GRINDING DIAMOND WHEEL, AND METHOD OF MAKING SAME

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ABSTRACT

A diamond grinding wheel for forming the edges of glass plates into desired cross-sectional shapes wherein the diamond layer of the grinding wheel is a radial cross-section passing through the axis of said wheel and has continuously varying and uniform distribution of the diamond abrasive in accordance with grinding work required for shaping the edges of the plates to be ground and the method of manufacturing such a wheel.

It is an object of the invention to prevent the uneven deterioration of the grinding surface of a pencil-edged diamond grinding wheel resulting from the grinding surface of the diamond layer of the wheels being deformed excessively from a given curvature radius in the process of grinding the cut edges of glass plates.

2 Claims, 11 Drawing Figures
GRINDING DIAMOND WHEEL, AND METHOD OF MAKING SAME

This is a continuation-in-part application of my co-pending application Ser. No. 868,518, filed Oct. 22, 1969, now abandoned entitled GRINDING DIAMOND WHEEL.

When prior grinding wheels are put to the grinding of the end faces of glass plates into desired contours, the configuration of their diamond layers gradually resembles the initial end face shape of the glass plate material to be ground. As a result, the consequent increase in the radius of the diamond layer is rendered virtually unusable for grinding work until the curvature radius is corrected. Previous attempts to lessen such deformation by increasing the content of abrasive diamond grains have been unsuccessful. Although increasing hardness throughout will certainly reduce deformation over a set span of time, this advantage is accompanied by additional cost and an unacceptable heat generated in the vicinity of a center portion of the cross section of the glass plate. Grinding speed is reduced because the glass will not stand further grinding until the temperature is reduced.

Another objective of this invention is to provide a method of manufacturing a wheel having the above-identified advantages and characteristics.

These and other objects of the invention will become more apparent to those skilled in the art by reference to the following detailed description when viewed in light of the accompanying drawings wherein:

FIG. 1 illustrates in cross section a conventional pencil-edged diamond grinding wheel;

FIG. 2a portrays in cross section a glass edge prior to grinding;

FIG. 2b portrays the edge of FIG. 2a after grinding;

FIG. 3 illustrates a grinding layer formed in accordance with this invention;

FIG. 4 illustrates an alternate shaped grinding edge;

FIG. 5 plots characteristic curves showing the comparative results of testing of the grinding wheels made in accordance with the present invention;

FIG. 6a is a top plan of an arrangement of diamond grain distribution;

FIG. 6b is a vertical cross-section of a diamond wheel having the dimensions of the wheel shown in FIG. 3;

FIG. 7 is a diagrammatic perspective of a container for the grain distribution shown in FIG. 6; and

FIG. 8 is a diagrammatic perspective of apparatus for feeding the contents of the container of FIG. 7 to a mold.

The following factors affect the hardness of a diamond grinding wheel:

a. the degree of contained abrasive diamond grains;

b. the strength and hardness of an employed wheel bond (the bonding agent for the abrasive grains);

c. the conditions of grinding.

Of the above three most influential elements, assuming the same working conditions for (b) and (c) in one grinding wheel, the factor (a) is the initial element which determines the hardness selection of the wheel. Now, to consider the elements which influence the deformation of the grinding surface of a wheel when grinding the edge face of a glass plate G into a given exemplary curvature radius such as that shown in FIG. 2b. It can be seen that the end sides of the glass plate must be ground by a quantity of machining height (a) while at the center portion B only a machining height (b) must be ground.

Since conventional wheels have uniform hardness throughout their abrasive layers, the amount of work done at A is ab/2 times that at B. Deformation of the layer will continue until the relation ab/b = 1 is obtained. There is, equality in the machining ratio between the area A and the area B suggests the linearity of the cross section of the diamond layer of the wheel. Any increase in hardness of a wheel for the purpose of minimizing the deformation of its diamond layer results in increased cost and undesirable heat.

In accordance with this invention, the ratio of the grinding abrasive with respect to the bonding material is gradually increased from a minimum at B to a maximum at the side A. The bonding material is oftentimes brass or a substance of similar qualities. The increased concentration of diamond particles is illustrated by a higher density of black dots on the drawings. Therefore, if increased variations in the rate of diamond content is given between A and B in proportion to the ratio of work to be done therebetween (or stated otherwise, with the ratio of consumption therebetween) the diamond layer is worn at a constant level of consumption and thus maintains the same cross-sectional shape thereof as at the beginning even though the amount of work done at the respective grinding areas A and B is different. The uniform wear of diamond layer contributes to increased grinding operations without repeated dressing and replacement. Consequently, by disposing a layer having a successively differing distribution of diamond particles in a cross section, the present invention enables continuous grinding work of a given shape determined so as to minimize the consumption of the diamond layer.

Although the foregoing explanation has been confined to arcuate grinding work, the end faces of glass plates of any shape besides arcs, such as the V-shape seen in FIG. 4. The FIG. 4 embodiment can grind exactly in accordance with their initial shapes by means of a wheel with a diamond layer having gradual variation in diamond content in proportion with grinding work done for the end faces.

In accordance with the foregoing, tests were made under the conditions as given in the Table below. The test results are graphically represented by the curves of FIG. 4.

In FIG. 5 curve 21 represents the result of the first test, curve 22 the result of the second test, and curve 23a and 23b show the result of a test in which a conventional wheel of uniform abrasive density was employed. For most purposes, if the edge of plate glass is formed with a curve struck by a radius of between 3.5 and 6 mm, it is considered safe. Those skilled in the art often times refer to such curves with the radius length preceding the letter R; e.g., a curve of 6 mm as 6R and a curve 4 mm as 4R. In this testing the configuration of the abrading surface was begun at 3.5R and over 6R was considered as unacceptable.
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The wheel used in the first test, represented by the curve 21 was equipped with the hardness ratio of 3:1, and the radius gradually increased up to the vicinity of 20,000 meters and thereafter showed no particular variation until a predetermined 6R came about at 34,580 meters. The curve 22 is a result of a test made on the basis of the result of the first test in the curve 21, in consideration of the rates of diamond content as seen in the Table. In this case, R remained within 4.4 until the lifetime of the wheel was exhausted and an amount of grinding work done was 42,850 meters in length. The curves 23 and 24 illustrate the result of a test on a conventional grinding wheel. A rapid increase to 6R occurred at 1,190 meters of machining. The R rapidly increasing even thereafter, so that grinding operation was stopped at 6R. After a redressing the same rapid growth in R was observed as before until the lifetime of the diamond layer came to an end at 5.8 R, when the total grinding work of 24,280 meters was obtained. The last is illustrated by curve 23b.

In FIG. 6b the plan of a rectangular shape (a, b, c, d) is shown which has an area identical with an area of a curved vertical cross section as shown in FIG. 6a. The FIG. 6b dimensions are the same as the area of a length L of a circular arc E and the width H of a neutral surface of the curved vertical cross-section of FIG. 6b. Therefore, its vertical cross-sectional area is equal to that of FIG. 6c. The circular arc E' of a radius R is drawn which passes each point of b, X, c in the rectangular vertical cross-section provided that X is the middle point. A design is formed of the dias having high hardness are initially on one side of circular arc curve E'. The border is arranged at the symmetrical areas A, A' of the X-x and the dias having low hardness are arranged in the symmetrical areas B, B'. As the total volume V of the diamond layer as initially designed is known, the depth Z of the distribution container 31 is automatically determined on the assumption that the upper and lower surface of the rectangular three-dimensional container shown in the see-through perspective view of FIG. 7 are similar and have identical areas. The distribution container 31 is separated into A and B portions by means of a suitable thin partition wall plate 30 which follows the arc E' and the dias of proper hardness which correspond to said portion are filled in the respective portions.

Now, the dias having variable hardness are mixed by taking arbitrary cross-sections which are in parallel with the line X-x and mixed, and how the hardness changes is obtained in each vertical cross-section as follows:

As shown in FIGS. 6 and 7, the line X-x is the center-line that divides into the rectangular cross section (a, b, c, d) and the circular arc C' and when the surface including the line Xx is disposed perpendicularly toward the bottom surface, it can be seen that this partition wall becomes the rectangular shaped area of XX'X'. From this it can be seen that the crossing points of the arbitrarily differentiated cross section YY'Y'y' which is in parallel with the surface XX'X'X' is represented by

\[ Co = S_{Cm} + S'CnS'S' = h_{Cm} + h'Cn \] (refer to FIG. 8)

provided that the crossing points of the upper and lower surfaces of the distribution container 31 with the circular arc E' are at K, K' points, and also the area of the differentiated cross section YY'd'd' forming the portion A at S and the rate of content of the dia is Cm percent, the area of differentiated cross section KK'y'y' forming the portion B is named S', the rate of content of the dia is named Cn percent, the average hardness of the differentiated cross section YY'y'y' is named Co percent and wherein Cm = Cn, the dia of the differentiated cross section from the ends a, b of the distribution container 31 toward the ends d, e is inversely proportional with respect to the maximum hardness Cm at the time of the design and the height h' of the circular arc E' and is reduced continuously gradually and becomes the minimum Cn over the center portion Xx and then is increased continuously gradually from that point and becomes again the maximum Cm at the differentiated cross section d, e.

The upper surface of the distribution container 31 is a pattern which is redrawn in the rectangular shaped area whose cross section is identical with the dia of FIG. 6a as shown in FIGS. 6 and 7. Therefore, the shape of the circular are E1 may be suitably drawn to the pattern of the dimensions which are individually enlarged or reduced in the direction of the length L of the width H of the rectangular by using the redrawn pattern as the reference dimensions of the original pattern.

However, as the total volume V of the dia is initially determined, a depth Z of the distribution container 29 can be obtained as the value of a function of the rectangular area.

The distribution container 29 which is prepared in accordance with the foregoing is disposed over the upper part of a funnel 32 of a shape shown in the perspective view of FIG. 8. The container moves in the direction of the arrow at a selected speed. When the dia

<table>
<thead>
<tr>
<th>Rate of diamond content (%)</th>
<th>Variation of grinding (nm)</th>
<th>Amount of grinding work done (length of m)</th>
<th>Ratio of diamond layer consumptions (A:B)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Result</strong></td>
<td><strong>A</strong></td>
<td><strong>B</strong></td>
<td><strong>Actual measurement</strong></td>
</tr>
<tr>
<td>first</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>test</td>
<td>69</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>(curve 21)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3.5</td>
<td>0</td>
<td>3:1</td>
</tr>
<tr>
<td>6</td>
<td>6.0</td>
<td>34,580</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>second</td>
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</tr>
<tr>
<td>test</td>
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<td>(curve 22)</td>
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</tr>
<tr>
<td>4</td>
<td>4.0</td>
<td>10,000</td>
<td>4:1</td>
</tr>
<tr>
<td>5</td>
<td>4.3</td>
<td>22,500</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3.5</td>
<td>0</td>
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</tr>
<tr>
<td>8</td>
<td>4.5</td>
<td>2,500</td>
<td></td>
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<tr>
<td>prior</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wheel throughout</td>
<td></td>
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</tr>
<tr>
<td>6</td>
<td>6.0</td>
<td>11,950</td>
<td>dressing</td>
</tr>
<tr>
<td>7</td>
<td>3.5</td>
<td>11,950</td>
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<td>8</td>
<td>4.5</td>
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<td></td>
</tr>
<tr>
<td>9</td>
<td>5.2</td>
<td>19,000</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>5.8</td>
<td>24,280</td>
<td></td>
</tr>
</tbody>
</table>
reach the protruding lower lip of the funnel 32, they drop continuously sequentially in parallel with the line X-x in the form of differentiated cross-section from the bottom portion of the distribution container 29. The dropping diast are completely mixed by means of a suitable mixing device 33 and into the mold M. The molding parts 34, 35, and 36 for the diamond wheel are rotated. The dropped diast become the deposited layer whose originally designed hardness continuously changes, and the deposited layer diast are maintained in parallel with the bottom surface by means of a suitable leveling plate or tab 38. The deposited layer of diast is molded by the press machine to the dimensions of FIG. 6A by using a pressure cover 39. After the molding is completed, the diamond wheel is completed through a suitable manufacturing process such as sintering.

In the structure of the mold, reference numeral 34 is an outer ring frame forming the curved vertical cross-section of the diast which corresponds to an outer periphery of the wheel having a radius of curvature R of FIG. 6A. Part 35 is its inner ring type frame and 36 is a cradle for supporting the ring frames and diast. These components are conveniently assembled so that the diast when molded, can be removed. The mold is disposed on a rotating platform 37. Reference numeral 39 indicates the pressure cover for press molding the deposited layered diast into the correct dimensions.

The diast can be fed to the hopper from container 31 by several convenient methods. One method is to have a slidable bottom 31. As container 29 is moved forwardly, the diast will be fed to the hopper 32 if the bottom is anchored. The rate of movement of container is coordinated with the rotation rate of the mold.

In a general manner, while there has been disclosed an effective and efficient embodiment of the invention, it should be well understood that the invention is not limited to such an embodiment as there might be changes made in the arrangement, disposition, and form of the parts without departing from the principle of the present invention.

I claim:

1. A grinding wheel for forming a generally convex peripheral surface from a generally flat peripheral surface in a glass plate whereby the amount of materials that have to be ground away from the generally flat peripheral surface varies from a minimum at the center of the peripheral surface to a maximum at its edges, a generally concave grinding layer of a selected thickness disposed about the periphery of said wheel and having a shape the complement of that to be imparted to said flat peripheral surface, said layer being comprised of a binder and diamond particles and the amount of said diamond particles varying uniformly and evenly in distribution throughout said thickness from a minimum concentration at the center of said concave surface to a maximum at its edges and in proportion to the amount of materials that have to be ground away from said flat peripheral surface to form said convex peripheral surface.

2. The grinding wheel of claim 1 wherein said concave grinding layer is "V" shaped.