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Williams et al.

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[54] CONTROLLED TOOL FOR MACHINING COMPOUND SURFACES

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[73] Assignee: **The O. K. Tool Company, Inc.**

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[52] **U.S. Cl.** .....**51/34 A**, 51/100 R, 51/225

[51] **Int. Cl.** **B24b 3/06**

[58] **Field of Search**...51/34 R, 34 A, 45, 100 R, 225, 51/288

[56] **References Cited**

UNITED STATES PATENTS

2,700,854	2/1955	Detrow	51/225 X
2,569,855	10/1951	Hertlein	51/225 X
2,484,590	10/1949	Rocheleau	51/225
3,030,744	4/1962	Mueller	51/225
2,035,163	3/1936	Holmberg	51/225

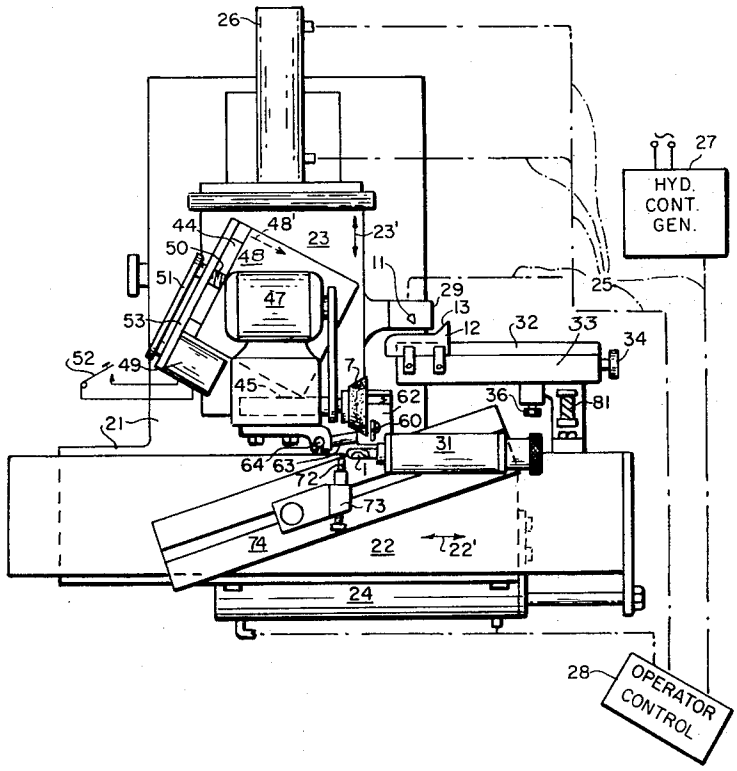
Primary Examiner—Donald G. Kelly

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[57] **ABSTRACT**

A machine tool with a wheel for precision grinding of a ball end mill with cylindrically surfaced lands and a hemispherical end includes a template conforming to the lands and ball end mounted on a hydraulic driven workpiece table on which the ball end mill is held in a rotatable chuck. The grinding wheel is mounted on another hydraulically driven table, relative movement of the tables being hydraulically controlled by a stylus which senses the template. During grinding the ball end mill is supported and rotated by a finger mounted on the grinding wheel table which engages in the flutes between the lands of the ball end mill closely adjacent the wheel. The wheel grinds along the lands and then as grinding continues around the ball end a sliding block supporting the finger engages a stop on the workpiece table and retracts the finger from the path of the wheel around the ball end. To maintain the same spacial relation between the wearing edge of the wheel and the ball end mill as the stylus has with the workpiece template, the wheel is dressed with a truing tool on the workpiece table under the control of a dressing template. The grinding wheel is first advanced toward the truing tool by a stepping motor independently of the hydraulic table drive so that when the wearing edge is trued, the original spacial relationship of wearing edge and ball end mill is restored.

6 Claims, 9 Drawing Figures



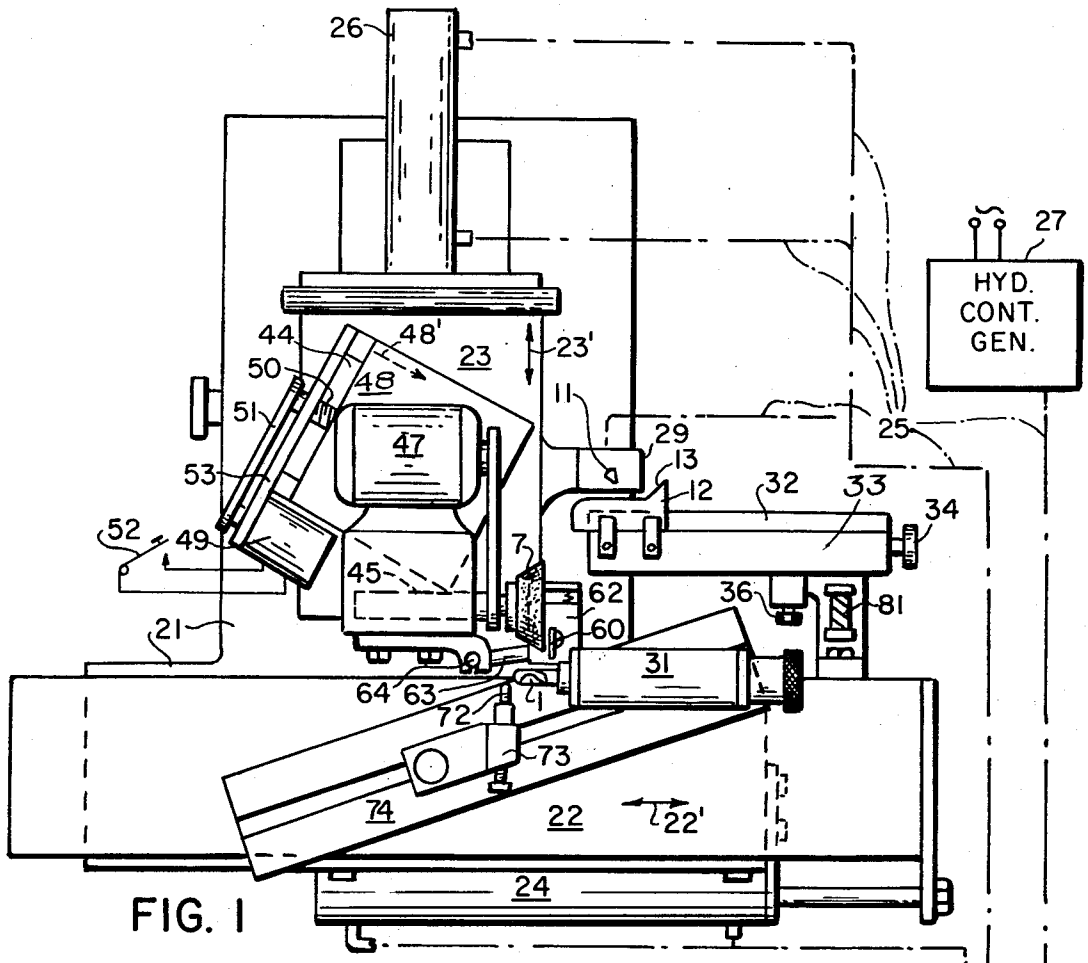


FIG. 1

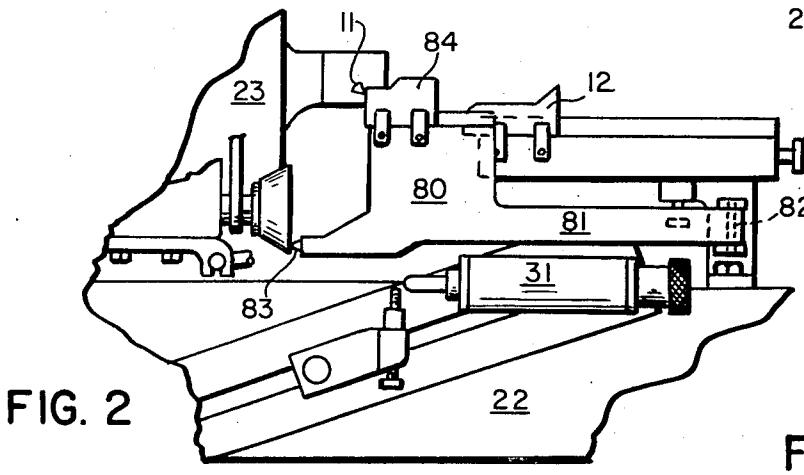


FIG. 2

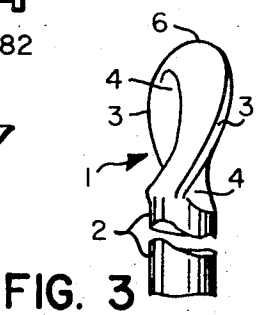
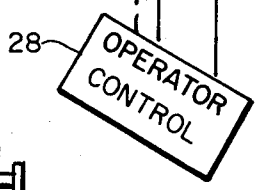


FIG. 3



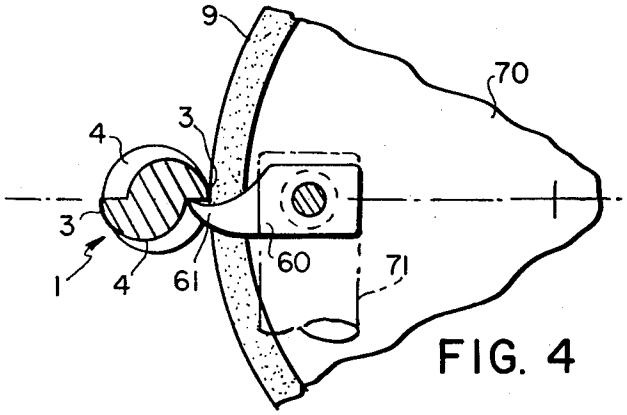


FIG. 4

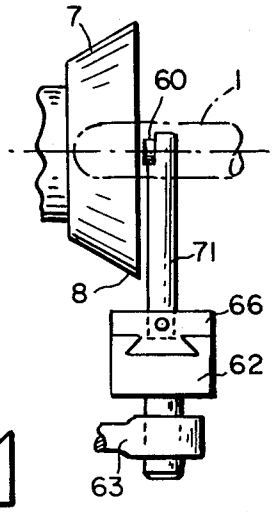


FIG. 5

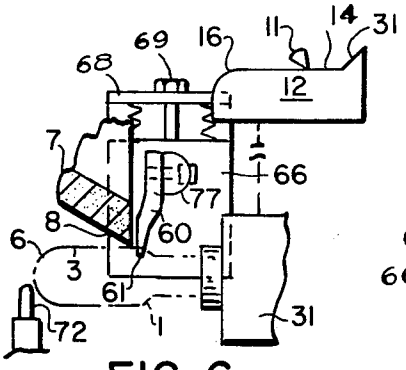


FIG. 6

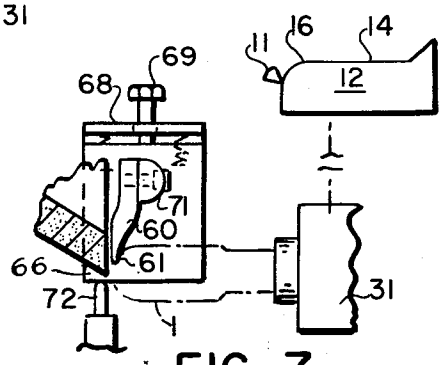


FIG. 7

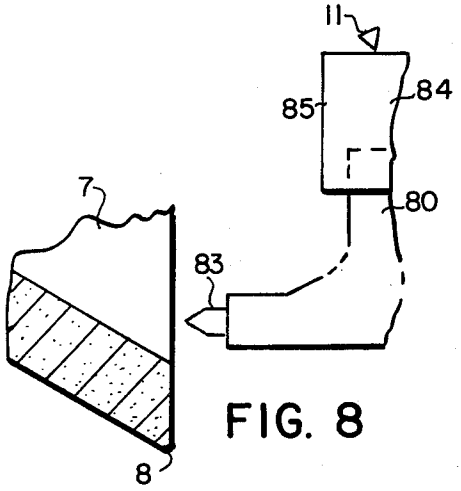


FIG. 8

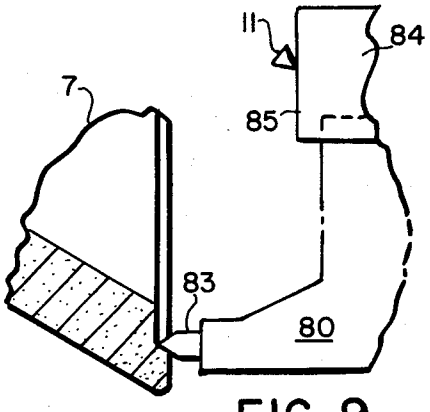


FIG. 9

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CONTROLLED TOOL FOR MACHINING COMPOUND SURFACES

Reference is made to U.S. Pat. No. 3,538,649 granted Nov. 10, 1970 to Thurston V. Williams.

BACKGROUND OF THE INVENTION

Various machined workpieces have compound surfaces which, after rough forming, require precision grinding, milling or like machining to close tolerances in the order of one or a few ten thousandths of an inch along a straight longitudinal surface of the workpiece and then along an adjacent surface which curves or angles away from the straight surface. Example of such workpieces are multiple diameter counterbores and ball end mills. A ball end mill has longitudinal lands and intermediate flutes terminating in a hemispherical or otherwise curved ball end whose curve may be tangent to or continuous with the generally cylindrical surface of the lands. In the usual method of grinding a ball end mill the ball end mill is held rotatably in a collet chuck and the land being ground is supported by a finger closely adjacent the grinding edge or wearing surface of the grinding wheel. The finger engages in a flute under the land keeping the land being ground in correct position and preventing deflection of the ball end mill. Hitherto, when grinding of the land was completed grinding could not be continued transversely of the land around the ball end because of the interposition of the finger between the grinding edge and the ball end, and the grinding machine had to be stopped and the machine manually readjusted, so that further grinding left an undesirable discontinuity between the land and ball end as well as expending time in stopping, readjusting and restarting grinding.

Thus one object of the present invention is to provide a way in which longitudinal and transverse portions of a workpiece such as the land and ball end may be supported by a finger and ground or otherwise machined in one continuous pass.

A further object is to make possible the continuous precision grinding of longitudinal and transverse portions of a workpiece under the control of a template and a follower for sensing the template.

A still further object is to maintain a precise predetermined relationship between the sensing follower and the wearing surface of the grinding wheel or similar work tool.

SUMMARY OF THE INVENTION

According to the invention apparatus for continuous machining of adjacent longitudinal and transverse portions of a workpiece comprises a work tool table holding a work tool, a workpiece table holding said workpiece, control means for said tables for causing relative machining movement of the work tool on a path along the portions of the workpiece, a finger yieldingly mounted on the work tool table for moving engagement of the workpiece and means on the workpiece table positioned to move the finger relative to the workpiece out of the path of the work tool as the template guides movement of the work tool on the transverse portion of the workpiece, whereby said relative machining movement proceeds between the longitudinal and the transverse portions of the workpiece uninterrupted by adjustment of the work tool or workpiece holder relative to their respective tables.

Further according to the invention the aforesaid control means comprises a guide template on the workpiece table conforming to the adjacent portions of the workpiece, a follower on the work tool table, for sensing the template, drive means for said tables responsive to the follower's sensing of the template for causing relative machining movement of the work tool on a path along the adjacent portions of the workpiece.

Still further according to the invention the aforesaid work tool has a wearing surface and the apparatus comprises a dressing tool on said workpiece table for truing said wearing surface when worn, a dressing template on the workpiece table disposed in the same spatial relation to the dressing tool as the first said template has to the workpiece, means, independent of the drive means, for advancing the work tool toward said dressing tool while maintaining said spatial relation between the dressing tool and dressing template, whereby said drive means, in response to the follower's sensing of the dressing template causes said dressing tool to dress said wearing surface to the aforesaid spatial relation.

DRAWINGS

For the purpose of illustration typical embodiments of the invention are shown in the accompanying drawings in which:

FIG. **1** is a plan view of a template controlled machine tool with a wheel for grinding a ball end mill, part being broken away;

FIG. **2** is a fragmentary plan view like FIG. **1** showing the broken away part;

FIG. **3** is an elevation of a ball end mill;

FIG. **4** is a side elevation, enlarged, of the grinding wheel and ball end mill of FIG. **1**;

FIG. **5** is a front elevation, enlarged, of the grinding wheel and adjacent parts of FIG. **1**; and

FIGS. **6** to **9** are plan views of details of FIG. **1**.

DESCRIPTION

Workpiece, Work Tool and Workpiece Template

Shown in FIGS. **1** and **2** is a machine tool set up for grinding a ball end mill **1** workpiece shown in detail in FIGS. **3** and **4**. The ball end mill has a shank **2** and two spiral lands **3** on a straight cylindrical surface and flutes **4** extending to a rounded end **6**. The cutting edges of the end mill extend longitudinally along the lands a constant distance from the center line of the end mill, and then generally transversely around the ball. The work tool for sharpening this cutting edge is a cup-shaped abrasive grinding wheel **7** having a grinding surface **8** which wears where its outer edge **9** grinds the land **3** (see FIG. **4**). As will be described in greater detail the ball end mill is ground under the control of a stylus or follower **11** which senses a template **12** having a lead in portion **13**, a straight portion **14**, and a quarter circular portion **16**. The straight and circular portions of the template conform precisely (within 1 mil or better) to the desired ground contour of the straight cylindrical portion of the lands and the ball end respectively.

Machine Tool As a Whole

Referring to FIG. **1**, the machine tool as a whole comprises a base **21** on which are slidingly mounted a workpiece table **22** and a work tool table **23**. The tables

22 and 23 may be reciprocated in the directions of the arrows 22' and 23' respectively by the usual manual adjustments (not shown) or by hydraulic pistons 24 and 26. Fluid is applied to the cylinders through conduits 25 from a hydraulic control generator 27 under the control of an operator control 28 and a valving or tracer box 29 operated by the template sensing stylus or follower 11. The template controlled hydraulic system is known available under the trademark TRUETRACE from True Trace Corp., Covina, Calif.

Attached to the workpiece table is a free rotating collet chuck 31 gripping the shank 2 of the ball end mill 1 to a repeatable depth and allowing the end mill to rotate. The workpiece template 12 is also mounted on an extension 32 of the workpiece table 22 by means of a clamp 33 which is micrometrically adjustable by thumb screws 34 and 36. In the preliminary setting up of the machine tool for precisely identical grinding of a number of ball end mills, the workpiece template 12 is adjusted to the same spatial relation with respect to the collet chuck 31 and the end mill 1 held therein as the template follower 11 bears to the wearing surface of the grinding wheel 7.

The grinding wheel 7 is carried on the shaft of a spindle 45 driven by an electric motor 47 attached to an auxiliary table 48. The auxiliary table 48 in turn is slidingly mounted on a base 44 attached to the work tool table 23. A stepping motor 49 is coupled to a worm 50 by a pulley 51. When the motor 49 is stepped one or more fractions of a revolution by closing a key 52 or like switching means in the operator control 28, the worm, which is journalled in a bracket 53 on the base 44, advances the auxiliary table 48 in the direction of the broken arrow 48' for a purpose to be explained in the section entitled *Work Tool Dressing*. As has been mentioned the work tool table 23 together with the auxiliary table 48 and grinding work tool 7 is reciprocated in the direction of arrow 23'.

In general operation of the machine tool, grinding of each ball end mill is initiated by using the operator control to supply the workpiece table hydraulic cylinder 24 and the work tool table hydraulic cylinder 26 simultaneously moving the workpiece table 22 to the left and the work tool table 23 toward the bottom from the positions shown in FIG. 1. This movement continues until the template follower 11 on the work tool table touches the lead in portion 13 of the template 12 on the workpiece table. After the follower senses the template the automatic hydraulic system precisely moves the tables so that the follower traces down the lead in portion 13 to the straight portion 14 of the template (FIG. 6). Simultaneously the wearing edge of the grinding wheel 7 approaches and begins grinding one land 3 of the ball end mill as the workpiece table 22 is now moved to the right.

Workpiece Support Finger

The template controlled guiding of the grind wheel 7 relative to the ball end mill workpiece 1 can machine the workpiece to within one thousandth of an inch and even greater accuracy. However, to hold such accuracy it is necessary to support the workpiece against flexing. Also in the case of a ball end mill with spiral lands the end mill must be rotated on its centerline as the grinding wheel passes along the land to present the portion of the land being ground to the wheel. For this purpose it is known to mount on the work tool table 23 a metal finger 60 having a tip 61 engaging a flat portion of the end mill flute 4 under the land 3 being ground (FIG. 4).

The finger is positioned very close, within a fraction of an inch, to the grinding wheel, and extends beyond the wheel as shown in FIG. 6. As the workpiece table moves to the left the finger 60 resists deflection of the end mill by the grinding force, and by sliding along the flute causes the end mill to rotate along with its free rotating chuck 31.

When however, the finger reaches the ball end its close proximity to the wheel interposes the tip between the wheel and the ball end. Hitherto it has been necessary to interrupt grinding at the end of the straight pass along the land and rotate the collet chuck 31 on a vertical axis during grinding around the ball end or other transverse portion of a workpiece. Consequently the original predetermined relation between the tracing template and the workpiece is disrupted preventing use of the template to control the ball end grinding and requiring time consuming and laborious manual resetting of the relation between the template 12 and workpiece. Moreover, the interruption of template control results in forming a discontinuity between the ground surface of the land and of the ball end. The ball end mill and whatever bore it is intended to mill will therefore have an angle or burr instead of a smooth blend desired between their straight and curved portions.

According to the present invention it is possible to blend the straight and curved portions and make one continuous template controlled grind by yieldingly mounting the finger 60.

As shown in FIGS. 1, 5, 6 and 7 the finger mount comprises a rectangular base block 62 supported on a rod 63 fixed to a clamp 64 on the auxiliary table 48 carried on the work tool table 23. Dovetailed into the block 62 is a slide 66. Springs 67 compressed between an upstanding back wall 68 and the slide yieldingly urge the slide away from the back wall to the distance shown in FIG. 6 limited by the head of a cap screw 69 set in the slide. A post 71 upstanding from the slide 66 has the finger 60 secured at its upper end. Thus the slide and finger are arranged to move relative to the grinding wheel 7 between the positions shown in FIGS. 6 and 7.

Whereas the grinding wheel 7 and the finger base block 62 are fixed relative to the auxiliary table 48 on the work tool table 23, a screw stop 72 is fixed relative to the workpiece table 22. The stop is mounted in a bracket 73 slidably adjustably in a slotted block 74 on the workpiece table so that the stop may be set opposite the dovetail slide 66. The stop is adjustable toward and away from the slide.

When during the grinding of the ball end mill 1 the grinding proceeds from the straight pass along the land 3 to the circularly transverse ball end portion 6, the stop engages the dovetail slide 66 as shown in FIG. 7, and relatively moves the slide and finger 60 rearwardly and inwardly of the grinding wheel 7. Actually the forward progress of the work tool continues while movement of the finger and slide is arrested by the stop. But, relative to the wheel 7 the finger moves out of the way of the grinding edges as the grinding edge passes half way around the ball end, while remaining in supporting engagement under the land being ground.

The land can thus be ground along its straight portion 3 and ball end 6 continuously and under the precise control of the straight and curved portions 14 and 16 of the workpiece template 12. The two portion grinding pass can be completed quickly without disrupting the original set up of the relation between the workpiece template 12 and the predetermined workpiece position in the collet chuck, and the same relation between the template follower 11 and the grinding edge of the wheel 7. Successive ball end mills can be repeatedly gripped in the same position in the chuck and a large number of end mills precisely ground to the same tolerance.

Dressing of Work Tool

While the grinding edge 8 of the wheel 7 holds its shape and its predetermined relation to the template follower stylus 11 for many passes it will ultimately wear or be chipped and, as shown in FIGS. 8 and 9, require dressing or truing. Further according to the present invention the wheel may be dressed and trued without destroying its aforesaid predetermined relation with the follower 11.

As shown in FIGS. 1 and 2 the machine tool is provided with a swinging bracket 80 having an arm 81 pivotted on a pin 82 supported on the extension 32 of the workpiece table. The bracket 80 carries a diamond point dressing tool 83 and a dressing template 84 in a predetermined stationary relationship, although the dressing template may be micrometrically adjusted like the workpiece template 12 in the initial set up of the machine tool.

For a dressing operation the collet chuck 31 and workpiece table are moved away from the wheel 7. The dressing bracket 80 is then swung down close to the position shown in FIG. 2 and the sliding block 62 and support finger 60 removed. The diamond point dressing tool 83 is then opposite the grinding wheel 7 and the dressing template near the stylus follower 11. The auxiliary table 48 is then stepped a few increments in the direction of the broken arrow 48' by closing the operator control 52 for the stepping motor 49 and worm 50. The amount of advance is slightly more than the amount of wear of the cutting edge 8 of the wheel 7. The stepped advance of the auxiliary table is independent of the hydraulically controlled movements of the work tool table and temporarily changes the relation between the follower 11 and the wheel 7.

The hydraulic system is then activated moving the work tool and workpiece tables so that the follower 11 is led into the dressing template 84 similiarly as with the workpiece template 14. Under hydraulic template control the stylus progresses along the template to the transverse portion (FIGS. 8 and 9). Simultaneously the diamond point 83 moves in and begins truing the face of the grinding wheel (FIG. 9). When the dressing pass is completed the wearing edge 8 will be trued to the original shape shown in FIGS. 5 to 7, and the predetermined relation between the stylus follower 11 and the wearing edges will be restored to equivalence with the relation between the workpiece 1 and workpiece template 12. The dressing bracket 84 may then be swung out of the way and grinding of ball end mill workpieces may be resumed without changing the original machine set up and with assurance that after dressing workpieces will be ground to the same precise dimensions as before dressing.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

We claim:

1. Apparatus for continuous machining of adjacent longitudinal and transverse portions of a workpiece, comprising:
- a work tool table holding a work tool,
- a workpiece table holding said workpiece,
- control means for said tables for causing relative machining movement of the work tool on a path along the portions of the workpiece,
- a workpiece support yieldingly mounted on the work tool table for moving engagement of the workpiece and
- actuating means on the workpiece table positioned to move the support relative to the workpiece out of the path of the work tool as the control means causes movement of the work tool on the transverse portion of the workpiece,
- whereby said relative machining movement proceeds between the longitudinal and the transverse portions of the workpiece uninterrupted by adjustment of the work tool or workpiece holder relative to their respective tables.

2. Apparatus according to claim 1 wherein said workpiece support comprises a finger engaging the workpiece in opposition to the working force of the work tool, said finger being mounted to move laterally of the direction of the working force.

3. Apparatus according to claim 2 wherein said finger is mounted on a sliding carrier.

4. Apparatus according to claim 3 wherein the aforesaid actuating means comprises a stop located in the path of the sliding carrier during machining movement on transverse portions of the workpiece.

5. Apparatus according to claim 4 wherein said finger is disposed in close proximity to the working surface of said work tool, and said stop and carrier are spaced away from the work tool.

6. Apparatus according to claim 1, wherein said control means comprises:
- a guide template on the workpiece table conforming to said adjacent portions of the workpiece,
- a follower on the work tool table, for sensing the template,
- drive means for said tables responsive to the follower's sensing of the template for causing relative machining movement of the work tool on a path along the adjacent portions of the workpiece.

* * * * *