MACHINE TOOL AND GAGING APPARATUS

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ABSTRACT

The disclosed gaging apparatus is primarily applicable to grinding machines, but is also applicable to other machine tools. The apparatus comprises a gaging head having a movable gaging member with a contact element made of extremely hard material for direct engagement with grinding wheel. Such engagement moves the gaging member to a position corresponding to the size of the workpiece after being ground by the wheel. The gaging head is provided with a clamping magnet or other device for mounting the gaging head on the workpiece or the work support. Retaining means are provided to hold the movable gaging member in any position to which it may be moved, such retaining means preferably providing frictional resistance to movement of the gaging member. The retaining means may comprise a magnet to produce a retaining force or a frictional spring acting between the gaging member and the gaging head. An indicator is provided for precisely indicating the position of the gaging member. Such indicator may be of an electronic or pneumatic type, for example.

18 Claims, 20 Drawing Figures
MACHINE TOOL AND GAGING APPARATUS

This invention relates to gaging apparatus which is particularly applicable to grinding machines, but may also be applied to machine tools of other types.

One object of the present invention is to provide a new and improved gaging apparatus which is particularly well adapted to indicate or otherwise respond to the position of a grinding wheel or other cutting tool, which is to be employed to make a cut on a workpiece. By precisely indicating the position of the grinding wheel, the gaging apparatus also provides a precise indication of the size of the workpiece after it has been ground by the wheel.

A further object is to provide new and improved gaging apparatus having a movable gaging member which is directly engageable with a grinding wheel or some other type of cutting tool, so that the gaging member will be movable to a position corresponding to that of the grinding wheel. The present invention also contemplates the provision of means for precisely indicating the position of the grinding wheel. Such means may include a meter, dial or the like, adapted to provide a visual indication of the position of the gaging member. Alternatively or additionally, such means may include some other type of responsive device such as an automatic control system which carries out any desired control functions in response to the movement or positioning of the gaging member. Such control functions may include the stopping of the feed of the machine tool and the retraction of the grinding wheel or other cutting tool, for example.

It is a further object to provide gaging apparatus which not only indicates when the workpiece has been ground or cut to the desired size, but also is capable of indicating that an approach is being made by the grinding or cutting operation to the desired size.

Another object is to provide gaging apparatus which is particularly well adapted for use in carrying out repetitive grinding or cutting operations upon successive workpieces.

It is another object to provide gaging apparatus which retains its full accuracy even though the grinding wheel is worn down by continued grinding operations. The gaging apparatus of the present invention does not require recalibration, even though it becomes necessary to dress the grinding wheel.

To carry out these and other objects, the gaging apparatus of the present invention preferably comprises a gaging head having mounting means whereby the head may be mounted on one of the workpieces or on the worktable or other support. In some cases, other mounting arrangements may be employed for the gaging head. A movable gaging member is preferably mounted on the gaging head and is provided with a contact element which is directly engageable with the grinding wheel or some other cutting tool. It is also possible to arrange the gaging apparatus so that the contact element of the gaging member is engageable with the workpiece. The contact element is preferably made of an extremely hard material, such as diamond, so that it will not be worn down by the engagement with the grinding wheel. Means are provided for precisely indicating or responding to the position of the gaging member. Such means may take the form of an electronic indicator, an air indicator, or some other type of indicator. On the other hand, such means may comprise an automatic control system for carrying out various control functions, in response to the positioning of the gaging member. Means are provided for retaining the movable gaging member in any position to which it may be moved. In this way, the reading on the indicator is retained between the successive passes of the grinding wheel. Such means preferably provide frictional resistance to the movement of the gaging member so that it will stay in any position to which it may be moved. A magnet or a magnetized portion of the head may be employed to provide a force on the gaging member so that its movement will be frictionally resisted. Another advantageous construction is to utilize a resilient frictional member which retains the gaging member in any position to which it may be moved.

The present invention is applicable to a wide variety of machine tool operations utilizing all different types of grinding wheels or other cutting tools.

Further objects, advantages and features of the present invention will appear from the following description, taken with the accompanying drawings, in which:

FIG. 1 is a diagrammatic sectional view showing gaging apparatus to be described as an illustrative embodiment of the present invention.

FIG. 2 is a longitudinal section of a gaging head which utilizes a resilient frictional member rather than the magnetically developed frictional retention, employed in the gaging head of FIG. 1.

FIG. 3 is an enlarged cross-section taken generally along the line 3—3 in FIG. 2.

FIG. 4 is a view similar to FIG. 1 but showing modified gaging apparatus using an air indicator, rather than the electronic indicator of FIG. 1.

FIG. 5 is a diagrammatic elevation, showing the manner in which the gaging apparatus may be applied to a surface grinding machine.

FIG. 6 is a plan view of the apparatus shown in FIG. 5.

FIGS. 7 and 8 are fragmentary front and side elevational views showing the manner in which the gaging apparatus may be applied to a grinding machine which utilizes a shaped or configured grinding wheel.

FIGS. 9 and 10 are fragmentary front and side elevations showing the manner in which the present invention may be applied to a step grinding setup, in which a grinding wheel is employed to grind a series of steps on a workpiece.

FIG. 11 is a diagrammatic front elevation showing another arrangement whereby the gaging apparatus may be applied to a surface grinding machine.

FIGS. 12 and 13 are fragmentary front and side views, partly in section, to show the manner in which the gaging apparatus may be applied to an internal grinding setup.

FIGS. 14 and 15 are fragmentary front and side elevations showing the manner in which the gaging apparatus may be applied to a centerless grinding machine.

FIGS. 16, 17 and 18 are plan, side and front views showing the manner in which the gaging apparatus may be applied to a taper grinding setup.

FIGS. 19 and 20 are front and side elevations showing the manner in which the gaging apparatus may be
utilized in a setup in which two grinding wheels are employed for grinding the opposite ends of a workpiece.

As just indicated, FIG. 1 illustrates grinding apparatus 22, which is particularly well adapted for indicating the position of a grinding wheel 24, but may be used in connection with any other suitable cutting tool. The gaging apparatus 22 comprises a gaging head 26 having a movable gaging member 28. A contact element 30 is provided on the gaging member 28, for direct engagement with the grinding wheel 24. The contact element 30 is preferably made of an extremely hard material, such as diamond, so that the contact element will not be appreciably worn down by the engagement with the grinding wheel.

The head 26 and the gaging member 28 may assume various forms. In this case, the head 26 comprises a body 32 which is formed with a bore 34. The illustrated gaging member 28 comprises a pin 36, which is slidable in the bore 34. A spherically rounded head 38 is provided on the pin 36. The contact element 30 constitutes the central portion of the round head 38.

Means are provided to indicate or respond to the position of movable gaging member 28. As shown in FIG. 1 such means take the form of an electronic indicating device 39, adapted to provide a precise visual indication of the position of the gaging member 28. Alternately or additionally, the indicating device may be arranged with an automatic control system 39a to carry out automatic control functions, such as the stopping of the feed, the retraction of the grinding wheel 24, and the release of the workpiece.

The illustrated electronic indicator 39 is of a known type utilizing a linear differential transformer 40 mounted within the gaging head. The transformer 40 has a movable core 42 which is mounted on the movable gaging member 28. As illustrated, the core 42 is supported by a stem or shaft 44, projecting from one end of the pin 36.

By means of a cable 46, the linear differential transformer 40 is connected to an indicator circuit 48 which utilizes an electrical meter 50 to provide a precise visual indication of the position of the movable gaging member 28. The indicator circuit 48 has variable controls 51 of the usual type for setting the meter 50 to a particular zero point or other mark on the scale of the meter, when the gaging member 28 is moved to a particular calibrated position, representing the position of the grinding wheel 24, in which the workpiece will be ground to the precise size which is desired. The reading of the meter 50 indicates not only the exact size desired, but also the approach of the gaging member 28 to the position representing exact size. Thus, the gaging apparatus makes it easy to advance the grinding wheel 24 through successive steps whereby the workpiece is ground to size by successive cuts or passes of the grinding wheel.

Means are provided to retain or hold the movable gaging member 28 in any position to which it may be moved. Preferably, such means provide frictional resistance to the movement of the gaging member 28. Only a small amount of frictional resistance is desirable, sufficient to prevent any accidental movement of the gaging member 28 due to vibration or other extraneous factors. The provision of light frictional resistance obviates the development of any damaging force between the grinding wheel 24 and the contact element 30.

It would be possible in theory to provide frictional resistance by carefully fitting the pin 36 within the bore 34. However, it is preferred to provide for the frictional resistance in a more dependable and positive manner. In the construction of FIG. 1, a portion of the gaging member 28 is magnetized to provide magnetic poles 52 and 54. The gaging member 28 is made of or includes magnetizable material so as to provide magnetic attraction between the gaging member and the magnetic poles 52 and 54. In this way, a magnetic force is exerted laterally upon the gaging member 28 so that there will be a positive and dependable frictional resistance to the sliding movement of the pin 36 within the bore 34. The magnetic attraction may be provided by a separate magnetic or in any other suitable manner.

It will be convenient to refer to FIGS. 5 and 6, which show a surface grinding machine 56 utilizing the grinding wheel 24. One or more workpieces 58 are clamped or otherwise secured to a worktable 60 or some other support. In the usual type of surface grinder, the worktable 60 can be fed horizontally in a direction parallel to the rotary plane of the grinding wheel 24 and also in a direction perpendicular to such rotary plane. The grinding wheel 24 can be moved vertically so as to adjust to the depth of the cut when the workpieces are fed under the grinding wheel.

In the setup of FIGS. 5 and 6, the gaging head 26 can be mounted on or attached to one of the workpieces 58 as indicated in full lines, or to the worktable 60 in various positions, as indicated in broken lines. The gaging head 26 is preferably positioned so that the contact element 30 of the movable gaging member 28 passes under the grinding wheel 24 shortly before or after one of the workpieces passes under the grinding wheel. The engagement of the grinding wheel 24 with the contact element 30 displaces the gaging member 28 to a position corresponding precisely to the ground size of the workpieces. The meter 50 indicates when the grinding wheel 24 has moved to the position in which the workpieces will be ground to the exact size desired. The meter also indicates when the exact size is being approached, so that the advancing movement of the grinding wheel can be regulated accordingly.

The gaging head 26 may be mounted on the worktable 60 or one of the workpieces 58 in any suitable manner. In one advantageous arrangement, a magnetic clamp or base 62 is provided on the gaging head 26, whereby the gaging head can be secured to the worktable 60 or one of the workpieces 58 by magnetic attraction. In the setup of FIGS. 5 and 6 the magnetic base 62 is arranged so that the gaging head 26 can be attached to one side of the worktable 60, or one side of one of the workpieces 58.

In the setup of FIGS. 5 and 6, the gaging apparatus can be easily calibrated by mounting the gaging head 26 on the side of a workpiece which is then placed on the surface plate of a conventional height gage. By using the height gage the contact element 30 of the movable gaging member 28 is adjusted to the desired height of the finished workpiece. The controls of the indicator circuit 48 are then adjusted to produce the desired zero reading on the meter 50. Such reading is usually near the center of the meter scale so that deviations in either direction can readily be observed.
The workpiece is then mounted on the supporting table 60 with the gaging head 26 still attached to the workpiece. The gaging member 28 is extended to its starting position, either manually or by some automatic means. The grinding wheel 24 is then employed to grind the workpieces by taking successive cuts in the usual manner. For each pass of the workpieces under the grinding wheel 24, the contact element 30 is brought under the grinding wheel so that the gaging member 28 will be moved downwardly. As the desired size is approached, the reading of the meter 50 approaches the zero reading. The grinding operation is terminated when the meter reaches the zero reading. Such termination may be accomplished manually or by the automatic control system 39a, operated by the indicator circuit 48.

In the setup of FIG. 5 the gaging head 26 may be mounted on the side of the worktable 60. FIG. 11 illustrates a modified arrangement in which the gaging head 26 is mounted on a fixture 66 which is clamped or otherwise secured to the top of the worktable 60, alongside one of the workpieces 58.

In the setup of FIG. 11 the gaging head 26 can easily be calibrated by grinding a workpiece to the exact size by conventional methods, and then leaving the grinding wheel 24 in its final position, corresponding to the exact size. The gaging head 26 is then moved under the grinding wheel 24 so that the gaging member will be moved to a position corresponding to the final position of the grinding wheel. The indicator circuit 48 is then adjusted to bring the meter 50 to the desired zero reading.

When additional workpieces are to be ground to size, the workpieces are mounted on the worktable 60. The movable gaging member 28 is extended to its starting position. The workpieces are then passed under the grinding wheel 24, usually several times, as the grinding wheel is progressively moved downwardly. During each pass, the table 60 is moved a sufficient distance to bring the movable gaging member 28 under the grinding wheel 24, so that the gaging member will be moved to a position corresponding to the ground height of the workpieces. As the desired size is approached, the reading on the meter 50 approaches the calibrated zero reading. At the exact size, the meter 50 is brought to the zero reading. During the intervals between the passes of the worktable 60, the reading of the meter 50 is held constant so that the progress of the grinding operation can be monitored very closely. With this gaging system, the workpieces can be brought to size with an extremely high order of precision.

Wear on the grinding wheel 24 does not appreciably affect the accuracy of the gaging system, because the movable gaging member 28 directly engages the grinding wheel. The wheel can be dressed repeatedly without affecting the calibration of the gaging apparatus.

FIGS. 2 and 3 illustrate a modified gaging head 76 having a movable gaging member 78, adapted to be retained mechanically in any position to which it may be moved. As before, the movable gaging member 78 comprises a pin 80 which is slidable in a bore 82, formed in a body 84. In this case, a resilient frictional device retains the pin 80 against accidental movement along the bore 82. As shown to best advantage in FIG. 3, such frictional device takes the form of a spring 86 mounted on the pin 80. The spring 86 is in the form of a piece of thin resilient sheet metal or other spring material, having flexed edge portions or flanges 88, slidably engaging the inside of the bore 82. The spring 86 is secured to the pin 80 by one or more screws 90, or some other suitable means. It will be understood that the spring flanges 88 provide a light drag along the inner surface of the bore 82, so that the pin 80 will remain in any position to which it may be moved.

In the arrangement of FIGS. 2 and 3, the range of movement of the pin 80 is limited by a stop illustrated as a curved segmental block 92 secured to the inside of the bore 82 by a screw 94 which extends through an opening 96 in the bore 84. The block 92 is slidable received in a slot or recess 98 formed in the pin 80. The range of movement of the gaging member 78 is determined by the difference between the length of the slot 98 and the length of the block 92.

As before, the movable gaging member 78 is provided with a contact element 100, preferably mounted on the central portion of a rounded head 102, formed on the pin 80. A flexible boot 104 is preferably provided between the gaging member 78 and the body 84 to exclude dust and other foreign material from the slidable surfaces of the pin 80 and the bore 82. In other respects, the gaging head 76 of FIGS. 2 and 3 may be the same as the head 26 of FIG. 1. Moreover, the other details of the gaging system may be the same as already described.

FIG. 4 illustrates a modified gaging system 122 which utilizes a gaging head 126 having a movable gaging member 128. Generally, the head 126 and the gaging member 128 are the same as described in connection with FIG. 1. Thus, the head 126 comprises a body 132 having a bore 134 therein. The gaging member 128 comprises a pin or shaft 136 which is slidable in the bore 134. The gaging member 128 includes a contact element 130 which is preferably mounted on a round head 138, formed on the pin 136.

In this case, the movable gaging member 128 is retained against accidental movement by magnetic means, illustrated as a separate magnet 141, mounted on one side of the body 132. The gaging member 128 includes magnetic material which is attracted by the magnet 141, so that substantial friction is produced between the pin 136 and the bore 134.

Instead of utilizing an electronic indicating system, the gaging apparatus 122 employs an air indicating or monitoring system, comprising an air nozzle 145 which directs a stream of air axially toward a valve member 147, connected to the lower end of the movable gaging member 128. As shown, an axial stem or shaft 149 is connected between the valve member 147 and the lower end of the pin 136.

As before, the contact element 130 of the gaging member 128 is preferably brought directly into engagement with the grinding wheel 24 or some other cutting tool. As the grinding wheel is moved in a direction to increase the depth of the cut, the gaging member 128 is moved downwardly, as shown in FIG. 4. Accordingly, the valve member 147 begins to shut off the stream of air from the nozzle 145. An air indicator 151 is connected to the air nozzle 145 to indicate the resulting change in the air pressure. The progressive closure of the air nozzle 145 by the valve member 147 makes it
possible for the air indicator 151 to show that the grinding wheel is approaching the position which will cause the workpieces to be ground to the exact size desired.

The air nozzle 145 is calibrated in much the same manner as the electrical indicating device of FIG. 1. As shown, the air nozzle 145 is provided with an adjusting screw 153, whereby the air nozzle can be advanced or retracted relative to the valve member 147. In this way, the air indicator 151 can be brought to a desired zero reading when the movable gaging member 128 is in its exact size position, corresponding to the position of the grinding wheel 24, in which the workpieces will be ground to the exact size desired. It will be understood that other indicating systems may be employed, in addition to the electrical system of FIG. 1 and the pneumatic system of FIG. 4.

FIGS. 7 and 8 illustrate a grinding setup in which the gaging system of the present invention is used in connection with a shaped grinding wheel 160, adapted to produce a desired contour on a workpiece 162. To produce such contour the illustrated grinding wheel 160 has an annular ridge 164 and an annular valley 166. Two of the gaging heads 26 are utilized to provide two movable gaging members 28, adapted to engage the grinding wheel 160 along the ridge 164 and the valley 166. The gaging heads 26 may be mounted directly on the workpiece 162, preferably by means of magnetic bases or clamps. The gaging heads 26 may also be mounted on the worktable or other work support for the workpieces 162.

FIGS. 9 and 10 illustrate another grinding setup in which the grinding wheel 24 is employed to grind a series of steps 170, 172, 174 and 176 on a workpiece 178. In this case, one of the gaging heads 26 is provided for each of the steps 170–176. The movable gaging member 28 of each gaging head 26 is adapted to engage the grinding wheel 24 while it is grinding the corresponding step on the workpiece 178. Here again, the gaging heads 128 may be mounted directly on the workpiece 178 or on the worktable.

FIG. 11 has already been described in connection with FIGS. 5 and 6. FIGS. 12 and 13 illustrate an application of the invention to a setup in which a grinding wheel 180 is employed to grind the inner surface of a sleeve or tube 182. A chuck or some other rotary work support 184 is provided to support the sleeve 182. The grinding wheel 180 is mounted on a shaft 186 which can be extended from its initial position so that the grinding wheel 180 will be moved into the sleeve 182. One of the gaging heads 26 is mounted so that its movable gaging member 28 will be engaged by the grinding wheel 180 when it is withdrawn from the sleeve 182. The position of the gaging head 26 is calibrated so that the gaging member 28 is brought to its zero position when the grinding wheel 180 is in a position so as to grind the inside of the sleeve 182 to the desired size.

The gaging head 26 in FIGS. 12 and 13 may be mounted on a fixture or base 188 which is in a fixed relation translationally relative to the work piece 182. While the work piece 182 may be rotated relative to the fixture 188, there is no relative translation therebetween.

FIGS. 14 and 15 illustrate the manner in which the gaging apparatus of the present invention may be applied to a centerless grinder 190, adapted to grind the cylindrical periphery of a pin or some other work piece 192. A series of such work pieces may be fed through the machine. The work piece 192 is supported by a work blade 194 and a regulating wheel 196, which is driven at a high speed so that the work piece 192 will be rapidly rotated by frictional engagement with the wheel 196. While the work piece 192 is being rotated, it is ground by a rapidly rotating grinding wheel 200. The work blade 194 is mounted on a holder 198.

As shown to best advantage in FIG. 14, one of the gaging heads 26 is preferably mounted on the work blade holder 198. In this case, an intermediate movable member 202 is provided between the gaging member 28 and the grinding wheel 200. The intermediate member 202 may assume various forms but is illustrated as an L shaped lever having one arm 204 for engaging the gaging member 28, and a second arm 206 with a contact element 208 adapted to engage the grinding wheel 200. As before, the contact element 208 includes or is made of an extremely hard material, such as diamond, so that it will not be worn down by engagement with the grinding wheel 200. The lever 202 has a pivotal support 210 on the work blade holder 198.

In the set-up of FIGS. 14 and 15, the gaging apparatus may readily be calibrated by grinding a work piece to the desired size, using conventional methods. This involves the precise positioning of the regulating wheel 196 relative to the work blade 194 and the grinding wheel 200. The slide or carriage for the regulating wheel 196 is then locked to the slide or carriage for the work blade holder 198. The movable gaging member 28 is adjusted so that the contact element 208 is in engagement with the grinding wheel 200. The controls for the indicator circuit 48 are then adjusted to produce the desired zero reading on the meter 50. Additional work pieces may then be ground as they are rotated between the regulating wheel 196 and the grinding wheel 200. To insure the grinding of the workpieces to the correct size, the regulating wheel 196 and the work blade holder 198 may be advanced in unison toward the grinding wheel 200 until the contact element 208 engages the grinding wheel and causes movement of the gaging member 28 to the previously calibrated zero position, as indicated by the reading on the meter 50.

FIGS. 16, 17 and 18 illustrate an application of the gaging apparatus to a taper grinding operation. As shown, a grinding wheel 212 is employed to grind a tapered surface 214 on a work piece 216, which may be mounted in a chuck or some other rotary work support 218. The position of the grinding wheel 212 may be indicated by utilizing one of the gaging heads 26. As in the previously described arrangement, an intermediate movable member 220 is arranged to be interposed between the grinding wheel 212 and the movable gaging member 28. As before, the movable member 220 is in the form of an L shaped lever having one arm 222 for engaging the gaging member 28, and a second arm 224 with a contact element 226 thereon, adapted to engage the grinding wheel 212. The contact element 226 includes or is made of an extremely hard material, such as diamond. The lever 220 has a pivotal support 228, mounted on a fixture 230, which also supports the gaging head 26. The fixture 230 is mounted so that translation does not occur between the fixture and the rotary work support 218. As before, the gaging apparatus may
be calibrated so that a zero reading is obtained on the associated meter 50 when the grinding wheel 212 engages the contact element 226 and causes movement of the gaging member 28 to the position corresponding to the desired exact size of the tapered work piece 216. 5

FIGS. 19 and 20 illustrate another set-up in which two grinding wheels 234 and 236 are employed to grind the opposite ends of a work piece 238. An arm or carriage 240 is provided to support the work piece 238 so that it may be swung between the grinding wheels 234 and 236. The arm 240 is swingable about a pivot or shaft 242.

To monitor the positions of the grinding wheels 234 and 236, two of the gaging heads 26 are mounted on the arm 240. Thus, one gaging member 28 is provided to engage the working surface of each of the grinding wheels 234 and 236. The gaging heads 26 are calibrated in the manner previously described.

While the various grinding set-ups of FIGS. 5-20 have been described as utilizing one or more of the gaging heads 26, it will be understood that any of the disclosed gaging heads may actually be used. Thus, the gaging head 76 of FIG. 2 or the gaging head 126 of FIG. 4 may be utilized instead of the gaging head 26 of FIG. 1.

The gaging apparatus of the present invention is especially advantageous for gaging the position of a grinding wheel or some other tool for removing stock from a work piece. For such applications, the movable gaging member is directly engageable with the grinding wheel or other tool. However, the gaging apparatus of the present invention is also highly advantageous for use in gaging the size of a work piece, in which case the gaging member is engageable with the work piece.

Various other modifications, alternative constructions and equivalents may be employed, as will be understood by those skilled in the art.

1. Apparatus according to claim 1, in which said retaining means comprises means for producing frictional resistance to movement of said gaging member relative to said gaging head, whereby the position of said gaging member is frictionally maintained after engagement of said gaging member with the grinding wheel.

2. Apparatus according to claim 1, in which said retaining means comprises magnetic means for producing frictional resistance to movement of said gaging member relative to said gaging head.

3. Apparatus according to claim 1, in which said retaining means comprises magnetic means for producing a retaining force between said gaging member and said gaging head.

4. Apparatus according to claim 1, in which said gaging member has a portion which is slidable relative to said gaging head, said retaining means including magnetic means for producing a retaining force between said gaging member and said gaging head.

5. Apparatus according to claim 1, in which said gaging head includes an opening for guiding said gaging member, said gaging member having a portion slidable received in said opening, said retaining means including magnetic means for producing a retaining force between said gaging member and said gaging head.

6. Apparatus according to claim 1, in which said gaging head includes a bore for receiving said gaging member, said gaging member including a pin slidable in said bore, said pin including magnetizable material, said retaining means including magnetic means to act on said magnetizable material for producing a retaining force between said gaging member and said gaging head.

7. Apparatus according to claim 1, in which said retaining means comprises a resilient frictional element acting between said gaging member and said gaging head to hold said gaging member in any position to which it may be moved.

8. Apparatus according to claim 1, in which said gaging head includes an opening for guiding said gaging member, said gaging member having a portion which is slidable received in said opening, said retaining means comprising a friction spring acting between said gaging member and said gaging head to hold said gaging member in any position to which it may be moved.

9. Apparatus according to claim 1, in which said gaging head includes an opening for guiding said gaging member, said gaging member including a pin which is slidable in said opening, said retaining means including a friction spring mounted on said pin and frictionally engaging the inside of said opening to hold said gaging member in any position to which it may be moved.

10. Apparatus according to claim 1, in which said mounting means includes a clamping magnet on said gaging head.

11. Apparatus according to claim 1, in which said responsive means includes an electronic indicator.

12. Apparatus according to claim 1, in which said responsive means includes an air indicator.
13. Apparatus according to claim 1, in which said contact element includes extremely hard material to withstand the grinding action of said grinding wheel.

14. Machine tool and gaging apparatus, comprising a stock removing tool, a work support for holding at least one workpiece to be acted upon by said tool, means mounting said work support and said tool for relative feeding movement, a gaging head, mounting means for holding said gaging head in a fixed relation to the workpiece, a movable gaging member mounted on said gaging head for movement relative thereto, said gaging member having a contact element thereon for direct engagement with said tool, such engagement being effective to move said gaging member relative to said gaging head to a position corresponding to the size of the workpiece after being acted upon by said tool, retaining means for holding said gaging member in any position to which it may be moved, and responsive means for precisely representing the position of said gaging member, whereby the reduction of the workpiece to a particular desired size will be represented by a predetermined response of said responsive means when the tool and the gaging member are brought into engagement.

15. Machine tool and gaging apparatus according to claim 14, in which said retaining means comprises means for producing frictional resistance to movement of said gaging member relative to said gaging head, whereby the position of said gaging member is frictionally maintained after engagement of said gaging member with the tool.

16. Machine tool and gaging apparatus according to claim 14, in which said retaining means comprises magnetic means for producing frictional resistance to movement of said gaging member relative to said gaging head.

17. Machine tool and gaging apparatus according to claim 14, in which said gaging member has a portion which is slideable relative to said gaging head, said retaining means including magnetic means for producing a retaining force between said gaging member and said gaging head.

18. Machine tool and gaging apparatus according to claim 14, in which said retaining means comprises a resilient frictional element acting between said gaging member and said gaging head to hold said gaging member in any position to which it may be moved.