METHODS AND APPARATUS FOR STRAIGHTENING OR BENDING ELONGATED WORKPIECES

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References Cited
UNITED STATES PATENTS
3,459,018 8/1969 Miller............................72/14

3,481,170 12/1969 Galdabini....................72/11

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ABSTRACT

A method of straightening an elongated workpiece, in which the workpiece is supported at two spaced points and straightening forces are applied between these points by an automatically controlled hydraulic ram, governed by a programming system which causes the first stroke of the ram to deflect the work beyond the desired final shape by a distance approximately equal to the calculated maximum elastic deformation, the load is then removed and the residual error sensed, and a further series of strokes applied at constant increments, the residual error being sensed between strokes and used to initiate a second series of stroke increments of smaller value until the residual error falls below a final preselected value at which acceptable straightness has been achieved.

6 Claims, 3 Drawing Figures
METHODS AND APPARATUS FOR STRAIGHTENING OR BLENDING ELONGATED WORKPIECES

This invention relates to processes and apparatus for carrying out straightening operations on elongated workpieces such as shafts or spindles. The term "straightening" as used herein is primarily intended to refer to a conventional straightening operation in which a workpiece is initially out of true straightness and is required to be returned or brought into a truly straight shape. The term is however also intended to include corrective bending operations on a workpiece, designed to impart a desired shape thereto, even when the final shape is not in fact straight.

The invention may be viewed as an improvement in or modification of the invention described in U.S. Pat. No. 3,481,170.

In the process described in the said patent a workpiece is straightened by a series of operations which includes a first straightening stroke arranged to impart to the workpiece a deformation beyond the desired final shape, this deformation being approximately equal to, or slightly greater than, the estimated maximum elastic deformation, the workpiece is then unloaded and the remaining error between its relaxed position and its desired final shape is then measured or sensed, after which at least one further straightening stroke is applied to impart a deformation beyond the final shape equal to the sum of the said estimated maximum elastic deformation and the sensed error remaining after the first stroke.

The maximum elastic deformation referred to above may be defined as the maximum deflection that can be imparted to the workpiece without any part of it entering into the plastic range. It will be understood that in the case of a bar the outer portions of the bar will be subjected to a higher stress and deformation when a bending strain is applied, then the inner portions, and the outer portions will therefore reach the elastic limit sooner, i.e. at a smaller total deflection of the bar. The maximum elastic deformation is reached when any part of the workpiece starts to enter into the plastic range.

In the straightening process described and claimed in the said U.S. Pat. No. 3,481,170, the value of each of the straightening strokes is dependent upon the residual error sensed after the previous stroke and is automatically adjusted by a control device having an input from an error sensing device which measures the residual error of the relaxed workpiece after each straightening stroke. In practice it is found that this process, though highly effective, requires somewhat elaborate control systems, and it is an object of the present invention to provide a simplified process and apparatus, operating on the same basic principles, and capable of achieving substantially equivalent results but with less complicated control stages and control equipment.

Broadly stated from one aspect, the invention consists in a method of straightening or applying controlled bending to an elongated workpiece, in which the workpiece is subjected to a bending stroke, which imparts to it a deformation beyond the desired final shape, this deformation (as measured beyond the desired final shape) being approximately equal to, or slightly greater than the estimated maximum elastic deformation, and the workpiece is then unloaded and subjected to a series of bending strokes which impart progressively increasing deformation to the workpiece on a preselected programme of increments and the residual error between the actual and desired shapes is sensed when the workpiece is unloaded between at least some of said strokes, and when the residual error falls below a first preselected value the workpiece is subjected to a further series of increasing strokes of smaller progressive increments, according to another preselected programme, and the residual error is again sensed when the workpiece is unloaded between strokes, and when the residual error falls below a second preselected value, the operation is terminated.

According to a preferred feature of the invention the first series of strokes are of progressively increasing length, the increments being of constant value, and the second series of strokes are also of progressively increasing length, with constant increments of smaller value than the increments of the first series.

Conveniently the residual error is sensed after each stroke, though in some cases it may be sufficient to sense the error only after a preselected number of strokes.

The method may be applied in practice to a workpiece in a number of different ways, with the workpiece supported in various different ways but the invention is particularly applicable to a method in which the workpiece is supported on two spaced supports, and the bending strokes are applied to the workpiece between the supports by a fluid-operated ram.

According to another preferred feature of the invention the length of each stroke is determined by an automatic control system having an input from an error sensor arranged to sense the residual error when the workpiece is unloaded, and an output connected to a ram for applying the bending or straightening strokes, so as to control the length thereof, the control system including a programming section arranged to apply one or two preselected programmes of increments to the output signal, depending upon whether the sensed residual error is above or below the first preselected value.

The invention also consists in an apparatus for performing the method of any of the preceding claims including an automatic control system associated with an error sensor and a fluid operated ram for applying straightening strokes to a workpiece supported between two support points, the output from the control system being operatively associated with the fluid operated ram so as to control the length of the strokes, and the control system including a programming section arranged to apply one or two preselected programmes of increments to the output signal to the ram, depending upon whether the sensed residual error occurring at the input is above or below a first preselected value.

The invention may be performed in various ways and one embodiment with certain possible modifications will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a load deflection diagram illustrating very diagrammatically and on an exaggerated scale the successive stages of a straightening operation according to the invention,
FIG. 2 is another diagram illustrating the physical straightening strokes or stages shown in the diagram of FIG. 1, and likewise on an exaggerated scale, and FIG. 3 is a block diagram illustrating the main components of a straightening apparatus according to the invention.

Referring first to FIGS. 1 and 2 the workpiece in this example is a metal bar 10 which has initially been bent or deformed, or otherwise departs from true straightness as shown in FIG. 2, and is placed over a pair of spaced supports 11,12 with its curvature upwards so that the center of the bar lies at point A immediately below a hydraulically operated straightening ram 13. The final required straight shape of the bar is shown by the straight line 14 extending between the two supports 11,12 and the corresponding position of the center of the bar is shown by the origin O.

In performing the straightening operation it is first necessary to calculate the maximum elastic deformation of the bar. This can be done without great difficulty and to reasonable accuracy, from a knowledge of the dimensions of the bar and its material. In the load deflection diagram of FIG. 1 the maximum elastic deformation Fp corresponds to the position P on the curve where the line of the curve begins to deviate from a straight line of constant gradient (the value Fp being measured from the original position A).

Having calculated this value Fp a first downward straightening stroke S1 is applied to the bar by means of the ram 13 so as to deform the bar beyond the desired final position O to an extent beyond the origin O approximately equal to, or possibly slightly greater than, this estimated value Fp. With the bar deformed by this first straightening stroke S1 the equivalent point on the load deflection curve is shown at Q1 in FIG. 1. The load on the bar is then removed by withdrawing the ram 13 upwards and the position of the point at the center of the bar returns to a new relaxed position R1 along the line Q1-R1 (parallel with AP).

An automatic sensing device (see FIG. 3) then measures the distance between this relaxed position R1, and the origin O and provides an output proportional to this residual measured error E1. If this residual error E1 is greater than a first preselected error value Ea, the process continues with a second stroke S2 which exceeds the first stroke S1 by an increment a. The corresponding position on the load deflection diagram is shown at Q2 and when the load is again removed the central point of the bar returns to position R2 along the line Q2-R2. The residual error is again sensed and since in this case the error is again larger than the first selected value Ea a further downward straightening stroke is applied to position S3, the added increment between S2 and S3 being equal to the previous increment a. When the load is again removed the central point on the bar returns along the line Q3-R3 and again the residual error is sensed. At this stage the residual error is found to be smaller than the first preselected value Ea and accordingly the next stage of the straightening programme is started. The next stroke S4 is accordingly taken down to a position where the added increment b between S2 and S4 is somewhat less than the constant increment a of the first series of strokes. From the corresponding position Q4 on the load deflection diagram the central point of the bar returns to position R4 when the load is relaxed, and since this value is still greater than the second preselected error value Eb a further downward straightening stroke S5 is applied with the added increment b the same as in the previous stroke. When the load is removed the central point of the bar then returns along the line Q4-R5 and the sensed error is again found to be slightly greater than the second preselected value Eb. A further straightening stroke S6 is therefore applied with the same added increment b and on relieving the load it is found that the relaxed position of the bar at R6 is less than the second error value Eb and accordingly the process is then terminated and the bar is removed from the apparatus since it now lies within the preselected final straightness limits.

In a possible modification, instead of maintaining constant increments a in the first stage of the programme and constant increments b in the second stage, the increments a of the first stage may be varied progressively; for example they may be progressively reduced in size towards the end of this stage, according to the pre-arranged programme. Likewise the increments b in the second stage may be progressively reduced. It is however important that the increments b of the second stage should be smaller than those of the first stage. It will also be understood that more than two stages may be used in the straightening programme if required, and if a third or additional stage is employed the value of the increments in each further stage will be smaller than those in the previous stage, and the change from one stage to the next will take place when the sensed residual error falls below a particular selected value.

A suitable apparatus for controlling the straightening process is illustrated diagrammatically in FIG. 3. In this apparatus the straightening ram 13 is powered by an electro-hydraulic power control unit 22 and the apparatus includes a positional pick-up or error sensor 16 and an electronic control device indicated generally by 17, including a computer with a digital memory 18, a programmer 19, a summing device 20, a differentiator 21, a control amplifier 23, and an external control panel 24.

After feeding from the control panel 24 to the programmer 19 the estimated maximum elastic deformation Fp, the two increments a and b, and the first and second preselected errors Eb and Eb, a button is pressed on the panel 24 and an electric signal is generated for beginning the straightening operation by operating the ram 13. The positional pick-up or error sensor 16 produces two signals one of which represents the total deflection applied by the ram, and is transmitted to the amplifier 23, whilst the other, representing the residual error e1 after the load has been relieved, is transmitted to the memory of the computer 18. This error signal is also compared with the first preselected error signal Eb by the differentiator 21 and as long as the residual error e1 is larger than the preselected value Eb an output signal is transmitted from 21 to the amplifier 23 to cause the ram to be energized again, the extent of its movement being governed automatically to produce an increment according to the first or second stage of the programme, as explained above.
This procedure and apparatus enable a workpiece to be straightened, or brought to a predetermined shape, in a very economical process involving only a small number of straightening strokes and without the complications imposed by controlling the added increment of each stroke in accordance with the sensed residual error after the previous stroke.

It will be appreciated that when straightening operations are applied to a group of similar manufactured workpieces such as shafts, all are approximately of the same dimensions and materials and characteristics, and the value of the increments \( a \) and \( b \) in the first and second stages of the programme can be selected by experience to produce the best possible results in the shortest possible time.

I claim:

1. A method of straightening or applying controlled bending to an elongated workpiece, in which the workpiece is subjected to a bending stroke which imparts to it a deformation beyond the desired final shape, this deformation as measured beyond the desired final shape being approximately equal to, or slightly greater than, the estimated maximum elastic deformation, and the workpiece is then unloaded and subjected to a series of bending strokes which impart progressively increasing deformation according to a preselected programme to the workpiece, and the residual error between the actual and desired shapes is sensed when the workpiece is unloaded between at least some of said strokes, and when the residual error falls below a first preselected value the workpiece is subjected to a further series of strokes of smaller progressive increments, according to another preselected program, and the residual error is again sensed when the workpiece is unloaded between strokes, and when the final residual error falls below a second preselected value, the operation is terminated.

2. A method according to claim 1, in which the first series of strokes are of progressively increasing length, the increments being of constant value, and the second series of strokes are also of progressively increasing length, with constant increments of smaller value than the increments of the first series.

3. A method according to claim 1, in which the residual error is sensed after each stroke.

4. A method according to claim 1, in which the workpiece is supported on two spaced supports, and the straightening or bending strokes are applied to the workpiece between the supports by a fluid-operated ram.

5. A method according to claim 1, in which the length of each stroke is determined by an automatic control system having an input from an error sensor arranged to sense the residual error when the workpiece is unloaded, and an output connected to a ram for applying the bending or straightening strokes, so as to control the length thereof, the control system including a programming section arranged to apply one of two preselected programs of increments to the output signal, depending upon whether the sensed residual error is above or below the first preselected value.

6. Apparatus for straightening or applying controlled bending to an elongated workpiece, including a power-operated ram, and means for controlling the ram including a position sensor for detecting the instantaneous position or shape of the workpiece, and a computer including a programming section and an information storage section, and a differentiator arranged to compare the input signal from the position sensor with a first preselected value, and to operate the ram on a first program of strokes with increasing amplitudes, until the input signal from the position sensor reaches the said preselected value, and then to operate the ram on a second program of strokes which increase with smaller increments.

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