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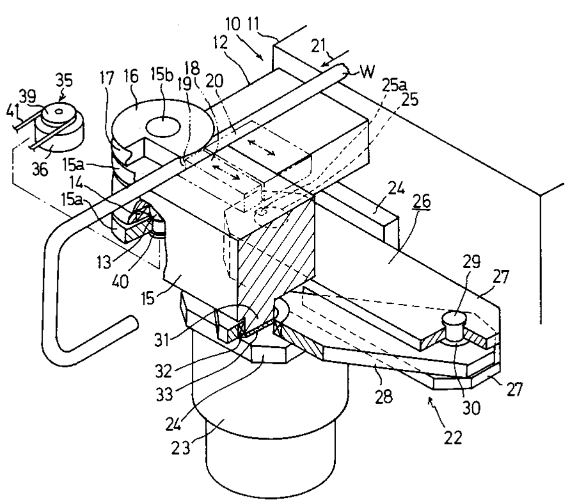
(54) Bending machine.

(57) A bend arm (15) is mounted for turning movement on a base frame (10). The bend arm (15) is provided with a bend die (16) and a clamp die (18). The bend arm (15) is connected by a link (28) with a drive arm (26) turned by a output shaft (25) of an electric motor (23). The turning output shaft (25) of the electric motor (23) turns the drive arm (26) directly and the bend arm (15) via the link (28). A work (W) clamped to the bend die (16) by the clamp die (18) is bent on the model of the bend die. The turning speed of the output shaft (25) of the electric motor (23) is controlled by a control system so that the bend arm (15) may be turned at a constant turning speed. It becomes thus possible to bend the work (W) at a prescribed angle accurately even with a bending machine having the electric motor as a drive source and the bend arm (15) moved via the link (28).

FIG. 1



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Background of the Invention

1. Field of the Invention

This invention relates to a bending machine in which a long work such as a pipe or a bar is sandwiched between a bend die and a clamp die and this, moving along a circular arc about the bend die, performs bending processes on the work.

2. Description of the Prior Art

Among conventional bending machines, there is one having the following structure. That is, a vertical shaft is provided for turning movement at the forward end portion of a base frame. The root portion of a bend arm is fixed at the intermediate portion of the shaft. A bend die is mounted on the upper end portion of the shaft and a clamp die to clamp a work to the bend die is mounted on the bend arm. A chain sprocket mounted at the lower portion of the shaft is connected by a chain to another chain sprocket mounted on the output shaft of an electric motor. The shaft of the bend arm is rotated, via the chain, by the electric motor and the work sandwiched between the bend die and the clamp die is bent on the model of the bend die. The bending machine of this type is exemplified by the specification of U.S.P No. 4,326,398.

The bending machine of this type is convenient since it can be operated by making use of a general purpose electric-power supply. In this machine, however, the sprocket disposed under the bend die is occasionally obstructive of bending processes on the work. For example, when the work is processed three-dimensionally, that is, when bending processes in different directions are performed one after another at plural places on the work, the front end portion of the work touches the sprocket at times.

As a bending machine to perform easily three-dimensional bending processes on the work, there is one having the following structure. That is, a bend arm is mounted for turning movement at the forward end portion of a base frame. The bend arm is provided with a bend die and a clamp die. A drive arm is mounted for turning movement at a place more backward than the place where the bend arm is mounted for turning movement in the base frame. The bend arm and the drive arm are connected by a link. An oil hydraulic cylinder is connected to the drive arm. When the oil hydraulic cylinder expands, the drive arm is turned and the bend arm is turned via the link. As a result, a work sandwiched between the bend die and the clamp die is bent on the model of the bend die. The bending machine of this type is exemplified by U.S.P. No. 4,938,047. This type of the bending machine, with an open space left under the bend die, can easily perform three-dimensional bending processes.

However, this type of the bending machine operated by the oil hydraulic cylinder requires large-scale incidental equipment such as oil hydraulic pumps and tanks.

The inventor tried to turn the drive arm by an electric motor in stead of the oil hydraulic cylinder. This is because any general purpose electric-power supply can be made use of as the drive source for the electric motor. That is, a simpler incidental equipment is sufficient for the electric motor compared with the oil hydraulic cylinder.

The bending machine with the drive arm adapted to be turned by the electric motor, however, has the following property. That is, the angle between the drive arm and the link and that between the link and the bend arm vary depending on the magnitude of the turn angle of the bend arm from its start position. Accordingly, the bending machine has the property that the turning speed of the bend arm varies following the change of the turn angle of the bend arm even though the drive arm is turned at a constant speed by the output shaft of the electric motor turning at a constant speed.

This property brings about a problem as described later in performing bending processes on the work. When the bending machine is operated to bend the work, the movements of the electric motor, the drive arm, the link and the bend arm are all affected by inertia. Accordingly, if the work is to be bent at a prescribed bend angle, the deceleration of the electric motor must be started when the bend arm has been turned through an angle smaller by a certain amount than a prescribed turn angle corresponding to the bend angle in order that the bend arm may be stopped without any shock accurately at the prescribed turn angle. On the other hand, the above mentioned property that the turning speed of the bend arm varies with the change of the turn angle of the bend arm brings about the following problem. Suppose that the deceleration of the bend arm is adjusted so that the bend arm may stopped just at the prescribed turn angle when it is equal to a specified angle. When the prescribed turn angle becomes another angle different from the specified angle, however, there appears a problem that the bend arm can not be stopped accurately at the prescribed turn angle because of the resulting change in the turning speed of the bend arm. If the turning speed of the bend arm is, for example, larger, the bend arm overruns the prescribed turn angle. If the turning speed of the bend arm is, on the contrary, smaller, the bend arm stops without reaching the prescribed turn angle. Either of these behaviors of the bend arm degrades the accuracy in the bend angle of the work.

Summary of the Invention

The present invention has been done in order to solve the above mentioned technical problems (technical objects).

An object of the present invention is to provide a bending machine capable of bending a work three-dimensionally with ease.

The construction of the present invention includes a bend arm adapted to be turned, via a link, by a drive arm disposed backward. Accordingly, only the bend arm is disposed under a bend die and an open space is left under the bend arm. The front end portion having been bent of a work can be freely situated in this open space. As a result, three-dimensional bending processes can be performed with ease.

Another object of the present invention is to provide a bending apparatus with an electric motor as a drive source for a drive arm. The electric motor has the convenience of being easily operated with use of a general purpose electric-power supply.

A still other object of the present invention is to provide a bending machine wherein the electric motor is used as the drive source and the bend arm is adapted to be driven by the link but the work can be bent accurately at a prescribed bend angle.

According to the present invention, the link is interposed between an output shaft of the electric motor and the bend arm but the bend arm is turned at a constant speed independently of the change in the turn angle of the bend arm by controlling the turning speed of the output shaft. This means that the turning speed of the bend arm is same at the time of starting the deceleration of the bend arm whatever the prescribed bend angle of the work may be when bending processes are performed on the work by the turning and deceleration of the bend arm due to the turning and deceleration of the electric motor, respectively. Accordingly, the bend arm can be stopped accurately at the prescribed turn angle by decelerating the electric motor in such a manner that the bend arm may be decelerated at a predetermined speed whatever the prescribed bend angle of the work may be. Namely, the work can be bent at the prescribed bend angle with a high accuracy.

Other objects and advantages of the invention will become apparent during the following discussion of the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a perspective view of a bending machine in partial section;
Fig. 2 is a side elevation of the bending machine;
Fig. 3 is a plane view of a drive mechanism for a bend arm;
Fig. 4 is a block diagram of a control system; and
Fig. 5 is a graph showing the relationship between the turn angle of a bend arm and the operation angle of an output shaft of an electric motor per 1° of the operation angle of the bend arm at the turn angle.

Description of the Preferred Embodiments

In Figs. 1, 2 and 3, a base frame 10 comprises a body frame 11 and a support frame 12 provided at the forward end of the body frame 11. A work W is supplied by a well known carriage (not shown) provided on the body frame 11 in a supply direction shown by an arrow 21 in Figs. 1 and 2. A pipe or a bar can be the work W and the cross section of the work may be circular or rectangular. In the present specification, the side toward which the work W is supplied (the right hand side in Fig. 2) is referred to as the forward side and the opposite side as the backward side. A vertical shaft 13 is mounted for turning movement on the support frame 12 by means of a taper roller-bearing 14. The top and bottom ends of the shaft 13 protrude from the support frame 12 upward and downward, respectively. A bend arm 15 is made bifurcate at the root portion thereof and bifurcate portions 15a and 15a are mounted on the protruding portions of the shaft 13. A shaft 15b to mount a bend die thereon is set up on the bend arm 15 in coaxial relationship with the shaft 13. A bend die 16 is mounted on the shaft 15b for dismount for exchange. The bend die 16 is formed, on the periphery thereof, with a groove 17 in which the work W fits. A clamp die 18 to clamp the work W to the bend die 16 is mounted on the bend arm 15 for movement in the longitudinal direction of the bend arm 15. The clamp die 18 is adapted to be transferred, in a well known manner, toward and away from the bend die

16 by a drive mechanism provided in the bend arm 15. The clamp die 18 is formed, at the side thereof facing the bend die 16, with a groove 19 in which the work W fits. On the support frame 12 is provided a receive die (called a pressure die as well) 20. The receive die 20 is adapted to receive the reaction force from the work when it is subjected to bending processes. The receive die 20 is adapted to be displaced in a horizontal direction perpendicular to the supply direction of the work W, as shown by an arrow, depending on the radius of the bend die 16 and the thickness of the work W.

In the next place, a drive mechanism 22 for turning the bend arm 15 together with the shaft 13 is explained. A driving electric motor 23 is mounted on a bracket 24 secured on the body frame 11. As this motor 23, a servomotor with a speed reducer is used. An output shaft 25 of the electric motor 23 is disposed vertically and more backward than the shaft 13. A drive arm 26 is secured, at one end thereof, to the output shaft 25 by a key 25a. The other end of the drive arm 26 is made bifurcate in the vertical direction. A link 28 connects the drive arm 26 and the bend arm 15. One end of the link 28 is disposed between bifurcate portions 27 and 27 and is connected, for turning movement, to a pin 29 secured in the bifurcate portions 27 and 27 by means of a bearing 30. The other end of the link 28 is connected, for turning movement, on a connection shaft 31 formed protrudingly from the bottom surface of the bend arm 15 by means of a bearing 32. An end cap 33 is adapted to prevent the link 28 from dropping off from the connection shaft 31.

As shown in Fig. 2, a detection mechanism 35 to detect the turn angle of the bend arm 15 is provided under the support frame 12. An encoder 36 used as an angle detector is mounted on the support frame 12 by means of stays 37. A timing pulley 39 is mounted on a rotation shaft (input shaft) 38 of the encoder 36. Another timing pulley 40 is mounted under the bifurcate portions 15a of the bend arm 15 in coaxial relationship with the shaft 13. A timing belt 41 connects both timing pulleys 39 and 40.

Now in reference with Fig. 3, the relationship among the bend arm 15, the drive arm 26, the link 28 and so on is explained. These members together with the aforementioned base frame 10 and the bracket 24 both functioning as a fixed link form a four-link mechanism. In the present embodiment, the relationship among the lengths L1 through L4 of respective links, that is, the distance L1 between the center 01 of the shaft 13 and the center 02 of the output shaft 25, the distance L2 between the center 01 of the shaft 13 and the center A of the connection shaft 31, the distance L3 between the center 02 of the output shaft 25 and the center B of the pin 29 and the distance L4 between the center A of the connection shaft 31 and the center B of the pin 29 is represented by the following inequality (1).

$$L3>L4>L2>L1 \qquad (1)$$

More concretely, L1 is 62.2 mm, L2 is 70 mm, L3 is 122 mm and L4 is 98.7 mm. With these numerals, the turn angle α of the bend arm 15 amounts to about 180° when the turn angle θ of the drive arm 26 is about 100° . Namely, the bend arm 15 is turned through an angle enlarged from the turn angle of the drive arm 26. The unequal relationship among the lengths of the respective links is not limited to that represented by inequality (1) but may be determined in such a way that a desired turn angle α of the bend arm 15 can be obtained for the turn angle θ of the drive arm 26.

Next in reference with Fig. 4, a control system 50 for the electric motor 23 is explained. The control system 50 comprises a bend angle setting means 51, a comparing means 52, servo amplifying means 53, a correcting means 54, a drive amplifying means 55 and the aforementioned angle detector 36. The bend angle setting means 51, the comparing means 52, the servo amplifying means 53 and the drive amplifying means 55 are same as those in a well known servo control mechanism. The correcting means 54 is intended for making a correction described later to the output of the servo amplifying means 53. The respective means represented by reference numerals 51 through 55 consist, for example, of computer hard wares and soft wares. These means, however, may consist of discrete electric circuits and then the respective means are referred to as a bend angle setter 51, a comparator 52, a servo amplifier 53, a correcting circuit 54 and a drive amplifier 55. Both constructions of the control system are not different in functions. The drive arm 26, the link 28 and the bend arm 15 all aforementioned are shown as members constituting a driven system 56.

Next, bending processes performed by the above mentioned bending machine on the work W are explained. When the bend arm 15 is at a start position shown by solid lines in Fig. 1 or 3 (a position where the bend arm 15 is perpendicular to the supply direction 21 of the work W in the present embodiment), the work W is supplied in the direction shown by the arrow 21 and a first place to be subjected to a bending process is positioned between the bend die 16 and the clamp die 18. Then this place is clamped to the bend die 16 by the clamp die 18. Furthermore, the receive die 20 is suitably displaced in the direction of the arrow and is caused to touch the work W. Next, the electric motor 23 is actuated under the control by the control system 50. The drive arm 26 is turned clockwise in Fig. 3 by the turning output shaft 25 of the electric motor 23. The turning force of the drive arm 26 is transmitted to the bend arm 15 via the link 28 and the bend 15 arm is turned clockwise. The bend die 16 and the clamp die 18 both on the bend arm 15, with the work W sandwiched therebetween, is turned about the center of the bend die 16 and the work W is bent on the model of the bend die 16. The bend arm 15 is turned up to a prescribed turn angle corresponding to a prescribed bend angle of the work W (an angle equal to the sum of the prescribed bend angle and the spring back of the work W). After the bend arm 15 has been turned through the prescribed turn angle, the electric motor 23 is stopped, the clamping of the work W by the clamp die 18 is released and the bend arm 15 is returned, by the reversal of the output shaft 25 of the electric motor 23, to the original start position. Thus the bending process at the first place is completed.

Operations of the type as mentioned above are repeated one after another at places on the work W to be subjected to bending processes and the work W is processed to be formed in a prescribed three-dimensional shape.

Next, the control of the electric motor 23 by the control system 50 in the case of the above mentioned bending process on the work W is explained. The prescribed turn angle of the bend arm 15 is beforehand set in the bend angle setting means 51. On the other hand, the turn angle from the start position of the bend arm 15 is detected by the angle detector 36. The comparing means 52 compares a signal given by the angle setting means 51 for the prescribed turn angle with a signal given by the angle detector 36 for a detected turn angle and outputs a signal in accordance with the difference of both signals. The servo amplifying means 53 receives the difference signal and outputs a signal (such as a voltage signal) corresponding to a turning speed at which the output shaft 25 of the electric motor 23 should be turned. In this case, the correcting means 54 receives the signal for the detected angle from the angle detector 36 and gives the servo amplifying means 53 a correction factor (a correction factor of the turning speed of the output shaft 25). Consequently, the output signal from the servo amplifying means 53 is a signal corrected with the correction factor. The drive amplifying means 55 receives the signal from the servo amplifying means 53 and supply electric power to the electric motor 23 in accordance with the signal. The output shaft 25 of the electric motor 23 is turned by the electric power to drive the driven system 56.

The correction by the correcting means 54 is explained here. In the driven system 56, the turning movement of the drive arm 26 actuated by the electric motor 23 is transmitted to the bend arm 15 via the link 28 and the bend arm 15 is turned. In this case, the angle between the drive arm 26 and the link 28 and the angle between the link 28 and the bend arm 15 vary in accordance with the magnitude of the turn angle measured from the start position of the bend arm 15. Thus the relationship between the turn angle of the bend arm 15 and the operation angle (change in turn angle) of the output shaft 25 of the electric motor 23 per certain operation angle (such as 1°) of the bend arm 15 at its instantaneous turn angle becomes, for example, such as shown in columns (a) and (b) of Table 1 presented later. Namely, this relation is represented by a curve shown in Fig. 5. Therefore, in the correcting means 54 are beforehand memorized those correction factors as shown in column (c) of Table 1 which cause the turning speed of the output shaft 25 of the electric motor 23 to vary along the curve of Fig. 5 as the turn angle of the bend arm 15 varies. The correction factors in column (c) have been obtained by dividing respective values in column (b) by that value in column (b) at the interval from 51° to 60° of the turn angle of the bend arm 15 which has been taken as an example of a reference value.

TABLE 1

(a) TURN ANGLE OF THE BEND ARM 15(°)	(b) OPERATION ANGLE OF THE OUTPUT SHAFT 25 PER 1° OF THE OPERATION ANGLE OF THE BEND ARM 15 (°)	(c) CORRECTION FACTORS
0~10	0. 601	0. 93
11~20	0. 635	0. 98
21~30	0. 652	1. 01
31~40	0. 659	1. 01
41~50	0. 657	1. 01
51~60	0. 650	1. 00
61~70	0. 638	0. 98
71~80	0. 622	0. 95
81~90	0. 604	0. 93
91~100	0. 582	0. 89
101~110	0. 560	0. 86
111~120	0. 536	0. 83
121~130	0. 513	0. 79
131~140	0. 490	0. 76
141~150	0. 470	0. 72
151~160	0. 453	0. 69
161~170	0.438	0. 68
171~180	0. 431	0. 66
181~190	0. 430	0. 66
191~195	0. 428	0. 66

The above mentioned correction factors are given to the servo amplifying means 53 by the correcting means 54 and the servo amplifying means 53 outputs a signal for turning the output shaft 25 of the electric motor 23 at a speed equal to the product of a speed determined by the signal from the comparing means 52 and the correction factor.

As a result of the controlled turning with the above mentioned correction of the electric motor 23, the turning speed of the output shaft 25 of the the electric motor 23 varies along the curve shown in Fig. 5 as the turn angle of the bend arm 15 varies. Thus the bend arm 15 is turned at a constant speed independently of the turn angle thereof.

When the turn angle of the bend arm 15 turning at the constant speed reaches an angle (referred to as a deceleration-start angle) smaller by a certain deceleration angle such as 10° than the prescribed turn angle, the electric motor 23 is decelerated in the following manner. Namely, when the signal from the comparing means 52 agrees with the signal for the certain deceleration angle, the servo amplifying means 53 decreases the output thereof. The output of the drive amplifying means 55 is decreased in turn and the turning speed of the output shaft 25 of the electric motor 23 is reduced. In this case, the servo amplifying means 53 decreases the output thereof on the basis of the signal from the comparing means 52 in such a manner that the turning speed of the bend arm 15 decreases by a prescribed amount such as the speed (constant speed) of the bend arm 15 divided by the deceleration angle at every time when the turn angle of the bend arm 15 increases, for example, by 1° . Thus the bend arm 15 is smoothly decelerated and is stopped accurately at the prescribed turn angle.

Next, various embodying manners are explained. When the bending machine is constructed so that the front end portion of the support frame 12 is disposed over the root portion of the bend arm 15, the bend die

16 may be mounted for turning movement on the base frame 12 in coaxial relationship with the center of turning of the bend arm 15. In this case, the work W is bent by the turning bend arm 15 similarly as in the case of the aforementioned embodiment. On the other hand, in the present case, the bend die 16 may be mounted fixedly on the support frame 12. Then the clamp die 18 revolutes about the bend die 16 as the bend arm 15 is turned. Consequently, the work W is pressed, at portions thereof one after another nearer to the front end thereof, against the bend die 16 by the clamp die 18 and is bent on the model of the bend die 16. In a still other embodiment, a bend die provided with upper and lower groves of different radii and a clamp die provided with upper and lower grooves conformable with the grooves of the bend die may be used. Furthermore, by determining the distances L1 through L4 properly, the bend arm 15 may be turned through an angle reduced from the turn angle θ of the drive arm 26. Namely, the bend arm 15 may be caused to generate a bending torque larger than the turning torque of the output shaft 25 of the electric motor 23.

As is mentioned above, it is an effect of the bending machine according to the present invention that three-dimensional bending processes can easily be performed on the work with the aforementioned objects attained, the bending machine, moreover, can be operated by making use of the general purpose electric-power supply and furthermore, the work can be bent at the prescribed bend angle with a high accuracy.

As many apparently different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific embodiments thereof except as defined in the appended claims.

Claims

1. A bending machine comprising

(a) a base frame,

(b) a bend arm mounted for turning movement at the forward end portion of said base frame,

(c) a bend die disposed in coaxial relationship with the center of turning of said bend arm,

(d) a clamp die mounted, for clamping a work, on said bend arm,

(e) a drive arm mounted for turning movement at a place situated more backward than the place where said bend arm is mounted for turning movement, and

(f) a link connecting said bend arm and said drive arm, wherein said bending machine further comprising

(g) an electric motor to turn said drive arm, the output shaft of said electric motor being connected to said drive arm and

(h) a control system for controlling the turning speed of said output shaft so that the turning speed of said bend arm may be constant.

2. A bending machine as set forth in claim 1 wherein the distance from the center of turning movement of said drive arm to the place where said link is connected to said drive arm is larger than the distance from the center of turning movement of said bend arm to the place where said link is connected to said bend arm.

3. A bending machine as set forth in claim 1 or 2, wherein said control system comprises an angle detector adapted to detect the turn angle of said bend arm, a bend angle setting means adapted to set a prescribed angle through which said bend arm is to be turned, a comparing means adapted to receive a signal for said prescribed angle from said angle setting means and a signal for said turn angle from said angle detector and to output a signal in accordance with the difference of said both signals, a correcting means adapted to receive a signal for said turn angle from said angle detector and to give a correction factor for said turn angle, a servo amplifying means adapted to receive said signal from said comparing means and said correction factor from said correcting means and to output a signal for turning said electric motor at a turning speed which is determined by said signal from said comparing means and corrected with said correction factor from said correcting means, and a drive amplifying means adapted to receive said signal from said servo amplifying means and to actuate said electric motor.

FIG. 1

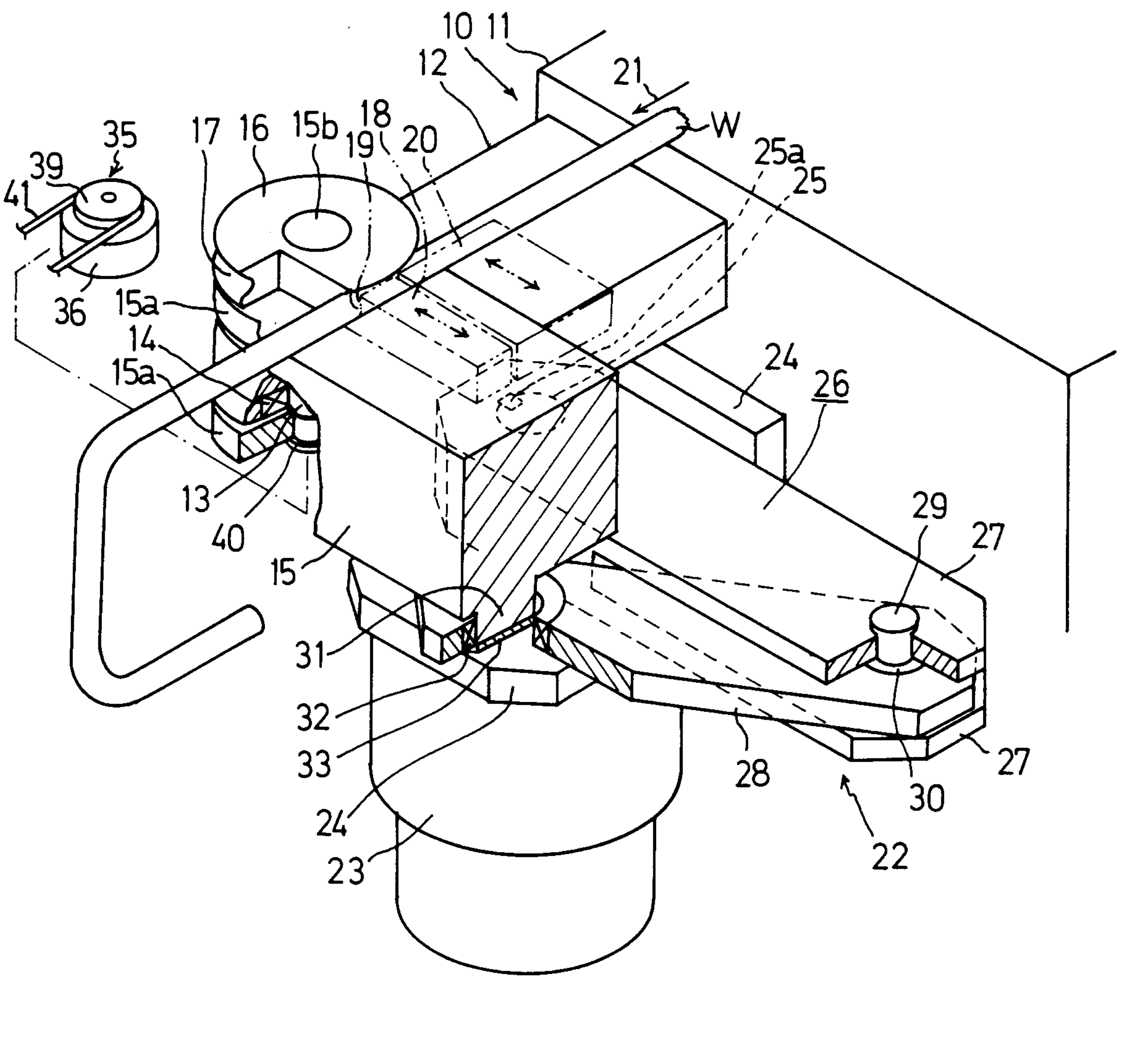
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FIG. 2

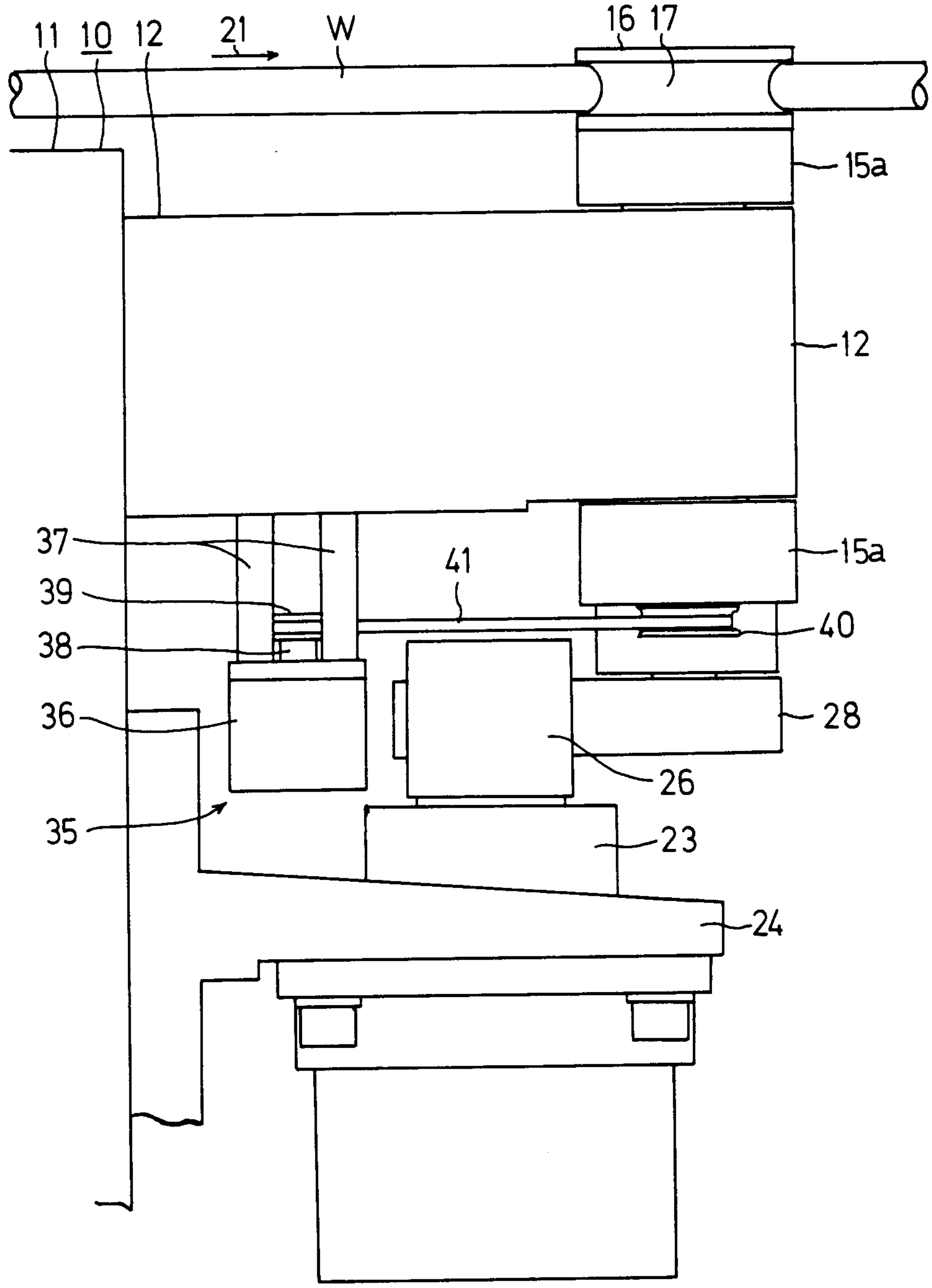


FIG. 3

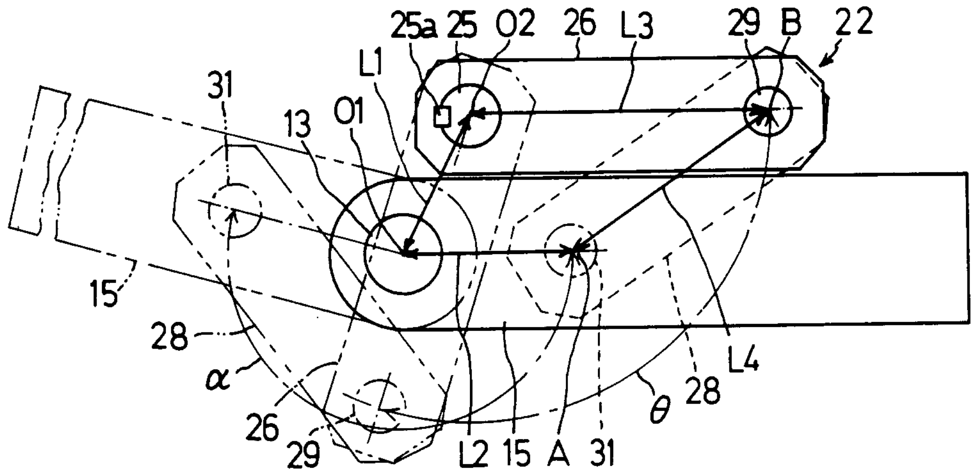


FIG. 4

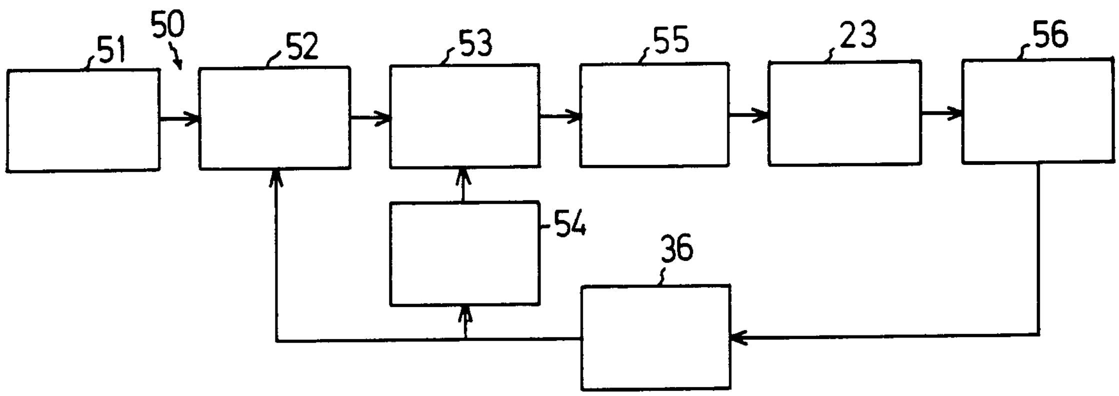
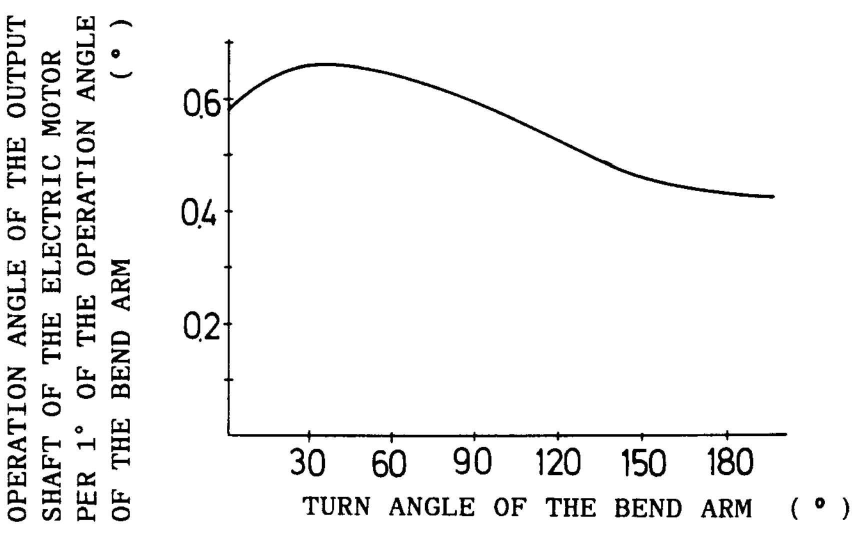


FIG. 5



European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 11 7235

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	US-A-4 552 006 (TERUAKI YOGO) * the whole document *	1,3	B21D7/024 B21D7/12
Y	US-A-4 719 577 (ELEY) * claims; figures *	1,3	
D,A	EP-A-0 370 485 (YOGO TERUAKI) * figures *	2	
A	GB-A-2 235 640 (USIU KOKUSAI SANGYO KAISHA LIMITED)		
A	US-A-4 750 346 (EATON)		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 DECEMBER 1992	PEETERS L.

CATEGORY OF CITED DOCUMENTS

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