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(54) Method and apparatus for the stepless positioning of a machine tool part

(57) To enable a machine part (2) to be steplessly positioned along a rectilinear path of movement (8), an independently displaceable stop (12,13) is arranged in the path. The stop (12,13) is moved into a predetermined position and held therein, the machine part (2) then being moved independently into the position predetermined by the stop (12,13).

Fig. 1

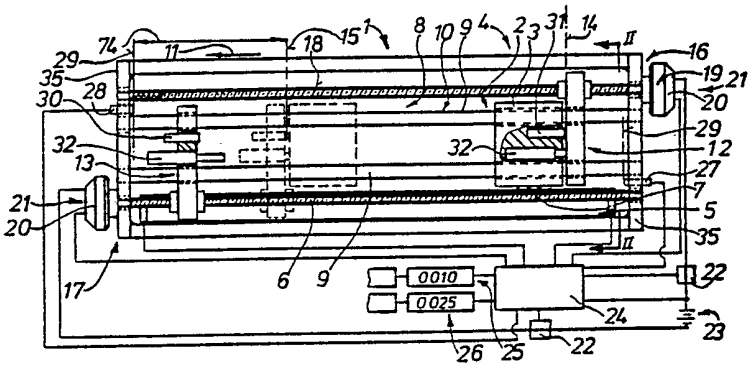

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Fig. 1

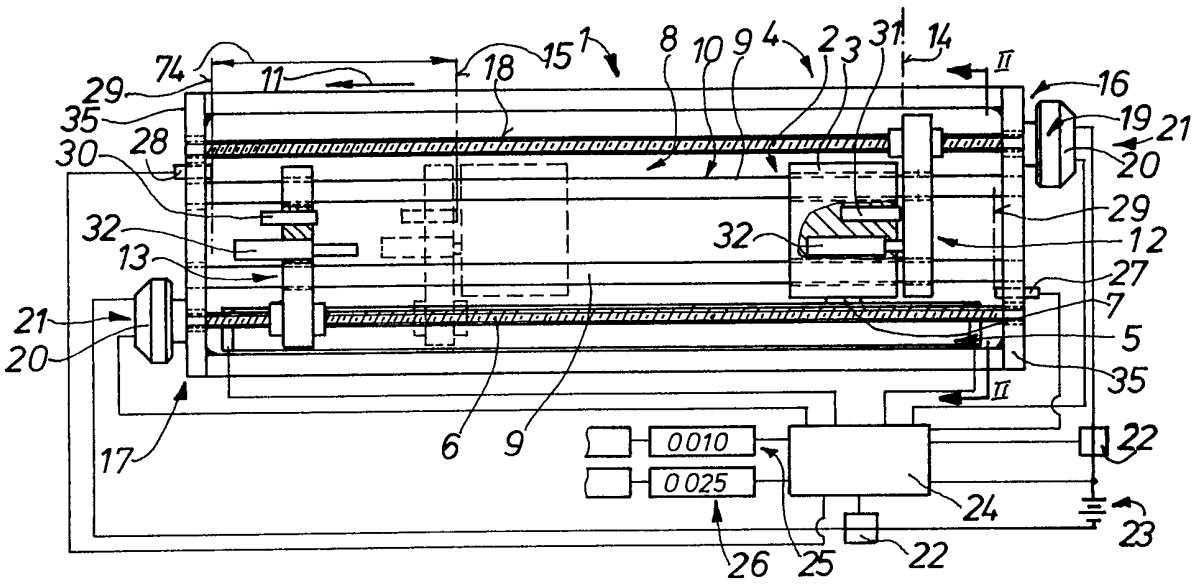

Fig. 2

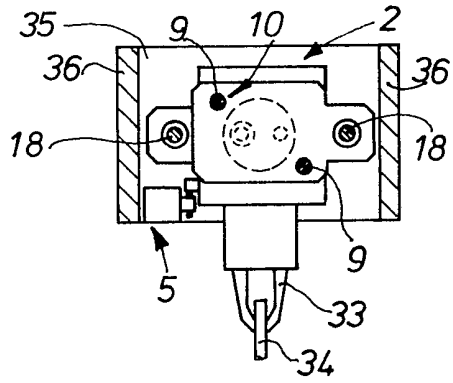

Fig. 3

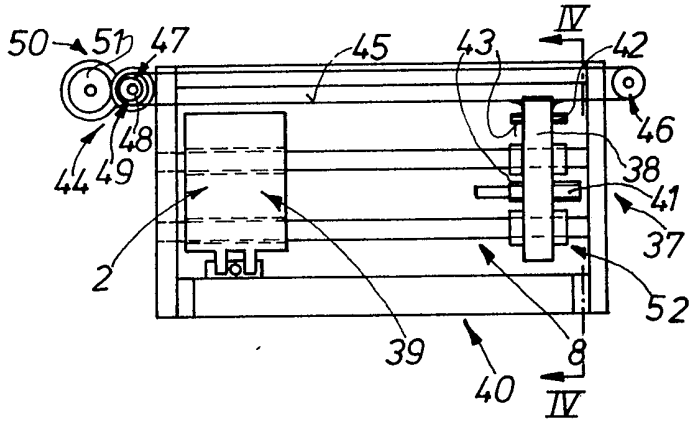

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Fig. 4

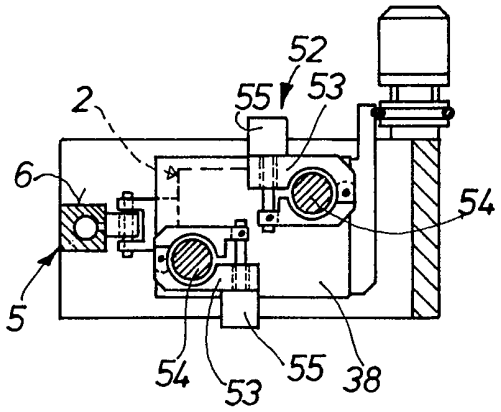


Fig. 5

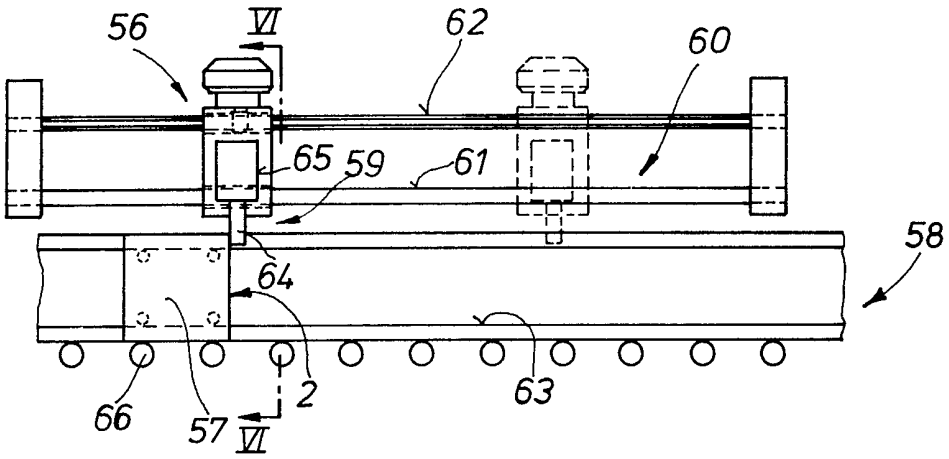
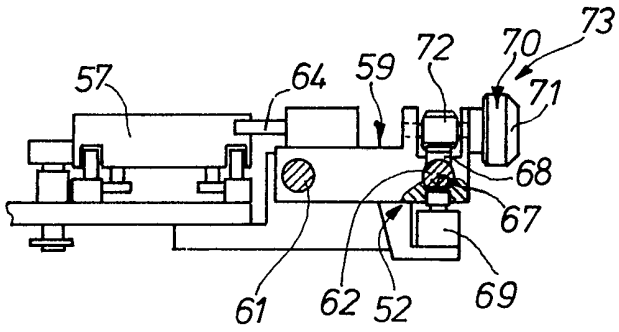


Fig. 6



SPECIFICATION

A manufacturing method including and apparatus for the stepless positioning of a machine part

The present invention relates to improvements in a method of manufacture including,and apparatus for steplessly positioning a machine part along a rectilinear path of movement by means of a stop independently displaceable in the path.

Published German patent application No. 3,035,191 discloses means for steplessly positioning an intermediate carrier of a manipulating device, which comprises several fixed stops in different positions for limiting the movement of the intermediate carrier. Depending on the desired position of the intermediate carrier, a selected one of the fixed stops is moved into the path of movement of the carrier. Shock absorbers are associated with the stops to damp the impact of the carrier moved against the selected stop. Furthermore, limit switches may be used to ascertain the end position of the intermediate carrier. These arrangements have been very successfully used in fully automated assembly lines since the desired end positions may be obtained with high accuracy even with a high number of operating possibilities. However, the advantages of these arrangements cannot be universally applied because the number of the stopped end positions of the intermediate carrier is, in fact, limited.

Manipulating devices with intermediate carriers or gripping arrangements displaceable along a guide track and positionable in predetermined positions by cooperating drives and position monitoring means are also known. Such linear positioning devices have become known as NC-axles. If such manipulating devices comprise three such positioning devices for stepless movement in three directions, they are called robots. These freely programmable displacement devices make it possible to assume any desired position along a guide track, which makes it readily possible to store new positions in the control if the course of operations is changed. However, the adaptation of the devices to different loads, particularly different part weights and velocities during movement, is limited so that these known robots cannot always be successfully used.

It is the primary object of this invention to provide a method and apparatus for the stepless positioning of a machine part along a rectilinear path of movement, which makes a precision positioning of the machine part possible in a multiplicity of predetermined positions even if the movements are frequently repeated.

It is another object of the invention to assure in such a method and apparatus that the machine part is rapidly moved and positioned in its various positions.

The above and other objects are accomplished according to the present invention by placing a stop in the rectilinear path of movement of the machine part, moving the stop to a predetermined position along the path, holding the stop in the predetermined position, and thereupon independently moving the machine part to the predetermined position. This method is carried out according to another aspect of this invention with an apparatus comprising a first displacement drive coupled to the machine part for moving the machine part along the path, a stop displaceably mounted in the path for association with the machine part, and a second displacement drive coupled to the stop for displacing the stop along the path. A means for monitoring the position of the stop along the path generates an output signal corresponding to the monitored position, and a control circuit connects the displacement drives, the control circuit including an element for setting a stop position for positioning the machine part, the stop position setting element generating an output signal corresponding to the set position, and the control circuit actuating the first displacement drive when the output signals of the stop position monitoring means and of the stop position setting element conform.

The unexpected advantages of the invention are attained by dividing the displacement, into a positioning stage and a movement stage. This enables the machine part to be brought rapidly and precisely into any desired end position along the path of movement in an unexpectedly simple manner because the stop has a small mass and, therefore, may be moved quickly and with great precision. At the same time, the measuring systems and precision drives, such as stepping motors, useful in this method and apparatus are simple and relatively cheap. The displacement movement may be effected at a high velocity to the end position of the machine part, even if the same has a considerable mass, because this end position is determined by the position of the stop, which is fixed. Since the drive for precisely positioning the stop is subject to small loads, its operating life is long while maintaining high precision so that the individual predetermined positions along the path of movement of the machine part stays exactly reproducible over a considerable number of operations.

The above and other objects, advantages and features of the present invention will become more apparent from the following detailed description of certain now preferred embodiments of the apparatus, taken in conjunction with the somewhat schematic accompanying drawing wherein

Figure 1 is a simplified top view of one embodiment of an apparatus for steplessly positioning a machine part along a rectilinear path, together with a diagram of the control circuit;

Figure 2 is an end view, partly in section along line II-II of FIG. 1, of the apparatus;

Figure 3 is a similarly simplified top view of another embodiment;

Figure 4 is an end view, partly in section along line IV-IV of FIG. 3, of the other embodiment;

Figure 5 is a similarly simplified top view of a machine part positioning apparatus associated with an assembly line; and

Figure 6 is an end view, partly in section along line VI-VI of FIG. 5.

Referring now to the drawing and first to FIGS. 1 and 2, there is shown apparatus 1 for steplessly positioning machine part 2 along rectilinear path of movement 8. The illustrated machine part is a carriage 3 of manipulating device 4. The rectilinear path of movement is constituted by guide columns 9 displaceably mounting machine part 2 for movement along guide track 10 in the direction of arrow 11. First displacement drive 5 is coupled to the machine part by entrainment element 7 for moving the machine part along the path of movement into different predetermend positions, drive 5 being illustrated as a cylinder-piston device without a piston. Stops 12, 13 are displaceably mounted on guide columns 9 in path of movement 8 for association with machine part 2 for determining and fixing the different predetermined positions of the machine part. Stop 12 is illustrated as being in position 14 indicated by a chain-dotted line for precisely positioning machine part 2 in this position. Stop 13 may be displaced from the position shown in full lines to that indicated in broken lines to assume predetermined end position 15 (shown by a chain-dotted line) for machine part 2 while the machine part is in position 14. Second displacement drive 16, 17 is coupled, respectively, to stop 12, 13 for displacing the respective stop along path of movement 8, the stops being displaceably mounted on guide columns 9 for movement along guide track 10. Since the second displacement drives are identical, their component parts are designated by the same reference numerals. Each of the illustrated displacement drives 16, 17 comprises threaded spindle 18, a nut displaceable along the spindle and coupled to the respective stop, and drive motor 19 for rotating the spindle whereby the nut and stop coupled thereto are displaced. In the illustrated embodiment, the drive motor is stepping motor 20 and constitutes means 21 for monitoring the position of the respective stop along path 8. For this purpose, position monitoring means 21 generates an output signal corresponding to the monitored position. A control circuit connects displacement drive 5 and displacement drives 16, 17. The control circuit includes switching member 22 connecting position monitoring means 21, i.e. stepping motor 20, to power source 23 and control 24. First displacement drive 5 is also connected to control 24. Respective element 25, 26 associated with stop 12, 13, respectively, is connected to control 24 for setting a respective stop position for positioning machine part 2 and each stop position setting element 25, 26 generates an output signal corresponding to the set position. The control circuit actuates first displacement drive 5 when the output signals of the stop position monitoring means and of the stop position setting element conform.

As shown in the drawing, the control circuit also includes limit switches 27, 28 determing reference positions 29 for stops 12, 13, the limit switches being connected to control 24. Furthermore, the illustrated control circuit includes limit switches 30, 31 respectively mounted on stop 13 and machine part 2 and connected to control 24.

Shock absorber 32 is mounted on the side of stop 13 facing machine part 2 and another shock absorber 32 is mounted on machine part 2 facing opposite stop 12. Limit switch means 31, 32 cooperate with the stop and the machine part and may be proximity fuses.

With this apparatus a stop is placed in path of movement 8 of machine part 2, the stop is moved by displacement drive 16, 17 to a predetermined position along the path, the stop is held in the predetermined position, and the machine part is thereupon moved independently to the predetermined position. The stop is moved to the predetermined position and held therein while the machine part is at a position along the path spaced from the stop. In the illustrated embodiment, stop 13 is moved along the path to reference position 29 whence it is moved to predetermined position 15 and held therein, stops 12 and 13 delimiting path of movement 8 of machine part 2 in opposite directions. The machine part is placed between the stops and stop 12 is in fixed position while stop 13 is moved. Each stop may be released from the predetermined position wherein it is held and the released stop is moved to fixed reference position 29. It is then moved a predetermined distance 74 from the fixed reference position to another position along the path and the stop is held in the other position. This increases the precision of the stop positioning, particularly if the second displacement drive constitutes the stop position monitoring means.

If the stop is moved to and held in the predetermined position while the machine part is spaced therefrom, more time is available for precisely positioning the stop without delaying the movement of the machine part. By placing the machine part between two stops delimiting respective end positions, the machine part is held in a precise end position one stop while the other stop is precisely positioned, thus avoiding possible positioning errors. A single measuring system suffices to monitor and position both stops.

With the apparatus of the invention, the control circuit operates the displacement drive for the stop in such a manner that the stop is moved precisely to the desired position and is held therein so that stops of little mass may be used to brake and position machine parts accurately along a path of movement. A means for holding the stop in position may also be connected to the control circuit whereby only the holding force of the stop as a function of the kinetic energy to be absorbed thereby need be measured to obtain precise positioning.

The use of guide columns along the displacement path and the spindle drive operated by a stepping motor provides a compact structure in which the displacement drive for the stop constitutes the position monitoring means therefor. Since the nut will remain in its position on the threaded spindle as soon as rotation of the spindle ceases, it constitutes a means for holding the stop in position at the moment the spindle rotation stops. The displacement drive for the stop can

have the same length as the guide track for the machine part. With the shock absorber and limit switch means described hereinabove, it is possible to brake the machine part by a precisely predetermined time delay while the end position of the machine part at the stop is ascertained.

As is shown in FIG. 2, the two guide columns 9, 9 are diagonally arranged, i.e. they define a plane enclosing an angle of 45° with the horizontal, which results in substantially the same stability of guide track 10 in horizontal and vertical directions. This enhances the accuracy of guidance for machine part 2. First displacement drive 5 is positioned below threaded spindles 18 of the second displacement drive. Machine part 2 has gripping or clamping device 33 for grasping structural part 34. End plates 35 are interconnected by side plates 36 to reinforce guide track 10, thus providing a stationary housing for guide columns 9, and the flexing forces exerted by machine part 2 on the guide columns are distributed over two bearing points to the massive housing.

FIG. 3 illustrates apparatus 37 for steplessly positioning stop 38 for machine part 2. The machine part is a holder 39 of machine tool 40. Shock absorber 41 and limit switch 42 are arranged on stop 38, the shock absorber and limit switch being mounted on the stop for adjustment in the direction of path of movement 8. For this purpose, the shock absorber and limit switch have circumferential threads 43 engaging threaded bores in the stop. Position monitoring means 44 for stop 38 comprises tackle 45 extending parallel to the path of movement of the stop and output signal generator 48 arranged along the tackle. The tackle comprises a rope trained over the pulleys 46, 47 and the output signal generator is a rotary potentiometer coupled to pulley 48. In this manner, the movement of the tackle rope and stop 38 coupled thereto along path of movement 8 of machine part 2 may be monitored, for which purpose potentiometer 48 serves as output signal generator transmitting a signal corresponding to the monitored position to control 24. At the same time, position monitoring means 44 constitutes second displacement drive 50, for which purpose pulley 47 is coupled to drive motor 51. Because the movement of the rope of tackle 45 is continuously monitored by control signal emitter 49, any type of drive motor may be used for driving the tackle. When stop 38 has reached the desired position, holding means 52 fixes it in this position. As shown in FIG. 4, holding means 52 for stop 38 is a brake means 53 engaging guide columns 54 displaceably mounting machine part 2 and stop 38. To hold stop 38 in position,. the clamping brake shoes of the brake means are pivoted towards each other by drive 55 so that columns 54 are clamped between the brake shoes.

In the illustrated embodiment, displacement drive 5 serves to move machine part 2 along path of movement 8 and is constituted by cylinder-piston device 6 whose housing interconnects the end plates of a housing in which guide columns 54 are arranged, similarly to the above-described arrangement in the embodiment of FIG. 1. If stop 38 is guided along guide columns 54 on anti-friction bearings, such as ball bearings, it may be driven therealong with very little power so that it is possible to replace drive motor 51 and signal emitter 49 by a stepping motor combining the functions of both. The accuracy of such a stepping motor is very high when the mass moved thereby is very small.

The embodiment of FIG. 3 provides a very economical and accurate measuring system for monitoring the position of the stop. Where the position monitoring means serves also as the displacement drive, the precise positioning monitoring is combined with the advantages of a low-cost construction.

FIG. 5 illustrates apparatus 56 for steplessly positioning a machine part constituted by workpiece carrier 57 of assembly line 58 for assembling multi-part workpieces. This apparatus comprises guide path 60 for stop 59, which is constituted by two parallel guide columns 61, 62 displaceably mounting the stop and extending parallel to rectilinear path of movement 63 of workpiece carrier 57. As shown in broken lines, additional stops 59 may be displaceably mounted on the guide columns for independent movement along guide path 60. Stop 59 carries abutment lever 64 for engagement with, and disengagement from, carrier 57, the abutment lever being adjustable perpendicularly to guide columns 61, 62 by drive 65 for engagement with, and disengagement from, the workpiece carrier. A series of drive rollers 66 are spaced along rectilinear path of movement 63 for moving workpiece carrier 57 therealong. Preferably, the drive rollers are connected to their drive by slip clutches so that, upon engagement of abutment lever 64 with the carrier, the drive rollers engaging the carrier stop rotating whereby wear of the drive rollers is reduced.

As illustrated in FIG. 6, guide column 62 has a flattened underside to constitute braking surface 67. Rack 68 is arranged on the opposite upper side of guide column 62. Brake shoe means 69 is mounted on stop 59 for cooperation with braking surface 67 and pinion 72 meshes with rack 68, the pinion being driven by displacement drive 70 constituted in the illustrated embodiment by stepping motor 71. Brake shoe means 69 cooperating with braking surface 67 constitutes means for holding stop 59 in position.

In this arrangement, additional costly supports are not required because the guide means for the machine part may be dimensioned according to its mass and may, therefore, absorb the kinetic energy of the machine part upon engagement with the stop. Furthermore, the force operating on the stop is transmitted in almost the same location to the guide columns serving as support means so that very light-weight stops may be used even if the delay energies are high.

As in the other embodiments, apparatus 56 for steplessly positioning workpiece carrier 57 along an assembly line also uses the principle of separating the positioning from the displacement of the carrier. Therefore, the stop or stops may be moved

independently of the movement of the workpiece carrier into the desired position at high speed and with great accuracy, and may then be held in position by brake means 69. Stepping motor 71 serves simultaneously as displacement drive 70 for the stop and means 73 for monitoring the position thereof.

Although the operation of the apparatus described hereinabove and illustrated in the drawing will be obvious from the description of its structure, it will be further elucidated hereinbelow in connection with the positioning of stops 12 and 13 of apparatus 1 shown in FIGS. 1 and 2.

While machine part 2 is in position 14 determined by stop 12, stop 13 is moved from the position shown in full lines to reference position 29 to obtain an exact starting point for obtaining a measuring value of distance 74 between reference position 29 and a desired position 15 shown in broken lines. Stepping motor 20 of displacement drive 17 is operated to move stop 13 and to hold it in the desired position by stopping the motor. Machine part 2 may then be rapidly moved to position 15 by applying pressure to cylinder-piston drive 5. Impacts on the stop and the machine part are absorbed by shock absorbers 32 which absorb the kinetic energy of the rapidly moved machine part and enable the machine part to engage the stop softly. Stop 13 is held in position automatically by the fact that the nut coupling the stop to spindle drive 18 remains fixed as soon as the spindle ceases to rotate. If the flanks of the spindle threads are suitably shaped, for example as trapezoidal threads, the stop will be sufficiently fixed in position if not subjected to undue loads. However, if desired, brake means may additionally be provided, as in the embodiment of FIG. 5, to hold the stop in a precisely predetermined position under all operating conditions.

If desired, an adjustable abutment plate for engagement by the machine part may be mounted on the stop and the shock absorber and/or limit switch means may be carried thereon, or the latter may be adjustably mounted directly on the stop, as shown in FIG. 3. This makes it possible to adjust the soft contact between the stop and the machine part very sensitively and accurately to adjust the end positions of the machine part additionally to the control by the stop position. In this manner, the precision positioning of the machine part is further enhanced.

While the invention has been described in connection with certain now preferred embodiments thereof, it will be clearly understood by those skilled in the art that it is not limited to the illustrated embodiments. For example, the displacement drives as well as the stop position monitoring and stop holding means may have any suitable structure serving the described purposes. For example, the displacement drive for the stop and the stop position monitoring means may be separate devices. While an electromechanical transducer has been used for the stop position monitoring means in the embodiment of FIG. 3, contactless electrical or electro-optical measuring devices may be used, such as capacitative or light beam measuring systems. The illustrated spindle, tackle and rack-and-pinion displacement drives may be replaced by other suitable drives, such as independent drive rollers operated by linear motors or steplessly operating cylinder-piston drives actuated by pressure fluids. The stops may be guided for displacement in any suitable manner. For example, the illustrated guide columns may be replaced by dovetailed guides and other conventional rectilinear guide means, the guide for the stop may be separate from that for the machine part. For instance, the stop may be mounted on a carriage moving on a roller conveyor. Similarly, any suitable means for holding the stop in position may be used, including latching systems, pressure-fluid operated brakes, clamping systems and the like. The number of stops in the path of the displaceable machine part is unlimited. If only some of these stops are to be used, they may be equipped with adjustable abutment parts for engagement with the passing machine part, as shown in FIGS. 5 and 6, and the abutment parts on all stops not being used are moved out of the path of the passing machine part.

CLAIMS

1. A manufacturing method including steplessly positioning a machine part along a rectilinear path of movement, comprising the steps of placing a stop in the path of movement, moving the stop to a predetermined position along the path, holding the stop in the predetermined position, and thereupon independently moving the machine part to the predetermined position.

2. The method of claim 1, wherein the stop is moved to the predetermined position and held therein while the machine part is at a position along the path spaced from the stop.

3. The method of claim 1, wherein one of two stops along the path is moved to the predetermined position and held therein, the two stops delimiting a path of movement of the machine part in opposite directions, the machine part being placed between the two stops and the other one of the two stops being in fixed position while the one stop is moved.

4. The method of claim 1, comprising the further steps of releasing the stop from the predetermined position wherein it is held, moving the released stop to a fixed reference position, stopping the stop in the fixed reference position, moving the stop a predetermined distance from the fixed reference position to another position along the path and holding the stop in the other position.

5. An apparatus for steplessly positioning a machine part along a rectilinear path of movement, comprising

(a) a first displacement drive coupled to the machine part for moving the machine part along the path,

(b) a stop displaceably mounted in the path for association with the machine part,

(c) a second displacement drive coupled to the

stop for displacing the stop along the path,

(d) a means for monitoring the position of the stop along the path, the monitoring means generating an output signal corresponding to the monitored position, and

(e) a control circuit connecting the displacement drives, the control circuit including

(1) an element for setting a stop position for positioning the machine part, the stop position setting element generating an output signal corresponding to the set position, and

(2) the control circuit actuating the first displacement drive when the output signals of the stop position monitoring means and of the stop position setting element conform.

6. The positioning apparatus of claim 5, further comprising a means for holding the stop in position, the stop holding means being connected to the control circuit.

7. The positioning apparatus of claim 5, further comprising guide columns for displaceably mounting the machine part and the stop for movement along the path.

8. The positioning apparatus of claim 5, wherein the second displacement drive comprises a threaded spindle, a nut displaceable along the spindle and coupled to the stop, and a drive motor for rotating the spindle whereby the nut and stop coupled thereto are displaced, the drive motor constituting the stop position monitoring means.

9. The positioning apparatus of claim 5, further comprising a guide path for the stop extending parallel to the rectilinear path of movement of the machine part, the second displacement drive being mounted on the guide path, and brake means arranged in the guide path for holding the stop in position.

10. The positioning apparatus of claim 9, wherein the second displacement drive is a rack-and-pinion drive.

11. The positioning apparatus of claim 5, wherein the stop position monitoring means comprises a tackle extending parallel to the path of movement of the stop and an output signal generator arranged along the tackle.

12. The positioning apparatus of claim 11, wherein the tackle comprises a rope and a pulley over which the rope is trained, the output signal generator being a rotary potentiometer connected to the pulley.

13. The positioning apparatus of claim 11, wherein the tackle constitutes the second displacement drive.

14. The positioning apparatus of claim 5, wherein the stop has a side facing the machine part, further comprising a shock absorbing means mounted on the stop side facing the machine part and limit switch means cooperating with the stop and the machine part.

15. The positioning apparatus of claim 14, wherein the limit switch means comprises proximity fuses mounted on the stop and the machine part, respectively.

16. The positioning apparatus of claim 14, wherein the shock absorbing and limit switch means are mounted for adjustment in the direction of the path of movement.

17. A method as claimed in claim 1 and substantially as described with reference to the accompanying drawings.

18. Apparatus as claimed in claim 5 and substantially as described with reference to the accompanying drawings.

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