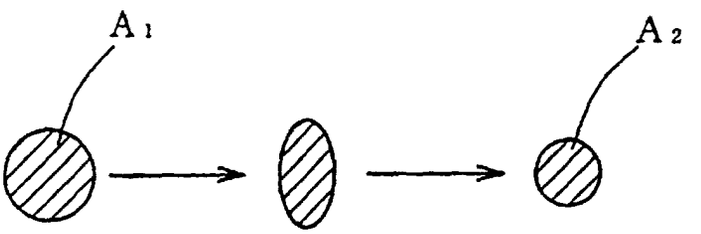

A1
A2

FIG. 3

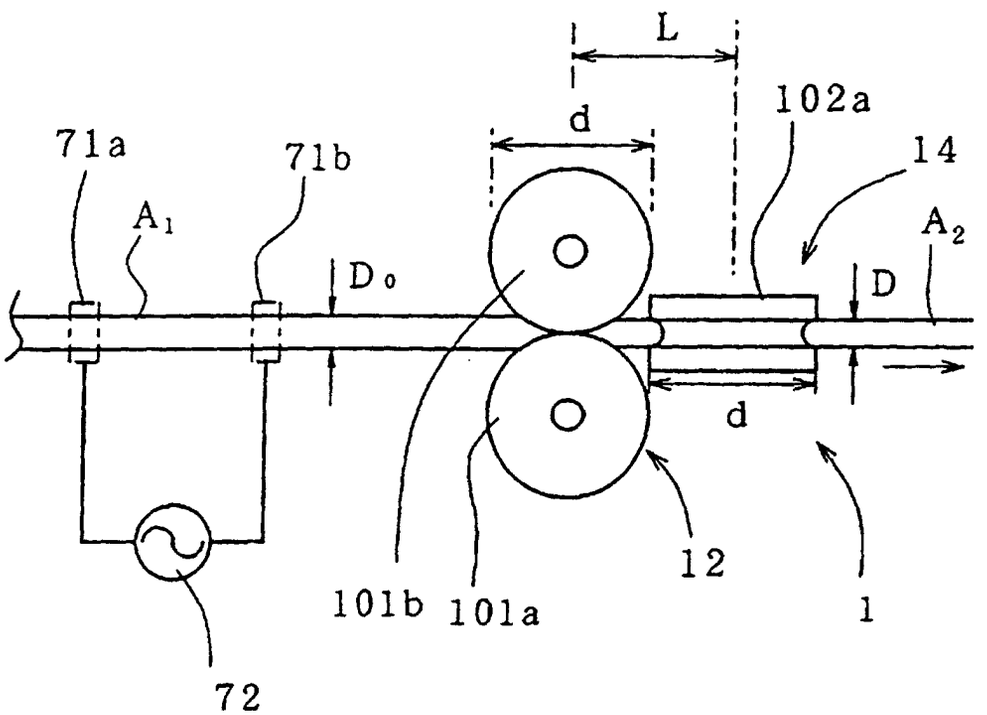


FIG. 4

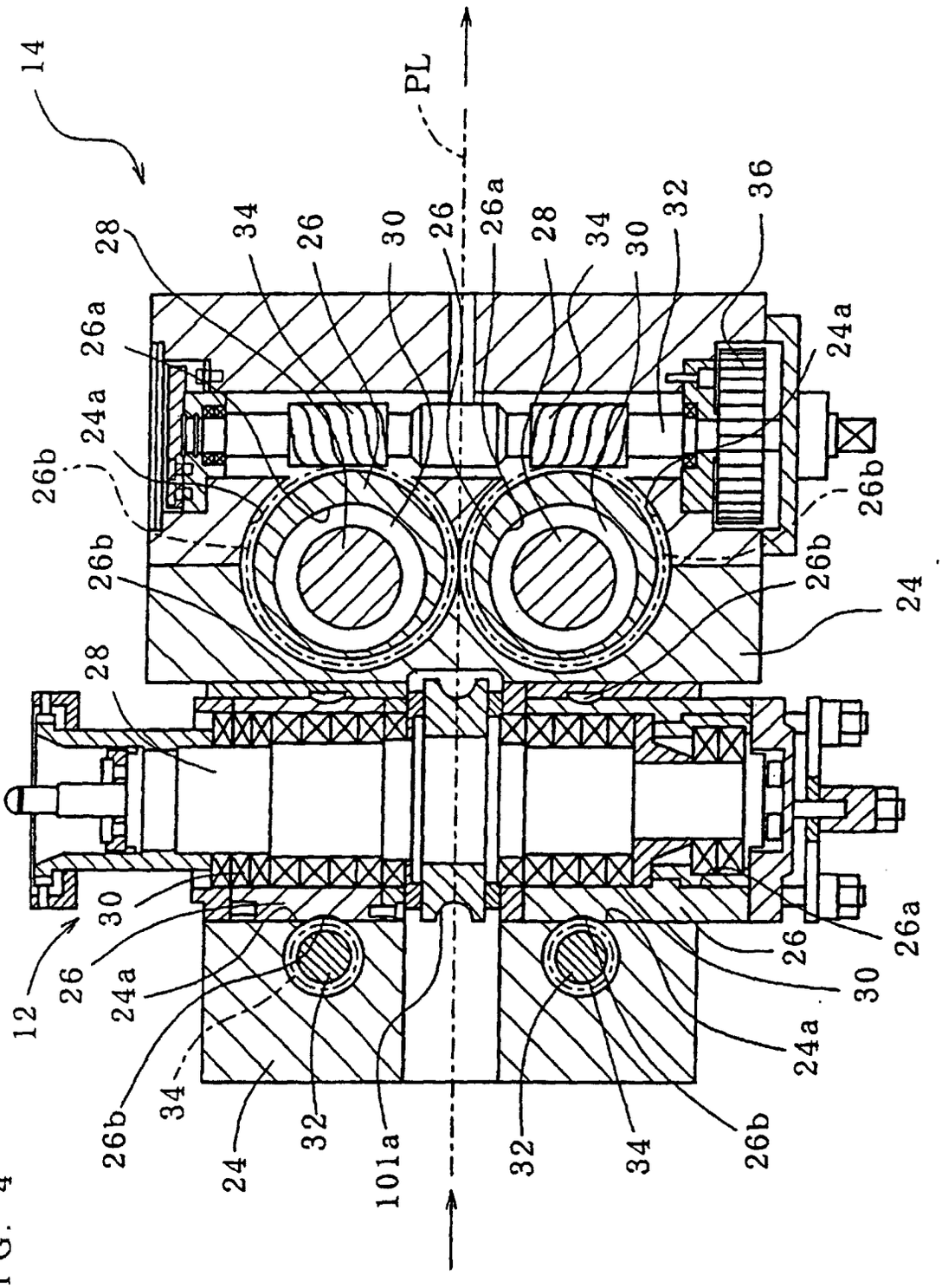
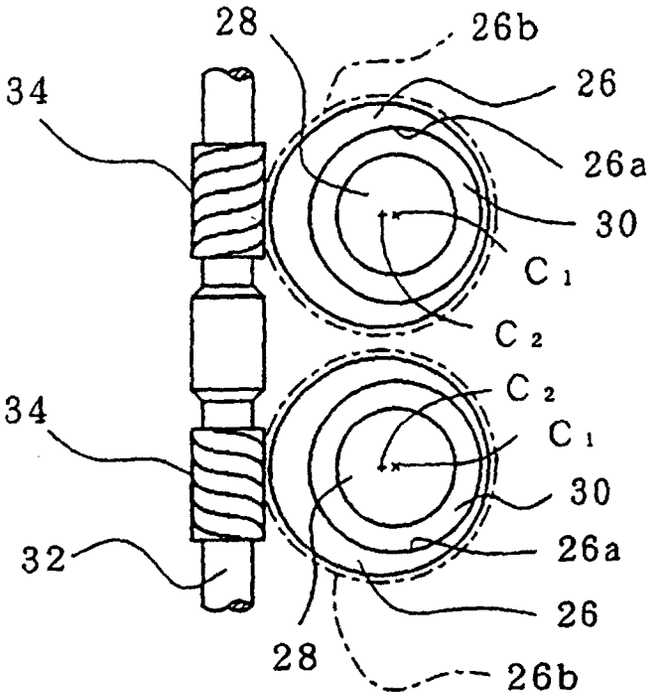

14
PL
28
34
26
30
26
26a
28
34
30
32
36
26a
24a
24a
26b
26b
26b
26b
24
28
30
26
24a
12
26
26
30
26a
24a
34
26b
24
32
101a
32
34
26b

FIG. 5

(a)


28
26b
34
26
26a
30
C 1
C 2
C 2
34
C 1
30
26a
32
26
28
26b

(b)

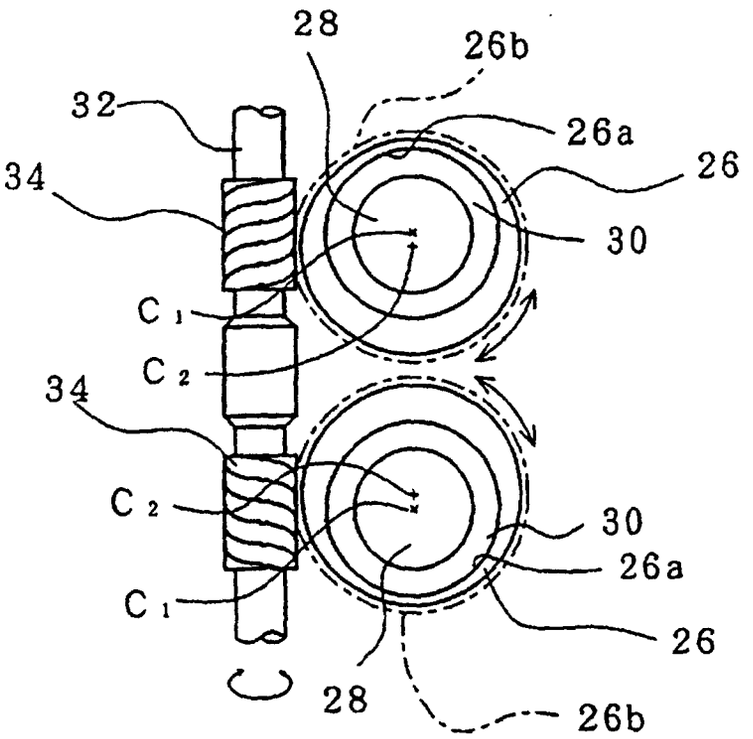

28
26b
32
26a
34
26
30
C 1
C 2
34
C 2
30
26a
C 1
26
28
26b

FIG. 6

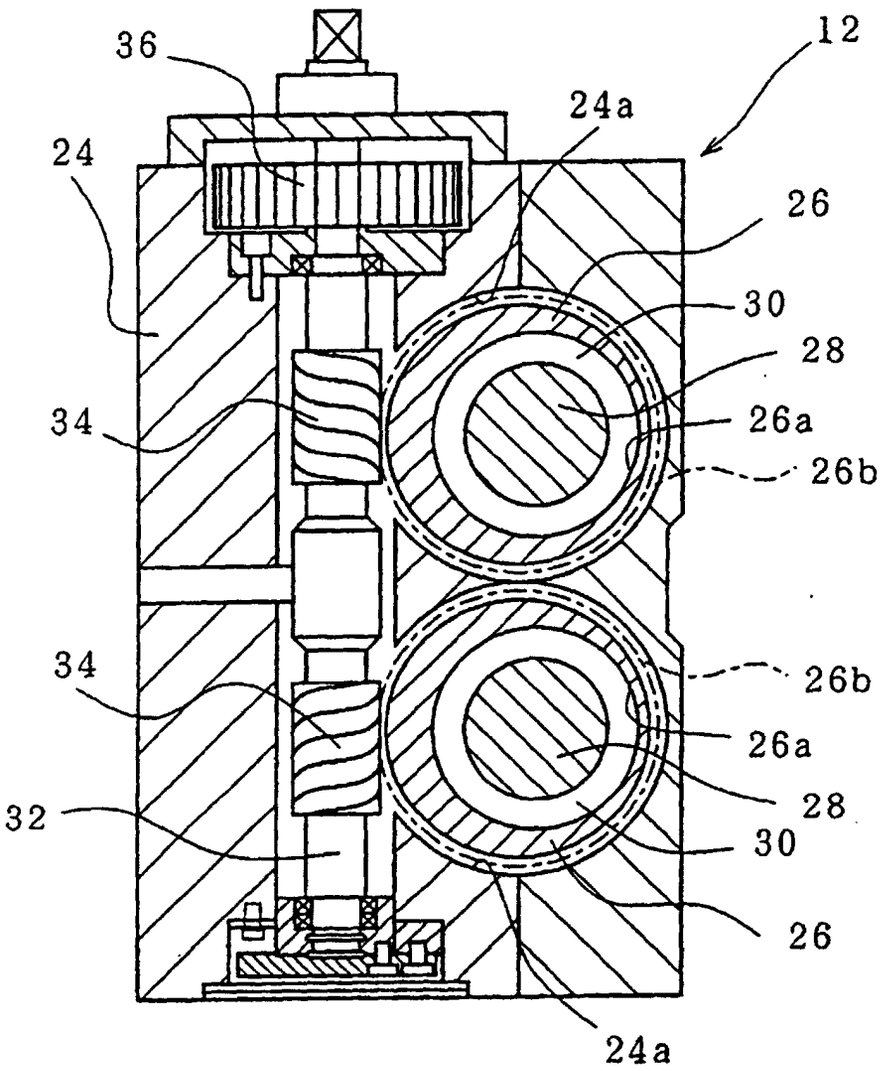


FIG. 7

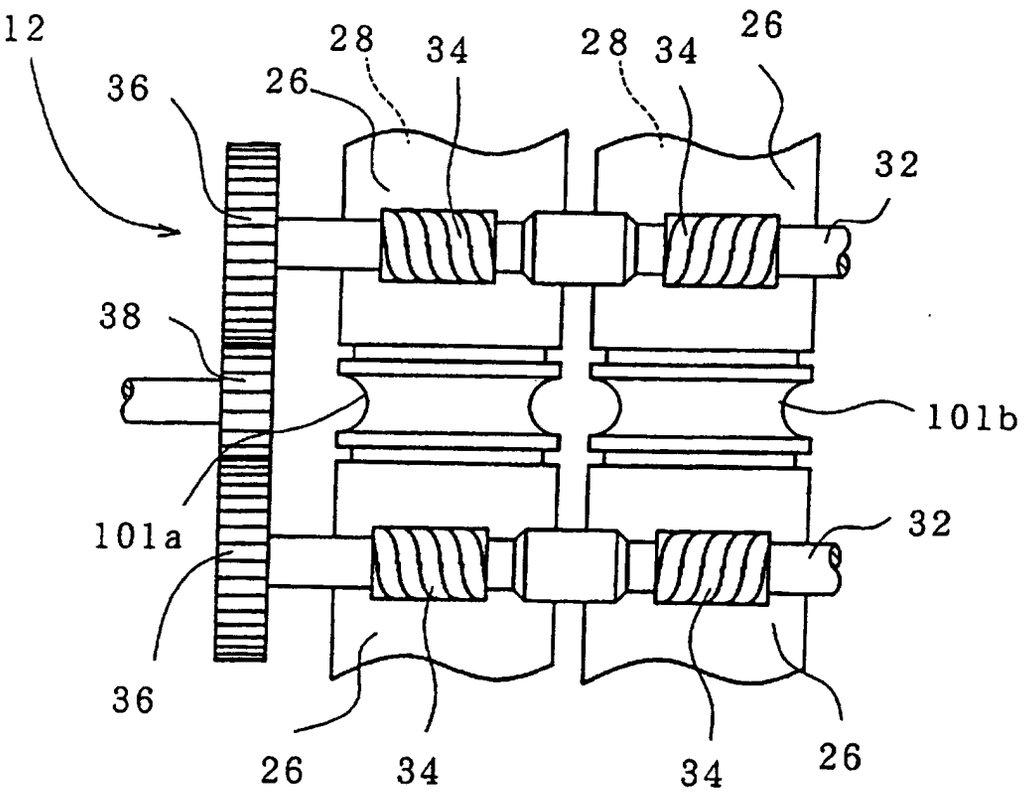


FIG. 8

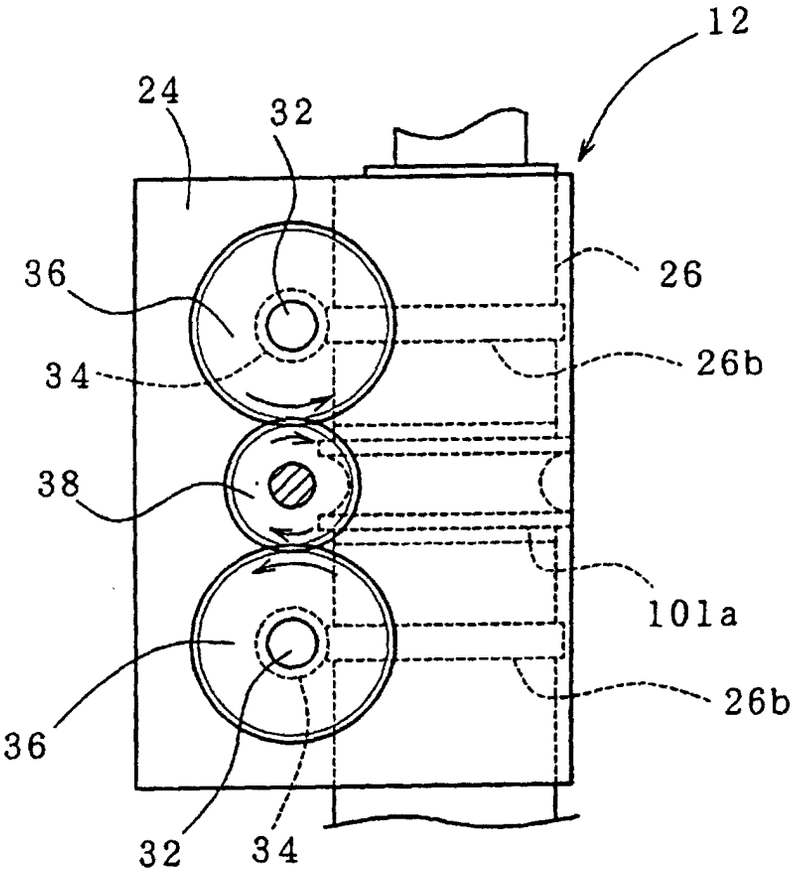
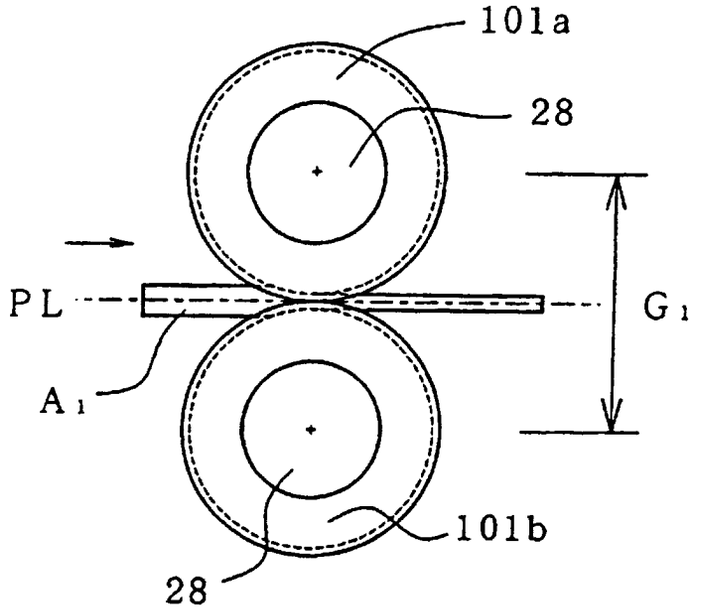


FIG. 9

(a)



(b)

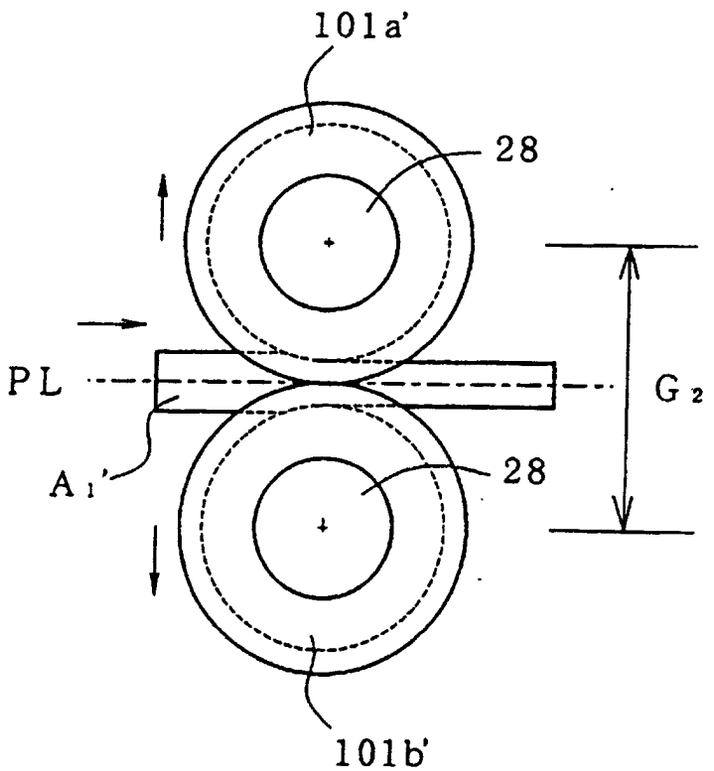
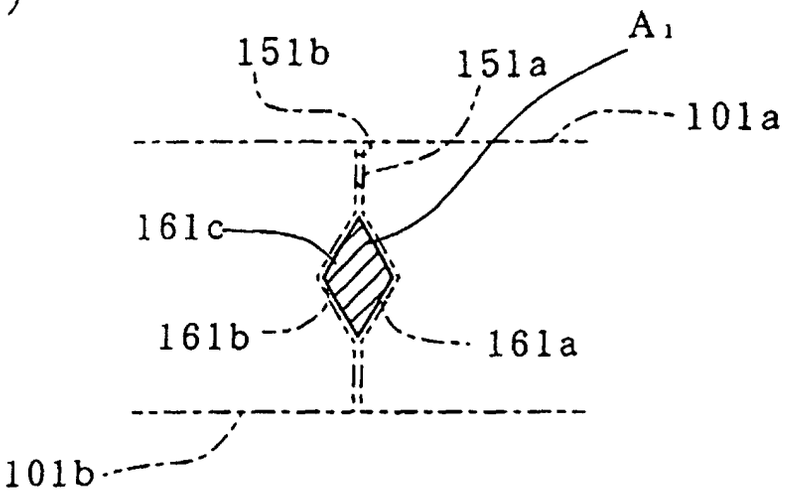
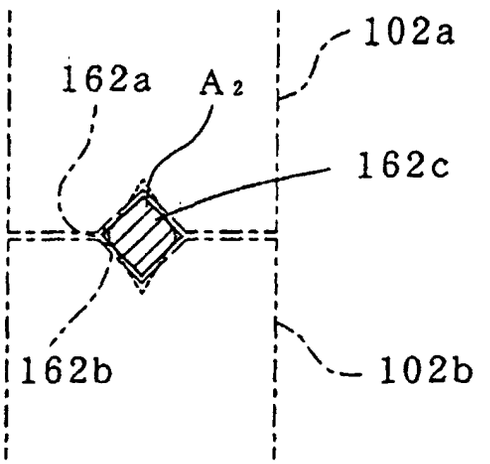


FIG. 10

(a)


151b
151a
A1
101a
161c
161b
161a
101b

(b)


102a
162a
A2
162c
162b
102b

(c)

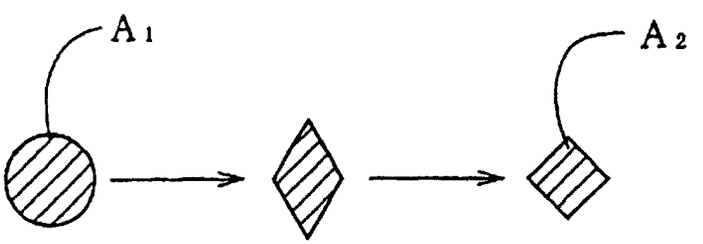

A1
A2

FIG. 11

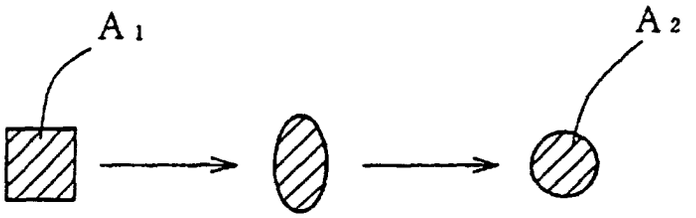


FIG. 12

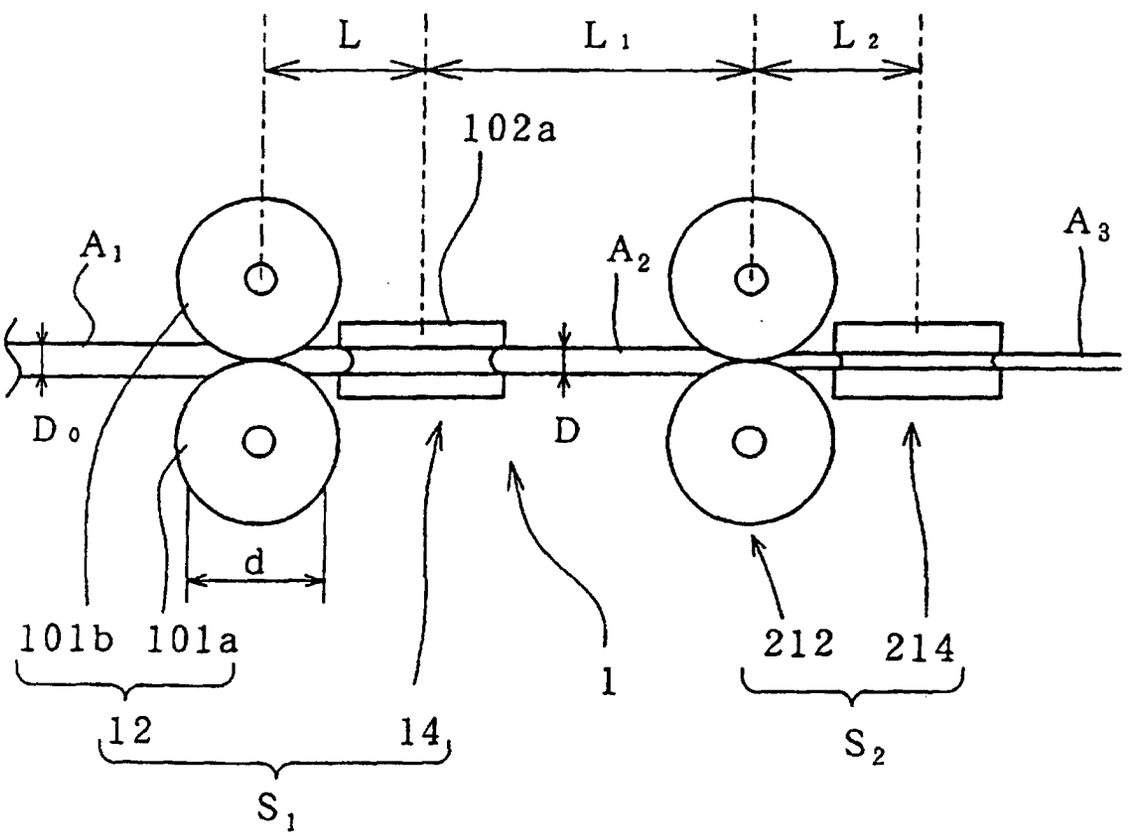


FIG. 13

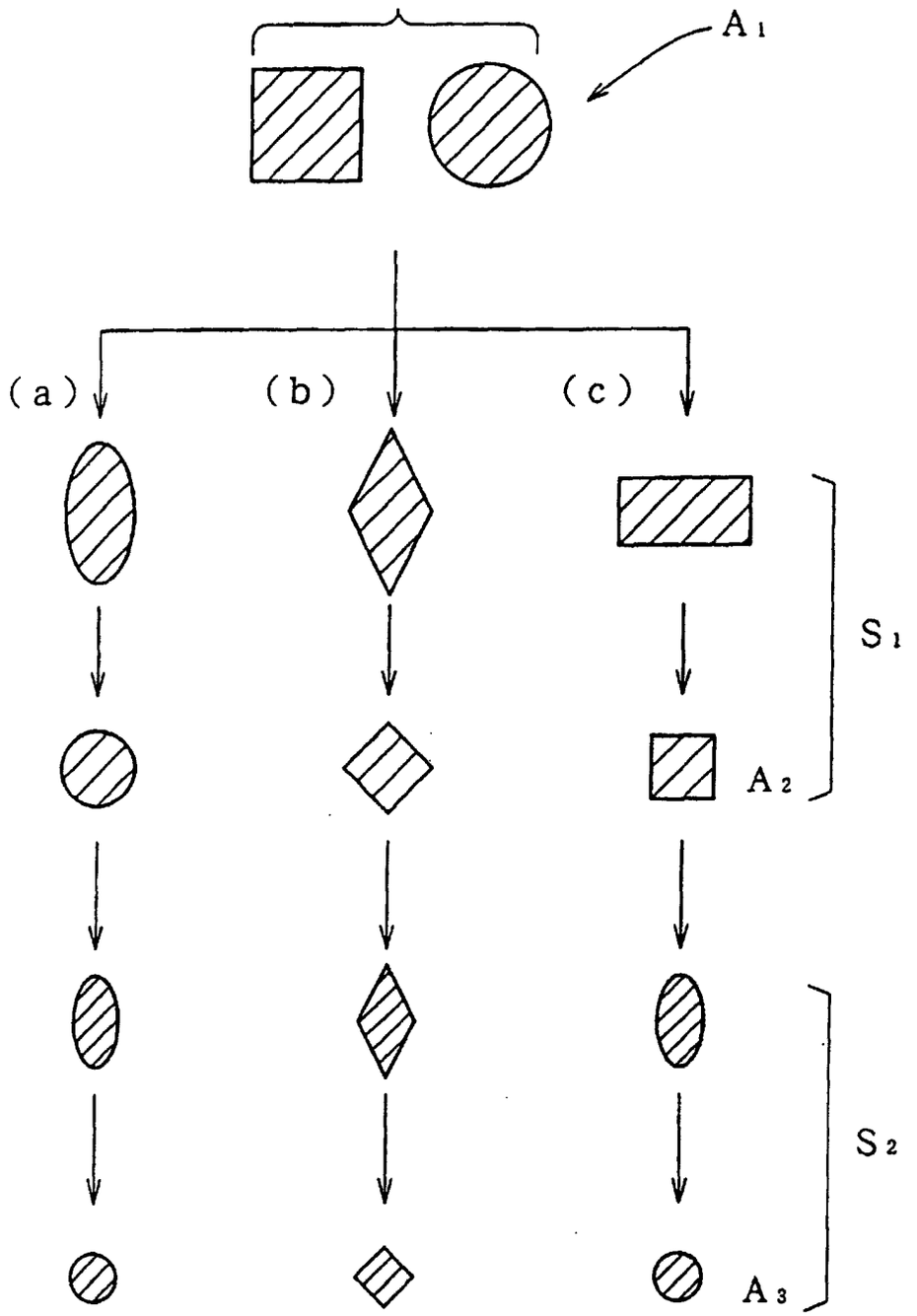


FIG. 14

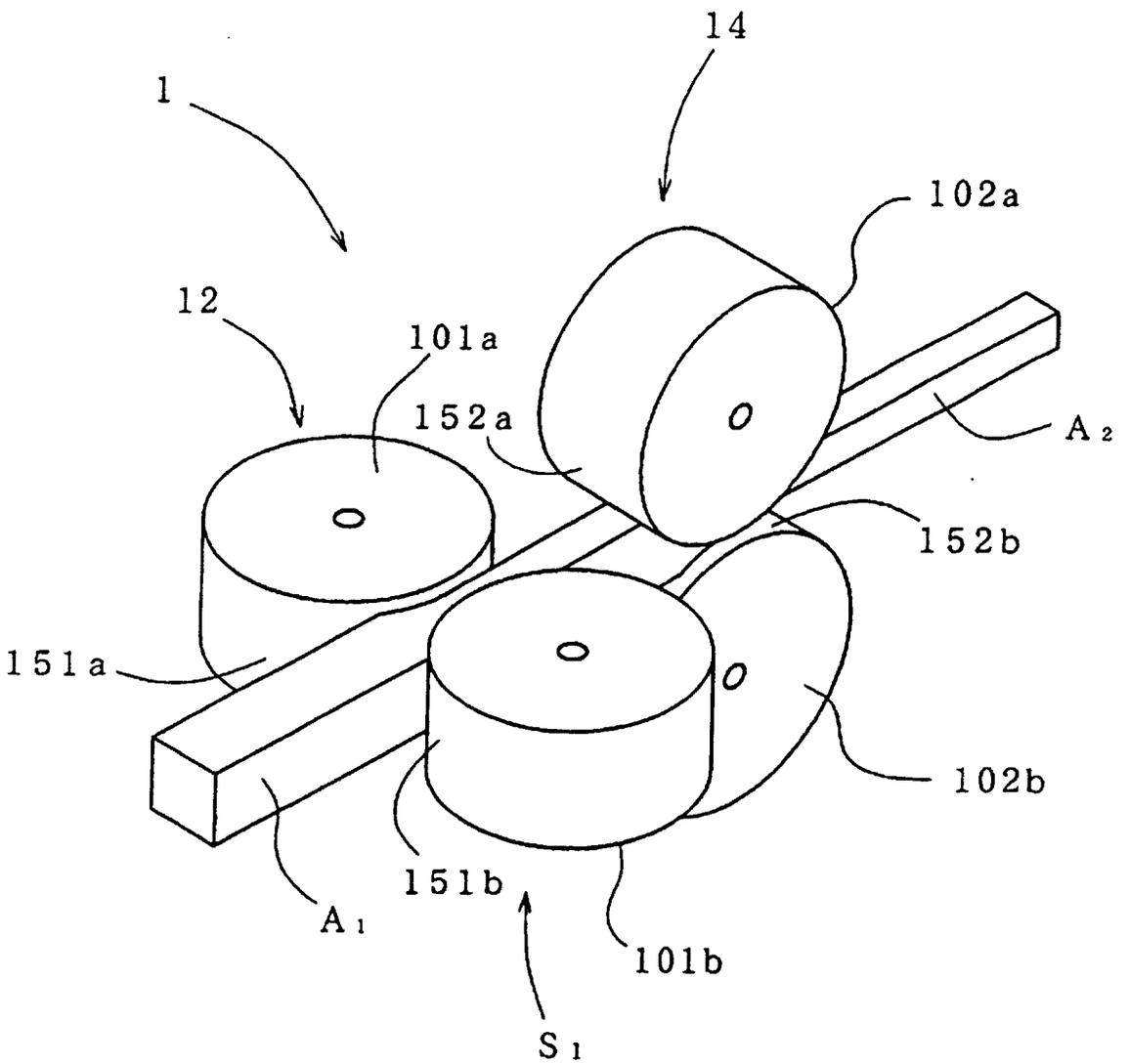
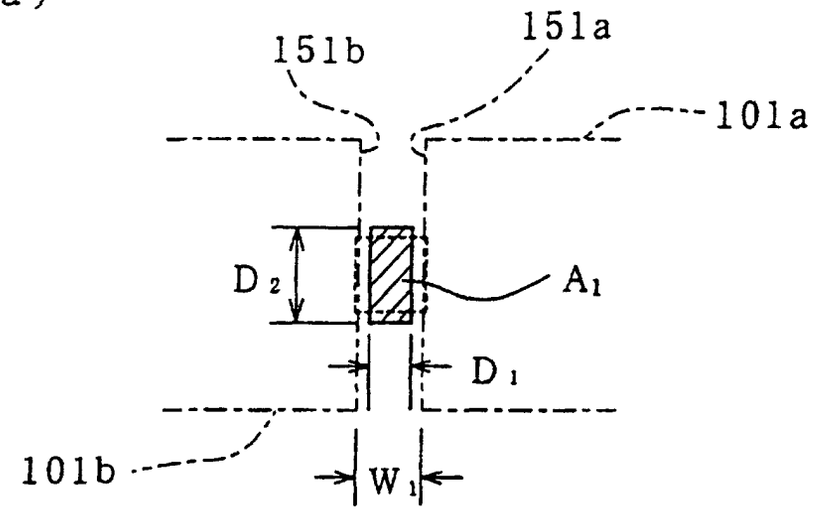
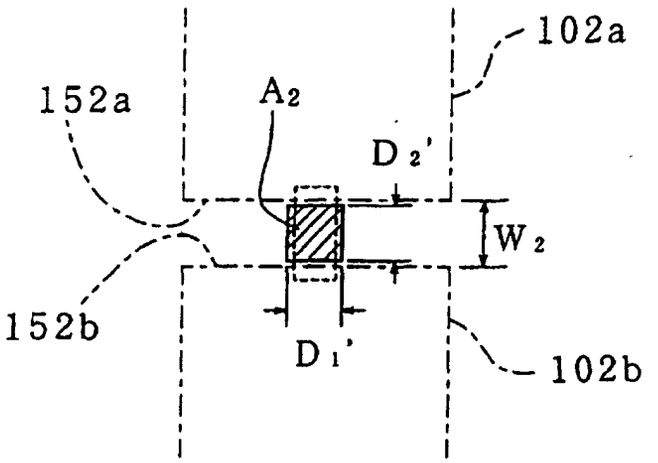


FIG. 15

(a)


151b
151a
101a
D 2
A 1
D 1
101b
W 1

(b)


102a
152a
A 2
D 2'
W 2
152b
D 1'
102b

(c)

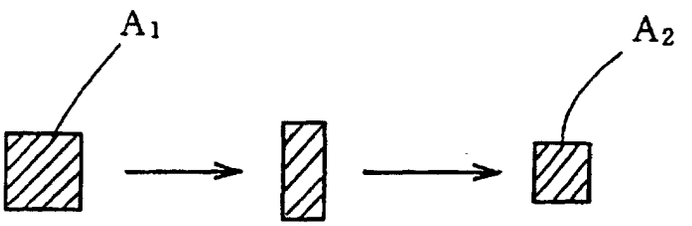

A 1
A 2

FIG. 16

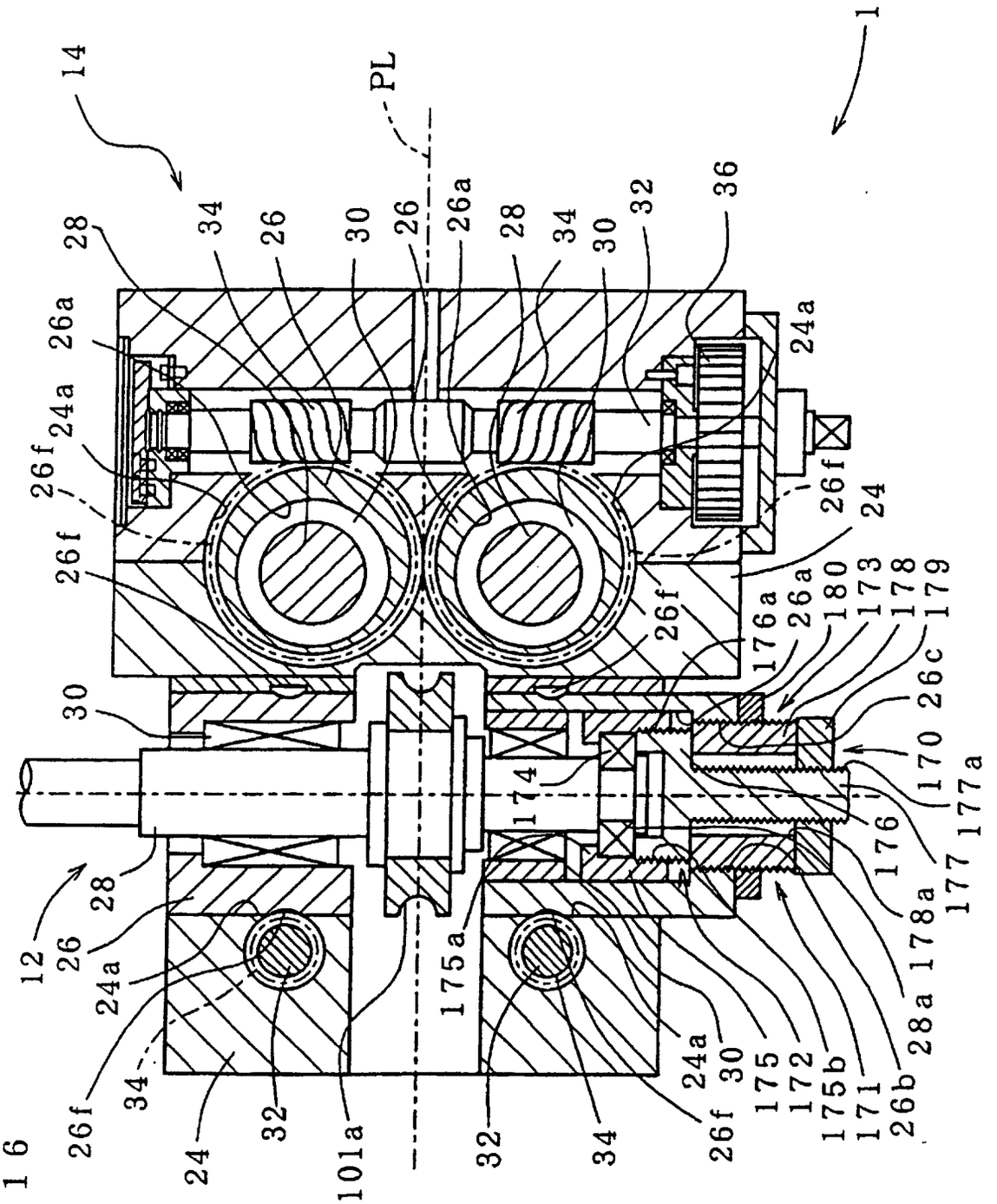

1
14
PL
12
101a
24
32
34
26f
24a
26
28
30
36
26a
24
174
175a
176
176a
177
177a
178
178a
179
180
173
175
172
175b
171
26b
26c
170

FIG. 17

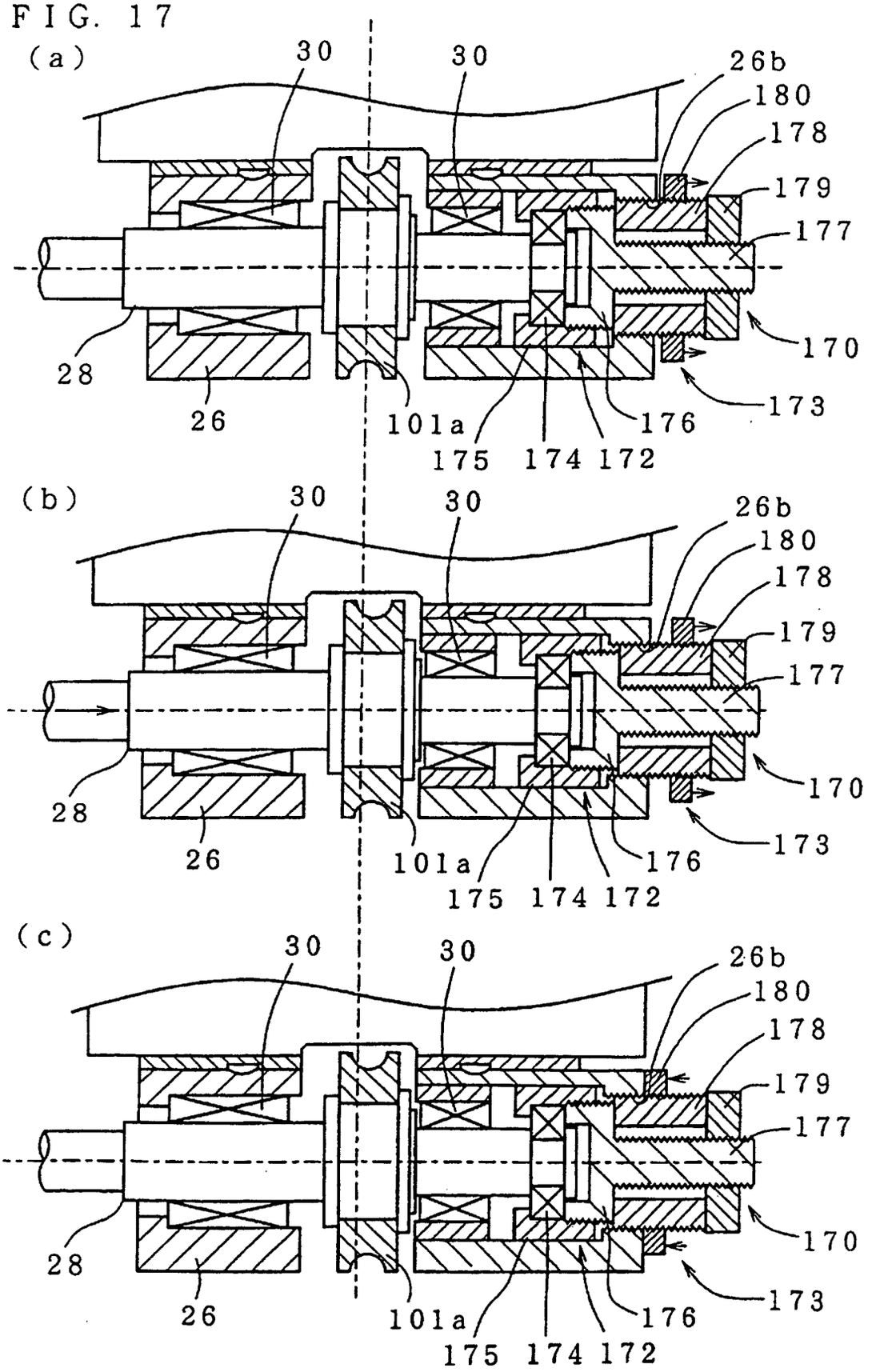
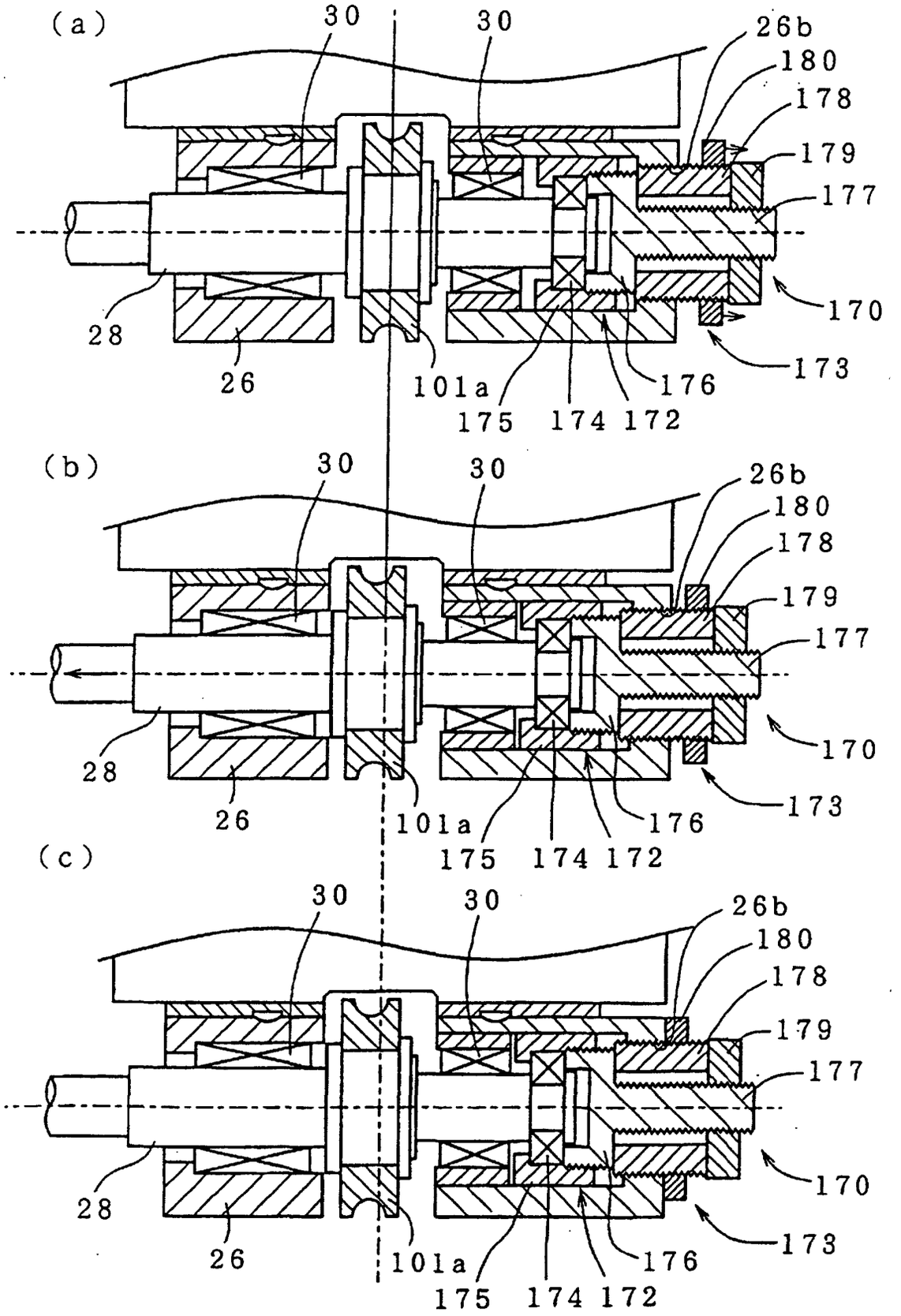

(a)
30
30
26b
180
178
179
177
170
173
28
26
101a
175
174
172
176
(b)
30
30
26b
180
178
179
177
170
173
28
26
101a
175
174
172
176
(c)
30
30
26b
180
178
179
177
170
173
28
26
101a
175
174
172
176

FIG. 18


(a)
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26b
180
178
179
177
170
173
28
26
101a
175
174
172
176
(b)
30
30
26b
180
178
179
177
170
173
28
26
101a
175
174
172
176
(c)
30
30
26b
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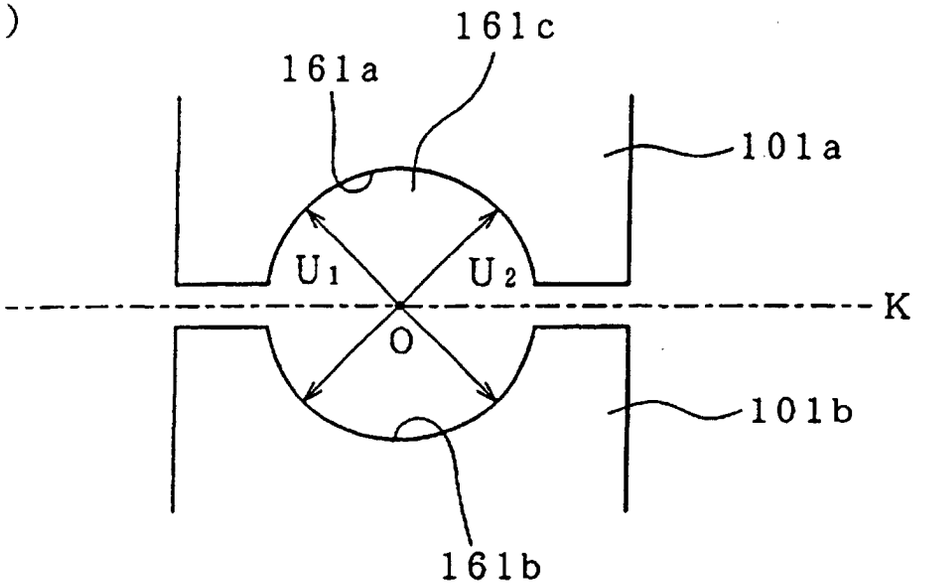
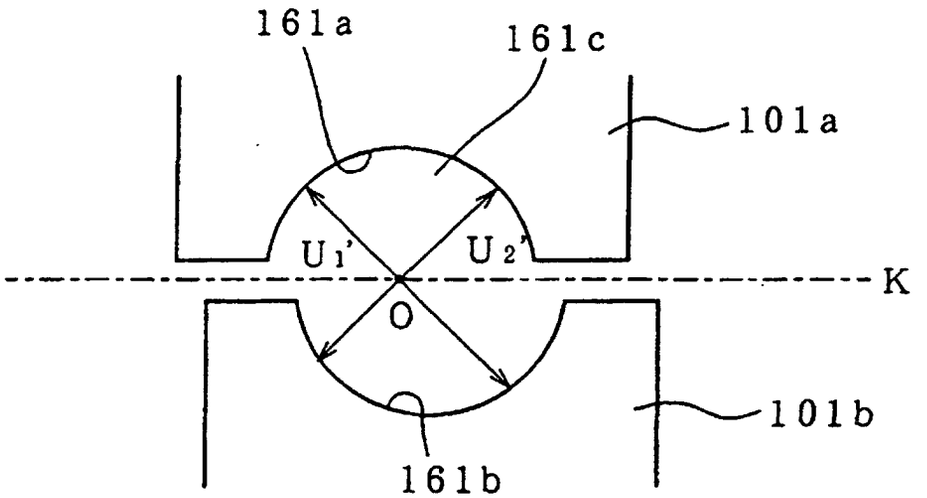
178
179
177
170
173
28
26
101a
175
174
172
176

FIG. 19

(a)



(b)



(U1' > U2')

FIG. 20

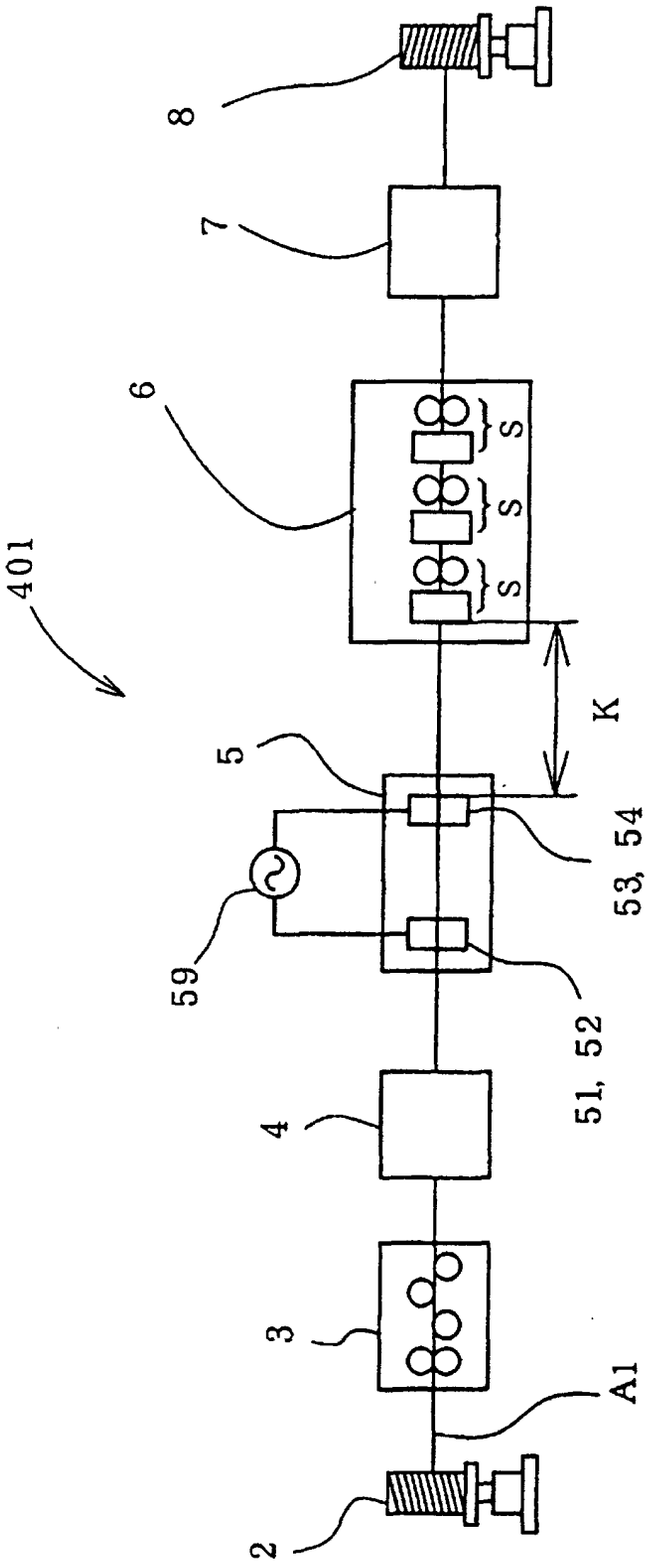


FIG. 21

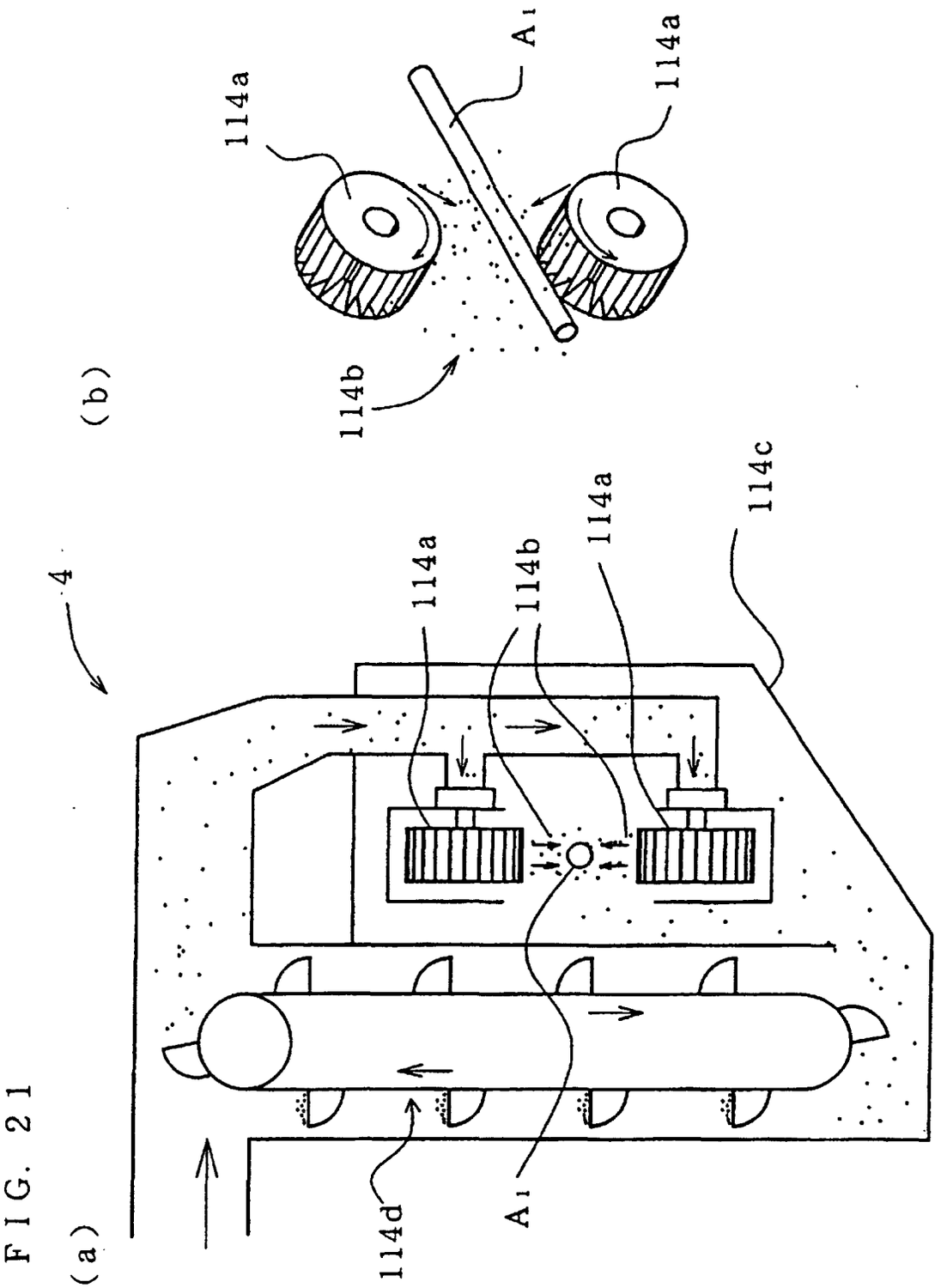


FIG. 22

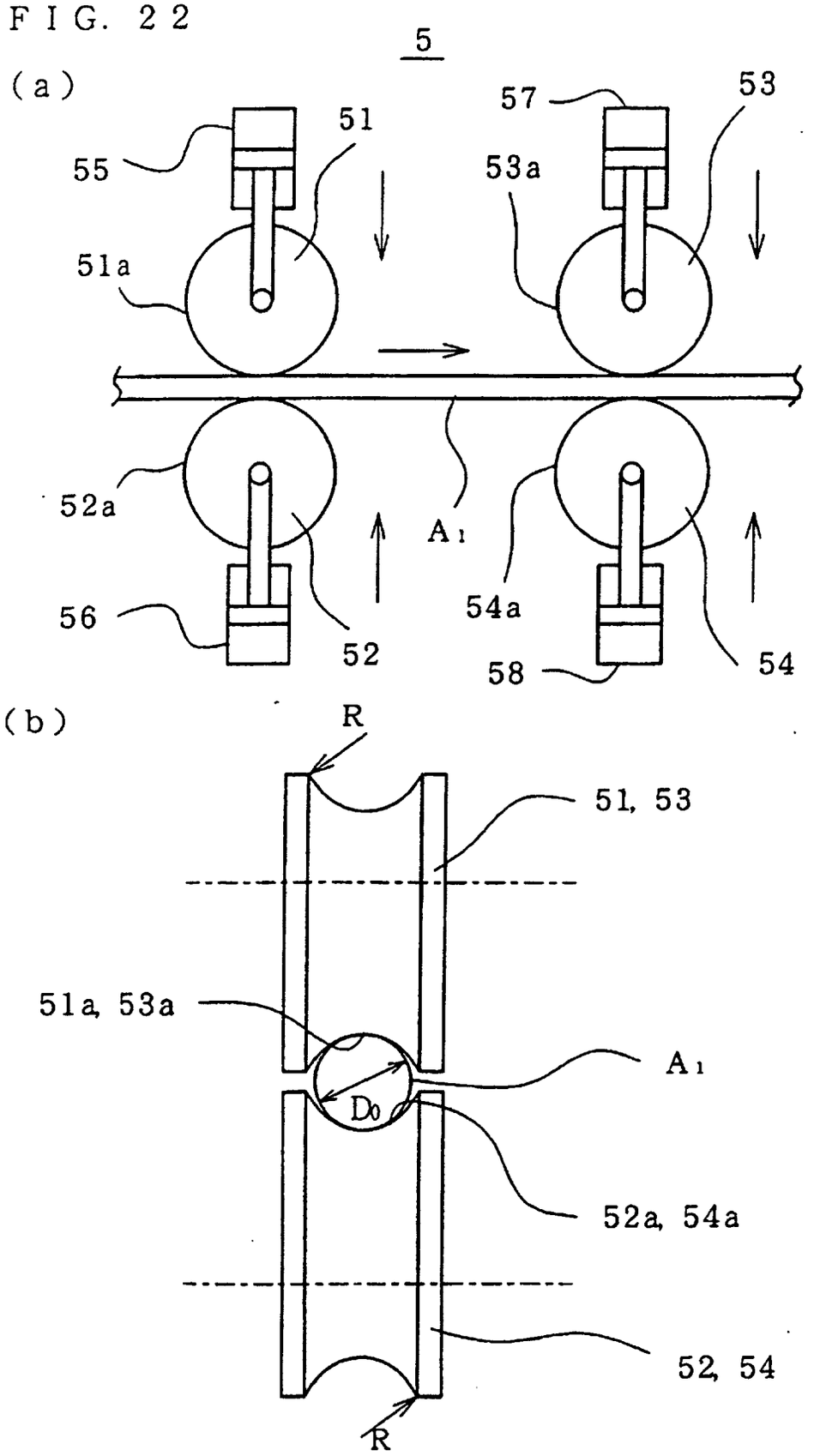

5
(a)
57
53
51
55
53a
51a
52a
A1
54a
56
52
58
54
(b)
R
51, 53
51a, 53a
A1
D0
52a, 54a
52, 54
R

FIG. 23

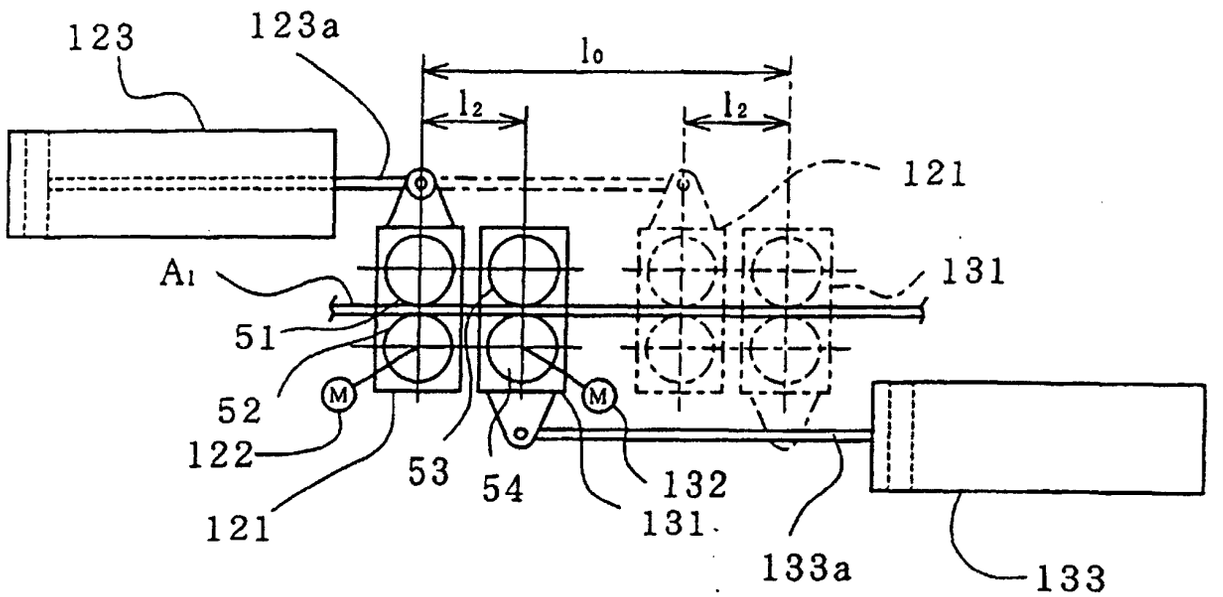

123
123a
l_0
l_2
l_2
121
131
A_1
51
52
122
121
53
54
132
131
133a
133
M
M

FIG. 24

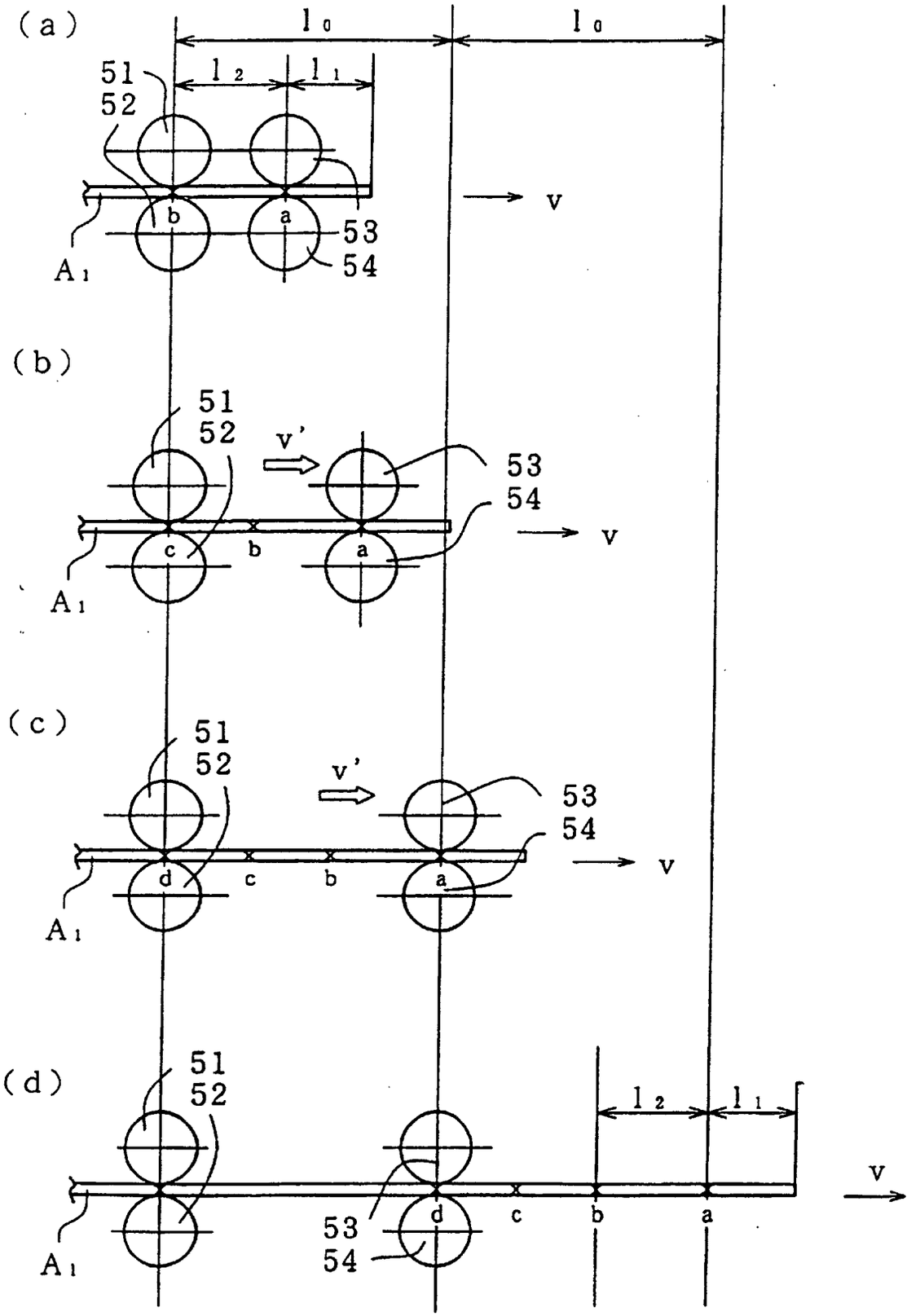
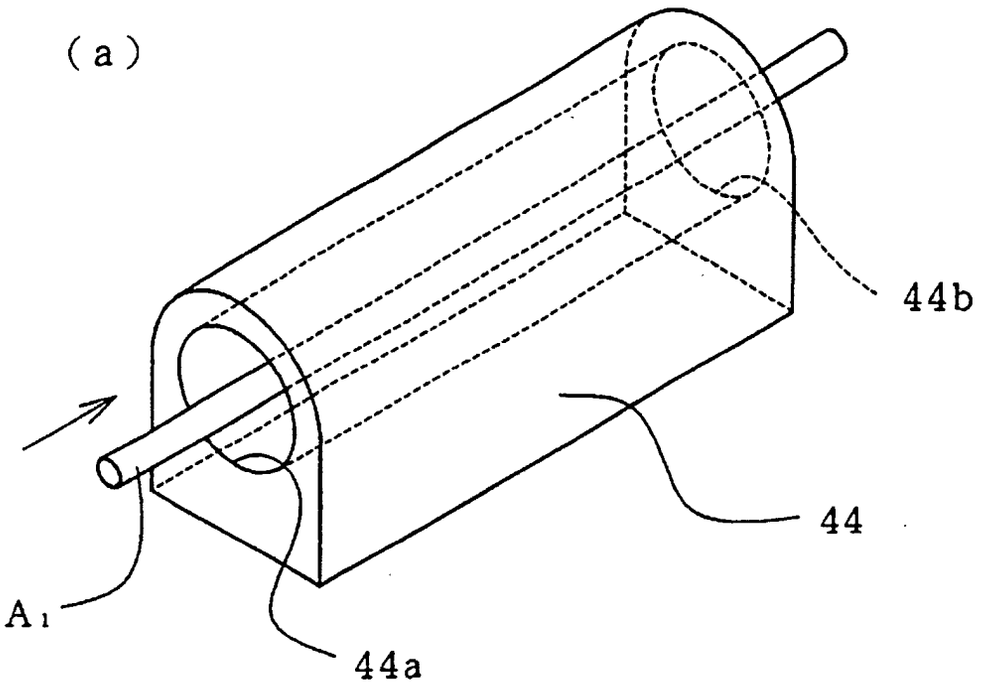

(a)
l0
l0
l2
l1
51
52
b
a
53
54
A1
v
(b)
51
52
v'
53
54
c
b
a
A1
v
(c)
51
52
v'
53
54
d
c
b
a
A1
v
(d)
51
52
l2
l1
53
54
d
c
b
a
A1
v

FIG. 25

(a)



(b)

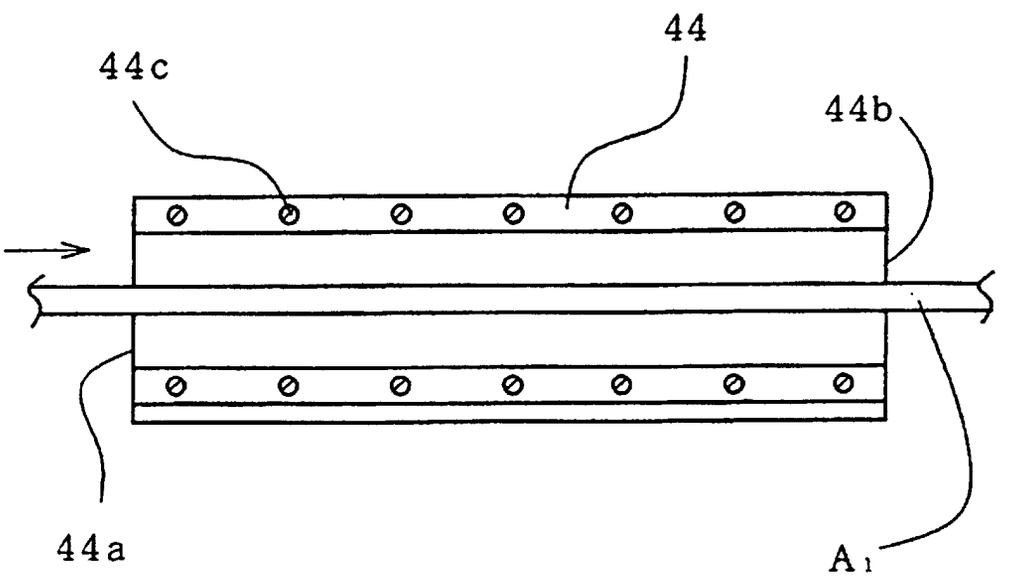


FIG. 26

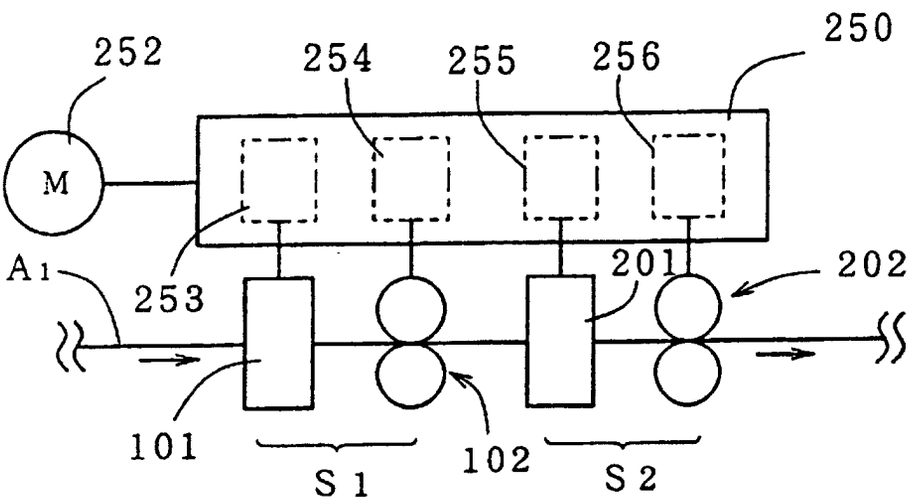


FIG. 27

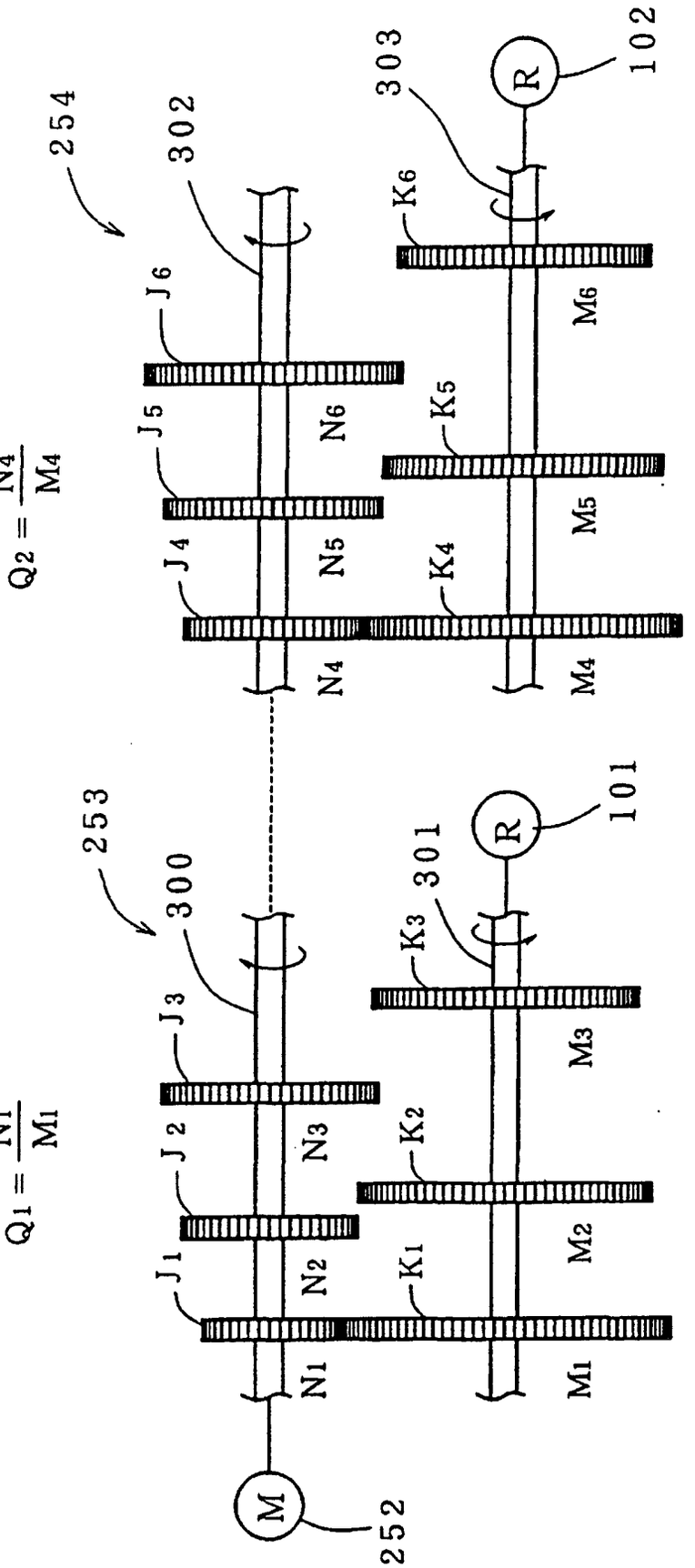

254
253
302
300
303
301
102
101
252
M
R
R
$Q_2 = \frac{N_4}{M_4}$
$Q_1 = \frac{N_1}{M_1}$
J6
J5
J4
J3
J2
J1
K6
K5
K4
K3
K2
K1
N6
N5
N4
N3
N2
N1
M6
M5
M4
M3
M2
M1

FIG. 28

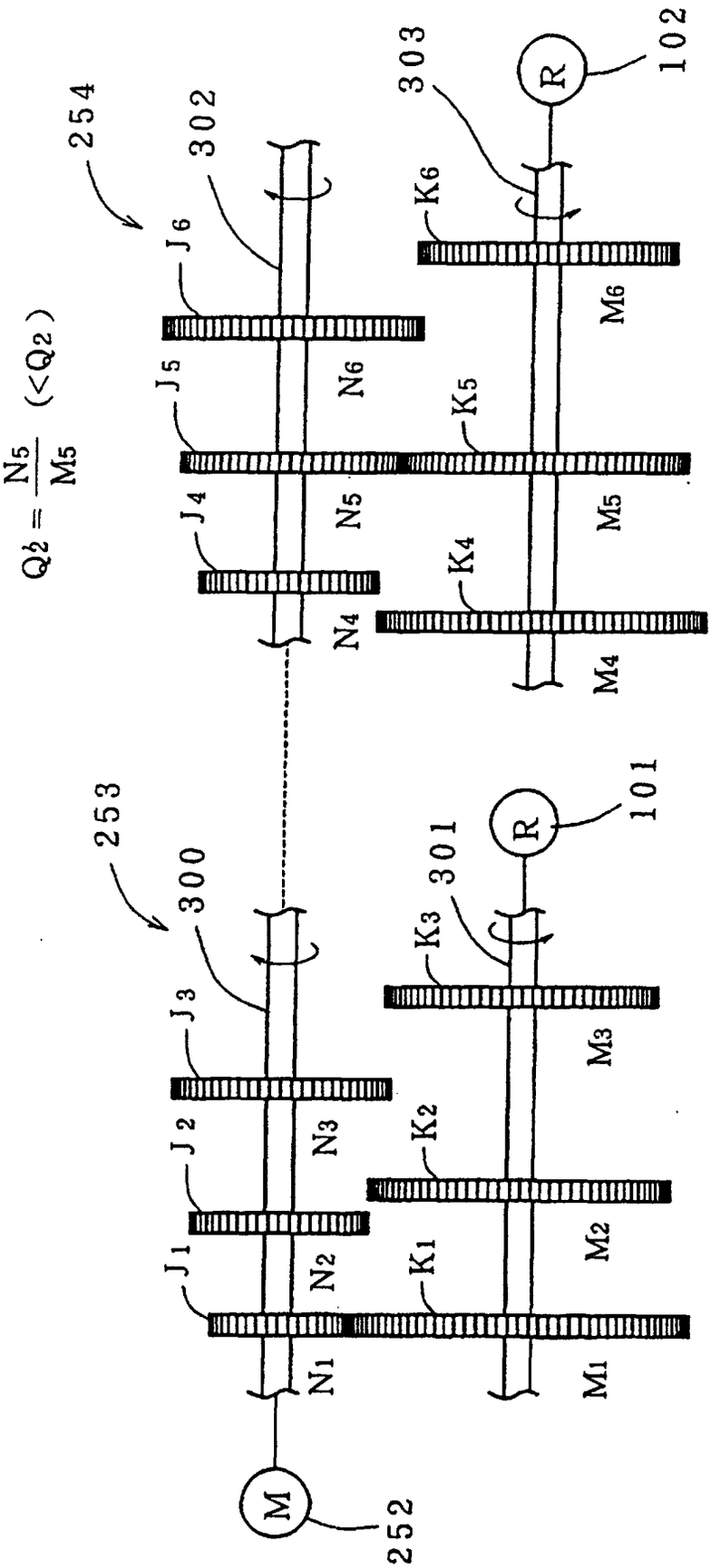
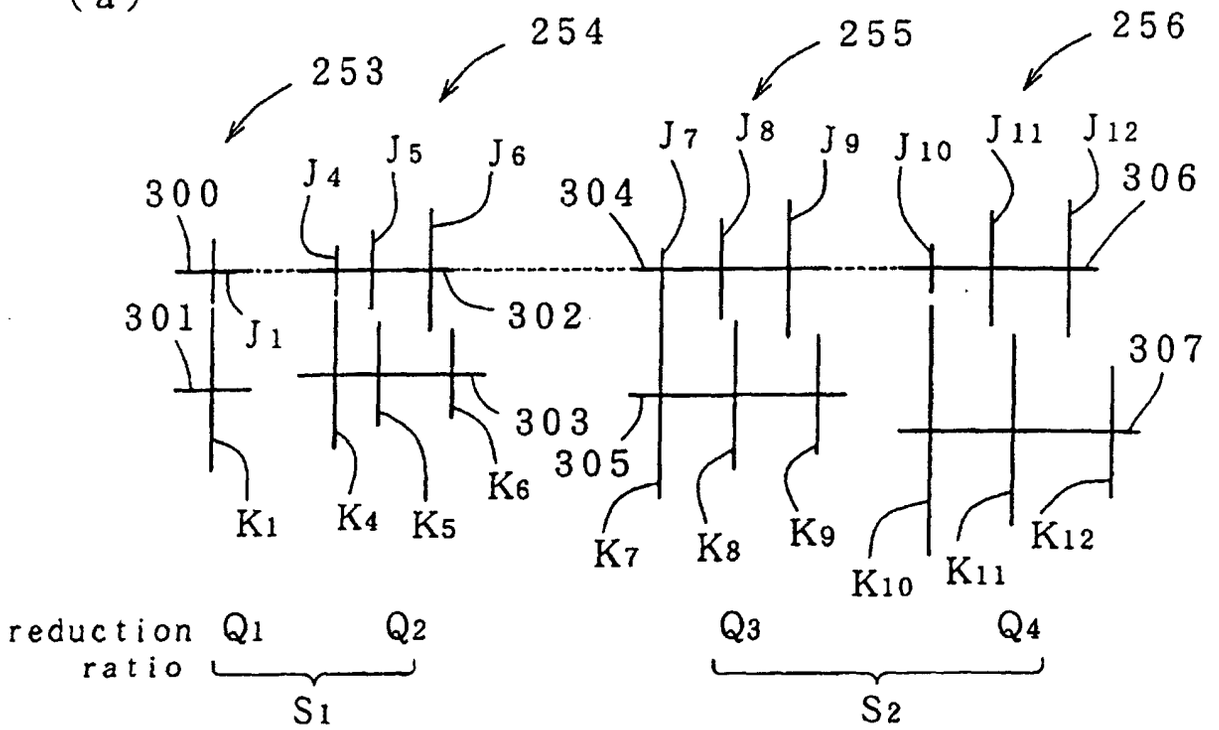

254
253
252
101
102
300
301
302
303
M
R
R
$Q_2' = \frac{N_5}{M_5}$ (<Q_2)
J1
J2
J3
J4
J5
J6
K1
K2
K3
K4
K5
K6
N1
N2
N3
N4
N5
N6
M1
M2
M3
M4
M5
M6

FIG. 29

(a)


253
254
255
256
300
J4
J5
J6
304
J7
J8
J9
J10
J11
J12
306
301
J1
302
307
303
305
K1
K4
K5
K6
K7
K8
K9
K10
K11
K12
reduction ratio
Q1
Q2
Q3
Q4
S1
S2

(b)

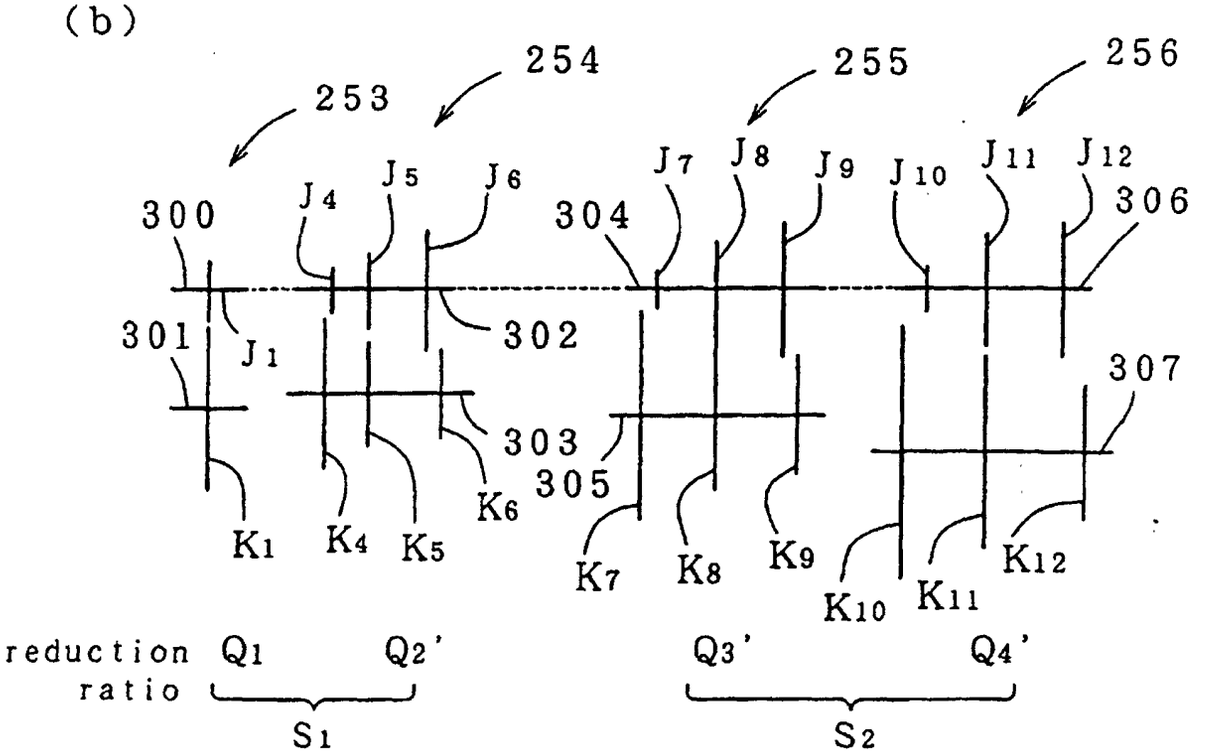
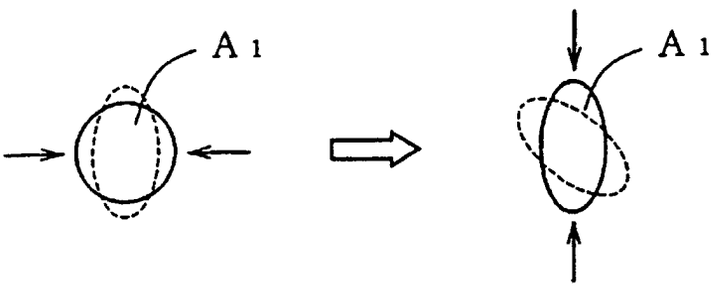

253
254
255
256
300
J4
J5
J6
304
J7
J8
J9
J10
J11
J12
306
301
J1
302
307
303
305
K1
K4
K5
K6
K7
K8
K9
K10
K11
K12
reduction ratio
Q1
Q2'
Q3'
Q4'
S1
S2

FIG. 30

(a)



(b)

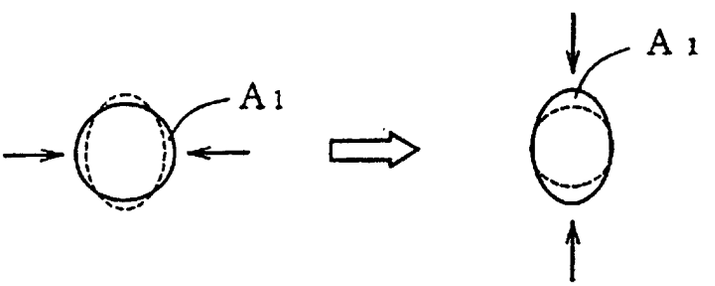
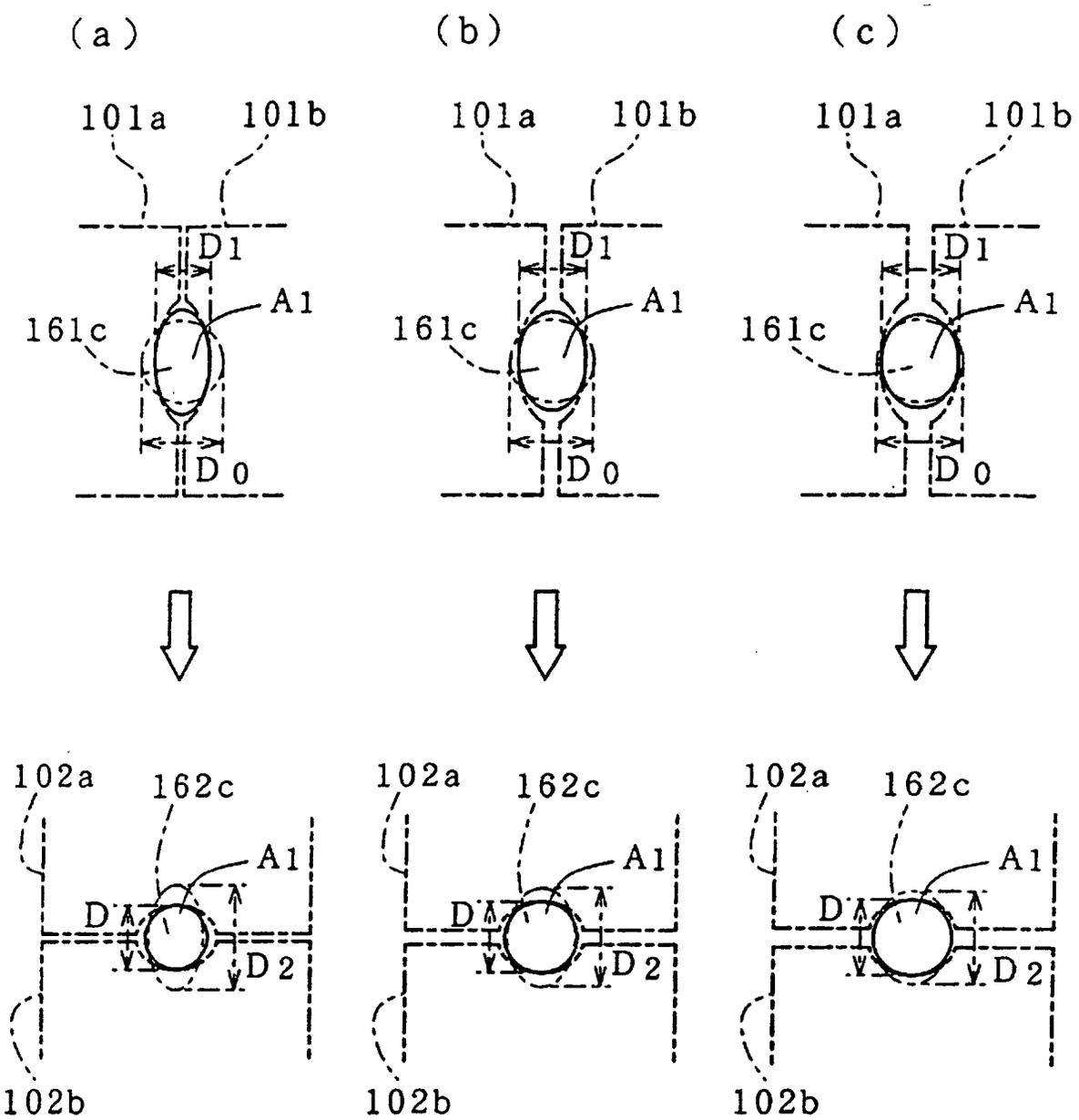



FIG. 31