

March 3, 1970

NOBUYOSHI HAGIHARA
FLEXIBLE GRINDING DISC

3,498,010

Filed June 3, 1965

4 Sheets-Sheet 1

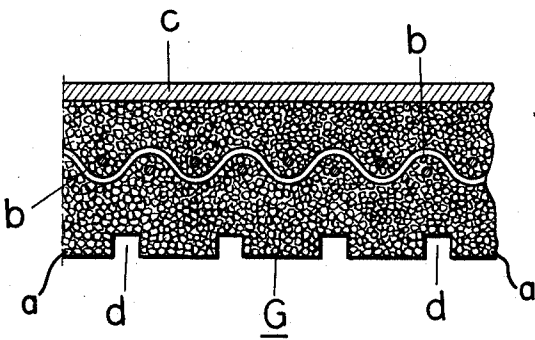
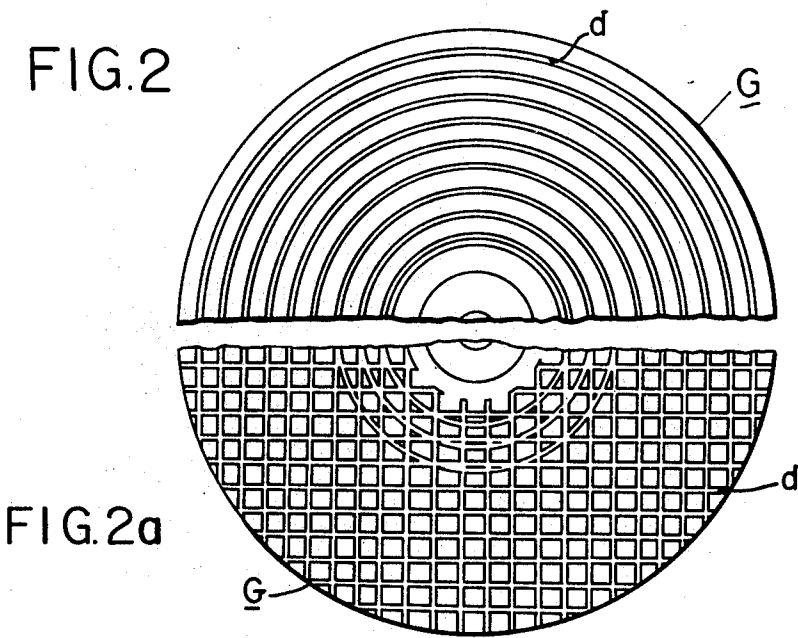
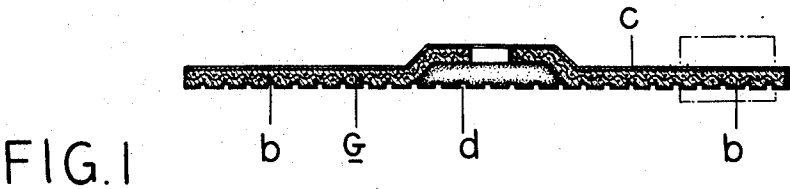


FIG. 3

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FIG.4

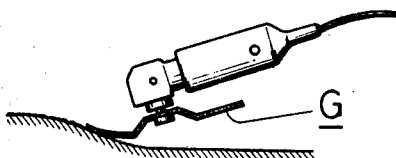


FIG.5

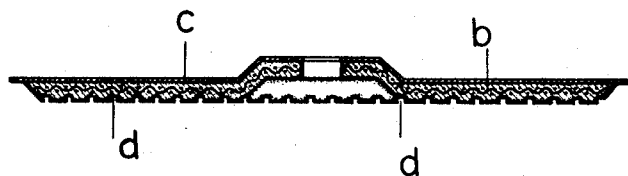
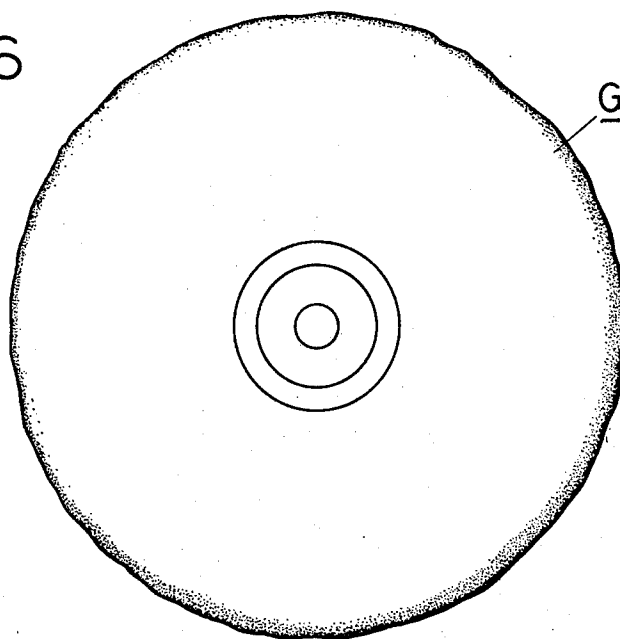


FIG.6



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FIG.7

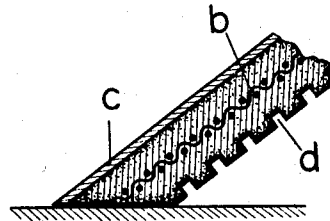
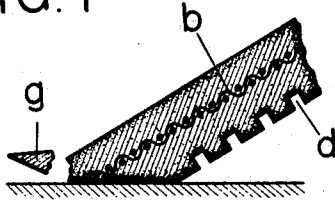


FIG.8

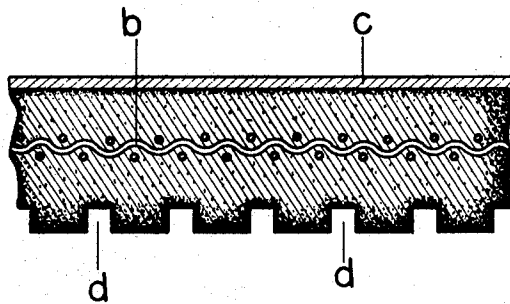


FIG.9

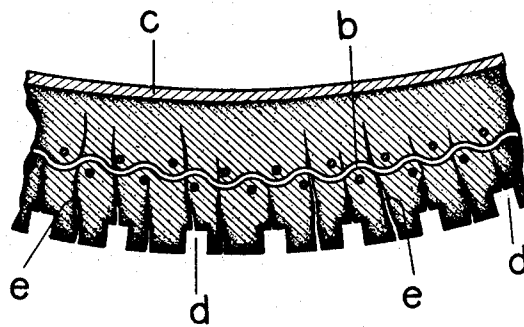


FIG.10

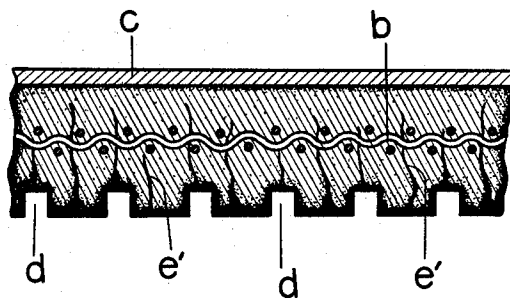


FIG.11

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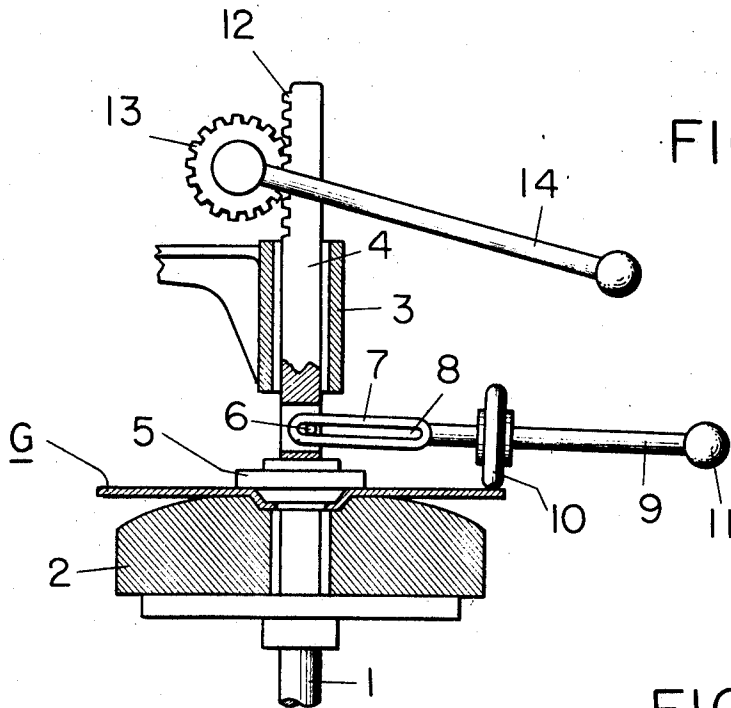
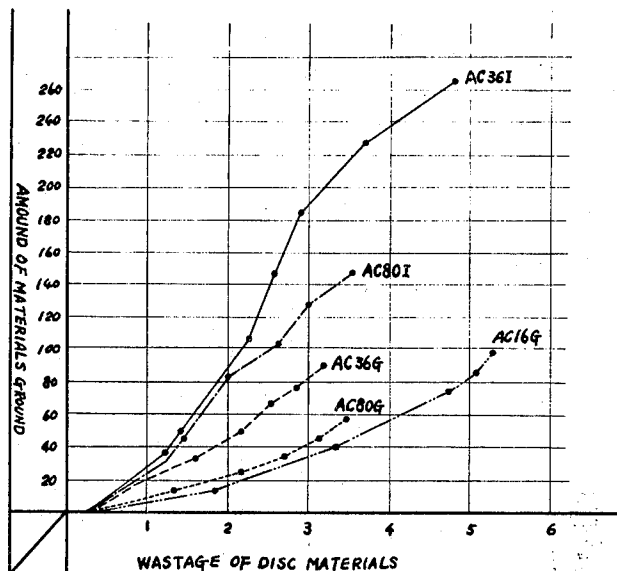


FIG. 12.

FIG. 13



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FLEXIBLE GRINDING DISC

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Filed June 3, 1965, Ser. No. 461,087
Int. Cl. B24b 11/00, 27/00

U.S. Cl. 51—395

5 Claims

ABSTRACT OF THE DISCLOSURE

A flexible grinding disc having a core of woven fabric coated with a bonding agent, a layer of grinding grains coated with a bonding agent on both faces of the disc, a reinforcing material saturated with a plastic bonding agent positioned on the surface opposite the grinding side, and the entire grinding part being cracked mechanically to such a degree that the cracks are invisible to the naked eye for dividing layers of grinding grains into innumerable small blocks connected with one another, the core and the reinforcing material.

This invention relates to a grinding disc. More specifically, this invention relates to a flexible grinding disc manufactured from a resinoid grinding stone of a recessed center or offset type (under Japan Industrial Standard Specification R-6213) or a thin straight type of nonflexible nature through the application of a special process to impart a suitable degree of flexibility thereto and another treatment to impart a greater flexibility and improved strength thereto.

The conventional resinoid grinding stone of offset type or a thin straight type having a thickness of 2-8 mm. is manufactured by the processes of first pressurizing evenly-arranged grinding grains coated with a phenolic synthetic resin to form a layer, then laying a plain-weave fabric of glass fiber coated with a phenolic synthetic resin between layers of the grinding grains thus produced at or around the central part thereof, and lastly heating the same for the aging operation.

Because of the fact that the component grinding grains are strongly bonded with one another by means of a phenolic synthetic resin, this type of grinding disc cannot be expected to function as a flexible grinding disc, since it possesses only a small degree of flexibility, a property inherent to a phenolic resin. With a view to eliminating the above defect, an attempt has been made so far to manufacture a grinding disc from a mixture of a phenolic resin and a synthetic rubber substance.

The manufacture of such a grinding disc, however, necessarily involves some problems, inasmuch as it is difficult at the present stage to carry out perfect copolymerization of a phenolic resin and synthetic rubber, resulting in a major portion of synthetic rubber substance being merely dispersed in the phenolic resin, with only a small portion thereof copolymerized with the resin.

It is true that the mixing of a rubber-like substance, such as acrylonitrile synthetic rubber, with a phenolic resin gives a far greater flexibility than obtained with the conventional phenolic resin, but when such rubber-like substance is added to a phenolic resin at the rate of 25% to the latter, the finished grinding disc fails actually to perform the required function of a flexible grinding disc, although it is known that such blended material possesses a substantial degree of flexibility. The use of an increased amount of a rubber-like substance tends to develop an undesirable tendency of deterioration in the grinding performance of the finished grinding disc.

The present invention makes it possible to manufacture a novel flexible grinding disc which can be used even at a

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considerably bent or angled position as shown in FIG. 4 whereby a grinding disc of the known type is first manufactured in the known manner, using either the conventional phenolic resin or its mixture with some amount of the abovementioned rubber substance as a bonding agent for the grinding grains, then the grinding disc is given sufficient reinforcement and finally a mechanical treatment to impart the optimum degree of flexibility to the whole disc body.

The nature and other advantages of the present invention will be understood more clearly and specifically with reference to the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a cross sectional view of the grinding disc according to my invention,

FIG. 2 is a fragmentary bottom plan view of a grinding disc, showing one embodiment of the present invention,

FIG. 2a is a similar view illustrating another embodiment,

FIG. 3 is a sectional view on an enlarged scale of the part of the grinding disc encircled by a chain line in FIG. 1,

FIG. 4 is a side elevation of the grinding disc, showing one example of its use,

FIG. 5 is a cross-sectional view of the grinding disc, showing its condition after one hour's use,

FIG. 6 is a plan view of the disc,

FIG. 7 is a fragmentary cross sectional view of the conventional grinding disc in its working position, showing the brittleness of its tip,

FIG. 8 is a similar view of the grinding disc of the invention in its working position, showing the effect of application of a reinforcing material on its upper surface,

FIGS. 9 to 11 are fragmentary cross-sectional views on an enlarged scale of part of the grinding disc of the invention, showing respectively its condition before, during and after the processing for flexibility in order to illustrate the principal of the process to impart flexibility to the grinding disc, according to my invention,

FIG. 12 is a view partly in elevation and partly in cross section of an apparatus for imparting flexibility to the grinding disc, and

FIG. 13 is a chart showing comparison of the performances of the conventional grinding disc and the grinding disc of the invention.

The first embodiment relates to a flexible grinding disc which is characterized by the following construction. A woven fabric of glass fiber, synthetic fiber, cotton, hemp or the like, coated with bonding agent, either a phenolic synthetic resin per se or containing a rubbery substance at the rate of less than 25%, is used as a core material at a central part of the cross section of an offset or recessed center type grindstone, and on both faces of which are pressed and bonded a layer of grinding grains coated with a bonding agent, either a phenolic synthetic resin per se or combined with a rubbery substance as mentioned above. A non-woven fabric or woven fabric well saturated with a plastic bonding agent containing more than 40% solid part, is laid as a reinforcing material on the surface opposite to the grinding face. The grinding part is cracked mechanically in its entirety, just like fine meshes, to such a degree that cracks are invisible to the naked eye, and thus the layer of grinding grains is divided into innumerable small blocks which are connected with each other with the aforementioned core material and surface reinforcing material.

The second embodiment relates to a method of manufacturing flexible grinding discs of the following condition.

In the manufacture of a grinding disc G, for grinding grains *a*, either artificial or natural, such as dissolved

alumina, silicon carbide, boron carbide, garnet, emery, talc, etc., a liquid resin of thermo-hardening resin such as phenol resin, xylene resin, polyester resin, epoxy resin, diallyl phthalate resin, melamine resin, etc. or a resin degenerated (to be flexible) therefrom, either by itself or containing a rubbery substance at the rate of less than 25%, or a wetting agent such as creosote oil, in a quantity of 3-10% of the grinding grains, is stirred up so that it may well spread over the surface of grinding grains. Then, a powdered resin of the aforesaid thermo-hardening resin (2-4 times as much as the liquid resin) is stirred up and bonded to the whole surface of the aforesaid grinding grains, and thus grinding materials having grinding grains coated with a resin of semi-dried condition are obtained.

As a core material *b* at a central part of the cross section of a grinding disc, a plain-weave fabric of high tensile strength and of high wear-resistance made of glass fiber, synthetic fibers, cotton, hemp or the like, is applied by saturating with a resin similar to that used as the coating of grinding grains and is left to dry.

As a surface reinforcing material *c*, a woven fabric or non-woven fabric made of synthetic fibers, cotton, hemp, glass fiber or the like, is cut into a round shape corresponding to the diameter of the grinding disc. Thus, the necessary materials are ready.

The surface reinforcing material already prepared is put on a metal mold for forming a given shape of grinding disc, such as indicated by FIGS. 1-2, and on top of which the aforesaid grinding material is put evenly, followed by the center core material and the grinding material.

The materials thus placed in layers are pressed with an upper metal mold at a pressure of 20 kg./cm.²-150 kg./cm.² for making grooves *d* of a given pattern such as a multiplex circle as shown by FIG. 2 (cross stripes, light blue spots, etc.) or a grid type pattern or combination of a grid type pattern with circles as shown in FIG. 2a and are temporarily molded in a width of 1.3-5.0 mm. In this pressing process, heating at 70-140° C. for 1-16 minutes will have a good effect on the combined condition of a temporarily-molded grinding disc.

The materials molded in the above way are heated at 30-180° C. for about 24 hours in order to harden the synthetic resin used as a bonding agent and upon complete hardening of the synthetic resin, they are made into a resinoid grinding disc of well-combined condition.

The surface reinforcing material is pressed with a press but does not stick fast to the grinding grains as they are only stuck together by the viscosity of the synthetic resin covering the grinding grains when it is dissolved and turns viscous before it hardens by heating. Therefore, by filling the gaps between fibers of the surface reinforcing material with a plastic bonding agent, such as an epoxy resin, polyester resin and others, having more than 40% solid part and flexibility, the grinding material and the surface reinforcing material are bonded together to the greatest degree.

As the grinding disc thus obtained is, as mentioned, hardened in a body and is non-flexible to a high degree, it is cracked, just like meshes of a net, by giving it a mechanical treatment as mentioned later, with the effect that cracks are invisible to the naked eye and thus, the layer of grinding grains is divided into many small blocks, which are connected with each other, with the core material made of woven fabric of glass fiber, etc. and with the surface reinforcing material.

The third embodiment relates to a processing apparatus to impart flexibility to the grinding disc, designed to give minute cracks to the resinoid grinding disc. An example of this apparatus is shown in FIG. 12. The apparatus in FIG. 12 comprises a positively rotatable shaft 1, a stand 2 rigidly secured to the upper end of the shaft, and the shaft being made of an elastic substance enlarge toward its center a non-rotatable shaft 4 is provided above the ro-

table stand and is caused to slide up and down in a guide sleeve 3. A disc-shaped roll 5 is supported at the bottom end of the non-rotatable shaft 4 in such a way as to rotate on the same center line as the shaft 1. A pin 6 provided on the non-rotatable shaft 4 is loosely accommodated in a slot 8 provided in a link member 7, and a bar 9 connected to the link member carries a roller 10 rotatably mounted thereon at a position toward the link member. A handle means 11 rigidly secured to the end of the bar is adapted to cause the roller to move up and down or forward and backward so that a material grinding disc G laid on the top end of the rotatable stand 2 can be pressed by the roller 10.

A detailed description of the operation of this apparatus is as follows:

A resinoid grinding disc G is placed inside out on the somewhat dome-shaped stand 2, and rotated under pressure by the disc-shaped roll 5. When roller 10 under pressure against the grinding disc G is moved from the outer circumference of the disc to the inner one, the grinding disc G is bent in line with the upper surface of the stand 2, yielding cracks like meshes all over it as in FIG. 10, in which the grinding grain layer *a* is divided into innumerable blocks linked by the core of glass fiber fabric, etc. *b* and upper surface reinforcing material *c*. The shaft 4 may be, for example, notched to form a rack 12 which may be geared with a pinion 13 with which a bar 14 is connected directly. By moving this bar up and down, the shaft can be displaced up and down.

According to an embodiment of the invented manufacturing method, the following materials are mixed and agitated to obtain coated grains (grinding material) first, in accordance with the publicly known manner.

Name of material:	Weight
Artificial grinding material A #60 -----kg--	10
Liquid phenolic resin -----gm--	680
Powder phenolic resin (combined with 5% acrylonitrile synthetic rubber) -----gm--	1,920

Note.—A #60 denotes the grain size number of JIS. R6001 artificial grinding and planing materials.

A 36 gram portion of this grinding material is measured out, put in a grinder-shaping metal mold of 180 mm. diameter, and levelled evenly. Then, a sheet of plain weave fabric of glass fiber saturated with phenolic resin degenerated by diallylphthalate is piled, and further on it an upper metal mold shaped complementary to the first mentioned mold and containing an evenly levelled 48 gm. portion of grinding material, is placed after which the entire assembly is pressed at a pressure of 40 kg./cm.². Then, all polyester non-woven fabric is inserted between the pressed grinding disc-shaped semi-manufacture and the lower metal mold. The grinding disc-shaped semi-manufacture placed in the metal mold is heated at 120° C. for 4 minutes, whereupon it is pressed again at 30 kg./cm.².

After this metal mold is cooled down, the semi-manufacture is taken out and the first semi-manufacture is obtained. Since this semi-manufacture has been heated at 120° C. for 4 minutes, the phenolic resin or bonding agent is now hardened to a slight degree but not to perfection. Heating is further continued with a gradual raise of temperature up to 170° C. ultimately. Heating of the grinding disc is completed in 23 hours in total, and the second semi-manufacture is obtained.

Then, on the upper surface of this semi-manufacture, sheeted with all polyester non-woven fabric, inserted and fixed at the time of mold pressing, the following epoxy resin (Solution A and B) is applied with a brush until the solution is fully saturated into the texture of the non-woven fabric, whereby intensive bonding of the grinding disc and the non-woven fabric is carried out.

Recipe for solution A

	Percent
Epoxy resin (shell-made) -----	80
Dibutylphthalate -----	20

Recipe for solution B

	Percent
Polyamide -----	86
Dibutylphthalate -----	5
Ethanol -----	4
Normal butanol -----	4
Hardening accelerator -----	4

As is seen in the recipe for the epoxy resin, since the resin is a type which hardens at medium temperature, the bonded materials are fully hardened under heating at 100° C. for one hour. The substance thus produced is the third semi-manufacture.

In the final stage, innumerable fine artificial cracks are produced on the overall surface of the grinding disc of the third manufacture by means of an apparatus to give flexible effect as shown in FIG. 12, and a flexible grinding disc in accordance with the present invention is obtained.

As aforementioned, cracks given artificially to the grinding disc are entirely different in nature from the splits caused by the forcible bending of the conventional resinoid grinding disc. In the case of the latter, splits are caused onto a part of the grinding disc in consequence of partial concentration of excessive load beyond the elasticity limit. Splits are rougher than cracks. In the case of splits, a partial collapse of grinding grain layers as well as breakage of a part of the core material such as fabric of glass fiber, etc. are noticeable, where, even if the load is withdrawn, the section does not ordinarily regain its original state. On the other hand, cracks given artificially are extremely fine in comparison with splits, spread like meshes all over the grinding disc. The cracked part shows a mere release of combination between grinding grains, and cracks do not go to the extent of collapse of the grinding grain layer. By cracking, the core material such as a fabric of glass fiber is extended only to a slight degree but is not cut.

Accordingly the grinding disc G, once processed with an apparatus as shown in FIG. 12 easily regains its original shape before processing because the interstices between the grinding grains in the cracks *e* shown in FIG. 10 extinguish as per FIG. 11 and contact each other as per *e*.

The grinding disc once cracked as abovementioned is imparted with a property of self-recovery. That is to say, even if such a load as may bend the grinding disc is given at the time of use, the load is no longer concentrated on a part of the grinding disc but is dispersed widely over each part of the cracks given like meshes, where slight interstices appear between the grinding grains with crevices as at the time of processing but the load workable on each part of the cracks is extremely minimized. Accordingly, when the load is withdrawn, the disc regains its original state by the elasticity of the core material such as fabric of glass fiber.

As explained above, when fine cracks are given artificially beforehand, even the non-flexible grinding disc which originally had scarce flexibility is imparted with flexibility as if it comprised an elastic substance, and a flexible grinding disc G which endures practical use as indicated in FIG. 1 is obtained.

The effect in practical use of the grinding disc related to this invention is explained below in detail.

With a conventional non-flexible grindstone, it has been impossible to obtain the smooth finished surface in grinding a plane surface and a curved surface, but the surface finished by a flexible grinding disc of the present invention is as smooth and beautiful as if it were buff-finished. As is indicated by the following comparative test results, the finished surface by a flexible grinding disc is most beautiful.

Fineness of grinding grains	Conventional grindstone (offset type)	Grinding disc of the present invention	Conventional grinding disc
A #36 -----	49S	7.5S	12S
A #60 -----	42S	6.0S	7.5S
A #120 -----	16S	3.5S	4.0S

REMARKS

(1) In this test, the finished surface produced by a most skillful operative, using an angle grinder of manual type, was measured.

(2) With a conventional grinding disc, a surface condition finished by it improves in proportion to the time of its use. In this test, therefore, the finished surface by using a new grinding disc for 10 minutes was made an object of test.

(3) Fineness of grinding grains is based on JIS R6111.

(4) S represents a symbol according to JIS Coarseness Indicating Method.

Because a conventional grinding disc has a vulcanized fiber plate laid on its upper side, it has a disadvantage in that with the wearing of the grinding-grain part, the vulcanized fiber plate protrudes gradually, involving slip and makes a grinding operation impossible.

A flexible grinding disc of the present invention has on its upper side a non-woven fabric or woven fabric filled with a bonding agent of flexible nature. This surface reinforcing material is worn by simple dressing and thus fresh grinding grains are allowed to be exposed to the grinding side at all times, thus resulting in higher work efficiency.

With a conventional grinding disc, the coarseness of the finished surface varies with the time of its use. On the other hand, a flexible grinding disc of the present invention ensures the finished surface of the same degree until its outside diameter grows smaller by wear, with a resultant regularity of operation and of the finished surface. This is an aid to the production of uniformly finished goods.

Because of the grooves cut on a grinding side of a flexible grinding disc, the removal of dust produced on the grinding side is easy, with the result that beautiful finished surface and high grinding efficiency are maintained.

While a flexible grinding disc of the present invention is quite efficient, being equipped completely with the three requisites for a grindstone, i.e., grinding grains, bonding agent and pores, a conventional grinding disc is of such construction that the grinding grains are bonded one by one to the surface of a vulcanized fiber plate and its grinding efficiency is inferior as indicated by FIG. 13. All samples tested are 80 mm. in diameter, with AC36I and AC80I as the grinding discs of the present invention and AC36G and AC80G as the corresponding conventional grinding discs, the same in grinding material and fineness of grains. The test result obtained with AC16G, a conventional grinding disc, is also shown as reference. Symbol A represents dissolved alumina, C a grinding material of silicon carbide, and numerals such as 36, 80, etc. the grain fineness numbers. Each sample was tested 6 times, each for 10 minutes, by using an angle grinder and JIS SS41 (rolled steel Class 2 for general construction) as the material to be shaved and ground.

Because a flexible grinding disc of the present invention uses epoxy resin of a flexible and elastic nature for its back non-woven fabric, it revolves at about 6,000 r.p.m. and yet shows high resistance to the repeated bending of 6,000 times per minute. Hence, it is capable of long use.

As a conventional grinding disc has a vulcanized fiber plate on its upper side, the dressing of its end is impossible. On the other hand, a flexible grinding disc of the present invention has a non-woven fabric or woven fabric bonded to the grinding material by filling in a plastic bonding agent of the epoxy group or polyester group between the

gaps of the fiber. This makes dressing easy and eliminates such a defect as indicated by FIG. 7 (a small broken piece).

Without the use of the abovementioned bonding agent, the surface reinforcing material has a disadvantage that its fiber element remains on the outer circumference of a grinding disc in a tufty condition and such are hard to remove by dressing.

A manufacturing method under the present invention improves a conventional grinding disc as mentioned above, strengthens a grinding disc by saturating a surface reinforcing material with a plastic resin, and imparts excellent flexibility to a grinding disc by a mechanical treatment.

Also, a processing device under the present invention is simple in structural details and generates very fine cracks in a non-flexible grinding disc so as to impart a flexibility like natural elasticity to the disc.

Having thus described the nature of the invention, what I claim herein is:

1. A flexible grinding disc comprising a heat hardened body including a reinforcing core layer embedded intermediate the opposite surfaces of the body comprising a woven fabric of fibers selected from the group consisting of glass, synthetic, cotton and hemp fibers, said fabric being saturated with a bonding agent selected from the group consisting of phenolic resin and phenolic resin containing less than 25% of a substance having the characteristics of rubber, on each side of said core layer, a layer of grinding grains coated with the first mentioned bonding agent, on the surface of one of said last-mentioned layers a surface reinforcing layer comprising a fabric selected from the group consisting of woven fabrics of synthetic, glass, cotton and hemp fibers and non-woven fabrics of synthetic, glass, cotton and hemp fibers, said reinforcing fabric layer being saturated with a synthetic plastic bonding agent containing more than 40% solids, said body having a multiplicity of mechanically induced fine cracks therein, extending transversely of the surface

of and throughout the active grinding area of the body, and said cracks being invisible to the naked eye and dividing the layers of coated grinding grains into small blocks connected with one another, with the core layer and with the surface reinforcing layer.

2. A flexible grinding disc as claimed in claim 1 in which the surface of said body opposite said surface reinforcing layer is grooved, said cracks extending inwardly from the grooved surface in both the grooved and ungrooved areas thereof.

3. A flexible grinding disc as claimed in claim 1 in which said core layer comprises a plain weave fabric of glass fibers coated with a bonding agent consisting of phenolic resin containing less than 25% of a substance having the characteristics of rubber and said surface reinforcing layer comprises a fabric of non-woven polyester fibers saturated with an epoxy resin-hardener mixture.

4. A flexible grinding disc as claimed in claim 3 in which the surface of said body opposite said surface reinforcing layer is grooved, said cracks extending inwardly from the grooved surface in both the grooved and ungrooved areas thereof.

5. A flexible grinding disc as claimed in claim 4 in which said body has a recessed center portion.

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