United States Patent

Millett

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[54] **PRECISION DISK GRINDER**

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[52] **U.S. Cl.** **51/132**

[51] **Int. Cl.** **B24b 7/04**

[58] **Field of Search** 51/109, 118, 132, 126

[56] **References Cited**

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[57] **ABSTRACT**

A grinder for producing a precise planar surface on a workpiece, the grinder being of the general type in which the chuck carrying the workpiece and the shaft carrying the grinding wheel are rotated about axes which are perfectly parallel to one another and perfectly normal to the desired planar surface. In the grinder of the invention, a grinding system, comprising a grinder motor and a grinding wheel, is mounted on a parallelogram linkage to be movable along the rotational axis of the grinding system.

A resilient actuator means urges the grinding system into grinding engagement. Preferably, the actuator means is a pneumatically cushioned hydraulic cylinder, and the pressure is adjustable to aid in adjusting to a predetermined grinding load.

The actuator means is opposed by an adjustable stop. The stop may be adjusted to precisely locate the plane of application of the grinding load. Operation of the actuator against the stop aids in bringing under control the deformation and displacement occurring in the grinder during operation.

In the preferred form of the invention, the stop and/or actuator may be adjusted during the grinding operation. In a further refinement of the preferred form, the grinder includes a continuous grinding load indicating means and a timer or clock for indicating the time period of application of each grinder load stage. Production of the desired surface on the workpiece is achieved by adjustment during grinding according to a predetermined load-time program.

19 Claims, 6 Drawing Figures

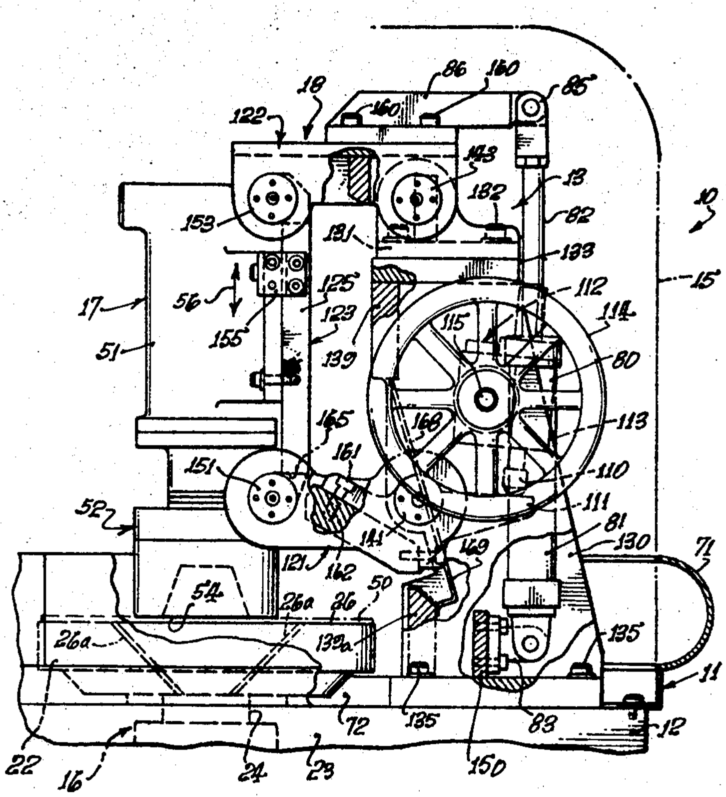

FIG. 1.

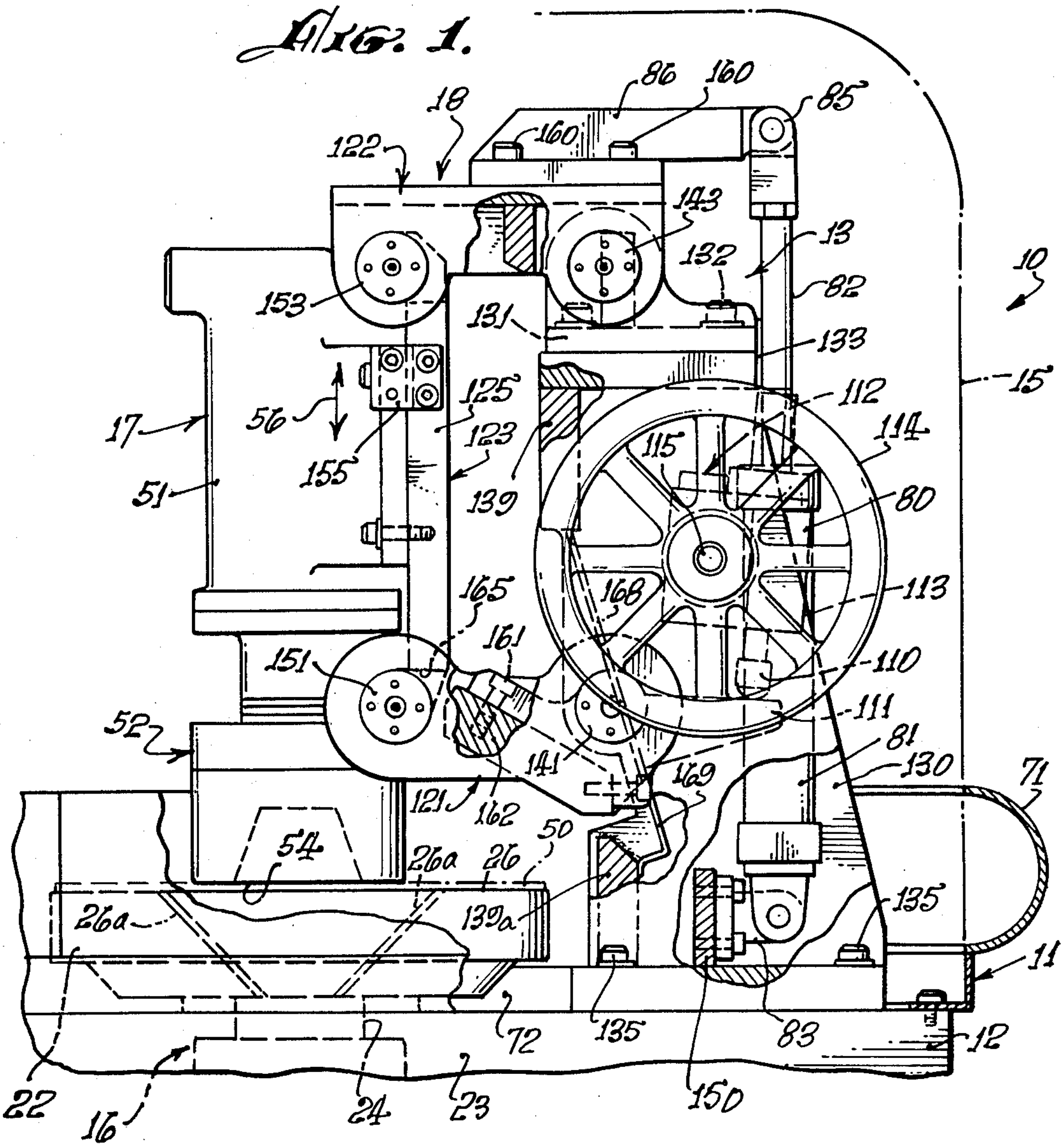

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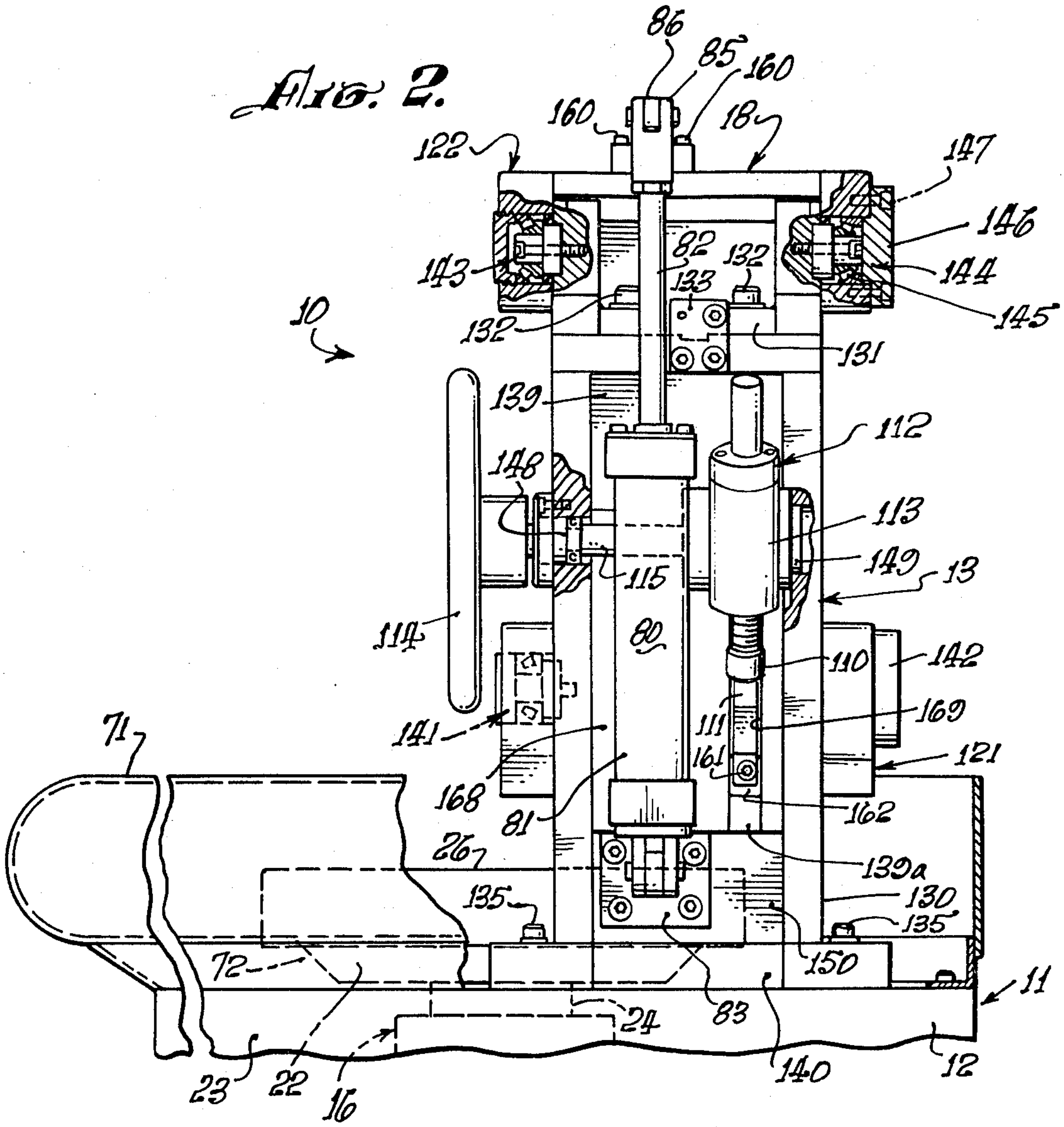
FIG. 2.



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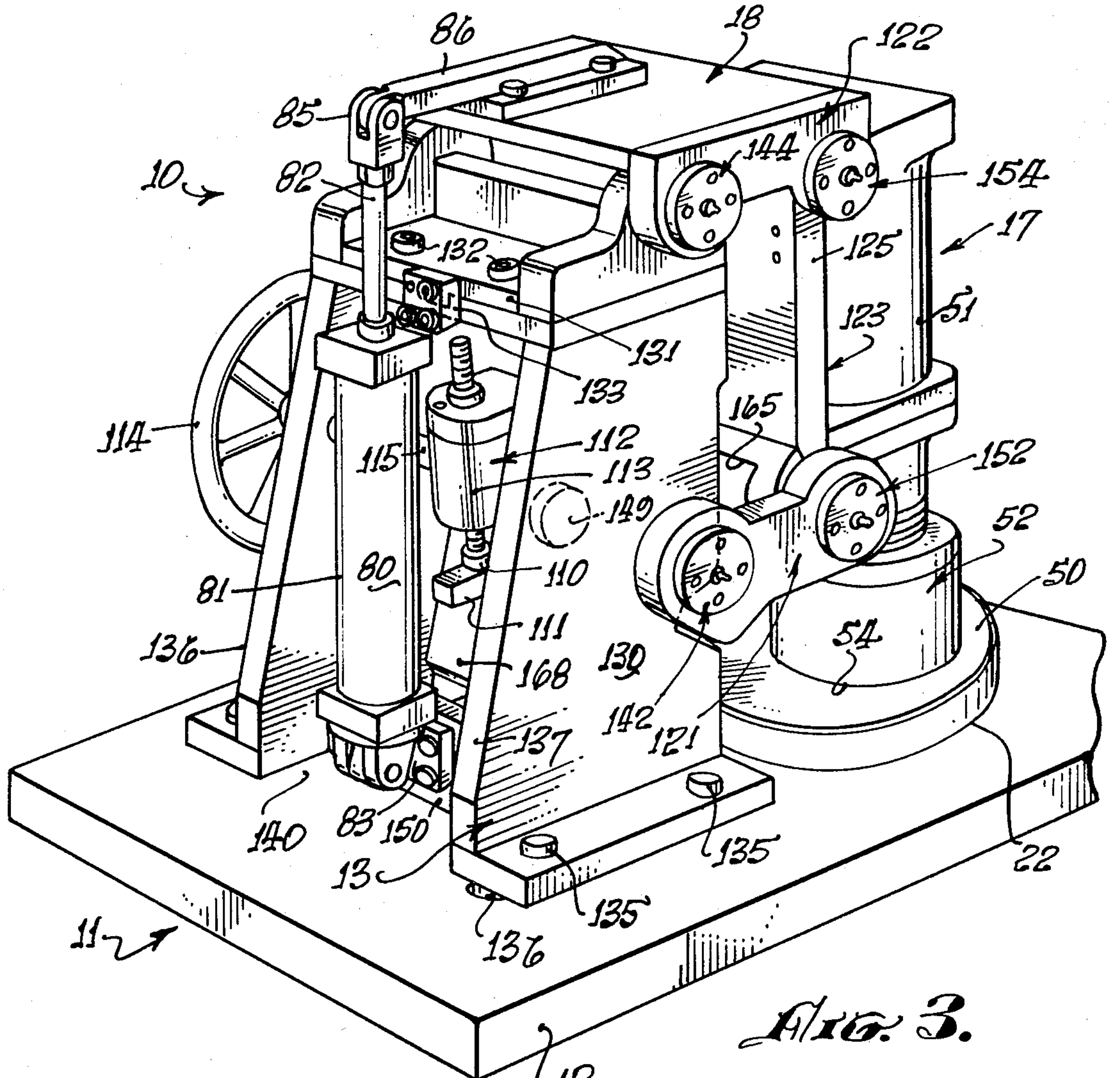

FIG. 3.

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Fig. 4.

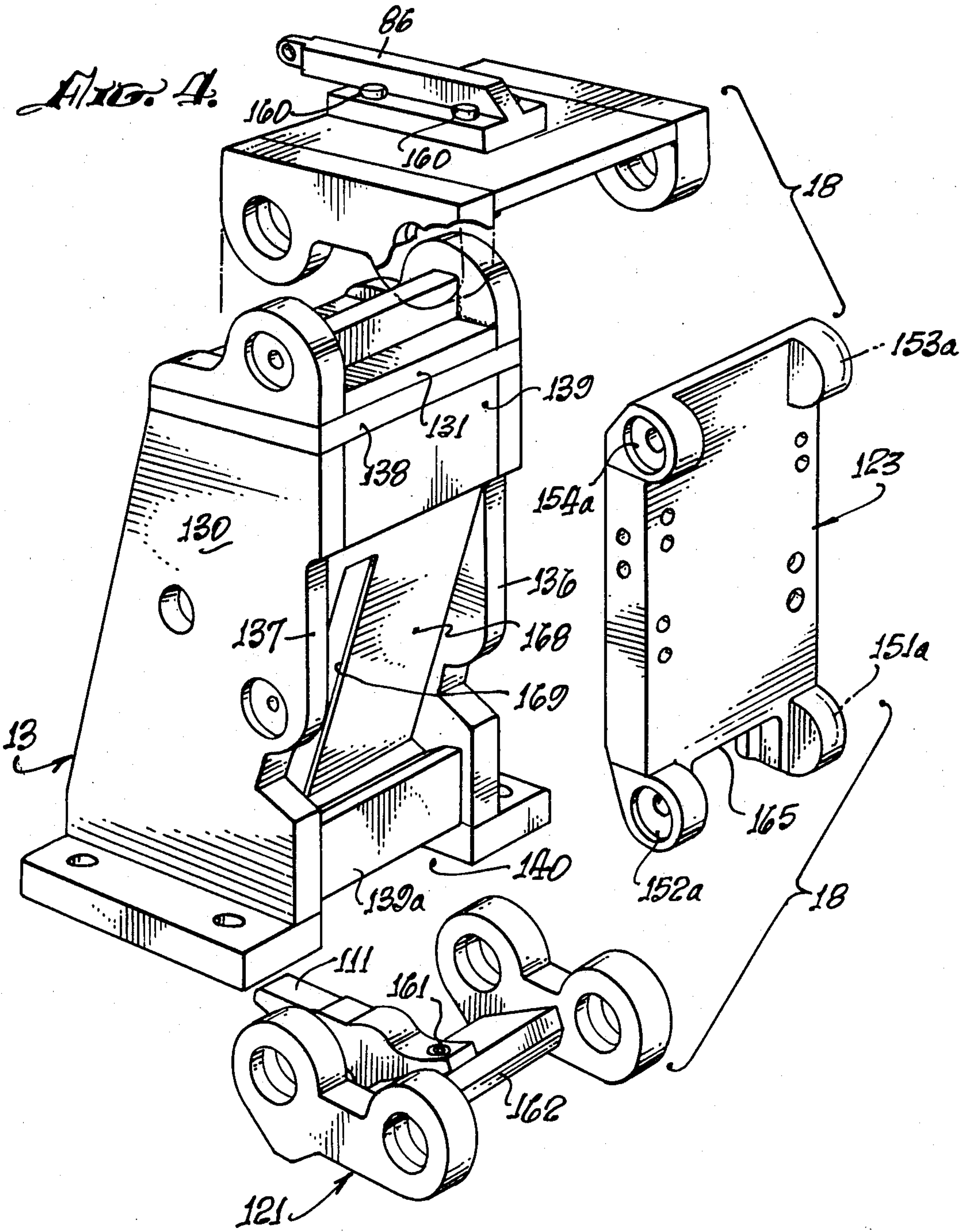

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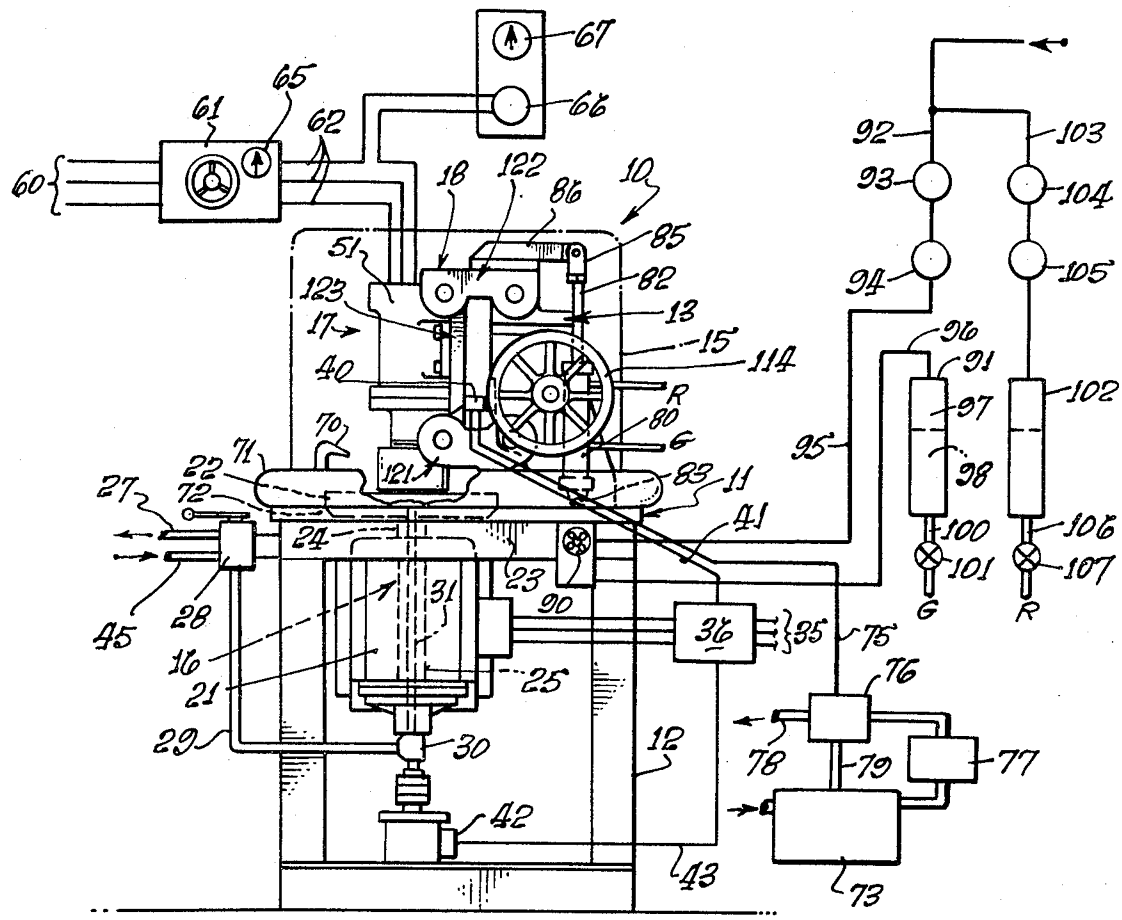
FIG. 5.



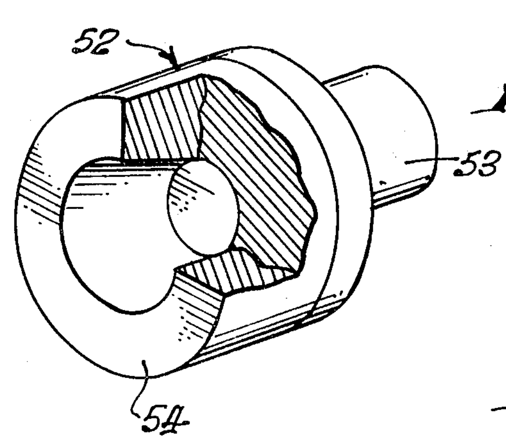


FIG. 6.

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PRECISION DISK GRINDER

The grinder of the present invention finds special application in grinding of flat faces on computer disks. The preferred tolerance for such disks is in the range of a few millionths of an inch, and previously known flat surface grinders are generally not reliable beyond tolerances of a few ten-thousandths of an inch. However, the utility of the grinder extends to applying a flat surface on any kind of workpiece, in which high precision tolerances justify the use of a high precision machine of the type of this invention.

The present invention is of the general type of surface grinder in which the workpiece is rotated at high speed about a chuck axis normal to the desired planar surface, while the grinding tool is also rotated at high speed about a tool axis, which is likewise normal to the planar surface desired, but is located at some distance, usually a few inches, to one side of the chuck axis. The grinding tool actually grinds only an annular band disposed substantially in the plane of desired flat surface. However, more extensive flat surfaces can be produced by moving the grinding tool axis or the chuck axis through different position spacings, during the successive grinding operations.

In the past, precision disk grinders have involved transport of the grinder or the workpiece on a carriage moving on a set of ways. It is impossible to machine a set of ways and produce straight-line movement with the same precision and freedom from vibration, as it has been found possible to achieve with the parallelogram linkage of the invention.

In the past, the chuck has generally been rotated on a shaft driven by belting or other indirect drive means. All of these generally used means have introduced slight tendencies toward vibration, which has been acceptable in most grinding applications of the past, but which produce minute ripples on the surface. Such ripples are not acceptable in computer memory disks or the like, since they prevent the surface smoothness within the tolerance desired.

In the present invention, a parallelogram linkage is supported in highly preloaded bearings, preferrably tapered roller bearings, which avoid the problems encountered with a carriage transported on ways.

Moreover, minute displacements and minute deformations, which cannot be avoided in precision machines, are controlled in the present invention by combining an actuator for resiliently applying grinding load, with an adjustable stop opposing the application of grinding load. In the preferred form of the invention, a pneumatically cushioned hydraulic cylinder is mechanically connected to the parallelogram linkage; controlled application of air to the oil supplied to the cylinder resiliently urges the parallelogram linkage, and the grinding system mounted upon it, into grinding load engagement with a workpiece mounted on a rotating chuck.

In the preferred form of the invention, movement of the parallelogram linkage into grinding position is opposed by a stop, which may be precisely and continuously adjusted in position during operation of the grinder.

The grinder of the present invention is uniquely adapted to precision grinding according to a predetermined program of grinding loads and time periods. At all times during operation, the grinding load is detected by a suitable load detection means, such as a meter measuring the current required by the grinder motor. As the grinding progresses, grinding load can be adjusted by adjustment of the adjustable stop, either continuously, or in a step-wise manner. In its preferred form, the grind includes a timer clock, indicating the time rate of grinder load change, or the time period for which a particular grinding load has been applied. The best combination of grinding loads and time periods may be predetermined for a given machine and a given workpiece by experimentation. Once established, the grinding load-timed program may be adjusted to maintain tolerance, as each successive workpiece is measured after grinding according to procedures well known to persons skilled in the art of precision tooling.

The timing and extent of stop adjustment, or other controlled changes of the grinder during the grinding operation may be accomplished by a human operator observing both grinding load and timer clock; or it may be accomplished automatically by automatic devices responded to detected grinding load, and grinding step time period, the automatic device being programmed according to predetermined grinding load-timer program, by any means of the many automatic programmable means available to those skilled in the art of precision tooling.

In an important preferred form of the invention, the parallelogram linkage has two bearings at each of its pivot axes. The spacing of the bearings laterally with respect to the central plane of parallelogram movement is sufficiently wide to permit the accommodation of the actuator, or the stop, or preferrably both, between opposite side bearings of the parallelogram linkage.

The foregoing and other objects and advantage of the invention will be understood from the following description of one preferred specific embodiment of the invention, which description should be read with reference to the accompanying drawings, in which:

FIG. 1 is a front elevational view of the grinder of the invention, except for the chuck driving system, which is illustrated in the digrammatic view of FIG. 5;

FIG. 2 is a right side elevational view of the grinder of FIG. 1;

FIG. 3 is a perspective view of the grinder of FIGS. 1 and 2, as seen from the right rear;

FIG. 4 is a perspective view of an exploded assembly of the column and linkage which carry the grinding system of the grinder;

FIG. 5 is a diagrammatic view of the grinder and its associated instruments and controls; and

FIG. 6 is a perspective view, partly sectioned, of a grinding wheel used in the grinder of FIGS. 1–5.

A general introductory description of the invention will make reference primarily to FIGS. 1 and 5. The particular embodiment of the grinder of the invention illustrated in the drawings is designated as a whole by the numeral **10**. A rigid, stationary base structure indicated generally by the numeral **11** (FIG. 5) is comprised principally of a chuck table **12** and a linkage support column **13**. It is preferred that column **13** be fastened to table **12** in a manner which permits some adjustment in their relative position; for example, assembly may be by bolts, as in the preferred embodiment illustrated, with one or more bolt holes in the form of straight or arcuate slots.

The principal mechanical parts of grinder **10** are best seen in FIG. **1**, whereas the associated instrumentation, and the chuck motor are best seen in the diagrammatic view of FIG. **5**, as will be described hereinafter.

A transparent plastic shield **15**, indicated in dashed line in FIGS. **1** and **5**, encloses the upper part of grinder **10** to confine oil spattering during the grinding operation; but this oil shield is omitted in most of the drawings for purposes of illustration clarity.

Grinder **10** contains two independently driven rotating systems, a chuck system indicated generally by the numeral **16**, and a grinding system indicated generally by the numeral **17**.

Grinding system **17** is vertically movable, being mounted on a parallelogram linkage **18**, which swings from linkage support column **13**. Although grinder **10** is illustrated with vertical rotational axes for chuck system **16** and grinding system **17**, and vertical movement for grinding system **17**, the invention includes within its scope grinders constructed with horizontal or oblique rotational axes. The illustrated grinder **10**, however, provides a construction which is convenient for observation and operation by a human operator.

The principal parts of chuck system **16** are a chuck motor **21** and a chuck **22**. Chuck motor **21** is securely mounted in table **12** immediately under a chuck-bearing wall **23**. Chuck **22** is rotationally mounted in chuck-bearing wall **23** by means of chuck bearing **24**, and is coupled directly to the shaft **25** of chuck motor **21**, without any intervening drive whatever.

Preferably, chuck **22** is of the vacuum type. The disk, or similar workpiece, is centered on the upper chuck surface **26**, and held in position by atmospheric pressure, because of a vacuum created at upper chuck surface **26**. A vacuum line **27** passes through a two-position chuck valve **28**, conduit **29**, rotating coupling **30**, and an axial passage **31** through motor shaft **25** to chuck **22**. Upper chuck surface **26** has numerous openings communicating with axial passage **31**, to accomplish firm vacuum holding of a workpiece disk on upper chuck surface **26**.

Preferably, chuck motor **21** is stopped by electric current reversal, and not by any braking system, since the latter might produce imperfections in the precision grinding operation on a workpiece mounted on chuck surface **26**. In the preferred form illustrated, FIG. **5**, chuck motor **21** is a three-phase alternating current motor, supplied with three-phase alternating current through power line **35**, reversing switch **26**, and motor line **37**. Reversing switch **36** starts the grinder motor **21** in grinding rotation when a microswitch **40** indicates that the grinding system **17** has been lowered into grinding position as illustrated in FIG. **5**. When the grinding system **17** is retracted upwardly at the conclusion of grinding workpiece, microswitch **40** indicates this change through reversing switch line **41**, whereupon reversing switch **36** is reversed, and in conjunction with a plugging switch **42** and plugging switch line **43**, supplies reverse current to chuck motor **21** until it is brought to a standstill.

Vacuum valve **28** is a two-position valve, so that it can be turned to a pressure-supply position, at the conclusion of the grinding operation, to supply pressure from pressure line **45**, through the line **29**, the axial passage **31**, and the openings in upper chuck surface **26**, to free the workpiece disk from the chuck **22** by pressure, so that the operator can remove the workpiece with facility.

In FIG. **1**, a workpiece **50** is seen as its upper surface is undergoing grinding. The vacuum openings **26*a*** are seen in dashed outline.

Grinding system **17** is seen to be comprised principally of a grinder motor **51**, and a grinding wheel **52** which is typically of a construction illustrated in detail in the partially sectioned perspective view of FIG. **6**. Grinding wheel **52** has a step **53** for mounting directly on the shaft of grinder motor **51**. At its opposite end, the grinding wheel **52** has an annular grinding surface **54** which is rotated in grinding engagement with the surface of workpiece disk **50** as seen in FIG. **1**. As in the case of the chuck system **16**, it is important in the grinder system **17** that grinding wheel **52** rotate integrally with the shaft of grinding motor **51**, without any intervening drive. Also, in this connection, the entire grinding system **17** is preferably carried as a unit on the parallelogram linkage **18**, and is movable upwards and downwards along a vertical line indicated by the doubleheaded arrow **56**, in FIG. **1**. Preferably, grinder motor **51** is of a type which can be speed controlled. In the preferred form illustrated, grinder motor **51** is a three-phase alternating current motor and is supplied with three-phase alternating electric current from power supply line **60**, frequency converter **61**, and grinder motor line **62**. Speed control of grinder motor **51** is achieved by increasing or reducing the alternating current frequency by means of frequency converter **61**, grinder motor speed being indirectly indicated by the alternating current frequency indicator **65**.

It is also seen from the diagrammatic view of FIG. **5**, that the electric current drawn by grinder motor **51** through grinder motor line **62** passes through an ammeter **66**. The current drawn by grinder motor **51**, and measured by ammeter **66**, indirectly indicates the grinding load at **67**. As grinding pressure is increased on workpiece **50**, the current detected by ammeter **66** increases, and vice versa.

During grinding, a liquid coolant is continuously sprayed on the surface of the workpiece **50** by a coolant nozzle **70**, seen in FIG. **5**. As already mentioned, the spraying of the coolant is confined by the transparent plastic hood **15**. Also, a metal shield **71** surrounds the chuck rotation zone **72** within which chuck **22** rotates. Coolant which is thrown from the chuck rotation zone **72** by centrifugal force is confined by shield **71**, and recycled by conduit not shown to coolant reservoir **73**. Micro switch **40** controls coolant circulation, in addition to controlling the reversing switch **36**. An electrical signal from micro switch **40** through valve control line **75** controls coolant valve **76**, through which valve a coolant pump **77** continuously circulates coolant from the coolant reservoir **73**. When the grinding system **17** is lowered into the grinding operation position indicated in FIGS. **1** and **5**, valve **76** is positioned to deliver coolant through line **78** to nozzle **70**. When the grinding system **17**, is upwardly retracted, indicating the discontinuance of grinding, valve **76** shifts to recirculate the coolant to the coolant reservoir through recirculation line **79**. As best seen in FIGS. **1** and **3**, the grinding wheel **52** is urged into grinding engagements with the workpiece **50** by the action of an actuator **80** upon the parallelogram linkage **18**. In the preferred form of the invention illustrated, actuator **80** is a pneumatically cushioned hydraulic cylinder, comprised of an actuator cylinder **81**, and actuator rod **82**. The cylinder **81** is pivotally anchored by pivotal anchor **83** to the lower part of column **13**, although it will be appreciated that any anchoring to the base structure **11** might be employed.

The upper end of the actuator rod **82** is pivotally connected by pivotal connection **85** to an arm **86** which extends from the parallelogram linkage **18**.

The diagrammatic view of FIG. **5** shows the manner in which the operator can control the lowering or upward retraction of grinding system **17** by means of a continuously adjustable actuator control valve **90**. Valve **90** admits compressed air under pressure into the upper end of a reservoir **91**. Compressed air supplied through line **92**, regulator **93**, pressure gauge **94**, line **95**, control valve **90**, and line **96**. Compressed air, indicated by the numeral **97**, in the upper part of cylinder **91**, expels oil, indicated by the numeral **98**, in the lower part of cylinder **91** through grinding actuation line **100** and valve **101**, communicating with the hydraulic cylinder **80**, and causing it to urge the grinding system **17** into grinding operation against workpiece **50** through the mechanical connections already described.

A second cylinder **102**, similar to cylinder **91**, receives compressed air through line **103**, pressure regulator **104**, and pressure indicating gauge **105**. Oil from cylinder **102** operates through actuator retracting line **106**, and valve **107**, to cause actuator **80** to upwardly retract grinding system **17**, at all times except when the operator of the grinder **10** has rotated actuator control valve **90** to apply sufficient pressure to lower the grinding system **17** into grinding engagement.

The resilient urging of actuator **80** to apply grinding load through the grinding system **17**, is opposed by a stop **110**, which bears on a seat **111**, which is in the form of an arm extending from parallelogram linkage **18**.

The exact position of stop **110** may be adjusted at all times, even during grinding, by means of a stop adjustment system indicated generally by the numeral **112**, and comprised principally of a worm gear **113** and an adjustment wheel **114**. Stop **110** is carried by worm gear **113**, which is in turn anchored to column **13** by a rotatably mounted shaft **115**.

A preferred construction for column **13** and parallelogram linkage **18** is shown in the illustrations, particularly in the perspective view of FIG. **3** and the exploded assembly of FIG. **4**. Linkage **18** is seen to be comprised of an inboard swinging link **121**, an outboard swinging link **122**, and a longitudinally moving link **123**. It will be seen that inboard link **121** carries the seat **111**, upon which the stop **110** makes bearing engagement. Outboard link **122** carries the arm **86** through which the grinding load is applied by operation of actuator **80**. Longitudinally movable link **123** provides the mounting platform **125** for the grinder system **17**.

Column **13**, which may be suitably constructed as a welded structure of massive steel plates, is comprised of two relatively adjustable parts, a main column structure **130**, and an adjustable bearing support **131**. Bearing support **131** is bolted to main column structure **130** by bolts **132**, which are received in slotted bolt openings in main column structure **130**, permitting a small degree of positioning along a line through the axis of rotation of grinding system **17**, by means of a toolmaker's adjustment block **133**, according to a construction well known in the toolmaker's art.

Preferably column **13** is slightly adjustable in position on chuck wall **23**, by virtue of attaching bolts **135** received in slotted openings **136**. Arcuate openings **136** are shown, although more restrictive movement might be achieved with longitudinal slots.

It is a preferred form of the invention that column **13** and parallelogram linkage **18** be connected by pairs of laterally spaced bearing members, and that both grinding load (applied by actuator **80**) and adjustable stop resistance (applied by adjustable stop **110**) be applied to the parallelogram linkage **18** between the laterally spaced bearing locations.

In the preferred form construction illustrated, the main column structure **130** is comprised principally of upright front and back sidewalls **136** and **137**, a top **138**, and transverse walls **139** and **139a**. Sidewalls **136** and **137** are separated by a lateral spacing **140**, which space apart inboard link bearings **141** and **142**, and outboard link bearings **143** and **144**.

Both actuator **80** and adjustable stop **110** are located in the lateral space **140** between the column sidewalls **136** and **137**, and the bearings **141** and **143**, at the front side, and bearings **142** and **144** at the back side of column **13**.

The view of FIG. **2** reveals that the spaced bearings **141** to **144** permit precision adjustments; in FIG. **2** outboard link bearings **143** and **144** are partially sectioned to reveal that they are preferably angle roller bearings as indicated at **145**, and that, in bearing **144**, slight tilting adjustments may be achieved on bearing **145** by adjustments in screws **146** on cap **147**. It should also be noted that there is no through shaft, but that bearings **143** and **144** are independently seated in bearing support **131**.

FIG. **2** also reveals that the actuator adjusting stop **115** is rotatably mounted in side members **136** and **137** by bearings **148** and **149**.

FIG. **2** also reveals that actuator cylinder pivotal mounting **83** is bolted to a cross member **150** extending between column sidewalls **136** and **137**.

FIGS. **1, 3** and **4** illustrate the grinding platform **125**, and the manner in which the grinder motor **51** is mounted on it. In the preferred form illustrated, the grinder platform **125** carries grinder motor **51** between laterally spaced inboard bearings **151** and **152**, and outboard bearings **153** and **154**, which are received in link **123** at bearing recesses ***151a*** to ***154a***, sequentially. It will be understood that bearings **151** to **154** are similar in construction to bearings **141** to **144**, and like them have one bearing on each side adjustable for minor precision adjustments according to means familiar to those expert in precision tool construction.

Another adjustment is provided by the toolmaker's adjustment block **155**, which permits grinder motor **51** to be adjusted slightly along a line tangential to the rotation of grinder **51**, thus providing a right angle complement to the adjustment permitted at adjustment block **133**.

It is preferred construction that the parallelogram linkage **18** have laterally spaced bearing locations and that the rotational axis of grinding system **17** is spaced between these locations and as near as possible to grinder platform **125**. Thus, in the preferred construction for linkage **18**, illustrated in the exploded assembly of FIG. **4**, the longitudinal link is constructed to receive grinder motor **51** and grinding wheel **52** within a recess defined by the forwardly projecting bearing locations **151***a* to **154***a*.

FIG. **4** also shows certain other details of construction. Actuator arm **86** is seen to be bolted by bolts **160** to the upper surface of outboard link **122**. Likewise, seat **111** is seen to be in the form of an arm attached by screws **161** to transverse member **162** of inboard link **121**.

It will be noted that the lower part of longitudinally movable link **123** is notched at **165** to permit rotation of grinding wheel **52** in a location partially recessed between bearing locations **151***a* and **152***a*.

A sheet metal spatter shield **168** is positioned between front and back side members **136** and **137** to protect actuator **80** and the stop **110** from coolant oil thrown during grinding. Shield **168** is slotted at **169** to accommodate the movement of seat **111**.

In operation, the workpiece **50** is placed in position with the grinding system **17** retracted into an upper position. Micro switch **40** detects this upwardly retracted position and consequently, the chuck **22** is stationary, and no coolant oil is permitted to flow from coolant nozzle **70**. The operator switches chuck control valve **28** to the vacuum line **27**, causing the workpiece **50** to be held by air pressure snugly in position on the upper surface **26** of chuck **22**.

Once the workpiece **50** is in position, the operator moves actuator control valve **90** to lower the grinding system **17** into grinding engagement with workpiece **50**. The operator may leave the grinding motor **51** continuously running, even in retracted position, or may have a stop-and-start switch within his control, depending upon the preferences for a particular application.

As grinding system **17** moves into grinding engagement, micro switch **40** moves to cause the startup of coolant flow from nozzle **70**, and to begin the rotation of chuck motor **21** and chuck **22**.

As soon as grinding engagement occurs, the operator can detect the grinding load being applied, by reading the load indicating ammeter **65**. He has three methods of load adjustment at his disposal, the application of pressure by actuator valve **90**, the adjustment of grinder rotation speed by frequency converter **61**, and the adjustment of the position of stop **110** by stop adjuster wheel **114**. Preferably, the only adjustments required during the grinding operation of a single workpiece **50**, or during the grinding of a succession of like workpieces, will be achieved by movement of stop adjustment wheel **114** to produce a predetermined grinding load indication at ammeter **66** and to maintain that grinding load for a period of time timed by timer clock **67**.

It is a feature of novelty and an advantage of the grinder of the invention that a load-timed program can be predetermined with a few trial runs for achieving grinding to very precise specifications. There is considerable variation in grinding wheels **52**, not only from one wheel to another, but even within the same wheel at different stages of wear. However, the workpiece material is very consistent and responds in a very consistent way to the precise application of a predetermined grinding load for a predetermined period of time. Thus, the trial workpiece may be carefully measured after trial grinding, and the load-timed grinding program revised in the light of experience to more closely approach the grinding specification desired. The workpiece is not ordinarily ruined by repeated trial runs, until a satisfactory grinding program has been determined. It will also be appreciated, that the present invention comprehends the replacement of a human operator with automatically operating programable devices known to the automatic machine tool art.

It is an important feature of novelty and an advantage of the present invention that the operator of grinder **10** has the power to control the minute deformations and minute displacements which necessarily and inevitably occur in the present grinder as they do in all precision machines. The action of actuator **80** against stop **110** makes it possible for the operator to raise the opposing forces thus applied until all potentially harmful deformation and displacement have occurred, and all harmful tendency to vibrate has been eliminated, prior to the application of the critical grinding load to workpiece **50**.

It will be obvious that the machine elements of grinder **10** are constructed as rigid as it is physically practical to make them. Also, bearings **141** to **144** and **151** to **154** are preloaded and adjusted and positioned under a substantial bearing load preliminary to any operating load, so that displacements are at a minimum. Nevertheless, some deformation and displacement are inevitable in the grinder **10**, as in every tool, but they are brought under control by the means described.

It is an important feature of the grinder of the invention that its construction permits the achievement of two things not readily achieved by grinders heretofore known:

a. deformation and displacement of an imperfect machine may be brought under control; and
b. a combination of controls on the forces in the grinder are available to an operator, so that precision grinding may be accomplished by following a predetermined grinding time-load program.

In the first place, the parallelogram linkage permits such adjustments and controls, not possible with other previously known systems employing parallel rotational axes for chuck and grinding wheel.

In the second place, the parallelogram linkage can be made to coact with an actuator system and an adjustable stop system which coact uniquely for both the aforementioned purposes (a) and (b).

In the grinder of the invention, grinding occurs on a workpiece surface at a grinding plane, while the workpiece, mounted on a rotating chuck, is rotated about the chuck axis. The planar end of grinding wheel **52** is applied only to a portion of the workpiece surface, lying within the grinding plane, referred to herein as the planar grinding area.

As the workpiece rotates with the chuck, the workpiece surface moves under the grinding wheel, and the planar grinding area produces a circumferential grinding path.

Persons skilled in this art recognize that a disk grinder of the type herein described can be operated to produce a great variety of grinding patterns, and a variety of these patterns are desired for different purposes, or to meet the specifications of different companies, or to accommodate different workpiece materials, or different grinding wheel compositions. It is, therefore, a valuable feature of the grinder of the present invention, that it has a diversity of controls which permit adaptation to achieve a variety of grinding patterns, and to arrive at substantially the same surface finish, with slight pattern variations, by delicate adjustments of different parts of the grinder.

In its preferred form, the grinder of the invention has great rigidity by virtue of the mechanical arrangement of the linkage column, and the relationship of that mechanical arrangement to the actuator and adjustable stop. It will be seen in the preferred form illustrated, that the column **13** is disposed along both sides of a linkage-movement plane, a vertical plane, normal to the grinding plane, and passing through the grinding axis of the grinding system **17**. It is not necessary that the linkage-movement plane be parallel with a diameter of the chuck **26**, on the contrary it will be recalled that the entire column **13** can be swiveled slightly by virtue of arcuate adjustment slot **136** (FIG. **3**). Also, it is not necessarily true that the linkage-movement plane is directly down the center of column **13**. However, it is much preferred that the column **13** and the entire parallelogram linkage **18**, as well as the transverse spacing of its four pairs of bearings, be spaced more widely than the planar grinding area as viewed from the direction of column **13**. Preferably, the virtues of rigidity are best realized if the width of the column, transverse to the linkage-movement plane, is not substantially less than the width of the planar grinding area, and preferably greater. It is further advantageous if the entire grinding system is nested into the parallelogram linkage toward the column **13**, although physical construction problems usually permit only a slight nesting beyond the axis lines of the pivot points of longitudinally movable link **123**.

I claim:

1. A disk grinder for grinding a workpiece surface in a grinding plane, said grinding being rotational about a grinding axis, said grinding being applied to a planar grinding area comprising only a portion of said workpiece surface, and said workpiece being rotated about a chuck axis parallel to said grinding axis during grinding to apply said planar grinding area to said workpiece surface in a circular grinding path, which grinder includes:

- a chuck table;
- a chuck system comprising:
  - a chuck motor mounted in said chuck table, and a chuck rotatably mounted in said chuck table and rotated about said chuck axis by said chuck motor, said chuck being adapted to hold and rotate said workpiece with said workpiece surface in said grinding plane, with a portion of said workpiece surface moving through said planar grinding area as said workpiece is rotated on said chuck axis;
- a linkage support column adjacent said chuck, said column projecting outboard of said chuck and normal to said grinding plane, said column being disposed along both sides of a linkage movement plane through said grinding axis, and said column having a linkage-bearing plane disposed transversely of said linkage-movement plane;
- a parallelogram linkage pivotally mounted on said column to swing in said linkage movement plane, said linkage comprising:
  - a pair of swinging links pivotally attached to said column at said linkage-bearing plane, and including an inboard link and an outboard link, the latter being spaced farther outboard on said column than the former; and
  - a longitudinally movable link carried on the swinging ends of said pair of swinging links, said link having a line of movement adjacent to said grinding axis and normal to said grinding plane;
- a grinder system mounted on said longitudinally movable link and comprising:
  - a grinder motor, and
  - a grinding wheel driven by said grinding motor to rotate about said grinding axis, said grinding wheel having a planar grinding end to make grinding engagement with a portion of said workpiece surface defined by said planar grinding area; and
- a grinding load system controllably urging said grinding wheel into grinding engagement with said workpiece surface.

2. A disk grinder as described in claim **1** in which said grinding load system comprises:

- a grinding load actuator adapted to urge said grinding wheel into grinding engagement with said workpiece surface; and
- an adjustable stop means for opposing the movement urged by said actuator.

3. A disk grinder as described in claim **1** in which said grinding load system includes:

- a grinding load actuator adapted to urge said grinding wheel into grinding engagement with a workpiece surface;
- an adjustable stop means for opposing the movement urged by said grinding load actuator;
- grinding load indicator means; and
- stop adjuster means for continuously altering said adjustable stop during grinding operation, to achieve a predetermined grinding program.

4. A disk grinder as described in claim **1** in which said parallelogram linkage is pivoted, on at least one of its axes, on a pair of bearings, one disposed on each side of said linkage movement plane, said bearings being spaced from each other transversely of said linkage movement plane an axial distance not substantially less than the projection on an axial line between said bearings of a parallel line within said planar grinding area.

5. A disk grinder as described in claim **1** in which said column and the links of said parallelogram linkage have a transverse extent on each side of said linkage movement plane, not substantially less than the transverse extent of said planar grinding area on the corresponding side of said linkage movement plane.

6. A disk grinder as described in claim **5** in which said parallelogram linkage is pivoted at each of its four pivot axes on a pair of bearings, the bearings of each pair being spaced from each other an axial distance transverse of said linkage movement plane not substantially less than the transverse extent of said planar grinding area on the corresponding side of said linkage movement plane.

7. A disk grinder as described in claim 6 in which said longitudinally movable link is formed to receive said grinding system at least partly between the pivot axes of said longitudinally movable link and said linkage-bearing plane.

8. A disk grinder as described in claim 1 in which said column is a hollow structure comprising a pair of sidewalls, each of said sidewalls being spaced transversely from said linkage-movement plane a distance not substantially less than the transverse extent of said planar grinding area on the same side of said linkage-movement plane; and

said grinding load system comprises:

an actuator accommodated between the spaced sidewalls of said column, and acting upon said grinding system through said linkage to urge said grinding wheel into grinding engagement with said workpiece surface;

a stop means also positioned between said spaced sidewalls of said column;

bumper means on said parallelogram linkage engaged by said stop means to resist the movement urged by said actuator; and

stop adjustment means for controllably positioning said stop.

9. A disk grinder as described in claim 1 in which said chuck motor and said chuck rotate as a unit on a common chuck axis.

10. A disk grinder as described in claim 9 in which said chuck motor and said chuck rotate on a common hollow shaft assembly, and said chuck system includes:

Walls defining air passages to the surface of said chuck receiving said workpiece; and

Selectively controllable air pressure and vacuum means communicating with said hollow shaft system for selectively retaining a workpiece on said chuck by vacuum, or displacing it therefrom by air pressure.

11. A disk grinder for grinding a workpiece surface in a grinding plane, said grinding being rotational about a grinding axis, said grinding being applied to a planar grinding area comprising only a portion of said workpiece surface, and said workpiece being rotated about a chuck axis parallel to said grinding axis during grinding to apply said planar grinding area to said workpiece surface in a circular grinding path, which grinder includes:

a chuck table;

a chuck system comprising:

a chuck motor mounted in said chuck table, and a chuck rotatably mounted in said chuck table and rotated about said chuck axis by said chuck motor, said chuck being adapted to hold and rotate said workpiece with said workpiece surface in said grinding plane, with a portion of said workpiece surface moving through said planar grinding area as said workpiece is rotated on said chuck axis;

a linkage support column adjacent said chuck, said column projecting outboard of said chuck and normal to said grinding plane, said column being disposed along both sides of a linkage movement plane through said grinding axis, and said column having a linkage-bearing plane disposed transversely of said linkage-movement plane; said column comprising:

a pair of sidewalls substantially parallel to said linkage-movement plane, and including an operator sidewall and a back sidewall, on opposite sides of said plane; and

transverse wall structure extending between said sidewalls;

an outboard bearing platform mounted on the outboard end of said column and longitudinally adjustable on said column in a direction parallel with said linkage-movement plane;

a parallelogram linkage pivotally mounted on said column and said outboard bearing platform to swing in said linkage-movement plane, said linkage comprising:

a pair of swinging links, including an inboard link pivoted to said column at two points, one in each of said column sidewalls; and an outboard link pivoted to said outboard bearing platform at two pivot points spaced transversely of said linkage-movement plane on opposite sides thereof; and

a longitudinally movable link pivoted at an outboard end to said outboard link at two pivot points spaced transversely of said linkage-movement plane, and at its inboard end pivoted to said inboard link at two pivot points spaced transversely of said linkage-movement plane, said longitudinally movable link having a line of movement adjacent to said grinding axis and normal to said grinding plane;

a grinder system mounted on said longitudinally movable link between planes spaced closer to said linkage-movement plane than the pivot points of said parallelogram linkage, said grinder system comprising:

a grinder motor mounted on said longitudinally movable link, said motor including a grinder motor shaft rotating coaxially with said grinding axis;

a grinding wheel mounted on the inboard end of said motor shaft, said grinding wheel having a planar grinding end to make grinding engagement with a portion of said workpiece at said planar bringing area; and

a grinding load system controllably urging said grinding wheel into grinding engagement with said workpiece surface, said system comprising:

a double-acting actuator between said column sidewalls, and connected to said parallelogram linkage, said actuator operating in a retraction direction to retract said grinding system from said workpiece surface, and in a grinding direction to urge said grinding wheel into contact with said workpiece surface; and

a stop means mounted between said sidewalls of said column, and engaging said parallelogram linkage, to stop the movement of said grinding system into grinding engagement with said workpiece surface, at a predetermined stop position; and stop adjustment means for changing the position of said stop to correspond to different grinding plane locations; and

grinding load indicator means for indicating grinding load being applied by said grinder system to said workpiece surface.

12. A disk grinder as described in claim 11 in which said double-acting actuator is a hydraulic cylinder, and pressure on the hydraulic liquid operating said cylinder is applied through the medium of a resiliently compressible gas, and said grinder includes operating means for controlling the pressure of said gas, whereby combinations of adjustment of said stop and control of the pressure of said actuator during grinding operation can be used in opposition to control deformation and displacement in said disk grinder.

13. A disk grinder as described in claim 11 in which said stop adjustment means comprises a right-angle, reduction-gear means, rotatably mounted between said operator sidewall and said back sidewall, and said stop adjustment means includes a control wheel means exterior to said column adjacent said operator sidewall.

14. A disk grinder as described in claim 11 in which said grinding system is at least partly nested between the operator side pivots and the back side pivots of said longitudinally movable link.

15. A disk grinder as described in claim 11 in which each of the four pivot axes of said parallelogram linkage is provided with a pair of pivot bearings, one on the operator side of said linkage-movement plane, and one on the back side of said linkage-movement plane; and one bearing of at least one of those pairs of bearings is adjustable in position with respect to the other bearing.

16. A disk grinder for grinding a workpiece surface in a grinding plane, said grinding being rotational about a grinding axis, said grinding being applied to a planar grinding area, comprising only a portion of said workpiece surface, and said workpiece being rotated about a chuck axis parallel to said grinding axis during grinding to apply said planar grinding area to said workpiece surface in a circular grinding path, which grinder includes:

a chuck table;

a chuck system mounted in said chuck table, said chuck system comprising a chuck motor, a chuck, and a chuck shaft system rotating as a unit about said chuck axis, said chick system further including:

an electrical reversing switch controlling electric power supplied to said chuck motor, said switch having a grinding position for driving said motor in an operating direction desired during grinding, and a stopping position for delivering current to said motor to resist rotation in the operating direction; and

a rotation sensing means for sensing the rotation of said chuck system, and coacting with said reversing switch when said switch is in said stopping position, to apply stopping current through said reversing switch to bring said chuck system to a stop;

a linkage support column adjacent said chuck, said column projecting outboard of said chuck and normal to said grinding plane, said column being disposed along both sides of a linkage-movement plane through said grinding axis, and said column having a linkage-bearing plane disposed transversely of said linkage-movement plane;

a parallelogram linkage pivotally mounted on said column to swing in said linkage-movement plane, said linkage comprising:

a pair of swinging links pivotally attached to said column at said linkage-bearing plane, and including an inboard link and an outboard link, the latter being spaced farther outboard on said column than the former; and

a longitudinally movable link carried on the swinging ends of said pair of swinging links, said link having a line of movement adjacent to said grinding axis and normal to said grinding plane;

a grinder system mounted on said longitudinally movable link and comprising:

a grinder motor, and

a grinding wheel driven by said grinder motor to rotate about said grinding axis, said grinding wheel having a planar grinding end to make grinding engagement with a portion of said workpiece surface

defined by said planar grinding area; and

a grinding load system controllably urging said grinding wheel into grinding engagement with said workpiece surface.

17. A disk grinder as described in claim 16 which includes a grinding position sensing means, which places said reversing switch in operating position when said grinding system is in position to bring said grinding wheel into grinding engagement with said workpiece surface; and said grinding position sensing means shifting said reversing switch to said stopping position when said grinding system is retracted from grinding engagement with said workpiece surface.

18. A disk grinder for grinding a workpiece surface in a grinding plane, said grinding being rotational about a grinding axis, said grinding being applied to a planar grinding area comprising only a portion of said workpiece surface, and said workpiece being rotated about a chuck axis parallel to said grinding axis during grinding to apply said planar grinding area to said workpiece surface in a circular grinding path, which grinder includes:

a chuck table;

a chuck system comprising:

a chuck motor mounted in said chuck table, and

a chuck rotatably mounted in said chuck table and rotated about said chuck axis by said chuck motor, said chuck being adapted to hold and rotate said workpiece with said workpiece surface in said grinding plane, with a portion of said workpiece surface moving through said planar grinding area as said workpiece is rotated on said chuck axis/

a linkage support column adjacent said chuck, said column projecting outboard of said chuck and normal to said grinding plane, said column being disposed along both sides of a linkage-movement plane through said grinding axis, and said column having a linkage-bearing plane disposed transversely of said linkage-movement plane;

a parallelogram linkage pivotally mounted on said column to swing in said linkage-movement plane, said linkage comprising:

a pair of swing links pivotally attached to said column at said linkage-bearing plane, and including an inboard link and an outboard link, the latter being spaced farther outboard on said column than the former; and

a longitudinally movable link carried on the swinging ends of said pair of swinging links, said link having a line of movement adjacent to said grinding axis and normal to said grinding plane;

a grinder system mounted on said longitudinally movable link and comprising:

a grinder motor, and

a grinding wheel driven by said grinding motor to rotate about said grinding axis, said grinding wheel having a planar grinding end to make grinding engagement with a portion of said workpiece surface defined by said planar grinding area; and

a grinding load system controllably urging said grinding wheel into grinding engagement with said workpiece surface, said grinding system comprising:

a double-acting hydraulic cylinder actuator mounted in said column and engaging said parallelogram linkage; adjustable pneumatic pressure means for supplying hydraulic fluid to said hydraulic cylinder under a pressure resiliently cushioned by gas and controllable to a predetermined pressure;

grinding load control means for operating said actuator in a direction to apply said grinding wheel to said workpiece surface;

retraction control means for operation of said actuator to retract said grinding system from said workpiece surface; and

adjustable stop means for opposing the operation of said actuator in a grinding load applying direction, when said grinding wheel reaches a predetermined grinding plane.

19. A disk grinder as described in claim **18**, in which said chuck motor is an alternating current motor, and in which said disk grinder includes:

a frequency changer system in the electrical current supply to said chuck motor, whereby to control the rotational speed of said grinding wheel during grinding;

a current indicating means associated with said chuck motor for continuously indicating the grinding load applied by said grinder; and

means for the operator to establish combinations of stop adjustment, actuator pressure, and grinding wheel rotation to conform to a predetermined grinding program.

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