United States Patent [19]

Peddinghaus

[11] **3,777,525**

[45] **Dec. 11, 1973**

[54] **MACHINE FOR BENDING CONCRETE-REINFORCING BARS**

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[22] Filed: **Aug. 30, 1971**

[21] Appl. No.: **176,078**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 879,428, Nov. 24, 1969, abandoned.

[30] **Foreign Application Priority Data**

Nov. 23, 1968 Germany .... P 18 10 533.4

[52] **U.S. Cl.** **72/22,** 72/702, 72/DIG. 22

[51] **Int. Cl.** **B21j 7/26**

[58] **Field of Search** .... 72/7, 8, 9, 21, 22, 72/26, 30, 702, DIG. 4, DIG. 22

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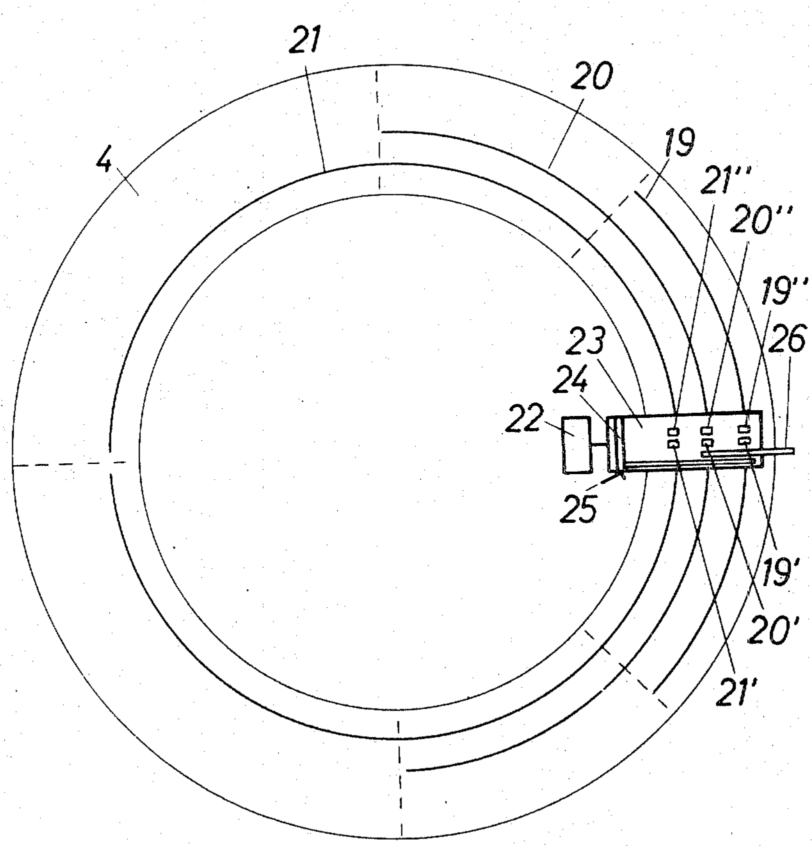
[57] **ABSTRACT**

A machine for bending concrete-reinforcing bars and the like is provided with automatic electric sequence control means for performing a desired sequence of bending operations of selected predetermined bending angles. The machine has slip rings of angular extents corresponding to the selectable angles and a contact drum cooperating with these. On the drum are a series of sets of pairs of selectable contacts; each set corresponds to one bending operation and the selected contact pair in the set cooperates with a corresponding slip ring to determine the bending angle for that operation. The drum is stepwise rotated to effect the sequence of operations. To compensate for elastic relaxation of the bar after bending, the bending may be continued beyond the predetermined angle by a further angle determined by measurement of energy absorption, or current consumption, or a time interval, for bending in the elastic range of the bar material. Means for effecting such compensation automatically are described.

16 Claims, 9 Drawing Figures



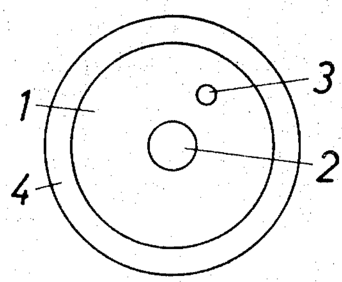


Fig.1

Fig.2

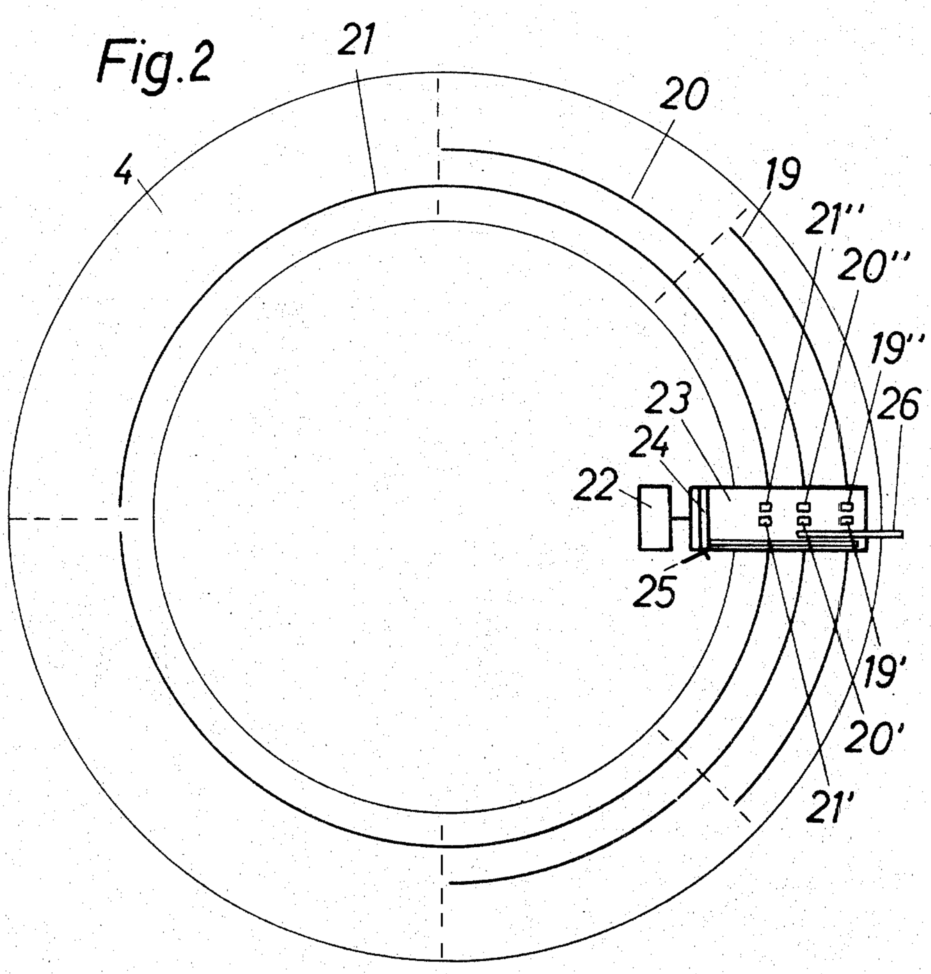


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Fig. 3

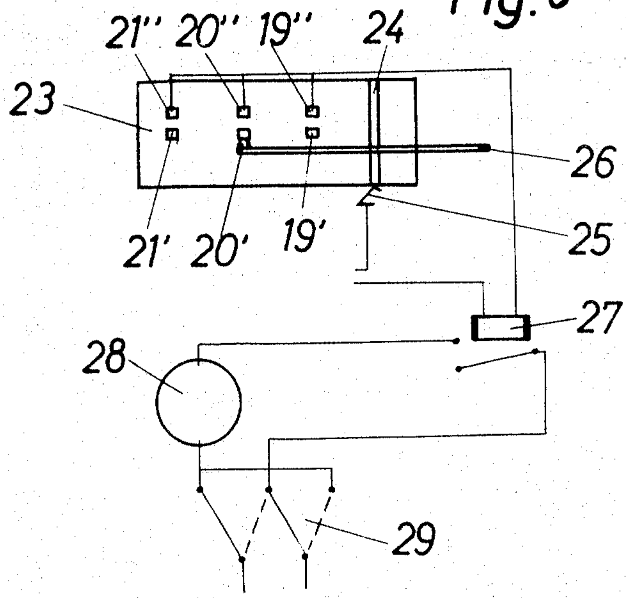
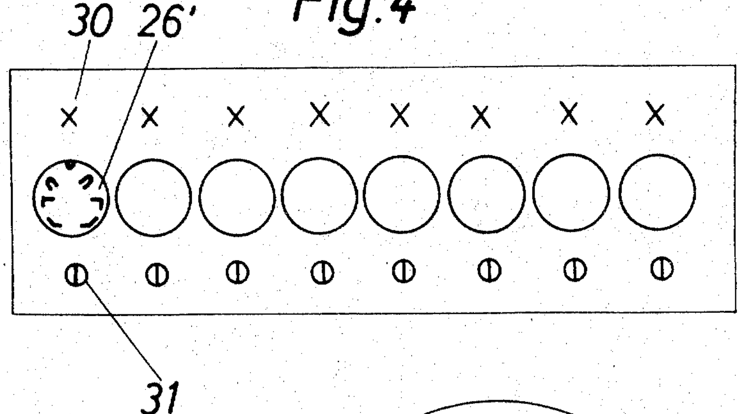


Fig. 4



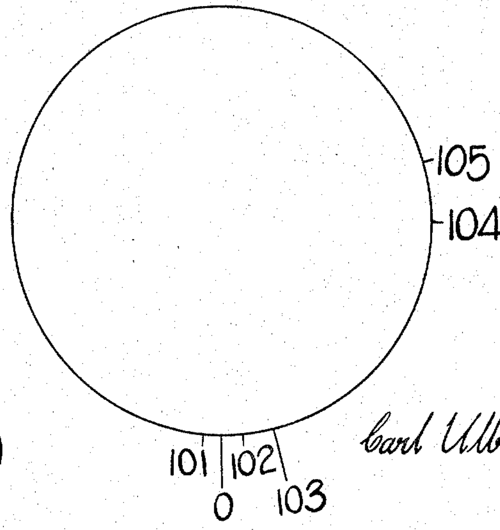


FIG. 9

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Fig. 5

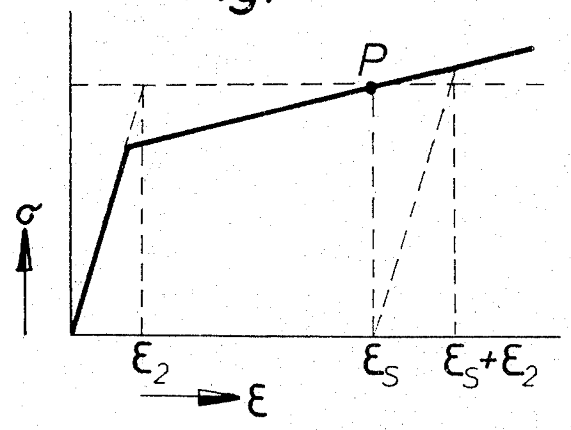
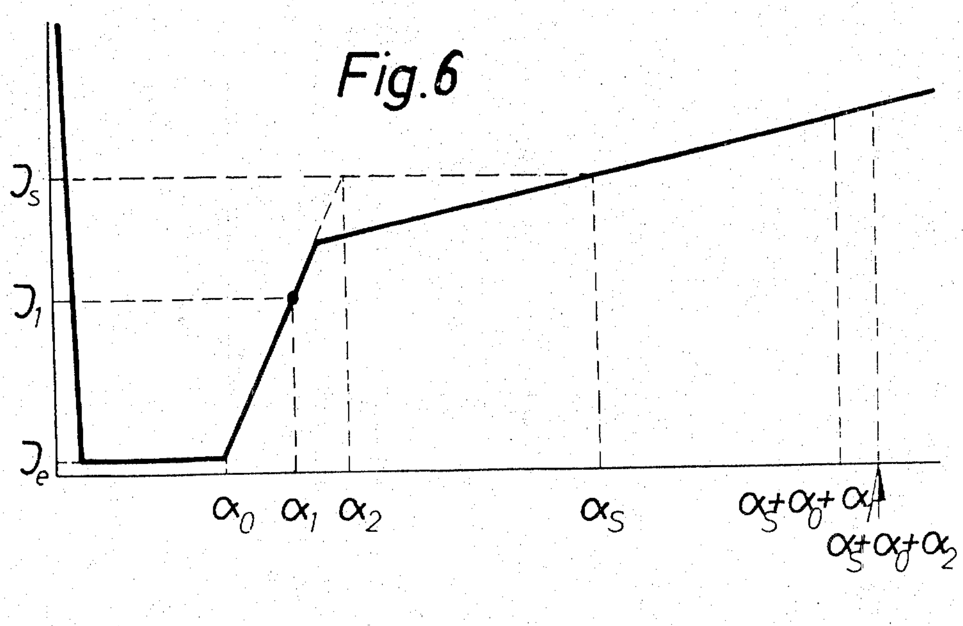


Fig. 6



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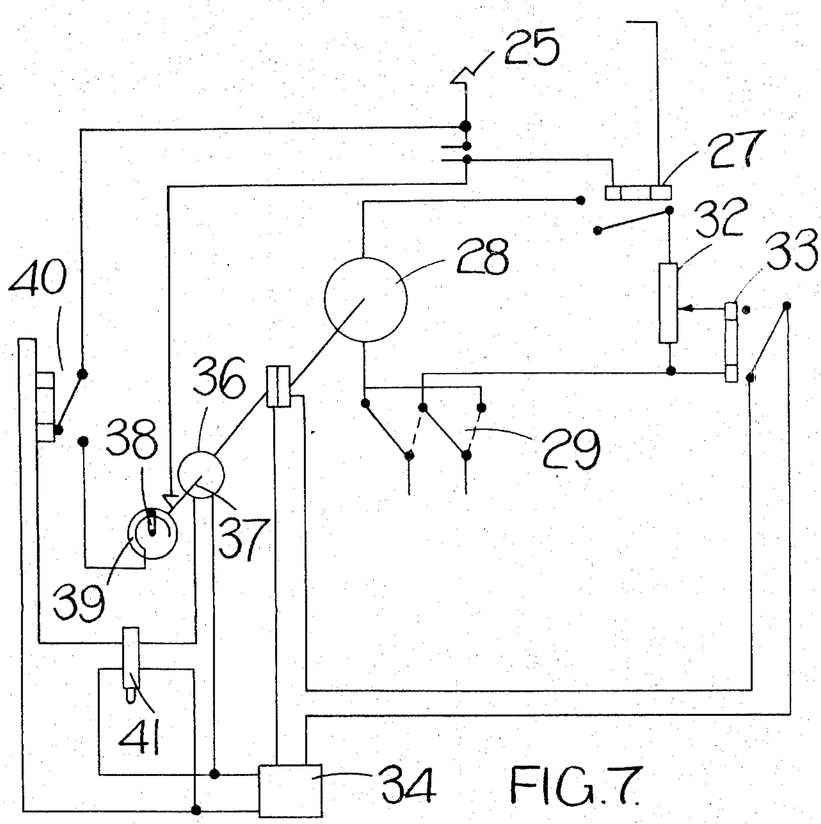

FIG. 7

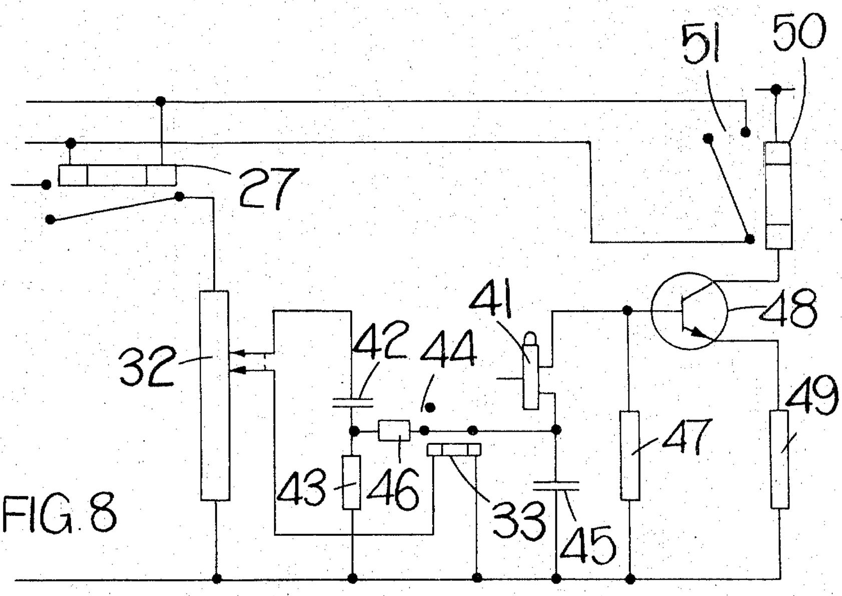

FIG. 8

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MACHINE FOR BENDING CONCRETE-REINFORCING BARS

This Application is a Continuation-in-part Application of Ser. No. 879,428 filed Nov. 24, 1969, now abandoned.

The invention relates to a bending machine for bars, wire and sections of steel and like materials, having a bending platen which supports the bending tools, is rotatable and can be driven in either angular direction, with the machine having setting means which can be used to bend a bar into various bending angles and in any desired sequence.

Bending machines of the kind heretofore described are known as reinforcing-bar bending machines. In order to bend a bar by means of such a machine, said bar is placed between the bending tools whereupon the motor driving the bending platen is switched on. As soon as a specified principal bending angle is reached, which may in particular correspond to an angle of rotation of the bending platen of 45°, 90° or 180°, the transmission for the bending platen is first switched off and then switched on once again for the return of the bending platen into its starting position in a direction opposite to the original bending direction. This directional control of the drive is provided both for clockwise as well as for anti-clockwise rotation of the bending platen. The setting means perform the function of switching off or switching to reverse the drive of the bending platen after the principal bending angle is obtained.

This method of operation assumes that the setting means are triggered by initiators. The prior art discloses mechanical initiators by means of which triggering from bend to bend is performed manually but this is subject to faulty operation in the event of insufficient attention being paid by the operating personnel, since moreover clockwise or anti-clockwise operation of the bending platen must also be manually controlled. Since not only a single bend is normally performed on a bar but usually several bends must be performed successively at certain distances on the bar, the sequence of the individual bends must be matched to the subsequent and final shape of the bent bar. Other known reinforcing bar bending machines, in which precisely predetermined bending angles are preset in a counting circuit and which are then triggered in a fixed sequence by means of a programme circuit, are also of only limited value for practical operation. For example if a principal bending angle of 45° is specified as the first angle, only this and no other angle can be bent in the first position of the sequence.

A further disadvantage of the known embodiments is due to the fact that differences between intended principal bending angles and bending angles actually obtained, which depend on the dimensions and changing tensile strength of the bars to be bent, can be compensated only by experiment, for example, by correcting the setting means positions by a certain amount.

It is one object of the invention to construct a bending machine of the kind heretofore described in such a way that the disadvantages mentioned hereinabove cannot occur. According to the invention this is achieved in that, after reaching a principal bending angle, specified as desired, the bending process is automatically continued by means of an electric control system. The control system may be so constructed that

continuation of the bending process starts only after the return of the bending platen and after a corresponding feed motion of the bar to be bent. In this case, and by using a plurality of control systems, a bending sequence programme is obtained which will be completed only when the bar to be bent has assumed the shape finally intended for it. However, it is also possible that the control system continues the bending operation immediately after the desired principal bending angle is obtained, that is to say, before the return motion of the bending platen has commenced. In this case it is possible for angular corrections to be performed automatically in order to compensate for deviations between the measured value and the required or set value of the principal bending angle.

It is essential in both cases that there should be no need for varying the principal bending angles once they have been specified, either for reasons of the bending sequence programme or for reasons of adjustment of a finished bending angle.

If several principal bending angles are combined according to the invention to form a bending sequence programme, an electric control circuit is appropriately provided for each bend, said electric control circuit triggering the setting means corresponding to the desired and specified principal bending angles, each control circuit being associated with one bending angle, the control circuits in their entirety corresponding to the bending sequence programme and being constructed to be variable in steps.

The setting means may be constructed in different forms if it merely reproduces the appropriate position of the bending platen or of the bending tools disposed thereon. In one suitable embodiment it comprises a disc which rotates in accordance with the bending angle. Contactors, corresponding to the specified principal bending angles, may be conveniently mounted on said disc, the aforementioned contactors being operated by the control circuit to assume their closed-circuit or open-circuit states respectively. The aforementioned contactors may for example comprise slipring sectors but may also operate without direct physical contact, for example by being magnets which act on magnetically energisable contacts of the control circuit.

Each individual control circuit is itself once again variable and comprises several switching positions which correspond to the principal bending angles. In order to correspond to the transfer from one principal bending angle to the next within a bending sequence programme, the individual control circuits, each containing a plurality of contacts, are formed by a setting switch, driven in steps, by means of which the contacts corresponding to a specified individual bend are connected with a control pulse potential, so that the contacts control the motor of the bending machine via the contactors disposed on the setting means. In a particularly advantageous embodiment the setting switch comprises a motor-driven drum having two slipring contacts on its end faces for control pulse currents, one of the two slipring contacts being adjustable by means of a setting slide to different positions of the drum circumference which are serially disposed in the axial direction of the drum while the other of the two slipring contacts can be adjusted to only two positions, disposed serially in the axial direction of the drum, by means of a further adjusting slide and provision is made to cause the aforemntioned positions on the drum circumference to bear upon the contact positions of the control circuits in the individual positions of the setting switch. The first of the two slipring contacts may be provided for adjusting the principal angle of, for example, 45°, 90° or 180°, while the second slipring contact is provided for selecting clockwise or anti-clockwise rotation of the bending platen. The contact positions on the drum circumference, to which the aforementioned slipring contacts can be adjusted, are closed when they are disposed in the operative zone of the setting means contactors. This may be easily achieved if the contactors of setting means constructed in disc form comprise slipring sectors (e.g. three slipring sector-shaped contacts) which close the circuit between contact positions comprising two touching contacts disposed serially in the circumferential direction of the drum. The circuit thus closed may then energise a relay which in turn maintains the motor of the bending machine in the switched-on state while contact is maintained.

While the arrangement described hereinabove enables any desired bending sequence programme to be established, merely by varying the position of the adjusting slides, it is also possible for a supplementary bending angle of a final bending angle to be adjusted which compensates the irregularites which occur in the principal bending operation for the principal specified bending angle. To this end, each principal bending angle is continued by a supplementary bending angle to be determined by the measurement of at least part of the energy absorption or current consumption or a time interval in the elastic deformation range of the material to be bent. It is therefore assumed that the material to be bent comprises substances which, particularly in the case of steel, have an elastic and a plastic deformation range which depends on the applied stress.

Immediately following the starting operation, the current consumption of the motor usually reaches a maximum value, then drops to a no-load value which is maintained under conditions of progressive rotation of the bending platen until the bending tools bear upon the material to be bent. This is followed by an approximately linear rise of the current consumption, corresponding approximately to the elastic deformation range of the material. Current consumption will be approximately linear, but with a substantially smaller slope, as soon as the yieldpoint is reached. It is possible to specify a certain current value which is reliably within the range of current consumption rise prevailing during elastic deformation and to utilise said current as the control current for energising a relay. A current of the aforementioned value can be easily determined by a few trial bends. The relay, energised on reaching the aforementioned current value, will then switch off a synchronous motor constructed as control motor and which will have started to operate from the time at which the motor of the bending machine was switched on. On reaching the specified principal bending angle or immediately prior thereto the synchronous motor or stepping motor is once again switched on but rotates backwards through its angle of rotation taken up during its first switching-on period and delaying the switching off of the bending machine motor until it returns into its starting position. Accordingly, the bending platen bends the material through a supplementary bending angle which corresponds to the entire idle travel before the bending tools bear upon the material to be bent, and to a substantial proportion of the elastic deformation of the material. In many cases a sufficiently good bending accuracy is obtained by these means alone.

Furthermore, the energy or current consumption in the elastic deformation range can be differentiated with respect to the change of bending angle and said differential quotient can be integrated over the entire bending process, the adjustment of the setting means being varied relative to the instantaneous value of said integral. Under these conditions, the setting of the setting means is the set value, specified by the principal bending angle, said set value in turn being automatically varied during the bending operation. Accordingly, the entire elastic deformation range is measured and taken into account by the change of set value. It is not absolutely necessary that the initially specified differentiation is performed over the entire elastic deformation range, instead, it is sufficient to form the differential quotient at a position which is reliably within the elastic deformation range.

If the above-mentioned "control" motor is constructed as synchronous motor, the current consumption will correspond to the angle of displacement between the rotor and stator poles. Said angle of displacement can be determined by known measuring means the value being stored, also in known manner, for the duration of the entire bending procedure in order to be used as the basis for determining the supplementary bending angle.

According to a further feature of the invention, an electrical quantity, corresponding to the displacement angle or to the bending angle depending on the differential quotient of the energy or current consumption, is stored as set value in a controller during a brief period of time following on the beginning of the bending operation during which therefore elastic deformation of the material to be bent takes place, an annular adjusting element being maintained in operation at a speed corresponding to the aformentioned electrical quantity by means of an annular setting element via a variable transmission or a speed-controlled servomotor until the bending operation is completed. In this way, the principal bending angle specified by the setting element is constantly increased by the amount corresponding to the elastic deformation.

In order to base the determination of the supplementary bending angle on the entire elastic deformation, determination of the energy or current consumption or of the electrical quantity corresponding to the displacement angle is controlled by a switch which in turn is energised when the electrical quantity or the differential quotient with respect to the bending angle deviates from the initially determined value by a specified small amount. As a rule, the aforementioned small amount is obtained by virtue of the transfer from the elastic into the plastic deformation range. For example, the aforementioned electrical quantity may be determined by a primary quotient transmitter which is supplied with an electrical quantity corresponding to the bending angle.

In order to accurately measure the deviation of the aforementioned electrical quantity which corresponds to the yieldpoint of the material to be deformed, it is fed into a compensating circuit in the form of a constant value based on the measurement performed at the beginning of the bending operation, the said compensating circuit being subsequently supplied with the value of the other measured electrical quantity or its differential quotient with respect to the bending angle and which is adapted to energise the control current of a switch while the deviation between the two electrical quantities is greater than a specified minimum value.

The change of set value of the principal bending angle specified on the setting means is obtained by providing the setting means with a toothed ring which meshes with a pinion, driven by a servomotor or by a gear transmission which co-rotates with the bending platen.

In order to remove the setting means as well as the servomotors or the like which vary its set values, from the direct zone of influence of the bending platen or from the severe mechanical vibrations emanating therefrom, it is possible for the setting means to be coupled to the bending platen and to be disposed at a position which is spacially more suitable. To this end it is advantageous to employ an electro-indicative coupling comprising a servomotor system which offers the advantage of dispensing with the need for movable contacts being disposed directly on the bending platen.

The invention will now be described by reference to diagrammatic drawings relating to embodiments and in which:

FIG. 1 is a diagrammatic plan view of a bending platen,

FIG. 2 shows setting means according to the invention with a control circuit,

FIG. 3 shows the control circuit,

FIG. 4 is a diagrammatic view of the control console of the bending machine,

FIG. 5 is the stress-strain diagram of material to be bent,

FIG. 6 shows the current consumptions during bending,

FIG. 7 and FIG. 8 are diagrammatic circuit diagrams, and FIG. 9 is a schematic representation of an angle diagram for a time-controlled arrangement.

A bending platen **1** shown in FIG. **1** supports two bending tools **2** and **3** which may be bending bolts of circular cross section or of some other shape. The bending platen is surrounded by an annular disc **4** which co-operates with a control circuit seen in FIG. **2.** To this end, and as shown in FIG. **2**, the annular disc **4** is provided with sector-shaped slipring contacts **19, 20** and **21,** corresponding to the principal bending angles 45°, 90° and 180°.

There is also provided a drum **23** drivable in a series of angular steps about its own axis by means of a motor **22** and on the surface of the drum there is provided a plurality of sets of pairs of contacts. For reasons of clarity, only one set is shown in FIGS. **2** and **3** and this set consists of three pairs of contacts, namely contacts **19'** and **19''**; **20'** and **20''**; **21'** and **21''**, said pairs being axially spaced from each other. There may, for example, be eight of such sets which are spaced circumferentially from each other and each set may be brought into a position in which the contacts of the set engage the aforesaid slipring contacts **19,20,** and **21** by appropriate angular movement of the drum **23.** Furthermore, with each set of contacts as above-described, there is associated an adjusting slide **26,** one of such slides being seen in FIGS. **2** and **3.**

In FIG. **2,** the drum **23** is shown in a central or zero position with respect to the slipring contacts **19,20** and **21.** A contact ring **24** which is a standard slipring contact on which a contact spring **25** bears, is on the drum and current can be fed to said spring **25.** The contact ring **24** is fixed and there is permanent electrical connection between the slide **26** and the ring **24.** The adjustment slide **26** can either abut directly on the ring **24** (FIG. **3**) or, if it is to be accessible from the end of the drum opposite ring **24,** it can be guided along a rail shown in FIG. **2.** Hence, the slipring contact **24** may be optionally switched to one of the contacts **19'**, **20'** or **21'**. The contacts **19''**, **20''** ad **21''**, disposed opposite to the last mentioned contacts, are all connected to each other and to a relay referenced by the numeral **27** in FIG. **3.** The contacts **19, 20** or **21** of the annular disc **4,** to which the control circuit responds, will be brought into use dependent upon the position of the adjusting slide **26.** For example, if the adjusting slide **26** is moved into its middle position, only the contact **20'** will be supplied with control current. The contact **20''** will therefore also be supplied with current through the sector-shaped contact rail **20** as long as the annular disc **4** rotates through an angle of 90° in either angular direction from the zero position seen in FIG. **2.** Subsequently, the connection between the contacts **20'** and **20''** will once again be opened. There is also provided a relay **27** which will be energised when any one of the pairs of contacts **19'** and **19''**; **20'** and **20''**; **21'** and **21''** are connected and this relay controls a motor **28** for driving the bending platen.

Each adjusting slide **26** is also associated with a reversing switch **29,** shown only diagrammatically in FIG. **3,** and by means of which the drive for the disc **4** can be switched to clockwise or anti-clockwise rotation respectively. Accordingly, the sector-shaped slipring contacts **19** to **21** on the disc **4** extend for the appropriate angular distance on each side of a central or zero datum shown by the position of the drum **23** in FIG. **2.**

Since three positions are required for the adjusting slide **26** to correspond to the angles 45°, 90° and 180° and two positions are required for the reversing switch **29** corresponding to clockwise and anti-clockwise operation, it is possible for an adjusting slide **26** and the associated reversing switch **29** to be electromechanically controlled in accordance with the appropriate bending sequence programme, for example by means of punched cards or by means of known five-track punched tape so that the orders for one day may be prepared by a central order preparation department.

As seen in FIG. **4,** the individual switching operations can be neatly grouped on a control panel, mounted on the bending machine. Eight adjusting handles **26'** (see the left-hand side of FIG. **4**), adapted to co-operate with the respective slides **26,** are disposed on the aforementioned control panel. A switch **29** for controlling clockwise or anti-clockwise rotation may also be associated with each adjusting handle **26'** so that by rotating an adjusting handle **26'** in an anti-clockwise direction the principal bending angles are obtained in the anti-clockwise bending direction while rotating the handle into the clockwise direction provides the clockwise bending direction. A signal lamp **30,** which is illuminated when a bending operation takes place, is also provided above each adjusting handle **26'**. An adjusting knob **31,** which is set if the bending operation selected by the adjusting handle **26'** is desired in the bending programme, is disposed below each adjusting handle **26'**. The adjusting knobs **31** are adjusted only once in their entirety and are then scanned by electrical or mechanical scanning means during the entire bending sequence programme. It is essential that each bending sequence programme can be started with any desired bending angle which in turn is selected by operating the adjusting slide **26.**

FIG. **5** shows a simplified stress-strain diagram in order to illustrate the conditions which accompany the bending operation. Bending angles α correspond to the elongations ϵ. A rapid rise of the stresses δ with progressively increasing elongation or bending angles, increasing substantially less rapidly after the yieldpoint is reached, can be recognised in the diagram. Reverse elastic travel takes place whenever a set elongation such as ϵ_s (corresponding to a bend of α_s) is obtained since the material will have absorbed elastic deformation. According to the invention the aforementioned reverse elastic travel is compensated by applying additional bending. The best compensation is obtained by extending the steeply rising straightline at the beginning of the diagram to meet a horizontal line through P (corresponding to elongation ϵ_s). The point of intersection of these lines lies at a distance of ϵ_2 from the vertical axis and this elongation ϵ_2 is then added to the previously set elongation ϵ_s. The actual or required bending angle therefore corresponds to the elongations $\epsilon_s + \epsilon_2$. Reverse elastic travel will take place if bending is stopped at this position so that merely the elongation ϵ_s or the desired principal bending angle is retained. Fully satisfactory correspondence between the specified principal bending angle and the bending angle actually obtained is however achieved in many cases even if not the entire elastic deformation but only a substantial part thereof is taken into account as the additional bending angle.

FIG. **6** illustrates the current consumption during the bending operation and the measures to be taken in accordance with the invention. In this illustration the bending angle α is plotted on the abscissa while the current consumption I is plotted on the ordinate. Immediately after the motor of the bending machine is switched on the current consumption I is very high and thereafter this current consumption drops to an idling or no-load value I_1 which is retained until the bending tools **2** and **3** act on the material to be bent. The current consumption will then initially rise proportionally with the bending angle. It is possible to select a certain current I_1 within the aforementioned linear rise and to adjust a relay to said current adapted to switch off a synchronous motor or stepping motor which was initially switched on together with the motor of the bending machine. Accordingly, the synchronous motor, acting as register, stores the bending angle α_0 and α_1. When the set value of the specified principal bending angle α_S is reached, the bending operation is continued by the bending angle α_0 and α_1, stored in the synchronous motor. This procedure makes due allowance for the entire no-load travel, thus providing adaptation to bending material of different thickness. Moreover, a substantial part of the elastic deformation α_1 is also covered. The motor of the bending machine therefore switches off only after reaching a bending angle $\alpha_s + \alpha_0 + \alpha_1$. A bending angle is thus obtained which generally agress satisfactorily with the selected principal bending angle.

An even closer approach may be obtained by not only including the angle α_1 in the manner already described but also the larger angle α_2 and using same together with the angle α_0 for adjusting the principal bending angle α_s which is to be regarded as the set value. If bending is completed only after the angle $\alpha_s + \alpha_0 + \alpha_2$ is reached, the bending angle thus obtained will in practic correspond completely with the specified bending angle.

The actual elements needed for performing the proposal according to the invention, such as synchronous motors, controllers, relays, differentiating and integrating circuit means, are part of the prior art.

FIG. **7** shows a diagrammatic circuit diagram according to which a supplementary bending angle or final bending angle is obtained by electro-mechanically acting means. To this end, an adjustable resistor **32,** whose wiper supplies the relay **33,** is connected in series with the circuit of the motor **28.** As soon as the current in the circuit of the motor **28** exceeds a value, which can be adjusted on the resistor **32,** the aforementioned relay will open a circuit comprising a voltage source **34** and an electromagnetic clutch **35,** the last mentioned being adapted to couple the motor **28** to a synchronous motor or stepping motor **36.** The rotor of the motor **36** is coupled to the shaft **37** the end of which supports a wiping finger **38.** The wiping finger **38** simulates the traversed angle of rotation of the synchronous motor or stepping motor **36** on a slipring **39.** The aforementioned finger stops immediately the circuit of the electromagnetic clutch **35** is interrupted after excitation of the relay **33.** The finger **38** and the slipring **39** are connected via the relay **40** in such a way as to bridge the circuit for the relay **27.** When the specified principal bending angle is reached, a limit switch **41,** cooperating with the drive of the bending machine, is switched on so that the synchronous motor or stepping motor **36** is supplied by the voltage source **34.** Accordingly, the synchronous motor or stepping motor **36** will rotate in the opposite direction but at the same speed thus causing the finger **38** to reverse upon the slipring **39.** The relay **27** therefore remains energised and maintains the motor **28** switched on for the duration of the return run of the finger **38.** At the end of the return run the finger **38** traverses beyond the beginning of the slipring **39** so that the energising circuit for the relay **27** is finally interrupted and the bending machine stops bending and is then driven into its return run. This causes the limit switch **41** to be switched for a second time thus energising the pulse relay **40** which interrupts the bridging circuit. The pulse relay **40** once again closes the aforementioned bridging circuit only during the next bending operation when the limit switch **41** is switched on by the forward operation of the bending platen so that a final bending angle may also be taken into account for this next bending operation.

A resistor **32,** adjustable by means of a double wiper so that the relay **33** is energised if a specified drive current is exceeded, ia also provided in the circuit of the motor illustrated in FIG. **8.** The resistor **32** may also be replaced by other apparatus, for example measuring transducers or the like. One of its two double wipers supplies, via suitable means, the differential element, comprising the capacitor **42** and the resistor **43.** The second of the two wipers, adapted to slide in parallel with the first mentioned wiper, supplies the relay **33** which keeps a contact **44** closed until the specified current flow is reached and by means of which the capacitor **45** is charged with respect to time and therefore integrally via the resistor **46.** When the aforementioned current is reached the contact **44** initially opens in such a manner as to prevent discharge of the capacitor **45.** When the specified principal bending angle is reached the limit switch **41** is operated and discharges the capacitor **45** in a time which corresponds to the charging time. In the adjoining part of the circuit, the numeral **47** refers to the base resistor of the transistor **48** whose emitter resistor is designated by the numeral **49.** The relay **50,** also connected to the transistor, corresponds to the operating resistance of the transistor and, provided sufficient current flows, maintains the bridging contact **51** for the circuit of the relay **27** in the closed condition. During discharge, the aforementioned circuit is once again opened so that the drive of the bending machine is switched off and the machine is driven in the reverse direction. On traversing the position of the specified principal bending angle the machine switches off the limit switch **41.**

The circuit examples illustrated only diagrammatically hereinabove can be adapted to the appropriate operating conditions by known means. In all cases a quantity, corresponding to the differential quotient of the energy or current consumption with respect to the bending angle will be stored as set value in some manner within a short period of time, following at least the beginning of the bending operation, and will be retained until the bending operation is completed while the drive of the bending machine will remain switched on for a period of time corresponding to the aforementioned set value after the specified principal bending angle is reached.

In an advantageous embodiment the aforementioned set value may be increased at the same rate of change as in the brief time following on to the beginning of the bending operation and for the duration of the entire bending process until the specified principal bending angle is reached and that after the specified bending angle is reached the drive of the bending machine remains switched on for a period of time corresponding to the increased set value. In this way it becomes possible to substantially and fully simulate the supplementary bending angle resulting from elastic deformation.

The more accurately the changeover from the elastic to the plastic deformation range can be determined for determining the energy of current consumption or the displacement angle of a machine constructed as synchronous motor, the more reliable is it possible to measure the corresponding electrical quantity ormits differential quotient with respect to the bending angle. In an advantageous embodiment the determination of the aforementioned electrical quantity or its differential quotient with respect to the bending angle is terminated as soon as a specified, small change of quantity occurs. Said change of quantity is the consequence of a kink at the point of transfer from the elastic into the plastic deformation range.

In an advantageous further development of the present invention, the addition of the supplementary or additional bending angle to compenstate for reverse elastic travel (or "spring-back") is achieved by arranging that the drive remains switched on for a period of time preset by a timer and defined, for a given principal bending angle, by the no-load speed and furthermore incorporating a supplementary time which can be preadjusted on the timer so as to be related to the velocity drop under load and to the proportion of elastic deformation.

No-load velocity in the above context refers to the velocity reached by the bending plate in an unloaded state. However, the said no-load velocity is not used as a basis for determining the entire bending operation but only for a part of the rotation which starts at a particular angle reached after the zero position. This procedure offers the advantage of enabling inaccuracies of the zero position to be compensated and also provides the bending platen with an initial and short period for starting. During the aforementioned starting period inertia forces are overcome with the acceleration of the rotational velocity from zero to the no-load velocity. If the timing of the bending operation were based only on the no-load velocity, an unloaded rotation of the bending platen would cause it to stop precisely at the angular position which was pre-set. The time would therefore then be pre-selected for a value shortened by the amount of time required for rotation at no-load velocity from the zero position to the angular position at which the time is switched on.

However, the actual bending operation is not in practice based on the no-load velocity but on a lower velocity, so that an additional time must be switched in. This additional time depends basically on the loss of angular velocity due to loading by the bending process. If the material is very thick, the additional time will be relatively long while it is shorter with correspondingly thinner material. Furthermore, the said additional time is calculated to make allowance for the elastic deformation of the material to be bent and which results in elastic recover after the bending process. Whilst the no-load velocity and the times related thereto for different bending angles depend on the power rating of the drive and the mass of the machine parts to be set in motion so that it is therefore necessary to define it once for each machine at prolonged intervals of time, the additional time referred to above depends on the cross-section of material to be bent and on the tensile strength thereof. It is therefore necessarry for this additional time to be determined for different thicknesses of material and tensile strengths thereof from case to case so that the additional time for the most important thicknesses of material and tensile strengths thereof may be called up from a data store after being empirically determined.

It is possible in the manner described hereinabove to perform bends without the need for these to be monitored or limited by a switching operation triggered by setting means connected in any manner with the bending platen. It is thus possible to dispense with the setting means and setting elements associated with the bending platen and it is also possible to dispense with the corresponding switches. Instead it is merely necessary to provide a timer which can be adjusted to different values. Timers of this kind can be constructed in preferred and very simple manner in known electrically operated form, for example in the form of known RC networks with adjustable resistance values or capacitance values. These operate practically free of wear and maintenance requirements. The values for setting such a timer can be obtained in simple manner. It is also advantageous that due to a practically continuous adjustability these timers can be set to any desired value, while in the case of known setting means with pins as setting elements it was only possible to vary the bending operation at defined angular intervals which are determined by the distance between the setting elements.

The angular position at which the timer is switched on is appropriately disposed at an angle of at least 3° from the zero position. However, the said angular distance can be positive or negative depending on whether rotation is to be in the clockwise or anti-clockwise direction. Rotation of the bending platen through the aforementioned angular zone compensates for displacements of the zero position and also enables the previously mentioned inertia forces to be overcome.

A limit switch is appropriately also provided in order to reverse the drive to return the bending platen after the completed bending operation. Said limit switch is the sole switching element co-operating directly or indirectly with the bending platen. To actuate said limit switch requires only one switching cam or the like which itself need not be constructed in adjustable form. The bending platen however does not instantly come to a stop when the limit switch is actuated because its mass can be decelerated only within a finite period of time. The resultant displacement of the zero position is compensated in the manner described.

Preferably, the timer is switched on by switches disposed respectively at a specified angle on both angular sides of the zero position. These switches, which may for example be actuated by a cam of the kind heretofore described, may be so constructed that they switch on the timer when actuated by the cams in the specified direction of rotation for bending and switch off the drive of the bending platen during the return motion thereof when the said switches are once again actuated so that the bending platen comes to rest with the switching cam between the aforementioned two switches. Since the acceleration period corresponds approximately to the deceleration period, the zero position will thus be obtained between the two switches. Switches of this kind, responding to two actuating operations and having different switching functions are known in themselves and are frequently embodied by a suitable relay circuit.

The above-described development will now be further explained with reference to FIG. **9** in which the circle indicates the circulating path of the movable bending tool disposed on the bending platen and bearing on the bar which is to be bent and which in turn bears on a fixed bending tool to bend said bar in the intended manner. Instead of illustrating the bending tool, the aforementioned circle could also illustrate the circulating path of a switching cam which rotates with the bending platen.

Firstly, the zero position designated with **0** may be seen. The angular switching positions **101** and **102** at which a suitable timer is switched on can be seen on either angular side of the zero position and at one angular distance of 3° from the zero position. At some position of the angular zone disposed between **0** and **103** (considering an anti-clockwise rotation) the movable bending tool will bear on the bar to be bent and an initial bending process will commence during which the elastic deformation of the material to be bent will be substantially overcome.

Let us assume that the bar has to be bent through an angle of 90° in the anti-clockwise direction. If the bending platen and therefore the movable bending tool has to be rotated precisely through an angle of 90°, starting from the zero position, the position designated with the numeral **104** would be reached and the intended bend would without doubt not yet be reached. The bend would only be reached if the rotation were to be continued to some position disposed between positions **104** and **105**.

Position **104** would be reached if the timer were to be set solely on the basis of the no-load velocity of the platen. The timer (and platen drive) would then run for a period of time required by the bending tool to traverse from the position **102** to the position **104** after the timing cycle has been switched on at position **102**. The time which the timer must however actually provide to ensure that the bending machine will traverse through the actually required bending angle is then determined by carrying out a trial bend. The timer will then provide the time at which the drive is stopped or at which its direction is reversed at some position which is, say, between position **104** and a position **105** so that the bending platen will then return until at position **102** the drive is switched off whereupon the bending tool or the switching cam returns into the zero position.

The total period of time for which the drive remains switched on therefore comprises several individual positions of time. If the total time were to be provided by the timer alone it would be necessary to include a frequently variable part time during which the bending tool traverses from zero to position **101** or **102** respectively so that a total time, determined once for a defined thickness of material and tensile strength thereof could not be reproduced for all subsequent bends of the same material. Switching out of the aforementioned part time however permits a precisely reproducible time to be provided. In theory, the bending tools may act on the material to be bent over the entire zone between positions **0** and **103**, so that bending may have commenced in the zone not covered by the pre-set time, but it is practically impossible for the bending tools to bear on the material to be bent at a position near the zero position. In practice, bending will commence near the position **102** so that substantially only the elastic deformation is initially overcome even if bending has already commenced before the tools have reached the position **102**.

In order to carry out the above-described time controlled arrangement, a circuit similar to that shown in FIG. **7** may be employed.

Thus, the motor **28**, which drives the bending platen, is constructed so that its shaft has a contact finger similar to the contact finger **38** seen in FIG. **7**. This contact finger is arranged to co-act with a slipring similar to the slipring **39** but which is adjustable beforehand to provide an angle of traverse of the contact finger of at least 3° from the starting position of said contact finger. The contact finger and slipring are connected in an electrical circuit so that during such traverse a current flows to switch on a control voltage for a period of time corresponding to said angle of traverse. Such period of time can be indicated on a suitable recorder. A relay corresponding to relay **27** remains switched on during the operation of the motor **28** whilst running through the principal set bending angle but at the end of this time the aforesaid control voltage switches off the initial circuit supplying the relay corresponding to relay **27** and switches in an overbridging circuit, keeping the relay closed and enabling the motor **28** to continue the bending operation for the previously selected time interval.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. A bending machine for bars, wire and sections of steel and the like materials including a bending platen which supports bending tools, said platen being rotatable and directionally controllably driven, setting means for different principal bending angles, said setting means having elements which correspond to the specified principal bending angles and which can be actuated in any desired sequence, and means comprising an electrically operated control system for automatically continuing a bending operation beyond a set principal bending angle to compensate for deviations between the actual bending angle achieve and the required bending angle which may otherwise occur, each individual principal bending operation being continued by a supplementary bending angle which is determined by measurement of at least part of the energy or current of a motor driving the bending platen in the elastic deformation range of the material to be bent.

2. The bending machine according to claim 1 wherein an electric control circuit is provided for each bending operation, adapted to trigger setting means elements corresponding to principal bending angles, specified as desired, each control circuit being associated with one bending angle, the whole of the control circuits corresponding to the bending sequence programme.

3. The bending machine according to claim 2 wherein the setting means is a disc which rotates in accordance with the bending angle.

4. The bending machine according to claim 3 wherein contactors, corresponding to the principal bending angles, are provided on the disc, said contactors being rendered operative or inoperative by the control circuit in use.

5. The bending machine according to claim 4 wherein the control circuits are variable in that a plurality of contacts and an adjusting switch, driven in steps, are provided by means of which the contacts corresponding to a specified individual bending operation may be connected with a control pulse voltage and that the contacts control the motor driving the bending platen by means of contactors disposed on the setting means.

6. The bending machine according to claim 1 wherein from the moment at which the motor is switched on to the time at which a given energy or current consumption in the elastic deformation range is reached, a control motor, constructed as synchronous motor or stepping motor, is driven and is then once again switched on, after the specified principal bending angle is reached, and is rotated in the reverse direction through the angle of rotation taken up by it during the period for which it was initially switched on, said control motor being adapted to retain the first named motor in the switched on condition until said control motor returns into its starting position.

7. The bending machine according to claim 1 wherein the energy or current consumption is differentiated with respect to the bending angle in the elastic deformation range of the material to be bent and said differential quotient is integrated with respect to the entire principal bending operation, the adjustment of the setting means being varied relative to the instantaneous value of the aforementioned integral.

8. The bending machine according to claim 1 wherein the motor is a synchronous motor, connected to measuring means for measuring the displacement angle between its rotor and stator poles and whose measured value is then stored during the entire bending operation.

9. A method for bending bars, wire and sections of steel and like materials on a bending platen supporting bending tools, with the platen being rotatable and directionally controllably driven and having setting means for different principal bending angles including elements corresponding to the specified principal angles and actuable in any desired sequence, and an electrically operated control system for automatically continuing a bending operation beyond a set principal bending angle to compensate for deviations between the actual bending angle achieved and the required bending angle which may otherwise occur, each individual principal bending operation being continued by a supplementary bending angle which is determined by measurement of at least part of the energy or current consumption of a motor driving the bending platen in the elastic deformation range of the material to be bent, with the energy or current consumption being differentiated with respect to the bending angle in the elastic deformation range of the material to be bent and the differential quotient being integrated with respect to the entire principal bending operation, and the adjustment of the setting means being varied relative to the instantaneous value of mentioned integral, the improvement comprising storing a quantity corresponding to the differential quotient of the energy or current consumption with respect to the bending angle as set value within a brief period of time, following onto at least the beginning of the bending operation and retained until the bending operation is completed and the specified principal bending angle reached, and maintaining the drive switched on for a period of time corresponding to the set value.

10. The method according to claim 9 including increasing the set value at the same rate of change as in the brief period of time following on to the beginning of the bending operation and for the duration of the entire bending operation until the specified principal bending angle is reached, and after the specified principal bending angle is reached maintaining the drive switched on for a period of time corresponding to the increased set value.

11. The method according to claim 9 including terminating the determination of the quantity corresponding to the energy or current consumption or the displacement angle as soon as the electrical quantity or its differential quotient with respect to the bending angle deviates by a specified small amount from its initially determined value.

12. The bending machine according to claim 1 wherein there is provided a timer which is arranged to maintain the drive of the bending platen after a set principal bending angle has been reached for a period of time preset on said timer and defined for any given principal bending angle by a time dependent upon the no-load speed of the platen together with a supplementary time which is related to the velocity drop of the platen under load and to the amount of elastic deformation suffered by the material being bent.

13. The bending machine as claimed in claim 12 wherein the timer is so arranged that it is not switched on until the bending platen has turned through an angle of at least 3° from the zero or start position.

14. The bending machine as claimed in claim **12** wherein there is provided a limit switch for controlling the return of the bending platen.

15. The bending machine as claimed in claim **12** wherein there are provided further switches disposed on either side of the zero position of said bending platen for switching on the timer.

16. The bending machine as claimed in claim **17** wherein said further switches are actuable during the return traverse of the bending platen to switch off the drive of said bending platen.

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