Dec. 2, 1969 W. A. BOYD, JR., ET AL 3,481,319

ROTARY TRUING DEVICE FOR GRINDING WHEELS

Filed Nov. 15, 1966 3 Sheets-Sheet 1

FIG. 1

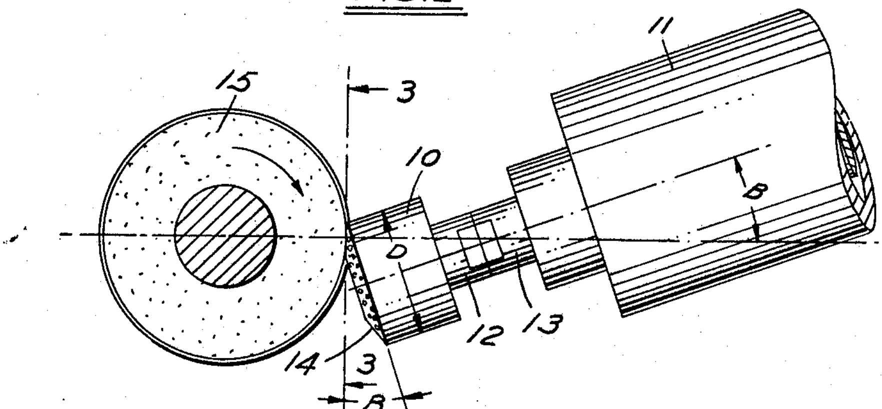


FIG. 2

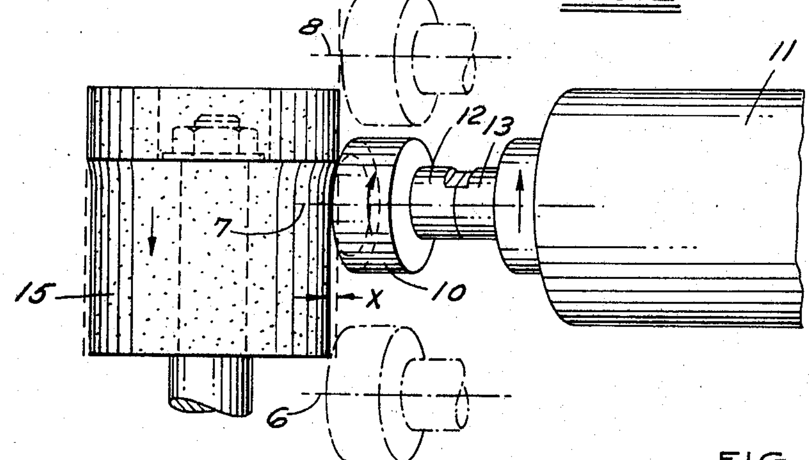


FIG. 3

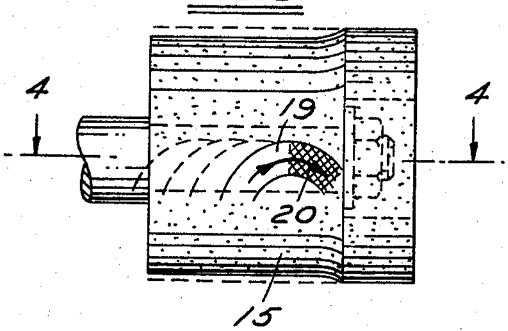
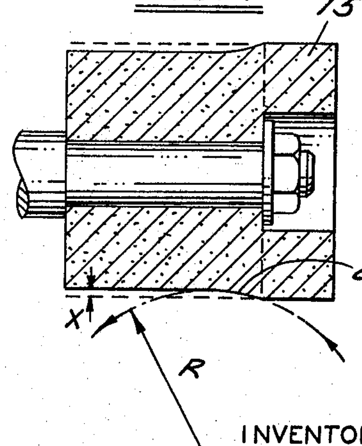


FIG. 4



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ROTARY TRUING DEVICE FOR GRINDING WHEELS

Filed Nov. 15, 1966 3 Sheets-Sheet 2

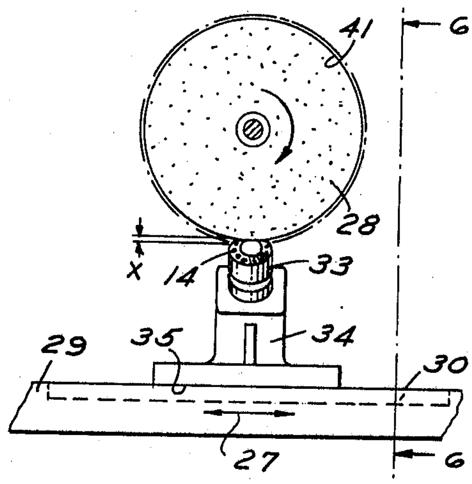

FIG.5

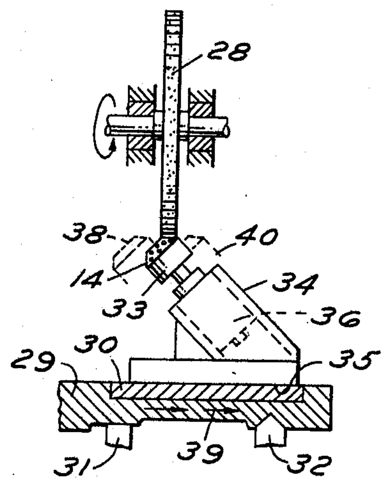

FIG.6

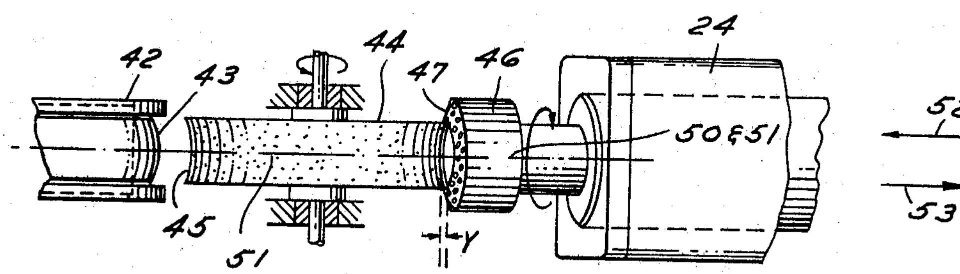

FIG.7

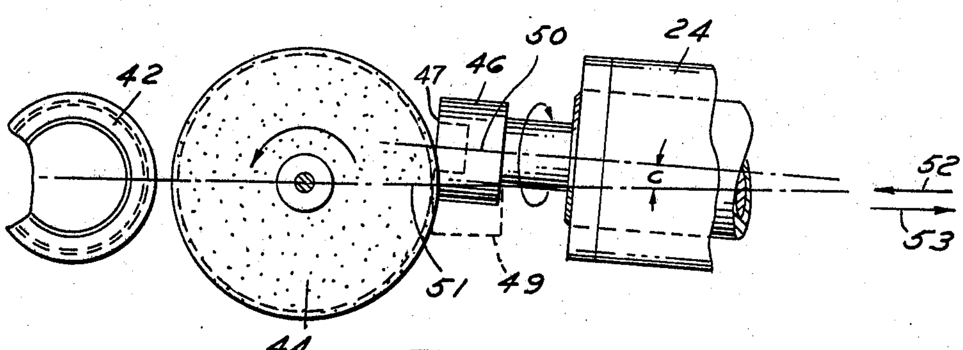

FIG.8

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FIG. 9

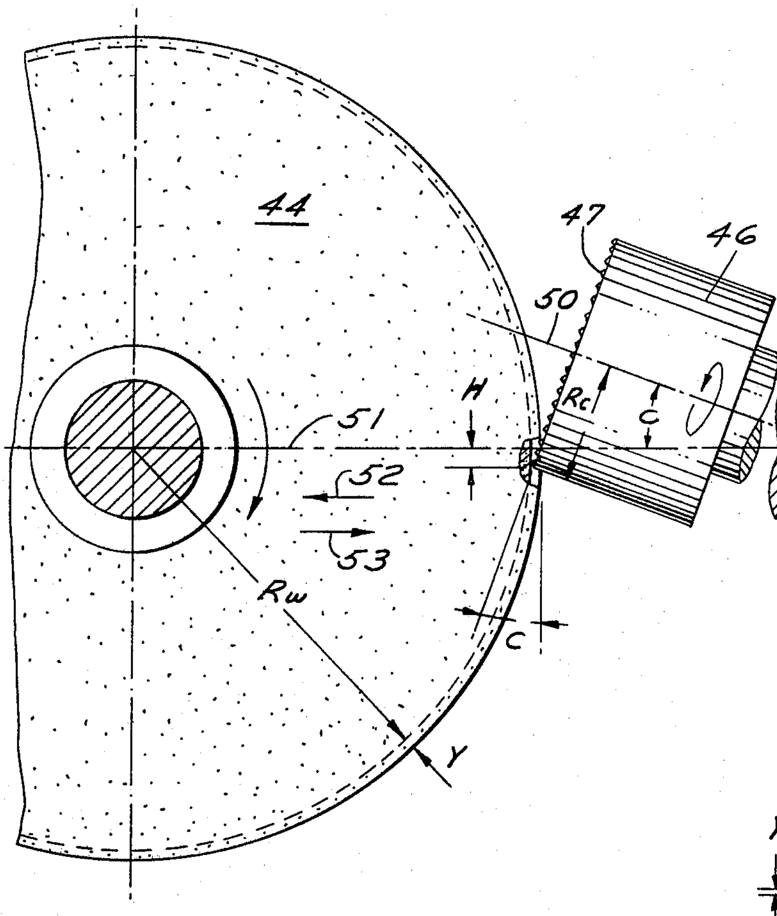


FIG. 11

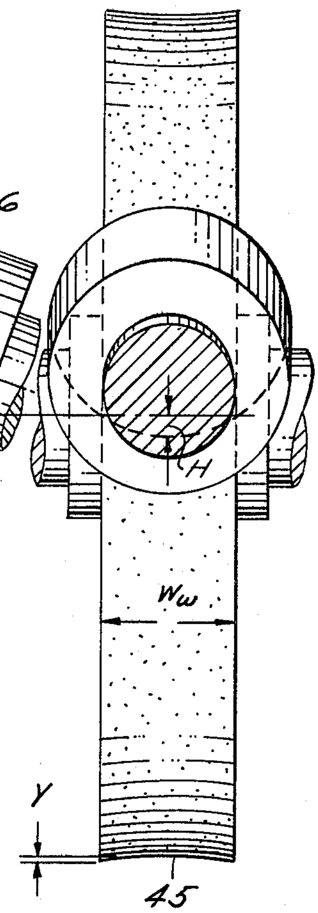
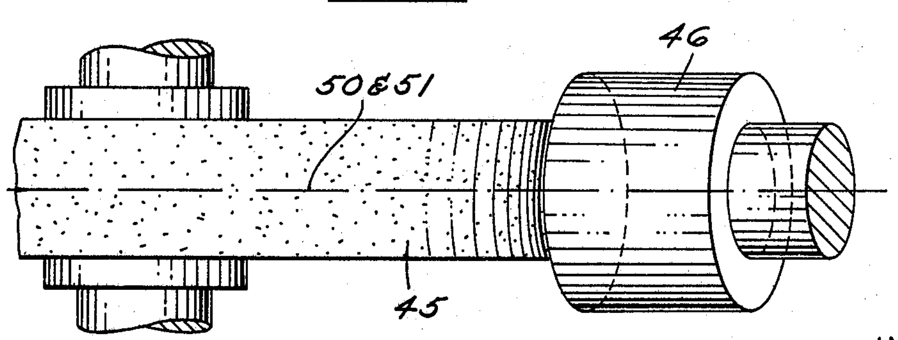


FIG. 10



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ROTARY TRUING DEVICE FOR GRINDING WHEELS

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Int. Cl. B24b *53/14*

U.S. Cl. 125—11 4 Claims

ABSTRACT OF THE DISCLOSURE

A rotating dressing cutter employing the end only, to which are attached diamond grits or other hard abrasive particles, is applied to the working surface of the rotating grinding wheel in a tangential manner. By tipping the cutter very slightly, a concave wheel can be produced for grinding crowned bearing races or the like.

This invention relates to grinding wheel truing, or accurate dressing, and—specifically—to an apparatus for truing a grinding wheel using the end face of a cylinder, covered with diamond or other abrasive particles, and mounted on a continuously rotating spindle.

In contrast to prior art which has employed either a single diamond or a multiplicity of diamonds on a stationary truing means, or a multiplicity of diamonds arranged on the periphery of a rotating cutter, the described invention is based on a cutter having its end face covered with diamonds or other abrasive grits and presented to the abrasive wheel in a manner employing the generating geometry of the cutter shape.

The advantages of substituting a multiplicity of diamonds for a single diamond are evident. Wear is distributed evenly and dressing tool life enhanced. Frequency of need for the machine operator to adjust the diamond is reduced with attendant increased production and reduced costs. In practice, these savings more than offset the additional cost of the truing tool.

A further advantage accrues in the greater consistency of the dressing action. For a far longer period of time, in terms of the successive production pieces ground, the truing forces remain at a low and nearly constant level. This cutting action, corresponding to the performance of a sharp, single point diamond, results in a more consistent truing, and a consequent more consistent grinding action. By the reduction in the magnitude of this variable in the grinding process a more accurate and predictable production quality is possible. Characteristic quality attributes which reflect this improvement are size, roundness, taper, and surface finish.

While these advantages may stem from the use of a dressing tool employing a multiplicity of diamonds, it is at once apparent that imparting a continuous motion to the surface carrying these diamonds will further enhance the truing by improved cutting action, dissipation of heat, and reduction of the dress time. Best truing tool life is achieved by presenting the maximum number of diamonds to the abrasive wheel at any instant. Reasons of machine space limitation and production costs would limit the gains possible simply by increasing the size of the truing cutter.

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Up to the present time, rotating diamond cutters used for dressing have, variously, ignored the gains possible by distributing the wear over the entire diamond surface. Some have made only mechanical provision in the truing mechanism for distribution of this wear; others have relied on changing abrasive wheel diameter. Similarly, the present state of the art requires a working diamond cutter to be made with the most nearly round truing surface possible, and further, that this surface rotate with the best concentricity and squareness on the truing cutter axis. Whether using a diamond cutter or single point diamond, the present practice limits the area of contact between diamond and abrasive wheel to either a point or a line. Finally, practical limits in the manufacture of diamond cutters restrict contours that can be trued into the abrasive wheel surface to accuracies no better than the order of 100 microinches. To these errors must be added those of mounting and rotating of the structure which presents the cutter to the abrasive wheel.

Present practice also requires a careful alignment of abrasive wheel to truing cutter contact. In the type of dresser where the axis of the diamond cutter must lie in the same plane which contains the work and abrasive wheel axes, good internal grinding practice requires a tolerance of $\pm.002''$ for average size work: smaller work requires tolerance to be cut in half. Not only is it difficult to make the first alignment adjustment to this limit, but it requires careful structure provisions to hold this alignment with continuous, automatic production.

With these limitations in mind, the described invention offers the following advantages:

(1) The geometry of the cutter-grinding wheel contact assures the maximum gain in efficiency of the rotating cutter while automatically, and without mechanical complication, assuring that most of the diamonds in the cutting face will come into play while truing. Thus, life is extended.

(2) The cutter uses a flat, or slightly conical, end-cutting face. It is markedly easier to achieve a true geometry in preparing a surface on the end face than on a surface of revolution that must run concentric with a mounting hole and square with a mounting face. It is observed, further, that a true running face is more easily achieved on a rotating spindle than a true running diameter.

(3) The use of the end face on the rotating diamond cutter provides an abrasive wheel-cutter contact geometry that gives a large area and a most favorable cutting angle. This geometry is intrinsic to the concept. Its direct result is that the truing operation can be carried out more rapidly, or, alternatively, at the customary rates with a corresponding improved fineness of truing quality.

(4) For those truing applications which require dressing of a controlled longitudinal curvature in the cylinder surface, and where accuracies require precise adjustment of the order of 10 microinches, the described invention presents a practicable solution for a curvature geometry approximating a true radius. This requirement is a frequent specification in the grinding of roller bearing races.

(5) The use of the end-cutting face of the diamond cutter to dress the abrasive wheel assures a geometry having a broad contact of wheel and diamonds in the vertical plane at this interface. Particularly in internal grinding it is important to assure that this wheel-diamond con-

tact lie in a plane normal to that containing the grinding wheel and work axes within close tolerances. The requirement is also true of external grinding machines, but to a lesser degree. The critical nature of this adjustment is operative whenever the diamond is used as a size reference and particularly in automatic machine operation. It is a special feature of the described truing apparatus that this critical requirement is easily met without the need for exacting machine operator setup procedures.

(6) The geometry of the truing diamond cutter itself, the width of its cutting face, its diameter, and the angle and reference of the truing cutter to the abrasive wheel offer new variables for control of the quality of wheel truing. Experience shows an enhanced degree of tooling control over dressing quality and making independent adjustment of these variables with the described apparatus.

With the foregoing limitations in mind, it is the main object of this invention to provide a diamond truing device with a cutter having a small size to keep the initial cost down, and therefore minimize the required space, while effectively increasing the geometry or area of diamond-to-grinding wheel contact in order to distribute the wear. Another object is to utilize the diamond truing cutter in such a manner that the length of cutting arc, or path of contact, of each individual diamond for the cutter with the grinding wheel will be as long as possible, while keeping the entry angle of each diamond shallow so as to provide a more uniform dressed surface on the grinding wheel.

A further object of the present invention is to provide a compact, self-contained unit which can be adapted to any internal, external, or surface grinding machine with a minimum of difficulty.

Various other objects and advantages will appear from the following description of several embodiments of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

The invention incorporating these features is illustrated below in which:

FIG. 1 shows the end view of a grinding wheel being dressed by the cylindrical diamond cutter which is mounted on a precision spindle;

FIG. 2 is a plan view showing relative positions of grinding wheel and diamond cutter;

FIG. 3 is a section through FIG. 1 showing the instantaneous pattern produced by the dressing diamonds on the end of the cutter;

FIG. 4 shows a section through FIG. 3 at the centerline of the grinding wheel;

FIG. 5 is a front elevation of the invention adapted to dress the wheel on a surface grinder;

FIG. 6 is the right hand elevation partly in section of FIG. 5;

FIG. 7 is a plan view of the invention as arranged to plunge dress a grinding wheel to grind a slightly crowned cylinder;

FIG. 8 is the elevation view of FIG. 7;

FIGS. 9, 10, 11 are an enlarged view of the dressing area of FIG. 7 and 8 showing the cutter relationship in front, bottom, and side elevations.

Referring now to the drawings in detail, we see in FIG. 1 a diamond truing cutter **10** of generally cylindrical shape, mounted on the quill **12**. The quill **12** is threadedly connected to a spindle **13** of rotating means **11**. The rotating means **11** can be any conventional motor, such as electric, fluid or otherwise. The end face **14** of diamond truing cutter **10**, which is shown as slightly conical, is coated with diamond particles attached in a suitable manner well known to those skilled in the art.

The quill **12** is mounted at a slight angle B with the line joining the point of dress and the center of the grinding wheel **15**. This angle also defined the side angles of the conical end face **14** with a plane normal to the axis of the truning cutter **10**. It is to be recognized that the angle B may have either positive or negative value.

When the grinding wheel **15** requires dressing or truing, the diamond cutter is brought into position **6** by means not shown relative to wheel **15** as shown in FIG. 2. As the rotating diamond face **14** and grinding wheel **15** are relatively moved past each other (as shown by the arrows), the truing cutter **10** is successively positioned at **6**, **7** and **8**. During this pass, the diamond truing cutter **10** is set to cut away a depth X from the face of the grinding wheel and exposes new sharp diamonds and fractures some dull ones to provide new cutting surfaces. The depth X is called "compensation."

Referring now to FIG. 3, the instantaneous pattern **19** made by the diamond face **14** passing through the abrasive surface of the wheel **15** is shown. It will be noted that the instantaneous contact path **20** of each individual diamond is considerably longer than if it were coated on the circumference of a diamond roll having the same diameter and compensated to the same depth X as in the usual type of roll dresser.

The shape of the conic section **21** through this pattern is shown in FIG. 4, and since only a small portion of the tip of such a section is used, it may be approximated as radius R. For example, experience has shown that if angle B is approximately 3° and diameter D of the cutter **10** is 1⅛ inches, then, for compensation X of .0015 inch, radius R equals approximately 10 inches. (As B approaches zero, radius R approaches infinity.) In other words, such a radius could only be achieved by dressing with a 20 inch diameter truing cutter in the conventional manner, however, the space required would make this impractical even if the cost were ignored.

Another embodiment shown in FIG. 5 and FIG. 6 shows the front and side elevations of the essentials of a conventional surface grinder, consisting of the grinding wheel **28** and the reciprocating table **29**, containing a magnetic chuck **30**. The table **29** oscillates back and forth longitudinally (as shown in FIG. 5 by the arrow **27**), on ways **31** and **32** which are supported in the grinder bed, not shown.

Seated on the magnetic chuck **30** of the table **29** is shown the rotary wheel truing or dressing cutter **33** spindled on motor **36**, which is rigidly mounted in support bracket **34**, held magnetically by the chuck **30**. The bracket **34** is constructed so that the cutting portion of the conical end face **14** of truing cutter **33**, where it contacts the wheel **28**, is parallel to the flat base portion **35**. The truing cutter **33** is rotated during the dress operation by the motor **36**.

In operation, the bracket **34** with truing cutter **33** and motor **36** in place, is magnetically clamped on the table **29** in position to pass under the wheel **28** as the table reciprocates. The motor **36** is started, and the wheel **28** is lowered manually (using the elevating apparatus of the conventional surface grinder), until the conical diamond surface **14** just touches the bottom of the grinding wheel **28**. The table **29** is then backed off to a position **38** shown in FIG. 6 in order to clear the wheel **28** in the crossfeed direction, i.e. opposite to the small arrows **39**. The wheel **28** is lowered an additional amount X shown in FIG. 5 for compensation, and the longitudinal oscillation as indicated by arrows **27** is started. As the table **29** reaches the end of its stroke in each direction indicated by arrows **27**, it advances a small increment in cross feed (represented by one of the small arrows **39**). This continues until the truing cutter **33** has reached position **40** shown in FIG. 6 where the table is stopped. The grinding wheel **28** has now been dressed or trued to a new diameter **41**, which is smaller than the diameter indicated as **28** by the amount of 2X.

A further adaptation of the end cutting truing tool is desirable when a crown is required on the ground surface of a work piece such as the inner race of certain types of roller bearings. This can be best attained by a plunge grind of the wheel which has been dressed in the following manner. Referring to FIG. 7, a roller bearing race **42** is shown having a crowned surface **43**. The dimension "Y" of the high and low surfaces of the crown surfaces are minute, somewhat on the order of 50 microinches.

The race **42** is shown adjacent to the grinding wheel **44** for ease of explanation, but it is not necessarily so located in an actual machine.

The grinding wheel surface **45** is adapted to plunge grind a crowned surface **43** in an exact counterpart of surface **45**, except that the surface **45** is concave, whereas the crowned surface **43** is convex.

In order to true the grinding wheel to such a shape, with so slight a concavity, the dressing or truing cutter **46** is designed with a flat end face **47**, coated with diamond grit. If the flat surface **47** were applied to the diameter of the wheel **44** in tangential relation to the circumference of the wheel as indicated in phantom lines at **49**, the surface **45** would be dressed to a true cylinder. However, as the axis of truing cutting rotation **50**, shown in FIGS. 8 and 11 is deviated from the centerline **51** by an angle C which is on the order of a fraction of a degree, the center of grinding wheel **44** will be dressed deeper by the desired amount Y. The axis of rotation **50** of the truing cutter **46** must, of course, be coincident with centerline **51**, when viewed as in FIG. 7 and in FIG. 10 in order to insure lateral symmetry in the dressed wheel. When this is properly lined up, the truing device is fed into the wheel along line **51**, as indicated by directional arrow **52** to a sufficient dress compensation depth, and then is withdrawn as shown by arrow **53**.

When dressing the slightly "concave" cylinder to a central depth of Y, below the outside wheel diameter, it is necessary to insure that the corner of the diamond face which penetrates to the depth Y, is below the centerline **51** by a minimum distance, H in FIG. 9 (H is the height of an arc of radius Rc whose chord is Ww).

If these conditions are met, then the angle

$$C=\tan^{-1}\frac{Y}{H}$$

For example, let

$Ww=.500$ in.
$Y=.000040$ in.
$Rc=.625$ in.

Solve for H

From standard math tables, if

$$\frac{\text{chord}}{\text{radius}}=\frac{Ww}{Rc}=\frac{.500}{.625}=.800$$

then, corresponding ratio

$$\frac{\text{height}}{\text{radius}}=\frac{H}{Rc}=.083$$

or height

$H=Rc\times .083$
$H=.625\times .083$
$H=.05175$ inch

now, having Y and H, solve for angle C

$$\tan C=\frac{Y}{H}=\frac{.000040}{.05175}=.000773$$

or C=0° 2½′

With the use of the end-face mounted diamonds to true a grinding wheel, and considering the several geometries possible in applying the cutter as well as the variable speed of the cutter, the operator is now equipped with a flexible control of the quality of dress, enabling him to adjust to specific manufacturing requirements.

Other applications will occur to one skilled in the art as the adaptability of the end coated diamond cutter becomes evident. Therefore, it will be seen that the objects and aims of the invention have been fully met and it will be understood that changes in angle of presentation, cutter diameters, and the like, as well as other modifications, may be made in the foregoing without departing from the scope or spirit of the invention, and it will be further understood that various changes in the details, materials, steps and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

What is claimed is:

1. A truing device for a grinding wheel, comprising:

(a) a dressing cutter having abrasive particles attached to a flat end thereof, said flat end face being arranged to engage said grinding wheel in a tangential manner, offset in the plane of tangency in a direction parallel to the sides of the grinding wheel, and tilted outward from said plane of tangency, yet maintaining the axis of said cutter in a plane normal to the axis of the grinding wheel, whereby said cutter can be plunged along a line normal to said plane of tangency to dress said grinding wheel to a smaller diameter at the midpoint than at the two sides by a precisely determined amount; and

(b) a driving motor adapted to rotate said cutter about its axis.

2. A method of dressing an accurate concavity on the grinding surface of a grinding wheel approximating a relatively large radius, comprising the steps of,

(a) selecting a flat faced cutter of diameter larger than the width of said grinding wheel,

(b) mounting said cutter,

(c) arranging said flat face to engage said grinding wheel in a tangential manner, offset in the plane of tangency in a direction parallel to the sides of the grinding wheel, and tilted outward from the said plane of tangency, yet maintaining the axis of said cutter in a plane normal to the axis of the grinding wheel,

(d) plunging said cutter into said wheel.

3. A truing cutter, of diameter $2Rc$, having a flat end face for truing the surface of a grinding wheel to a diameter smaller by 2Y at the midpoint than at the two sides, said end face offset in the plane of tangency of said grinding wheel to a predetermined height H parallel to the sides of said wheel and tilted from said plane by a predetermined angle C, determined as follows, using standard tabulated circular functions:

Given:
wheel width (chord), Ww
cutter diameter, $2Rc$
central depth, Y
then

$$\frac{Ww}{Rc}=\frac{\text{Chord}}{\text{Radius}}=\text{Ratio 1}$$

and

$$\frac{H}{Rc}=\frac{\text{Height}}{\text{Radius}},\text{ a function of Ratio 1}=\text{Ratio 2}$$

therefore $H=Rc\times\text{Ratio 2}$, and

$$C=\tan^{-1}\frac{Y}{H}$$

whereby said cutter is adapted to be plunged along a line normal to said plane of tangency to dress said grinding wheel to said smaller diameter at the midpoint than at the two sides by said predetermined amount, 2Y.

4. A truing device for a grinding wheel, comprising:

(a) a dressing cutter having abrasive particles attached to a flat end face thereof, said flat end face being arranged to engage said grinding wheel in a tangential manner, offset in the plane of tangency in a direction parallel to the sides of the grinding wheel, and tilted outward from said plane of tangency, yet maintaining the axis of said cutter in a plane normal to the axis to the grinding wheel, said normal plane bisecting the width of said grinding wheel, whereby said cutter can be plunged along a line normal to said plane of tangency to dress said grinding wheel to a smaller diameter at the midpoint than at the two sides by a precisely determined amount; and

(b) a driving motor adapted to rotate said cutter about its axis.

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U.S. Cl. X.R.

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