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### (54) TOOL GRINDING MACHINE

WERKZEUGSCHLEIFMASCHINE  
MACHINE DE MEULAGE D'OUTIL

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**Description****Field of the Invention**

5 [0001] The present invention is directed to machine tools, such as tool grinding machines, and in particular to multi-axis, high precision, computer controlled machine tools for grinding of relieved tooth profiles of rotary cutting tools.

**Background of the Invention**

10 [0002] In the grinding of tooth profiles of cutting tools, such as gear hobs, worm gear hobs, constant pitch normal base hobs, and milling cutters with module sizes greater than 8 module, a multitude of grinding wheels are used to complete the entire tooth profile on both flanks and tip features. As the module size increases from 8 to approximately 16, different approaches to grinding can be used depending on the desired finished tooth re-sharpening life and the width of the tooth space at the root of the profile. The tooth re-sharpening life or length of the cam relieved tooth surface can be maximized  
 15 using pencil-shaped tapered cone grinding wheels having relatively small diameters in comparison to length. The relieved length of the tooth surface is dependent on the interference point of the grinding wheel with the next adjacent tooth when radial cam grinding the relief along the tooth helix of the hob thread or the index position in the case of a milling cutter.  
 [0003] Dependent of geometry of the tooth space there is a practical surface speed limit for grinding and bending/shear strength weakness of the tip of the pencil-shaped wheel that must be considered. When approaching the pencil-shaped  
 20 wheel grinding practical application limitations, a different process of grinding utilizing cup-shaped grinding wheels with relatively larger diameters compared to width can be employed. Surface speed of grinding and strength of the portion of the wheel grinding the root portion of the tooth are overcome. However, a disadvantage of cup-shaped grinding wheels is that their larger diameters limit the length of the cam relieved tooth surface to the interference point as described previously. As the module size increase above 16 module and up to 50 module, the use of a cup-shaped wheel is  
 25 restricted because of the wheel to adjacent tooth interference described. In most cases, a pencil-shaped tapered cone grinding wheel must be used for module hob tooth sizes over 16 module in order to provide an adequate tooth relieved length for re-sharpening life.

[0004] Current tool manufacturing practices use the blending of profiles produced from multiple grinding wheels and wheel shapes to grind the tooth flanks, tooth tip radii, and tooth tip outside diameter separately in multiple (e.g. up to five) setups. With CNC machine motion technology and rotary truing/dressing devices it is possible to contour the above mentioned pencil-shaped or cup-shaped grinding wheels to incorporate multiple features, for example, the tooth bottom radius/ramp, tooth pressure angle flank, tooth tip radius, and tooth tip outside diameter. In the example mentioned, the finish grinding process may be reduced to blending profiles of just two pencil-shaped or cup-shaped grinding wheels. Probing of profiles, utilizing probes such as the Renishaw 3-D with acoustical touch sensing, assists in the relative positioning of the grinding wheel to the left and right tooth reference points and blending of profiles to achieve the required tooth profiles and tooth thickness.

[0005] Given the above, many tool manufacturing facilities employ a plurality of grinding machines dedicated to either pencil-shaped wheels or cup-shaped wheels. A few incorporate a machine tool design to allow the exchange of spindle assemblies and drive mechanisms to accommodate the physical orientation for either pencil-shaped wheels or cup-shaped wheels. Most require the use of dedicated machines with physical orientation as capable for only pencil-shaped wheel or only cup-shaped wheel grinding. In most if not all cases, the cam relief motion on the machine tools use one axis to provide the radial motion for the cam relief which limits the machine's flexibility.

[0006] GB 1 530 900 discloses a machine according to the preamble of claim 1, having two or more tool spindles.

**Summary of the Invention**

45 [0007] The present invention provides a machine according to claim 1. It is directed to a machine tool with an angular oriented spindle that can be angularly positioned (swivel) thereby providing the flexibility to utilize both cup-shaped and pencil-shaped grinding wheels for grinding of hob and milling cutter relieved tooth geometry without exchanging grinding spindles assemblies or modifying the machine construction to accommodate two types of grinding methods or utilizing an additional machine axis for the spindle re-orientation. The present invention is also directed to a method of grinding rotary cutting tools according to claim 11.

**Brief Description of the Drawings**

55 [0008] Figures 1 (a), 1(b) and 1(c) illustrate the lead setting angular relationships of a cup-shaped grinding wheel to a hob tooth profile of universal module size.  
 [0009] Figures 2(a), 2(b) and 2(c) illustrate the lead setting angular relationships of a pencil-shaped grinding wheel to

a hob tooth profile of universal module size.

[0010] Figure 3 shows the design planes relative to the radial cam relieving motion from the front to back profiles of the hob along the involute helicoids.

[0011] Figure 4 illustrates the change in pressure angle from front to back of the constant base pitch hob tooth profile.

5 [0012] Figure 5 illustrates the relationships and direction of cam relief for the machine major components, hob workpiece and grinding wheel spindle assembly orientated for using pencil-shaped grinding wheels.

[0013] Figure 6 illustrates the relationships and direction of cam relief for the machine major components, hob workpiece and grinding wheel spindle assembly orientated for using cup wheels

10 [0014] Figure 7 is an enlarged view of the inventive grinding spindle assembly in its operative position in a machine.

[0015] Figure 8 is an enlarged view of an automatic wheel exchange unit attached to the machine base for exchanging grinding wheel packs and coolant manifolds between the grinding spindle mounting interface and storage stations.

#### Detailed Description of the Preferred Embodiment

15 [0016] Before any features and at least one construction of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other constructions and of being practiced or being carried out in various ways. Also, it is understood that the phraseology and terminology used herein is for the purposes of description and should not be regarded as limiting, to the invention as defined by the appended claims.

20 [0017] Figures 1(a), 1(b) and 1(c) show the angular relationships of a grinding wheel in a coordinate system for a cup-shaped grinding wheel 1 in contact along a involute helicoid 2 of one of a sequential series of hob teeth 3 along a thread path 4 with single or multiple starts with a front profile 5 at the cutting face defined by the intersection of the thread involute helicoid 2 and a straight or helical flute 6 and with a relieved back profile 7 near the end of the sharpening life of the tooth position that is restricted in length by the interference point 8 of the grinding wheel 1 with the adjacent hob tooth 9 along the involute helicoid 2. Relationships defined in Figures 1(a), 1(b) and 1(c) are the fixed angle HA (angle 10) of the grinding spindle assembly, the grinding wheel pressure angle PA (angle 11), and the axial pressure angle APA (angle 12) of the hob tooth, the lead angles LAS<sub>1</sub> and LAS<sub>2</sub> of the involute helicoids 13 as viewed from the front, and the swivel setting angle setting 14 of the grinding head assembly as viewed from the front, and the relieving direction 15 relative to the coordinate system.

25 [0018] Figures 2(a), 2(b) and 2(c) show the angular relationships of the grinding wheel in a coordinate system for a pencil-shaped or cone-shaped grinding wheel 16 in contact along a involute helicoid 17 of one of a sequential series of hob teeth 18 along a thread path 19 with single or multiple starts with a front profile 20 at the cutting face defined by the intersection of the thread involute helicoid 17 and a straight or helical flute 21 and with a relieved back profile 22 near the end of the sharpening life of the tooth position that is restricted in length by the interference point 23 of the grinding wheel 16 with the adjacent hob tooth 24 along the involute helicoid 17. Relationships defined in the Figures 2(a), 2(b) and 2(c) are the fixed angle 25 of the grinding spindle assembly, angle B (angle 26) which is difference between pressure angle PA trued/dressed on the grinding wheel and the axial pressure angle APA (angle 27) of the hob tooth, the lead angles LAS<sub>1</sub> and LAS<sub>2</sub> of the involute helicoids 28 as viewed from the front, and the swivel setting angle setting 29 of the grinding head assembly as viewed from the front, and the relieving direction 30 relative to the coordinate system.

30 [0019] Figure 3 defines the design planes used for optimizing the grinding wheel geometry to reduce deviation from the theoretical tooth profiles with or without involute modifications and the inherent error of the hob tooth grinding wheel to tooth pressure angle conjugant contact points. Design planes are defined at the front 31, midpoint of cam relief 32 and back 33 sections. Also shown are the related nominal hob outside radius 34, nominal hob midpoint radius 35, and 35 end of sharpening life nominal hob radius 36.

40 [0020] Figure 4 shows the characteristic error for a hob tooth of an involute profile produced by ordinary machine tool manufacturing methods. Theoretically, a new and different hob is produced every time the hob is sharpened from front to back. A sharpened hob will cut a gear only to the approximate form as the new hob. In addition, the more the hob is sharpened back, the worse the error becomes. Figure 4 shows two axial sections of the hob tooth involute helicoid profile, without involute modifications for the illustration, representing the theoretically correct front position of a new hob 37 and the sharpened back position 38 near the end of the sharpening life along the tooth involute helicoid. The inherent error 39 (error A and error B) occurs when a grinding wheel or form tool, which by nature has a fixed geometric profile, attempts to contact this helicoid surface at both sections 37 and 38 when driven in a fixed path by the machines relieving motions.

45 [0021] The recognition of the inherent error problem discussed above and attempts to solve are known from "Buckingham, Earl, Spur Gears, McGraw-Hill Book Co. Inc., NY, 1928", wherein it is discussed relieving hob tooth surfaces utilizing special characteristic of the involute helicoids. With the disclosed method, contact between the relieved surface and the grinding wheel will be the straight line generatrix of the involute helicoids and the relieved surface itself will be

an involute helicoid. However this method makes no provision for modifications such as semi-topping ramps, involute modifications, and protuberance. For fine pitch hobs the inherent error is negligible and for coarse pitch hobs of low quality the magnitude of the error is unimportant. For accurate hobs the inherent error point of can be identified with the following equation:

5

10

$$Q = \frac{(\text{Hob Outside Diameter (mm)})}{(\text{Normal Module (mm)} \times \text{Number of Hob Threads})} \quad (1)$$

**[0022]** When the Q factor is greater than 20, it marks the approximate region where hobs with a straight-line axial profile will cut gears which, for all practical purposes, have true involute profiles. As the Q factor decreases, the hob tooth axial profile becomes more curved and the potential for inherent error increases.

**[0023]** Computer analysis of the grinding wheel contact pattern with modified tooth involute helicoid, setup angles and offset of the grinding wheel can optimize the grinding process to reduce the inherent error but can not eliminate it. Corrective machine motions to change the pressure angle relations during the relieving process can minimize the inherent error to acceptable level to provide a more accurate, longer life, hobs. The grinding wheel head assembly 40 (Figure 6) of this invention can provide the grinding wheel oscillating motion synchronized with the relieving motion to minimize the inherent error.

**[0024]** The CNC Controller (such as a Fanuc 160iB computer control) of the inventive grinding machine is operable to provide the radial or offset radial cam relieving motion either from a single axis moving in a horizontal plane when the grinding head assembly is positioned about a horizontal plane for using cup wheels for grinding, or at a compound angle about the vertical plane using multiple axes to provide the cam relieving motion when the grinding head assembly is positioned about a vertical plane for using pencil wheels for grinding. In addition, the grinding head assembly is capable of imparting an oscillating motion to the grinding wheel superimposed on the radial or offset radial cam relieving motion which acts to change the swivel orientation of the grinding wheel relative to the pressure angle of the hob tooth profile thereby reducing the tooth pressure angle at the back of the hob tooth relative to the front and midpoint of the relieved tooth profile. This motion makes it possible to manufacture constant normal base pitch hobs which could not be produced by hob grinding prior to the present invention.

**[0025]** Figure 5 illustrates the inventive machine having a table 41, direct motor driven head stock 42, live center tailstock 43, steady rests 44 to assist loading arbors assemblies, work holding arbor 45 (Figure 6), hob work piece 46, linear motor driven drive longitudinal axial slide assembly 47, linear motor driven vertical slide assembly 48, linear motor driven horizontal radial in-feed slide assembly 49, grinding spindle swivel assembly 50 orientated for pencil wheel grinding, the slanted (preferably 25 degrees) grinding spindle housing 51 with spindle 65, and pencil grinding wheel 52 with spindle mounted adapter 66. Vector 53 illustrates the relative compound angle radial relieving motion (i.e. cam relieving motion). Five axes synchronization is needed for the head stock 42 and the longitudinal axial slide 47 to generate the hob thread lead, the vertical slide assembly 48 and horizontal slide assembly 49 combined to generate the cam relieving motion 53, and the optional oscillation of the grinding wheel swivel assembly 50 superimposed on the cam relieving motion 53 to minimize the inherent pressure angle profile errors.

**[0026]** Figure 6 illustrates machine table 41, direct motor driven head stock 42, live center tailstock 43, the steady rests 44 to assist loading arbors assemblies, work holding arbor 45, hob work piece 46, linear motor driven drive longitudinal axial slide assembly 47, linear motor driven vertical slide assembly 48, linear motor driven horizontal radial in-feed slide assembly 49, grinding spindle swivel assembly 50 orientated for cup-shaped wheel grinding, slanted grinding spindle housing 51 (preferably 25 degrees) with spindle 65, cup-shaped grinding wheel 55 with spindle mounted adapter 66. Vector 56 illustrates the relative compound angle radial relieving motion (i.e. cam relieving motion). Three axes synchronization is needed to produce the cam thread relieving positioning the head stock 42 and the longitudinal axial slide 47 to generate the hob thread lead, the horizontal slide assembly 49 to generate the cam relieving motion 56. The offset setting angle of the grinding wheel swivel assembly 50 and vertical axes 48 height are held at a fixed position during the cam relieving process during cup wheel grinding.

**[0027]** The grinding wheel head assembly 40 mounted for vertical motion preferably comprises a variable speed high frequency grinding spindle and capable of being automatically swung through a vertical plane arc of at least plus or minus 120 degrees to a desired setup compound angle dependent on the profile of grinding wheel, thread lead of the cutter, and orientation of the grinding spindle. The grinding spindle housing 51 is orientated from a vertical swivel plane of the grinding wheel head 40 and in a fixed angular position, preferably 25 degrees from the vertical plane, with the grinding wheel position closer to the work piece and the direct drive motor of the spindle 65 away from the work piece.

**[0028]** The preferred 25 degree orientation of the grinding spindle 65 provides additional clearance between the grinding spindle motor housing 51 and the outside diameter of the work piece when using cup shaped grinding wheels

55 (Figure 6), with grinding wheel head 40 positioned approximately plus or minus 30 degrees from a horizontal plane, and with relief grinding using a quick horizontal motion combined with rotary and longitudinal motions. The preferred 25 degree orientated grinding spindle can also facilitate pencil shaped grinding wheels 52 (Figure 5) with the grinding wheel head 40 positioned approximately plus or minus 40 degrees or thereabout from a vertical plane resulting in a relief grinding motion using both quick vertical and horizontal motions combined with rotary and longitudinal motions. In addition to the motions described, the grinding wheel head assembly can be oscillated approximately plus or minus 3½ degrees from the setup angular position during the relief motions to produce coarse module normal base pitch hobs which will have corrected tooth profile pressure angle at the back as well as at the front relieved hob tooth flank. While the fixed 25 degree orientated of the grinding spindle is preferred, the present invention is not limited thereto. Other angular orientations are contemplated and are within the scope of the present disclosure.

5 [0029] Figure 7 illustrates additional machine construction including a grinding wheel exchanger cabinet 57, the grinding wheel swivel assembly 50 that includes the slanted grinding spindle 51, a probe 58 (e.g. Renishaw 3D) for setup and inspection functions and a table mounted rotary dresser (wheel truing) assembly 59. The automatic grinding of hobs and blending of multiple wheel profile preferably includes the in-cycle exchange of grinding wheel packs mounted on spindle adapters, determination of the rough grinding wheel locations relative to pitch points on respective tooth flanks of a tooth space by use of the probe 58, use of acoustical touch sensing to verify the contact position of the grinding wheel profile to the hob existing tooth profile, contouring using the machine axes with acoustical touch sensing for generating grinding wheel profiles on a multitude of grinding wheel technologies (including super abrasives like CBN) with the use of the table mounted dresser 59, measuring of ground profile for blending and error correction with the probing system 58, and the automatic analysis and feedback for error correction of profiles.

10 [0030] Figure 8 illustrates an example of an automatic wheel exchanger 60 with multiple stations mounted on a rotary carousel 61 that stores wheel pack assembled to grinding spindle adapters (collectively 62) and associated coolant manifolds 63. A programmable slide assembly 64 facilitates the simultaneous exchange of wheel packs 62 and coolant manifolds 63 between the grinding spindle 51 and the multiple stations on the carousel 61. The automatic wheel and coolant manifold exchange device 60 (located in cabinet 57) is attached to the machine tool to facilitate complete automatic grinding of a hob or milling cutter. The automatic wheel changer device can stage a multitude of grinding wheels mounted on spindle adapters with associated coolant manifolds and automatically exchange the grinding wheel pack with coolant manifolds between the device and grinding spindle thus automatically providing the multitude of wheels needed to complete the entire hob or milling cutter tooth profile. The standard number of stations in the wheel changer device is preferably 8 but magazine storage devices can be interfaced to the wheel exchanger to increase the number of available wheel packs with coolant manifolds available or only limited by space restrictions. A probing system (e.g. Renishaw 3D) is incorporated to provide the tooth space setup positioning to multiple grinding wheels as well as post-grinding inspection with automatic profile path correctional feedback for truing/dressing. Measuring and reporting of ground profile quality according to current AGMA and DIN internationally accepted hob and milling cutter standards is also contemplated.

15 [0031] The inventive machine is capable of grinding single and multiple start hobs preferably greater than 200 mm outside diameter and in the range of about 8 to about 50 module tooth sizes with tooth cutting faces defined by multiple straight or helical flutes (gashes). The machine can also relief grinding large milling cutters preferably greater than 200 mm with axial indexing of teeth and tooth cutting faces defined by multiple straight or helical flutes. The machine preferably incorporates programmable quick response direct and linear motor driven axes with precision glass scale position feedback in a defined combination of rotational, vertical, horizontal, longitudinal, and grinding head swivel motions to relief grind each tooth profile of a hob or milling cutter. Tapered or contoured outside diameter hobs and milling cutters may also be ground. Multiple grinding wheels may be required for grinding each tooth space to complete the left and right flanks, tip radii, and tip diameter.

20 [0032] While the invention has been described with reference to preferred embodiments it is to be understood that the invention is not limited to the particulars thereof. The present invention is intended to include modifications which would be apparent to those skilled in the art to which the subject matter pertains without deviating from the scope of the appended claims.

## 50 Claims

1. A machine for grinding rotary cutting tools (1; 16), said machine comprising:

- 55 a table (41),  
 a workpiece spindle for rotation of a workpiece about a workpiece axis;  
 a tool spindle (65) for rotation of a tool about a tool axis,  
 a vertical assembly (48) having a first side facing said workpiece spindle;

said tool spindle being located on said first side and being movable vertically along said first side of said vertical assembly, said tool spindle being capable of swiveling about a swivel axis extending generally perpendicular to said first side; **characterized in that**

said tool spindle (65) is oriented slanted with respect to said first side at a predetermined slant angle.

- 5      2. The machine of claim 1 wherein said vertical assembly (48) is located on said table (41) and is movable in at least one of a longitudinal direction of said table and a width direction of said table.
- 10     3. The machine of claim 1 or 2 wherein said slant angle is 25 degrees.
- 15     4. The machine of any of claims 1 to 3 wherein said tool comprises a pencil-shaped grinding wheel (16).
- 20     5. The machine of any of claims 1 to 3 wherein said tool comprises a cup-shaped grinding wheel (1).
- 25     6. The machine of any of claims 1 to 5 wherein said tool spindle is located in a swivel assembly (50) with a probe being positioned on said swivel assembly.
- 30     7. The machine of any of claims 1 to 6 further including an automatic tool changing device (60) comprising multiple tool storing stations.
- 35     8. The machine of any of claims 1 to 7 being operable to provide at least one of a radial cam motion and an offset radial cam motion of said tool relative to said workpiece.
- 40     9. The machine of claim 8 being further operable to additionally impart an oscillating motion of said tool superimposed on said at least one of a radial cam motion and an offset radial cam motion.
- 45     10. The machine of any of claims 1 to 9 wherein said workpiece comprises a single start hob, a multiple start hob or a milling cutter.
- 50     11. A method of grinding rotary cutting tools with a grinding wheel on a grinding machine, said method comprising:
  - providing for rotation of said rotary cutting tool about a workpiece axis;
  - providing for rotation of said grinding wheel about a tool axis;
  - providing relative movement between said rotary cutting tool and said grinding wheel in up to three mutually perpendicular directions;
  - providing for swiveling of said grinding wheel about a swivel axis, said swivel axis being perpendicular to a vertically oriented first side of a vertical assembly on said grinding machine, said first side facing said rotary cutting tool,
  - bringing said grinding wheel and said rotary cutting tool into engagement with one another and moving said grinding wheel and said rotary cutting tool relative to one another to effect at least one of a radial cam motion and an offset radial cam motion,**characterized in that**

said grinding wheel is oriented slanted with respect to said first side at a predetermined slant angle.
- 55     12. The method of claim 11 further comprising oscillating said grinding wheel and superimposing the oscillating on said at least one of a radial cam motion and an offset radial cam motion.
- 60     13. The method of claim 11 or 12 wherein said slant angle is 25 degrees.
- 65     14. The method of any of claims 11 to 13 wherein said grinding wheel comprises one of a pencil-shaped grinding wheel or a cup-shaped grinding wheel.
- 70     15. The method of any of claims 11 to 14 wherein said workpiece comprises a single start hob, a multiple start hob or a milling cutter.

**Patentansprüche**

1. Maschine zum Schleifen von Rotationsschneidwerkzeugen (1; 16), wobei die Maschine umfasst:
  - 5 einen Tisch (41),  
eine Werkstückspindel zur Drehung eines Werkstücks um eine Werkstückachse;  
eine Werkzeugspindel (65) zur Drehung eines Werkzeugs um eine Werkzeugachse,  
eine vertikale Anordnung (48) mit einer ersten Seite, die der Werkstückspindel zugewandt ist;  
wobei die Werkzeugspindel sich auf der ersten Seite befindet und entlang der ersten Seite der vertikalen  
10 Anordnung vertikal beweglich ist, wobei die Werkzeugspindel in der Lage ist, sich um eine Dreh- bzw. Schwenk-  
achse zu drehen bzw. zu schwenken, die sich im Allgemeinen perpendikular zur ersten Seite erstreckt; **dadurch  
gekennzeichnet, dass**  
die Werkzeugspindel (65) in Bezug auf die erste Seite in einem vorgegebenen Neigungswinkel geneigt ausge-  
richtet ist.
- 15 2. Maschine nach Anspruch 1, wobei die vertikale Anordnung (48) sich auf dem Tisch (41) befindet und in zumindest  
eine von einer Längsrichtung des Tisches und einer Breitenrichtung des Tisches beweglich ist.
3. Maschine nach Anspruch 1 oder 2, wobei der Neigungswinkel 25 Grad beträgt.
- 20 4. Maschine nach einem der Ansprüche 1 bis 3, wobei das Werkzeug ein stiftförmiges Schleifrad (16) umfasst.
5. Maschine nach einem der Ansprüche 1 bis 3, wobei das Werkzeug ein tassenförmiges Schleifrad (1) umfasst.
- 25 6. Maschine nach einem der Ansprüche 1 bis 5, wobei sich die Werkzeugspindel in einer Dreh- bzw. Schwenkanordnung  
(50) befindet, wobei ein Messtaster auf der Dreh- bzw. Schwenkanordnung positioniert ist.
7. Maschine nach einem der Ansprüche 1 bis 6, die weiterhin eine automatische Werkzeugwechseleinrichtung (60)  
beinhaltet, welche mehrere Werkzeugspeicherstationen umfasst.
- 30 8. Maschine nach einem der Ansprüche 1 bis 7, die betreibbar ist, um zumindest eine von einer Radialnockenbewegung  
und einer Versatzradialnockenbewegung des Werkzeugs in Bezug auf das Werkstück bereitzustellen.
9. Maschine nach Anspruch 8, die weiterhin betreibbar ist, um dem Werkzeug zusätzlich eine Oszillationsbewegung  
35 zu verleihen, die auf die zumindest eine von einer Radialnockenbewegung und einer Versatzradialnockenbewegung  
aufgebracht wird.
10. Maschine nach einem der Ansprüche 1 bis 9, wobei das Werkstück einen eingängigen Wälzfräser, einen mehrgän-  
40 gigen Wälzfräser oder einen Fräser umfasst.
11. Verfahren zum Schleifen von Rotationsschneidwerkzeugen mit einem Schleifrad auf einer Schleifmaschine, wobei  
das Verfahren umfasst:
  - 45 Sorgen für Rotation des Rotationsschneidwerkzeugs um eine Werkstückachse;  
Sorgen für Rotation des Schleifrads um eine Werkzeugachse;  
Bereitstellen relativer Bewegung zwischen dem Rotationsschneidwerkzeug und dem Schleifrad in bis zu drei  
zueinander perpendikularen Richtungen;
  - 50 Sorgen für das Drehen bzw. Schwenken des Schleifrads um eine Dreh- bzw. Schwenkachse, wobei sich die  
Dreh- bzw. Schwenkachse perpendikular zu einer vertikal ausgerichteten ersten Seite einer vertikalen Anord-  
nung auf der Schleifmaschine verhält, wobei die erste Seite dem Rotationsschneidwerkzeug zugewandt ist,  
In-Eingriff-Bringen des Schleifrads und des Rotationsschneidwerkzeugs miteinander, und Bewegen des Schlei-  
frads und des Rotationsschneidwerkzeugs in Bezug zueinander, um zumindest eine von einer Radialnocken-  
bewegung und einer Versatzradialnockenbewegung zu bewirken,  
**dadurch gekennzeichnet, dass**
  - 55 das Schleifrad in Bezug auf die erste Seite in einem vorgegebenen Neigungswinkel geneigt ausgerichtet ist.
12. Verfahren nach Anspruch 11, das weiterhin das Oszillieren des Schleifrads und das Aufbringen des Oszillierens  
auf die zumindest eine von einer Radialnockenbewegung und einer Versatzradialnockenbewegung umfasst.

13. Verfahren nach Anspruch 11 oder 12, wobei der Neigungswinkel 25 Grad beträgt.
  14. Verfahren nach einem der Ansprüche 11 bis 13, wobei das Schleifrad eines von einem stiftförmigen Schleifrad und einem tassenförmigen Schleifrad umfasst.
  15. Verfahren nach einem der Ansprüche 11 bis 14, wobei das Werkstück einen eingängigen Wälzfräser, einen mehrgängigen Wälzfräser oder einen Fräser umfasst.

10 Revendications

- Machine destinée au meulage d'outils rotatifs de coupe (1 ; 16), ladite machine comprenant :
    - une table (41),
    - une broche pour pièce à usiner destinée à faire tourner une pièce à usiner sur un axe de pièce à usiner ;
    - une broche pour outil (65) destinée à faire tourner un outil sur un axe d'outil,
    - un ensemble vertical (48) présentant un premier côté faisant face à ladite broche pour pièce à usiner ;
    - ladite broche pour outil étant située sur ledit premier côté et pouvant être déplacée verticalement le long dudit premier côté dudit ensemble vertical, ladite broche pour outil étant capable de pivoter sur un axe de pivotement qui s'étend de manière globalement perpendiculaire audit premier côté ; **caractérisée en ce que**
    - ladite broche pour outil (65) est orientée inclinée par rapport audit premier côté selon un angle d'inclinaison prédéterminé.
  - Machine selon la revendication 1, dans laquelle ledit ensemble vertical (48) est situé sur ladite table (41) et est déplaçable dans au moins une direction parmi une direction longitudinale de ladite table et une direction de la largeur de ladite table.
  - Machine selon la revendication 1 ou 2, dans laquelle ledit angle d'inclinaison est de 25 degrés.
  - Machine selon l'une quelconque des revendications 1 à 3, dans laquelle ledit outil comprend une roue de meulage (16) en forme de crayon.
  - Machine selon l'une quelconque des revendications 1 à 3, dans laquelle ledit outil comprend une roue de meulage (1) en forme de coupe.
  - Machine selon l'une quelconque des revendications 1 à 5, dans laquelle ladite broche pour outil est située dans un ensemble pivotant (50), une sonde étant placée sur ledit ensemble pivotant.
  - Machine selon l'une quelconque des revendications 1 à 6, comprenant en outre un dispositif automatique de changement d'outil (60) comprenant des postes de conservation d'outils multiples.
  - Machine selon l'une quelconque des revendications 1 à 7, susceptible d'être mise en oeuvre pour fournir au moins un déplacement parmi un déplacement de came radial et un déplacement de came radial décalé dudit outil par rapport à ladite pièce à usiner.
  - Machine selon la revendication 8, encore susceptible d'être mise en oeuvre pour produire en outre un déplacement d'oscillation dudit outil superposé audit au moins un déplacement parmi un déplacement de came radial et un déplacement de came radial décalé.
  - Machine selon l'une quelconque des revendications 1 à 9, dans laquelle ladite pièce à usiner comprend une fraise-mère à départ unique, une fraise-mère à départ multiple ou une fraise.
  - Procédé de meulage d'outils rotatifs de coupe à l'aide d'une roue de meulage sur une machine à meuler, ledit procédé comprenant :
    - la mise en oeuvre d'une rotation dudit outil rotatif de coupe sur un axe d'une pièce à usiner ;
    - la mise en oeuvre d'une rotation de ladite roue de meulage sur un axe d'outil ;
    - la mise en oeuvre d'un mouvement relatif entre ledit outil rotatif de coupe et ladite roue de meulage dans, au

maximum, trois directions mutuellement perpendiculaires ;  
la mise en oeuvre d'un pivotement de ladite roue de meulage sur un axe de pivotement, ledit axe de pivotement étant perpendiculaire à un première côté à orientation verticale d'un ensemble vertical de ladite machine à meuler, ledit premier côté faisant face audit outil rotatif de coupe,  
la réalisation d'une mise en prise entre ladite roue de meulage et ledit outil rotatif de coupe l'un avec l'autre, et le déplacement de ladite roue de meulage et dudit outil rotatif de coupe l'un par rapport à l'autre pour réaliser au moins un déplacement parmi un déplacement de came radial et un déplacement de came radial décalé,  
**caractérisé en ce que**  
ladite roue de meulage est orientée inclinée par rapport audit premier côté selon un angle d'inclinaison pré-déterminé.

12. Procédé selon la revendication 11, comprenant en outre l'oscillation de ladite roue de meulage et la superposition de l'oscillation sur au moins un déplacement parmi un déplacement de came radial et un déplacement de came radial décalé.

13. Procédé selon la revendication 11 ou 12, dans lequel ledit angle d'inclinaison est de 25 degrés.

14. Procédé selon l'une quelconque des revendications 11 à 13, dans lequel ladite roue de meulage comprend une roue de meulage en forme de crayon ou une roue de meulage en forme de coupe.

15. Procédé selon l'une quelconque des revendications 11 à 14, dans lequel ladite pièce à usiner comprend une fraise-mère à départ unique, une fraise-mère à départ multiple ou une fraise.

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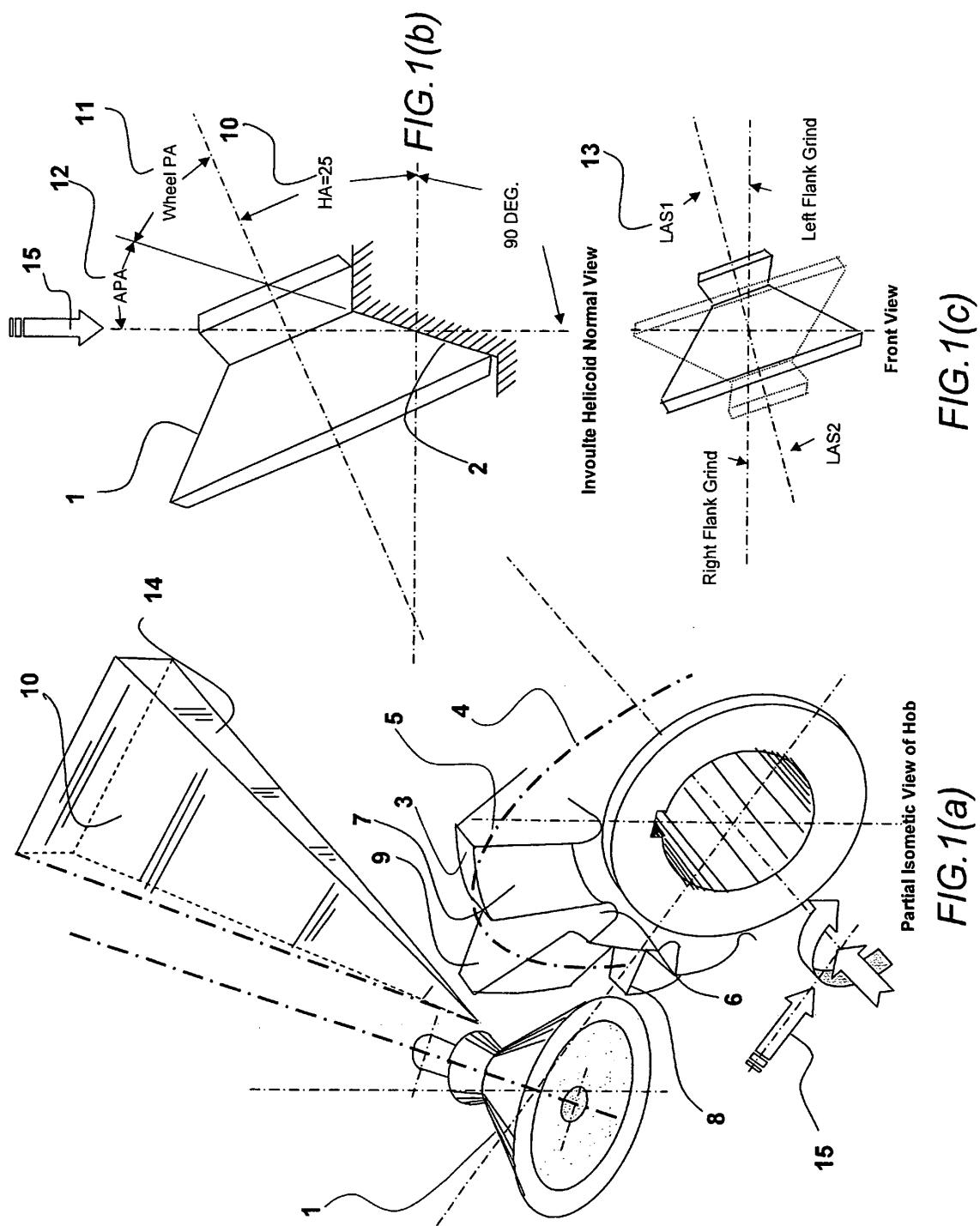
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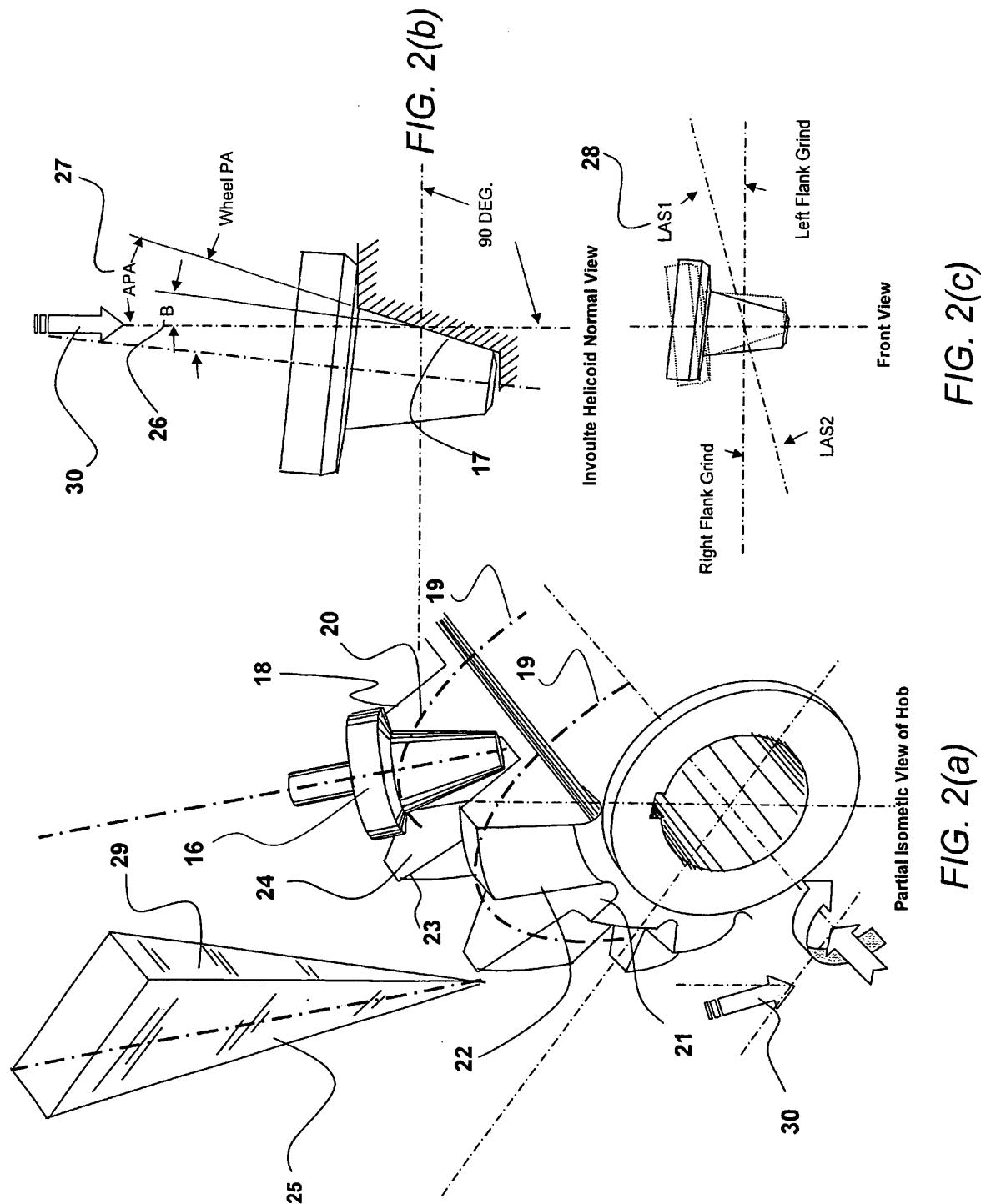
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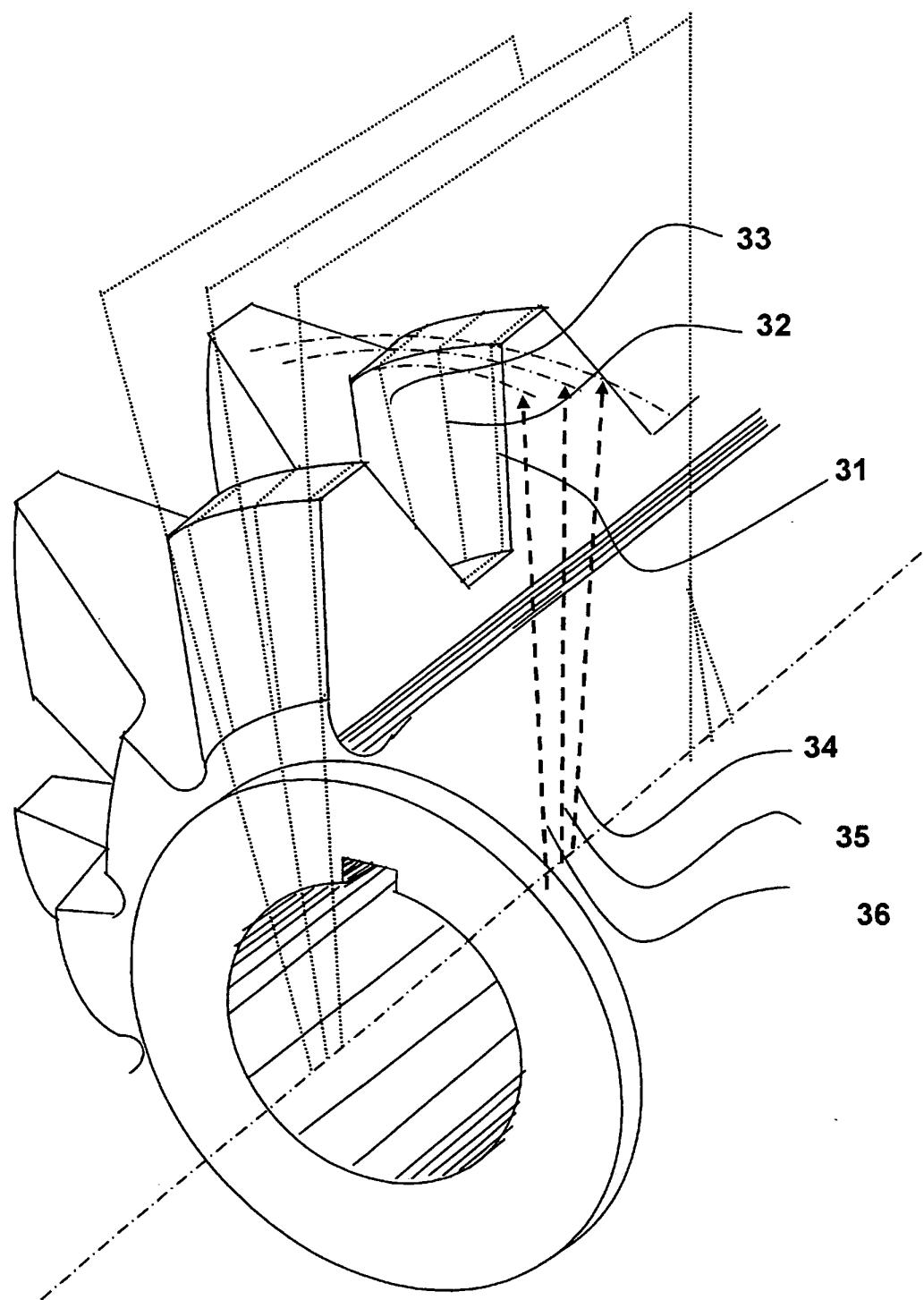
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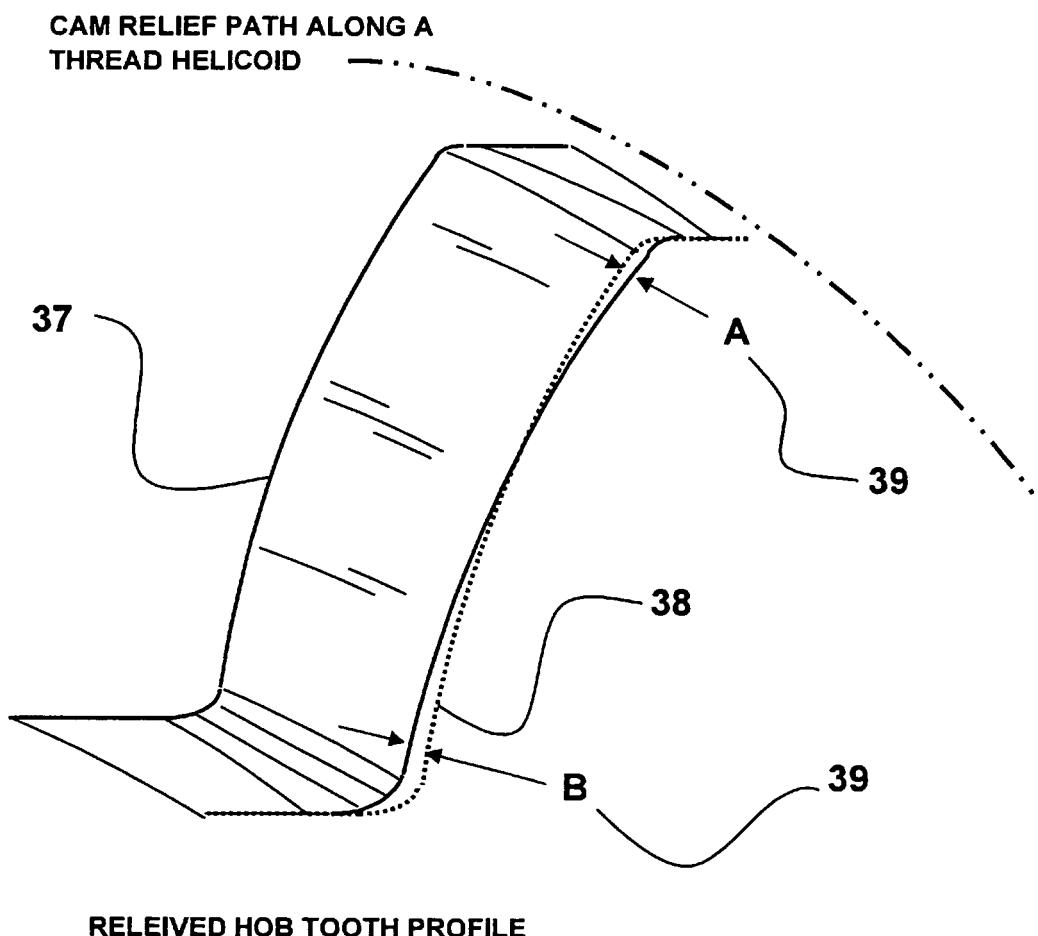
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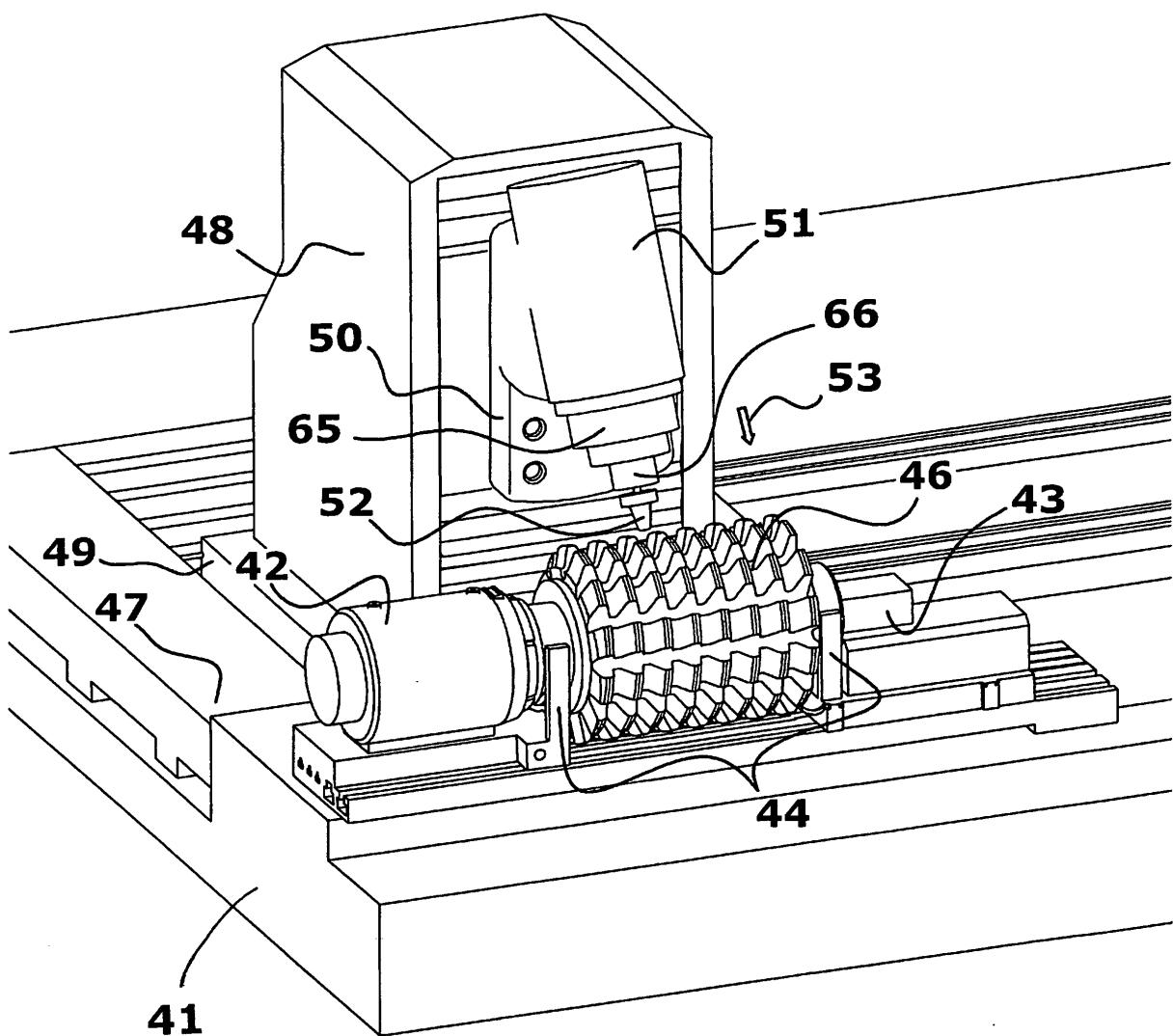




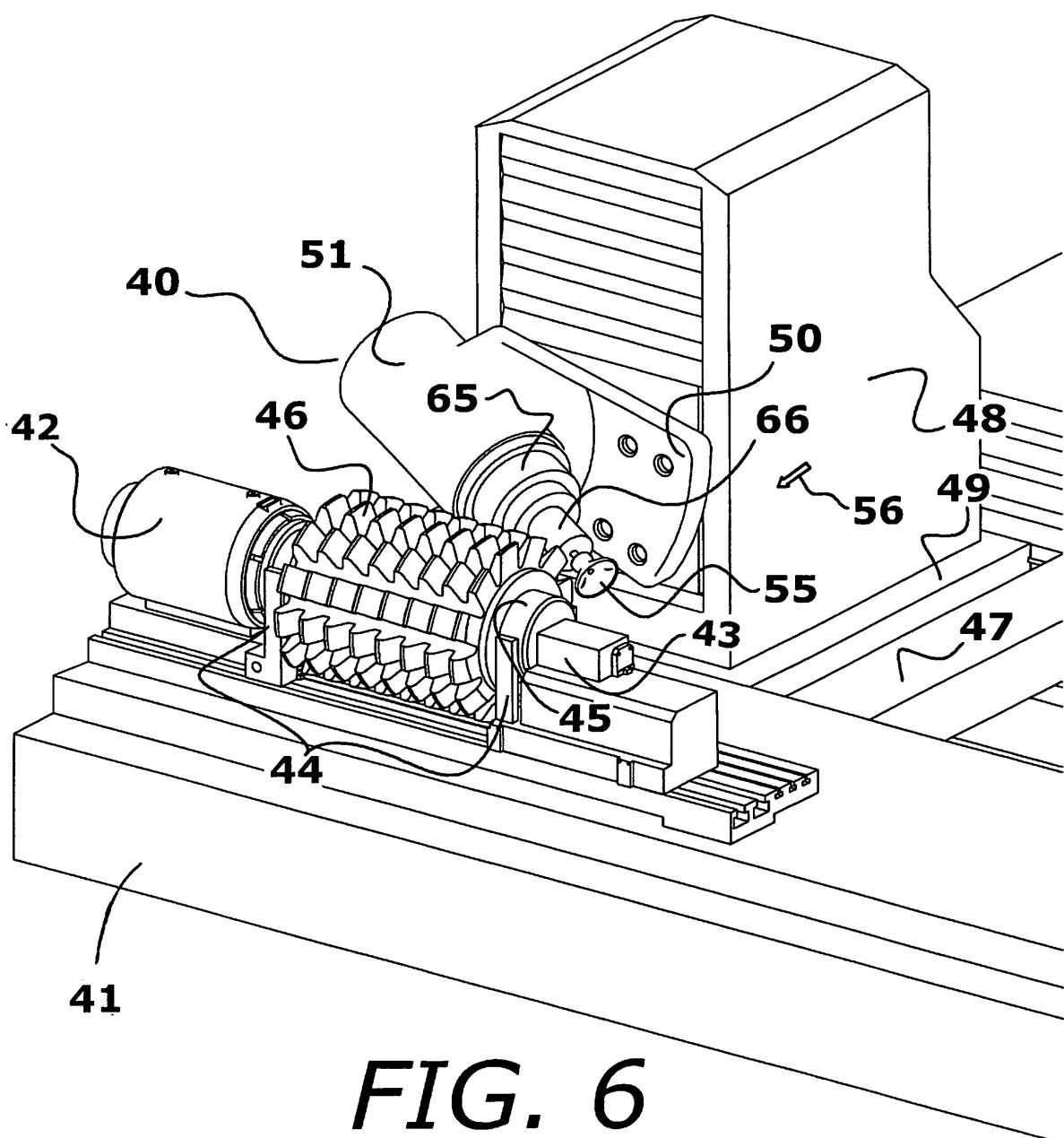
**FIG. 3**



*FIG. 4*



*FIG. 5*



*FIG. 6*

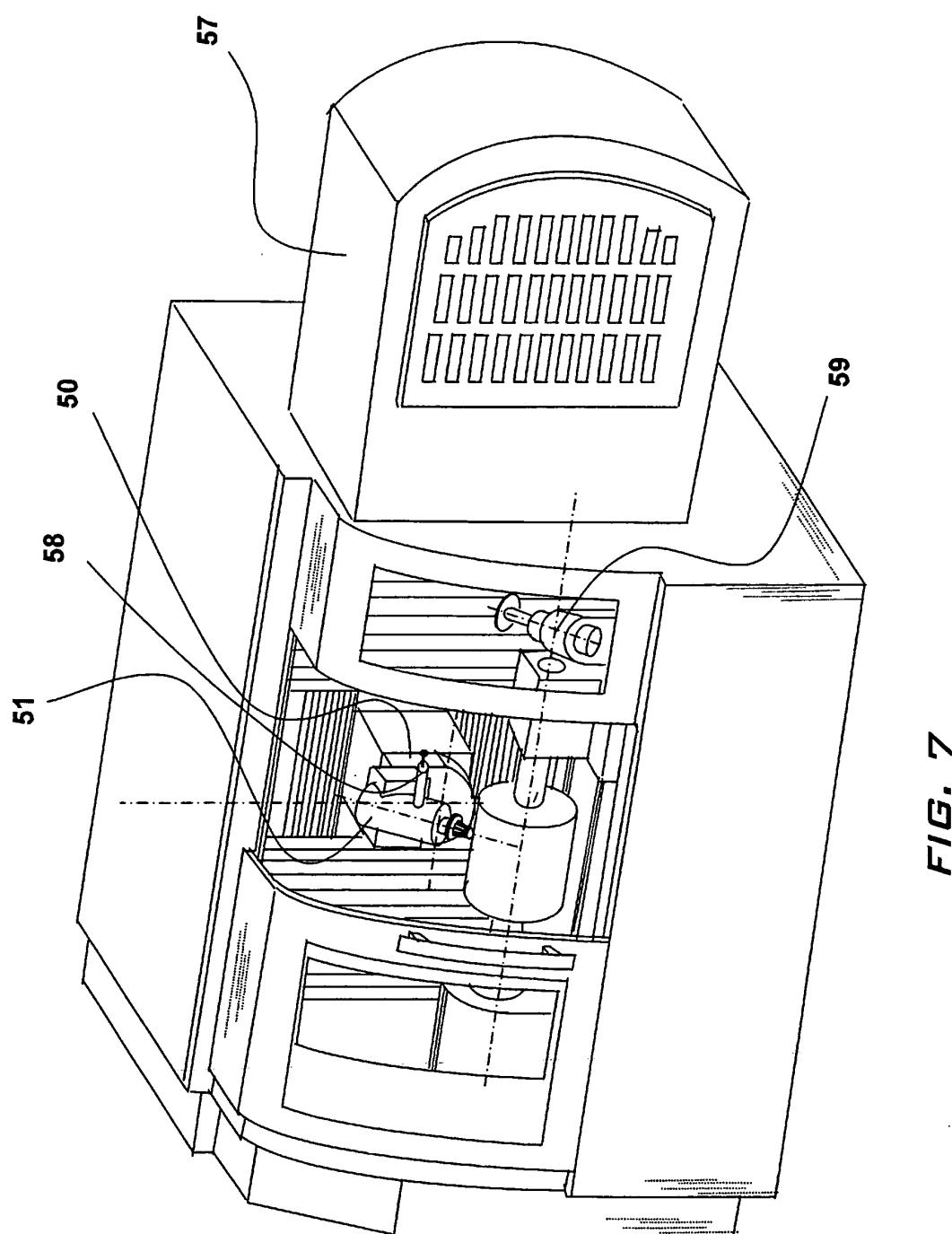
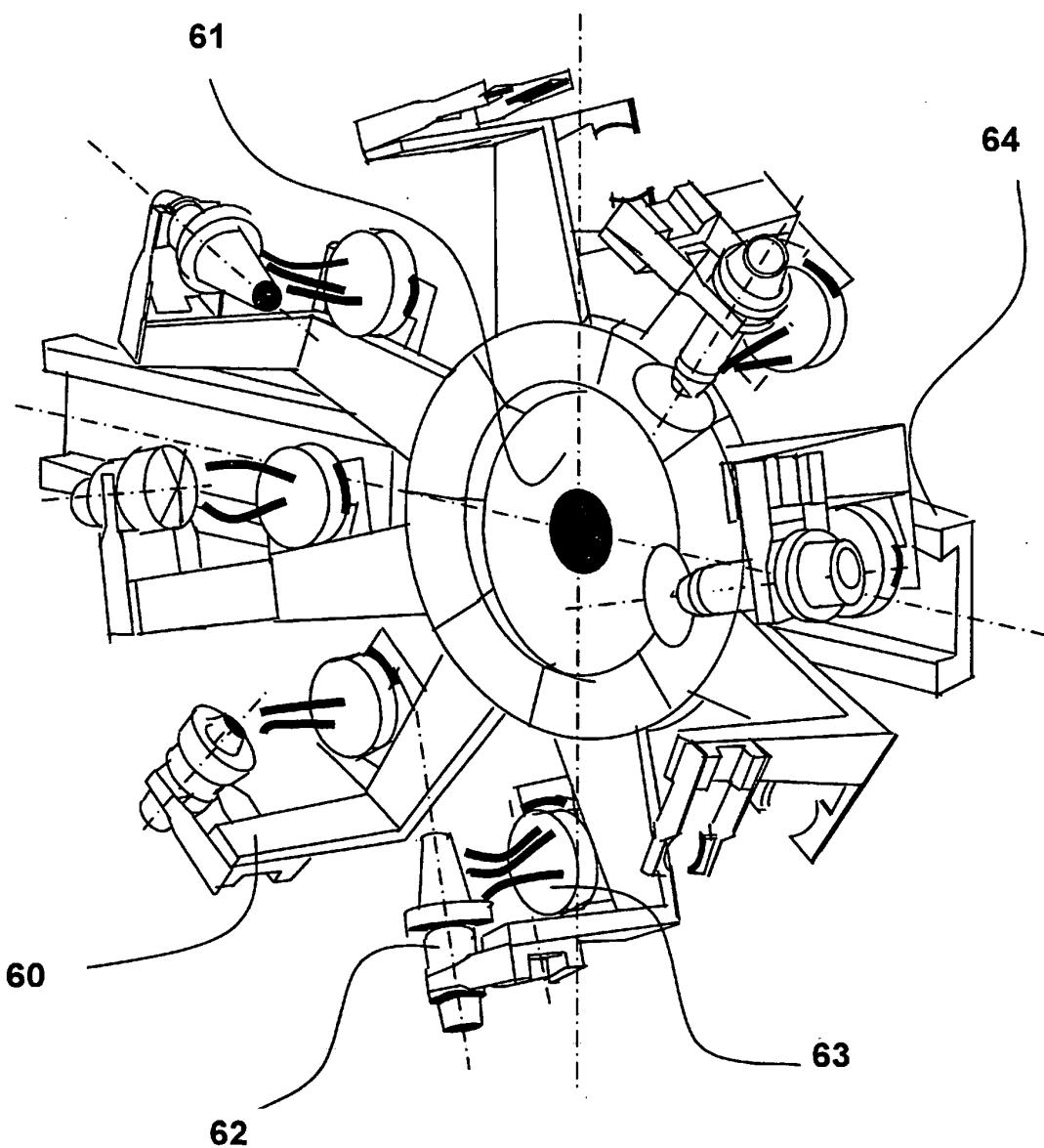


FIG. 7



***FIG. 8***

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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**Non-patent literature cited in the description**

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