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(54) MEASURING AND CONTROL APPARATUS FOR INTERNAL GRINDING MACHINES

(71) I, MARIO POSSATI T/A FINIKE ITALIANA MARPOSS—Soc. in Accomandita Semplice Di Mario Possati & C.—, an Italian Citizen of 40010 Bentivoglio-S. Marino (BO), Via Saliceto, 13, Italy, do hereby declare the invention for which I pray that a Patent may be granted to me, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to measuring and control apparatus for internal grinding machines.

Internal grinding machines with resting shoes for co-operating with the outer surface of the workpiece, and associated with apparatus for carrying out measurements of linear dimensions on the workpieces, for controlling and regulating the machine, and particularly its grinding wheel, are already known: in these known machines the internal diameter of the workpiece is measured during the machining ("in process") by a gauge connected to control devices of the grinding machine which regulate the grinding process depending on the instantaneous measured values of the diameter; the control devices include stepping-motor or similar control systems, which control the feed and the positioning of the grinding wheel, while permitting measurements of the relevant displacements.

External grinding machines are known too, in which the machining cycle control is dependent on the measurement of the outer diameters of the workpieces, carried out after the machining. Depending on the measurements made and/or combination and processing of them (e.g. obtaining the arithmetical mean of a predetermined number of consecutive measurements), correction displacements of the tool are brought about. In these machines, therefore, the measurements on the workpieces are of "post-process" type.

Other known machines, in which "in process" measurements of the workpieces are made, include grinding machines for external grinding of male parts to be matched with female parts. The female part is measured on a bench while contemporaneously the male part is measured in process and the machine control is effected depending on the comparison of the measurements and the value of the desired clearance in the matching.

As to the in-process measurements, it is pointed out that they cannot be carried out in all cases, due to the practical impossibility of housing the gauge on the grinding machine. The in-process measurements, when possible, take place however in rather adverse conditions, which sometimes cause measurement errors or lack of precision, poor efficiency of the machine, or failures of the gauge. This is due, for example, to the flow of coolant running over the workpiece and the gauge, the heating, the vibrations and strains of the workpiece, the necessity to lengthen the operating cycles in order to carry out the measurements, possible impacts of the gauge against the workpiece or the grinding wheel, or explosions of the grinding wheel (these are relatively frequent on internal grinding machines having high production).

For the internal grinding machines, with externally resting shoes, in which in-process measurement is carried out, there are further problems, besides those mentioned above, due to possible differences in the outer diameter of the workpieces. As a matter of fact, due to these differences in diameter, gauges with two contact feelers measure along a chord line of the workpiece, and not along a diameter, while for gauges having a single contact feeler every displacement of the feeler due to changes of the outer diameter causes measurement errors.

In control apparatus based on past-process measurements it is generally difficult to obtain acceptable compromises taking into account the opposite requirements of machining accuracy, and promptness and stability of the correction controls. In particular, the arrival at the machine of anomalous workpieces (e.g. workpieces having too high values of stock size with respect to the normal values) can cause wrong machinings of both the anomalous workpieces and subsequent workpieces.

It is therefore an object of the invention to achieve an improved measuring and control apparatus for an internal grinding machine.

According to the present invention, there is provided a measuring and control apparatus which controls an internal grinding machine having resting devices co-operating with the outer surfaces of the successive workpieces to be machined, the apparatus comprising:

control means which control the displacement of the grinding wheel relative to the workpiece to be machined, the control means including measuring means which measure the grinding wheel displacement;

gauging means carrying out measurements of dimensions of the successive workpieces, the gauging means including a first pre-process gauge adapted to provide a signal responsive to the diameter of said outer surface of the workpieces and a second pre-process gauge adapted to provide a second signal responsive to the internal diameter of the workpieces;

processing means connected with the gauging means and with the control means, the processing means setting the measuring means of the control means to permit the control means to control the grinding wheel feed, for the grinding of the internal surface of the workpieces to be machined in dependence on the gauged outer diameter of the workpieces and the desired internal diameter to be obtained by the grinding operation; and

an ejection device arranged between the gauging means and the grinding machine, the ejection device being connected to the processing means for controlling the ejection of scrap workpieces and that of workpieces having internal and outer diameters which would render unsafe the grinding machine operation.

Arrangements according to the invention will now be described in more detail by way of example and with reference to the accompanying drawings, wherein:

Fig. 1 is a diagram showing a grinding machine for machining internal grooves of bearing rings and an apparatus according to a preferred embodiment of the invention;

Fig. 2 is a block form diagram of the machine and the apparatus of Fig. 1;

Fig. 3 is a block diagram of a variant of the circuit for controlling the dressing of the grinding wheel of the machine of the preceding Figures;

Fig. 4 is a block form diagram of the synchronizing and enable circuits of the apparatus of Figs. 1 and 2.

In Fig. 1 under reference numerals 11, 12, 13 there are shown, respectively, a first automatic measuring machine, a grinding machine of the type with resting shoes for the workpiece, for grinding the internal grooves of bearing rings, and a second automatic measuring machine. The two automatic measuring machines 11, 13 one located upstream and the other downstream of grinding machine 12, are of types substantially known per se and their constructional details do not concern the present invention, so that the Figure only shows some elements of the machines. The rings 15 are conveyed to the first measuring machine 11, afterwards from it to grinding machine 12, then from the grinding machine 12 to the second measuring machine 13, and finally removed from the second measuring machine by synchronous conveyors, also substantially known per se, which carry out step movements and are provided with equally spaced seats for receiving the rings. In Fig. 1 the conveyors are symbolized by arrows 17.

The first measuring machine 11 includes a guide 18 leading rings 15 towards a measuring head 19 located at a side of the guide. Head 19 has a feeler 20 adapted to contact the outer surface of ring 15 and thrust the latter towards a mechanical reference 21 disposed at the opposite side of ring 15. Another mechanical reference 22, which is movable, is adapted to block every workpiece arriving at machine 11, cooperate with reference 21 in keeping it in a reference position during measurement and finally withdraw to clear the passage so the ring 15 can be output from the machine 11.

Moreover, machine 11 includes a measuring plug 23 provided with two feelers 24, 25. Plug 23, axially movable, is inserted into ring 15 after the latter has been arrested in the reference position and it then carries out measurement along the diameter of the inner groove of the ring.

Thereafter, the plug 23 returns to its rest position, by withdrawing out of the ring. The displacement of plug 23 towards the measuring position inside ring 15 and its return to rest position is controlled by probes, not shown in Fig. 1, which detect the positioning of the ring and the end of the relevant measurements. One of the probes is shown in Fig. 4, as is described hereinafter. Head 19 and plug 23 are connected, respectively, to electrical detecting and indicating units 26, 27, which provide signals proportional to the deviations of the outer diameter and the diameter of the inner groove of consecutive rings 15 from the relevant nominal values.

Machine 11 further includes a control group 29 which controls the cycles of operation. Group 29 is connected to units 26, 27. Measuring machine 13 includes a guide 28 guiding rings 15 towards a movable mechanical reference 31, adapted to block each ring, keep it in a reference position during the measurement and finally withdraw to clear the passage for permitting the ring to go out of machine 13. The measuring devices of machine 13 include a measuring plug 33 provided with two feelers 34, 35.

Plug 33, axially movable, is inserted into ring 15 for measuring the deviation, from the relevant nominal value, of the diameter of the inner groove, the surface of which has been previously ground. Plug 33 is connected to an electric detecting and indicating unit 37 which provides a signal proportional to said deviation. Moreover machine 13 includes a control group 39, connected to unit 37.

Detecting and indicating units 26, 27, 37 are connected to a processing and control unit 40, which in its turn, is connected to a control group 42 of grinding machine 12. The other elements of grinding machine 12 shown in Fig. 2 comprise two resting shoes 44, 45 on which ring 15, rotated by a magnetic spindle, not shown, rests with its outer surface, and internal grinding wheel 47.

The radial displacements of grinding wheel 47 are controlled by control group 42 through the functional connection shown by dot-dash line 49.

With reference to Fig. 2, the output of unit 26, where there is a signal proportional to the deviation S_E of outer diameter D_E of ring 15 measured by head 19, from the nominal value D_{En}, is connected to the negative input of a comparator 51 and to the positive input of a comparator 53. Comparator 51 receives at the positive input a voltage proportional to the (negative) value $S_{Ei}=D_{Ei}-D_{En}$, where D_{Ei} is the lower limit of tolerance of outer diameter D_E. Comparator 53 receives at the negative input a voltage proportional to a value $S_{Ea}=D_{Ea}-D_{En}$, the meaning of which will be explained herebelow.

Between the output of comparator 51 and ground is connected the coil of a relay 55 having a contact, open in the rest condition, arranged in an input circuit of an ejection device 56 being part of machine 11.

Between the output of comparator 53 and ground is connected the coil of a relay 57 having a contact, open under the rest condition, arranged in said input circuit of ejection device 56.

The output of unit 27 receives a signal proportional to the deviation S_I of diameter D_I of the inner groove of ring 15 from the nominal value D_{In}, and it is connected to the positive inputs of two comparators 61, 62. Comparator 61 receives at its negative input a voltage proportional to the value $S_{Is}=D_{Is}-D_{In}$, where D_{Is} is the upper limit of tolerance of inner diameter D_I.

Comparator 62 has its negative input connected to ground. Between the output of comparator 61 and ground there is connected the coil of a relay 64 having a first contact, open under the rest condition, connected to said input circuit of ejection device 56.

Between the output of comparator 62 and ground there are connected in series a delay circuit 65, a second contact 66, closed under the rest condition, of relay 64, and the coil of a relay 67 having a contact, open under the rest condition, connected to a second input circuit of ejection device 56.

Comparator 51 generates an output signal which energizes the coil of relay 55, closing the relevant contact, when the condition $D_E<D_{Ei}$ takes place, that is when the measured ring 15 is a scrap part irreclaimable by further machinings, since it has an outer diameter below the lower limit of tolerance.

Comparator 61 generates an output signal which energizes the coil of relay 64, closing the relevant contact, when the condition $D_I>D_{Is}$ takes place, that is when the measured ring 15 is a scrap part, irreclaimable because the diameter of its inner groove is above the upper limit of tolerance. In this condition, also comparator 62 is triggered, but the presence of delay circuit 65 and the opening of contact 66 prevent the energization of the coil of relay 67.

When the condition $D_{Is}>D_I>D_{In}$ takes place, the output signal generated by comparator 62 energizes the coil of relay 67, closing the relevant contact that is open in the rest condition. The closure of the contact of relay 55 or of that, open under the rest condition, of relay 64 causes the operation of ejection device 56, which ejects, through a first ejection outlet of machine 11, the irreclaimable scrap parts, preventing their displacement towards grinding machine 12.

Ejection device 56 also intervenes as a consequence of the actuation of relay 67, but in this case the ejection of the relevant ring is carried out through a second outlet of machine 11. As a matter of fact in this case the workpiece, apart from possible shape errors of the inner groove, has diameter D_I above the nominal value, but within the tolerance range.

Finally ejection device 56 also intervenes after the actuation of relay 57, for preventing grinding machine 12 from receiving rings 15 having dimensions which would bar or render unsafe the insertion of the grinding wheel 47 into the bores of the ring. For this purpose, the reference value $S_{Ea}=D_{Ea}-D_{En}$ is chosen depending on the limit value D_{Ea} below which it is sure that rings 15—normally measured in measuring machine 11 after insertion of plug 23—permit, when located on shoes 44, 45 of machine 12, the insertion of grinding wheel 47, also supposing that this insertion must take place in the most critical condition as to the diameter of the grinding wheel, the position and wear of shoes 44, 45 and so on.

Unit 26 is also connected to the input of a delay circuit 70 having a terminal for zero-setting control connected to an output circuit of the ejection device 56. The output of delay circuit 70 is connected to an analogue-to-digital converter 71 which converts the analogue signal into a digital signal in BCD (Binary Coded Decimal) form. Similarly, unit 27 is connected to the input of a delay circuit 72 having a zero-setting terminal connected to said output circuit of the ejection device 56 and an output connected to an analogue-to-digital converter 74 which converts the analogue signal into a digital signal.

Delay circuits 70, 72 are provided for taking into account the delay occurring from the "pre-process" measurements of rings 15 on machine 11 to the subsequent machining in grinding machine 12; the delay circuits are both zero-set by a signal from the already mentioned output circuit of ejection device 56 when the latter ejects a ring, preventing in this way that measurements of ejected rings reach grinding machine 12.

The output of converter 71 is connected to the negative input of a difference circuit 73 which receives at a positive input the signal coming from an output of a summing circuit 75. With reference to converter 71, it is evident that although for simplicity's sake previously and herebelow reference has been made to an "output" of the converter and a single-wire connection has been shown in the drawings, in actual fact the converter has several terminals and output connections, for permitting a parallel transfer of digital signals. Similar comments are also valid for other circuits.

The summing circuit 75 receives at an input a digital signal, in BCD code, indicative of a pre-set number $\bar{Z}$ of feed steps of grinding wheel 47 and at another input a signal indicative of a correction of the value $\bar{Z}$ obtained depending on the diameter measurement made on machine 13 and/or regulations made on grinding machine 12, as will be explained herebelow.

The output of difference circuit 73, on which there is a signal indicative of a desired number Z' of feed steps of the grinding wheel, corrected with regard to value $\bar{Z}$ taking into account both the pre-process and the post-process measurements, is connected to the input of a control unit 77 which controls the operation of a stepping-motor 78. Stepping motor 78 carries out, through the connection 49, the grinding wheel 47 movements of fast approach, feed and retraction.

The functional connection 80 between unit 77 and motor 78 has the function of transmitting to the latter the driving pulses which control the steps of movement of the motor. A connection 81 from an encoder 76 coupled to motor 78 to unit 77 transmits to the latter signals indicative of the steps made by motor 78 in clockwise or counterclockwise direction.

Unit 77, of a type substantially known per se, includes circuits which provide voltage references, circuits which convert these references into frequency signals, driving circuits of motor 78, a receiver 84 of the signals of encoder 76 and a counter 79 which counts the steps made by motor 78 both in the phase of retraction of grinding wheel 47 from the ground surface and in the approach and machining phases.

A comparator 82 receives at a first input, from counter 79, a signal in BCD code indicative of the steps $\bar{Z}(t)$ made by motor 78 in the phase of grinding wheel retraction, and at a second input the signal, in BCD code, present at the output of difference circuit 73. When the two input signals of comparator 82 become equal, the comparator provides at its output connected to unit 77 a signal for control of cycle end and, subsequently, a signal to start the phase of approach of the grinding wheel towards the surface of a new ring to be ground.

The signal controlling the end of the cycle also controls the cancellation of the signal indicative of the number of steps Z' made, forwards and backwards, by grinding wheel 47 for the ring 15 previously ground.

An indicating device 83 receives at its input an output from unit 77 in the form of a signal in BCD code indicative of the difference between the number Z' and the steps made forwards by grinding wheel 47. This output of unit 77 is also connected to relevant inputs of three comparators 85, 86, 87.

Comparator 86 receives at a second input a signal in BCD code indicative of the theoretical size $|S_{I1}|=|D_{I1}-D_{In}|$ of the inner groove of rings 15 in correspondence with which it is desired to effect the changeover from rough grinding speed to fine grinding speed; when the two signals at the inputs of comparator 86 are equal, the comparator controls, through an output connected to unit 77, said changeover. Similarly, comparator 87 receives at a second input a signal in BCD code indicative of the theoretical size $|S_{12}|=|D_{12}-D_{1n}|$ of the inner groove of rings 15 in correspondence with which it is desired to carry out a spark-out (end of grinding) phase; when the two signals at the inputs of comparator 87 are equal, the comparator controls, through an output connected to unit 77, the end of the fine grinding phase and the start of the spark-out phase, the duration of which is adjusted through a timer, not shown. Comparator 85 has another input connected to the output of a difference circuit 89. Circuit 89 has two inputs, the first of which, negative, is connected to the output of converter 74, while at the second, positive, input there is present a reference signal indicative of a value K the meaning of which will be explained below. The output signal of circuit 89, indicative of the value $-S_1+K$ (S_1 is normally negative), is used for controlling, through comparison with the signal received at the first input of comparator 85, the end of the fast approach displacement (end of the 'air cut') of the grinding wheel 47 towards the surface of the groove of workpiece 15 and the start of the rough grinding phase. This control is operated through an output connected to unit 77, when equality of the input signals of comparator 85 occurs. Since the setting of the controls of stepping motor 78 is made, as already mentioned, in such a way that when $Z(t)=Z'$ grinding wheel 47 is in position at the end of the retraction stroke from the workpiece and when $Z(t)=O$ the grinding wheel is in the position corresponding, at the end of the spark-out, to the attainment of the final inner diameter, theoretically equal to D_{1n}, it follows that the theoretical condition in which—during the approach of the grinding wheel 47 towards workpiece 15—the contact of the wheel with the surface to be ground takes place, is the attainment, on indicating device 83, of a count $Z_c=|S_1|$.

It follows, then, that the control for the end of the 'air cut' is operated when the count on indicating device 83 has the value Z_c+K. The value K is set for regulating, for purposes of safety, the control operation with regard to the theoretical contact of the grinding wheel with the workpiece. The signal which reaches an input of summing circuit 75, for correcting the value $\bar{Z}$ depending on the post-process measurements made on machine 13 and/or depending on adjustments made on machine 12, is obtained as follows. The output of unit 37 is connected to the input of an inhibit circuit 91 which transmits or inhibits the input signal depending on the value of an enable signal present at a terminal 92 connected to an indicating circuit of a group 93 for dressing control of grinding wheel 47. Terminal 92 is also connected to the pushbutton for starting of the apparatus. A mean circuit 95 receives the signals transmitted through inhibit circuit 91 and determines the mean S_{1m} of a pre-set number of consecutive signals, or an exponential mean, for example as described in Italian Patents No. 931,738 and No. 931,735. The output of mean circuit 95 is connected to the input of an analogue-to-digital converter 96, having in its turn an output connected to the negative input of a difference circuit 97. The positive input of circuit 97 is connected to control group 93, while the output is connected to summing circuit 75. Control group 93 controls the dressing of grinding wheel 47 after the machining of a pre-set number of workpieces 15 has taken place and also controls the "grinding wheel compensation" operation.

In the apparatus shown in Fig. 2 the operation of grinding wheel compensation is performed electrically. In fact, the connection between control group 93 and circuit 97 provides to the latter the progressively increasing sum, obtained through a totalizer circuit 99 of group 93, of the subsequent dressing amounts (or, since the dressing amount is usually constant, the product of this amount and number of dressing operations, which progressively increases until the replacement of the grinding wheel). The compensation signal is summed, in circuit 75, with the signal indicative of value $\bar{Z}$. The value $\bar{Z}$ is also corrected, by this compensation signal, by a signal indicative of the mean deviation S'_{1m} of diameter D'_1 of the workpieces ground, measured just after every dressing operation, from nominal value D_{1n}. In this way it is possible to compensate for the wear of the dressing device, that of the resting shoes, and other sources of machining errors. As is evident from what is said above, the mean deviation S'_{1m} is obtained because after every dressing operation group 93 provides to inhibit circuit 91 an enable signal which allows the passage of the post-process measurement signals relating to a pre-set number of workpieces ground just after the dressing operation. A similar enable signal is sent to circuit 91 at the starting of the apparatus.

The circuit of Fig. 3 shows a further use of the pre-process and post-process measurements. This circuit enables control of the dressing of grinding wheel 47 as soon as the grinding wheel has removed a pre-set amount of stock, rather than after machining of a pre-set number of rings, as outlined with reference to Fig. 2. In this way the initiation of dressing is better related to the need for dressing.

The output of delay circuit 72 is connected, through a further delay circuit 101, to the negative input of a difference circuit 103 which receives at the positive input the output signal of unit 37. Delay circuit 101 allows obtaining at the output of difference circuit 103 signals proportional to the difference of the sizes of the same ring before (S_1) and after (S'_1) machining. These signals reach the input of an integrating circuit 105 which calculates the sum of the stock amounts actually removed by grinding wheel 47 from successive rings 15, up-dating this sum when a terminal 104 receives an enable signal, as will be explained afterwards. The output signal of integrator 105 reaches the positive input of a comparator 106 which receives at the negative input a pre-set reference voltage, indicative of the maximum amount of stock that can be removed by a grinding wheel 47 while maintaining a sufficient cutting capacity between one dressing and the subsequent dressing.

Between the output of comparator 106 and ground there is inserted the coil of a relay 108 having a contact, open under rest conditions, connected with a zero-set terminal 109 of integrator 105 and also with a terminal 110 of a dressing control circuit of a group 112 for dressing control, substantially the same as group 93, at least as regards the mechanical parts.

Moreover, the contact of relay 108 is also connected with the already mentioned enable terminal 92 of the inhibit circuit 91 of the apparatus of Fig. 2, which otherwise is unchanged.

It is evident that a signal for dressing control is obtained due to the closure of relay 108 contact, when the voltage at the positive input of comparator 106 goes above that present at the negative input. Moreover the closure of the contact causes the zero setting of integrator 105 and the generation of the enable signal to inhibit circuit 91.

By numerals 120, 121, 122 there are shown in Fig. 4 probes, suitably arranged on measuring machines 11, 13 and on grinding machine 12, so as to feel the arrival and the positioning of the rings in the measurement and machining positions, respectively.

Probes 120, 121, 122 have outputs connected to relevant inputs of a logic, summing circuit 125. The output of the logic summing circuit 125 is connected to a terminal 127 of a control device 129, which controls conveyors 17 through connections symbolized in the Figure by dot-dash lines 131, 132, 133, 134. Terminal 127 receives, as soon as a workpiece is positioned on at least one of machines 11, 13 and/or grinding machine 12, a signal which stops conveyors 17. Another terminal 136 of control device 129 is connected to the output of an AND circuit 139 having two inputs connected to comparator 82 and control group 93, respectively.

When at the output of comparator 82 there is present the relevant control voltage (this also happens when no workpiece is present on the grinding machine), while at the same time the circuits of control group 93 provide a signal indicating the end of a dressing cycle of the grinding wheel or the lack of a dressing control, terminal 136 receives an enable signal for the movement of conveyors 17. Then the conveyors move synchronously, provided that a stop signal is not present on terminal 127.

Probes 120, 121, 122 have other outputs 140, 141, 142 which control, when the relevant probe feels the positioning of a workpiece, the starting of a cycle of the measuring machine 11 and/or 13 and/or of grinding machine 12.

These machines carry out then the relevant measurement and/or grinding cycles, which terminate with the removal of the workpiece from the measuring or working position and then the removal, at terminal 127, of the stop signal for conveyors 17.

Probe 121 has a third output 144 connected, through a delay circuit 146, to terminal 104 of integrator circuit 105, for controlling the updating of the calculation made by the same integrator circuit.

The operation of the circuits of Fig. 4 will be now described with reference to some of the eight possible conditions which may take place as to the arrival of workpieces 15 at measuring machines 11, 13 and grinding machine 12.

If grinding machine 12 as well as measuring machines 11, 13 receive respective rings 15, after a synchronous forward step of relevant conveyors 17 and subsequent loading—through loading devices and/or guides for gravity sliding—, in machining and measuring position, probes 120, 121, 122 control the stopping of conveyors 17 and the actuation of the respective operation cycles of grinding machine 12 and machines 11, 13. The measuring cycles of machines 11, 13 end before that of the grinding machine. After the end of the latter and the end of a possible dressing cycle, conveyors 17 make another forward step, carrying the workpiece measured by machine 11 on to grinding machine 12 (provided that the workpiece is not ejected), the ground workpiece on to measuring machine 13 and the workpiece measured by this machine towards a container. In another possible condition, measuring machines 11, 13 receive respective rings 15, while grinding machine 12 does not receive any ring. In this case machines, 11, 13 carry out the measuring cycles, while grinding machine 12 does not operate. After the end of the measuring cycles, conveyors 17 carry out a further synchronous forward step.

The operation of the apparatus in the other possible circumstances is evident from what is explained above and therefore is not described.

By means of the circuits of Fig. 4 and other auxiliary enable and control circuits of measuring machines 11, 13 and grinding machine 12, the synchronism of the pre-process measurements, the post-process measurements and the grinding operation is maintained and possible troubles, which may derive from variations of the duration of the grinding cycles and/or variations of the dressing times, are avoided.

The construction of the synchronizing and enable circuits may be different from that shown in Fig. 4, depending on the particular features of grinding machine 12 and measuring machines 11, 13.

Measuring machines 11, 13 may be of automatic or semi-automatic type, with incorporated devices transporting, loading and unloading the workpieces, gravity sliding guides and so on. As already mentioned, the measurement of the diameter of the internal groove of the rings, made before the machining, can be utilized to modify the operating cycle of the grinding machine 12 in such a way as to control the end of the 'air cut' depending on the initial stock value.

The regulation of the operating cycle depending on the initial stock value can also be extended to other phases of the machining as described in Italian Patent No. 968,059.

Measuring machines 11, 13 can be provided with further measuring gauges and devices, in such a way as to carry-out additional pre-process and post-process checkings and measurements.

These additional checkings and measurements may be used for controlling the grinding machine 12, for classifying the workpieces and for selecting them. In particular, it may be advantageous to carry out, on the different surfaces of each workpiece, measurements of concentricity errors, out-of-roundness, perpendicularity errors and so on.

WHAT I CLAIM IS:—

1. A measuring and control apparatus which controls an internal grinding machine having resting devices co-operating with the outer surfaces of the successive workpieces to be machined, the apparatus comprising:

control means which control the displacement of the grinding wheel relative to the workpiece to be machined, the control means including measuring means which measure the grinding wheel displacement;

gauging means carrying out measurements of dimensions of the successive workpieces, the gauging means including a first pre-process gauge adapted to provide a signal responsive to the diameter of said outer surface of the workpieces and a second pre-process gauge adapted to provide a second signal responsive to the internal diameter of the workpieces;

processing means connected with the gauging means and with the control means, the processing means setting the measuring means of the control means to permit the control means to control the grinding wheel feed, for the grinding of the internal surface of the workpieces to be machined in dependence on the gauged outer diameter of the workpieces and the desired internal diameter to be obtained by the grinding operation; and

an ejection device arranged between the gauging means and the grinding machine, the ejection device being connected to the processing means for controlling the ejection of scrap workpieces and that of workpieces having internal and outer diameters which would render unsafe the grinding machine operation.

2. Measuring and control apparatus according to claim 1, wherein said processing means include circuits receiving the measurement signal of the second gauge for operating the control means depending on the stock to be removed from the workpiece.

3. Measuring and control apparatus according to claim 2, wherein said circuits receive also the measurement signal of the first gauge for providing to the control means a signal controlling the changing from fast approach speed of the grinding wheel towards the workpiece inner surface to feed speed for stock removal depending on both the internal diameter and the outer diameter gauged.

4. Measuring and control apparatus according to claim 1 or claim 2 or claim 3, including enabling and inhibiting means arranged in the gauge means and in the grinding machine for respectively preventing the gauge means and grinding machine operation in absence of a workpiece to be respectively gauged or ground.

5. Measuring and control apparatus according to any one of claims 1 to 4, further including: transfer means for transferring in succession workpieces from the first and second pre-process gauges to

the grinding machine, and away from the grinding machine; synchronizing means connected with the gauging means, the transfer means and the grinding machine for synchronizing their operation; and a post-process gauge, the transfer means being adapted to transfer the ground workpieces to the post-process gauge and away from the latter, the synchronizing means being adapted to synchronize the operation of the post-process gauge with those of the pre-process gauge, transfer means and grinding machine, the post-process gauge including an internal diameter gauge providing a signal responsive to the diameter of the ground surface, the processing means being connected with the internal diameter gauge for providing to the control means a correction signal responsive to deviations of the diameter of the ground surface from said desired diameter.

6. Measuring and control apparatus according to claim 5, for a grinding machine which includes a dressing device for controlling the dressing of the grinding wheel depending on the volume of stock removed, wherein said processing means includes a dressing control circuit connected with the second pre-process gauge and the post-process gauge for calculating the progressive amount of stock removed from successive workpieces.

7. Measuring and control apparatus according to any one of claims 1 to 6, wherein said control means comprises a stepping motor and stepping motor control means and said measuring means includes a device calculating the steps carried out by the motor from determined positions, the processing means being connected to the stepping motor control means and to the device for calculating the steps carried out by the motor.

8. A measuring and control apparatus for internal grinding machines, substantially as described with reference to Figures 1, 2 and 4 of the accompanying drawings, or as modified according to Figure 3.

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1563376 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

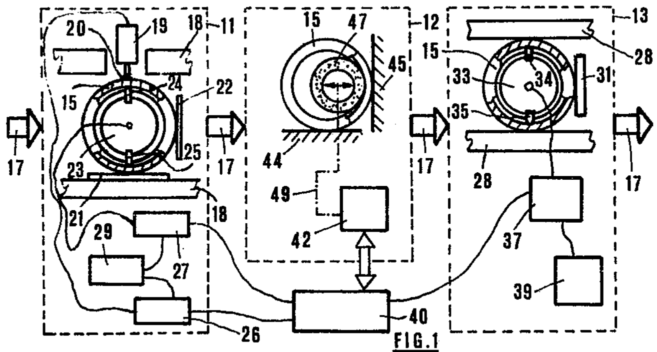

FIG.1

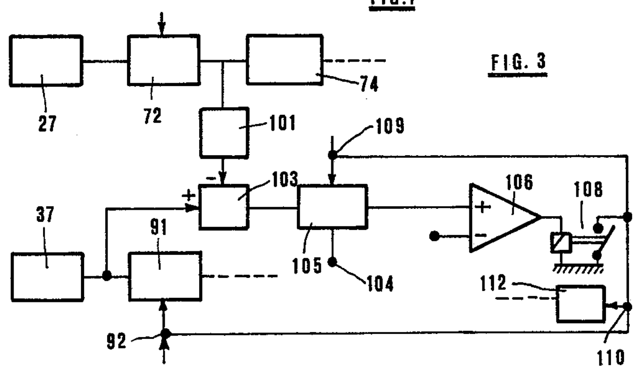

FIG. 3

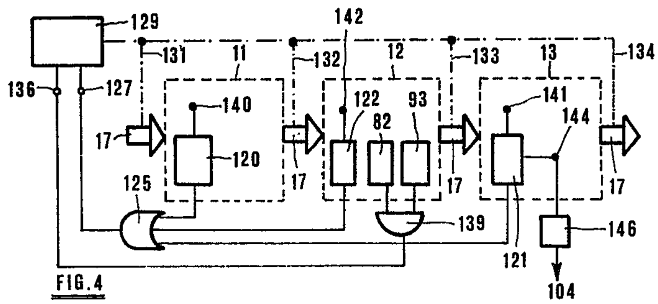

FIG.4

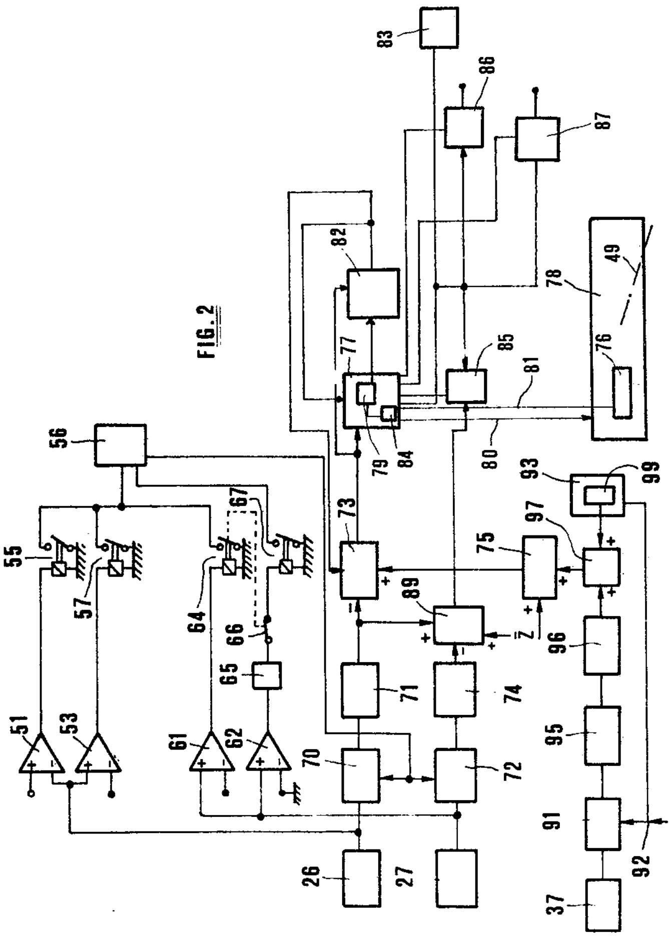

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FIG. 2