# United States Patent [19]

**Iida**

[11] **3,869,897**

[45] **Mar. 11, 1975**


[54] **APPARATUS FOR CORRECTING DEFORMATION OF A SLENDER METALLIC PRODUCTS**


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[22] Filed: **Dec. 18, 1973**

[21] Appl. No.: **425,850**

[52] **U.S. Cl.** ..... **72/125,** 72/112

[51] **Int. Cl.** ..... **B21d 3/00**

[58] **Field of Search** ..... 72/112, 120, 121, 125, 72/318; 140/147



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*Attorney, Agent, or Firm*—Henry R. Lerner



[57] **ABSTRACT**

The present invention relates to an apparatus for correcting deformation of a slender metallic product using the so-called "Bauschinger Effect" which comprises a fixed support to fix a part of a slender metallic product thereon, a fixing means to forcibly fix a deformed part of said product fixed on said support at a position in which there is substantially no deformation, a swing motion creating means to give a swing motion to said fixing means, said swing motion being of the type of that initially the center of amplitude is on the center of the swing motion and in one direction grows gradually larger, and then is reversed in the opposite direction, and a swinging board which is engaged with said swing motion creating means and swings upwards and downwards, and from left to right.


**8 Claims, 10 Drawing Figures**

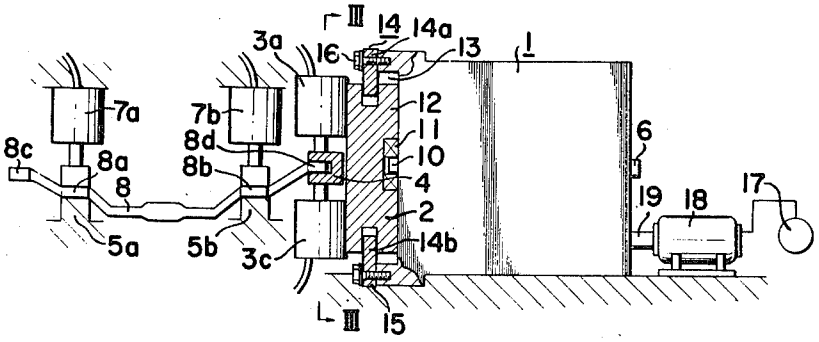
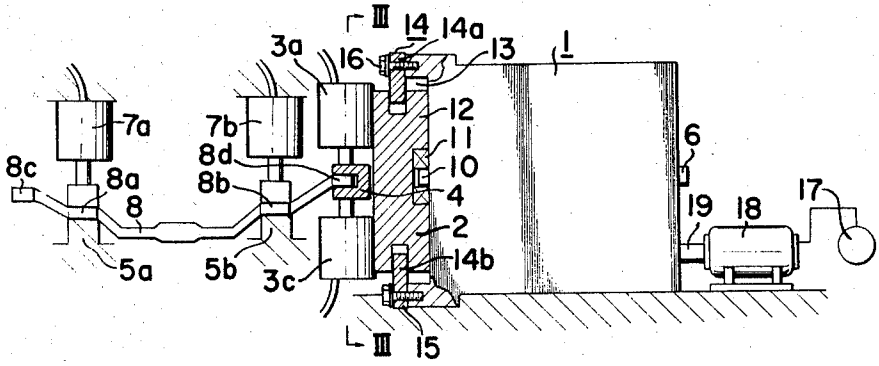


FIG. 1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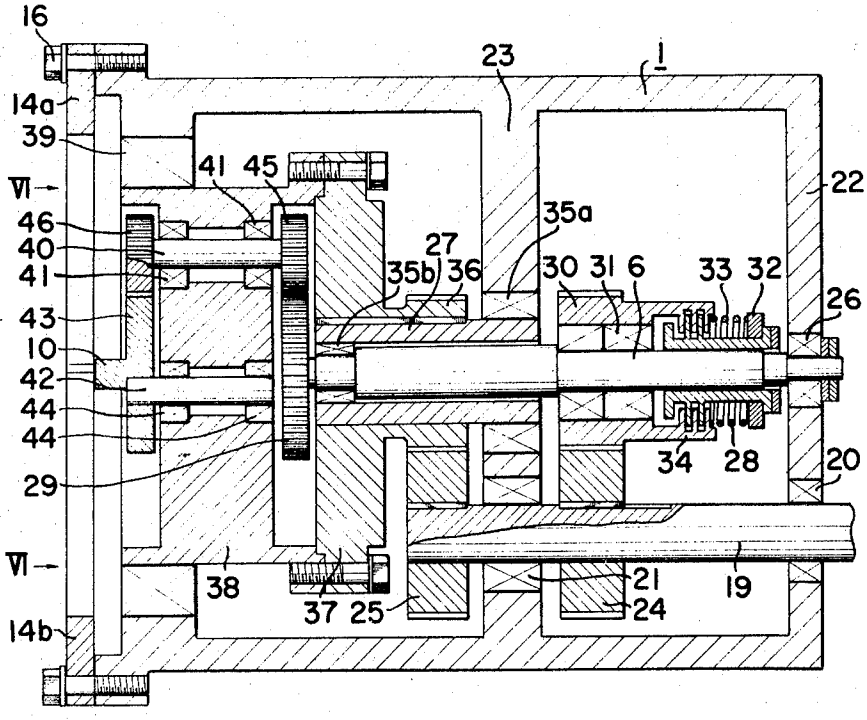
3a
16
13
1
12
11
10
4
2
14b
7a
7b
8d
8b
8c
8a
8
5a
5b
3c
6
19
18
17
III
15

FIG. 2


16
14a
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VI
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40
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42
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44
29
VI
14b
41
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1
22
35a
27
35b
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6
33
32
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38
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21
24
19

FIG. 3

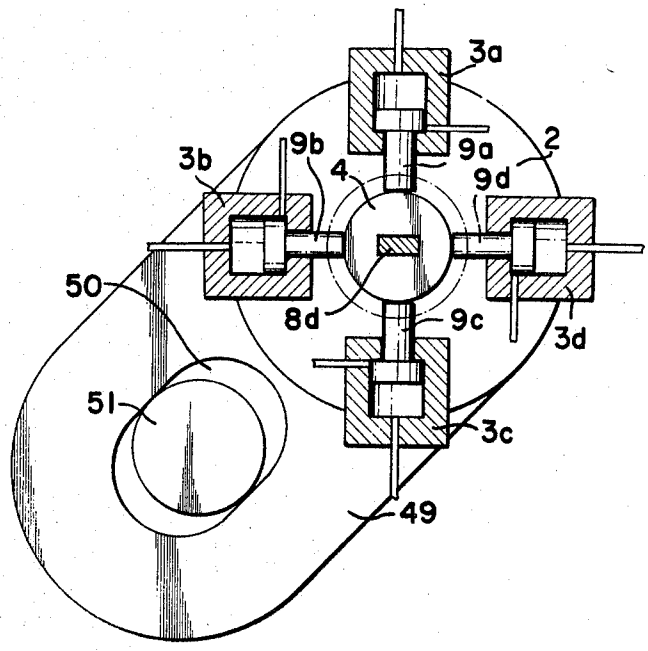



FIG. 4

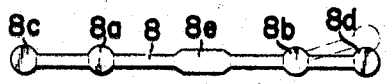



FIG. 5

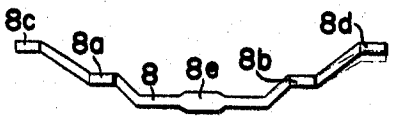


FIG. 6

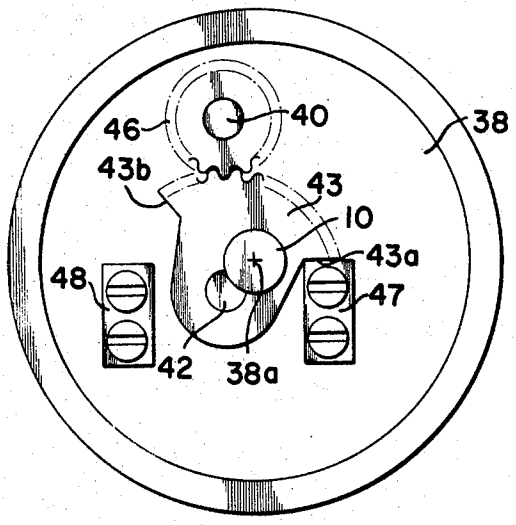
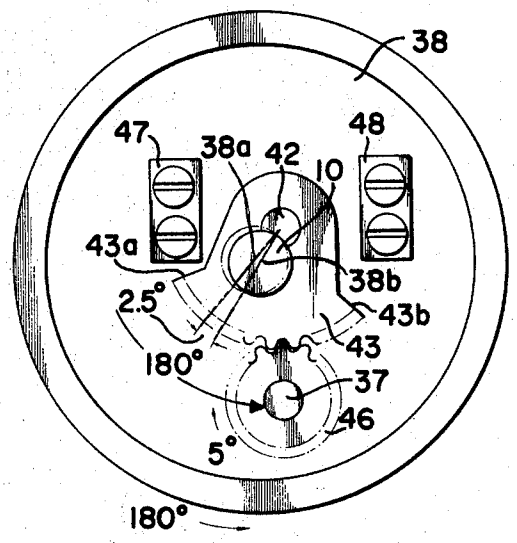

46
40
38
43b
43
10
43a
48
47
42
38a

FIG. 7


38
47
38a
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48
43a
38b
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43b
180°
43
37
46
5°
180°

FIG. 8

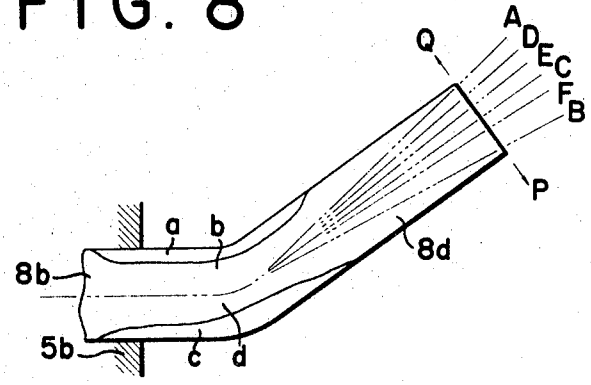



FIG. 9

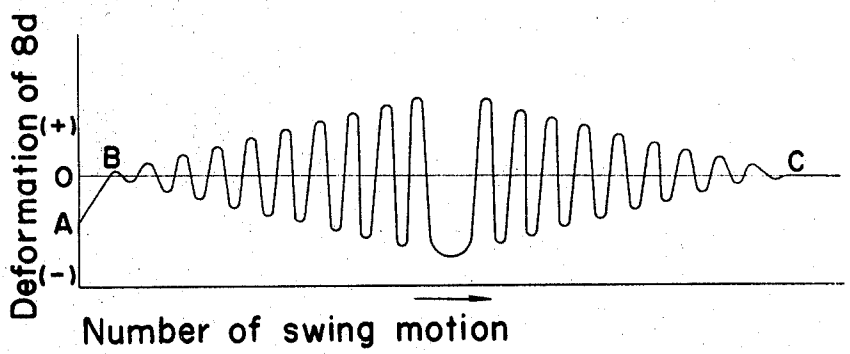
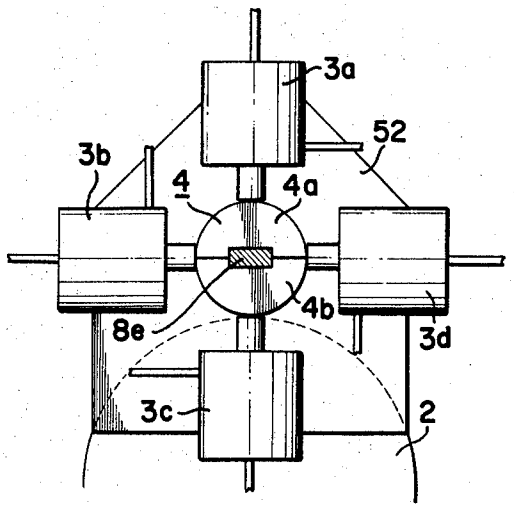



FIG. 10



# APPARATUS FOR CORRECTING DEFORMATION OF A SLENDER METALLIC PRODUCTS

The present invention relates to an apparatus for correcting deformation of a slender metallic product.

A deformation of a slender metallic product, excepting such as a round rod having a simple form of a circular section and being elongated longitudinally, had hitherto corrected only by hand finishing, and therefore, such correcting operation is very inefficient.

An object of the present invention is to mechanically correct deformation of a slender metallic product which has a complicated form in section and a complicated longitudinal form.

According to the present invention, in correcting treatment of a complicated form in section and a complicated longitudinal form, firstly an angular deformation of the product along its longitudinal axis can mechanically be corrected, secondarily deformation of a linear part of the product can mechanically be corrected and straightened, and thirdly torsional deformation in direction of its axis can mechanically be removed.

In this invention, the so-called Bauschinger Effect is utilized, and the most important feature of its effect is that correcting deformation can accurately be effected by forcibly putting a deformed part of a slender metallic product fixed by its other part in accord with a center of swing motion, by giving a swing motion to said deformed part in one direction, the amplitude of which motion being gradually made larger, and by imparting a reverse swing motion in other direction to said deformed part.

The word "deformation" used in this specification is not intended to represent a strain for the stress in the material sciences jargon, but to represent a difference between the size of a finished product and its intended size and shape.

According to this invention, an apparatus is provided for correcting deformation of a slender metallic product in which an apparatus for correcting deformation of a slender metallic product comprising a fixed support to fix a part of a slender metallic product, thereon, a fixing means to forcibly fix a deformed part of the slender metallic product fixed on said fixed support to a position at which there is substantially no deformation, a swing motion creating means to give a swing motion to said fixing means, said swing motion being of the type of that initially the center of amplitude is on the center of the swing motion and in one direction grows gradually larger, and after then is reversed in the opposite direction, and a swinging board which is engaged with said swing motion creating means and swings upwards and downwards, and from left to right.

These and other features of the present invention will be apparent from the following description with reference to an embodiment represented by the way of an example in the accompanying drawings, in which;

FIG. 1 is a front elevation of an apparatus according to the present invention partly in section,

FIG. 2 is a sectional elevation of a swing motion creating means which is a main part of the apparatus according to the present invention,

FIG. 3 is a side elevation viewed along line III—III of FIG. 1,



FIG. 4 is a plan view of a slender metallic product, as an example, to be corrected by the apparatus according to the present invention,

FIG. 5 is a elevation view of the same product,

FIG. 6 is a side view of the part of FIG. 2 along the line VI—VI of FIG. 2,

FIG. 7 is a similar view to FIG. 6 after rotating the part therein,

FIG. 8 is a diagram for explaining the theory used in the present invention,

FIG. 9 is a diagram representing a result of an experiment according to the present invention, and

FIG. 10 is a side view of another embodiment of the present invention for correcting deformation of a straight portion.

Referring FIGS. 1, 2 and 3, numeral 1 represents general means for creating a swing motion which forms a main part of the apparatus for correcting deformation of a slender metallic product according to the present invention. A swinging board 2 is provided on the left side of said means 1. On the surface of said swinging board 2, there are radially fixed four hydraulic cylinders 3*a*, 3*b*, 3*c* and 3*d*, and piston rods 9*a*, 9*b*, 9*c* and 9*d* for supporting an adapter 4. Fixed supports 5*a* and 5*b* are arranged in desired relation with an auxiliary shaft 6 of said means for creating a swing motion. Above said fixed supports 5*a* and 5*b*, hydraulic cylinders 7*a* and 7*b* are provided, and their piston rods are adapted to press a slender metallic product 8 to be corrected for its deformation against said fixed supports 5*a* and 5*b* as shown in FIG. 1.

Said slender metallic product 8 is shown as an example in FIGS. 4 and 5. As shown in said figures, said product is in a complicated form, and it has standard points 8*a*, 8*b*, outer ends 8*c*, 8*d*, and a center point 8*e* in design size. In said figures, contours represented by a solid line is that for the desired design, and contours represented by a chain line is that for the deformed product.

In operation, said slender metallic product is fixed on the apparatus as shown in FIG. 1, that is, standard points 8*a* and 8*b* are fixed between the fixed supports 5*a* and 5*b* and piston rods of the corresponding hydraulic cylinders 7*a* and 7*b*, respectively, and the one outer end 8*d* to be corrected is inserted into a center hole of said adapter 4 as shown in FIGS. 1 and 3.

Said hydraulic cylinders 3*a*, 3*b*, 3*c* and 3*d* constitute a fixing means for the product with said adapter 4, and they are fixed on the swinging board 2 at upper, lower, right hand and left hand parts of its surface. All of their pistons 9*a*, 9*b*, 9*c* and 9*d* are initially open at their outer ends, but when the adapter 4 into which the outer end 8*d* is forcibly placed between four pistons, and oil pressure is applied to hydraulic cylinders from the outside, the center of said adapter 4 is forcibly aligned with the axis of the auxiliary shaft 6, and all the pistons then automatically stop to advance. The outer diameter of the adapter 4, the length of the pistons 9*a*, 9*b*, 9*c* and 9*d*, the stroke length of the hydraulic cylinders 3*a*, 3*b*, 3*c* and 3*d*, and the positions of the fixing supports 5*a* and 5*b* are determined in order to be able to achieve the abovementioned function. The circle of the chain line in FIG. 3 shows the range of maximum movement by upwards, downwards, lefthanded, and righthanded motion of the adapter due to the existence of deformation in the outer end 8*d* of the slender metallic product 8.

The center of the righthand surface of the swinging board **2** is engaged with a swinging pin **10** through a bearing **11**, the righthand part **12** of the swinging board **2** is engaged with a groove **13** formed between the end wall of the swing motion creating means **1** and the left side wall **14**, and the central groove **15** provided at the periphery of said swinging board **2** is engaged with said left side wall **14**. Said left side wall **14** consists of two up and down divided semi-circular rings **14***a*, **14***b*, and both rings **14***a* and **14***b* are individually engaged with said central groove **15**, and subsequently they are fixed by means of screws **16**.

In FIG. **1**, numeral **17** shows a switch, and **18** represents an electric motor. The switch **17** is of the type of an automatic control system, and able to rotate the motor in one direction for a fixed duration and to rotate automatically in the reverse direction and to stop automatically its rotation after a fixed time. Since it is necessary to absorb rapidly the inertia of the motor, said motor **18** may preferably be a strong braking motor.

Referring now to FIG. **2**, an input shaft **19** connected with said motor **18** is mounted on radial and thrust bearings **20** and **21** on the right side wall **22** and the central wall **23** of the swing motion creating means **1**, and has two gears **24**, **25** keyed thereon. The auxiliary shaft **6** is mounted on a bearing **26** at its right end, and passed through the center of the main shaft **27** by its mid-part, and the left end of the auxiliary shaft **6** is supported by a bearing **35***b* provided at the inside periphery of said main shaft **27**. Said auxiliary shaft **6** also has a safety clutch **28** and a gear **30** clutched thereon. The gear **30** of the safety clutch **28** is meshed with said gear **24** and has gear teeth, the number of which is one less than the number of gear teeth of said gear **24**, and it is supported by a bearing **31** on said auxiliary shaft **6**. Said safety clutch **28** and the gear **30** are conventionally constructed with a push board **32**, a spring **33** and a friction disc **34**. The right end of the main shaft **27** is supported with a bearing **35***a* on the mid-wall **23**, and the left end of it is supported on the auxiliary shaft **6** via a bearing **35***b*, and a gear **36** meshed with said gear **25** and a disc plate **37** are keyed on the shaft **27**, the number of the teeth of said gear **36** being the same number of teeth of the gear **25**. The right end of an operating disc **38** is fixed to said disc plate **37** by means of screws, and the left end of it is supported with a bearing **39** at the left inner edge of said swing motion creating means **1**, so that this results in that the left end of the main shaft **27** is supported by the bearing **39** through the disc plate **37** and the operating disc **38** on the left side of said means **1**. In said operating disc **38**, the operating rod **40** is supported by means of bearings **41**, **41**, and a shaft **42** of a segment gear **43** is supported with bearings **44**, **44**. The operating rod **40** is provided with gears **45**, **46** keyed thereon, the number of teeth of said gears **45** being less than that of the gear **29** keyed on auxiliary shaft **6**. The shaft **42** of the segment gear **43** is keyed on said gear **43**, which being meshed with the gear **46**, has a radius which is greater than that of the gear **46**. As shown in FIG. **6**, the segment gear **43** is fixedly provided with the swinging pin **10** on the center line of the auxiliary shaft **6**, and a right end notch **43***a* is adapted to engage with a right stop **47** for the segment gear **43** fixed on the operating disc **38** and a left end notch **43***b* is adapted to engage with a left stop **48** for the segment gear **43** fixed on the operating disc **38**.

As shown in FIG. **3**, the swinging board **2** is provided at its down and left side with a yoke **49** being provided with an elongated hole **50** which is adapted to engage with a stop pin **51** set up on the frame of the swing motion creating means **1**.

Now, the process of the correcting operation effected by the apparatus which is constructed in such a manner as has been previously described is as follows;

The outer end **8**d of the slender metallic product **8** is forcibly inserted into the adapter **4**, standard points **8***a*, **8***b* in design of the slender metallic product **8** are fixed on defined positions of the fixing support **5***a*, **5***b* respectively, by operating the hydraulic cylinders **7***a*, **7***b*, and the four hydraulic cylinders **3***a*, **3***b*, **3***c* and **3***d* are applied with hydraulic pressure at their end so that the center of said adapter **4** is forced to be aligned with the center line of said auxiliary shaft **6**. Then, the switch **17** is switched on, and the motor **18** rotates in one direction, accordingly, the input shaft **19**, the gears **25** and **36**, the main shaft **27**, the disc plate **37** and the operating disc **38** are rotated in one direction driven by the motor and at the same time, the gear **24**, the safety clutch gear **30**, the friction disc **34**, the push board **32**, the safety clutch **28**, the auxiliary shaft **6**, the gear **29**, the gear **45**, the gear **46** and the segment gear **43** are also rotated.

In this preferable embodiment, the gear **25** has **60** teeth, the gear **36** has **60** teeth, the gear **24** has **73** teeth, the safety clutch gear **30** has **72** teeth, the gear **29** has **24** teeth, the gear **45** has **12** teeth, the gear **46** has **11** teeth, and the segment gear **43** has **22** teeth. Viewing the apparatus from the left side of FIG. **2**, when the input shaft **19** rotates clockwise 360°, then the operating disc **38** rotates counterclockwise 360°, and the auxiliary shaft **6** rotates counterclockwise 365°. If assuming that only the operating disc **38** rotates counterclockwise 360°, and the auxiliary shaft **6** and the gear **29** do not rotate, the operating rod **40** and the shaft **42** of the segment gear **43** revolve round the shaft **6** counterclockwise 360°, while the gear **45** moves twice around the periphery of the gear **29** which is stationary. Accordingly, the gear **46** and the operating rod **40** will rotate counterclockwise 720°, and the segment gear **43** and its shaft **42** will rotate 360°. Then, fixing the operating disc **38** at the position as it is, and rotating the auxiliary shaft **6** counterclockwise 365°, the segment gear **43** rotates counterclockwise 365° via the gear **29**, the gear **45** and the gear **46**. That is, if the operating disc **38** rotates 360° and the auxiliary shaft **6** rotates 365° counterclockwise at the same time, the segment gear **43** will rotate counterclockwise by 5°. The center of swinging pin **10** fixed on said segment gear **43** is initially on the center line of the auxiliary shaft **6**, that is, on the center of rotation of the operating disc **38**, said swinging pin **10** rotates by 5° every time that the input shaft **19** rotates clockwise one revolution.

FIG. **7** shows the situation changed from that shown in FIG. **6**, and in which the input shaft **19** rotates clockwise 180°, and the operating disc **38** rotates counterclockwise 180°, then the center of the swinging pin **10** which is initially at **38***a* on the two points chain line, comes to **38***b* on the chain line after its rotation in 2.5°. However, after the center of said swinging pin **10** is based and located at **38***b*, if the operating board **38** rotates, the swinging pin **10** revolves counterclockwise round the axis of the auxiliary shaft **6** with a radius of rotation of the length of a distance between **38***a* and

38*b*. And with the progress of the clockwise rotation of the input shaft **19**, the radius of revolution of the swinging pin **10** increases gradually. In the embodiment represented, the maximum biased quantity of swing motion required to correct deformation, that is, the maximum quantity of excursion of the swinging pin **10** is 5 mm, and this value corresponds to a 50° rotation of the excursion angle of the segment disc **43**. Accordingly, when the input shaft **19** rotates clockwise ten times and the excursion angle of the segment gear **43** grows into **50**, and the swinging pin **10** has been displaced to the left by 5 mm, the switch **17** operates and reverses the rotation of the motor **18**. If the input shaft **19** rotates counterclockwise, the segment gear **43** and the swinging pin **10** rotate clockwise in the opposite direction of that abovementioned, and when the input shaft **19** rotates counterclockwise 10 times, the center of the swinging pin **10** returns to **38***a*, and the switch **17** automatically stops the motor **18**, and at that time the right end notch **43***a* of the segment gear **43** engages with the right stop **47** for the segment gear and said segment gear **43** stops its rotation. In case the operation of the switch **17** is not sufficient and the motor **18** does not reversibly rotate even if the left notch **43***b* engages with the left stop **48** for the segment gear and the rotation of the segment gear **43** is stopped, the friction disc **34** of the safety clutch **28** slides and the auxiliary shaft **6** stops its rotation, whereby the swinging pin **10** continues to revolve together with the operating disc **38** with a radius of the greatest quantity of the excursion. In case the operation of the switch **17** is not sufficient and the motor **18** does not still stop rotating even if the right notch **43***a* of the segment gear engaged with the right stop **47** for the segment gear and the rotation of said segment gear is stopped, the friction disc **34** of the safety clutch slides whereby it stops the rotation of the auxiliary shaft **6**, while the main shaft **27** and the operating disc **38** is still rotating, but at this time as the swinging pin **10** is situated at the center of the rotation of the operating disc **38**, it merely rotates and does not revolve. As abovementioned, the swinging pin **10** firstly revolves counterclockwise with the radius of revolution growing gradually larger, second reversing its direction of revolution, the swinging pin **10** revolves clockwise with a radius of revolution growing gradually smaller, the swinging board **2** engaged with the swinging pin **10** through the bearing **11** makes first the swing motion counterclockwise with an amplitude changing from a small quantity to a large quantity gradually, second it makes the swing motion in the opposite direction, that is, clockwise with an amplitude changing from a large quantity to a small quantity, and last it stops its revolution, its amplitude becoming zero. When the swinging board **2** makes the swing motion as abovementioned, the outer end **8***d* of the slender metallic product **8** which is driven into the center of the adapter **4** fitted on the swinging board **2** by four hydraulic cylinder **3***a*, **3***b*, **3***c* and **3***d* makes the same swing motion as said swinging board **2**. That is to say, first the outer end **8***d* is forcibly fixed in the position in which the deformation is nil, but it swings gradually from a small amplitude to a large amplitude, and subsequently it swings, in the opposite direction of the swing motion, from a large amplitude to a small amplitude, and lastly it stops its swing motion in the position in which the deformation is nil. In other words, means for gripping the slender rod are moved in a form of an involute substantially outwardly expanded to stress the slender rod beyond its elastic limit, returned in a form of an involute substantially inwardly contracted until said means for gripping reaches to the position where there is no distortion of the slender rod.

Further, regarding to the Baushinger Effect for iron and steel, which constitutes a theoretically basis utilized for the present invention, it cannot be said that it has been made clear, but is possible to draw deduction as follows;

Referring now to FIG. **8**, after the outer end **8***d* of the slender metallic product, the center of which has firstly occupied the position represented with A, is fixed by means of the fixed support **5***b* and pulled down to the position represented with B by the force P over its elastic limit, when the force P is removed, the center of the outer end **8***d* will occupy the position represented with C because of spring back force. This quantity by elasticity depends on the internal stress of the material and the other, but it is sure that the line C is inside of the line A. In the situation of spring back, the zone (a) is a zone of expansive plastic deformation, a zone (b) is a zone of elastic deformation and has tensile stress tending to restore the rod to the original state, so that the zone (a) is subjected to the compressive stress. Similarly, zone (c) is a zone of compressive plastic deformation, zone (d) is a zone of elastic deformation and has compressive stress tending to restore the rod to the original state, so that the zone (c) is subjected to the tensile stress. Due to the balance of the internal stresses of these zones of plastic deformation and elastic deformation, the position of spring back is defined.

Then, after pulling the outer end **8***d* from the line C to the line D with the force Q, when the force Q is removed, the outer end **8***d* springs back to the line E. In such a manner, the quantity of spring back becomes smaller and smaller. Accordingly, it is possible to make the spring back zero. Of course, the position at which the spring back is zero is effected at the position at which deformation is nil.

In connection with the direction at right angles to the paper surface of FIG. **8**, there is a similar function, so in this embodiment this invention achieves its object by swinging the product upwards and downwards, and from left to right.

A result of an experiment in correcting deformation is represented in FIG. **9**. In FIG. **9**, the metallic product which first has deformation of OA is fixed at the point B, and then given the swing motion which is firstly small amplitude and gradually grows to large amplitude over its elastic limit, and subsequently it is subjected to positive and negative deformation from large amplitude to small amplitude, and reaches to the point C, thus the deformation of the product becomes nil.

An embodiment according to the present invention which is utilized when the deformation in straight parts, for example the center portion **8***e* of the straight part of said slender metallic product **8** is deformed, is represented in FIG. **10**. In this embodiment, the adapter **4** is divided into two upper and lower parts, and the swinging board **2** and hydraulic cylinders **3***a*, **3***b*, **3***c* and **3***d* are arranged in the direction of a right angle to the slender metallic product **8**, and the swinging board **2** is placed under the product **8**, and said swinging board **2** and hydraulic cylinders **3***a*, **3***b*, **3***c* and **3***d* are connected with a connecting material **52**.

Further, according to the present invention, torsional deformation can be corrected with the following method.

In FIG. **1**, in order to correct the twist of the center point **8***e* for the point **8***a* or **8***b*, the points **8***a* and **8***b* are fixed, and by the method represented in FIG. **10** the point **8**e is given the swing motion, in the upward and downward directions, and left and right movements, then the point **8***e* can be straightened, and at the same time, according to the same principle as represented in FIG. **8**, the twist in the point **8***e* can be corrected. Again, in order to correct the twist deformation of the point **8***c* or **8***d* for the point **8***a* or **8***b*, the method described regards to FIG. **3** is applicable. As in FIG. **3** the pivot **51** set up on the frame of the swing motion creating means **1** permits the upwards and downwards motion between the swinging board **2** and the yoke **49**, but does not permit the motion from left to right, so that the swing motion of the swinging board **2** becomes the motion in the upward and downward directions, and from left to right with a fulcrum of said pivot **51**. If there is not a pivot **51**, the position of the swinging board **2** in upper and lower, left and right position is defined the swinging pin **10** of the operating disc **38**, but its rotation is free. When first the point **8***d* is fixed with hydraulic cylinder **3***a*, **3***b*, **3***c* and **3***d*, by the action of the pivot **51**, said point **8***d* is fixed at the position at which the twist deformation of the point **8***d* for the point **8***b* is nil, while as the point **8***d* is upwardly bent with certain angle for the point **8***b*, when the swinging board **2** is counterclockwise swinging, in the upper half passage of said swing motion, the point **8***d* is twisted counterclockwise, and in the lower half passage of said swing motion, the point **8***d* is twisted clockwise. Thus, due to the same principle as represented in FIG. **8**, the twist deformation can be corrected. Furthermore, as the swinging board **2** swings clockwisely after its counterclockwise swing motion, the correcting the twist deformation can be achieved effectively.

Instead of the switch **17**, limit switches for automatic controlling the motor **18** may be used, such as for instance, by a limit switch provided on the fixed supports **5***a*, **5***b*, and a limit switch provided on hydraulic cylinders **7***a*, **7***b*, **3***a*, **3***b*, **3***c* and **3***d*, the motor may automatically start, and by a limit switch provided on the left stop **48** for the segment gear **43**, the motor **18** may be automatically reversed, and by a limit switch provided on the right stop **47** for the segment gear **43**, the motor **18** may automatically stopped.

The present invention has therefore provided an apparatus for correcting deformation of a slender metallic product which has a large correcting accuracy, is extremely efficient, and is relatively inexpensive to tool and build. In the present situation, the initial position and the final position of the swinging pin are strictly on the position where there is substantially no distortion of the slender rod. In other words, the initial position of the involute motion of the means for gripping the slender rod are strictly on the position where the distortion of the slender rod is nil, so that the accuracy of correcting distortion is very high.

Since many changes could be made in the above construction and many apparently widely differing embodiments of this invention could be made departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

**1.** Apparatus for correcting deformation of a slender metallic rod in which linear, angular, and torsional distortion exist, said apparatus comprising fixed supports to support said slender rod at at least two standard points thereof, fixing means for forcibly fixing said rod at a position where at least one of said distortions is substantially nil, a swing motion creating means to impart a swing motion to said fixing means, said swing motion comprising a swing motion in one direction growing gradually larger, and thereafter a swing motion in the opposite direction growing gradually larger, and a swinging board which is coupled to said swing motion creating means and swings upwardly and downwardly and from left to right.

**2.** An apparatus according to claim **1**, comprising hydraulic cylinders cooperating with said fixed support.

**3.** An apparatus according to claim **1**, wherein said fixing means comprises four hydraulic cylinders fixed on said swinging board and an adapter connected between said four cylinders adapted to hold an end of said rod.

**4.** An apparatus according to claim **1**, wherein said swing motion creating means comprises an operating disc, a motor, an input shaft, a main shaft and a disc plate, said operating disc driven by said motor coupled through said input shaft, main shaft and disc plate, a segment gear which is provided with a swinging pin and driven by the motor through said input shaft, and an auxiliary shaft and an operating rod passed through said operating disc.

**5.** An apparatus according to claim **1**, wherein said swinging board is integrally provided with a yoke having an elongated hole adapted to engage with a pivot set up on the frame of said swinging creating means.

**6.** Apparatus for correcting deformation of a slender metallic rod in which linear distortion, angular distortion and torsional distortion exist so that said distortions are reduced to nil, said apparatus comprising fixed supports,

means for supporting said slender rod at at least two standard points on the fixed supports,

holding means for forcibly holding the slender rod so that the distortions are reduced to nil, and

moving means for moving the holding means in a form of an involute substantially outwardly to stress the parts of the slender rod being held beyond their elastic limit until they reach a state of equilibrium, and then returning said holding means in a form of an involute substantially inwardly until said distortions of the slender rod become nil to overcome the inherent spring back in the slender rod.

**7.** Apparatus as recited in claim **6**, wherein said moving means comprises:

an input shaft and a main shaft,

an operating disc which is driven by said input shaft and said main shaft,

a segment gear supported eccentrically on the operating disc,

an auxiliary shaft and a shaft of said segment gear,

said segment gear being driven by said auxiliary shaft and said shaft of the segment gear,

a swinging pin fixed on the segment gear at an extension line of the axis of the auxiliary shaft when the

segment gear is at an initial point so that the swinging pin does not move in an orbit at the initial time of the rotation of the main shaft and the auxiliary shaft,

a plurality of gears coupling said segment gear to said main shaft, said segment gear, said auxiliary shaft, and said operating disc, said gears provided with a number of teeth so that said segment gear rotates in the same direction as the direction of the rotation of the operating disc and has a larger displacement than the rotation of the operating disc, whereby the distance between the centers of the swinging pin and the operating disc grows gradually larger, said distance being an instantaneous radius of the gyration of said moving involute,

a right stop which sets the initial position of the segment gear,

a left stop which sets the final position of the segment gear at the end of the outward involute motion of the swinging pin,

means for returning the input shaft when the segment gear reaches the left stop,

a swinging board which is coupled with the swinging pin, and

means for gripping the slender rod which is fixed on the swinging board.

**8.** Apparatus as recited in claim **7**, wherein said swinging board comprises:

a yoke which is provided with an elongated hole,

a pivot which is fixed on the swing motion creating means and adapted to engage with said elongated hole,

an adapter for holding an end of said rod, and

means for gripping the outer plane of the adapter.

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