Feb. 8, 1966 R. J. BEST ETAL 3,233,370

PRODUCTION OF PARALLEL LAPPED SURFACES

Filed July 19, 1963 3 Sheets-Sheet 1

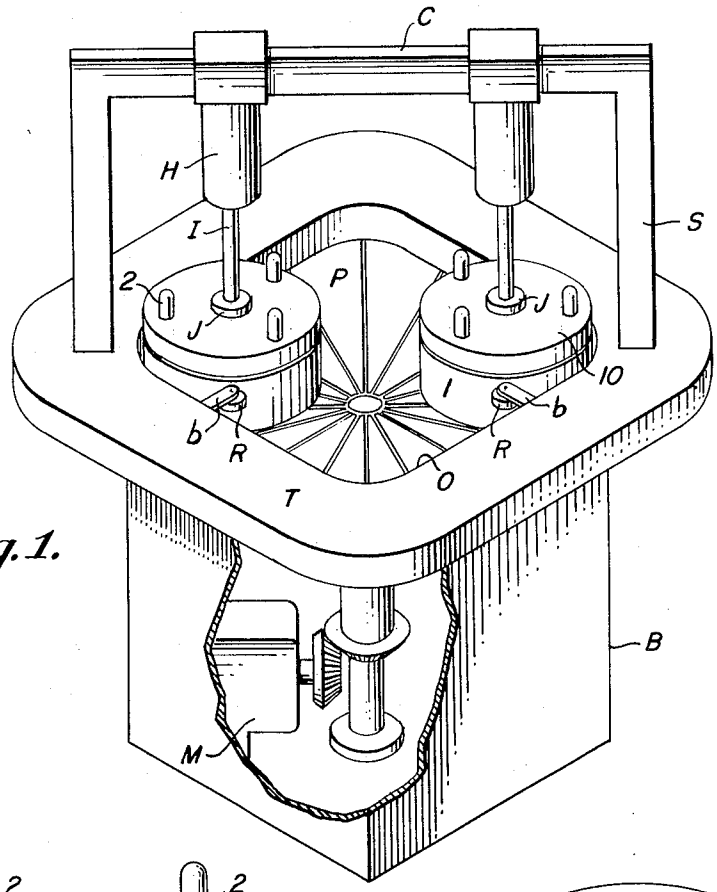


Fig. 1.

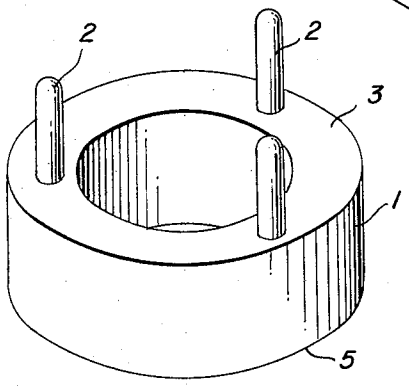


Fig. 2.

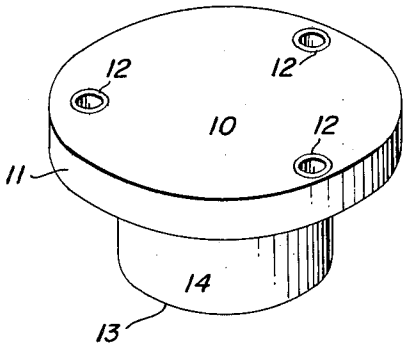


Fig. 3.

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Feb. 8, 1966 R. J. BEST ETAL 3,233,370

PRODUCTION OF PARALLEL LAPPED SURFACES

Filed July 19, 1963 3 Sheets-Sheet 2

Fig. 4.

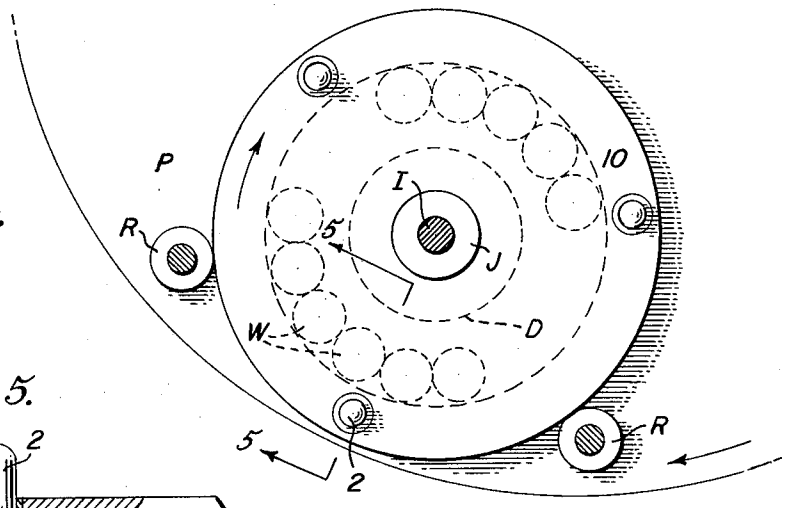
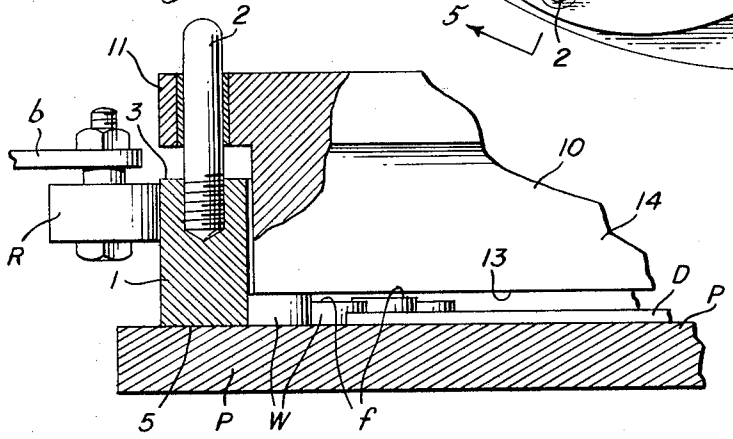



Fig. 5.



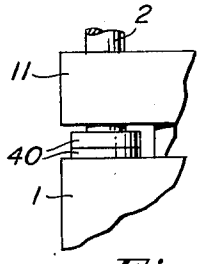




Fig. 5a.

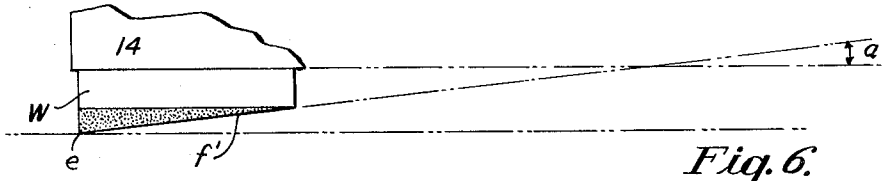



Fig. 6.

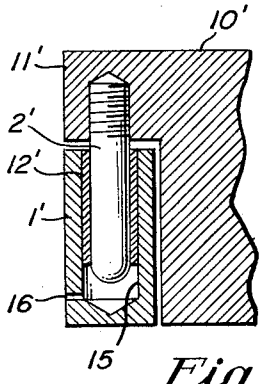



Fig. 7.

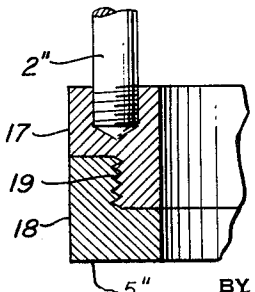



Fig. 8.

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PRODUCTION OF PARALLEL LAPPED SURFACES

Filed July 19, 1963 3 Sheets-Sheet 3

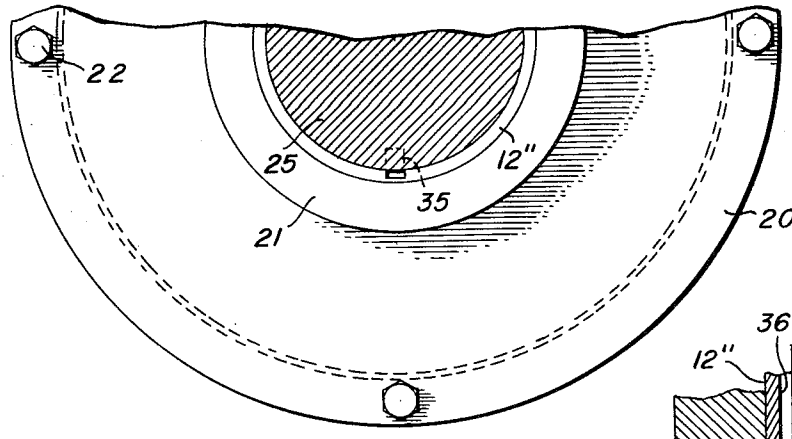


Fig. 11.

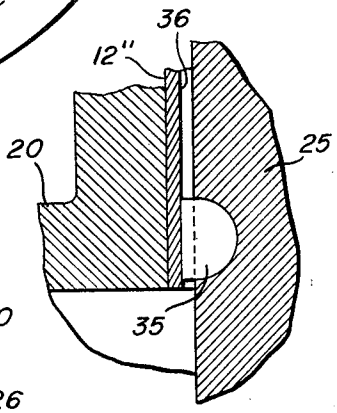


Fig. 10.




Fig. 9.

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United States Patent Office

3,233,370

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3,233,370

# PRODUCTION OF PARALLEL LAPPED SURFACES

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2 Claims. (Cl. 51—131)

This invention relates to lapping machined articles, particularly those to the opposite faces of which it is desired to impart not only a high degree of conformity to spaced planes but also as nearly as practical precise parallelism.

There have been long in use lapping machines comprising a lap plate supporting one or more retainer rings which by suitable means are held on the plate and surround articles to be lapped by movement of the plate under them, pressure applying means often supplementing the force of gravity in pressing the articles into continuous heavy bearing against the plate, the latter of course normally having its surface covered by an abrasive-carrying fluid vehicle.

Pressure applying means presently employed frequently include a circular plate freely disposed within each retainer ring and rotatable with it in more or less random fashion insofar as parallelism with the lap plate is concerned so the circular plate is free to assume a position non-parallel thereto when a plurality of articles of different thicknesses are placed under it to be lapped, and when this condition prevails the articles acquire a generally corresponding non-parallelism between their opposite faces while the second face is being lapped.

Today's machine part specifications often call for tolerances much smaller than heretofore and it will be understood that where formerly accuracy was contemplated in terms of microns, thousandths of an inch, or other relatively gross linear measurements currently tolerances are often expressed in terms of millimicrons, millionths of an anch, or even "light bands" of relatively few Angstrom units ($1A.=10^{-8}$ cm. or $3.937\times10^{-9}$ in.) especially with reference to departures from parallelism of opposed lapped surfaces of small parts and occasionally even in parts of considerable size.

It is therefore a principal object of the invention to provide for association with a lapping machine novel apparatus comprising a retaining ring for articles to be lapped, a ram for applying pressure to said articles while in the ring and means for insuring during the lapping operation parallelism to within very small tolerances between the article contacting face of the ram and the lap plate whereby the opposed faces of the lapped articles may be reduced to parallelism within the aforesaid tolerances with reproducible accuracies of the order of a few millionths of an inch, or less.

A further object is to provide means associated with a retaining ring suitable for use in conjunction with a flat lap plate comprising a ram coaxial with the ring and movable axially with respect thereto and means for maintaining extremely close parallelism between one face of the ram and an adjacent end face of the ring during lapping operations whereby the faces of articles after lapping have a corresponding parallelism imparted while they were being individually reduced to planar accuracy of a generally corresponding order.

Another object in certain embodiments is the provision of means for accurately gauging the spacing apart of the opposed surfaces of a work piece while one of said faces is being lapped into parallelism with the other.

Still another object is the provision of a method of lapping articles having opposed generally parallel faces which comprises the step of maintaining one of said faces of each article, preferably after it has been lapped to substantial planarity, parallel to the surface of a planar lap plate while the latter is operating upon the other of said faces to bring it to like planarity in a plane parallel with the plane of the first face.



Other objects, purposes and advantages of the invention will be understood or will appear from the following description of a presently preferred and certain modified embodiments of apparatus constructed in accordance therewith and suitable for practicing the method thereof during which reference will be had to the accompanying drawings wherein:

FIG. 1 is a perspective diagrammatic view of a typical lapping machine and apparatus embodying the invention associated therewith;

FIG. 2 is a perspective view of one of the elements of said apparatus removed from the machine;

FIG. 3 is a like view of another of said elements;

FIG. 4 is an enlarged somewhat diagrammatic fragmentary top plan view of said apparatus in association with a lapping plate and certain auxiliary mechanisms;

FIG. 5 is a further enlarged fragmentary side elevation partly in section on line 5—5 in FIG. 4;

FIG. 5*a* is a fragmentary reproduction of a portion of FIG. 5 showing use of certain auxiliary elements;

FIG. 6 is a still further enlarged fragmentary side elevation of one element of the apparatus in operative association with a typical work piece the departure from parallelism of whose opposite faces is exaggerated, the plane of the lap plate being indicated by a broken line and the material to be removed from the work piece to bring its opposed faces into parallelism being stippled;

FIG. 7 is a fragmentary section of a modified embodiment of the invention;

FIG. 8 is a like section of another modification;

FIG. 9 is a side elevation partly in radial section showing another embodiment of the invention;

FIG. 10 is a fragmentary vertical section on line 10—10 in FIG. 9, and

FIG. 11 is a fragmentary horizontal section on line 11—11 in FIG. 9.

Apparatus constructed in accordance with the invention may be utilized in conjunction with any of a great variety of specifically different lapping machines and we have chosen as merely typical of them that diagrammatically illustrated in FIG.1 comprising a base B supporting a horizontal circular lap plate P for rotation about a vertical axis when a motor M geared to its shaft is energized. A table T having a central opening O over the lap plate and also supported from the base carries on adjustable brackets *b* rollers R suitable for guiding the retaining rings in which the articles to be lapped are placed, the illustrated machine being arranged to accommodate two such rings but it will be appreciated a greater or fewer number may be used as preferred. Mounted on the table is a bridge structure S having a single cross bar C above the lap plate but it is typical only as it like the machine as thus far described constitutes no part of the invention.

The retaining rings in the machine shown are similar so a description of one will suffice for either. Thus each ring 1 is of substantial radial thickness in relation to its inside diameter and in the embodiment illustrated in FIGS. 1–5*a* inclusive carries a plurality of studs 2 projecting from its upper end face 3, the lower end face 5 being adapted to rest on the lap plate while the apparatus is in use; rollers R then engage the outer cylindrical surface of the ring to hold the latter in relatively fixed eccentric relation to the lap plate but freely rotatable about its own axis. Associated with each ring is a generally cylindrical ram 10 having a peripheral flange 11 in which are fitted spaced bushings 12 respectively adapted

to receive studs 2. These studs and bushings are made to close tolerances with clearances of the order of 0.0005" whereby although the ram is movable axially with respect to the ring its deviation from true axial movement with respect thereto is substantially inhibited. The bottom face 13 of the ram is plane and preferably lapped to conform to precise parallelism with end face 5 of the ring, while the cylindrical portion 14 of the ram below flange 11 fits fairly snugly within the ring but with sufficient clearance to avoid material frictional resistance to relative axial movement of these parts.

For purposes which will hereafter appear we prefer to connect each ram to bridge structure S by means of a hydraulic or pneumatic cylinder H depending from the bridge with its piston rod I, coaxial with the ring and ram, engaging the latter through a self-aligning thrust bearing J of any suitable type disposed at the center of the ram. As the principal purpose of the cylinder and associated mechanism is to supplement the force of gravity in applying downward pressure to the ram it is obvious they may be dispensed with when such supplementary force is not required, or other force applying means may be substituted therefor if desired.

In the modified embodiment of the invention fragmentarily illustrated in FIG. 7 the ring 1' is provided with a plurality of spaced vertical bores 15 containing bushings 12' while depending studs 2' are carried by flange 11' of ram 10', these parts like studs 2 and bushings 12 being lapped to minimum clearance. When this modification is utilized bores 15 preferably do not extend entirely through the ring and are provided with relatively small lateral air vents 16 to prevent development of air cushions below studs 2'.

The modification illustrated in FIG. 8 contemplates forming the ring in two complementary members secured together while in use but separable to permit replacement of the lower one when worn to unserviceable condition. Thus the upper member 17, carrying studs 2", corresponds to the upper part of ring 1 while the lower member 18 corresponds to the lower part of that ring and thus rests on the lap plate when the apparatus is in use; being subject to continual abrasion its lower end face 5" receives the greatest wear and to permit its replacement while continuing the upper member in service a threaded joint 19 between the members is provided, in the present instance through a male thread on the upper and a female thread in the lower one although it is obvious this relation may be reversed.

*Operation*

It will now be assumed the apparatus thus far herein described is to be used to bring into parallelism opposed faces of one or more work pieces W; that one face *f* of each has already been lapped to flatness within the prescribed tolerance, and that the pieces have been disposed on the lap plate within a ring 1 with their lapped faces *f* uppermost and the unlapped ones *f'* therefore confronting the working face of the plate. Before rotation of the latter is initiated the ram is lowered into the ring and rests on the work pieces; assuming faces *f, f'* of the latter depart from true parallelism by an angle *a* (FIG. 6) which is much exaggerated in the drawing the ram by engaging the lapped face *f* of the work piece throughout its extent then actually derives its suport from the area of greatest thickness of the piece. The downward pressure of the ram, usually supplemented by the pressure developed by cylinder H, is therefore concentrated at that portion of lower face *f'* of the work piece which is most distant from its upper face *f*, for example at point *e* in FIG. 6. As the lap plate is now set in motion, of course being supplied with grit in oil or other brading fluid from a suitable source (not shown), maximum abrasion occurs initially at point *e* and as the grit tends to accumulate between the work piece and the lap plate where the concentration of pressure is less, the upper face *f* of the piece is constrained to remain in contact with the lower face of the ram while the lapping continues. The area of greatest concentration of pressure on the workpiece of course gradually enlarges as the excess material represented by stippling in FIG. 6 is progressively abraded away and ultimately becomes coextensive with lower face *f'* as parallelism with the upper face *f* is attained, the lapping operation concurrently imparting flatness to it in accordance with known principles.



It will be appreciated that our or any other suitable lapping apparatus may be used for the initial lapping of the first face *f* of the work piece for obviously parallelism cannot be attained until one face has been lapped to adequate flatness for service as a base plane or guide into parallelism with which the other face is to be brought, and that while the exaggeration of angle *a* in FIG. 6 is intended to indicate it has a measurable angularity, the difference in thickness between the thickest and thinnest parts of a work piece is usually measurable only in terms of units smaller than 0.0001", conveniently with the aid of a monochromatic light beam capable of detecting flatness and parallelism to within, for example, $11.6\times10^{-6}$" when a helium yellow-green beam is used.

We have thus far described the operation of our apparatus with reference especially to its use in lapping a single work piece and shown that in such use the ram is incapable of tilting to bring its lower face non-parallel to the lap plate when its natural tendency if not restrained would be to do so, as when supported from a single work piece in an eccentric position and having nonparallel faces. It will be recognized however that the same principles apply when a plurality of work pieces are being lapped simultaneously (FIGS. 4 and 5). Furthermore, under this condition it may be assumed the pieces W are of different thicknesses (greatly exaggerated in the drawing); hence excepting only in the very unusual case in which the thickest of them are of the same thickness and are uniformly distributed on the lap plate within the ring, the tendency of the ram would be to rest on the thick and thin more or less equally were it free to tilt its axis relatively to the lap plate but since in our apparatus it is not free to do this it remains resting on the thickest of the work pieces (FIG. 5), exerting greatest pressure against them until they have been lapped to the thickness of the next thicker pieces when the latter begin to receive some of the load and this progressive transfer of pressure occurs until all pieces have been brought to the same thickness with their opposite faces parallel. It may be noted that when a large number of small pieces are to be lapped simultaneously we prefer to place a circular plate D, thinner than the final thickness of the pieces, on the lap plate substantially coaxial with the ring to exclude the pieces from the center of the latter where during its rotation on the lap plate they would receive minimum lapping as compared with pieces revolving about the ring axis closer to the periphery of the ring.

It will be appreciated the principal advantages of the invention as thus far described are realized after one side of each piece has been lapped but, as stated, it is immaterial whether that operation is performed with the aid of our apparatus or otherwise provided corresponding accuracy as to flatness is attained, for unless the face contacting the ram is flat within reasonable tolerances the apparatus can bring the opposite face parallel only to the plane of its final surface when it is thereafter lapped in the ordinary way. Naturally, however, if our apparatus is used for lapping both faces the entire lapping operation is most simplified as the pieces after lapping of one face to required flatness have merely to be turned over on the lap plate preparatory to bringing their second faces to parallelism with the first.

In the embodiment of the invention illustrated in FIGS. 9, 10 and 11 provision is made for insuring coaxial

relation between a ring 1" and a ram 10" through utilization of a reciprocal bearing coaxial with those elements and means are provided also for indexing their relative positions in respect to their common axis and hence with relation to lap plate P' when operatively disposed thereon. Thus in this embodiment a cover plate 20 having an axial boss 21 overlies ring 1" and is peripherally coextensive therewith, being rigidly secured thereto by cap screws 22, the boss having press fitted a bushing 12" coaxial with the ring and preferably lapped with a vertical shaft 25 carrying at its lower end a ram head 10". Above boss 21 this shaft is threaded for a considerable distance to its upper end and is received in a micrometer sleeve 26 the lower horizontal end face of which engages the upper end of the boss; its bore from its lower end to its internally threaded portion is relieved as at 27 sufficiently to allow axial movement in it of the adjacent unthreaded portion of shaft 25. The threads are preferably precision-made with tolerances of the order of those of a standard micrometer. The periphery of the lower end of micrometer sleeve 26 has graduated scale markings 28 and the upper end of the boss has an index point 29 adjacent thereto for a purpose which will hereinafter appear. Above sleeve 26, which is knurled to facilitate manual adjustment, the shaft carries a knurled and threaded locking nut 30 and the upper end of the shaft supports a conventional self-aligning thrust bearing J' against which pressure applying means such as the piston rod I' of one of the hydraulic cylinders H shown in FIG. 1 may bear. While in this embodiment of the invention it is contemplated the ring and ram may be relatively rotatable nevertheless provision preferably is made for inhibiting it such as by a Woodruff key 35 in a slot in shaft 25 projecting into a longitudinally extending keyway 36 in bushing 12".

Operation of this embodiment of the invention in respect to securing parallelism of the faces of the work pieces being lapped is similar to that previously described since the shaft and bushing are rigid respectively with ram 10" and ring 1" and are made and fitted with close tolerance as to their departure from coaxial relation so that the bottom face of the ram is always as close as possible to parallelism with the lower end face of the ring.

This embodiment has the advantage, however, of including means whereby the rate of progress of the lapping operation toward attaining the desired final thickness of the lapped work pieces may readily be visually ascertained.

This advantage is obtained through the medium of the micrometer sleeve 26 the lower end of which as noted is parallel to and coaxial with the upper end face of ring plate boss 21 and also parallel to the lower face of the ram and hence to the lower end face of the ring. In consequence, when, for example, a number of pieces are to be lapped to a given thickness, say 0.250", with their end faces in parallelism, before placing the pieces in the ring the micrometer sleeve is adjusted to bring the ram face into the plane of the lower end face of the ring with the sleeve in contact with the boss and a "zero" reading is taken from the scale on the sleeve. The latter is then rotated relatively to the ram shaft to raise the ram above the plane of the ring end just sufficiently to afford beneath the ram and above the plane of the ring end a space equal to the desired finish thickness of the pieces or, preferably, a fraction of a mil higher, and with the aid of the locking ring the sleeve is fixed in this position on the shaft. The pieces are then placed in the ring on the lap plate and since all, even if of uniform thickness, are thicker than the desired finish thickness the ram, resting on the thickest of them, is raised above the lap plate by a distance corresponding to the thickness of said thickest pieces. This creates a clearance between the micrometer sleeve and the ring boss which approximately corresponds to the vertical thickness of the metal to be removed from said thickest pieces to reduce them to said finish thickness. As lapping proceeds, therefore, the width of this clearance is gradually reduced and as it can be estimated by visual observation it affords an indication of the rate of progress of the lapping. Thus if initially the clearance appears to be of the order of .001" and after 30 minutes appears to have been reduced to .0005" it can be assumed that in about 30 minutes longer the clearance will closely approach zero indicating the final desired thickness has been nearly reached. As noted, it is preferable to adjust the micrometer sleeve initially so the said clearance will be zero when the ram face is still slightly above the position corresponding to final thickness by a few light bands, say 0.00005" or so when minute tolerances are prescribed, and final thickness then can be approached with maximum precision by backing off the micrometer ring a few degrees of arc after it contacts boss 21 and then proceeding with the lapping until contact is again made, interspersing these manipulations if desired with periodic precision checks, and thereafter progressively reducing the arc through which the sleeve is backed off until final thickness is attained. Since on contact of the sleeve with the boss pressure of the ram against the pieces is relieved their further appreciable abrasion is prevented even if the lap plate continues rotating for a considerable period thereafter as without pressure the grit fluid partakes more of the character of a lubricant than that of an abradant.

A measurable amount of wear of the lower end of the ring may occur during each lapping operation but this is immaterial since each zero reading is valid only for the operation in contemplation to provide a base from which the adjustment of the sleeve for that operation is made; if for a succeeding operation the zero reading appears at a different point on the scale from the preceding one said different point becomes the base from which the subsequent adjustment is made. The ring usually is worn away only slightly during each lapping operation so successive zero readings on the sleeve index scale generally are not more than a few degrees of arc apart. Thus if the lead of the micrometer threads on the sleeve and ram shaft is 0.10" each degree of arc on the sleeve scale represents a vertical adjustment of the ram of 0.10"/360 or .000267"; the scale is most conveniently calibrated, however, to read like an ordinary micrometer in terms of fractions of a linear unit of axial adjustment whether according to metric or other standard as preferred.

Like control of final thickness may be carried out while using the embodiments of the invention shown in the preceding figures as well as with the apparatus just described. Thus, for example, accurately formed rings or spacers 40 of known thickness aggregating that of the final thickness of the pieces being lapped may be disposed on studs 2 to prevent by engagement with ram flange 11 (FIG. 5*a*) approach of the ram face to the lap plate more closely than a distance corresponding to the thickness of the spacers, assuming the ram and ring are so proportioned that the plane of the ram face coincides with that of the lower end of the ring when the ram flange is resting on the upper end of the ring.

It will be apparent that while we have herein shown and described certain specific embodiments of our invention we do not desire or intend thereby to limit or confine ourselves in any way as other modifications in the form, structure, arrangement and relationship of the several components and elements of our apparatus and in the practice of our method will readily occur to those skilled in the art and may be utilized without departing from the spirit and scope of the invention as defined in the appended claims.

Having thus described our invention, we claim and desire to protect by Letters Patent of the United States:

1. Lapping apparatus comprising a lap plate, a retaining ring adapted to seat thereon for movement relatively to the plate parallel to its surface, a ram axially movable with respect to the ring, movable therewith relatively to the plate and having a portion entering and conforming to the interior of the ring and presenting a flat face in op-

position to and paralleling the plate surface, a plurality of mutually parallel elongated elements projecting from the end of the ring remote from the plate and substantially paralleling the ring axis and a radial flange presenting a corresponding plurality of mutually parallel bores in another portion of the ram respectively adapted to receive the elongated elements to retain the ram face parallel to said plate surface while the ring is seated on the plate.

2. Lapping apparatus comprising a lap plate, a retaining ring adapted to seat thereon for movement relatively to the plate parallel to its surface, a ram axially movable with respect to the ring, movable therewith relatively to the plate and having a portion entering and conforming to the interior of the ring and presenting a flat face in opposition to and paralleling the plate surface, a radially



outwardly projecting flange constituting another portion of the ram, said flange and the ring being provided with aligned bores in mutual parallelism and an elongated element extending from each of the ring bores into the corresponding flange bore for retaining the ram face parallel with said plate surface while the ring is seated on the plate.

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