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Carlson

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[54] AUTOMATIC TAPE-CONTROLLED WORK FINISHING MACHINE

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[52] **U.S. Cl.**.....**15/97 R,** 51/165.71, 235/151.11, 318/568

[51] **Int. Cl.**.....**B24b 29/00**

[58] **Field of Search**....15/97 R, 21, 102; 112/121.11, 112/121.12; 118/1, 11, 6, 7, 8; 250/202; 51/138, 124 R, 124 L, 107, 86, 101 R, 101 LG, 165.71, 165.77, 35, 44, 45; 74/2; 318/567, 576, 568–570

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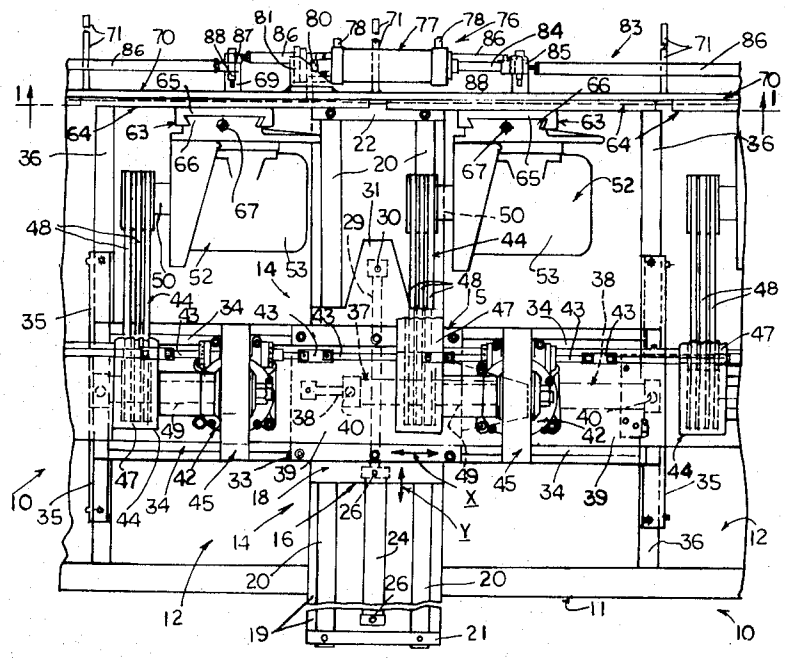
[57] **ABSTRACT**

A multiple head buffing machine featuring a plurality of like work holders and a like number of motor-driven buffing wheels thereabove has these wheels coupled for simultaneous identical tilting action in operating on work pieces on the holders. The latter are carried for side-to-side and front-to-rear indexing motions, or equivalent compound motions in polishing, by a dual carriage assembly; and the universal movements of motorized finishing wheels and carriage-borne work holders, as directly powered by electrical and/or hydraulic motor means of one sort or another, are under the sole and master automatic control of a magnetic tape or equivalent tape or card type programming and feed-back system, which forwards "on-off," rate timing or equivalent signals to such motor means.

3 Claims, 5 Drawing Figures



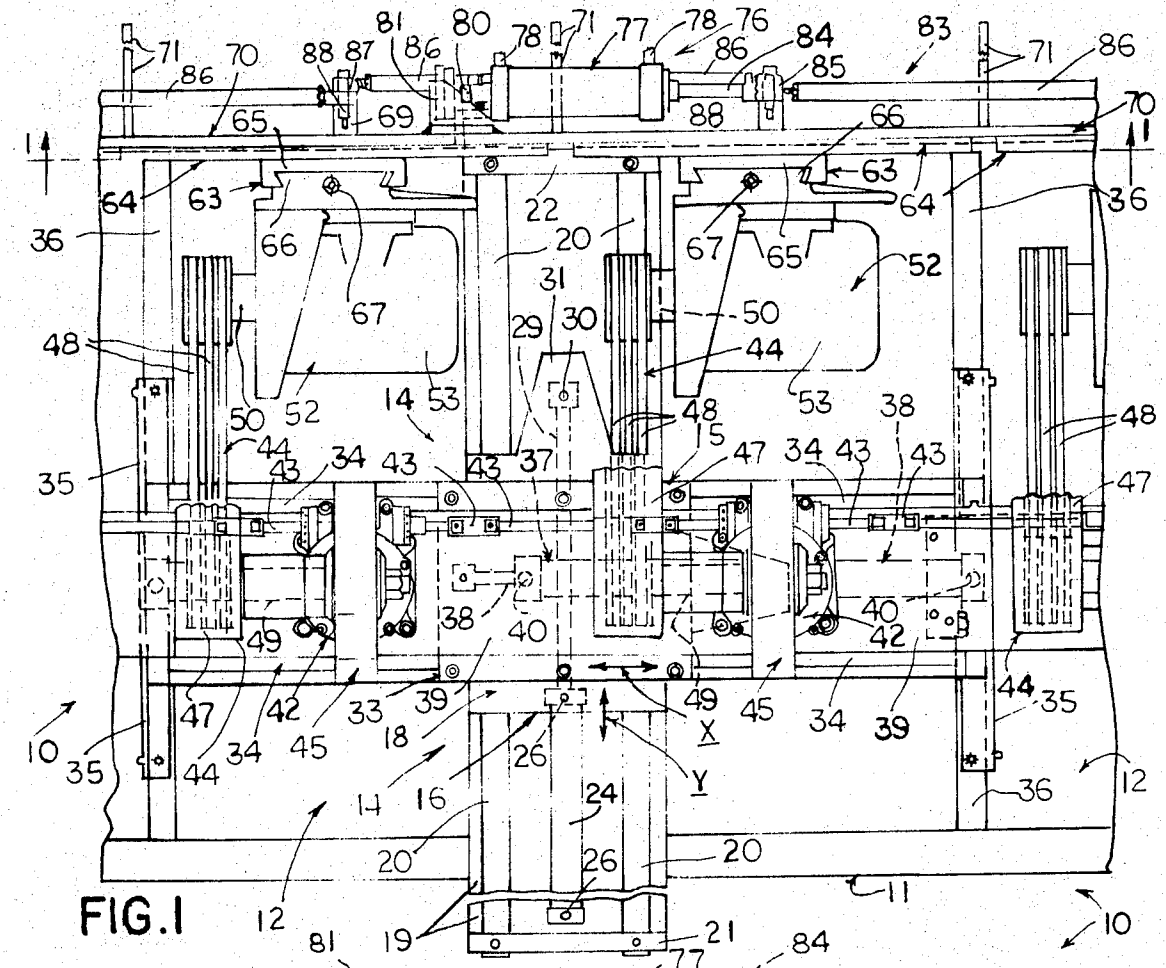


FIG. 1

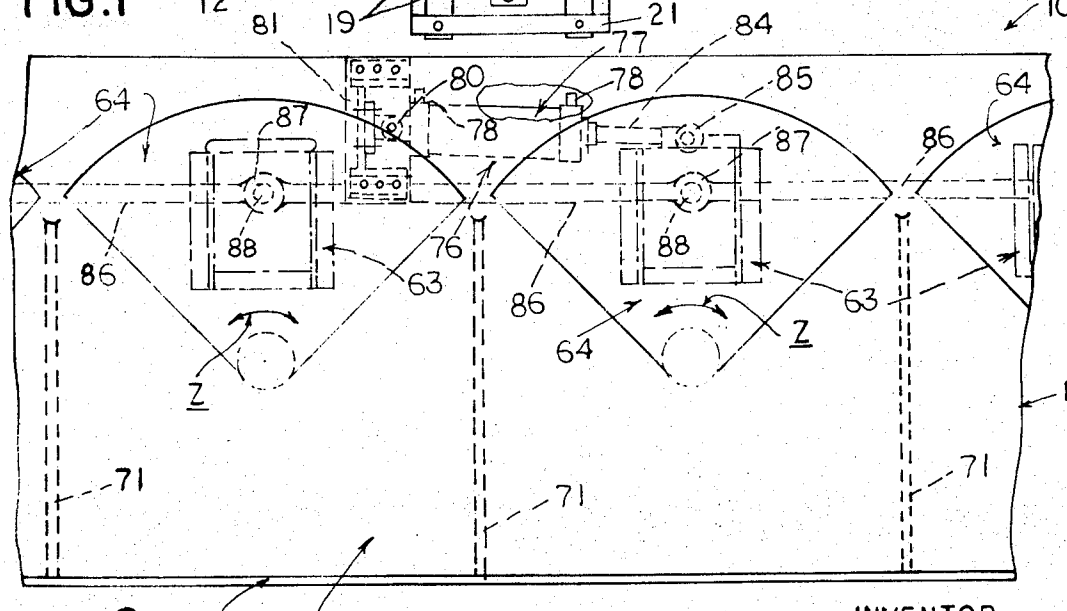


FIG. 2

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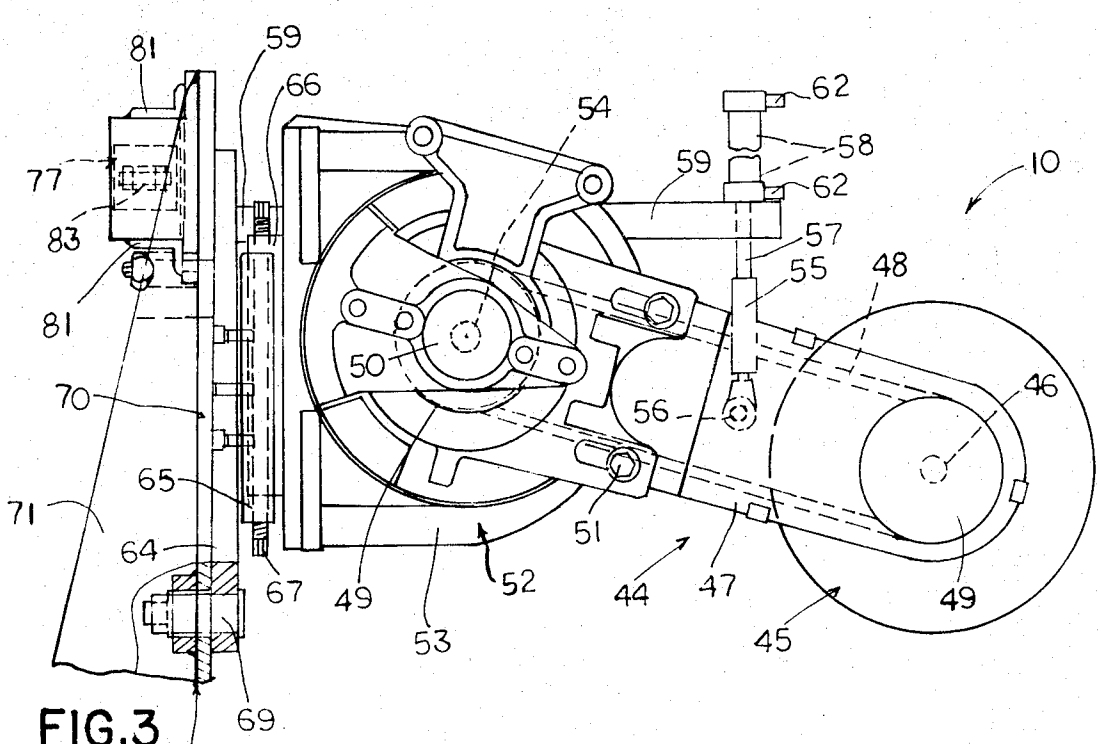

FIG.3

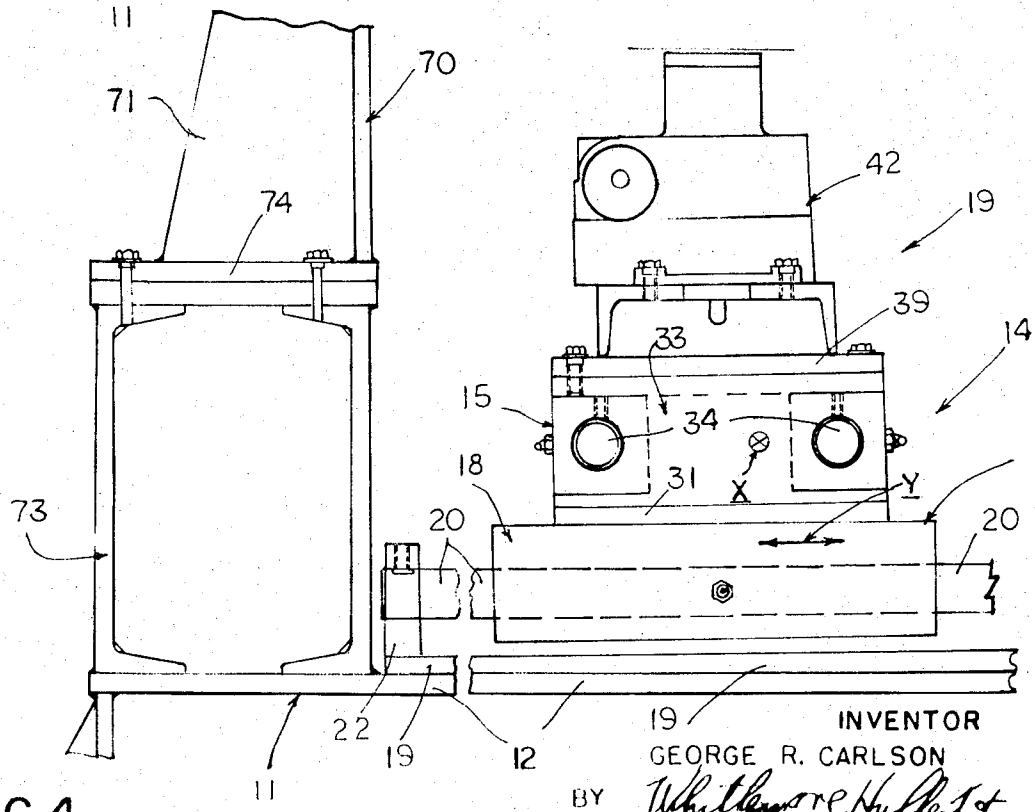

FIG.4

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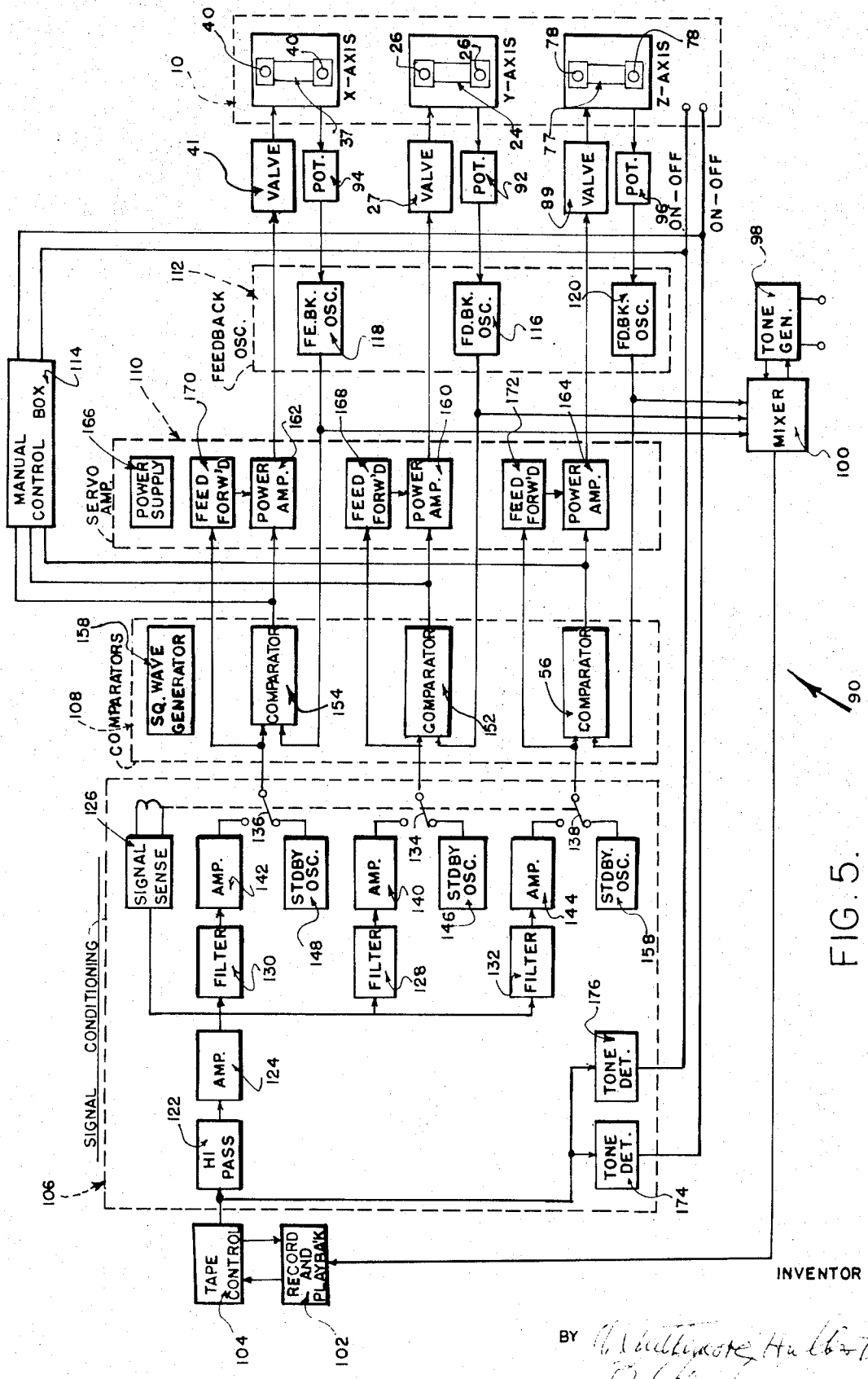

FIG. 5.

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AUTOMATIC TAPE-CONTROLLED WORK FINISHING MACHINE

CROSS REFERENCE TO RELATED APPLICATION

My copending application, Ser. No. 779,860, filed Nov. 29, 1968 and entitled "Automatic Cycle Contour Finishing Machine", now U.S. Pat. No. 3,589,075 of June 29, 1971, illustrates and describes equipment in which a single motor-driven work finishing head and a single carriage-borne workpiece holder operate in compound motions similar to those involved in the operation of the equipment disclosed herein. However, the head and holder motions are controlled in this earlier machine by limit switch, template and follower and related types of mechanical-electrical subassembly, rather than by a single integrated, computer-type master control system.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The equipment of the present invention finds application in the quantity but high quality production-polishing or equivalent finishing of relatively complexly contoured, three dimensional workpieces which may be of a wide variety. Examples are those mentioned in my application mentioned above, i.e., steam or combustion engine turbine-type blades, plowshares, also automobile bumpers, tail lamp housings, plumbing fixtures, etc. More particularly, the equipment of the invention will have usage as a multiple head installation in a factory or job shop by which typically as many as four workpieces may be quality finished at a time, with at most only a general supervision of an attendant.

2. Description of the Prior Art:

To my knowledge, Kraft, U.S. Pat. No. 3,324,493 of June 13, 1967 and U.S. Pat. No. 3,439,371 of Apr. 22, 1969, are the most pertinent prior art patents insofar as disclosure of compound multiple head and workpiece motions is concerned. The machines of these patents are governed for such motions by control means no more pertinent than that of my pending application identified above.

SUMMARY OF THE INVENTION

As herein illustrated, described and claimed, the equipment comprises a universal, compound motion sub-assembly of superposed workpiece supporting carriages or slides, upon the uppermost of which plural identical workpiece holders are mounted. These holders may be and are preferably of a type enabling simultaneous rotary indexing thereof, over and above the movements of their carriage means, so as to selectively present different contours of the workpiece thereon for identical buffing or like action by individual, motor-driven rotary members, the equivalent which may be found in belt-backing rollers in a belt-type finishing operation, as in my prior application.

Compound motions of the universally acting workpiece carriage assemblies or units are shown herein as being directly produced by solenoid valve-controlled hydraulic motors of the cylinder type, one for each carriage sub-assembly; and the individual electric motorized drive units for the finishing members are simultaneously adjustable tiltingly in a vertical plane to further accommodate them to compound curvatures of

the workpiece; again by solenoid-controlled hydraulic motor means. It is to be understood, however, that in the broadest sense the invention contemplates other equivalent types of individual motivation for the work holder and tool means; and that although in the description to follow reference is made to axes X and Y as denoting rectilinear carriage movements, and to axis Z as denoting an arcuate motor tilt movement, these designations are simply illustrative of typical finishing machine motions (per my prior application) and may be interchangeably referenced, as well as applied to machine motions other than the carriage traverse and index and the motor and wheel tilt.

Essential to the invention is that all of the basic ones of these motions are governed in common by a known computer-type of control system utilizing, for example, a magnetic cartridge pick-up and feed-back master tape, or in the alternative, a coded punched tape or cards. An advantage of a magnetic tape master control resides in the fact that necessary control data coding may be input to the tape in a set-up or direct programming run of the machine under manual control, identical electrical feed-backs to solenoid valve, motor and related machine components automatically governing subsequent multiple production runs of the equipment, without the need for office punching of tape or card control means. Conventional logic circuitry such as limit switches, starters, relays, timers, is dispensed with.

Computer-type automatic control of a buffing or similar work finishing machine (per that herein shown or in accordance with my earlier application), as distinguished from known automated machine tool equipment employing multiple diverse tooling or fixturing components, affords important advantages other than as just referred to.

Thus, the invention vastly reduces the tooling cost involved in utilizing multiple work holding fixture heads necessary to the latter type machine, also extensive conveyor costs, and the like. Such tooling may require as many as 20 or 30 part holding mounts or fixtures for the performance of each of perhaps seven complete machining jobs. By contrast, the improved work holder carriage sub-assembly or system of the invention will, for any given job, require the use, in a multiple of, say, four, of but a single type of work holder. This may, indeed, be capable of use in more than one phase of a job.

Furthermore, preparatory set-up time is extremely small, even as compared with the set-up of equipment according to my prior application. It is unnecessary in effecting different job assemblies to replace multiple cams, limit switches, relays and/or other mechanical or mechanical-electrical controls. It is only necessary at most to replace a single type of work holder, and cassette or like computer control means programmed for the changed operating cycle. Operating tooling usually remains the same, in the form of the operating wheel and general work holding sub-assemblies. All of the replacement requirements are, in effect, built into the computerized control system.

Still further, the improved machine exhibits great flexibility and versatility of use as compared with prior combinations, for example, in regard to various different patterns of compounded operation of the work

carriage structure, also of the finishing heads. Moreover, whether the equipment is intended for relatively low production or for output on a much more substantial scale, the present apparatus does not require the presence of a skilled operator or operators; once an original set-up has been made. Production skills have been built into the computer system, and the sole duty of an attendant is, in the main, to chuck and remove workpieces. During the period of a cycling operation which may be quite extensive the attendant is also free to perform other duties such as the loading or unloading of another machine or machines, the performing of any necessary hand work on work pieces whether finished or not, and the like.

It will be seen that the improved machine of the invention has a unique capability, under automatic programming control, for both individual, point-to-point relative motions in different directions of finishing and work holding units, and also such relative motions as simultaneously compounded.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary top plan view, partially broken, illustrating arrangements of the machine for mounting and operating the horizontally acting, longitudinal and transverse workpiece-supporting carriage components thereof, also the individual motorized drives for the several rotary finishing wheel and the means to secure the desired tilting adjustments of such wheels;

FIG. 2 is a fragmentary view in front elevation, partially broken, showing certain of the wheel mounts, and fluid pressure controlled means for obtaining the tilting adjustment of the mounts;

FIG. 3 is somewhat larger scale fragmentary view in end elevation, being partially broken away and in vertical section, of a typical buffing wheel and its motor drive means, as mounted for tilting adjustment in a plane paralleling the wheel axis;

FIG. 4 is a fragmentary view to the scale of FIG. 3 showing one of several like, typical work holders means as mounted to the longitudinally and transversely acting slide or carriage assembly of the machine; and

FIG. 5 is a schematic layout or diagram showing proposed electrical and fluid pressure arrangements of a proposed master tape controlled system contemplated by the invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIGS. 1–4, the machine of the invention, generally designated 10, is made up of a number of basic component assemblies which, to the extent that they relate to motorized finishing wheel and work carriage structure and the mounting and driving means thereof, are basically similar to what is illustrated and described in my copending application, Ser. No. 779,860, except that as mentioned above multiple identical individual wheel drives and work mounts are shown. Moreover, certain of the direct operating provisions are considerably simpler than the corresponding arrangements of the earlier application. All operating components of the apparatus 10 are mounted upon a very rugged, buttressed base and frame structure 11 which is essentially composed of a welded angle iron, plate and channel parts.

Certain of these rigidly sustain a flat horizontal and rectangular base plate 12 of large area which, as best shown in FIGS. 1 and 4, supports a combined horizontal front-to-rear and horizontal side-to-side hydraulic carriage or slide assembly which is generally designated by the reference numeral 14. The assembly 14 is composed of a first upper, longitudinal or side-to-side traversing sub-assembly or unit 15, which unit moves a set of workpiece holders, to be described, in continuous slow strokes, and possibly variable stroke speed and throw, as governed by the master tape control system hereinafter described, in the longitudinal side-to-side direction of the double-headed arrow axis X appearing in FIG. 1. Traverse carriage unit 15 is supported by a second, lower front-to-rear indexing sub-assembly or unit 16 of the hydraulically powered carriage assembly 14, which periodically indexes the sub-assembly 15 bodily in a transverse direction, or reversely front-to-rear of machine 10, as indicated by the double-headed arrow axis Y appearing in FIGS. 1 and 4.

As basically depicted in those figures, the front-to-rear indexing sub-assembly 16 comprises a carriage or slide block unit 18 of a generally rectangular shape in plan, which member is guided for slide above an elongated mounting plate 19 fixed on top of machine base plate 12, through the agency of a pair of transversely elongated parallel guide tubes or rods 20. These are fixedly supported at front and rear ends thereof by upright end members 21, 22, respectively, on mount plate 19; and guide components of the carriage block 18 are provided with aligned parallel bores through which the guide rods 20 extend for a stably guided, sliding front-to-rear action of carriage sub-assembly 16 along the rods.

As in the case of my copending application, such front-to-rear movements of the lower carriage 16 are powered by a double acting hydraulic cylinder 24 having reversing port fittings 26 at opposite ends thereof, through which hydraulic pressure fluid is applied to the cylinder 24 under the agency of the electrical and hydraulic circuitry of the tape control system of FIG. 5. Specifically, in this connection, the reversing supply of power to the fittings of cylinder 24 is under the control of a solenoid-operated valve 27 (FIG. 5), whose output is appropriately connected by conduitry (not shown) connecting to the opposite fittings 26.

An operating plunger 29 of cylinder 24 (FIG. 1) extends rearwardly to a point of connection at 30 to the lower side of an extension plate 31 fixed atop the carriage block 18. In this fashion, front-to-rear successive indexing motions (and vice versa) of the carriage 18, along with the carriage sub-assembly 15 on its top, are accomplished in the directions of the axis Y appearing in FIGS. 1 and 4.

A very similar arrangement affords the longitudinal side-to-side reversing traverse motions of the upper carriage sub-assembly 15, in the direction of the axis X in FIG. 1. Thus, this sub-assembly comprises a flat rectangular carriage block unit 33, parts of which are provided with parallel, longitudinally extending bores in which fixed tubular guide rods 34 are received. Opposite longitudinal ends of these rods are fixedly mounted to parallel transversely extending, elongated slide members 35, which are themselves guided to slide on fixed transversely extending guide bars 36 on the

machine base plate 12. Hence the upper carriage sub-assembly 15, as guided longitudinally on rods 34, also assists in the transverse zones of bars 36 in the stable guidance of the lower carriage sub-assembly 16, and of the hydraulically powered carriage assembly 14 as a whole.

A longitudinally elongated, double acting hydraulic power cylinder 37 is fixedly mounted on the base plate 12 in a horizontal plane beneath carriage block 33 and paralleling the latter's guide rods 34. This cylinder is operatively connected by its plunger 38 to the bottom of block 33 in the same way as the plunger of cylinder 24 is connected to the block 18 of carriage 16. An elongated horizontal plate 39 is fixedly mounted on top of the several slide or carriage block 33 of sub-assembly 15, this plate serving as a common support for work holder units to be described.

Cylinder 37 has reversing port fittings 40 adjacent its ends, which are appropriately connected by hydraulic conduitry (not shown) to a solenoid-controlled valve 41 appearing in FIG. 5; and in this fashion the horizontal side-to-side traverse reversing motions of the upper carriage sub-assembly 15 are accomplished in the direction of the axis X appearing in FIGS. 1 and 4.

Again, it is to be understood that while the axes X and Y referred to above have been specifically described as relating to directions of movement of the carriage sub-assemblies 15, 16 under power from hydraulic cylinder motor means, they may be considered generally as applying to other motions of parts of the apparatus relative to one another in either a rectilinear or non-rectilinear sense, all depending upon the nature of the machine involved, and that of other compounded motions such as it will require in its operation as an installation of finishing equipment.

FIGS. 1 and 4 generally show a typical workpiece supporting unit, of which there will be an identical four in the illustrated machine 10. Such holder is generally designated by the reference numeral 42, and its specific construction is of no particular significance in the present invention. It will preferably be such as to be capable of 180° indexing action about its upright axis, for the purpose of selectively presenting opposite sides of a workpiece (not shown) mounted thereon to a buffing or equivalent wheel directly thereabove, during a longitudinal side-to-side shift of the carriage assembly 14 in one or the other direction along axis X. Various types of work holder spindle, chuck or equivalent work presenting unit are contemplated; and it is to be understood that in the event they are of an indexable type, appropriate mechanical, electrical or fluid pressure motor means powering such movement will be under the governance of the automatic control system typically shown in FIG. 5, or an equivalent thereof. A longitudinal series of links or connecting rods 43, joined together by flexible couplings 43', serves to articulate successive work support units 42 to one another for stability of simultaneous shift in the action of the carriage assembly 14, on the top plate 39 of which supports 42 are borne.

Referring particularly to FIGS. 1 and 3, each of the work holder units 42 presents its workpiece to an individual polishing or finishing assembly 44 thereabove, of which there will typically be four. This is shown as being a buffing wheel type having a rotary buff 45 rotatably mounted at 46 on a pivoted support frame arm 47 that is suitably housed for safety. An endless belt or chain 48 is trained above a pulley or sprocket 49 coaxially carried by buff wheel 45, the opposite end of the flexible drive member being trained above a pulley or sprocket 49 secured to the shaft output structure 50 of a suitably rated electrical motor 52 of, for example, 7½ hp operating at 1,800 rpm.

The wheel support arm 47 has appropriate bolt and slot provisions at 51 for adjustment of its length; and it is pivotally swingable at one end of the motor housing 53 about a supporting journal axis at 54 coinciding with the output axis of motor 52.

Pivotal adjustments of the arm about this axis are automatically effected, for the purpose of illustration only, through the agency of an adjustable turnbuckle type connection 55 between a side pivot pin 56 on wheel supporting arm 47 and the operating plunger 57 of a pneumatic actuator cylinder 58, which is a double acting one. This cylinder is suitably sustained fixedly on an appropriate horizontal frame bracket 59 of the machine structure 11, the operating plunger 60 of the cylinder plunger 57 extending past bracket 59 to be adjustably connected to turnbuckle connector 55. Pneumatic cylinder 58 (or an equivalent hydraulic or other reversing motor) has reversing port fittings 62 at opposite ends thereof; and a reversing flow of pneumatic or hydraulic pressure fluid may take place through these fittings for the elevation or lowering of the wheel 45 under the control of solenoid-valve means such as controls the reversing action of the fluid pressure power cylinders 24 and 38 of the carriage assembly 14, or of the reversible tilt of motor and wheel mounts, as now to be described.

Referring to FIG. 2 in conjunction with FIGS. 1 and 3, each of the electric motors 52 has a vertically adjustable dove-tail type connection 63 to an individual motor mounting plate 64 which is tiltable in a vertical plane paralleling the motor and wheel axes. The plate is shown in FIG. 2 as being of a quadrantal outline, only because of the existence of one of various possible modes of controlling its swing utilizing segmental gearing. However, this is not the type of plate operation contemplated herein; the quadrantal outline is incidental.

Typically, the motor-to-plate connection 63 may, as appears best in FIG. 3, comprise a fixed upright dove-tail recessed plate or block 65 bolted onto the front of tilting plate 64, with an externally dove-tailed, mating rear extension 66 on the housing 53 of motor 52 being slidably received in the recess of plate 65. An elongated adjustment screw 67, as restrained from axial movement relative to fixed dove-tail block 65, threadedly engages motor housing extension member 66 to permit a desired vertical positioning, within certain limits, of the motor 52 and parts carried thereby relative to the plate 64 mounting the same for tilt.

As shown in FIGS. 2 and 3, each of the motor mounting and tilting plates 64 is pivotally mounted adjacent its lower extremity, as by a journal pin unit 69, to an upright rear frame plate 70 of machine 10 which is rigidly connected in the manner illustrated in FIG. 4 to the horizontal base structure. Plate 70 is strongly braced by a number of welded buttress brackets 71 spaced lengthwise therealong; and a rigid connection to

the machine base is had through the agency of a box-like channel and plate structure 73 welded along the rear of base plate 12. Upright plate 70 and its brackets 71 are also welded to tie means 74, which is in turn bolted or screwed to top flanges of channels of the box structure 73.

A reversible tilting swing of the plates 64 about their respective axes at 69 is effected by a double-acting power cylinder means, generally designated 76, mounted to the rear of the upright frame plate 70; and as best shown in FIG. 1, this unit comprises a double-acting hydraulic or pneumatic cylinder 77 having reversing port fittings 78 adjacent its opposite ends. Cylinder 77 is pivotally anchored for limited vertical swing about an upright fixed axis at one end thereof, as by an eye-member 80 (FIG. 2) encircling a fixed pin carried by a bracket unit 81 welded to the rear of plate 70.

A horizontally elongated linkage, generally designated by the reference numeral 83, positively connects the plunger 84 of reversing cylinder 77 to the several motor mounting and tilting plates 64, whereby they are simultaneously tiltable about their respective axis at 69, thus to afford a tape-controlled adjustability of the angle of attack of the several buffing wheels on workpieces as the latter are traversed longitudinally sidewise beneath the respective wheels.

As perhaps best illustrated in FIGS. 1 and 2, the cylinder plunger 84 has a pivotal connection, as through an eye fitting 85, to the rear of the closest adjacent tilting plate 64; and this particular plate 64 is operatively connected positively to corresponding plates on either side thereof by identical rigid elongated rods 86 of the linkage 83. Each of these is pivotally connected at 87 to a pin 88 projecting from the rear of the plate 64 in question. Accordingly, tilting adjustment of the plates 64 and motor-driven buff wheels 45 thereon is simultaneously made, under the control of the system of FIG. 5, about the respective plate pivots at 69. The reversible swing is in the direction of the double-ended arrows appearing in FIG. 2, and is referred to as an adjustment on the axis Z.

Like other cylinder motor means described above, the tilting cylinder 77 is reversibly pressurized at its end fitting 78 under the control of a solenoid valve 89 (FIG. 5); and, as before, when descriptive reference is made herein to the axis Z, it is to be construed as not only the swing axis as specifically related to the motions of the plate 64, but also in a broader sense as an axis of reversible motion of some other control component, for example, that of an indexing rotation of the workpiece holder 42.

FIG. 5 illustrates the control circuit 90 for providing actuating signals to the electro-hydraulic servo valves 27, 41 and 89 to control the movement of the plungers of cylinders 26, 40 and 78, respectively, and which receives a feedback signal from the potentiometers 92, 94 and 96 in accordance with the movement of the cylinders 24, 37 and 77, respectively. The circuit 90 includes a tone generator 98 having terminals for connection to external events switches, a mixer 100, a record and playback amplifier 102, and automatic tape control structure 104. Other basic components of the circuit system 90 are a signal conditioning circuit 106, a comparator circuit 108, a servo amplifier circuit 110, a feedback ascillator circuit 112 and a manual control box circuit 114.

The mixer 100 receives frequency variable signals from the feedback oscillators 116, 118 and 120 in the feedback oscillator circuit 112 due to movement of the cylinders 24, 37 and 77 and signals from the tone generator 98 from external event switches representing external instructions, which signals are mixed and recorded in the tape control structure 104 through the record and playback amplifier 102.

The signal conditioning circuit 106 receives signals from the tape control structure 104, which signals are passed through the high pass filter 122 and the amplifier 124 to the signal sensing circuit 126 and to the filter circuits 128, 130 and 132. The signal sensing circuit 126 is operable on sensing a signal to change the state of the switches 134, 136 and 138, so that the frequencies associated with only the Y, X or Z axis passed by filters 128, 130 and 132 pass through the particular amplifiers 140, 142 and 144 when a signal is present. When no signal is present through the amplifier 124, the switches 134, 136 and 138 are in the condition illustrated in FIG. 5 and fixed frequencies are provided as an output from the signal conditioning circuit 106 over the standby oscillators 146, 148 and 150.

The comparator circuitry 108 includes the individual frequency comparator circuits 152, 154 and 156 each of which receive signals from the square wave generator 158 and signals which vary in frequency in accordance with the filters 128, 130 and 132 through the amplifiers 140, 142 and 144 or signals from the standby oscillators 146, 148 and 150 and provide an output to the power amplifiers 160, 162 and 164 in the servo amplifier circuit 110. The output from the comparator circuit 108 to the servo amplifier circuit 110 is a suppressed carrier output from the comparators 152, 154 and 156.

The servo amplifier circuit 110 includes a separate feed forward circuit 168, 170 and 172 in conjunction with each power amplifier 160, 162 and 164. The power supply 166 supplies operating power to the feed forward and power amplifier circuits of the servo amplifier 110. Each of the power amplifier and feed forward circuits are constructed to provide a signal to the electro-hydraulic servo valves associated therewith in accordance with the output of the comparators 152, 154 and 156.

The feedback oscillators 116, 118 and 120 are connected to the potentiometers 92, 94 and 96 and are operable to provide a feedback frequency to the comparators 152, 154 and 156 and to the mixer 100 having a frequency depending upon the position of the cylinders 24, 37 and 77.

The manual control circuit 114 is operable when the circuit is operating in a manual condition to provide operating power to the power amplifiers 160, 162 and 164, directly to cause movement of the cylinders 24, 37 and 77 in accordance with the desires of an operator actuating on-off controls in the manual control circuit 114. The manual control circuit 114 is also operable to pass signals from the tone detectors 174 and 176 to the power amplifiers 160, 162 and 164, which signals are initially generated in the tone generator 98.

In the overall operation of the control circuit 90, the cylinders 24, 37 and 77 are first caused to go through

the sequence of operations which it is desired to repeat by use of the manual control circuit **114**. During the movement of the cylinders **24**, **37** and **77** through the desired sequence of operations, the oscillators **116**, **118** and **120** are caused to feed to the mixer frequency signals depending on the movement of the cylinders **24**, **37** and **77** which are fed into the mixer **100** along with signals from the tone generator **98**. The signals from the mixer **100** are during this time recorded in the tape control structure **104** through the record and playback amplifier **102**.

When it is desired to repeat the movement of the cylinders **24**, **37** and **77** for a repeated machining operation, signals from the automatic tape control structure **104** are passed through the high pass filter **122** through the amplifier **124** and actuate the signal-sensing circuit **126** to move the switches **134**, **136** and **138** to their opposite position. The individual frequencies passed by the filters **128**, **130** and **132** are thus fed to the comparators **152**, **154** and **156** and to the feed forward circuits **168**, **170** and **172**.

The signals from the feedback oscillators **116**, **118** and **120** are compared to the signals from the tape control structure **104** at the comparators **152**, **154** and **156** providing signals to the power amplifiers **160**, **162** and **164** which energize the electrohydraulic servo valves **27**, **41** and **89** to move the cylinders **24**, **37** and **77** in the same path as previously followed. As the cylinders approach the positions previously attained in the sequence of operations programmed, the feedback signals from the oscillators **116**, **118** and **120** will become substantially the same as the input signals from the signal conditioning circuit **106**, and the movement of the cylinders will stop at the position they previously attained during manual control.

At any time during this operation that a low frequency tone from the tone generator **98** through the mixer **100** and on the tape control structure **104** is present, the signal through the tone detectors **174** and **176** will cause the required instruction to be implemented through the power amplifiers **160**, **162** and **164** and the manual control circuit **114**.

The same automatic sequence of events may again be repeated any number of times through the record and playback amplifier and the tape control structure **104**, since the program for the previous automatic cycle may be retained, or alternatively, a new automatic program may be recorded through the mixer **100** if desired. The placing of a new program in the tape control may be accomplished by means of the manual control circuit **114** as before.

While a relatively detailed description of the operation of the control circuit **90** has been included above, it will be understood that that circuit is a conventional 3-axis control with two or more events channels. The specific control circuit as such, therefore, forms no part of the present invention and is in fact part of the known prior art.

As indicated above either inductive or reactive-type means may be substituted for resistive-type means, represented by potentiometers **92**, **94** and **96**, for the feeding back of the desired variable electric signal.

As also mentioned previously, all the relative motions of the work finishing unit and the work holding unit may be either of an individual, successive, point-to-point nature, as represented, only for example, by successive like side-to-side traversing strokes of the work holder separated by front-to-back indexing strokes; or these motions may be simultaneously compounded, all under the control of the programming circuitry **90**, in a single non-rectilinear motion, for example, one in which the finisher is swept by the work in a contoured stroke. What is more the machine **10** has the unique capability, and is ordinarily intended to be used in a single work cycle, to perform both the point-to-point and the simultaneous compound motion phases, as specially programmed at its record and play-back unit.

What is claimed is:

1. A work surface finishing machine comprising at least one workpiece finishing unit operable to smooth the surface of a workpiece, at least one bodily and linearly translatable unit to support a workpiece for smoothing by said first-named unit upon translation of the support unit relative to the finishing unit, electrically responsive means for effecting linear translative motions of said supporting unit in paths in angularly crossing relation to one another in a cycle of operation of the machine in which a piece is so finished, and a system of the electronic record and playback programming type operatively connected to said motion-effecting means and including circuitry for electrically signalling in a way to control said relative translative motions of said supporting unit in said cycle, said system circuitry further functioning for the purpose of recording manually controlled motions of said motion-effecting means, and including electrical devices connectable to a record portion of said system and directly controlled respectively by linear bodily translations of said motion-effecting means in said respective paths, said devices being responsive to said respective translations to transmit electrical signals as factors in the signalling of said circuitry.

2. A work finishing machine comprising at least one work piece finishing unit, at least one unit to support a workpiece for finishing by said first-named unit, electrically responsive means for effecting relative motion of said finishing and supporting units in angular relation to one another in a cycle of operation of the machine in which a piece is so finished, at least one of said units being bodily translatable linearly, and a system of the electronic record and playback programming type operatively connected to said motion-effecting means and including circuitry for electrically signalling in a way to control said relative motion of said finishing and supporting units in said cycle, said system circuitry further functioning for the purpose of recording manually controlled motions of said motion-effecting means, and including an electrical device connectable to a record portion of said system and directly controlled by said linear bodily translation of a unit by said motion-effecting means, said device being responsive to said relative motion to transmit an electrical signal as a factor in the control signalling of said circuitry, said supporting unit being the bodily translatable one and said finishing unit being a rotative one, said finishing unit also having electrically responsive means for effecting an adjusting motion thereof relative to the supporting unit, said system circuitry further including another electrical device connectable to said record

portion of the system to control said motion of the finishing unit.

3. The machine of claim 1, in which said supporting unit is the bodily translatable one and said finishing unit is a rotative one, said finishing unit also having electrically responsive means for effecting an adjusting motion thereof relative to the supporting unit, said system circuitry further including another electrical device connectable to said record portion of the system to control said motion of the finishing unit.

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