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GRINDING MACHINE

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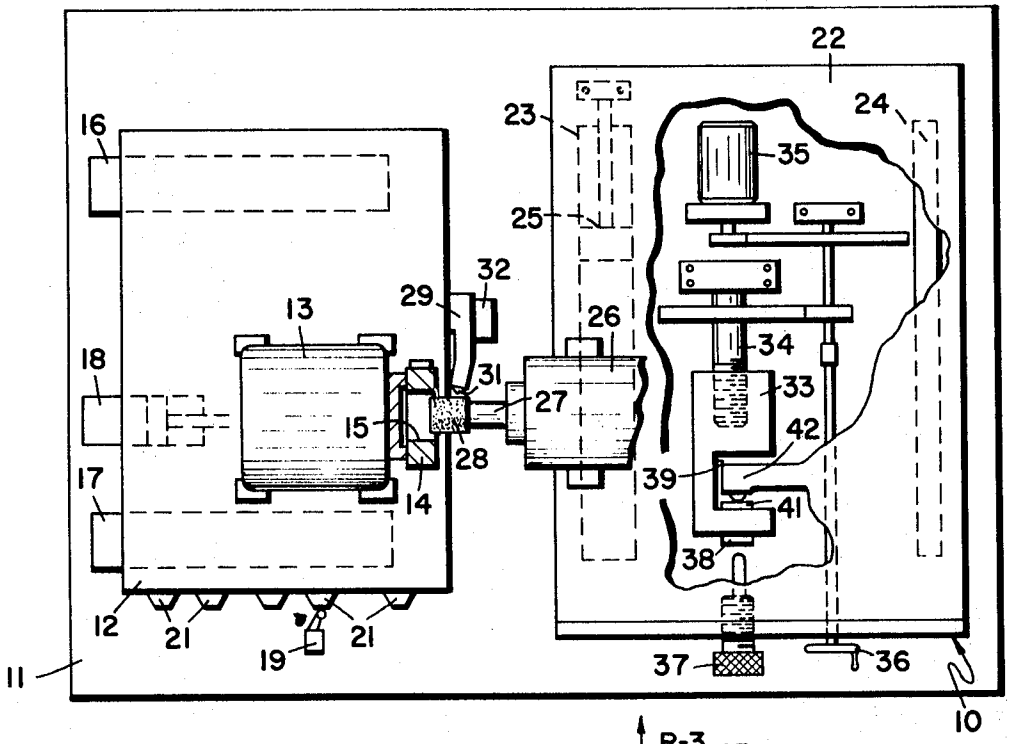

FIG. 1

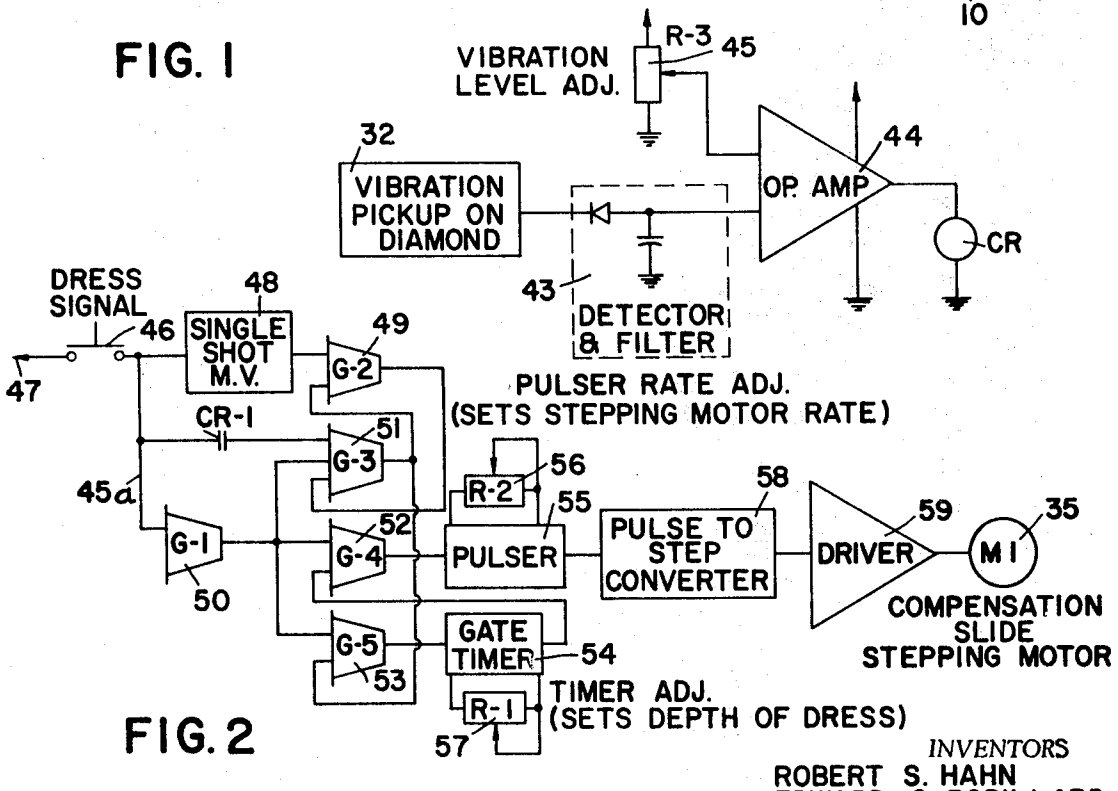

FIG. 2

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GRINDING MACHINE

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ABSTRACT OF THE DISCLOSURE

This invention relates to a grinding machine and, more particularly, to apparatus for generating a surface of revolution by the abrasive process, wherein means is provided for assuring that the amount of material removed from an abrasive wheel during a dressing operation is the same, irrespective of variations in the amount of wear on the wheel.

BACKGROUND OF THE INVENTION

In the art of machining by the abrasive process, it is common practice to dress the abrasive wheel by removing a small portion of its diameter from time to time. This is done by passing a diamond parallel to the axis of the wheel. The operation may be performed during every grinding cycle, or alternatively, according to the procedure called "skip dressing," wherein the dressing takes place after a predetermined number of cycles. Unfortunately, because of variations in the wheels and in the grindability of the workpiece, the wheel wear varies from time to time, For this reason, it has been necessary in the past to select an amount of compensation such that a portion of the wheel will be removed, even in the most extreme wear situation. This means that, in many cases, the wheel is reduced in diameter by more (and, therefore, needs to be replaced much sooner) than is absolutely necessary. It also means that the amount of wheel removed varies from one dress to the next. When little wear has taken place on the wheel since the last dress, a present dress will remove a great deal of material from the wheel. On the other hand, if the wear has been very great, the dress will remove little material. Since the quality of the workpiece and the rate at which the wheel will remove metal is dependent on the nature of wheel surface, it can be seen that, because various amounts of wheel are removed at various times, the surface of the wheel after the dress will vary also. These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the invention to provide a grinding machine in which the amount removed from the abrasive wheel during a dressing operation is the same, irrespective of the amount of wheel wear.

Another object of this invention is the provision of a grinding machine in which the quality of the surface of the abrasive wheel is the same after every dressing operation.

A further object of the present invention is the provision of a grinding machine in which the surface of the wheel, after dressing, bears a known relationship to the base of the machine.

It is another object of the instant invention to provide a grinding machine in which the quality of the finished surface does not vary because of differences in wheel surface.

A still further object of the invention is the provision of a grinding machine in which the quality of the abrasive surface is always dressed to an optimum value.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

SUMMARY OF THE INVENTION

In general, the invention consists of a grinding machine having a rotatable spindle which carries an abrasive wheel and which has apparatus for performing a dressing operation on the wheel. Feed means is provided for bringing about relative movement between the spindle and the apparatus in a direction extending transversely of the axis of the spindle. A transducer is provided indicating engagement of the wheel with the dressing apparatus. Control means is provided operative upon a signal from the transducer to cause the feed means to advance the wheel and the dressing apparatus toward one another a predetermined amount and then to bring about a dressing operation.

BRIEF DESCRIPTION OF THE DRAWINGS

The character of the invention, however, may be best understood by reference to one of its structural forms, as illustrated by the accompanying drawings, in which:

FIG. 1 is a schematic plan view of a grinding machine embodying the principles of the present invention, and

FIG. 2 is an electrical schematic diagram of a control forming a portion of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, wherein are best shown the general features of the invention, the grinding machine, indicated generally by the reference numeral **10**, is provided with a base **11** on which is mounted a workhead table **12**. The table carries a workhead **13** which supports a workpiece **14** and rotates it about the axis of a surface of revolution **15** which is to be formed. Ways **16** and **17** are formed on the base and the table **12** is slidable on them in the direction of the axis of the surface of revolution **15**. This movement takes place under the impetus of a hydraulic cylinder **18** and is regulated by a switch **19** which is mounted on the base **11** and which is engageable with dogs **21** mounted on the front of the table **12**.

Also mounted on the base **11** is a wheelhead table **22** which is carried on ways **23** and **24** for movement transversely of the axis of the surface of revolution **15**. Forming part of the way **23** is a hydraulic cylinder **25**. Carried on the upper surface of the table **22** is a wheelhead **26** rotatably carrying and driving a spindle **27** on the outer end of which is carried an abrasive wheel **28**.

The workhead **13** is provided with an internal motor for rotating the workpiece, while the wheelhead **26** is similarly provided with an internal motor for driving the spindle **27** and the wheel **28**. A dressing apparatus **29** is mounted on the table **12** and provides a diamond **31** adjacent the path of the wheel **28**. Fastened to the side of the dressing apparatus is a transducer **32**. This transducer is of the usual type containing a piezoelectric crystal which generates an electrical impulse proportional to the amount of force placed on it; this means that any bending of the dressing apparatus or vibrations within it will result in a corresponding electrical signal from the transducer.

Slidably mounted on the upper surface of the base **11** is a compensation slide **33** which can be driven transversely across the base by means of a screw **34**. This screw can be driven alternatively by a stepping motor **35** or a handwheel **36**. Mounted at the front of the table **22** is an adjustable stop **37** adapted to engage a hardened metal button **38** on the front end of the compensation slide **33**. The compensation slide and all of its associated apparatus are contained in a recess formed on the bottom of the table **22** and the compensation slide is provided with a

recess 39 having at a forwardly-located rearwardly-facing surface a button 41. This button is engaged on occasion by a horn 42 extending downwardly from the underside of the table 22 into the recess. It is this button 41 and its engagement with the horn 42 that determines the position of the wheel 28 when it is carried across the diamond 31 for dressing.

Referring now to FIG. 2, it can be seen that the transducer 32 operates the coil of a relay CR after its signal has been rectified in the detector and filter unit 43 and has been passed through an operational amplifier 44. The voltage on the operational amplifier may be adjusted by means of a potentiometer 45. A contactor CR–1 associated with the relay CR is located in the control 45*a*. A dress signal switch 46 connects a voltage source 47 to one side of a single-shot multivibrator 48. It is also connected to a logic unit 50. The multivibrator 48, the contactor CR–1, and the logic unit 50 are connected to four logic units 49, 51, 52, and 53 which, in turn, are connected to a gate timer 54 and a pulser 55. The pulser rate can be adjusted by means of a potentiometer 56, while the gate timer 54 can similarly be adjusted by means of a potentiometer 57. The pulser 55 is connected to a pulse-to-step converter 58 and this operates through a driver 59 to operate the compensation slide stepping motor 35.

The operation of the apparatus will now be readily understood in view of the above description. The usual machine controls (of the type shown and described in the patent of Hohler et al. No. 3,197,921) operate on the workhead 13 to rotate the workpiece 14, on the wheelhead 26 to rotate the spindle 27 and the abrasive wheel 28, on the cylinder 18 to cause the table 12 to move along the ways 16 and 17 to produce reciprocatory motion, and on the cylinder 23 to produce the cross-feed. The cams 21 are so located and operate on the switch 19 in such a way as to carry the table 12 to several positions, one of which is the position wherein the wheel 28 lies within the workpiece 14. Other positions are where the wheel lies outside of the workpiece but beside the dressing apparatus 29 for reciprocation past the diamond 31 and where the abrasive wheel is well away from both workpiece and diamond for the loading of new workpieces. As shown in FIG. 1, one cam 21 is located so that the table 12 is stopped in such a position that the diamond 31 lies adjacent the center of the wheel 28.

The cross-feed, i.e., the motion of the table 22 along the ways 23 and 24, takes place in various ways. The cylinder 25 forces the abrasive wheel 28 against the workpiece on the back side and grinds the surface 15. When the table advances rearwardly far enough for the stop 37 to strike the button 38 on the compensation slide 33, the surface of revolution has reached the desired size. The wheel is then backed off until the horn 42 on the table strikes the button 41 on the compensation slide. The table 12 is moved outwardly to remove the abrasive wheel from the bore and to place it beside the dressing apparatus 29. It is then ready for the dressing operation.

Probably one of the most important variables in any grinding system is the depth of diamond penetration into the grinding wheel during dressing or the "depth of dress." At some constant dress-lead (inches of linear motion of the diamond along the wheel axis per revolution of the wheel) variations in the depth-of-dress cause large changes in the wheel's cutting ability. Thus, controlling the depth-of-dress is a desirable capability. However, in a "skip-dress" grinding operation, the amount of wheel wear is generally unknown and the compensation setting must be varied until one is found allows proper dressing to occur. In such an operation, however, when the wheel wear changes, the depth of dress is changed resulting in fluctuations in the wheel's cutting ability. Thus, a system which will automatically locate the wheel surface using the diamond as a probe and then set up a constant but adjustable depth-of-dress and then dress the wheel is the subject of the present invention. Such a system will eliminate the guessing of compensation settings and consistently produce wheels with nearly identical cutting capabilities by holding the depth-of-dress constant.

The signal for a dressing operation takes place in the regular machine controls and the table 12 is positioned so that the diamond 31 is approximately at the center of the wheel 28. When this position is reached, the switch 19 will be operated by the cam 21 which, in turn, will operate the switch 46 to actuate the automatic compensation circuit shown in FIG. 2. The start signal will actuate the single-shot multivibrator 48 to produce a pulse at the set input of a memory circuit consisting of NOR gates 49 and 51. This will cause the output of gate 51 to go to a logic ONE and hold the output of gate 53 at a logic ZERO. The start signal will also cause the output of gate 52 through gate 50 to go to a logic ONE and start the pulser 55. The pulser will move the compensation slide 33 by operating the compensation slide stepping motor 35. The grinding wheel is moved toward the diamond 31 at a rate determined by the setting of the variable resistor 56.

The abrasive wheel 28 will next contact the diamond and produce an audio vibration that will be picked up by the transducer 32 mounted on the bracket of the dressing apparatus 29. The electrical signal from the transducer will be rectified and filtered in the unit 43 and then fed into a comparator circuit consisting of the operational amplifier 44. When this voltage rises above a preset level (as determined by the setting of the potentiometer 45), the comparator circuit will actuate the relay CR. This will close the normally-open contactor CR–1 and will close and produce a logic ONE signal to reset the memory circuit consisting of gates 49 and 51.

This, in turn, will cause the output of gate 53 to be at a logic ONE and will start the pulse gate timer 54. After a preset time, as determined by the variable resistor 57, a logic ONE signal will be produced at an input to the gate 52. This will cause the output of gate 52 to be at a logic ZERO to stop the pulser 55 and end the compensation cycle. This has caused the diamond to advance into the wheel by the suitable compensation distance and the table 12 will then be moved longitudinally to carry the diamond across the face of the wheel to produce the dress.

Because of the calibrated timer and pulse rate, this circuit will always produce a fixed number of pulses after the signal from the vibration transducer 32 is received. This will cause the depth of dress to be constant even though the total compensation may be variable, due to variable wheel wear.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desired to secure by Letters Patent is:

1. A grinding machine for generating a surface of revolution on a workpiece, comprising:

(a) a base,

(b) a workhead carrying the workpiece mounted on the base for sliding movement longitudinally of the axis of the surface of revolution,

(c) a wheelhead carrying a rotatable spindle on which an abrasive wheel is mounted, the wheelhead being mounted on the base for sliding movement transversely of the said axis,

(d) a dressing apparatus mounted on the workhead,

(e) a transducer mounted on the dressing apparatus to generate an electrical signal when the dressing apparatus engages the wheel, and

(f) control means moving the workhead longitudinally until the dressing apparatus lies opposite the center of the wheel, advancing the wheelhead transversely

toward the dressing apparatus, receiving a signal from the transducer when engagement takes place between the dressing apparatus and the wheel, advancing the wheelhead transversely a predetermined amount, and causing the workhead to move longitudinally to bring about a dressing operation.

2. A grinding machine as recited in claim 1, wherein the transducer signal is rectified and filtered, wherein an operational amplifier compares the signal to a preset voltage, and wherein a relay is energized by the amplifier when the voltage of the transducer signal exceeds the preset voltage.

3. A grinding machine as recited in claim 2, wherein a switch at the end of the grinding cycle is operated and an electrical charge is passed through the switch to a normally-open contactor of the relay and to a single shot multivibrator, wherein the contactor and multivibrator operate through logic gates to a pulser and a gate timer, and wherein the pulser operates through a pulse-to-step converter and a driver to operate a stepping motor.

4. A grinding machine as recited in claim 3, wherein the stepping motor operates through a screw to move a compensation slide transversely, and wherein the slide acts as a retraction stop for the wheelhead during the dressing operation.

5. A grinding machine as recited in claim 3, wherein the control means includes a first, second, third, fourth and fifth "NOR" gate, wherein the switch is connected to one input of the first gate and its output is connected to an input of the third, fourth, and fifth gates, wherein the output of the multivibrator is connected to one input of the second gate, wherein the contactor is connector to an input of the third gate, wherein the output of the third gate is connected to inputs of the second and fifth gates, wherein the output of the second gate is connected to an input of the third gate, wherein the output of the fourth gate is connected to the input of the pulser, and wherein the output of the fifth gate is connected to the input of the gate timer.

6. A grinding machine for generating a surface of revolution on a workpiece, comprising:

(a) a base,

(b) a workhead table mounted on the base for sliding movement, the table having a workhead for carrying the workpiece,

(c) a wheelhead table mounted on the base for sliding movement, the table having a wheelhead carrying a rotatable spindle on which an abrasive wheel is mounted,

(d) means bringing about relative sliding motion between the tables in a first direction parallel to the axis of the surface of revolution and in a second direction perpendicular to the said axis,

(e) a dressing apparatus mounted on the workhead table,

(f) a transducer mounted on the dressing apparatus to generate an electrical signal when the dressing apparatus engages the wheel, and

(g) control means bringing about relative movement between the tables in the first direction until the dressing apparatus lies opposite the center of the wheel, bringing about relative movement in the second direction to advance the wheelhead transversely toward the dressing apparatus, receiving a signal from the transducer when engagement takes place between the dressing apparatus and the wheel, bringing about the relative movement in the second direction to advance the wheelhead transversely a predetermined amount, and bringing about the relative movement in the first direction to bring about a dressing operation.

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LESTER M. SWINGLE, Primary Examiner

U.S. Cl. X.R.

51—165.8, 165.9