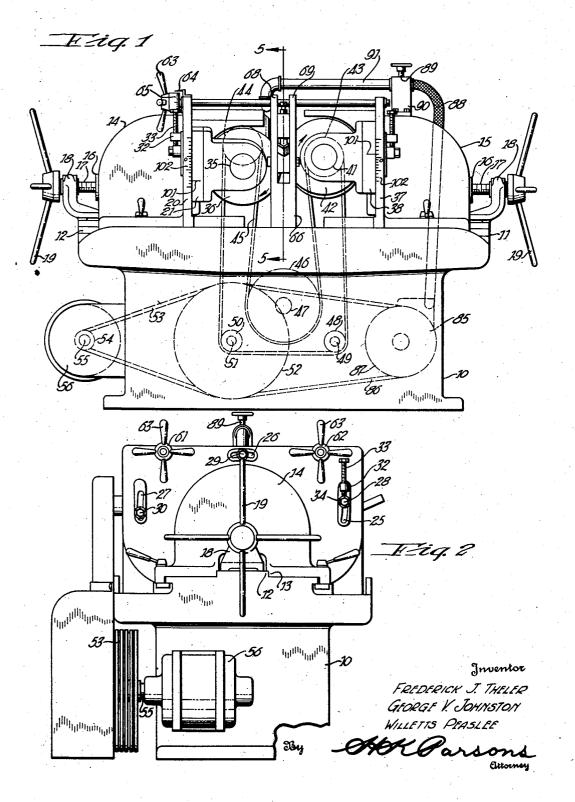
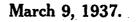
March 9, 1937.

F. J. THELER ET AL 2,073,079 LAPPING MACHINE

Filed July 15, 1932



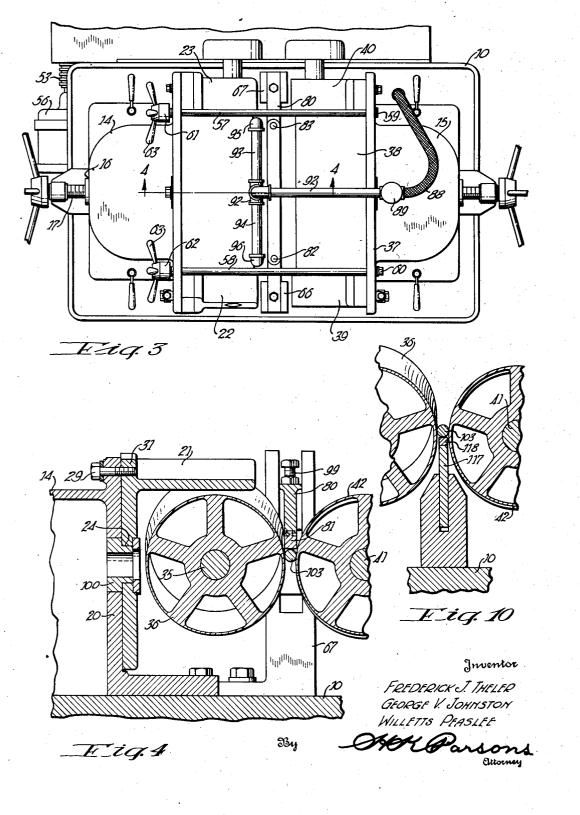


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LAPPING MACHINE

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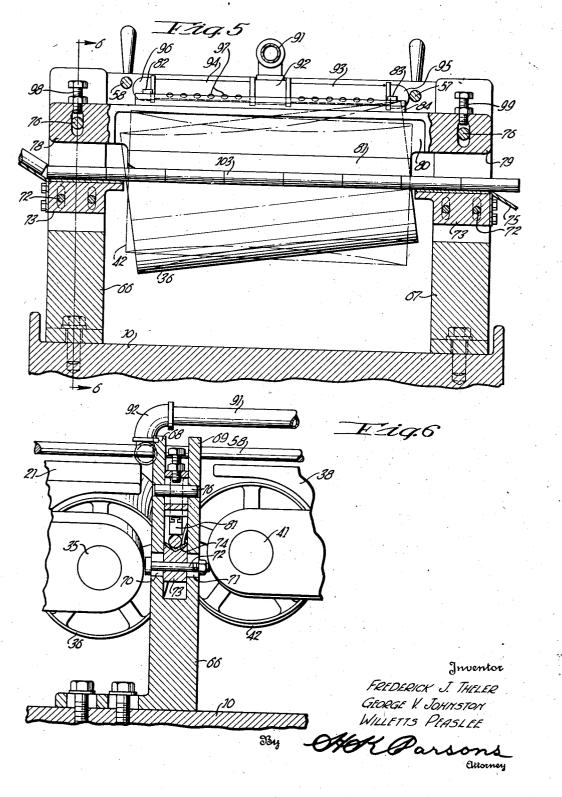
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LAPPING MACHINE

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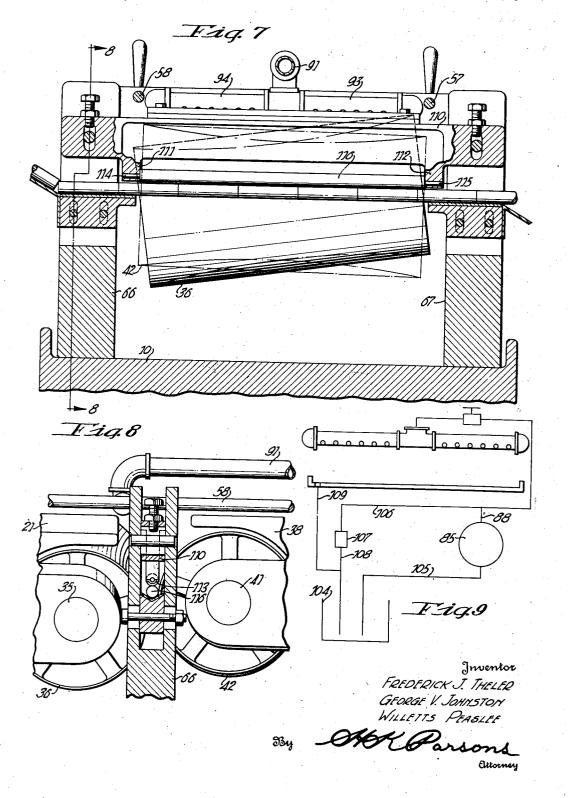
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2,073,079

LAPPING MACHINE

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Application July 15, 1932, Serial No. 622,662

15 Claims. (Cl. 51-103)

This invention relates to improvements in machine tools and especially to a machine for providing smooth surfaces on work pieces, which surface is devoid of grooves or scratches.

- An object of the invention is the provision of such a machine capable of continuous high production and in which the work is finished with a uniform diameter from end to end.
- Another object of the invention is the pro-10 vision of an improved lapping machine operable at a high production rate and embodying a new principle of lapping.

A further object of the invention is the provision of a lapping machine having universal

15 adjustment whereby all sizes of work pieces within the range of the machine may be expeditiously produced.

Other objects and advantages of the present invention should be readily apparent by refer-

20 ence to the following specification considered in conjunction with the accompanying drawings, forming a part thereof, and it is to be understood that any modifications may be made in the exact structural details there shown and described

25 within the scope of the appended claims, without departing from or exceeding the spirit of the invention.

In the drawings:

Figure 1 is a front elevation of a machine em-30 bodying the principles of this invention.

- Figure 2 is an end elevation thereof as seen from the left hand side in Figure 1.
- Figure 3 is a top plan view of the machine shown in Figures 1 and 2.
- Figure 4 is a fragmentary longitudinal sec-35 tional view as seen along line 4-4 on Figure 3. Figure 5 is a transverse sectional view as seen along line 5-5 on Figure 1.
- Figure 6 is a sectional view taken on line 6-40 of Figure 5.

Figure 7 is a sectional view similar to Figure 5 showing a modified structure for performing the invention.

Figure 2 is a sectional view taken on line 8-8 45 of Figure 7.

- Figure 9 is an hydraulic diagram illustrating the mechanism for circulating the abrasive material used with the machine.
- Figure 10 is a fragmentary sectional view of a 50 modification showing the work supported on a separate support.

Throughout the several views of the drawings similar reference characters have been employed to denote the same or similar parts.

55 A machine embodying this invention may be

mounted on any suitable type of support, such as the bed io which has formed on its upper surface at opposite ends the guides 11 and 12 being received in correspondingly shaped guideways 13 formed in heads or slides 14 and 15 mounted respectively at the left and right hand sides of the bed 10, as viewed in Figure 1. The head 15 may be conveniently termed the work control head while the head 14 is the operating head and since the heads are substantially duplicates of one :0 another it is deemed sufficient if in the main but one of them be described in detail.

Accordingly, the head 14 has secured therein against rotation and independent axial movement, a nut 16 in threaded engagement with an 15 adjusting screw 17 rotatably journaled against axial movement in a bearing 18 secured to the extreme end of the guide 11. The screw 17 projects beyond the bearing 18 and has secured thereto a hand or pilot wheel 19 whereby said 20 screw is rotated for effecting the adjustment of the slide or bracket 14 relative to the way 11.

The head 14, at its forward end, is provided with a face plate 20 against which is butted an oscillatable or tiltable carrier 21 (Figure 4) 25 which includes journal bearings 22 and 23 (Figure 3). The carrier 21 is oscillatably mounted on the bearing portion 24 of a trunnion 100 carried by the face plate 20 of the head 14. The wall or face plate 20 of the head is provided with 30 a plurality of elongated arcuate slots 25, 26 and 27 (Figure 2) through which respectively extend clamping bolts 28, 29 and 30. The bolts 28 and 30 respectively enter the base of the trunnion bearings 22 and 23, while the bolt 29 is re-35 ceived in a threaded hole formed in a flange 31 formed along the upper end of the carrier 21. From the foregoing it will be noted that the carrier 21 may be oscillated relative to the face plate 20 or adjusted about the axis of trunnion 24 and clamped in said oscillated or adjusted position by means of the bolts 28, 29 and 30. In order to minutely oscillatably adjust the said carrier, the face plate 20 has projecting from its rear surface a lug or ear 32 (Figure 2) hav- 45 ing formed therethrough a threaded hole into which an adjusting bolt 33 is threaded having its one end abutting a collar or roller 34 carried by the stud or bolt 28. To determine the amount of oscillation given to the carrier 50 21 it has formed on or secured to the end thereof a pointer or zero mark 101, see Figure 1, which co-operates with suitable graduations 102 carried by the adjacent end of the slide face plate 20.

Extending through the carrier journal bear- 55

ings 22 and 23 is a shaft or spindle 35 (Figures 1 and $4)^{i}$ to which is secured a comparatively long roll or drum 36 (Figure 5) adapted to rotate with the shaft and adapted to have its axis

5 disposed at an angle depending upon the adjustment of the carrier 21 around the axis of the trunnion 24.

The head 15 is likewise provided with a face plate 37 (Figures 1 and 3) against which is butted 10 a carrier 38 having integral therewith the jour-

nal bearings 39 and 40. Rotatably mounted in the journal bearings 39 and 40 is a spindle or shaft 41 to which is secured for rotation therewith a roll or drum 42 (Figures 1 and 4). The 15 carrier 38 and parts carried thereby are adapted to be oscillated or adjusted about a trunnion secured in the bracket or slide 15 which trunnion is similar to the trunnion 100 of the slide or

head 14. The peripheries of the rolls or drums 20 36 and 42 are spaced from one another to form a work receiving throat through which the work 103 passes while being operated upon.

In order to rotate the shafts or spindles 35 and 41 they are each respectively provided on one ²⁵ end with a sprocket 43 or 44 about which is extended a sprocket chain 45. The sprocket chain is also trained about an idler sprocket 46 rotatably journaled on a stud 47 secured in the bed 10, at a point substantially midway between ³⁰ the sprockets 43 and 44 near the base thereof as well as about a second idler sprocket 48 rotatably journaled on a stud 49 projecting from the bed 10 to one side of the stud 47. The chain 45 is further passed around the driven sprocket ³⁵ 50 keyed or otherwise secured to one end of a countershaft 51 rotatably journaled in the walls of the bed 10. The countershaft 51 also carries a sheave 52 having a plurality of V-shaped grooves therein each receiving a V-type belt ⁴⁰ 53 which belts are in turn trained about a driving sheave 54 secured in any desirable manner to the motor shaft 55 of the electrical motor or prime mover 56 secured to one end of the bed 10. From the foregoing it will be noted that the

 45 drums 36 and 42 are simultaneously rotated in the same direction from a single source of power such as the motor 56 (Figure 1). It should also be noted that the sprockets 43 and 44 are of slightly different diameters so that a slight dif-50 ferential in rotation between the drums 36 and 42 is had. Further, the direction of rotation of the drums is such that the proximate points thereof, which form the work receiving throat, rotate or move in opposite directions, namely, 55 the face or periphery of drum 42 in the throat travels upwardly as indicated by the arrow associated therewith in Figure 1 while the thereto opposed periphery of the drum 36 travels downwardly, again as indicated by the arrow asso-

60 ciated therewith.

Work pieces produced by this machine must not only have the surface thereof smooth and devoid of scratches and grooves, but must be held circular from end to end within very narrow limits. ⁶⁵ Therefore, in order to maintain the parts in adjusted positions and prevent deflection thereof during operation, the face plates 20 and 37 have extending between them a pair of tie rods 57 and 58 (Figure 3) being respectively positioned at 70 the rear and forward sides or ends thereof. As seen in Figure 3, the tie bars 57 and 58 each have one of their ends secured respectively at 59 and 60 in the face plate 37 and have their other ends extending through the face plate 20, which ex-⁷⁵ tending ends are threaded to receive nuts 61 and

62, each nut being provided with handles 63 whereby it may be readily rotated or adjusted. The face plate 20 adjacent each of the nuts 61 and 62 is provided with a pointer 64 (Figure 1) which overlies the nut for co-operating with graduations 65 placed around the exterior of the nuts adjacent the face plate 20. In the operation of the machine, if it is found that the pins do not feed through the work throat at a uniform rate, or one end of the throat pinches the work 10 more than the other, the proper nut 61 or 62 is actuated to either reduce or enlarge that end of the work receiving throat.

As shown in the drawings and because of the tiltable carriers 21 and 38 as above described, 15 the drums 36 and 42 are adapted to have their axes disposed at an angle to one another and each has its axis disposed at an angle to the horizontal plane of the machine. The drum 42 of the work control head has its axis disposed 20 at a relatively slight angle to the horizontal extending upwardly from right to left, as seen in Figure 5, or having its axis disposed at an angle extending upwardly from the rear toward the front end of the machine, the direction of extent 25 of this angle being such as to automatically feed work pieces from the front or entrance side of the machine to the discharge or rear thereof. The drum 36 of the operating head has its axis disposed at a much steeper angle than the axis 30 of the drum 42 and in an opposite direction, or extending upwardly from left to right, as seen in Figure 5, or extending upwardly from the front end toward the rear end of the machine. This roll or drum provides the finish on the work 35 as it is axially fed by the control roll or drum 42

As shown in Figure 4 in connection with one embodiment of the mechanical features of our invention, the axis of the work 103 is disposed 40 above the plane or line joining the axes of the rolls at the points where the axes of said rolls cross each other when viewed, for example, from the left-hand end of the apparatus as seen in Figure 1, which as shown in Figure 5, is sub-45 stantially midway of the length of the rolls. In other words and as is later more fully described and for reasons later herein set forth in greater detail, the line through which or the path of travel along which the axis of the work is moved (from 50 left to right in Figure 5) is above any line joining the axes of the opposed rolls or drums 36 and 42. The proximate points of the said rolls are spaced from one another a suitable distance to provide this relationship, which distance is less than the 55 diameter of the work and represents the point or points above the point where the roll 36 tends to pull the work downwardly through the throat, as viewed in Figure 4, for thereby, as is later explained in greater detail, we are enabled to 30 gain certain advantages flowing from the fact that the work pieces, throughout their entire travel from left to right, as viewed in Figure 5, are supported by the two rolls or drums 42 and 36 and from the fact that thereby we may dis-65 pense with a separate work carrier or support underneath the work pieces; in Figures 4 and 5 it will be noted that the space immediately underneath the work pieces 103, throughout the region in between the operating member 36 and the $_{70}$ control member 42, is devoid of means for supporting the work pieces along their lowermost faces. All of this is more clearly described hereinafter.

In order to maintain proper contact between 75

the periphery of said rolls or wheels 36 and 42 and work 103, the bed 10 has secured to it substantially midway of its length and at opposite ends of the grinding threat, posts 66 and 67 (Fig-

- 5 ure 5) having their upper ends bifurcated or forked to provide arms 68 and 69 (Figure 6). Near the lower ends of the arms 68 and 69 they are provided in alignment with one another with slots 70 and 71 through which extends clamp
- 10 bolts 72 for securing in adjustable position a block 73 having a trough 74 formed at the upper end thereof. The trough 74 is faced with soft rubber, felt or other material to avoid scratching or marring of the work as it is introduced into
- 15 the machine. Trough 74 is positioned or alined with respect to the faces of the rotary members 42 and 36, the latter being trued or shaped as hereinafter described, to introduce the work pieces 103 (see Figure 5) in between these two
- 20 members to be supported thereby and operated upon. The post 67 carries a similar mechanism including a block similar to block 13 for providing a discharge trough or chute 75 (Figure 5), likewise faced with soft, non-scratching mate-
- 25 rial receiving the work from the throat. Trough 75 is also appropriately alined with respect to the operative faces of the members 36 and 42 at the right-hand end thereof, as viewed in Fig-
- ure 5, in order to receive the work pieces from 30 these members and virtually to form an alined continuation of the support for the work pieces 103 formed by the rotary members 36 and 42 themselves, in this embodiment or form of their invention. 35
- Near the upper ends of the arms 58 and 69 they support a pin 76 (Figures 5 and 6) which passes through an elongated slot 77 formed in lugs 78 and 79 projecting from opposite ends of a pressure shoe 80. The pressure shoe 80 has
- 40 secured to its lower end a soft rubber, felt or other non-scratching contact strip 81 (Figures 5 and 6) which bears on the upper surface of the work to hold it in contact with the peripheries of the drums 36 and 42. The pressure
- 45 shoe 80 (see Figure 3) contacts with the work or work pieces 103 and tends to force or hold them downwardly (see Figure 4) but because the proximate points of the rotary members 36 and 42 are spaced from one another by a distance
- 50 which is less than the diameter of the work 103, as already above pointed out, the work 103 cannot drop downwardly, as viewed in Figure 4, nor can the pressure shoe 80 cause the work to be forced downwardly and hence out of the operat-
- 55 ing throat and into the above-mentioned free space immediately underneath the work 103 (see Figure 4). The pressure shoe 80 is held in contact with the work by gravity only and is weighted in any suitable manner to vary the pressure on
- 60 the work. In order to vary this pressure, and hence the pressure of contact between the work and the rotary members 42 and 36, the shoe has projecting upwardly from it a pair of studs 82 and 83 (Figure 5) adapted to receive weights 65 such as 84 which may be one or more in number
- depending on the necessary or desired pressure to be had on the work. The surface on the work is produced by the

coaction with the above described parts of a cir-70culating abrading material which may be any known lapping compound in which a liquid and a fine abradant material are employed. The abradant material and liquid are thoroughly agitated to insure the proper suspension in the liq-75 uid of the abradant material, which is circu-

lated by a suitable pump 85 (Figure 1) secured to the rear end of the bed 10 and driven by multiple V-belts or the like 86 which extend in turn about an extension of the sheave 52 on the countershaft 51 and a sheave 87 associated with the pump 85. Extending from the pump 85 is a flexible hose or conduit 88 which terminates in a valve 89 carried by a bracket 90 secured to the head 15. Extending from the other side of the valve 89 is a pipe 91 terminating, as shown in 10 Figures 3 and 5, in a T 92 from which branch distributor pipes 93 and 94 extend, the latter terminating in caps 95 and 96. The branch distributor pipes are each provided with a plurality of holes or slits 97 through which the abrading material flows against the side of the pressure shoe for distribution along the drum 36.

To limit the ultimate drop of the pressure shoe 80, as when there is no work in the throat, the lugs 78 and 79 have threaded into them stop 20 bolts 98 and 99, respectively, adapted to engage with the pins 76. Suitable lock nuts are associated with the bolts for locking them in adjusted positions. When desired to grind different diameters of work, the bolts 98 and 99 are ad-25 justed to properly position the wear strip 81 relative to the axis of the work.

The lapping compound is normally contained in a tank or sump 104, shown diagrammatically in Figure 9, disposed within the bed 10 from 30 which it is drawn by the pump 85 through a suction pipe 105. In order to keep the lapping compound thoroughly mixed the pipe or conduit 88 has extending from it a conduit 106 in which is placed a relief valve 107 connected by a pipe 108 35 to the tank or sump 104. The pump 85 has a capacity greatly in excess of the amount of lapping compound needed or capable of being discharged through the orifices 97 in the branch distributor pipes 93 and 94 so that a large amount of the lapping compound is returned to the tank or sump 104 through the relief valve 107 at such a speed and in such quantities that it constantly agitates the material therein. The compound actually dicharged through the dis-45 tributor pipes 93 and 94 is collected on a suitable drain board provided in the machine (diagrammatically indicated in Figure 9-compare Fig. ures 5 and 7) for returning same to the sump or tank by way of the conduit 109 connected at op-50 posite ends with the drain board and conduit 108.

In the modification shown in Figures 7 and 8, the pressure shoe [10 is supported in the same manner as disclosed in Figure 5 and described above. The pressure shoe, however, does not carry a yieldable or soft wear strip, but instead has formed adjacent the ears 78 and 79 lugs 111 and. 112 having a semi-circular bearing formed therein. The bearing is completed by means of removable caps 113, see Figure 8, and respective-60 ly receives the ends 114 and 115 of a roller 116. The roller 116 is in the nature of a bar and contacts with the work pieces for holding them in the work receiving throat in simultaneous contact with the lapping and governing rollers or 65 wheels. The pressure shoe 110, similar to the pressure shoe 80, has projecting from its upper ends suitable lugs receiving the weights for supplying the desired pressure on the work to maintain the proper contact with the wheels. 70

In the embodiment shown in Figure 10 the mechanism is shown with the proximate portions of the wheels spaced further from one another so that the work piece, instead of being entirely supported by the wheels as in the embodi- 75

3

ment above described in connection with Figures 4, 5 and 6, may be supported on a work rest blade 117 or the like. This work rest blade 117 either is made of some relatively non-scratching 5 material or is provided with a strip or surface, as shown at 118 in Figure 10, made of such a non-scratching material. In this construction the operating or lapping member is tilted at the same relatively steep angle as was above de-10 scribed while the control or feed member is tilt-

ed at the opposite bút very slight angle.

In ordinary grinding machines the axis of the work is disposed in a plane parallel with the plane of the axis of the grinding wheel or par-15 allel with the abrasive periphery of the wheel so that a line contact is had between the wheel and work parallel with the axis of the work. Any vibration or lateral movement of either the work or the wheel causes the wheel to dig into the 20 work and thereby results in work having ridges and valleys extending the full length of the work and around it so that a smooth surface is not formed thereon. These ridges and valleys constitute what is commercially known as chatter. 25 on the work, which when the work is placed in use results in relatively rapid wearing of the

part until the ridges are completely removed.

By the use of this machine and with the operating or lapping member disposed with its axis 30 at a relatively steep angle to the axis of the work, the direction of motion of the surface of the lapping member, this being the direction in which the finely divided abradant material of the lapping compound is made effective upon the 35 work, is oblique to the line of contact between the periphery of the member and the surface of the work, whereby the operating or lapping member simultaneously engages the tops of a plurality of ridges and operates upon the latter oblique-

- 40 ly to the line of contact between the work and member. In other words, the line of movement of a point on the lapping member to traverse that point across the line of contact of the member with the work is not at an angle of 90 de-
- grees to the axis of the work, but is obliquely disposed relative thereto whereby the above-mentioned point on the lapping member. which point may be considered to be an abrasive particle, actually contacts with and obliquely 50 traverses the tops of the ridges between a pair of the valleys and thereby insures the reduction
- of said ridges to the level of the valleys, and results in work pieces having a smooth surface absolutely devoid of any chatter. By this ac-55 tion, therefore, no abrasive particle or point on the lapping member can move in a path to carry
- it clear through a valley, but it must obliquely traverse a ridge and thereby must do its share of the work in reducing that ridge.

It will be noted that in the mechanism illus-60 trated in Figures 1 to 8, inclusive, and as already set forth above, there is no work support of any type and that the work pieces are solely supported by the peripheries of the opposed oper-65 ating and control members. By this construction no imperfections in the supporting member or members due either to being non-parallel or out of alignment or for any other cause are transferred to the work since the work is influenced 70 only by and is under control of the opposed members which have their peripheries trued or shaped to the necessary and desired form. In certain circumstances the operative surfaces of either or both of these opposed members may be slight-75 ly concaved so that either or both members con-

tact the work piece throughout its length. The concave shapes of the members 42 and 36 are indicated in the drawings, the operating or lapping member 36 being tilted at a greater angle and having a somewhat greater degree of con-5 cavity than that of the regulating member 42. Furthermore, by supporting the work on the peripheries of the wheels, no scratches are imparted to the work as would be the case if a relatively hard supporting blade or the like were provided, 10 which would also be subject to considerable wear, as is well known in standard commercial centerless grinding practice. In order to maintain proper pressure of contact between the work and the peripheries of the operating and control 15 members at the respective and opposed lines of tangency or of contact of the latter with the work, the overhead pressure shoe, above de-scribed, is provided. By the use of the soft rubber or felt contact strip with either the overhead 20 pressure shoe or work supporting blade such as that shown in Figure 10, the abrasive grains and particles which are carried by the work during its rotation, are wiped off or embedded in the surface 25 thereof. In other words, the soft pressure shoe yields and allows any abrasive grains that are carried thereto by the work to embed themselves therein so that the grains do not dig into the work and scratch or mar the surface thereof. This is of substantial advantage and the results 30 are preferable to those achieved if a relatively non-yielding pressure shoe or supporting strip were employed without some provision against the action of abrasive grains, for such a nonyielding pressure shoe or support might act as 35 a bed for the abrasive grains as they are carried by the work and hold same in position to dig into and scratch the work.

It has further been found in practice, as suggested above, that a very low differential in pe-40 ripheral speed between the work and operating or lapping member is essential to the production of a proper flat lapped finish on the work. In normal grinding this differential of speed is considerable since the grinding wheel travels at 45 about 6000 peripheral feet a minute while the work travels but 150 peripheral feet a minute. In the present machine it has been found that with a peripheral speed of the operating member in the neighborhood of 440 peripheral feet a min- 50 ute and with the control member and work travelling at about 410 peripheral feet a minute, the best results are obtained. This ratio produces a very flat (smooth or devoid of grooves and ridges) lapped finish and as the ratio is increased 55 the finish produced approaches a grinding finish, which as is well known is composed of alternate grooves and ridges, but due to the angle of the operating member the grooves and ridges are not formed circumferentially of the work, as is 60 usual grinding practice as above described, but are formed diagonally thereof. In other words, the nearer the ratio between the peripheral speed of the wheel and work approaches 1 to 1, the flatter and finer the finish, while the greater this 65 ratio becomes, the nearer the finish approaches a grinding finish. It being understood, of course, that the grit of the abrasive grains must be within a certain range of fineness to obtain these results.

In the operation of the machine illustrated in the drawings, the abrasive material circulated by the pump 85 is equally distributed by the overhead pressure shoe along the periphery of the operating member so that an equal action is 75

had throughout the length thereof. It has further been found that with the wheels properly aligned and trued the overhead pressure shoe holds the work in contact with the wheels 5 throughout its length and with equal pressure,

- so that should the work piece be slightly tapered the larger end thereof is held against the members with greater force or under greater pressure until it is reduced to substantially the same di-
- 10 ameter as the other or smaller end whereby the machine in addition to providing a lapped finish on the work also produces work pieces that are round and straight from end to end.
- As is clear from the drawings and as is in-15 dicated also above, the lapping and controlling members are preferably of substantial axial length, illustratively and preferably (see, for example, Figures 3, 5 or 7) of an axial length in excess of their diameters; throughout the length
- 20 of the controlling member 42 and along its line of contact with the work piece or pieces 103. the member 42, due to its tilt with respect to the axis or path of travel of the work and hence
- due to the inclination between the path of 25 movement upwardly (Figure 1) of its operative surface with respect to the path of movement or axis of the work piece, steadily effects a feeding movement of the work pieces from the front or entrance side of the machine to the discharge or
- 30 rear thereof (left to right, as viewed in Figures 5 and 7) while the higher speed member (member 36) performing the lapping action has, as above described, such an opposite inclination or obliqueness between the generally downward
- 35 (see Figure 1) movement of its operative surface and the path of travel or axis of the work piece that any point on the member 36, such as an abrasive particle moves obliquely to the circumferential ridges and valleys (resulting from
- 40 the grinding of the work prior to being subjected to the operation of our apparatus) and at an obliqueness opposed to the direction of feeding or axial travel of the work 103, all while the latter is being rotated, and thereby the reduction
- 45 or levelling off of the ridges is dependably and quickly achieved. The action of the abrasive particles throughout the extent of the line of contact between the work and the lapping member 36 is thus made to be effective in a direction
- 50 oblique to this line of contact and hence not parallel to the direction in which the grooves or valleys extend circumferentially about the work piece and as the work piece is continuously rotated and moved through the machine, the effect
- 55 is somewhat like wiping this obliqueness of action, opposed to the direction of feed, continuously around the whole work piece in a manner to cause abrasive particles to traverse (rather than to line up with) the ridges and valleys and
- 60 hence to achieve a rapid and dependable reduction of high points on the work. This reduction takes place whether the high points are due to longitudinal chatters or circumferential grinding grooves, or scratches, or both.
- 65 From the foregoing it will, therefore, be noted that the machine of this invention is particularly advantageous in the production of fine surfaces on circular work pieces and that there has been provided a mechanism that will rapidly, con-
- 70 tinuously and at a high rate of production produce work pieces having a lapped surface or finish thereon, thereby materially reducing the cost of manufacture of such work pieces. What is claimed is:

751. In a lapping machine of the class described

the combination of a bed, a pair of opposed peripherally operative controlling and lapping members adapted to be rotated at slightly different speeds, the controlling member having its axis disposed at an angle to the intended axial position of a work piece to be operated upon and extending in a given direction, the lapping member having its axis disposed at a greater opposite angle than that of the controlling member, means supporting one of said members for adjustment toward and away from the other to space the proximate portions of the peripheries thereof a distance less at all points than the diameter of the work to be operated upon, said members engaging the work in respective 15 lines of contact spaced apart by a distance substantially equal to the diameter of the work and lying in a plane above said proximate portions of the peripheries of said members, and pressure means having a non-scratching contact strip 20 above the work for engagement with the work to hold the same in contact with the peripheries of said members, means carried by the bed adjacent the ends of said members for supporting the pressure member, means operatively related 25 to the pressure means for varying the pressure thereof on the work, means carried by one of said pressure member supporting means for supplying unfinished work to said members, and means carried by the other of said pressure member 30 supporting means for receiving the work from said members.

2. In a lapping machine of the class described the combination of a bed, a work head and control head mounted on opposite ends of the bed, \$5 means adjacent each end of the bed for actuating the heads toward and from one another to position same, a rotating control member carried by the control head and operable at a given rate of speed, a lapping member rotatably carried by 40 the operating head and operable at a speed slightly in excess of the speed of the control member, the adjusting means of said heads being adapted to position the members a distance apart less than the diameter of the work to be operated 45 upon, a post at each end of the control and operating members, a pressure member supported by the posts for contact with the work to hold same in engagement with the control and operating members, a non-scratching contact surface 50 between the work and pressure member, and means carried by the posts for supplying work pieces to the members and receiving same therefrom.

3. In a lapping machine of the class described 55 the combination of a bed, a work head and control head mounted on opposite ends of the bed, means adjacent each end of the bed for actuating the heads toward and from one another to position same, a rotating control member carried 60 by the control head and operable at a given rate of speed, a lapping member rotatably carried by the operating head and operable at a speed slightly in excess of the speed of the control member, the adjusting means of said heads being adapted 65 to position the members a distance apart less than the diameter of the work to be operated upon, a post at each end of the control and operating members, a pressure member supported by the posts for contact with the work to hold 70 same in engagement with the control and operating members, a non-scratching contact surface between the work and pressure member, means carried by the posts for supplying work pieces to the members and receiving same therefrom, and 75

means securing the control and operating members to their respective heads for tilting adjustment relative thereto whereby the axes of the members may be disposed at an angle to one an-5 other and to the bed.

4. In a lapping machine of the class described the combination of a bed, a work head and control head mounted on opposite ends of the bed, means adjacent each end of the bed for actu-

- 10 ating the heads toward and from one another to position same, a rotating control member carried by the control head and operable at a given rate of speed, a lapping member rotatably carried by the operating head and operable at a speed slight-
- 15 ly in excess of the speed of the control member, the adjusting means of said heads being adapted to position the members a distance apart less than the diameter of the work to be operated upon, a post at each end of the control and operating
- 20 members, a pressure member supported by the posts for contact with the work to hold same in engagement with the control and operating members, a non-scratching contact surface between the work and pressure member, means carried
- 25 by the posts for supplying work pieces to the members and receiving same therefrom, means securing the control and operating members to their respective heads for tilting adjustment relative thereto whereby the axes of the members 30 may be disposed at an angle to one another and
- to the heads, and means for supplying an abrasive compound to the operating member. 5. In apparatus for lapping the surface of ar-

ticles of round cross-section, in combination, a

- 35 regulating wheel, a lapping wheel having extremely fine grit, a member against which the article to be lapped may rest in a position between said wheels and in contact with the peripheries of both of the same, means driving said
- 40 regulating wheel at a rate whereby it positively rotates said article at a predetermined speed, means adapted to guide a series of articles to be lapped to said position, means mounting said lapping wheel in a position in which its active
- 45 surface will move across said article in a direction inclined with respect to the axis thereof, means adapted to drive said lapping wheel in a direction of rotation about its axis substantially the same as that of said regulating wheel and
- 50 at a surface speed which exceeds the surface speed of the article upon which it operates by an amount which is below the effective cutting speed of a grinding wheel, means adapted to vary the angular position of said regulating wheel 55 with respect to the path of the article and there-
- by vary the rate of feed of the article, and means adapted to adjust independently the angle between said path and said lapping wheel to vary the angle of travel of the lapping surface with 60 respect to the direction of travel of the surface

of the article which it contacts.

6. In apparatus for lapping the surface of articles of round cross-section having elongated ridges extending lengthwise along its surface, in 65 combination, a regulating wheel, a lapping wheel having extremely fine grit adapted to act upon the surface of the article to be lapped without substantial reduction in size thereof, a member along which articles to be lapped may travel 70 axially in a series into and out of position between and in contact with the peripheries of said wheels, said regulating wheel being driven at such rate as positively to rotate said articles in accordance with its surface speed and being adapted to feed

75 said articles in an axial direction, and said lap-

ping wheel being mounted with its active surface moving in a direction inclined with respect to the axis of said articles, and means driving said lapping wheel in a direction of rotation about its axis substantially the same as that of said regulating wheel and at a surface speed which exceeds the surface speed of the article being acted upon by an amount which is below and only a fraction of the effective cutting speed of a grinding wheel, the line of contact between said lap-10 ping wheel and said article extending circumferentially about said article to bridge a plurality of said ridges.

7. In apparatus for lapping the surface of articles of round cross-section having elongated 15 ridges extending lengthwise along its surface, in combination, a regulating wheel, a lapping wheel having fine grit, said wheels being adapted to receive a cylindrical article therebetween in contact with the peripheries of both of them and said lap-20 ping wheel having its active surface moving in a direction inclined with respect to the axis of said article, means driving said regulating wheel at such rate and direction as to cause it positively to rotate and feed said article, means driving said 25 lapping wheel in a direction of rotation about its axis the same as that of said regulating wheel and at a surface speed exceeding the surface speed of the article being operated upon by an amount which is below the effective cutting speed of a grinding wheel, the length of said wheels in the direction of the axis of said articles being sufficient to cause the line of contact of said lapping wheel with said article to extend circumferentially about said articles to a substantial ex-35 tent and to bridge a plurality of said ridges, means adapted to adjust the angle of said regulating wheel to vary the rate of feed of the article, and means adapted to adjust independently the angle at which the active lapping surface travels with 40 respect to the article.

8. In apparatus for lapping the surface of articles of round cross-section, in combination, a guiding member along which articles to be lapped may travel, a regulating wheel mounted at one 45 side of said guiding member with its axis inclined thereto and driven at such speed as to positively rotate and feed in an endwise direction the articles to be lapped, a lapping wheel having fine grit opposed to said regulating wheel and 50 adapted to operate upon the surface of said articles in a predetermined and substantially constant direction oblique to the axis thereof and driven in a direction of rotation about its axis substantially the same as that of said regulating 55 wheel and at a surface speed which exceeds the surface speed of the article upon which it operates by a speed below the effective cutting speed of a grinding wheel, both of said wheels being elongated with respect to their diameter and be-60 ing oppositely inclined with respect to the path of travel of the article, and means adapted independently to adjust the angle of each of said wheels with respect to said path of travel whereby the rate of feed of the article and the inclination 65 of the effective path of the lapping wheel may be independently varied.

9. In apparatus for lapping the surface of articles of round cross-section having ridges extending lengthwise along the surface thereof, in 70 combination, a regulating wheel adapted to engage with its periphery and positively to rotate the article to be lapped at a predetermined rate, a lapping wheel having extremely fine gr't adapted to engage said article with its periphery 75

and mounted so as to cause its active surface to travel obliquely with respect to the direction of movement of the surface of the article which it contacts, means adapted to guide a series of

- 5 articles into said position between said wheels, means driving said lapping wheel in a direction of rotation about its axis substantially the same as that of said regulating wheel and at such low rate as will exceed that of the article which it
- 10 contacts by a speed which is below the effective cutting speed of a grinding wheel, the inclination of said lapping wheel with respect to the article being such that its line of contact therewith will extend circumferentially about the article to
- 15 bridge a plurality of said ridges, and means adapted independently to adjust the angularity between each of said wheels and the path of travel of the article.
- 10. In apparatus for lapping the surface of 20 articles of round cross-section, in combination, a guiding member along which articles to be lapped may travel, a regulating wheel mounted at one side of said guiding member with its axis inclined thereto and driven at such speed as to
- ²⁵ positively rotate and feed with its periphery in an endwise direction the articles to be lapped, a lapping wheel having extremely fine grit opposed to said regulating wheel and adapted to operate upon the surface of said articles with
- ³⁰ its periphery in a predetermined and substantially constant direction oblique to the axis thereof, means adapted independently to adjust the angles of each of said wheels relative to the path of travel of the article, and means driving
- ³⁵ said lapping wheel in a direction of rotation about its axis substantially the same as that of said regulating wheel at a surface speed which exceeds the surface speed of the article upon which it operates, the surface speeds of the lapping wheel
- ⁴⁰ and the article being lapped being closely approximate each to the other and such as to alter substantially the direction of the path of contact of particles on the lapping wheel with the article, said path of contact being the vectorial re-
- ⁴⁵ sultant of vectors representing respectively the speed and direction of movement of a particle on the lapping wheel and the speed and direction of movement of that portion of the article engaged by the lapping wheel particle, and said 50 resultant being at an any speed of more than 20° and 50 resultant being at an any speed of more than 20° and 50 resultant being at an any speed of more than 20° and 50 resultant being at an any speed of more than 20° and 50 resultant being at an any speed of more than 20° any speed at a speed
- ⁵⁰ resultant being at an angle of more than 20° and less than 70° with a plane perpendicular to the axis of the article.

11. In apparatus for lapping the surface of articles of round cross-section having longitudi-⁵⁵ nally extending ridges on its surface, in combination, a regulating wheel adapted to engage with its periphery and positively to rotate the article to be lapped at a predetermined rate, a

- lapping wheel having extremely fine grit adapted
 to engage said article with its periphery and
 mounted so as to cause its active surface to travel
 obliquely with respect to the direction of movement of the surface of the article which it con tacts, means adapted to guide a series of articles
- ⁶⁵ into said position between said wheels, and means driving said lapping wheel in a direction of rotation about its axis substantially the same as that of said regulating wheel and a rate of surface speed in excess of that of said article which is
- ⁷⁰ below and only a fraction of the effective cutting speed of a grinding wheel, and is such as to cause the paths of contact of its particles with said article to be substantially altered in direction by the movement of the surface of said article, ⁷⁵ with the limit of and a the limit in the direction.

75 and the length of said wheels in the direction

of the axis of said articles being sufficient to cause the line of contact of said lapping wheel with said articles to extend circumferentially about said articles to a substantial extent and to bridge over a plurality of said ridges.

12. In apparatus for lapping the surface of articles of round cross-section, in combination, a regulating wheel adapted to engage with its periphery and positively to rotate the article to be lapped at a predetermined rate, said regulat-10 ing wheel being arranged with respect to the axis of said article to effect an axial feeding component thereon, a lapping wheel having extremely fine grit adapted to engage with its periphery said article and mounted so as to cause 15 its active surface to travel obliquely with respect to the direction of movement of the surface of the article which it contacts, each of said wheels having an active surface longer than the diameter thereof, means adapted to swing one of said 20 wheels in a horizontal plane relative to the other, means adapted to guide a series of articles into said position between said wheels, and means driving said lapping wheel in a direction of rotation about its axis the same as that of said 25 regulating wheel and at a rate of surface speed relative to that of the work and in excess of that of the article and so far below the effective cutting speed of a grinding wheel as to cause the paths of contact of its particles with said article 30 to be substantially altered in direction by the movement of the surface of said article, the line of contact between said lapping wheel and said article extending circumferentially about the article to a substantial extent. 35

13. The art of lapping the surface of articles having elongated ridges thereon which consists in passing said articles in succession into and out of a position between a regulating wheel and a lapping wheel the active particles of which 40 lapping wheel are greatly finer than the width of said ridges, said articles in said position being in engagement with said regulating wheel and also with said lapping wheel along a helical line which bridges a plurality of said ridges, rotating 45 said regulating wheel at such rate as will cause it to govern the rotation of an article in contact therewith, and simultaneously moving the active surface of said lapping wheel relatively to the surface of said article in a direction substantially 50 opposite to that of the neighboring surface of said regulating wheel and inclined with respect to said ridges, and the surface speed of said article being substantially equal to that of said regulating wheel and being exceeded by the surface 55 speed of said lapping wheel in contact therewith by an amount which is below and only a fraction of the effective cutting speed of a grinding wheel.

14. The art of lapping the surface of cylindrical articles which consists in feeding them end- 60 wise in series between and in contact with the peripheries of a regulating wheel and a lapping wheel having an extremely fine abrasive surface, moving the surface of said regulating wheel in such direction as to tend to feed said articles 65 endwise and at such speed as to control and determine the rate of rotation and rate of feed of said articles, rotating said lapping wheel in a direction of rotation about its axis substantially the same as that of said regulating wheel and 70 at such surface direction and speed relative to the surface speed of said article in contact therewith as will exceed that of said article and cause the path of contact of the particles of said lapping wheel with said article to be distorted into a 75

direction lying between 20° and 70° away from a plane transverse to the axis of the article by reason of the relatively substantial surface speed of the article.

15. The art of perfecting cylindrical articles K by removing elongated projecting ridges from the surface thereof which consists in advancing said articles endwise at constant speed along a path in which they contact the concave periphery of

10 an abrasive member of fine grit along a helical line which extends from end to end of the member and which bridges a plurality of said ridges at an acute angle, rotating said articles at constant speed as they advance and simultaneously rotating said abrasive member about an axis with a radius shorter than the axial length of the member and at a speed which is below and only a fraction of the effective cutting speed of 5 a grinding wheel, whereby the abrasive action of said member is localized upon said ridges and said member is reduced to true cylindrical form without injury to the surface thereof by such action.

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