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REINFORCED GRINDING WHEEL AND REINFORCING STRUCTURE THEREFOR

James T. Zawodni, Birmingham, and Robert J. Markotan, Allen Park, Mich., assignors to Acme Abrasive Co., Warren, Mich., a corporation of Michigan
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The present invention relates to improvements in a reinforced grinding or abrasive wheel, in particular such as the snagging wheels widely used in the steel foundry and related industries where a high rate of metal removal is desired, although other types of abrasive wheel are contemplated. The invention also relates to a novel reinforcing structure or component of such wheel, rendering the latter proof against the all-too-well known danger of bursting as the result of abuse. This hazard attends the development of a crack or cracks extending radially outwardly from the inner periphery of the wheel, and it is necessary to discard the wheel upon discovery of the damage.

Many efforts have been made to meet the problem of wheel cracking and disintegrating by internally reinforcing the granular abrasive structure of the wheel. Metal reinforcing components of ring-like or other nature have been embedded in the wheel body; but they must be positioned relatively closely adjacent the inner periphery of the wheel in order to preserve some practical measure of effective life of the latter before the metal is exposed; and the likelihood of developing dangerous wheel cracks outwardly thereof still exists. Likewise, non-metallic fabric materials have been incorporated in the wheel body, as in layers, chopped or chunk fabric disposed therein in a random or ordered fashion, cord materials, and the like. However, for one reason or another little success has accompanied these efforts, particularly in respect to larger diameter snagging wheels.

More recently it has been proposed to employ fiberglass cloth or cording embedded in the abrasive mass of the wheel for the purpose, as in the form of rings coaxial with the wheel axis or fiberglass cords arranged in one special pattern or another in relation to the axis. However, considerations of cost or other considerations have obstructed these expedients. Particularly in instances in which fiberglass strand or cord material is embedded in the wheel in a special outline intended to combat the radial stress factor, objections arise which it is the object of the present invention to eliminate.

That is, when the glass fiber reinforcing material takes the form of a coaxial ring, the progression of wear on the wheel at high snagging speed soon exposes the reinforcing annulus about its entire periphery, thereby materially diminishing the effectiveness of the wheel. On the other hand, when the fiberglass cord is built in the wheel in a special, non-circular pattern, the overlap of cord lengths upon one another under quite heavy axial compression in the molding procedure causes the cord material at overlap zones to be strongly compressed. Then, upon release of pressure on the molded wheel, the cords tend to spring apart, thereby setting up an internal, axially directed stress in the wheel to de-laminate the latter. This introduces a further weakening effect, over and above the stress which the reinforcement is intended to combat.

Therefore, the present invention provides an internal reinforcing structure of an improved sort for an abrasive wheel, and a wheel reinforced strongly by such component, in which the reinforcement takes the form of elongated fiberglass cord material, preferably a single cord, which is spirally arranged in a single plane, with the convolutions thereof substantially and preferably uniformly, spaced radially from one another in progression from the inner diameter to the outer periphery of the wheel.

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The cord is composed of a plurality of slightly or loosely twisted strands and the strands are each in turn composed of a multiplicity of fiberglass filaments or so-called "ends."

The invention is based on the concept that the most important of the stresses to be resisted in the reinforcing of an abrasive wheel against bursting is a tangential one, not radial.

Thus, in the case of glass fiber cord material laid out spirally and in a single plane paralleling that of the wheel and within its axial confines, the successive convolutions of the cord, in progression radially outwardly thereof, present successive barriers at which the internal stress apt to occasion radial outward cracking of the granular mass, thus initiating the tangential forces, is at once opposed and blocked by the reinforcing cord in tension.

In this type of uni-planar, spirally developing layout of cord material, only a single tail end of the cord will be exposed under wheel wear at any given moment, so that the reduction of grinding area is insignificant, as compared, for example, with that of a ring-reinforced wheel, or a wheel reinforced by cord material having a large number of radially extending components.

Further in accordance with the invention, the filaments or ends of fiber glass of component strands and the ends themselves, are impregnated in a resinous material compatible with the resin binder of the abrasive wheel body in which the reinforcing structure is embedded.

Another object of the invention is to provide an abrasive wheel having a reinforcing structure of the type described, in which the strands of the spiral reinforcing material are twisted, or otherwise conformed, only slightly or slackly, and, as bonded by the resinous material referred to, remain substantially linear and parallel parts of the cord. The reason for this is that an excessive twisting or braiding of the strand components (heretofore alleged to increase the bonding interlock of the strand with the abrasive and bonding material) has been found by us actually to cause the braided or twisted elements to exert a cutting and weakening action on one another, both under axial compression and circumferential tension.

In further accordance with the invention, a single spiral reinforcing member of the character described may be incorporated in the wheel, or a plurality of layers of such elements, depending upon the axial thickness of the wheel.

Moreover, the invention contemplates the provision of tie means of one form or another acting to hold the spiral convolutions of the reinforcing structure in place prior to molding of the wheel. Such tie means may take the form of a length or lengths of material (preferably the same as that of the spiral cord) which may be fixedly associated with the convolutions for the desired purpose. By preference, and as shown herein, the tie means is constituted by a plurality of generally radially extending tie elements intersecting the successive convolutions, and substantially coextensive in the radial direction with the innermost and outermost convolutions.

By further preference, the tie component means in question is threaded through the body of successive convolutions of the reinforcement, rather than being laid above, below or interwoven with the convolutions. Thus the possibility of weakening arising from the yielding and springing back of the cord material, referred to above, is minimized. However, alternative ways of fixedly associating the tie means to the convolutions are contemplated by the invention.

In general, it is an object of the invention to provide a reinforced abrasive wheel, and a reinforcing structure therefor, which by reason of its spiral configuration and ready wearability, will strongly reinforce the wheel at

all of its successive convolutions under tangential stress, yet will still be exposed at only minute zones as the abrasive mass wears away. While the disclosure to follow, particularly in relation to the specific construction of the reinforcing cord, per se, and its performance, is in terms of glass fiber material, it is to be understood that other cord materials suitable to the purpose may be employed as hereinafter mentioned.

The foregoing as well as other objects will become more apparent as this description proceeds, especially when considered in connection with the accompanying drawing illustrating the invention, wherein:

FIG. 1 is a plan view showing the improved fiber glass reinforcing structure of the invention as embedded in an abrasive wheel, the inner and outer peripheries of which are shown in dotted line;

FIG. 2 is a fragmentary view in section along line 2—2 of FIG. 1, being somewhat enlarged in scale;

FIG. 3 is a fragmentary view in still larger scale in section along line 3—3 of FIG. 1;

FIG. 4 is a fragmentary perspective view illustrating a portion of a typical, lightly wound cord length of the reinforcing structure, incorporating, for example, six strands; and

FIG. 5 is a view in radial section through an abrasive wheel in which a plurality of the reinforcing structures of the invention are incorporated, this being expedient in a wheel of a greater axial thickness.

As illustrated in FIG. 1 of the drawing, the improved reinforced wheel of the invention is generally designated by the reference numeral 10, its inner diameter periphery 12 and its outer diameter periphery 14 being shown in dotted line. The glass fiber reinforcing structure of the wheel is generally designated by the reference numeral 16; and it preferably comprises a single continuous length of a suitably impregnated glass fiber cord material 18, of, say, three-sixteenths inch thickness. However, the thickness of gauge of the cord or cording 18 may vary within reasonable limits. This cord is laid out in a single plane in a spiral outline, successive convolutions 20 of which develop outwardly in a uniform radial spacing.

The reinforcing structure 16 further comprises a plurality (shown as six) of radially extending tie elements 22, in this case of the same material, spaced equally in the circumferential direction from one another, and of respective radial lengths such as to only slightly radially over-extend the innermost and outermost convolutions 20 of the strand series which they tie together stably. As indicated above, however, other types of cord tie-in arrangement may be utilized.

Physical and dimensional relationships of the wheel 10 and its reinforcing structure 16 will be hereinafter described in further detail; and while FIGS. 1-3 and 5 of the drawing (in particular FIGS. 2 and 5) schematically and for convenience show the cord 18 as being truly circular in cross-section, this, of course, cannot actually be the case in any cord which is a twisted one. The shape is depicted more accurately in FIG. 4. Furthermore, the mentioned dimensional factors are subject to change within reasonable limits.

In connection with FIG. 4, the cord 18 is shown as being composed typically of six strands 24 which are twisted only enough to hold the same stably together, as impregnated and thus loosely formed; so that the effect is one of substantially linear, parallel and longitudinal cord components. For example, the degree of twist may be only such as to impart a full 360° helical pitch for each 4½"-5" of length of the cord 18. The invention is not unduly limited, however, in this respect, but the fact remains that the absence of a tightly twisted or braided formation eliminates a cause of inter-cutting of the strand filaments and ends under tension and axial compression, and does not significantly decrease the strength of the cord 18.

As those skilled in the art will readily appreciate, the

composition of the abrasive body of the wheel 10 proper may vary considerably, and such variations (consistent with the primary intended purpose for use in a grinding wheel) are of course contemplated by the invention.

Typically, however, the abrasive mass will have an approximate composition, by volume, as follows: (a) aluminum oxide, silicon carbide or other abrasive grit, 56%; (b) a suitable bonding agent (including filler), such as a powdered, phenolic, epoxy or other bonding agent available to those skilled in the art, 24%; and (c) voids or porosity, 20%.

The above composition is one suitable for the production of a wheel under a conventional cold press molding procedure; those skilled in the art will be aware of a correspondingly effective composition for use in the hot press type of production. Liquids capable of use as wetting agents are furfuraldehyde, cresylic acid, furfuryl alcohol, an appropriate liquid resin, or other suitable wetting and dispersing agents known to those skilled in the art. Similarly, any appropriate filler may be utilized. The molding of the abrasive mass, with the reinforcing structure 16 embedded therein, will be in accordance with any suitable molding procedure.

The fiber glass strand or cord material of the reinforcing structure 16 may be produced under any known specification adapted to the purpose, typical of which is a cord of plural strands of glass fiber filaments, designated as Owens Corning No. 801-F/500-60 end, impregnated in a phenolic bonding agent (or other agent compatible with the binder of the abrasive body). The above product yields a tensile strength of 270,000 p.s.i. (U.S.P.). It has a normal or average resistance in tension of about 5.8 pounds per end, hence about 1350 pounds average for the contemplated six strands of 60 end stock. It is contemplated that the cord 18 may also aggregate 360 ends by employing but three strand components, each of 120 end rating, or any other combination may be used. As indicated, the above specific designation of the strand is only illustrative, and material of an equivalent nature is available to those skilled in the art. In general, we contemplate the use of a strand totalling from 180 to 480 ends or filaments.

As in the case of the abrasive mass, the twisted glass fiber cord 18 may be produced in accordance with any known technique, with which the present invention is not concerned, save, as mentioned above, in regard to the degree of tightness of intertwine of its components 24.

Structurally speaking, the abrasive wheel 10 shown in FIG. 1 may be instanced, for the purpose of setting forth certain physical and positional relationship, as being of an I.D. at 12 of 12 inches, an O.D. at 14 of 30 inches, and an axial width of three inches. In this setting, the terminus at 26 of the innermost strand convolution is located about ½ inch-¾ inch radially outwardly of the inner wheel diameter 12, the spacing of this and successive further convolutions from one another is about ¾ inch, and the outermost convolution terminus at 28 is about ½ inch-¾ inch radially inward of outer wheel periphery 14. It is contemplated that this general relationship will obtain in the case of wheels of greater and lesser size. Three of the reinforcing structures 16 will preferably be employed in a wheel having the stated dimensions; as in the wheel, specially designated 30, in FIG. 5. In wheels of greater or lesser axial thickness, the number of the reinforcing structures 16 may vary accordingly.

As arranged pursuant to FIG. 1, the several convolutions 20 are stably held in place by the tie elements 22. These, as spaced at equal circumferential intervals, are positioned (FIG. 3) through the axial midpoint of the body of the successive convolutions. While the elements 22 are flattened somewhat under pressure in the molding procedure, the threaded arrangement of the tie elements 22 very greatly minimizes a cause of weakening of the wheel structure, present if the tie elements are superposed above or below the convolutions of cord 18, or woven

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across the latter, due to the spring-back of the material upon release of molding pressure, setting up internal delaminating stress, as mentioned above. However, as indicated above, the threaded relationship of tie element to cord may be dispensed with.

It can be shown mathematically that the following tangential and radial stress factors exist in a rotating grinding wheel, if R is the wheel radius to its outer diameter, r is the radius of its hole at 12, and r_x is the radius at any given point within the wheel O.D. and I.D.:

[r/R]

	0 (solid wheel)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Maximum Tangential Stress Factor.....	0.98	2.01	2.02	2.05	2.08	2.13	2.17	2.23	2.28
Maximum Radial Stress Factor.....	0.96	0.81	0.64	0.50	0.36	0.26	0.16	0.09	0.04
r_x/R	0.1	0.3	0.4	0.5	0.6	0.7	0.76	0.82	0.9

Thus, under varying values of the ratio r_x/R , it is seen that the maximum tangential stress factor builds up and out increasingly as that ratio increases; whereas the maximum radial stress factor diminishes outwardly. Accordingly, the ability to withstand circumferential or tangential stress should control in the design of a reinforcing fiber glass structure of the kind under consideration; and it is under and in recognition of this principle that the present invention has evolved, as distinguished from certain heretofore proposed fiber glass reinforcing structures which emphasize the importance of resistance to radial stress.

It is seen by reference to FIG. 1 that the outer radial termini of the tie elements 22 and the progressively receding tail 28 of the outer cord convolution 20 have a negligible exposure, once the body of the wheel has worn down to them.

The foregoing conclusions have been borne out by tests. In one test a wheel operating at 12,500 surface feet per minute was shot, using a 30 caliber rifle at a distance of about a foot and about three inches from its hole. It was then halted and a radial crack extending from the hole to the outer periphery was observed. The wheel was run again at the same surface speed for five minutes. No breakage occurred. This was a wheel of 24 inches by 3 inches thickness by 12 inches.

In a second test, a similar wheel was intentionally cracked across its full diameter. It was then run up to 18,000 surface feet per minute before its destroyed itself.

In a third test, another wheel dimensioned 30" x 2" x 12" was shot about 3 inches from its outer periphery, while running at 12,500 s.f.p.m. The impact knocked a five pound segment from the outer surface of the wheel. No other disintegration occurred.

The reinforcing effect of the spiral fiber glass reinforcing structure was proved beyond question by such tests. It can be concluded that, while, as in the case of any abrasive wheel, abuse may give rise to radially inner cracks, the convolutions 20 of the reinforcing structure 16 serve as effective barriers to wheel disintegration.

As indicated above, fibers other than of glass may be utilized in the making of the reinforcing structure 16, including its cord 18 and tie elements 22, such as asbestos fibers, synthetic fibers or blends of the same with glass fibers and/or other fiber materials satisfactory to the objective of the invention.

It is to be understood that in the claims to follow the expression "cord" is intended to signify cording or cord material in a single length or in plural lengths associated with one another in the desired spiral outline; and that the term "strand," unless so qualified, is intended to designate a cord component 24, whether loosely twisted, as disclosed, more tightly twisted or braided, or quite unformed in any such sense, i.e., substantially rectilinear.

The foregoing description of the improved reinforcing structure 16 specifically relates its use in connection with

the reinforcement of an abrasive wheel and, by reasonable extension, to any analogous rapidly rotating element wherein centrifugal force is to be resisted, whether in a material removing tool or not. Indeed, it is reasonable to expect that the adaptability of the structure 16 to such uses will suggest to those skilled in the art others of a more or less related nature. Accordingly, the claims to follow, unless otherwise specifically limited, should be construed in the broadest sense consistent with the state of the art of reinforcing structures.

What we claim as our invention is:

1. A reinforcing structure, comprising glass fiber cord arranged in a spiral outline in substantially a single plane; and a plurality of elongated, circumferentially spaced and generally radially extending tie elements holding the convolutions of the cord in their spiral outline, said tie elements being threaded through the body of successive convolutions.

2. A reinforcing structure, comprising glass fiber cord arranged in a spiral outline in substantially a single plane; and a plurality of elongated circumferentially spaced and generally radially extending tie elements of material similar to said strand holding the convolutions of the cord in their spiral outline, said tie elements being threaded through the body of successive convolutions and being substantially coextensive radially with the respective innermost and outermost convolutions of said cord.

3. A reinforcing structure, comprising a single length of glass fiber cord arranged in a spiral outline in substantially a single plane and having radially progressive convolutions in substantially uniform radially spaced relation to one another, said cord comprising a plurality of elongated strands, each strand being composed of a multiplicity of glass fiber filaments, said strands being in a loosely twisted union so as to be substantially rectilinear and parallel; and a plurality of elongated, circumferentially spaced and generally radially extending tie elements holding the convolutions of the cord in their spiral outline, said tie elements being threaded through the body of successive convolutions and being substantially coextensive radially with the respective innermost and outermost convolutions of said cord.

4. An abrasive wheel having a reinforcing structure of generally annular character embedded therein generally coaxially thereof, said structure comprising a single length of glass fiber cord arranged in a spiral outline in substantially a single plane paralleling the sides of the wheel and having radially progressive convolutions in substantially uniform radial spacing relative to one another, and elongated, circumferentially spaced and radially extending tie means threaded through the body of successive convolutions of the cord and substantially coextensive radially with the respective innermost and outermost convolutions of the cord.

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ROBERT C. RIORDON, *Primary Examiner*.

D. G. KELLY, *Assistant Examiner*.