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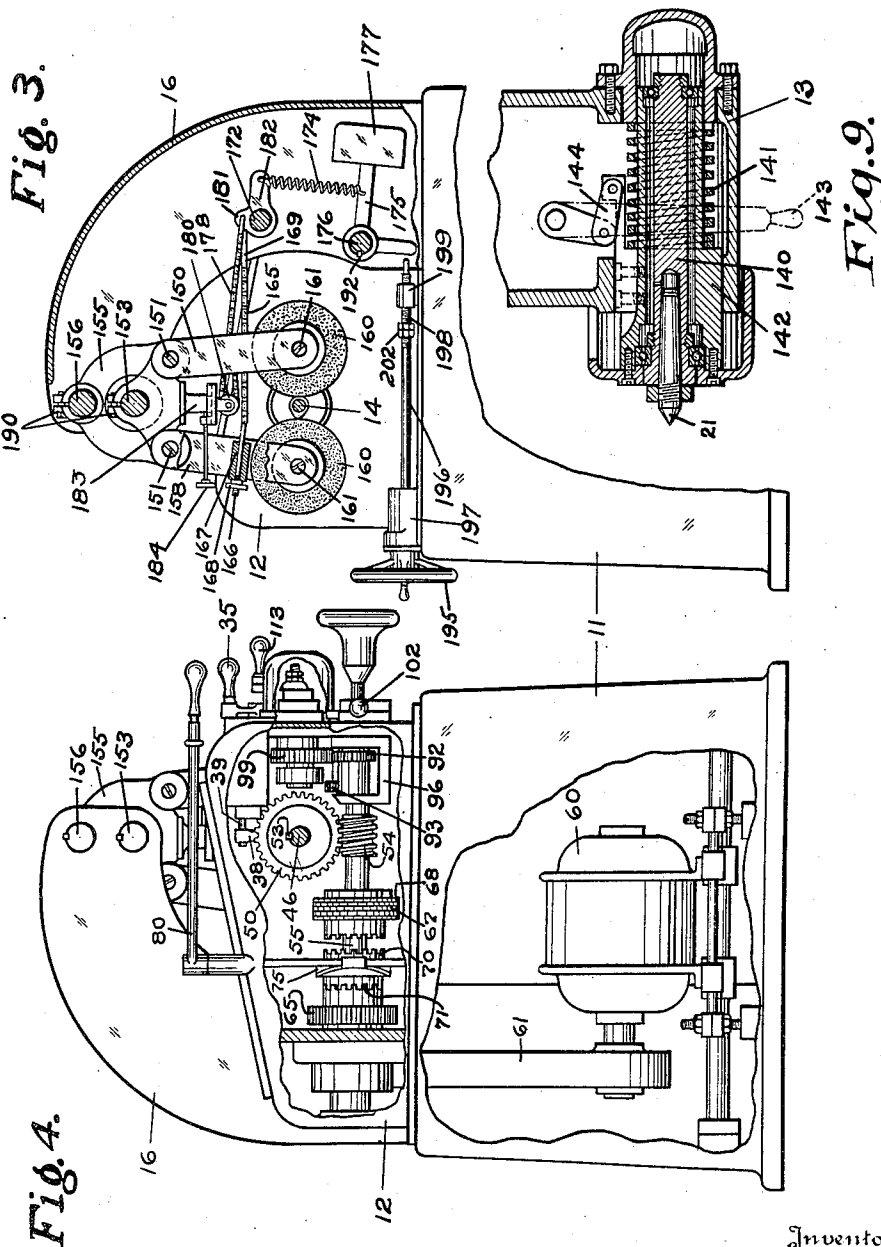
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1,843,301

CAM LAPPING MACHINE

Filed Sept. 28, 1929

5 Sheets-Sheet 3



25 witnesses

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5 Sheets-Sheet 4

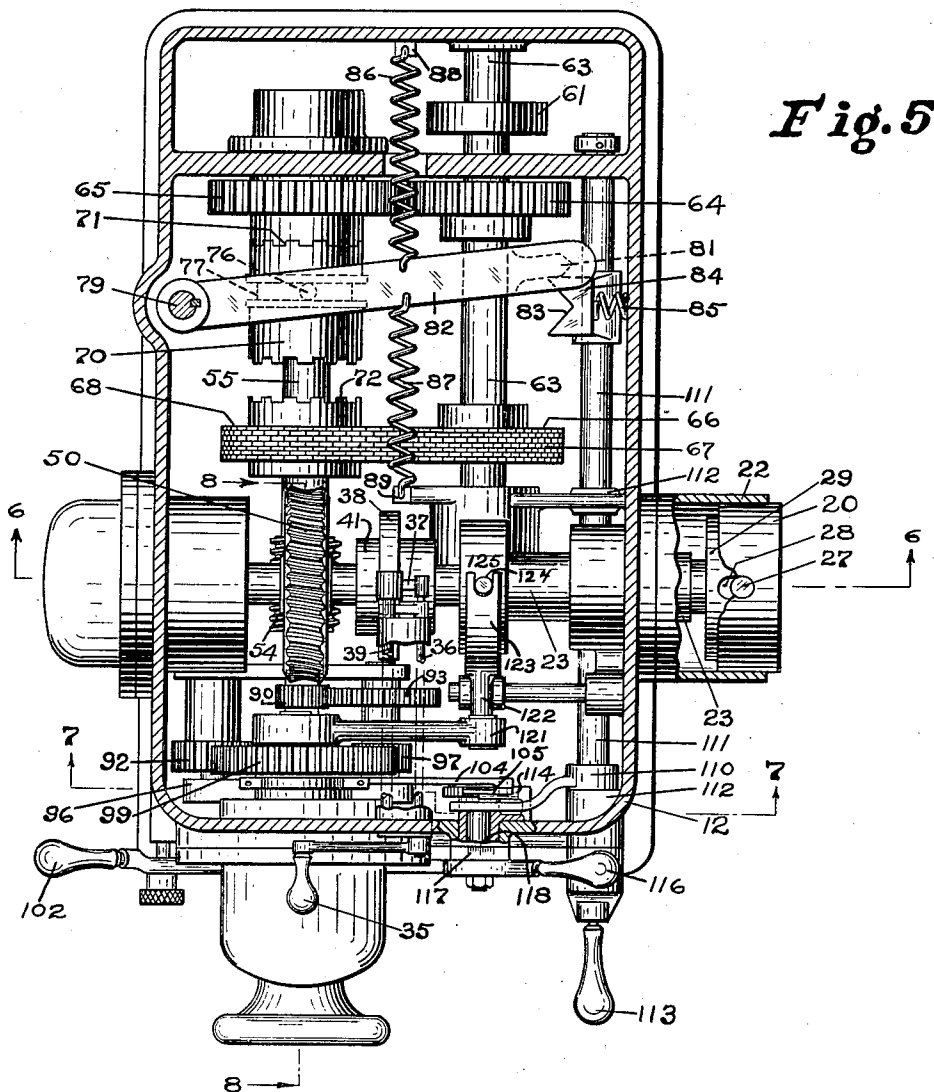


Fig. 5

Witnesses

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5 Sheets-Sheet 5

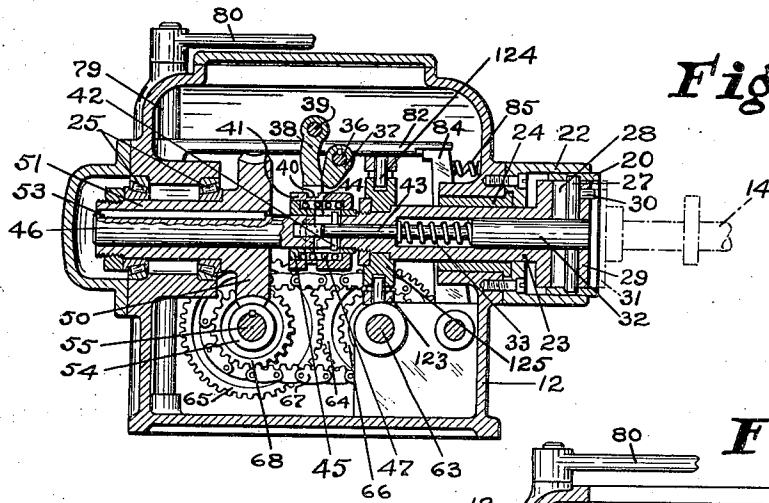


Fig. 6

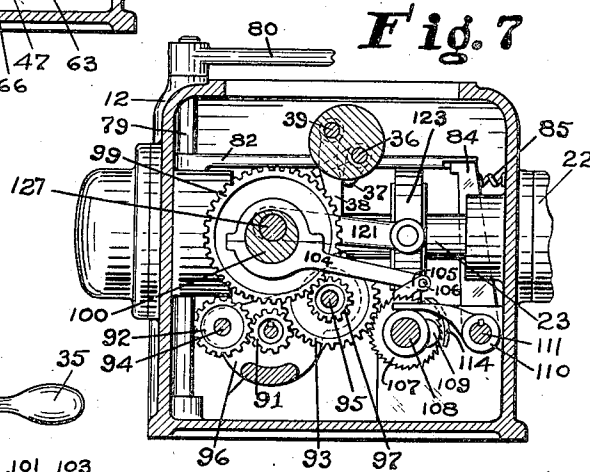


Fig. 7

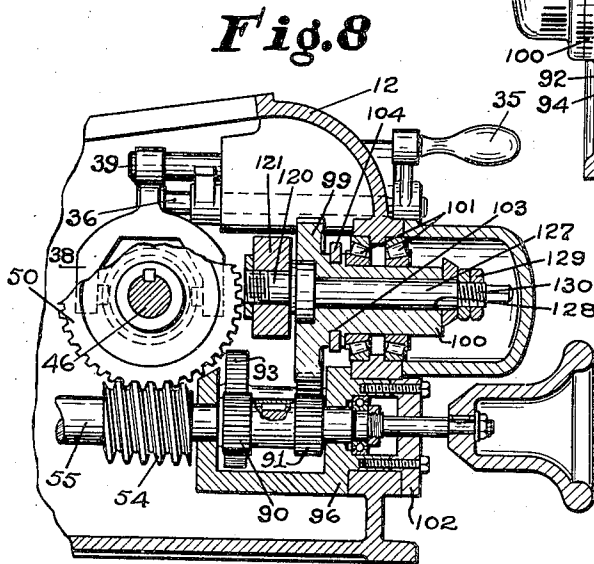


Fig. 8

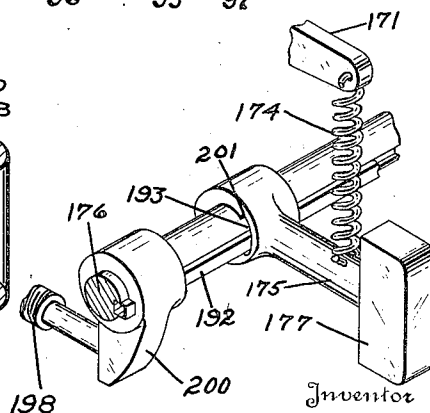


Fig. 11

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UNITED STATES PATENT OFFICE

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CAM LAPPING MACHINE

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This invention relates to lapping machines, and particularly one which will serve to lap an irregular body, such as a cam, whose periphery is not concentric with its axis of rotation and which is not of equal diameter throughout.

Heretofore, various lapping machines have been developed for producing an accurate and highly finished surface on a flat or cylindrical work piece which has previously been ground to approximately the required size. Such lapping machines and lapping methods as developed in the past have not been adapted in any way for lapping work of irregular contour, such as a cam, whose periphery is not isodiametrical or concentric with the axis of rotation.

A camshaft used in automobile engines and the like is required to revolve at very high speed and to move the engine valves with a fine degree of precision and in such an accurately timed relationship that the valves will open and shut at correct times relative to the timing of the spark and the compression of the gas. It is necessary that the cam be correctly shaped; hence, the accuracy with which the surface has been finished is of vital importance. A rough surfaced cam is likely to wear the cam follower or to produce a noisy effect or otherwise act detrimentally. The automobile makers therefore appreciate that it is desirable to provide such a cam with a smooth surface and one which is true in shape. These cams are ordinarily finished by a grinding operation but there are many problems involved in grinding such an irregularly shaped body, owing to its not having a surface concentric with its axis of rotation, and the grinding machines which form these cams are not able to produce a highly finished surface within a reasonable production time and expense. Consequently, the cams even after finish grinding have grain markings and rough chatter marks or other irregularities which make the cams noisy and act inefficiently. This makes it desirable to finish the cam by a lapping operation.

It is accordingly the primary object of this invention to provide a machine which will lap a cam or other non-isodiametric body, the

surface of which is not concentric with its axis of rotation, and particularly to provide a machine which will lap such an article efficiently, quickly and without excessive production cost and which will not detrimentally affect the shape of the article being lapped.

The cams, such as used in the modern gasoline engine, are shaped so that there is a rapid rise and fall on the cam to quickly open and close the valve. To obtain a proper finish on a work piece which is being abraded, it is desirable to maintain a substantially uniform relative surface speed between the work and the lapping or abrading elements. In case of a camshaft which has a plurality of spaced cams arranged at intervals along the shaft and which have their rises and falls timed at different intervals, it is impossible to rotate the shaft so as to maintain a uniform surface speed between the cam and the lapping or abrading elements, but the shaft must be rotated at a substantially uniform angular speed. In this case, the lapping member tends to cut heavier on the rise of the cam as the cam is being rotated toward the lapping element and to cut lighter as the cam rotates and the lapping element follows down the fall on the cam. This means that a greater amount of lapping action is obtained on the rise than on the fall of the cam.

It is another object of this invention to provide a suitable mechanism to compensate for the difference in the abrading action on the rise and fall of the cam so that both the rise and the fall may be lapped a uniform amount.

It is a further object to provide a suitable driving mechanism for the camshaft so that it may be rotated first in one direction for a definite period and then reversed and rotated for an equal period in the opposite direction, whereby both the rise and fall of the cam are lapped uniformly.

It is a further object of this invention to provide a suitable support and regulating mechanism for the lapping elements so that they may be maintained in yielding contact with the periphery of the object being lapped at substantially a uniform pressure regardless of the contour of the object.

A further object is to provide a suitable

mechanism which permits both the speed and the extent of reciprocation of the work to be varied relative to the rate of work rotation, and thereby give the operator better control over the finish of the work.

A further object is to provide a method of lapping rotatable, non-isodiametric work, such as a cam, whereby the surface thereof will be finished to a desired degree of smoothness and particularly throughout all portions of its periphery.

With these and other objects in view as will be apparent to one skilled in the art, this invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

In accordance with this invention, we have found that it is feasible to lap an irregularly shaped or non-isodiametric body, the surface of which is not cylindrical or concentric with its axis of rotation, such as a cam, by means of a lapping member which is pressed against the surface of the work during relative rotation of the two, and is held in operative contact therewith by means, independent of the work itself, which serves to provide a desired lapping pressure. Also, the lap or the work may be given a motion longitudinally of the work axis which aids in or causes the lapping operation. The preferred form of lapping member is a rotatable body of suitable material, such as an abrasive wheel of exceedingly fine grit size or a metal lap charged with abrasive or one used with loose abrasive powder. The lapping member is preferably mounted for free rotation, so that it may be driven by frictional contact with the positively rotated work piece. It may be held in operative contact with the work by means of a support which is arranged to move back and forth relative to the work axis as the work revolves and to hold the lapping member in contact with the surface of the work. The desired pressure of contact may be obtained by suitable mechanism, such as a weight or spring, which may be adjusted to give a proper degree of pressure between the lapping elements and the work. If more than one cam is to be lapped, a series of independently arranged lapping elements are provided, each one being so spaced and arranged that it will contact with the proper cam on the work and will follow its contour as the cam rotates.

A special feature of this invention involves the provision of means for lapping the work while it rotates in one direction through a given cycle of operations and reversing the direction of rotation so as to lap the work in the opposite direction through an equal cycle. This serves to lap both the rise and fall of the cam to the same extent. It is preferably accomplished by means of a timing mechanism arranged to throw a clutch and stop the relative rotation between the work and the lapping member after a predetermined num-

ber of rotations. Then, by means of a reversing mechanism, the work is rotated in the opposite direction for the same number of turns and the clutch is again thrown. The speed and the extent of relative reciprocation between the work and the lap may also be varied so as to give the operator better control over the lapping action.

It will also be apparent from the following description, as well as the scope of the appended claims, that a machine embodying various aspects of this invention is also applicable for lapping other types and shapes of work, such as a cylindrical piece, which is rotated about its own center.

One embodiment of this invention has been illustrated in the accompanying drawings, in which like reference numerals indicate like parts:

Fig. 1 is a diagrammatic perspective view of the operating parts of this mechanism;

Fig. 2 is a front elevation of this camshaft lapping machine having parts broken away to more clearly show the driving mechanism;

Fig. 3 is a right-hand end view of the machine, as shown in Fig. 2, with part of the upper frame broken away to more clearly show the arrangement of the lap supporting heads and operating parts.

Fig. 4 is a left-hand end view of the machine, as shown in Fig. 2, having the headstock and part of the base broken away to more clearly show the arrangement of the operating parts;

Fig. 5 is a horizontal sectional view on an enlarged scale, on the line 5—5 of Fig. 2, to illustrate the operating parts of the work rotating and reciprocating mechanisms in the headstock;

Fig. 6 is a cross sectional view on a reduced scale, taken approximately on the line 6—6 of Fig. 5;

Fig. 7 is a cross sectional view on a reduced scale, taken approximately on the line 7—7 of Fig. 5;

Fig. 8 is a fragmentary sectional view taken approximately on the line 8—8 of Fig. 5;

Fig. 9 is a horizontal sectional view through the footstock taken approximately on the line 9—9 of Fig. 2 showing the operating handle and associated parts in broken lines;

Fig. 10 is a fragmentary perspective view, on an enlarged scale, showing the mechanisms for adjusting the length of reciprocation for the work spindle; and

Fig. 11 is a fragmentary perspective view on an enlarged scale showing the mechanism for simultaneously releasing the tension of the spring and weight upon the lapping members.

As shown in the drawings, a camshaft may be lapped by a machine in which the work is both rotated and reciprocated, while each cam is independently lapped by means of a freely rotatable abrasive wheel held yielding-

ly, but independently of the work, in operative peripheral contact therewith. Such a camshaft lapping machine may comprise a base 11 which serves as a support for a headstock 12 and a footstock 13 arranged to support a work piece 14 for rotation about its axis. The lapping members 160 are pivotally mounted on the frame 16 which is in turn supported rigidly on the base 11. These lapping members are arranged to engage and follow the surface of the work at a plurality of stations along the work piece so that they may be simultaneously lapped.

15 *Work rotating and reciprocating mechanism*

A suitable headstock mechanism is provided so that the work piece 14 to be lapped may be rotated and reciprocated for a variable but predetermined time to produce the desired lapping action upon the work piece. The work piece is supported at one end by a rotatable sleeve 20 which is slidably mounted within the flange 22 projecting from the headstock 12. A spindle 23 is rotatably mounted in the bearing 24 at one end and bearings 25 at the other end and is arranged to transmit a rotary motion to the sleeve 20 by means of a pin 27 which is fixed relative to the sleeve 20 and passes through an elongated slot 28 within a disk-shaped projection 29 on the end of the spindle 23. A work driving pin or dog 30 is fixed to the pin 27 and passes through an aperture in the projection 29. The pin 30 engages a driving plate or dog 31 fixed to an end of the work and serves as a driving member to rotate the work piece relative to the lapping members. The pin 27 is arranged so that it may be retracted to telescope the sleeve 20 and the driving pin 30 within the flange 22 to permit placing a piece of work in the machine and then sliding the sleeve 20 and the driving pin 30 into operative relation with the work. The sleeve 20 and driving pin 30 are moved relative to the spindle 23 by means of a rod 32 which is slidably mounted within a central aperture in the spindle 23. The rod 32 is normally held in an operating position by a spring 33 which engages a shoulder within the spindle 23 and a shoulder on the rod 32. The movement of the rod 32 may be controlled by any suitable mechanism, such as a manually operable lever 35 pivotally mounted in the front of the machine. This lever is connected to the forward end of a shaft 36 which has on its other end a projecting arm 37 adapted to engage the surface of a yoke 38 mounted to rock on a shaft 39. The yoke 38 engages an annular groove 40 in a sleeve 41 which is in turn connected by a pin 42 with the reduced portion 43 of the rod 32. The pin 42 passes through an elongated slot 44 in the spindle 23 so that the movement of the yoked member 38 is transmitted through the sleeve 41 and pin 42 to

move the pin 27, sleeve 20 and pin 30 endwise as desired.

To produce the desired lapping action, the work is reciprocated relative to the lapping members while they are relatively rotated. To permit the reciprocation of the spindle 23 and at the same time provide a driving connection with the work piece, it is necessary to provide a suitable yielding connection between the spindle 23 and the sleeve 41 so that the driving pin 30 will always be maintained in operative engagement with the work during reciprocation thereof. To accomplish this, a sleeve 45 is secured to a reduced portion 46 of the spindle 23 and is provided with an outwardly extending flange to take the thrust of a spring 47 in one direction while an inwardly projecting flange on the sleeve 41 serves to engage the opposite end of the spring so that the tension of the spring is at all times maintained to hold the spindle 23 in a direction toward the right, as shown in Fig. 6, and thereby maintain the driving dog 30 and the sleeve 20 in proper driving and supporting contact with the work during the lapping operation while the work is being rotated and reciprocated.

The spindle 23 may be rotated by any suitable mechanism, such as a worm gear 50, which is mounted on a sleeve 51 rotatably supported by the bearings 25. The sleeve 51 is slidably keyed to the reduced portion 46 of the spindle 23 by means of a key 53, so as to rotate the spindle 23 while it is being reciprocated. The worm gear 50 meshes with a worm 54 which is keyed to a cross shaft 55. A motor 60, pivotally mounted in the base of the machine, is connected by a driving belt 61 to rotate a pulley 62 on the shaft 63. This shaft is connected by a suitable gear mechanism to rotate the shaft 55 and the spindle 23 at the desired speed in either direction. As illustrated in the drawings, the shaft 63 is provided with a gear 64 which meshes with a gear 65 on the shaft 55 to rotate the worm 54 and spindle 23 in one direction. The shaft 63 is provided with a sprocket 66 connected by a link chain 67 with a sprocket 68 on the shaft 55 to rotate the worm 54 and also the spindle 23 in the opposite direction. Either the gear 65 or the sprocket 68 may be connected to rotate the shaft 55, in either direction, by engaging a clutch member 70 with the clutch teeth 71 on the gear 65 or the clutch teeth 72 on the sprocket 68. The clutch member 70 is slidably keyed to the shaft 55 and may be shifted by any suitable mechanism, such as by means of a yoked member 75 having projecting pins 76 engaging an annular groove 77 in the clutch member 70. The yoked member is mounted on a vertical shaft 79 which may be rocked by a manually operable lever 80 to engage either set of driving members to rotate the spindle 23 in the desired direction. The

clutch may be held in a neutral position by swinging the manual control lever 80 so that an arrow point 81 on an arm 82 will engage a correspondingly shaped recess 83 in a pivotally mounted lever 84. The lever 84 is held in engagement with arm 82 by means of a spring 85. A pair of springs 86 and 87 are connected to the arm 82 at their inner ends and to fixed studs 88 and 89 respectively at their other ends to tend to maintain the arm 82 in a neutral position so that the arrow point 81 is in engagement with the corresponding notch 83.

For lapping various types of work, it is essential that a suitable timing mechanism be provided to control the extent and duration of the lapping operation so that each object to be lapped may be given a definite lapping action and the lapping operation will then be terminated automatically. In the lapping of cams and the like, due to the thrust of the lapping members as they roll in engagement with the surface of the cam, it is essential that the shaft be rotated first in one direction for a definite period and then shifted into a reverse direction so that the lapping action on the rise and fall of the cam will be equalized. To accomplish this result suitable connections are provided so that the clutch 70 may be automatically disengaged after a predetermined number of rotations of the work piece. As illustrated, this timing mechanism may comprise two gears 90 and 91 keyed to the shaft 55 and meshing with a pair of tumbler gears 92 and 93 which are rotatably supported on studs 94 and 95 respectively on tumbler gear frame 96. The frame 96 is supported to rock on the shaft 55. The stud 95 also supports a gear 97 which is keyed to rotate with the gear 93 and is arranged to rock into and out of engagement with a gear 99. The latter is provided with an extending hub 100 which is rotatably mounted in suitable bearings 101 in the frame 12 of the headstock. A manually operable lever 102 is mounted on the end of the frame 96 so that the frame 96 may be rocked to mesh either the gear 92 or the gear 97 with the gear 99 to produce either a fast or a slow speed of rotation of the gear 99.

An eccentric portion 103 is provided on the gear 99 which is engaged by a connecting rod 104. A pawl 105 is mounted on a stud 106 on the other end of the rod. The pawl 105 engages the teeth of a ratchet wheel 107 which is mounted on the end of a shaft 108. A cam 109 is mounted on the shaft 108 and is engaged by a follower 110 keyed to a shaft 111. The shaft 111 is mounted in suitable bearings 112 in the headstock frame 12 and serves as a support to rock the lever 84. The cam 109 is so shaped that after a predetermined number of teeth on the ratchet wheel 107 have been picked by the pawl 105, a high portion of the cam 109 will rock the follower

110 and also the shaft 111 and thereby rock the lever 84, compressing the spring 85, to swing the projection 83 towards the right, as viewed in Figs. 1 and 5, and thereby permit the released tension of the spring 87 to throw the arm 82 and clutch 72 into a neutral position and stop the rotation and reciprocation of the work piece.

It will be apparent from this construction that the operator may, by swinging the lever 80 towards the right, engage the clutch member 70 with the clutch teeth 71 and move the parts connected thereto into the position as illustrated in Figs. 1 and 5. The rotation and reciprocation of the work piece is then started and continues until the cam 109 rocks the follower 110 after a predetermined number of reciprocations of the rod 104, and so rocks the shaft 111 and moves the projection 83 so as to permit the arm 82 to swing to a neutral position and thereby disengage the clutch 70. The lever 80 may then be moved towards the left to move the clutch member 70 into engagement with the clutch teeth 72, thereby engaging the sprocket 68 to rotate the shaft 55 to rotate the spindle 23 and the work in the opposite direction. Rotation in this direction continues until the cam 109 rocks the follower 110 and shaft 111 to shift the lever 84 so that the released tension of the spring 86 will move the arm 82 towards the right, as viewed in Figs. 1 and 5, so that the arrow point 81 engages the correspondingly shaped notch 83 thereby stopping rotation of the work in the reverse direction. A lever 113 is mounted on the outer end of the shaft 111 so that the operator may readily rock the lever 84 manually to release the arm 82 and permit the spring 86 to throw the clutch member 70 to a neutral position at any time desired during the cycle of operation.

To permit varying the cycle of operation, so that the period of lapping may be varied according to the desires of the operator, a shield 114 is mounted on a support 115 which is rotatably mounted on the shaft 108 and is arranged to surround a portion of the ratchet wheel 107. The operator may readily adjust the position of the shield 114 so that one or more teeth of the ratchet may be picked up at each reciprocation of the rod 104. The number of teeth thus picked up will vary the speed at which the cam 109 is rotated and consequently vary the timing of the cycle of lapping operation. A manual control lever 116 is mounted on the outer end of the support 115 so that the operator may readily turn the shield 114 from the operating position in front of the machine. The lever 116 is provided with a suitably graduated scale 117 and a fixed portion of the headstock 12 with an index point 118. The operator, by manipulation of this control, may turn the

shield to produce the proper timing of the lapping cycle.

Where the periphery of a work piece is to be lapped, it is desirable that the work piece and lapping members be given both a rotating and reciprocating motion relative to each other to produce the desired lapping action. In the preferred construction, the work piece is given a combined rotary and reciprocating motion. To accomplish the reciprocation of the work, an eccentric pin 120 is held in fixed relation with the gear 99 during rotation thereof, and a connecting rod 121 in engagement with the eccentric pin 120 at one end is connected at the other end to a projection 122 of a yoked member 123 which engages the pins 124 in the collar 125. The collar 125 is rotatably mounted on a portion of the wheel spindle 23 and is held against rotation by engagement of the pins 124 with projections of the yoked member 123 while the spindle rotates. The parts are arranged so that reciprocation of the yoked member 123 is transmitted to reciprocate the spindle 23 and the work piece 14. When the spindle 23 is rotated during the lapping operation, the shaft 55, through the gear mechanism, rotates the gear 99 and revolves the eccentric pin 120 to simultaneously reciprocate the spindle 23 and the work piece 14.

For certain types of work, it is desirable that the extent of reciprocating motion be adjustable so as to obtain the desired lapping action. To accomplish this, the pin 120 is mounted on an eccentric stud 127 which is journaled within a hole 128 in the sleeve 100. The pin 120 is eccentric to the stud 127 and the hole 128 is eccentric to the axis of rotation of the sleeve 100 so that by rotating the stud 127 relative to the sleeve 100, the eccentricity of the pin 120 may be varied to change the length of reciprocation of the work spindle 23. The stud 127 is provided with nuts 129 engaging a threaded portion 130 on the outer end of the stud 127 so that after the adjustment of the eccentric pin 120, the stud 127 may be locked into rigid engagement with the sleeve 100 and the gear 99.

Footstock

The footstock end of the work is supported by a center 21 mounted on the outer end of a rotatable spindle 140 so that the spindle and center rotate freely as the shaft is rotated during the lapping operation. Due to the reciprocation of the work piece during the lapping operation, it is essential that the center 21 be maintained in contact with the end of the work piece with sufficient pressure to properly support the work during the reciprocation thereof. As illustrated in Fig. 9 of the drawings, a spring 141 surrounds the spindle supporting sleeve 142 and is arranged to exert a pressure sufficient to maintain the center 21 in operative engagement with the work. A

suitable lever 143 and a toggle connection 144 are provided to move the sleeve 142 longitudinally to retract the center from its operating position when it is desired to replace the work piece after the lapping operation has been completed.

Lapping arms

To produce the desired lapping action on the work piece, which has a plurality of spaced portions to be lapped, it is preferable to provide a plurality of lapping members arranged to simultaneously engage the various portions to be lapped so that the entire work piece may be lapped in one operation. The lapping members and the work piece are rotated relative to each other as well as reciprocated relatively to produce the desired lapping action. It is preferable that the lapping members be maintained in yielding contact with the work with sufficient pressure so as to produce a substantially equal lapping action during the entire rotary engagement between the lapping members and the periphery of the work piece. As shown in the drawings, a mechanism has been illustrated which is particularly adapted for the lapping of camshafts in which the plurality of cams on the shaft are simultaneously lapped. The laps are mounted on freely movable arms and the work is rotated and reciprocated relative to the laps. The lapping arms 150, 154, 158 and 159 are pivotally mounted on the studs 151 supported on brackets 152 and 155 on shafts 153 and 156 which are supported in the frame 16.

The camshafts used in the modern gasoline motor are designed with the cams spaced closely together on the shaft. It is consequently desirable to provide suitable supports for the lapping members so that they may be arranged to contact with the cams on the camshaft. To accomplish this alternate lapping arms 154 are mounted on supports 155 which are in turn supported on a shaft 156 journaled in the frame 16. By utilizing this construction it is possible to provide adequate support for the lapping arms so that they may be arranged to correspond with the closely spaced cams on the camshaft.

To increase the lapping action, it is preferable to provide a second set of laps mounted on lapping arms 158 and 159 which are pivotally connected to the supports 152 and 155 and shafts 153 and 156 respectively. Suitable laps 160 are mounted on the lower ends of the arms 150, 154, 158 and 159 and are arranged to engage the rear of the work. These laps may be of any suitable construction, such as a rotatable lapping wheel which may be either freely rotatable on the studs 161 or such as fixed lapping blocks as would be provided if the abrasive blocks were held non-rotatable. The laps may be either of metal charged with abrasive powder, lapping elements to

which loose abrasive compound is fed, or preferably made of a bonded abrasive structure like a grinding wheel as illustrated. In the latter case, the wheel is ordinarily made of abrasive grains of very fine size bonded into an integral mass by a suitable bond, such as vitrified ceramic material or an organic bond of the phenolic resin type. As illustrated in the drawings, however, the lapping wheels 160 are freely rotatable on the supporting studs 161 and arranged so that they may be maintained in frictional rolling contact with the periphery of the work piece being lapped.

Due to the irregular contour of the work piece, it is necessary that the lapping members be provided with suitable supports so that they may be held in yieldable contact with the work and move towards and from the work center as they follow the periphery of the irregularly shaped rotating work piece. It is desirable, also, that the lap be maintained in contact with the surface of the cams with a substantially uniform pressure at all times during the lapping operation. This may be accomplished by a mechanism comprising a link chain 165 connected to a link 166 projecting through a portion 167 of the lapping arm 150. The link 166 is threaded and provided with a nut 168 to permit adjustment of the link and chain 165 relative to the lapping arm. The other end of the chain 165 is connected by a link 169 to the short arm 170 of the bell crank lever 171. The bell crank lever 171 is mounted to rock on a shaft 172 mounted in the frame 16. The other arm 173 of the bell crank lever 171 is connected to one end of a spring 174, the other end of which is connected to a pivotally mounted lever 175 which is pivoted to a supporting shaft 176 journaled in the frame 16. The other end of each lever 175 is provided with a suitable weight 177 of sufficient size to maintain the desired tension on each spring 174. All of the arms 150 and 154 are provided with similar chain and weight mechanisms.

Likewise, the arms 158 and 159 respectively supporting the laps 160 on the opposite side of the work piece 14 are connected by link chains 178 which are connected to blocks 179 on the arms 158 and 159 and pass over idler pulleys 180 and are connected by arms 181 on a set of bell crank levers 182. To permit adjustment of the chains 178 relative to the lapping arms 158 and 159, a suitable mechanism may be provided, such as adjustable brackets 183 which support the idler pulleys 180. The brackets 183 are mounted on the supporting members 152 and 155 and are adjusted by means of screws 184 which are connected so as to adjust the brackets 183 relative to the supporting members 152 and 155. The bell crank levers 171 and 182 are in turn connected to springs 174 and levers 175 which are supported and arranged as

above described. It will be readily apparent from this disclosure that the weights 177 acting through the springs 174 will provide suitable tension on the chains 165 and 178 and maintain the laps 160 in yielding contact with the surface of the cam being lapped at a substantially uniform pressure during the lapping operation. Each of the lapping arms 150, 154, 158 and 159 is provided with independent spring and weight mechanisms so that each lapping wheel is held independently in yielding contact with the work. The supports 152 and 155 are provided with suitable clamping screws 190 so that they may be adjusted longitudinally of the supporting shafts 153 and 156 and then locked rigidly relative to the shaft.

In accordance with this invention, mechanism has been provided so that when the lapping operation on a camshaft has been completed the yieldable pressure on all of the lapping wheels may be simultaneously released so that the operator may readily remove the finished piece of work and replace it by a new piece. To accomplish this, the machine is so arranged that all of the weights may be raised to release the tension on the springs 174. As shown, the shaft 176, which supports the levers 175, is provided with a key 192 which extends the entire length of the shaft 176. Each of the levers 175 has a keyway 193 of sufficient width to permit a limited rotary motion of the shaft 176 without disturbing the position of the levers 175. In order that the levers 175 and weights 177 may be simultaneously raised to release the tension of the springs 174 and consequently relieve the pressure of the lapping wheels on the work, a suitable mechanism is provided to rock the shaft 176. This may comprise a hand wheel 195 which is mounted on the front end of the shaft 196 carried in a bearing 197 on the base 11. The rear end of the shaft 196 is provided with a threaded portion 198 engaging a nut 199 fixed to the base 11. The end of the shaft 196 is arranged to engage an arm 200 which is rigidly keyed to the shaft 176. It will be readily apparent from this construction that when the operator turns the hand wheel 195 rotary motion of the screw 198 relative to the nut 199 moves the end of the screw relative to the arm 200. When this screw is moved in a direction towards the right, as viewed in Figs. 4 and 11, the shaft 176 will be rocked relative to the levers 175 until the key 192 engages the opposite end face 201 of the enlarged keyway 193 in all of the levers 175 and further rotation of the shaft 176 rocks all of the levers 175 lifting the weights 177 and thereby simultaneously releases the tension on the springs 174. A pair of lock nuts 202 are provided on the screw 198 to limit the longitudinal movement of the screw in a rearward direction.

The operation of the machine will be ap-

parent from the foregoing disclosure. The operator places a camshaft or other suitable work piece in the machine in alignment with the work supporting sleeve 20 and driving pin 30 at one end and the footstock center 21 at the other end. He then swings the lever 143 to bring the footstock center 21 into engagement with the work. Swinging the lever 35 moves the work supporting sleeve 20 and driving pin 30 into driving and supporting engagement with the other end of the work piece. The lapping operation may then be started by moving the lever 80 towards the right, as viewed in Fig. 1, to engage the clutch member 70 with the clutch teeth 71 connected with the gear 65 to rotate the shaft 55 and the spindle 23 and work piece 14 in one direction. This rotation continues until the cam 109 raises the follower 110 and rocks the shaft 111 and arm 84 and permits the released tension of the spring 87 to throw the clutch into a neutral position and stop the lapping operation in that direction. The operator then shifts the lever 80 towards the left (Figs. 1 and 2) so that the clutch member engages the clutch teeth 72 and locks the gear 68 into driving engagement to rotate the shaft 55, the spindle 23, and the work piece 14 in the opposite direction. This rotation in the opposite direction continues for a similar period until the cam 109 rocks the follower 110 and shaft 111 to swing the arm 84 so that the released tension of the spring 86 will swing the arm 82 towards the left, as viewed in Fig. 1, to move the clutch member 70 into a neutral position. During this rotation of the shaft in each direction the reciprocating mechanism operated by the gear 99 produces an axial reciprocation of the work piece. The equal cycles of rotating in each direction insure an equal lapping action on the rise and fall of the cam, thereby eliminating any tendency of one lapping element to run away from the surface while rolling up the rise or when rolling down the fall of the cam.

Having thus described the invention, what is claimed as new and desired to secure by Letters Patent is:

1. A machine for lapping rotatable non-isodiametric work, comprising means to support the work, a lap frictionally engaging the periphery of the work, means to rotate the work and the lap about the work axis, one relative to the other, and thereby cause a lapping action, and means acting independently of the work to maintain said lap with a positive but substantially uniform pressure against said non-isodiametric work throughout the entire lapping operation.

2. A machine for lapping rotatable non-isodiametric work, comprising a work support, a lap, a support for said lap arranged to maintain it in frictional contact with the work, means to rotate and reciprocate the work and the lap, one relative to the other,

and thereby cause a lapping action, and means independent of the work to hold the lap in operative contact with the non-isodiametric work so that it may move towards and from the axis of the part being lapped during said rotation.

3. A machine for lapping non-isodiametric work comprising a work support, a lap frictionally engaging the work periphery as the parts are relatively rotated, rotative means for relatively moving the work surface and the lap about the work axis, and thereby causing the lap to drag against and lap the work, means whereby the lap may move towards and from the axis of the part being lapped and maintain contact with the non-isodiametric work surface during such relative movement, and means for relatively reciprocating the lap and the work to provide a break-up motion in the lapping operation.

4. A lapping machine for lapping rotatable non-isodiametric work, comprising a support for the work, means to rotate and reciprocate said work, and two independently movable laps arranged to frictionally engage opposite sides of the non-isodiametric work and move towards and from the axis of the part being lapped as the latter is rotated and reciprocated.

5. A lapping machine for rotatable non-isodiametric work comprising a work support, a lapping element, means to rotate and reciprocate said work and lapping element, one relative to the other, and with respect to the work axis, means independent of the work to maintain said lapping element in operative contact with one side of the non-isodiametric work with a predetermined but uniform pressure, and means for adjusting said pressure.

6. A machine for lapping non-isodiametric work comprising a work support, a lap frictionally engaging the work periphery as the parts are relatively rotated, rotative means for relatively moving the work surface and the lap about the work axis, and thereby causing the lap to drag against and lap the work, means whereby the lap may move towards and from the axis of the part being lapped and maintain contact with the non-isodiametric work surface during such relative movement, means for relatively reciprocating the lap and the work to provide a break-up motion in the lapping operation, and means for holding the lap against the work surface with a substantially uniform pressure for all positions of the work.

7. A lapping machine for rotatable non-isodiametric work comprising a support for the work, a freely rotatable lap peripherally engaging the work, means to rotate the work and lap relatively about the work axis, means to reciprocate the work and the lap relatively parallel with the work axis, and a support for the lap which acts independently of the

work to hold the lap in operative engagement with the non-isodiametric work during the lapping operation.

8. A lapping machine for rotatable, non-isodiametric work comprising means to support and rotate a work piece, a freely rotatable lap, means independent of the work to hold the periphery of the lap in operative engagement with the periphery of the work, means to reciprocate said work and lap, one relative to the other, and means for yieldingly impressing a desired uniform pressure upon the work by the lap.

9. A machine for lapping rotatable non-isodiametric work, comprising means to rotate and reciprocate the work upon its axis, freely rotatable laps engaging opposite sides of the work which are independently movable toward and from the center of work rotation, and independent means to impose a predetermined pressure by each lap upon the work piece during the lapping operation.

10. A lapping machine comprising a support for a rotatable work piece, a lap operatively associated therewith, means for reciprocating the work piece and lap relatively, driving mechanism for rotating the work about its axis, and clutch mechanism for reversing the direction of rotation of the work.

11. A lapping machine for rotatable work, comprising a support for the work piece, means to reciprocate said work axially, a lap, means to maintain said lap in operative contact with the periphery of said work, means to rotate said work in either direction for a predetermined period, and a reversing mechanism for changing the direction of rotation thereof.

12. A lapping machine for rotatable work, comprising a support for the work, a lap operatively associated therewith, reversible driving mechanism to rotate the work in either direction relative to the lap and about the work axis, and automatic mechanism acting in timed relation with the driving mechanism to stop the work rotation after a predetermined lapping period.

13. A lapping machine for lapping rotatable non-isodiametric work, comprising means to support and rotate the work upon its axis, lapping members on each side of the work movable independently towards and from the center of work rotation, means to maintain substantially uniform pressures of the laps against the periphery of the work piece during its rotation, and means acting in timed relation with the work rotation to stop the lapping operation upon completion of a predetermined cycle of the work rotation.

14. A lapping machine for lapping rotatable work having a plurality of portions to be lapped, comprising a work support, means to rotate the work thereon, a set of independent laps operatively contacting with

said portions of the surface of the work, means to hold each lap against the work under a definite uniform pressure during the lapping operation, and means to release the pressure of all the laps simultaneously.

15. The method of lapping a camshaft having a plurality of spaced cams of non-isodiametric shape comprising the steps of rotating the camshaft first in one direction for a definite period and then in the opposite direction for an equal period while it is being reciprocated and abrading the surface of the work by a lap under equal pressures during both periods of rotation.

Signed at Worcester, Mass., this 27th day of September, 1929.

SYDNEY PLAYER.
HERBERT S. INDGE.

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