United States Patent [19]

Elbe

[11] **3,886,695**

[45] **June 3, 1975**

[54] **METHOD FOR GRINDING A GEM STONE**

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[73] Assignee: **Colorant Schmuckstein GmbH**, Hamburg, Germany

[22] Filed: **May 17, 1973**

[21] Appl. No.: **361,037**

[52] **U.S. Cl.**..... **51/283;** 51/216 LP; 51/322

[51] **Int. Cl.**..... **B24b 1/00;** B24b 9/16

[58] **Field of Search**..... 51/283, 229, 216 LP:127, 51/121, 122, 123 R, 125, 125.5, 322, 323; 125/30

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Primary Examiner—Donald G. Kelly

Attorney, Agent, or Firm—Michael S. Striker

[57] **ABSTRACT**

A gem stone to be ground is placed against a rotating grinding wheel, and thereupon the gem stone is turned relative to the grinding wheel until an ideal orientation has been determined for the gem stone relative to the grinding wheel. The frictional heating of the gem stone is measured in the region of contact of the same with the grinding wheel, and the contact pressure at which the gem stone contacts the grinding wheel is controlled as a function of the measured temperature and in such a manner as to maintain the temperature constant. The respective facets of the gem stone are thereupon ground with the grinding wheel.

4 Claims, 13 Drawing Figures

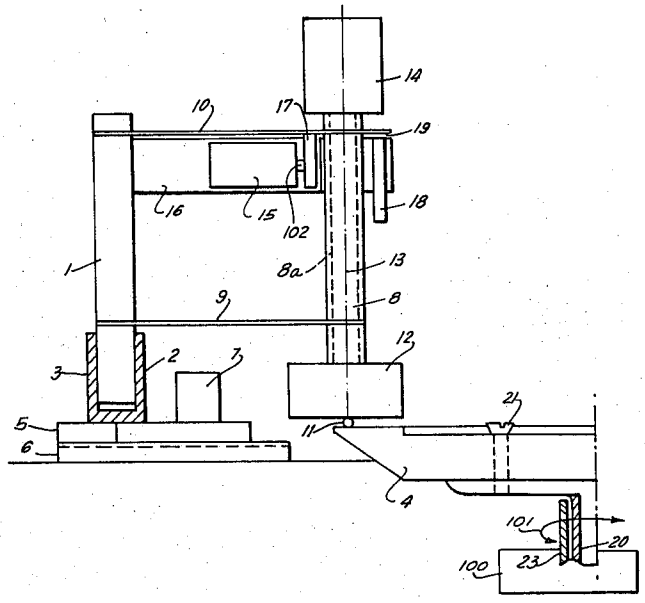
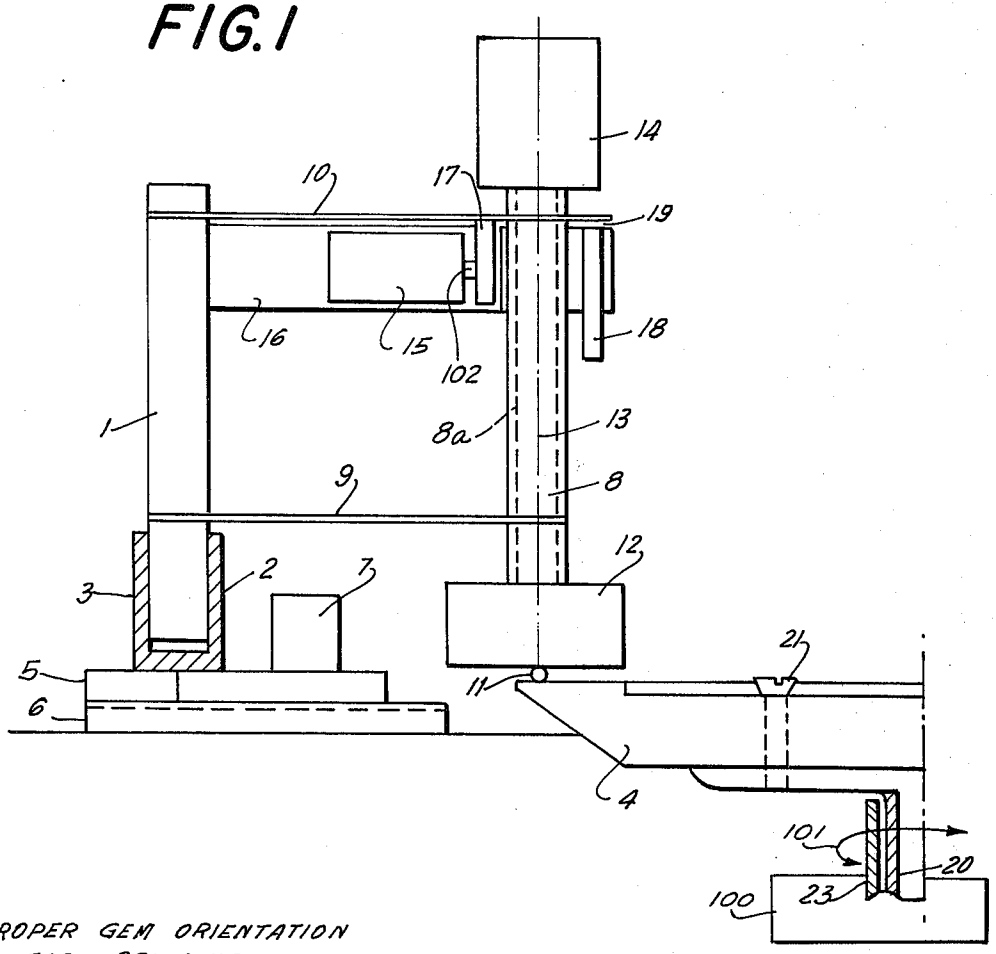


FIG. 1



PROPER GEM ORIENTATION FOR GRINDING

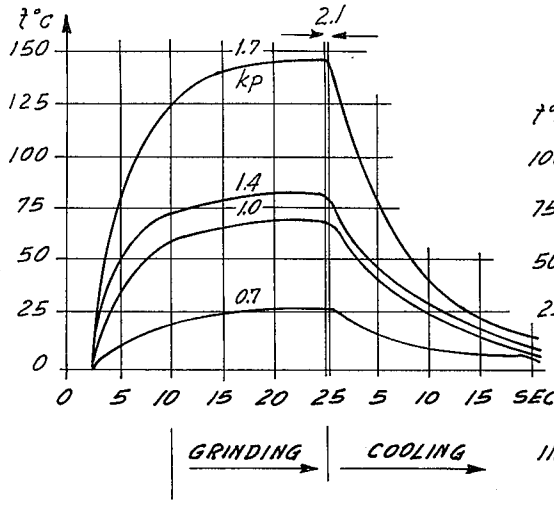


FIG. 2A

IMPROPER GEM ORIENTATION FOR GRINDING

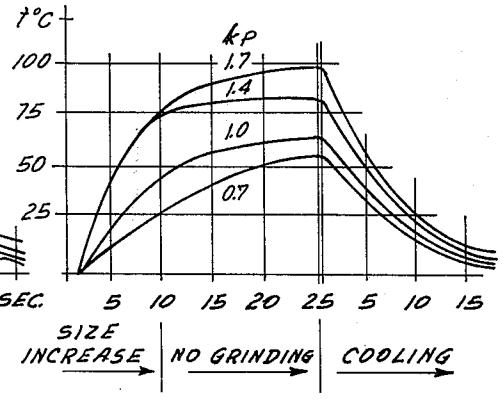
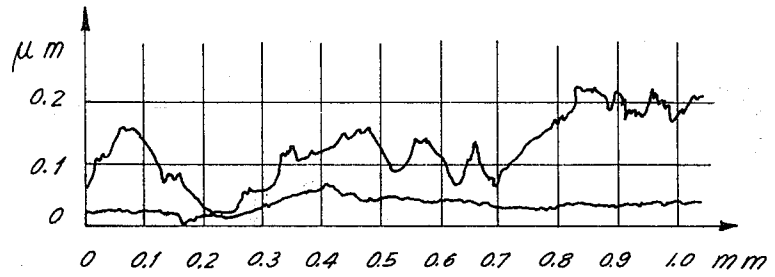


FIG. 2B

FIG. 3



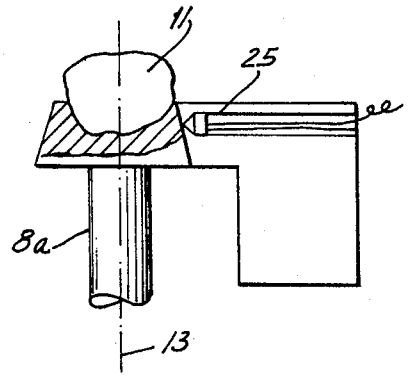


FIG. 4

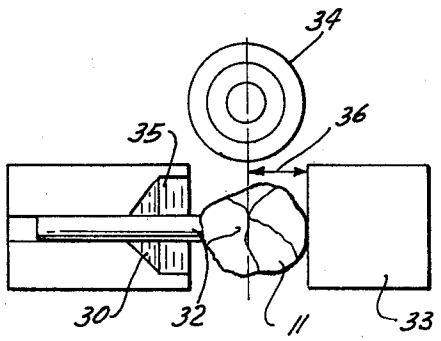


FIG. 5

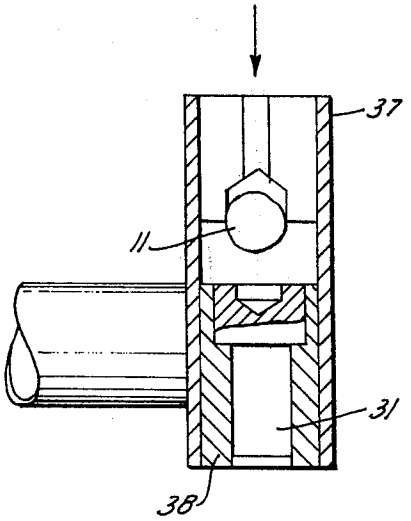
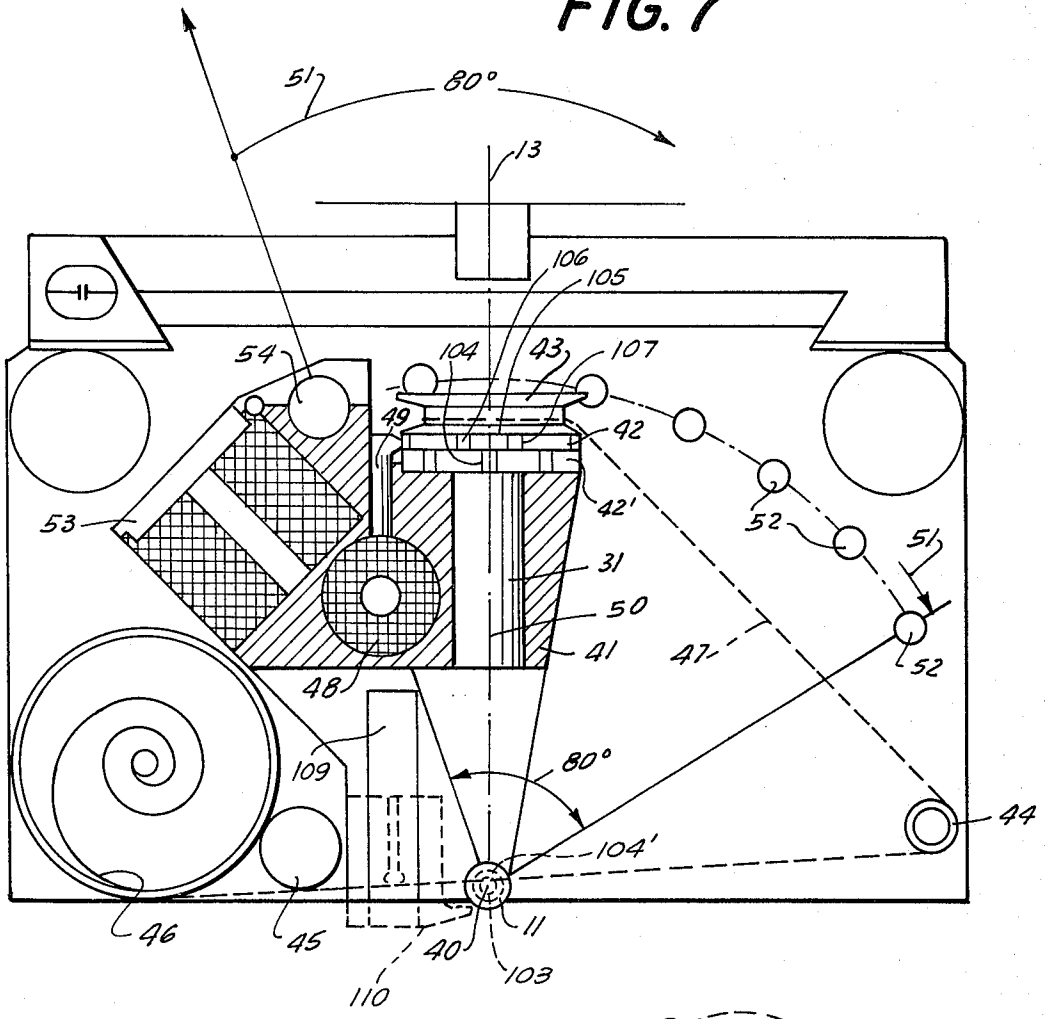


FIG. 6

FIG. 7


51
80°
13
106
105
54
104
43
107
49
42
42'
53
52
51
31
50
41
47
52
48
109
80°
44
104'
46
45
40
11
103
110

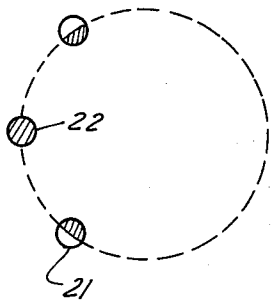

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FIG. 8

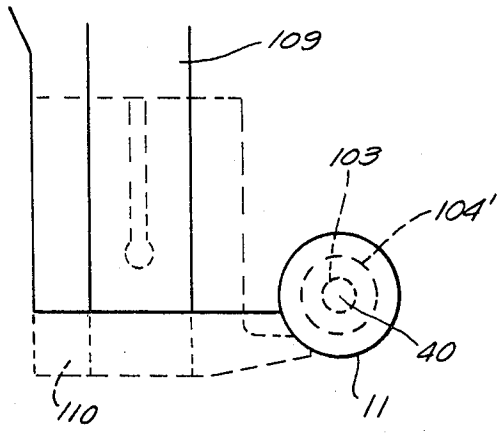


FIG. 7a

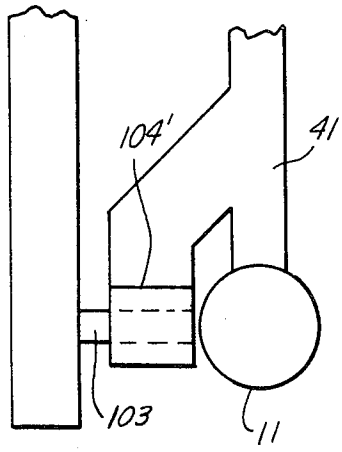


FIG. 7b

FIG. 7c

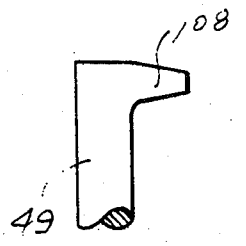
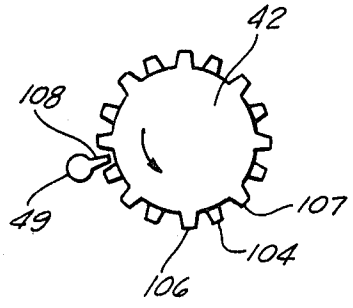


FIG. 7d



METHOD FOR GRINDING A GEM STONE

BACKGROUND OF THE INVENTION

The present invention relates to a method of grinding a gem stone, and to an apparatus for carrying out the method.

The term "gem stone" as employed in the present disclosure is intended to refer in general to all precious stones, and in particular to diamonds of all types, including diamonds which are used for industrial purposes. In other words, the invention is not intended to be limited to diamonds exclusively, nor is it intended to be limited to diamonds or other precious stones which are exclusively used for decorative purposes, but also those which are intended to be used for industrial and other applications.

In many respects, the prior art is not satisfactory insofar as the approach to the grinding of gem stones is concerned, as well as the equipment for effecting such grinding. It is therefore acknowledged in the industry that further improvements are highly desirable, but heretofore such futher improvements have not been forthcoming.

SUMMARY OF THE INVENTION

It is, accordingly, a general object of the present invention to provide such further improvements and to overcome the disadvantages of the prior art.

More particularly, it is an object of the present invention to provide an improved method of grinding a gem stone which is not possessed of the prior-art disadvantages.

Another important object of the invention is to provide an improved apparatus or machine for grinding of gem stones.

The present invention is intended to make it possible to determine the ideal grinding direction for the facets of a gem stone, particularly a diamond, that is the ideal orientation which the diamond should have with respect to the grinding wheel as facets are being produced. Futhermore, the respective facet is to be ground to a specific predetermined depth (the term "depth" referring to the material removal beginning from the outer surface at which grinding originates) and to so polish it that at least one side of the gem stone can be completed by resort to the present invention without requiring any further additional processing steps. The angles of the facets should be reproducible, they should be capable of being produced in a short period of time and with maximum precision, and a minimum amount of the material of the gem stone should be lost during the production of the facets.

Of all gem stones, diamonds provide, of course, the most difficulties in attaining the objects of the present invention, because the diamond is the only gem stone in which it is necessary to determine an appropriate orientation of the stone relative to the grinding wheel for each facet, in order to produce a cut of high quality. This is not to say that in particular the apparatus and, of course, the method according to the present invention cannot be used with other gem stones, as has indeed already been pointed out above. Such other gem stones may be all precious or even semi-precious stones, not only natural ones but also synthetic ones, and in fact, even glass. However, the invention can be best described by referring to the diamond which is the most difficult workpiece to process.

It is known in the art that a diamond has hardness differentials of 1:4000, that is depending upon the orientation which the diamond is given with respect to the grinding wheel, the degree of hardness of the diamond (and therefore the degree of difficulty of grinding it) may vary within the above ratio. This means then that an economically and qualitatively acceptable grinding result on the diamond facets can be obtained only when the diamond is ground in a specific direction (for each facet), which direction is predetermined by the crystalline structure of the diamond. The specific most advantageous direction must be determined for each and every facet being produced.

The invention proposes three different approaches to this problem.

On the one hand, the specific most advantageous grinding direction can be determined by the amount of material which can be removed from the diamond per unit time. Evidently, in the "soft" grinding direction the thus-calculated "grinding speed" will be greater in a relationship of 4000:1 than in the "hard" grinding direction. Depending upon the orientation of the particular facet with respect to the crystal lattice the most advantageous "ideal" grinding direction may occur between 1 and 4 times.

During grinding, even in the non-ideal grinding directions, a temperature will develop in the diamond and the holder in which the diamond is held for the grinding operation, which will result in an expansion of the holder which substantially equals and is opposite to the amount of material being removed. As long as the diamond is oriented in one of the non-ideal directions with reference to the rotating grinding disc, this heating causes the diamond to seemingly "grow", whereas when the diamond is oriented in the ideal direction it will seemingly grow and also have material removed, so that the criterion for the amount of material removed is unambiguous. It is clear that the temperature changes resulting in a seeming "growing" of the diamond due to the expansion of the holder, necessitate a period during which the grinding apparatus must be adjusted to allow for this "growth". Because this adjustment must be repeated as the ideal grinding direction for each and every facet is determined, it has been found that it is advantageous if the grinding temperature can be regulated. Once the diamond and the apparatus have reached a certain temperature during grinding of the first facet, a regulating arrangement can maintain this temperature constant during the grinding of all other facets, independently of the direction or orientation of the diamond relative to the rotating grinding wheel during the grinding of a particular one of the subsequent facets.

The manner in which the grinding temperature can be maintained constant, may be selected from various possibilities. The most advantageous one of these is to vary the pressure at which the gem stone contacts the rotating grinding wheel. Of course, electrical, infrared or other heating or cooling, for instance indirect heating or cooling of the holder which holds the gem stone, would have the same effect. The temperature sensing device is directly adjacent to the gem stone to be ground and may be a resistor having a negative or a positive temperature coefficient, or a thermal element whose change in resistance or voltage—caused by changes in the sensed temperature—is amplified and is transmitted to an instrumentality which changes the

pressure at which the gem stone contacts the rotating grinding wheel.

Maintaining the grinding temperature constant has a significant advantage, namely in that the finished facet can be removed from further grinding at a substantial and well defined grinding depth, independently of the thermal expansion of the holder. Details of this will be discussed subsequently.

A second possibility is to determine the ideal grinding direction or orientation by determining the temperature which the gem stone assumes as it is being ground. It has been found that this grinding temperature will be greater if the diamond is ground in the ideal direction than in one of the non-ideal directions. To determine this, the pressure at which the stone contacts the rotating grinding wheel is maintained constant, and the temperature sensor influences the orientation of the gem stone with reference to the grinding wheel (i.e., changes the orientation) until the ideal grinding direction has been reached, which is determined by the fact that in this grinding direction the gem stone will become heated, during frictional contact with the rotating grinding wheel, to a higher temperature than in the other directions.

The third possibility envisions that the ideal grinding direction is pre-programmed for a particular cut of a gem stone, for instance to produce a brilliant cut, in that the optimum or ideal grinding direction for each facet is determined by appropriate orientation of a sample gem relative to the crystalline structure thereof, and the thus-obtained information is recorded in suitable manner, for instance on magnetic tape. Thereafter, all facets of other gem stones to be similarly cut are produced by grinding in the pre-programmed direction. It is, of course, to be assumed in this case that the gem stones to be ground have been previously oriented in the same manner as the sample stone, that is they must be inserted into the holder in the same manner in which the sample stone was previously inserted.

All three possibilities mentioned above have the advantage that several arrangements of the same type can be used simultaneously and independently of one another in conjunction with a single rotary grinding wheel. Evidently, this is a highly economical proposition because the grinding apparatus itself can be utilized economically, the expensive grinding wheel can be very evenly and uniformly utilized, and the quality of each ground facet in terms of its planarity and its smoothness prior to polishing can be improved.

Experiments with the first-mentioned proposal have shown that a distance sensor sensing the travel of the gem stone in the direction towards the plane of the grinding wheel, with subsequent differentiation, i.e., a grinding speed indicator can properly serve to adjust the drive which in turn moves the gem stone until the latter has reached its ideal orientation relative to the grinding wheel. The relatively low grinding speed in the ideal grinding direction or orientation, namely 3.6 mm. per hour (i.e., 1 micron per second) requires that the entire machine and all components thereof be very precisely made to exacting standards. It is, of course, well known that gem cutting, and particularly brilliant cuts, require that the surface of each facet be of high quality, that is that it be polished to a high degree of smoothness so that any tracks left by the grinding device disappear and cannot even be found under the jeweler's loupe. Moreover, the individual facets must extend at very precise angles relative to one another, because this relationship determines the brilliance of the finished gem stone. The same requirements essentially apply also to industrial diamonds, because the proper smooth polish of a facet determines a sharp angle relative to adjoining facets and thus provides for the desired sharp edge which is required of industrial diamonds, and, of course, the angles of the facets relative to one another are determinative of the manner in which the diamond can be used as a tool.

Economic grinding in terms of the time required can be carried out on a coarse diamond grinding wheel, but heretofore this was found to be unsatisfactory for subsequent polishing. This meant that the gem stone has always had to be polished by using a separate fine grinding wheel. In order to provide the same geometry for many facets, a particularly stringent degree of precision cooperation between the two grinding wheels and the grinding apparatus is necessary. If, however, the gem stone is supplied for contact with the grinding wheel via a spring parallelogram without pivots and without play in direction normal to the general plane of the grinding wheel, and if the gem stone is turned about its previously determined ideal orientation or grinding direction through small well-defined angles, while at the same time the contact pressure between gem stone and grinding wheel is reduced, then it has been found that a thoroughly acceptable polishing of the gem stone can be obtained even on a coarse grinding wheel without leaving behind any tracks on the stone. This eliminates the need for a subsequent operation and for the employment of a fine grinding wheel. Moreover, using a spring parallelogram arrangement the desired angles of the individual facets relative to one another can be obtained within narrow tolerance limits. A sliding arrangment of the apparatus according to the present invention assures that the gem stone is evenly moved over the entire grinding wheel, so that the latter is evenly used and worn away, particularly if several grinding arrangements are utilized with one and the same grinding wheel.

Since it is well known that diamonds are expensive, this also being true of industrial diamonds, it is hardly necessary to emphasize that any machine for grinding and polishing of a diamond must have as one of its important characteristics the requirement that it remove as little as possible of this expensive material while, however, properly grinding and polishing the diamond at all sides, that is on all regions where facets are to be provided. According to the present invention this requirement is met in that the precise center of the diamond is placed into the center of one axis of a rotary component of the grinding machine, or at the point of intersection of two axes of respective turnable components. This will be discussed in more detail later, but it is pointed out that the necessary adjustment is advantageously carried out by means of a device, for instance a so-called profile projector, which permits a positioning of the center of the diamond with reference to the center of rotation of the one axis or the point of intersection of the two axes, with a deviation of less than 0.01 mm. One of the important determinatives for the proper adjustment is the holder which holds the uncut diamond or the hemispherically cut diamond in the grinding apparatus. It is necessary that the gem stone be so adjusted that its precise center is located on the center of the axis of rotation of the holder, an adjust-

ment which again is carried out by means of a profile projector. It is advantageous if the holder is itself of or is embedded in a material having a low coefficient of thermal conductivity, in order for the time constant of the grinding temperature to be small, so as to permit a more economical grinding operation.

A further consideration in determining the precision of the finish-ground facets is the possible inaccuracy which might be introduced by the journal for the grinding machine spindle. It has been found that a hydrostatically journalled grinding machine spindle having a deviation from true rotational movements of less than 0.2 microns will provide substantial improvements over a similar spindle which is mounted in a ball bearing. The latter permits movements of the spindle which act upon the gem stone as if the latter were being subjected to constant hammer blows.

In addition, the present invention provides for a possibility of maintaining the expensive rotating grinding wheel against deterioration, to the maximum possible extent, in that the grinding wheel is mounted on its flange not only by means of tension screws but also by means of additional pressure screws, which prevent it, at least largely, from becoming distorted as a result of the heating to which it is subjected during the grinding operation. Heretofore, such distortion was unavoidable, and it was then necessary to grind the grinding wheel in order to make its grinding surface planar again, resulting in a substantial loss of material.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments, when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a somewhat diagrammatic side-elevational view of a machine according to the present invention, with certain portions omitted as not essential for an understanding;

FIG. 2A is a diagram illustrating the grinding operation when the gem stone is properly oriented with reference to the grinding wheel;

FIG. 2B is a diagram similar to FIG. 2A, but illustrating the grinding operation in a condition in which the gem stone is not properly oriented;

FIG. 3 is a diagram showing surface uneveness of a polished and a non-polished facet of a diamond which has been ground with a rotating grinding wheel;

FIG. 4 is a fragmentary partially sectioned enlarged detail view illustrating a temperature sensor;

FIG. 5 is a diagrammatic detail view partially in diagrammatic section of a temporary holder for a gem stone, together with a portion of a sighting screen of a profile projector;

FIG. 6 is a fragmentary partly sectioned detail view of a permanent holder for the gem stone;

FIG. 7 is a partly sectioned detail view of an enlarged scale of a portion of the machine shown in FIG. 1;

FIGS. 7*a*–7*d* are fragmentary detail views, showing various details of FIG. 7; and

FIG. 8 is a diagrammatic top-plan view illustrating the arrangement of tension and pressure screws used to counteract buckling or distortion of a diamond grinding wheel.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Discussing firstly FIG. 1, it will be seen that reference numeral 1 identifies an upright or column which is vertically adjustable so that it can be adjusted to the size of a diamond or gem stone 11 which is to be ground. The column 1 has an end portion that is received in a socket 2 wherein it is adjustably held by means of a screw 3. It will be evident that various ways well known to those skilled in the art can be utilized for permitting the column 1 to be raised and lowered in FIG. 1. The socket 2, in turn, is rigidly connected with a plate 5, for instance a brass plate the underside of which may be provided with two or more elongated grooves extending in the direction from the left towards the right in FIG. 1, and in which grooves respective rails 6, for instance of steel, are received so that the plate 5 can be shifted radially towards and away from the rotatable grinding wheel 4. The movement of the plate 5 is effected by means of a motor 7 which is connected with the plate 5 in a manner well known to those skilled in the art. This arrangement provides for a particularly small degree of displacement of the column 1 in vertical direction (see FIG. 1), so that the stone 11 to be ground will slide radially over the surface of the grinding wheel 4 without undergoing any change in the contact pressure with which it engages the latter. Such displacement in vertical direction would be undesirable, contrary to intentional displacement to accommodate different size stones 11.

A further upright or column 8 extends in parallelism with the column 1, laterally spaced from the same as shown in FIG. 1. The columns 1 and 8 are connected with one another by means of two sets or packages 9 and 10 of leaf springs whose opposite ends are connected to the respective columns as shown. Thus, the springs and the columns form a spring parallelogram. The lower end of the column 8 has a carrier 12 for the stone 11, which carrier is connected with a turnable shaft 8*a* extending through the column and rotating about the axis 13. The upper end of the column 8 carries a motor 14 for rotating the shaft 8*a*. The stone 11 is held in the carrier and with this arrangement the stone 11 is supplied into contact with the upper surface of the grinding wheel 4 directly normal to this surface, without play and at a constant angle which is independent of the size of the stone. The motor 14 can turn the shaft 8*a* and therefore the stone 11 through 360°. The purpose of this is to move the gem stone 11 to its ideal orientation relative to the grinding wheel 4, that is to turn it until it has assumed this ideal orientation in which it will be ground in the ideal direction which is dictated by the considerations outlined earlier.

Reference numeral 18 identifies a sensing device with amplifier and differentiator, which can sense the grinding speed, that is the speed at which material is being removed from the gem stone 11. Such devices are well known to those skilled in the art and require no detailed discussion. The device 18 controls the operation of the motor 14 so that the latter turns the shaft 8*a* and thereby the gem stone 11 until the latter has been moved to the ideal orientation relative to the rotating grinding wheel 4. In this position, the gem stone is retained until a facet has been ground on it. Immedi-

ately prior to completion of the grinding of the facet, the device **18** supplies a signal to the motor **14** via a flip-flop circuit, causing the motor **14** to turn the gem stone **11** in opposite directions from the previously selected ideal orientation, up to **10** angular degrees in each direction. The result of this movement is a polishing effect on the just-produced facet, and reference to FIG. **3** will show that within only a few seconds the relatively uneven surface produced during the grinding operation (see the upper line in FIG. **3**) which has deviations from a planar condition of as much as 0.2 micron which could be determined by the naked eye, is polished to a smoothness (see the lower line in FIG. **3**) where these deviations are below 0.01 micron. This is effected without having to change the coarse rotating grinding wheel **4**, that is without having to have recourse to a fine grinding wheel. Advantageously, the polishing operation is carried out while simultaneously the gem stone **11** is displaced by the motor **7** over the entire radial width of the grinding wheel **4**, under constant reduction of the contact pressure between the gem stone **11** and the grinding wheel **4**.

This reduction is effected in a manner which will now be described. It will be seen that a second regulating circuit is provided which utilizes a temperature sensor **25** shown in FIG. **4**, a motor **15**, a rigid connection **16** between the columns **1** and **8**, and an eccentric **17**. The temperature sensor **25** is connected with an amplifier (not shown, but conventional) which, in turn, supplies the signals received and amplified to the motor **15**. The latter is mounted on the rigid support **16** and turns the eccentric **17** in such a manner that during small angular adjustments of the eccentric **17** the contact pressure with which the gem stone **11** engages the grinding wheel **4** is either reduced or increased without, however, permitting the gem stone **11** to move out of engagement with the grinding wheel. This makes it possible to maintain the grinding temperature to which gem stone **11** is heated by its frictional engagement with the grinding wheel **4**, constant to within fractions of a degree centigrade with reference to a reference value that can be preset. This, in turn, means that the ideal direction or orientation can be determined independently of the temperature of the gem stone **11**. In addition, the arrangement has the advantage that the grinding depth of each facet (the depth to which material is removed from the outermost surface of the gem stone until the grinding of the particular facet is completed) with an accuracy of 0.001 mm. Moreover, the device **18** whose upper end **19** cooperates with the spring package **10**, will cause shortly before completion of the grinding operation of the respective facet a gradual reduction in the aforementioned contact pressure. This is the result of the signal supplied to the motor **15** which causes the eccentric **17** to turn gradually until the motor **15** receives a further signal from the device **18** which causes it to turn the eccentric **17** through 180°, whereby the gem stone **11** is raised out of contact with the grinding wheel **4** by a distance of up to approximately 1 mm. In this condition, the stone **11** is reoriented for grinding of the next facet, whereupon the motor **15** and the eccentric **17** are turned again until the temperature regulating arrangement described above is again operative. Initially, the new facet to be ground will offer a very small surface area to the grinding wheel **4** for contact with the same. This means that the initial amount of material removed is relatively high, so that the criterion for the high grinding speed is well defined and the new ideal orientation for the newly ground facet can be rapidly determined. The entire cycle will be completed the quicker, the less the temperature of the gem stone **11** is allowed to drop between the grinding of consecutive facets, and a comparison of FIGS. **2A** and **2B** will clearly indicate this, as well as the importance of the proper orientation of the gem with respect to the grinding wheel **4**. It should be pointed out that this relatively high-speed operation is of considerable importance in terms of the economics of grinding gem stones, because it is now possible to machine grind gem stones relatively rapidly and to produce a quality of the surface finish which is at least equal to that obtained by hand grinding. Heretofore it was not possible to obtain such quality by resorting to machine grinding.

The rapid operation is also in part dictated by the thermal time constant which determines the temperature rise as well as the constancy of the temperature. It has been found that it is advantageous if the holder for the gem **11**, and the holder for the temperature sensor **25** (see FIG. **4**) are of a material having a low coefficient of thermal conductivity, for instance chrome nickel steel, the type of steel designated in some parts of the industry as V2A steel, or ceramic material. FIGS. **2A** and **2B** diagrammatically and graphically show the conditions which develop at the gem stone when time and temperature are calculated at different contact pressures (between 0.7 and 1.7 kg.) and with the gem having different orientations relative to the grinding wheel. It will be seen in FIG. **2A** that for instance at a contact pressure of 1.7 kg. the gem stone **11** will reach a grinding temperature of almost 150°C. if it is oriented so as to have the ideal orientation relative to the grinding wheel, whereas FIG. **2B** shows that if the orientation is not the ideal one, the grinding temperature will barely reach 100°C. It might be assumed from this that it is most advantageous to select the ideal orientation in accordance with the highest grinding temperature, while maintaining the contact pressure constant. However, it has been found that even if very small thermal time constants are employed, this approach requires substantially more time for determining the ideal orientation than if the first of the three earlier mentioned approaches is used, namely to use the grinding speed as the determining factor. Utilizing the highest temperature as the determining factor has a particular disadvantage in that it is possible that the time required for determining the ideal orientation of the gem is longer than the time required for grinding a facet thereon. In this case, it would be possible that the facet has already been completely ground but would not be polished because insufficient time has elapsed for determining the ideal orientation of the gem relative to the grinding wheel.

It is pointed out that the signal which terminates the grinding and polishing operation for each facet need not necessarily be derived from a device such as the device **18** which was previously described. Other possibilities exist and it is merely necessary that whatever other arrangement is utilized be sufficiently sensitive and operate sufficiently accurately. For instance, optical arrangements, such as photo-silicone elements, can be used, electrical arrangements which provide the signal as a result of changes in capacitance or inductivity, or even as a result of measuring the expansion or contrac-

tion of the gem, or else mechanical arrangements such as microcators.

It has already been pointed out earlier that the fact that the polishing operation for each facet can be carried out on the same coarse grinding wheel which is used to grind the facet in the first place, without having to resort to a second operating step utilizing a fine grinding wheel, is of importance in terms of the economics of the automatic operation of the grinding procedure. A more detailed description of the effect which is obtained with the present invention, as shown in FIG. **3,** is therefore in order. The diagram in FIG. **3** directly compares the high and low points of the surface of the facet after grinding and after polishing. The high values in microns are relative. It is clear, however, that the gemmologist will immediately note the poor quality of the surface of a gem facet (even with the naked eye) if the height and depth variations amount to 0.2 microns. On the other hand, the lower line in FIG. **3,** which represents the height and depth variations of the facet surface after only a few seconds of the polishing operation utilizing the same grinding wheel which has been used to produce the facet in the first place, is representative of a facet surface finish requiring the most sophisticated viewing and measuring devices before any traces of the grinding operation can be detected. This advantageous effect, utilizing the same grinding wheel which has been used to grind the facet in the first place, results from the fact that during small angular movement of the gem stone to and from its ideal orientation (i.e., during the polishing operation) particles of the grinding wheel will act upon the gem stone which are not the particles which have previously produced the low points or depressions in the facet surface. This means that during such movements the high points are ground off, before the previously produced low points come again in contact with those grinding wheel particles which produced them in the first place. This means that the high points are removed as desired. If during this operation the grinding pressure or contact pressure is also reduced, then a surface is obtained whose quality will be thoroughly satisfactory not only for industrial diamonds but also for decorative gems without, as pointed out before, having to use a fine grinding wheel to obtain it.

The regulation of the temperature of the gem stone, that is the maintenance of the temperature at constant level, has a further advantage in that it prevents loosening of the gem in the holder due to the significant differences in the coefficient of expansion of diamonds ($10^{6\circ}$C.) and the holder material (greater than $10^{5\circ}$C.). The desired maintenance of the temperature at a constant level can, of course, be obtained in other ways than by changing the contact pressure, for instance by means of infrared radiators or electrical heaters, to name just two possibilities.

Various different types of holders for holding a gem to be ground are known in the art, and they can be used in the machine according to the present invention. However, it has been found that it is particularly advantageous if the gem stone **11** to be ground is first connected to a temporary holder **30** (see FIG. **5**) and after an adjustment, which will subsequently be described, is transferred to and held in a permanent holder **31.** Known holders are in form of clamps which require that the diamond be "rondiert", i.e., that it be rubbed against another diamond. This involves an additional operating step which can be carried out only by a highly trained specialist and which leaves behind in the thus-treated diamond hairline fissures which remain visible under magnification even after the gem has been ground. The problem is avoided by connecting the diamond in its raw form to a pin **32,** for instance by means of an adhesive, whereupon it is turned manually relative to a profile projector **34** (a device known in the gemological art) in contact with an abutment **33.** A viewing screen of the projector **34** is provided with circles of different sizes which are concentric, as shown, and a shadow profile of the stone **11** is produced on this viewing screen. It is then merely necessary to so turn the stone **11** until by reference to these various circles the largest shadow profile is obtained. Thereupon, the holder **30,** into the recess of which a suitable adhesive such as cement or the like has been previously introduced, is pushed against the diamond **11** (the pin **32** is slidable in the passage of the holder **30,** as shown) so that the diamond is now arrested in the optimum orientation which has been determined with the aid of the profile projector **34.** The distance identified by the double-headed arrow **36,** which can be measured on the screen of the projector, represents a direct measure of the physically inaccessible exact center of the diamond. The radius of the largest circle covered by the shadow profile of the diamond can be controlled by a micrometer measurement. The pin **32** is now removed from the holder **30** and after the temperature-resistant cement has been hardened, the diamond **11** can be ground in the holder **30** in which it is centered in such a manner that a minimum loss of material will occur during grinding. This is sufficient for gems having a grinding angle of up to 45°, for instance diamonds on which a brilliant cut is to be produced. However, the diamond has been given a "bed" in this manner.

In many instances, however, such a mounting in the holder is not sufficient, because there are not really any satisfactory adhesives for diamonds, especially for diamonds already having ground facets. Also, there are circumstances when it is desired that a diamond is to be ground at an angle of up to 80°, i.e., with its facets inclined to the girdle plane at such a degree, in which case the diamond must either be further secured in the holder **32** by having the upper facets or the table engaged by a holding device, or it must be secured in a holder which is of metal, for instance copper, aluminum or steel.

FIG. **6** shows this second possibility of a permanent holder **31** into which the diamond can be transferred after it has been first centered in the temporary holder **30** of FIG. **5.** It will be seen how the diamond secured in the holder **30** can be transferred into the holder **31,** for which purpose the metal which is to hold the diamond is advantageously heated to a temperature of between 350° and 600°C. before the diamond **11** with the holder **30** and the cement **35** is pushed into the permanent metallic holder **31.** The insertion can be guided by means of a guide tube **37.** It is advantageous if the shell **38** of the holder can be opened in order to permit the removal of the holder **31** with the diamond **11** which might otherwise be difficult in the event clamping due to thermal expansion should take place.

It has been made clear that the present invention seeks to provide a method and apparatus which permits the automatic grinding of the various facets of a gem stone, such as a diamond. This requires that the angle

between the individual facets (which has been previously calculated) must actually be obtained during grinding, or that deviations in excess of only a few minutes must not be permitted. If the grinding angle is maintained exactly within a tolerance of a few minutes, then it is possible to produce a gem stone, for instance a brilliant, whose facets are ground with such precision that it will have the desired brilliance. To obtain the requisite positioning of the facets during grinding, the apparatus according to the present invention uses an arrangement which is shown in detail in FIG. **7.** Generally speaking, the arrangement in FIG. **7** makes it possible to control all movements electrically and to fix the gem stone in all positions necessary for grinding facets having certain predetermined facets relative to one another. It is important in this connection to differentiate between two types of angles, namely an angle included by one facet and the adjacent facet of a ring of such facets, and an angle included between two rings of facets. The arrangement in FIG. **1** can be set for both possibilities and positively arrested in either setting.

The diamond or other gem stone **11** will be seen in FIG. **1** to have its exact center **40** located on the point at which the vertical axis **13** (see also FIG. **1**) intersects a horizontal axis about which a carrier **41** can pivot. The carrier **41** can turn about the axis **13** which extends normal to the plane of the upper surface of the grinding wheel **4** (see FIG. **1**). The carrier **41** should be understood to correspond to the carrier **12** shown in FIG. **1** and is configured with an approximately cylindrical cross section in the illustrated embodiment. It surrounds the holder **31** for the gem stone **11,** which holder is mounted turnable about its own longitudinal axis. The upper end of the carrier **41** is provided with two ratchet wheels **42, 42'**. The shaft **8***a* rotatable about the axis **13** carries above the ratchet wheels **42,** 42' a pulley **43** from which a taut rope or the like extends via guide rollers **44** and **45** to a spring **46** which can be tensioned, for instance a watch spring or the like. This spring is shown only diagrammatically but it will be understood that it serves to maintain the rope **47** in taut condition.

A coil **48** of an electromagnet acts upon a pin **49** which can extend between the projections of the ratchet wheels **42** and **42'** in order to provide for a switch-over of the arrangement. The coil **48** and the pin **49** are operated by an electrical signal which originates when a facet is completely ground and polished. In this condition, the carrier **41** is slightly lifted so that the gem stone **11** is out of engagement with the grinding wheel by the aforementioned approximately 1 mm. distance. When one of the ratchet wheels **42, 42'** is disengaged by operation of the pin **49,** the holder **31** turns about the axis **50,** until the next projection of one of the ratchet wheels becomes engaged. The distance in circumferential direction of this rotary movement corresponds to the amount by which the stone **11** must be turned, in order to be able to grind the next adjacent facet of the same ring of facets of which one facet has just been completed. By selecting ratchet wheels **42,** 42' having a requisite number of projections which are equally distributed over their circumference, it is possible to pre-program the grinding of the facet rings having a desired predetermined number of facets.

When a facet ring has been completed, that is when all of its facets have been ground, the device is to be capable to switch-over so that the next facet ring can be automatically ground. For this purpose, the carrier **41** with the holder **31,** the wheel **42, 42'**, the coil **48** and the pin **49** is pivotable in the direction of the double-headed arrow **51** approximately 80°, about the aforementioned horizontal axis which passes through the center **40** of the gem **11.** The position illustrated in FIG. **8** shows the arrangement in the leftmost possible position, that is at a 0° pivotal deflection. It will be seen that moving towards the right from this position there are provided six arresting portions **52,** for instance holes, so that the arrangement can be arrested in six additional positions by engagement with respective ones of the arresting portions **52.** The spacing of these positions in the direction of the double-headed arrow **51** corresponds to the size of the angle included between the facets of individual facet rings relative to one another. An electromagnet **53** is provided, having a pin **54** which can enter into the respective holes **52.** A movement of the arrangement in the direction towards the next hole **52** can be initiated by the tension of the rope **47** when the ratchet wheels **42, 42'** are stationary, and this pivoting from one position to another takes place so rapidly (both when the arrangement is adjusted to provide for grinding of the successive facets of a single ring, as well as when it is adjusted to provide for grinding of succesive rings) that a noticeable cooling of the stone need not be feared).

In some instances, for instance where industrial or tool diamonds are to be ground, it is necessary to form certain ground radii on the diamond. For this reason, the carrier **41** must be capable of being continuously pivoted about the horizontal axis passing through the center **40,** as well as about the vertical axis **50.** In this case, the spring **47** must be provided with a drive which effects the desired pivoting.

Coarse sintered grinding wheels which are used in accordance with the present invention, are not planar because of the sintering operation. Of course, they are processed so as to become planar, but they tend to warp nevertheless, especially when they are mounted on a flange by means of tension screws **21.** The present invention provides a way of overcoming this problem by locating intermediate circumferentially successive ones of the tension screws **21** respective pressure screws **22** (compare FIGS. **8** and **1**). This means that even in the installed operating condition the grinding wheel can be rapidly readjusted without having to remove the many precisely adjusted devices cooperating with it, simply by operating one or more of the pressure screws **22** in such a manner as to reestablish the planarity of the grinding surface of the wheel. The necessary measurements can be carried out by appropriate measuring devices.

It is advantageous that more than one stone can be ground simultaneously on one and the same grinding wheel, using the apparatus according to the present invention. In particular, if more than two stones are ground simultaneously, then the uniformity and planarity of the surface of the grinding wheel will, in fact, improve during use so that the surface quality of the facets of the ground stones will similarly improve. Also, by grinding two or more stones simultaneously, the grinding wheel will be worn uniformly which is important from an economic point of view because grinding wheels are expensive.

It has already been pointed out earlier how it is possible to provide a pre-orientation of a sample stone, and

to subsequently use the information thereby obtained for programming the ideal orientation of later stones to be ground, with the information for the sample stone having been obtained for each facet to be ground. It should be mentioned in this connection that the ideal orientation or direction of grinding in this case can be experimentally determined with respect to the sample stone, without resorting to the other possibilities disclosed in the introduction to the present specification. Of course, if such a pre-programming operation is desired, that is if the subsequent stones are to be cut in accordance with the information obtained by grinding the sample stone, then it is clear that the subsequent stones must be inserted into the grinding apparatus in the same orientation in which the sample diamond was previously inserted, or at most within a tolerance of a few degrees, because otherwise there will be no proper correspondence of the ideal grinding direction or orientation of the gems to be ground and of the sample stone or gem.

Finally, it is also pointed out that an emergency switch may be provided which may act upon the motor **15** and rapidly lift the gem out of contact with the grinding wheel (either triggered manually or automatically) if this should become necessary for any reason. Relative to FIG. **7** the following should be noted:

At the center **40** there is a horizontal axis **103.** This axis or shaft **103** (See FIG. 7*a*) consists of at least one section in the FIG. **1** behind the gem stone **11** resp. the holder **30.** The carrier **41** is stepped up at the side in the direction of the axis. On this axis **103** the carrier **41** is pivotable supported by a mechanical sleeve **104'** surrounding the horizontal axis **103** (see FIG. 7*b*). In case of two mounting plates, one of which is to be seen in FIG. **7,** two sections of the axis **103** can be provided, one behind and another before the holder **30** in FIG. **1.** In this case the lower end of the carrier will be bifurcated.

The respective position of the carrier **41** about the horizontal axis **103** will be settled by the pin **54** operated by the electromagnet **53.** The pin enters in the holes forming the arresting portions **52.**

The ratchet wheels **42, 42'** have radial extending teeth or projections. The ratchet wheels **42, 42'** are connected to another in such a way that the teeth of the one wheel are staggered against the teeth of the other wheel. This means the teeth of the one wheel are arranged in the projection of the gap between the teeth of the other wheel. In FIG. 7*a* tooth **104** of the wheel **42'** is arranged in the projection of the gap **105** between the teeth **106, 107** of the wheel **42.** The gaps between the teeth are larger than a tooth.

The pin **49** movable by the electromagnetic actuator **48** has on its end a nose **108** (see FIG. 7*c*) extending in a gap between two teeth of one of the wheels **42** or **42'** (see FIG. 7*d*). The actuator **48** moves the pin **49** between two positions. In the higher position the nose **108** extends in a gap between two teeth of the wheel **42,** in the lower position the nose extends in a gap between two teeth of the wheel **42'**. In both positions the rope **47,** which is biased by the spring **46,** arranged in a winding roller at **46,** draws the unit about the axis **50** that one side of a tooth engages the nose **108.** If the pin will be moved in the other position the rope **47** rotates the carrier until a tooth of the other wheel contacts the nose.

The carrier **41** is provided with a groove **109** as mounting device of a counter-holder **110** for support the diamond in case of position of the carrier in an angle that means during the grinding of facets. During the grinding operation with vertical directed carrier **41** the counter-holder **110** will be removed.

FIG. **1** shows the grinding wheel **4.** This grinding wheel is mounted on a spindle **20.** This spindle is mounted in a bearing **23** with very small tolerances. It is preferred to use a hydrostatic bearing of the Kugellagerfabrik Fischer, Germany. The spindle is driven by a unit **100,** according to the arrow **101.**

As it can be seen in FIG. **1** the rigid support **16** extending from the column **1** is mounted in a level lower than the link or leaf **10.** The motor **15** which may be a geared engine, has a shaft **102** on which is mounted the eccentric **17** so that the eccentric contacts the link or leaf **10.** If the eccentric rotates the link or leaf **10** and also the column **8** with a shaft **8***a* will be lowered or raised.

The sensing device **18** with an upper end or sensor **19** is a device of the firm Novotechnik Stuttgart, Germany, with the name Linostat type F 205. This device **18** is a measury instrument for a distance.

In the example the temperature sensor **25** is a device of the firm Philipps, Germany or Netherlands, type NTC.

The profile projector **34** is a device of the firm Ernst Zeiss, Wetzlar. It has an enlargement factor of 1:100 at least.

As another possibility in respect to the device 18 microcators are named. These are known instruments of the firm Johannson, Sweden, type Microcator 500 A/4. This dial gauge functions without gears, therefore with high exactness.

The word "bed", previously mentioned, means that with the described means the diamond has been embedded in a holder-material adapting itself to the shape of the embedded part of the diamond.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of constructions differing from the type described above.

While the invention has been illustrated and described as embodied in a machine for the grinding and polishing of gem stones, it is not intended to be limited to the details shown since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

1. In a method of grinding a gem stone, particularly a diamond, the steps of placing a gem stone to be ground against a rotating grinding wheel; turning said gem stone relative to said grinding wheel for determination of an ideal orientation of said gem stone relative to said grinding wheel; measuring the frictional heating of said gem stone; controlling the contact pressure at

which said gem stone contacts said grinding wheel, as a function of the temperature of said gem stone and in such a manner as to maintain said temperature constant; determining the amount of material removal which takes place during the preceding steps; terminating the turning of said gem stone when said ideal orientation is reached; and grinding respective facets of said gem stone with said grinding wheel.

2. A method as defined in claim **1**, and further comprising the steps of turning the gem stones—immediately prior to completion of a respective facet being ground—through up to 10° from said ideal orientation while reducing said contact pressure.

3. A method as defined in claim **1**, further comprising the step of polishing said gem stone; and wherein all of said steps are carried out on the same grinding wheel and without re-positioning said gem stone.

4. A method as defined in claim **1**, wherein the step of measuring comprises sensing the seeming growing of said gem stone under the influence of said frictional heating.

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