Aug. 4, 1964 W. R. BACKER 3,142,944

COMPENSATED GRINDING WHEEL FACE POSITION INDICATOR FOR GRINDING MACHINES

Filed June 21, 1963

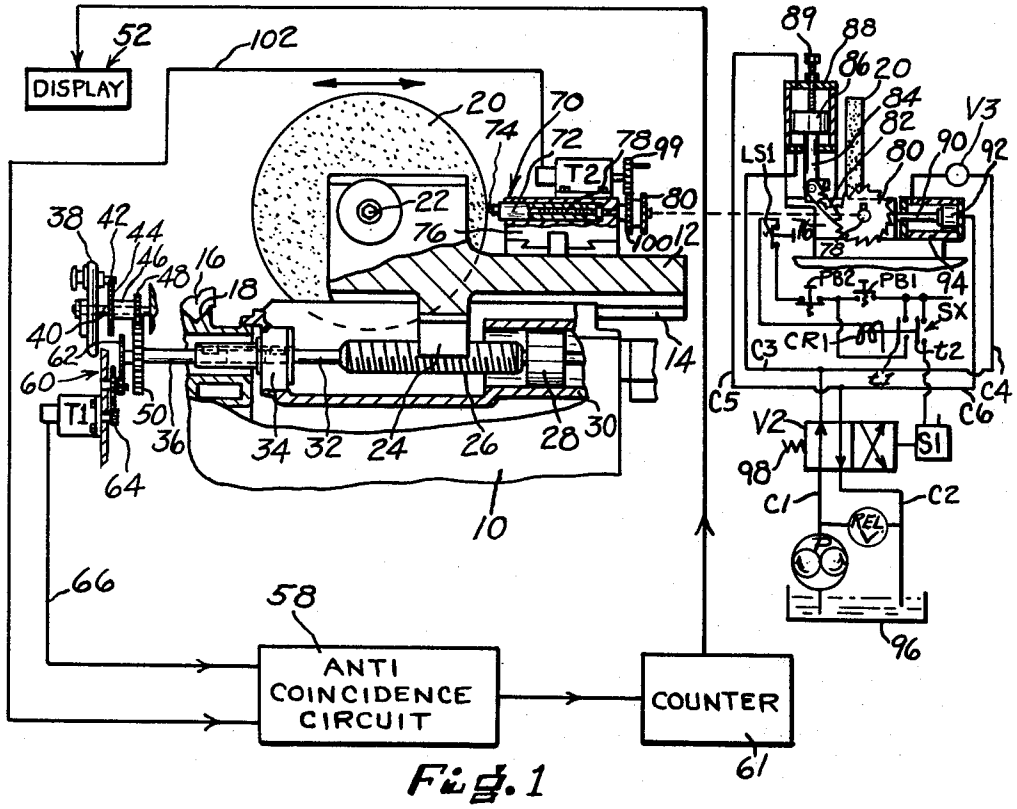


Fig. 1

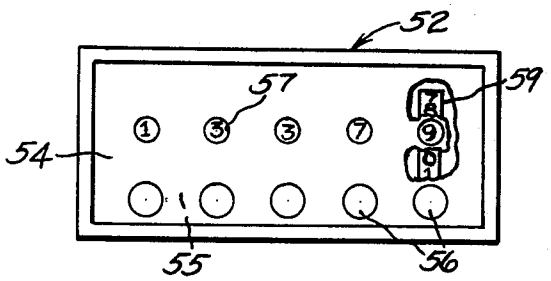


Fig. 2

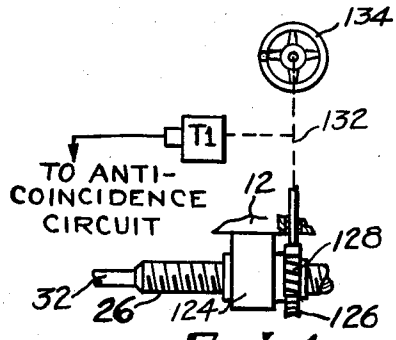


Fig. 4

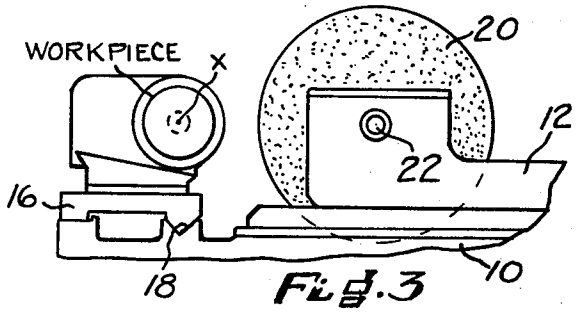


Fig. 3

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COMPENSATED GRINDING WHEEL FACE POSITION INDICATOR FOR GRINDING MACHINES

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This invention relates to grinding machines equipped with indicators in the form of digital counters to facilitate feeding of the grinding wheel relative to the work to grind the work to the correct size, and, in particular to improvements providing for automatic compensation of the indicator reading when the size of the grinding wheel is changed by a truing operation on the grinding wheel.

In a grinding machine equipped with a wheel feed indicator provided with a digital read-out, it is common practice to adjust the digital read-out sot hat it continuously indicates a dimensional relationship between the position of a grinding wheel and a fixed reference point which may conveniently be a point on the axis of rotation of a work piece supported in the grinding machine. Such a dimensional relationship varies directly with the radius of an imaginary circle concentric of the axis of rotation of a work piece and tangent to the nearest point on the surface of a grinding wheel, which circle corresponds with the surface of the work piece as long as the grinding wheel is in contact with the work piece. Since the desired dimension of the work piece is commonly expressed in terms of its diameter rather than its radius because its diameter is more readily measured, and since the diameter of a work piece is a direct function of its radius, it is most convenient to couple the sensing element of a digital counter to the wheel feed mechanism through a train of such a gear ratio that the reading on the digital counter may be set to indicate and to vary with the diameter of a work piece rather than its radius.

The arrangement described above may be described as a wheel face position indicator only so long as the diameter of the grinding wheel remains unchanged. However, the grinding wheel wears and also becomes dull in use so that it must be trued periodically, thus reducing the radius of the grinding wheel. Accordingly, the initially established relationship between the peripheral face of the grinding wheel and the reference point changes by the amount the radius of the grinding wheel is reduced, making it necessary to correct the setting of the indicator each time the grinding wheel is trued.

The principal objects of this invention are to provide not only for adjustment of the indicator reading consistent with each change in the position of the grinding wheel relative to the aforesaid reference point, but also for initiating compensatory re-setting of the indicator reading in response to movement of the truing device into position preparatory to the truing operation; to provide a device which will consistently indicate the position of the face of the grinding wheel relative to the reference point and hence to the work piece throughout successive grinding operations and periodic truing operations, including retraction of the grinding wheel as required for grinding different diameters and retraction of the grinding wheel and the truning device as necessary for installing and truing a new grinding wheel substantially larger than a worn-out grinding wheel; and to provide a device which is of relatively simple construction and can be incorporated in existing grinding machines without substantial modification thereof.

As herein illustrated, the invention resides in the combination with a grinding machine of the kind having an indicator constructed and arranged to indicate, by the position of the grinding wheel, when the work has been reduced to the desired dimension, and a truing device for retruing the grinding wheel; of automatically operable means operable, in response to the actuation of the truing device, to reset the indicator to compensate for the resulting reduction in the radius of the grinding wheel. More specifically, the combination comprises an indicator operative, at any given instant of grinding, to indicate, in response to the position of the face of the grinding wheel relative to a predetermined reference, the dimension of the work piece as it is being ground to size, a first transducer having an output proportional to the change in position between the face of the grinding wheel and the reference point due to displacement of the wheel slide as the work piece is reduced in size, a second transducer having an output proportional to the change in position between the face of the grinding wheel and the reference point as the radius of the grinding wheel is reduced, and means selectively operative to transmit the outputs from the two transducers to the indicator. The transducers may be in the form of pulse generators which are designed to transmit pulses to a selector, the latter comprising, in one suitable form, an anti-coincidence circuit.

The invention will now be described in greater detail with reference to the accompanying drawings wherein:

FIG. 1 illustrates diagrammatically the control for effecting automatic resetting of an indicator applied to a grinding machine, provided with a manual feed and with a truing device operable at the will of the operator, both the grinding machine and the truing device being illustrated fragmentarily;

FIG. 2 is an elevation of an indicator broken away in part to show one of the digital counting wheels;

FIG. 3 is a fragmentary elevation showing the relation of the axis of rotation of the work on the work support and the grinding wheel; and

FIG. 4 is a schematic partial view of an alternative embodiment of the wheel feed mechanism illustrated in FIG. 1, showing an arrangement in which the instant invention may be used for setting up the wheel feed mechanism when it is to be fed automatically.

Referring to the drawings, the base **10** of the grinding machine supports a grinding wheel slide **12** on V-shaped and flat ways **14** of the usual kind for movement forwardly and rearwardly, as indicated by the double-headed arrow, relative to a work support. The work support is a table **16** mounted on suitable V-shaped and flat ways **18** situated at right angles to the ways **14** for supporting a work piece for movement widthwise of the grinding wheel **20**, the latter being supported on the slide **12** for rotation about the horizontal axis of the shaft **22**. The work piece may be rotatably mounted on the table **16** by suitable fixtures for rotation about an axis X parallel to the axis of the shaft **22**.

The simplest form of a grinding machine to which the instant invention is applicable is one in which a wheel slide is fed entirely by hand as by a feed screw rotated by a hand wheel and threadably engaged by a nut connected to the wheel slide. The instant invention is also applicable to operation of grinding machines incorporating hydraulically actuated fast and slow wheel feed mechanisms suitable for semi-automatic operation and also selectively operable at the slow feeding rate by means of a manually controlled hand wheel.

When a grinding machine is equipped with a wheel feed mechanism suitable for either semi-automatic or manual operation, such as that illustrated in Patent No. 2,522,485, and is also equipped with an indicator arranged to operate according to the teachings of the instant invention, the wheel slide may be fed toward the work hydraulically with the stop set to terminate the wheel feed when the work is ground to the desired size.

In such an application, the indicator may be set in the manner described in detail below so that the operator may monitor the semi-automatic operation of the grinding machine.

The instant invention is also applicable to grinding machines provided with a wheel feed mechanism including a separate means for setting up the wheel slide to grind a particular dimension. One such arrangement is illustrated schematically in FIG. 4 in which the half nut 24 is replaced with a full nut 124 rotatably supported on the wheel slide 12 and threadbly engaging the feed screw 26. The full nut 124 is selectively rotated to set up the wheel slide 12 by a suitable drive train which may include a worm wheel 126 engaged by a worm 128 rotatable with a drive train 132 shown schematically in FIG. 4 in turn coupled to a suitable drive means such as a feed wheel 134. In this embodiment of the instant invention, the transducer T1 is coupled to and rotatable with the drive train 132. In this configuration, the reading on the indicator will be changed as the position of the wheel slide is changed during the set up and it will be changed as the result of each truing operation. However, the reading on the indicator will not change when the wheel slide 12 is moved during a normal feeding operation by separate drive means such as hydraulically actuated means for effecting longitudinal displacement of the feed screw to produce a fast feed and hydraulically actuated means for rotating the feed screw to effect a slow feed, for example, in the manner described and illustrated in Patent No. 2,522,485.

Noting that, in the embodiment of the instant invention illustrated in FIG. 1, the counter 61 produces an output signal continuously indicative of the position of the grinding wheel face relative to a predetermined reference, this signal may alternatively or additionally be supplied to an automatic control system for a grinding machine such as a conventional numerical control system for machine tools. The details of such a system are not included in this application since they form no part of the instant invention.

The wheel feed mechanism illustrated in FIG. 1 is a simplified schematic representation of a conventional feed mechanism suitable for semi-automatic or manual operation such as that illustrated and described in detail in Patent No. 2,522,485. FIG. 1 also includes a simplified representation of the arrangement for coupling the hand wheel to the wheel feed mechanism, since such arrangements are well known in the art and since one such arrangement for selectively coupling the hand wheel to such a feed mechanism is shown and described in detail in Patent No. 2,572,529.

Referring still to FIG. 1, a grinding machine suitable for use in connection with the instant invention is shown therein as being provided with a rapid feed mechanism for moving the grinding wheel slide 12 and the grinding wheel 20 supported thereby into a position close to the work piece, and also as being provided with a manually controlled slow feed for grinding the work piece to size. As illustrated in FIG. 1, the grinding wheel slide 12 has a downwardly projecting half-nut 24 in threaded engagement with a feed screw 26, one end of which is secured to a piston 28 slidable in a cylinder 30 on the base and the other end of which has an integral spindle 32 which passes through a bearing 34 and is held telescopically engaged at its forward end with and slidably keyed to a shaft 36. The rapid feed is effected by supplying a pressure fluid to the cylinder 30 behind the piston 28 which bodily moves the screw 26 and hence the grinding wheel slide 12, which is coupled thereto by the half-nut 24, up to the face of the work piece. The slow feed is effected manually by a hand wheel 38 rotatably mounted on a shaft 40. The hand wheel supports an adjustable knob provided with a pinion for selective engagement with a gear 44 fixed to one end of a hub 46 also rotatably mounted on the shaft 40, so that rotation of the hand wheel effects rotation of the hub. The hub 46 has at its other end a gear 48 which meshes with a gear 50 on the shaft 36. Thus rotation of the hand wheel 38 with the pinion 42 engaged with the index plate 44 will rotate the feed screw 26 slidably keyed to the shaft 36 and hence effect a slow feed of the grinding wheel.

To expedite grinding operations and, at the same time, maintain the precision desired, an indicator 52 (FIG. 2) is mounted on the machine frame in a position to constitute a display easily observed by the operator.

As illustrated in FIG. 2, the indicator, which may be included in counter 61, has a conventional transparent cover plate 54 behind which there is an opaque panel 55 containing holes 57. Behind each hole 57 in the opaque panel there is a counting disc 59 bearing digits arranged so that only one digit shows through the hole at a time. The several counting discs 59 may, for example, bear values representing units, tenths, hundredths, thousandths, and the like. Reset knobs 56 are provided for the several counting discs.

Referring more particularly to the mode of using the indicator 52 described above, a work piece (FIG. 3) is mounted on the table 16 for rotation about its horizontal axis X. The grinding wheel 20 is advanced by means of the rapid feed up close to the work piece and then is manually fed into the work piece by the hand wheel 38 until a predetermined calipered dimension is attained, this establishing a predetermined relative position between the face of the grinding wheel and the axis X. With the work piece mounted for rotation about the axis X, the grinding wheel may be advanced so as to grind the work piece down to a calipered diameter of one inch, for example, by advancing the grinding wheel 20 manually. When this dimension is reached, the indicator is set by rotation of the knobs 56 to show the digits 1.0000, indicating the diameter of the work piece at this position. It is to be understood however that the position of the face of the grinding wheel may be established relative to any predetermined reference point on the work support and hence to the work piece and that the indicator may be thereafter suitably set to indicate a desired dimension of the work piece when the grinding wheel is moved into engagement with the work piece and thence to that position.

The indicator 52 has been illustrated as a mechanical counter of a well known type in order to simplify the description of the procedure for setting the proper reading on the indicator. However, it should be understood that the indicator 52 may in fact comprise a conventional electronic counter including counter tubes coupled to digital indicating tubes such as those known commercially as "Nixie" tubes, since the instant invention works equally well with such an indicator and since the details of the indicator form no part of the instant invention.

The indictor 52 is connected to the manual feed means so as to be actuated thereby, that is, to have units added to or subtracted from it in consonance with the movement of the grinding wheel 20 toward or away from the work piece. Movement of the slide 12 supporting the grinding wheel is communicated to the indicator by a transducer T1, which is reversible, so as to be operated by movement of the grinding wheel in either direction. The output of the transducer T1 is proportional to the change of relative position between the axis of the grinding wheel and the reference point referred to above, to wit, the axis X of rotation of the work piece and is transmitted to the indicator by way of a selector 58 which is contained within and forms part of the counter 61. The transducer T1 is directly connected for operation to the shaft 36 as the latter is rotated by a train of gears indicated at 60, the first of which 62 is fixed to the shaft 36 and the last of which 64 is fixed to a shaft extending from the transducer T1.

As herein illustrated, the transducer T1 is in the form of a pulse generator, for example, of the kind manufac-

tured by Wang Laboratories, Inc., of Natick, Massachusetts, and will deliver positive or negative pulses, depending upon the direction of rotation, through a conductor 66 to the selector 58, the latter being commonly known as an "anti-coincidence circuit" and from thence to the digital counter 61 which, in turn, effects rotation of the digit carrying discs 59 in the indicator, shown diagrammatically in FIG. 1 as the box labeled "Display." Thus, when the work piece has been calipered to size and the indicator 52 set to indicate the calipered size with the grinding wheel positioned in contact with the work piece, the grinding wheel 20 may be backed-off and then returned to grind another portion of the work piece or to grind another piece of the work to the same size or to a different size by the simple expedient of watching the counting discs of the indicator as the grinding wheel is advanced during grinding.

This procedure will produce accurately sized work pieces so long as the diameter of the grinding wheel remains unchanged. However, the grinding wheel 20 wears as it is used and must be trued periodically to insure precision cutting. Truing, of course, reduces the diameter of the grinding wheel and hence, with the foregoing arrangement, the indicator would be rendered in error by the truing operation in an amount corresponding to the reduction in radius of the grinding wheel. This invention has for its purpose automatically to reset the indicator each time the grinding wheel is trued, thereby relieving the operator of the responsibility of resetting the indicator after each truing operation and eliminating the errors which would be introduced in the absence of such resetting.

Other factors than the truing operation do affect the accuracy of the indicator reading. For example, the diameter of the grinding wheel may be changed slightly due to wear between successive truing operations, but the adverse effect of this factor can be minimized by truing frequently enough that the inaccuracy of the indicator reading due to wheel wear between successive truing operations does not exceed the dimensional tolerance of the work pieces being ground. Changes in the ambient temperature and other factors producing thermal drift in the machine may eventually introduce small errors in the indicator reading, but these are typically relatively minor sources of error which accumulate over relatively much longer time intervals. Accordingly, such errors can be eliminated by occasionally resetting the indicator as necessary to actually indicate the dimensional relation between the grinding wheel and the reference point.

As herein illustrated (FIG. 1), the truing device 70 is of a conventional kind comprising a spindle 72 having, at its forward end, a diamond point 74. The spindle is supported in a sleeve 75 mounted for movement toward and away from the face of the grinding wheel on a slide 76. The slide 76, in turn, is mounted on the wheel slide 12 for movement widthwise of the face of the grinding wheel. Movement of the spindle 72 is effected by a screw 78, the rear end of which has fixed to it a ratchet wheel 80 with which there is engaged a ratchet 82. The ratchet 82 is pivotally connected to the rod 84 of a piston 86 mounted in a cylinder 88, by means of which the ratchet 82 may be caused to rotate the ratchet wheel 80 the distance of one tooth or more as determined by the setting of the stop screw 89. The slide 76 is connected to the rod 90 of a piston 92 mounted in a cylinder 94 whereby the slide 76 may be moved transversely, that is, widthwise of the grinding wheel.

Pressure fluid is supplied to the cylinders 88 and 94 by means of a pump P which has an intake in a sump 96. Oil is delivered by the pump P from the discharge side through a conductor C1 to the cylinders and is returned to the sump from the cylinders through a conductor C2. A relief valve Rel-V provides for bypassing oil from the pump to the sump in the event of excessive pressure developed within the system. A solenoid-operated valve V2, biased in one direction by a spring 98 and displaced in the opposite direction by the solenoid S1, controls the flow of the oil. Conductors C3 and C4 connect the conductor C1 with one end of each of the cylinders 88 and 94 for delivering oil under pressure thereto and conductors C5 and C6 connect the opposite ends of the cylinders 88 and 94 for supplying oil under pressure from the conductor C1 to the opposite ends of the cylinders by shifting of the valve V2. A valve V3, interposed in the conductor C4, delays the flow of pressure fluid to the cylinder 94 so as to permit the piston 86 in the cylinder 88 to ratchet the screw 78 and hence the diamond point 74 forwardly toward the face of the grinding wheel a predetermined amount prior to the traversing movement of the truing point widthwise of the grinding wheel.

Operation of the truing device 70 is initiated manually by pressing a normally open push-button PB1 which completes a circuit through a normally closed push-button PB2 and limit switch LS1 to the coil of a control relay CR1 which, when energized, shifts a switch SX provided with a pair of contacts *t*1 and *t*2 to establish a holding circuit for the control relay CR1 and, at the same time, to energize the solenoid S1. Energization of the solenoid S1 shifts the valve V2 so as to permit oil to flow through the conductors C5 and C6 to the upper end of the cylinder 88 and to the right-hand end of the cylinder 94, as illustrated in FIG. 1, to move the piston 86 downwardly in its cylinder thereby to rotate the ratchet wheel 80 the distance of one tooth and thereafter to move the slide 76 from right to left transversely, that is, widthwise of the grinding wheel. When the slide 76 reaches the left-hand side of the grinding wheel, it opens, by contact therewith, the limit switch LS1 thus breaking the circuit and de-energizing the control relay CR1. De-energizing the relay CR1 shifts the switch SX to the left, opening the contacts *t*1 and *t*2. Opening contact *t*2 de-energizes the solenoid S1 thereby permitting the spring 98 to displace the valve V2 toward the right. Displacement of the valve V2 to the right connects the conductors C5 and C6 to the conductor C2 so as to return oil to the sump and simultaneously connects the conductors C3 and C4 to the conductor C1 for delivering oil to the opposite ends of the cylinders thereby to retract the ratchet 82 and to move the slide 76 back to the right side of the grinding wheel preparatory to the next truing operation. The normally closed push-button PB2 provides for interrupting the circuit in the event of mishap of some kind.

In order to compensate for the reduction in diameter of the grinding wheel 20 by the truing operation, a transducer T2 of the same type as transducer T1 is mounted on the truing slide 76 and is connected to the screw 78 for operation by a gear 99 fixed to the shaft of the transducer T2 and a gear 100 fixed to the screw 78, the gears being so proportioned that an advance of the truing point a predetermined amount toward the face of the grinding wheel will produce a signal which will be fed into the signal selector 58 through a line 102, which is of an order to reset the counter by an amount proportional to the reduction in radius of the wheel. If the indicator is so geared to the wheel feed mechanism that it reads in the terms of the diameter of the work piece, the transducer T2 must be so geared to the truing device that the change in the indicator reading will be in terms of the change in diameter of the work piece produced by the reduction in radius of the grinding wheel resulting from the truing operation. Such a gear ratio is readily obtained by taking into account the evident relationship between the change in the radius of the grinding wheel and the change in the radius of the work piece on which the change in the diameter of the work piece directly depends.

While the transducer T2 is operated only in one direction by the ratchet and ratchet wheel which effect rotation of the screw 78 only on downward movement of the piston 36, the transducer T2 must be reversible so that it is responsive to the reverse movement of the truing device required before a grinding wheel worn down to a stub can be replaced with a new full size grinding wheel. Thus, the transducer T2 appropriately modifies the reading on the indicator as the truing device is retracted by any suitable means for rotating the screw 78 such as a hand wheel, not shown, effective to rotate the screw 78 in the reverse direction, when the screw 78 is uncoupled from the feeding mechanism including the ratchet wheel 80 and the ratchet 82 or the feeding mechanism is otherwise rendered inoperative as by disengaging the ratchet 82 from the ratchet wheel 80.

As shown herein, the transducers T1 and T2 are operably connected to the feed screws 26 and 78 by means of which the grinding wheel and truing device are advanced, respectively, toward the work and toward the grinding wheel. It is to be understood however that operation of these transducers may be effected through any suitable means such as a rack and pinion and a suitable gear train moved in consonance with the movement of the grinding wheel or truing device.

It is important that the transducers T1 and T2 be capable of producing signals which indicate the sense as well as the magnitude of the movements they detect, and it is equally important that the selector such as an anti-coincidence circuit be sensitive to the sense as well as the magnitude of the signals received from the respective transducers, because it is essential that the output of the counter be the algebraic sum rather than the sum of the absolute values of the respective signals. For example, the signals generated by the transducer T1 as the grinding wheel is fed toward the work piece being ground will be of a sense such as to indicate that the diameter of the work piece is being reduced, while the signals generated by the transducer T2 during each truing operation will be of a sense such as to indicate that the diameter of the work piece is relatively larger after the truing operation. Conversely, the signals produced by transducer T1 as the grinding wheel slide is retracted will increase the reading on the indicator in proportion to this displacement, while the signals from transducer T2 will decrease the reading on the indicator as the truing device is retracted to accommodate a grinding wheel of larger diameter.

The counter, the digital display, and the anti-coincidence circuit are not described or illustrated in detail in this application, because such details form no part of the instant invention, and because units embodying such components are available commercially, for example from Wang Laboratories, Inc., of Natick, Massachusetts.

This means of automatically compensating for truing operations enables the operator to true the grinding wheel as often as desired without having to manually reset the indicator and thereby to avoid any significant dimensional error over a relatively extended period after each truing operation. Recalling that the reading on the indicator most conveniently represents changes in diameter of the work piece, it is necessary in setting up the device to employ gear ratios for connecting the respective transducers to the respective screws such that the signals they produce represent changes in diameter of a circle concentric with the axis X of the center supporting the work piece.

While the truing device may be fed radially of the grinding wheel and be traversed across the face of the grinding wheel manually, the hydraulic arrangement for feeding and traversing the truing device sequentially is preferable because it insures that the radial displacement of the truing device sensed by the transducer T2 will be followed by the traversing movement necessary to actually change the diameter of the grinding wheel in consonance with the correction of the indicator. In other words, using the manual control for the truing device it would be possible by means of radial displacement of the truing device to generate a signal with the transducer which would effect a change in the indicator reading without actually truing the grinding wheel. This would be particularly objectionable because it would result in grinding the work piece undersize if the operator relied solely on the indicator.

While the instant invention has been described above as applied to a plunge type cylindrical grinding machine in which the grinding operation is performed by feeding the grinding wheel toward a work piece fixedly positioned relative to the base of the machine, it will be evident that the device disclosed herein is also applicable to the type of cylindrical grinding machine in which the feed mechanism advances a work support and a work piece mounted thereon toward a rotating grinding wheel fixedly positioned relative to the base of the machine.

The instant invention is also applicable to the type of cylindrical grinding machines known as angular grinders in which the grinding wheel is fed toward a work piece along a path not perpendicular to the axis of rotation of a work piece. As in the embodiment described and illustrated above, the transducer T1 would, of course, be coupled to the feed mechanism by a drive train with a gear ratio such that the transducer would indicate changes in the relative position of the grinding wheel and a work piece along a line perpendicular to the axis of rotation of a work piece. However, since a conventional truing mechanism would still be advanced along a path perpendicular to the axis of rotation of the grinding wheel and hence not perpendicular to the axis of rotation of a work piece, the gear ratio of the drive train for transducer T2 would have to be selected to measure the change in relative position between the grinding wheel and a work piece along a line perpendicular to the axis of rotation of a work piece taking into account the angular relationship between this line and a path along which the grinding wheel is fed.

The instant invention is also applicable to surface grinding machines wherein a grinding wheel mounted for movement lengthwise of a vertical column is fed downwardly toward a work piece secured to a flat table. In such a machine the transducer T1 is coupled to the wheel feed mechanism to indicate changes in the relative position between the face of the grinding wheel and a predetermined reference point, for example at the surface of the work supporting table, due to displacement of the grinding wheel by the wheel feed mechanism, and transducer T2 is coupled to the wheel truing mechanism to indicate changes in the relative position between the face of the grinding wheel and a work piece due to each truing operation. Thus the application of the instant invention to a surface grinder is accomplished in essentially the manner described above in relation to a cylindrical grinder so that the indicator may be set to indicate the vertical dimension of a work piece being ground as it is ground to the desired dimension.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. In combination with a grinding machine including a grinding wheel and of the kind having an indicator constructed and arranged to indicate, by indicating the position of the grinding wheel, when the work has been reduced to the desired dimension and having a truing device for truing the grinding wheel; automatically operable means operable, in response to actuation of the truing device, to reset the indicator to compensate for the effect upon the size of the work of the reduction

in radius of the grinding wheel resulting from each truing operation.

2. In combination with a grinding machine provided with a grinding wheel mounted for displacement relative to a work support with an indicator operative, at any given instant of grinding, to indicate, by indicating the relative position of the axis of a grinding wheel of a given radius relative to a predetermined reference point on the work support, the dimension of a work piece as it is being ground to size, and with a first transducer having an output proportional to the change in relative position between the face of a grinding wheel of a given radius and said reference point as a work piece is reduced in size; a second transducer coupled to a wheel truing device and having an output proportional to the change in position between the face of the grinding wheel and said reference point when the radius of the grinding wheel is reduced by a truing operation, and means selectively operative to transmit the outputs from the two transducers cumulatively to said indicator.

3. The combination according to claim 2, wherein the transducers are reversible and the outputs from the respective transducers are in the form of signals proportional to both the magnitude and the sense of changes in position and the signals are added algebraically whether the signals are of the same or opposite sense.

4. The combination according to claim 3, wherein the indicator is a digital counter, the transducers are pulse generators, and the digital counter includes means to receive pulses selectively from the respective transducers.

5. In combination with a grinding machine including a grinding wheel mounted for movement relative to a work support and having an indicator operative, at any given instant of grinding, to indicate, in response to the position of the face of the grinding wheel relative to a predetermined reference on the work support, the dimension of a work piece as it is being ground to size, a first transducer having an output proportional to the change in relative position between the face of the grinding wheel and said reference point due to displacement of the grinding wheel as a work piece is reduced in size, and a truing device operative to true the grinding wheel by removing material from the face of the grinding wheel; a second transducer coupled to the truing device and having an output proportional to the change in relative position between the face of the grinding wheel and said reference point brought about by the operation of the truing device, and means selectively operative to transmit the outputs from the two transducers cumulatively to said indicator so that the indicator reading is compensated for each displacement of the face of the grinding wheel resulting from a truing operation.

6. In combination with a grinding machine including a grinding wheel mounted for feeding movement relative to a work support and having an indicator operative, at any given instant of grinding, to indicate, in response to the position of the face of a grinding wheel of a given radius relative to a predetermined reference on the work support, the dimension of a work piece as it is being ground to size, a first transducer having an output proportional to the change in position between the face of a grinding wheel of a given radius and said reference point on the work support as a work piece is reduced in size, a truing device operative to true the grinding wheel by removing material from the face of the grinding wheel, and means for effecting operation of said truing device; a second transducr having an output proportional to the change in position between the face of the grinding wheel and said reference point as the radius of the grinding wheel is reduced by the truing operation, and means selectively operative to transmit the outputs from the two transducers to said indicator so that the respective outputs are added algebraically.

7. In combination with a grinding machine including a grinding wheel mounted for movement relative to a work support and having an indicator in the form of a digital counter operative, at any given instant of grinding, to indicate, in response to the position of the face of a grinding wheel of a given radius relative to a predetermined reference on the work support, the dimension of a work piece as it is being ground to size, a first reversible pulse generator having an output of pulsed signals in the sense corresponding to and of a quantity proportional to the change in position between the face of a grinding wheel of a given radius and said reference point as a work piece is reduced in size, a truing device, and means for effecting operation of said truing device; a second reversible pulse generator having an output of pulsed signals in the sense corresponding to and of a quantity proportional to the change in position between the face of the grinding wheel and said reference point as the radius of the grinding wheel is reduced in size, and means selectively operable to transmit the pulsed signals from the respective pulse generators cumulatively to said digital counter.

8. The combination according to claim 7, wherein the last-named means comprises an anti-coincidence circuit.

9. In a grinding machine of the kind in which there is a work support, a grinding wheel movable toward and from the work support, a hand wheel operable to effect movement of the grinding wheel, an indicator operative, at any given instant of grinding, to indicate the dimension of a work piece as it is ground to size, a first pulse generator operative to produce a signal in proportion to and in the same sense as the change in position between the face of the grinding wheel and the work support due to movement of the grinding wheel toward or from the work, a truing device for truing the grinding wheel, and means for effecting operation of the truing device; a second pulse generator automatically operative to produce a signal in proportion to and in the same sense as the change in position between the face of the grinding wheel and said reference point due to operation of said truing device, and means for selectively transmitting the signals from the first pulse generator and from the second pulse generator to said indicator.

10. A grinding machine according to claim 9, wherein said second pulse generator is automatically operative, in response to radial movement of the truing device into a position to effect a truing operation, to produce a pulsed signal in proportion to and in the same sense as the change between the face of the wheel and said reference point that will result from the truing operation.

11. A grinding machine according to claim 10, wherein said means for effecting operation of the truing device includes means for delaying wheel traversing movement of the truing device until radial movement of the truing device and the responsive operation of the second pulse generator are completed and means thereafter operable automatically to complete wheel traversing movement of the truing device.

12. In a grinding machine of the kind in which there is a work support for supporting a work piece for rotation about a predetermined axis, a grinding wheel transversely movable toward and from the work support and rotatable about an axis of rotation parallel to the predetermined work piece supporting axis of the work support, a hand wheel manually operable to effect transverse movement of the grinding wheel, an indicator operative, at any given instant of grinding, to indicate the dimension of a work piece as it is ground to size, a first pulse generator operative to produce pulses in a quantity in proportion to and in the sense of the change in relative position between the face of the grinding wheel and the axis of rotation of a work piece on the work support due to movement of the grinding wheel, a device for truing the grinding wheel, and means for effecting a first positioning movement of the truing device into a position for truing and thereafter effecting a second truing movement of the truing device; a second pulse generator operative

in response to the first positioning movement of the truing device to produce pulses in a quantity in proportion to and in the sense of the change in relative position between the face of the grinding wheel and the axis of rotation of a work piece on the work support due to the truing operation, and means for selectively transmitting the pulses from the two pulse generators to said indicator so that they indicate the net change in relative position between the face of the grinding wheel and the axis of rotation of a work piece on the work support.

13. In combination with a grinding machine including a grinding wheel mounted for movement relative to a work support and having a signal source operative, at any given instant of grinding, to indicate, in response to the position of the face of the grinding wheel relative to a predetermined reference on the work support, the dimension of a work piece as it is being ground to size, a first transducer having an output proportional to the change in relative position between the face of the grinding wheel and said reference point due to displacement of the grinding wheel as a work piece is reduced in size, and a truing device operative to true the grinding wheel by removing material from the face of the grinding wheel; a second transducer coupled to the truing device and having an output proportional to the change in relative position between the face of the grinding wheel and said reference point brought about by the operation of the truing device, and means selectively operative to transmit the outputs from the two transducers cumulatively to said signal source so that the output signal from said signal source is compensated for each displacement of the face of the grinding wheel resulting from a truing operation.

14. In a grinding machine of the kind in which there is a work support, a grinding wheel movable toward and from the work support, a hand wheel operable to effect movement of the grinding wheel, a signal source operative, at any given instant of grinding, to produce an output signal proportional to the instantaneous dimension of a work piece as it is ground to size, a first pulse generator operative to produce pulses in proportion to and effective in the same sense as the change in relative position between the face of the grinding wheel and the work support due to movement of the grinding wheel toward or from a work piece, a truing device for truing the grinding wheel, and means for effecting operation of the truing device; a second pulse generator operative to produce pulses in proportion to and effective in the same sense as the change in relative position between the face of the grinding wheel and said reference point due to operation of said truing device, means for selectively transmitting the pulses from said first pulse generator and from said second pulse generator to said signal source, and means for combining the pulses algebraically to produce an output signal proportional to the dimension of a work piece as it is ground to size.

15. In combination with a grinding machine including a work support, a movable slide, a grinding wheel rotatably mounted upon said movable slide, a truing device mounted upon said movable slide and operable to true the grinding wheel, and having a plurality of slide displacing means to effect displacement of said movable slide toward or away from the work support, a grinding wheel face position indicator, a first sensing means operable automatically to actuate said indicator in response to the amount of slide displacement produced by operation of at least one of said slide displacing means and independent of the slide displacement produced by at least one other of said slide displacing means, and a second sensing means operable automatically in response to operation of the truing device to reset said indicator to compensate for the change in grinding wheel size determined by the operation of the truing device.

16. In combination with a grinding machine including a rotatable grinding wheel mounted for bodily displacement relative to a work support, a first displacing means operable to produce bodily displacement of the grinding wheel relative to the work support, and second displacing means operable to produce bodily displacement of the grinding wheel relative to the work support, a grinding wheel face position indicator, means operable automatically to actuate said indicator in response to the displacement of the grinding wheel relative to the work support produced by said first displacing means and independent of displacement of the grinding wheel relative to the work support produced by said second displacing means, a truing device operable automatically to true the grinding wheel, and means operable automatically in response to operation of said truing device to compensate said indicator for the change in the size of the grinding wheel determined by the operation of said truing device.

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