



## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

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REPLY TO  
ATTN OF: GP

TO: KSI/Scientific & Technical Information Division  
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General  
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,820,286

Government or  
Corporate Employee : U.S. Government

Supplementary Corporate  
Source (if applicable) : \_\_\_\_\_

NASA Patent Case No. : LAR-10,450-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES  NO

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

*Bonnie L. Woerner*

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Enclosure

- [54] **GRINDING ARRANGEMENT FOR BALL NOSE MILLING CUTTERS**  
 [75] **Inventor:** Charles F. Burch, Hampton, Va.  
 [73] **Assignee:** The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, Washington, D.C.  
 [22] **Filed:** Sept. 14, 1972  
 [21] **Appl. No.:** 289,017

- [52] **U.S. Cl.:** 51/97 R, 51/225, 51/234  
 [51] **Int. Cl.:** B24b 3/08  
 [58] **Field of Search:** 51/96, 97 R, 94 R, 94 C, 51/124, 219 R, 219 PC, 234, 100 R, 225

[56] **References Cited**  
**UNITED STATES PATENTS**

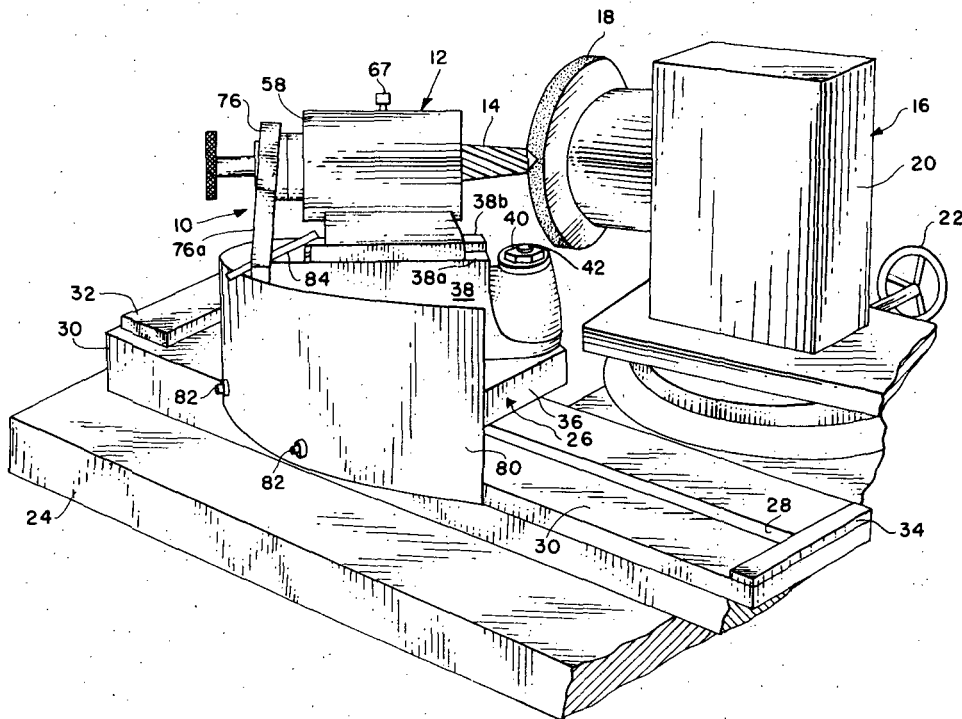
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*Primary Examiner*—Al Lawrence Smith  
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[57] **ABSTRACT**

A grinding arrangement for spiral fluted ball nose end mills and like tools includes a tool holder for positioning the tool relative to a grinding wheel. The tool is mounted in a spindle within the tool holder for rotation about its centerline and the tool holder is pivotably mounted for angular movement about an axis which intersects that centerline. A follower arm of a cam follower secured to the spindle cooperates with a specially shaped cam to provide rotation of the tool during the angular movement of the tool holder during the grinding cycle, by an amount determined by the cam profile. In this way the surface of the cutting edge in contact with the grinding wheel is maintained at the same height on the grinding wheel throughout the angular movement of the tool holder during the grinding cycle.

**4 Claims, 8 Drawing Figures**





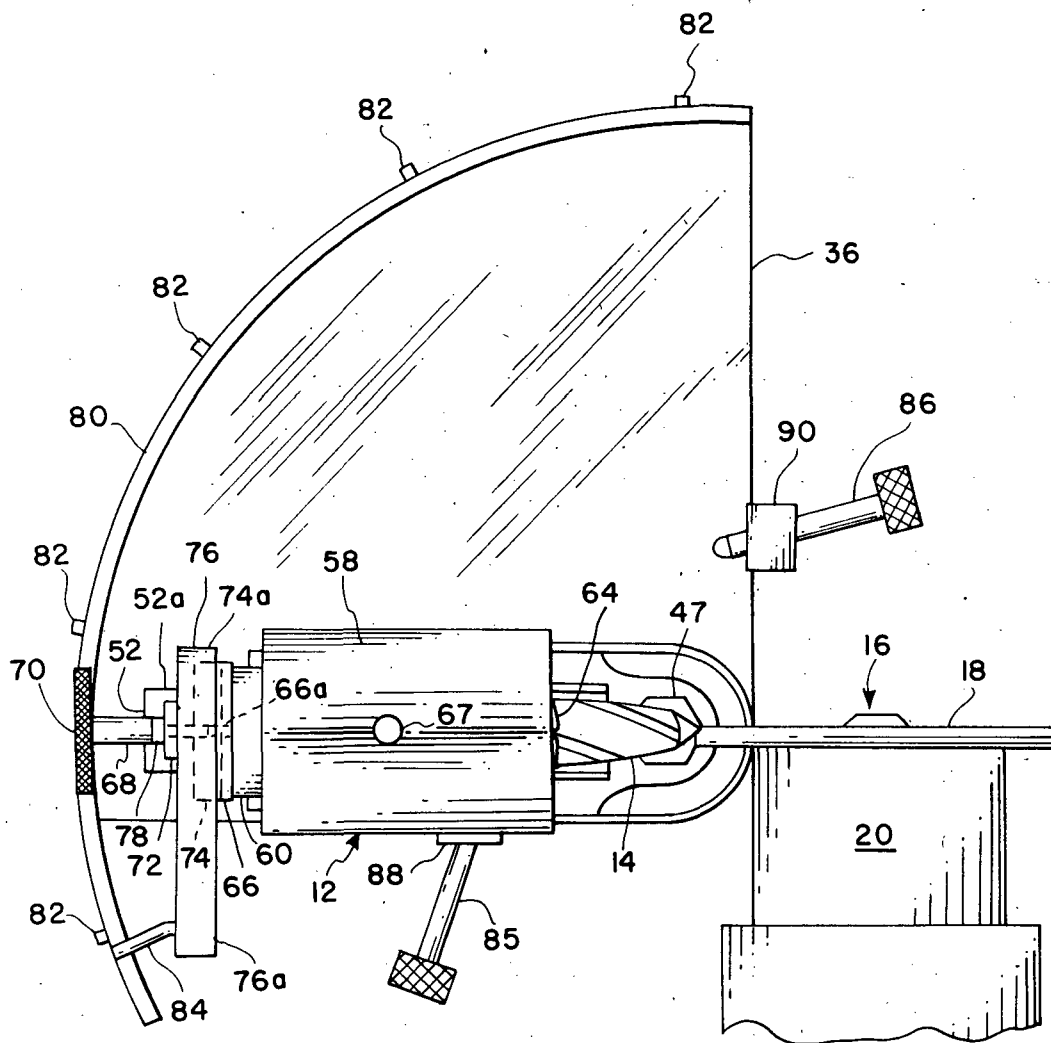


FIG. 2

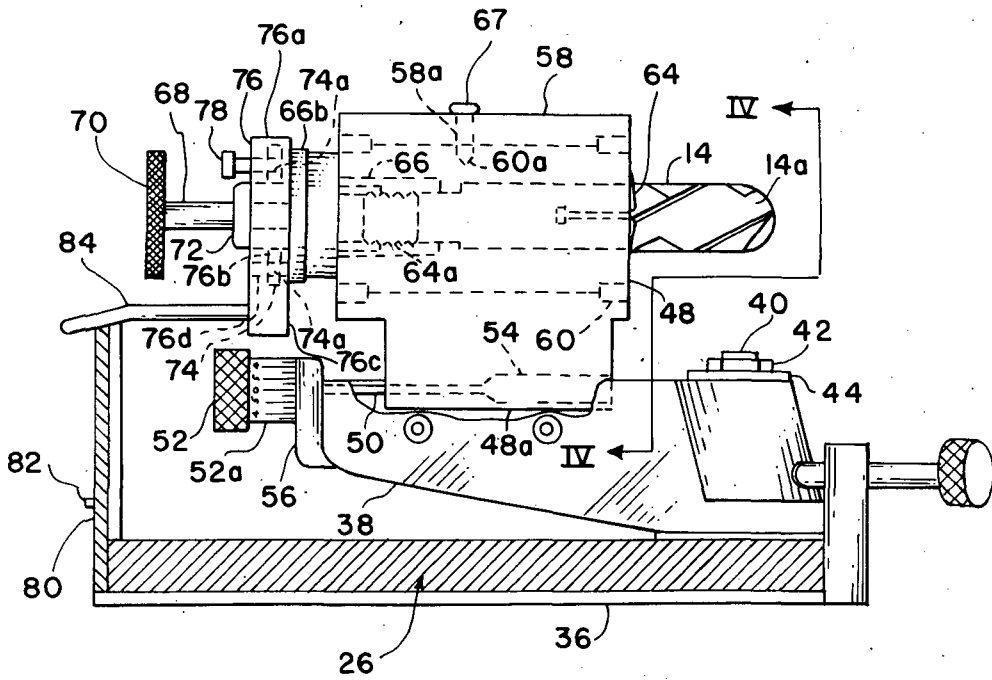


FIG. 3

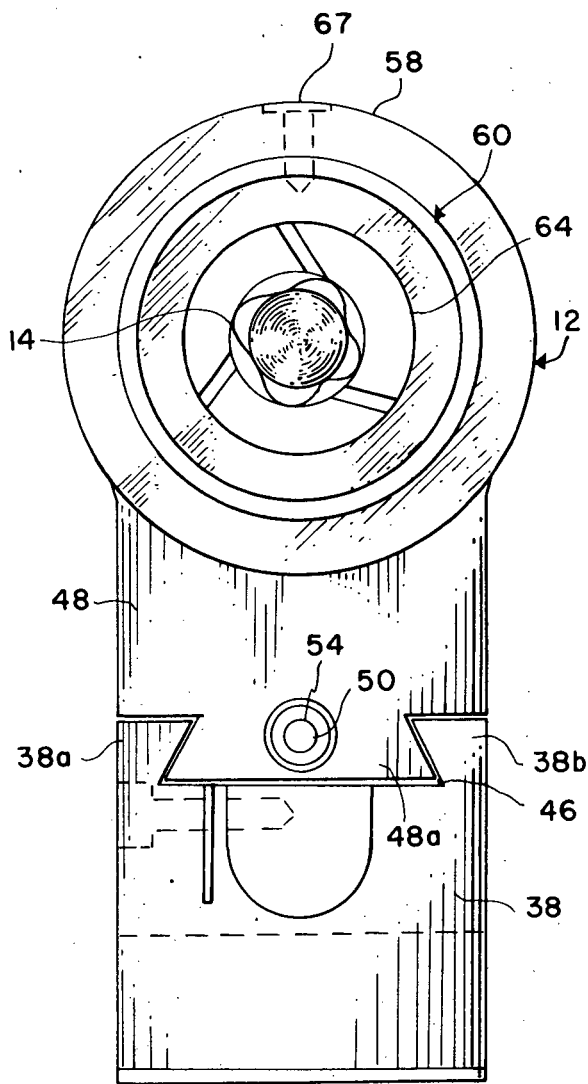


FIG. 4

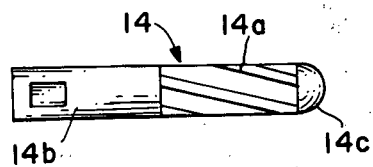


FIG. 5

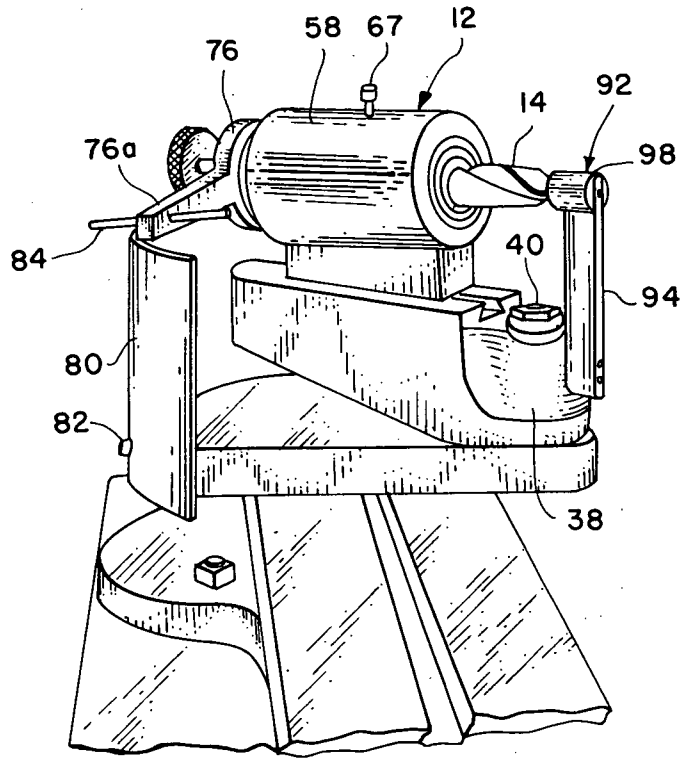


FIG. 6

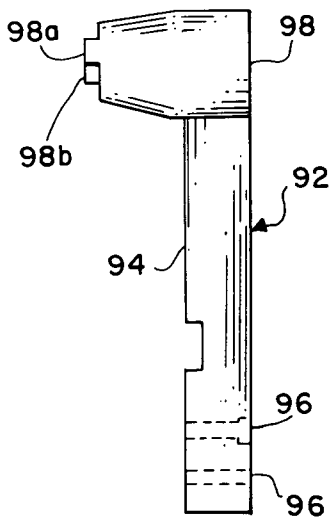


FIG. 7

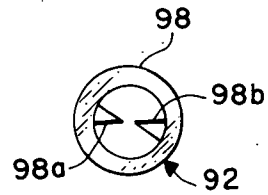


FIG. 8

# GRINDING ARRANGEMENT FOR BALL NOSE MILLING CUTTERS

## ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

## FIELD OF THE INVENTION

The present invention relates to grinders for cutting tools and, more particularly, to an improved grinding arrangement which enables high precision grinding of spiral fluted ball nose milling cutters and the like.

## BACKGROUND OF THE INVENTION

Fluted cutting tools such as spiral fluted end mills and the like present serious difficulties in grinding or re-grinding the cutting edges, where high precision is necessary. This is a particular problem in relatively small shops since available grinding devices simply cannot provide the necessary degree of accuracy required. In fact, because of this it has been found necessary in order to provide this precision to return the cutting tools to the manufacturer for re-grinding. Hence, a definite need existed prior to the present invention for a relatively simple and inexpensive grinding arrangement which would be capable of providing high precision grinding of end mills and other cutters presenting irregular or difficult to grind cutting surfaces, such as those presented by spiral fluted cutting tools.

## SUMMARY OF THE INVENTION

In accordance with the invention, a grinding arrangement is provided which permits highly accurate, precision grinding of end mills and similar cutting tools. The arrangement is particularly adapted to enable high precision grinding of tools of this type which include multiple spiral flutes, such tools, as discussed above, causing particularly difficult grinding or re-grinding problems because of the irregular surfaces presented thereby.

The arrangement of the invention includes a tool holder which permits grinding of the cutting edge relief angle by using the edge of a standard grinding wheel, by raising or lowering the axis of the grinding wheel above or below the centerline of the cutting tool, thus providing a conical type relief which has uniform clearance around the entire profile of the cutting edge of the tool. One end of the tool holder is rotatable about a vertical axis which intersects, and is perpendicular to, the centerline of the tool. Because of the spiral flutes in the cutting tools, a tool holder is provided which enables rotation of the cutting tool about its centerline so that the point on the cutting edge that is being ground is maintained at the same height on the grinding wheel as the tool holder is moved angularly, i.e., rotated, during the cutting cycle. The tool holder includes a follower arm which contacts a control cam which, as the tool holder is moved angularly, causes the cutting tool to rotate an amount dictated by the shape of the cam, i.e., by the cam profile, and which is designed to keep the cutting edge of the tool in contact with the same point on the grinding wheel at all times.

The cam profile is designed to match the spiral angle of the flutes for each cutter size and is determined using

a leveling device which levels the flutes with respect to the ball nose radius generating rotation of the tool holder. The follower arm is then connected to the tool holder and an indicator is placed on the face of the cutting edge of the tool at the center. The holder is rotated angularly as described above and the indicator is maintained at zero. The indicator in question is a commercially available instrument which provides for transfer of the movement of a surface of mass at its contact point to a dial which produces a visual indication of the movement. At closely spaced intervals during the rotation of the holder, a cam plate is suitably marked and the cam profile cut from these markings. A cam so produced is, of course, suitable for use in grinding all similar cutting tools having the same spiral angle.

The tool holder cam follower apparatus preferably includes an indexing device which indexes the holder for each flute being ground so that after one flute is ground the next is indexed into position.

Other features and advantages of the invention will be set forth in, or apparent from, the detailed description of a preferred embodiment found hereinbelow.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a grinding arrangement for ball nose end mill or cutter in accordance with a presently preferred embodiment of the invention, illustrating the general layout of the elements,

FIG. 2 is a plan view of a portion of the arrangement of FIG. 1 illustrating the tool holder and grinder;

FIG. 3 is a side elevational view of the tool holder of FIG. 2;

FIG. 4 is an end elevational view of the tool holder taken generally along line IV-IV of FIG. 3;

FIG. 5 is a side elevational view of a ball nose end mill;

FIG. 6 is a perspective view, with portions cut away, illustrating the arrangement used in producing the control cam mentioned above;

FIG. 7 is a side elevational view of the leveling device shown in FIG. 6; and

FIG. 8 is an end view of a detail of the leveling device of FIG. 7 showing the face of the device.

## DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIG. 1, a grinding or re-grinding arrangement for a ball nose milling or cutting tool, or end mill, is shown. The arrangement, which is generally denoted 10, includes a tool holder 12 for an end mill 14 and a grinder 16. Grinder 16 includes a conventional "straight" grinding wheel 18 driven by an electric motor 20. A handwheel 22 controls the elevation of the wheel 18 with respect to tool holder 12. The grinder 16 and associated positional controls are of conventional construction and further description thereof is deemed unnecessary.

Both tool holder 12 and grinder 16 are mounted on a table 24. Tool holder 12 includes a carriage portion 26 which is slidably mounted for reciprocal longitudinal movement along a keyway 28 formed on a base plate 30 rigidly secured to table 24. The travel of carriage 26 along keyway 28 is limited by a pair of end stops 32 and 34.

Carriage 26 of tool holder 12, which can best be seen in FIGS. 2 and 3, includes a quadrant-shaped base plate 36 (see FIG. 2) having a depending key (not shown)



which rides in the keyway 28 mentioned above. Tool holder 12 further includes an elongate support member 38 which is pivotably mounted at one end thereof at the vertex of base plate 36 for rotation about a vertical shaft, the threaded end of which, denoted 40, is shown in FIG. 3. Suitable means such as a nut 42 and a washer 44 prevent disengagement of support member 38 from shaft 40. As is shown in FIG. 4, support member 38 is substantially rectangular in cross section and includes upwardly extending parallel flanges or rails 38a and 38b integral therewith which form a V-way 46 therebetween.

Tool holder 12 also includes a second, toolholding or tool-carrying carriage 48 which is slidably mounted for reciprocal longitudinal movement along support member 38, carriage 48 including a downwardly depending, dove-tailed flange portion 48a which rides in V-way 46. Thus, carriage 48 is positionable both angularly and radially with respect to grinder 16. The radial or longitudinal position of carriage 48 is controlled by an adjustment screw 50 (see FIG. 3) through a control knob 52. Adjustment screw 50 is threadably received in a longitudinal bore 54 in carriage 48. As shown in FIG. 3, the portion of bore 54 in which screw 50 is received is of reduced cross section with respect to the remainder of the bore, the entire carriage 48 acting as a "traveling nut" and riding along screw 50 responsive to rotation thereof. Screw 50 is rigidly affixed to knurled knob 52 which includes an associated graduated scale portion 52a for providing an indication of the longitudinal position of carriage 48. Knob 52 and screw 50 are rotatably mounted on support member 38 by a bracket 56 which, itself, is rigidly secured to member 38 by suitable means such as screws (not shown).

The tool carrying portion of tool-holder carriage 48 includes an integral, cylindrical mounting sleeve 58 in which is mounted a cylindrical spindle 60. As shown in FIG. 3, spindle 60 has a longitudinal bore 62 which therethrough the forward end of which is shaped to receive a standard collet chuck 64, the chuck 64, in turn, supporting the end mill 14. As shown in FIG. 3, end mill 14 includes spiral grooves or flutes 14a in the surface thereof and the shank end 14b, the opposite end from the ball nose end 14c (see FIG. 5); is, of course, received in collet 64. The threaded end 64a of collet chuck 64, which is shown in phantom lines in FIG. 3, is received in the threaded end of a bore 66a in a collet locking nut 66, this end portion also being shown in FIG. 3. The annular head 66b of locking nut 66 is located rearwardly of the end of spindle 60 as shown. Nut 66 is secured to a locking screw 68 by suitable means (not shown). Rotation of screw 68 causes corresponding rotation of locking nut 66, and consequent longitudinal movement of collet 64, to release or tighten the hold on end mill 12. A locking pin or screw 67 extends through a hole or aperture 58a in sleeve 58 into an aligned hole 60a in spindle 60 to prevent rotation of the latter with respect to sleeve 58. Thus, rotation of shaft 68 will, by acting through collet locking nut 66, cause opening and closing of collet 64 as described.

Locking screw 68 terminates in a knurled control knob 70, and includes an integral retaining collar 72 which limits the axial movement of screw 68. An indexing collar 74 also shown in phantom lines in FIG. 3, is mounted on screw shaft 68 and includes four equally spaced indexing holes or apertures two of which denoted 74a are shown. A cam follower 76 is mounted on

indexing collar 74, follower 76 including an annular body portion 76a including a recess 76b in the forward face thereof in which collar 74 is received and a follower arm portion 76c extending outwardly from the body portion 76a (see also FIG. 2). The cam follower 76 also includes an aperture 76d which can be selectively aligned with apertures 74a of indexing collar 74. The apertures when so aligned cooperate with an indexing pin 78 so that the movement of cam follower 76 is transmitted to screw shaft 68 and, with pin 67 disengaged, ultimately to collet chuck 64 and end mill 14.

This movement of cam follower 76 is determined by a cam plate 80 which is detachably secured to the curved edge of base plate 36 by suitable means such as screws or bolts 82. The free end of a follower pin 84 secured to follower arm 76c engages the upper, camming edge surface of cam plate 80 to sense the cam contour. As can best be seen in FIG. 2, a pair of control or limit screws 85 and 86 respectively mounted in brackets 88 and 90 located adjacent the straight sides of base plate 36, form adjustable stops which limit the angular or arcuate movement of support member 38.

As discussed hereinabove, because end mills such as shown at 14 include spiral flutes corresponding to those shown at 14a in FIGS. 3 and 5, such mills present particular grinding problems. The apparatus described above permits such cutting tools to be sharpened or re-ground to precise geometrical tolerances using a standard straight grinding wheel 18 and raising and lowering the axis of wheel 18 above or below the centerline of end mill 14. In particular, cam 80 controls rotation of spindle 60 and, hence, end mill 14 mounted in chuck 64, such that end mill 14 always contacts the same point on grinding wheel as holder 12 is being rotated about vertical shaft 40.

Cam 80 is produced using the leveling device 92 shown in FIGS. 6 to 8. As shown in FIG. 7, leveling device 92 includes an elongate body portion 94 including suitable means represented by apertures 96 for securing device to support member 38 at a location proximate to shaft 40 as shown in FIG. 6, and a head portion 98. Head 98 includes integral, specially shaped lands 98a and 98b which, with leveling device 92 mounted on holder 12 as shown in FIG. 8, engage the flutes of the end mill 14 and provide proper positioning of the flutes with respect to cam 80 and follower pin 84. To produce the desired cam contour, a reference end mill which corresponds to tool 14 and which has been previously ground to the precise geometrical specifications desired is mounted in holder 12 and leveling device 92 is mounted as described above to provide leveling of the flutes of tool 14. With leveling device 92 so mounted, the cam follower 76 is mounted on indexing collar or annulus 74 and an indicator (not shown) is placed on the cutting edge of tool 14 at the center. The tool holder 12 is then rotated, i.e., moved angularly, through the cycle and the indicator, which, as described above, provides an indication of a surface relative to its contact point, is kept on zero. In this way the surface of the cutting edge is maintained at the same height throughout the angular movement of the tool holder during the construction cycle of the cam. At closely spaced intervals in the cycle, circles are inscribed on the cam plate 80. These circles are then faired with a spline and cut out so as to produce a cam contour of the desired shape. It will be appreciated that

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the cam so produced can be used in grinding all cutting tools with the same spiral fluting.

To briefly consider the overall operation of the apparatus of the invention, with the grinding wheel 18 mounted on grinder 16 and the tool 14 to be ground or reground inserted into chuck 64 in tool holder 12, the centerline of the grinding wheel 18 is raised or lowered a predetermined amount above the centerline of cutter 14. A cam 80 is then selected having a profile which matches the helix or spiral of the cutter fluting 14a. The cam 80 is then mounted to the tool holder 12, and in particular to base 36, using screws 82. Leveling device 92 is then mounted on tool holder 12 and, as described above, the flutes 14a of cutter 14 are leveled. The cam follower 76 is then mounted on tool holder 12, and, in particular on indexing collar 74, and follower pin 84 is placed in contact with cam 80. The pin 84 is positioned on the high point of cam 80 and the tool holder is locked using locking screw 68. The leveling device 92 is then removed and the grinding wheel 18 moved into position. With the side flute of the cutter 14 parallel to the edge of the grinding wheel 18, the pivot point of cutter 14 can be set for the desired radius by moving grinder 16. The grinding wheel 18 is then started by energizing motor 20 and the cutter 14 is moved forward using knob 52 to remove the required metal from the cutter. After the first flute is ground, index pin 78 is pulled and the holder 12 is rotated to cut the next flute.

Although the invention has been described with respect to a presently preferred, exemplary embodiment thereof it will be understood that variations and modifications may be effected in this embodiment without departing from the scope and spirit of the invention.

I claim:

1. A grinding arrangement for ball nose end mills and like cutting tools comprising:
  - a support table,
  - a grinder means fixedly supported by said table and including a grinding wheel and means for adjusting the elevation of said wheel relative to said support table,
  - a first base plate secured to said support table and provided with a keyway on an exposed surface thereof,
  - an arcuately shaped carriage member slidably keyed to said keyway in said first base plate,
  - a vertically extending plate having one end configured and attached to said arcuate carriage member

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and the opposite end thereof provided with a cam surface,

a second base plate pivotally attached at one end to said carriage member with the opposite end thereof being free and movable about the pivoted end to span the arcuate area within said vertically extending plate,

a keyway formed in the upper surface of said second base plate,

tool holder means having a rectangular base keyed and slidably disposed within said keyway in said second base plate and a hollow cylindrical sleeve portion integral with said rectangular base,

said hollow cylindrical sleeve portion having a cylindrical spindle mounted coaxially therein and provided with a longitudinal bore therethrough,

a collet chuck disposed at one end of said spindle and adapted to retain a spiral fluted ball nose end mill therein in position for engaging said grinding wheel,

cam follower means disposed on the opposite end of said spindle and having structure thereon adapted to bear against said cam surface,

said cam surface having a profile shaped in accordance with the grinding surface presented by the tool to thereby cause rotation of said spindle and attached ball mill as said second base plate is pivoted to keep the spiral flute of said ball mill in contact with the grinding wheel during a resharpening grinding operation thereof.

2. The grinding arrangement of claim 1 and further including indexing means for indexing the rotational position of said tool holder in accordance with the position of the tool surface contour being ground.

3. The grinding arrangement of claim 2 wherein said indexing means includes means defining circumferentially spaced apertures in the tool holder, means defining an indexing aperture in said cam follower and a detachable indexing pin for aligning said indexing aperture in said cam follower with a selected tool holder aperture.

4. The grinding arrangement of the claim 1 and further including adjustment means for positioning said carriage member relative to said first base plate and lock means associated therewith to lock said carriage member in the desired position along said keyway in said base plate.

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