Oct. 11, 1966 R. G. MAZUR 3,277,610

LAPPING AND POLISHING APPARATUS

Filed July 12, 1963 3 Sheets-Sheet 1

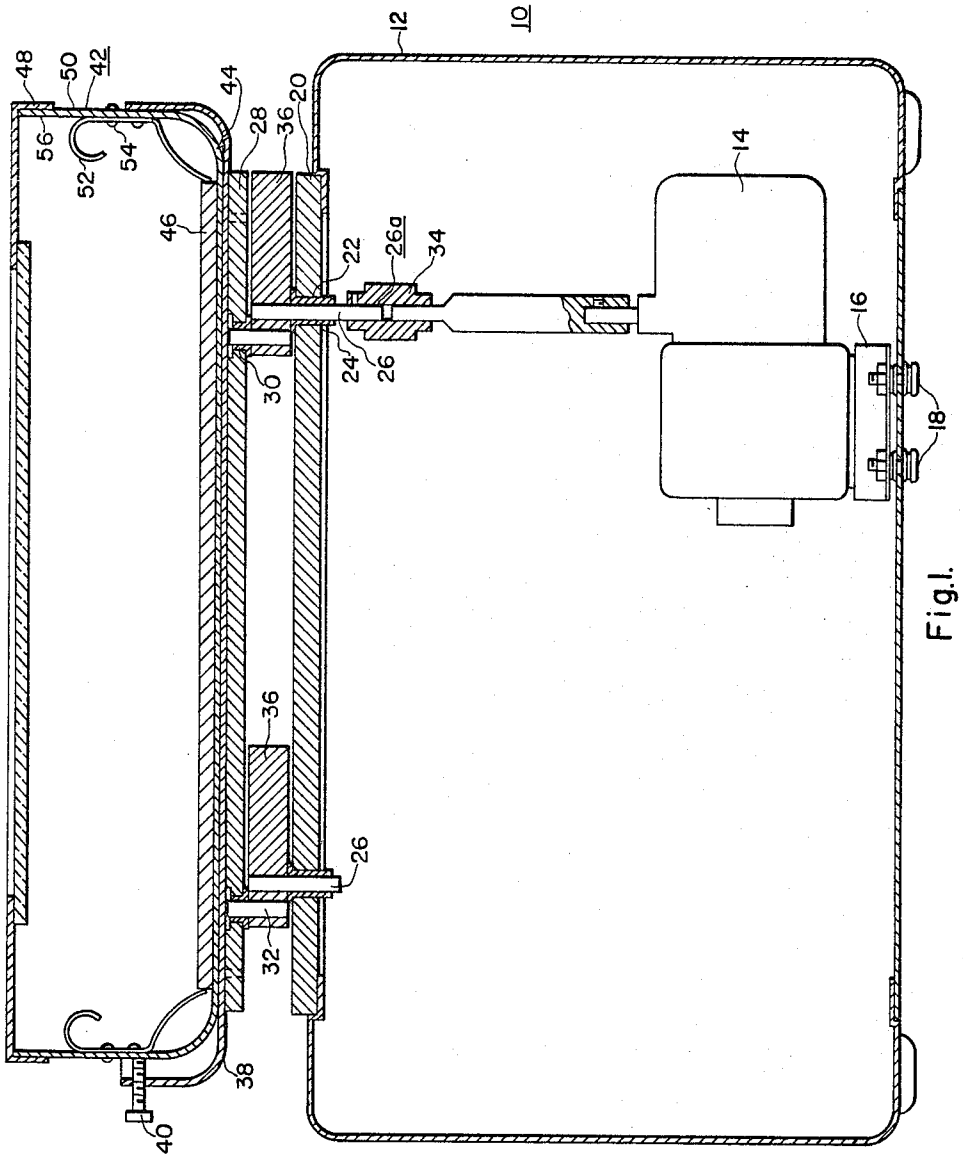


Fig. 1.

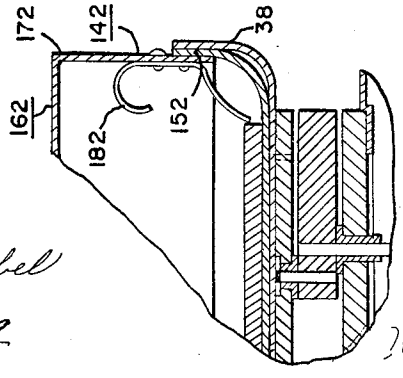


Fig. 7

WITNESSES

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LAPPING AND POLISHING APPARATUS

Filed July 12, 1963 3 Sheets-Sheet 2

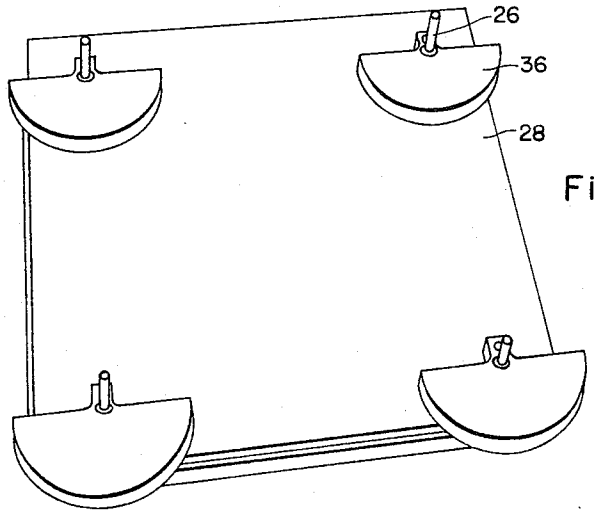


Fig.2.

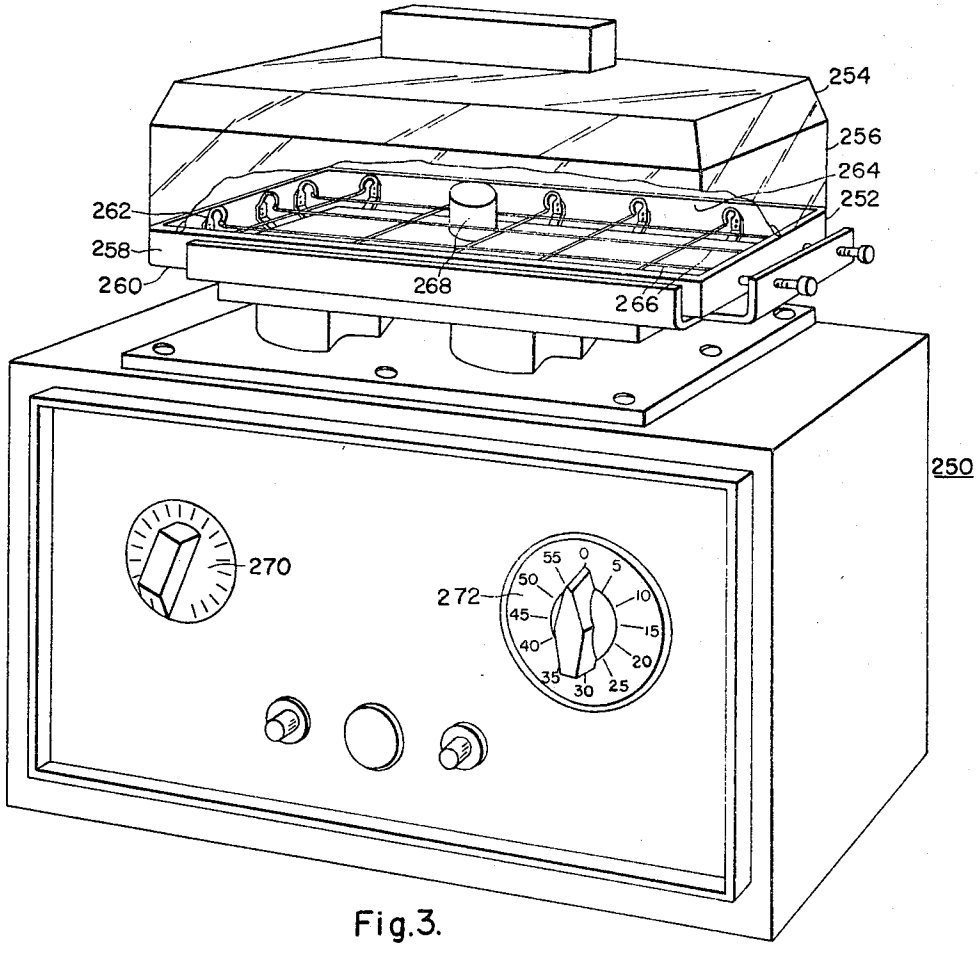


Fig.3.

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LAPPING AND POLISHING APPARATUS

Filed July 12, 1963 3 Sheets-Sheet 3

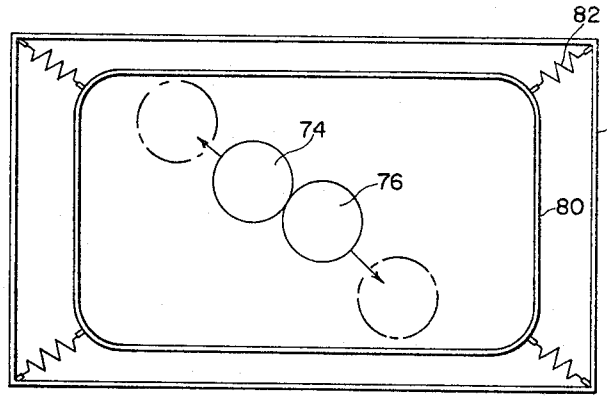


Fig.4.

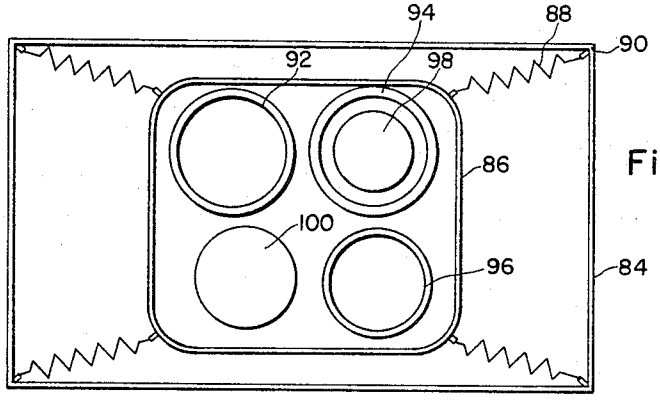


Fig.5.

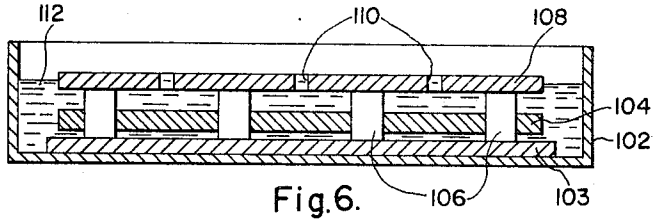


Fig.6.

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3,277,610

LAPPING AND POLISHING APPARATUS

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6 Claims. (Cl. 51—119)

The present invention relates to apparatus for abrading work.

In the process of machining metals, semiconductors and other materials, a subsequent operation often required is the lapping or polishing of flat, cylindrical or odd-shaped pieces or surfaces. Some of the factors that influence the lapping and polishing operation are: the materials involved, for example, workpiece, lapping or polishing compound, and the lapping of polishing plate or base; the size of the particles of which the lapping or polishing compound is composed; the pressure exerted on the workpiece; the relative velocity of workpiece and plate; and, the arrangement provided for constraining and loading the work during the operation. Economy urges a high rate or removal of material, lending to the use of a relatively coarse lapping or polishing compound, high pressure on the work, and rapid relative motion of work and lapping or polishing plate. On the other hand, in many situations, a smooth surface finish demands the use of a fine abrasive or polish, light loads and a very low rate of removal of material. The prior art solution to this problem is to use successive lapping or polishing abrasives, possibly with changes of pressure and motion so that a very high initial rate of removal and a very slow final rate lead to an overall relatively rapid rate of material removal and a fine surface finish.

In addition, economy also dictates the use of simple, rugged equipment that lends itself to a variety of operations and ease of maintenance, while the desired surface finish usually requires considerable care and relatively complex means to avoid contamination of finer abrasives by previously used coarser materials or airborne particles to avoid scratches. The lapping or polishing process may be carried out by hand; but, in most cases, the time and physical labor required for a proper finish necessitates the use of various lapping and polishing machines. The utility of a particular lapping or polishing machine may be judged on the basis of its success in meeting the requirements for different jobs as delineated above relative to its cost, the basic criterion being the machine's versatility or the case with which it may be adapted to various work programs that arise in practice.

Commercial lapping or polishing machines heretofore known in the art use combinations of opposed simple and planetary rotations of a lapping plate and work holders, cam operated translations and rotations combined to produce figure eight motion of the work relative to the lapping plate or mechanically or electrically generated repetitive translations or vibrations of the lapping plate. All of these machines are designed to provide relative motion of the work and lapping plate to assure even lapping of the workpiece, which is desirable. However, these machines all involve heavy and expensive construction, with an attendant lack of flexibility and require excessive care and maintenance for proper operation.

An object of this invention to overcome the difficulties and disadvantages of prior-art apparatus and to provide apparatus for and a method of abrading, polishing, lapping and the like for accomplishing this object.

Another object of the present invention is to provide a versatile and relatively simply designed lapping and polishing apparatus.

Another object of the invention is to provide an abrading apparatus having removable and interchangeable lapping and polishing trays.

Another object of the invention is to provide an apparatus for abrading the face of a workpiece wherein the workpiece moves freely on an eccentrically rotating abrasive surface, the motion being randomized by the essentially random forces acting between the abrasive surface and the work.

Other objects of the invention will appear hereinafter.

To fully understand the nature and scope of the invention, reference should be had to the following detailed description and drawing in which:

FIGURE 1 is an elevation view partly in cross section of the apparatus of the invention;

FIG. 2 is a perspective view of the support plate of the apparatus of the invention;

FIG. 3 is a perspective view of the apparatus of the invention;

FIG. 4 is a plan view of a lapping and polishing tray with workpieces thereon;

FIG. 5 is a plan view of a lapping and polishing tray adapted to provide uniform movement of work;

FIG. 6 is a plan view of a lapping and polishing tray adapted to simultaneously abrade both sides of the workpiece; and

FIG. 7 is a fragmental view in section showing a modification of this invention.

In accordance with the present invention and in attainment of the foregoing objects, there is provided an apparatus for abrading a workpiece. The apparatus comprises a work supporting means, for instance, a relatively flat plate including a work supporting abrasive surface. The abrasive surface may consist of loose abrasive material or a rigid abrasive sheet or the like. The apparatus also contains a plurality of shafts each rotatable about an axis displaced from the axis of said shaft. Driving means are connected to at least one of the shafts to move the one shaft about the displaced axis. Means are provided for connecting the one shaft in driving relationship with the supporting means to move the work supporting abrasive surface as the one shaft is driven. Means are also provided for connecting the other shafts in supporting relationship with the supporting means and rotatable therewith. Finally, a counterweight is attached to each shaft and is rotatable therewith no counterbalance dynamically the masses of each shaft and the portion of the supporting means moving therewith.

Referring to FIG. 1, there is shown a lapping and polishing apparatus **10**. The apparatus **10** comprises a sheet metal box housing **12** containing a variable-speed A.C. motor **14** which is secured to the housing **12** by means of bracket **16** and hardware **18**. On the upper end of the housing is disposed and attached thereto a base support portion **20** having a plurality of apertures **22** each containing a bearing member **24**. A plurality of arms or shafts **26** are disposed in the apertures **22** in the support portion **20** within the bearings **24** in a vertical plane such that each shaft **26** is rotatable about its axis in the bearing. The support portion **20** has disposed thereon another apertured plate **28** containing bearings **30** therein in such a manner that the portion **32** of the shaft **26** displaced from the axis of the shaft **26** fits into and is securably seated within the apertures referred to containing the bearings **30**. The displacement of the portion **32** of the shaft from the axis of the shaft **26** is such that the plate **28** eccentrically rotates about the center of the base support portion in a circle ranging from about 0.5 inch to 1 inch in diameter depending on the spacing between pin **32** and shaft **26**.

One of the arms or shafts **26***a* rotatably secured in the base support **20** and the plate **28** is driven by the motor **14** through a flexible coupling **34** which is secured to the main axis of shaft **26***a*. Each shaft **26** has secured thereto a counterweight **36** to dynamically counterbalance the rotating mass and thus eliminate vibration of the support portion **20** and the plate **28**.

The plate **28** is provided with an angle bracket **38** containing adjustable screws **40** which are capable of securing a removable lapping and polishing set **42** consisting of a tray **44**, a lapping and/or polishing sheet **46** and a cover **48**. However, other suitable means for securing the set may be employed. Thus it can be appreciated that a separate tray, lapping and polishing sheet and cover may be employed for each grade of lapping compound or polish employed.

As is indicated in the drawing, the tray **44** contains upstanding side walls **50** with a hooked bracket member **52** being secured by means of a bolt or rivet **54** to the inner surface **56** thereof. The hooked bracket **52** is designed to support a resilient or elastic member extending crossways from side wall to side wall as needed to provide a resilient wall to contain the work during lapping and polishing or to subdivide the lapping plate as is desired.

Alternatively, instead of employing the particularly designed lapping and polishing set **42** shown in the drawing, a set **142** may be employed wherein the height of the upstanding side wall **152** is substantially the same as the height of the bracket **38** on the plate **28**. A cover **162** having relatively long downwardly extending side walls **172** is designed to fit within the upstanding side walls **152** of the tray and hooked brackets **182** are secured to the inner surfaces of the cover instead of to the walls of the tray, as is shown in FIGURE 1, to serve the same purpose.

Referring to FIG. 2, there is shown the bottom side of the plate **28** of FIG. 1 in order to more fully appreciate the spaced relationship of the shafts **26** and counterweights **36**. The disposition of the shafts **26** and counterweight **36** at each corner of the plate **28** in a substantially equal spaced relationship has been considered particularly satisfactory for the size and shape of the counterweights employed to counterbalance dynamically the masses of the shafts **26** and the portion of the plate **28** moving therewith. However, it should be understood that counterweights of different design and a different spaced relationship of a number more or less than the number of shafts and counterbalances shown in the drawing is within the scope of the invention so long as the plate **28** is counterbalanced.

Referring to FIG. 3, the lapping and polishing apparatus **250** is shown in perspective with a slight modification in the lapping and polishing set. With respect to the cover **254**, the drawing shows that the cover having relatively long downstanding side walls **256** fits on top of the upstanding side walls **258** of the lapping and polishing tray **260**. A plurality of hooked members **262** are secured to the inner surfaces **264** of the upwardly extending side walls **258**. Rubber bands **266** are then easily disposed on the hooked members on one wall and are stretched across to the opposing wall and are disposed on a hooked member thereat to subdivide the tray **260**. A workpiece **268** is shown in position for the lapping and/or polishing operation within the subdivision delineated by the rubber bands **266**. The apparatus **250** also includes a motor speed control **270** and a timer **272**.

A particular feature of the lapping and polishing apparatus described herein is its versatility. The basic machine or apparatus may be easily and inexpensively adapted to any type of work desired. Specifically, the use of a removable lapping and polishing set consisting of a tray and a lapping and polishing sheet with an abrasive surface and cover, allows a change of abrasives from the coarsest lapping compound to the finest polishes in seconds with a minimal possibility of contamination. The lapping and/or polishing plates may be easily subdivided as indicated in FIG. 3 to allow independent motion of the separated workpieces or jigs or the workpieces may be placed loosely together on the plate to completely randomize the motion.

With reference to FIG. 4, an application of the randomized motion principle is shown. The workpieces **74** and **76** are disposed on the polishing or lapping tray **78** which contains a loose abrasive surface. When the eccentric motion is imparted to the tray, the regions of the tray on which the workpieces are disposed undergo acceleration so that the workpieces are moved by inertial forces relative to the tray surface. The spacing of the workpieces is such in relation to the frictional forces on the workpieces exerted by the tray surface that as the workpieces **74** and **76** are moved by the inertial forces they contact each other so that the workpieces are displaced over a substantial area of the surface during their movement. A resilient member **80** is disposed along the outer periphery of the tray and is suspended a slight distance above the surface of the tray **78** by means of springs **82** to facilitate continuous inertial movement without damage to the workpieces.

Referring to FIG. 5, another application of the above principle is shown but with limited and more uniform movement of the work over the lapping or polishing surface. In FIG. 5, there is shown a lapping and polishing tray **84** with a resilient member **86** disposed within the periphery of the tray and suspended therein by a spring member **88** attached to each corner **90** of the tray **84** and a portion of the resilient member **86** similar to that shown in FIGURE 4. Merely as an example, the drawing shows three members cylindrical metal **92**, **94** and **96**, the ring **96** having a workpiece **98** disposed within its periphery on the surface of the tray **84** and a workpiece **100** disposed on the lapping or polishing tray **84** in closely spaced relationship. The closely spaced relationship is provided so that the workpiece **100** moves uniformly over the lapping or polishing plate with the members **92**, **94** and **96** so that when the tray **84** is concentrically rotating in a counterclockwise direction, the cylindrical members and workpiece will move in a clockwise direction each maintaining the same relative position with respect to the other moving members.

It should be appreciated that cylindrical members are employed since their size and shape are readily controllable thus facilitating a desired spaced relationship on the tray. This is important since all of the workpieces desired to be polished may not be of a uniform size and shape to provide a desired closely spaced relationship and thus detract from the uniform movement of the workpieces. However, since the cylindrical members have a hollow center, a workpiece of any reasonable size and shape may be disposed within each of the members so that a plurality of workpieces may be lapped or polished simultaneously and the objective of uniformity may be fully met.

If desired, continuous conditioning of the lapping or polishing plate may be achieved by disposing a suitably shaped relatively large plate on the lapping plate. Such a plate will in general move randomly with respect to the basic lapping or polishing plate, and if provided with suitable openings for workpieces or jigs, will allow lapping or polishing of the work while keeping the lapping or polishing plate flat. With reference to FIG. 6, there is shown an application of the above principle. The lapping or polishing tray **102** containing a lapping or polishing sheet **103** has disposed on its upper surface a flat circular apertured plate **104** in which apertures a plurality of workpieces **106** are disposed. In addition, another suitably shaped relatively large plate **108** with or without apertures **110** is disposed on the exposed surfaces of the

workpieces **106**. Accordingly, when eccentric motion is imparted to the lapping or polishing sheet **103** both the lower plate **104** containing the workpieces **106** and the upper plate **108** will move in a random fashion thus lapping or polishing both sides of the workpiece **106** simultaneously. The abrasive may be applied by immersing both plates and workpieces in a liquid abrasive material **112** or alternatively the lower end of the workpieces may be abraded by applying a loose abrasive or a rigid abrasive sheet to the lapping or polishing sheet **103** and the upper ends may be abraded by feeding a loose abrasive through the apertures **110** in the upper plate.

To show with more particularity the versatility of the lapping and polishing apparatus, the following examples are considered to be indicative.

EXAMPLE I

An optical flat was lapped using an alumina abrasive with a water vehicle on the lapping tray having a glass lapping sheet thereon. The optical flat was 1.5 inches in diameter and was originally flat to only one fringe (using helium light, this is 0.295 micron). The average particle size of the alumina abrasive was about 5 microns. The optical flat was lapped for a period of the order of 15 minutes and the flat was rechecked by interference techniques against a master flat and was found to be still flat to one fringe. This illustrates the ability of the apparatus to maintain a degree of flatness within close parameters.

EXAMPLE II

A plurality of silicon slices having a thickness of about 0.004 inch were polished in the apparatus of the invention using a pitch lap base with a cerium oxide vehicle. The surface finish achieved was regarded as being as good as or better than the finish obtained with standard methods heretofore used in polishing silicon.

EXAMPLE III

Silicon carbide slices were polished with both 6 micron and ¼ micron diamond on a cloth lap affixed to a glass plate using kerosene as a vehicle. The polishing times for silicon carbide on the diamond laps ranged from one-half hour to an hour which was sufficient to remove all but a very few scratches visible at magnifications as high as 200×.

It is intended that the foregoing description and drawing be construed as illustrative and not in limitation of the invention.

I claim as my invention:

1. Apparatus for abrading a workpiece comprising a housing having a base support portion, a plurality of eccentric arms vertically disposed in and passing through the base support portion in a predetermined spaced relationship, a plurality of counterweights rotatably secured to the eccentric arms, a support plate operably secured to said eccentric arms to provide eccentric movement in a substantially horizontal plane, a removable lapping and polishing tray having an abrasive surface disposed on the support plate, the tray having upstanding side walls provided with resilient band means extending over and across said surface which when engaged by said work in motion, mechanically interacts with said work to produce an elastic impact on said work, and means within the housing for rotating at least one of the eccentric arms.

2. Apparatus for abrading a workpiece comprising a housing having a base support portion, bearing discs disposed in apertures in said support portion, a plurality of eccentric arms vertically disposed in and passing through the bearing discs, a plurality of counterweights rotatably secured to the eccentric arms, a support member operably engaged with said eccentric arms, a lapping and polishing tray capable of supporting a mass of loose abrasive material on a surface thereof disposed on the support plate, means for detachably securing the tray on said support plate, a grid of resilient bands extending over said surface in resilient engagement with said workpiece, and a motor within the housing for rotating at least one of the eccentric arms to produce eccentric movement of the tray in a substantially horizontal plane.

3. Apparatus for abrading a non-rigidly constrained workpiece comprising a housing having a base support portion, a plurality of eccentric arms vertically disposed in and passing through the base support portion, a plurality of counterweights rotatably engaged with the eccentric arms, a support member operably secured to said eccentric arms so that the upper surface thereof is disposed in a substantially horizontal plane, a removable lapping and polishing tray capable of supporting a mass of loose abrasive material disposed on the support plate, the plate having upstanding peripheral sidewalls, a cover having downwardly extending sidewalls disposed on the tray, the downwardly extending sidewalls fitting within the upstanding peripheral sidewalls of the tray, the extending sidewalls of the cover containing a plurality of fixtures capable of supporting a resilient means to contain the workpiece during abrading and means for rotating one of the eccentric arms.

4. Apparatus for abrading a workpiece comprising a housing having an apertured, rectangular base support portion, bearing discs disposed in the apertures, a plurality of eccentric arms vertically disposed in each corner of the base portion and passing through the bearing discs, a plurality of counterweights rotatably secured to the eccentric arms, an apertured support member with bearing discs in the apertures operably secured to said eccentric arms, a lapping and polishing tray capable of supporting a mass of loose abrasive material disposed on the support plate, means for detachably securing the tray on said support plate, the tray having upstanding peripheral sidewalls, a cover having downwardly extending sidewalls disposed on the tray, the downwardly extending sidewalls fitting within the inner periphery of the upstanding peripheral sidewalls of the tray, the extending sidewalls of the cover containing a plurality of fixtures capable of supporting a resilient means to contain the workpiece during abrading and means within the housing for rotating one of the eccentric arms to eccentrically rotate the tray and cover assembly in a substantially horizontal plane to produce random inertial movement between a non-rigidly constrained workpiece and said abrasive material.

5. Apparatus for abrading work comprising work supporting means including an abrasive surface supporting said work in abrading relationship, a plurality of shafts each rotatable about an axis displaced from the axis of said shaft, driving means connected to at least one of said shafts to move said one shaft about said displaced axis, means connecting said one shaft in driving relationship with said supporting means to move said surface as said one shaft is moved, means connecting said other shafts in supporting relationship with said supporting means rotatable thereby, a counterweight means connected to the dynamic system including said shafts and said supporting means to counterbalance dynamically the masses of said last-named shaft and the portion of said supporting means moving therewith, and resilient band means extending over and across said surface to engage said work resiliently and to exert reactive forces on said work as said work is moved over said surface by the movement of said surface.

6. Apparatus for abrading work comprising work supporting means including an abrasive surface supporting said work in abrading relationship, a plurality of shafts each rotatable about an axis displaced from the axis of said shaft, driving means connected to at least one of said shafts to move said one shaft about said displaced axis, means connecting said one shaft in driving relation-

ship with said supporting means to move said surface as said one shaft is moved, means connecting said other shafts in supporting relationship with said supporting means rotatable thereby, a counterweight means connected to the dynamic system including said shafts and said supporting means for counterbalancing dynamically the mass of said system, and a grid of resilient bands extending over said surface to engage said work resiliently and to exert reactive forces on said work as said work is is moved over said surface by the movement of said surface.

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