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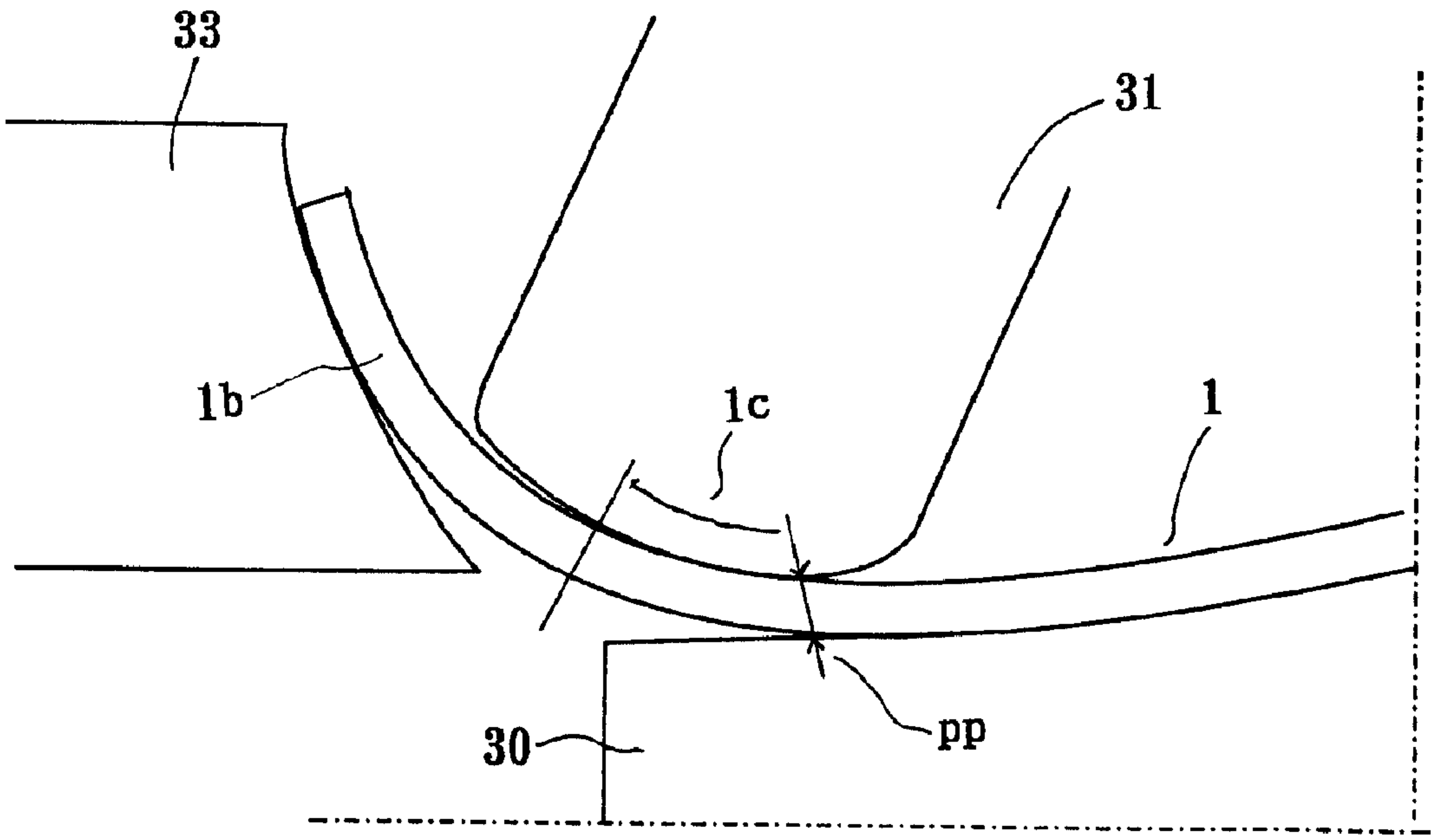


(57) Abrégé/Abstract:
It is an object of the present invention to provide a novel roll-forming method for steel pipes and equipment for same with which (1) the evidence that forming work in the FF forming method is mainly carried out at the cluster forming portion showing the poor formability is modified and improved without any deteriorating the advantage of the common-utilization of rolls in the FF forming method which employs basically the circular-bend method, and (2) the forming function at the breakdown forming portion is enhanced. Accordingly, the pinch-point formed by the upper and lower rolls is set at a boundary area between the target forming zone in the material's width direction and previously-formed zone or un-formed zone. The target forming zone is wound around a certain caliber of the upper roll on the bend-inner side, and bend-formed in such a way that the target forming zone is almost in non-contact with the lower roll. As a result, the formability is remarkably improved and occurrences of roll flaws and roll marks or buckling can be prevented.

ABSTRACT OF THE DISCLOSURE

It is an object of the present invention to provide a novel roll-forming method for steel pipes and equipment for same with which (1) the evidence that forming work in the FF forming method is mainly carried out at the cluster forming portion showing the poor formability is modified and improved without any deteriorating the advantage of the common-utilization of rolls in the FF forming method which employs basically the circular–bend method, and (2) the forming function at the breakdown forming portion is enhanced. Accordingly, the pinch-point formed by the upper and lower rolls is set at a boundary area between the target forming zone in the material's width direction and previously-formed zone or un-formed zone. The target forming zone is wound around a certain caliber of the upper roll on the bend-inner side, and bend-formed in such a way that the target forming zone is almost in non-contact with the lower roll. As a result, the formability is remarkably improved and occurrences of roll flaws and roll marks or buckling can be prevented.

METHOD FOR ROLL FORMING STEEL PIPES, AND EQUIPMENT FOR SAME

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a roll forming method for welded steel pipes; with said method the common-utilization of rolls can be realized regardless of the wide variation in dimensions of materials to be formed. The present invention, more specially, relates directly to a novel roll forming method for welded steel pipes by setting the pinch-point (which is a specified location for holding the material to be formed with upper and lower rolls) at the boundary area between the target forming zone and formed or un-formed zone along the width direction of the material, and by making said target forming zone in contact with the pre-determined caliber of the upper roll which is placed on the bend-inner side but not making the bend-outer side of the target forming zone in contact with the lower roll to perform the bend forming process, so that the bend-formability can be remarkably improved, roll-flaws or roll-scratches can be avoided, and accordingly the common-utilization of rolls can be realized at the break-down forming portion for the edge-bend method.

Description of the prior arts:

In roll forming of welded steel pipes, a required cross sectional profile will be made by bending the band steel subsequently in the material's width direction using forming rolls. At the breakdown forming portion which indicates the early stage of roll-forming process, the material to be formed (which is the band steel plate) is, in advance, formed into a semi-circular shape. The thus pre-formed material is then processed through the cluster forming and the fin-pass portion, where the material is formed into an open-shape circular cross-sectional profile.

At the aforementioned breakdown forming portion, mainly two types of forming methods are employed such as the roll-flowers as seen in Figure 1. With the edge-bend method, the material to be formed is divided into several portions along the width direction and is formed portion by portion to approach the final circular shape. (In the followings, the bend-inner side is referred to the position above the steel plate; while the bend-outer side is referred to the position below the steel plate.) On the other hand, in the circular-bend method, the curvature of the total width of the material is increased stepwise.

In each of the methods described in the above, one pair of upper and lower contour rolls is normally used in the conventional breakdown forming stand, as seen in Figure 2A. For example, the pair of rolls consists of a lower roll 2 with concave roll surface(caliber) and an upper roll 3 with convex caliber. The target forming zone of the material 1 to be formed(in other words, both sides of bend-inner and bend-outer sides of the material) is pressed in the pre-set roll gap.

When using such conventional forming methods, it is required to pre-set the uniform roll-gap which is equivalent to the wall thickness of the band steel plate in order to provide the pre-determined radius of curvature to the material (which is the band steel plate). This forming method possesses following practical drawbacks.

As there are unavoidable variations in the plate thickness, and the material is also subjected to the variation in thickness during the deformation, even if the uniform roll gaps being equivalent to the plate thickness are pre-set, the roll surface and the band steel plate surface will not be perfectly in contact. They will rather be in contact in a discontinuous manner. Furthermore, the contacting zone as well as the contacting forces changes with time, and it is impossible to predict these variations.

As a result of the aforementioned technical problems associated with the conventional type of bending methods, it is difficult to set the reference diameter of the roll (which is a diameter corresponding to the roll surface portion having an equivalent rotational speed to the moving speed of the material in the longitudinal direction). Consequently, it is very difficult to synchronize the rotational speeds of rolls within each stand, and there could be more loss in driving forces as well as their energies. Also, the surface of the final roll-formed product will suffer from surface scratches and flaws. Furthermore, since the forming load and driving force are asymmetric along the width direction of the material, the band steel plate is apt to twist in the forming process.

Because both lower and upper rolls are used to form a desired roll gap, there is no flexibility to accommodate to the forming of the steel pipe with various sizes. For example in the edge-band method, when either the outer diameter or the wall thickness of the product changes all forming rolls need to be exchanged. On the other hand, in the circular-bend method, if the outer diameter of the products remains the same value, rolls can be commonly-employed in forming pipes with various wall thicknesses (if they are within a certain limit) by adjusting the roll-gaps.

As a result, the circular-bend method is considered to be more practical than the edge-bend method. However, when forming material with relatively thin wall thickness, the roll-gaps will become uneven and constraint on the material is not sufficient, so that the expected formability can not be achieved. In other words, such common-utilizing of rolls might negatively impact the resultant formability.

In order to solve the technical problems of the operational performance and productivity associated with the exchanging operation of rolls, technologies have been developed with regard to the common-utilization of rolls. One example of such advanced methods is the so-called cage-forming mill.

In cage-forming mills, the common-utilization of rolls has been proposed by arranging a plurality of small-size rolls (cage rolls) instead of the conventional type of cluster rolls. At the breakdown forming portion, as in the case for the conventional type of mills, the common-utilization of rolls is not realized. In order to reduce the number of rolls which have to be exchanged, not only the forming load at the cluster forming portion but also a part of the forming load which is originally carried out at the breakdown forming portion are shifted to the cage-forming portion, so that the number of breakdown forming stands can be reduced.

However, the forming function of the cage rolls is extremely limited. Namely, since the contact area between the cage rolls and the material to be formed is very small, each cross-sectional portion of the material is formed under the non-uniform bending moment. The formability of such a free-bending method depends strongly upon the size and material properties of the products. Accordingly, it is extremely difficult to obtain the desired curvature distribution as has been designed.

Particularly, there are many occasions when the over-bending phenomenon is exhibited at the central portion of the steel plate, on which the largest bending moment usually acts. Even if the inner roll (which is the convex roll) is employed, it is impossible to make the bending moment uniform.

Because the excess forming work is allotted to the cage forming portion, adverse effects impinge on the forming function and stability of the entire mill system. Accordingly, there are many problems recognized with these types of roll common-utilizing mill system.

In order to overcome the aforementioned drawbacks associated with the cage-type mill system, a roll-forming method has been proposed(which is, hereafter, referred as to an FF – flexible forming - method), see U.S.P. No. 4770019. In the FF forming method, the common-utilization of rolls can be achieved not only at the cluster forming portion but also at the breakdown forming portion by using a special roll whose caliber is an involute (which changes its radius curvature either continuously or step-wisely) and employing a position-controlling mechanism for transferring and rotating such rolls.

In order to bend the edge portion of the material which is the most difficult portion to form, the roll arrangement as seen in Figure 2B is normally used for the so-called No. 1 breakdown stand. According to the roll arrangement for the FF forming method, suitable involute curves are provided to the upper roll 3 (convex roll) and the lower roll 2 (concave roll) respectively, corresponding to the limits of inner and outer diameters of products to be formed.

Although the roll gaps formed with these rolls are normally not uniform, the upper and lower roll positions are determined so as to form the favorable roll-gaps at the edge portion of the material 1, corresponding to the size of the product to be formed. By employing this forming method, it is possible to perform edge-bending without any roll exchange, so that the overall mill formability is improved.

However, even with the FF forming method, the circular-bend type forming method is used for stands other than the No. 1 breakdown stand. As a result, most of the forming work is still carried out at the cluster forming portion.

Summary of the Invention

In order to overcome the problems found in the above described art, it is, therefore, an object of the present invention to provide a novel roll forming method and equipment for same, in which, without mitigating any advantages of the common-utilization of rolls in the FF forming method which uses the circular-bend method, the formability can be enhanced at the breakdown forming portion and the overall formability can be improved.

A novel forming method (Japan Patent Application Laid-Open No. Hei10-255319, PCT/JP98/04962) has been proposed by the present inventors in which the edge-bend method is introduced to the FF forming method and a plurality of edge-bending stands are used at the breakdown forming portion in order to enhance the forming function and a zone approximately half of the plate's width is formed, portion by portion, from its edges (sides).

In the aforementioned method (which is now called FF/X forming method), the overall formability and stability of the mill system are improved. However, the bending method as seen in Figure 2B of the FF forming method is conventionally used only for forming the material's edge portions and it is difficult to set the suitable roll-gaps for the case when the target forming zone is relatively wide.

In these advanced FF or FF/X methods, the basic system concept does not differ from the conventional method in that the inner and outer surfaces of the material are sandwiched between a pair of concave and convex rolls and pressed in the roll gap. Moreover, this forming method has a technical concept such that although the target forming zone is not expected to be in contact with both concave and convex rolls when the involute calibers are used, the appropriate roll surface portions of convex and concave rolls are selected in order to bend the material in the roll gap into a shape similar to that of roll gap as possible.

Experiments and analyses have been conducted to investigate the relationships between roll arrangement/orientation and forming functions in order to enhance the forming function at the breakdown forming portion while effectively achieving all advantages of the FF, FF/X forming methods which make it possible to common-utilize the rolls at the pipe mill system. As a result of extensive investigations, it has been concluded that, in order to bend the material into a desired shape, it is not essentially necessary to employ a pair of concave and convex contour rolls.

It has been found that, by winding a portion of the cross-section of the material to be formed (which is hereafter referred merely as to a target forming zone) around either an entire or a portion of the surface of the convex roll having a roll caliber with a certain curvature distribution, the approximately same curvature distribution can be printed onto the target forming zone of the material without constraining the opposing surface by using the concave roll. This new bending method is referred to as 'embrace-bending'.

For example, the same forming can be achieved by employing a roll arrangement wherein instead of providing a pair of convex and concave rolls as seen in Figure 2A the control of the curvature distribution is mainly conducted by an upper convex roll. Although a pair of left and right lower rolls is used, the principle function of these rolls is to provide a supporting force in order to wind the target forming zone around the convex roll surface, so that the embrace-bending can be performed. In other words, the target forming zone of the material can be controlled and supported in such a way that it can be in contact with the convex roll caliber portion whose curvature distribution is expected to be printed.

There are several important points associated with the aforementioned embrace-bending method. Firstly, the pinch-point defined by a minimum distance between the convex and concave rolls is set at a specific location so as to control the position of material along its width axis. Secondly, the target forming zone of the material is wound around a caliber portion of the convex roll on its bend-inner side to print the expected curvature distribution to the target forming zone without constraining it from the bend-outer side.

When a driving force needs to be generated, the minimum distance between the convex and concave rolls at the pinch-point should be set to be equal to the wall thickness in order to obtain a sufficient amount of pressure or frictional force. Both surfaces of the material are simultaneously constrained only at the pinch-point.

Normally, such a pinch-point is designed and set in a boundary area between the target forming zone and other portions of the material; which is, in turn, the portion being formed previously including the bending non-sensitive zone of the material's edge portion or un-formed portion of the material.

On the other hand, when the driving force is not required, it is not essential to constrain the inner and outer surfaces of the material simultaneously at the pinch-point. Instead, it is simply required to set the position for the concave roll in order to wind the target forming zone around the convex roll surface.

In summarizing the above, the present novel bending method is characterized in that (1) a zone along the width axis of the material to be formed at a certain stand is a target forming zone, (2) the pinch-point is set at the boundary between the target forming zone and other portions of the material in order to print the desired curvature distribution by winding the target forming zone around the surface of the convex roll mounted on a bend-inner side, and (3) the lower roll caliber is set in such a way that this roll will not contact the target forming zone from the bend-outer side (in other words, the target forming zone except the area at or near the pinch-point is not constrained by the lower roll). Consequently, it is not necessary to provide the conventional type of roll caliber since the concave roll is not directly involved in controlling the curvature distribution of the target forming zone.

In accordance with one aspect of the present invention there is provided a method of roll forming a material for welded steel pipe, the material having a bend-inner side, a bend-outer side opposite the bend-inner side, a target forming zone defined along a width axis of the material and boundary areas defined between the target forming zone and one of a previously formed zone and an unformed zone of the material, the method comprising the steps of: forming the target forming zone by winding the material around a roll surface on the bend-inner side of the material; and pushing on the material proximate the boundary areas on the bend-outer side using a contact roll; wherein the contact roll does not constrain the target forming zone on the bend-outer side of the material.

In accordance with another aspect of the present invention there is provided a roll forming apparatus for forming a material for welded steel pipe, the material having a bend-inner side, a bend-outer side opposite the bend-inner side, a target forming zone defined along a width axis of the material and boundary areas defined between the target forming zone and one of a previously formed zone and an unformed zone of the material, the apparatus comprising: a lower roll, being one of a one-piece and a separate type, for pushing on the material proximate the boundary areas on the bend-outer side; a pair of upper rolls arranged along the width axis of the material for forming the target forming zone by winding the material on the bend-inner side of the material around the pair of upper rolls; and a pair of side rolls oriented horizontally proximate the edges of the material.

In accordance with yet another aspect of the present invention there is provided a roll forming apparatus for forming a material for welded steel pipe, the material having a bend-inner side, a bend-outer side opposite the bend-inner side, a target forming zone defined along a width axis of the material and boundary areas defined between the target forming zone and one of a previously formed zone and an unformed zone of the material, the apparatus comprising: a lower roll, being one of a one-piece and a separate type, for pushing on the material proximate the boundary areas on the bend-outer side; a pair of upper rolls arranged along the width axis of the material for forming the target forming zone by winding the material on the bend-inner side of the material around the pair of upper rolls; and a plurality of side rolls arranged longitudinally to contact the bend-outer side proximate edges of the material.

In accordance with still yet another aspect of the present invention there is provided A method of roll forming a material, the material having a bend-inner side, a bend-outer side opposite the bend-inner side, a target forming zone defined along a width axis of the material and a boundary area defined between the target forming zone and one of a previously formed zone and an unformed zone of the material, the method comprising the steps of: positioning a pinch-point, formed by a pair of upper and lower rolls, at the boundary area; and forming the target forming zone by winding the material around a roll surface on the bend-inner side of the material; wherein the target forming zone is not constrained on the bend-outer side of the material.

According to the present novel roll-forming method, because the target forming zone of the material is constrained by only the convex roll, severe deformation is mitigated. Moreover, occurrence of the excess deformation strain is minimized, resulting in that steel pipes with excellent secondary-formability can be produced. This is the first advantage of the present novel roll-forming method.

Furthermore, when the rolls are driven, the roll diameter at the pinch-point can be considered as the reference roll diameter. Since the position of the pinch-point is very clearly identified and does not vary, it is very easy to synchronize the driving speeds within each stand. This is the second advantage of the roll-forming method according to the present invention.

Moreover, even if the surface pressure at the pinch-point is varied within a certain limited range due to the variation of the wall thickness, the symmetry with respect to left and right sides can be maintained, and twisting of the material is not caused because the contacting condition between the material and rolls is not altered. This is another advantage of the present novel roll-forming method.

As a result, it becomes possible to greatly improve the formability and stability of the mill system by introducing the embrace-bending concept of the present invention to the conventional breakdown forming portion. Moreover, according to the present invention, since it is not required that both concave and convex rolls have the exclusive calibers corresponding to the size of product to be formed, it is possible to achieve the common-utilization of rolls. This is a further advantage of the present novel roll-forming method.

According to the present novel roll-forming method for welded steel pipes, the whole area of the target forming zone along the width axis of the material is formed mainly by winding it around the surface of the convex roll located at the bend-inner side without constraining the target forming zone from the bend-outer side. Furthermore, the pinch-point formed by at least one pair of upper and lower rolls is positioned at the boundary area between the target forming zone and previously-formed material (which might include the bending non-sensitive zone of the material's edge portion) or unformed portion, so that the target forming zone can be bent along the roll surface at the bend-inner side without constraining the whole target forming zone from the bend-outer side.

BRIEF DESCRIPTION OF DRAWINGS

The above and many other objectives, features and advantages of the present invention will be fully understood from the ensuing detailed description of the embodiments of the present invention whose description should be read in conjunction with the accompanying drawings.

Figure 1 is a drawing to explain the roll-flower at the breakdown forming portion; A is for the edge-bend method and B is for the circular-bend method.

Figure 2 is an explaining figure of the roll arrangement of the conventional type of breakdown forming stands; A is for a pair of upper and lower rolls, and B is of the rolls for the FF forming method.

Figure 3 is a figure of the roll arrangement to explain the “embrace-bending” concept of the present invention.

Figure 4A and 4B show the roll arrangements in which the “embrace-bending” concept of the present invention is applied to the breakdown forming stands.

Figure 5 shows a breakdown forming stand where the “embrace-bending” concept of the present invention is applied to welded steel pipe forming with common-utilizing of rolls; A is for the case of forming large diameter pipe, whereas B is for the case of forming the small diameter pipe.

Figure 6A, 6B, and 6C show the roll forming method and roll arrangements of the roll stands for the breakdown forming portion as one of the embodiment of the present invention.

Figure 7A shows a perspective view of roll arrangement of the pipe mill when the roll forming method and its equipment of the present invention are applied; while 7B is a figure to explain the roll arrangement of the reverse-bend forming portion; and 7C is a figure to explain the roll arrangement of the cluster forming portion.

Figure 8A, 8B, and 8C show the roll arrangement of the roll stand for the breakdown forming portion as another embodiment when the roll forming method and equipment of the present invention are applied.

Figure 9A is a perspective view of the roll arrangement of the another pipe mill when the roll forming method and equipment of the present invention are applied; while 9B is a figure to explain the roll arrangement of the reverse-bend forming portion and 9C is a figure to explain the roll arrangement for the cluster forming portion.

Figure 10 shows a case when the auxiliary rolls are mounted to the breakdown forming stand; A is a front view and B is a side view.

Figure 11 shows the loci of the edge portion of the material at the breakdown forming portion; A and B are side view and upper view when the pass-line is set in order to have the bottom of the roll flower to be a straight line; while C is a side view when the pass-line is arranged in order to have the edge locus to be a straight line.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

According to the present invention, the embrace-bending method is applicable to all types of forming mills and forming methods and it is possible to rationalize the existing forming processes. However, when it is employed as a portion of the common-utilization technology of rolls, the superior function which can not be realized with the conventional forming methods can be achieved.

The bending method according to the present invention is indispensable in order to establish the advanced common-utilization technology of rolls based on the edge-bend forming method having a strong forming function similar to that of the aforementioned FF/X forming method. The following describes the roll arrangements and roll forming method by which the "embrace-bending" concept can be practiced and the common-utilization of rolls can be realized.

As seen in Figure 4, the roll arrangements at the breakdown forming stand of Figure 2B is modified in order to perform the "embrace-bending" method of the present invention. First, as seen in Figure 4A, the pinch-point, pp, is provided at a location spaced apart from the plate edge with a certain distance. The area from the pinch-point, pp, to the plate edge is called the bending non-sensitive portion 1a since the sufficient bending moment is not normally obtained.

Although the range of the bending non-sensitive portion 1a depends upon the product's dimensions and material type, it can be defined as to be almost the same as the plate thickness. The bending non-sensitive portion 1a being located on the outer side of the pinch-point, pp, is supported by the lower roll 20, and the target forming zone 1b located on its inner side is wound around the upper roll surface 21 in order to be bent.

Therefore, the pinch-point, pp, is set between the bending non-sensitive portion 1a and the target forming zone 1b. The contacting surface of the lower roll 20 has a flat surface in order to avoid constraining the target forming zone from the bend-outer side.

In order to correspond to various diameters, it is necessary to adjust the positions of upper and lower rolls. A portion of the upper roll surface must be selected with an appropriate curvature distribution to contact the target forming zone, since the degree of forming is mainly controlled by the roll caliber of the upper roll 21.

When the range of the common-utilization of rolls for products' outer diameter is relatively wide, similarly to the FF forming method, it is preferable to provide an involute caliber at the upper roll 21 and use the supporting mechanism with which the supporting axial direction of the roll can be freely changeable in order to not only parallel-move but also rotate the roll, so that an appropriate portion of caliber can be selected to contact the target forming zone.

It is not necessary to provide the involute caliber to the lower roll 20, as has been described previously. If the roller flower is properly designed, it is possible to correspond to forming operation of various pipe sizes even with the linear caliber, as seen in Figure 4A.

If the occurrences of roll-marks or roll-flaws are suspected to be related to the type of material or wall thickness-diameter ratio, t/D, the involute caliber may also be provided to the lower roll 20, so that the material edge portion can be supported by the roll surface portion having the curvature close to that of the product.

On the other hand, although the embrace-bending does not necessarily need to provide the central roll 22 and to form the W-shape cross-section of the material, it possesses a beneficial effect to widen the range of the target forming zone. The shape of the central roll 22 and its position can be set in such a manner that, for forming all different sizes of products, the expected target forming zone should be certainly wound around the upper roll 21.

The roll arrangement seen in Figure 4A is very effective to bend the edge portion, and is also applicable to bend other portions of material. However, when the range of the common-utilization of rolls is wide, while providing the pre-determined curvature distribution to the target forming zone, it is also necessary to support the previously-formed zone to prevent the bending-back phenomena.

Hence, the roll arrangement as seen in Figure 5A is extremely effective to form target forming zones other than the formed edge portion. With this roll arrangement, although the central roll 30 is similar to that in Figure 4A, it is used not only to improve the embrace-bending efficiency, but also to form the pinch-points, pp, by combining with a pair of upper rolls 31,32 to generate the driving force.

Furthermore, in the roll arrangements seen in Figures 5A and 4B, compared with that in Figure 4A, side rolls 33,34 are provided. The side rolls 33,34 are in contact with the above mentioned previously-formed zone in order to prevent the bending-back phenomenon. At the same time, by using the bending moment caused by the forming force from the side rolls 33,34, the target forming zone 1c located at the outer side of the pinch-point, pp is wound around the upper rolls 31,32 efficiently.

Referring to Figure 4B, the bending moment acting on the previously-formed zone 1b is small; namely the arm for the bending moment is short because the operating point of the side rolls is within the previously-formed zone; so that this zone is not subjected to a large deformation.

Small size of rolls can be employed instead of side rolls 33,34 to prevent the previously-formed zone from bending-back, so that it is possible to arrange a plurality of small rolls along the longitudinal direction of the material in the above roll arrangement.

Since the control of the curvature distribution of the target forming zone is achieved by the upper rolls 31,32 even with the above mentioned roll arrangements, it is preferable to use the involute caliber to these rolls 31,32 and rotate and/or parallel-move these rolls 31,32 along the width direction of the material to select the caliber portion to contact the target forming zone of the material.

The side rolls 33,34, similarly to the lower rolls 10,11 in Figure 3, are required to provide parallel-movement in order to correspond to the forming of various product sizes. Moreover, it is preferable to provide an appropriate type of involute caliber in order to prevent the occurrences of roll-flaws or roll-marks to the utmost. Figure 5A shows the roll arrangement for the case when pipes with relatively large diameter are formed; while Figure 5B shows the roll arrangement for the case when the pipes with relatively small diameter are formed.

A similar description can be made for the central rolls. It is preferable to employ the separate-type rolls such as two-part-type or three-part-type rolls, which is preferred to having a single roll as seen in the figure. It is easier to make the target forming zone of the material attach to a certain portion of the caliber of the upper roll by appropriately selecting the position of central roll in width or vertical direction.

On the other hand, at the breakdown forming stands, especially at the forming stand where edge-bending is performed, the forming rolls suffer from the wear damage due to large forming load. Moreover, it is known that edge stretch, which is the main cause of the edge wave, is apt to take place at these stands.

Roll wear and edge wave mentioned above may occur even when using the embrace-bending method of the present invention. However, it has been found that, small-size auxiliary rolls being in contact to the edge of the material can be mounted at vicinity of the upper and/or lower stream of the breakdown forming stands, so that some of the forming load will be allotted to the auxiliary roll, resulting in that the forming load and surface pressure which are acting on the lower roll will be reduced.

With reference to the drawings, the auxiliary roll will be described in detail below. As seen clearly from Figures 6A and 6B, the edge portion of the material 1 will be gradually rising while approaching to the center of the upper roll 40 or lower roll 41 at the breakdown forming stand. At an early stage of the contacting process, only the sharp outer edge corner of the material will be in contact to the lower roll surface 40.

At this stage, since the contact is almost the point contact, roll wear could take place easily due to the abnormally high surface pressure. In order to avoid this abnormal roll wear, as seen in Figure 7A, a pair of small-size non-driven type second auxiliary rolls 53,55 is mounted at a vicinity of the upper and lower stream close to the lower rolls 50,51 to attach to the outer edge corner of the material 1, so that the edge portion of the material 1 can be supported.

When the auxiliary rolls 53,54 are provided at the upper stream as described in the above, the outer edge corner of the material will become in contact to the auxiliary rolls 53,54 before contacting to the forming rolls 50,51. In such a case, when the material is moving towards forming rolls 50,51, the edge portion of the material has already been raised to some extent. After contacting to the lower rolls 50,51, the contact area increases rapidly, so that the abnormally high surface pressure can be prevented.

Moreover, the contact with the auxiliary rolls 53,54 dulls the outer edge corner of the material and reduces the possibility of occurrence of the abnormally high surface pressure. Furthermore, by mounting the second auxiliary rolls 53,54, some of the forming load will be allotted to the auxiliary rolls 53,54 and the forming load and surface pressure acting on the lower rolls 50,51 can be reduced.

When the auxiliary roll 53 is provided at only the upper stream, it is preferable to constrain firmly the material along the longitudinal direction by mounting the auxiliary roll 55 at the lower stream side of the forming stand since the steel band will rotate along the longitudinal direction around the upper roll 52 as a supporting point and the effect of the auxiliary roll 53 will be reduced if there is no auxiliary roll mounted at the lower stream side of the forming stand.

In the present invention, the wear problem of the auxiliary roll can not be avoided. However, since the auxiliary roll according to the present invention is a small-size non-driven type, the roll per se as well as its supporting mechanism can be very simply compared with the forming rolls, so that the equipment and maintenance cost will be low and exchanging operation for polishing these roll surfaces will also be easier and simpler.

Moreover, since the essential function of the second auxiliary roll is to support the edge of the material and it only contacts the edge corner of the material, formability and product quality will not adversely been affected even if they are worn. For such a case, it is not required to exchange and polish these auxiliary rolls.

The above mentioned auxiliary roll not only controls the wear phenomenon of the forming roll, but also exhibits a great effect to prevent the so-called edge wave of the material caused by the excessive edge stretch during the forming process. The occurrence of the edge stretch is most noticeable at the breakdown forming area.

It is believed that a spatial transferring distance at the width edge portion of the material that is longer than that at other portions due to the spring-back between the stands is a main cause of the edge stretch. Through extensive experiments and analyses, it has been found that the effect of the spring-back on the differences in the spatial locus is not large, rather the edge wave takes place mainly due to the fact that the edge portion is locally stretched when it rises along the roll surface.

As seen in Figure 10B, when the material 1 is entering the roll gap, the edge portion winds around the surface of lower roll 40 and rises. Since, during this short period of time, the S-shaped spatial locus 42 created by the edge portion is much longer than nearly-liner loci created by other portions, a large amount of edge stretch will take place. Moreover, due to such an edge stretch, downward-warp will occur on the longitudinal direction of the material after the material passes through the roll gap, causing the same rising problem at the subsequent stand.

In order to solve the problem, the height of the edge portion can be set prior to entering the roll gap to the same level as the edge portion in the roll gap or slightly higher than that in order to make the locus of the edge portion to close to be linear as possible.

However, even if the pass-line 44 is set as described in the above, since the height of other portions of the material goes down due to the constraint of rolls 40,41, the edge portion will leave from the pre-set pass-line 44 and continuously goes down until the position where it balances with the locus 46 of other portions. Then, the locus 45 of the edge portion will rise along the lower roll surface 40. As a result, the effect of reducing the rising of the edge portion by setting the pass-line 44 is very small.

As will be clearly understood from the aforementioned analyses, it is found that, before entering the roll gap, the rigidity itself of the material's edge portion can not keep the pre-set pass-line. However, the mounting of the second auxiliary roll as seen in Figure 11 can solve this problem.

According to the present invention, since the auxiliary roll does not contribute directly to the forming of the products, it is not required to design the roll caliber with respect to the products' dimension as done for the forming rolls. The flat rolls can be used if the edge corner of the material can be supported at the desired position. Furthermore, the auxiliary roll requires only a simple supporting device being mounted before and after the forming stand, so that the exclusive stand just for the auxiliary roll is not needed.

In the present invention, the shorter the distance (pitch) from the supporting point of the material's edge corner to center of the lower roll, the larger various effects obtained from the auxiliary rolls. The shorter distance (pitch) can be obtained if the auxiliary roll is placed at the same stand as the lower roll. Moreover, in order to obtain the short pitch, as seen in Figure 11B, it is extremely effective to decline the axis of the auxiliary roll toward the center of the lower roll along the longitudinal direction.

When the size of the product changes and the same auxiliary roll does not correspond to this change, it is necessary to exchange rolls. However the common-utilization of the auxiliary rolls can be achieved if the roll flowers are designed in such a way that the positions of the edge corners are on a certain curve.

Embodiments

Embodiment 1

With reference to Figures 8 and 9, an embodiment of applying the roll forming method and equipment of the present invention to the roll arrangements No.1 through 3 in the break-down forming portion in the pipe mill system of FF/X forming method, which the present inventors have previously proposed, will be described. In such a pipe mill system, as clearly seen in Figure 9A, roll stands BD1,BD2,BD3 at the breakdown forming portion are arranged, followed by roll stand RB at the reverse-bend portion, cluster roll C1 through C6 in the cluster forming portion, and roll stands FP1,FP2 at the fin-pass forming portion.

At the roll stand BD1 of the break-down forming portion, as seen in Figure 8A, a rotation-type pair of left and right upper rolls which is changeable to the contacting direction against the material and a pair of left and right lower roll together with the central roll having a narrow width are mounted. Between such upper and lower rolls, the pinch-point is set at the boundary area between the target forming zone along the material's width direction which is ready to form at the BD1 stand and the bending non-sensitive material's edge portion. Such a pinch-point possesses the same mechanism and function as described in Figure 4A to perform a certain edge-bending operation.

The roll stand BD2 seen in Figure 8B consists of a rotation-type pair of left and right upper rolls, a wide lower central roll, and a pair of horizontal rolls to support the edge potion of the material which was previously formed at the BD1 roll stand. Between the upper roll and shoulder portion of the central roll, the pinch-point is provided at the boundary area between the target forming zone which is planned to be formed at the stand BD2 and the un-formed zone of the material's central portion, to exhibit the same mechanism and function as described in Figure 4B to perform the bending operation.

The roll stand BD3 has the same mechanism and function as the previous roll stand BD2 does, and is used to bend a target forming zone which is closer to the center of the material. The portion of material at the outer side of the target forming zone, which has already been formed at previous roll stands BD1 and BD2 is supported by the horizontal roll with an involute caliber, so that the bending-back of the formed portion at the outer side of the target forming zone is prevented.

In the next step, the central portion of material which is pushed upwardly by the central rolls at BD1, BD2 and BD3 is reversed at roll stand RB as seen in Figure 9B. Hence, introducing the material into the cluster forming portion will be much easy. Furthermore, the cross-section of the material will be formed into a profile near an open circle by subsequent fin pass forming portions FP1,FP2.

By employing the pipe mill system as seen in Figure 9A of the present invention, the edge–bend forming method without exchanging rolls can be realized at the breakdown forming portion, so that formability is extremely improved and the common-utilization of rolls in a range of about three-fold in terms of diameter ratio can be achieved.

Embodiment 2

In the conventional type of the FF forming method, another embodiment of applying the roll forming method and equipment of the present invention to the roll arrangements No.1 through 3 of the breakdown forming portion will be described by referring to Figures 6 and 7. The pipe mill, as seen in Figure 7A, comprises of roll stands BD1, BD2, BD3 at the breakdown forming portion, roll stand RB of the reverse forming portion, cluster roll stands C1,C2,C3, and roll stands FP1,FP2 in the fin-pass forming portion.

In the roll stand BD1 in the breakdown forming portion, as seen in Figure 6A, a rotation-type pair of left and right upper rolls which are changeable in the contacting direction with the material, a narrow central roll, and a pair of left and right lower rolls with involute calibers are mounted. Between the upper and lower pairs of rolls, the pinch-point is provided at the boundary area between the target forming zone which is ready to be formed at the roll stand BD1 and the bending non-sensitive zone of the material's edge portion. Such a pinch-point possesses the same mechanism and function as described in the Figure 4A to perform the edge-bending operation. The target forming zone is not in contact with the roll caliber of the lower roll except its boundary at the pinch-point (not seen in Figure).

At the roll stand BD2 as seen in Figure 6B, a rotation-type left and right pair of upper rolls and a pair of left and right lower rolls are provided. Between the upper rolls and lower rolls having involute calibers, the pinch-point is provided at the boundary area between the target forming zone which is ready to be formed at the roll stand BD2 and the previously-formed zone formed at the roll stand BD1. Such a pinch-point exhibits same mechanism and function as described in Figure 4B. Here again, the target forming zone is not in contact with the roll caliber of the lower roll except its boundary at the pinch-point. On the contrary, the material's edge portion which was previously formed at the roll stand BD1 is in contact and supported with the involute caliber of the lower roll to maintain the expected formability.

The roll stand BD3, as seen in Figure 6C, possesses the same mechanism and function as previous roll stand BD2 does. At this stand, a target forming zone which is closer to the central of the material is bent. The material's edge portion which was already formed by previous roll stands BD1 and BD2 is supported along the involute caliber of the lower roll, so that the bending-back of the formed portion is avoided.

In the next step, the central portion pushed upwardly by central rolls at BD1, BD2 and BD3 is reversed at the roll stand RB as seen in Figure 7B. Hence, introducing the material into the cluster forming portion will be much easier, as seen clearly in Figure 7C. Furthermore, the cross-section of the material will be formed into a profile near an open circle by subsequent fin pass forming portions FP1,FP2.

By employing the pipe mill system as seen in Figure 7A of the present invention, the edge–bend method without exchanging rolls can be realized at the breakdown forming portion, so that formability is extremely improved and the common-use of rolls in a range of about 2.5-fold in terms of diameter ratio can be achieved.

Embodiment 3

Using the pipe mill system for the welded steel pipes which employs three units of forming stands to the break-down forming portion according to the FF/X forming method, the auxiliary rolls are provided with an attachable manner before and after the breakdown forming portion. The edge stretch of the steel plate was measured at each stand at the breakdown forming portion. Table 1 shows the results for three cases; namely they include (1) without any auxiliary roll, (2) auxiliary rolls before and after the roll stand BD1, and (3) auxiliary rolls before and after roll stands BD1 and BD2.

In the case when the auxiliary roll is not mounted, a large edge stretching was observed at roll stands BD1 and BD 2. On the other hand, in the case when the auxiliary rolls were mounted before and after the roll stand BD1, although the edge stretching can not be eliminated completely, the value of the edge stretching recorded was less than half at the BD1 and about one quarter at BD2.

Moreover, when the auxiliary rolls were also provided before and after the roll stand BD2 to support the edge portion of the steel plate, the edge stretching at stand BD2 was furthermore reduced down to another half. From this result, it is clearly understood that the auxiliary roll possesses very effective function to prevent the edge stretch.

Furthermore, Table 2 shows the results of effects of the auxiliary roll on the thrust and forming load at the roll stand BD2. From results presented in Table 2, it is obvious that the thrust on the BD2 roll stand and forming load acting on the lower roll are clearly different between the case when the auxiliary roll is not provided before and after the roll stand BD1 and the case when the auxiliary roll is provided before and after the roll stand BD1.

Introduction of the material into roll gap can be greatly improved due to the fact that the edge rising is remarkably reduced due to the effects of the auxiliary roll. Moreover, the effect on the thrust and forming load is very significant.

Table 1

	without auxiliary roll	auxiliary roll before & after BD1	auxiliary roll before & after BD1,2
BD1 stand	2.25%	1.1%	1.1%
BD2 stand	1.8%	0.48%	0.25%
BD3 stand	0.5%	0.48%	0.48%

Table 2

when the auxiliary roll is not provided before and after BD1 stand		when the auxiliary roll is provided before and after BD1 stand	
forming load acting on the lower roll of BD2 stand	thrust at BD2 stand	forming load acting on the lower roll of BD2 stand	thrust at BD2 stand
6,530kg	-10kg	2,750kg	180kg

According to the present invention, the pinch-point formed by the upper and lower rolls is set at the boundary area between the target forming zone along the material's width direction and previously-formed zone or un-formed zone. The target forming zone is wound around a certain caliber of the upper roll being positioned at the bend-inner side, and bend-formed in such a manner that the lower roll is in almost no-contact condition with the target forming zone. As a result, the bending formability can be greatly improved, and roll flaws and roll-marks can be prevented.

According to the roll forming method of the present invention, the concave roll does not contribute directly to control of the curvature distribution of the target forming zone. On the other hand, the target forming zone is constrained only by the convex roll, so that the excess deformation is reduced and the occurrence of the superfluous deformation strain can be prevented.

Moreover, when the roll is driven, the maximum surface pressure is generated at the pinch-point. Since the roll diameter corresponding to this pinch-point is used as a roll reference diameter and the position of the pinch-point is clearly identified and not changed, the driving force within each roll stand can be synchronized easy.

Furthermore, in the roll forming method of the present invention, the contacting condition between the material and rolls is stable regardless of variations in wall thickness of the material, so that the twist phenomena is not induced.

According to the roll forming method of the present invention, since it is not necessary that both concave and convex rolls are rolls with exclusive roll caliber corresponding to the product to be formed, the common-utilization roll is easy to realize. Also, the forming function and operativity of mill can be greatly improved by introducing it to the breakdown forming portion.

Furthermore, by providing the auxiliary roll in the vicinity of up stream and down stream of the lower roll of the breakdown forming stand to support the edge of the material to the pre-set height, the forming load and surface pressure acting on the lower roll can be reduced. As a result, the local wear on the roll can be reduced. Also forming defects such as the edge wave caused by the localized stretching of the edge portion can be eliminated.

While this invention has been described with respect to preferred embodiments and examples, it should be understood that the present invention is not limited to those embodiments and examples; rather many modifications and variations would present themselves to those of skill in the art without departing from the scope and spirit of the present invention, as defined in the appended claims.

CLAIMS

1. A method of roll forming a material for welded steel pipe, the material having a bend-inner side, a bend-outer side opposite the bend-inner side, a target forming zone defined along a width axis of the material and boundary areas defined between the target forming zone and one of a previously formed zone and an unformed zone of the material, the method comprising the steps of:

forming the target forming zone by winding the material around a roll surface on the bend-inner side of the material; and

pushing on the material proximate the boundary areas on the bend-outer side using a contact roll;

wherein the contact roll does not constrain the target forming zone on the bend-outer side of the material.

2. The roll forming method of claim 1, wherein a central portion of the material defined along its width axis is pushed from the bend-outer side by the contact roll to form a W-shaped cross-section in the material.

3. The roll forming method of claim 1, wherein the roll surface's shape is defined by a plurality of arcs.

4. The roll forming method of claim 1, further having the step of:

supporting edges of the material at a height previously arranged during the roll forming of the material;

wherein the edges are supported by an auxiliary roll in contact with the edges.

5. A roll forming apparatus for forming a material for welded steel pipe, the material having a bend-inner side, a bend-outer side opposite the bend-inner side, a target forming zone defined along a width axis of the material and boundary areas defined

between the target forming zone and one of a previously formed zone and an unformed zone of the material, the apparatus comprising:

a lower roll, being one of a one-piece and a separate type, for pushing on the material proximate the boundary areas on the bend-outer side;

a pair of upper rolls arranged along the width axis of the material for forming the target forming zone by winding the material on the bend-inner side of the material around the pair of upper rolls; and

a pair of side rolls oriented horizontally proximate the edges of the material.

6. A roll forming apparatus for forming a material for welded steel pipe, the material having a bend-inner side, a bend-outer side opposite the bend-inner side, a target forming zone defined along a width axis of the material and boundary areas defined between the target forming zone and one of a previously formed zone and an unformed zone of the material, the apparatus comprising:

a lower roll, being one of a one-piece and a separate type, for pushing on the material proximate the boundary areas on the bend-outer side;

a pair of upper rolls arranged along the width axis of the material for forming the target forming zone by winding the material on the bend-inner side of the material around the pair of upper rolls; and

a plurality of side rolls arranged longitudinally to contact the bend-outer side proximate edges of the material.

7. A method of roll forming a material, the material having a bend-inner side, a bend-outer side opposite the bend-inner side, a target forming zone defined along a width

axis of the material and a boundary area defined between the target forming zone and one of a previously formed zone and an unformed zone of the material, the method comprising the steps of:

positioning a pinch-point, formed by a pair of upper and lower rolls, at the boundary area; and

forming the target forming zone by winding the material around a roll surface on the bend-inner side of the material;

wherein the target forming zone is not constrained on the bend-outer side of the material.

8. The roll forming method of claim 7, wherein side rolls are in contact with the previously-formed zone of the material from the bend-outer side to prevent bending-back phenomena.

9. The roll forming method of claim 7, wherein a central portion of the material defined along its width axis is pushed from the bend-outer side by a contacting roll to form a W-shaped cross-section in the material.

10. The roll forming method of claim 7, wherein the roll surface's shape is defined by a plurality of arcs.

11. The roll forming method of claim 10, wherein in an involute is employed as a roll caliber of the roll surface.

12. The roll forming method of claim 7, wherein the method is employed in a breakdown forming portion of roll forming of welded steel pipes.

13. The roll forming method of claim 7, further having the step of:

supporting edges of the material at a height previously arranged during the roll forming of the material;

wherein the edges are supported by an auxiliary roll in contact with the edges.

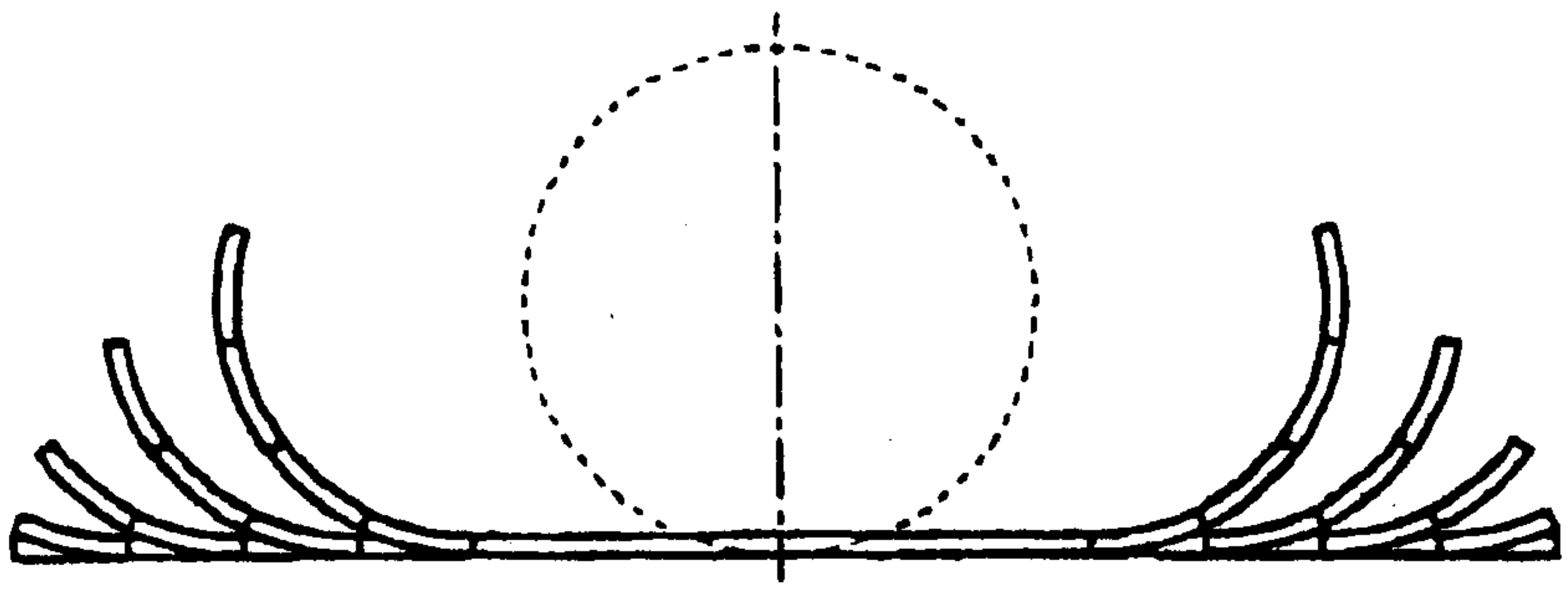


Fig. 1A
(PRIOR ART)

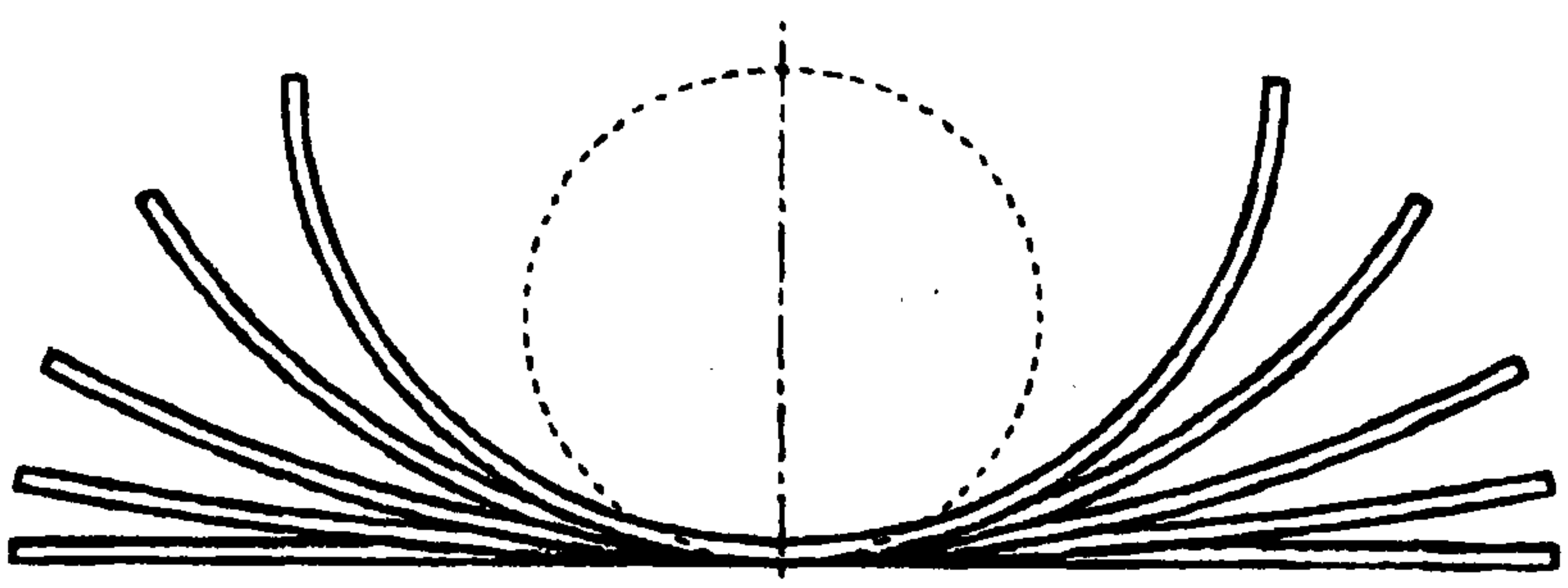
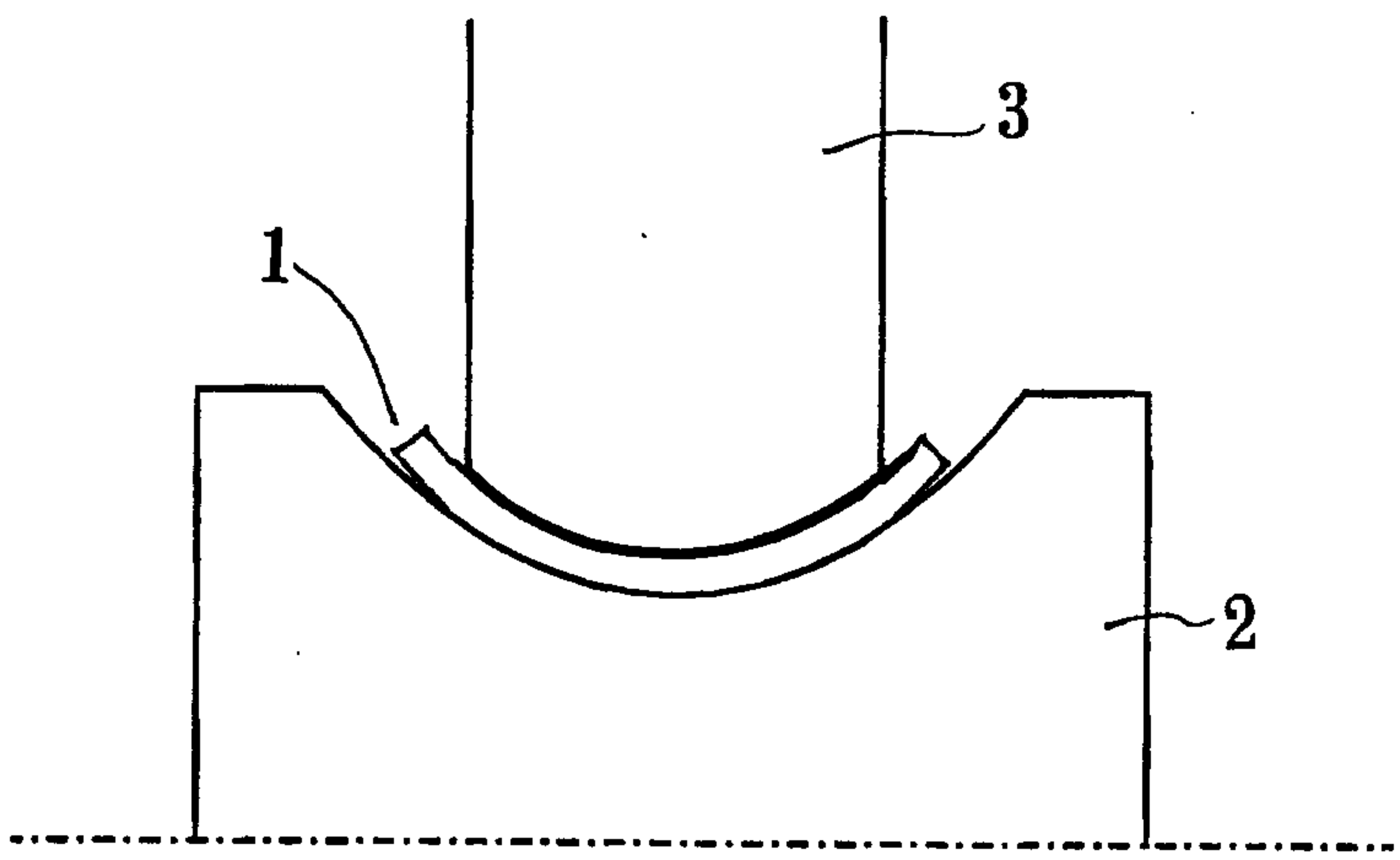
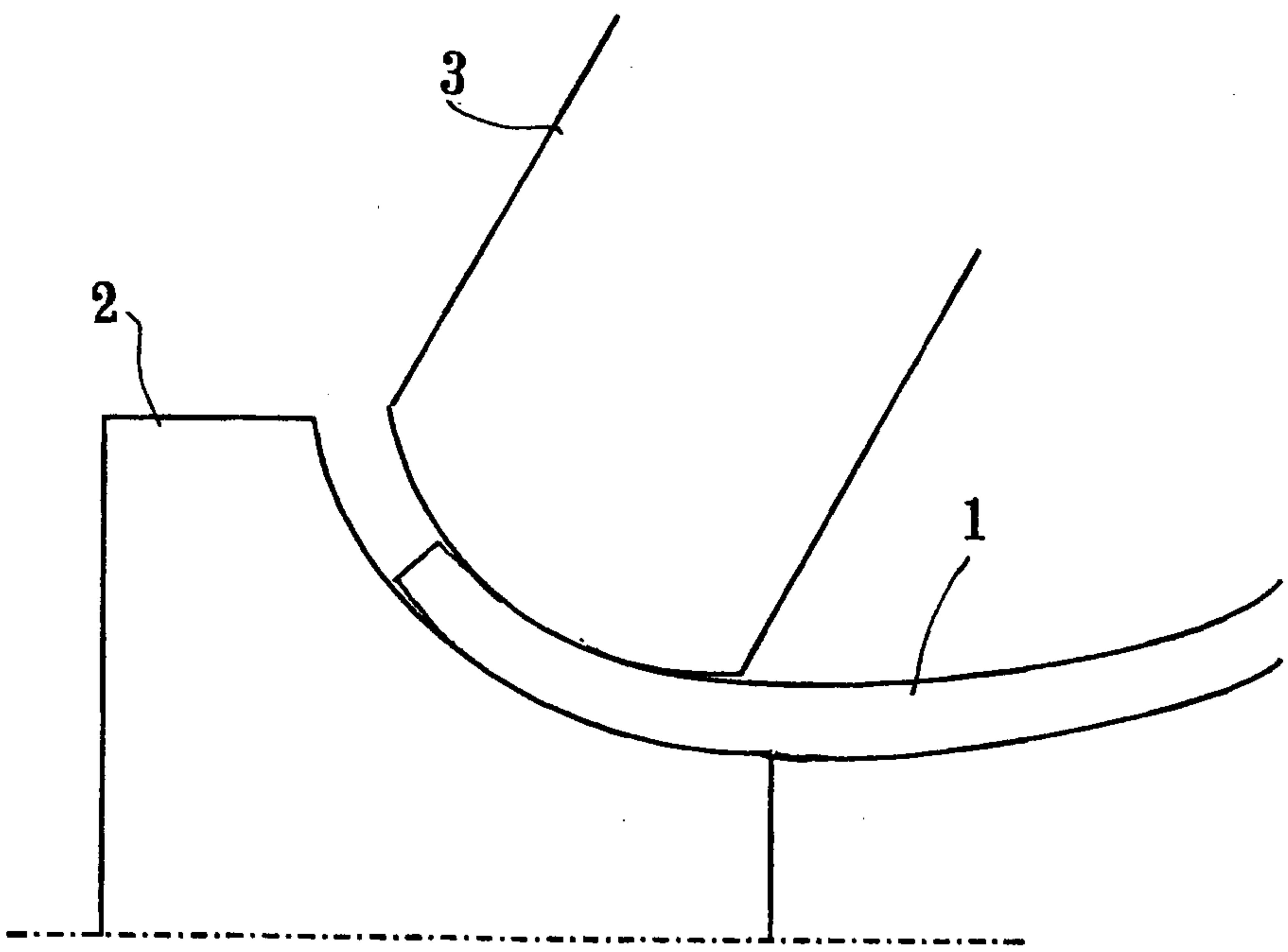


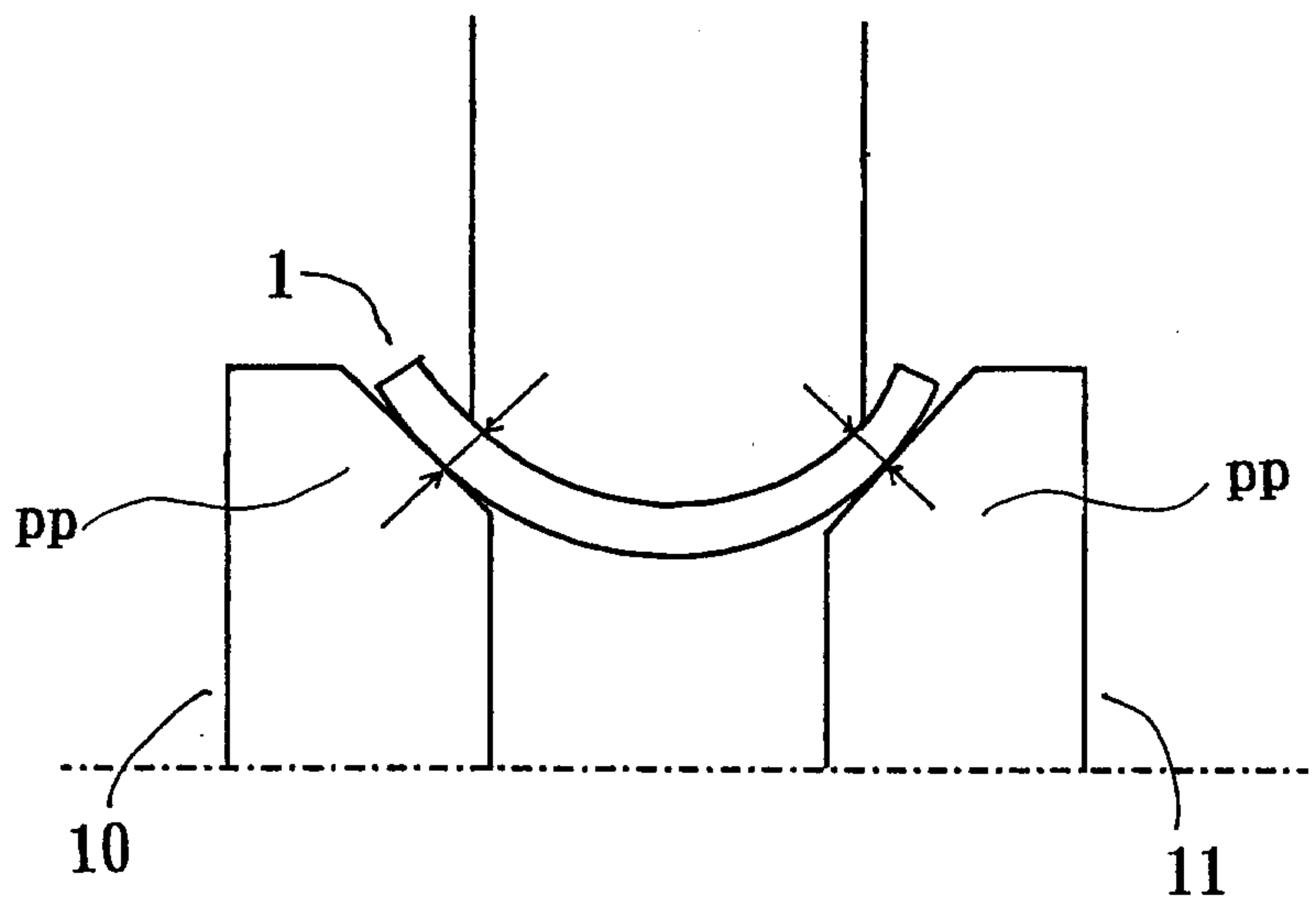
Fig. 1B
(PRIOR ART)



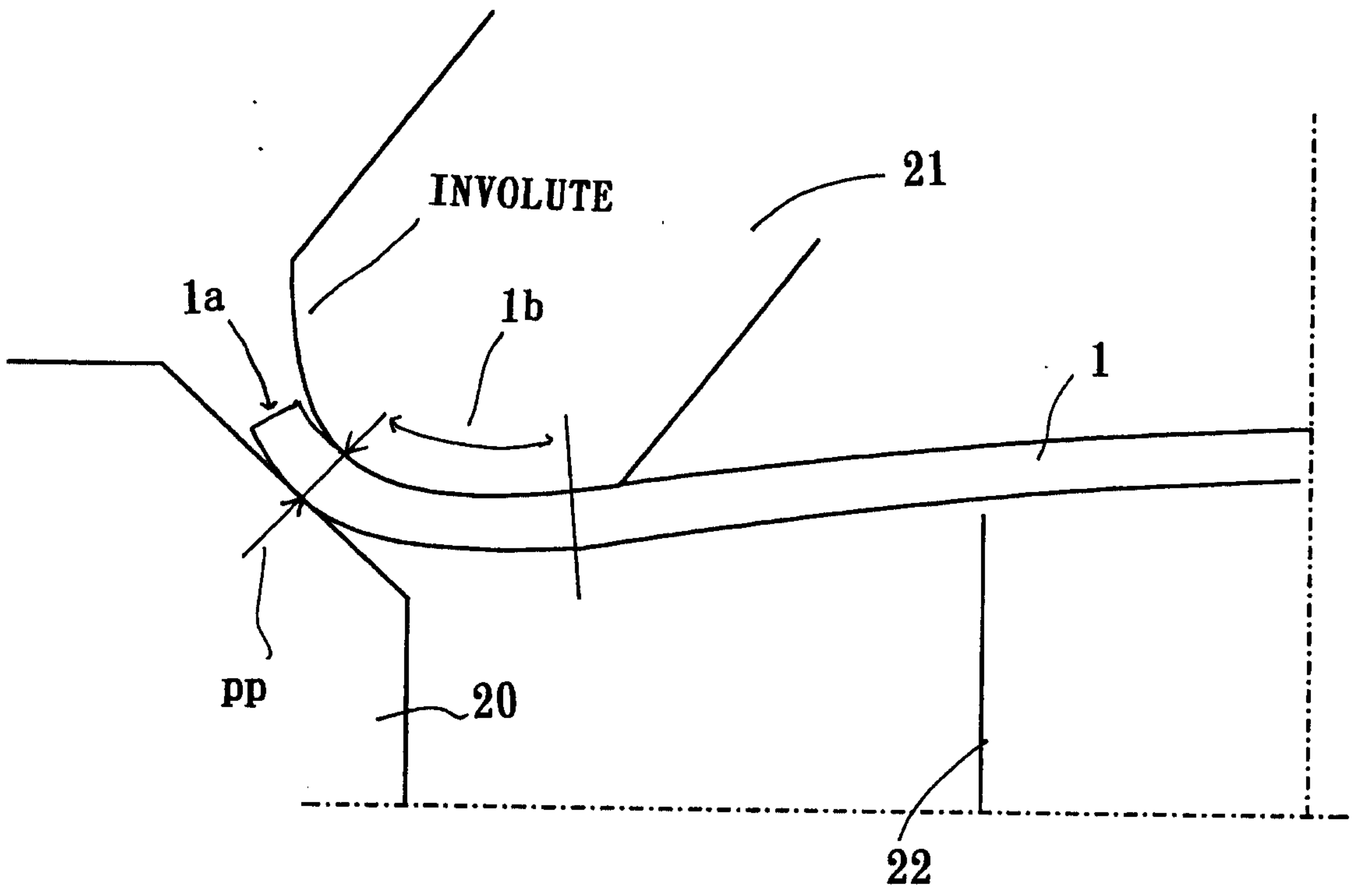
F i g. 2 A
(PRIOR ART)



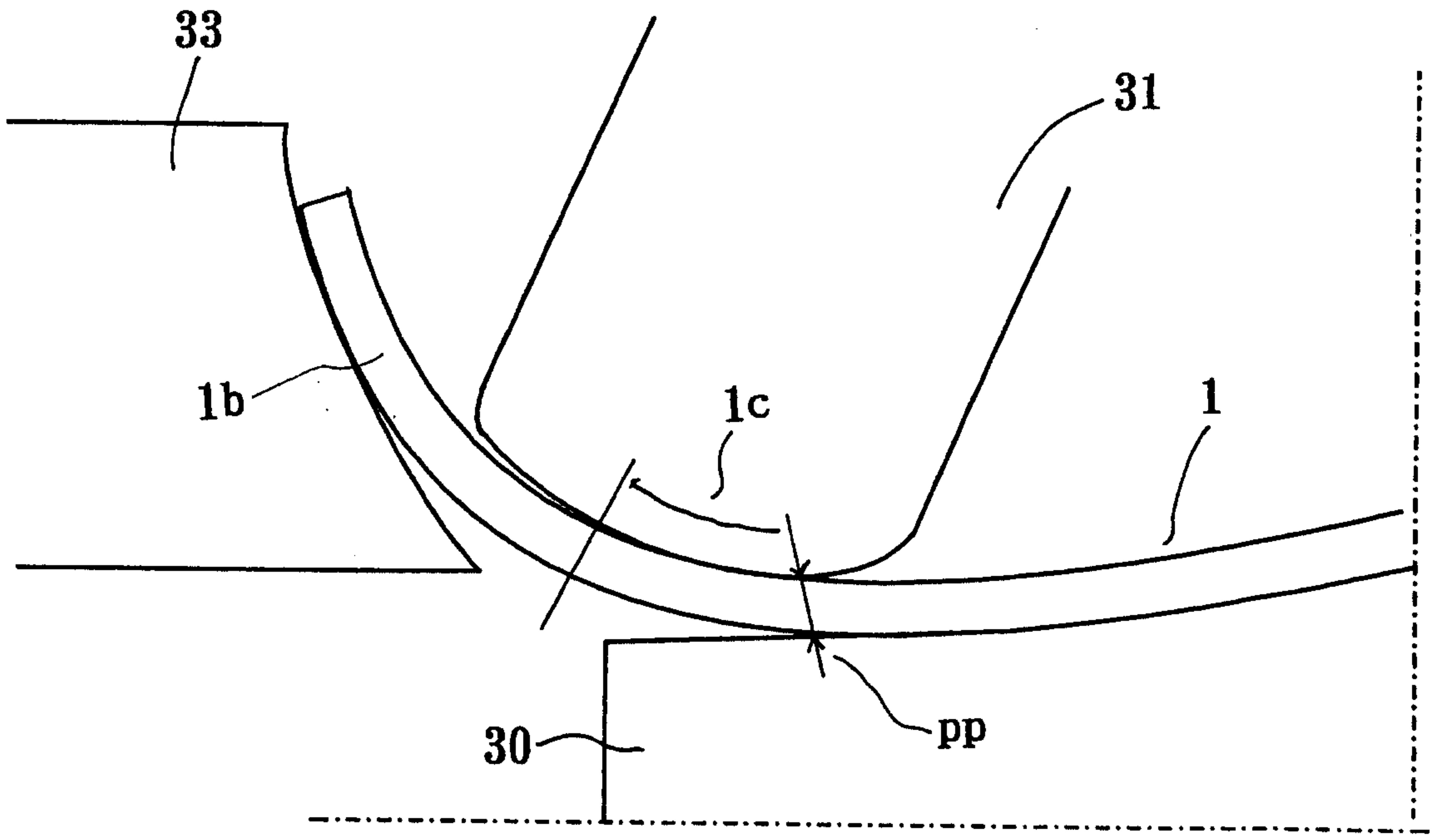
F i g. 2 B
(PRIOR ART)



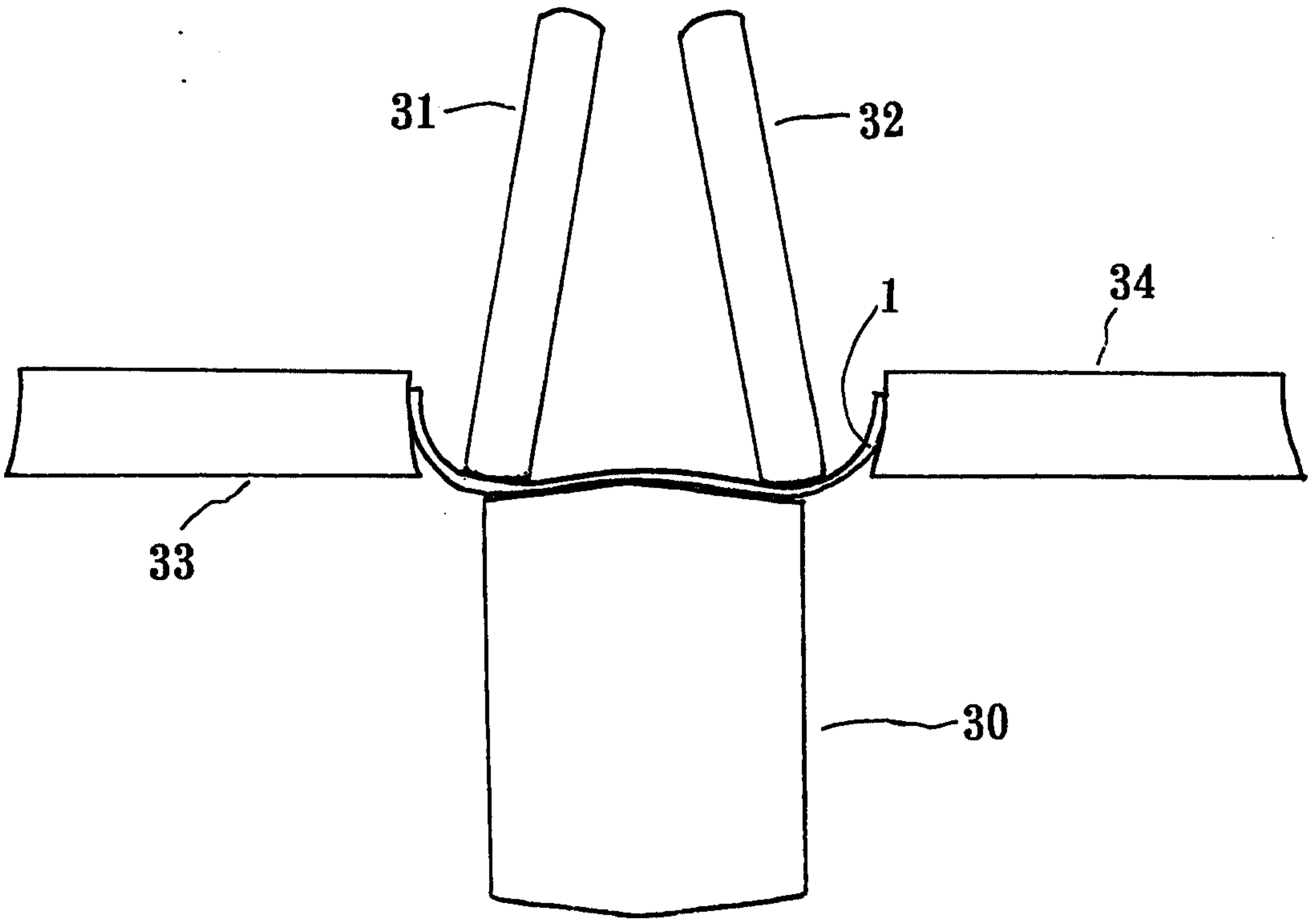
F i g. 3



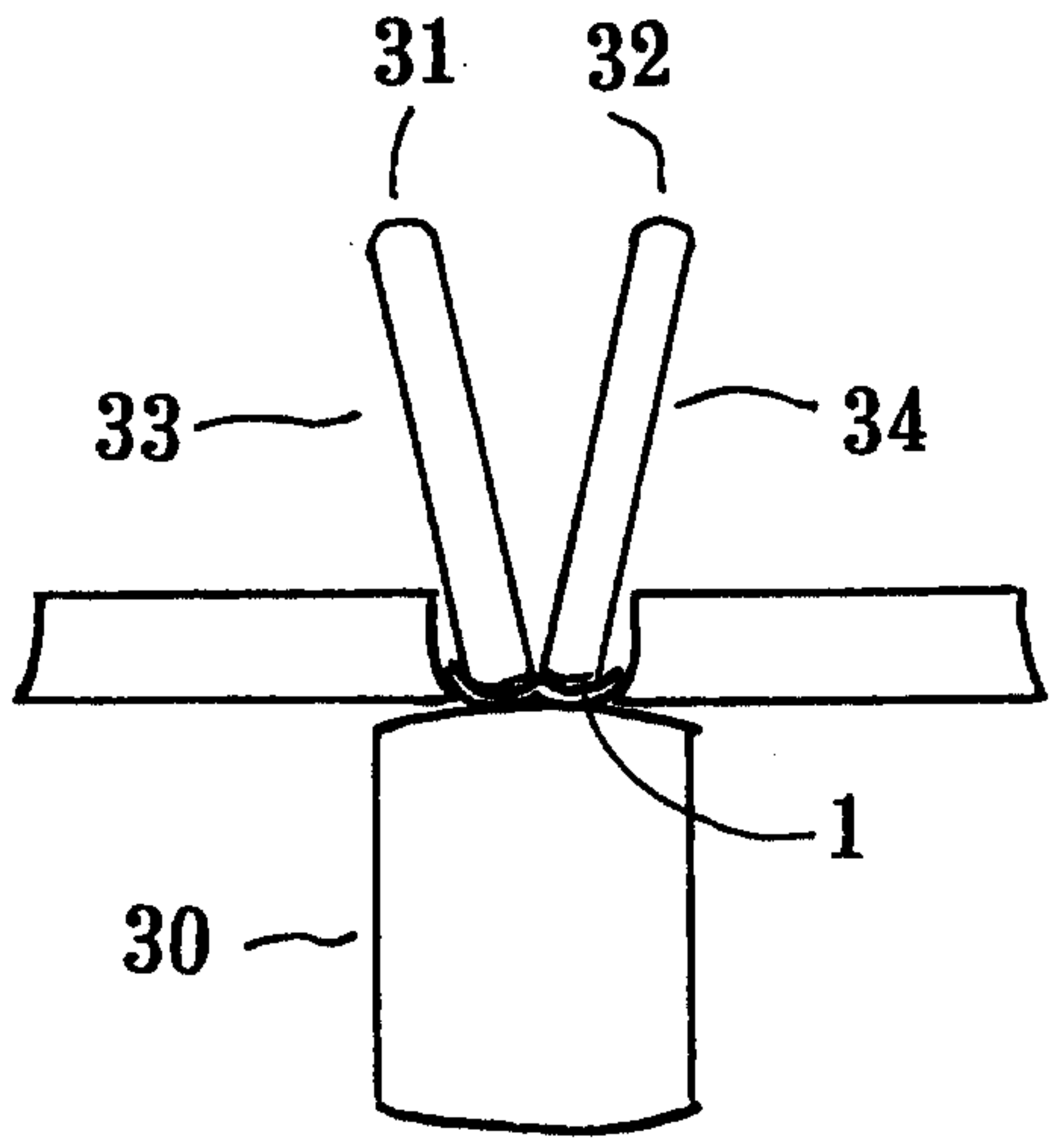
F i g. 4 A



F i g. 4 B



F i g. 5 A



F i g. 5 B

Fig. 6A

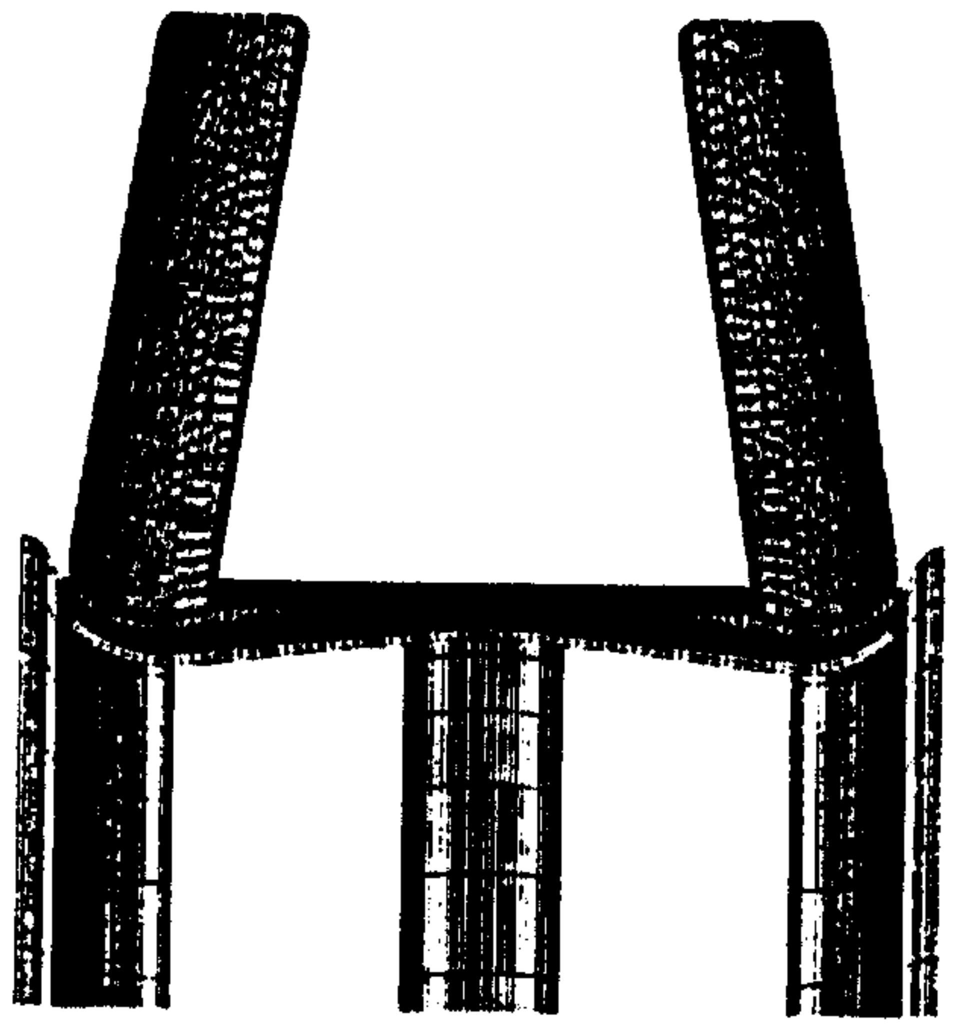


Fig. 6B

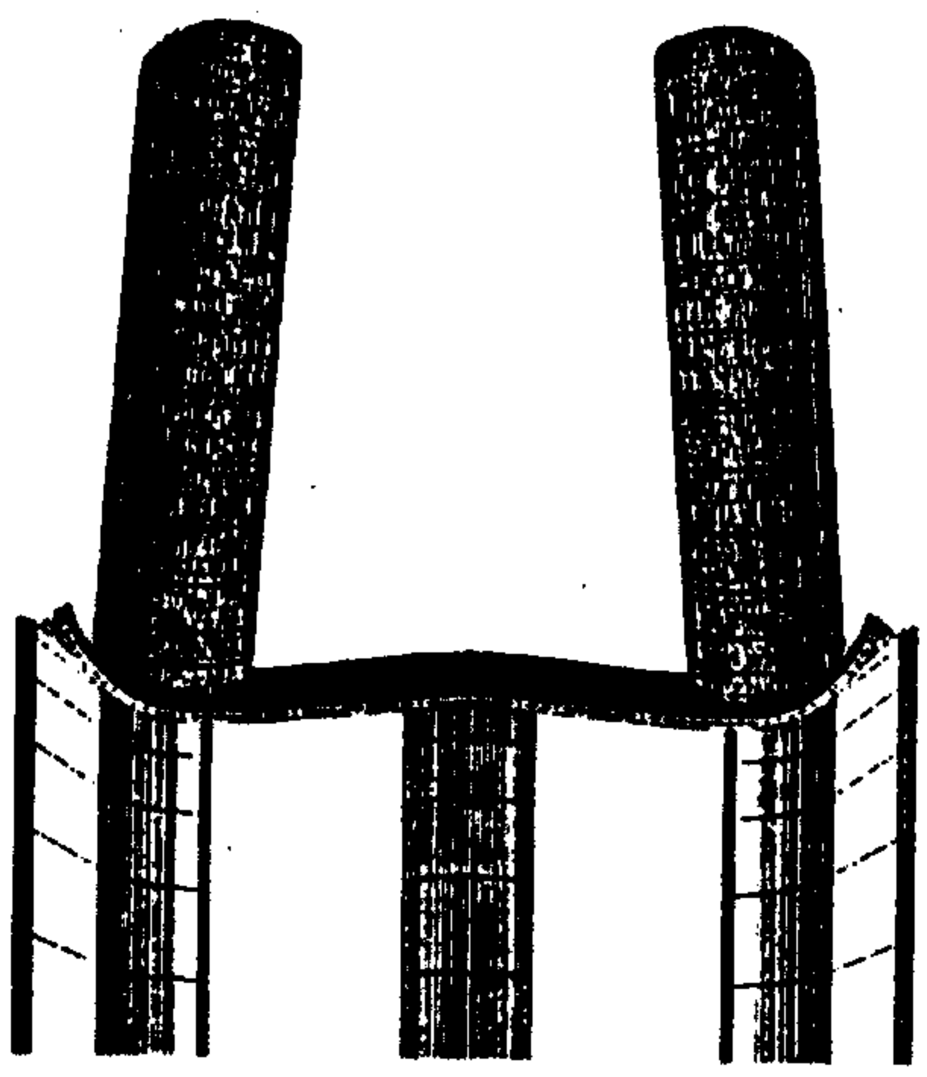
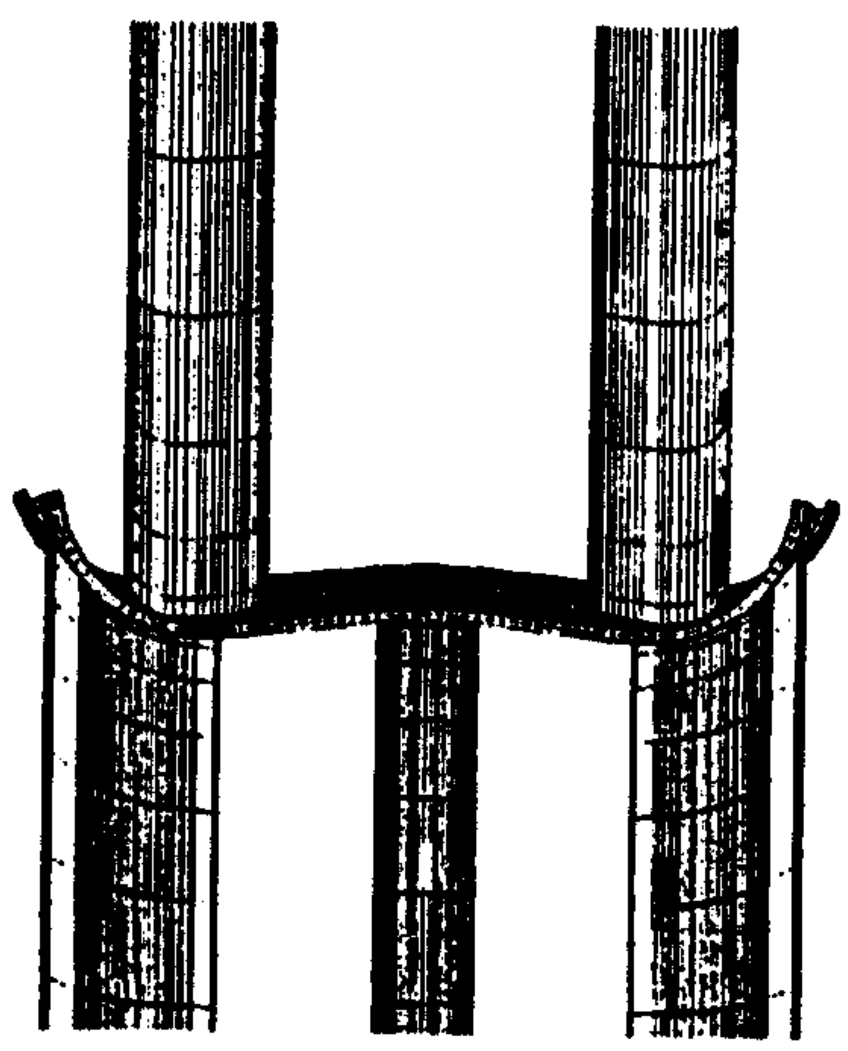


Fig. 6C



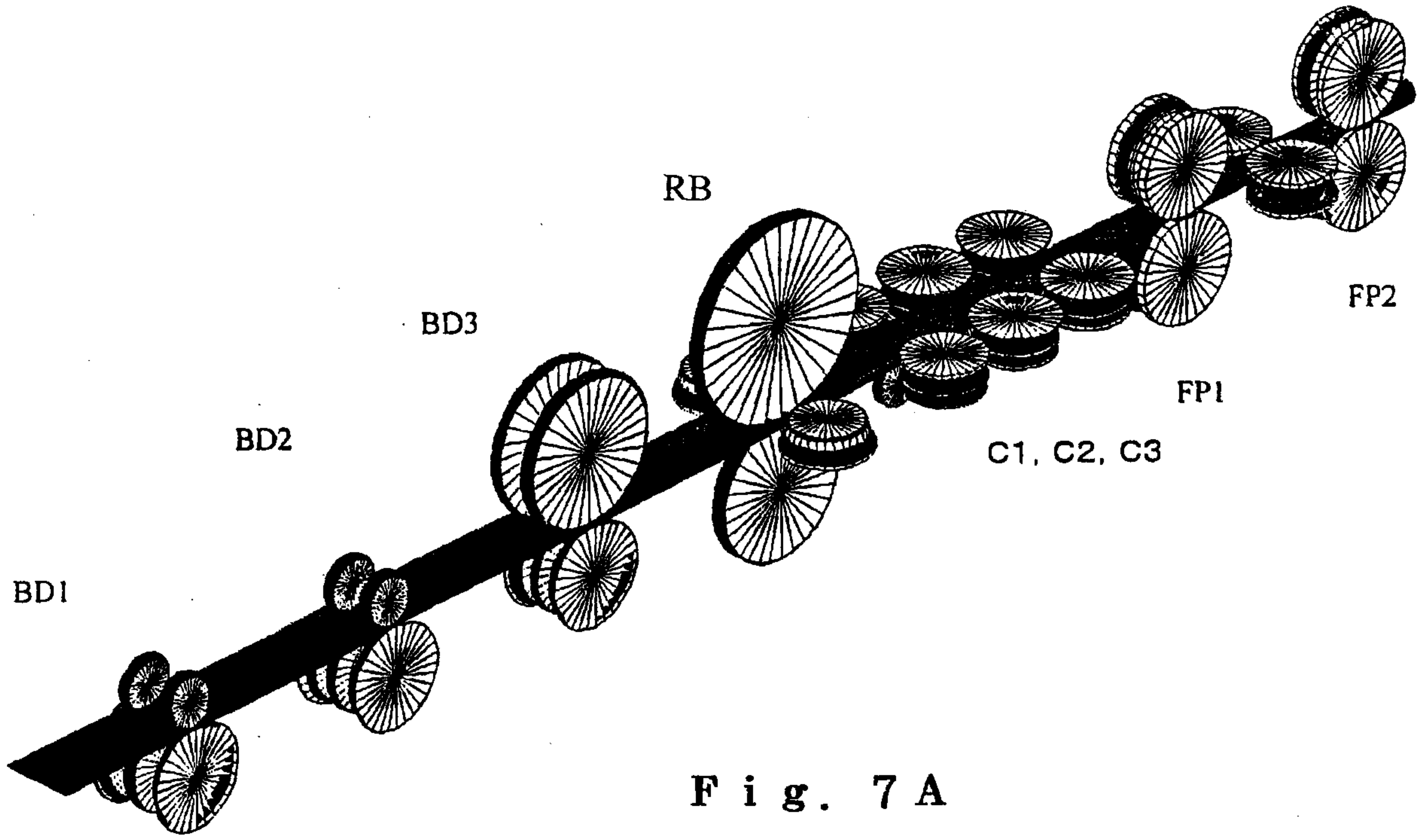


Fig. 7A

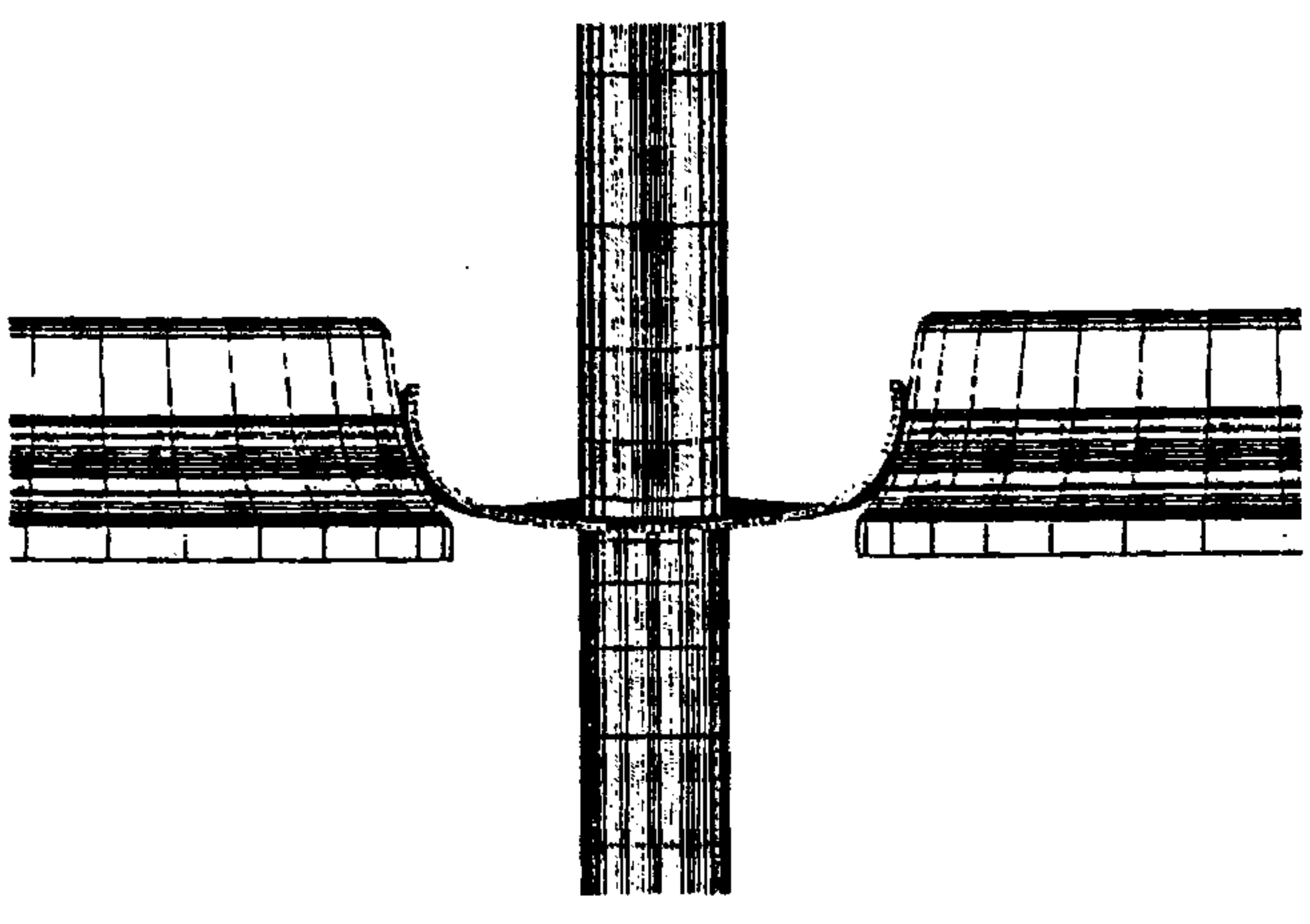


Fig. 7B

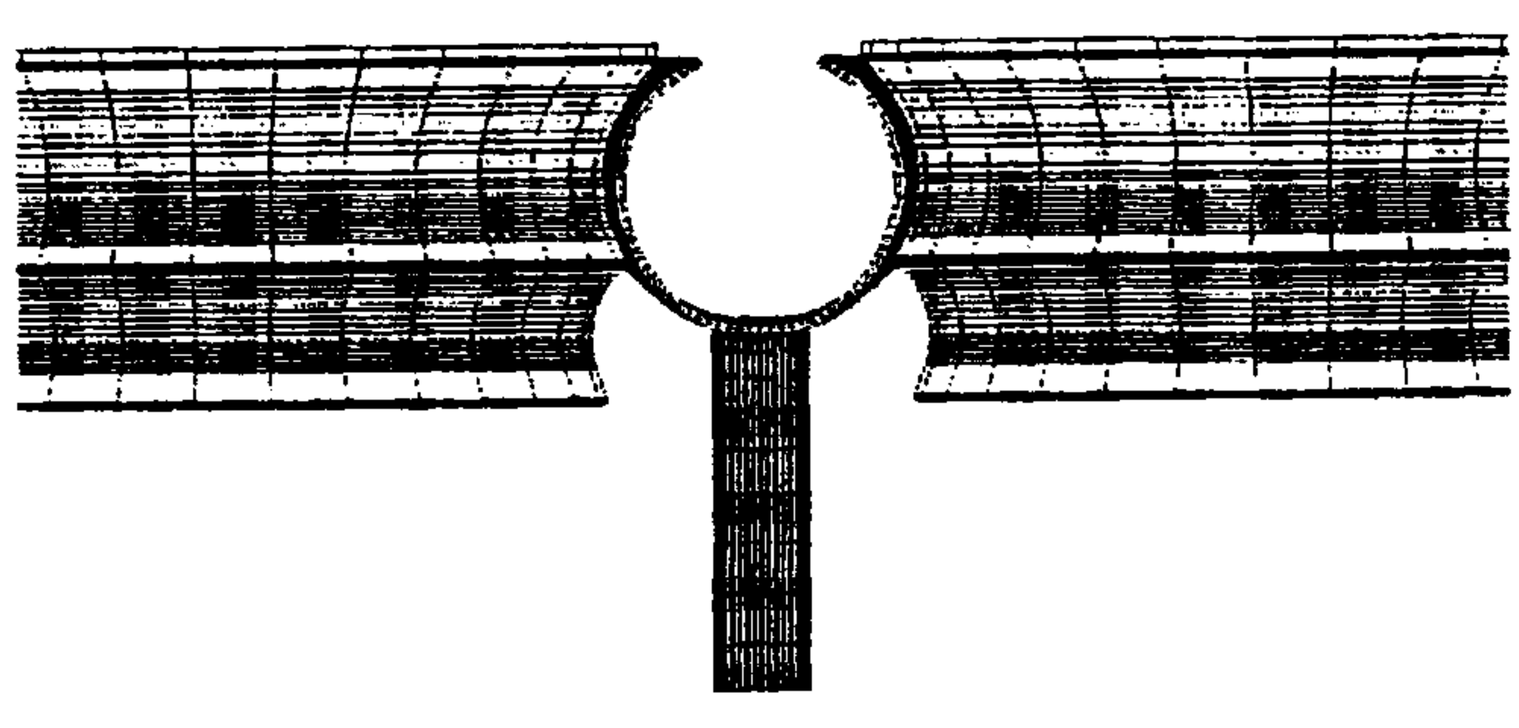


Fig. 7C

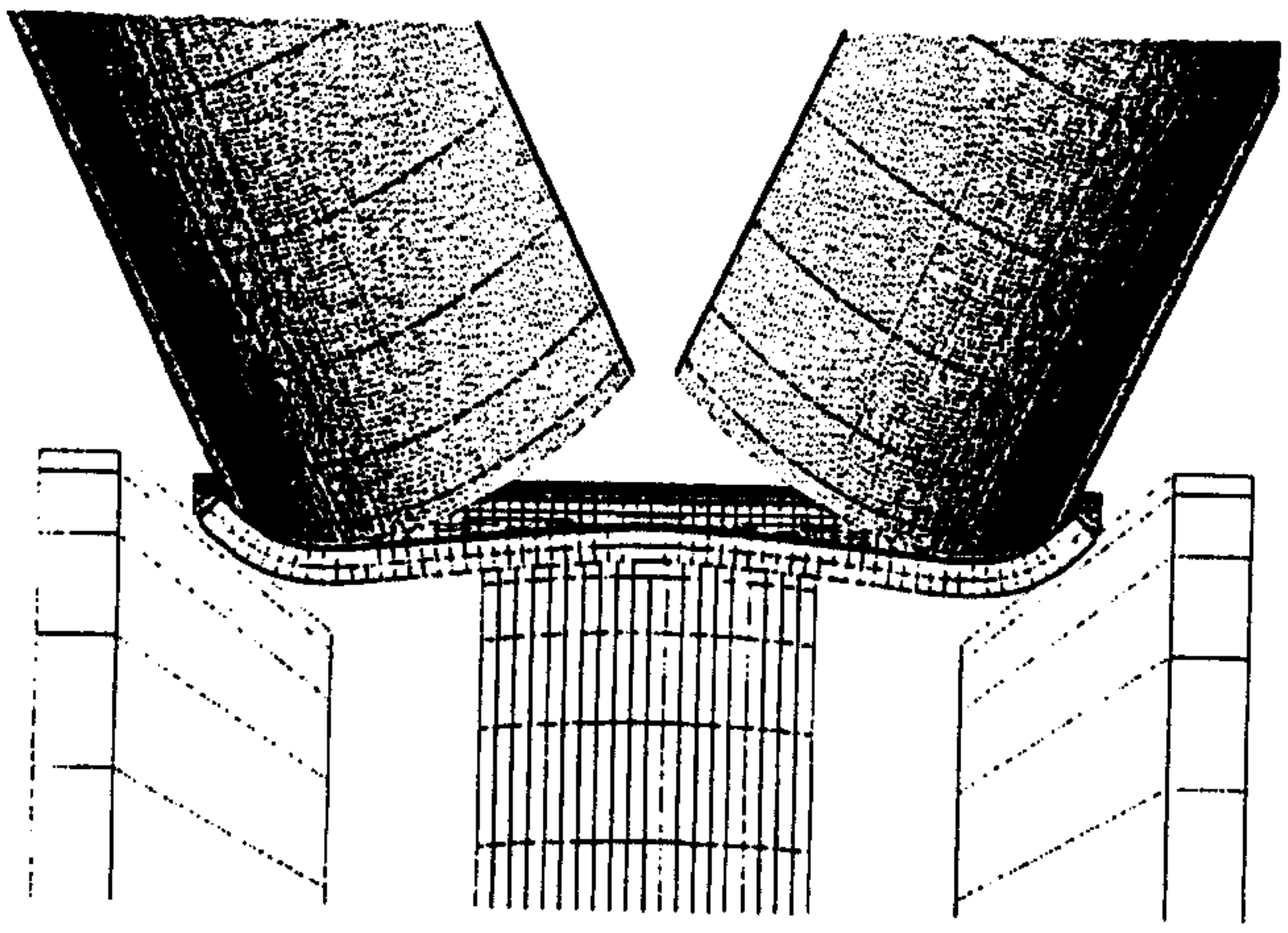


Fig. 8A

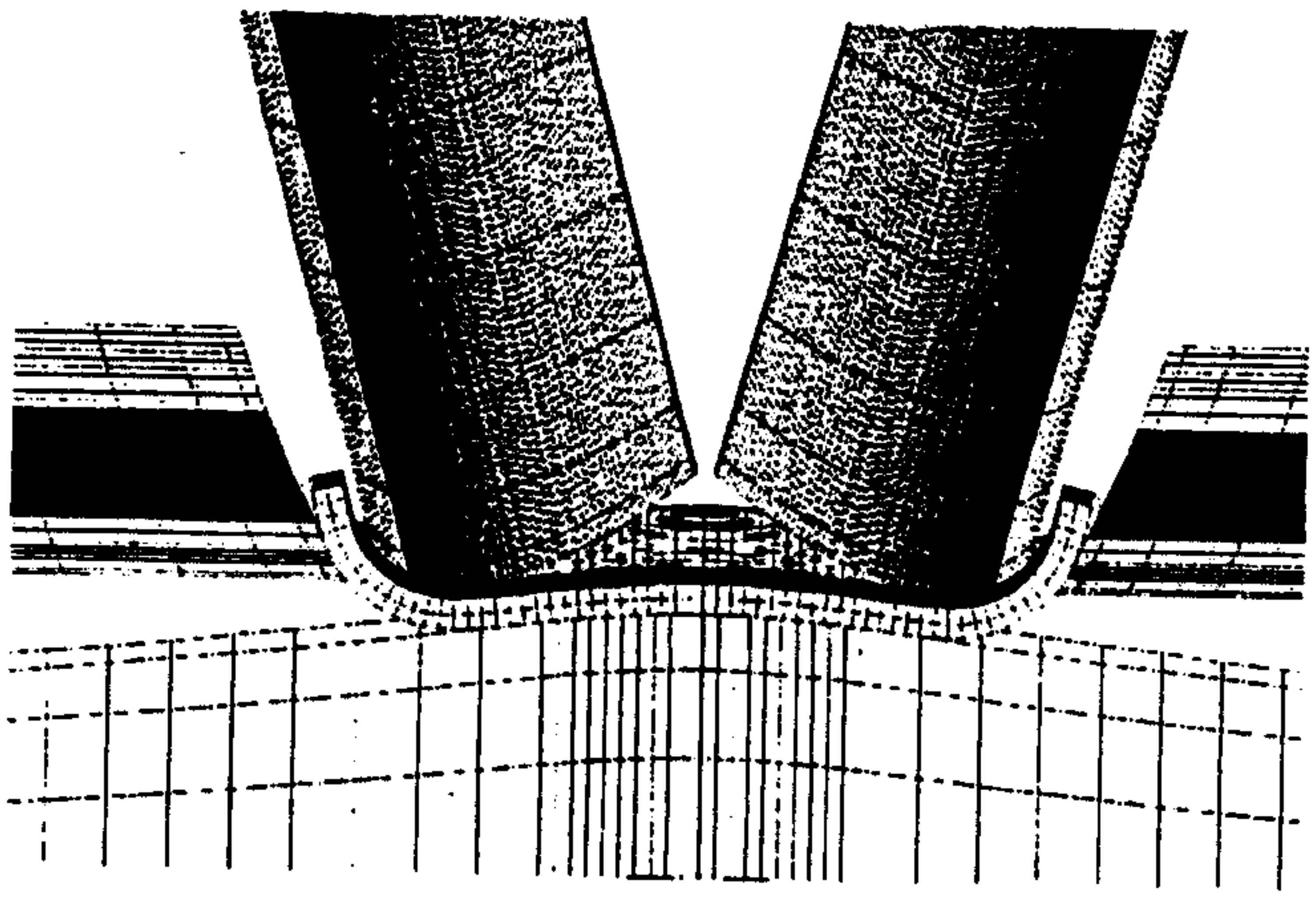


Fig. 8B

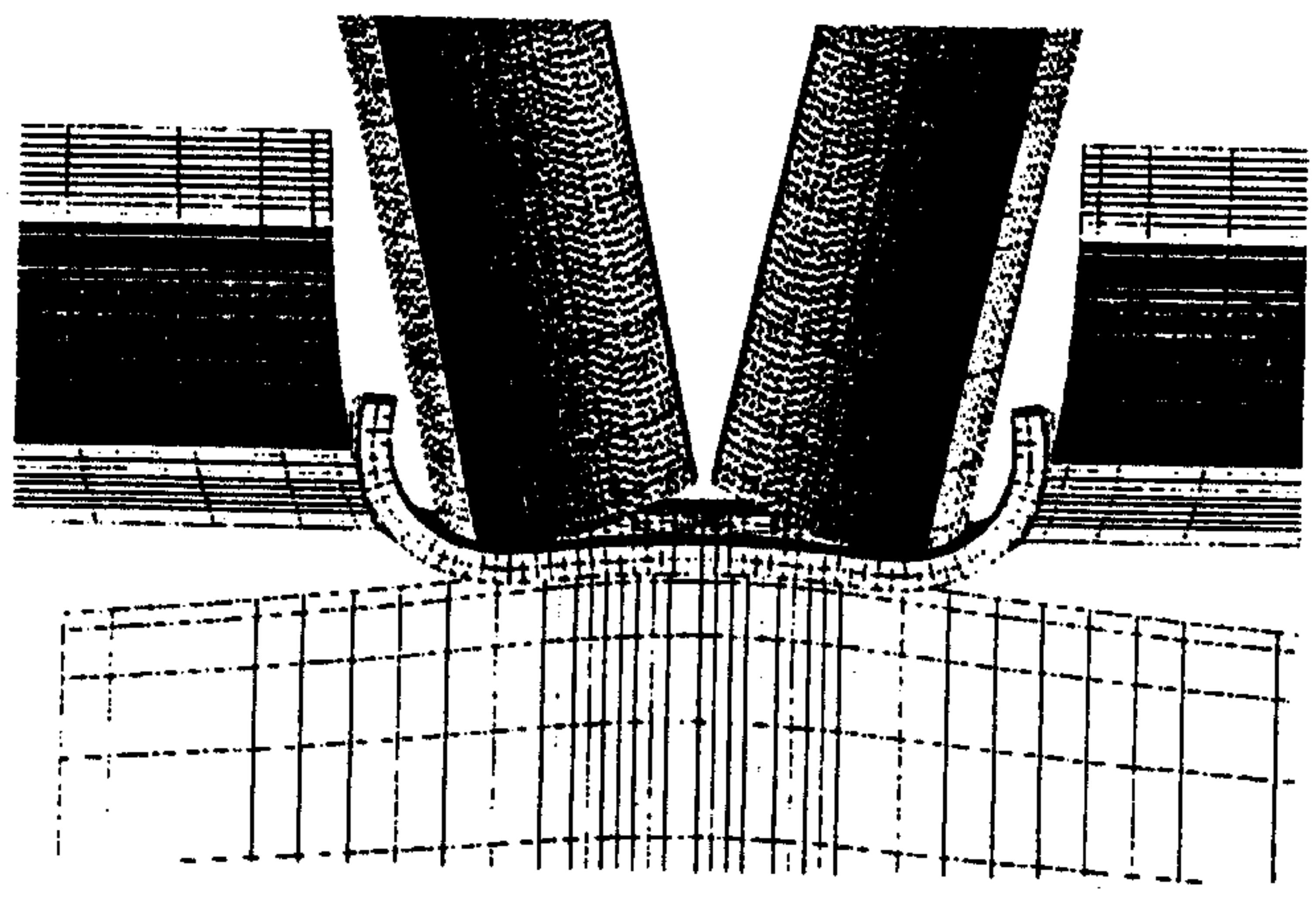


Fig. 8C

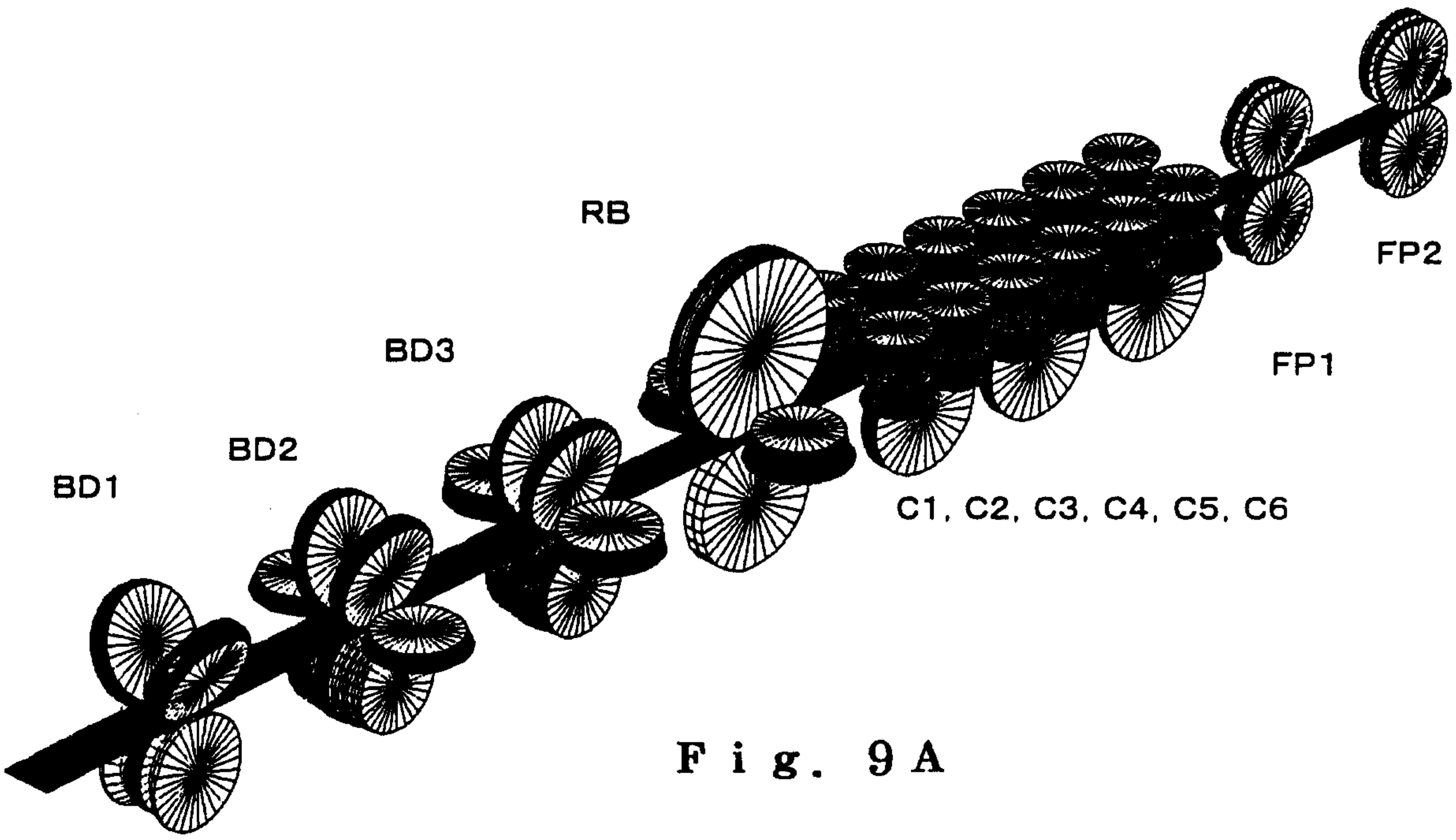


Fig. 9A

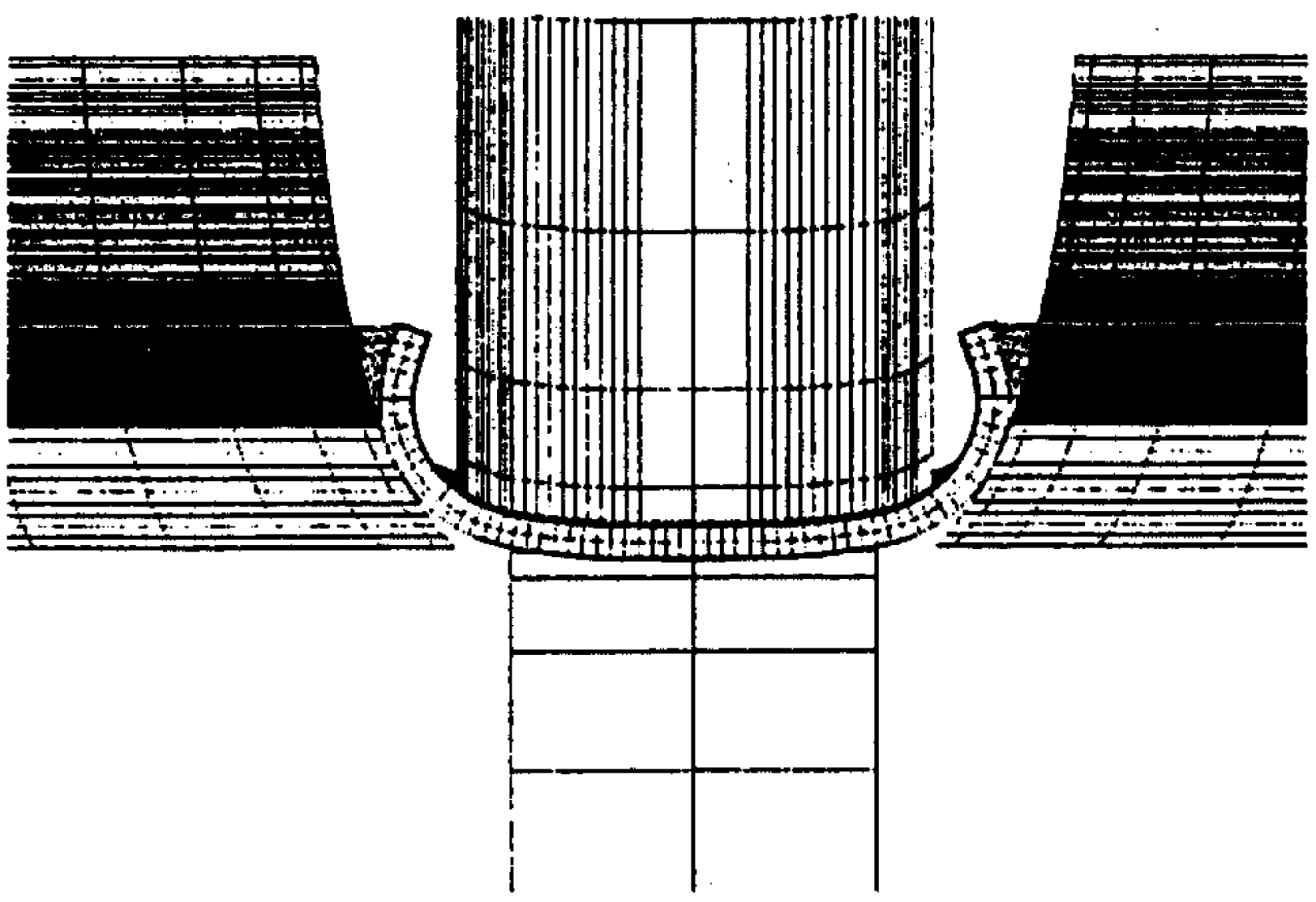


Fig. 9B

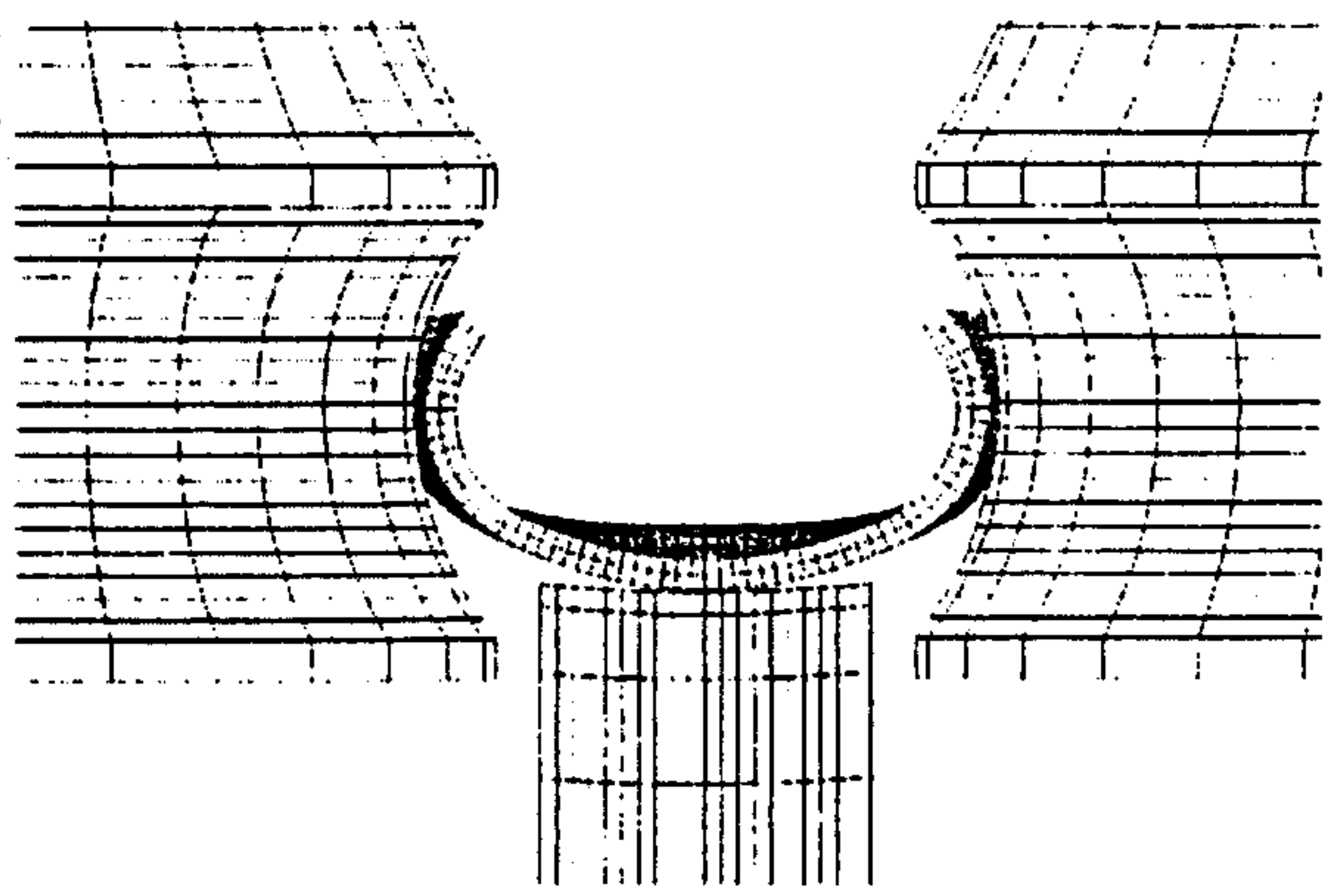


Fig. 9C

Fig.10A

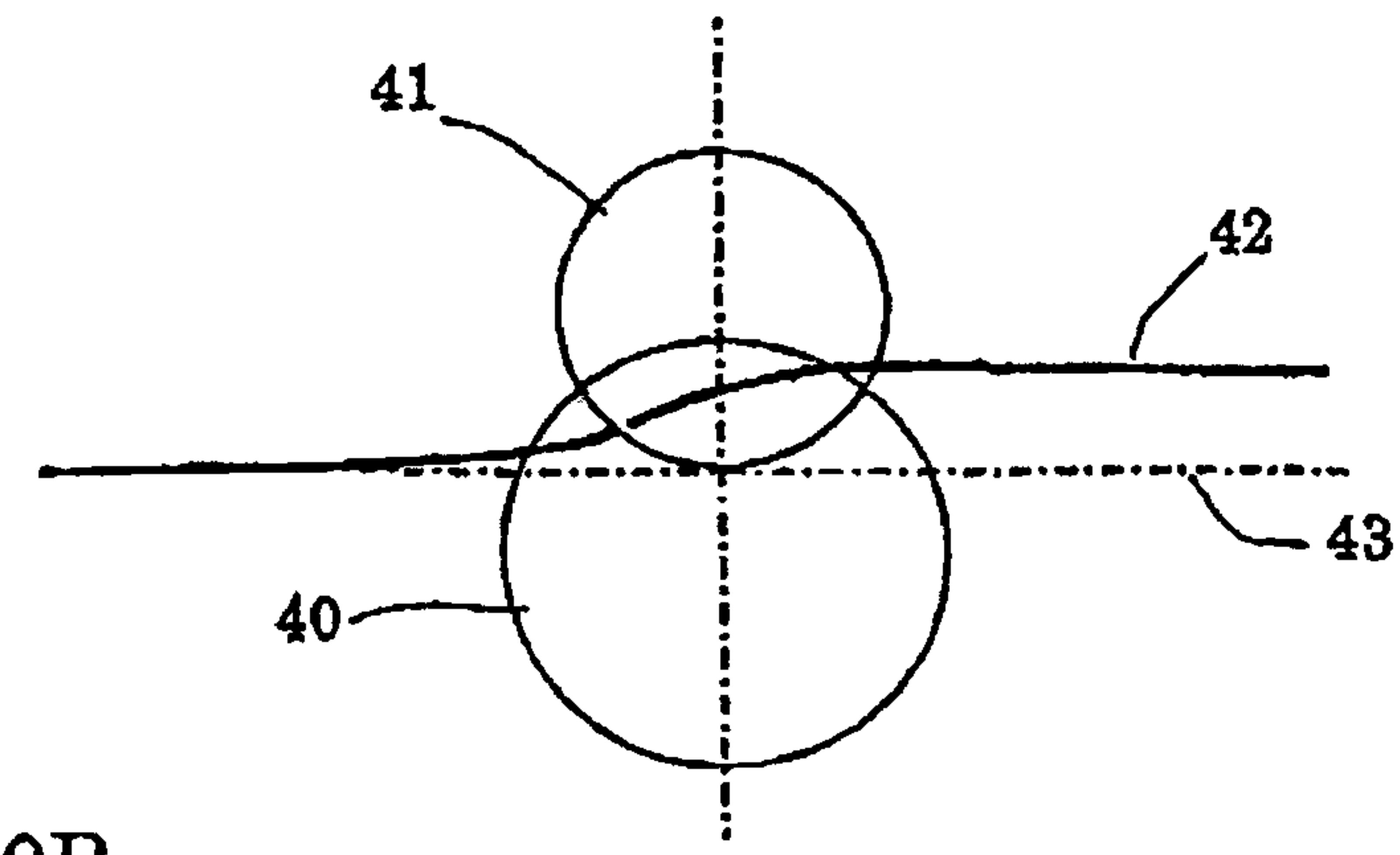


Fig.10B

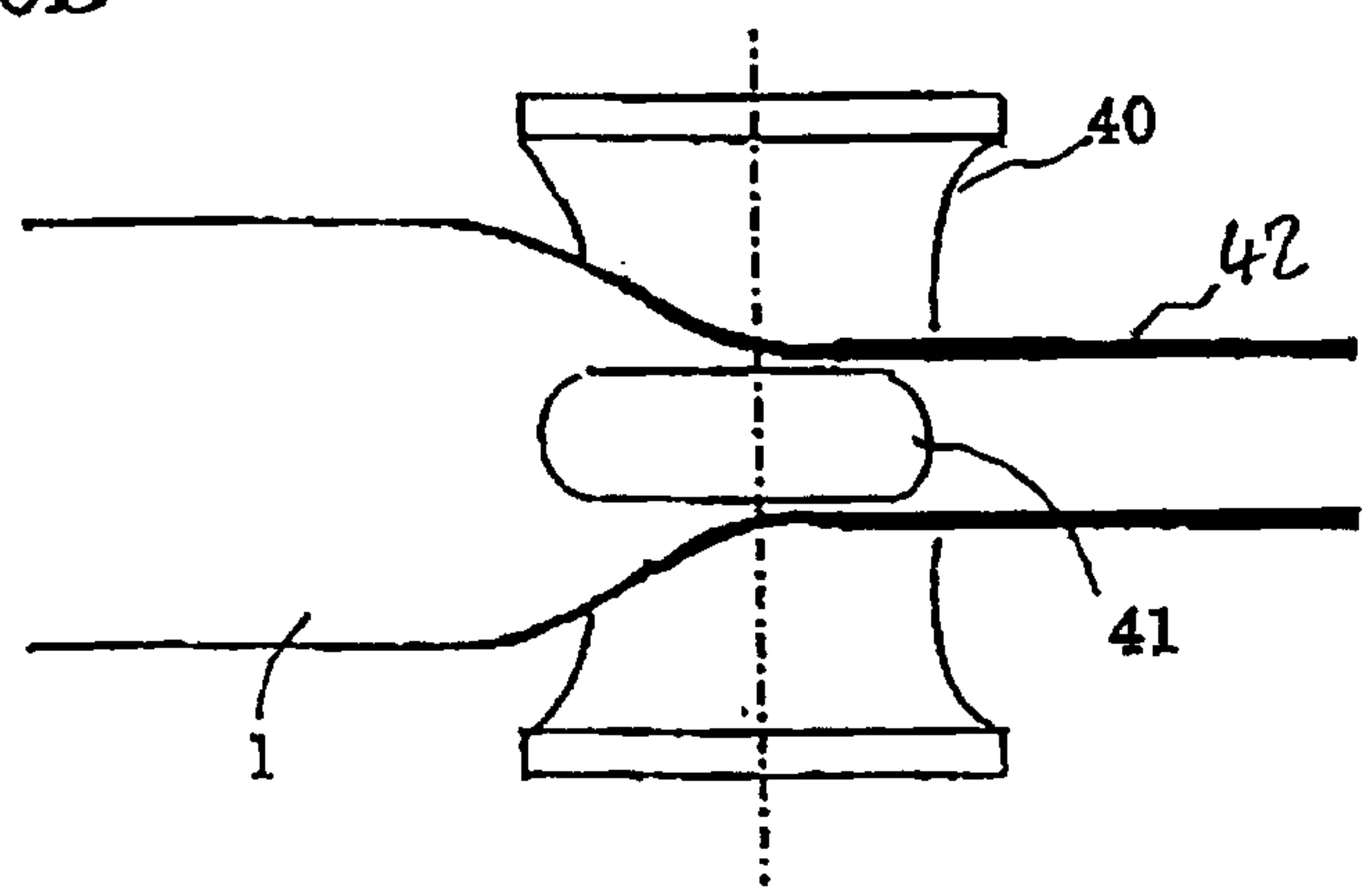


Fig.10C

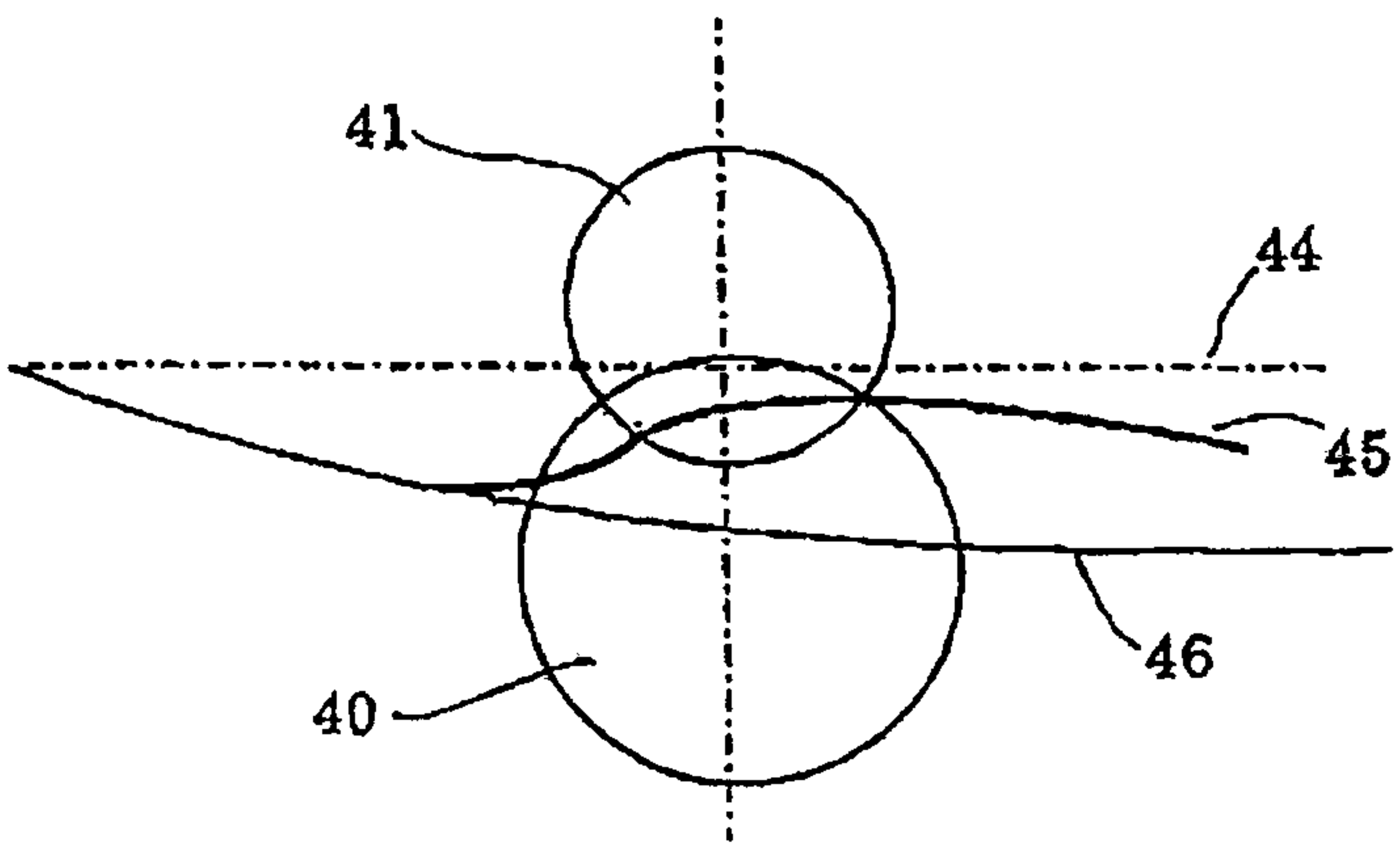


Fig.11A

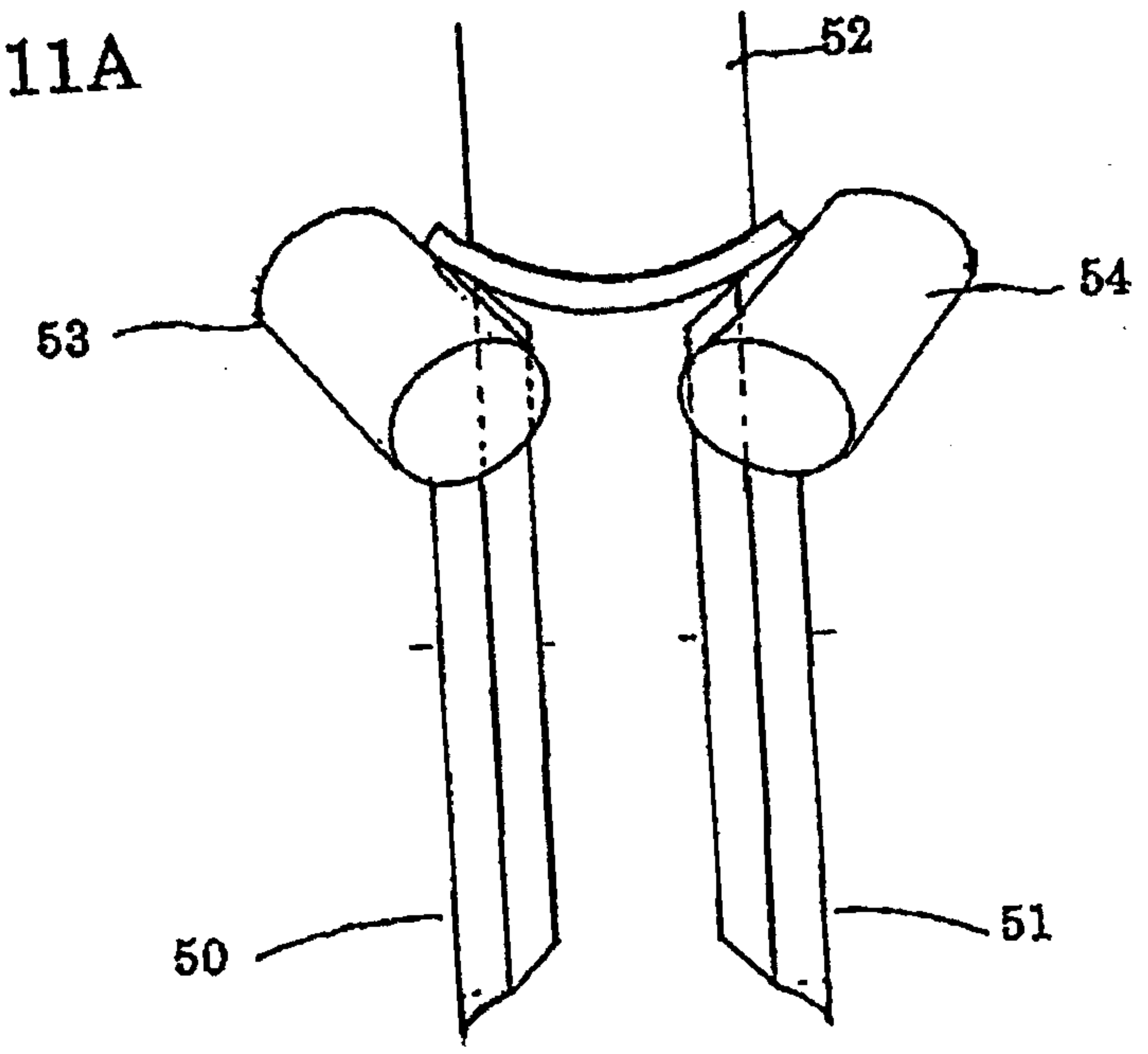
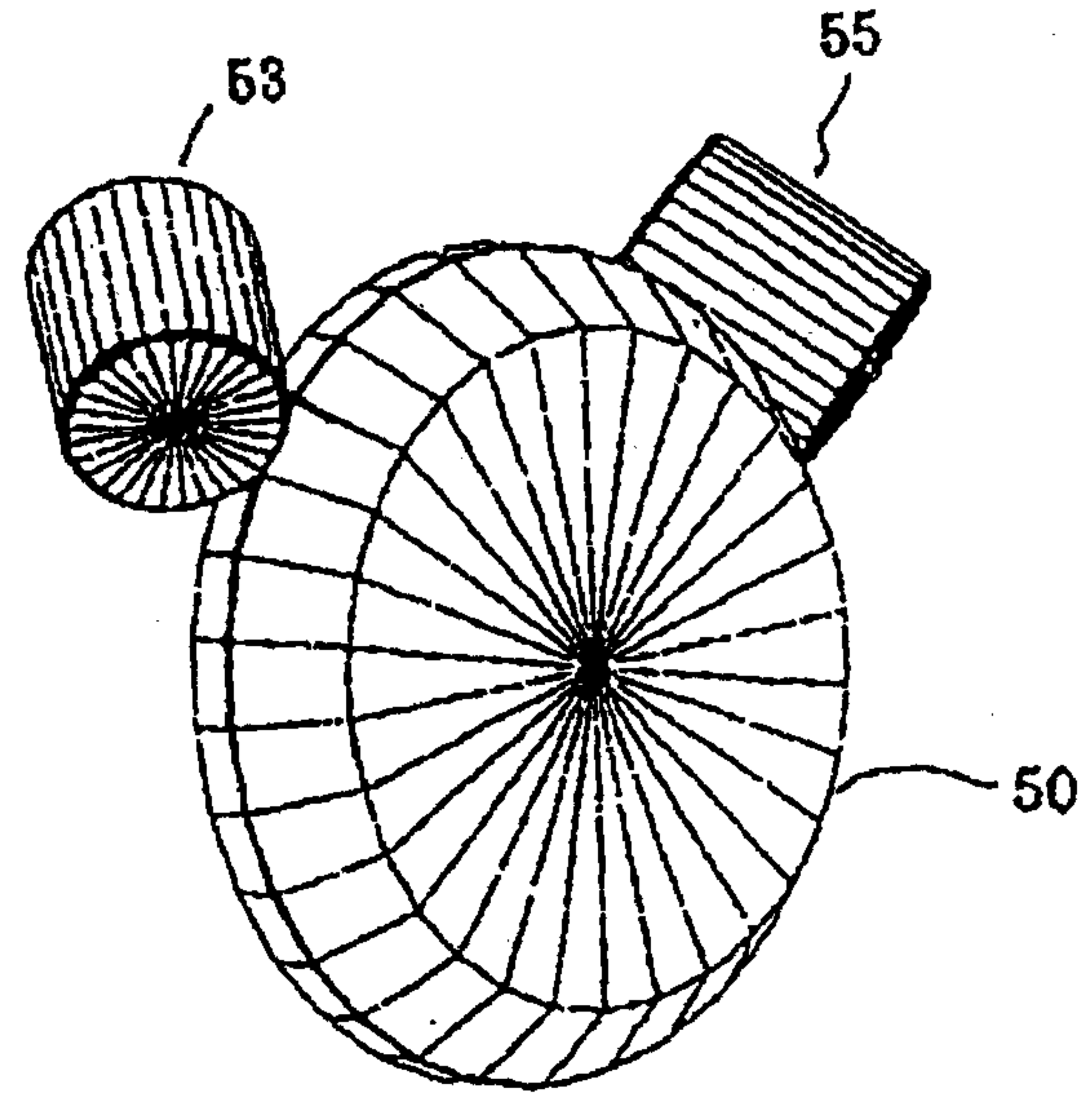
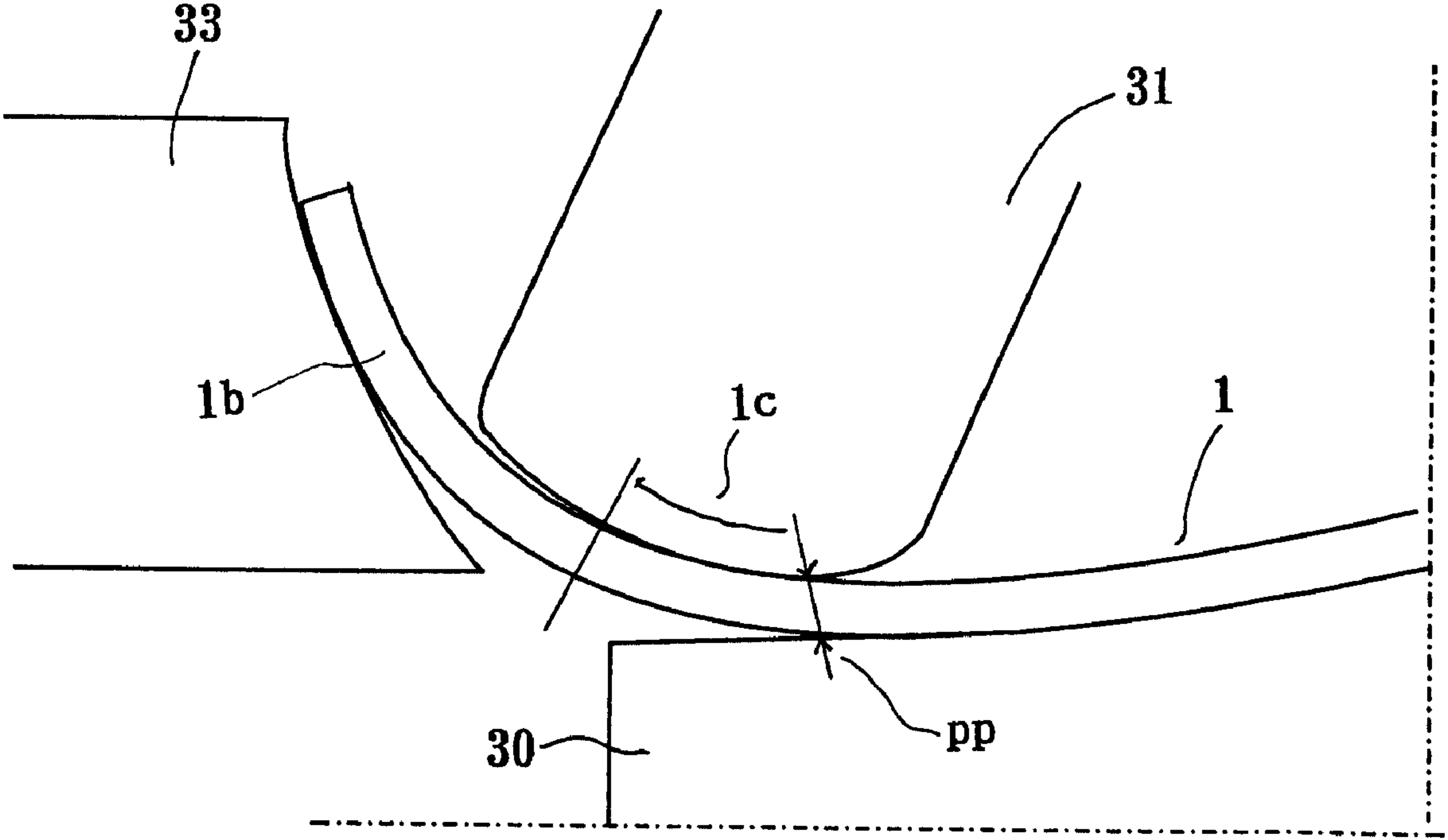


Fig.11B




33
31
1b
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30