United States Patent

Uhtenwoldt et al.

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[54] GRINDING MACHINE

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[52] **U.S. Cl.** **51/165.92**, 51/3, 51/5

[51] **Int. Cl.** **B24b 49/08**

[58] **Field of Search** .... 51/165, 165.01, 165.18, 165.03, 51/165.07, 165.08, 165.09, 3, 5, 71, 105, 105 SP

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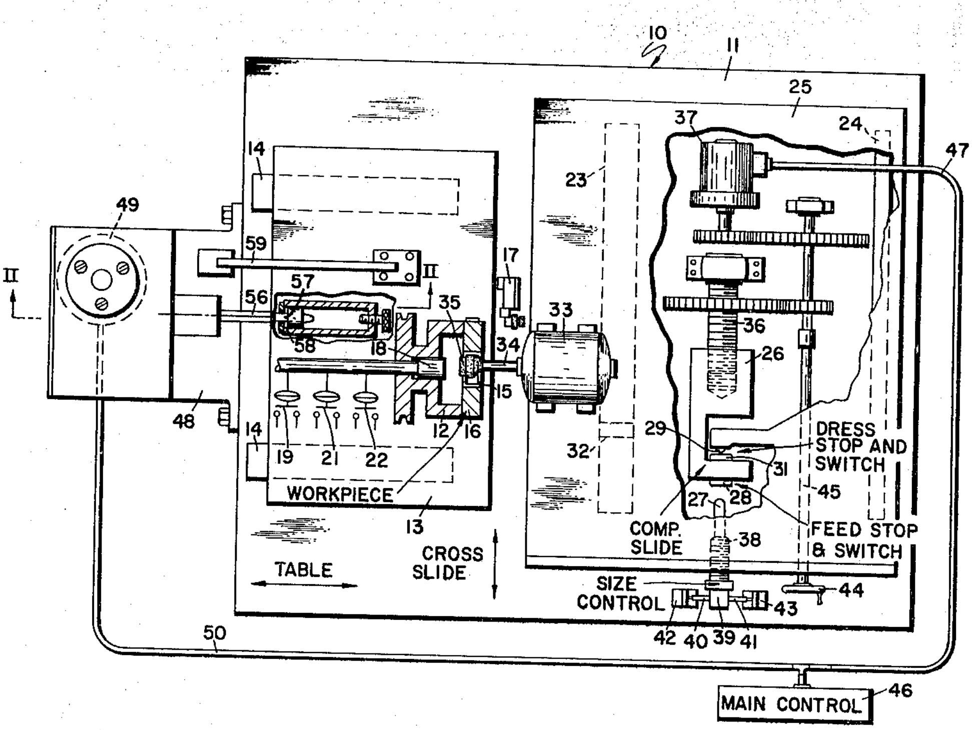
[57] ABSTRACT

This invention relates to a grinding machine and, more particularly, to apparatus for simultaneously finishing by the abrasive process surfaces which lie at substantial angles to one another in a workpiece.

5 Claims, 6 Drawing Figures



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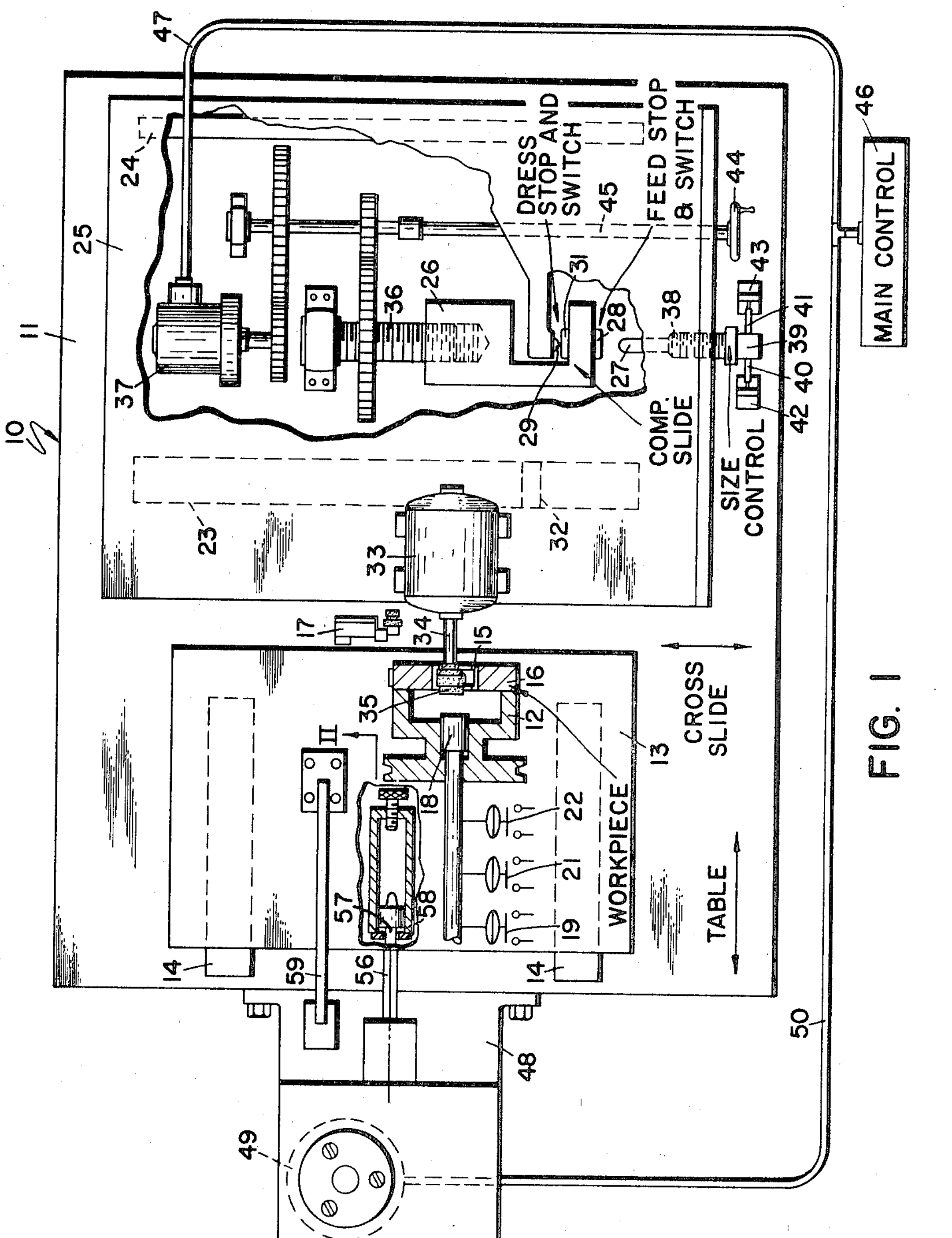

FIG. 1

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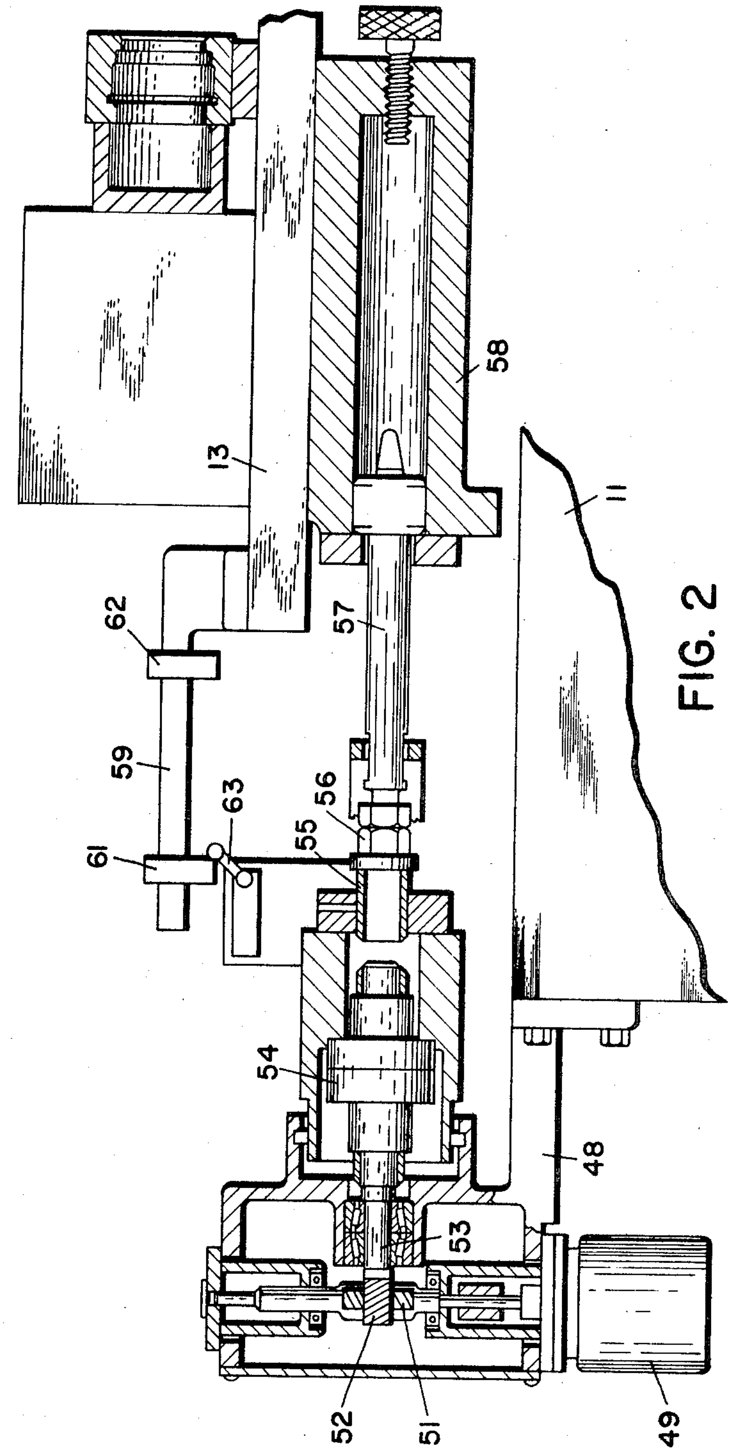


FIG. 2

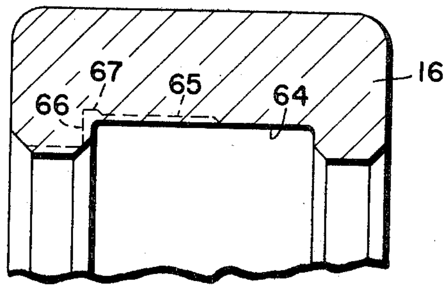


FIG. 3

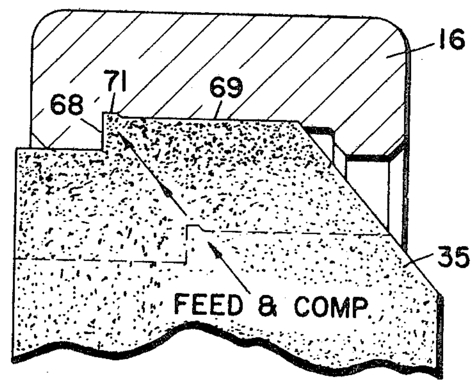


FIG. 4

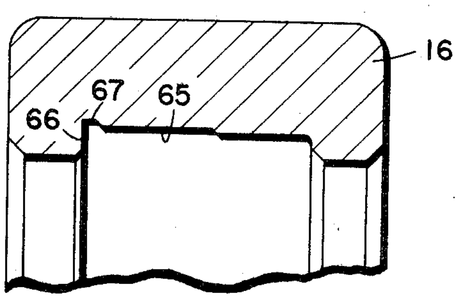
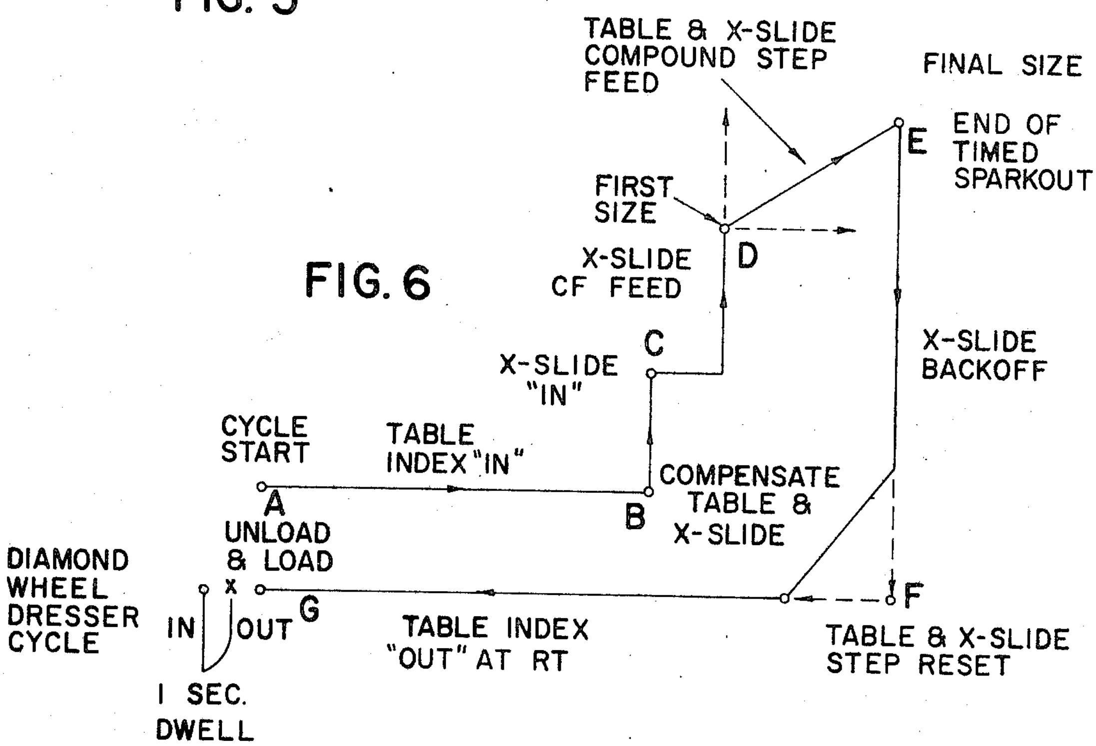


FIG. 5

FIG. 6



GRINDING MACHINE

BACKGROUND OF THE INVENTION

There are situations in the grinding of the surfaces of workpieces when it is desirable simultaneously to grind surfaces of quite a different nature. Such a situation arises, for instance, in the grinding of the corner of a groove of the outer race of a roller bearing. This corner is formed by a radial surface and a cylindrical (or sometimes tapered) surface of revolution. In the past, these surfaces have been ground simultaneously by using a contoured or formed abrasive wheel. This wheel has the same shape as the finished surfaces and, therefore, has a radial surface which grinds the radial surface of the workpiece and a peripheral surface which fits the outer cylindrical surface of the groove in the workpiece. In the past, such a contoured wheel has been used in accordance with the plunge method of grinding. The wheel is advanced axially into the bore of the workpiece and then is moved exactly radially outwardly cutting the radial surface of the groove first until the wheel comes in contact with the cylindrical surface and then plunging through the cylindrical surface to the finish point. Since the radial side of the groove is always much deeper in a radial direction than the amount of metal to be removed from the cylindrical surface, this means that a great deal of grinding is done by the cylindrical peripheral surface of the wheel, while the radial surface does nothing but rub against the radial surface of the groove. The result is that there is a tendency to burn the sides, the wheel must be dressed very frequently, and the wear and reduction in diameter is very great, so that the wheel does not last very long. Furthermore, since in plunge grinding the quality of the finished surface depends on the shape of the wheel at the time of finish, and in this case the wheel has been subjected to a long "grit" path, the quality of the finished lips and groove suffers. The problem of extreme wear of the abrasive wheel and poor quality in the finished product has militated against the use of this method for finishing simultaneously the surfaces of deep roller bearing grooves. Generally speaking, therefore, it has been necessary to finish the surfaces (lips) by two separate operations, which is time consuming and costly. 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 for simultaneously finishing two surfaces of a workpiece.

Another object of this invention is the provision of a grinding machine for finishing a radial surface and an axially extending surface of a workpiece at the same time while maintaining high quality of finished surface and little wear in the abrasive wheel.

A further object of the instant invention is to provide a grinding machine for efficiently plunge grinding with a contoured wheel workpiece surfaces having a deep radial surface.

It is another object of the instant invention to provide a grinding machine for effectively grinding the corners of a groove of rectangular cross section.

A still further object of the invention is the provision of a grinding machine for plunge grinding the radial surface of a groove or the like without extreme wear on the peripheral surface of the wheel.

It is a further object of the invention to provide a grinding machine for plunge grinding the corner of a groove or the like while maintaining high quality of finished surface.

A still further object of the invention is the provision of a grinding machine for grinding the corner of a groove or the like wherein the work of removing stock is equally shared by the radial and the peripheral surfaces of the abrasive wheel.

Another object of the invention is the provision of a grinding machine which operates to grind a corner in a workpiece and which brings about equal wear of the radial and peripheral surfaces of the wheel to maintain the corner of the wheel sharp at all times.

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 for simultaneously finishing a workpiece having axially and radially extending surfaces. This machine is provided with a base on which are mounted a wheelhead having means to rotate the workpiece about the axis of the axially extending surface, and a wheelhead having an abrasive wheel with grinding surfaces which match the said surfaces of the workpiece. A first means is provided for moving the workhead and the wheelhead axially relative to one another, a second means is provided for moving the wheelhead and the workhead radially relative to one another, and a control is provided to operate the first means and the second means in synchronization to advance the abrasive wheel into the workpiece surfaces along an optimum path.

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 plan view of a grinding machine embodying the principles of the present invention,

FIG. 2 is a vertical sectional view of the machine taken on the line II—II of FIG. 1,

FIG. 3 is a sectional view of a workpiece before grinding,

FIG. 4 is a sectional view of a workpiece during grinding,

FIG. 5 is a sectional view of a workpiece after a grinding operation, and

FIG. 6 is a cycle diagram of the operation of the grinding machine.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The grinding machine, indicated generally by the reference numeral **10**, is of the general type shown and described in the copending patent application of Robillard et al., Ser. No. 672,222, filed Oct. 2, 1967, now U.S. Pat. No. 3,503,158 dated Mar. 31, 1970. Generally speaking, it makes use of a stop which contacts the compensation slide portion of the wheelhead and makes electrical as well as mechanical contact, so that the final size gage becomes operative. Then, instead of the stop being retracted, the compensation slide (and, therefore, the wheelhead) is moved by a stepping motor to the rear of the machine at a preset rate, i.e., 0.000050-inch increments in the preferred embodiment. In most cases, the rate would be set at a maximum (say, 100 steps per sec. on the stepping motor) and the slide will only step far enough to break electrical contact between the slide and the stop. This occurs rapidly in small increments, so that there is very low force buildup on the stop. The compensation slide acts, therefore, as a "floating stop." This stop will be synchronized with the wheelhead cross-slide when the dress signal is obtained from the size gage. At this time, the stepping motor stops the feed and a circuit is energized to remember the number of pulses of feed required. The cross-slide is reset to "zero" on the start feed position. After the dressing operation has been completed, the compensation slide is retracted and, because the force or pressure of the wheel on the workpiece is always the same at the dress point, the retraction setting does not have to be set for the worst case condition.

The cross-slide will next feed until the stop recontacts the compensation slide. When this happens, the compensation slide under the impetus of the stepping motor will retract to the dress size position at the 100-step-second rate, the number of pulses required to do this being retrieved from the memory circuit. When this position (at which the gage had previously indicated that dress should take place) is reached, the fine finish feed takes place by moving the compensation slide rearwardly. Eventually, the gage will indicate the arrival of the workpiece size; this will terminate the fine feed and grinding will continue under sparkout conditions due to the pressure of the deflection in the spindle until the gage indicates that the final size has been reached.

At final size, the compensation slide will be reset to the "-zero" or start feed position. A feedback circuit will also be energized to compare the number of pulses required to obtain the final size to a standard number of pulses. If the number of feed pulses is below the "early gage" limit, a feedback signal will shift the "first size" point to a smaller point. On the other hand, if it is above the "late gage" limit, the feedback signal will shift the "first size" point to a larger point. If the number of pulses is between the two limits (normal gage), there will be no feedback signal.

The grinding machine 10 consists of a base 11 on which is mounted a workhead 12 carried on a workhead table 13 which is capable of sliding motion on ways 14 extending parallel to the axis of a surface 15 of revolution of a workpiece 16 which is to be finished. Also mounted on the workhead table 13 is a dressing apparatus 17 having a diamond. Extending through the workhead 12 for engagement with the workpiece bore (surface of revolution 15) is a pneumatic gage 18 of the type shown and described in the patent of Schmidt et al., U.S. Pat. No. 2,771,714 of Nov. 27, 1956. This gage is suitably connected to suitable pressure switches, such as a pressure switch 19, capable of indicating when the size of the bore 15 has reached the size at which it is necessary to dress the wheel, a pressure switch 21 indicating when the bore has reached an intermediate size at which the finish grind is to be terminated, and a pressure switch 22 which is operative when the size of the bore has reached the final size.

Also mounted on the base 11 is a wheelhead table 25 which is slidable on ways 23 and 24 to move transversely of the axis of the surface of revolution 15. Both the table 13 and the table 25 are movable under the impetus of hydraulic linear actuators to produce their respective motions. Lying on the base 11 and slidable over its surface is a compensation slide 26. Extending from the wheelhead table 25 is a finger 27 arranged to engage a forwardly facing feed stop 28 which is mounted on the forward face of the compensation slide. The finger 27 and the feed stop 28 are also arranged as an electrical switch for placing the pneumatic gage 18 in operative condition on occasion.

The wheelhead table 25 is also provided with a downwardly extending horn or finger 29 which is in position to engage a rearwardly directed dress stop 31 formed on the compensation slide 26. There is a considerably greater distance between this finger 27 and the finger 29 than there is between the feed stop 28 and the dress stop 31, so that the table 25 is capable of a wide range of operative movement between those two portions under the impetus of a suitable hydraulic cylinder 32. This cylinder is arranged with the usual servo valves and control equipment to produce rapid action in moving the wheelhead table 25 from a first position where the finger 27 engages the feed stop 28 to the second position at which the finger 29 engages the dress stop 31. Mounted on the wheelhead 25 is a wheelhead 33 carrying a rotatable spindle 34, the outer end of which carries an abrasive wheel 35. The cylinder 32 is provided with hydraulic fluid at a carefully regulated pressure so that it is possible to predetermine the force producible by the cylinder and use that force for engagement of the abrasive wheel 35 with the workpiece 16 according to the well-known "controlled-force" grinding principle. The back end of the compensation slide 26 is threadedly engaged with a screw 36 which is driven through suitable gearing by a stepping motor 37. The stepping motor, the screw 36, and the compensation slide 26 operate to give a readily selected accurate compensation at the time of dress in accordance with the teaching set forth in the said patent application of Robillard, U.S. Pat. application Ser. No. 672,222.

The finger 27 is engaged with the front of the cross-slide or wheelhead table 25 through a screw 38 to provide a certain degree of adjustment. This adjustment takes place by a ratchet 39 mounted on the front of the screw 38 and operated in opposite directions by pawls 40 and 41 slidable back and forth by cylinders 42 and 43. A handwheel 44 operates through a rod 45 to permit manual operation of the screw 36 to provide for minor adjustments of the compensation slide 26. A main control 46 feeds a pattern of electrical pulses through a cable 47 to the main stepping motor and, at the same time, to a control panel not shown.

Attached to the left side end of the base 11 is a housing 48 to the lower end of which is attached a stepping motor 49 similar to the stepping motor 37 associated with the table 25. On the stepping motor shaft is mounted a worm 51 which engages a horizontal worm gear 52 mounted on a horizontal shaft 53. The shaft 53 operates through ball screw 54 and a differential screw 55 to produce a substantial reduction from the stepping motor 49 to an output shaft 56. This output shaft is attached to the piston rod 57 of the table cylinder 58. The ratio between the stepping motor and the shaft 56 is similar to the ratio between the stepping motor 37 and the compensation slide 26; that is to say, one step of the stepping motors 37 and 49 produce the same linear motion in their respective tables 25 and 13, except, of course, that the motion is transverse in one case and longitudinal in the other case. Attached to the table 14 is a bar 59 having adjustable dogs 61 and 62 which operate a limit switch 63.

Referring now to FIGS. 3, 4, and 5, it can be seen that the workpiece 16 is an illustration shown as being the outer race of a roller bearing. It is already provided with a preformed groove 64 but is desired to recess the groove even further to provide a surface of revolution 65 of cylindrical form and a radial flat surface 66. In addition, a small relief groove 67 is to be formed at the intersection of these two surfaces. For that purpose, the wheel 35 is formed with a radial surface 68, a cylindrical peripheral surface 69, and a ridge 71, these last-named three surfaces making up a complex shape which will provide the surfaces 65, 66, and 67 on the finished workpiece. The wheel in this form is known as a contoured wheel and is produced by dressing the wheel in the manner shown and described in the patent application of Hohler et al., U.S. Pat. application No. 710,123, filed Mar. 4, 1968, now abandoned. In the past, the shapes described on the finished workpiece would be produced by feeding the wheel 35 exactly transversely to its axis, and this would result in a number of deleterious effects. For one thing, the spindle 34, when subjected to strong radial forces on the wheel, tends to deflect or bend, thus throwing any radial surface 68 at a slight angle. Furthermore, plunge grinding, as it has been described, in the old way, produces a cutting action through the metal along the finished surface 66, which grinding is done entirely by the corner of the wheel 35 at the intersection of the wheel surfaces 68 and 69, or the sharp edge of the ridge 71. This produce extreme wear on this corner and results in the finished shape being different from the dressed shape to which the wheel was formed. Furthermore, constant dressing of the contour of the wheel results in a reduction of the wheel in a very rapid time and, or course, such dressing is necessary in order to maintain any kind of a proper finished surface. In addition, the surface 68 rubs against the finished surface 66 producing a poor finish at that point and burning of the wheel and workpiece.

The operation of the present apparatus will now be readily understood in view of the above description. In accordance with the invention, the wheel 35 (referring to FIG. 4) is fed in along the 45° angle indicated by the arrow. In a combined motion of the wheel which, for the purpose of the present patent application, will be referred to as "conjugate" grinding, to produce this effect, the cylinder 58 is actuated to bring the abrasive wheel 35 into the bore in the workpiece 16. At that point, the feeding motion of the cylinder 58 is terminated and motion due to the two stepping motors 37 and 49 takes place. The main control 46 issues pulses in accordance with the prior art teaching to both of these stepping motors, so that they operate through their gear reduction gearing and screws to produce transverse and longitudinal motion of their respective tables.

The stepping motor **37** will move the slide **26** rearwardly, and this will engage the finger **29** of the table **25** and move the table rearwardly along with the wheelhead **33** and the abrasive wheel **35**. At the same time, the same pulses emitting from the main control **46** carries through a table **50** to the stepping motor **49**, thus bringing about longitudinal motion of the table **13** and similar motion of the workpiece **16** toward the abrasive wheel **35**. The net result is that the wheel **35** and the workpiece **16** move relative to one another along a 45° line, so that the corner of the wheel is introduced directly into the corner of the desired finished shape. The radial surface **68** of the wheel grinds directly into the workpiece **16** to produce the finished surface **66** and the peripheral surface **69** of the wheel grinds directly radially to produce the finished cylindrical surface **65**. Also, the ridge **71** produces the groove **67** in the workpiece.

The manner in which dressing takes place by means of the dressing apparatus **17** is well described in the aforementioned U.S. Pat. application Ser. No. 710,123, now abandoned. In the present case, the contour dressing apparatus dresses the surface **68** and the surface **69** and the ridge **71** of the workpiece, removing abrasive material from the wheel and restoring it to a predetermined shape. In both cases, if no compensation were to take place, the surface of the wheel when returned to the next workpiece in succession to be finished would be a considerable distance away from the surface and the wheel would be "cutting air" before contact with the rough workpiece took place. This would make the cycle of grinding longer and longer as time progressed. Therefore, compensation takes place in the well-known manner by means of the compensation pulses produced by the main control **46** to the stepping motor **37**. This produces a permanent compensation movement of the slide **26** to a new position. In the same way, compensation pulses are introduced to the stepping motor **49** to produce a permanent change in the position of the piston rod **57** in the table cylinder. The net effect is that, at the end of every dressing motion, the spindle **34** is advanced rearwardly in the machine, while the table **13** is advanced to the right, so that as the abrasive wheel gets smaller and smaller there is no gap between the wheel and the workpiece surface to be finished.

The operation of the machine can be best understood by referring to the grinding cycle shown in FIG. 6 of the drawings. This is a simple grinding cycle in which the dressing of the wheel **35** takes place during the loading and unloading of a new workpiece, rather than during the grinding cycle itself. With the parts in the condition following dress and loading of a new workpiece, the abrasive wheel is in a position withdrawn from the workpiece bore at the point A. The cylinder **58** operates to move the table **13** to the right to the point B where the abrasive wheel lies within the bore in the workpiece. The cylinder **32** operates to move the table **25** rearwardly to the point C where the wheel is close to the part of the groove **64** of the workpiece that is to be finished. The cylinder **32** continues to press the wheel into the work for a first engagement for a rough grind to the point D. The stepping motor **49** being operated at that point to move the workpiece longitudinally toward the abrasive wheel to produce cutting with the wheel surface **68**. Eventually, the finger **27** strikes the stop **28** on the slide **26** and motion of the table **25** is restricted to motion produced by introduction of pulses to the stepping motor **37**, moving the slide **26** rearwardly and carrying the table with it, the finger **27** being kept in contact with the stop **28** on the slide **26** by the cylinder **32**.

This is the finished portion of the cycle to the point E, the last part of the feed taking place by sparkout to relieve deflections in the wheel spindle and the like. When the final size is reached, at the point E, the slide **25** retracts under the impetus of the cylinder **32** to the point F, and the table **13** is moved by the cylinder **58** back to the point of return G. The position of the parts at points A and G will be approximately the same, but the A of the next cycle will be different because of the dressing and compensating action that takes place during the unloading and loading of the successive workpieces.

The advantages of the invention can be readily seen in view of the above discussion. For instance, the surfaces **68** and **69** as well as the ridge **71** are being subjected to an equal amount of wear during the grinding cycle so, presumably, the shape of the wheel will remain substantially the same right up to the end of the cycles, so that the finished surfaces **65**, **66**, and **67** of the workpiece will be exactly as desired and as produced by the dressing apparatus **17** on the abrasive wheel **35**. Since the peripheral surfaces of the wheel, i.e., surface **69** and ridge **71**, are not plunging directly through the metal beside the surface **66**, they are not subjected to an extreme amount of wear, so that extreme dressing does not have to take place, the net result being that the wheel is dressed by smaller amounts and, therefore, last longer during a grinding of a succession of workpieces.

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 simultaneously finishing an internal surface of revolution of a workpiece having axially and radially extending surfaces, comprising

a. a base,

b. a workhead having means to rotate the workpiece about the axis of the axially extending surface,

c. a wheelhead having an abrasive wheel with radial and cylindrical grinding surfaces which match the said surfaces of the workpiece,

d. a first means moving the workhead and the wheelhead axially relative to one another,

e. a second means separate from the said first means for moving the workhead and the wheelhead radially relative to one another, and

f. a control to operate the first means and the second means in synchronization to advance the abrasive wheel into the workpiece surfaces along an optimum path.

2. A grinding machine as recited in claim **1**, wherein the path in which the corner defined by the intersection of the radial and cylindrical surfaces travels is short.

3. A grinding machine as recited in claim **1**, wherein the abrasive wheel is dressed to the contour of the said axially and radially extending surfaces.

4. A grinding machine as recited in claim **1**, wherein each of the first and second means includes a screw mechanism driven by a stepping motor and wherein the control provides pulses to each of the stepping motors for the said advance of the wheel into the workpiece.

5. A grinding machine as recited in claim **4**, wherein the control also provides a predetermined number of pulses after the dressing of the wheel to each stepping motor to provide compensating movement both in the radial and the axial direction.

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