Feb. 11, 1947. B. E. LUBOSHEZ 2,415,646

METHOD AND APPARATUS FOR GRINDING AND POLISHING A SURFACE

Filed May 26, 1944 2 Sheets-Sheet 1

Fig. 1.

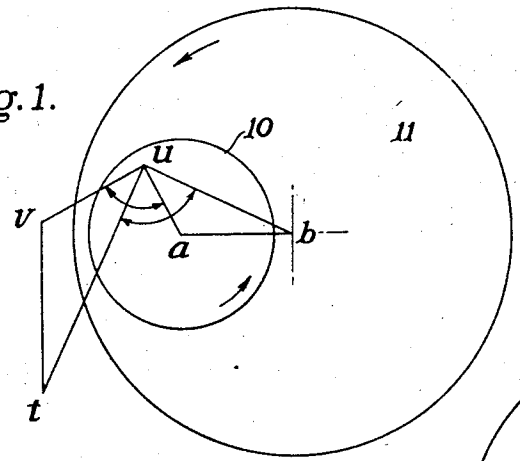


Fig. 2.

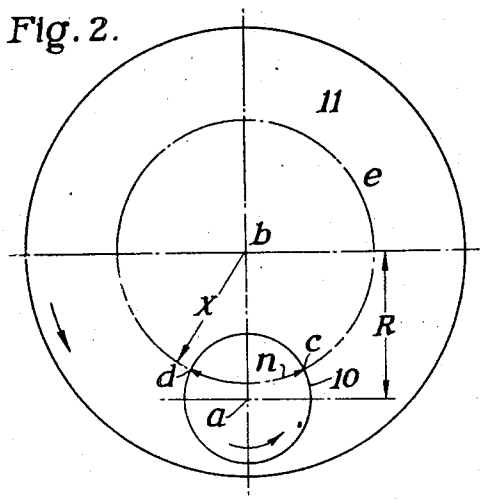


Fig. 3.

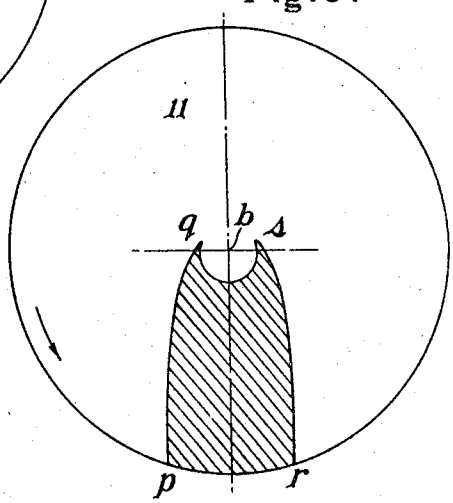


Fig. 4.

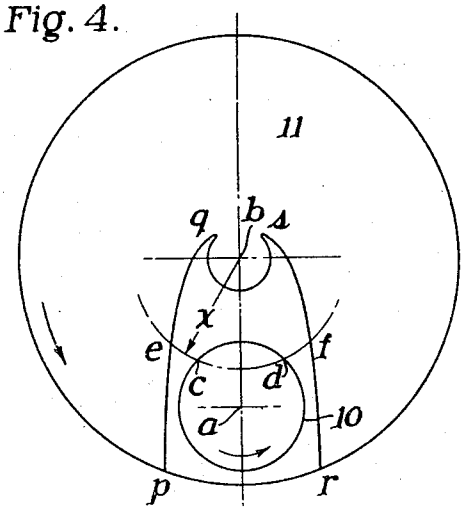
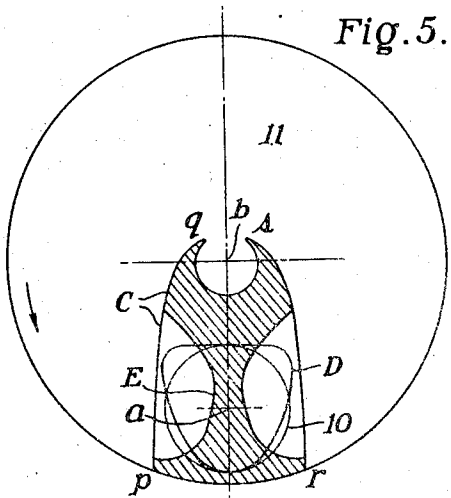


Fig. 5.



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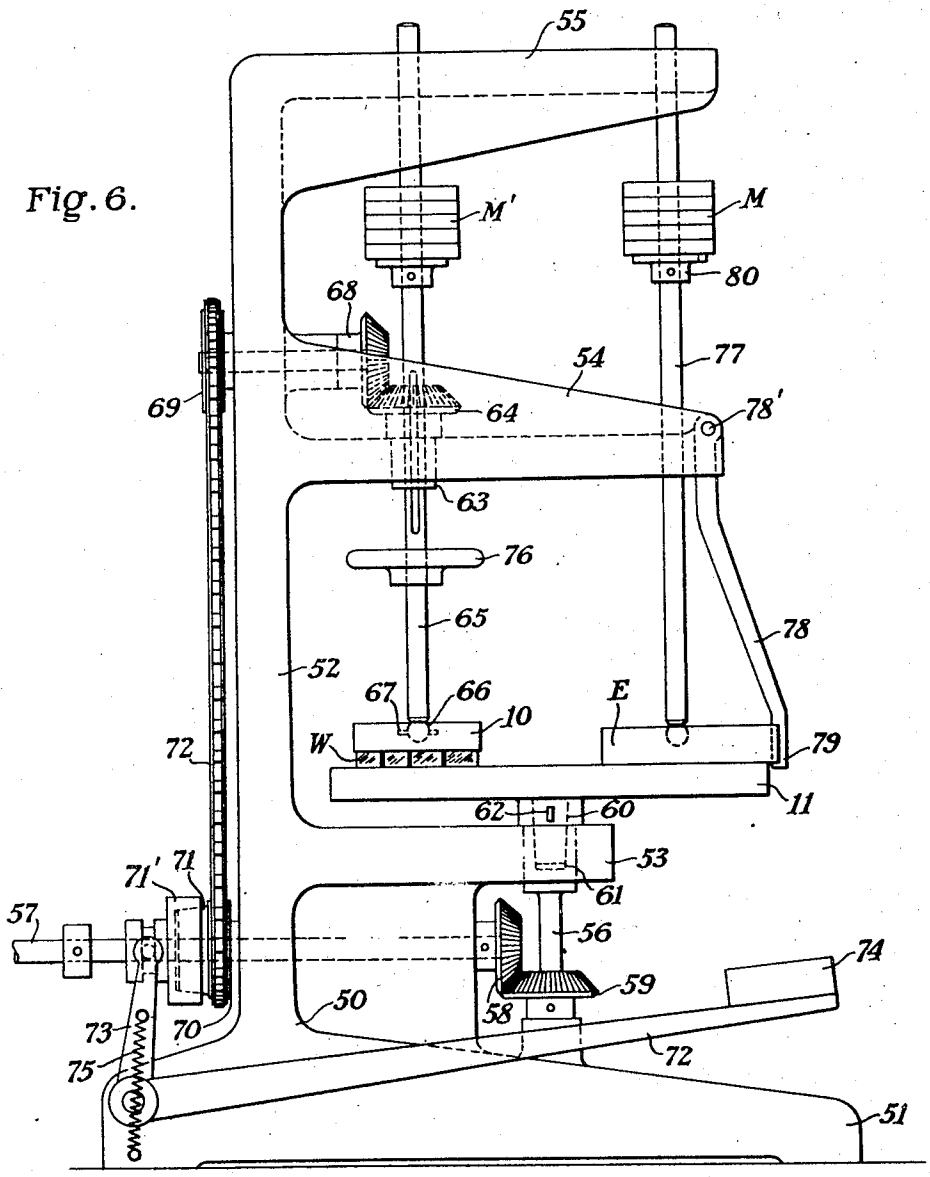
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ATTORNEYS

Feb. 11, 1947. B. E. LUBOSHEZ 2,415,646

METHOD AND APPARATUS FOR GRINDING AND POLISHING A SURFACE

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Fig. 6.



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UNITED STATES PATENT OFFICE

2,415,646

METHOD AND APPARATUS FOR GRINDING AND POLISHING SURFACES

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Application May 26, 1944, Serial No. 537,410

3 Claims. (Cl. 51—131)

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The present invention relates to the grinding and polishing of surfaces, and particularly to a method and apparatus which is conducive to automatic operation since uniform wear on all parts of the surface being ground and/or the tool being used is obtained by the use thereof.

When grinding and polishing a flat surface, it is highly desirable that from the moment contact of the surface with a flat tool has everywhere been established, the wear at all points on the surface shall be the same. Of course, in practice, neither the plane being surfaced nor the tool is absolutely flat as they both exhibit slight humps and depressions which by an averaging-out process are gradually reduced to tolerable values. With this qualification, the above statement expresses one condition which, if fulfilled, would enable flat surfaces, once obtained in rough grinding, to be maintained and perfected during subsequent smoothing and polishing.

No present-day grinding machine reaches or even attempts this ideal but relies almost entirely upon the averaging-out process to produce the desired results. Sufficient averaging-out (i. e., non-repetitive relative movement between the tool and work over a wide range of movements) can be relied upon to produce almost perfect smooth optical surfaces, but cannot be relied upon to produce a surface of the desired curvature or to produce a flat surface which, of course, is the special case of a curved surface of infinite radius. In order to attain the desired curvature (or a plane) continual adjustment of the machine is necessary and by this means, a skillful operator is able, by a series of approximations, to produce a chosen curvature or flat plane. The system is thus in no sense of the word automatic and requires a skilled attendant who knows by long experience how to balance opposing tendencies of various uneven wearing conditions to attain the desired end. With even wear taking place at all points, this method of "feeling one's way" is not necessary and renders automatic production possible. This question of even wear is not only of importance in connection with the production of a plane surface as such, but also is of prime importance in maintaining a desired angle between different plane surfaces on an optical prism or wedge.

One object of the present invention is to provide a method and apparatus for producing surfaces of a desired curvature automatically and with a minimum of adjustment during the grinding and polishing process.

Another object is the provision of a method and

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apparatus of the type set forth wherein uniform wear is obtained on the work by disposing the work to one side of the axis of rotation of the tool, regulating the sizes of the two so that the work is always covered by the tool, and simultaneously rotating the tool and work in the same direction and at the same angular velocity.

Another object is to provide a method and apparatus of the type set forth by means of which uniform wear on all parts of the tool is obtained by a compensating shoe frictionally engaging the tool and having an area proportioned in accordance with the grinding action of the work on the tool.

And still another object is to provide a method and apparatus of the type set forth of such a nature that by a simple adjustment in the drive of the parts a correct angle relationship between the planes of a prism or wedge can be obtained, the angle, once obtained, being maintained constant automatically.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its methods of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings in which:

Fig. 1 is a diagrammatic view showing a block of work engaging a much larger tool entirely to one side of the latter, and used in proving that when the work is so disposed on a tool that the wear on the work will be uniform at all points if the tool and work are rotated in the same direction at the same angular velocity,

Figs. 2–5 are diagrammatic views showing how the work is disposed relative to the tool and how the compensating shoe is designed in order to obtain a uniform wear on the tool and work in an automatic manner, and

Fig. 6 shows a grinding and polishing apparatus constructed in accordance with the present invention and incorporating the principles set forth in Figs. 1–5 and fully described in the specification.

Like reference characters refer to corresponding parts throughout the drawings.

Briefly, according to the present invention, a regime of equal wear is maintained over the work by making the work holder enough smaller than the tool so that it can be mounted with its axis of rotation to one side of the axis of rotation of the tool and be covered at all times by the tool.

The work and tool are then rotated simultaneously in the same direction at the same speed. Uniform wear of the tool surface is maintained by the use of a compensating shoe which frictionally engages the tool, and the effective area of which is proportioned so as to compensate for the grinding action of the work on the tool. Correct angles between two plane surfaces of a piece of work can be obtained by stopping the work in a given position and continuing to rotate the tool. After the correct angle is obtained, it is maintained constant automatically by again starting to rotate the work in the same direction and at the same speed as the tool.

Fig. 1 shows diagrammatically a work holding block 10 and a much larger tool 11 having axes of rotation *a* and *b*, respectively. As is well known in the art, the work to be finished is mounted on the block 10 in any suitable manner, so that the surface, or surfaces, to be ground and polished is adapted to be presented to the grinding tool. Suppose block 10 and tool 11 to rotate in the same direction (shown by arrows in Fig. 1) and at the same angular velocity. Let *u* be any point on the block 10. Then the point *u* upon block 10 will, at the chosen instant, be moving at right angles to line *au* with a speed proportional to the length of *au*. Likewise, considered from the point of view of the tool 11, a point immediately under *u* will be moving at right angles to *ub* at a speed proportional to the length of *ub*. The resultant velocity of the point *u*, which is upon block 10, relative to the tool 11 is obtained by the triangle of velocities *utv* in which *uv* represents the velocity of *u* and is proportional to *au* and *ut* represents the velocity of a point immediately under *u* on tool 11 and is proportional to *ub*.

To obtain the resultant velocity relative to tool 11, the direction of *ut* in Fig. 1 has to be reversed. It is clear that this triangle of velocities is exactly similar to the triangle *aub* turned through a right angle and in which *au* represents *uv*, *ub* represents *ut* and *ab* represents the resultant *vt*. But *ab* is constant for any given separation of centers, and since *u* was assumed to be any point on block 10, the velocities of all points on block 10 relative to corresponding points on tool 11 below them, must be constant and proportional to the distance between the centers of the block and tool, the direction of this resultant velocity is always at right angles to the line joining the centers.

The arrangement described, in which a small disk is placed upon a large one, and in which both rotate at the same angular velocity and in the same direction, provides a method of obtaining uniform wear at all points of the smaller disk so long as it is at all times completely covered by the larger one.

Since the magnitude of the uniform wear is dependent upon the separation between the centers, there is every advantage for quick surfacing in making this separation as large as possible The "figure" of the surface requires no regulation since flatness is maintained automatically, but it is easy to provide for correction if necessary. For instance, by rotating the block 10 faster than the tool 11 a convex surface is produced; and by running out partially beyond the borders of the tool 11 the surface of the work block upon block 10 can be made concave.

To maintain even wear at all points of the block, several other practical considerations must be taken into account. The pressure between the tool and work must be equal at all points and this means applying it at the center of gravity of the area of the block 10, and the size of the block 10 relative to the tool 11 must not be such as to never completely uncover all parts of the tool. The latter requirement is an important practical one for the sizes and movements must be such that all parts of the tool receive equal opportunities of drying since the working of abrasives is very sensitive to the amount of lubricant present.

In order to obtain the correct angular relationship between surfaces of a prism or wedge, assuming this is the type of work being ground, the rate of wear must be changed in a linear manner across the surface of the block in the direction required and so the conditions of equal wear must be temporarily upset. A convenient way of doing this with the present arrangement is to stop the rotation of the block 10 in the required position and to continue rotation of tool 11 until the desired angle has been obtained. When the block is stopped, more wear is taking place at points on the block remote from the center of the tool than at points on the block closer to the center of the tool in proportion to their respective distances radially of the tool. This gives a simple method of controlling the angle of the surface relative to another previously finished surface, and as soon as the correct value has been obtained, the rotation of the block is commenced. Surfacing then is continued under conditions of uniform wear and the angle is maintained.

Once the desired condition of uniform wear on the surface being ground has been achieved, attention can be turned to the question of maintaining uniform wear at all points on the tool as well. The importance of maintaining the flatness of the tool is secondary only to that of maintaining flatness of the work. For automatic production the value of this refinement is obvious and one object of this invention is to maintain the flatness of both the work and the tool automatically.

In Fig. 2, 10 again represents a work holding block resting upon a tool 11, the centers of the two being *a* and *b* respectively. It is clear that if the whole of the tool 11 were always covered by block 10, the wear upon the tool would be uniform at all points, but in that case, the wear upon the block 10 would no longer be uniform over those parts not always covered by the tool. The reason why uneven wear takes place on the tool can be seen from Fig. 2. Consider any one of the concentric circles drawn with *b* as a center. On the circle *cde* the arc *cd* represents the amount of block 10 that passes over any point on the tool 11 (on the circle in question) during one cycle. It is clear that this is not the same as the lengths at other radial distances from center *b*. In fact, the wear upon the tool 11 due to block 10 is proportional to the length of the intercept *cd* of the arc *cde*. Also, the wear due to unit lengths of any arc such as *cd* is inversely proportional to the distance from center *b*. Thus if:

R=distance between centers *a* and *b*

w=wear at any distance *x* from the center *b* compared to wear at distance R

n=length of arc intercepted by the circle 10 upon a circle of radius *x* and center *b*

then, since the wear per unit area is constant under block 10,

$$w=n.R/x \qquad \text{(Eq. 1)}$$

In Fig. 3, the maximum value of *cd* is taken and set off along each of the concentric circles having *b* as the center. The result is the shaded figure *pqrs*. A surface of this shape pressed uniformly upon the rotating tool would produce uniform wear at all points of the tool except at the inner circular area, which, in the limit, is bounded by a circle whose circumference is equal to the arc *qs* or *pr*. This small area need never be used in practice and could be cut away on the tool. The uniform wear upon tool 11 produced by the area *pqrs* is of course, proportional to the constant length of the arc *pr* chosen.

Although the wear upon the tool 11 due to the surface *pqrs* is uniform, the wear upon *pqrs* is by no means uniform and is, in fact, proportional at all points to the distance from the center *b*.

In Fig. 4 the surface *pqrs*, which we will hereinafter refer to as a compensating shoe, since as finally developed it is to compensate for unequal wear of the tool due to the grinding action of the block 10, is again shown touching upon the rotating tool 11. The constant lengths *pr* or *qs* along any arc is made slightly greater than the maximum intercept *cd*, Fig. 2, of the block of work to be finished, so that room is left within the confines of the area *pqrs* for cutting out a disk to accommodate block 10 or the surface to be worked upon. Suppose for the moment that the block 10 is not rotated about its center and that like the shoe *pqrs* it is kept stationary. If the pressure per unit area upon block 10 and the shoe is the same and is applied at the centers of gravity at the respective areas, and if the material be the same, the wear at all useful points of the rotating tool will be constant.

In Fig. 4, suppose a circle on tool 11 at a distance x from center *b* to cut the circumference of block 10 at *c* and *d* as before, and the figure at *e* and *f*.

Let *ce* plus *df* equal N, and *cd* equal *n*.

Then when block 10 does not rotate, we have seen that uniform wear (on tool 11) takes place when

$$n+N=\text{constant}$$

or $$N=L-n \text{ where L is a constant}$$

and this enables N to be calculated for different values of x in any given case.

Fig. 5 shows the various shapes concerned for the given proportions of block 10 and tool 11. 10 is the original block rotating on tool 11. C is the same as area *pqrs* in Fig 4. *D* is the shape arrived at by multiplying *n* (the length of the arc cut off by block 10) by R/x. The wear upon the tool 11 due to this shape D (not rotating) is equivalent to the wear upon tool 11 due to the block 10 when it is rotating. The final area E (shaded) shows the differences (measured along the arcs having *b* as a center) between figures C and D. Hence, with a compensating shoe of the shape of E frictionally engaging the tool and made of the same material as the work carried by the block 10, and with the pressure applied to the center of gravity of the area, of such an amount as to give the same pressure per unit of area as that upon block 10, the wear due to both a compensating shoe of shape E and block 10 (rotating), is uniform at all useful points upon the rotating tool 11.

It is believed apparent that the compensating shoe E and block 10 are shown in superposed relation on tool 11 in Fig. 5 merely to show the development of the area of shoe E, and that in practice the shoe would be spaced circumferentially of the tool with respect to the work, see Fig. 6. In practice, so that the relative movement between the tool and block will not be repetitive, the speeds of rotation of the tool and block may not be exactly identical although very nearly so. During surfacing, the rotating block 10 and the non-rotating shoe E may be moved back and forth in unison over a small distance radially to and from center *b* to further prevent repetitive movement between the block and tool. If this be the case, in a practical shape, the end *pr* of the shoe E may be extended beyond the circumference of the tool 11 and the central area around the center *b* may be filled in. The shoe E may have the shape shown in Fig. 5 or it may be divided into sections, each section being spaced at different points around the tool in proper radial position relative to the work. By way of example, the shoe E shown in Fig. 5 may be divided right in half longitudinally or transversely of its length, the two parts then being relatively spaced around the tool at any suitable point so that the combined action of the two is the same as that for the single shoe. The effect of the shoe is the same, regardless of its number of components and their relative dispositions, so long as the lengths along the arcs are correct. Likewise, when several blocks are being surfaced upon the same tool at the same time, a single compensating shoe can be proportioned to compensate for them all or a separate shoe may be provided for each one.

Since, in practice, the blocks of prisms, or other work, are made up of a number of small prisms, or pieces, of various shapes, the whole circular area of the block 10 does not necessarily represent glass surface. The average error due to this cause must be taken into account in designing the compensating shoe, and, although the general shape of the shoe will remain the same, the correction will vary for each blocking arrangement used for the work. On the other hand, if the work being finished is a disk placed with its center in alignment with the axis of rotation of the block, the conditions set forth are fully met.

In Fig. 6 there is shown an actual machine constructed so as to carry out the method of grinding and polishing set forth above. As shown, the machine comprises a frame 50 consisting of a base 51, which is adapted to rest upon a bench or the floor; an upright 52 and three arms 53, 54, and 55, looking from bottom to top, extending from the upright 52. Journaled in the base 51 and the lower arm 53 is a stub shaft 56, which is adapted to be driven from a motor-driven drive shaft 57 through bevel gears 58 and 59. The grinding tool may be positively connected to the sub shaft 56 to be rotated thereby by having a conical post 60 extending from the bottom of the tool engaging a corresponding recess 61 in the upper end of the shaft, the tool being held against rotation by a pin or key arrangement 62.

Rotatably mounted in the middle arm 54, to one side of the axis of rotation of the tool, is a tubular shaft 63 to which a bevel gear 64 is attached. Keyed to this bevel gear, to be free to move vertically relative thereto, is a work spindle 65. The upper end of this spindle is further guided against sidewise play by passing through a bore in the upper arm 55. The work holding block 10, on which the work W is mounted in a known manner, is fixed to the lower end of the

spindle by the ball and socket joint 66 which is of ordinary construction with the exception that the ball of the joint includes a horizontal pin 67 which engages corresponding slots in the socket to give a driving connection between the spindle and block, and a connection which permits a relative pivotal movement between the block and spindle in one direction.

The work spindle is adapted to be driven in the same direction and at the same angular velocity as the tool by virtue of the drive including the bevel gear 68 meshing with bevel gear 64 and fixed to a shaft journaled in the upright of the frame and having a chain sprocket 69 on the other end. This sprocket is connected to a second sprocket 70 rotatably mounted on the drive shaft 57, and including a male clutch member 71, by a chain 72. The sprocket 70 is adapted to be clutched to, and released from, the drive shaft when the female clutch member 71', which is slidably keyed to shaft 57, is moved into and from engagement, respectively, with the clutch member 71 on the sprocket. The position of the female clutch member is controlled by a treadle 72 including a yoke ended arm 73 engaging the slotted collar of the female clutch member, as is well known, and the treadle is weighted by a weight 74 to normally engage the clutch. To disengage the clutch the treadle is raised by the toe, or hand, and when the yoke arm 73 passes the dead center position, the treadle is held up by the action of a tension spring 75 which is connected at one end to a pin on the yoke arm and is fastened at the other end to a pin on the base 51 located vertically below the pivot point of the treadle and yoke arm. In the lowered position of the treadle shown in Fig. 6, this spring acts to aid the weight 74 in holding the clutch in engagement. Should it be desired to prevent non-repetitive rotation of the tool and work, this can be done by placing one less tooth in the bevel gear 64 than in the bevel gear 59, or vice versa. The work spindle 65 has fixed thereto a handle wheel 76 which may be used to rotate the work relative to the tool to position the work properly for angle control, as mentioned above, or for raising the work from the tool for any reason whatsoever.

Slidably mounted in the middle and upper arms 54 and 55, respectively, is a second vertical spindle 77. To the lower end of this spindle the compensating shoe E is connected by a ball-and-socket joint, and this joint is so located that downward pressure on the shoe is applied at the center of gravity of the effective area of the shoe so that the pressure will be distributed evenly over the entire effective area of the shoe. The same holds true for the location of the ball-and-socket joint between the block 10 and the work spindle 65. The compensating shoe is refrained from rotation by a stop lever 78 pivoted at 78' to the middle arm 54 of the frame and the lower end 79 of which is adapted to engage a slot, not shown, in the edge of a shoe. Downward pressure is applied to the compensating shoe E by removable weights M embracing the spindle and resting on a stop 80 fixed to the spindle. Downward pressure is likewise applied to the work spindle 65 by removable weights M'. The weights M and M' are proportioned in accordance with the areas of the work and compensating shoe so that the same pressure will be applied to both the work and shoe per unit area.

The advantages of the improved system of surfacing for automatic production are obvious, for

both the work and the tool wear uniformly and require a minimum amount of adjustment. The irregular wear that would normally occur on the tool is transferred to the compensating shoe E where it can be more readily dealt with. As the shoe is stationary, the wear upon it is proportional to the distance from the center of rotation of the tool and, hence, if the pressure is applied through a universal joint over the center of gravity of the area of the shoe, the shoe will automatically remain at all points in contact with the tool in spite of wear upon itself. This is very important for it means that the compensating shoe also is self-maintaining and requires a minimum amount of adjustment. Actually, there is a tendency for the surface of the compensating shoe E to grind to a slightly conical shape, but to a first approximation, the above statement is true. In any case, further slight complications arise when the shoe is given a to and fro movement as previously explained. These effects, however, are of the order of a correction upon a correction and as soon as they become sufficiently important, the shoe can be easily resurfaced.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be limited to the precise details of construction shown and described but is intended to cover all modifications coming within the scope of the appended claims.

Having thus described my invention, what I claim is new and desire to secure by Letters Patent of the United States is:

1. In a grinding apparatus the combination of a rotatable circular grinding disc; a rotatable circular block on which the work to be finished is adapted to be mounted, the diameter of said block being less than the radius of said grinding disc; means for mounting said block relative to said disc so that the block lies entirely to one side of the center of the disc and is completely covered thereby; means for rotating said disc and tool at substantially the same angular velocity and in the same direction, whereby the work is subjected to uniform wear throughout its area; and an elongated stationary compensating shoe frictionally engaging the grinding face of said disc, said shoe extending radially of said disc and having an area varying longitudinally of the shoe and proportioned so as to compensate for the non-uniform wear of the tool resulting from said arrangement of grinding disc and tool which is conducive to uniform wear of the work.

2. In a grinding apparatus the combination of a tool; of a rotatable block for supporting the work and holding it against said tool, said block being disposed with its axis of rotation to one side of the axis of rotation of said tool and having a work supporting area of a size to be completely covered by said tool at all times; means for rotating said tool and block at substantially the same angular velocity and in the same direction, whereby all parts of the work are subjected to uniform wear; and stationary means frictionally engaging said tool to continually dress the same during the grinding operation; said last-mentioned means comprising a single friction compensating shoe extending radially from the axis of rotation of the tool to the outer edge thereof; those portions of the shoe not covering the annular area of the tool engaged by the work being made up of a plurality of arcuate sections

concentric to the axis of rotation of the tool, each arcuate section being of the same length and at least as long as the diameter of the working area of said block; said portions of the shoe being joined by an area reduced in proportion to the grinding action on the tool by the work.

3. In a grinding apparatus the combination of a tool; of a rotatable block for supporting the work and holding it against said tool, said block being disposed with its axis of rotation to one side of the axis of rotation of said tool and having a work supporting area of a size to be completely covered by said tool at all times; means for rotating said tool and block at substantially the same angular velocity and in the same direction, whereby all parts of the work are subjected to uniform wear; and stationary means frictionally engaging said tool to continually dress the same during the grinding operation; said last-mentioned means comprising a plurality of substantially stationary friction compensating shoes engaging the surface of the tool at points spaced from one another both radially and circumferentially of the tool; each of said shoes having an area proportioned in accordance with its position relative to the block radially of the tool and in accordance with the grinding action of the work on the tool to compensate for non-uniform wear of the tool by the work.

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