

Feb. 18, 1969

L. COES, JR
GRINDING APPARATUS

3,427,754

Filed Nov. 29, 1966

Sheet 1 of 3

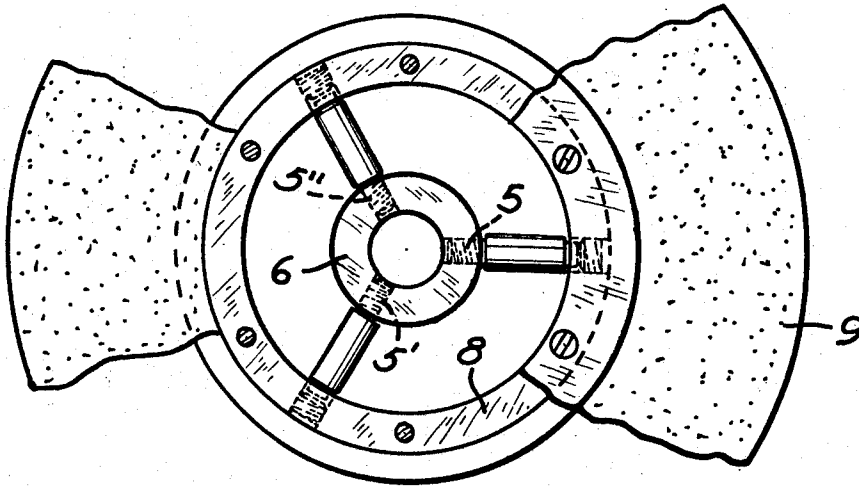


Fig. 1

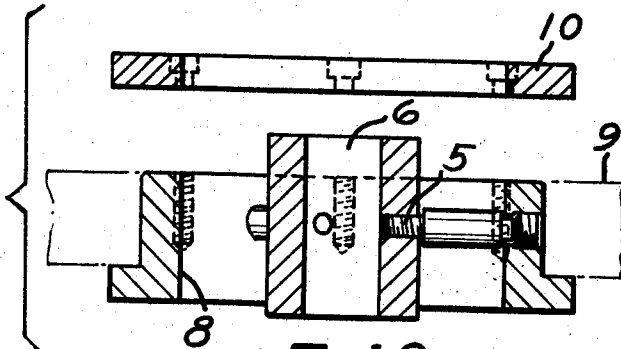


Fig. 2

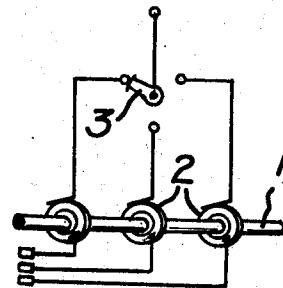


Fig. 4

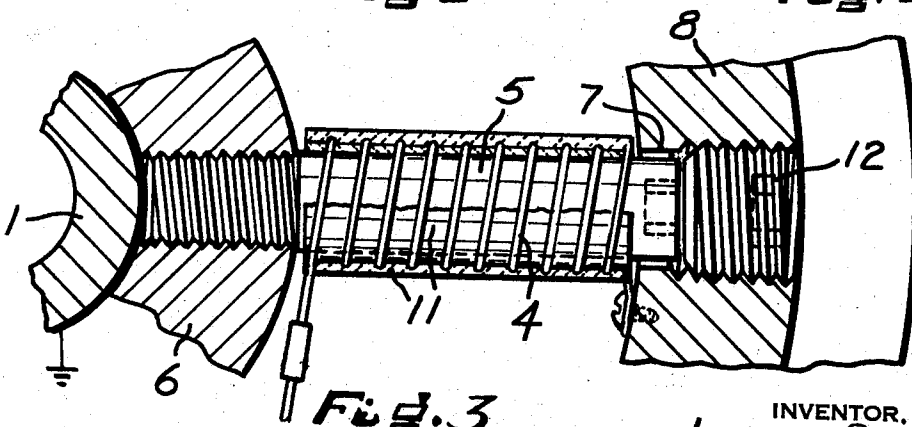


Fig. 3

INVENTOR,
LORING COES, JR.
BY *Alfred Redrow*
ATTORNEY

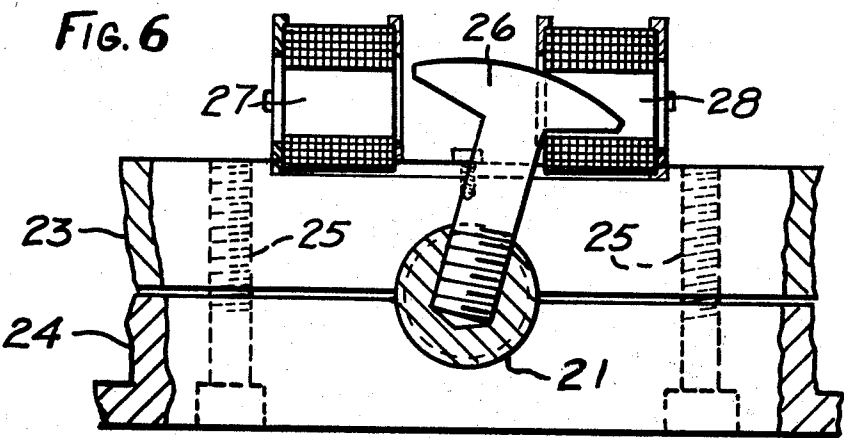
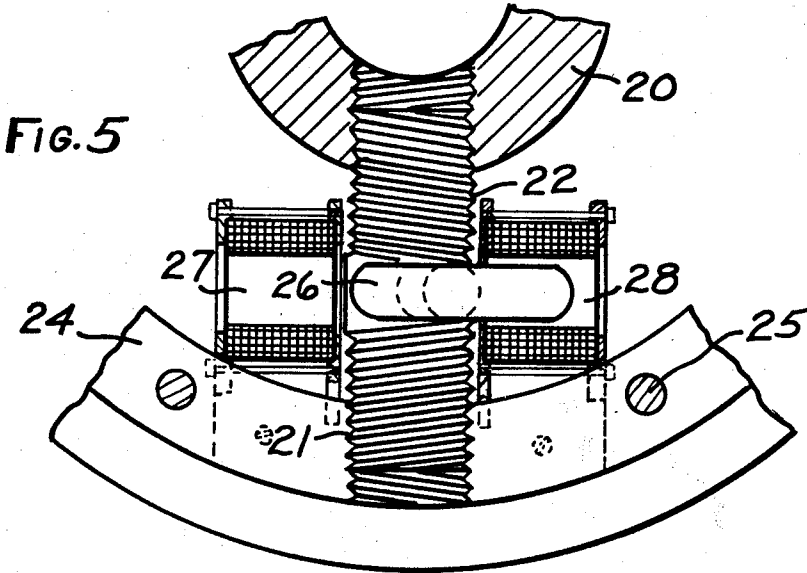
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Sheet 2 of 3



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LORING COES, JR.
BY *Alfred Redros*
ATTORNEY

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Fig. 7

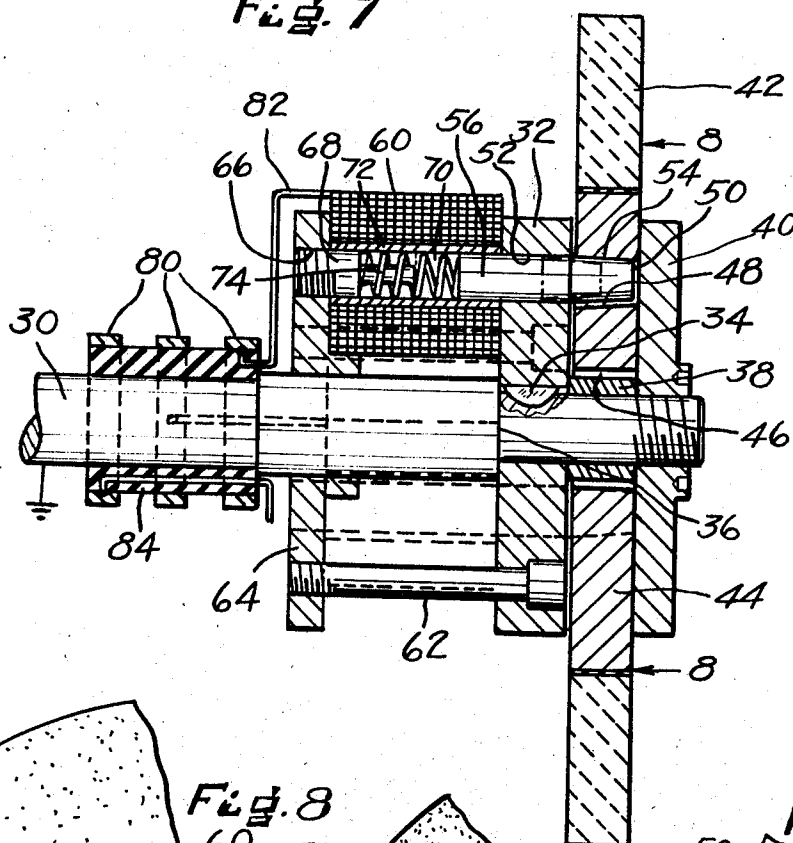


Fig. 8

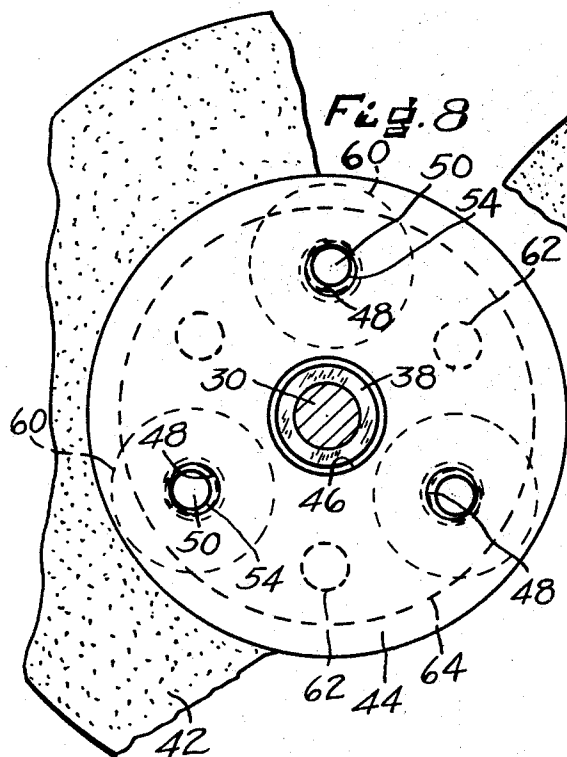
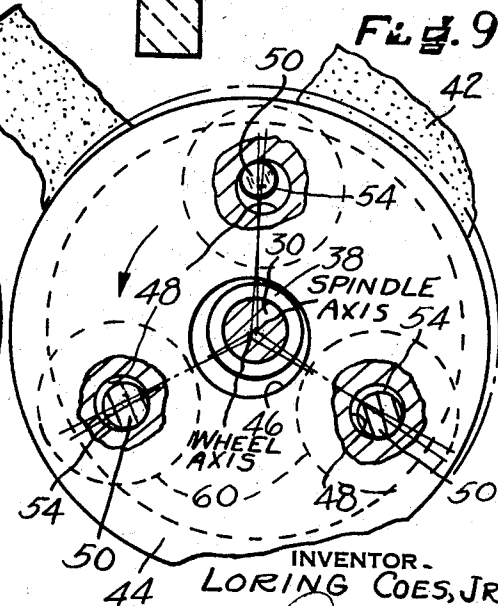


Fig. 9



INVENTOR -
LORING COES, JR.

BY
Attorney

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3,427,754

GRINDING APPARATUS

Loring Coes, Jr., Princeton, Mass., assignor to
Norton Company, Worcester, Mass., a corpo-
ration of Massachusetts

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13 Claims

Int. Cl. B24b 7/00, 9/00, 41/00

ABSTRACT OF THE DISCLOSURE

Apparatus for intermittently changing the eccentricity of grinding wheels during the grinding process.

In the preferred embodiments of the present invention, the eccentricity of a hub mounted, revolving grinding wheel in contact with a workpiece is intermittently changed and the center of revolution is displaced about 0.020 of an inch by alternatively changing the length or position of one of a plurality of equally spaced spokes or drive pins mounted at angles about the hub.

Background of the invention

In the prior art grinding processes it has been observed that grinding efficiency decreases over a period of time when a grinding wheel is applied to a given piece of work under constant conditions. In order to maintain the grinding efficiency relatively constant, various methods of reducing the contact time have evolved.

Some of these prior methods comprise inducing a vibration in the revolving grinding wheel or workpiece, or by changing the configuration of the wheel. The vibrations are induced by having the operator strike the grinding wheel or workpiece, but these actions are not recommended because of the possibility of breaking the grinding wheel with the resulting danger to the operator. The configuration of the grinding wheel may be changed by cutting or perforating the periphery of the wheel. Any cutting or perforation, of the wheel, however, reduces the inherent strength and normally increases the cost of manufacture.

It has been shown mathematically that the grinding cost can be reduced by reducing the fraction of time the grinding wheel is in contact with the workpiece. The mathematical proof proceeds as follows:

When a metal workpiece is ground under a fixed force P, the metal is removed according to the equation—

$$(1) \quad M = \frac{KPVW}{(a+W)}$$

where:

M=metal removal rate in lbs./hr.;

W=wheel wear rate in cubic inches/hr.;

P=interfacial force in lbs.;

V=wheel speed in surface feet/minute;

K=dimensional constant;

a=specific wear of the abrasive on the metal being ground in cubic inches/hr.

Under conditions of intermittent contact (when the grinding wheel is actually making contact, a fraction f of the time the work is in grinding position);

$$(2) \quad \begin{aligned} P &= \bar{P}/f \\ M &= \bar{M}/f \\ W &= \bar{W}/f \end{aligned}$$

where $\bar{P}$, $\bar{M}$ and $\bar{W}$ refer to the average time the work is in grinding position from (1) and (2):

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$$(3) \quad \bar{M} = \frac{KPV\bar{W}}{fa + \bar{W}}$$

and since the grinding cost is based on the average quantities (assuming an operator is paid on an hourly basis):

$$(4) \quad C = \frac{(A\bar{W} + L)}{\bar{M}}$$

where

A=abrasive cost in cents/cubic inch;

L=hourly cost of labor and overhead in cents;

C=total cost of metal removal in cents/lb.

from (3) and (4)

$$(5) \quad C = \frac{(A\bar{W} + L)(af + \bar{W})}{KPV\bar{W}}$$

if in equation (5) $\bar{W}$ is assumed constant and the cost C is differentiated with respect to the fraction of the time f then:

$$(6) \quad \frac{dC}{df} = \frac{a(A\bar{W} + L)}{KPV\bar{W}}$$

and from this equation it can be seen that for a constant average wheel wear rate the grinding cost will decrease as the contact time decreases.

Description of the invention

It is, therefore, an object of the present invention to reduce the cost and improve the efficiency of grinding wheel processes.

Another object of the invention is to provide a grinding apparatus having a relatively constant grinding removal rate.

Other objects of the invention are improved apparatus for reducing the fraction of contact time between revolving grinding wheels and workpieces.

A particular object of the invention is a grinding apparatus for intermittently changing the eccentricity of a revolving grinding wheel relative to the axis of its drive shaft while it is being applied to a workpiece.

Another particular object of the invention is an apparatus for mounting a grinding wheel having means for changing the eccentricity of the grinding wheel while it is revolving.

Further objects and the broad scope of the invention will become obvious to one skilled in the art upon further study of the specification and claims and the drawings submitted herewith.

Particular and preferred embodiments for carrying out the objects of the present invention are illustrated in the accompanying drawings, wherein:

FIGURE 1 is a fragmentary view of a grinding wheel having a hub that can be energized electrically to produce unsymmetrical thermal expansion to shift the wheel slightly off center;

FIGURE 2 is a disassembled cross section through the hub;

FIGURE 3 is an enlarged fragmentary section on the central plane of the hub;

FIGURE 4 is a perspective view of the wheel spindle with slip rings thereon;

FIGURE 5 is a fragmentary cross section of a modified hub that can be energized electrically to rotate the individual spokes to increase or decrease their effective lengths;

FIGURE 6 is a transverse section through an outer portion of the hub of FIGURE 5;

FIGURE 7 is a vertical cross section through the preferred embodiment of the invention;

FIGURE 8 is a fragmentary cross section taken on line 8—8 of FIG. 7; and

FIGURE 9 is a fragmentary cross section similar to

FIGURE 8 showing the eccentricity of the wheel relative to the spindle.

In the construction shown in FIGURES 1 to 4, the hollow spindle 1 carries slip rings 2 connected respectively to the contact points of a rotary switch 3 for connecting the heating coil 4 of and individual spoke 5 to a source of electricity while disconnecting an adjacent spoke therefrom, the preferred number of spokes being three, with an angular spacing of 120°. Each spoke is screwed radially into an inner hub sleeve 6 carried directly by the spindle 1 and terminates in a radial bore 7 in the outer hub ring 8. The inner hub sleeve 6 may be integral with spindle 1 or separate as shown in FIGURE 3. To permit mounting of the grinding wheel 9, one of the flanges 10 of the outer hub ring is separable as shown in FIGURE 2.

In an alternative form, each of the coils is covered by a layer of heat stable insulation 11 such as asbestos. An electric conductor 4 is wound upon the spoke 5 with one end grounded while the other end is connected through a preferably hollow spindle 1 with one of the slip rings 2. When the switch 3 is in position to send electric current through the conductor 4, the spoke on which the conductor is wound is heated by thermal conduction from the hot wire if the latter is made of electric resistance material. By whatever method the spoke is heated, it is caused to expand longitudinally. The hub ring is shifted eccentrically relative to the inner hub sleeve 6 when one of the spokes is heated.

The grinding operation is then continued until the metal removal rate falls to an unsatisfactory value as sensed by the amount of electric power that is drawn by the machine, the tangential force and/or the appearance of the spark stream. The switch 3 is then moved to the next position without stopping the grinding operation, and the expansion is repeated with another spoke. Each time the switch is shifted to a new position, the spoke that has been heated is allowed to cool while the next spoke is simultaneously heated at about the same rate.

In the construction shown in FIGURES 5 and 6, a similar embodiment of a hollow spindle with slip rings is used, but the shifting from one eccentric position to another is performed electromechanically by providing each spoke with a right hand screw thread 21 at one end and a left hand screw thread at the other end 22. The thread 22 is in screw threaded connection with the inner hub sleeve 20 while thread 21 is in oppositely threaded connection with the two-piece outer hub ring comprising half-sections 23, 24 which are held together by screws 25.

The same result could also be accomplished by threading each spoke at only one end, or by providing its two ends with screw threads having different pitches.

Each of the three radial spokes carries a radial T-shaped arm 26 of soft iron or other material with high magnetic permeability so that it can be swung over a controlled distance such as 30° in one direction or the other by energizing one or the other of a pair of solenoids 27, 28. Conversely, the head of the T-shaped member could have its two free ends permanently magnetized as N and S poles which could then be swung over in one direction or the other by energizing the solenoids in the proper directions. Each time when the arm 26 is swung in one direction, the oppositely threaded spoke has its effective length slightly increased, whereas each time when the arm is swung in the opposite direction, the effective length of the spoke is diminished by the same amount. As the arm 26 of the first spoke is actuated in a particular direction, the arms 26 of the other two spokes are actuated simultaneously in the other direction in order to prevent any stress on the outer hub ring 23, 24.

In assembling the apparatus of FIGURES 1 to 4, the spokes 5, at room temperature, fit loosely into the hub 8 with a combined tolerance of 0.001 to 0.100 of an inch and a preferred tolerance of 0.020 of an inch between the end of the spokes 5 and the inner surface of the threaded plug 12. As each of the spokes 5 is alterna-

tively heated, the spoke expands to fill the space between the end of the spoke 5 and the plug 12, while the other two spokes are also displaced and the center of revolution is shifted by approximately the tolerance limit. The limiting factors in the upper tolerance limit of 0.100 of an inch are the loss of operator comfort and a spalling condition of the wheel resulting from the vibration of the wheel against the workpiece. The lower tolerance is limited by the need to change the eccentricity frequently as a result of wheel wear.

In the assembly of the embodiment shown in FIGURES 5 and 6, the three screws having threads 21 and 22 are positioned loosely between half-sections 23 and 24. One of the arms 26 is actuated in one direction and the other two arms 26 are actuated in the opposite direction. With arms 26 actuated and threads 21 and 22 properly positioned, the screws 25 are tightened and the assembly is complete. The threads 21 and 22 are so selected that the partial rotation of the arm 26 through about 30° is sufficient to displace the half-sections 0.001 to 0.100 of an inch, and preferably 0.020 of an inch.

In another embodiment of the invention shown in FIGURES 7-9 a spindle 30 has connected to it a ring or drive member 32 by means of a key 34. The ring or drive member 32 is held against axial movement between a shoulder 36 on the spindle 30 and a spacer or bushing 38 by a nut or flange 40 threaded onto the end of the spindle 30. If desired the drive member and the spacer could be an integral part of the spindle or integral unit with one or the other.

A grinding wheel 42 is fixed to a support or center hub 44, loosely mounted between the ring or drive member 32 and the nut 40. The wheel support 44 has a central hole 46 larger than the outside diameter of the spacer 38 and is of the same or preferably slightly less in axial length than the spacer in order that the support center 44 and wheel 42 can be moved freely off the center of rotation of the spindle 30. The wheel support or center hub 44 has a plurality of, but preferably three equally spaced tapered holes 48 into which extend an equal number of axially movable tapered drive pins 50 slideably journaled or mounted in holes 52 in the drive member 32.

As shown, the tapered surface 54 of each pin 50 has tangential line contact with the surface of the wheel support 44 within each of the larger mating tapered holes 48, and by which the wheel support is driven and maintained in position.

Each pin 50 is constructed of ferrous material showing a high magnetic permeability and has a core end portion 56. Axially aligned with and around each core end portion 56 of the pins 50 is an electromagnetic device or solenoid 60 clamped by screws 62 between a retainer plate 64 on the spindle and the drive member 32.

The retainer plate 64 has a plurality of equally spaced threaded holes 66 in each of which is an adjustable threaded member 68 extending within the central bore 70 of a non-ferrous sleeve or bushing 72 within each solenoid 60. Within each bore 70 is a resilient member or spring 74 situated between each threaded member 68 and the core end 56 of pin 50 and which normally force or bias the pins 50 to the right. When so biased the tapered surfaces 54 engage the surface of the wheel support or center 44 within each tapered hole 48 and axially aligns the axis of the wheel 42 with the axis of rotation of the spindle 30 as shown in FIG. 8. Upon energization of one of the solenoids 60 the highly magnetic ferrous core end 56 and hence the tapered end surface 54 of the pin 50 (such as the top pin in FIG. 9) is drawn to the left in FIG. 7 a predetermined adjustable amount and allows the previously aligned axis of the freely movable wheel 42 and center 44 to shift and be rotated eccentrically to the axis of the spindle 30 as shown in FIG. 9. The axis of the wheel is shifted away from the axis of the spindle by a slight adjustment of the positions of the tapered end

surfaces 54 within each tapered hole 48 whereby all the tapered surfaces 54 make line contact with a different portion of the surface of the wheel support within the holes and take up the lost motion or free play created by the withdrawal of one of the pins.

Upon contact by all of the tapered surfaces 54 within each tapered hole 48 the wheel 42 is maintained and driven eccentrically about the axis of the spindle until a further adjustment of the eccentricity by moving one of the other pins in and releasing the other two to be resiliently urged to the right as shown in FIG. 7.

Spaced slip rings 80 and a circuit similar to that shown in FIG. 4 are provided for energizing each of the solenoids 60. One end of each conductor 82 from the coil of each solenoid passes through an insulating bushing 84 fixed to the spindle 30 and is connected to one of the rings while the other end of the coil contacts disc 32 upon clamping and goes to ground by way of the spindle.

During a cutting operation each solenoid is alternately energized one at a time for a predetermined length of time in order to change the relative eccentricity of the grinding wheel and its drive means and thereby distribute the wear about the periphery of the wheel 42.

The amount of eccentricity is determined by adjusting the member 68 relative to the core end 56 of the pin 50 which determines the extreme left hand position of the pin 50 by limiting the stroke or amount the pin 50 is withdrawn. The spring 72 being selected to be sufficiently strong to recenter the wheel when pin 56 is released from the solenoid and to be overcome by the pull of the solenoids 60 on pin 56 when the solenoid is energized.

The adjustable member or stop 68 can be so adjusted as to produce from .001 to .100 of an inch eccentricity but .020 is to be preferred as stated previously. This is due to the mating of the tapered surfaces 54 on the pins 50 and with the tapered surfaces of the center hub 44 within the tapered holes 48. Obviously, instead of being tapered the holes could be straight and the end 54 of the pins 50 could have a series of axially spaced steps of different diameters with sloping shoulders between each of the steps to guide successive steps into position for engaging and driving the center hub 44 as the pins are moved in and out. However, a greater range and finer adjustment are made possible by using equally tapered surfaces.

Obviously two or more than the preferred number of three spaced drive pins 50 may be used; in this way the wheel wear would be distributed at two or more frequent intervals about the periphery of the wheel or cutting tool.

Also various combinations of fixed and retractable drive pins 50 can be used. For example the following combinations are some of the many possible arrangements of fixed and retractable pins which can be utilized: one fixed pin and one or two retractable pins, two fixed pins and one retractable pin. In general two or more spaced pins of which at least one pin is retractable can be used; and it is not necessary that the pins be equally spaced.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following preferred specific embodiments of the process are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the specification and claims in any way whatsoever.

Example 1

The grinding process is carried out with a grinding wheel selected from the group such as those disclosed in the book "Abrasives and Grinding Wheels," published by the Norton Company, Worcester, Massachusetts, 1965 edition.

One such wheel is a resin bonded grinding wheel, suitable for snagging operations. It has an aluminum oxide grain size of 16, a ZZ bond, an outside diameter of 24

inches, a thickness of 3 inches, and an internal diameter of 12 inches. The grinding wheel is mounted on the hub disclosed in FIGURES 1 to 4 and the hub is mounted on a floor stand grinding machine. The grinding machine is equipped with a hydraulic feed for the workpiece and a pressure dial indicating the pounds of load applied. A wattmeter having a dial indicating kilowatts is connected to the grinding machine motor to measure the power used in grinding.

One of the spokes 5 of the hub shown in FIGURE 1 is heated by actuating the switch 3 of FIGURE 4, and the center of revolution of the grinding wheel is displaced about 0.020 of an inch. The grinding wheel is revolved and a peripheral speed of 9500 surface feet per minute is maintained. A steel casting is fed to the face of the grinding wheel and a load of 100 lbs. of force is applied.

The metal removal rate at the start of grinding is about 40 lbs./hr. and the power consumed by the grinding machine is about 7 kilowatts. After about 15 minutes the grinding wheel is worn to be substantially concentric with its drive shaft and the metal removal rate and power consumption fall to about 20 lbs./hr. and 3 kilowatts respectively.

The switch 3 of FIGURE 4, is then rotated to another position and as the first spoke 5 cools, another spoke 5' is heated and expanded so that the center of revolution again shifts about 0.020". With the shift in the center of rotation, the rate of metal removal is again restored to about 40 lbs./hr. and the power consumption returns to about 7 kilowatts. Again after about 15 minutes, the grinding wheel is worn concentric and the metal removal rate and power consumption fall off.

The switch 3 is then rotated to another position and, as spoke 5' cools, spoke 5'' expands so that the center of revolution again shifts about 0.020".

By changing the eccentricity of the grinding wheel in successive stages, the rate of metal removal is maintained relatively constant and at a high rate.

It will be understood that this invention is susceptible to modification in order to adapt it to different usages and conditions and, accordingly, it is desired to comprehend such modifications within this invention as may fall within the scope of the appended claims.

I claim:

1. A structure for adjustably supporting, rotating, and shifting the central axis of a rotatable grinding wheel to relatively eccentric positions with respect to a fixed axis of rotation comprising:

- (a) a spindle rotatable about the fixed axis;
- (b) means co-operating with the spindle for supporting and driving the grinding wheel;
- (c) said means including a plurality of members spaced angularly around the fixed axis and positioned between the wheel and said supporting and driving means; and
- (d) means to move at least one of said members to effect radial adjustment of the wheel at angularly spaced positions relative to the fixed axis.

2. A structure for adjustably supporting, rotating, and shifting the central axis of a rotatable grinding wheel to relatively eccentric positions with respect to a relatively fixed axis of rotation comprising:

- (a) a spindle rotatable about the fixed axis;
- (b) a drive member on the spindle adapted to be rotated by the spindle;
- (c) a wheel support about the spindle, adapted to support a grinding wheel thereon;
- (d) a plurality of members at least one of which is movable, spaced angularly about the drive member and axis of the spindle, and extending from the drive member into engagement with the wheel support for driving the wheel support and shifting the axis of

rotation of the wheel support relative to the axis of rotation of the spindle; and

- (c) means about each of the movable members for varying the effective axial length of that portion of at least one of said movable members which extends from the drive member to alter the eccentric position of the wheel relative to the relatively fixed axis.

3. The structure of claim 2 wherein the plurality of movable members comprises:

- (a) equally spaced drive pins each slidable in the drive member and having a tapered surface at one end extending into a tapered hole in the wheel support of larger size than the tapered end and into tangential line contact with a mating tapered surface in the wheel support within each hole.

4. The structure of claim 2 wherein the plurality of members are axially movable and the means for varying the effective axial length of the axially movable members comprise:

- (a) electromagnetic devices fixed to the drive member to motivate each of the axially movable members that is to be moved;
- (b) an adjustable member at one end of each of the devices for engaging the movable member whereby to limit its movement in one direction;
- (c) means rotatable with the spindle for successively energizing each of the electromagnetic devices while deenergizing all the others; and
- (d) resilient means, adjacent each of the movable members, for returning the movable members to a predetermined initial position upon deenergization of the electromagnetic device.

5. The structure of claim 4 wherein the wheel support is mounted between the drive member and a nut fixed a predetermined axial distance from the drive member on the spindle and which is adapted to allow relative eccentric movement of the wheel support relative to the axis of the spindle upon axial movement of at least one of the drive pins.

6. The structure of claim 4 wherein the drive pins are movable along axes which are substantially parallel to the axis of the spindle.

7. A structure of claim 1 wherein the members are

interposed between the wheel and spindle and in which said means for supporting and driving the wheel includes:

- (a) hub;
- (b) said hub having radial spokes fixed at one end to the drive member spaced about 120° apart; and
- (c) said spokes each being movable to effect radial adjustment of the wheel axis relative to the spindle axis.

8. The structure of claim 7, wherein said spokes initially have a small amount of free play between the ends of the spokes and the wheel support until said radial adjustment is made.

9. The structure of claim 8 wherein the free play is within a range of about 0.001 to 0.100 of an inch.

10. The structure of claim 8 wherein the free play is about 0.020 of an inch.

11. The structure of claim 8, wherein at least one of the spokes has means for varying its effective axial length comprising electrical resistance means affixed respectively to the spoke.

12. The structure of claim 7, wherein each spoke is provided with different screw threads at its two ends to effect said radial adjustment.

13. The structure of claim 12, wherein a rotation of about 30° of the spoke varies the effective length of the spoke by about 0.020 of an inch.

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LESTER M. SWINGLE, *Primary Examiner.*

40 D. G. KELLY, *Assistant Examiner.*

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