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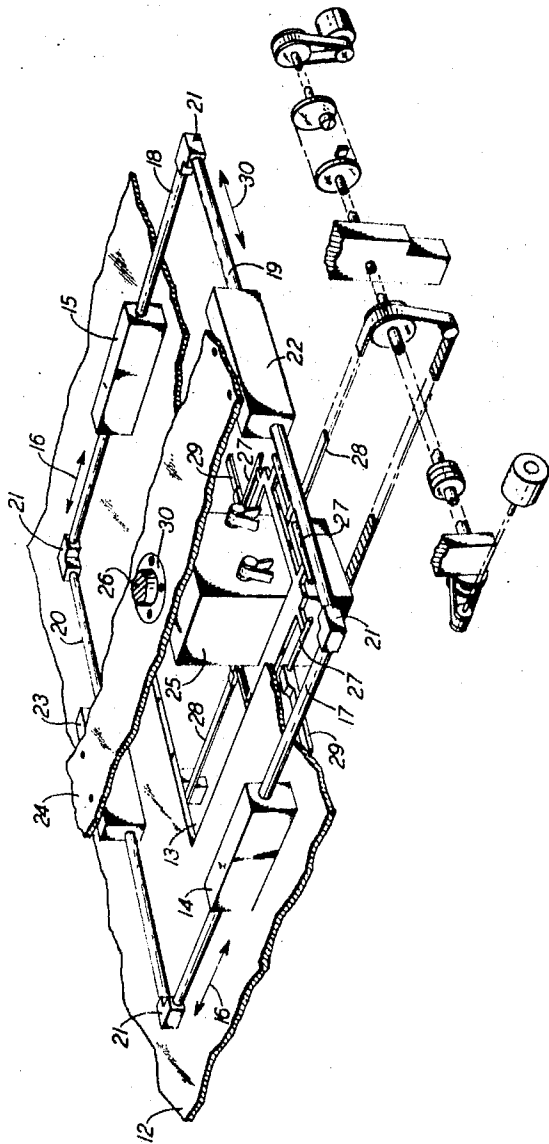
K. REZNICEK
LAPPING MACHINE

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FIG. 2



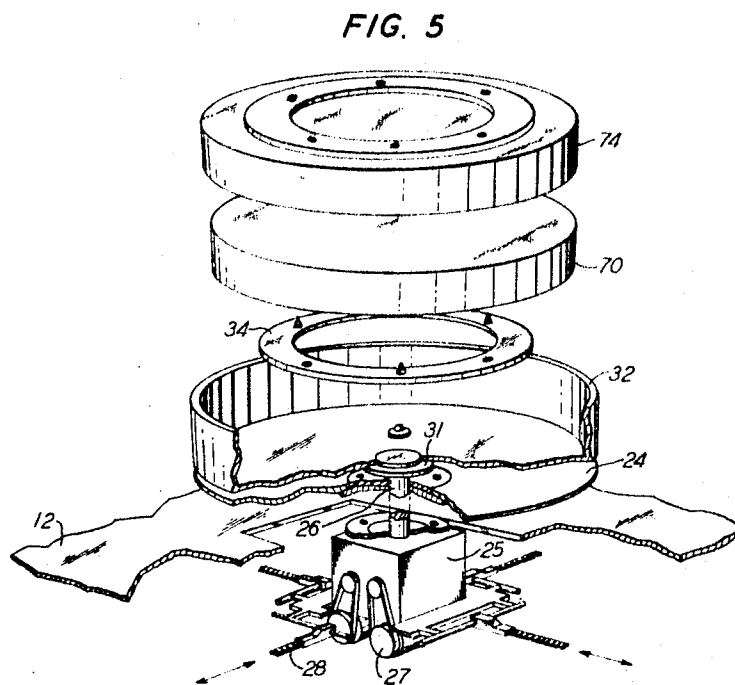
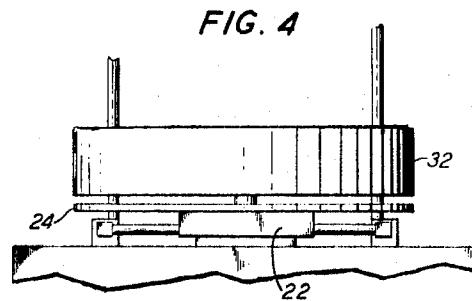
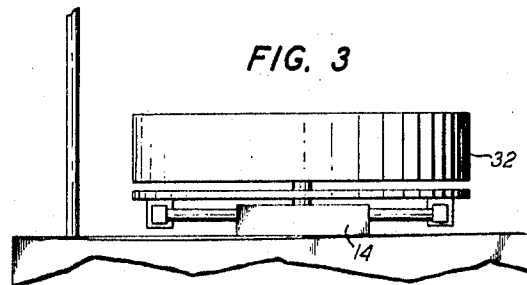
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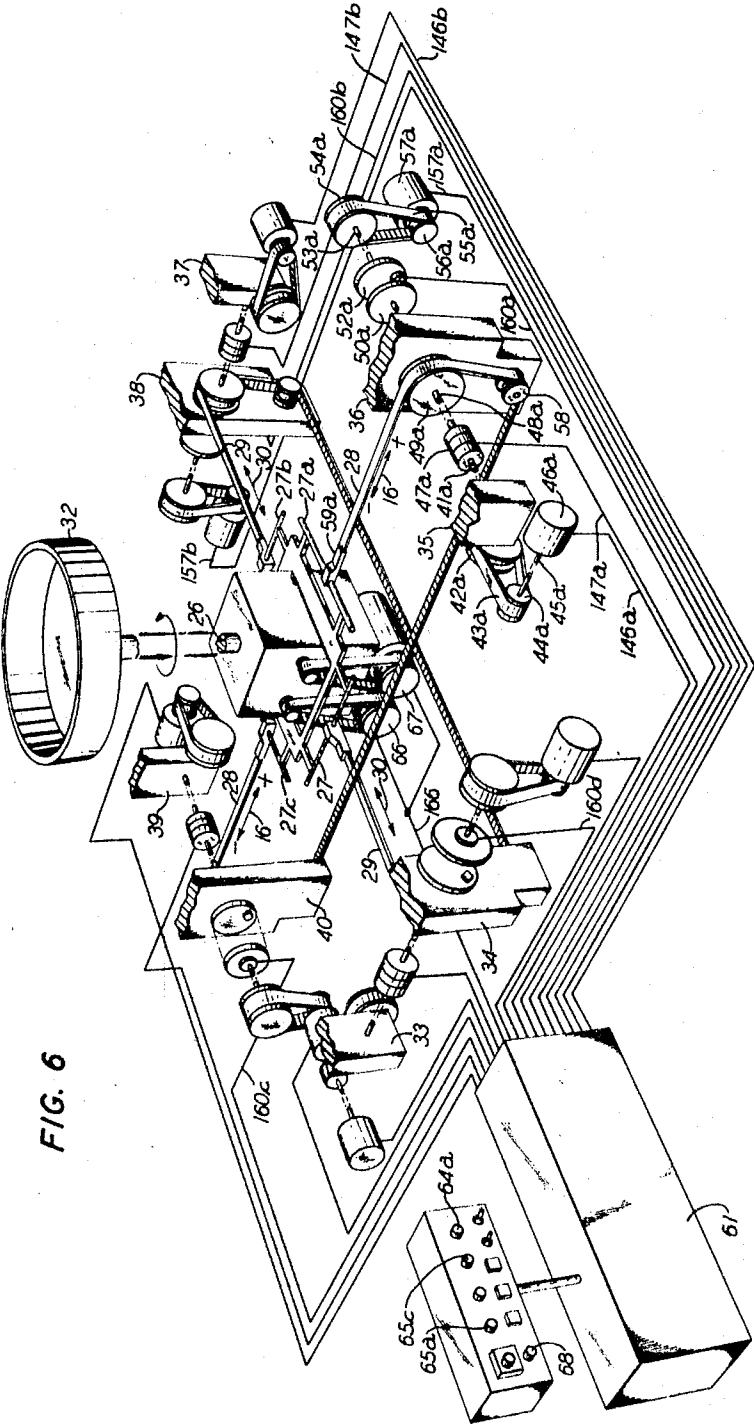


FIG. 6

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FIG. 7

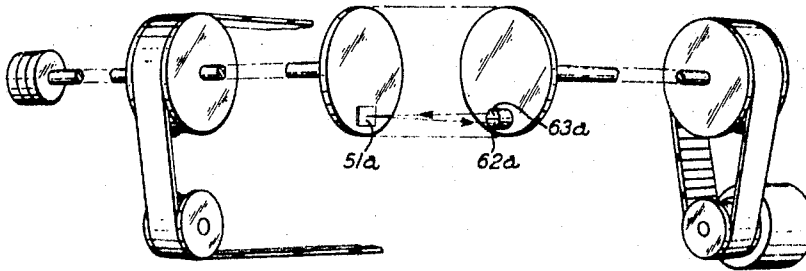


FIG. 8

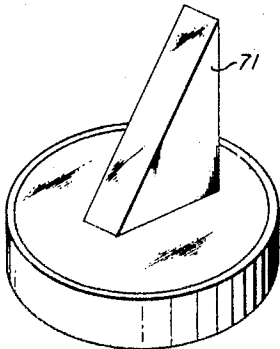


FIG. 9

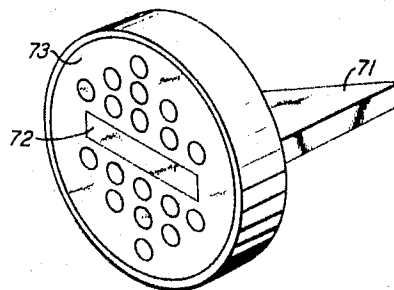
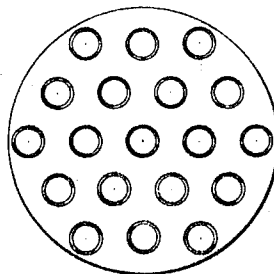


FIG. 10



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LAPPING MACHINE

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U.S. Cl. 51—35

3 Claims

ABSTRACT OF THE DISCLOSURE

This disclosure concerns a machine for lapping optical surfaces in which the lapping bed rotates and also reciprocates in X and Y directions. The rotation rate and both reciprocation rates are controlled independently.

This invention relates to lapping and polishing machines, and specifically to a new machine that in the space of a two foot square automatically laps to a high degree of flatness and uniformity surfaces of 15-20 inches in diameter.

Certain critical design requirements of new art optics such as dispersive delay lines have been extremely difficult or impossible to meet with known conventional flat-lapping machines. One typical requirement for example, calls for a high order of flatness on a given elongated surface. A second such requirement relates to surface smoothness or finish generally characterized by an absence of scores, scratches, or other surface imperfections of even a ¼ micron in width and length. These faults must not be detectable under a 10× magnification. For a variety of reasons, existing lapping technology falls short of meeting these and other needs.

For example, the lapping motion produced by known machines is not uniformly applied over the lapped surface. Typically the lapping plate and the surface undergo a relative pivotal movement in which one is pivotally swept across the other as the latter rotates in place. Inevitably, the surface portion farthest away from the pivot point moves and hence is lapped more. The resulting lap is proportionately out of flat even under otherwise ideal conditions. Merely to lengthen the pivot arm and thus minimize this sweep differential is no solution since it is never quite eliminated; and further, lengthening requires still more space for a machine that already occupies thirty or more square feet.

A further reason for the failure of prior lapping machines to produce the extreme surface flatness and smoothness now desired is that their motions invariably at one point or another introduce a nonrandomness in the lap. This problem encompasses the one just noted, but is broader because it can stem from a host of causes. One cause is a lingering or hesitation in whatever relative movement exists between lapping plate and surface. If at this time the lapping action is momentarily unequal for other reasons, the lapping will progress unevenly for the duration of the pause. Another cause is the tendency of the lapping slurry to flow outwardly toward the rim of the lapping plate which makes the lapping rate greater at the rim area. This latter problem is compounded by the conventional cross-hatch plate groove pattern and further by the referred-to conventional pivotal movement still so often employed. Other causes of nonrandomness are prolonged jerky motions and sinusoidal accelerations and decelerations between plate and surface, and the tendency of known lapping mixtures to agglomerate because of insufficient wetting.

It has been possible in the past for a highly skilled optical finisher to produce the desired surface by hand-finishing. Herein, however, lies cause for further concern with existing lapping technology. There is a chronic short-

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age of such technicians. The skills are esoteric and their methods not generally understood. The hand operation literally takes weeks and months to complete. Finally, the experienced yield rate of satisfactorily finished surfaces is under 40 percent. Needless to say, the cost per good surface is considerable.

Accordingly, each of the following are important and immediate objects of the invention:

To produce highly flat, smooth optical surfaces entirely by machine;

To reduce substantially the overall cost of lapping such optical surfaces;

To increase the working capacity of general purpose lapping machines without increasing their size;

To eliminate hand-finishing and all other costly labor charges in the production of such surfaces;

To cut, in a major way, the time required to produce such surfaces;

To improve, markedly, the yield of satisfactory surfaces generated during the lapping and polishing steps; and

To make the outcome of these processes predictable.

These and other objects are achieved pursuant to the invention, broadly, by a lapping bed rotatable at various speeds in its horizontal X-Y plane and also reciprocal at various speeds in both X and Y directions, the work piece being positioned atop the bed and able to rotate with it but restrained from translational movement.

In one illustrative embodiment described in detail below, the lapping bed supports a circular lapping plate. The work piece—a 12" x ½" substrate quartz surface for example—is embedded flush in a second or top circular lapping plate which rests freely of its own weight upon the bottom plate. Restraining rollers of rubber or the like are adjustably positioned at intervals along the circular rim of the top plate. Rotation of the bottom plate will be imparted to the top plate, but translation of the bottom plate in its X-Y plane will not be imparted to the top plate except to the slight degree allowed by the clearance between rollers and rim.

Hence, the relative motion between the contacting plate surfaces is a complex and constantly changing amalgam of lateral and rotational slippage. The resulting lap and polish is benefited in several ways. First, there is nothing akin to the objectionable pivot-arm movement characteristic of the earlier machines. Second, the relative plate movement follows a completely nonrecurring pattern, as the following will illustrate. Starting at a random time and with bottom and top plates in a given juxtaposition each with a given angular velocity and with the bottom plate undergoing certain X and Y velocities, the likelihood that the plates will return even once in a finite cycle to the same juxtaposition and thereafter undergo the same relative movement sequence as occurred earlier, is infinitesimally small. For this reason alone, a very high degree of random or nonrecurring relative movement is assured, which contributes importantly to achieving the flat, smooth surface desired.

The random plate movement is further enhanced in accordance with another aspect of the invention by programming the bottom plate for certain angular velocities and also X and Y velocities or reciprocating rates which have been ascertained in advance to maximize the randomness of the movement. There doubtless are many such combinations and some have been found empirically. The whole range, however, requires computer calculation.

Additionally, by retarding the rotation of the upper plate periodically for brief intervals by a braking mechanism, a further improvement of the final quality of the lapped surface is achieved in some special instances. Such retardation will occur each time the bottom plate reaches

the limits of the X position and cause about a tenth of a radian slippage each time.

A further aspect of the invention concerns mechanisms by which the X and Y movements are quickly and smoothly reversed at the extremes of a reciprocation. The problem of lingering and sinusoidal speed variations earlier referred to thus becomes de minimus. The same mechanism assures a constant X or Y velocity during a stroke which prevents the jerky or jittery movements.

The sought-after quality of lap is realized through two further highly desirable—although not necessary—adjuncts to the invention. It has been found that the lapping plate is more effective when employing circular grooves cut in a specific pattern upon the surface of the lapping plate. This pattern comprises, generally, six such grooves evenly spaced to form an inner circle with its center as that of the plate, and 13 similar grooves similarly spaced to form an outer concentric circle. The basic generator matrix for all grooves is an equilateral triangle. Secondly, a foundation of lapping slurry not heretofore employed has been found particularly resistant to agglomeration, a problem which has plagued earlier efforts to produce even-textured laps.

One feature of the invention, accordingly, resides in a bottom lapping plate which rotates and translates at selectable speeds, and a top lapping plate containing the surface for lapping that rests freely upon the bottom plate and rotates with it but does not translate with it.

Another feature of the invention concerns a quick-reverse mechanism to enhance the reciprocating movements of the bottom plate.

A further feature of the invention lies in the independent speed controls for all movements of the bottom plate.

A general feature of the invention relates to the capability of the machine to be set initially and thereafter perform all lapping necessary to achieve the desired surface.

These and other objects and features of the invention are made evident in the description to follow of an illustrative embodiment and in the drawing in which:

FIG. 1 is a frontal perspective of the machine;

FIG. 2 is a schematic diagram of the lapping bed mountings;

FIG. 3 is a side view of the mountings;

FIG. 4 is a front view of the mountings;

FIG. 5 is an exploded front perspective of the lapping bed and plates;

FIG. 6 is a schematic mechanical and electrical diagram of the drive means for the lapping bed;

FIG. 7 is a schematic diagram showing the translational reversing means;

FIGS. 8 and 9 are schematic diagrams showing a lap piece mounted in the top plate; and

FIG. 10 is a top view of a lapping plate.

STRUCTURE

The overall lapping machine is illustrated in FIG. 1 and designated as 10. All the components are mounted on a table stand 11 with a flat top surface 12 having a cutout midsection designated 13 as shown in FIG. 2. Surface 12 embraces the entire area in which the lapping machine 10 functions, being typically no more than 24 inches on a side.

Mounted on opposite sides of surface 12, as shown in FIGS. 1 and 2, are two blocks 14, 15. These provide a slidable mount in an X direction, as designated by the arrow 16, for a frame consisting of slide bars 17, 18, 19, and 20. Four angle blocks 21 secure together the end portions of the slide bars in rigid fashion. As seen in FIG. 2, block 14 slidably mounts on bar 17, and block 15 slidably mounts on bar 18.

Two other mounting blocks 22, 23 are slidably accommodated on slide bars 19 and 20, respectively. Whereas blocks 14 and 15 are attached to surface 12 as shown,

for example, in FIG. 3, blocks 22, 23 are disposed above surface 12 as seen in FIG. 4. A circular plate 24 is attached rigidly at its periphery to mounting blocks 22, 23, as shown in FIG. 2.

Plate 24 supports an undercarriage 25, as seen in FIGS. 2 and 5. Undercarriage 25 comprises a vertical shaft 26 driven by two motors 66, 67 in a manner to be described, and four harness bars 27a, 27b, 27c, and 27d rigged outwardly on each of the four sides of undercarriage 25. A one piece belt 28, as seen in FIG. 2, is drivably attached to harness bars 27a and 27c; and a second one piece belt 29 is drivably attached to harness bars 27b and 27d.

It is seen from the foregoing that motion for undercarriage 25 in the X direction as indicated by arrow 16 is effected by movement of belt 28 in the X direction. Similarly, movement of undercarriage 25 in the Y direction as indicated by arrow 30 is effected by movement of belt 29 which draws blocks 22 and 23 in sliding movement along their respective bars 19, 20. In addition to this X and Y direction movement, it is seen that simultaneously shaft 26 rotates.

A suitable bearing such as 30 is employed to insure that shaft 26 has no radial or axial play with respect to plate 24, but is supported thereon for smooth rotation. An end flange 31 attached to shaft 26, as seen in FIG. 5, is adapted to mount a circular lapping bed 32 which receives a lower lapping plate 70. Lapping plate 70 is positively coupled to the bottom surface of bed 32 through a coupling disc 34 that maintains plate 70 symmetrically around the vertical axis of shaft 26.

In accordance with a main facet of the invention, both the speed and the stroke length of undercarriage 25 in the X direction and in the Y direction can be varied. The structure that effects this result will now be described.

A number of structural struts, shown in FIG. 6 and designated 33, 34, 35, 36, 37, 38, 39, and 40, are constructed integrally with table stand 11. One pair of struts, for example 35, 36, is associated with each of the four sides beneath top surface 12. The apparatus which each of these strut pairs such as 35, 36 supports is substantially identical in structure and function. In the description to follow, like numbers refer to like parts, but are distinguished as to their location by letter suffixes.

As seen in FIG. 6, a shaft 41a is mounted in strut 35 for rotational motion which is imparted to it through a gear box in strut 35 (not shown) by a drive belt comprising pulley 42a, belt 43a, pulley 44a, drive shaft 45a, and motor 46a. Pulley 44a and motor 46a are mounted by suitable means (not shown) rigidly to table stand 11. On shaft 41a there is mounted a magnetic clutch 47a which connects and disconnects shaft 41a with another shaft 48a. Shaft 48a is mounted in strut 36 in alignment with shaft 41a. A drive pulley 49a is secured to the approximate center of shaft 48a; and, as seen in FIG. 7, at the end of shaft 48a is mounted a disc 50a with a mirror 51a. Facing disc 50a is a second disc 52a mounted on a shaft 53a that is positionable through pulley 54a, belt 55a, drive pulley 56a, and motor 57a. Motor 57a, as well as shaft 53a, is rigidly secured by means (not shown) to the underside of table stand 11. A photocell 60a is mounted on disc 52a and interacts with mirror 51a in a manner described later.

A positively-loaded idler pulley 58a tensions belt 28 which feeds over drive pulley 49a and attaches to harnesses 27a, 27c by end members 59a, 59c. The latter ride in ball bearings along harness bars 27a, 27c.

Each of the above-described components 41a through 59a have counterparts 41b through 59b associated with strut pair 37, 38; 41c through 59c associated with strut pair 39, 40; and finally 41d through 59d associated with strut pair 33, 34. The description given above with respect to the interrelationships and structure of components 41a through 59a applies exactly with respect to each of the other three sets of like-numbered components. Their operational interrelationships will be described in detail below.

Another magnetic clutch, designated 78 in FIG. 1, is supported on a rigid shaft 79 suspended by some suitable means, such as support frame 80, above the upper lapping plate 74. Clutch 78 can be fastened by well-known gimbal mechanisms (not shown) to upper plate 74, by lowering it downwardly on frame 80. An electrical connection 178 is made between clutch 78 and control unit 61 which contains means (not shown) for intermittently engaging clutch 78 automatically. When so engaged, clutch 78 momentarily stops the sympathetic rotation of upper plate 74, for perhaps two or three degrees. This action is a further randomness available for inclusion in the lapping program and contributes in special cases to the desired surface uniformity in the end product.

Suitable electrical interconnections 146a, 147a, and 157a are provided between a control unit 61 and motor 46a, clutch 47a, and motor 57a. In like manner, electrical connections 146b, 147b and 157b to control unit 61 are effected for motor 46b, clutch 47b and motor 57b. Similarly connections 146c, 147c, and 157c are effected respectively between motor 46c, clutch 47c and motor 57c and the control unit 61. Also, connections 146d, and 147d, and 157d are effected between motor 46d, clutch 47d, and motor 57d and the control unit 61. In addition, electrical connection 166 is effected between unit 61 and motors 66, 67.

Finally, photocell 60a as well as photocells 60b, 60c, and 60d are positively connected through arrangements (not shown) via connections 160a, 160b, 160c, and 160d respectively to control unit 61.

OPERATION

The stroke and speed in the X direction may both be varied independently of one another and also of all other motion undergone by lapping bed 32. Certain other supporting features of the invention come into play in the effectuation of this motion to insure smooth movements as well as smooth transitions. The manner of achieving X movement and stroke is identical to the manner of achieving Y movement and stroke; and accordingly only the X movement will be described, it being understood that the description applies equally to movement in the Y direction.

The description to follow is taken in conjunction with FIGS. 6 and 7. It will be noted that mirror 51a is mounted on the periphery of disc 50a. Accordingly, mirror 51a undergoes an angular displacement equal to the angular displacement of pulley 49a, which is mounted on the same shaft 48a. In turn, pulley 49a undergoes a total angular displacement dependent on the X direction freedom of movement of belt 28 to which, of course, undercarriage 25 is attached. The limits of the X displacement undergone by carriage 25 thus relate to the angular displacement of mirror 51a.

As seen in FIG. 7, the photocell 60a includes a light transmitting portion 62a and a light receiving portion 63a. The angular position of photocell 60a may be varied within prescribed limits by adjusting of the motor 57a through rheostat 64a in control unit 61.

In accordance with the invention, the diameter of drive pulley 49a can be chosen with respect to the total X direction displacement of carriage 25 so that pulley 49a rotates less than 360 degrees as undercarriage 25 traverses its entire X displacement. Accordingly, in this instance the angular displacement of mirror 51a on disc 50a is less than 360 degrees—say for illustration purposes, 270 degrees. As a consequence, if mirror 51a begins its angular rotation from a point where it is in alignment with photocell 60a, then at the end of its angular displacement 270 degrees later, mirror 51a will be 270 degrees removed from photocell 60a. In the same period, undercarriage 25 has translated from its extreme desired positive X position, as it were, to its extreme desired negative X position. During this interval, pulley 49a undergoes rotation

in response to the movement of belt 28. If the diameter of pulley 49c is the same as that of pulley 49a, then each will be displaced an equal angular amount for a given movement of carriage 25, in this case 270 degrees. Additionally, in this case the two mirrors 51a and 51c will undergo the same angular displacement for a given movement of carriage 25, in this case again 270 degrees.

Let it now be assumed that, at the extreme desired point of travel of undercarriage 25 in the negative X direction, mirror 51c and photocell 60c are in alignment. As with photocell 60a and mirror 51a, a light signal transmitted by light transmitting portion 62c will be reflected by mirror 51c back to light receiving portion 63c. At this point of alignment a signal is thus generated. Similarly, a signal is generated when mirror 51a is in angular alignment with photocell 60a at the limit of travel of carriage 25 in the positive X direction. Accordingly, two signals are generated representing the extremes of travel of carriage 25 in its X direction of movement. These signals are turned to advantage in the manner now to be described.

Magnetic clutches 47a and 47c are engaged and disengaged in response to signals received from control unit 61. Whether engaged or not, the motors 46a and 46c, and their associated belt, pulley and gear driving train, are continuously driving the drive side of each clutch 47a and 47c. The rotational direction of clutch 47a is such that when engaged will drive belts 28 in the plus X direction; and the rotational direction of clutch 47c is such that when engaged will drive belt 28 in the minus X direction. By means of relay switches (not shown) in control unit 61, magnetic clutch 47a is disengaged in response to the occurrence of a signal between photocell 60a and mirror 51a upon the occasion of their coming into alignment. In response to the same signal, and also by means of relays (not shown) in control unit 61, magnetic clutch 47c—which is disengaged while undercarriage 25 is moving in the positive X direction, is engaged simultaneously with the disengagement of clutch 47a. The force vector applied to undercarriage 25 thus changes from a plus direction to a minus direction, as drive motor 57c picks up the load. Travel in the minus X direction for undercarriage 25 continues until mirror 51c comes into alignment with photocell 60c. At the point of alignment, a signal is generated in photocell 60c. In response to this signal, again by means of relays (not shown) in control unit 61, clutch 47c is disengaged and simultaneously clutch 47a is engaged. Movement of undercarriage 25 in the minus X direction is immediately arrested, and movement in the plus X direction is commenced.

This oscillatory movement in the X direction of undercarriage 25 continues between the limiting points described above, as determined by the amount of travel allowed undercarriage 25 before alignment of a photocell with its respective mirror occurs. It has been found desirable to provide a total X direction displacement of approximately four inches to achieve the lapping motions pursuant to the invention when using a lapping plate of about twelve inches in diameter. Obviously, this stroke can be varied to whatever amount is desired, by means, for example, of varying the diameter of drive pulleys 49a and 49c. Additionally, it is obvious that a 1—1 rotation ratio between pulley 49a and disc 50a, as described above, can be varied by conventional means such as reduction gears to achieve a stepped down ratio so that disc 50a will rotate proportionately less than pulley 49a. A longer stroke length for the same angular displacement of disc 50a with respect to photocell disc 52a accordingly is possible.

Pursuant to a further important aspect of the invention, it is possible to vary the stroke length of undercarriage 25 in either direction of its X direction travel, simply by adjusting the angular position at which the mirrors come into alignment with their respective photocells. Suppose, for example, that as above, disc 50a and its mirror 51a

has traveled a full 270 degrees away from photocell 60a during the movement of undercarriage 25 in the negative X direction. If now photocell 60a is turned a number of degrees toward mirror 51a—for example, 90 degrees—then in the rotational return movement of disc 50a as undercarriage 25 moves in the plus X direction, the alignment of mirror 51a in photocell 60a will occur after disc 50a has rotated 180 degrees instead of 270 degrees. Thus the signal generated between photocell 60a and 51a will occur earlier; and in response to this the reversing of direction of undercarriage 25 will occur earlier. In accordance with the invention, the precise point at which undercarriage 25 reverses from a positive X direction to a negative X direction can be chosen to be any point in its X direction travel simply by realignment of photocell 60a with respect to mirror 51a. Similarly, by readjusting the position of photocell 60c with respect to mirror 51c, it is possible to select the precise point at which undercarriage 25 will reverse from negative X movement to movement in the positive X direction.

The angular position of photocells 60a and 60c is adjusted through the motors 57a and 57c, respectively, which are controlled by rheostat controls 65a and 65c, respectively. It is also possible to vary the speed of drive motor 46a and 46c so that they run faster or slower or at the same or different speeds.

All of the foregoing description with respect to the X direction movement of carriage 25, applies exactly to the Y direction of movement of carriage 25 except that, of course, the parts with *b* and *d* subscripts, as shown in FIG. 6, are used. All of the variations and adjustments of the stroke of undercarriage 25 provided for the X direction are provided in exactly the same method for the Y direction.

Pursuant to another aspect of the invention the planes of operation of both belts 28 and 29 are fixed, although undercarriage 25 translates in both X and Y directions. The end members 59a and 59c of belts 28 are provided with ball bearings (not shown) which ride along the rods 27a and 27c respectively. Thus, as undercarriage 25 translates in a Y direction, the aforementioned rods slide within the ball bearings of end members 59a and 59c. The extremes of movement in the Y direction are set in the embodiment described by the travel which the mountings of rod 27a on undercarriage 25 will allow before they contact end piece 59a. In the same fashion, end pieces 59b and 59d ride in ball bearings (not shown) upon rods 27b and 27d, respectively, as undercarriage 25 translates in the X direction. The same restrictions as to extremes in movement apply here also.

It is desirable in promoting smooth vibration-free translational movement, that the nondriving clutch at a given moment, for example 47c, drag slightly against the driving clutch—47a in this instance—so that the driving or upper portion of belt 28 is always under tension. This is achieved in the magnetic clutches themselves simply by causing a certain adjustable residual magnetism to occur in the non-driving clutch, as the driving clutch is fully engaged.

Shaft 26 is driven by two worms mounted in undercarriage 25 which in turn are driven by two separate motors 66 and 67. These motors are set to rotate at slightly different speeds so that one motor is always dragging on the other. In this fashion, any backlash between shaft 26 and its two drive worms is substantially eliminated and a smooth continuous rotation of shaft 26 thus is promoted. As earlier noted, motors 66 and 67 are powered and controlled from control unit 61 through electrical connection 166 and rheostat 68. At all rotational speeds, however, one motor is dragging against the other. There are never any abrupt or jerky motions in shaft 26 as a consequence.

It is desirable that belts 28 and 29 be of the type that have gripping teeth on their inner edges, so that the chance of slippage occurring between the belt and its drive pulleys is eliminated,

Lapping of surfaces is achieved in the following fashion. A lower lapping plate 70 is placed as described in bed 32. Lapping plate 70 is provided advantageously with a pattern of circular grooves such as shown in FIG. 10. This pattern is characterized by a maximum possible number of these grooves for a given lapping plate, none of these grooves being intersected by the periphery of this given plate, the centers of these grooves lying on equal equilateral triangles, and the width and depth of these grooves being specific for a given lapping plate. An article such as 71 seen in FIGS. 8 and 9 includes a surface 72 which is to be lapped. Surface 72 accordingly is embedded in a second lapping plate 73 which also has a pattern of circular grooves similar to that of lapping plate 70. The circular grooves help to keep the lapping slurry evenly distributed. Surface 72 is flush with the lapping surface of plate 73, as shown in FIG. 9. Good lapping practice also calls for a third lapping plate 74, shown in FIG. 5.

A suitable lapping compound is applied to the lapping surface of lower plate 70, and lapping plate 73 with its surface 72 to be lapped, is placed face downward on lapping plate 70. Its weight is supported entirely by lapping plate 70. Four arms designated 75 are adjustably mounted in supports 76 which are spaced 90 degrees apart upon the surface 12 of table 11. Each arm 75 mounts a rotatable rubber wheel 77 that contacts the vertical surface of the lapping plate which rests on lower plate 70. The purpose of the arms 75 and wheels 77 is to restrict lateral movement of the upper lapping plate while lower plate 70 is translating in X and Y directions.

The clutch drive motors 46a, 46b, 46c, 46d are turned on and shaft drive motors 66, 67 actuated, all from control unit 61. The stroke in the X and Y directions of undercarriage 25 is set in the manner described above. From this point on, lapping occurs entirely automatically and in a completely random but uniform pattern.

Importantly, all three motions contributing to the lapping are performed by movement of lower plate 70 with respect to the relatively fixed upper plate, the advantages of which are several fold: It is possible in this scheme to perform a lap on any odd sized shape such as, for example, the triangular shaped article 71. The lapping is not limited merely to flats. Secondly, all of the lapping forces on the plates have very slight moment arms associated therewith. There are no moment arms which tend to cause a top plate to dig an edge into the bottom plate. Further, a fifteen inch surface can be lapped and polished in accordance with this invention in the space of a two foot square, whereas in prior art machines, at least a twelve foot space was required. Most importantly, it is possible to generate, by this invention, without any dependence on the skill of technicians, the most precise flat surfaces known, i.e., the optical flats.

It should be noted that the stroke limits can be varied pursuant to the invention while the machine is in operation. In prior art machines it was generally necessary to stop the lapping operation if an adjustment in stroke were desired. Any such interruption in a lapping operation tends to generate scratches or unevenness, which severely handicap the capability of a machine to produce smooth surfaces.

It has been found highly advantageous to employ in connection with the above-described invention a lapping compound consisting of the following materials and proportions: One pound abrasive grain such as aluminum oxide; one pound medical grain talcum powder; one cc. aerosol OT (sodium dioctylsulfosuccinate); and two pounds water. The working batch is produced of ten percent basic slurry and 90 percent water. The aerosol OT acts as a wetting agent for the abrasive compounds, allowing them to spread uniformly across the work surface without agglomerating and causing gouging to the work-piece.

It is to be understood that the invention as defined in the claims to follow is not limited to the embodiments discussed, which are purely illustrative; but rather is intended to cover also the many obvious modifications and variations that will occur to those skilled in the art.

What is claimed is:

1. Lapping apparatus comprising a lower lapping plate, a bed for supporting said lower plate, means for rotating said bed, and means for reciprocating said bed in an X direction and in a Y direction,
- means for limiting the X direction and the Y direction reciprocations of said body,
- means for effecting changes in both said limiting means while said X direction and said Y direction reciprocations are occurring,
- an upper lapping plate including means for flush mounting therein a surface to be lapped,
- said upper plate resting freely upon said lower plate and rotating in response to rotation thereof, and means for restraining translation of said upper plate.
2. Apparatus pursuant to claim 1, further including

means for varying the X and Y direction translational velocities and the angular velocity of said bed all independently of one another.

3. Apparatus in accordance with claim 1, further comprising means for retarding periodically the rotational movement of said upper plate with respect to said lower plate.

References Cited

UNITED STATES PATENTS

2,195,065	3/1940	Wallace	51—56	X
3,225,492	12/1965	Day et al.	51—3	
749,961	1/1904	Fischer	51—3	
2,991,594	7/1961	Brown et al.	51—59	
3,015,914	1/1962	Roney	51—59	X
1,963,884	6/1934	Budd	51—3	

JAMES L. JONES, JR., Primary Examiner

U.S. Cl. X.R.

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