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Klievoneit

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[54] **RADIAL SURFACE FINISHING APPARATUS**

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[52] **U.S. Cl.** **51/118,** 51/168

[51] **Int. Cl.** **B24b 7/16,** B24b 5/00

[58] **Field of Search** 51/111, 117, 118, 206.4, 51/165.87, 168

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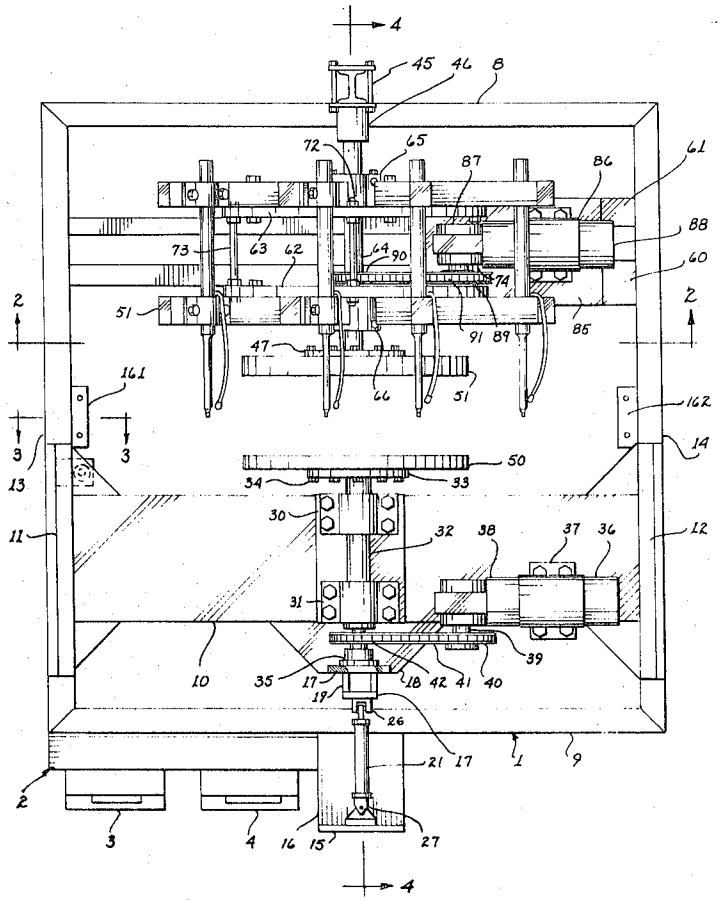
Primary Examiner—Othell M. Simpson

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[57] **ABSTRACT**

Apparatus is disclosed for grinding parallel surfaces upon a plurality of rotatable workpieces. A primary grinding wheel, of massive and rigid configuration, is rotated about an axis substantially parallel to the axis of rotation of the workpieces. An axially movable secondary grinding wheel, of massive size with respect to the grinding surface but somewhat resilient with respect to the axis of rotation, is rotated about an axis essentially in alignment with the axis of the primary grinding wheel. Each workpiece is mounted upon an axially shiftable rotatable shaft, which mounting permits each workpiece to rotate and move axially. Each workpiece is compressively positioned intermediate the primary and secondary grinding wheels, and the grinding wheels are rotated in the same direction. The workpieces are mounted approximately equiangularly about the grinding wheels. In operation, the workpieces tend to align themselves in a plane parallel to the plane defined by the grinding surface of the primary grinding wheel. The grinding surface of the secondary grinding wheel, on contacting the workpieces, will also tend to align itself in a plane parallel to the plane of the primary grinding surface. As the grinding wheels rotate in a first direction, the friction between the grinding wheels and the workpieces tends to cause the workpieces to rotate in the opposite direction. The resulting counter-rotation causes the workpieces to be ground radially. The axially shiftable workpieces accommodate the wear on the grinding wheels and the reduced thickness of the workpieces without affecting the alignment or grinding pressure applied to either side of the workpiece. Controls are provided to vary the pressure, rate of rotation and direction of rotation. Means are also disclosed for truing the grinding wheels.

7 Claims, 9 Drawing Figures



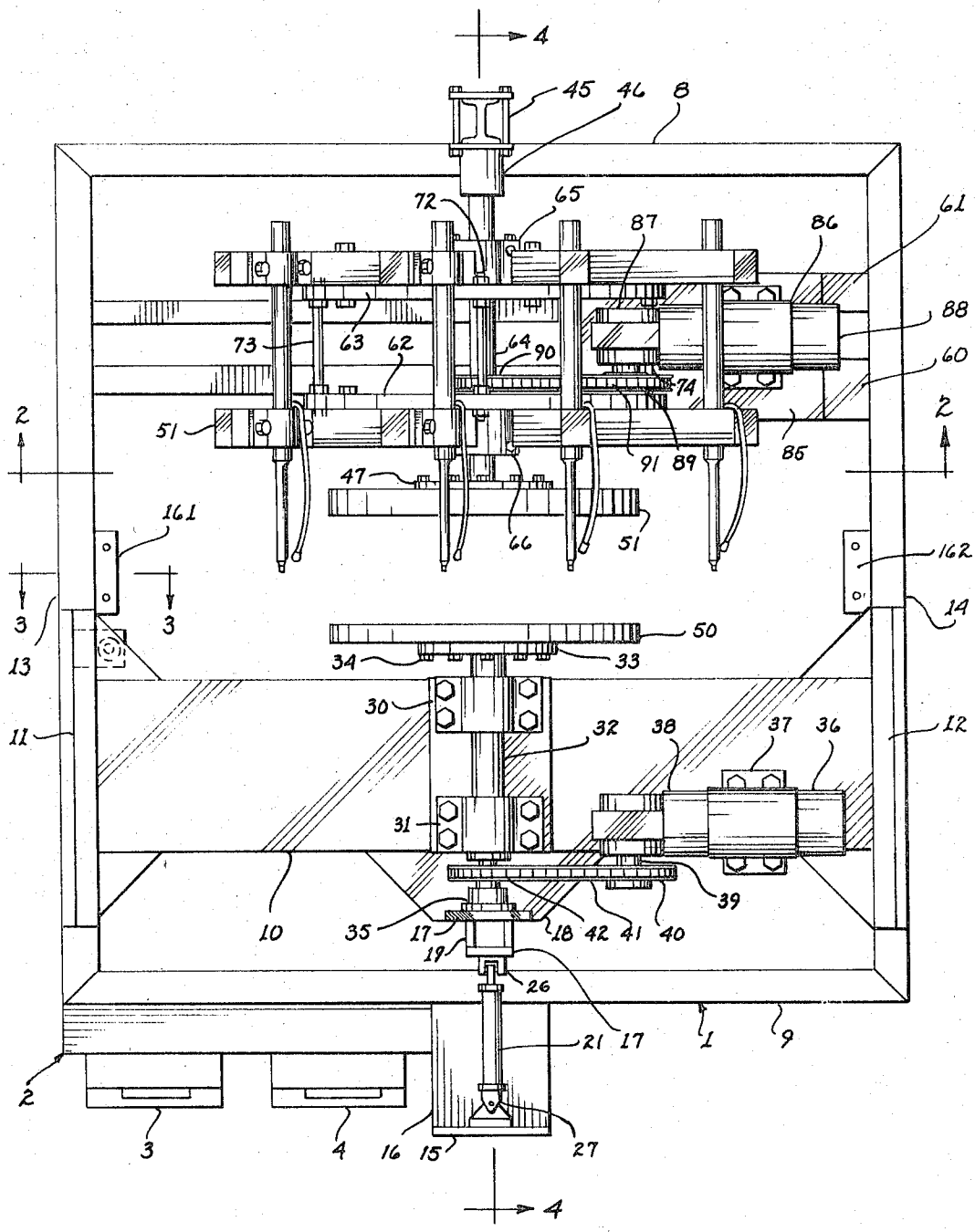
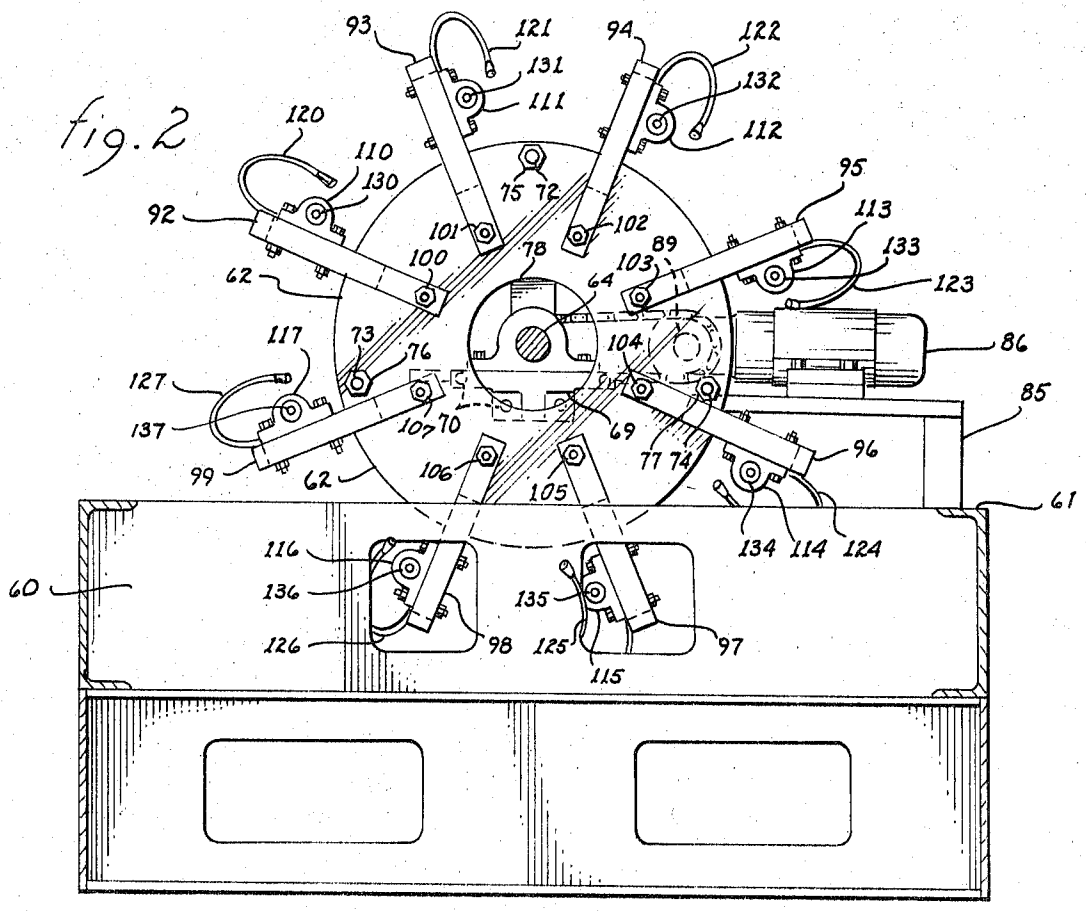

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Fig. 1

Fig. 2


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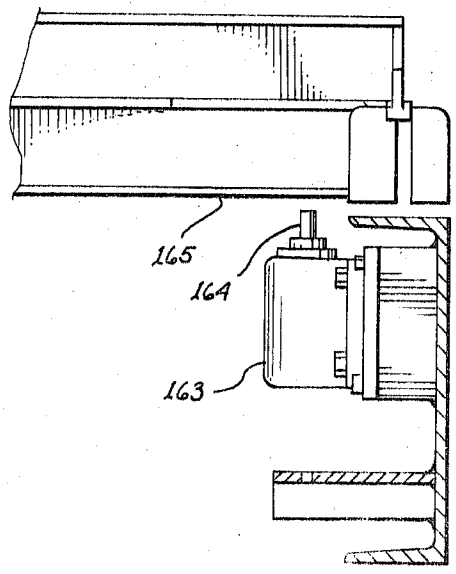

165
164
163

Fig. 3

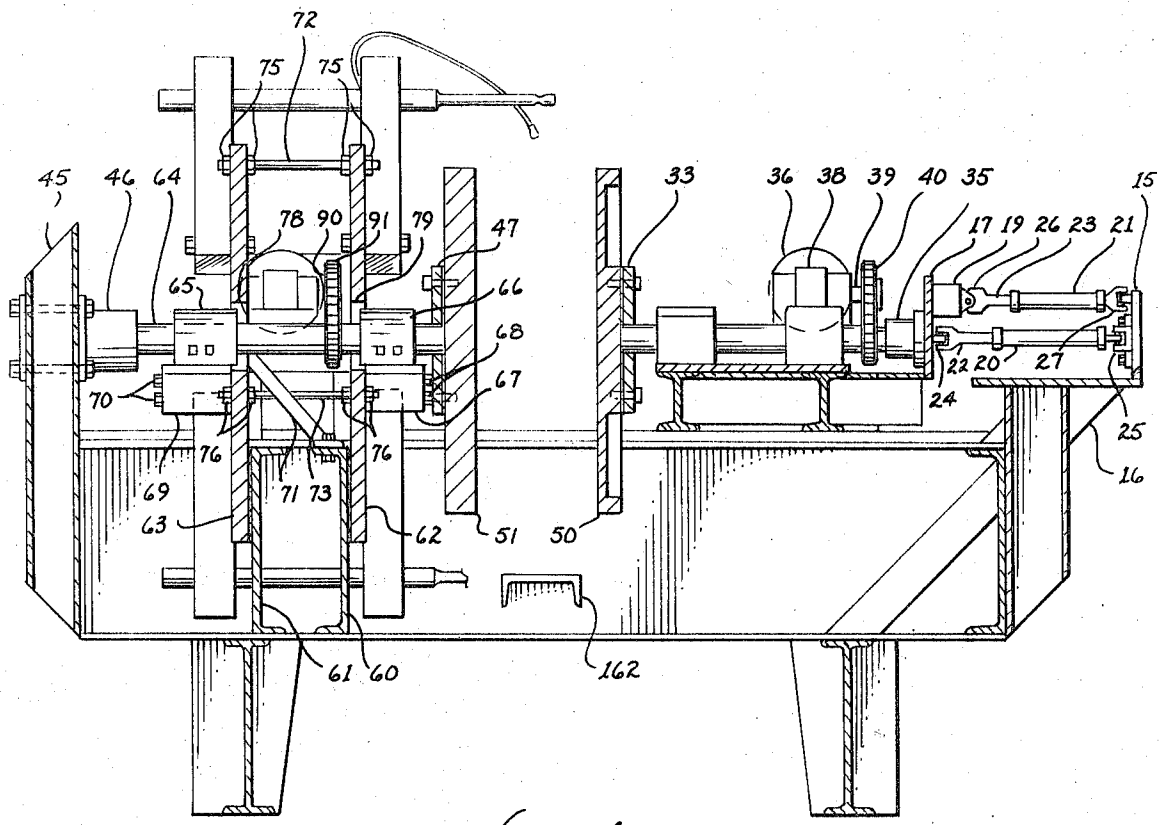

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Fig. 4

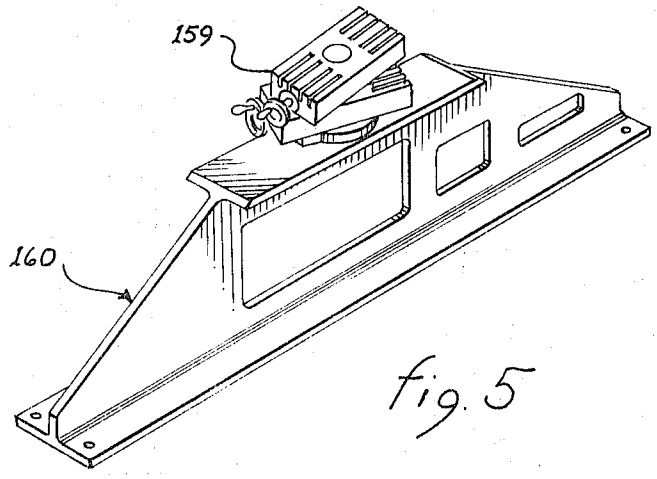

159
160

Fig. 5

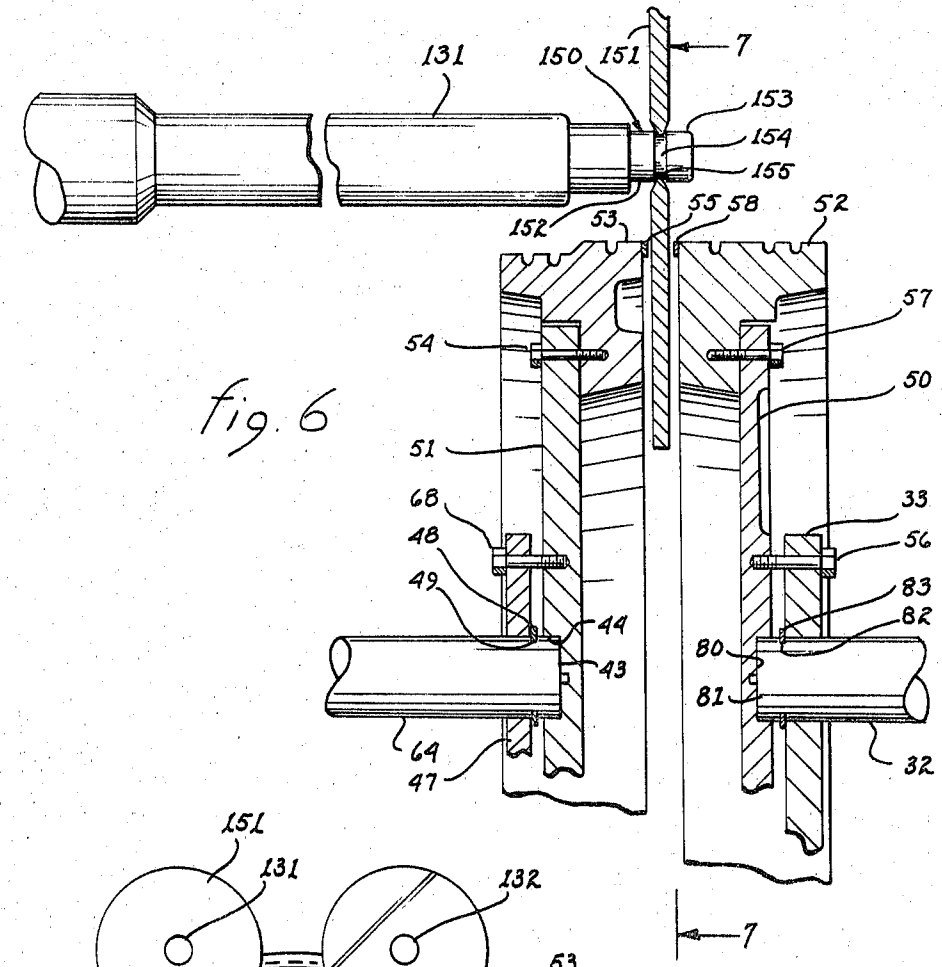

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152
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52
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Fig. 6

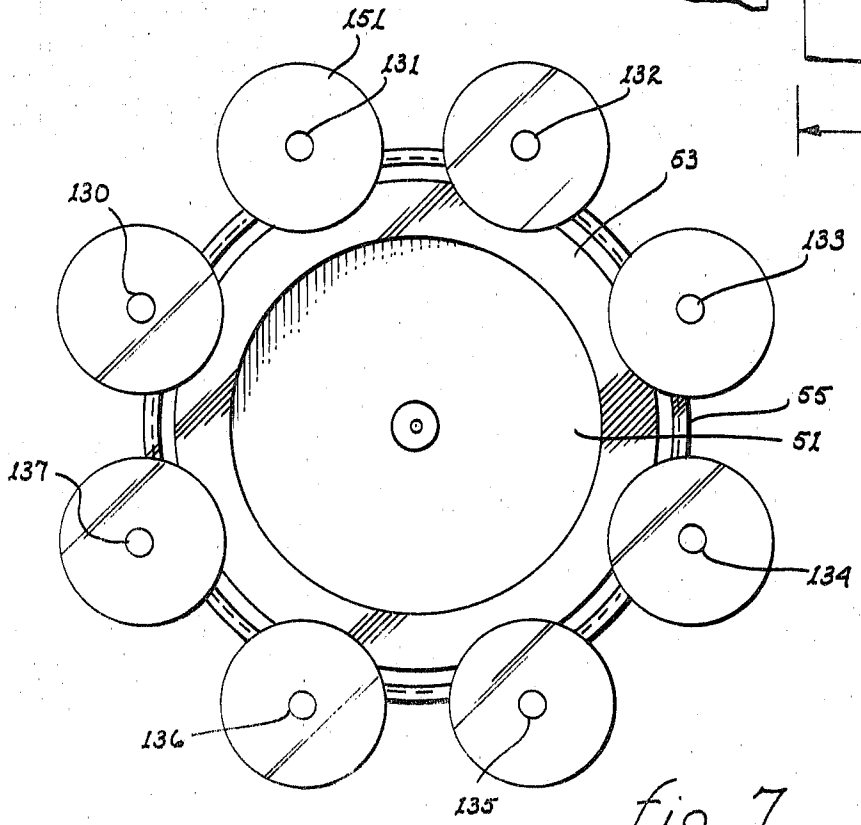

151
131
132
63
130
133
55
51
137
134
136
135

Fig. 7

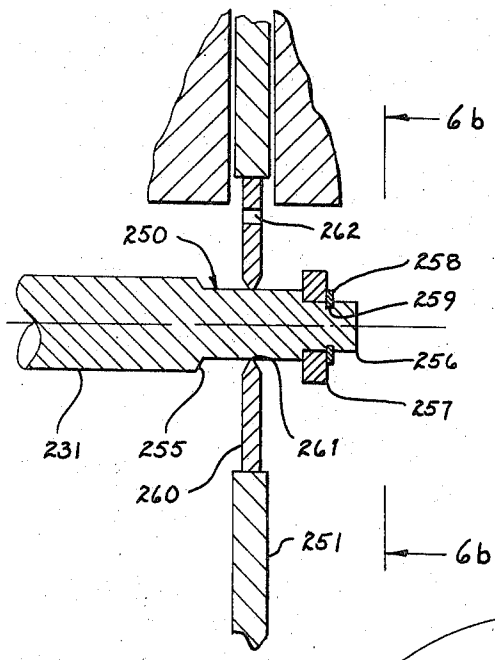

6b
250
262
258
259
256
257
231
255
261
260
251
6b

fig. 6a

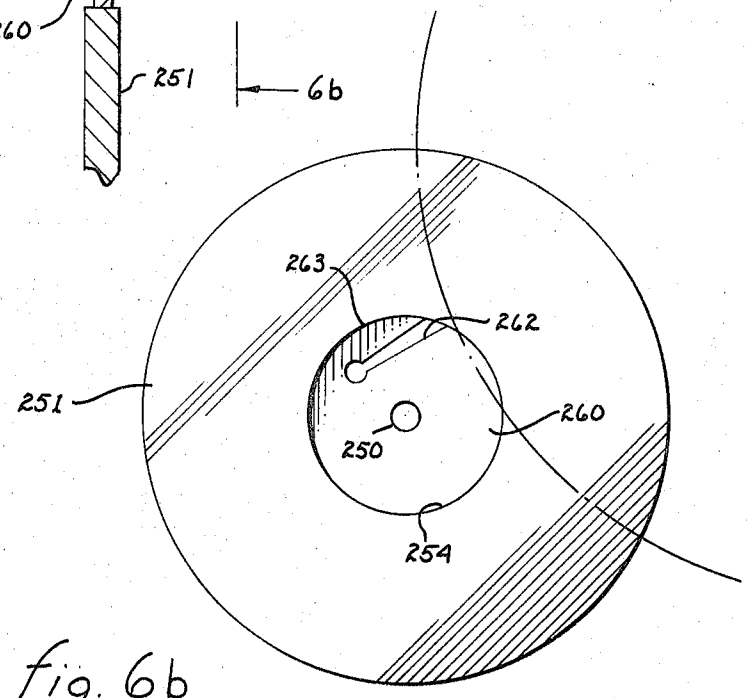

263
262
251
260
250
254

fig. 6b

RADIAL SURFACE FINISHING APPARATUS

The present invention relates to grinding apparatus, and, more particularly, to apparatus for grinding parallel surfaces on a workpiece.

In the prior art, a problem has always existed in attempting to machine and grind parallel surfaces on a workpiece. Many types of apparatus have been employed and their configuration has varied. However, the fundamental mode of operation has had a single common thread.

The commonality existing in each of the apparatus may be described as follows. One side of the workpiece is aligned with the grinding surface. That one side is then ground to the desired tolerance. On completion, the workpiece is turned 180°, and the opposite side is ground to the required tolerance. Although the individual surfaces may be nearly perfectly planar, the necessary realignment restricts the two sides from being parallel to one another with a tolerance measured in terms smaller than thousandths of an inch. Another contribution factor to maintaining a relatively large tolerance of parallelism is the grinding operation itself. The degree of grinding and the alignment of the workpiece and the grinding wheel are established by peripheral or artificial keys or gauges. Thus, the plurality of elements which must be in alignment is the major contributory factor in inhibiting the obtainment of parallel ground surfaces.

It is therefore a primary object of the present invention to provide apparatus for grinding parallel surfaces on a workpiece without requiring realignment of the workpiece or the grinding surfaces during the grinding operation.

Another object of the present invention is to provide apparatus including grinding wheels for grinding parallel surfaces wherein the grinding wheels and workpiece in combination provide the requisite alignment.

Yet another object of the present invention is to provide apparatus for simultaneously grinding two parallel surfaces on a workpiece.

Still another object of the present invention is to provide apparatus for grinding parallel surfaces by using two grinding wheels where the axis of the grinding wheels do not have to be in near perfrect alignment.

A further object of the present invention is to provide apparatus for grinding parallel surfaces using two grinding wheels wherein the direction of rotation, rate of rotation and pressure exerted by each of the grinding wheels may be varied.

A yet further object of the present invention is to provide apparatus having grinding wheels for grinding parallel surfaces which includes means for readily varying the degree of abrasiveness of the grinding wheels.

A still further object of the present invention is to provide apparatus for grinding parallel surfaces upon a shaft-mounted workpiece which permits the workpiece to tilt about its shaft without affecting the degree of parallelism of the ground surfaces.

A still further object of the present invention is to provide means for initially truing facing grinding wheels with respect to a given reference plane and further means for truing the facing grinding wheels with respect to each other.

The subject matter of the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however,

both as to organization and method of operation, may best be understood by reference to the following description taken in connection with the accompanying drawings, of which:

FIG. 1 illustrates the top view of the dual grinding wheel apparatus of the present invention.

FIG. 2 illustrates a sectional view of the present invention taken along lines 2—2 as shown in FIG. 1.

FIG. 3 illustrates a sectional view of the present invention taken along lines 3—3 as shown in FIG. 1.

FIG. 4 illustrates a sectional view of the present invention taken along lines 4—4 as shown in FIG. 1.

FIG. 5 illustrates a truing beam for truing the grinding wheels of the present invention.

FIG. 6 illustrates a cross-sectional view of the grinding wheels in position adjacent the workpiece.

FIG. 6*a* illustrates a modification of the workpiece mounting structure.

FIG. 6*b* illustrates a sectional view of the structure shown in FIG. 6*a*.

FIG. 7 illustrates a sectional view of the workpiece positions with respect to a grinding wheel, taken along lines 7—7 as shown in FIG. 6.

Referring to FIG. 1, there is shown a top view of a pair of grinding wheels mounted upon a frame 1. The frame is structurally rigid and sufficiently robust to provide a stable platform upon which the grinding wheels, their associated mechanisms and the workpieces are mounted. A control panel 2 is located at one end of frame 1 and may include a plurality of cabinets 3 and 4. Cabinets 3 and 4 house controls for varying the rotational speed and direction of rotation of the grinding wheels and further controls for varying the pressure exerted by the grinding wheels.

A movable platform 10 is mounted upon frame 1 by means of linear bearings disposed within the extremities 11 and 12 of the platform and adjacent sides 13 and 14, respectively, of frame 1. Referring now jointly to FIGS. 1 and 4, the movement of platform 10 will be described in further detail. A vertical support 15 is attached to frame 1 by means of a shelf 16 extending exterior to the frame. A second vertical support 17 is secured to platform 10 by means of a shelf 18. Intermediate supports 15 and 17, there are disposed a pneumatic cylinder 20 and a hydraulic cylinder 21 including plungers 22 and 23, respectively. The plunger 22 of pneumatic cylinder 20 is secured to support 17 by a universal joint 24, and the pneumatic cylinder is secured to support 15 by another universal joint 25. Similarly, the plunger 23 of hydraulic cylinder 21 is secured to a spacer 19 extending from the support 17 by a universal joint 26, and the hydraulic cylinder is secured to support 15 by a further universal joint 27.

A shaft 32 is journalled upon platform 10 within bearings 30 and 31. A thrust bearing 35 is secured to support 17 and engages one end of shaft 32. Pneumatic cylinder 20, connected to an appropriate air pressure source, operates as the prime mover for displacing shaft 32, via thrust bearing 35, with respect to side 9 of frame 1. Hydraulic cylinder 21, connected to an appropriate hydraulic fluid pressure source, serves as a damper and control cylinder for regulating the rate of movement of shaft 32. Control of both hydraulic cylinders 20 and 21 may be effected by controls positioned within control panel 2. It is, of course, understood that the movement of platform 10 follows the movement of shaft 32.

Shaft 32, includes a collar 33 disposed at another end thereof. Disc 50 is secured to collar 33 by means of a plurality of bolts 34 extending through collar 33. An electric motor 36 is mounted upon platform 10 by means of a mount 37. Electric motor 36 drives a reduction gear 38 to provide an output via output shaft 39. The output shaft 39 drives a sprocket 40 which, in turn, drives sprocket 42 secured to shaft 32 by means of chain 41. In this manner, disc 50 is selectively caused to rotate by energization of electric motor 36.

Referring now jointly to FIGS. 1, 2 and 4, a pair of channel beams 60 and 61 extend across sides 13 and 14 of frame 1. These two beams provide the support structure for housing the assembly associated with disc 51.

An apertured circular disc 62 is welded or otherwise secured to the upper part of beam 60 and extends thereabove. A platform 67, generally T shaped in cross-section, is attached to the outer side of disc 62 by a plurality of bolts 68. Platform 67 serves as the mounting for a bearing 66, which bearing journals shaft 64. Another apertured circular disc 63 is welded or otherwise secured to beam 61 and extends upwardly therefrom. A further platform 69, similar to platform 68, is attached to the outer side of disc 63 by a plurality of bolts 70, Platform 69 serves as the mounting for bearing 65, which bearing also journals shaft 64.

Platforms 67 and 68 are affixed to their respective discs 62 and 63 such that the centerline of bearings 66 and 65 are generally aligned with the center of apertures 78 and 79. Actually, when assembling the apparatus, shaft 64 is axially aligned with shaft 32. Such alignment will usually center shaft 64 within the center of apertures 78 and 79.

Disc 63 may be further braced by one or more braces 71 extending intermediate beam 60 and the disc. Discs 62 and 63 are positionally stabilized with respect to one another by a plurality of rods, such as threaded rods 72, 73, and 74. Sets of nuts 75, 76, and 77, respectively, secure the rods to the discs.

A further platform 85 is mounted on the top of beams 60 and 61. Platform 85 serves as a pedestal for electric motor 86 driving a gearbox 87. The output shaft 88 of gearbox 87 drives a sprocket 89 which, in turn, drives a sprocket 90 secured to shaft 64 by means of a chain 91. In this manner, electric motor 86, when energized, rotates shaft 64.

Still referring to FIGS. 1, 2 and 4, the appendages secured to each of the discs 62 and 63 will be described in further detail. A plurality of sets of arms extend from each one of the discs 62, 63. In the drawings, eight sets of arms are shown. For the sake of brevity, only the arms attached to disc 62 will be described in detail. It is to be understood that the matching one of each set of arms associated with disc 63 are functionally and positionally equivalent to the to-be-described arms. The corresponding elements associated with discs 63 are identified in the respective drawings with the same numbers having a prime (') identification symbol. Each of the arms 92, 93, 94, 95, 96, 97, 98 and 99 are attached to disc 62 by means of nut and bolt combinations 100, 101, 102, 103, 104, 105, 106 and 107, respectively. The orientation of each of the arms, shown as being radial, may be varied to suit the size of the workpiece or may be varied for other considerations. In example, the arms may be offset so that each workpiece shaft journalled thereon can be repositioned along the respective arm parallel to shaft 64 on a common radial. At the approximate extremity of each of these arms, there is located a bearing 110, 111, 112, 113, 114, 115, 116, and 117, respectively, for journalling the shaft, upon which shaft the workpiece is mounted. Each of the arms may further include a grinding fluid spray unit 120, 121, 122, 123, 124, 125, 126 and 127, respectively. In the alternative, only the four uppermost arms may include a spray unit with the expectation that the fluid would drop onto th lower ones of the workpieces.

A workpiece shaft, such as shafts 130, 131, 132, 133, 134, 135, 136 and 137 is journalled within one of the bearings 110, 111, 112, 113, 114, 115, 116, and 117 and its mate, respectively. These shafts are free to travel within the bearings in the axial direction.

Referring now primarily to FIGS. 1 and 4, the stabilization and configuration of shaft 64 will be described in further detail. A vertical post assembly 45 is secured to side 8 of frame 1 and extends upwardly therefrom. A thrust bearing 46 is secured to post 45 and interacts with shaft 64 to counteract axial movement of the shaft toward the post.

Referring now in particular to FIG. 6, the attachment of the grinding wheels 52 and 53 to their respective shaft 32 and 64, will be described in further detail. A collar 47 is fitted onto shaft 64 until it clears annular groove 49 which groove is disposed about the shaft. A split ring 48 is inserted within groove 49 to prevent movement of collar 47 therepast toward the end 43 of shaft 64. Disc 51, including a central cavity 44 for receiving end 43, is secured to collar 47 by a plurality of bolts 48. Collar 47, being restrained from axial movement by ring 48, serves as an anchor point for the heads of of bolts 48. By selectively tightening and loosening the bolts, disc 51 is drawn toward shaft 64 and can be aligned perpendicular to shaft 64. The spacing between collar 49 and disc 51, nominally one-fourth inch, permits the collar and disc to be non-parallel to one another. Grinding wheel 53 is, in turn, secured to disc 51 by a further plurality of bolts 54. Grinding wheel 53 is a generally solid wheel which is nonresilient and nondeformable within the range of loads expected to be applied. Therefore, one of its lateral surfaces can serve as a circular planar surface to which the abrasive or grinding compounds may be attached. The grinding compound is represented as a plurality of blocks 55 which are secured to the planar surface of grinding wheel 53 adjacent its periphery.

Collar 33 is fitted onto shaft 32 until it clears annular groove 82, which groove is disposed about the shaft. A split ring 83 is inserted within groove 82 to prevent movement of collar 33 therepast toward the end 81 of shaft 32.

Disc 50 is secured to collar 33 by a plurality of bolts 56. Collar 33, being restrained from axial movement by ring 83, serves as an anchor point for the heads of bolts 56. by selectively tightening and loosening the bolts, disc 50 is drawn toward shaft 32 and can be aligned perpendicular to shaft 32. The spacing between collar 33 and disc 50, nominally one-fourth inch, permits the collar and disc to be non-parallel to one another. Grinding wheels 52, is, in turn, secured to disc 50 by a further plurality of bolts 57. Grinding wheel 52 is a generally solid wheel which is nonresilient and nondeformable for the loads expected to be applied. It forms a relatively rigid planar surface upon which abrasives or

grinding compound may be applied. As with grinding wheel **53**, grinding wheel **52** has disposed on its lateral surface and adjacent to its periphery a plurality of blocks **58**, which blocks comprise the grinding compound.

Disc **50** is undercut as shown in order to permit grinding wheel **52** to accommodate forces applied at its periphery in the axial direction by tilting the grinding wheel rather than bending or deforming it. In this manner, if there exists any axial misalignment between shafts **32** and **64**, the lateral surfaces of grinding wheels **52** and **53** will remain parallel to one another with the misalignment being accommodated by a slight flexing of disc **50**.

Referring again to FIG. **6**, the extremity **150** of shaft **131** is of reduced diameter to receive a centrally located aperture **155** in workpiece **151**. The extremity **150** may include a sleeve **152** and a retainer **153**, wherebetween a channel **154** is formed. The width of channel **154** is approximately equal to the width of a workpiece **151** adjacent aperture **155**. The sleeve **152** and retainer **153** are removable and replaceable in order to accommodate workpieces of various thicknesses. The interior edge of aperture **155** of the workpiece **151** is beveled so as to form a relatively narrow point of contact between extremity **150** and the workpiece. Thus, workpiece **151** can move readily to tilt in response to any misalignment between shaft **131** and shafts **32, 64**. If the width of contact between shaft **131** and workpiece **151** were not small, a certain amount of torque might be generated and deleteriously affect the grinding operation. The workpiece **151** is keyed (not shown) to shaft **131** to prevent rotation therebetween. If such rotation did occur, particules of the abrasive material might become lodged therebetween and enlarged aperture **155**.

Referring now to FIGS. **6a** and **6b** there is shown a modification of extremity **150** (see FIG. **6**) and an ancillary fitting to accommodate workpieces having a large central aperture. Shaft **231** is turned to obtain a reduced diameter extremity **250** and a further reduced diameter shaft extension **256**. A fixture **260**, having an aperture **261**, is mounted on extremeity **250**. The width and configuration of aperture **261** is similar to the configuration of aperture **155** of workpiece **151**, shown in FIG. **6**. A collar **257** is fitted on shaft extension **256** and secured thereon by a retainer ring **258** seating within annular groove **259**. Collar **257** in combination with shaft extension **250** and shoulder **255** form a channel within which fixture **260** is free to travel.

A saw cut **262** is made in fixture **260** to form tab **263**. The tab is defomed outwardly slightly to define, in combination with the remaining part of fixture **260**, a circle having a slightly larger diameter than that of the fixture. The diameter of fixture **260** is specifically configured to approximate the diameter of the aperture **254** within workpiece **251**. The workpiece **251** is slipped onto fixture **260** by depressing tab **263** slightly. The outward force exerted by tab **263** tends to restrain the workpiece from slipping off the fixture. However, the restraint of tab **263** is insufficient to prevent the workpiece **251** from being easily manually removed after the grinding operation is completed. The absence of any keying members or additional positioning members permits rapid attachment and detachment of the workpiece **251**.

During the grinding operatin, the workpiece **251** is inhibited from sliding off fixture **260** by the grinding wheels disposed on either side. The axial movement of the workpiece **251** that may occur during the grinding operation is accomodated by the freedom of fixture **260** and hence the workpiece, to move axially between shoulder **255** and collar **257**.

As is shown in FIG. **6**, the peripheral surface of grinding wheel **53** approximately duplicates the cross-sectional configuration of shaft **131**. This duplication, or mating, permits the periphery of the grinding blocks **55** and **58** to be practically immediately adjacent the central aperture of the workpiece **151**. Thus, almost the full sides of the workpiece **151** can be ground parallel to one another.

Referring now to FIG. **7**, there are shown a plurality of workpieces mounted upon their respective shafts **131, 132, 133, 134, 135 136** and **137**. If it is assumed that grinding wheel **53** turns in a clockwise direction as shown, each of grinding blocks **55** will, in turn, pass across one of the surfaces of each of the workpieces **151**. As there exists a frictional force between blocks **55** and each of the workpieces **151**, a force will be exerted upon each workpiece. The force will tend to cause each workpiece to rotate in a counterclockwise direction. The clockwise rotation of grinding wheel **53** and counterclockwise rotation of each workpiece **151** will tend to cause the grinding blocks **55** to grind each workpiece along a curved radial path. For some applications, it may be expeditious to drive the workpiece shafts with sufficient force to overcome the friction between the workpiece shafts and their respective bearings.

A summary of the operational features of the above described apparatus may be stated as follows. A first axially fixed circular planar grinding surface and a second axially shiftable circular planar grinding surface are established. The second planar grinding surface is essentially parallel to and faces the first planar grinding the axis of rotation of each of the grinding surfaces are aligned with one another. A bias is applied to urge the second grinding surface toward the first grinding surface. A freely rotatable and axially shiftable workpiece is disposed intermediate the two planar grinding surfaces and defines the separation therebetween. The axis of rotation of the workpiece is outside the periphery of the grinding surfaces. In operation, the grinding surfaces are rotated in a first direction. The friction between the grinding surfaces and the high points on the surfaces of the workpiece in a second direction. The different directions of rotation causes the surfaces of the workpiece to be ground along curved radial lines. The constant axial pressure applied by the second grinding surface causes the workpiece and second grinding surface to be axially shifted toward the first grinding surface. The fixed parallel relationship between the first and second grdinding surfaces grinds the surfaces of the workpiece parallel to one another despite discontinuities in the workpiece.

In one test run, the opposing sides of several workpieces were worked by conventional techniques to true the sides of each workpiece parallel to one another. By measurement, variations in parallelism on the order of 25/10,000 ths of an inch existed. The same workpieces were then mounted and ground on the present invention. The resulting surfaces were mirror smooth and the opposite surfaces were parallel to one another to the

degree that no variations could be detected by standard micrometer techniques.

Some of the elements contributing to the excellent results achievable are due to the physical arrangement which permits the use of readily available speed control means for independently controlling the rate of rotation of each grinding wheel. The physical arrangement also permits the exerted pressure to be produced from a single unit. By using standard pneumatic pressure controls and feedback systems, with hydraulic dampens, infinitesimal pressure variations can be effected. In conventional grinding apparatus, roll-off may occur due to either poor speed and pressure regulation or to the rolling of the slurry. In the present invention, both the speed and pressure are accurately controllable and roll-off can be prevented. Further, the vertical orientation and the use of washed grinding blocks inhibits rolling slurry and thus prevents the formation of roll-off.

Referring now to FIGS. **1, 2, 4** and **6,** there will be described a means for initially aligning the grinding blocks **55, 58** (FIG. **6**) of each of the grinding wheels **53, 52,** respectively. An alignment tool **160** (see FIG. **5**) is bolted to flanges **161** and **162** extending inwardly from sides **13** and **14,** respectively, of frame **1.** A machinist's pedestal **159,** which pedestal includes means for accurately positioning a cutting tool (not shown) along two axis, is mounted atop alignment tool **160.** The machinists cutting tool, when mounted upon the machinist's pedestal **159,** is approximately adjacent the grinding surface, or blocks **55,** or grinding wheel **53.** The grinding wheel **55** is rotated and the cutting tool is used to obtain a true surface on blocks **55.** In the same manner, the cutting tool may also be used to obtain a true surface on grinding blocks **58** secured to grinding wheel **52.** By this operation, the working surfaces of blocks **55** and **58** are made parallel to one another. The alignment tool **160** is then removed and the grinding wheels are ready to be used.

After due time, the working surfaces of blocks **55** and **58** may have formed undulations or other discrepancies such that they no longer respectively define two parallel planes. The working surfaces of blocks **55** and **58** may once again be trued with respect to one another by the following operation.

Platform **10** is moveable in the direction of the axis of shaft **32** with respect to frame **1** by means of linear bearings intermediate the extremity **11** and side **13** and extremity **12** and side **14.** The bearings intermediate extremity **12** and side **14** permit platform **10** to be rotated about the bearings therein for a finite distance. Further, the bearings within extremity **11** permits extremity **11** to be raised above side **13** for a finite distance. The raising of extremity **11** is accomplished by a pneumatic system **163** having a plunger **164** extending therefrom. Plunger **164** acts upon a plate **165** disposed beneath platform **10.** When plunger **164** is extended from within pneumatic system **163,** platform **10** will rotate upwardly about the bearings disposed adjacent extremity **12.** After rotation, the axis of shaft **32** will still remain parallel to the axis of shaft **64,** however, shaft **32** will be offset by a fractional amount. The slight offset between the two shafts will cause the working surfaces of grinding blocks **55** and **58** to also be offset from one another. The grinding wheels **52** and **53** are rotated in opposite directions. The offset of the grinding blocks causes the high point of the undulations of each set of grinding blocks to be ground upon one another until the working surfaces are once again planar and parallel to one another. On completion of the operation effecting parallelism of the working surfaces of the grinding blocks, the pneumatic system **163** is operated to permit the plunger **164** to retract and lower platform **10,** once again aligning shafts **32** and **64** with one another.

The capacity of the above described grinding machine may be doubled by adding the to be described components and making some minor adaptations of existing components. First, post **45** is removed and side **8** is displaced by extending sides **13** and **14** in the direction of side **8.** Second, a grinding wheel, similar to grinding wheel **53** is secured to the extremity of shaft **64.** Third, a movable platform assembly, similar to platform **10** supporting grinding wheel **52,** shaft **32,** means for rotating the grinding wheel and means for axially positioning the shaft, is movably mounted on extended sides **13** and **14** approximately adjacent displaced side **8.** Shafts **130–137** are replaced by paired shafts telescopically coupled to one another to permit independent axial movement. The extremities of each pair of shafts are configured to receive a workpiece. Fourth, further spray units, similar to spray units **120–127** may be mounted adjacent the extremities of the additional workpiece shafts. Fifth, grinding wheel truing mechanisms, as described above, may also be duplicated to align the grinding surfaces of the added grinding wheels. The operation, advantages and results discussed above for the single unit apparatus can also be obtained from the two unit apparatus.

While the principles of the invention have now been made clear in an illustrative embodiment, there will be immediately obvious to those skilled in the art many modifications of structure, arrangement, proportions, the elements, materials, and components, used in the practice of the invention which are particularly adapted for specific environments and operating requirements without departing from those principles.

I claim:

1. Apparatus mounted upon a frame for grinding parallel surfaces on a workpiece, said apparatus comprising:

A. a first grinding wheel, said first grinding wheel being axially non-displaceable and configured to present a first non-deformable rigid planar surface perpendicular to its axis of rotation;

B. a second grinding wheel, said second grinding wheel being essentially parallel to and axially aligned with said first grinding wheel and configured to present a second non-deformable rigid planar surface substantially perpendicular to its axis of rotation;

C. positioning means for axially displacing said second grinding wheel with respect to said first grinding wheel;

D. mounting means for rotatably supporting a workpiece intermediate said first and second grinding wheels, said mounting means comprising:

1. a shaft, said shaft being essentially adjacent the periphery of said first grinding wheel;

2. arm means for supporting said shafts in general alignment with the axis of rotation of said first and second grinding wheels, said shafts being radially removed from the periphery of said first and second grinding wheels; and

E. motive means for individually rotating each of said first and second grinding wheels; whereby, said first and second grinding wheels, rotating in a first direction, contact the respective sides of said workpiece and the friction between said first and second grinding wheels causes said workpiece to rotate in a second direction to produce a curved radial grind on said workpiece.

2. The apparatus as set forth in claim **1** wherein each one of said plurality of workpieces are mounted equiangularly about said first and second grinding wheels.

3. The apparatus as set forth in claim **1** wherein each said shaft includes means for accommodating limited axial displacement of said associated workpiece with respect to said shaft.

4. The apparatus as set forth in claim **3** including a fixture disposed intermediate each of said shafts and the respective ones of said workpieces for supporting said workpieces upon respective ones of said shafts.

5. The apparatus as set forth in claim **4** wherein each said fixture includes means for restraining independent rotation between each said fixture and the respective ones of said workpieces.

6. Apparatus mounted upon a frame for grinding parallel surfaces on a workpiece, said apparatus comprising:

A. a first grinding wheel, said first grinding wheel being axially non-displaceable;

B. a second grinding wheel, said second grinding wheel being essentially parallel to and axially aligned with said first grinding wheel;

C. positioning means for axially displacing said second grinding wheel with respect to said first grinding wheel, including means for maintaining the parallel relationships existing between the axis of rotation of said first and second grinding wheels, said maintaining means comprising:

1. a platform for supporting said second grinding wheel;

2. bearing means disposed at opposite sides of said platform and intermediate said platform and the frame for supporting said platform; and

3. means disposed at one of said opposite sides for pivoting said platform about the other of said opposite sides; whereby the axis of rotation of said second grinding wheel is displaced from the axis of rotation of said first grinding wheel while maintaining parallelism between said respective axis of rotation;

D. mounting means for rotatably supporting a workpiece intermediate said first and second grinding wheels; and

E. motive means for individually rotating each of said first and second grinding wheels; whereby, said first and second grinding wheels, rotating in a first direction, contact the respective sides of said workpiece and the friction between said first and second grinding wheels causes said workpiece to rotate in a second direction to produce a curved radial grind on said workpiece.

7. Apparatus for grinding parallel surfaces on a workpiece, said apparatus comprising:

A. a first rotatably mounted grinding wheel, said grinding wheel having an abrasive surface perpendicular to the axis of rotation;

B. a movable platform, said platform being movable with respect to said first grinding wheel in a direction parallel to the axis of rotation of said first grinding wheel;

C. a second rotatably mounted grinding wheel disposed on said platform, said second grinding wheel having an abrasive surface perpendicular to the axis of rotation, and including resilient means associated with said second grinding wheel to accommodate any misalignment existing between the axis of rotation of said second grinding wheel with respect to said first grinding wheel;

D. displacement means connected to said second grinding wheel for positioning said second grinding wheel with respect to said first grinding wheel;

E. individual motive means associated with each of said first and second grinding wheels for effecting selective rotation thereof;

F. rotatable support means adjacent the periphery of said first grinding wheel for positioning a plurality of workpieces intermediate said first and second grinding wheels; and

G. adjustable means for varying the distance between said support means and the periphery of said first grinding wheel to accommodate a plurality of workpieces of various sizes; whereby, said first and second grinding wheels rotating in a first direction on contacting opposite sides of said workpieces, cause said workpieces to rotate in a second direction to grind said workpieces along curved radial lines.

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