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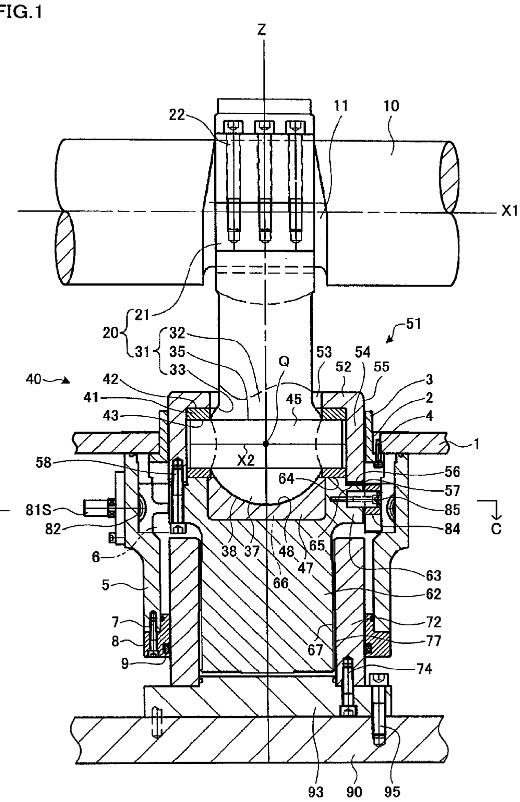
(54) Slide drive device

(57) A slide drive device implements a high-precision press operation due to a small amount of backlash. The slide drive device is configured so that a slide (90)-side female spherical surface (48) and a connecting rod (20)-side male spherical surface (38) come in contact with each other during press forming so that a press-forming load (Pprs) is transmitted to the connecting rod through the female spherical surface (48) and the male spherical surface (38), and an upper side (52) of a holding member (51) is suspended on a circular member (41) during a period other than a press-forming period so that the female spherical surface (48) and the male spherical surface (38) are separated from each other, and a slide load (Psrd) is transmitted to the connecting rod (20) through the circular member (41) and a horizontal pin member (45).

FIG.1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a slide drive device that drives a slide while converting the rotational motion of a crank shaft into the upward/downward motion of the slide through a connecting rod and a suspension mechanism.

[0002] A slide drive device includes a crank shaft, a connecting rod, a suspension mechanism, and the like, and moves a movable slide (upper die) upward or downward so that the slide moves away or approaches a stationary bolster (lower die).

[0003] The slide drive device disclosed in the related art (JP-UM-A-61-31600, for example) is configured so that the upper end of the connecting rod (2) has a ring shape, and is fitted into the eccentric section of the crank shaft (1), and the lower end of the connecting rod (2) has a spherical shape, and is rotatably connected to the suspension mechanism (8, 7). The suspension mechanism has a frame assembly structure that includes the upper frame (8) having a hemispherical inner surface that is convex upward, and the lower frame (7) having a hemispherical inner surface that is convex downward. The suspension mechanism can suspend the slide (12), and move the slide upward and downward within a given stroke.

[0004] The suspension mechanism normally includes a slide height adjustment section (die height adjustment mechanism). The die height adjustment mechanism adjusts the interval (die height) between the upper side of the bolster and the lower side of the slide. Specifically, the die height adjustment mechanism moves the internally threaded member (13) by rotating the externally threaded member (10) using a rotation means (endless screw (3) and worm gear (4)) to adjust the relative positions of the lower end of the connecting rod (2) and the slide (12) in the vertical direction.

[0005] The connecting rod (2) swings around the (spherical) lower end when rotating the crank shaft (eccentric section). The lower end of the connecting rod (2) rotates within the frame assembly structure (8, 7), and is located at a vertical position corresponding to the swing angle (tilt of the rod). Specifically, the slide (12) can be moved upward and downward.

[0006] The connecting rod (2) receives the upward press-forming load (press reaction force) through the suspension mechanism (frame assembly structure) during press forming, and receives the downward slide load (i.e., the full load including the die height adjustment mechanism and the like) during a period other than a press-forming period(before or after press forming).

[0007] Other related art (JP-UM-A-5-70800, for example) discloses a slide drive device that has an identical basic function, and is configured so that the lower end of the connecting rod is fitted into the wrist pin 22. The overall (basic) structure of the slide drive device is similar to the above-described structure (JP-UM-A-61-31600).

[0008] An improvement in precision of a press machine including a slide drive device has been strongly desired. The precision of the slide drive device is improved by minimizing a change and a variation in the vertical position of the slide. Specifically, the precision of the slide drive device is improved by minimizing the amount and a variation in mechanical backlash in the vertical direction.

[0009] In both of the above-described related art, the backlash of the slide drive device generally occurs in (due to) a first connection area of the upper end of the connecting rod and the crank shaft (eccentric section), a second connection area of the lower end of the connecting rod and the suspension mechanism, and a third connection area of the suspension mechanism and the slide.

[0010] Since the first connection area has a simple structure, the backlash in the first connection area is determined within a range corresponding to the part machining accuracy and the assembly accuracy. Therefore, it is difficult to achieve a significant improvement in precision by modifying the mechanical structure. Since the suspension mechanism (internally threaded member) and the slide are integrally fastened in the third connection area, the backlash in the third connection area is determined by the engagement accuracy of the externally threaded member and the internally threaded member. Therefore, since the backlash in the third connection area is determined within a range corresponding to the thread machining accuracy and the assembly accuracy, it is difficult to achieve a significant improvement in precision by modifying the mechanical structure. Note that the backlash in the third connection area during the press operation can be eliminated by providing a hydraulic locking means that can integrally secure the externally threaded member and the internally threaded member. In JP-UM-A-61-31600, the hydraulic locking means is formed by providing the hydraulic chamber 16. In JP-UM-A-5-70800, the hydraulic locking means is formed by providing the oil chamber 35.

[0011] The second connection area has a complex structure, and requires that precisely machined parts be accurately assembled in order to maintain a smooth and stable swing/vertical motion of the connecting rod, and reliably provide resistance to the load that changes in direction depending on the presence or absence of the press operation and the inertial force that occurs due to a change in speed of the slide, for example. Moreover, it takes time to establish the desired accuracy (precision). These requirements hinder a reduction in cost. However, the basic structure has been limited as in the above-described related art, and has not been substantially modified.

SUMMARY

[0012] According to one aspect of the invention, there is provided a slide drive device that drives a slide while converting a rotational motion of a crank shaft into an upward/downward motion of the slide through a connecting rod and a suspension mechanism, characterized in that a lower end of the connecting rod is formed by a male curved-surface member having a male curved surface that is convex downward, and is provided with a horizontal pin member that is rotatably held by a circular member, a holding member is provided so that a lower side of the holding member is connected to a female curved-surface member having a female curved surface that is convex downward, and an upper side of the holding member can be fitted onto the circular member, the female curved surface and the male curved surface come in contact with each other during press forming so that a press-forming load is transmitted to the connecting rod through the female curved surface and the male curved surface, and the holding member and the circular member are held in a non-contact state, and the upper side of the holding member is suspended on the circular member during a period other than a press-forming period so that the female curved surface and the male curved surface are held in a non-contact state, and a slide load is transmitted to the connecting rod through the holding member, the circular member, and the horizontal pin member.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0013]

FIG 1 is a front vertical cross-sectional view illustrating a slide drive device according to one embodiment of the invention.

FIG 2 is a side vertical cross-sectional view illustrating a slide drive device according to one embodiment of the invention.

FIG 3 is a cross-sectional view taken along the line C-C in FIG 1.

FIG 4A is a diagram illustrating a slide drive motion during press forming. FIG 4B is a diagram illustrating a slide drive motion during a period other than a press-forming period.

FIGS. 5A to 5C are diagrams illustrating a slide drive motion and a problem of the above-described related art (slide drive device).

FIG 6 is a front vertical cross-sectional view illustrating a slide drive device according to one embodiment of the invention.

FIG 7 is a side vertical cross-sectional view illustrating a slide drive device according to one embodiment of the invention.

FIG 8A is a diagram illustrating a slide drive motion during press forming. FIG 8B is a diagram illustrating a slide drive motion during a period other than a press-forming period.

FIG 9A is a diagram illustrating an example of the structure of a male cylindrical member. FIG 9B is a diagram illustrating an example of the structure of a female cylindrical member.

DETAILED DESCRIPTION OF THE EMBODIMENT

[0014] The invention may provide a slide drive device that implements a high-precision operation due to a small amount of backlash.

[0015] As a result of a detailed study of each connection area, it was found that it is possible to improve the precision of the entire device and address the future trend of the press forming technology by reducing the amount of backlash in the second connection area by half.

[0016] In the above-described related art (JP-UM-A-61-31600), the clearance C21 between the lower end (spherical body 2B) of the connecting rod and the hemispherical inner surface of the upper frame (8) and the clearance C22 between the lower end (spherical body 2B) of the connecting rod and the hemispherical inner surface of the lower frame (7) are determined taking account of a severe thermal factor (thermal expansion) during a continuous press operation (see FIG 5B, for example). The clearance C21 is the same as the clearance C22. Specifically, an identical clearance is provided around the entire spherical body 2B.

[0017] When a press-forming load Pprs that occurs during press forming is received by the hemispherical inner surface of the lower frame (7) and the outer circumferential surface of the lower end (spherical body 2B) of the connecting rod that comes in contact with the hemispherical inner surface of the lower frame (7), and is transmitted to the connecting rod, the amount of backlash between the hemispherical inner surface of the upper frame (8) and the outer circumferential surface of the lower end (spherical body 2B) of the connecting rod is C2 (=C21+C22) (see FIG 5A). When a press-forming load Psrd that occurs during a period other than a press-forming periodis received by the hemispherical inner surface of the upper frame (8) and the outer circumferential surface of the lower end (spherical body 2B) of the connecting rod that comes in contact with the hemispherical inner surface of the upper frame (8), and is transmitted to the connecting rod, the clearance between the hemispherical inner surface of the lower frame (7) and the outer circumferential surface of the lower end (spherical body 2B) of the connecting rod is C2 (=C21+C22) (see FIG 5C).

[0018] The diameter of the sliding area in the second connection area is smaller than that of the first connection area. However, a sufficient amount of backlash is required for the second connection area. Specifically, the sliding speed of the sliding area due to the swing motion of the connecting rod is lower than the sliding speed of the sliding area in the first connection area due to rotation of the crank shaft. However, the heat capacity in the second connection area is lower than the heat capacity in the first connection area although the applied load is the same. The second connection area cannot be effectively cooled by forced lubricant circulation taking the structure into consideration. Therefore, since the temperature of the second connection area increases to a large extent, it is necessary to increase the amount of backlash (clearance) in the second connection area. The amount of backlash (C2) in the second connection point in which the lower end of the connecting rod always moves relative to the suspension mechanism is larger than the amount of backlash (C3) in the third connection point in which the suspension mechanism and the slide are normally in a stationary state relative to each other. Since the press-forming speed of an electronic part tends to be increased, and a continuous press operation over a long time tends to be employed, the amount of backlash (C2) must be further increased when employing the related-art structure.

[0019] Therefore, it is possible to significantly improve the precision of the entire slide device by reducing the amount of backlash (C2) in the second connection area by half. Moreover, since the precision of the entire slide device can be improved as compared with the above-described related art even if the amount of backlash (C3) in the third connection area is the same, it may be unnecessary to provide the hydraulic locking means. Since the die height can be adjusted during the press operation by omitting the hydraulic locking means, the press forming mode and the press machine operation mode can be expanded. Moreover, a reduction in cost can be achieved.

[0020] The invention relates to a unique modification that breaks a longstanding practice concerning a slide drive device, and separately and independently provides a mechanical structure in the second connection area that receives the press-forming load Pprs and the slide load Psrd in opposite directions and transmits them to the connecting rod.

[0021] According to one embodiment of the invention, there is provided a slide drive device that drives a slide while converting a rotational motion of a crank shaft into an upward/downward motion of the slide through a connecting rod and a suspension mechanism, characterized in that a lower end of the connecting rod is formed by a male curved-surface member having a male curved surface that is convex downward, and is provided with a horizontal pin member that is rotatably held by a circular member, a holding member is provided so that a lower side of the holding member is connected to a female curved-surface member having a female curved surface that is convex downward, and an upper side of the holding member can be fitted onto the circular member, the female curved surface and the male curved surface come in contact with each other during press forming so that a press-forming load is transmitted to the connecting rod through the female curved surface and the male curved surface, and the holding member and the circular member are held in a non-contact state, and the upper side of the holding member is suspended on the circular member during a period other than a press-forming period so that the female curved surface and the male curved surface are held in a non-contact state, and a slide load is transmitted to the connecting rod through the holding member, the circular member, and the horizontal pin member.

[0022] The slide drive device can implement a high-precision press operation due to a small amount of backlash.

[0023] In the slide drive device, the suspension mechanism may be provided to include the circular member, an externally threaded member that engages a slide-side internally threaded member, and the holding member, and suspend the slide, the lower side of the holding member being connected to the externally threaded member, and the female curved-surface member having the female curved surface that has a shape corresponding to a shape of the male curved surface and is convex downward may be disposed on an upper side of the externally threaded member.

[0024] The slide drive device can implement a high-precision press operation due to a small amount of backlash, can be easily produced, and can reduce cost.

[0025] In the slide drive device, a clearance between the female curved surface and the male curved surface in a non-contact state may be able to be adjusted by increasing or decreasing a space between a lower end face of the holding member and an upper end face of the externally threaded member by using a spacer.

[0026] The slide drive device allows an easy adjustment of the clearance between the female curved surface and the male curved surface, and can implement a high-precision operation by setting the minimum clearance.

[0027] In the slide drive device, the male curved-surface member and the horizontal pin member may form an integral structure in a state in which no space is formed between the male curved-surface member and the horizontal pin member.

[0028] In the slide drive device, the female curved-surface member and the externally threaded member may be able to be relatively rotated around a vertical axis line that passes through an imaginary center.

[0029] The slide drive device allows a smooth die height adjustment.

[0030] In the slide drive device, a shoulder positioned above the horizontal pin member provided at the lower end of the connecting rod may not come in contact with the holding member.

[0031] The slide drive device makes it possible to further reduce the production cost of the lower end of the connecting rod and the holding member.

[0032] In the slide drive device, a thrust-receiving guide may be provided between an upright outer circumferential surface of the holding member and a crown that receives the crank shaft.

[0033] The slide drive device can implement a smoother press operation.

[0034] In the slide drive device, the male curved-surface member having the male curved surface may be a male spherical member having a male spherical surface, and the female curved-surface member having the female curved surface may be a female spherical member having a female spherical surface.

[0035] The slide drive device can implement a high-precision press operation due to a small amount of backlash.

[0036] In the slide drive device, the male curved-surface member having the male curved surface may be a male cylindrical member having a male cylindrical outer surface, and the female curved-surface member having the female curved surface may be a female cylindrical member having a female cylindrical inner surface.

[0037] The slide drive device can implement a high-precision press operation due to a small amount of backlash.

[0038] Exemplary embodiments of the invention are described in detail below with reference to the drawings.

1. First embodiment

[0039] According to a first embodiment of the invention, a slide drive device illustrated in FIGS. 1 to 4B includes a male spherical member 37 having a male spherical surface 38, and a female spherical member 47 having a female spherical surface 48. The slide drive device is characterized in that a lower end 31 of a connecting rod 20 is formed by the male spherical member 37 having the male spherical surface 38 that is convex downward, and is provided with a horizontal pin member 45 that is rotatably held by a circular member 41, a holding member 51 is provided so that a lower side (lower end face 56) of the holding member 51 is directly or indirectly connected to a female spherical member 47 having a female spherical surface 48 that is convex downward (concave upward), and an upper side (inner surface 52I) of the holding member 51 is fitted onto the circular member 41, the female spherical surface 48 and the male spherical surface 38 come in contact with each other during press forming so that a press-forming load Pprs is transmitted to the connecting rod through the female spherical surface 48 and the male spherical surface 38, and the upper side of the holding member 51 is suspended on the circular member 41 during a period other than a press-forming period so that the female spherical surface 48 and the male spherical surface 38 are separated from each other, and a slide load Psrd is transmitted to the connecting rod through the circular member 41 and the horizontal pin member 45.

[0040] Note that the lower side (lower end face 56) of the holding member 51 and the female spherical member 47 (female spherical surface 48) are indirectly connected through an externally threaded member 62 (flange section 63).

[0041] Specifically, the lower end 31 of the connecting rod 20 is formed by the male spherical member 37 having the male spherical surface 38 that is convex downward and formed around an imaginary center Q illustrated in FIG 1, and is provided with the horizontal pin member 45 that is disposed around a horizontal axis line X2 that passes through the imaginary center Q, and extends in the direction of the horizontal axis line (X2), a suspension mechanism 40 is provided to include the circular member 41, the externally threaded member 62, and the holding member 51, and suspend a slide 90, the female spherical member 47 having the female spherical surface 48 that has a shape corresponding to the shape of the male spherical surface 38 and is convex downward (concave upward) is disposed on the upper side (66) of the externally threaded member 62, the female spherical surface 48 and the male spherical surface 38 are held in a contact state due to the press-forming load Pprs, and the holding member 51 (52I) and the circular member 41 (42) are held in a non-contact state during press forming, and the holding member 51 (inner surface 52I of a holding ceiling section 52) and the circular member 41 (outer circumferential surface 42) are held in a contact state due to the slide load Psrd, and the female spherical surface 48 and the male spherical surface 38 are held in a non-contact state during a period other than a press-forming period.

[0042] The slide drive device illustrated in FIGS. 1 and 2 is configured to drive the slide 90 while converting the rotational motion of a crank shaft 10 into the upward/downward motion of the slide 90 through the connecting rod 20 and the suspension mechanism 40.

[0043] The crank shaft 10 is rotatable around a horizontal axis line X1 by a motor (not shown) that is provided within a crown 1 that makes up the press main body. In this embodiment, the motor is a servomotor that can be changed in rotational speed and rotation direction. Therefore, the slide speed can be changed. Moreover, the slide 90 can be stopped at an arbitrary position in the direction of a vertical axis line Z, and the upward/downward motion of the slide 90 can be repeatedly changed within a preset position range. Development of a slide drive device that implements a high-precision operation due to a small amount of backlash has been desired in order to reliably utilize the characteristic functions of the servo press.

[0044] As illustrated in FIG 2, an upper end 21 of the connecting rod 20 includes upper and lower semicircular assembly structures (21U, 21D) that can be joined (separated) using a bolt 22, and is fitted into the crank shaft 10 (eccentric section 11). A clearance C1 between the upper end 21 and the crank shaft 10 (eccentric section 11) is the same as that of the above-described related art (e.g., 7/100 mm).

[0045] The vertical axis line Z orthogonally intersects the horizontal axis line X1. The vertical axis line Z extends in a direction Z. A horizontal axis line X2 is parallel to the horizontal axis line X1. An imaginary center Q is the intersection point of the vertical axis line Z and the horizontal axis line X2.

[0046] In FIG 1, the left section and the right section around the vertical axis line Z differ in cross-sectional position. Specifically, the left section illustrates a state viewed along an arrow A illustrated in FIG 3, and the right section illustrates a state viewed along an arrow B illustrated in FIG 3 (i.e., three locations at equal intervals of 120 degrees). Each left section and each right section are shifted by 60 degrees. Note that FIG 3 is taken along the line C-C in FIG 1.

[0047] The lower end 31 of the connecting rod 20 is formed by a spherical structure (spherical section 32), and part of the spherical structure is formed as the male spherical member 37 having the male spherical surface 38 that is convex downward. The female spherical surface 48 that is opposite to the male spherical surface 38 in the direction Z is formed on the upper side of the female spherical member 47. The female spherical surface 48 has a shape (concave upward (convex downward)) corresponding to the shape (convex shape) of the male spherical surface 38. The female spherical member 47 (female spherical surface 48) is disposed on (fitted into) the upper side (receiving section 66) of the externally threaded member 62.

[0048] The center of the spherical section 32 is the same as the imaginary center Q illustrated in FIG 1. Specifically, the male spherical surface 38 (i.e., part of the male spherical member 37) is formed around the imaginary center Q. The spherical section 32 includes a through-hole 35 that is formed around the horizontal axis line X2 that passes through the imaginary center Q. The horizontal pin member 45 has a columnar shape, and is fitted into the through-hole 35. Specifically, the horizontal pin member 45 is disposed around the horizontal axis line X2 that passes through the imaginary center Q, and extends in the direction of the horizontal axis line X2. The clearance between the inner circumferential surface of the through-hole 35 and the outer circumferential surface of the horizontal pin member 45 is zero (0). Specifically, the spherical section 32 (male spherical member 37) and the horizontal pin member 45 form an integral structure in a state in which a space is not formed between the spherical section 32 (male spherical member 37) and the horizontal pin member 45. Each side (right side and left side) of the spherical section 32 is cut at a position indicated by a dotted line taking account of the relationship with the horizontal pin member 45.

[0049] The male spherical member 37 (male spherical surface 38) is formed by the spherical part of the spherical structure (spherical section 32) that is positioned below the horizontal pin member 45. The spherical part (shoulder 33) of the spherical section 32 that is positioned above the horizontal pin member 45 is placed within a through-hole 53, and does not come in contact with the holding member 51 (holding ceiling section 52).

[0050] The clearance between the outer circumferential surface of the horizontal pin member 45 and the inner circumferential surface 43 of the circular member 41 is set so that relative rotation around the horizontal axis line X2 is not hindered. The clearance between the outer circumferential surface of the horizontal pin member 45 and the inner circumferential surface 43 is irrelevant to the amount of backlash in the second connection area.

[0051] The suspension mechanism 40 includes the circular member 41, the holding member 51, and a slide height adjustment section 61 (e.g., externally threaded member 62, internally threaded member 72, endless screw 81, and worm gear 82), and can suspend the slide 90. The slide height adjustment section 61 forms a die height adjustment mechanism.

[0052] The externally threaded member 62 illustrated in FIGS. 1 and 2 has a columnar structure, and includes the flange section 63 on the upper side. An external thread 67 provided on the outer circumferential surface of the lower side of the externally threaded member 62 engages the slide (90)-side internally threaded member 72 (internal thread 77). A receiving section 66 having a bottomed cylindrical shape is formed in the flange section 63 around the vertical axis line Z. The female spherical member 47 (female spherical surface 48) fitted into the receiving section 66 comes in contact with, or is separated from, the male spherical member 37 (male spherical surface 38) in the direction Z.

[0053] The spherical surface processing range (female spherical surface 48) on the upper side of the female spherical member 47 may be a relatively small range that allows the female spherical surface 48 to follow the rotation range of the male spherical surface 38 due to the swing motion of the connecting rod 20. Specifically, the female spherical member 47 (female spherical surface 48) can be easily and inexpensively produced with high surface machining accuracy as compared with the case of producing the lower frame (7) having a hemispherical inner surface disclosed in the above-described related art (JP-UM-A-61-31600).

[0054] Since the shoulder 33 need not receive the slide load Psrd, the holding member 51 can be formed to have a small and simple structure. Specifically, the holding member 51 can be easily and inexpensively produced with high surface machining accuracy as compared with the case of producing the upper frame (8) having a hemispherical inner surface disclosed in the above-described related art (JP-UM-A-61-31600). Moreover, the vertical dimension from the holding member 51 to the female spherical member 47 can be reduced as compared with the vertical dimension from the upper frame (8) to the lower frame (7) disclosed in the above-described related art (JP-UM-A-61-31600). This makes it possible to reduce the size and the weight of the suspension mechanism 40.

[0055] The female spherical member 47 is rotatable relative to the externally threaded member 62 around the vertical axis line Z that passes through the imaginary center Q. Specifically, the female spherical member 47 having a short columnar shape is rotatably fitted into the receiving section 66 having a bottomed cylindrical shape in a state in which a minimum clearance is provided. This reduces the load applied when adjusting the die height, so that the externally threaded member 62 can be smoothly rotated.

[0056] When the swing angle of the connecting rod 20 is small (i.e., the slide stroke is small), for example, the externally threaded member 62 and the female spherical member 47 may be integrally formed. In this case, the male spherical surface 38 and the female spherical surface 48 with a small swing (rotation) range are relatively rotated around the vertical axis line Z.

[0057] A first horizontal end face 64 and a second horizontal end face 65 are formed on the upper end face of the flange section 63. The first horizontal end face 64 is positioned opposite to the circular member 41 (outer circumferential surface 42), and the second horizontal end face 65 is positioned opposite to the lower side (lower end face 56) of the holding member 51.

[0058] The holding member 51 generally has a cylindrical shape. The through-hole 53 that allows the connecting rod 20 (lower end 31) to pass through in the direction Z is formed in the holding ceiling section 52. The lower end face 56 of a skirt section 54 can be placed on the flange section 63 (second horizontal end face 65). The holding member 51 and the externally threaded member 62 are integrally connected (secured) through a spacer 57 using a bolt 58.

[0059] As illustrated in FIGS. 1, 4A, and 4B, the inner surface 52I of the holding ceiling section 52 presses the circular member 41 (outer circumferential surface 42) downward. Specifically, the upper side (holding ceiling section 52 and inner surface 52I) of the holding member 51 can be suspended on the circular member 41, and the lower side (skirt section 54 (lower end face 56)) is connected to (secured on) the externally threaded member 62.

[0060] The lower side (lower end face 56) of the holding member 51 is functionally connected to the female spherical member 47 in the direction Z, and the upper side (inner surface 52I) of the holding member 51 can be fitted onto the circular member 41 (outer circumferential surface 42). Note that the externally threaded member 62 (flange section 63) and the female spherical member 47 may be integrally formed, and the lower side (lower end face 56) of the holding member 51 may be directly connected to the female spherical member 47.

[0061] The spacer 57 is used to adjust the clearance C2d (see FIG 4B) between the female spherical surface 48 and the male spherical surface 38 in a non-contact state by increasing or decreasing the space between the lower end face 56 of the holding member 51 (skirt section 54) and the upper end face (second horizontal end face 65) of the externally threaded member 62.

[0062] The slide (90)-side internally threaded member 72 is fitted onto the externally threaded member 62, and secured on the externally threaded member 62 upon engagement of the internal thread 77 and the external thread 67. The internally threaded member 72 can be moved in the direction Z relative to the externally threaded member 62 by rotating the externally threaded member 62. A plate 93 is secured on the internally threaded member 72 using a bolt 74. The slide 90 is secured on the plate 93 using a bolt 95. Specifically, the slide 90 can be moved in the direction Z relative to the connecting rod 20 (lower end 31) by rotating the externally threaded member 62.

[0063] The flange section 63 of the externally threaded member 62 and the worm gear 82 are connected through a cotter 84 (see FIGS. 1 and 3) so that the flange section 63 and the worm gear 82 can be rotated around the vertical axis line Z in synchronization. The cotter 84 is rotatably secured on the flange section 63 using a cotter pin 85 so that the cotter 84 can slide relative to the worm gear 82 in the vertical direction. Therefore, the height (i.e., die height) of the slide 90 can be adjusted by rotating an endless screw shaft 81S (endless screw 81) using an external motor (not shown).

[0064] The endless screw shaft 81S is rotatably attached to the inside (attachment section 6) of a worm case 5 (see FIG 1) through a ball bearing 83 (see FIG 3). As illustrated in FIG 2, the upper side of the worm case 5 is secured on the crown 1 using a bolt 15. A guide section 8 (seal section 9) is secured on the lower side of the worm case 5 using a bolt 7. The guide section 8 (seal section 9) guides the vertical movement of the internally threaded member 72.

[0065] A thrust-receiving guide 3 that slidably guides the skirt section 54 in the vertical direction, and receives a thrust force component when driving the slide is provided between an outer circumferential surface 55 (upright outer circumferential surface) of the holding member 51 (skirt section 54) and the crown 1 (opening (inner circumferential surface of the opening)) (see FIG 1). The thrust-receiving guide 3 is secured using a bolt 4.

[0066] As illustrated in FIG 4A that schematically illustrates a press-forming operation, when the slide 90 (externally threaded member 62)-side female spherical surface 48 comes in contact with the connecting rod (20)-side male spherical surface 38 (no clearance), the press-forming load Pprs can be transmitted to the connecting rod (20) through the female spherical surface 48 and the male spherical surface 38.

[0067] In this case, the holding ceiling section 52 (inner surface 52I) does not come in contact with the circular member 41 (outer circumferential surface 42) in the vertical direction, and the clearance C2u between the holding ceiling section 52 (inner surface 52I) and the circular member 41 (outer circumferential surface 42) is the same as the clearance C2d between the male spherical surface 38 and the female spherical surface 48 illustrated in FIG 4B.

[0068] In FIG 4A, the first horizontal end face 64 of the externally threaded member 62 (flange section 63) does not come in contact with the circular member 41 (outer circumferential surface 42). This prevents a situation in which the upward press-forming load Pprs applied to the externally threaded member 62 is directly applied to each end of the horizontal pin member 45 (i.e., is not applied to each end of the horizontal pin member 45 through the male spherical surface 38 and the female spherical surface 48). Therefore, the clearance C2ms between the first horizontal end face 64 and the outer circumferential surface 42 may be appropriately set to a small value (e.g., 2/100 mm or less) as long as the non-contact state can be maintained. This is because the press-forming accuracy is not directly affected by the clearance C2ms.

[0069] Specifically, the slide (90)-side female spherical surface 48 and the connecting rod (20)-side male spherical surface 38 can be held in a contact state, and the holding member 51 (inner surface 52I) and the circular member 41 (outer circumferential surface 42) can be held in a non-contact state. In this case, the first horizontal end face 64 of the externally threaded member 62 and the female spherical member 47 do not come in contact with the circular member 41 (42).

[0070] In FIG 4B that illustrates an operation during a period other than a press-forming period, the upper side (inner surface 52I of the holding ceiling section 52) of the holding member 51 and the circular member 41 (outer circumferential surface 42) can be held in a contact state, and the female spherical surface 48 and the male spherical surface 38 can be held in a non-contact state. In this case, the first horizontal end face 64 of the externally threaded member 62 and the female spherical member 47 do not come in contact with the circular member 41 (outer circumferential surface 42). The clearance C2ml is larger than the clearance C2ms illustrated in FIG 4A by the clearance C2u.

[0071] Specifically, the upper side (holding ceiling section 52) of the holding member 51 (the lower side (skirt section 54 (lower end face 56)) of the holding member 51 is connected to (secured on) the externally threaded member 62 (female spherical member 47)) is suspended on the circular member 41 so that the female spherical surface 48 and the male spherical surface 38 can be held in a non-contact state, and the slide load Psrd can be transmitted to the connecting rod (20) through the externally threaded member 62 (female spherical member 47), the holding member 51, the circular member 41, and the horizontal pin member 45.

[0072] In this case, the clearance C2d between the female spherical surface 48 and the male spherical surface 38 can be reduced to a value equal to or smaller than the clearance C21 (=C22) in the above-described related art (JP-UM-A-61-31600). Specifically, the upper and lower frames (8, 7) disclosed in the above-described related art form a closed space (closed structure). Moreover, the press-forming load Pprs and the slide load Psrd are applied alternately. This results in a large amount of thermal deformation (omnidirectional thermal expansion). This makes it necessary to provide the clearance C21 (C22) that is large and identical in each diametrical direction. The sum (C21+C22) of these clearances is the amount of backlash.

[0073] According to this embodiment, since the female spherical member 47 and the like form an open space (open structure), only a small amount of heat is generated, and the generated heat is quickly dissipated. Specifically, the amount of thermal expansion of the male spherical member 37 (and the female spherical member 47) can be reduced. Therefore, the clearance C2d can be reduced as compared with the above-described related art.

[0074] Moreover, the clearance C2d can be minimized using the spacer 57 within a range that is optimum for the press operation state (e.g., continuity, load, and press-forming speed) and ensures a stable operation. Specifically, the spacer 57 having an appropriate thickness is provided between the lower end face 56 of the skirt section 54 and the second horizontal end face 65 of the externally threaded member 62 (see FIGS. 4A and 4B), and the skirt section 54 and the flange section 63 are firmly joined using the bolt 58 illustrated in FIG 1.

[0075] According to the above-described related art, since a transition from the state illustrated in FIG 5A to the state illustrated in FIG 5C occurs when the load changes from the press-forming load Pprs to the slide load Psrd, a large amount of backlash (C21+C22) occurs. A large amount of backlash (C21+C22) also occurs when the load changes from the slide load Psrd to the press-forming load Pprs.

[0076] According to this embodiment, since a transition from the state illustrated in FIG 4A to the state illustrated in FIG 4B occurs when the load changes from the press-forming load Pprs to the slide load Psrd, the amount of backlash (C2u=C2d) is small. Since a transition from the state illustrated in FIG 4B to the state illustrated in FIG 4A occurs when the load changes from the slide load Psrd to the press-forming load Pprs, the amount of backlash (C2d=C2u) is also small.

[0077] Specifically, the amount of backlash (C2d) in the second connection area can be reduced at least by half (1/2) as compared with the above-described related art (C21+C22) due to the improvement (structural modification) that causes the slide load Psrd and the press-forming load Pprs to be applied to different positions.

[0078] It is thus possible to implement a press operation in which the total amount of backlash (accuracy (precision)) is reduced to a value equal to that of the above-described related art (that provides the hydraulic locking means) without providing the hydraulic locking means. It is also possible to deal with the demand for a frequent die height adjustment during the press operation since the hydraulic locking means that constrains the externally and internally threaded members is not provided. Specifically, high-quality products can be stably produced.

[0079] Note that the amount of backlash in the second connection area of the lower end of the connecting rod and the suspension mechanism can be significantly reduced (C2d=C2×1/2) as compared with the above-described related art (C2=C21+C22) by further providing the hydraulic locking means.

[0080] Since a change in the amount of backlash in the vertical direction can be reduced when frequently moving the slide 90 upward and downward, an impactless and smooth operation can be implemented. Moreover, vibrations can be reduced. The slide drive device is suitable for a servo press that implements a press operation that selectively achieves various slide motions.

[0081] Note that the clearance C2ml between the flange section 63 (first horizontal end face 64) and the circular member 41 (outer circumferential surface 42) after adjustment is the sum of the clearance (C2ms) illustrated in FIG 4A and the clearance C2d. In this case, since the holding ceiling section 52 (inner surface 52I) comes in contact with the circular member 41 (outer circumferential surface 42), the clearance C2u is zero.

[0082] The effects and the operation according to the first embodiment are described below.

1-1. Initial state

[0083] In an initial state in which the slide 90 is set at an initial position (e.g., top dead center), the holding member 51 (holding ceiling section 52) is supported by the horizontal pin member 45 (spherical section 32) through the circular member 41 (see FIG 4B). The clearance between the male spherical surface 38 and the female spherical surface 48 is C2d. The clearance C2ml between the circular member 41 (outer circumferential surface 42) and the first horizontal end face 64 is larger than the clearance C2d. Specifically, the slide load Psrd is transmitted to the connecting rod 20 (lower end 31) through the horizontal pin member 45.

1-2. Press operation

[0084] When the crank shaft 10 is rotated, the upper end 21 of the connecting rod 20 is rotated eccentrically around the horizontal axis line X1. The upper end 21 swings around the lower end 31 (spherical section 32). Specifically, the horizontal pin member 45 supported by each end of the circular member 41 rotates around the horizontal axis line X2. The lower end 31 (spherical section 32) moves in the vertical direction (Z) depending on the swing angle of the connecting rod 20. Since the thrust-receiving guide 3 is provided, the thrust force component due to the swing motion can be dispersed.

1-3. Downward movement of slide

[0085] The slide 90 descends toward the bottom dead center along with the swing motion of the connecting rod 20. In this case, the state illustrated in FIG 4B is maintained.

1-4. Press forming

[0086] When the slide 90 has reached a given position (e.g., a position near the bottom dead center), the upper die comes in contact with the workpiece placed in the lower die. Specifically, a press-forming motion (operation) occurs. Therefore, the press-forming load Pprs occurs. The press-forming load Pprs (upward reaction force) is transmitted to the slide 90, the plate 93, the internally threaded member 72, the externally threaded member 62, and the female spherical member 47 (see FIG 1) in this order. Therefore, the female spherical surface 48 changes from the state illustrated in FIG 4B to the state illustrated in FIG 4A, and comes in contact with the male spherical surface 38. The backlash (C2d) occurs when the female spherical surface 48 changes from the state illustrated in FIG 4B to the state illustrated in FIG 4A. Since the female spherical surface 48 comes in contact with the male spherical surface 38, the press-forming load Pprs is transmitted to the male spherical member 37 (spherical section 32), and transmitted to the connecting rod 20 (lower end 31). The press-forming load Pprs is eventually received by the crank shaft 10 as the press load. The clearance C2u between the holding ceiling section 52 (inner surface 52I) and the circular member 41 (outer circumferential surface 42) increases as illustrated in FIG 4A. The clearance C2u is the same as the clearance C2d illustrated in FIG 4B. However, since the holding member 51 and the circular member 41 (horizontal pin member 45) are not directly involved in transmission of the press-forming load Pprs, the clearance C2u does not serve as backlash that decreases the overall accuracy. Specifically, the amount of backlash is not the sum (C2d+C2u) of the clearances, differing from the above-described related art. Therefore, the amount of backlash in the second connection area is reduced by half (C2d).

1-5. Upward movement of slide

[0087] After completion of press forming, the slide 90 moves upward. Therefore, the slide load Psrd occurs instead of the press-forming load Pprs. The slide load Psrd (downward load) is transmitted to the slide 90, the plate 93, the internally threaded member 72, the externally threaded member 62, and the holding member 51 in this order. Therefore, the female spherical surface 48 changes from the state illustrated in FIG 4A to the state illustrated in FIG 4B. Specifically, the female spherical surface 48 moves downward (i.e., is separated from the male spherical surface 38). The clearance C2d increases, but does not serve as backlash. Specifically, the slide load Psrd (downward load) is applied to the holding member 51 through the second horizontal end face 65 of the externally threaded member 62 that is connected to the holding member 51. Since the holding member 51 moves downward, and comes in contact with the circular member 41 (outer circumferential surface 42), the slide load Psrd (downward load) is transmitted to the connecting rod 20 through the circular member 41, the horizontal pin member 45, and the spherical section 32. The clearance C2u between the holding member 51 (inner surface 52I) and the circular member 41 (outer circumferential surface 42) changes from the maximum value illustrated in FIG 4A to zero (0) (see FIG 4B). Since the clearance C2u is directly involved in transmission of the slide load Psrd (downward load), the clearance C2u serves as backlash.

However, since the female spherical surface 48 and the male spherical surface 38 in a non-contact state are not directly involved in transmission of the slide load Psrd, the clearance C2d does not serve as backlash.

1-6. Slide upward/downward inversion motion

[0088] A press operation that repeatedly moves the slide 90 upward and downward at a given position or within a given position range may be selected. In this case, the slide 90 is alternately moved upward and downward by changing the rotation direction of the crank shaft 10. Since the amount of backlash (C2d=C2u) in the second connection area is half of that (C21+C22) of the above-described related art, an impact and noise that occurs when changing the motion of the slide 90 are significantly reduced as compared with the above-described related art. This makes it possible to continuously implement a press operation that utilizes the characteristic functions of a servo press.

1-7. Relationship with third connection area

[0089] Since the amount of backlash (C2d=C2u) in the second connection area is half of that (C2) of the above-described related art, a product having a quality equal to or higher than that achieved by the above-described related art can be produced without providing the hydraulic locking means. This is because the amount of backlash (C2d) can be minimized by the space (gap) adjustment. Note that the hydraulic locking means may be provided. In this case, a product of higher quality can be produced since the accuracy can be significantly improved. Specifically, the slide drive device according to this embodiment has high adaptability with regard to the product quality as compared with the above-described related art.

1-8. Clearance adjustment

[0090] An accuracy optimum for specific operation conditions (e.g., operation time/period, product quality, press load, press speed, and surrounding environment) can be obtained by adjusting the clearance C2d by replacing the spacer 57 provided between the holding member 51 and the externally threaded member 62, for example.

1-9. Die height adjustment

[0091] When it is necessary to adjust the die height (i.e., take measures for achieving conditions suitable for the press operation, product form, quality, and the like), the worm gear 82 is rotated around the vertical axis line Z by rotating the endless screw 81 (81 S) (see FIGS. 1 and 3) by controlling an external motor. The internally threaded member 72 is moved in the vertical direction depending on the amount of rotation of the externally threaded member 62. This makes it possible to adjust the die height. Since the hydraulic locking means is not provided, the die height can be adjusted during the press operation. This makes it possible to minimize a variation in accuracy and quality of the product. Since the female spherical member 47 (female spherical surface 48) can be rotated around the vertical axis line Z, the die height can be adjusted smoothly and quickly.

1-10. Termination of press operation

[0092] When the crank shaft 10 is stopped, the connecting rod 20 (upper end 21) is not rotated eccentrically around the horizontal axis line X1. The swing motion of the connecting rod 20 around the lower end 31 (spherical section 32) stops. The rotation of the horizontal pin member 45 supported by each end of the circular member 41 around the horizontal axis line X2 also stops. The slide 90 is normally returned to the top dead center position (initial position) to terminate the press operation. The lower end 31 (spherical section 32) moves in the vertical direction (Z) depending on the swing angle of the connecting rod 20. The suspension mechanism 40 is held stationary in the state illustrated in FIG 4B.

[0093] Since the slide drive device is configured so that the female spherical surface 48 and the male spherical surface 38 come in contact with each other during press forming so that the press-forming load Pprs is transmitted to the connecting rod through the female spherical surface 48 and the male spherical surface 38, and the upper side of the holding member 51 is suspended on the circular member 41 during a period other than a press-forming period so that the female spherical surface 48 and the male spherical surface 38 are separated from each other, and the slide load Psrd is transmitted to the connecting rod through the circular member 41 and the horizontal pin member 45, a high-precision press operation can be implemented due to a small amount of backlash, and a high-quality pressed product can be produced.

[0094] Since the suspension mechanism 40 is provided to include the circular member 41, the externally threaded member 62, and the holding member 51, and suspend the slide 90, the female spherical member 47 having the female spherical surface 48 is disposed on the upper side (66) of the externally threaded member 62, the female spherical surface 48 and the male spherical surface 38 are held in a contact state due to the press-forming load Pprs, and the holding member 51 and the circular member 41 are held in a non-contact state during press forming, and the holding member 51 and the circular member 41 are held in a contact state due to the slide load Psrd, and the female spherical surface 48 and the male spherical surface 38 are held in a non-contact state during a period other than a press-forming period, a more reliable suspension function can be easily implemented at low cost.

[0095] Since the clearance C2d between the female spherical surface 48 and the male spherical surface 38 in a non-contact state can be adjusted by increasing or decreasing the space between the holding member 51 (56) and the externally threaded member 62 (64) using the spacer 57, the clearance between the female spherical surface and the male spherical surface can be easily adjusted. Therefore, the clearance can be minimized while facilitating handling. This makes it possible to produce a product of higher quality, and ensures high adaptability to the press operation, the press installation environment, and the product quality.

[0096] Since the male spherical member 37 and the horizontal pin member 45 form an integral structure (i.e., no space is formed between the male spherical member 37 and the horizontal pin member 45), undesired backlash can be eliminated, and the production cost of the connecting rod (20) can be reduced.

[0097] Since the female spherical member 47 and the externally threaded member 62 can be relatively rotated around the vertical axis line Z that passes through the imaginary center Q, the externally threaded member 62 can be rotated smoothly and accurately without affecting the lower end 31 (male spherical surface 38) of the connecting rod. Therefore, the die height can be adjusted smoothly.

[0098] Since the lower end 31 of the connecting rod is formed by a spherical structure (spherical section 32) including the male spherical member 37, and the shoulder 33 of the spherical structure positioned above the horizontal pin member 45 need not come in contact with the holding member 51, the production cost of the lower end of the connecting rod and the holding member 51 can be further reduced.

[0099] Since the thrust-receiving guide 3 is provided between the upright outer circumferential surface (55) of the holding member 51 and the crown 1, a smoother press operation can be implemented.

[0100] Since the weight of the entire device and the dimension of the device in the direction Z can be reduced by reducing the size and the weight of the main elements (37, 45, 51) of the suspension mechanism 40, a press machine that can continuously produce high-quality electronic parts and the like at high speed can be implemented so that it will come into wide use.

2. Second embodiment

[0101] According to a second embodiment of the invention, a slide drive device illustrated in FIGS. 6 to 9B includes a male cylindrical member 37Ta having a male cylindrical outer surface 38Ta (i.e., a male curved member having a male curved surface), and a female cylindrical member 47Ta having a female cylindrical inner surface 48Ta (i.e., a female curved member having a female curved surface). The slide drive device is characterized in that a lower end 31a of a connecting rod 20a is formed by the male cylindrical member 37Ta having the male cylindrical outer surface 38Ta that is convex downward, and is provided with a horizontal pin member 45a that is rotatably held by a circular member 41a, a holding member 51a is provided so that a lower side (lower end face 56a) of the holding member 51a is directly or indirectly connected to the female cylindrical member 47Ta having the female cylindrical inner surface 48Ta that is convex downward (concave upward), and an upper side (inner surface 52Ia) of the holding member 51a is fitted onto the circular member 41a, the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta come in contact with each other during press forming so that the press-forming load Pprs is transmitted to the connecting rod through the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta, and the upper side (holding ceiling section 52a) of the holding member 51a is suspended on the circular member 41a during a period other than a press-forming period so that the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta are separated from each other, and the slide load Psrd is transmitted to the connecting rod through the circular member 41a and the horizontal pin member 45a.

[0102] Note that the lower side (lower end face 5 6a) of the holding member 51a and the female cylindrical member 47Ta (female cylindrical inner surface 48Ta) are indirectly connected through an externally threaded member 62a (flange section 63a) and a holder 49a.

[0103] Specifically, the lower end 31a of the connecting rod 20a is formed by the male cylindrical member 37Ta having the male cylindrical outer surface 38Ta that is convex downward and formed around an imaginary center Qa illustrated in FIG 6, and is provided with the horizontal pin member 45a that is disposed around a horizontal axis line X2a, and extends in the direction of the horizontal axis line (X2a), a suspension mechanism 40a is provided to include the circular member 41a, the externally threaded member 62a, and the holding member 51a, and suspend a slide 90a, the female cylindrical member 47Ta having the female cylindrical inner surface 48Ta that has a shape corresponding to the shape of the male cylindrical outer surface 38Ta and is convex downward (concave upward) is disposed on the upper side (66a) of the externally threaded member 62a, the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta are held in a contact state due to the press-forming load Pprs, and the holding member 51a (52Ia) and the circular member 41a (42a) are held in a non-contact state during press forming, and the holding member 51a (inner surface 52Ia of a holding ceiling section 52a) and the circular member 41a (outer circumferential surface 42a) are held in a contact state due to the slide load Psrd, and the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta are held in a non-contact state during a period other than a press-forming period.

[0104] The slide drive device illustrated in FIGS. 6 and 7 is configured to drive the slide 90a while converting the rotational motion of a crank shaft 10a into the upward/downward motion of the slide 90a through the connecting rod 20a and the suspension mechanism 40a. The connecting rod 20a includes an upper end 21a, a rod section 25a, and the lower end 31a.

[0105] The crank shaft 10a is rotatable around a horizontal axis line X1a by a motor (not shown) that is provided within a crown 1a that makes up the press main body. The motor is a servomotor that can be changed in rotational speed and rotation direction. Therefore, the slide speed can be changed. Moreover, the slide 90a can be stopped at an arbitrary position in the direction of a vertical axis line Za, and the upward/downward motion of the slide 90a can be repeatedly changed within a preset position range. Development of a slide drive device that implements a high-precision operation due to a small amount of backlash has been desired in order to reliably utilize the characteristic functions of the servo press.

[0106] As illustrated in FIG 7, the upper end 21a of the connecting rod 20a includes upper and lower semicircular assembly structures (21Ua, 21Da) that can be joined (separated) using a bolt 22a, and is fitted into the crank shaft 10a (eccentric section 11a). A clearance C1a between the upper end 21a and the crank shaft 10a (eccentric section 11a (see FIG 6)) is the same as that of the above-described related art (e.g., 7/100 mm).

[0107] The vertical axis line Za orthogonally intersects the horizontal axis line X1a. The vertical axis line Za extends in a direction Za. The horizontal axis line X2a (see FIG 7) is parallel to the horizontal axis line X1a. The imaginary center Qa is the intersection point of the vertical axis line Za and the horizontal axis line X2a.

[0108] The cylindrical members according to this embodiment are described below in connection with the male cylindrical member 37Ta formed at the lower end 31a of the connecting rod 20a and the female cylindrical member 47Ta disposed on (fitted into) the upper side (receiving section 66a) of the externally threaded member 62a. The cylindrical member differs from the sphere (spherical member) disclosed in the above-described related art (JP-UM-A-61-31600, for example). The term "cylindrical member" used herein includes a cylindrical body and a cylindrical object obtained by removing part of the outer circumferential surface of a cylindrical body. Note that the term "cylindrical member" used herein excludes a polygonal columnar member that cannot achieve a smooth relative sliding motion along the inner surface or the outer surface.

[0109] The relative contact motion of a spherical body (outer circumferential surface) and a hollow spherical body (inner circumferential surface) that includes the spherical body is compared with the relative contact motion of a small cylindrical body (outer circumferential surface) and a large cylindrical body (inner circumferential surface) that includes the small cylindrical body from the viewpoint of the functions of the connecting rod 20a (lower end 31a). When using the spherical body, the contact state tends to become non-uniform, and the motion varies (changes) to a large extent. Moreover, it is difficult to increase the contact area. When using the cylindrical body, the contact area can be increased, the contact state can be easily made uniform, and the motion varies (changes) to only a small extent. Moreover, the cylindrical body has a reduced weight, can be easily processed, is inexpensive, and can be easily assembled accurately as compared with the spherical body.

[0110] Specifically, the slide drive device illustrated in FIGS. 6 and 7 is configured so that the mechanical structure in the second connection area that receives the press-forming load Pprs and the slide load Psrd in opposite directions and transmits them to the connecting rod is separately and independently provided, and it is possible to easily implement the device, quickly and easily perform assembly/accuracy work, and implement a high-precision press operation due to a small amount of backlash while significantly reducing cost by effectively utilizing the advantages of the cylindrical body over the spherical body (the above-described related art). Moreover, the size and the weight of the device can be reduced.

[0111] As illustrated in FIGS. 6 and 7, the lower end 31a of the connecting rod 20a is formed by a cylindrical body 32a. Specifically, the male cylindrical member 37Ta is formed by the cylindrical body 32a that is provided around the horizontal axis line X2a and extends in the direction of the horizontal axis line X2a, and part of the male cylindrical member 37Ta forms the male cylindrical outer surface 38Ta that is convex downward. As illustrated in FIG 9A, the cylindrical body 32a has a thick (t1a) hollow shape. The horizontal pin member 45a is inserted into a through-hole 35a. The male cylindrical outer surface 38Ta is a circular surface formed around the imaginary center Qa.

[0112] The male cylindrical member 37Ta may be formed by a cylindrical object (hatched area) obtained by cutting the circumferential surface area of the cylindrical body 32a at an angle $\theta 1a$. When the inner diameter, the outer diameter, and the length in the direction of the horizontal axis line X2a are fixed, the angle $\theta 1a$ may be determined taking account of the load applied to the male cylindrical member 37Ta. The angle $\theta 1a$ is preferably set to 180 degrees or more from the viewpoint of relative contact motion. It is advantageous to set the angle $\theta 1a$ to 360 degrees (cylindrical body 32a) from the viewpoint of strength and cost.

[0113] The female cylindrical inner surface 48Ta that is opposite to the male cylindrical outer surface 38Ta in the direction Z is formed on the upper side of the female cylindrical member 47Ta. The female cylindrical inner surface 48Ta has a shape (concave upward (convex downward)) corresponding to the shape (convex shape) of the male cylindrical outer surface 38Ta. The female cylindrical member 47Ta (female cylindrical inner surface 48Ta) is disposed on (fitted into) the upper side (receiving section 66a) of the externally threaded member 62a. The female cylindrical member 47Ta is provided through a holder 49a (see FIG 6).

[0114] The female cylindrical member 47Ta is formed by a halved cylindrical body 46a illustrated in FIG 9B. The female cylindrical member 47Ta (halved cylindrical body 46a) is provided around the horizontal axis line X2a, and extends in the direction of the horizontal axis line X2a. Part of the female cylindrical member 47Ta forms the female cylindrical inner surface 48Ta that is convex downward. The halved cylindrical body 46a has a thin (i.e., the thickness thereof is smaller than that of the cylindrical body 32a (t2a<tla)) hollow semi-cylindrical shape. The male cylindrical member 37Ta is inserted into the halved cylindrical body 46a. The female cylindrical inner surface 48Ta is a circular surface formed around the imaginary center Qa, and is opposite to the male cylindrical outer surface 38Ta.

[0115] The female cylindrical member 47Ta is formed by a cylindrical object (hatched area) obtained by cutting the circumferential surface area of the cylindrical body 32Ba at an angle θ2a (180 degrees). Note that the angle θ2a may be determined so that the male cylindrical outer surface 38Ta and the female cylindrical inner surface 48Ta can be always held in a contact state during the press operation. Specifically, the angle θ2a may be set to a value equal to or smaller than 180 degrees as long as the rotation range of the male cylindrical outer surface 38Ta along with the swing motion of the connecting rod 20a can be followed. The angle θ2a may be set to a value equal to or larger than 180 degrees when the swing angle of the connecting rod 20a is small. Note that it is advantageous to set the angle θ2a to 180 degrees (halved cylindrical body 46a) since processing/assembly is facilitated, and cost can be reduced.

[0116] The upper side of the female cylindrical member 47Ta (halved cylindrical body 46a) is secured on a holder 49a using a bolt 49Ba (see FIG 7). The inner circumferential surface of the holder 49a corresponds to the outer circumferential surface of the female cylindrical member 47Ta (halved cylindrical body 46a). The circular surface processing range of the holder 49a may be arbitrarily set as long as the female cylindrical member 47Ta can be stably held during the press operation.

[0117] As illustrated in FIG 6, the horizontal pin member 45a has a columnar shape, and is fitted into the through-hole 35a formed in the cylindrical body 32a. The horizontal pin member 45a is disposed around the horizontal axis line X2a that passes through the imaginary center Qa, and extends in the direction of the horizontal axis line X2a. The clearance between the inner circumferential surface of the through-hole 35a and the outer circumferential surface of the horizontal pin member 45a is zero (0). Specifically, the cylindrical body 32a (male cylindrical member 37Ta) and the horizontal pin member 45a form an integral structure in a state in which a space is not formed between the cylindrical body 32a (male cylindrical member 37Ta) and the horizontal pin member 45a. The amount of backlash is zero.

[0118] As illustrated in FIGS. 8A and 8B, the male cylindrical member 37Ta is positioned below the horizontal pin member 45a at the lower end 31a (cylindrical body 32a) of the connecting rod 20a. The area (shoulder 33a) positioned above the horizontal pin member 45a at the lower end 31a (cylindrical body 32a) is placed inside a through-hole 53a formed in the holding member 51a, and does not come in contact with the holding member 51a (holding ceiling section 52a).

[0119] The clearance between the outer circumferential surface of the horizontal pin member 45a and the inner circumferential surface 43a of the circular member 41a may be arbitrarily set as long as relative rotation around the horizontal axis line X2a is not hindered. This is because the clearance between the outer circumferential surface of the horizontal pin member 45a and the inner circumferential surface 43a of the circular member 41a is irrelevant to the amount of backlash in the second connection area.

[0120] The suspension mechanism 40a includes the circular member 41a, the holding member 51a, and a slide height adjustment section 61a (e.g., externally threaded member 62a, internally threaded member 72a, endless screw 81a, and worm gear 82a), and can suspend the slide 90a. The slide height adjustment section 61a forms a die height adjustment mechanism.

[0121] As illustrated in FIGS. 6 and 7, the externally threaded member 62a is a columnar structure that has the flange section 63a on the upper side thereof. An external thread 67a provided on the outer circumferential surface of the lower side of the externally threaded member 62a engages the slide (90a)-side internally threaded member 72a (internal thread 77a). The receiving section 66a that has a bottomed cylindrical shape and is formed around the vertical axis line Za is formed in the flange section 63a. The holder 49 is placed in the receiving section 66a, and the female cylindrical member 47Ta (female cylindrical inner surface 48Ta) is fitted into the holder 49a. The female cylindrical member 47Ta (female cylindrical inner surface 48Ta) comes in contact with (or is separated from) the lower area of the cylindrical body 32a (i.e., male cylindrical member 37Ta (male cylindrical outer surface 38Ta)) in the direction Za.

[0122] The circular surface processing range of the holder 49a may be set to a small value as long as the female cylindrical member 47Ta can be stably held during the press operation. It suffices that the circular surface of the holder 49a have a shape corresponding to the female cylindrical outer surface (back side of the female cylindrical inner surface 48Ta) of the female cylindrical member 47Ta. Therefore, the holder 49a can be easily and inexpensively produced with high surface machining accuracy as compared with the case of producing the lower frame (7a) having a hemispherical inner surface disclosed in the above-described related art (JP-UM-A-61-31600).

[0123] Since the shoulder 33a need not receive the slide load Psrd, the holding member 51a can be formed to have a small and simple structure. Specifically, the holding member 51a can be easily and inexpensively produced with high surface machining accuracy as compared with the case of producing the upper frame (8a) having a hemispherical inner surface disclosed in the above-described related art (JP-UM-A-61-31600). Moreover, the vertical dimension from the holding member 51a to the female spherical member 47Ta can be reduced as compared with the vertical dimension from the upper frame (8a) to the lower frame (7a) disclosed in the above-described related art (JP-UM-A-61-31600). This makes it possible to reduce the size and the weight of the suspension mechanism 40a.

[0124] The female cylindrical member 47Ta (holder 49a) is rotatable relative to the externally threaded member 62a around the vertical axis line Za that passes through the imaginary center Qa. Specifically, the holder 49a (female cylindrical member 47Ta) having a short columnar shape in the lower area in the direction Za is rotatably fitted into the receiving section 66a having a bottomed cylindrical shape in a state in which a minimum clearance is provided. This reduces the load applied when adjusting the die height, so that the externally threaded member 62a can be smoothly rotated.

[0125] A first horizontal end face 64a and a second horizontal end face 65a are formed on the upper end face of the flange section 63a. The first horizontal end face 64a is positioned opposite to the circular member 41a (outer circumferential surface 42a), and the second horizontal end face 65a is positioned opposite to the lower side (lower end face 56a) of the holding member 51a.

[0126] The holding member 51a generally has a cylindrical shape. The through-hole 53a that allows the connecting rod 20a (lower end 31a) to pass through in the direction Za is formed in the holding ceiling section 52a. The lower end face 56a of a skirt section 54a can be placed on the flange section 63a (second horizontal end face 65a). The holding member 51a and the externally threaded member 62a are integrally connected (secured) through a spacer 57a using a bolt 58a (see FIG 6).

[0127] As illustrated in FIGS. 6, 8A, and 8B, the inner surface 52Ia of the holding ceiling section 52a presses the circular member 41a (outer circumferential surface 42a) downward. Specifically, the upper side (holding ceiling section 52a and inner surface 52Ia) of the holding member 51a can be suspended on the circular member 41a, and the lower side (skirt section 54a (lower end face 56a)) is connected to (secured on) the externally threaded member 62a.

[0128] The lower side (lower end face 56a) of the holding member 51a is functionally connected to the female spherical member 47Ta in the direction Za, and the upper side (inner surface 52Ia) of the holding member 51a can be fitted onto the circular member 41a (outer circumferential surface 42a). Note that the externally threaded member 62a (flange section 63a) and the female cylindrical member 47Ta may be integrally formed, and the lower side (lower end face 56a) of the holding member 51a may be directly connected to the female cylindrical member 47Ta. Note that the clearance C2da (described below) can be easily adjusted by employing the above configuration.

[0129] Specifically, the spacer 57a is used to adjust the clearance C2da (see FIG 8B) between the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38 Ta in a non-contact state by increasing or decreasing the space between the lower end face 56a of the holding member 51a (skirt section 54a) and the upper end face (second horizontal end face 65a) of the externally threaded member 62a.

[0130] The slide (90a)-side internally threaded member 72a is fitted onto the externally threaded member 62a, and secured on the externally threaded member 62a upon engagement of the internal thread 77a and the external thread 67a. The internally threaded member 72a can be moved in the direction Za relative to the externally threaded member 62a by rotating the externally threaded member 62a. A plate 93a is secured on the internally threaded member 72a using a bolt 74a. The slide 90a is secured on the plate 93a using a bolt 95a. Specifically, the slide 90a can be moved in the direction Za relative to the connecting rod 20a (lower end 31a) by rotating the externally threaded member 62a.

[0131] The flange section 63a of the externally threaded member 62a and the worm gear 82a are connected through a cotter 84a (see FIG 7) so that the flange section 63a and the worm gear 82a can be rotated around the vertical axis line Za in synchronization. The cotter 84a is rotatably secured on the flange section 63a using a cotter pin 85a so that the cotter 84a can slide relative to the worm gear 82a in the vertical direction. Therefore, the height (i.e., die height) of the slide 90a can be adjusted by rotating an endless screw shaft 81Sa (endless screw 81a) using an external motor (not shown).

[0132] The endless screw shaft 81Sa is rotatably attached to the inside (attachment section 6a) of a worm case 5a (see FIG 6) through a ball bearing 83a (see FIG 6). As illustrated in FIG 7, the upper side of the worm case 5a is secured on the crown 1a using a bolt 15a. A guide section 8a (seal section 9a) is secured on the lower side of the worm case 5a using a bolt 7a. The guide section 8a (seal section 9a) guides the vertical movement of the internally threaded member 72a.

[0133] A thrust-receiving guide 3a that slidably guides the skirt section 54a in the vertical direction, and receives a thrust force component when driving the slide is provided between an outer circumferential surface 55a (upright outer circumferential surface) of the holding member 51a (skirt section 54a) and the crown 1a (opening 2a (inner circumferential surface of the opening)) (see FIG 6). The thrust-receiving guide 3a is secured using a bolt 4a.

[0134] As illustrated in FIG 8A that schematically illustrates a press-forming operation, when the slide 90a (externally threaded member 62a)-side female cylindrical inner surface 48Ta comes in contact with the connecting rod (20a)-side male cylindrical outer surface 38Ta (no clearance), the press-forming load Pprs can be transmitted to the connecting rod (20a) through the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta.

[0135] In this case, the holding ceiling section 52a (inner surface 52Ia) does not come in contact with the circular member 41a (outer circumferential surface 42a) in the vertical direction, and the clearance C2ua between the holding ceiling section 52a (inner surface 52Ia) and the circular member 41a (outer circumferential surface 42a) is the same as the clearance C2da between the male cylindrical outer surface 38Ta and the female cylindrical inner surface 48Ta illustrated in FIG 8B.

[0136] In FIG 8A, the first horizontal end face 64a of the externally threaded member 62a (flange section 63a) does not come in contact with the circular member 41a (outer circumferential surface 42a). This prevents a situation in which the upward press-forming load Pprs applied to the externally threaded member 62a is directly applied to each end of the horizontal pin member 45a (i.e., is not applied to each end of the horizontal pin member 45a through the male cylindrical outer surface 38Ta and the female cylindrical inner surface 48Ta). Therefore, the clearance C2msa between the first horizontal end face 64a and the outer circumferential surface 42a may be appropriately set to a small value (e.g., 2/100 mm or less) as long as the non-contact state can be maintained. This is because the press-forming accuracy is not directly affected by the clearance C2msa.

[0137] Specifically, the slide (90a)-side female cylindrical inner surface 48Ta and the connecting rod (20a)-side male cylindrical outer surface 38Ta can be held in a contact state, and the holding member 51a (inner surface 52Ia) and the circular member 41a (outer circumferential surface 42a) can be held in a non-contact state. In this case, the first horizontal end face 64a of the externally threaded member 62a and the female cylindrical member 47Ta do not come in contact with the circular member 41a (42a).

[0138] In FIG 8B that illustrates an operation during a period other than a press-forming period, the upper side (inner surface 52Ia of the holding ceiling section 52a) of the holding member 51a and the circular member 41a (outer circumferential surface 42a) can be held in a contact state, and the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta can be held in a non-contact state. In this case, the first horizontal end face 64a of the externally threaded member 62a and the female cylindrical member 47Ta do not come in contact with the circular member 41a (outer circumferential surface 42a). The clearance C2mla is larger than the clearance C2msa illustrated in FIG 8A by the clearance C2ua.

[0139] Specifically, the upper side (holding ceiling section 52a) of the holding member 51a (the lower side (skirt section 54a (lower end face 56a)) of the holding member 51a is connected to (secured on) the externally threaded member 62a (female cylindrical member 47Ta)) is suspended on the circular member 41a so that the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta can be held in a non-contact state, and the slide load Psrd can be transmitted to the connecting rod (20a) through the externally threaded member 62a (female cylindrical member 47Ta), the holding member 51a, the circular member 41a, and the horizontal pin member 45a.

[0140] In this case, the clearance C2da between the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta can be reduced to a value equal to or smaller than the clearance C21 (=C22) in the above-described related art (JP-UM-A-61-31600). Specifically, the upper and lower frames (8a, 7a) disclosed in the above-described related art form a closed space (closed structure). Moreover, the press-forming load Pprs and the slide load Psrd are applied alternately. This results in a large amount of thermal deformation (omnidirectional thermal expansion). This makes it necessary to provide the clearance C21 (C22) that is large and identical in each diametrical direction. The sum (C21+C22) of these clearances is the amount of backlash.

[0141] According to this embodiment, since the female cylindrical member 47Ta and the like form an open space (open structure), only a small amount of heat is generated, and the generated heat is quickly dissipated. Specifically, the amount of thermal expansion of the male cylindrical member 37Ta (and the female cylindrical member 47Ta) can be reduced. Therefore, the clearance C2da can be reduced as compared with the above-described related art.

[0142] Moreover, the clearance C2da can be minimized using the spacer 57a within a range that is optimum for the press operation state (e.g., continuity, load, and press-forming speed) and ensures a stable operation. Specifically, the spacer 57a having an appropriate thickness is provided between the lower end face 56a of the skirt section 54a and the second horizontal end face 65a of the externally threaded member 62a (see FIGS. 8A and 8B), and the skirt section 54a and the flange section 63a are firmly joined using the bolt 58a illustrated in FIG 6.

[0143] According to the above-described related art, since a transition from the state illustrated in FIG 5A to the state illustrated in FIG 5C occurs when the load changes from the press-forming load Pprs to the slide load Psrd, a large amount of backlash (C21+C22) occurs. A large amount of backlash (C21+C22) also occurs when the load changes from the slide load Psrd to the press-forming load Pprs.

[0144] According to this embodiment, since a transition from the state illustrated in FIG 8A to the state illustrated in FIG 8B occurs when the load changes from the press-forming load Pprs to the slide load Psrd, the amount of backlash (C2ua=C2da) is small. Since a transition from the state illustrated in FIG 8B to the state illustrated in FIG 8A occurs when the load changes from the slide load Psrd to the press-forming load Pprs, the amount of backlash (C2da=C2ua) is also small.

[0145] Specifically, the amount of backlash (C2da) in the second connection area can be reduced at least by half (1/2) as compared with the above-described related art (C21+C22) due to the improvement (structural modification) that causes the slide load Psrd and the press-forming load Pprs to be applied to different positions.

[0146] It is thus possible to implement a press operation in which the total amount of backlash (accuracy (precision)) is reduced to a value equal to that of the above-described related art (that provides the hydraulic locking means) without providing the hydraulic locking means. It is also possible to deal with the demand for a frequent die height adjustment during the press operation since the hydraulic locking means that constrains the externally and internally threaded members is not provided. Specifically, high-quality products can be stably produced.

[0147] Note that the amount of backlash in the second connection area of the lower end of the connecting rod and the suspension mechanism can be significantly reduced (C2da=C2×1/2) as compared with the above-described related art (C2=C21+C22) by further providing the hydraulic locking means.

[0148] Since a change in the amount of backlash in the vertical direction can be reduced when frequently moving the slide 90a upward and downward, an impactless and smooth operation can be implemented. Moreover, vibrations can be reduced. The slide drive device is suitable for a servo press that implements a press operation that selectively achieves various slide motions.

[0149] Note that the clearance C2mla between the flange section 63a (first horizontal end face 64a) and the circular member 41a (outer circumferential surface 42a) after adjustment is the sum of the clearance (C2msa) illustrated in FIG 8A and the clearance C2da. In this case, since the holding ceiling section 52a (inner surface 52Ia) comes in contact with the circular member 41a (outer circumferential surface 42a), the clearance C2ua is zero.

[0150] The effects and the operation according to the second embodiment are described below.

2-1. Initial state

[0151] In an initial state in which the slide 90a is set at an initial position (e.g., top dead center), the holding member 51a (holding ceiling section 52a) is supported by the horizontal pin member 45a (spherical section 32a) through the circular member 41a (see FIG 8B). The clearance between the male cylindrical outer surface 38Ta and the female cylindrical inner surface 48Ta is C2da. The clearance C2mla between the circular member 41a (outer circumferential surface 42a) and the first horizontal end face 64a is larger than the clearance C2da. Specifically, the slide load Psrd is transmitted to the connecting rod 20a (lower end 31a) through the horizontal pin member 45a.

2-2. Press operation

[0152] When the crank shaft 10a is rotated, the upper end 21a of the connecting rod 20a is rotated eccentrically around the horizontal axis line X1a. The rod section 25a (upper end 21a) swings around the lower end 31a (spherical section 32a). Specifically, the horizontal pin member 45a supported by each end of the circular member 41a rotates around the horizontal axis line X2a. The lower end 31a (spherical section 32a) moves in the vertical direction (Za) depending on the swing angle of the connecting rod 20a. Since the thrust-receiving guide 3a is provided, the thrust force component due to the swing motion can be dispersed.

2-3. Downward movement of slide

[0153] The slide 90a descends toward the bottom dead center along with the swing motion of the connecting rod 20a. In this case, the state illustrated in FIG 8B is maintained.

2-4. Press forming

[0154] When the slide 90a has reached a given position (e.g., a position near the bottom dead center), the upper die comes in contact with the workpiece placed in the lower die. Specifically, a press-forming motion (operation) occurs. Therefore, the press-forming load Pprs occurs. The press-forming load Pprs (upward reaction force) is transmitted to the slide 90a, the plate 93a, the internally threaded member 72a, the externally threaded member 62a, and the female cylindrical member 47Ta (see FIG 6) in this order. Therefore, the female cylindrical inner surface 48Ta changes from the state illustrated in FIG 8B to the state illustrated in FIG 8A, and comes in contact with the male cylindrical outer surface 38Ta. The backlash (C2da) occurs when the female cylindrical inner surface 48Ta changes from the state illustrated in FIG 8B to the state illustrated in FIG 8A. Since the female cylindrical inner surface 48Ta comes in contact with the male cylindrical outer surface 38Ta, the press-forming load Pprs is transmitted to the male cylindrical member 37Ta (cylindrical body 32a), and transmitted to the connecting rod 20a (lower end 31a). The press-forming load Pprs is eventually received by the crank shaft 10a as the press load. The clearance C2ua between the holding ceiling section 52a (inner surface 52Ia) and the circular member 41a (outer circumferential surface 42a) increases as illustrated in FIG 8A. The clearance C2ua is the same as the clearance C2da illustrated in FIG 8B. However, since the holding member 51a and the circular member 41a (horizontal pin member 45a) are not directly involved in transmission of the press-forming load Pprs, the clearance C2ua does not serve as backlash that decreases the overall accuracy. Specifically, the amount of backlash is not the sum (C2da+C2ua) of the clearances, differing from the above-described related art. Therefore, the amount of backlash in the second connection area is reduced by half (C2da).

2-5. Upward movement of slide

[0155] After completion of press forming, the slide 90a moves upward. Therefore, the slide load Psrd occurs instead of the press-forming load Pprs. The slide load Psrd (downward load) is transmitted to the slide 90a, the plate 93a, the internally threaded member 72a, the externally threaded member 62a, and the holding member 51a in this order. Therefore, the female cylindrical inner surface 48Ta changes (moves downward) from the state illustrated in FIG 8A to the state illustrated in FIG 8B. Specifically, the female cylindrical inner surface 48Ta moves downward, and is separated from the male cylindrical outer surface 38Ta. The clearance C2da increases, but does not serve as backlash. Specifically, the slide load Psrd (downward load) is applied to the holding member 51a through the second horizontal end face 65a of the externally threaded member 62a that is connected to the holding member 51a. Since the holding member 51a moves downward, and comes in contact with the circular member 41a (outer circumferential surface 42a), the slide load Psrd (downward load) is transmitted to the connecting rod 20a through the circular member 41a, the horizontal pin member 45a, and the lower end 31a (cylindrical section 32a). The clearance C2ua between the holding member 51a (inner surface 52Ia) and the circular member 41a (outer circumferential surface 42a) changes from the maximum value illustrated in FIG 8A to zero (0) (see FIG 8B). Since the clearance C2ua is directly involved in transmission of the slide load Psrd (downward load), the clearance C2ua serves as backlash. However, since the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta in a non-contact state are not directly involved in transmission of the slide load Psrd, the clearance C2da does not serve as backlash.

2-6. Slide upward/downward inversion motion

[0156] A press operation that repeatedly moves the slide 90a upward and downward at a given position or within a given position range may be selected. In this case, the slide 90a is alternately moved upward and downward by changing the rotation direction of the crank shaft 10a. Since the amount of backlash (C2da=C2ua) in the second connection area is half of that (C21+C22) of the above-described related art, an impact and noise that occurs when changing the motion of the slide 90a are significantly reduced as compared with the above-described related art. This makes it possible to continuously implement a press operation that utilizes the characteristic functions of a servo press.

2-7. Relationship with third connection area

[0157] Since the amount of backlash (C2da=C2ua) in the second connection area is half of that (C2) of the above-described related art, a product having a quality equal to or higher than that achieved by the above-described related art can be produced without providing the hydraulic locking means. This is because the amount of backlash (C2da) can be minimized by the space (gap) adjustment. Note that the hydraulic locking means may be provided. In this case, a product of higher quality can be produced since the accuracy can be significantly improved. Specifically, the slide drive device according to this embodiment has high adaptability with regard to the product quality as compared with the above-described related art.

2-8. Clearance adjustment

[0158] An accuracy optimum for specific operation conditions (e.g., operation time/period, product quality, press load, press speed, and surrounding environment) can be obtained by adjusting the clearance C2da by replacing the spacer 57a provided between the holding member 51a and the externally threaded member 62a, for example.

2-9. Die height adjustment

[0159] When it is necessary to adjust the die height (i.e., take measures for achieving conditions suitable for the press operation, product form, quality, and the like), the worm gear 82a is rotated around the vertical axis line Za by rotating the endless screw 81a (81Sa) (see FIGS. 6 and 7) by controlling an external motor. The internally threaded member 72a is moved in the vertical direction depending on the amount of rotation of the externally threaded member 62a. This makes it possible to adjust the die height. Since the hydraulic locking means is not provided, the die height can be adjusted during the press operation. This makes it possible to minimize a variation in accuracy and quality of the product. Since the female cylindrical member 47Ta (female cylindrical inner surface 48Ta) can be rotated around the vertical axis line Za, the die height can be adjusted smoothly and quickly.

2-10. Termination of press operation

[0160] When the crank shaft 10a is stopped, the connecting rod 20a (upper end 21a) is not rotated eccentrically around the horizontal axis line X1a. The swing motion of the connecting rod 20a around the lower end 31a (cylindrical section 32a) stops. The rotation of the horizontal pin member 45a supported by each end of the circular member 41a around the horizontal axis line X2a also stops. The slide 90a is normally returned to the top dead center position (initial position) to terminate the press operation. The lower end 31a (cylindrical section 32a) moves in the vertical direction (Za) depending on the swing angle of the connecting rod 20a. The suspension mechanism 40a is held stationary in the state illustrated in FIG 8B.

[0161] Since the slide drive device is configured so that the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta come in contact with each other during press forming so that the press-forming load Pprs is transmitted to the connecting rod through the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta, and the upper side of the holding member 51a is suspended on the circular member 41a during a period other than a press-forming period so that the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta are separated from each other, and the slide load Psrd is transmitted to the connecting rod through the circular member 41a and the horizontal pin member 45a, a high-precision press operation can be implemented due to a small amount of backlash, and a high-quality pressed product can be produced.

[0162] Since the suspension mechanism 40a is provided to include the circular member 41a, the externally threaded member 62a, and the holding member 51a, and suspend the slide 90a, the female cylindrical member 47Ta (female cylindrical inner surface 48Ta) disposed on the upper side (66a) of the externally threaded member 62a, the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta are held in a contact state due to the press-forming load Pprs, and the holding member 51a and the circular member 41a are held in a non-contact state during press forming, and the holding member 51a and the circular member 41a are held in a contact state due to the slide load Psrd, and the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta are held in a non-contact state during a period other than a press-forming period, a more reliable suspension function can be easily implemented at low cost.

[0163] Since the male cylindrical member 37Ta is formed by the cylindrical body 32a (part of the cylindrical body 32a), and the female cylindrical member 47Ta is formed by the halved cylindrical body 46a, the production cost can be significantly reduced, and assembly/accuracy work can be quickly and easily performed. Moreover, the size and the weight of the device can be reduced.

[0164] Since the clearance C2da between the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta in a non-contact state can be adjusted by increasing or decreasing the space between the holding member 51a (56a) and the externally threaded member 62a (64a) using the spacer 57a, the clearance between the female cylindrical inner surface 48Ta and the male cylindrical outer surface 38Ta can be easily adjusted. Therefore, the clearance can be minimized while facilitating handling. This makes it possible to produce a product of higher quality, and ensures high adaptability to the press operation, the press installation environment, and the product quality.

[0165] Since the male cylindrical member 37Ta and the horizontal pin member 45a form an integral structure (i.e., no space is formed between the male cylindrical member 37Ta and the horizontal pin member 45a), undesired backlash can be eliminated, and the production cost of the connecting rod (20a) can be reduced.

[0166] Since the female cylindrical member 47Ta and the externally threaded member 62a can be relatively rotated around the vertical axis line Za that passes through the imaginary center Qa, the externally threaded member 62a can be rotated smoothly and accurately without affecting the lower end 31a (male cylindrical outer surface 38Ta) of the connecting rod. Therefore, the die height can be adjusted smoothly.

[0167] Since the shoulder 33a positioned above the horizontal pin member 45a at the lower end 31a of the connecting rod 20a does not come in contact with the holding member 51a, the production cost of the lower end 31a of the connecting rod and the holding member 51a can be further reduced.

[0168] Since the thrust-receiving guide 3a is provided between the upright outer circumferential surface (55a) of the holding member 51a and the crown 1a, a smoother press operation can be implemented.

[0169] Moreover, since the weight of the entire device and the dimension of the device in the direction Za can be reduced by reducing the size and the weight of the main elements (37Ta, 45a, 51a) of the suspension mechanism 40a, a press machine that can continuously produce high-quality electronic parts and the like at high speed can be implemented so that it will come into wide use.

[0170] It is explicitly stated that all features disclosed in the description and/or the claims are intended to be disclosed separately and independently from each other for the purpose of original disclosure as well as for the purpose of restricting the claimed invention independent of the composition of the features in the embodiments and/or the claims. It is explicitly stated that all value ranges or indications of groups of entities disclose every possible intermediate value or intermediate entity for the purpose of original disclosure as well as for the purpose of restricting the claimed invention, in particular as limits of value ranges.

Claims

1. A slide drive device that drives a slide (90, 90a) while converting a rotational motion of a crank shaft (10, 10a) into an upward/downward motion of the slide (90, 90a) through a connecting rod (20, 20a) and a suspension mechanism (40, 40a), **characterized in that** a lower end (31, 31a) of the connecting rod (20, 20a) is formed by a male curved-surface member (37, 37Ta) having a male curved surface (38, 38Ta) that is convex downward, and is provided with a horizontal pin member (45, 45a) that is rotatably held by a circular member (41, 41a), a holding member (51, 51a) is provided so that a lower side (56, 56a) of the holding member (51, 51a) is connected to a female curved-surface member (47, 47Ta) having a female curved surface (48, 48Ta) that is convex downward, and an upper side (52, 52a) of the holding member (51, 51a) can be fitted onto the circular member (41, 41a), the female curved surface (48,

48Ta) and the male curved surface (38, 38Ta) come in contact with each other during press forming so that a press-forming load (Pprs) is transmitted to the connecting rod (20, 20a) through the female curved surface (48, 48Ta) and the male curved surface (38, 38Ta), and the holding member (51, 51a) and the circular member (41, 41a) are held in a non-contact state, and the upper side (52, 52a) of the holding member (51, 51a) is suspended on the circular member (41, 41a) during a period other than a press-forming period so that the female curved surface (48, 48Ta) and the male curved surface (38, 38Ta) are held in a non-contact state, and a slide load (Psrd) is transmitted to the connecting rod (20, 20a) through the holding member (51, 51a), the circular member (41, 41a), and the horizontal pin member (45, 45a).

2. The slide drive device according to claim 1, wherein the suspension mechanism (40, 40a) is provided to include the circular member (41, 41a), an externally threaded member (62, 62a) that engages a slide-side internally threaded member (72, 72a), and the holding member (51, 51a), and suspend the slide (90, 90a), the lower side (56, 56a) of the holding member (51, 51a) being connected to the externally threaded member (62, 62a), and the female curved-surface member (47, 47Ta) having the female curved surface (48, 48Ta) that has a shape corresponding to a shape of the male curved surface (38, 38Ta) and is convex downward is disposed on an upper side of the externally threaded member (62, 62a).

3. The slide drive device according to claim 2, wherein a clearance (C2d, C2da) between the female curved surface (48, 48Ta) and the male curved surface (38, 38Ta) in a non-contact state can be adjusted by increasing or decreasing a space between a lower end face (56, 56a) of the holding member (51, 51a) and an upper end face of the externally threaded member (62, 62a) by using a spacer (57, 57a).

4. The slide drive device according to any one of claims 1 to 3, wherein the male curved-surface member (37, 37Ta) and the horizontal pin member (45, 45a) form an integral structure in a state in which no space is formed between the male curved-surface member (37, 37Ta) and the horizontal pin member (45, 45a).

5. The slide drive device according to any one of claims 2 to 4, wherein the female curved-surface member (47, 47Ta) and the externally threaded member (62, 62a) can be relatively rotated around a vertical axis (Z, Za) line that passes through an imaginary center (Q, Qa).

6. The slide drive device according to any one of claims 1 to 5, wherein a shoulder (33, 33a) positioned above the horizontal pin member (45, 45a) provided at the lower end (31, 31a) of the connecting rod (20, 20a) does not come in contact with the holding member (51, 51a).

7. The slide drive device according to any one of claims 1 to 6, wherein a thrust-receiving guide (3, 3a) is provided between an upright outer circumferential surface of the holding member (51, 51a) and a crown (1, 1a) that receives the crank shaft.

8. The slide drive device according to any one of claims 1 to 7, wherein the male curved-surface member (37, 37Ta) having the male curved surface (38, 38Ta) is a male spherical member having a male spherical surface, and the female curved-surface member (47, 47Ta) having the female curved surface (48, 48Ta) is a female spherical member having a female spherical surface.

9. The slide drive device according to any one of claims 1 to 7, wherein the male curved-surface member (37, 37Ta) having the male curved surface (38, 38Ta) is a male cylindrical member having a male cylindrical outer surface, and the female curved-surface member (47, 47Ta) having the female curved surface (48, 48Ta) is a female cylindrical member having a female cylindrical inner surface.

FIG.1

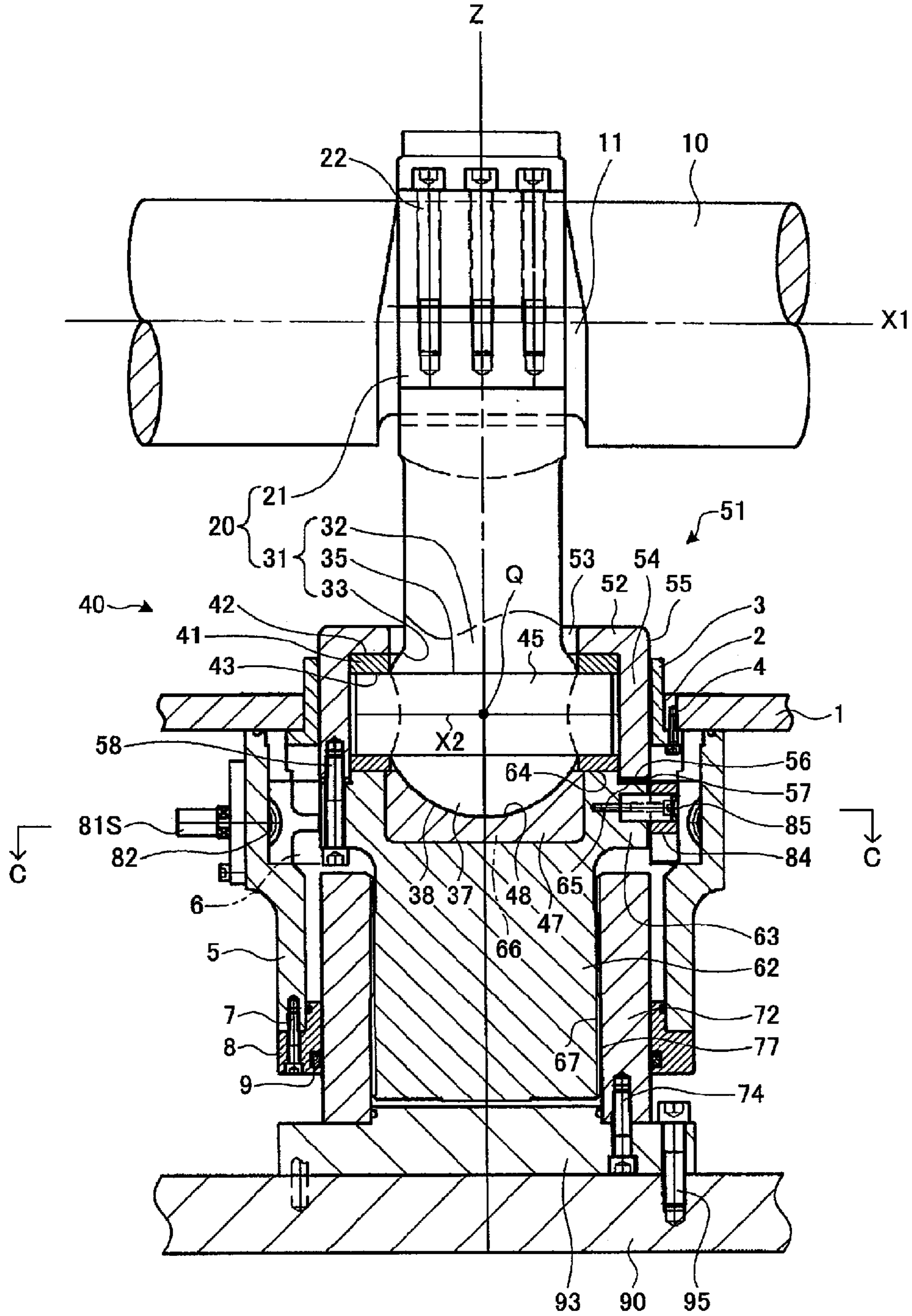

Z
22
11
10
X1
21
20
31
32
35
33
51
53
54
52
55
Q
40
42
41
43
45
3
2
4
1
X2
58
56
64
57
81S
85
C
C
82
84
38
37
48
65
6
47
66
5
63
62
7
72
8
77
67
9
74
93
90
95

FIG.2

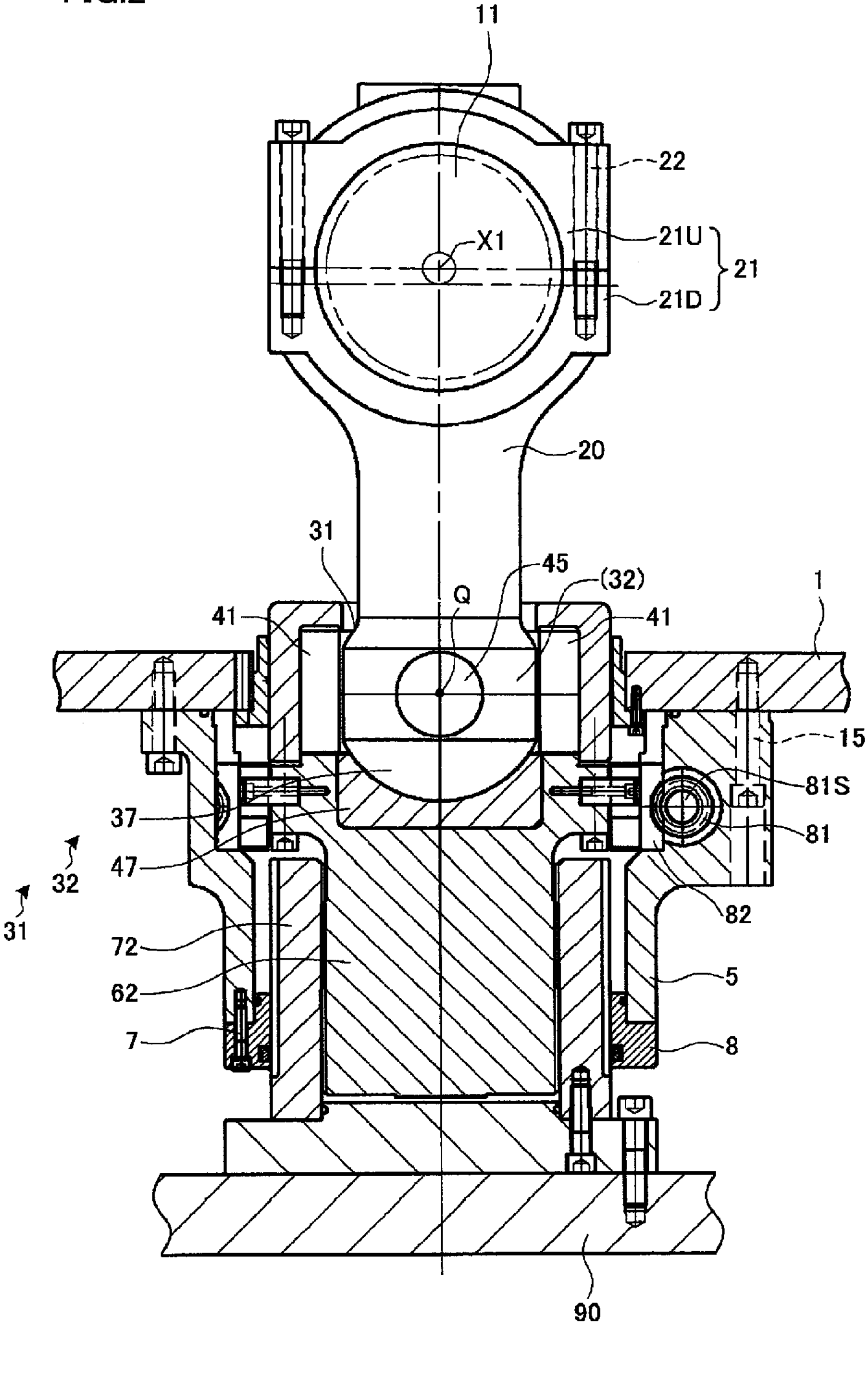

11
22
X1
21U
21
21D
20
31
45
(32)
Q
1
41
41
15
81S
37
81
32
47
31
82
72
5
62
7
8
90

FIG.3

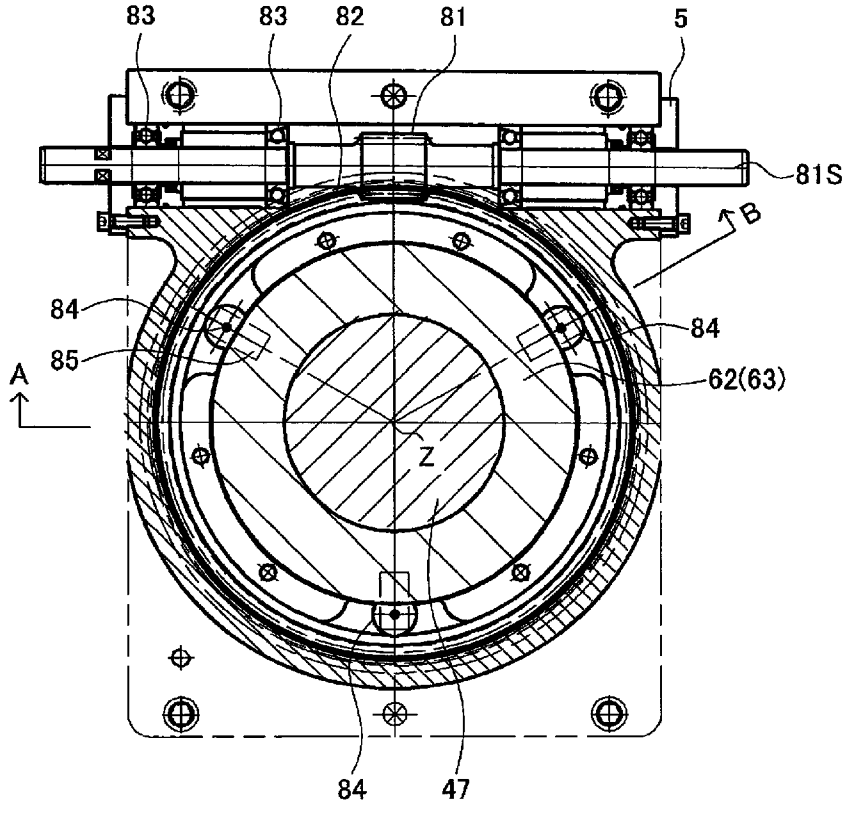
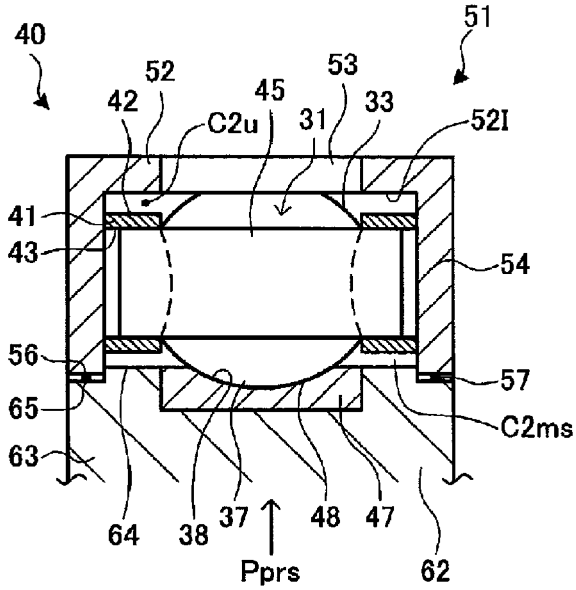


FIG.4A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52
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42
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33
C2u
31
52I
41
43
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C2ms
63
64
38
37
48
47
Pprs
62

FIG.4B

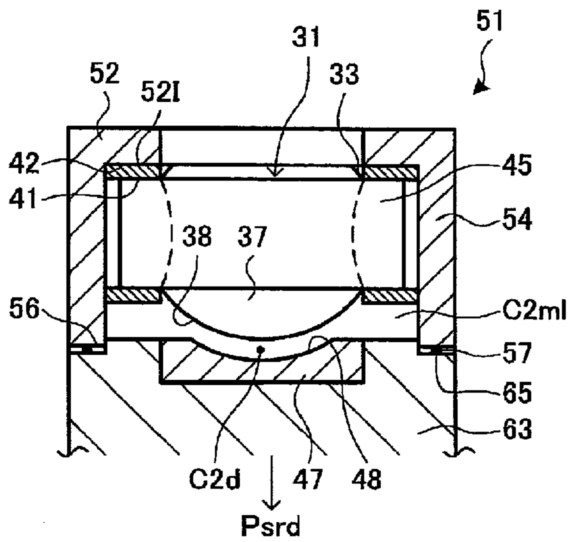


FIG.5A

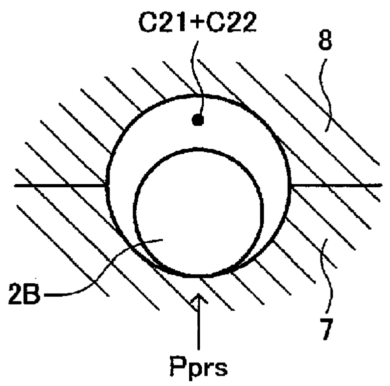


FIG.5B

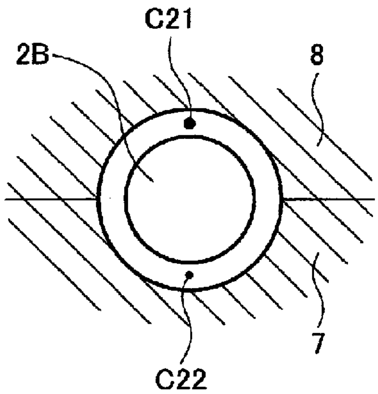


FIG.5C

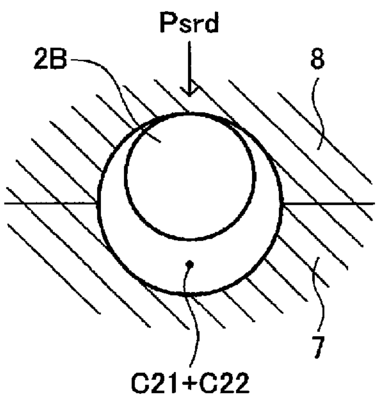
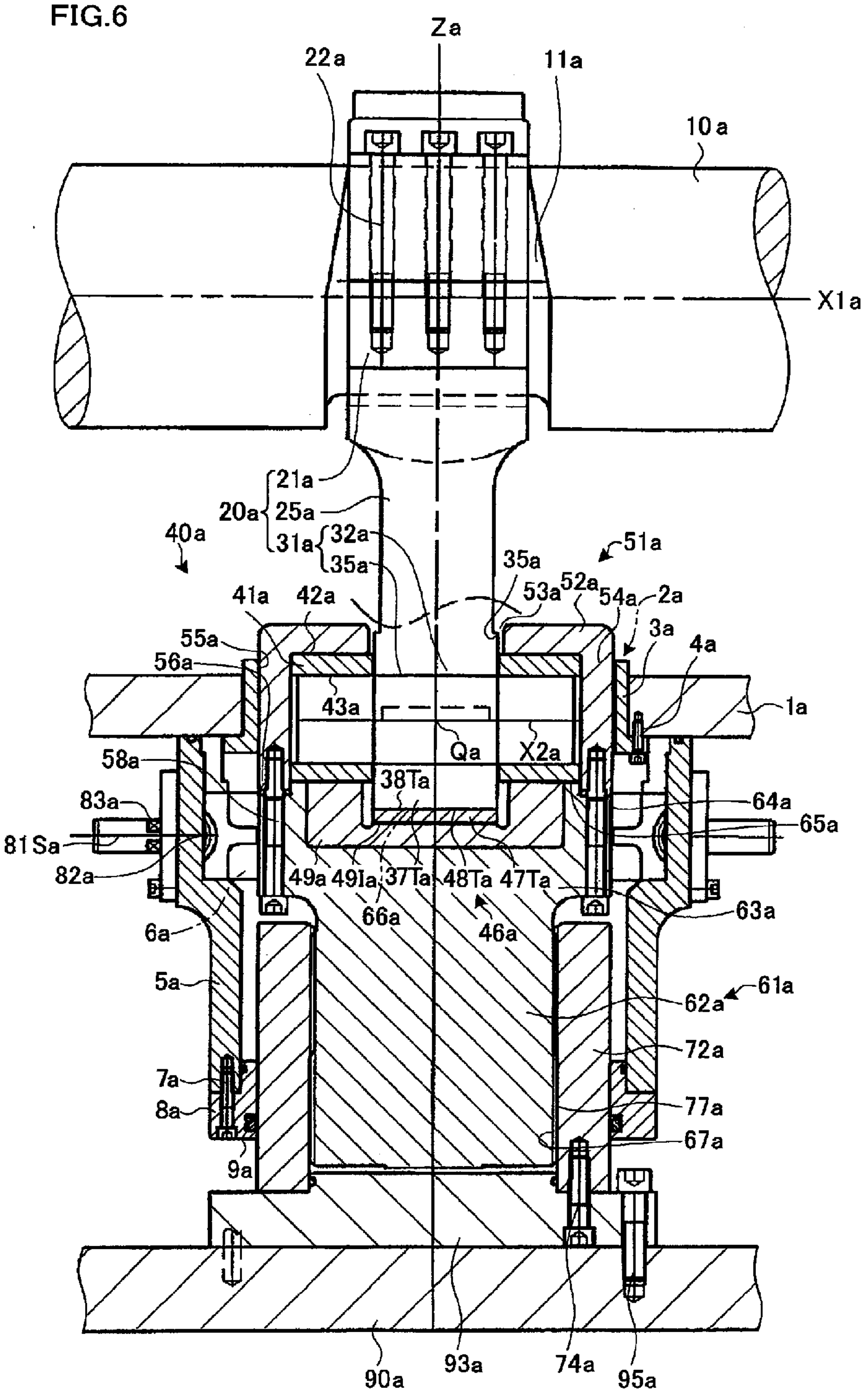


FIG.6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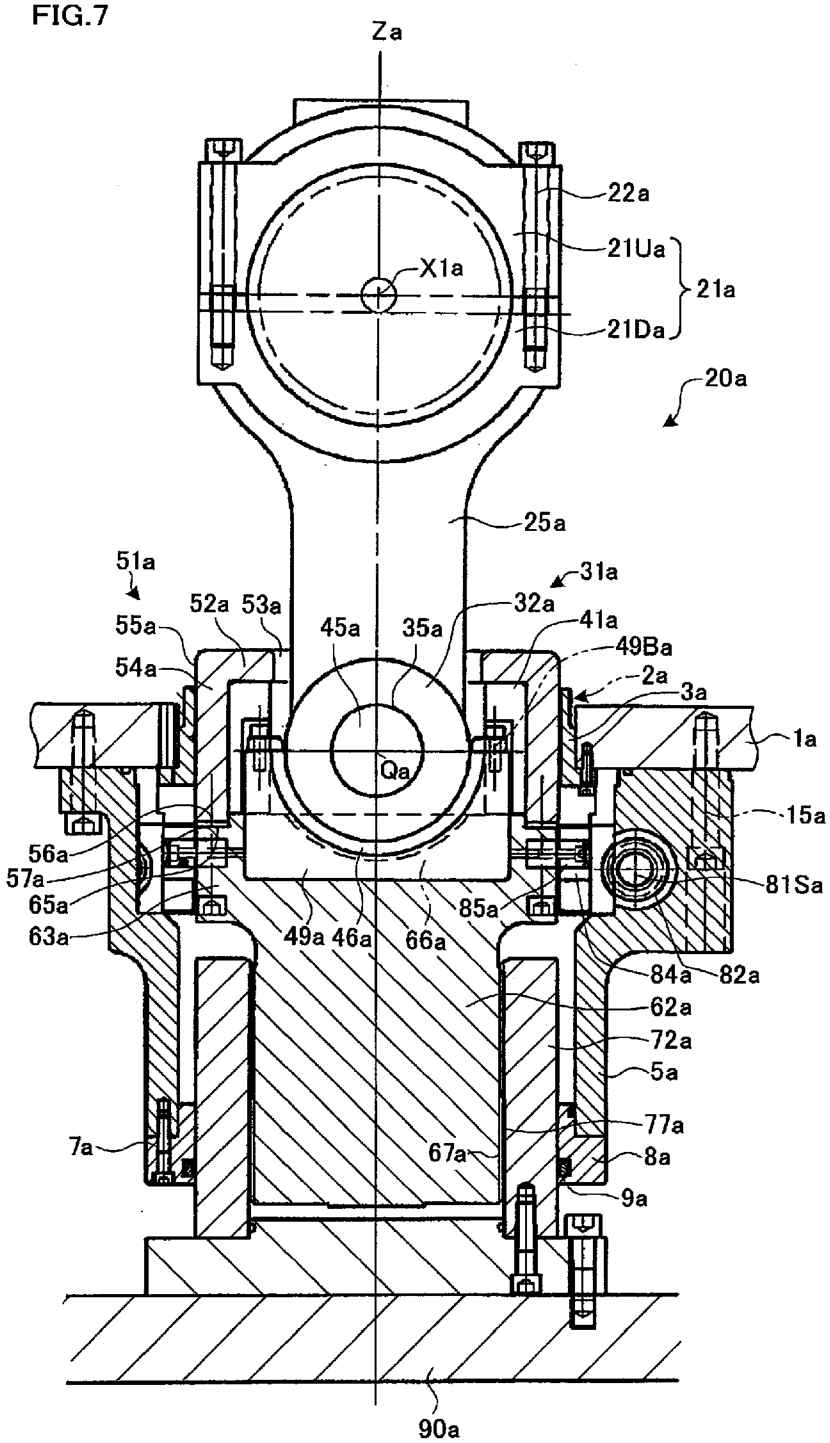
53a
52a
54a
2a
3a
55a
4a
56a
1a
43a
Qa
X2a
58a
38Ta
64a
83a
65a
81Sa
82a
49a
49Ia
37Ta
48Ta
47Ta
66a
46a
63a
6a
5a
62a
61a
72a
7a
77a
8a
67a
9a
90a
93a
74a
95a

FIG.7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53a
32a
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45a
35a
41a
49Ba
54a
2a
3a
1a
Qa
15a
56a
57a
81Sa
65a
85a
63a
49a
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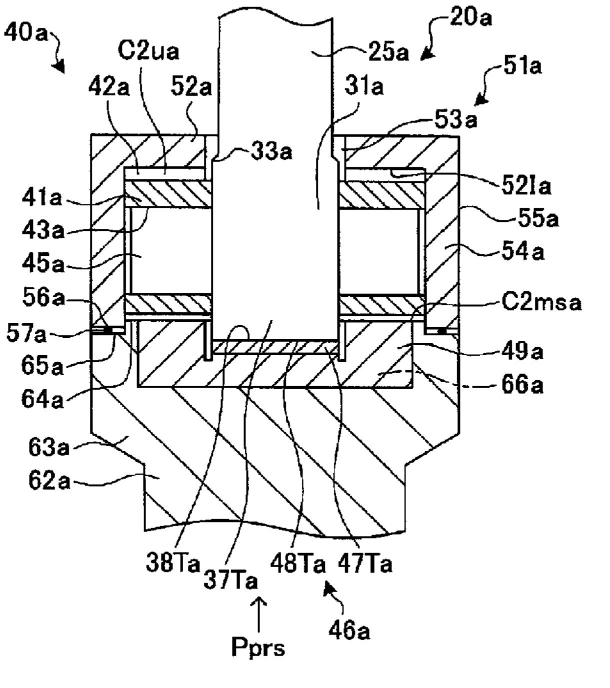
66a
84a
82a
62a
72a
5a
77a
7a
67a
8a
9a
90a

FIG.8A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43a
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56a
57a
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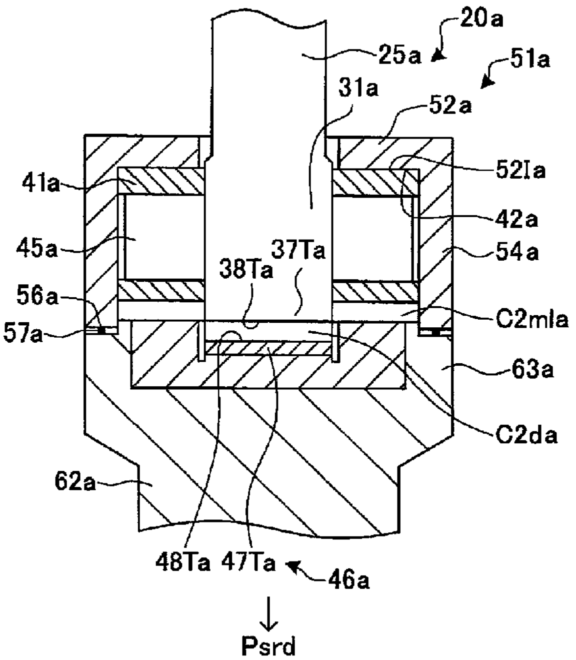
64a
63a
62a
52Ia
55a
54a
C2msa
49a
66a
38Ta
37Ta
48Ta
47Ta
Pprs
46a

FIG.8B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51a
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52Ia
41a
42a
45a
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38Ta
56a
C2mla
57a
63a
C2da
62a
48Ta
47Ta
46a
Psrd

FIG.9A

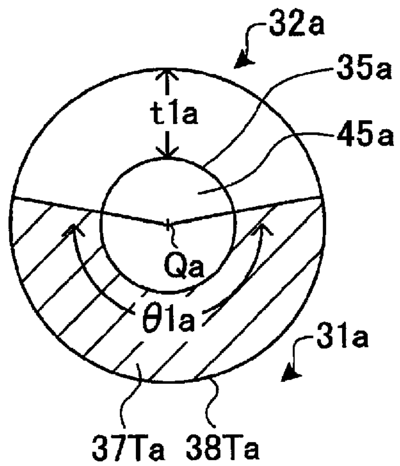
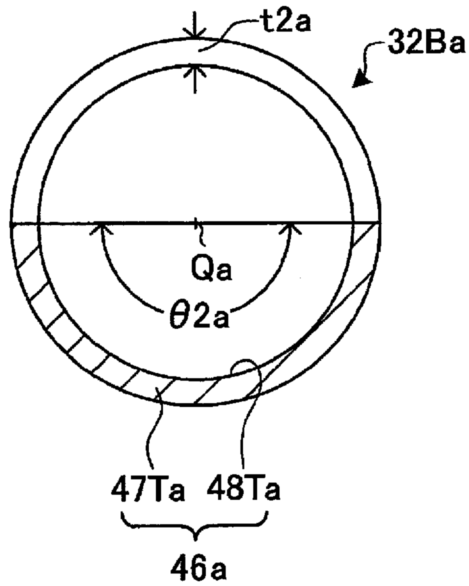


FIG.9B



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- JP 61031600 A **[0003] [0007] [0010] [0072] [0140]**
- JP 5070800 A **[0007] [0010]**