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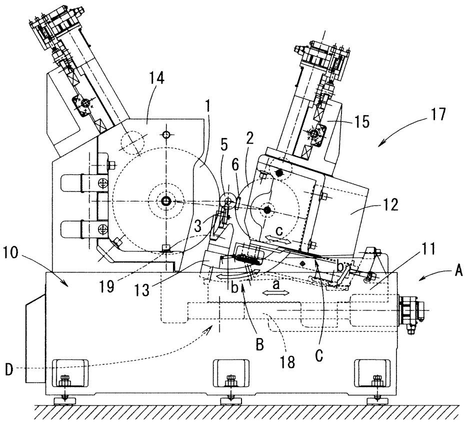
(54) CENTERLESS GRINDING MACHINE

(57) A centerless grinding machine is provided of which the position of a regulating wheel (2) can be easily and simply set and adjusted according to the outer diameter of a grinder (1), the outer diameter of the regulating wheel (2) and the outer diameter of the workpiece (5). The grinding machine includes a table (11) mounted on a bed (10) through a horizontal slide mechanism (A). A swing base (13) is mounted on the table (11) through a γ -swing slide mechanism (B). An upper slider (12) is mounted on the swing base (13) through a lateral slide mechanism (C). The regulating wheel (2) is mounted on the upper slider (12). The horizontal slide mechanism (A) moves the regulating wheel (2) while grinding the workpiece (5) according to the outer diameter of the workpiece (5) by moving the table (11) in a horizontal direction relative to the bed (10). The γ -swing slide mechanism (B) swings the swing base (13) about the center axis (w) of the workpiece (5). The lateral slide mechanism (C) is capable of moving the upper slider (12) relative to the swing base (13). By swinging the swing base (13) with the γ -swing slide mechanism (B), it is possible to adjust a center height angle (γ) of the workpiece (5) relative to the regulating wheel (2). Thus it is possible to always keep constant the center height angle (γ).

Fig.1



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Description

TECHNICAL FIELD

[0001] This invention relates to a centerless grinding machine.

BACKGROUND ART

[0002] When grinding a cylindrical workpiece 5 such as cylindrical rollers on a centerless grinding machine 7, grinding accuracy is greatly influenced by the height H of the center axis of the workpiece and a center height angle γ.

[0003] Figs. 11(a) to 11(c) show a conventional centerless grinding machine, which includes a grinder 1, a regulating wheel 2 arranged parallel to and spaced from the grinder 1, and a blade 3 disposed between the grinder 1 and the regulating wheel 2. The regulating wheel 2 is rotated at a low speed and the grinder 1 is rotated at a high speed in the same direction as the regulating wheel 2, about their respective axes. As shown in Fig. 5, this grinding machine further includes opposed pairs of guide plates 6 used to guide the workpiece 5 during what is known as through-feed grinding. That is, the guide plates 6 guide the workpiece 5 into the space between the grinder 1 and the regulating wheel 2, and out of this space, while sandwiching the workpiece 5 therebetween.

[0004] As shown in Fig. 12, the position of the blade 3 is determined such that the center axis w of the workpiece 5 is higher by height H than the line connecting the center axis g of the grinder 1 to the center axis r of the regulating wheel 2. The height H is called the "workpiece center height" (hereinafter simply referred to as the "center height H").

[0005] The acute angle γ between the line Gr connecting the center axis g of the grinder 1 to the center axis w of the workpiece 5 (this line is hereinafter referred to as the "grinding centerline Gr") and the line connecting the center axis w of the workpiece 5 to the center axis r of the regulating wheel 2 is called the center height angle relative to the regulating wheel 2 (hereinafter simply referred to as the "center height angle γ). The center height angle γ satisfies the equation given by $\gamma = \gamma a + \gamma b$
where γ a is the angle between the line connecting center axis g of the grinder 1 to the center axis r of the regulating wheel 2 and the grinding centerline Gr, and γ b is the angle between the line connecting the center axis g of the grinder 1 to the center axis r of the regulating wheel 2 and the line connecting the center axis w of the workpiece 5 to the center axis r of the regulating wheel 2.

[0006] It is considered that if the center height angle γ is too small, the cross-section of the workpiece 5 tends to be a strain circle having an odd number of corners but equal in diameter at any portion thereof, and if the center height angle γ is too large, the cross-section of the workpiece 5 tends to be a strain circle having an even number of corners and different in diameter at different portions thereof.

[0007] But in an ordinary centerless grinding machine, when the outer diameters of the grinder 1. regulating wheel 2 change with use. and/or a workpiece 5 having a different outer diameter is used, the center height angle γ changes.

[0008] For example, if the outer diameters of the grinder 1 and the regulating wheel 2 decrease, the angles γ a and γ b increase to γ a' and γ b', respectively (Fig. 12), so that the center height angle γ increases. If the outer diameter of the workpiece 5 changes from the state shown by phantom line in Fig. 13 to the state shown by solid line, the center axis r of the regulating wheel 2 moves from r1 to r2. This increases γ b to γ b', thus correspondingly increasing the center height angle γ. When the center height angle γ changes in this manner, no accurate grinding of the workpiece 5 is possible.

[0009] In order to keep the center height angle γ constant when the outer diameter of the grinder 1 decreases, the center height H has to be repeatedly reduced. The following complicated steps are necessary in order to reduce the center height H.

[0010] It is first necessary to calculate the center height H that achieves the required center height angle γ, and then to adjust the height of the blade 3 necessary to achieve the calculated center height H. After changing the center height H, the regulating wheel 2 has to be subjected to truing so that the workpiece 5 and the regulating wheel 2 contact each other along a straight line.

[0011] Since the center height H changes, it is also necessary to change the diamond height Ht of the truing device (corresponding to the distance from the grinding centerline Gr to the contact point between the regulating wheel 2 and the workpiece 5; see Fig. 13). It is further necessary to adjust the positions of the guide plates 6 located closer to the regulating wheel 2.

[0012] As shown in Fig. 12, when the outer diameters of the regulating wheel 2 and the workpiece 5 change during grinding, the contact point between the regulating wheel 2 and the workpiece 5 moves from v1 to v2. Thus it is necessary to adjust the positions and directions of the guide plates 6 and the diamond height Ht during truing of the regulating wheel 2.

[0013] But in many cases, even when the outer diameter of the workpiece 5 and/or the center height angle γ changes, truing conditions are not changed. This results in a change in locus of the workpiece 5 when the workpiece 5 moves from the inlet to outlet of the grinder. The change in locus of the workpiece 5 changes the contact point of the workpiece with the grinder. Thus it was necessary to adjust this contact point using a swivel mechanism D.

[0014] The swivel mechanism D adjusts the way how the workpiece 5 contacts the grinder 1 and the regulating wheel 2 from the inlet to outlet of the grinder (distribution of depth of cutting). The distribution of depth of cutting is adjusted e.g. by adjusting the parallelism between the grinder 1 and the regulating wheel 2 by changing the direction of the center axis r of the regulating wheel 2 as shown by the arrow d in Fig. 11(c).

[0015] But while grinding the workpiece 5, since the outer diameter of the grinder 1 changes due to wear and thus the center height angle γ changes correspondingly with time, it is not practical to gradually lower the center height H by repeatedly performing the above-mentioned adjustment.

Thus, ordinarily, the above-mentioned adjustment of the center height angle γ is performed only when, or immediately before, the center height angle γ changes to such an extent as to detrimentally influence the grinding accuracy by interrupting the grinding operation.

[0016] The shape of the regulating wheel 2 is adjusted by truing such that the workpiece 5 comes into line contact with the regulating wheel 2, i.e. the workpiece 5 comes into contact with the regulating wheel 2 along a straight line. But for this purpose, it is known that truing has to be performed with the diamond height Ht and the truing inclination angle θt adjusted to values given by the respective equations:

[0017]

[0017]

$$Ht \approx H\{1-1/2 \cdot (D/Dc + D)\}$$

$$\theta t \approx \theta\{1-1/2 \cdot (D/Dc + D)\}$$

where H is the center height of the workpiece; θ is the inclination angle of the regulating wheel during grinding; D is the diameter of the workpiece; Dc is the diameter of the regulating wheel; Ht is the diamond height for truing the regulating wheel; and θt is the inclination angle of the regulating wheel during truing.

[0018] In order to eliminate the necessity of adjusting the guide plates 6 during setup, thereby solving the above problem, it is known to keep the contact position between the workpiece 5 and the regulating wheel 2 throughout the grinding operation as constant as possible (see e.g. Patent document 1).

[0019] In this arrangement, as shown in Fig. 10, the grinder 1 and the grinder base supporting the grinder are placed on a bed 10, and a swivel plate 18 and an upper slider 12 supporting the regulating wheel 2 are provided on the bed 10 through a horizontal slide mechanism such that the line connecting the center axis g of the grinder 1 to the center axis r of the regulating wheel 2 is inclined relative to a horizontal plane.

[0020] Since the line connecting the center axis g of the grinder 1 to the center axis r of the regulating wheel 2 is inclined, by moving the upper slider 12 and the regulating wheel 2 horizontally relative to the table 11 according to the diameter of the workpiece 5, the contact point between the workpiece 5 and the regulating wheel 2 can be always kept constant. This, it is believed, makes it possible to minimize the change in center height angle γ when the outer diameter of the workpiece 5 changes, compared to ordinary centerless grinding machine.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0021] Patent document 1: JP Patent Publication 2008-149387A (page 7, paragraphs 0031 to 0032, and page 10, Figs. 1 and 2)

SUMMARY OF THE INVENTION

OBJECT OF THE INVENTION

[0022] In such conventional arrangements, the center height angle γ of the workpiece 5 relative to the regulating wheel 2 changes when the outer diameter of the grinder 1 and/or the outer diameter of the regulating wheel 2 changes.

[0023] This makes it necessary to recalculate the center height H corresponding to the desired center height angle γ of the workpiece 5 relative to the regulating wheel 2 every time the outer diameter of the grinder 1, the outer diameter of the regulating wheel 2 and/or the outer diameter of the workpiece 5 changes. It is also necessary to calculate the desired diamond height Ht and inclination angle θt during truing of the regulating wheel 2 according to the outer diameter of the grinder 1, the outer diameter of the regulating wheel 2 and the outer diameter of the workpiece 5. Patent document 1 is not free of this problem.

[0024] That is, in the arrangement disclosed in Patent document 1, it is not easy to set the center height angle γ to a desired value, as in the case with any other conventional centerless grinding machines.

[0025] An object of the present invention is to make it possible to easily and simply set and adjust the position of the regulating wheel 2 according to the outer diameter of the grinder 1, the outer diameter of the regulating wheel 2 and the outer diameter of the workpiece 5.

MEANS TO ACHIEVE THE OBJECT

[0026] In order to achieve this object, the present invention provides a centerless grinding machine comprising a bed, a table mounted on the bed through a horizontal slide mechanism, a swing base mounted on the table through a γ -swing slide mechanism, an upper slider mounted on the swing base through a lateral slide mechanism, a regulating wheel mounted on the upper slider, a grinder mounted on the bed so as to be in juxtaposition with the regulating wheel, wherein a workpiece can be placed between the grinder and the regulating wheel, wherein the grinder has a center axis which is located higher than a center axis of the regulating wheel by an predetermined amount, and a blade provided between the grinder and the regulating wheel and supporting the workpiece from under the workpiece, the blade being capable of keeping constant a center axis of the workpiece, wherein the horizontal slide mechanism is capable of moving the regulating wheel relative to the bed according to the workpiece by moving the table in a direction of a line connecting the center axis of the grinder to the center axis of the workpiece, wherein the γ -swing slide mechanism is capable of adjusting a center height angle of the regulating wheel relative to the workpiece by swinging the regulating wheel about a swing axis which is parallel to the center axis of the regulating wheel, wherein the lateral slide mechanism is capable of moving the regulating wheel relative to the table in a direction of a line connecting the center axis of the workpiece to the center axis of the regulating wheel when the center height angle is determined at any value by the γ -swing slide mechanism.

[0027] Since the γ -swing slide mechanism is capable of swinging the regulating wheel about a swing axis extending parallel to the center axis of the regulating wheel, it is possible to adjust the center height angle to any desired value. It is thus possible to easily set the center height angle to an optimum value according to the shape of the workpiece and the grinding conditions.

It is considered that the optimum center height angle would be around 7° but varies according to the grinding steps and the shape of the workpiece. Thus, it is advantageous that the center height angle can be adjusted to any desired value.

[0028] In a conventional centerless grinding machine, in order to adjust the center height angle, it is necessary to first calculate the center height corresponding to the target center height angle and then move the blade to the height corresponding to the calculated center height. In this regard, with the arrangement of the present invention, the height of the center axis of the workpiece is kept constant, and thus the center height angle is determined solely by the inclination angle of the regulating wheel, which is changed by the γ -swing slide mechanism. This eliminates the necessity of changing the height of the blade and recalculating the center height based on the new blade height when adjusting the center height angle. That is, since the center height angle is determined solely by the movement of the γ -swing slide mechanism, it is not necessary to change the height of the blade in order to adjust the center height angle. In other words, when the center height angle changes, it is not necessary to change the blade height.

[0029] The center axis of the workpiece may be always kept at the same height as the center axis of the grinder.

[0030] Since it is not necessary to change the blade height when the center height angle changes, the regulating wheel and the blade can be configured such that they move in unison with each other, except when the lateral slide mechanism is moved.

In one arrangement for this purpose, the blade is mounted to the swing base, and the blade is configured to be swung about the swing axis by the γ -swing slide mechanism together with the regulating wheel, and further configured to be moved by the horizontal slide mechanism together with the regulating wheel.

[0031] In any of the above-described arrangements, since the center height angle of the workpiece is easily adjustable, it is possible to configure the horizontal slide mechanism, the γ -swing slide mechanism, and the lateral slide mechanism such that they are capable of keeping constant the center height angle irrespective of the outer diameter of the grinder and the outer diameter of the regulating wheel.

By keeping constant the center height angle even when the diameters of the grinder and the regulating wheel change due to wear during grinding, continuous and stable grinding is possible.

[0032] In order to keep constant the center height angle by the horizontal slide mechanism, the γ -swing slide mechanism, and the lateral slide mechanism, based on the center height angle as measured by a known reading device, the horizontal slide mechanism, the γ -swing slide mechanism, and the lateral slide mechanism may be manually operated to adjust the center height angle to the predetermined constant value. Otherwise, the center height angle may be automatically controlled to the constant value by automatically detecting the outer diameters of the grinder, regulating wheel and workpiece, and the center height angle by means of a known reading device, and automatically controlling, based on these detected values, the horizontal slide mechanism, the γ -swing slide mechanism, and the lateral slide mechanism so as to adjust the center height angle to the constant value.

[0033] In the arrangement for keeping constant the center height angle, the horizontal slide mechanism, the γ -swing slide mechanism, and the lateral slide mechanism may be configured such that they are capable of keeping constant the contact point between the grinder and the workpiece and the contact point between the regulating wheel and the workpiece irrespective of the outer diameter of the grinder and the outer diameter of the regulating wheel.

[0034] In the arrangement for keeping constant the center height angle, the horizontal slide mechanism, the γ -swing slide mechanism, and the lateral slide mechanism may be configured so as to be capable of keeping constant the contact point between the regulating wheel and the workpiece irrespective of the outer diameter of the workpiece.

[0035] By keeping constant the center height angle, even when the outer diameter of the grinder and/or the outer diameter of the regulating wheel changes, or the grinder and/or the regulating wheel is changed to a new one having a different outer diameter, it is possible to keep substantially constant the contact point between the grinder and the workpiece (and thus the position of this contact point relative to the frame supporting the grinder) and the contact point between the regulating wheel and the workpiece (and thus the position of this contact point relative to the frame supporting the regulating wheel). This eliminates the necessity of adjusting the directions and positions of the guide plates of the grinder and the regulating wheel.

[0036] In this regard, in the case of a conventional centerless grinding machine, when the outer diameter of the grinder and/or the outer diameter of the regulating wheel changes, or the center height angle is changed, the contact point between the regulating wheel and the workpiece inevitably changes. This makes it necessary to readjust the position of the guide plates on the side of the regulating wheel.

But with the arrangement of the present invention, when the outer diameter of the grinder and/or the outer diameter of the regulating wheel changes, or the center height angle is changed, the contact point between the regulating wheel and the workpiece remains unchanged. Thus it is not necessary to adjust the guide plates on the side of the regulating wheel, provided the guide plates are mounted to e.g. the spindle head of the regulating wheel or otherwise fixed in position relative to the frame supporting the regulating wheel. Otherwise, it is necessary to adjust these guide plates every time the outer diameter of the regulating wheel changes.

[0037] With the arrangement of the present invention, since it is possible to keep constant the contact point between the regulating wheel and the workpiece irrespective of the outer diameters of the grinder and the regulating wheel and the center height angle, it is also possible to minimize the change in the locus of the workpiece from the inlet to outlet of the grinder. This in turn reduces the change in the grinding contact condition even when the regulating wheel is ground under the same truing conditions after the outer diameter of the workpiece and/or the center height angle has been changed.

[0038] With the arrangement in which it is possible to keep constant the center height angle, even when the outer diameter of the workpiece changes or when the workpiece is changed to a new one having a different outer diameter, it is possible to keep substantially constant the contact point between the grinder and the workpiece (and thus the position of this contact point relative to the frame supporting the grinder) and the contact point between the regulating wheel and the workpiece (and thus the position of this contact point relative to the frame supporting the regulating wheel). This also eliminates the necessity of adjusting the directions and positions of the guide plates of the grinder and the regulating wheel.

[0039] Since it is possible to keep substantially constant the contact point between the regulating wheel and the workpiece, when truing the regulating wheel such that the regulating wheel is brought into line contact with the workpiece, the diamond height is kept constant during truing. This simplifies the positioning adjustment of a truing device used for truing.

[0040] In any of the above-described arrangements, the swing axis of the γ -swing slide mechanism may coincide with the center axis of the workpiece.

[0041] By arranging the swing axis of the γ -swing slide mechanism so as to coincide with the center axis of the workpiece, it is possible to easily calculate the swing amount of the γ -swing slide mechanism.

By arranging the swing axis of the γ -swing slide mechanism so as to coincide with the center axis of the workpiece, it is possible to more accurately keep constant the contact point between the workpiece and the regulating wheel, which in turn makes it possible to further simplify the positioning adjustment of the truing device.

[0042] In any of the above-described arrangements, the γ -swing slide mechanism may comprise at least one first arcuate surface formed on a top surface of the table, and at least one second arcuate surface formed on a bottom surface of the swing base, wherein when the regulating wheel swings about the swing axis, the first arcuate surface and the second arcuate surface slide relative to each other, thus guiding the swing motion. With this arrangement, since the swing motion is guided by the surface contact between the first and second arcuate surfaces, the regulating wheel can be swung about the swing axis more reliably and stably.

[0043] In this arrangement, the at least one first arcuate surface may comprise two concentric arcuate surfaces having different radii from each other and formed on the top surface of the table, and the at least one second arcuate surface may comprise two concentric arcuate surfaces formed on the bottom surface of the swing base and configured to be slidable relative to the respective two arcuate surfaces formed on the top surface of the table. With this arrangement, the regulating wheel can be swung more reliably and stably.

[0044] In the arrangement in which the arcuate surfaces are kept in sliding contact with each other, the at least one first arcuate surface and the at least one second arcuate surface may be pressed against each other by a shift prevention preloading mechanism. Preferably, the arcuate surfaces are pressed against each other under the biasing force of an elastic member such as a spring.

[0045] The shift prevention preloading mechanism may comprise a bolt extending through an elongated hole formed in the swing base and threadedly engaged in a threaded hole formed in the table, wherein the bolt is movable in the elongated hole when the swing base is swung.

[0046] In any of the above-described arrangements, a swivel mechanism may be provided between the table and the bed, wherein the swivel mechanism is capable of adjusting the directions of the center axis of the grinder and the center axis of the regulating wheel, and wherein the horizontal slide mechanism is capable of moving the table relative to the bed after the directions of the axes of the grinder and the regulating wheel have been adjusted by the swivel mechanism.

[0047] By providing the swivel mechanism, it is possible to adjust the way how the workpiece contacts the grinder and the regulating wheel from the inlet to outlet of the grinder (distribution of depth of cutting). That is, it is possible to adjust the distribution of depth of cutting by adjusting the parallelism between the grinder and the regulating wheel.

The horizontal slide mechanism performs the above moving function after the swivel mechanism has adjusted the direction of the center axis of the regulating wheel relative to the center axis of the grinder, while keeping the adjusted direction of the center axis of the regulating wheel.

[0048] In any of the above-described arrangements, the horizontal slide mechanism moves the table relative to the bed in the direction of the line connecting the center axis of the grinder with the center axis of the workpiece, thereby moving the regulating wheel according to the workpiece. The direction in which the table is moved relative to the bed by the horizontal slide mechanism may be a horizontal direction or may be inclined relative to a horizontal direction.

ADVANTAGES OF THE INVENTION

[0049] According to the present invention, since the γ-swing slide mechanism is capable of swinging the regulating wheel about a swing axis extending parallel to the center axis of the regulating wheel, it is possible to adjust the center height angle so as to be constant even when the outer diameter of the grinder or the outer diameter of the regulating wheel changes. This eliminates the necessity of complicated control of the regulating wheel when the outer diameter of the grinder or the outer diameter of the regulating wheel changes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050]

Fig. 1 shows a first embodiment in its entirety.

Fig. 2 schematically shows the positional relationships between a grinder, a workpiece, a regulating wheel and a blade.

Fig. 3 shows the positional relationships between the grinder, workpiece, regulating wheel and blade, when the outer diameter of the regulating wheel has decreased.

Fig. 4 shows the positional relationships between the grinder, workpiece, regulating wheel and blade, when the outer diameter of the grinder has decreased.

Fig. 5 shows the positional relationships between the grinder, workpiece, regulating wheel and blade, when the outer diameters of the grinder and the regulating wheel have both decreased.

Fig. 6 shows the positional relationships between the grinder, workpiece, regulating wheel and blade, when the regulating wheel has been swung by a γ-swing slide mechanism.

Fig. 7 shows the positional relationships between the grinder, a workpiece having a different diameter, the regulating wheel and the blade.

Fig. 8 shows the positional relationship between the workpiece and the regulating wheel.

Fig. 9 shows in detail a swing base.

Fig. 10 shows a conventional grinding machine in its entirety.

Figs. 11(a) and 11(b) are perspective views of conventional arrangements; and Fig. 11(c) is a plan view of a conventional arrangement.

Fig. 12 shows how the center height angle changes in a conventional arrangement.

Fig. 13 shows how the center height angle changes in another conventional arrangement.

BEST MODE FOR EMBODYING THE INVENTION

[0051] Figs. 1 to 9 show a centerless grinding machine 17 embodying the present invention, which is used to grind cylindrical workpieces 5 such as cylindrical rollers.

[0052] As shown in Fig. 1, the grinding machine includes a grinder 1 having a circular cross-section, a regulating wheel 2 arranged parallel to and spaced from the grinder 1, and a blade 3 disposed between the grinder 1 and the regulating wheel 2. A workpiece 5 having a circular cross-section is fed into the gap between the grinder 1 and the regulating wheel 2. In the embodiment, as shown in Fig. 2, the center axis g of the grinder 1 and the center axis w of the workpiece 5 are at the same height. Thus, the grinding centerline Gr is horizontal.

[0053] As shown in Fig. 1, the grinding machine further includes a bed 10 placed on a floor, and a table 11 placed on the bed 10 through a horizontal slide mechanism A so that the table 11 is horizontally movable relative to the bed 10.

[0054] The horizontal slide mechanism A can horizontally move the table 11 relative to the bed 10 while the workpiece 5 is being ground, thereby moving the regulating wheel 2 toward or away from the grinder 1 according the outer diameter of the workpiece 5 in the direction perpendicular to the center axis r of the regulating wheel 2 as viewed from the top of the grinding machine.

The moving direction of the regulating wheel 2 may be substantially parallel to the grinding centerline Gr and preferably strictly parallel to the grinding centerline Gr, as viewed from one side of the grinding machine (see e.g. Fig. 2). In the embodiment, since the grinding centerline Gr is horizontal, the table 11 also moves horizontally.

[0055] The grinding machine further includes a swivel mechanism D between the table 11 and the bed 10. The swivel mechanism D includes a swivel plate 18 which can laterally swivel the table 11 relative to the bed 10 (in the direction of the arrow d in Fig. 11(c)), thereby finely adjusting the directions of the center axis g of the grinder 1 and the center axis r of the regulating wheel 2. By adjusting the directions of these center axes, it is possible to adjust how the workpiece 5 contacts the grinder 1 and the regulating wheel 2 (grinding amount distribution) from the inlet to outlet of the grinder. Ordinarily, a plurality of such workpieces 5 are fed continuously from the inlet to outlet of the grinder and ground (see the arrow e in Fig. 11(c)).

[0056] The horizontal slide mechanism A is provided at a higher level than the swivel mechanism D. With the axis g of the grinder 1 and the axis r of the regulating wheel 2 adjusted to predetermined directions by the swivel mechanism D, the horizontal slide mechanism A can move the regulating wheel 2 horizontally while keeping the adjusted direction of the center axis r of the regulating wheel 2.

When the swivel mechanism D swivels the center axis r of the regulating wheel 2 by a certain angle, the horizontal slide mechanism A and the table 11 are also swiveled by the same angle.

[0057] A swing base 13 is mounted on the table 11 through a γ -swing slide mechanism B.

[0058] The γ -swing slide mechanism B can swing the swing base 13 about a swing axis s which is parallel to the center axis r of the regulating wheel 2. In the embodiment, the swing axis s coincides with the center axis w of the workpiece 5.

[0059] An upper slider 12 is mounted on the swing base 13 through a lateral slide mechanism C. The lateral slide mechanism C can slide the upper slider 12 in a straight line in the direction of the line connecting the center axis w of the workpiece 5 to the center axis r of the regulating wheel 2 (direction indicated by the arrow c in Fig. 2), relative to the swing base 13. The inclination angle of the swing base 13 relative to the table 11 changes by swinging the swing base 13 with the γ -swing slide mechanism B, and the direction in which the upper slider 12 is moved by the lateral slide mechanism C varies with the inclination angle of the swing base 13. That is, according to the inclination angle of the swing base 13, the upper slider 12 may slide horizontally or in any other direction. But irrespectively of the inclination angle of the swing base, when the upper slider slides, the regulating wheel 2, which is mounted on the upper slider 12, is moved such that its center axis r moves toward or away from the center axis w of the workpiece 5.

[0060] The regulating wheel 2 is supported by a frame of the upper slider 12 so as to be rotatable about its axis r, and can be driven by a driving source such as an electric motor. The upper slider 12 carries on its top a truing device 15. The regulating wheel 2 is supported by a spindle head to which guide plates 6 at the inlet and outlet of the grinder on the side of the regulating wheel 2 are fixed so as to be moved in the directions of the arrows a, b and c together with the regulating wheel 2.

[0061] The grinder 1 is mounted on the bed 10 in juxtaposition with the regulating wheel 2. The grinder 1 is supported by a frame of a grinder base 14 so as to be rotatable about its axis g, and can be driven by a driving source such as an electric motor. The grinder base 14 may be configured to be capable of moving the grinder 1 horizontally in parallel to the regulating wheel. Guide plates 6 corresponding to the respective guide plates 6 on the side of the regulating wheel 2 are provided on the side of the grinder 1 in a fixed state (by being fixed to a workpiece rest 19).

[0062] In principle, the grinder 1 and the regulating wheel 2 are positioned such that their respective center axes g and r extend parallel to each other, and if necessary, they are positioned such that their axes form a feed angle necessary for through-feed grinding.

[0063] There is a difference in height Hg between the center axis g of the grinder 1 and the center axis r of the regulating wheel 2, with the axis g higher than the axis r.

[0064] The γ -swing slide mechanism B can adjust the center height angle γ of the workpiece 5 relative to the regulating wheel 2 by swinging the swing base 13 about the swing axis s, which is parallel to the axis r of the regulating wheel 2 (in the direction of the arrow b in Fig. 2).

[0065] As shown in Fig. 9, the γ -swing slide mechanism B includes at least one arcuate surface formed on the top surface of the table 11, and at least one arcuate surface formed on the bottom surface of the swing base 13 and in sliding contact with the at least one arcuate surface on the table 11. When these two arcuate surfaces slide, the swing base 13 swings about the swing axis s. When the swing base 13 swings in the direction of the arrow in Fig. 9, the center axis of the regulating wheel 2 moves from r' to r".

[0066] In the embodiment, the at least one arcuate surface formed on the top surface of the table 11 is made up of two concentric arcuate surfaces 11a and 11b having different radii from each other, while the at least one arcuate surface formed on the bottom surface of the swing base 13 is made up of two concentric arcuate surfaces 13a and 13b which are in surface contact with, and adapted to slide on, the respective arcuate surfaces 11a and 11b, so that the swing base 13 can reliably swing relative to the table 11.

[0067] Since the arcuate surfaces 11a and 13a have different diameters from the arcuate surfaces 11b and 13b, respectively, it is possible to support the swing base 13 by surface contact at two spaced apart end portions of the table 11. This allows stable, vibration-free swing motion of the swing base 13.

[0068] The arcuate surface 11a, which is located nearer to the swing axis s than the arcuate surface 11b, and the corresponding arcuate surface 13a of the swing base 13 are pressed against each other by a shift prevention preloading mechanism 16.

[0069] As shown in Fig. 9, the shift prevention preloading mechanism 16 includes a presser member 16c provided on the swing base 13, and bolts 16b extending through the presser member 16c and threaded into threaded holes 11c formed in the table 11. The presser member 16c has an elastic member 16a in the form of a spring which elastically biases the swing base 13 against the table 11. This allows smooth sliding movement of the arcuate surfaces 11a and 13a relative to each other.

[0070] The swing base 13 has an elongated hole 13c in which the bolts 16b can move when the swing base 13 swings about the swing axis s. Another similar shift prevention preloading mechanism may be provided between the other arcuate surfaces 11b and 13b.

[0071] The γ -swing slide mechanism B of this centerless grinding machine 17 can adjust the center height angle γ of the regulating wheel 2 relative to the workpiece 5 by swinging the regulating wheel 2 about the swing axis s, which is parallel to the center axis r of the regulating wheel 2 (the swing axis s being the center axis w of the workpiece 5). Thus, it is possible to keep constant the center height angle γ.

[0072] The operation of this grinding machine is now described. In the state of Fig. 3, the center axis g of the grinder 1 is located by higher than the axis r of the regulating wheel 2 by distance Hg, and thus the center height angle γ is formed with respect to the grinding centerline Gr.

[0073] Suppose now that the outer diameter of the regulating wheel 2 changes, due to wear, from the state shown by phantom line in Fig. 3 to the state shown by solid line. At this time, the lateral slide mechanism C moves the upper slide 12 and the regulating wheel 2 in the direction of the arrow c1 until the axis r of the regulating wheel 2 moves to the position shown by r'. The blade 3 moves together with the regulating wheel 2. When the regulating wheel 2 moves in this manner, the workpiece 5 and thus its center axis w remain stationary.

[0074] The center height angle γ of the workpiece 5 relative to the regulating wheel 2 remains unchanged before and after the regulating wheel 2 has been moved in the above manner. This is because the regulating wheel 2 is moved by the lateral slide mechanism C in the direction of the line connecting the center axis w of the workpiece 5 to the center axis r of the regulating wheel 2. That is, in Fig. 3, which is a sectional view, after the regulating wheel 2 has been moved by the lateral slide mechanism, its center axis r' is located on the line connecting the center axis w of the workpiece 5 to the center axis r of the regulating wheel 2 before the regulating wheel 2 is moved by the lateral slide mechanism.
The difference in height Hg between the center axis g of the grinder 1 and the center axis r of the regulating wheel 2 decreases to Hg'.

[0075] Now, if the outer diameter of the grinder 1 changes from the state shown by phantom line in Fig. 4 to the state shown by solid line, since the workpiece 5 moves toward the grinder 1 as the wear of the grinder 1 progresses, the horizontal slide mechanism A moves the regulating wheel 2 until its center axis r moves to the position shown by r' in the horizontal direction shown by the arrow a1 in Fig. 4. At this time, the blade 3 moves together with the regulating wheel 2, and the center axis w of the workpiece 5 remains unchanged.

[0076] The center height angle γ of the workpiece 5 relative to the regulating wheel 2 remains unchanged before and after the regulating wheel 2 has been moved in the above manner. That is, the angles γ and γ' in Fig. 4 are equal to each other. This is because the regulating wheel 2 is moved by the horizontal slide mechanism A in the direction parallel to the grinding centerline Gr.
The difference in height Hg between the center axis g of the grinder 1 and the center axis r of the regulating wheel 2 remains unchanged before and after the regulating wheel 2 is moved in the above manner.

[0077] Now suppose that the outer diameters of the grinder 1 and the regulating wheel 2 both decrease due to wear from the states shown by phantom lines in Fig. 5 to the states shown by solid lines. At this time, since the workpiece 5 gradually moves toward the grinder 1 as the wear of the grinder 1 progresses, the lateral slide mechanism C moves the regulating wheel 2 such that its center axis moves from the position shown by r in the direction of the arrow c2 in Fig. 5. But the blade 3 is not moved by the lateral slide mechanism C at this time. The height of the center axis w of the workpiece 5 remains unchanged at this time.

[0078] Thereafter, the regulating wheel 2 is moved by the horizontal slide mechanism A in the horizontal direction shown by the arrow a2 in Fig. 5, together with the blade 3. At this time too, the height of the center axis w of the workpiece 5 remains unchanged.

[0079] The center height angle γ of the workpiece 5 relative to the regulating wheel 2 remains unchanged before and after the regulating wheel 2 has been moved in the above manner. That is, the angles γ and γ' in Fig. 5 are equal to each other. The difference in height Hg between the center axis g of the grinder 1 and the center axis r of the regulating wheel 2 decreases to Hg' in Fig. 5.

[0080] Since the center height angle γ is kept constant when the outer diameter of the grinder 1 and/or the outer diameter of the regulating wheel 2 changes due to wear during grinding, it is possible to grind workpieces continuously and stably. The fact that the center axis g of the grinder 1 and the center axis w of the workpiece are both kept at constant heights makes it possible more stably grind workpieces continuously.

[0081] Since the horizontal slide mechanism A, γ -swing slide mechanism B, and lateral slide mechanism C are configured to automatically keep constant the center height angle γ irrespective of the outer diameters of the grinder 1 and the regulating wheel 2, it is possible to eliminate the necessity of complicated position adjustment of the regulating wheel 2, which was necessary in conventional arrangements.

[0082] Now description is made of how the center height angle γ is changed.

[0083] In order to change the center height angle γ of the regulating wheel 2 relative to the workpiece 5, the swing base 13 is swung relative to the table 11 from the position shown by phantom line in Fig. 6 to the position shown by solid line by the γ -swing slide mechanism B, together with the blade 3.
Since the swing base 13 and thus the regulating wheel

2 are swung about the swing axis s, which is parallel to the center axis r of the regulating wheel 2, and which coincides with the center axis w of the workpiece 5 in the embodiment, as shown by the arrow b1 in Fig. 6, it is possible to change the center height angle γ. In Fig. 6, the center height angle is changed from γ to γ'.

[0084] Thus, in the above-described manner, the center height angle γ of the regulating wheel 2 relative to the workpiece 5 can be easily changed to an optimum value every time the shape of the workpiece 5 and/or the grinding conditions change.

[0085] As shown in Fig. 6, when the center height angle is changed in the above manner, the contact point between the regulating wheel 2 and the workpiece 5 (position of this contact point relative to the frame supporting the regulating wheel 2) never changes. Thus, it is not necessary to adjust the positions of the guide plates 6 on the side of the regulating wheel 2. This is because the guide plates 6 on the side of the regulating wheel 2 are fixed to the frame supporting the regulating wheel 2 (such as the spindle head of the regulating wheel 2 or the upper slider 12).

[0086] Now description is made when grinding a workpiece 5 having a different outer diameter from the previously ground workpiece. Suppose, for example, that the workpiece 5 to be ground next has an outer diameter as shown by solid line in Fig. 7, and the previously ground workpiece 5 had an outer diameter as shown by phantom line in Fig. 7.

[0087] In this case, adjustment is made so that the swing axis s, about which the swing base 13 is swung, coincides with the center axis w of the workpiece 5. This adjustment is made by moving the blade 3 in the direction of the arrow f in Fig. 7 to adjust its height, and moving the upper slider 12 in the direction of the arrow c3 in Fig. 7 by means of the lateral slide mechanism C to adjust the position of the regulating wheel 2. Then, the table 11 is moved in the direction of the arrow a3 in Fig. 7 by means of the horizontal slide mechanism A. By moving the table 11, the positions of the regulating wheel 2, workpiece 5 and blade 3 are adjusted relative to the grinder 1.

[0088] Before and after the above adjustments, the center height angle γ of the workpiece 5 relative to the regulating wheel 2 remains unchanged. That is, the angles γ and γ' are equal to each other. The difference in height between the center axis g of the grinder 1 and the center axis r of the regulating wheel 2 decreases from Hg to Hg'.

[0089] Since the center height angle γ of the workpiece 5 relative to the regulating wheel 2 remains unchanged, the contact point between the regulating wheel 2 and the workpiece 5 remains unchanged too. Thus, it is not necessary to adjust the positions of the guide plates 6 on the side of the regulating wheel 2, as in the case where the center height angle γ is adjusted.

[0090] As shown in Figs. 7 and 8, if the outer diameter of the regulating wheel 2 remains the same, even if the outer diameter of the workpiece 5 changes, the contact point between the regulating wheel 2 and the workpiece 5 remains unchanged. Also, as shown in Fig. 6, when the regulating wheel 2 is swung about the center axis w of the workpiece 5, while the center height angle γ changes, the contact point between the workpiece and the regulating wheel remains unchanged. Thus, it is possible to configure the system such that the contact point between the regulating wheel 2 and the workpiece 5 remains unchanged at all times.

[0091] That is, the horizontal slide mechanism A, the γ -swing slide mechanism B and the lateral slide mechanism C are capable of keeping constant the contact point between the grinder 1 and the workpiece 5 and the contact point between the regulating wheel 2 and the workpiece 5 irrespective of the outer diameter of the grinder 1 or the outer diameter of the regulating wheel 2. Also, the horizontal slide mechanism A, the γ -swing slide mechanism B and the lateral slide mechanism C can keep constant the contact point between the regulating wheel 2 and the workpiece 5 irrespective of the outer diameter of the workpiece 5.

[0092] As described above, that the contact point between the regulating wheel 2 and the workpiece 5 is constant means that the position of this contact point relative to the frame supporting the regulating wheel 2 is also constant. Since this contact point scarcely changes, even when the grinder 1 and the regulating wheel 2 become worn, it is not necessary to change the positions and directions of the guide plates 6 mounted to the grinder and the regulating wheel, respectively.

DESCRIPTION OF THE NUMERALS

[0093]

1. Grinder
2. Regulating wheel
3. Blade
5. Workpiece
6. Guide plate
7. 17. Centerless grinding machine
10. Bed
11. Table
11a, 11b. Arcuate surface
12. Upper slider
13. Swing base
13a, 13b. Arcuate surface
13c. Elongated hole
14. Grinder base
15. Truing device
16. Shift prevention preloading mechanism
16a. Elastic member
16b. Bolt
16c. Presser member
18. Swivel plate
19. Workpiece rest
A. Horizontal slide mechanism
B. γ-swing slide mechanism

C. Lateral slide mechanism
D. Swivel mechanism
Gr. Grinding centerline
g, r, w. Center axis
H. Center height
γ, γ'. Center height angle

Claims

1. A centerless grinding machine comprising a bed (10), a table mounted on the bed (10) through a horizontal slide mechanism (A), a swing base (13) mounted on the table (11) through a γ-swing slide mechanism (B), an upper slider (12) mounted on the swing base (13) through a lateral slide mechanism (C), a regulating wheel (2) mounted on the upper slider (12), a grinder (1) mounted on the bed (10) so as to be in juxtaposition with the regulating wheel (2), wherein a workpiece (5) can be placed between the grinder (1) and the regulating wheel (2), wherein the grinder (1) has a center axis (g) which is located higher than a center axis (r) of the regulating wheel (2) by an predetermined amount (Hg), and a blade (3) provided between the grinder (1) and the regulating wheel (2) and supporting the workpiece (5) from under the workpiece (5), the blade (3) being capable of keeping constant a center axis (w) of the workpiece (5),
wherein the horizontal slide mechanism (A) is capable of moving the regulating wheel (2) relative to the bed (10) according to the workpiece (5) by moving the table (11) in a direction of a line connecting the center axis (g) of the grinder (1) to the center axis (w) of the workpiece (5), wherein the γ -swing slide mechanism (B) is capable of adjusting a center height angle (γ) of the regulating wheel (2) relative to the workpiece (5) by swinging the regulating wheel (2) about a swing axis (s) which is parallel to the center axis (r) of the regulating wheel (2), wherein the lateral slide mechanism (C) is capable of moving the regulating wheel (2) relative to the table (11) in a direction of a line connecting the center axis (w) of the workpiece (5) to the center axis (r) of the regulating wheel (2) when the center height angle (γ) is determined at any value by the γ -swing slide mechanism (B).

2. The centerless grinding machine of claim 1, wherein the center axis (w) of the workpiece (5) is always kept at a same height as the center axis (g) of the grinder (1).

3. The centerless grinding machine of claim 1 or 2, wherein the blade (3) is mounted to the swing base (13), and wherein the blade (3) is configured to be swung about the swing axis (s) by the γ-swing slide mechanism (B) together with the regulating wheel (2), and further configured to be moved by the horizontal slide mechanism (A) together with the regulating wheel (2).

4. The centerless grinding machine of any of claims 1 to 3, wherein the horizontal slide mechanism (A), the γ -swing slide mechanism (B), and the lateral slide mechanism (C) are capable of keeping constant the center height angle (γ) irrespective of an outer diameter of the grinder (1) and an outer diameter of the regulating wheel (2).

5. The centerless grinding machine of claim 4, wherein the horizontal slide mechanism (A), the γ -swing slide mechanism (B), and the lateral slide mechanism (C) are capable of keeping constant a contact point between the grinder (1) and the workpiece (5) and a contact point between the regulating wheel (2) and the workpiece (5) irrespective of the outer diameter of the grinder (1) and the outer diameter of the regulating wheel (2).

6. The centerless grinding machine of claim 4 or 5, wherein the horizontal slide mechanism (A), the γ -swing slide mechanism (B), and the lateral slide mechanism (C) are capable of keeping constant the contact point between the regulating wheel (2) and the workpiece (5) irrespective of an outer diameter of the workpiece (5).

7. The centerless grinding machine of any of claims 1 to 6, wherein the swing axis (s) of the γ -swing slide mechanism (B) coincides with the center axis (w) of the workpiece (5).

8. The centerless grinding machine of any of claims 1 to 7, wherein the γ -swing slide mechanism (B) comprises at least one first arcuate surface formed on a top surface of the table (11), and at least one second arcuate surface formed on a bottom surface of the swing base (13), wherein when the regulating wheel (2) swings about the swing axis (s), the first arcuate surface and the second arcuate surface slide relative to each other, thus guiding the swing motion.

9. The centerless grinding machine of claim 8, wherein the at least one first arcuate surface comprises two concentric arcuate surfaces (11a and 11b) having different radii from each other and formed on the top surface of the table (11), and the at least one second arcuate surface comprises two concentric arcuate surfaces (11b and 13b) formed on the bottom surface of the swing base (13) and configured to be slidable relative to the respective two arcuate surfaces (11a and 11b) formed on the top surface of the table (11).

10. The centerless grinding machine of claim 8 or 9, wherein the at least one first arcuate surface and the

at least one second arcuate surface are pressed against each other by a shift prevention preloading mechanism (16).

11. The centerless grinding machine of claim 10, wherein the shift prevention preloading mechanism (16) comprises a bolt (16b) extending through an elongated hole (13c) formed in the swing base (13) and threadedly engaged in a threaded hole (11c) formed in the table (11), wherein the bolt (16) is movable in the elongated hole (13c) when the swing base (13) is swung.

12. The centerless grinding machine of any of claims 1 to 11, further comprising a swivel mechanism (D) provided between the table (11) and the bed (10), wherein the swivel mechanism (D) is capable of adjusting the directions of the center axis (g) of the grinder (1) and the center axis (r) of the regulating wheel (2), and wherein the horizontal slide mechanism (A) is capable of moving the table relative to the bed after the directions of the axes of the grinder and the regulating wheel have been adjusted by the swivel mechanism (D).

13. The centerless grinding machine of any of claims 1 to 12, wherein the horizontal slide mechanism (A) moves the table (11) relative to the bed (10) in a direction inclined relative to a horizontal direction.

Fig.1

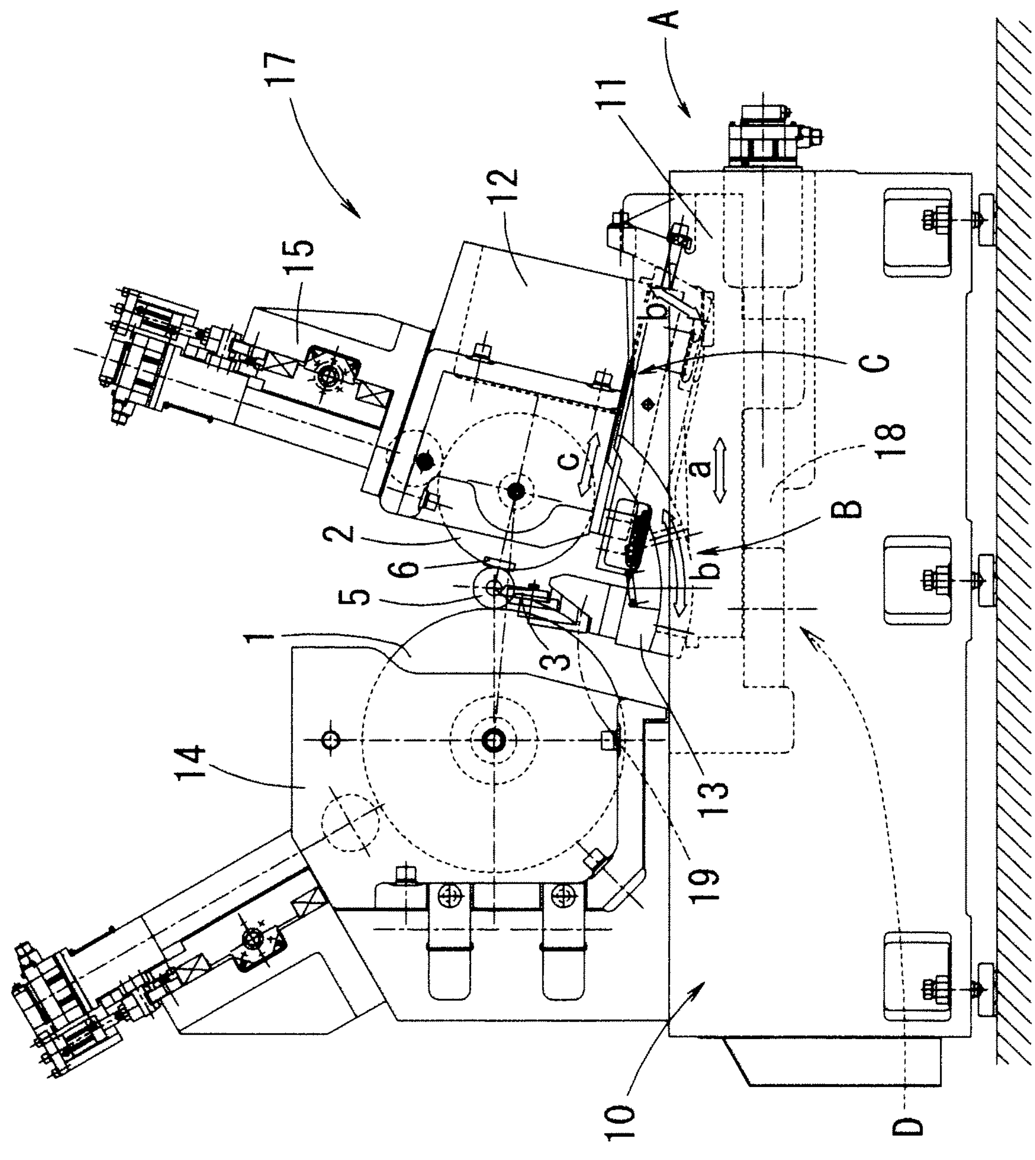


Fig.2

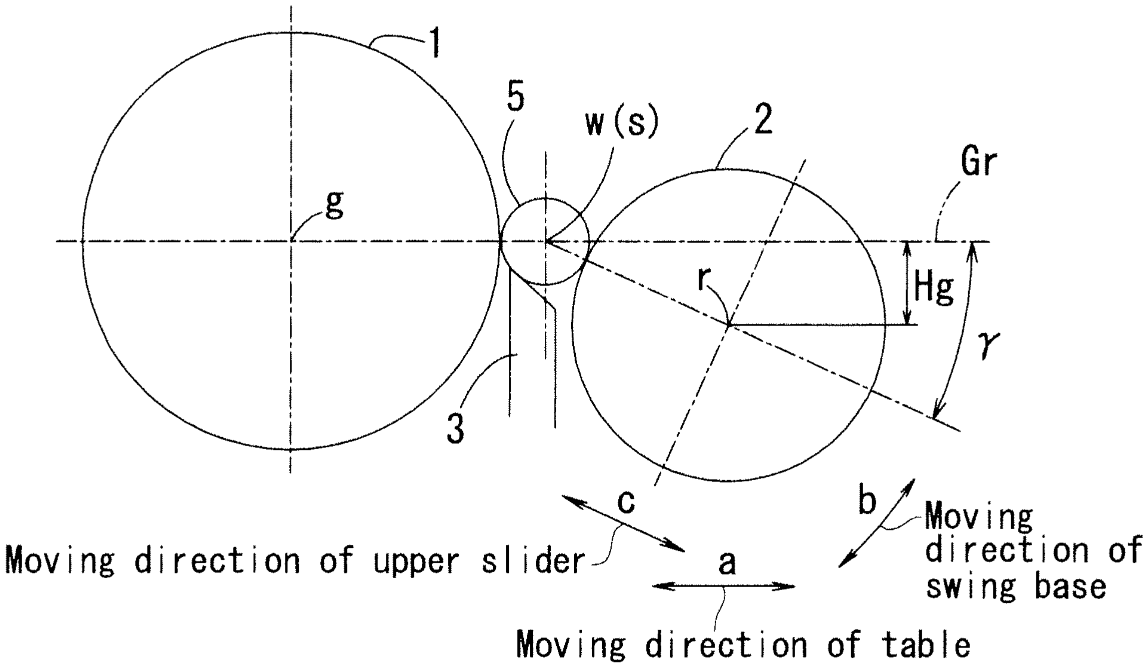

1
5
w(s)
2
Gr
g
r
Hg
γ
3
c
b
Moving direction of swing base
Moving direction of upper slider
a
Moving direction of table

Fig.3

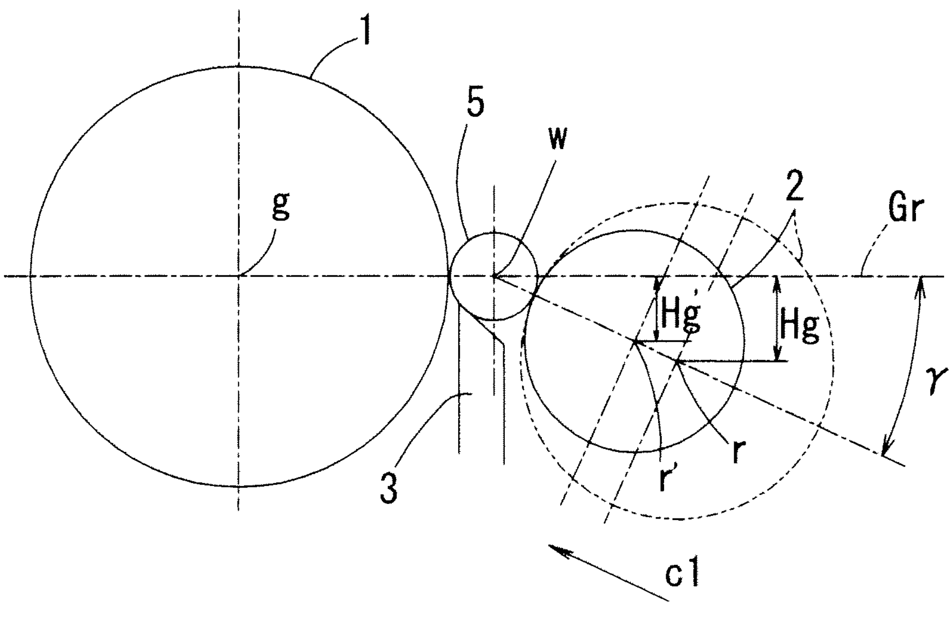

1
5
w
g
2
Gr
Hg'
Hg
γ
3
r'
r
c1

Fig.4

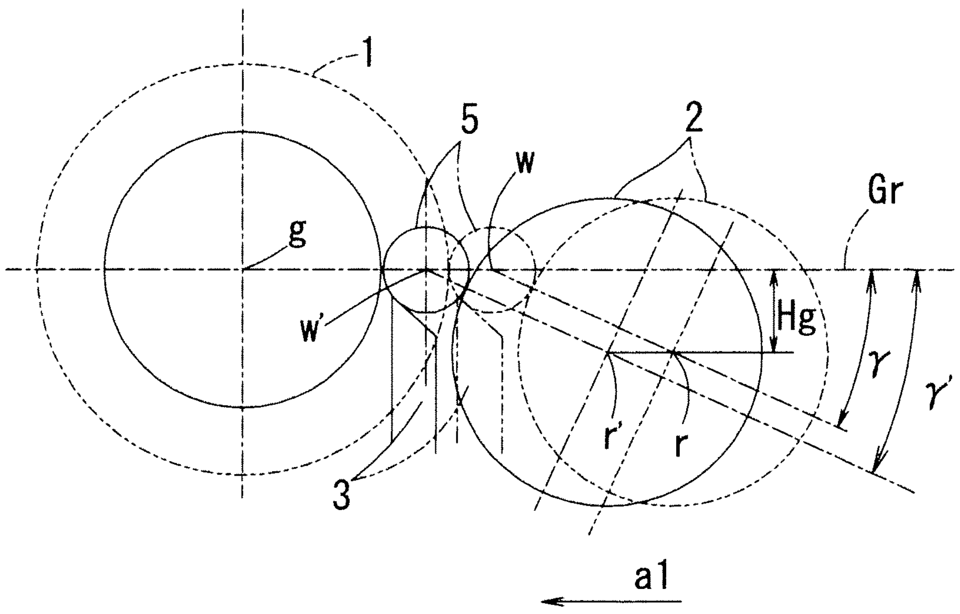


Fig.5

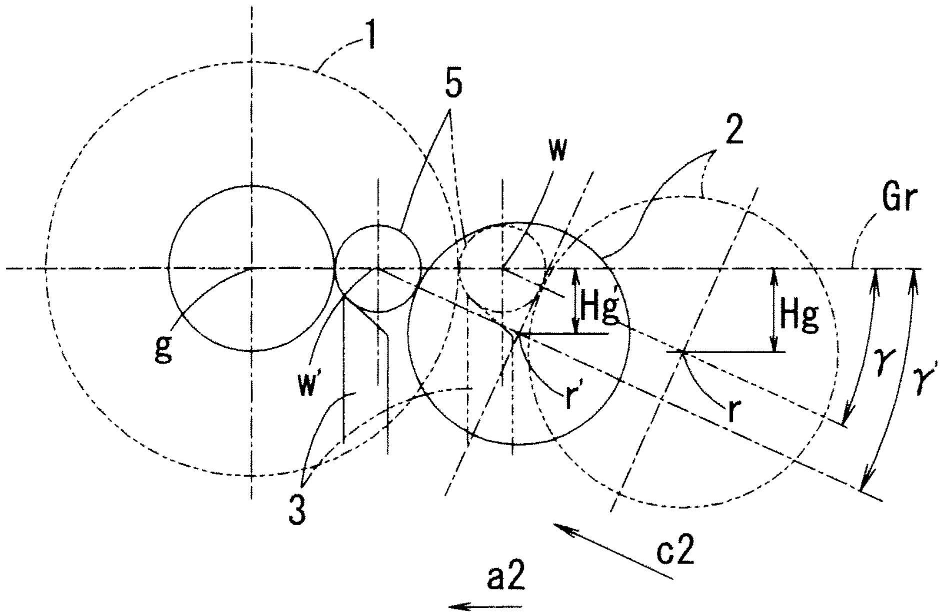


Fig.6

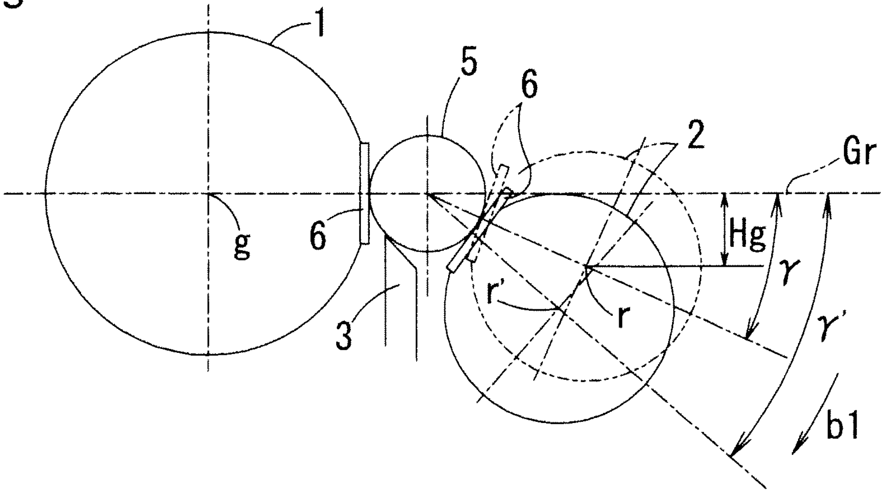


Fig.7

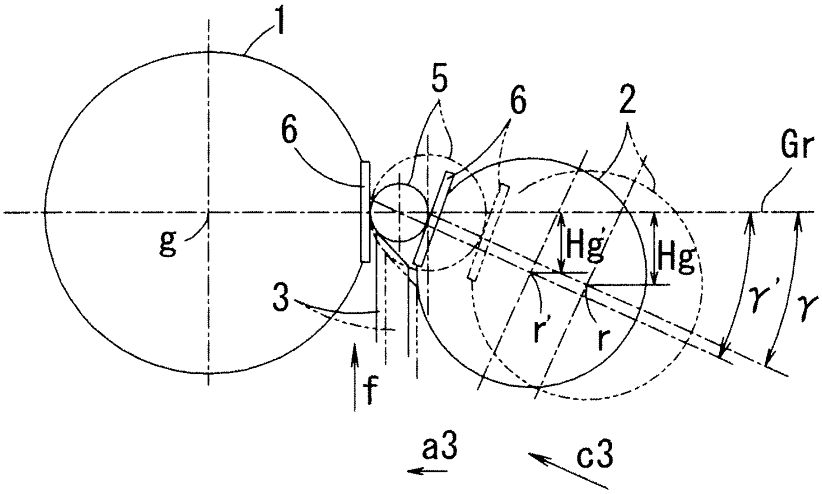


Fig.8

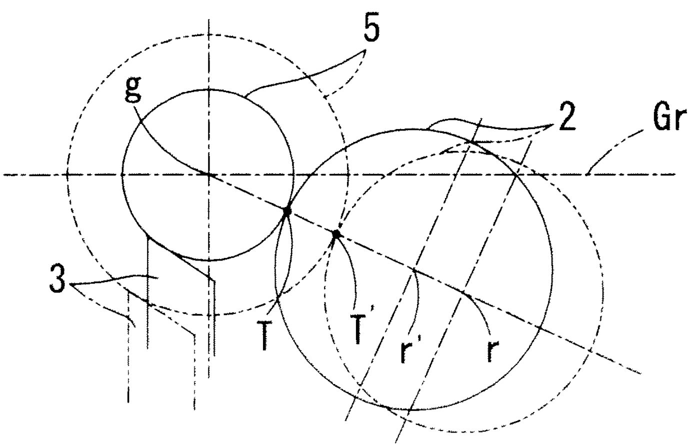


Fig.9

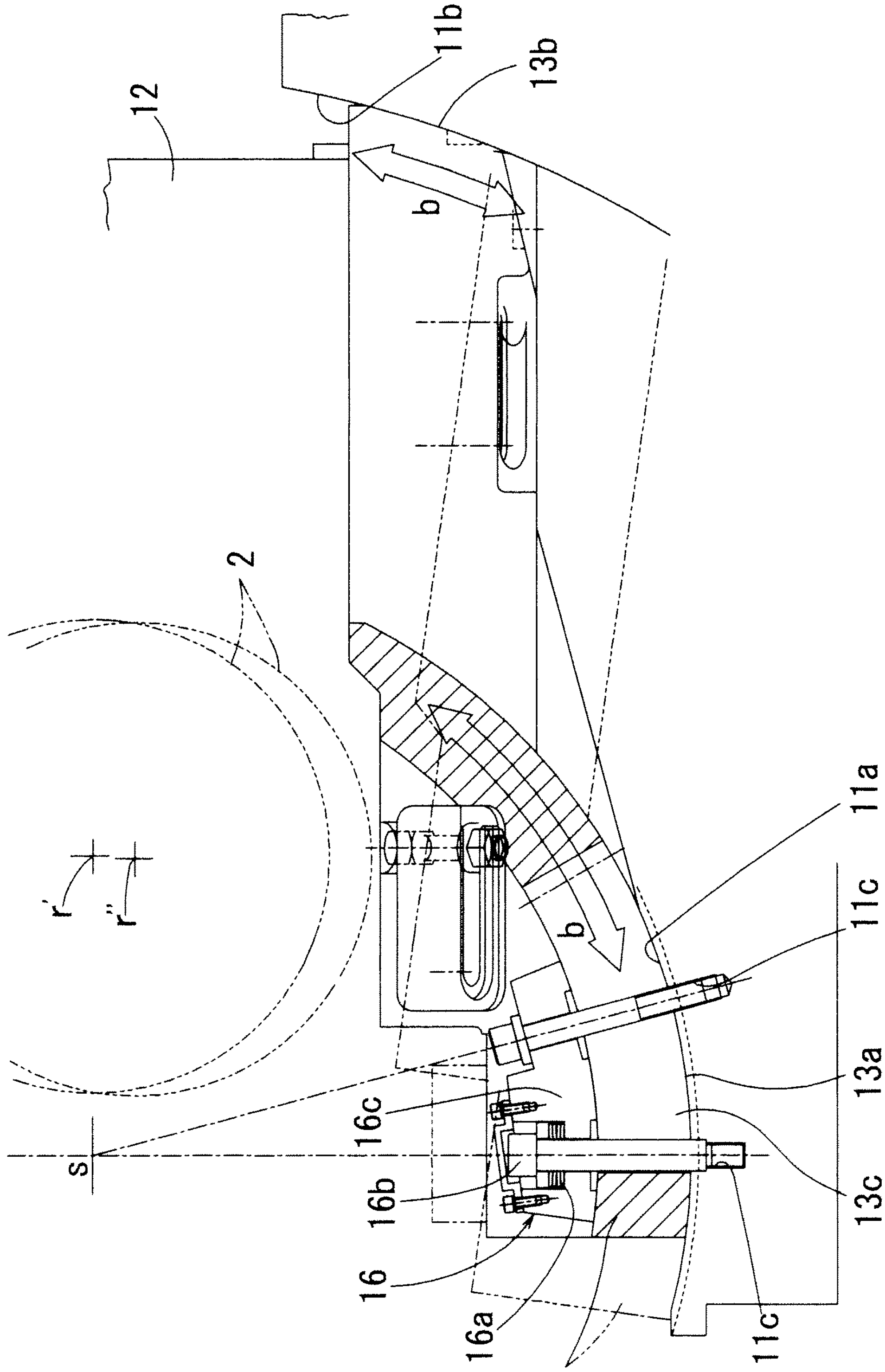


Fig.10

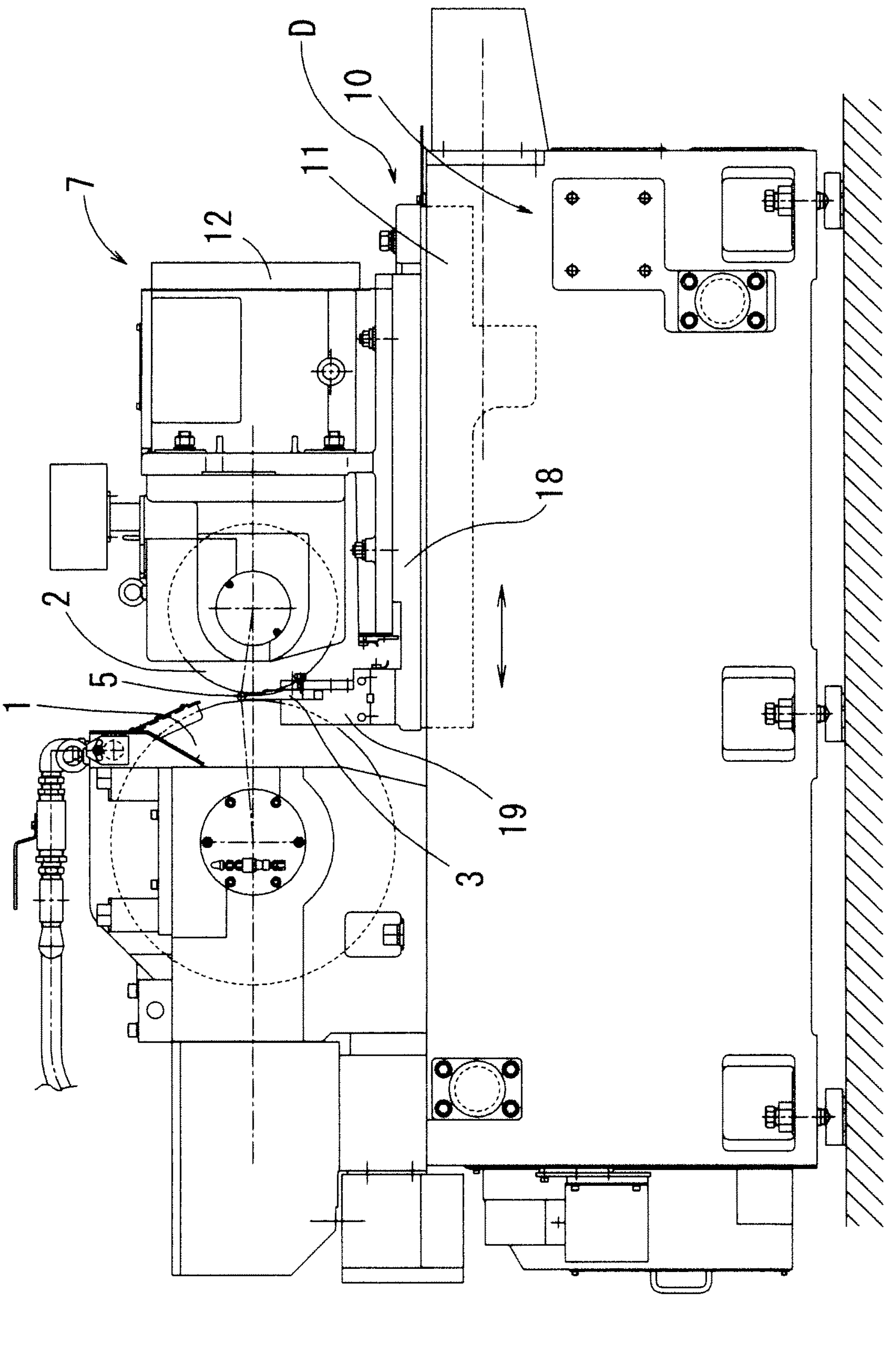


Fig.11

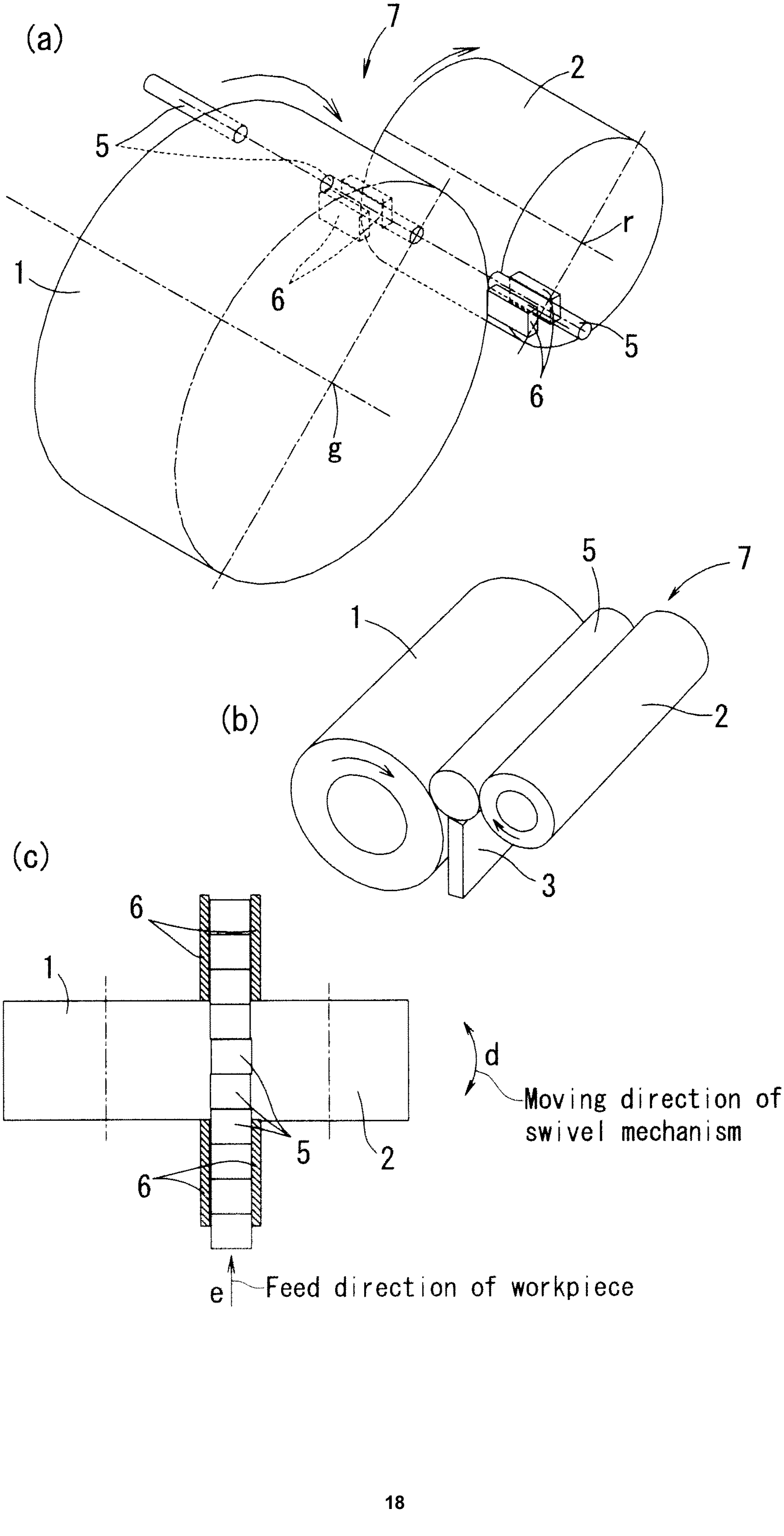

(a)
7
2
5
r
1
6
5
6
g
5
7
1
(b)
2
3
(c)
6
1
d
Moving direction of swivel mechanism
5
2
6
e
Feed direction of workpiece

Fig.12

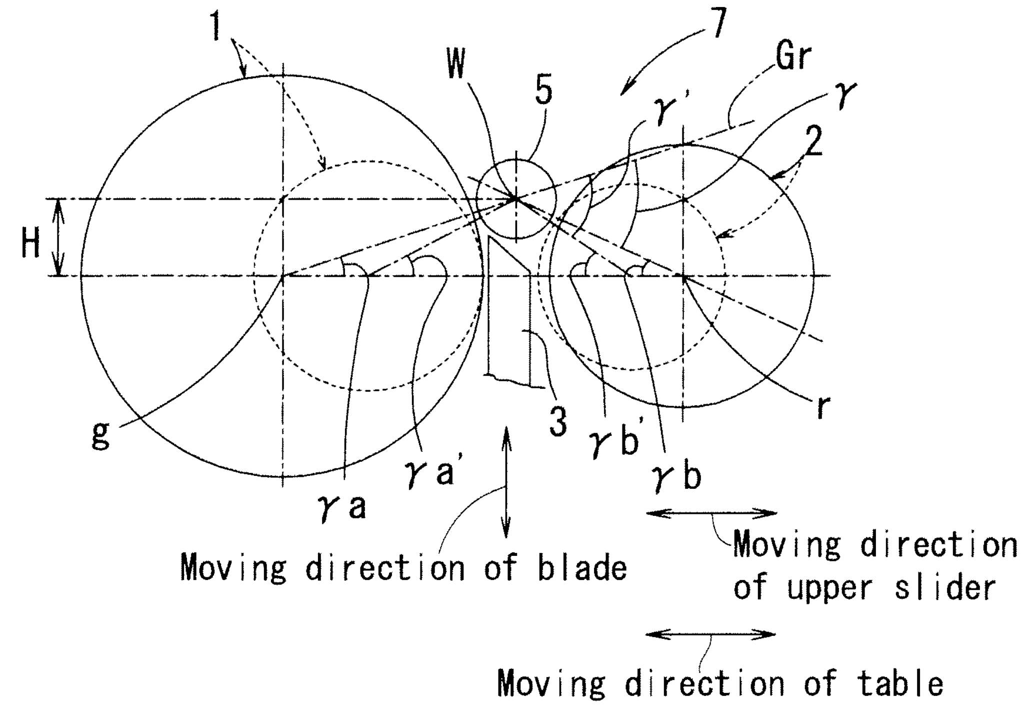
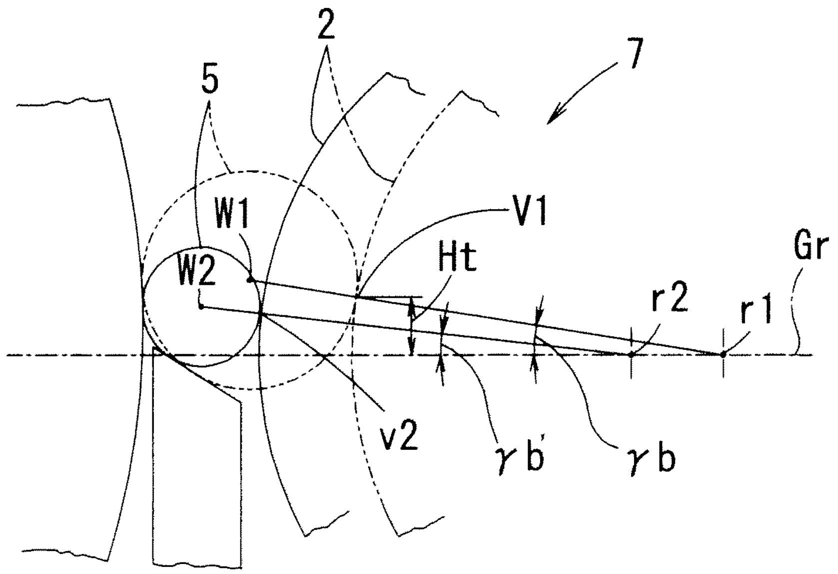

1
W
5
7
Gr
γ'
γ
2
H
g
3
γb'
γb
r
γa'
γa
Moving direction of blade
Moving direction
of upper slider
Moving direction of table

Fig.13


2
7
5
W1
V1
W2
Ht
Gr
r2
r1
v2
γb'
γb

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/065594

A. CLASSIFICATION OF SUBJECT MATTER
B24B5/18(2006.01)i, *B24B5/30*(2006.01)i, *B24B41/02*(2006.01)i, *B24B41/06*(2006.01)i, *B24B47/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B24B5/18, B24B5/30, B24B41/02, B24B41/06, B24B47/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 5-305311 A (Canon Inc.), 19 November 1993 (19.11.1993), paragraph [0022]; fig. 2 & US 5595848 A & EP 0553876 A1 & CN 1082211 A	1-2,4-6, 12-13 3,7-11
Y A	JP 6-246608 A (Koyo Machine Industries Co., Ltd.), 06 September 1994 (06.09.1994), paragraphs [0018] to [0032]; fig. 1 to 4 (Family: none)	1-2,4-6, 12-13 3,7-11
Y A	JP 2000-317752 A (Lidkoeping Machine Tools AB.), 21 November 2000 (21.11.2000), paragraphs [0009] to [0016]; fig. 1 & EP 1048395 A2 & CN 1271639 A	1-2,4-6, 12-13 3,7-11

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

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 August, 2011 (30.08.11)	13 September, 2011 (13.09.11)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/065594

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 8-19944 A (Micron Machinery Co., Ltd.), 23 January 1996 (23.01.1996), entire text; all drawings (Family: none)	1-13

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

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- JP 2008149387 A **[0021]**