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Doman

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(54) **ELECTRONIC BEVEL ANGLE INDICATOR FOR A HOLLOW GRINDER**

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(52) **U.S. Cl.** **451/5**; 451/9; 451/241; 451/410; 451/234; 451/545

(58) **Field of Search** 451/5, 6, 8, 9, 451/10, 11, 241, 340, 364, 367, 369, 410, 405, 414, 420, 234, 231, 545

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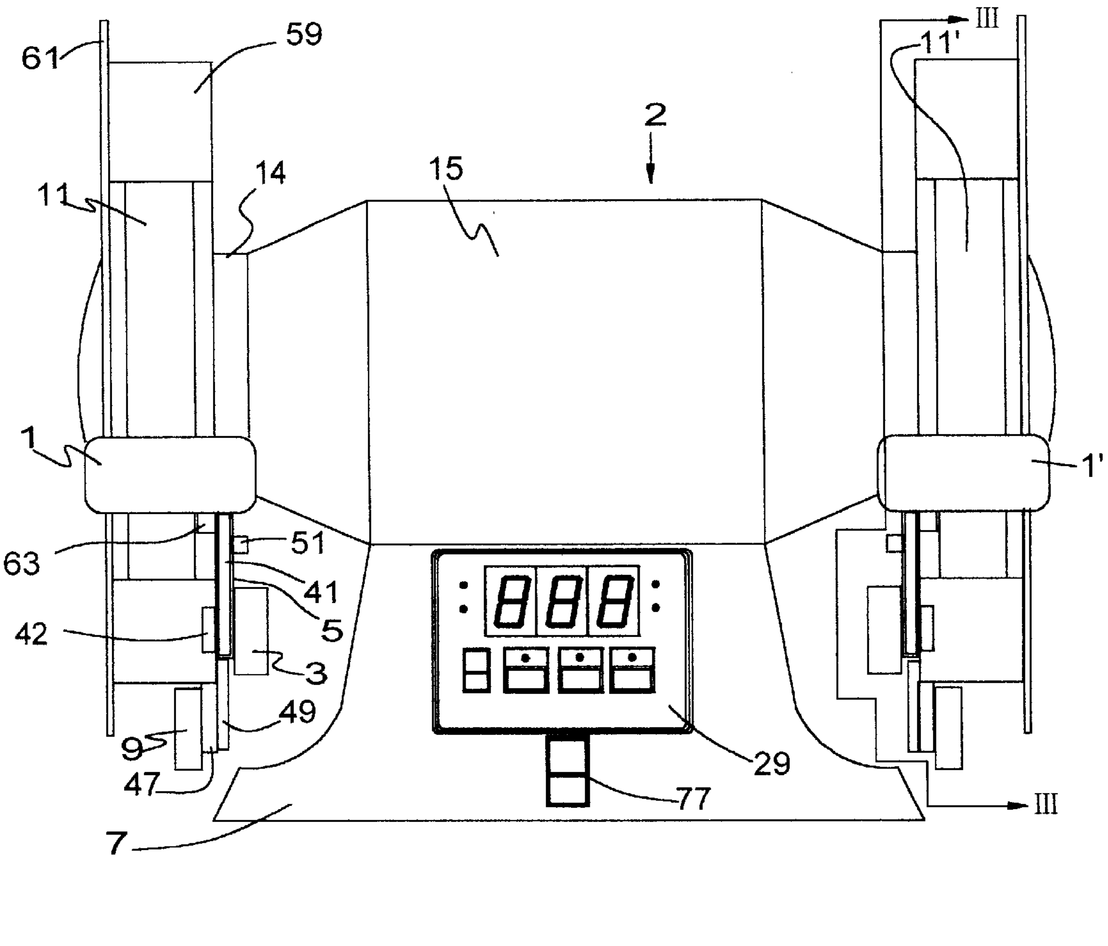
(57) **ABSTRACT**

An electronic hollow grinder bevel angle indicator wherein a microprocessor calculates the grinding bevel angle that will be obtained when a tool is placed flat upon a tool rest and presented to the periphery of a rotating grinding wheel. The calculated bevel angle is the acute angle of intersection between the tool rest plane and a plane tangent to the grinding wheel periphery at the line of intersection between the grinding wheel periphery and the tool rest plane. The microprocessor also calculates the air-gap between the tool rest and grinding wheel, and warns the operator when the air gap exceeds a specified safety threshold.

6 Claims, 7 Drawing Sheets



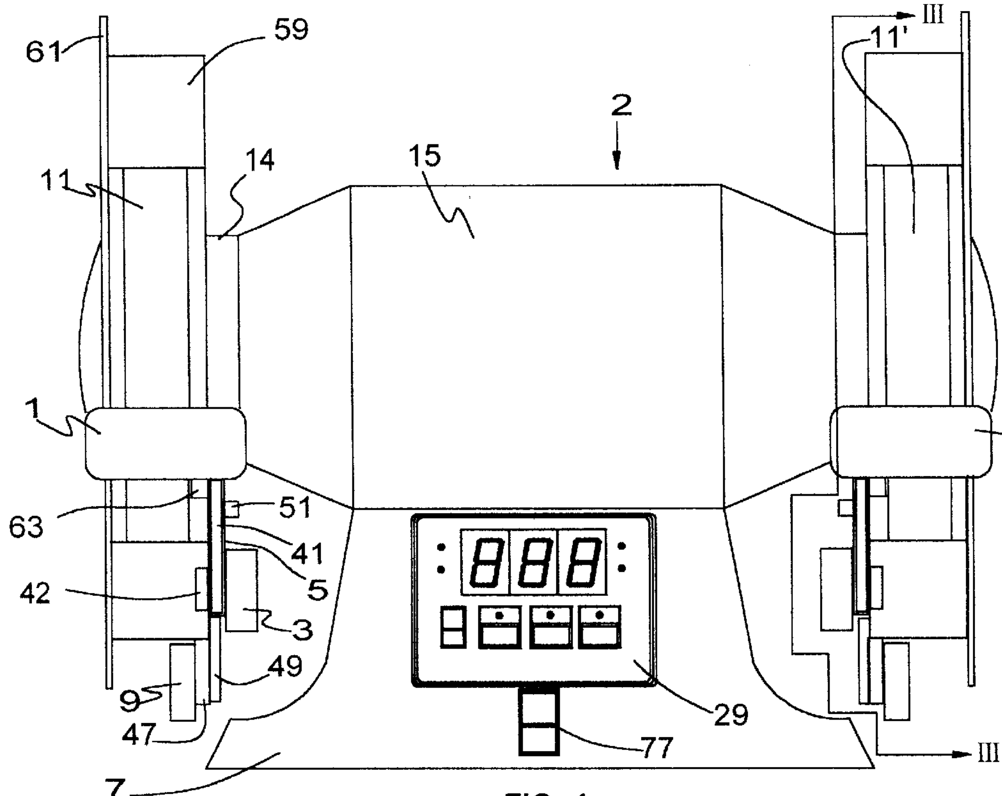


FIG. 1

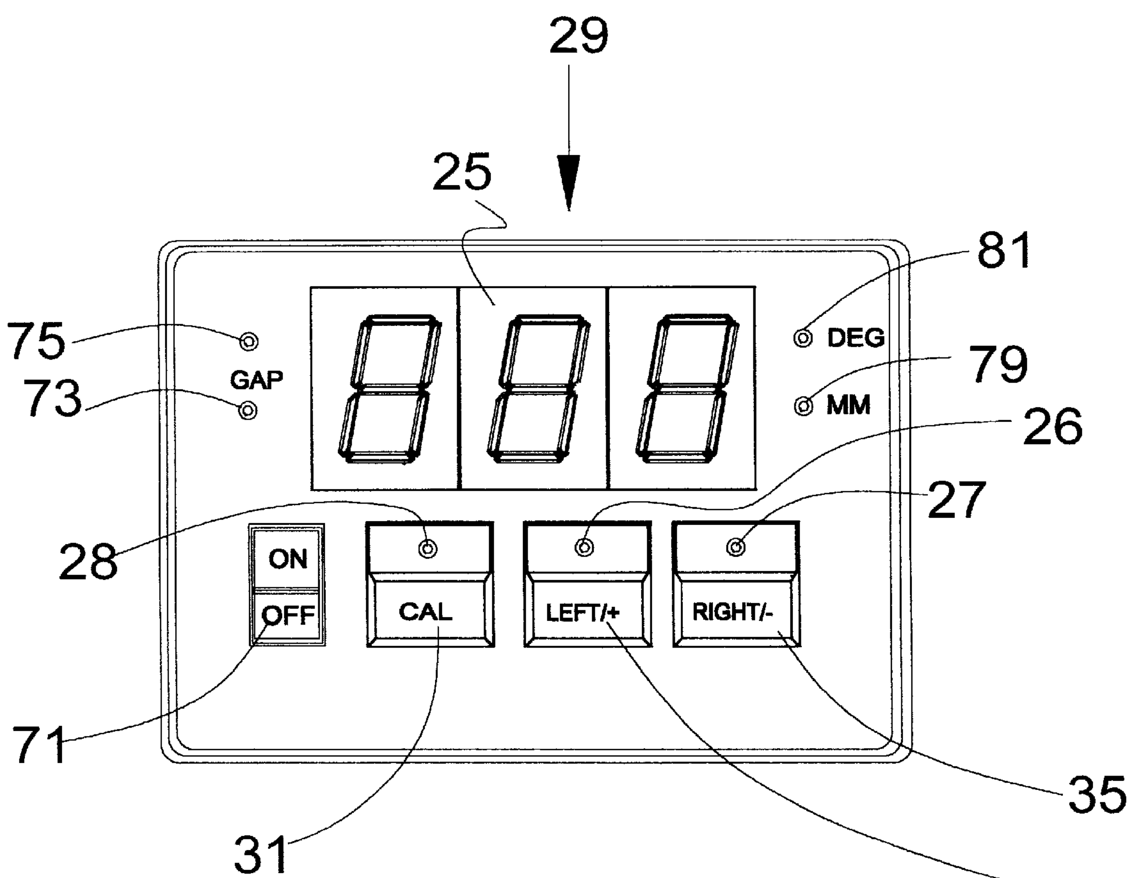

29
25
81
75
DEG
GAP
79
73
MM
26
27
28
ON
OFF
CAL
LEFT/+
RIGHT/-
71
35
31
33

FIG. 2

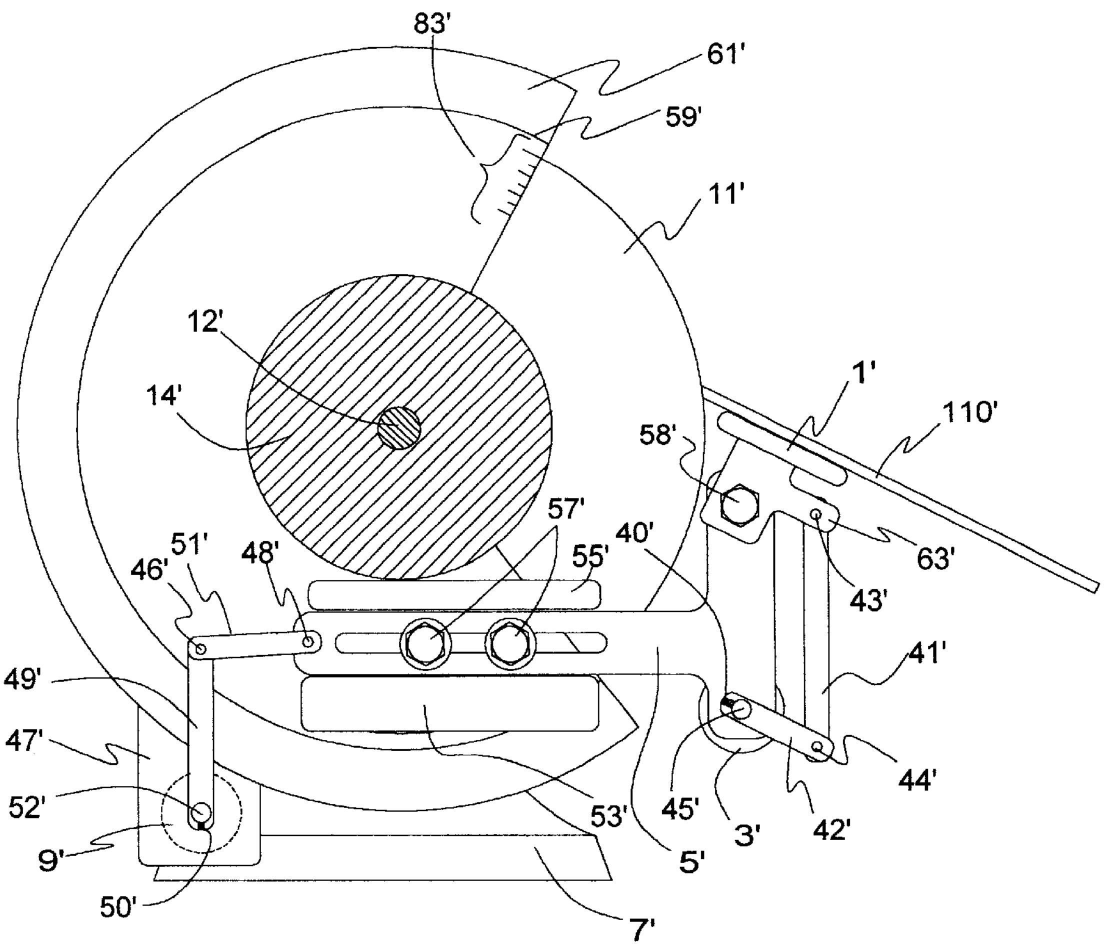

83'
61'
59'
11'
12'
14'
1'
110'
58'
57'
40'
55'
63'
51'
48'
46'
43'
41'
49'
47'
44'
45'
52'
53'
3'
42'
9'
5'
50'
7'

FIG. 3

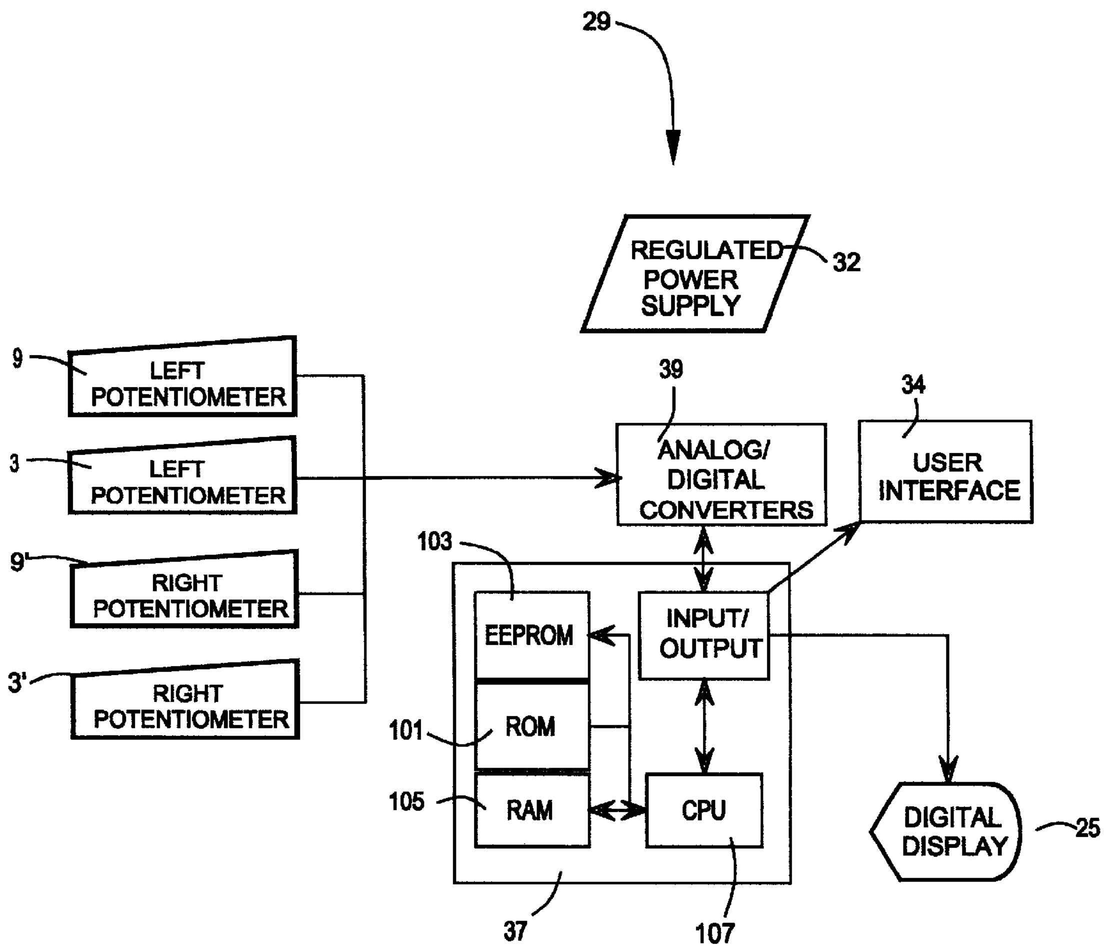

29
REGULATED POWER SUPPLY
32
9
LEFT POTENTIOMETER
3
LEFT POTENTIOMETER
9'
RIGHT POTENTIOMETER
3'
RIGHT POTENTIOMETER
39
ANALOG/ DIGITAL CONVERTERS
34
USER INTERFACE
103
EEPROM
INPUT/ OUTPUT
101
ROM
105
RAM
CPU
DIGITAL DISPLAY
25
37
107

FIG. 4

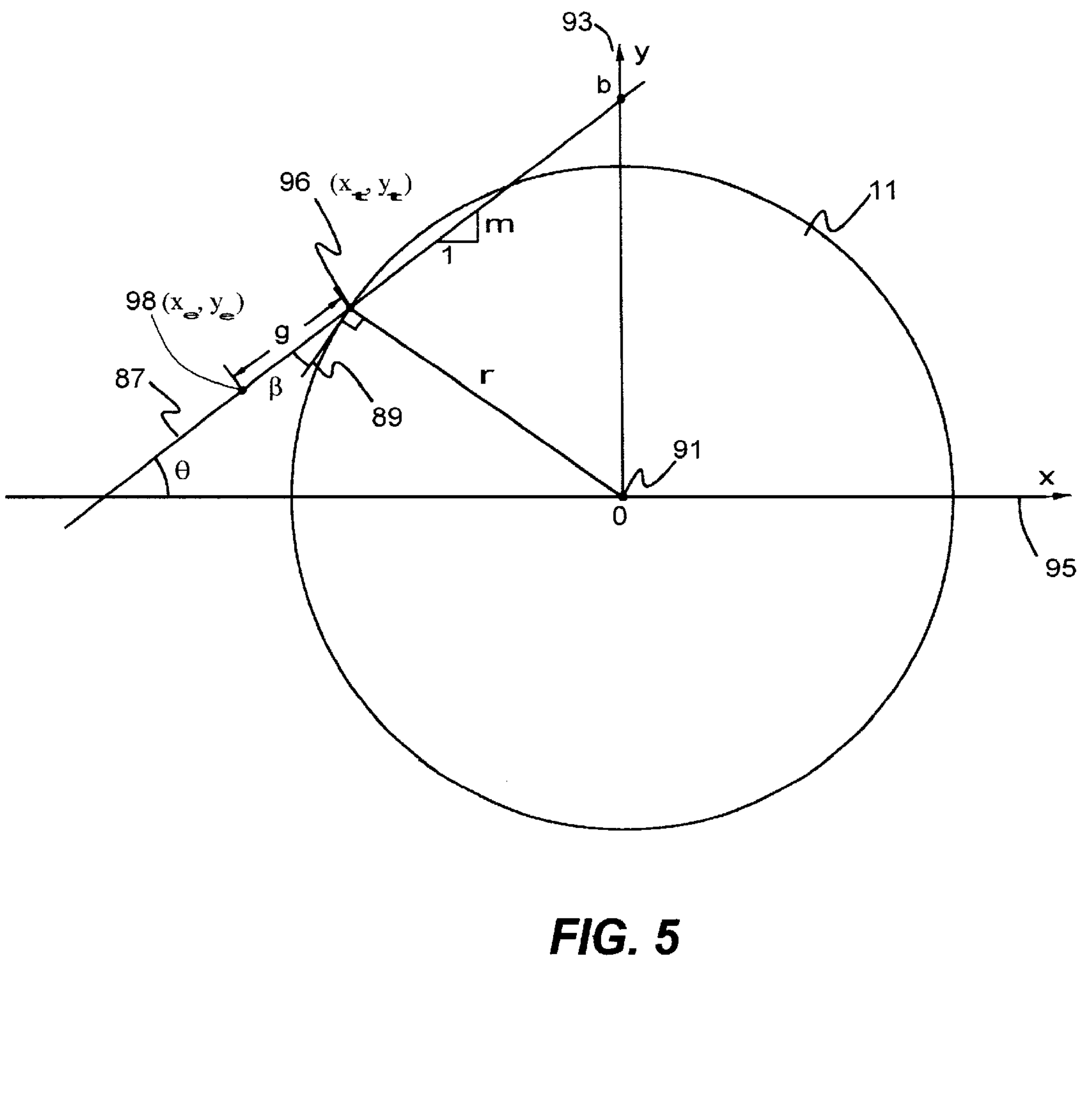


FIG. 5

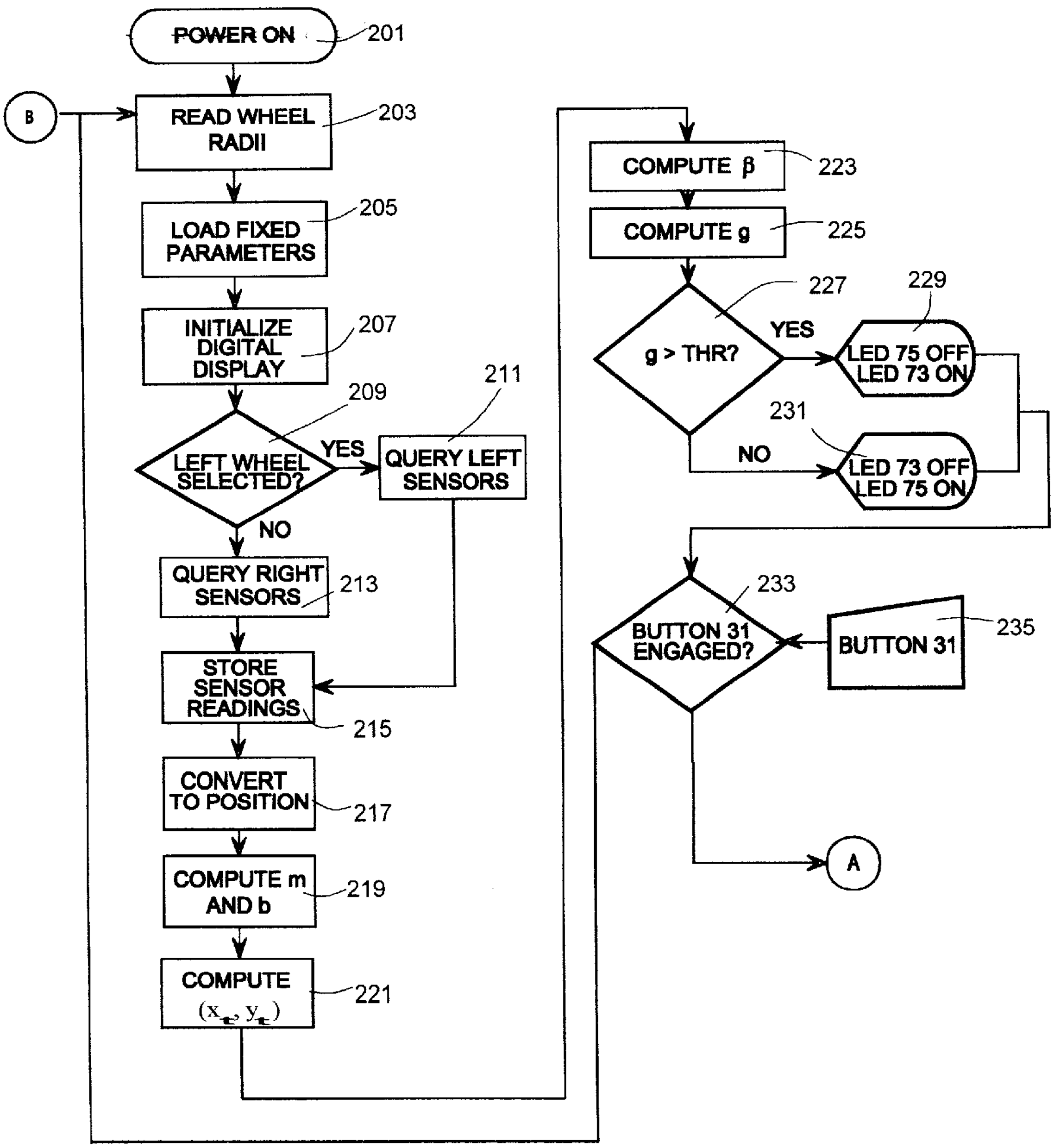

POWER ON
201
B
READ WHEEL RADII
203
LOAD FIXED PARAMETERS
205
INITIALIZE DIGITAL DISPLAY
207
209
LEFT WHEEL SELECTED?
YES
NO
211
QUERY LEFT SENSORS
QUERY RIGHT SENSORS
213
STORE SENSOR READINGS
215
CONVERT TO POSITION
217
COMPUTE m AND b
219
COMPUTE (x, y)
221
COMPUTE β
223
COMPUTE g
225
227
229
g > THR?
YES
LED 75 OFF LED 73 ON
231
NO
LED 73 OFF LED 75 ON
233
BUTTON 31 ENGAGED?
BUTTON 31
235
A

FIG. 6

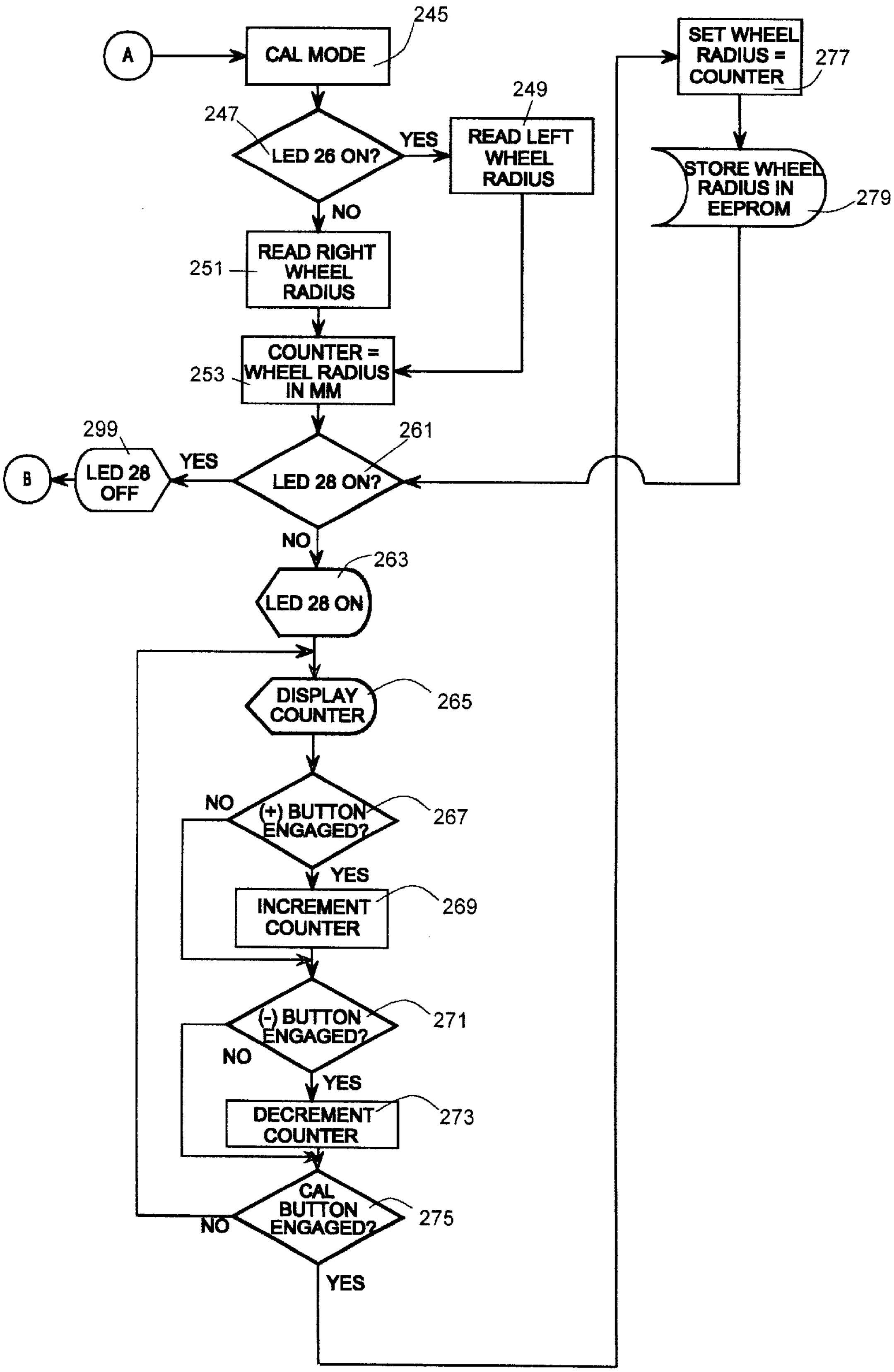

A
CAL MODE
245
247
LED 26 ON?
YES
249
READ LEFT WHEEL RADIUS
NO
251
READ RIGHT WHEEL RADIUS
253
COUNTER = WHEEL RADIUS IN MM
299
LED 28 OFF
YES
B
261
LED 28 ON?
NO
263
LED 28 ON
DISPLAY COUNTER
265
NO
(+) BUTTON ENGAGED?
267
YES
INCREMENT COUNTER
269
(-) BUTTON ENGAGED?
271
NO
YES
DECREMENT COUNTER
273
CAL BUTTON ENGAGED?
NO
275
YES
SET WHEEL RADIUS = COUNTER
277
STORE WHEEL RADIUS IN EEPROM
279

FIG. 7

ELECTRONIC BEVEL ANGLE INDICATOR FOR A HOLLOW GRINDER

TECHNICAL FIELD

This invention pertains to hollow grinding machines, and more particularly to an electronic device that calculates and displays the bevel angle that will be ground upon a tool, using sensor measurements of the tool rest position and orientation.

BACKGROUND OF THE INVENTION

Hollow grinders are commonly used for sharpening tool blades, and typically include a tool rest for maintaining a desired orientation of the blade relative to the grinding wheel. This orientation determines the grinding or bevel angle with respect to the longitudinal axis of the tool blade.

The tool rest is typically adjustable with two or more degrees of freedom to facilitate adjustment of the height and attitude of the tool blade, while maintaining a sufficiently small air gap between the tool rest and the grinding wheel to prevent operator injury. Simultaneously achieving a desired bevel-angle and air-gap can be both difficult and time consuming, and most hollow-grinding machines have no mechanism for determining the bevel angle that will be achieved with a given setting of the tool rest. Furthermore, the bevel angle varies with the radius of the grinding wheel, which decreases with use. My prior U.S. Pat. No. 6,381,862, issued on May 7, 2002, discloses a bevel angle indicator utilizing a novel tool rest support mechanism that maintains a prescribed and coordinated height-attitude relationship of the tool rest with respect to the grinding wheel axis, and a pointer that can be adjusted according to the radius of the grinding wheel. However, it would be advantageous from a cost standpoint to utilize a more conventional tool rest support mechanism, and in many applications, a digital readout of the bevel angle is desired.

SUMMARY OF THE INVENTION

The present invention is directed to an improved bevel angle indicator for a hollow grinding machine that utilizes a conventional tool rest adjustment mechanism, and that detects the position of the adjustment mechanism for purposes of calculating and displaying the bevel angle that will be achieved when a tool is placed flat on the tool rest and presented to the periphery of a rotating grinding wheel. The grinding wheel radius may be sensed or directly entered through a user interface. The calculated bevel angle is the acute angle of intersection between the tool rest plane and a plane tangent to the grinding wheel periphery at the line of intersection between the grinding wheel periphery and the tool rest plane. Additionally, the indicator of this invention determines the air-gap between the tool rest and grinding wheel, and warns the operator when the air gap exceeds a specified safety threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a frontal view of a hollow grinder equipped with the bevel angle indicator of the present invention, including a microprocessor-based display unit.

FIG. **2** is a frontal view of the display unit of FIG. **1**.

FIG. **3** is a partial sectional view of the hollow grinder of FIG. **1**, taken along the line A—A depicted in FIG. **1**.

FIG. **4** is a functional block diagram of the display unit of FIGS. **1** and **2**.

FIG. **5** is an idealized model of the grinder of FIG. **1**, including the grinder wheel and tool rest.

FIG. **6** is a flowchart that describes a software routine executed by the display unit of FIG. **1**.

FIG. **7** is a flowchart that describes the operation of an interrupt service routine executed by the display unit of FIG. **1** to allow operator modification of the grinder wheel radius.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, and particularly to FIGS. **1–3**, the present invention is illustrated in the context of a hollow bench grinder **2** having left-hand and right-hand grinding wheels **11**, **11'** mounted on an arbor **12** that is powered by an electric motor **15**. Since the left-hand and right-hand sides of grinder **2** are similarly constructed and equipped, the following description applies to both left-hand and right-hand sides even though the reference numerals have been omitted in FIG. **1** for the right-hand side. In cases where a reference numeral is used to designate a component associated with the right-hand side of the grinder **2**, the number is primed to distinguish it from the corresponding component on the left-hand side.

As seen in FIGS. **1** and **3**, a shroud **59** and an end-plate **61** supported on the motor end housing **14** partially enclose grinding wheel **11** to capture sparks and grinding debris. Upper plate **55** and lower plate **53** are attached to shroud **59** to serve as guides that ensure that a tool rest support **5** can translate along a line parallel to the ground plane without rotating. A tool rest **1** is attached to tool rest support **5** via a bolt **58**. Tool rest **1** can rotate about the longitudinal axis of bolt **58** to change the angular orientation of said tool rest's working surface. Bolts **57** are tightened to restrict linear translation of tool rest support **5** while the grinder is operating. Bolts **57** are loosened to enable linear translation of tool rest support **5** in order to adjust the linear position of tool rest **1**. Tool rest pitman arm **63** is connected to coupler bar **41** via a rivet **43**. Coupler bar **41** is connected to idler arm **42** via rivet **44**. Idler arm **42** is rigidly coupled to a shaft **45** of a rotary potentiometer **3** via setscrew **40**. Tool rest support **5** is connected to a linkage arm **51** via rivet **48**. Linkage arm **51** is connected to linkage arm **49** via rivet **46**. Linkage arm **49** is rigidly coupled to a shaft **52** of a rotary potentiometer **9** via setscrew **50**. Potentiometer **3** is mounted on the tool rest support **5**, and potentiometer **9** is mounted on a support bracket **47** attached to shroud **59**. Potentiometers **9** and **3** are connected to a display unit **29** via insulated copper wires (not shown).

As depicted by the block diagram of FIG. **4**, the display unit **29** houses a regulated power source **32** for the potentiometers **3**, **3'**, **9**, **9'** and a number of other components including an analog-to-digital converter unit **39**, a microprocessor **37**, a user interface **34**, and a digital display **25**. The analog-to-digital converters **39** convert voltages from the potentiometers **3**, **3'**, **9**, **9'** into 10-bit binary numbers that are uniquely correlated to the linear position of tool rest support **5** and the angular orientation of the working surface of tool rest **1**. Microprocessor **37** stores a computer program in read-only-memory (ROM) **101** that is executed by central processing unit (CPU) **107** to calculate the bevel angle that will be achieved when a tool **110** is placed flat on the working surface of tool rest **1** and presented to the periphery of grinding wheel **11**. The bevel angle is displayed on digital display **25** in units of degrees. The user interface **34** includes a number of pushbuttons **31**, **33**, **35**, and allows the grinder operator to switch operating modes.

Referring to FIG. **2**, pushbutton **31** is used to toggle between a calibration mode and bevel angle display mode. LED **28** is illuminated when display unit **29** is in the calibration mode. Pressing pushbutton **33** in bevel angle display mode causes LED **26** to illuminate and the digital display **25** to display the bevel angle that will result when a tool **110** is placed flat on the working surface of left-hand tool rest **1** and presented to grinding wheel **11**. Similarly, pressing pushbutton **35** while in bevel angle display mode illuminates LED **27** and causes the digital display **25** to display the bevel angle that will result when a tool **110** is placed flat on the working surface of right-hand tool rest **1**' and presented to grinding wheel **11**'. When the digital display **25** operates in bevel angle display mode, LED **81** is illuminated to indicate that the unit is displaying bevel angle in units of degrees. A green LED **75** is illuminated when the air gap between the leading edge of the tool rest **1** and the periphery of the grinding wheel **11** is less than or equal to a specified maximum safe distance. The air gap is a derived measurement that is computed by microprocessor **37**, based upon known fixed tool rest geometry and sensor measurements. Similarly a red LED **73** is illuminated when the air gap exceeds the specified maximum safe distance.

When display unit **29** operates in calibration mode, LED **28** illuminates, air gap LEDs **75** and **73** are turned off, and LED **79** illuminates to indicate that digital display units are in millimeters. In calibration mode, digital display **25** indicates the radius of the left or right grinding wheel **11**, **11**'. The LEDs **26** and **27** indicate which wheel radius is being displayed, while pushbuttons **33** and **35** increment and decrement the wheel radius shown on digital display **25**. The user cannot switch wheels when in calibration mode; wheel selection must occur before entering calibration mode. When the user has manipulated pushbuttons **33** and **35** so that digital display **25** displays the correct wheel radius, the user can switch back to bevel angle display mode by pushing pushbutton **31**. As seen in FIG. **3**, indicia **83** are printed on shroud **59** to assist the user in measuring the radius of grinding wheel **11**'. The user simply places a straight-edge on the wheel periphery and reads the wheel radius from the indicia **83** at the point where the straight edge and index line intersect. An alternative embodiment could use a slide potentiometer in place of the scale to convert wheel radius measurements into an electrical signal that is processed by display unit **29** in a manner similar to the signals from potentiometers **3**, **3**', **9**, **9**'. All pushbuttons and LEDs interface with microprocessor **37**. Switch **71** turns display unit **29** on and off, and switch **77** turns the grinder motor **15** on and off.

FIG. **5** shows an idealized model of the tool rest and grinding wheel geometry. The grinding or bevel angle β is defined as the acute angle of intersection between two planes: a plane **87** that is coincident with the working surface of tool rest **1**, and a plane **89** that is tangent to the periphery of grinding wheel **11** at the line of intersection between plane **87** and grinding wheel **11**. FIG. **5** shows a two dimensional cross-section of these planes; thus, without loss of generality, the planes are shown as lines, and lines parallel to the axis of rotation of grinding wheel **11** are shown as points. A right-handed Cartesian coordinate system is defined by an origin **0** (point **91**) at the grinding wheel axis of rotation, an x-axis **95** parallel with the ground-plane that supports grinder **2**, and a y-axis **93** perpendicular to such ground-plane. The line representing plane **87** can be written in slope-intercept form as y=(m*x)+b, where x and y are Cartesian coordinates referenced from the origin O, m is the slope of the line with respect to the x-axis **95**, and b is the y-intercept of the line. One formulation for the bevel angle β is given by:

$$\beta = \arccos\left(\frac{y_t}{r}\cos\theta - \frac{x_t}{r}\sin\theta\right) \quad (1)$$

where the point **96** (x_t, y_t) is the point of intersection between the periphery of grinding wheel **11** and the plane **87**, r is the radius of said grinding wheel and θ=arctan(m). The x-coordinate of the point **96** is given by:

$$x_t = \frac{-2mb - \sqrt{4m^2b^2 - 4(m^2+1)(b^2-r^2)}}{2(m^2+1)} \quad (2)$$

while the y-coordinate of the point **96** is given by:

$$y_t = mx_t + b \quad (3)$$

The flowcharts shown in FIGS. **6** and **7** describe the operations that are carried out by microprocessor **37**. Microprocessor **37** is responsible for processing sensor measurements, carrying out all computations, handling user input and driving the digital display **25**. The main routine is shown in FIG. **6** while FIG. **7** describes an interrupt service routine (ISR) that is used to handle user input and display output when the user wishes to manually update the grinding wheel radii. Note that the ISR can halt the execution of the main routine at any point in the flowchart in FIG. **6** when the user pushes the CAL mode button **31**.

Referring to FIG. **6**, block **201** designates power-up of the CPU **107** when the user turns on switch **71**. The most recent values of wheel radii are read from non-volatile Electrically Erasable Programmable Read Only Memory (EEPROM) **103**, as indicated at block **203**. Fixed geometric parameters are loaded into Random Access Memory (RAM) **105** at block **205**; such parameters specify the dimensions and relative locations of tool rest **1** and tool rest support **5** as well as the sensor calibration parameters. Block **207** initializes the digital display **25** in the bevel angle display mode, and block **209** determines which grinding wheel has been selected. The blocks **211**, **213**, **215** and **217** are then executed to obtain and store the sensor readings for the selected grinding wheel, and to convert the stored readings into physically meaningful floating point measurements of tool rest position and attitude using empirically derived calibration curves. The block **219** then computes the slope and y-intercept of the line representing the tool rest plane **87**, based on the fixed geometric parameters and sensor measurements. For example, the reading of potentiometer **3** provides the angle θ of the tool rest **1** with respect to the x-axis **95**, the slope m of the plane **87** is tan(θ), and the readings of potentiometers **3** and **9** provide the y-intercept b. The coordinates (x_e, y_e) of a point **98** on the front edge of the tool rest **1** are also determined at this time based on the fixed geometric parameters. The intersection point **96** of the tool rest plane **87** and grinding wheel periphery is then calculated at block **221** using Equations (2) and (3). The grinding or bevel angle β is then calculated at block **223** using Equation (1). Finally, the block **225** calculates the air gap g between the front edge of the tool rest **1** and grinding wheel **11** using the expression:

$$g = \sqrt{(x_t - x_e)^2 + (y_t - y_e)^2} \quad (4)$$

In other words, the air gap g is defined as the distance between points **98** and **96**, as shown in FIG. **5**. The blocks **227**, **229** and **231** determine if the air gap g exceeds a specified safety threshold, turn on the green LED **75** if the air gap is does not exceed the threshold, and turn on the red LED warning light **73** if the air gap does exceed the threshold. If at any time the user presses CAL button **31**, as indicated at blocks **235**, the block **233** is answered in the affirmative, and the ISR of FIG. **7** is called to permit adjustment of the wheel radii stored in EEPROM **103**.

Referring to FIG. **7**, the calibration mode is entered at block **245**, which turns on the LED **79** to reflect that the left or right wheel radius will be displayed in units of millimeters. Then block **247** determines which grinding wheel is selected, as indicated by the state of LEDs **26** and **27** when the CAL button **31** is depressed. If LED **26** is illuminated, then the user can change the radius of the left-hand wheel **11**, and block **249** reads the most recent radius of the left-hand wheel **11** from EEPROM **103**. If LED **27** is illuminated, then the user can change the radius of the right-hand wheel **11**', and block **251** reads the most recent radius of the right-hand wheel **11**' from EEPROM **103**. The block **253** then stores the respective wheel radius value in an integer counter variable (Counter). The blocks **261** and **263** turn on the calibration mode LED **28** to indicate that the display unit **29** is in calibration mode and to indicate that the function of buttons **33** and **35** have changed from wheel selection buttons to increment and decrement buttons. The block **265** causes the value of the counter variable to be displayed on the digital display **25**. If the user presses button **33**, as determined at block **267**, the block **269** increments the displayed counter variable by 1. If the user pressed button **35**, as determined at block **271**, the block **273** decrements the displayed counter variable by 1. If the user presses the calibration button **31**, as determined at block **275**, the blocks **277** and **279** set the wheel radius equal to the counter variable and store its value in non-volatile EEPROM **103**, whereafter the blocks **261** and **299** turn off the calibration mode LED **28**, completing the calibration mode ISR.

While the present invention has been described in reference to the illustrated embodiments, it is expected that various modifications in addition to those mentioned above will occur to those skilled in the art. For example, there are many types of angular and linear position sensors that could be employed to characterize the tool rest plane. Furthermore, many variants of tool rest support mechanisms can be found on hollow grinding machines. The method and apparatus described herein can be used to determine tool bevel angles for any hollow grinding machine that is equipped with a mechanical tool rest, provided that it can be outfitted with sensors that allow one to characterize the tool rest plane. Automatic measurement of wheel radius could also be

employed to eliminate the wheel calibration mode of the illustrated embodiment. Thus, it will be understood that mechanisms incorporating these and other modifications may fall within the scope of this invention, which is defined by the appended claims.

What is claimed is:

1. An electronic indicator for a hollow grinder including a circular grinding wheel supported about an axis of rotation, a tool rest having a working surface for supporting a tool blade with respect to a grinding surface of the grinding wheel, and a tool rest support mechanism positionable to adjust a height and an attitude of said tool rest with respect to said grinding surface, comprising:

sensor means for sensing a current position of said support mechanism;

a microprocessor responsive to said sensor means and a radius of said grinding wheel for mathematically characterizing a first plane including the working surface of said tool rest, and a second plane tangent to said grinding surface at an intersection between said first plane and said grinding surface, and for calculating an acute angle of intersection between said first and second planes; and

an electronic display for displaying the calculated angle of intersection as an indication of an achieved bevel angle of said tool blade with respect to said grinding surface.

2. The electronic indicator of claim **1**, wherein said tool rest has a leading edge, and the microprocessor (1) identifies said leading edge in terms of said first plane based on a known geometry of said tool rest, and (2) calculates a tool rest air gap according to a distance between the identified leading edge and said intersection.

3. The electronic indicator of claim **2**, wherein said microprocessor compares said tool rest air gap to a specified maximum gap, and said electronic display indicates a result of such comparison.

4. The electronic bevel angle indicator of claim **1**, wherein said microprocessor includes a memory in which said radius is stored, and said electronic display includes a user interface permitting a user to modify the stored radius.

5. The electronic bevel angle indicator of claim **4**, wherein said electronic display displays said stored radius during a mode of operation in which said user is permitted to modify said stored radius.

6. The electronic bevel angle indicator of claim **1**, wherein said sensing means senses a radius of said grinding wheel.

* * * * *