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[54] **LAPPING MACHINE AND VIBRATORY DRIVE SYSTEM THEREFOR**


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[51] **Int. Cl.** ..... **B24b 7/00,** B24b 9/00

[58] **Field of Search** ..... 51/7, 58, 59, 59 SS, 51/57, 161, 163



[56] **References Cited**

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| | | | |
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| 3,088,247 | 5/1963 | Mushrush | 51/58 X |
| 3,643,384 | 2/1972 | Isaacson | 51/163 |



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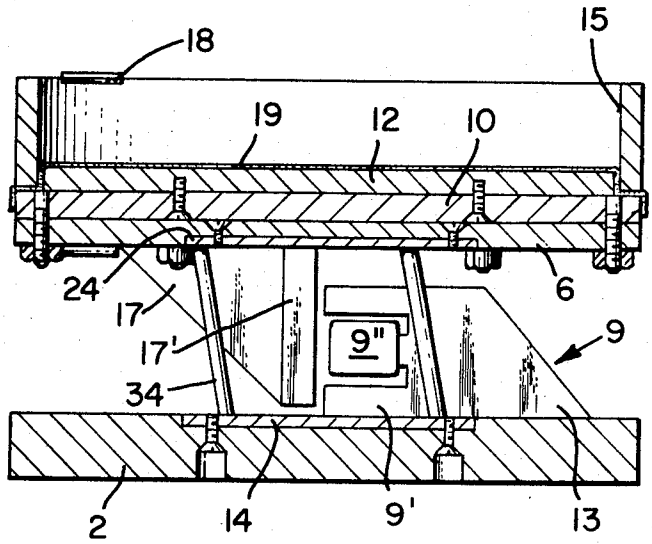


[57] **ABSTRACT**

Disclosed is a unitary spring assembly for a lapping machine whereby a lapping plate may be reciprocally vibrated at mechanical resonance at varying loads. Drive or vibration is provided by peripherally mounted electromagnetic solenoids whose force is applied tangential to the direction of rotation (or in the direction of displacement of the lapping plate).

This invention relates to the art of lapping and polishing articles by abrasion so as to provide such articles with one or more surfaces having a high finish, free of blemishes such as scratches or the like as might result from cutting or sawing. More particularly, the invention relates to a mechanically resonant vibratory drive system capable of producing a continuous lapping and polishing action or motion between a surface of an article and an abrasive or polishing member.


**6 Claims, 3 Drawing Figures**



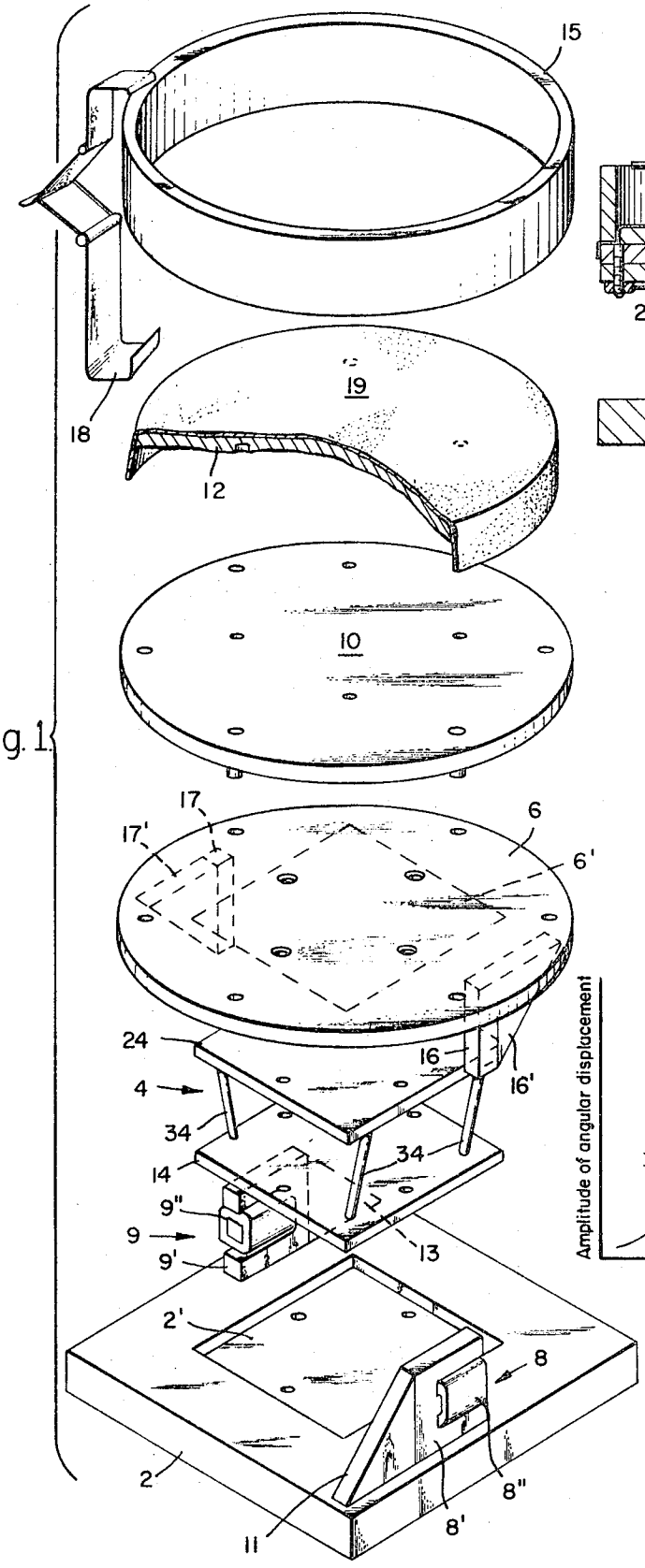



Fig. 1.

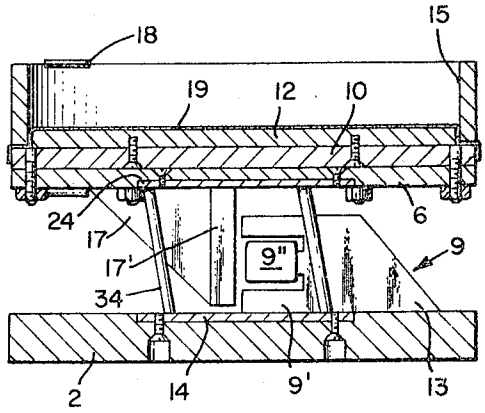
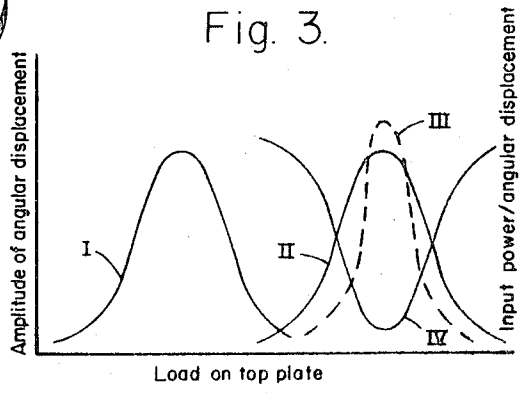



Fig. 2.

Fig. 3.



# LAPPING MACHINE AND VIBRATORY DRIVE SYSTEM THEREFOR

## BACKGROUND OF THE INVENTION

There are a wide variety of articles which must be lapped and polished to provide them with one or more surfaces having a high, flaw-free finish. It is also quite often necessary to uniformly reduce the thickness of an article from opposite, parallel sides or surfaces. Of particular interest in connection with the art of lapping and polishing is the semi-conductor industry which requires highly polished wafers of silicon or germanium free of mechanical damage. Such wafers are usually obtained by sawing or slicing ingots of single crystalline silicon or germanium, for example, which leaves these wafers with "damaged" surfaces exhibiting saw marks and scratches or the like. Since this industry also requires such wafers to be extremely thin (i.e., of the order of thousandths of an inch) and since materials such as silicon and germanium are very brittle, it will be appreciated that it is either impossible or economically unattractive to saw or slice wafers thereof to the desired thickness. It is therefore necessary to lap and polish these wafers on opposite surfaces to not only remove the blemishes or "damage" therefrom but to also uniformly reduce the wafers to some predetermined thickness.

Heretofore the motion for creating the abrading-lapping action has been provided by the reciprocatory motor-driven vibratory movement of a lapping plate in an inclined arcuate path which effectively conveys the articles to be lapped over and in contact with the abrasive surface of the lapping plate. The movement of the abrasive surface is provided by a motor, usually electromagnetic and of the type shown and described in U.S. Pat. No. 3,088,247 to W. G. Mushrush. As shown in this patent the lapping plate is connected to an electromagnetic reciprocatory motor via a base member and four sets of discrete cantilever leaf springs symmetrically disposed with one set on each side of the base member. The electromagnetic motor, through its armature, is coupled to the base member so that when the coil is energized, the energy impulses of the coil draws the armature downwardly forcing the springs to both rotate and flex so as to move the lapping member in a helical or inclined arcuate path. When the energy impulses pass or cease, the springs recoil so as to reverse the movement of the lapping member equal in magnitude and opposite in direction from that of the motion imparted during the energy impulse cycle. In this prior art arrangement the motor armature is centrally mounted relative to a vertical central axis as well as with respect to the cantilever springs which support the lapping member thereabove. It will thus be appreciated that rotational motion on the part of the lapping member is imparted thereto by a force applied in a direction perpendicular (or nearly so) to the surface or plane of rotation of the lapping member.

Because the vibratory drive systems of the prior art provide the force to achieve rotation of the lapping member in a direction of perpendicular to the plane of rotation, the efficiency of these systems to accommodate a variety of loads has been greatly impaired. In addition, the multiple cantilever spring units each comprising a plurality of discrete leaf springs, utilized in these prior art systems required the springs in each unit to be firmly secured together by bolts, for example, as shown in the aforementioned patent to Mushrush. These same bolts are also employed to secure the cantilever springs to an upper frame or member (which supports the lapping plate) and to a base member. This construction therefore makes it extremely tedious and difficult to change the cantilever spring units in order to accommodate varying loads.



## OBJECTS OF THE INVENTION

It is therefore an object of the present invention to provide an improved vibratory drive system.

Another object of the invention is to provide an improved vibratory drive system for lapping and polishing apparatus.

Yet another object of the invention is to provide an improved vibratory drive system for lapping and polishing apparatus which is capable of accommodating a wide load range.

Sti'l another object of the invention is to provide an improved vibratory drive system for lapping and polishing apparatus which drive system can be easily and quickly adapted or changed to meet different load demands.

Another object of the invention is to provide an improved vibratory drive system for lapping and polishing apparatus which can be easily and quickly adapted or changed to permit either material removal and/or polishing.

Yet another object of the invention is to provide an improved spring assembly for a vibratory drive system in lapping and polishing apparatus.

## SUMMARY OF THE INVENTION

These and other objects of the invention are realized by providing a peripherally driven interchangeable unitary spring unit. More particularly, the unitary spring unit of the invention comprises a pair of superimposed plate members separated by and secured together by a plurality of symmetrically disposed unitary spring members. A base plate member and a lapping plate member are provided which are adapted to receive therebetween the spring unit as a whole (or more particularly, to receive the upper and lower plate members of the spring unit respectively). In addition, the armatures of a pair of electromagnetic solenoid drive members are disposed on diametrically opposite points of the base plate so as to impart a torque thereto and to the lapping member, the direction of the torque being tangential to the direction of rotation of the lapping member. Since the drive unit acts on peripheral portions of the driven members, maximum torque is exerted, thus permitting a wide range of loads to be accommodated. The spring unit, since its individual springs are unitary therewith, avoids the necessity of assembling and disassembling individual springs. Hence spring units may be quickly and easily replaced to accommodate various load conditions or operational needs (i.e., lapping and polishing).

## DESCRIPTION OF THE DRAWINGS

The invention will be described in greater detail by reference to the drawings in which:

FIG. 1 is an exploded view in perspective of lapping and polishing apparatus according to the invention;

FIG. 2 is an elevational view in section of an assembled lapping and polishing apparatus according to the invention; and

FIG. 3 is a set of curves useful in explaining the operation and advantages of the invention.

## DETAILED DESCRIPTION

Referring now to the drawings the lapping and polishing apparatus of the invention comprises an electromagnetic vibratory drive unit for driving a lapping and polishing plate and bowl assembly. More particularly, the vibratory drive unit includes a base plate member **2**, a spring unit **4**, a top plate member **6**, and a pair of electromagnetic solenoid drive units **8, 9**. The lapping and polishing plate and bowl assembly includes a bowl base plate member **10**, a lap surface support **12**, a lap surface retaining ring **15**, and a pair of toggle clamps **18**. It will be understood that the lapping and polishing plate and bowl assembly is mounted onto the vibratory drive unit as will be described more fully hereinafter.

The base plate member **2** of the vibratory drive unit may be of stainless steel, for example, and is provided with a "blind" hole or recess **2'** symmetrically located at the center of the plate **2** with the opening or recess portion being disposed in the top surface thereof. By means of brackets **11, 13**, the coil and armature portions of a pair of solenoid drive units **8, 9** are affixed to diametrically opposite points on the surface of the base plate **2** and adjacent the periphery thereof. The solenoid drive units each include an E-shaped armature **8'** having an electromagnetic field coil **8''** mounted on the middle "leg" of the E. It will be understood that the field coils **8''** are force-fitted onto the armature members **8'** and are adapted to be connected to a source of alternating current for operation. The "legs" of each armature member extend in opposite linear directions (or in the same angular direction, i.e., counterclockwise).

The novel spring unit assembly **4** of the invention comprises a pair of plates **14** and **24**, one being disposed above the other and the two being secured together by a cage-like assembly of spring rods **34** of which there may be four in number. The bottom plate **14** is configured and adapted to fit into the recessed portion **2'** of the base plate **2** so as to be flush with the top surface thereof and secured thereto by means of machine screws, for example. The spring rods **34**, which may be of tempered, unhardened steel about three-fourths inch in diameter, are more or less permanently affixed to the top and bottom plates **14** and **24** as by welding or the like. Each spring element or rod is preferably positioned so as to lie on the surface of an imaginary cylinder disposed between the plates **14** and **24** with the axis of each spring element being uniformly or equally inclined in the same direction and to the same extent with respect to the axis of the cylinder. Typically the angle of inclination may be 17°, for example, and the extent thereof determines the extent of vertical displacement of the top plate **24** upon rotation.

The vibratory drive unit assembly is completed by a top plate member **6** which contains a "blind" hole or recessed portion **6'** which is configured and adapted to receive the upper plate **24** of the spring unit assembly **4** and to be secured thereto by means of screws or the like. Pendent from beneath the top plate member **6** are a pair of magnetically attractable bar members **16** which may be I-shaped bars of laminated soft iron, for example. The I-bars **16** are disposed on diametrically opposite peripheral portions of the top plate member **6** and are adapted to be adjacent but slightly spaced from the ends of the E-shaped armatures **8'** mounted on the base plate **2**. The I-bars **16** are secured to the top plate **6** by means of bracket members **16'**.

The lapping and polishing bowl assembly is mounted onto the drive unit assembly as follows. The bowl base member **10** is bolted to the top plate **6** of the drive unit by means of the threaded bolts **10'** depending from the bowl base member. The lap surface support member or plate **12** is then affixed to the bowl base member **10** by means of screws or the like inserted up through the bowl base plate **10** and threaded into the screw holes **12'** provided in the under-surface of the lap surface support plate **12**. The diameter of the support plate **12** is somewhat less than the diameter of the bowl base plate **10**. A suitable lapping surface may then be provided in the form of an abrasive cloth **19** or the like which is placed over the lap surface support plate **12**. It will be understood that the abrasive cloth will be larger in extent than the support plate **12**. The retaining ring member **15** is then placed onto the periphery bowl base plate **10** with the overhanging peripheral portions of the abrasive cloth **19** being contained between the retaining ring **15** and the bowl base plate **10**. The inside diameter of the retaining ring **15** is just slightly greater than the diameter of the support plate **12** so that the ring may fit snugly therearound and, when pressed down in position, will draw the abrasive cloth **19** taut across the surface of the lap surface support plate **12**. The retaining ring is held firmly in place by means of toggle clamps **18** which also permit quick and easy disassembly of the bowl assembly for the changing of abrasive cloths or the like.

## OPERATION

Upon energizing the solenoid coil members **8''** with alternating current the I-bars **16** affixed to the top plate **6** will be attracted toward the armatures affixed to the bottom plate **2** so as to cause the top plate **6** and hence the bowl assembly to start to rotate (in a clockwise direction, for example). Rotation against the spring unit **4** however also results in a downward vertical displacement of the top plate member **6** and the bowl assembly. The bowl assembly thus moves in a reciprocatory manner with angularly different (i.e., vertical and horizontal) components of displacement resulting in movement of the lapping surface in an inclined arcuate path. It will also be appreciated that one component (i.e., the horizontal) of displacement is greater than the other (i.e., the vertical). The resultant direction may also be described as a displacement normal to the inclination of the spring members. Articles placed in the lapping bowl will experience short, repeated rotational thrusts which imparts a circular motion thereto as explained below. Due to centrifugal force the articles will also move outwardly into contact with the retaining ring which thereafter restricts the path of the articles to circumferential portions of the lapping surface. Articles having a diameter less than the radius of the lapping surface will rotate about the axis of the lapping surface since the magnitude of the horizontal component of displacement increases as the distance from the center of the lapping surface increases. Rotation of the articles is produced since elements thereof closest to the outer edge of the lapping surface are given the greatest horizontal displacement whereas elements of the articles closer to the center of the lapping surface will be given smaller horizontal displacement forces.

The frequency and amplitude of the vibratory movement of the bowl is governed by the frequency of the alternating current and power energizing the solenoid. It will be understood, however, that the effective reciprocationg movement may be varied by the use of controls known to the vibratory motor art. Thus the reciprocating movement may be the same as, one-half, or double that of the alternating current frequency.

Thus, the movement of the lapping surface produces a rotary motion of the article being lapped about its own axis as well as simultaneously moving this article around the axis of the plate. Thus the lapping or polishing action is applied to the face of the articles in constantly changing directions. This produces a smoothly lapped surface, free of scratches or unequal reduction in thickness.

It is also possible to lap opposite surfaces of an article simultaneously, simply by placing a weighted abrasive member on the top of the article or articles. The bowl assembly of the invention also permits usage of lapping materials whether they be liquid, powder suspended in liquid, or merely powder. It will be understood that the lapping slurry will be retained along with articles being lapped by the retaining ring member **15.** It is also possible to provide a polishing surface by utilizing a cloth or covering of cork, felt, or flannel.

Upon the application of alternating current to the solenoid coils of a frequency equal to the mechanical frequency of the system, resonance vibration will occur. The natural mechancial frequency may be adjusted by appropriate selection of the diameter of the spring rods in the spring unit. For example, ¾ inch diameter rods are used at a vibratory frequency of 120 cps with a lapping fixture weighing 18 lb. to achieve resonance vibration. To attain a resonance vibration at this same frequency with a lapping fixture weighing 22 lb., rods of ⅞ inch in diameter are employed. Conversely, a spring unit change to achieve a different spring rate will cause a lapping fixture of a given weight to vibrate at a different resonant frequency. Thus, a spring unit having a greater soring rate (i.e., one having stiffer springs) will have a mechanical resonance at a higher frequency for lapping fixtures of the same weight. The unique aspects of the invention and its advantages are clearly illustrated by reference to FIG. **3.** In this figure the amplitude of angular displacement of the load on the top plate of the spring unit is plotted against the load on the top plate for Curves I, II, and III. The imput power per angular displacement is plotted against the load on the top plate for Curve IV.

Curves I and II illustrate the mechanical loading distribution for two different spring units at a fixed power imput and frequency. These curves show that different loads can be made to vibrate at the same frequency by utilizing different spring units. Thus, by maintaining mechanical resonance maximum or any desired displacement can be achieved with a minimum of power imput.

Curve III illustrates the mechanical loading distribution of prior art vibratory drive systems wherein drive is conventionally applied in the direction of the vertical component of displacement. This curve indicates that the fixed spring systems of the prior art could accommodate narrower load ranges in comparison with the apparatus of the present invention. Thus, in the prior art systems small load changes can result in a large reduction in the displacement. In contrast, the present invention achieves a much broader load range by providing peripheral drive in the direction of the horizontal component of displacement.

Curve IV illustrates the imput power per angular displacement required to maintain a constant displacement over a range of loads. At the maximum of the loading distribution (mechancial resonance), the power demand is minimum. Conversely, if the power imput is constant, a maximum of displacement will occur at the minimum point of Curve IV.

It will be appreciated that the disposition of the electromagnetic driving or motor means on the periphery of the vibratory drive unit permits the attainment of maximum torque to sustain large radial displacements under maximum loading conditions. In addition, peripheral drive also permits the one to maintain large displacements when lapping fixtures of widely different weights are utilized.

By the present invention a vibratory lapping apparatus is provided which utilizes the principle of resonance vibration at different frequencies. In addition, the present invention makes it possible to obtain maximum torque over wide loading ranges. Furthermore, mechanical resonance according to the invention is easily tuneable by means of readily replaceable unitary spring units. Thus, both lapping and polishing can be readily and quickly accomplished since the length of the working stroke is readily adjustable so as to permit material removal or polishing. It is to be understood that as used herein the term "lapping" is intended to be generic for both material removal as well as polishing.

What is claimed is:

**1.** In a lapping machine having a base member and a lapping member adapted to be moved reciprocally with angularly different components of displacement, at least one of which is radial, the improvement comprising:

means for applying a displacement force to said lapping member tangential to the direction of said radial component of displacement.

**2.** The invention according to claim **1** wherein said means includes motor means mounted on peripheral portions of said base member and a unitary spring assembly disposed between and coupling said lapping member and said base member.

**3.** A lapping machine comprising:

a. a base member,

b. a lapping member,

c. motor means mounted on peripheral portions of said base member for applying a rotational displacement force to said lapping member,

d. and a unitary spring assembly disposed between and coupling said lapping member and said base member.

**4.** The invention according to claim **3** wherein said unitary spring assembly comprises a plurality of spring rods affixed between first and second support members coupled, respectively, to said base member and said lapping member.

**5.** The invention according to claim **4** wherein said spring rods are inclined in the same direction and to the same extent between said first and second support members.

**6.** The invention according to claim **3** wherein said motor means includes a pair of electromagnetic solenoids mounted on diametrically opposite peripheral portions of said base member.

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