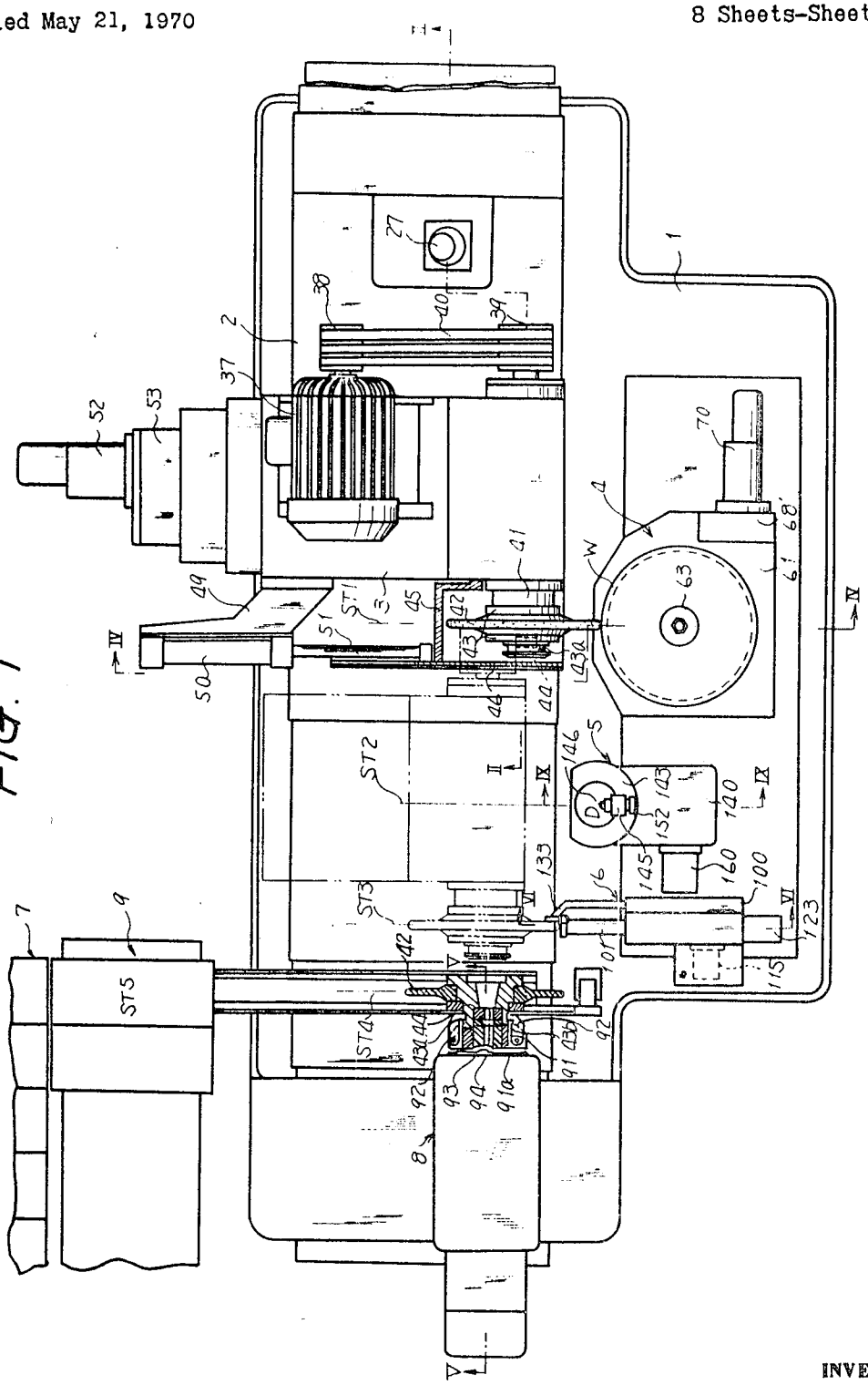
Dec. 14, 1971 HIROAKI ASANO 3,627,490

GRINDING MACHINE WITH AUTOMATIC WHEEL EXCHANGE DEVICE

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FIG. 1



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GRINDING MACHINE WITH AUTOMATIC WHEEL EXCHANGE DEVICE

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FIG. 2

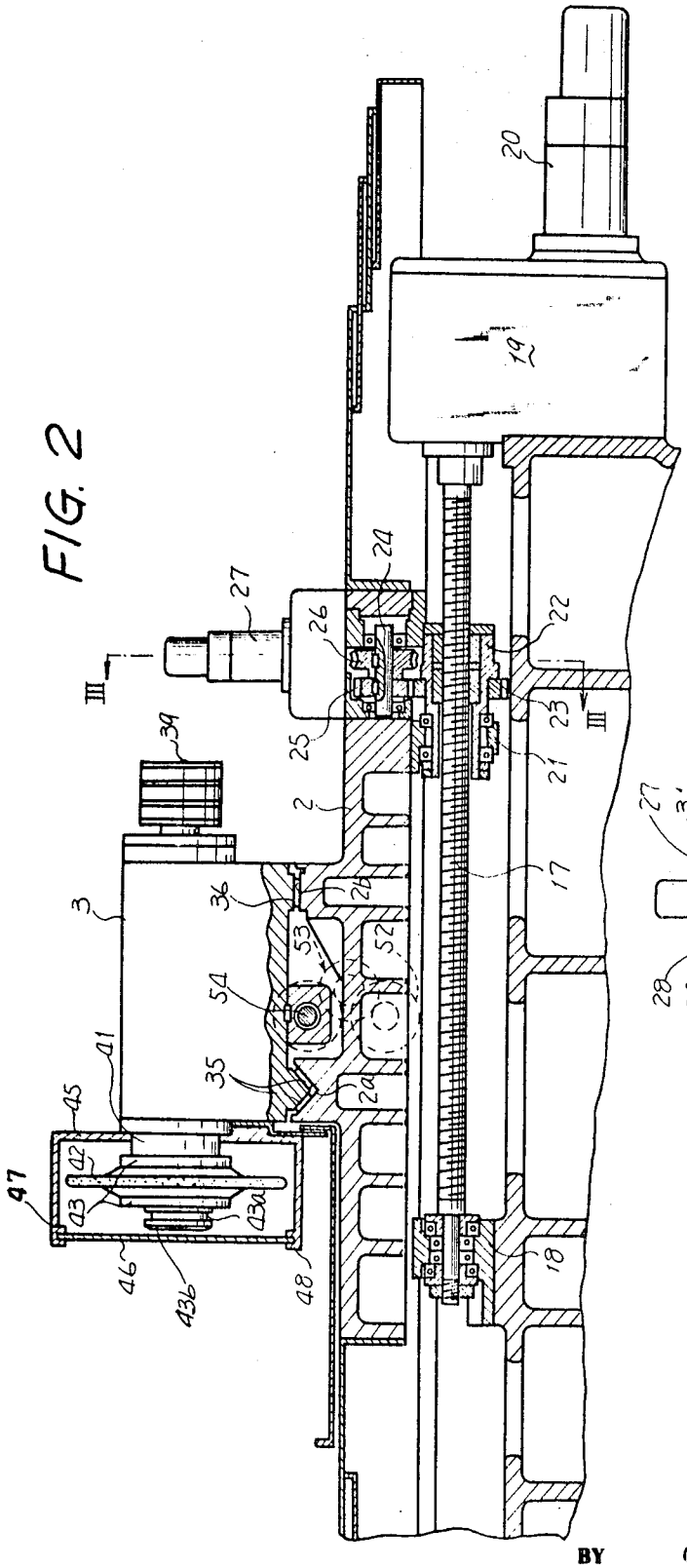
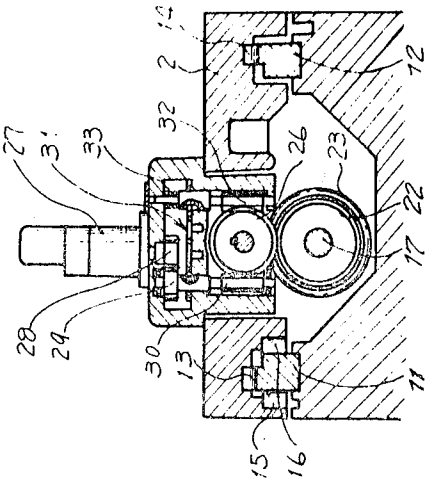


FIG. 3



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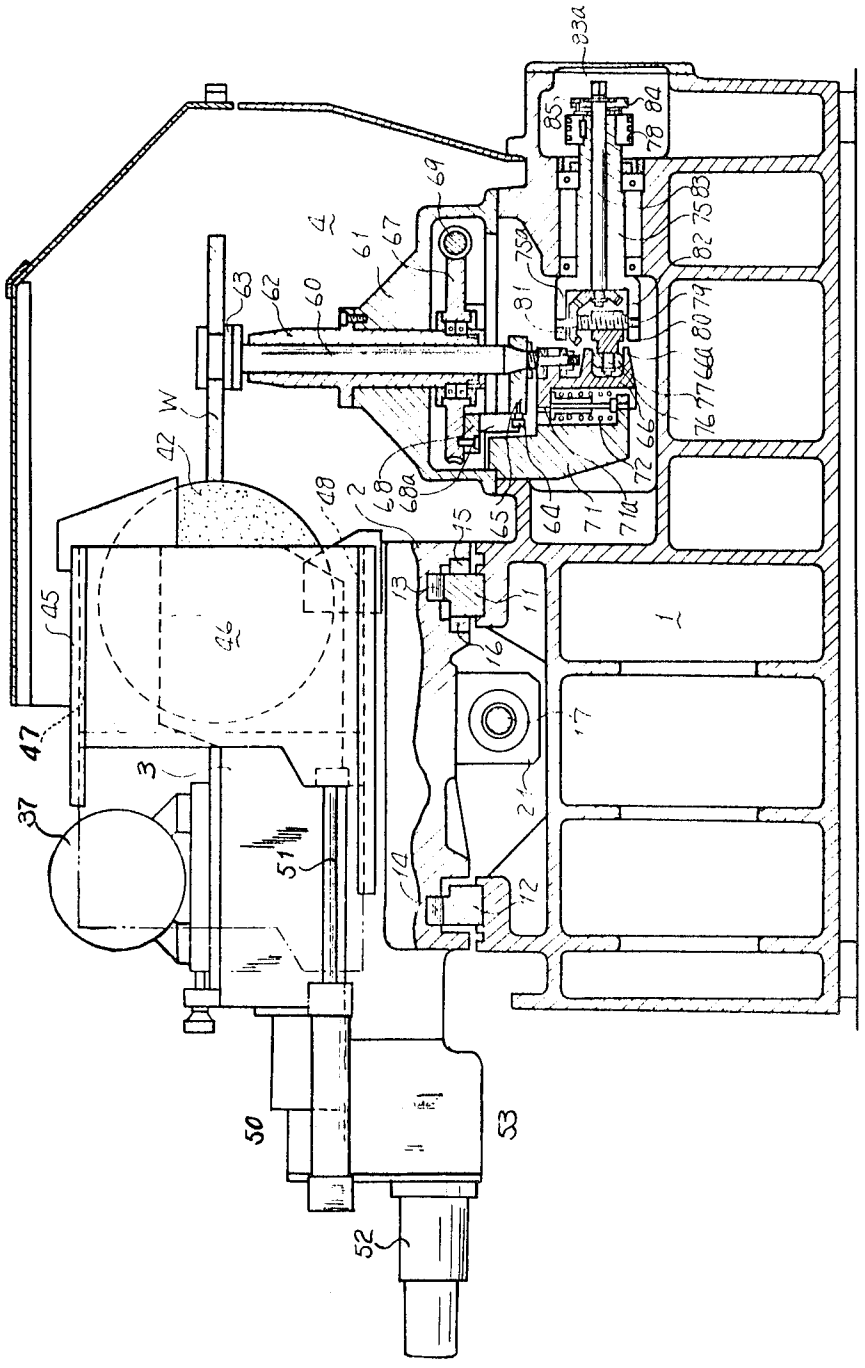
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GRINDING MACHINE WITH AUTOMATIC WHEEL EXCHANGE DEVICE

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FIG. 4



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GRINDING MACHINE WITH AUTOMATIC WHEEL EXCHANGE DEVICE

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FIG. 5

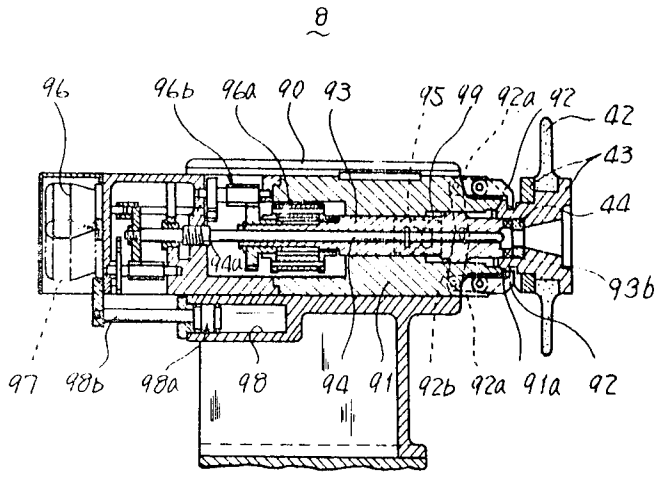
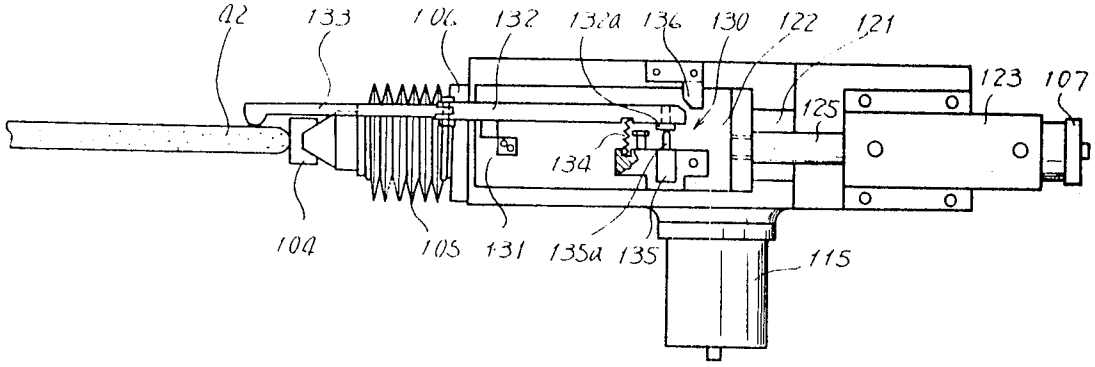


FIG. 8



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GRINDING MACHINE WITH AUTOMATIC WHEEL EXCHANGE DEVICE

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FIG. 7

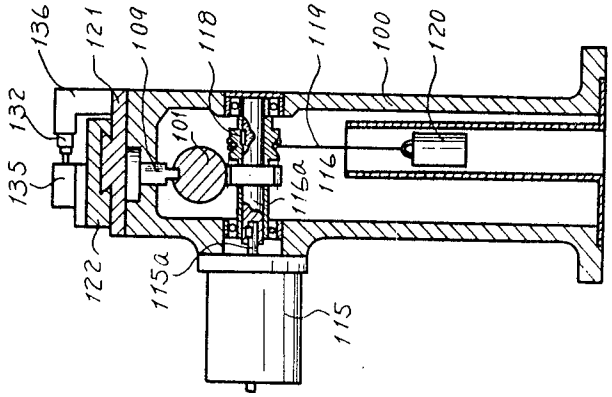
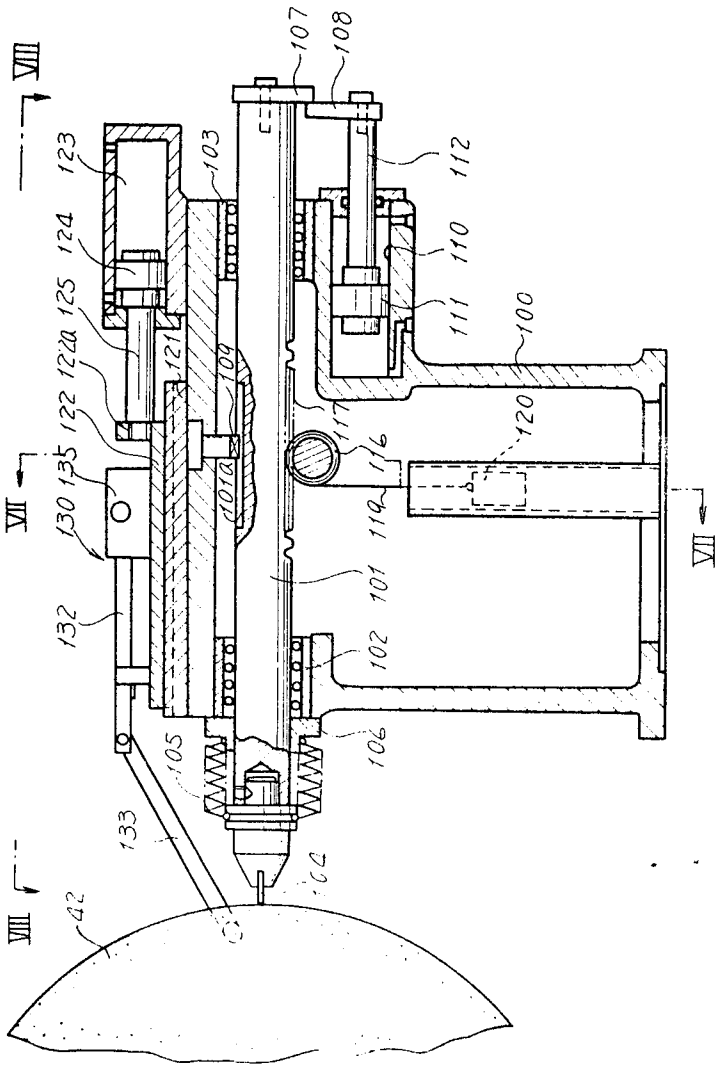


FIG. 6



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FIG. 10

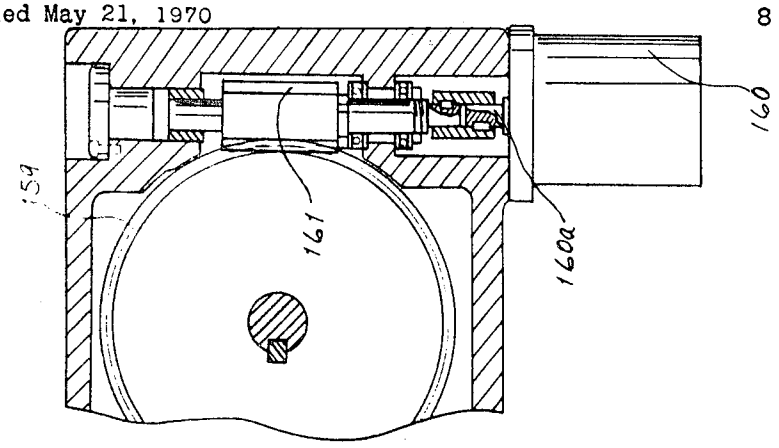
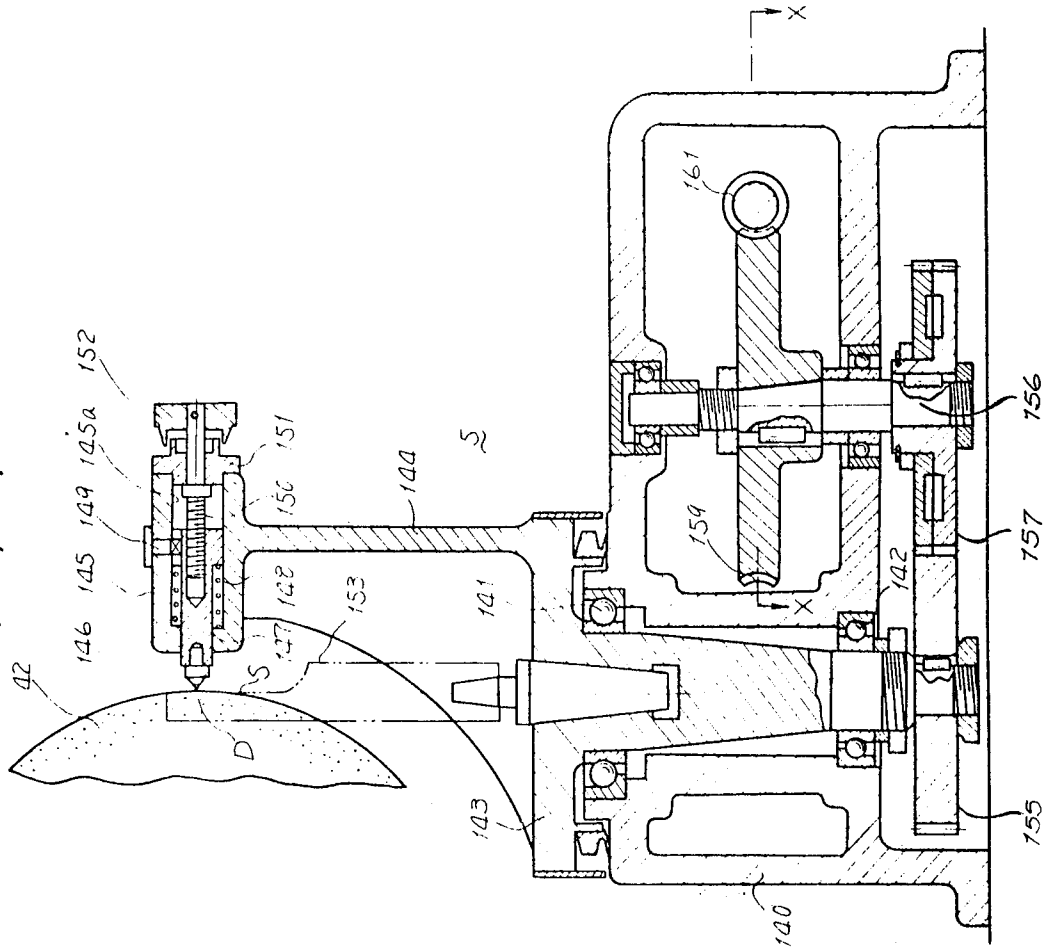


FIG. 9



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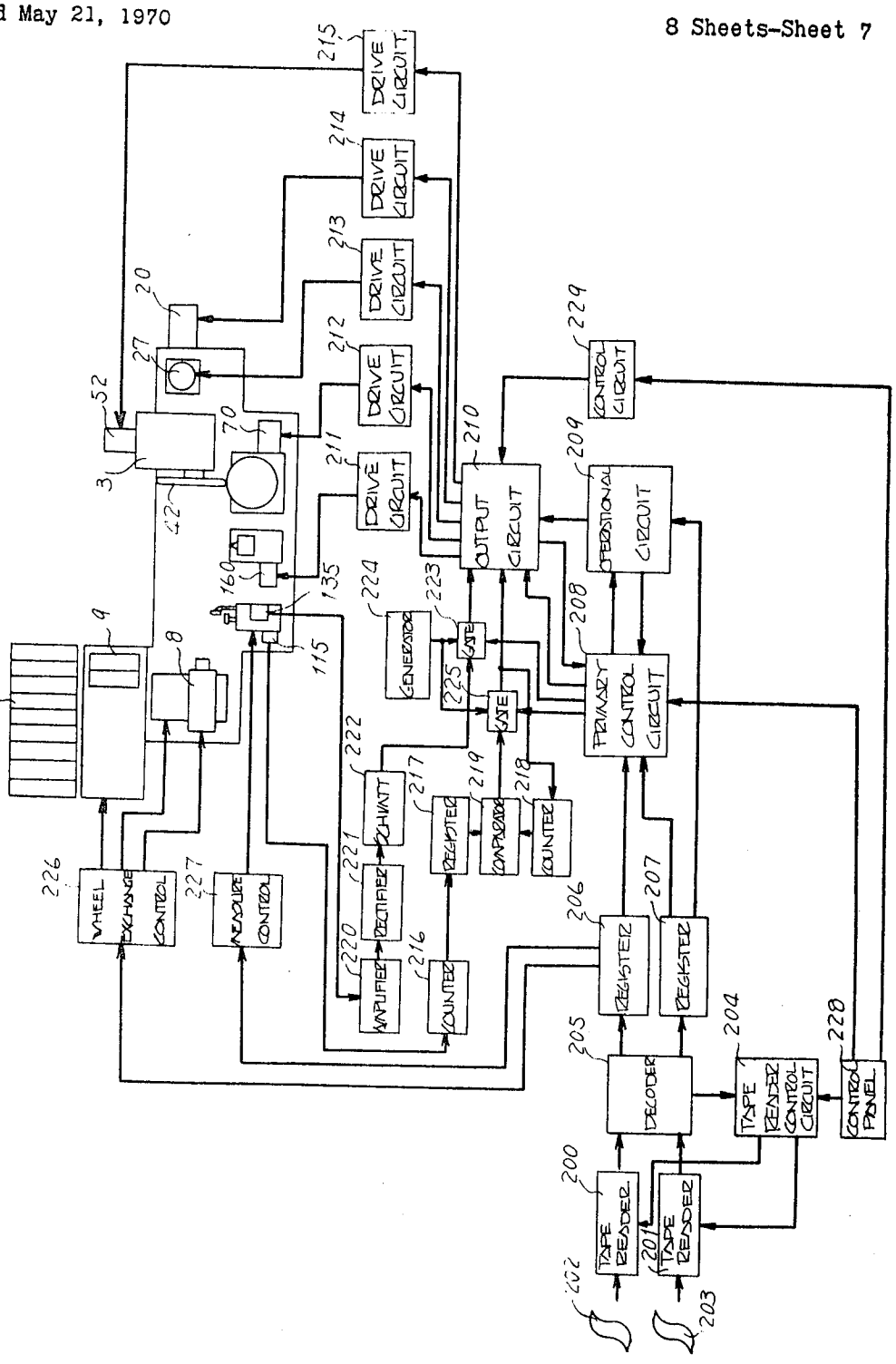
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GRINDING MACHINE WITH AUTOMATIC WHEEL EXCHANGE DEVICE

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FIG. 11



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GRINDING MACHINE WITH AUTOMATIC WHEEL EXCHANGE DEVICE

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FIG. 12

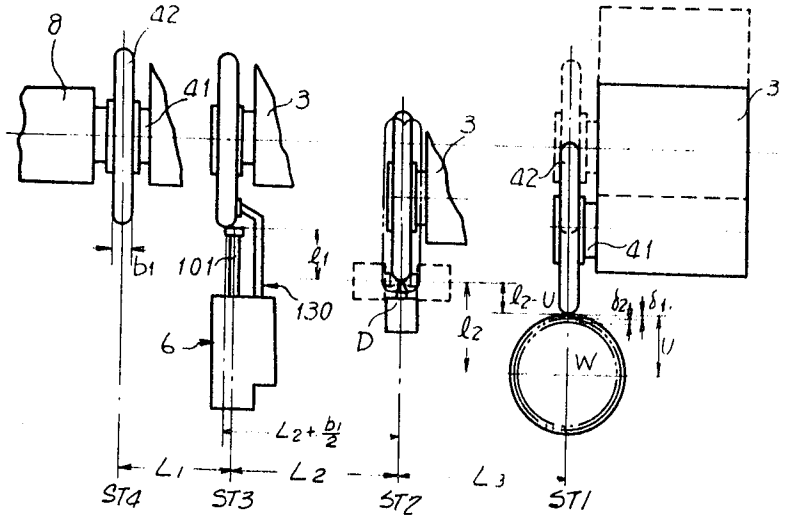
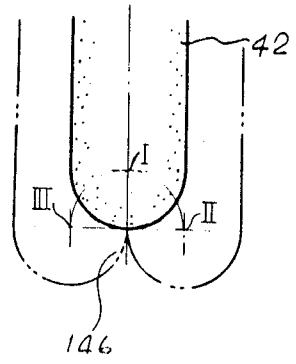


FIG. 13



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United States Patent Office 3,627,490
Patented Dec. 14, 1971

3,627,490

GRINDING MACHINE WITH AUTOMATIC WHEEL EXCHANGE DEVICE

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Filed May 21, 1970, Ser. No. 39,243
Claims priority, application Japan, May 29, 1969, 44/41,933
Int. Cl. B24b *51/00*
U.S. Cl. 51—165.87 15 Claims

ABSTRACT OF THE DISCLOSURE

A grinding machine with an automatic grinding wheel exchange device which is operative for performing a programmed grinding operation without being affected by changes occurring in the grinding wheel diameter. The lateral distance between the periphery of an exchanged wheel and a dressing device which is in a predetermined position with respect to the workpiece support is measured by a measuring device for thereafter bringing the periphery of the wheel into proper contact with the dressing device and positioning the side face of the wheel in a predetermined relationship with respect to the dressing device. The dressing device dresses the wheel into a predetermined shape according to a predetermined program and the dressed grinding wheel then effects the desired grinding operation by using the dressing device as a reference position for controlling movement of the grinding wheel support with respect to the workpiece support device according to the predetermined program.

BACKGROUND OF THE INVENTION

This invention relates generally to grinding machines and more particularly to a grinding machine for forming a predetermined profile on a workpiece in which one grinding wheel may be automatically exchanged for another for effecting various grinding operations without varying the construction of the grinding machine.

Conventional grinding machines presently available do not provide for automatically exchanging grinding wheels being employed therein and therefore are not entirely satisfactory for efficiently performing the various grinding operation. Thus, in conventional grinding apparatus of the character described, a relatively heavy grinding wheel is manually and laboriously exchanged, and a substantial amount of time is thereby consumed in making such wheel exchange. Moreover, the space where the grinding wheel is mounted on and demounted from the wheel spindle by an operator is generally somewhat limited so that, during these exchanges, there heretofore has been required such exposure during the handling thereof that the dangerous likelihood that the wheel may be damaged has always posed a problem. Accordingly, there has been a demand for the provision of an automatic wheel exchange device to prevent such disadvantages in making wheel exchanges. Until now, however, no one has been able to build an automatic wheel exchange device which automatically effects grinding operations of various kinds of workpieces, primarily because of certain problems peculiar to grinding wheels, which are hereinafter set forth. The main difficulty which has been encountered arises because of the fact that the wheel dimension or diameter of grinding wheels continuously decreases during grinding and dressing operations. The decrease in the wheel diameter causes modification of the grinding operation program and varies the position of the wheel support from that originally held with respect to the workpiece. Programming taking the decrease in the wheel diameter into consideration is almost impossible and even

if it could be realized, it would be very laborious. Thus, it becomes evident that there are even more problems to be resolved in order to satisfactorily effect the desired automatic grinding operations of various kinds of workpieces than merely providing for automatically exchanging the grinding wheel.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a grinding machine having an automatic grinding wheel exchange device and which is operative for satisfactorily carrying out a programmed grinding operation without being affected by changes occurring in the grinding wheel diameter.

Another object of the present invention is to provide a grinding machine having an automatic grinding wheel exchange device and which effects the grinding operation by using a dressing device as a reference position with respect to a workpiece support device.

Another object of the present invention is to provide a grinding machine having an automatic grinding wheel exchange device which effects the grinding operation by using a dressing point of a dressing device as a reference position with respect to a workpiece support device.

According to the present invention, the foregoing objects and their attendant advantages are realized by a grinding machine which comprises a bed having a wheel support slidably mounted thereon for rotatably supporting a grinding wheel in one station of the bed. A wheel storage device is provided for another station on the bed for storing at least one grinding wheel to be exchanged for the one positioned on the wheel support and a wheel exchange device for executing the exchange of the grinding wheel on the wheel support for a predetermined grinding wheel in the wheel storage device is disposed adjacent thereto. The slidable wheel support is operative to convey the exchanged wheel to a measuring station wherein the precise lateral and longitudinal positions of the peripheral edges thereof are determined. The wheel support is responsive to signals representative of these measurements for moving the exchanged wheel to a dressing station where the periphery of the wheel is contacted by a dressing tool and formed into a predetermined shape in cross-section according to a predetermined program. Thereafter, relative movement of the wheel support having the dressed wheel thereon with respect to a workpiece support device mounted on the bed is controlled by using the dressing device as a reference position relative to the workpiece support device in accordance with the predetermined program, thereby to grind the workpiece into a predetermined size and shape.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the present invention will be more readily appreciated as the same becomes better understood from the following description in detail of a preferred embodiment of the present invention when considered in connection with the accompanying drawings, wherein like reference characters designate like or corresponding parts throughout the several figures, and in which:

FIG. 1 is a plan view of a grinding machine constructed according to the present invention and showing the grinding wheel in several of the stations through which it is conveyed during a wheel exchange cycle;

FIG. 2 is a sectional view of a slide base feeding mechanism taken along the line II—II of FIG. 1;

FIG. 3 is a sectional view taken along the line III—III of FIG. 2;

FIG. 4 is a sectional view of a wheel support and a workpiece supporting device taken along the line IV—IV of FIG. 1;

FIG. 5 is a sectional view of a wheel exchange device taken along the line V—V of FIG. 1;

FIG. 6 is a sectional view of a measuring device taken along the line VI—VI of FIG. 1;

FIG. 7 is a sectional view taken along the line VII—VII of FIG. 6;

FIG. 8 is a view taken along the line VIII—VIII of FIG. 6;

FIG. 9 is a sectional view of a wheel dressing device taken along the line IX—IX of FIG. 1;

FIG. 10 is a sectional view taken along the line X—X of FIG. 9;

FIG. 11 is a block diagram showing a control system of the grinding machine according to the present invention;

FIG. 12 is a schematic illustration showing the interrelationship between the respective wheel exchange, measuring, dressing and grinding stations and the grinding wheel as it is transported therebetween; and,

FIG. 13 is a schematic illustration showing the dressing operation for a circular arc grinding wheel periphery.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

With reference now to these drawings, a preferred embodiment of the present invention applied to a grinding machine for forming a cam surface on the peripheral edge of a workpiece will be described.

Referring now to FIGS. 1 to 4, inclusive, the grinding machine according to the present invention comprises a bed **1** on which are fixedly mounted a pair of guide members **11** and **12** having slide surfaces thereon. A slide base **2** is slidably mounted on the guide members **11** and **12** by means of way bearings **13**, **14**, **15**, and **16** for movement in a longitudinal direction. The bed **1** has thereon a supporting member **18**, FIG. 2, which carries one end of a feed screw **17**, permitting the same to rotate therewithin while preventing relative movement therebetween. The other end of the feed screw **17** is drivingly connected to a pulse motor **20** for effecting rapid movement of the slide base **2** through a speed reduction gearing **19**. A supporting member **21** extending from the lower surface of the slide base **2** supports a nut member **22** in such a manner as to permit rotation thereof while preventing relative movement therebetween. The nut member **22** is engaged with the feed screw **17**, and has secured thereto a gear **23** which engages with a gear **25** keyed to a countershaft **24** rotatably mounted in the slide base **2**. The countershaft **24** has keyed thereto a worm **26** which engages with a worm **30** connected through gears **28** and **29** to a pulse motor **27** mounted on the slide base **2** for providing slow movement of the slide base **2**. A worm **32**, connected to the worm **30** through a gear train **31**, is urged downwardly by a compressed coil spring **33**, and engages with the worm gear **26** for eliminating backlash between the worm **30** and the worm gear **26**.

The slide base **2** has formed therein a V-shaped groove **2***a* and a flat surface **2***b* on which a wheel support **3** is slidably mounted over needle rollers therein, **35** and **36**, respectively, for movement in a lateral direction perpendicular to the longitudinal direction. In the wheel support **3** there is rotatably mounted a wheel spindle **41** having at one end a pulley **39** connected by V-belts **40** to a pulley **38** of a motor **37**. A wheel sleeve **43** holding a grinding wheel **42** thereon is clamped to the other end of the wheel spindle **41** by a nut **44**. The wheel sleeve **43** has an annular groove **43***a* in the side thereof being clamped by the nut **44** and an outer tapered face **43***b* adapted for being engaged by a grasping mechanism of a wheel exchange device **8**, as described hereinafter.

A wheel guard **45** surrounding the wheel **42** is fixedly secured to one side of the wheel support **3**. A vertically disposed side guard plate **46** is slidable on an edge thereof in guide ways **47** and **48** formed respectively in upper and lower portions of the wheel guard **45**. The side guard plate **46** is connected to a piston rod **51** of a cylinder **50** secured through a bracket **49** to the one side of the wheel support **3**. Thus, the side guard plate **46** protects the grinding wheel **42** during the grinding operation and may be retracted by the cylinder **50** when the wheel **42** is to be exchanged.

The wheel support **3** also has a feed mechanism, comprising a feed screw **54** driven through a speed reduction gearing **53** by a pulse motor **52** mounted on the slide base **2**, for moving the same in the lateral direction on the slide base.

In FIG. 4, a workpiece supporting device **4** defining a working station ST1 has a vertically oriented workpiece support spindle **60** slidably and rotatably mounted in a sleeve shaft **62**. The sleeve shaft **62** encloses the upper portion of the spindle **60** and is secured to a housing **61** mounted on the bed **1**. A workpiece support member **63** is secured to the upper end of the spindle **60** for for supporting a workpiece W. An arm **65** having a radially projecting roller **64** is secured to the lower portion of the spindle **60**. A slide member **66** having a bifurcated portion **66***a* engaging a roller **77** carried by a reduced portion **76** of a nut member **80** is mounted by bearings on the lower end portion of the spindle **60** for permitting the rotation thereof. Journalled on the lower end of the sleeve shaft **62** is a worm gear **67** which is engaged with a worm **69** connected through a speed reduction gearing **68'** to a pulse motor **70** for rotating the workpiece W. An engaging member **68**, secured to the worm gear **67**, has a projecting slotted portion **68***a* with which the roller **64** of the arm **65** is continuously engaged during the oscillating movement of the spindle **60**, to be described hereinafter, for transmitting a driving force from the worm gear **67** to the spindle **60**. The slide member **66** is slidably mounted on a guide way **71***a* of a bracket **71** secured to the bed **1**. A compressed spring **72** is seated between the slide member **66** and the bracket **71** so as to balance the weights of the slide member **66**, the spindle **60** and the workpiece W.

A hollow spindle **75** is rotatably mounted on bearings in the base **1** and has at one end thereof a pulley **78** which is connected by belts to a suitable driving means, not shown. The spindle **75** has a bifurcated yoke **75***a* at its other end for carrying a rotatable screw shaft **79** which is engaged with the nut member **80**. An adjusting shaft **83** is rotatably mounted in the hollow spindle **75** and has at one end a bevel gear **82** which engages a bevel gear **81** supported by the screw shaft **79**. The adjusting shaft **83** has a head portion **83***a* of square cross-section at its other end. Thus, by rotating the head portion **83***a* of the adjusting shaft **83**, the nut member **80** is caused to be shifted eccentrically with respect to the center axis of the spindle **75** for adjusting the stroke or range of the oscillating movement of the slide member **66**. After adjustment of the stroke of the slide member **66**, a stop collar **84** fastened to an end of the adjusting shaft **83** may be locked with respect to the spindle **75** by tightening a set of clamping screws **85** therein. Thus, since the workpiece W is oscillated up and down, the controls of rotation of the workpiece W and the feed movement of the wheel **42** in the station ST1 with respect to the workpiece W permit a cam surface parallel to the axis of the spindle **60** to be formed at the periphery of the workpiece W.

In FIG. 5, the wheel exchange device **8** defines a wheel exchange station ST4, and comprises a housing **90** and a spindle **91** which is slidably mounted on a longitudinal path therein and also is coaxial with the wheel spindle **41** when the same is positioned in the station ST4. The end of the spindle **91** extends outside the housing **90** toward the wheel spindle **41** in the station ST4 and has an inner tapered face **91***a* adapted to be engaged with

the outer tapered face 43*b* of the wheel sleeve 43 during the exchanging operation. Two diametrically opposed clamping jaws 92 are pivotally mounted on the spindle 91 through connecting rods 92*a* and 92*b*. The jaws 92 are adapted to be engaged with the annular groove 43*a* of the wheel sleeve 43 in the station ST4 by means of the operation of a cylinder 95 secured to the side of the spindle 91. A shaft member 93 is rotatably and slidably mounted in the spindle 91 and has at one end an engaging member 93*b* adapted to engage with the nut 44. The shaft member 93 is connected through a hammer mechanism 96*a* for producing an impact rotary torque and a gear train 96*b* to a driving means 96 for rotation thereby. Thus, in order to loosen the nut 44 from the wheel spindle 41 having been moved into the station ST4, the engaging member 93*b* is engaged with the nut 44 and rotated by means of the hammer mechanism 96*a* with the wheel sleeve 43 being clamped by the jaws 92 to the spindle 91. A press rod 94 is slidably mounted in the shaft member 93 and is provided with a threaded portion 94*a* which engages the wall of the spindle 91. The press rod 94 is connected through a gear train to a driving means 97. Thus, the press rod 94 is moved in the axial direction by means of the driving means 97. In order to relieve the locked engagement between the wheel sleeve 43 and the wheel spindle 41 in the station ST4 after the nut 44 has been loosened from the wheel spindle 41, the press rod 94 is moved forward and is engaged with the end of the wheel spindle 41 while the wheel sleeve 43 is clamped by the jaws 92 to the spindle 91. Then, to demount the wheel sleeve 43 from the wheel spindle 41, a cylinder 98 is provided in the housing 90 which has a piston 98*a* slidably disposed therein and a piston rod 98*b* connected at one end to the piston 98*a* and at the other end to the end of the spindle 91. The cylinder 98 is operated after the locked engagement between the wheel sleeve 43 and the wheel spindle 41 is relieved by the press rod 94. The shaft member 93 is moved to engage with and disengage from the nut 44 by the operation of a cylinder 99 formed between the spindle 91 and the shaft member 93.

The wheel exchange device 8 may be moved toward a selector 9 defining an intermediate station ST5 where the used wheel is exchanged for a new one to be used in successive working operation, which is stored in a storage device 7. The selector 9 may be moved along the storage device 7 so as to return back the used wheel from the exchange device 8 to its original position in the storage device 7 and to take out the new wheel from the storage device to give the same to the exchange device 8. The wheel exchange device 8, upon receiving the new wheel, is returned back to the wheel exchange station ST4. The nut 44 is then threadedly engaged with the wheel spindle 41 by rotation of the shaft member 93 and is locked thereto by the hammer mechanism 96*a*. Thereafter the jaws 92 are relieved from the annular groove 43*a* of the wheel sleeve 43 and finally the spindle 91 is retracted by the operation of the cylinder 98 to complete the wheel exchange operation.

At a measuring station ST3 adjacent to the wheel exchange station ST4, there is provided a measuring device 6 which has a housing 100 fixedly mounted on the bed 1. A measuring rod 101 is slidably mounted on bearings 102 and 103 in the housing 100. The measuring rod 101 has at its forward end a feeler 104 to be engaged with the periphery of the wheel 42 in the station ST3 and at its other end a collar 107. A protective bellows 105 is expansible secured between the feeler 104 and a plate 106 secured to the one side of the housing 100. In the housing 100 there is provided a cylinder 110 having a piston 111 slidably mounted therein, and a piston rod 112 being integrally joined at one end to the piston 111 and having at the other end a collar 108 adapted to engage with the collar 107 of the measuring rod 101. Thus, the measuring rod 101 is retracted from the wheel 42 in the station ST3 by the operation of the cylinder 110. The measuring rod 101 has a key way 101*a* formed in the longitudinal surface thereof into which a pin 109 is projected for preventing rotation of the measuring rod 101, and has at another longitudinal surface portion a rack 117 engaged with a pinion 116 formed on a shaft 116*a*. The shaft 116*a* is rotatably mounted in the housing 100 and is connected at one end to an output shaft 115*a* of a position coder 115. The position coder 115 generates pulse signals in response to rotation of the output shaft 115*a*. The shaft 116*a* has thereon a circumferentially V-grooved wheel 118 around which a wire 119 is wound. One end of the wire 119 is connected to a weight 120 so as to eliminate the backlash between the pinion 116 and the rack 117, and to urge the feeler 104 against the wheel 42 in the station ST3 by a constant force with the cylinder 110 released.

A guide way member 121 on which a slide member 122 is slidably mounted is supported on an upper surface of the housing 100. A side face measuring device 130 is provided on the slide member 122. The slide member 122 has an upper projection 122*a* connected to a piston rod 125 of a cylinder 123 mounted on the housing 100 so that the slide member 122 and the measuring device 130 are moved toward and away from the wheel 42 in the station ST3 by the actuation of the piston 124 in the cylinder 123. An arm 132 is fixed to a spring member 131 secured on the slide member 122 so as to be pivotal in a horizontal plane. The arm 132 is connected at its forward end to a feeler 133 which is adapted to engage the side face of the wheel 42 in the station ST3 and is urged at its other end by a compressed spring 134 to generate a contacting pressure on the wheel 42. The arm 132 has at its rear end a pin 132*a* opposite a feeler 135*a* of a differential transformer 135. The differential transformer 135 generates a voltage level in response to displacement of the feeler 135*a*. A projection 136 is mounted on the guide member 121 opposite the rear end of the arm 132 so as to move the feeler 133 away from the side face of the wheel 42 upon engagement of the rear end of the arm 132 with the projection 136, when the slide member 122 is moved to the right.

At a dressing station ST2, a dressing device 5 is provided, as shown in FIG. 9, which comprises a housing 140 mounted on the bed 1. A swing table 143 is rotatably journalled on bearings 141 and 142 about a vertical axis in the housing 140. The table 143 has an upstanding integral wall 144, on the upper portion of which a boss 145 having a bore 145*a* therein is integrally formed. A tool holder 147 having at one end a tool 146 for dressing the periphery of the wheel 42 in the station ST2 is slidably mounted in the bore 145*a*. The other end of the tool holder 147 is engaged with a screw shaft 150. Rotation of the tool holder 147 upon turning of the screw shaft 150 therein is prevented by a key 149. A compressed spring 148 is seated between the wall of the boss 145 forming one end of the bore 145*a* and the end of the tool holder 147 engaged by the screw shaft 150 for eliminating any backlash between the tool holder 147 and the screw shaft 150. The screw shaft 150 extends beyond a cap 151 secured to the boss 145 for closing the open end of bore 145*a* and has a knob 152 fixed to the end thereof. Rotation of the knob 152 is effective for moving the tool holder 147 toward and away from the wheel 42 in the station ST2. The dressing point D of the tool 146 is aligned with the axis of rotation of the swing table 143 by adjustment of the tool holder 147 which is effected through rotation of the knob 152 so that the tool holder may be moved in a direction perpendicular to the peripheral edge of the exchanged wheel to be dressed. It is convenient to use a reference bar 153 mounted on the swing table 143 and having a reference surface S which is aligned with the vertical axis of rotation of the swing table 143 in adjusting the dressing point D of the tool 146.

The lower portion of the swing table **143** has secured thereto a gear **155** which is engaged with a gear **157** secured to a vertically disposed countershaft **156** also rotatably mounted in the housing **140**. The countershaft **156** also has secured thereto a worm gear **159** which is shown in FIG. 10 as being engaged with a worm **161** connected to an output shaft **160***a* of a pulse motor **160**. Thus, the swing table **143** may be rotated through a predetermined angle, the amount of rotation being controlled by pulses generated from the pulse motor **160**. However, the dressing point D of the tool **146** remains aligned with the axis of rotation of the swing table **143** on any angular displacement of the swing table **143**. Therefore, the dressing point D of the tool holder **147** in alignment with the axis of the swing table **143** also is maintained in a predetermined position relative to the axis of the workpiece support spindle **60**, which is parallel to the swing table axis. The dressing device **5** may dress several kinds of shapes of wheels, for example, a circular surface in cross-section or an angular surface in cross-section merely by controlling the rotary movement of the swing table **143** and the longitudinal and lateral feed movements of the wheel support **3**.

The control system for the grinding machine according to the present invention will now be described. In FIG. 11, reference numerals **200** and **201** indicate tape readers, respectively, which read informations stored in sequence and profile tapes **202** and **203**. A tape reader control circuit **204** controls the operations of the tape readers **200** and **201**. Informations read by the tape readers **200** and **201** are fed to and decoded by a decoder **205** and then registered in information and numerical registers **206** and **207**. Reference numerals **208** and **209** indicate a primary control circuit and an operational circuit, respectively, which select the element to be controlled and distribute command pulses in response to the registered data. An output circuit **210** is responsive to command pulses from the primary control circuit **208** and the operational circuit **209** to direct the operations of pulse motor driving circuits **211**, **212**, **213**, **214**, and **215** for actuating, respectively, the associated pulse motors **160**, **70**, **27**, **20**, and **52**. Reference numerals **228** and **229** indicate a control panel and a control circuit which serve to start and stop the machine and to select either the manual or automatic operational modes of the machine. A wheel exchange control device **226** controls the exchanging operations of the wheel exchange device **8** and the selector **9** in response to the wheel exchange commands received from the information register **206**. A measuring control device **227** controls the movement of the measuring device **6** toward and away from the wheel **42** in the station ST3 to effect measurement of the positions of the peripheral edge and the side face of the wheel in response to the measuring commands also being received from the information register **206**. Pulses generated from the position coder **115** and responsive to changes in the diameter of the wheel **42** being measured are fed to a counter **216** and are registered in a register **217** after counting the distance of the wheel from the dressing point D. Pulses from a pulse generator **224** through a gate **225**, which is opened when the wheel **42** is in the dressing station ST2, are fed to both the output circuit **210** and a counter **218**. The counted pulses in the counter **218** are fed to a comparator **219** so as to be compared with the preset pulses from the register **217**. When the pulses from the counter **218** become equal to the preset pulses from the register **217**, the gate **225** is closed. Thus, the pulses equal to the preset pulses are fed to the output circuit so as to rotate the pulse motor **52** for the lateral feed movement of the wheel support **3** in the station ST2 through the driving circuit **215** to feed the wheel **42** to the lateral position wherein the peripheral edge of the wheel **42** contacts the dressing tool **146**. The output voltage in the differential transformer **135** responsive to the change in the position of the side face of the wheel **42** in the station ST3, or to a change in the thickness of the wheel, is fed through an amplifier **220** and a rectifier circuit **221** to a Schmidt triggering circuit **222** wherein the output voltage is compared with the preset voltage therein corresponding to a reference position of the side face of the wheel **42** to control the opening or closing of a gate **223**. When the side face of the wheel **42** is out of the reference position, the gate **223** is opened to feed pulses from the generator **224** to the pulse motor **27** through the output circuit **210** and the driving circuit **213** to cause the wheel support **3** to be moved in the longitudinal direction. When the side face of the wheel **42** arrives at the reference position, the output voltage becomes equal to the preset voltage, and the Schmidt circuit **222** is actuated to close the gate **223**.

As described above, the measuring device **6** measures the distance between the peripheral edge of the wheel **42** in the measuring station ST3 and the dressing point D and automatically compensates for any difference in the position of the side face of the wheel and the reference side position set within the Schmidt circuit **222**. Furthermore, the dressing point D of the dressing tool **146** is in a predetermined position with respect to the axis of workpiece support spindle **60**. Therefore, programmings of the dressing and grinding operations may be established irrespective of changes occurring in the dimensions or diameters of exchanged wheels. Such programs, which are set on the tapes **202** and **203** are read by tape readers **200** and **201** so that the primary control circuit **208** and the operational circuit **209** can distribute command pulses into the appropriate predetermined pulse motors to control the operations of the dressing device **5**, wheel support **3** and the workpiece support device **4**. Thus, the operations of dressing the wheel and then forming the desired cam profile on the workpiece may be effectively automatically controlled in the desired manner.

The sequence of the operation with reference to the above-mentioned preferred construction will now be described. As shown in FIG. 12, the grinding wheel **3** is returned from the grinding position on the workpiece W to the original position, shown in phantom, after the grinding operation. The slide base **2** supporting the wheel **42** is then moved to the wheel exchange station ST4 by means of high speed pulse motor **20**. The wheel exchange device **8** operates to demount the wheel from the wheel sleeve **41** in the wheel exchange station ST4 and to return the wheel to its original position in the storage device **7** through the selector **9**. Then the wheel exchange device **8** takes a successive wheel selected by the selector **9** and carries the same into the wheel exchange station ST4 wherein the successive wheel is inserted onto the wheel sleeve **41**. After inserting the wheel into the wheel spindle **43**, the slide base **2** is moved distance L_1 to the measuring station ST3 by means of the high speed pulse motor **20**.

In the measuring station ST3, the measuring rod **101** is moved forwardly under the action of the weight **120** until the feeler **104** contacts the peripheral edge of the wheel **42**. In accordance with the amount of movement of the measuring rod **101**, the position coder **115** is rotated through the rack **117** and the pinion **116** to detect the lateral distance between the wheel **42** in the measuring station ST3 and the dressing point D, or the axis of rotation of the swing table **143**, in digital signals. At the same time, the feeler **133** is also moved forwardly by operation of the cylinder **123** to then bring the same into contact with the side face of the wheel **42** under the force of the spring **134**. Thus, the longitudinal position of the wheel on the bed **1** is detected as the output of the differential transformer **135**. The output of the differential transformer **135** operates to open the gate **223** to control the low speed pulse motor **27** for moving the slide base **2** and the wheel support **3** slightly in the longitudinal direction until the side face of the wheel **42** reaches the reference side position preset in the Schmidt circuit **222**. Namely, the side face of the wheel is aligned with the central axis of the measuring rod **101** by setting the Schmidt circuit so as to be actuated upon alignment of the feeler **133** with

the central axis of the measuring rod **101**. Since the reference side position, that is, the central axis of the measuring rod **101**, is constant with respect to the dressing point D, programming of the width of the wheel permits the wheel to be positioned in a predetermined relationship with respect to the dressing point D, even when the shape in cross-section of the wheel is any configuration. Assuming that the longitudinal distance between the reference side position, or the central axis of the measuring rod **101**, and the dressing point D of the dressing tool **146** is L_2 and that the width of the wheel, which has been programmed as well as wheel exchange command, is b_1, movement of the slide base by means of the high speed pulse motor **20** from the measuring station in the direction of the dressing station ST2 by the distance $L_2+b_{1/2}$ enables the center of the wheel to coincide with the dressing point D.

In the dressing station ST2, the digital signals fed from the position coder **115** to the register **217** through the counter **216** control the pulse motor **52** through the output circuit **210** and the driving circuit **215** to cause the wheel **42** to be moved toward the dressing point D through the lateral distance l_1, that is, to bring the edge of the wheel **42** into contact with the dressing point D of the dressing tool **146**. Thereafter, any desired shape in cross-section of the wheel is formed by controlling the lateral and longitudinal movements of the wheel by means of pulse motors **52** and **27** and maintaining the rotation of the dressing tool by means of pulse motor **160** in a predetermined relationship therewith in response to programmed commands. For example, as shown in FIG. 13, in dressing the wheel **42** having a circular peripheral edge or face, the center of the circular peripheral face of the wheel is moved I→II→I→III→I along an arcuate path having the same radius as the peripheral face of the wheel with the center on the dressing point D. The dressing point is swung to be directed to the center of the circular peripheral face of the wheel in response to movement of the wheel.

Since the dressing point D is in a predetermined position with respect to the axis of the workpiece support spindle **60**, namely, a lateral distance l_2, if distance U between the axis of the spindle **60** and the starting position of the grinding operation on the workpiece is known, programming of the distance (l_2-U) between the dressing point D and the starting position of the grinding operation on the workpiece will effect the grinding operation irrespective of the wheel dimension or diameter.

After the dressing operation, the wheel support **3** is moved distance L_3 to the working station ST1 by means of the high speed pulse motor **20**. In the working station ST1, the wheel support **3** is moved by means of pulse motor **52** toward the workpiece W by the distance (l_2-U) to bring the wheel edge to the start position of the grinding operation on the workpiece. Thereafter, a rough grinding operation for removing an amount δ_1 from the workpiece is effected by controlling the longitudinal and lateral feed movements of the wheel by means of pulse motors **27** and **52** and the rotation of the workpiece by means of pulse motor **70** with the workpiece being vertically oscillated. Finally, a fine grinding operation for removing an amount δ_2 from the workpiece is effected in a similar manner to the rough grinding operation, whereby the workpiece is finished.

As described above, the grinding operation is effected irrespectively of the changes occurring in the wheel diameters. Consequently, specific programming taking the change in the wheel diameter into consideration is unnecessary.

While the present invention is applied to the grinding machine for forming a cam profile on the workpiece, it should be understood that the invention may be applied to a usual cylindrical grinding machine by providing the usual workpiece support devices, such as, the headstock and tailstock.

Obviously, many modifications and variations are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed and desired to be secured by Letters Patent is:

1. A grinding machine comprising

a bed,

a wheel support slidably mounted on said bed,

a grinding wheel rotatably and demountably mounted on the wheel support,

wheel storage means for storing at least one additional grinding wheel,

wheel exchange means for exchanging said grinding wheel on said wheel support for a predetermined grinding wheel in said wheel storage means,

measuring means mounted on said bed for measuring the position of the peripheral edge of the exchanged wheel relative to a given point,

dressing means mounted on the bed for dressing the exchanged wheel,

workpiece support means mounted on the bed for supporting a workpiece to be ground, said dressing means being in a predetermined position with respect to the workpiece support means,

feeding means for moving the wheel support,

means for operating said feeding means to move the wheel support in response to the position of the exchanged wheel measured in said measuring means for bringing the peripheral edge of the exchanged wheel into contact with the dressing means,

means for operating said dressing means and said feeding means in a predetermined relation according to a predetermined program to form the periphery of the exchanged wheel into a predetermined shape in cross-section, and

means for operating said feeding means and said workpiece support means in a predetermined relation according to said predetermined program to control relative movement of the wheel support having the dressed wheel thereon with respect to the workpiece support means by using said dressing means as a reference position with respect to the workpiece support means, thereby to grind the workpiece in a predetermined shape and size.

2. A grinding machine comprising

a bed,

a wheel support slidably mounted on said bed for movement in two directions which are substantialy perpendicular to each other,

a grinding wheel rotatably and demountably mounted on the wheel support,

wheel storage means for storing at least one grinding wheel to be exchanged,

wheel exchange means for exchanging said grinding wheel on said wheel support for a predetermined grinding wheel in said wheel storage means,

measuring means mounted on said bed for measuring the peripheral position of the exchanged wheel,

dressing means mounted on the bed and having a dressing point for dressing the exchanged wheel,

workpiece support means mounted on the bed for supporting a workpiece to be ground,

said dressing point of the dressing means being in a predetermined position with respect to the workpiece support means,

first feeding means for moving the wheel support in one of said two direction along the axis of the wheel,

second feeding means for moving the wheel support in the other direction,

means for operating said first feeding means according to a predetermined program to move the wheel support in said one direction from the measuring means to the dressing means,

means for operating said second feeding means to move the wheel support in said other direction in response to the peripheral position of the exchanged wheel measured in said measuring means for bringing the peripheral edge of the exchanged wheel into contact with the dressing point of the dressing means,

means for operating said dressing means and said first and second feeding means in a predetermined relation with one another according to said predetermined program to form the periphery of the exchanged wheel into a predetermined shape in cross-section,

means for operating said first feeding means according to said predetermined program to move the wheel support in said one direction from the dressing means to the workpiece support means, and

means for operating said second feeding means and said workpiece support means in a predetermined relation with each other according to said predetermined program to control relative movement of the wheel support having the dressed wheel thereon with respect to the workpiece support means by using said dressing point as a reference position with respect to the workpiece support means, thereby to grind the workpiece in a predetermined shape and size.

3. A grinding machine as claimed in claim 2, wherein said last named means operates said first and second feeding means and said workpiece support means.

4. A grinding machine comprising

a bed,

a wheel support slidably mounted on said bed for movements in two directions which are substantially perpendicular to each other,

a grinding wheel rotatably and demountably mounted on the wheel support,

wheel storage means for storing at least one grinding wheel to be exchanged,

wheel exchange means for exchanging said grinding wheel on said wheel support for a predetermined grinding wheel in said wheel storage means,

measuring means mounted on said bed for measuring the peripheral position of the exchanged wheel relative to a given point,

dressing means mounted on the bed and having a dressing point for dressing the exchanged wheel,

workpiece support means mounted on the bed for supporting a workpiece to be ground,

said dressing point of the dressing means being in a predetermined position with respect to the workpiece support means,

first feeding means for moving the wheel supoprt in one of said two directions along the axis of the wheel at a relatively high speed,

second feeding means for moving the wheel support in said one direction at a relatively low speed,

third feeding means for moving the wheel support in the other direction,

means for operating said first feeding means according to a predetermined program to move the wheel support in said one direction from the measuring means to the dressing means,

means for operating said third feeding means to move the wheel support in said other direction according to said peripheral position of the exchanged wheel measured in said measuring means for bringing the periphery of the exchanged wheel into contact with the dressing point of the dressing means,

means for operating said dressing means and said second and third feeding means in a predetermined relationship with one another according to said predetermined program to form the periphery of the exchanged wheel into a predetermined shape in cross-section,

means for operating said first feeding means according to said predetermined program to move the wheel support in said one direction from the dressing means to the workpiece support means, and

means for operating the third feeding means and said workpiece support means in a predetermined relation with each other according to said predetermined program to control relative movement of the wheel support having the dressed wheel thereon with respect to the workpiece support means by using said dressing point as a reference position with respect to the workpiece support means, thereby to grind the workpiece in a predetermined shape and size.

5. A grinding machine as claimed in claim 4, wherein said last named means operates said second and third feeding means and said workpiece support means.

6. A grinding machine comprising

a bed,

a wheel support slidably mounted on said bed,

a wheel spindle rotatably mounted on the wheel support and having a threaded portion at one end,

a grinding wheel,

a wheel sleeve holding said grinding wheel and demountably mounted on the one end of the wheel spindle,

a nut member adapted to be threadedly engaged with said threaded portion of the wheel spindle for clamping said wheel sleeve to said wheel spindle,

said wheel sleeve being formed with an engaging portion at one end,

wheel storage means for storing at least one grinding wheel to be exchanged,

wheel exchange means for exchanging said grinding wheel on said wheel spindle for a predetermined grinding wheel in said wheel storage means,

said wheel exchange means comprising grasping means adapted to be engaged with said engaging portion of said wheel sleeve adjacent to the wheel exchange means,

means adapted to be engaged with said nut member and having hammer means for loosening and clamping said nut member with the grasping means engaged with the engaging portion of the wheel sleeve,

means for relieving the locked engagement between the wheel sleeve and the wheel spindle with the nut member loosened from the threaded portion of the wheel spindle and with the grasping means engaged with the engaging portion of the wheel sleeve, and

means for mounting and demounting the wheel sleeve holding the grinding wheel thereon from the wheel spindle,

measuring means mounted on said bed for measuring the peripheral position of the exchanged wheel relative to a given point,

dressing means mounted on the bed and having a dressing point for dressing the exchange wheel,

workpiece support means mounted on the bed for supporting a workpiece to be ground,

said dressing point of the dressing means being in a predetermined position with respect to the workpiece support means,

feeding means for moving the wheel support,

means for operating said feeding means to move the wheel support in response to the peripheral position of the exchanged wheel measured by said measuring means for bringing the peripheral edge of the exchanged wheel into contact with the dressing point of the dressing means,

means for operating said dressing means and said feeding means in a predetermined relation with each other according to a predetermined program to form the periphery of the exchanged wheel into a predetermined shape in cross-section, and

means for operating said feeding means and said workpiece support means in a predetermined relation with each other according to said predetermined program to control relative movement of the wheel support

having the dressed wheel thereon with respect to the workpiece support means by using said dressing point as a reference position with respect to the workpiece support means, thereby to grind the workpiece in a predetermined shape and size.

7. A grinding machine comprising

a bed,

a wheel support slidably mounted on said bed,

a grinding wheel rotatably and demountably mounted on the wheel support,

wheel storage means for storing at least one grinding wheel to be exchanged,

wheel exchange means for exchanging said grinding wheel on said wheel support for a predetermined grinding wheel in said wheel storage means,

measuring means mounted on said bed for measuring the peripheral position and the side position of the exchanged wheel relative to give points,

dressing means mounted on the bed and having a dressing point for dressing the exchanged wheel,

workpiece support means mounted on the bed for supporting a workpiece to be ground,

said dressing point of the dressing means being in a predetermined position with respect to the workpiece support means,

feeding means for moving the wheel support,

means for operating said feeding means to move the wheel support responsive to the side position of the exchanged wheel measured in said measuring means for locating the side position of the exchanged wheel at the measuring means in a predetermined position with respect to said dressing point of the dressing means,

means for operating said feeding means according to a predetermined program to move the wheel support from the measuring means to the dressing means to locate the side position of the exchanged wheel at the dressing means in a predetermined position with respect to the dressing point,

means for operating said feeding means to move the wheel support responsive to the peripheral position of the exchanged wheel measured in said measuring means for bringing the peripheral edge of the exchanged wheel into contact with the dressing point,

means for operating said dressing means and said feeding means in a predetermined relation with each other according to said predetermined program to form the periphery of the exchanged wheel into a predetermined shape in cross-section, and

means for operating said feeding means and said workpiece support means in a predetermined relation with each other according to said predetermined program to control relative movement of the wheel support having the dressed wheel thereon with respect to the workpiece support means by using said dressing point as a reference position with respect to the workpiece support means, thereby to grind the workpiece in a predetermined shape and size.

8. A grinding machine as claimed in claim 1, wherein said measuring means comprises

a housing mounted on said bed,

a measuring rod slidably mounted in said housing,

a feeler mounted on one end of said measuring rod and adapted to be engaged with the periphery of the exchanged wheel adjacent to the measuring means,

a position coder responsive to rotation of an output shaft thereof for detecting the peripheral position of the exchanged wheel,

said measuring rod being operatively connected to said output shaft of the position coder for rotation thereof, and

means to slide said measuring rod relative to the housing.

9. A grinding machine as claimed in claim 1, wherein said measuring means comprises

a housing mounted on said bed,

a measuring rod slidably mounted in said housing,

a feeler mounted on one end of said measuring rod and adapted to be engaged with the periphery of the exchanged wheel adjacent to the measuring means,

a position coder responsive to rotation of an output shaft thereof for detecting the peripheral position of the exchanged wheel,

said measuring rod being operatively connected to said output shaft of the position coder for causing rotation thereof,

means to slide said measuring rod relative to the housing,

a slide member slidably mounted on the housing,

a second feeler pivotally mounted on said slide member, said second feeler being adapted at one end to be engaged with the side face of the exchanged wheel adjacent to the measuring means under the force of a resilient biasing means,

a differential transformer engaged with the other end of said second feeler and responsive to displacement thereof, and

means for sliding said slide member relative to the housing.

10. A grinding machine as claimed in claim 1, wherein said dressing means comprises

a housing mounted on said bed,

a swing table rotatably mounted on said housing,

a tool holder slidably and adjustably mounted in said swing table,

a tool mounted on one end of said tool holder and having said dressing point thereon,

said dressing point of the tool being aligned with the axis of rotation of said swing table whereby said tool holder is directed in a direction perpendicular to the periphery of the exchanged wheel to be dressed, and

means for rotating said swing table according to said predetermined program.

11. A grinding machine as claimed in claim 1, wherein said workpiece support means comprises

a housing mounted on said bed,

a support spindle slidably and rotatably mounted in said housing for supporting said workpiece to be ground,

means for rotating the support spindle according to said predetermined program, and

means for oscillating the support spindle.

12. A grinding machine comprising:

a supporting bed,

a wheel support slidably disposed on said bed for rotatably supporting a grinding wheel,

means on said bed for removing the grinding wheel on said wheel support and replacing the same with another grinding wheel,

workpiece support means on said bed for supporting a workpiece to be ground,

means for moving said wheel support from said wheel removing and replacing means to said workpiece support means in successive first and second stages and for returning said wheel support to said wheel removing and replacing means,

means disposed on said bed at said first and second stages for, respectively, measuring the position of the peripheral edge of the grinding wheel on said wheel support relative to a given point on said bed and for dressing the wheel accordingly in a predetermined manner.

13. The grinding machine of claim 12 wherein said wheel dressing means is in a predetermined position relative to said workpiece support means, and

said wheel support moving means moves said wheel support from said second dressing stage to said workpiece support means according to a predetermined

program using said dressing means as a reference position with respect to the workpiece support means, thereby to grind the workpiece in a predetermined shape and size.

14. The grinding machine of claim **13** wherein said workpiece support means comprises means for rotating said workpiece and for oscillating said workpiece along the axis of rotation thereof.

15. The grinding machine of claim **14** wherein said wheel support moving means comprises means for moving said wheel support reciprocably along one line of travel, and means for moving said wheel support reciprocably along another line of travel peripendicular to said one line of travel.

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