

- [54] METHOD OF ORIENTING ABRASIVE PARTICLES IN MAKING ABRASIVE ARTICLES**

3,599,288	8/1971	Eakman	264/40
3,759,383	9/1973	Inoue	209/111.5

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- [52] **U.S. Cl.** **51/293; 51/298; 51/309;**
156/350; 209/81; 209/111.5

- [51] **Int. Cl.**..... **B24d 17/00**

- [58] **Field of Search** 264/22, 24, 108; 51/293,

- 51/298, 309; 198/288, 262; 156/297, 298,
350; 209/111.5, 81

- [56]
- References Cited**

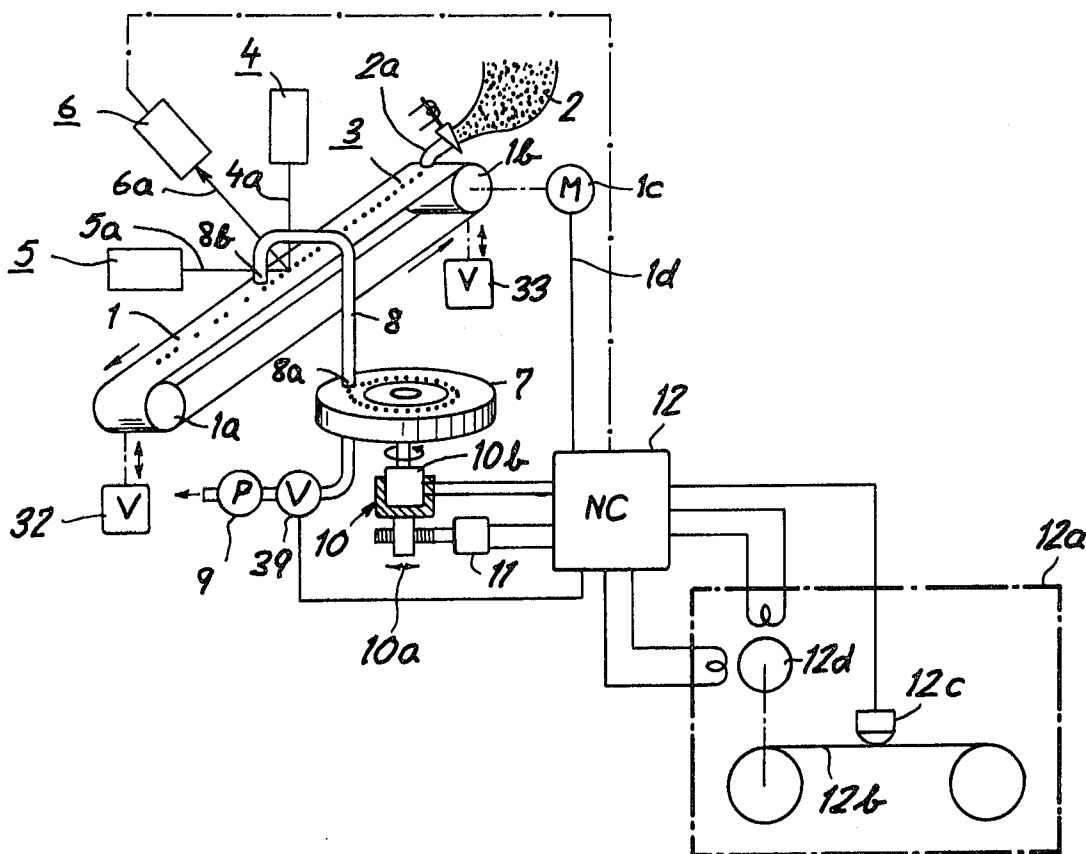
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- [57]
- ABSTRACT**

A method of and an apparatus for making abrasive articles, e.g. wheels, disks and the like abrasive particles wherein a train of the particles is displaced along a transport path and means is provided for automatically detecting the crystallographic orientation of the individual particles. Particles of appropriate orientation are withdrawn from the transport path and carried with fixed orientation to the wheel, disk or other substrate into which it is implanted. The individual particles are set in predetermined locations of the disk whose motion is governed by numerical control means.

7 Claims, 4 Drawing Figures



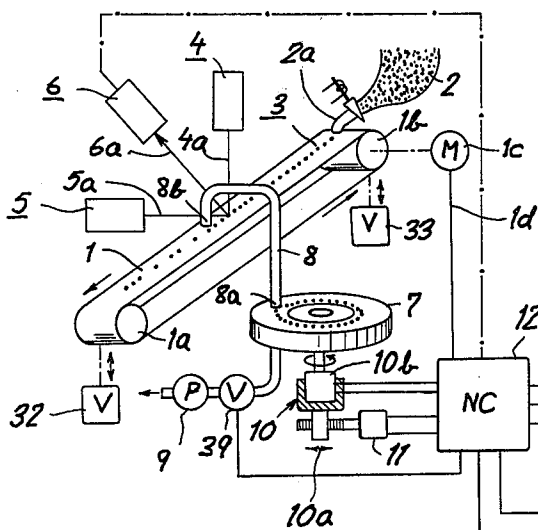


FIG. 1

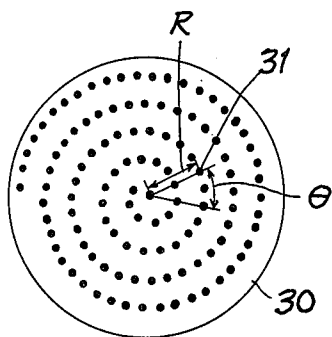
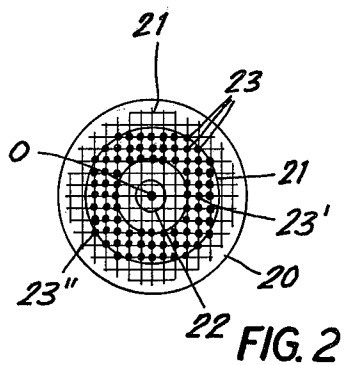


FIG. 3

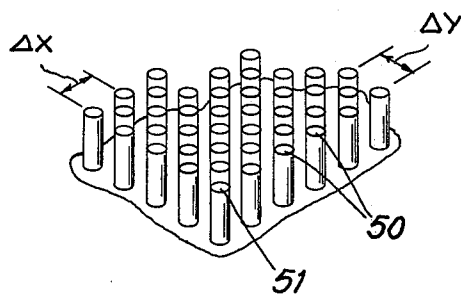


FIG. 4

METHOD OF ORIENTING ABRASIVE PARTICLES IN MAKING ABRASIVE ARTICLES

This application is a division of Ser. No. 168,092, filed Aug. 2, 1971, now U.S. Pat. No. 3,759,383.

FIELD OF THE INVENTION

My present invention relates to the production of abrasive articles and, more generally, to the production of articles in which a crystalline body is set with predetermined orientation in a substrate or support. The invention also relates to a method of and producing abrasive articles such as grinding disks, wheels and the like.

BACKGROUND OF THE INVENTION

While numerous methods have been proposed heretofore for the production of abrasive articles, e.g. grinding wheels and disks, substantially all of these techniques have disadvantages which are more or less apparent. For example, grinding wheels and disks have been provided heretofore by mixing abrasive particles, e.g. particles of a crystalline material of high hardness, with a binder, and casting the resulting composition with or without pressure. When the binder sets, the particles appear to be more or less homogeneous throughout the body of the article and engage the workpiece along the surface thereof. Since the binder wears more readily than the abrasive particles, fresh surfaces of the abrasive material are constantly exposed. However, such systems are characterized by poor utilization of the crystalline abrasive because the latter wears more or less rapidly depending upon the crystal orientation and has a greater or lesser cutting effect depending upon such orientation. Thus it is known that diamond particles, for example, form low-wearing, high efficiency cutting members when held with the axes perpendicular to the direction of movement of the abrasive article and to the surface of the workpiece which is to be modified. When the particle is rotated so that its axis lies parallel to the surface to be modified, wear of the particle increases with little cutting effect. Furthermore, diamond and other particles of high crystallinity, e.g. alumina, ruby, must be provided with a predetermined orientation of the cutting faces of the crystal to the workpiece, the cutting faces having a fixed relationship for each crystal, to the predominant crystal axes. Thus, if the proper orientation of the particle is not observed, the cutting effect is reduced or rendered negligible. The aforescribed technique for the production of abrasive articles randomly distributes the particles and does not permit of any predetermined orientation thereof.

Hence it has been proposed to produce abrasive articles cutting tools and the like by forming a wheel or similar member with individual pockets, recesses or notches adapted to receive individual high-hardness members which may be of a crystalline configuration. In these systems, proper orientation of the facets of the cutting members is obtained by manually inserting them into the support. This arrangement has the obvious disadvantage of increased cost, high requirements of skilled labor, and sensitivity to human error.

Finally, I might suggest that an obvious method of producing abrasive articles with a pointed grain and crystal structure, is to position a large number of crystals in predetermined orientation upon a surface and then to introduce into the interstices between these

particles a hardenable binder adapted to form a matrix which, when hardened, contains the particles in predetermined orientation. The system, however, likewise has the disadvantage that skilled labor is required and must of the operations must be done manually.

It is also noted that there are many other applications in which oriented crystal bodies are desirable. Invariably, this has taken considerable labor and skilled work. The cost of such articles is consequently high and the danger of inaccurate position increases.

OBJECTS OF THE INVENTION

It is the principal object of the present invention to provide an improved system for setting crystalline particles so as to eliminate the disadvantages discussed hereinabove and to provide improved articles having oriented crystalline particles fixed therein.

It is another object of the invention to provide an improved abrasive article with oriented abrasive particles, which can be made in a simple and automatic manner.

Still another object of the invention resides in the provision of a system for making abrasive articles at low cost, with high accuracy and with considerable uniformity.

SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter, are attained, in accordance with the present invention, by passing a succession of crystalline particles along a predetermined transport path, scanning the particles as they pass along the path, past a viewing station, detecting the orientation of the particles as they move along the path, and selecting particles of a predetermined orientation from a succession and transporting them, in turn, with fixed orientation, to a support in which the particle is planted.

According to an important feature of this invention, the transport means consists of an endless conveyer provided at one end with means for delivering a supply of the crystalline particles to the upper stretch of the conveyer, preferably in a row of spaced-apart particles. Trained on this row, at a location downstream of the detector station, is a guide tube having its mouth closely juxtaposed with the conveyer belt and leading to the substrate. The tube constitutes the guide means of the present invention and is activated to draw a selected crystal from the belt, retain its predetermined orientation with respect to a crystallographic axis and convey the crystal to the support into which it is to be implanted.

Advantageously, the detector station comprises at least one and preferably two sources of electromagnetic radiation and/or high-energy particles capable of projecting beams of subatomic particles at the successive crystals as they arrive at the detecting station. The detector may respond to the diffraction effect of the crystal upon the respective beams. Alternatively, the detector may respond to refraction or some other characteristic related to the crystallographic orientation. Preferably, the sources of electromagnetic radiation are X-ray-beam sources arranged so that the respective beams intersect at the location traversed by the row of particles, the detector being an X-ray-diffraction detector. In this case, the invention makes use of a principle long recognized in the crystallographic art, namely, that the crystal planes and axes can be established by sweeping the crystal with an X-ray-beam and detecting

the defraction pattern resulting from the X-ray scanning of the crystal. The system is based, in part, upon the fact that the respective crystal planes function as the lines of a diffraction grating and cause interference and reinforcement patterns. Either crystal or the beam is rotated in a conventional diffraction-pattern crystallographic analysis, but I have found that no such rotation is required where only proximity to the correct orientation of a crystallographic axis is desired. In other words, the beams may be fixed and may scan the individual particles as they move past the detection station, the sensor registering a predetermined output when the axis of the crystal is not in proper orientation vis-a-vis the desired orientation. At this point, the detector triggers the system for implanting the crystal in a support.

The control system of the present invention is preferably of the numerical type, e.g. may be provided with a memory in which are stored co-ordinates of the sites at which the individual crystals are to be implanted. In general, the memory may consist of a band, tape or the like in which the information is digitally recorded and represents two coordinates capable of defining any point in the plane of the surface in which the particles are to be seated. The inputs to the memory may be calculated mathematically but also can be established by mutually setting a stylus or pointer to the desired position over the surface and then registering the two coordinates of the stylus in the recording medium.

The present invention is applicable also to the production of articles with discrete crystal tips, e.g. scribes, glass cutters or the like. In this case, entire arrays of such elements may be provided in place of the disk or support wheel and the discharge end of the guide tube can be aligned with these tubes to receive individual particles also under numerical control.

To insure a random positioning of the particles upon the conveyer and to guarantee that the particles will remain in set positions during their movement toward the detection station, also to impart some relative movement to the particles and the detector station, I have found it to be advantageous to provide means for vibrating the conveyer. The patterns in which the crystal particles can be arrayed are, of course, variable within the capabilities of numerical control. In this respect, I must mention that the coordinates may be of the Cartesian type, (i.e. orthogonal to one another) or of the polar type, depending upon the results desired. When polar coordinates are employed, it is a simple matter to implant the particles in a spiral or concentric circular arrangement while the use of Cartesian coordinates facilitates the positioning of the particles in rectangular arrays.

DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is a diagonal perspective view of an apparatus for carrying out the method of the invention;

FIG. 2 is a plan view of a grinding wheel in which the orthogonal arrays of particles have been illustrated diagrammatically,

FIG. 3 is a view similar to FIG. 2 wherein, however, the particles lie in a spiral array; and

FIG. 4 illustrates a system for producing diamond-tipped styli according to the present invention.

SPECIFIC DESCRIPTION AND EXAMPLE

In FIG. 1 of the drawing, I have shown diagrammatically an apparatus for the production of diamond grinding, cutting, scraping and finishing wheels, as represented diagrammatically in FIG. 2. Each wheel is here shown to have an inner zone 21, surrounding a hub 22, and provided with seats 23 for the crystal particles according to the present invention. As can be seen from FIG. 2, moreover, each of the particles 23 lies at the intersection of a vertical coordinate 24 and the horizontal coordinate 25 and can be described by two numbers represented digitally in any conventional numerical control system. Taking the point 0 as the origin, therefore, the particle located at 23' will be described as having the coordinates (4,0) while the particles at 23'' will have the coordinates (-4, -2). Each of these numbers, of course, has a digital value which can be recorded and represents a translation of the wheel beneath the discharge end 8a of a guide tube, as will be apparent hereinafter. The matrix in which the particles are lodged, may be prepunched to form the seats for the particles, whereby a binder composition, preferably of metal, synthetic resin or an elastomer, is introduced into the interstices between the particles.

In FIG. 3, I have shown another wheel 30 wherein the particles 31 are located along a spiral pattern with the respective coordinates being defined by the angle θ and the radius R. For example, a value of θ and R will define each location on the surface of the disk.

In FIG. 1, a row of crystal particles 3 is carries by the intermittently or continuously driven belt conveyer 1 having a pair of rolls 1a and 1b which may be driven by a motor 1c from a stepping circuit of the numerical control source 12 as represented by the dot-dash line 1d. The conveyer is slightly vibrated by means 32, 33 which permit the individual particles to reach stable conditions suitable for detection. At a location along the transport path, a guide tube 8 has a downwardly turned mouth 8b terminating just above the surface of the conveyer. A suction can be generated in this conveyer by a vacuum pump 9 and can be cut off by a valve 39. The sides 8c and 8a of the guide tube 8 terminate on opposite sides of the disk which, as already noted, is perforated to accommodate the particles. When the valve 39 is opened, therefore, suction is induced in line 8 and a particle is drawn upwardly and then downwardly to lodge in the disk 7.

The disk 7 is, in turn, mounted upon a support 10 and the latter can be displaced linearly in the direction of arrow 10a by a motor 11 triggered by the numerical control device 12. A similar motor may be provided at 10b to rotate the disk 7 (see FIG. 3) and thereby allow the angular displacement θ and the radial displacement R to be made with ease.

The hopper 2 at the upstream side of the conveyer 1 opens in a narrow gap 2a so that practically individual particles are discharged onto the conveyer. Upstream of the scanning site, I provide a pair of X-ray-diffraction sources 4 and 5 whose beams 4a and 5a intersect along the row of particles 3. The beams 4a and 5a have been shown to be orthogonal in accordance with the preferred case. A detector 6 receives the refracted beam at 6a and operates the numerical control system to energize the suction source 6, induce a properly oriented particle into the supporting matrix, and thereafter advance the support through an increment

of each coordinate and position the next receptive site below the mouth of the tube 8.

The numerical control system generally represented at 12 is shown to comprise a memory 12a, preferably in the form of a perforated band 12b, which is scanned by a detector 12c and which has its motor 12d stepped whenever a crystal is properly implanted in the support.

In operation, the locations of the particles to be formed on the disk are established in accordance with design criteria and are transformed into digital coordinates recorded upon the perforated or magnetic tape 12b. A row of diamond or other high-hardness crystalline particles is caused to pass downwardly along the conveyer belt as shown at 3 with slight vibration. As each particle intercepts the X-ray beams 4a and 5a, the diffraction pattern produced in detector 6 establishes whether, within the predetermined tolerances, the location of a crystal plane or a crystallographic axis of the particle is acceptable. If the response is in the affirmative, the numerical control device is triggered to operate valve 39 and draw the particle along the tube without varying its orientation, and emplace it in the support.

Numerical control devices of the type used herein are described generally at pages 25 ff. of *Advances in Machine Tool Design and Research*, MacMillan Co., New York, 1964, and in the papers by Monk & Catlin, *International Journal of Machine Tool Design and Research*, London, 1963. In general, the control devices comprise a memory which, as described earlier, can be constituted by a memory bank, a punched tape, a magnetic band or other information storage means, input means for tracing positions and converting them into digital signals representing two coordinates of movement, e.g. the X and Y coordinates when the disk is to have the layout shown in FIG. 3, and means for scanning the memory and for stepping same to generate digital output signals for operating respective servomotors controlling the two coordinates on the abrasive-setting apparatus shown in FIG. 1. In particular, the servomotors may drive a pair of mutually orthogonal lead screws of the longitudinal feed and the cross feed of a conventional machine tool carriage or may rotate the disk through the angle θ as shown for the motor 10 and translate the disk through the distance R as produced by the motor 11. In either case, after implanting the abrasive particle in the support, the support is stepped to position another seat in line with the guide means and enable the next particle to be properly positioned.

It has already been observed that in place of a sensor input for the numerical control apparatus, a mathematically established input can be provided. The body of the wheel may be of a self-bonding, e.g. a vulcanizable material, so that after implantation of the abrasive particles, the disk can be thermally activated to bond the particles to the support. It is also possible to cast over the implanted particles a thermosetting material, such as an epoxy resin, to form a binder. Any other conventional means of setting the abrasive may be used. Finally, I might note that the system can be employed for setting abrasive and other mineral particles in individual seats as illustrated in FIG. 4 by way of example. In this Figure, an entire array of styluses or scribes 50 is found in accordance with the coordinate system, here shown to be a rectangular array because rectangular

coordinates are employed. The seats 51 of the scribes are turned upwardly and may be provided with a thermally activated layer of adhesive and the spacing between adjacent scribes is represented at ΔX and ΔY respectively. In this case, the scribe may be held in a frame driven by a pair of lead screws in the X and Y directions through increments of ΔX and ΔY respectively. In this specific Example, the particles are industrial diamond.

Reverting to FIGS. 1 - 3, we should note that the numerical control apparatus may be provided with a clock-pulse generator which serves to step the servomotors and to initiate the driving of the conveyer belt to start the next cycle. The substrate, after implantation of the particle, may also be coated by electro-deposition methods with a thin layer of metal serving as the bonding agent.

The improvement described and illustrated is believed to admit of many modifications within the ability of persons skilled in the art, all such modifications being considered within the spirit and scope of the invention except as limited by the appended claims.

I claim:

1. A method of mounting abrasive crystal particles on a support therefor, comprising the steps of:
 - advancing a succession of particles along a predetermined transport path;
 - scanning said particles with a beam of energy affected by the crystalline orientation of said particles;
 - detecting a modification of the scanning energy indicative of the existence of a predetermined particle orientation of selected particles along said transport path; and
 - selectively removing particles from said path with said orientation and carrying the removed particles away from said path in a positionally oriented manner into a bonding engagement with said support, while continuing to advance nonremoved particles with other orientations along said path.
2. The method defined in claim 1 wherein said particles are inorganic crystals and said source is an X-ray diffraction source projecting at least one beam of X-rays against the particles advanced along said path.
3. The method defined in claim 2 wherein at least two beams of X-rays at right angles to one another are projected at each particle along said path simultaneously.
4. The method defined in claim 1 wherein the selected particles are carried pneumatically to said support.
5. The method defined in claim 1 wherein said particles are abrasive crystals and said support is a substrate adapted to be bonded to abrasive particles, said method further comprising the step of incrementally shifting the location at which each successive selective particle is set on said support after the setting of previous particles.
6. The method defined in claim 1 wherein the abrasive crystal particles are selected from the group consisting of diamond, ruby and alumina.
7. The method defined in claim 1 wherein the abrasive crystal particles are removed from the predetermined transport path by suction.

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