

June 21, 1966

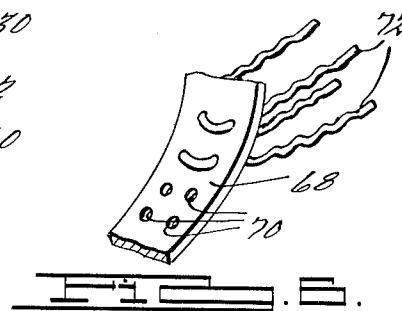
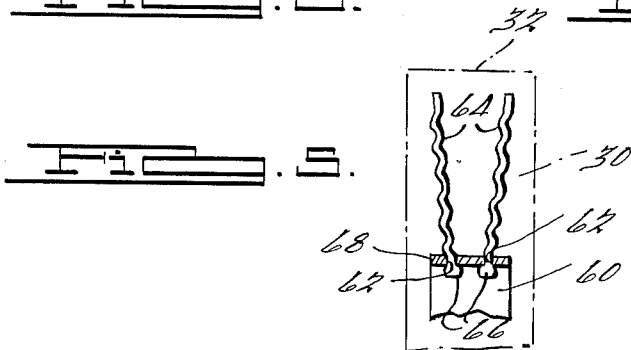
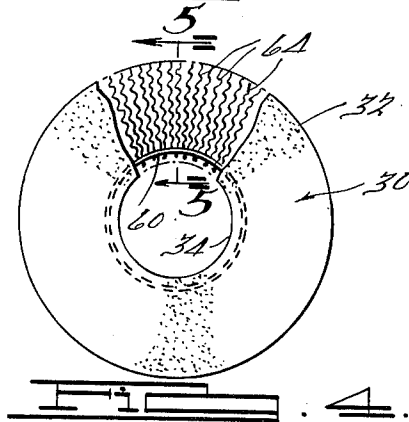
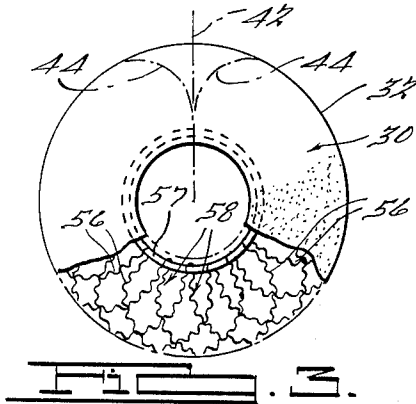
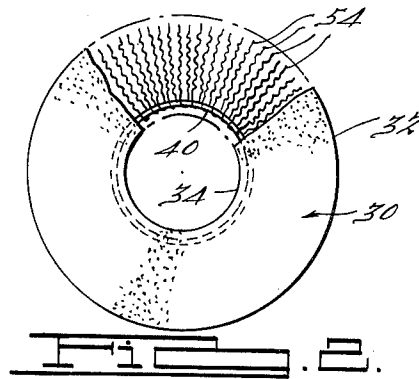
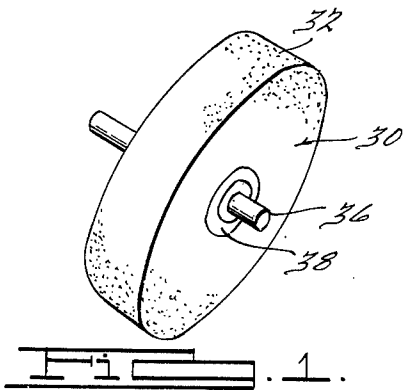
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3,256,644

REINFORCED SNAGGING WHEEL

Filed Jan. 14, 1963

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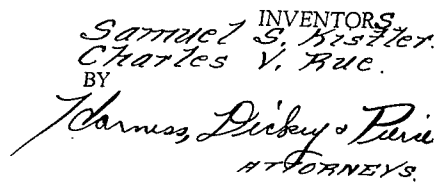


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REINFORCED SNAGGING WHEEL

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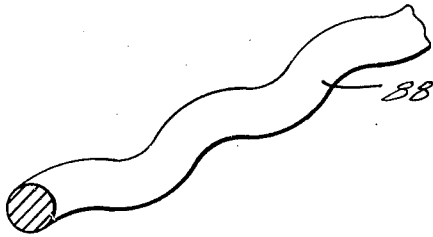


FIG. 12.

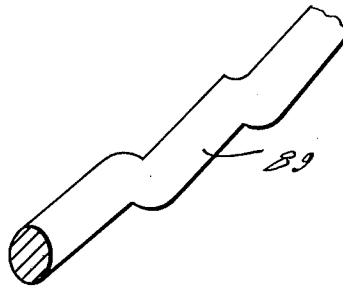


FIG. 13.

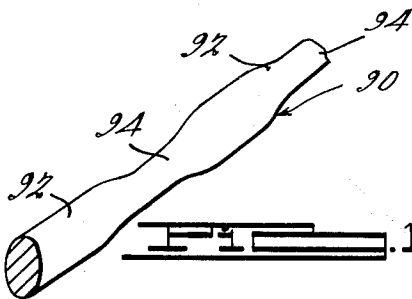


FIG. 14.

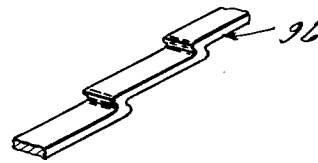


FIG. 15.

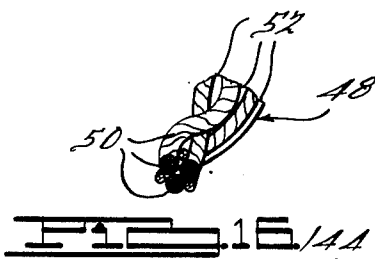


FIG. 16.

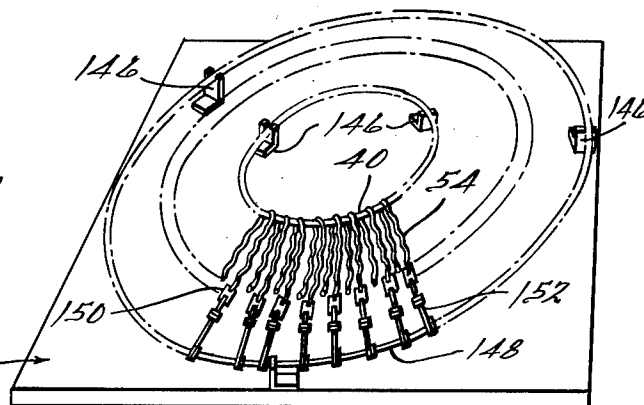


FIG. 17.

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3,256,644

REINFORCED SNAGGING WHEEL

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Filed Jan. 14, 1963, Ser. No. 251,228
11 Claims. (Cl. 51-206)

The present invention broadly relates to reinforced abrasive articles and more particularly to abrasive grinding wheels such as snagging wheels incorporating therein a unique reinforcing network which enables the wheel to be rotated at substantially higher peripheral speeds without a threat of fracture or disintegration of the abrasive wheel structure. The present application is related to a prior copending continuation-in-part application Serial No. 228,435, filed October 4, 1962, now Patent No. 3,123,948 entitled "Reinforced Grinding Wheel and Reinforcing Structure Therefor," which is based on a prior parent application Serial No. 78,171, filed December 23, 1960, now abandoned, both of which are assigned to the same assignee as the present invention.

Reinforced grinding wheels of the type to which the present and the aforementioned prior patent applications are directed are of a comparatively large size and are conventionally employed for snagging steel and the like. In a snagging operation, the grinding wheels are rotated at relatively high speeds and are usually employed without the use of any ancillary cooling fluids. Because of the relatively large size of such snagging wheels and the abusive heavy duty operating conditions to which they are subjected, a safety hazard is presented to operating personnel in the vicinity and to the grinding machine itself as a result of the fracture or disintegration on the snagging wheel. Usually, the progressive failure of a snagging wheel is first evidenced by the development of a plurality of radial cracks which extend inwardly from the periphery of the wheel resulting in a substantial reduction in the strength and integrity of the abrasive matrix. It has heretofore been customary, for this reason, to discard snagging wheels as soon as the development of such radial cracks are observed in spite of the fact that a wheel in such condition may nevertheless provide many additional days of satisfactory operation. In spite of this precaution, however, snagging wheels occasionally do break, sometimes resulting in serious injury to the operator as well as frequently causing serious physical damage to the grinding machine.

In order to increase the strength and to reduce the tendency of such snagging wheels to disintegrate, various reinforcing techniques have heretofore been used or proposed for use. These techniques include the embedding of metallic rings, fabrics of various compositions, haphazardly arranged textile and glass fibers, and short lengths of metal fibers known as metal wool in the abrasive material to increase the strength thereof. Almost invariably the various reinforcing elements heretofore employed in grinding wheels are spaced a substantial distance from the peripheral surface of the wheel to prevent their exposure at the grinding surface in order to avoid interference with the grinding action thereof. Typically, when reinforcing rings are employed, the rings are disposed contiguous to the hole or arbor through the center of the grinding wheel and the remaining portion of the wheel extending radially therefrom is unreinforced. As a result, radial cracks develop and move radially inwardly to a point adjacent to the outermost extension of the reinforcing network and thereafter move tangentially around the wheel which eventually results in segments of the outer unreinforced portion of the wheel to fly off during its operation. The resulting unbalance

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causes severe vibration and damage to the grinding machine coupled with eventual disintegration of the remaining portions of the abrasive material.

In the aforementioned prior patent application to which the present invention is related, a fiber glass reinforcing network of a prescribed cusped geometrical pattern is disclosed which affords substantially superior reinforcing characteristics of such snagging wheels without incurring any appreciable interference with the grinding action of the wheel. In accordance with the reinforcing network comprising the present invention, still further improvements in the strength of snagging wheels are attained enabling such wheels to be rotated at substantially higher speeds or alternatively enabling wheels incorporating the reinforcing network to be rotated at conventional peripheral speeds with a relatively minimal hazard of wheel fracture or disintegration.

It is accordingly a primary object of the present invention to provide an improved grinding wheel incorporating therein a reinforcing network which increases the strength thereof beyond that heretofore attainable by reinforcing techniques heretofore known.

Another object of the present invention is to provide an improved grinding wheel incorporating a reinforcing network embedded therein and which reinforcing network extends from a point contiguous to the hole or arbor through the grinding wheel to a point contiguous to the periphery thereof providing reinforcement for the entire abrasive body of the wheel and maintaining the integrity of the structure in spite of the formation of radial cracks therethrough.

Still another object of the present invention is to provide an improved grinding wheel incorporating therein a reinforcing network comprising a high strength ring disposed contiguous to the hole or arbor of the grinding wheel in combination with a high strength tempered steel wire network disposed and embedded in the annular portion of the wheel between the reinforcing ring and the periphery thereof which is oriented in a preselected pattern providing a high degree of reinforcement up to and including the grinding face of the wheel without interfering with the grinding efficiency thereof.

A further object of the present invention is to provide an improved snagging wheel whereby one or a plurality of the reinforcing networks or combinations thereof are appropriately positioned and oriented within the abrasive matrix comprising the grinding wheel so as to provide a rotatable abrasive article and particularly a snagging wheel which is of high strength, safe operation, excellent durability, excellent grinding efficiency and of economical manufacture.

The foregoing and other objects and advantages of the present invention are based on the discovery that the embedding of high strength tempered steel or steel alloy wires of a controlled size which preferably are of an irregularly shaped or crimped configuration and located in the region between the bore or arbor through a snagging wheel to a point on or contiguous to the peripheral grinding surface thereof and disposed in a generally radially oriented pattern provides for superior reinforcement for a minimal volume of total reinforcing material over the reinforcing networks of the types heretofore known while simultaneously avoiding any impairment in the snagging efficiency of the wheel. In accordance with the preferred forms of the present invention, the high strength wire network is mechanically interlocked at the inner ends thereof to one or more high strength reinforcing rings disposed contiguous to the arbor hole therethrough. It is also contemplated within the scope of the present invention that the reinforcing network can comprise combinations of the high strength steel wire sub-

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stituted in whole or in part by or interwoven with continuous fiber glass filaments forming a composite high strength cord or cable having surface irregularities therealong so as to provide for mechanical interlocking of the network within the abrasive matrix in which it is embedded. It is further contemplated that the steel wire and/or composite steel and fiber glass cord reinforcing network can be embedded singly or in the form a plurality of tiers or layers forming therewith an integrally bonded high strength snagging wheel.

Other objects and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a perspective view of a typical snagging wheel to which the present invention is applicable;

FIGURE 2 is a side elevational view partly in section of a snagging wheel incorporating one form of the reinforcing network therein;

FIGURE 3 is a side elevational view partly in section of an alternate satisfactory form of the reinforcing network shown in FIGURE 2;

FIGURE 4 is a side elevational view partly in section illustrating still another alternate satisfactory reinforcing network from that shown in FIGURES 2 and 3;

FIGURE 5 is a fragmentary transverse sectional view of the grinding wheel and reinforcing network shown in FIGURE 4 and taken along the lines 5—5 thereof;

FIGURE 6 is a fragmentary perspective view of an alternate satisfactory method or construction of securing the radially extending reinforcing elements to the inner circular rim;

FIGURE 7 is a fragmentary enlarged perspective view partly in section of a reinforcing ring comprising a plurality of loops of a high strength tempered steel wire in lieu of the reinforcing rings comprising a solid rod as shown in FIGURE 9;

FIGURE 8 is a side elevational view partly in section of a reinforcing network wherein the reinforcing loops are interwoven with and mechanically interlocked to the reinforcing ring;

FIGURE 9 is a transverse sectional view of the wheel and reinforcing network shown in FIGURE 8 and taken along the line 11—11 thereof;

FIGURE 10 is a side elevational view partly in section of a grinding wheel incorporating a reinforcing network therein constructed in accordance with still another alternate satisfactory embodiment of the present invention wherein a helically wound coil of reinforcement element is employed with the loops thereof disposed substantially parallel to the axis of rotation of the wheel and which are mechanically interlocked with a reinforcing ring around the hole or arbor through the wheel;

FIGURE 11 is a fragmentary transverse sectional view of the wheel shown in FIGURE 10 and taken along the line 11—11 thereof;

FIGURES 12 through 15 are fragmentary perspective views of typical alternate satisfactory wire configurations formed with surface irregularities along the length thereof so as to effect a mechanical interlock with the abrasive matrix in which they are embedded;

FIGURE 16 is a fragmentary enlarged perspective view partly in section illustrating a composite braided cable comprising continuous fiber glass rovings interwoven with continuous high strength tempered steel wires; and

FIGURE 17 is a perspective view of a jig employed for forming and resin bonding a reinforcing network of the type illustrated in FIGURE 2.

Referring now in detail to the drawings and with particular reference to FIGURES 1—15, a series of alternate satisfactory reinforcing members or networks are illustrated which, when embedded, either singly or in the form of a plurality of layers disposed in parallel spaced relationship provide for a substantial improvement in the

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strength of the grinding wheel. A typical heavy duty grinding or snagging wheel 30 is illustrated in FIGURE 1 having a cylindrical peripheral surface 32 comprising the grinding face thereof and which is formed with a bore or arbor 34 (FIGURE 2) extending axially through the center thereof for receiving a shaft 36 provided with clamping flanges 38 for rotatively supporting the wheel. The clamping flanges 38 overlie the side faces of the wheel 30 from a point conventionally extending from the hole or arbor 34 through the wheel to a point spaced outwardly therefrom ranging up to about one-third of the radial depth of the wheel. The radial depth of the wheel as herein used is defined as the distance measured along a radius between the surface of the arbor hole and the periphery of the wheel.

The region of the grinding wheel disposed between the hole or arbor through the wheel and a cylindrical surface spaced radially outwardly and concentrically therefrom a distance up to about one-third the radial depth of the wheel comprises a portion of maximum stress concentration within the abrasive wheel matrix as the result of the outward radial force imposed thereon by centrifugal force acting on the peripheral portions of the wheel. In accordance with the practice of the present invention, a circular reinforcing element such as a ring 40 illustrated in FIGURE 2, is embedded within the matrix of the wheel and disposed concentric to the bore 34 there-through and is of a diameter ranging between that of the cylindrical surface disposed approximately one-third the radial depth of the wheel outwardly from the bore to that approaching the diameter of the bore.

The stresses imposed on the grinding wheel matrix during high speed rotation thereof are not purely in a radial direction but include a tangential component as the result of the hoop stress created by the centrifugal forces acting on the wheel. The inner portion of the wheel adjacent to the arbor hole is subjected to a stress which is almost purely radial and upon movement radially outwardly therefrom, the resultant stress becomes progressively more tangential until the peripheral surface of the wheel is reached at which the stress pattern is exclusively in a tangential direction. This stress gradient is illustrated diagrammatically in FIGURE 3 wherein a radius indicated at 42 corresponds to a purely radial force acting on the grinding wheel matrix. It will be noted that at the inner portion of the wheel adjacent to circular reinforcing element, the stress is substantially purely radial, but that on radial movement outwardly along the radius 42 the direction of the resultant stress follows the stress lines indicated at 44 which sweep outwardly in an arcuate substantially parabolic curvature becoming tangent to the periphery of the wheel indicating the presence of a purely tangential stress. The magnitude of the stresses illustrated by the stress pattern will vary depending on the diameter of the arbor hole 44, the outside or peripheral diameter of the wheel, the density of the abrasive matrix comprising the wheel, as well as the speed of rotation of the wheel expressed either in revolutions per minute or, more conventionally, in terms of its peripheral speed expressed in units of surface feet per minute (s.f.p.m.).

In view of the reinforcement provided by the circular reinforcing element such as the ring 40 shown in FIGURE 2, the portion of the abrasive wheel disposed inwardly of the ring is subjected to a stress which is substantially purely tangential, whereas the stresses adjacent to the periphery of the ring are substantially purely radial. In order to reinforce the annular portion of the grinding wheel disposed radially outwardly of the ring 40, the reinforcing networks comprising the present invention embody a continuous or a plurality of reinforcing elements arranged in a substantially radially oriented pattern within the annular portion which can be mechanically interlocked to the circular reinforcing element and which extend radially outwardly therefrom to a point contiguous

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to the periphery of the wheel. In each case the reinforcing elements extend to a point such that the ends or end portions thereof become exposed at the grinding face as a result of the progressive wear of the peripheral surface 32 of the snagging wheel 30. It has been found that in spite of the exposure of these reinforcing elements at the grinding surface of the wheel, by controlling the configuration and disposition of these elements in accordance with the present invention, no significant impairment in the grinding efficiency of the wheel is encountered.

The circular reinforcing elements as well as the reinforcing elements disposed in the annular portion of the grinding wheel for the purposes of the present invention can comprise high strength steel rods and wires, a fiber glass cord or cable comprising a plurality of interwoven fiber glass rovings comprising a plurality of fine sized continuous fiber glass filaments, or interwoven combinations between the fiber glass cords or rovings and the high strength wire forming a composite reinforcing element.

The specific size and number of circular elements and reinforcing elements to be employed in a grinding wheel as well as the number of individual reinforcing networks embedded within the abrasive matrix of the wheel will vary depending on the material of which the reinforcing elements and circular elements are comprised as well as the characteristics of the abrasive matrix to be reinforced in addition to the intended rotative operating speed of the wheel. An exemplary mathematical analysis will subsequently be discussed for determining the appropriate reinforcement for a wheel of a given composition, size, and intended operating speed.

For the purposes of the present invention, the circular reinforcing element disposed adjacent to the arbor through the wheel and located in the region extending radially outwardly therefrom, up to one-third the radial depth of the wheel may comprise a high strength steel rod having the ends thereof rigidly united together such as by welding, for example. It has been found that rings made of a relatively soft steel which are conventionally employed for reinforcing grinding wheels, have an ultimate tensile strength in the order of about 70,000 p.s.i. The use of relatively soft steel rings necessitates the inclusion of an excessive quantity thereof. In order to satisfactorily reinforce wheels in accordance with the present invention enabling rotative speeds of up to about 24,000 s.f.p.m. to be attained, it is necessary to employ high strength steels having an ultimate tensile strength in the order of at least about 200,000 p.s.i. While such high strength steel rods can be satisfactorily employed for forming the circular reinforcing element, it has been found that the welding of the abutting ends of the ring does not provide a satisfactory high strength joint having a tensile strength corresponding to the remaining portions thereof and accordingly it is preferred when employing steel as the material for the circular element that a coil 45 comprising a plurality of wires 46 as shown in FIGURE 7 is used in lieu of an integral ring. By virtue of the use of a coil, hard drawn oil tempered steel wires, having an ultimate tensile strength of at least 200,000 p.s.i., can be wound in any desired number of turns to provide the requisite strength. The ends of the wire comprising the coil can be suitably mechanically interlocked to each other forming a ring having substantially uniform strength along the entire length thereof.

For the reinforcing elements disposed in the annular portion of the wheel and adapted to become exposed at the grinding surface thereof, steel wires of the type similar to that employed for forming the coil shown in FIGURE 7 can satisfactorily be employed. It has been found that in order to avoid any impairment in the grinding efficiency of the wheel as a result of the exposure of the end portions of the wire reinforcing elements at the grinding surface of the wheel, hard drawn oil tempered steel

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wires having a diameter ranging from about 0.030 inch to about 0.130 inch can be satisfactorily employed. Wires having a diameter or equivalent cross sectional area greater than circular wires of a diameter of about 0.130 inch have been found to introduce some difficulty in abrading or melting the ends thereof as they become exposed at the grinding face resulting in some impairment in the grinding efficiency of the wheel. On the other hand, wires of a diameter of less than about 0.030 inch, or irregularly shaped wires having an equivalent cross sectional area, have been found to possess insufficient individual load carrying capacity necessitating the inclusion of an extensive number thereof in the wheel to provide the requisite total reinforcement necessary. It is for this reason that the diameter of the wire employed for the reinforcing elements exposed at the periphery of the wheel should be controlled within a range of from about 0.030 to about 0.130 inch.

In lieu of or in combination with the steel reinforcing rings and/or steel wires hereinabove described, the circular reinforcing elements as well as the reinforcing elements extending through the annular portion of the grinding wheel may be comprised of a fiber glass cord or cable which comprises a plurality of interwoven or twisted rovings each of which in turn is comprised of a plurality of continuous fine sized fiber glass filaments. It has been shown that fine sized individual fiber glass filaments having a diameter of about 0.0002 inch have a tensile strength of about 450,000 p.s.i. Accordingly, fiber glass cables or cords made of a plurality of strands or rovings, each comprising a plurality of such filaments, have an extremely high tensile strength ranging from about 200,000 p.s.i. up to about 450,000 p.s.i. or conservatively, a net tensile strength of about 200,000 p.s.i. A composite fiber glass wire cord 48 is illustrated in FIGURE 16 comprising three fiber glass strands or rovings 50, each of which in turn is comprised of a plurality of continuous fiber glass filaments which are intertwined or braided together in combination with three high strength steel wires 52. In a composite cord or cable 48 of the type shown in FIGURE 16, either comprising only the fiber glass strands 50 without the steel wires 52 or including the steel wires therein, it is conventionally preferred to intertwine or braid the individual strands 50 together forming therewith a cord having an irregular surface contour which varies in cross sectional area so as to provide for an improved mechanical interlocking of the cable with the abrasive matrix of the grinding wheel in which it is embedded.

The number of fiber glass filaments comprising each strand 50 as well as the number of strands employed in the fiber glass cord can be varied consistent with the net desired tensile strength of the resultant cable. Similarly, the number and arrangement of the steel wires 52 intertwined with the fiber glass strands 50 can be varied from 0 to any desired number consistent with the resultant strength desired. It will be appreciated, however, that as hereinabove set forth, when a composite cord 48 of the type shown in FIGURE 16 is employed as a reinforcing element which is adapted to be exposed at the grinding surface of the wheel, considerations of the diameter of the wire and the number employed must be made so as to avoid any impairment in the resultant grinding efficiency of the wheel. Fiber glass cords comprising exclusively a plurality of the strands 50 or a composite cord 48, as shown in FIGURE 16, are eminently satisfactory for use in forming the circular reinforcing members or rings disposed adjacent to the arbor of the wheel.

A series of typical satisfactory reinforcing networks which can be satisfactorily employed individually, in multiples or in combinations thereof, are illustrated in FIGURES 2-11. As shown in FIGURE 2, a reinforcing network is illustrated comprising the circular reinforcing element or ring 40 which is disposed concentric to the bore 34 through the snagging wheel 30 and around which a plu-

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ality of U-shaped reinforcing elements 54 are mechanically interlocked and extend radially therefrom to a point contiguous to the periphery 32 of the wheel. The reinforcing elements 54 are affixed at substantially equal arcuate increments around the ring 40 and the leg portions thereof are formed with an irregularly shaped surface contour to facilitate mechanical engagement with the abrasive matrix of the grinding wheel.

An alternate satisfactory arrangement of the reinforcing network is illustrated in FIGURE 3, wherein each leg 56 of a U-shaped reinforcing element 58 mechanically interlocked to a ring 57, extends radially and arcuately outwardly in opposite directions in a path of curvature corresponding substantially to the resultant stress lines 44 as indicated in dotted lines in FIGURE 3. Each leg 56 of the reinforcing elements 58 are similarly provided with an irregularly shaped surface contour to facilitate mechanical interlock within the abrasive matrix of the wheel.

Another alternate satisfactory embodiment of a reinforcing network is illustrated in FIGURES 4 and 5 comprising a rim 60 which is formed with a plurality of perforations 62 therethrough as best seen in FIGURE 5, through which radially extending reinforcing elements 64 extend and are mechanically interlocked to the rim such as by an enlarged head 66 formed on the inner end portions thereof. The rim 60 is positioned concentric to the bore 34 through the grinding wheel 30 and is spaced therefrom a distance sufficient to provide inward radial clearance of the enlarged heads 66.

A similar alternate satisfactory construction is fragmentarily illustrated in FIGURE 6, wherein a rim 68 having a plurality of perforations 70 is mechanically interlocked to a plurality of radially extending U-shaped reinforcing elements 72 disposed with the bight portion thereof overlying the inner surface of the rim.

Another alternate satisfactory arrangement is illustrated in FIGURES 8 and 9 wherein a continuous reinforcing element 78 formed with a plurality of overlapping loops disposed in a plane substantially perpendicular to the axis of rotation of the wheel 30, is mechanically interwoven and interlocked at its inner ends with a ring 80 disposed concentric to the bore 34 through the center of the wheel. The overlapping of the loops of the reinforcing element 78 is best seen in FIGURE 9 wherein a typical arrangement is shown of a grinding wheel 30 employing a pair of reinforcing networks in appropriate axially spaced substantially parallel relationship. It will further be noted in accordance with FIGURES 8 and 9, that the individual loops comprising the reinforcing elements 78 vary in size so as to stagger the progressive break-through of the outermost portions of the reinforcing elements during the progressive wear of the periphery 32 of the grinding wheel.

Still another alternate satisfactory reinforcing network is illustrated in FIGURES 10 and 11 which comprises a ring 82 disposed concentric to the bore 34 through the center of the grinding wheel 30 and a spirally wound continuous reinforcing element 84 comprising a plurality of angularly offset loops which are disposed in substantially equal angular increments and extend radially within the annular portion of the grinding wheel. Each of the loops formed by the reinforcing element 84 is disposed in a plane extending substantially transversely of the side faces of the grinding wheel and in a direction substantially parallel to the axis of rotation of the wheel. Each of the spiral loops can be of a substantially circular configuration or of an elliptical configuration as illustrated in FIGURE 11. The inner portions of each loop of the reinforcing elements 84 preferably underlie the surface of the ring 82 forming a mechanical interlock therewith and project radially outwardly therefrom to points variably spaced from the peripheral surface 32 of the grinding wheel 30.

In order to provide for the mechanical interlocking 75

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of the reinforcing elements within the abrasive matrix comprising the grinding wheel, the reinforcing elements are formed with suitable surface irregularities therealong providing for variations in their cross sectional area so as to mechanically engage the body of the grinding wheel supplementing the adhesive attachment between the reinforcing elements and the abrasive matrix. When the reinforcing elements are comprised exclusively of a fiber glass cable or of a composite cable such as the cable 48 shown in FIGURE 16, the individual strands of the cable or cord are braided or interwoven in a manner so as to form surface irregularities therealong. When the reinforcing elements are comprised of a high strength hard drawn tempered steel wire, appropriate surface irregularities can be achieved by deforming the wire in a manner as illustrated in FIGURES 12-15.

A circular wire 88 is illustrated in FIGURE 12 which is formed with a plurality of undulations therein enhancing mechanical engagement of the wire within the abrasive matrix and preventing separation thereof and slippage of the wheel body relative to the reinforcing element. Similarly, a wire 89 is illustrated in FIGURE 13 which is formed with a crimped configuration which also enhances mechanical engagement of the reinforcing element with the abrasive matrix. An alternate satisfactory wire configuration is illustrated in FIGURE 14 wherein segments of a wire 90 are alternately deformed providing therewith sections 92 of an elliptical cross section separated by and integrally connected to sections 94 of a circular cross section. It is also contemplated that wires of an irregular cross section such as the substantially flat configuration of a crimped wire 96 illustrated in FIGURE 15 can be satisfactorily employed.

The specific arrangement, size and number of reinforcing elements employed, as well as the number of reinforcing networks used for reinforcing a grinding wheel matrix can be accurately approximated in accordance with the following mathematical analysis: In computing the quantity of reinforcement necessary, the calculations ignore the inherent strength of the abrasive matrix itself which conventionally can be estimated to withstand a stress of about 6000 p.s.i. Accordingly, the values mathematically determined are conservative and provide a safety factor. The cross sectional area of a circular reinforcing element or ring or a plurality of such rings required to withstand the tensile stress imposed on the wheel during high speed rotation thereof, can be calculated in accordance with the following equation:

$$F=1.25 \times 10^{-6} b d r V^2 (1-a^3)$$

wherein:

F =the force in pounds

b =the width of the wheel in inches

d =the specific gravity of the wheel

V =the peripheral speed of the wheel (s.f.p.m.)

r =the outside radius of the wheel in inches

a =the ratio of the radius of the internal hole in the wheel to the radius of the periphery of the wheel.

For a typical snagging wheel having an external diameter of 24 inches, an internal hole or arbor having a diameter of 12 inches, a thickness or width of 3 inches, a specific gravity of 3 grams per cubic centimeter, the bursting forces imposed on a wheel rotating at different peripheral speeds is listed in the following table:

Peripheral speed (s.f.p.m.):	Bursting force, lb.
12,000 -----	17,000
15,000 -----	26,500
18,000 -----	38,000
24,000 -----	68,000

Since high strength tempered steel wires or rods of the type hereinbefore described, as well as fiber glass cords or cables made from a plurality of interwoven strands or rovings, each comprising a plurality of continuous fiber

glass filaments, can withstand a tensile stress of at least about 200,000 p.s.i., one or a plurality of circular reinforcing elements such as the rings or rims illustrated in FIGURES 2-11 either of a fiber glass, composite wire and fiber glass, or wire or coil of wires reinforcing elements having a total cross sectional area of about .17 square inch would be adequate to hold a cracked wheel together at 24,000 s.f.p.m. Accordingly, it has been found that three coils 45 of the type shown in FIGURE 7, each comprising 23 turns of a high strength tempered wire having a diameter of 0.080 inch, are satisfactory to hold a cracked wheel of the foregoing dimensions together to at least 25,000 s.f.p.m.

It can also be mathematically shown that the stresses imposed on a grinding wheel through centrifugal forces increase progressively on moving in a radial direction inwardly from the periphery toward the center of the wheel. This can be determined by calculating the force acting on each segment of the wheel bounded by two radii extending out from the center of the wheel and disposed 1 inch apart at the peripheral surface thereof. The force acting on each segment can be calculated by using the following equation which is similar to that previously employed but omitting therefrom the outside radius *r* of the wheel.

$$F=1.25 \times 10^{-6} b d V^2 (1-a^3)$$

For a wheel of the same dimensions and composition as previously described, the number of reinforcing elements required in the annular portion of the wheel beyond the circular reinforcing element or ring can be calculated employing the foregoing formula. For example, in determining the number of U-shaped reinforcing elements 54 required when employing a reinforcing network of the type illustrated in FIGURE 2, let it be assumed that the elements comprised a steel wire having a diameter of 0.031 inch having an ultimate tensile strength of 200,000 p.s.i. and 250,000 p.s.i. respectively. The results are given in the following table for different peripheral speeds of the wheel which provide satisfactory reinforcement of the abrasive matrix.

Peripheral Speed (s.f.p.m.)	Number of U-shaped Reinforcing Elements Required	
	(200,000 p.s.i.)	(250,000 p.s.i.)
12,000	163	142
15,000	255	221
18,000	365	316
24,000	650	567

Hard drawn tempered steel wires as well as fiber glass cords or cables are available having ultimate tensile strengths of 200,000 p.s.i. By employing fiber glass cables, steel wires, or composite interwoven fiber glass and wire cables having a tensile strength of 250,000 p.s.i., a corresponding decrease in the total number of reinforcing elements required at each of the peripheral speeds listed in the table, is achieved.

The foregoing mathematical approach can be readily applied to each of the specific geometrical configurations of the reinforcing networks hereinbefore shown and described in order to arrive at a network which is adequate for reinforcing a specific size wheel of a specific composition at its intended operating speed. The reinforcement as hereinbefore mentioned may comprise a plurality of one specific type of reinforcing network or alternate layers of different reinforcing networks disposed in spaced substantially parallel relationship.

The reinforcing networks of the types shown in FIGURES 2-11 can conveniently be formed into an integrally united network by employing a forming jig of the type illustrated in FIGURE 17. The forming jig as illustrated, comprises a base 144 provided with a plurality of brackets 146 which are formed with slots in the upper edges there-

of for receiving the inner circular reinforcing ring 40 of a reinforcing network of the type illustrated in FIGURE 2 and an exterior ring 148 on which a plurality of clamps 150 are resiliently mounted by springs 152. The appropriate number of U-shaped reinforcing elements 54 are mechanically interlocked such as by wrapping or twisting around the reinforcing ring 40 and are extended radially outwardly therefrom having the ends thereof securely held by the clamps 150 in appropriate radially projecting relationship. The reinforcing elements 54 and the reinforcing ring 40 can thereafter be sprayed or brushed with a suitable adhesive securely attaching the reinforcing element to the ring forming therewith a unitary reinforcing network which can be simply handled and be positioned in the mold for forming the grinding wheel. Adhesives suitable for this purpose are well known in the art and can comprise bonding agents such as epoxy, polyester, and phenolic resins, for example. Alternatively, the points of contact between the reinforcing element 54 and the ring 40 can be rigidly secured to each other by means of tack welding, brazing, soldering and the like, as desired.

The resultant reinforcing network or networks of the desired configuration either in a rigidified or non-rigidified condition can be readily incorporated within the body of the abrasive grinding wheel by any one of a number of techniques well known in the art such as cold pressing, hot pressing, and preferably by a casting method as set forth in U.S. Patent No. 2,860,961 and assigned to the same assignee as the present invention. The displacement casting method as disclosed in the aforementioned patent has the advantage of not requiring excessive pressures for forming the preliminary abrasive article and also avoids deformation and possible injury to the reinforcing networks as a result of the substantially high pressures required in the hot and cold pressing methods.

Conventionally, the grinding wheel incorporating one or a plurality of the reinforcing networks therein comprises from about 40% to about 64% by volume of suitable abrasive grains and from about 36% to about 60% by volume of a bonding material including various amounts of resins, fillers, plasticizers, the reinforcing network, pores and other additives. The improved reinforcing characteristics of a grinding wheel as a result of the reinforcing networks comprising the present invention are obtained regardless of the particular type of any one of the conventional abrasive grains, binder resins, fillers, etc. that are employed. The abrasive grains may comprise any of the types well known in the art including silicon carbide, boron carbide, tantalum carbide, tungsten carbide, or other hard metal carbides; alumina, diamond grains, glass, quartz, garnet, etc. In addition, any of the conventional filler materials such as powdered cryolite feldspar, iron oxide, and others which are inert or which improve cutting efficiency can be satisfactorily employed. When a bonding composition employing furfuraldehyde is employed, it is usually preferred to include lime as a filler material.

Binding agents which can be satisfactorily employed for forming the abrasive matrix of the grinding wheel include thermosetting type resins which are heat hardenable or convertible into a hard strong bond. These resins include phenol aldehyde resins, cresol aldehyde resins, resorcinol aldehyde resins, urea aldehyde resins, melamine formaldehyde resins, furfuryl alcohol resins, and the like, as well as mixtures thereof. Of the foregoing binding agents the condensation product of phenol itself with formaldehyde constitutes the preferred bonding agent.

In the hot or cold pressing techniques for making grinding wheels, the abrasive particles are conventionally coated with a suitable resin such as phenol aldehyde A-stage resin either in a powdered or liquid form in addition to the desired quantities of filler materials, plasticizers, etc. The resultant coated abrasive particles are disposed around a reinforcing network and are cold

pressed under a pressure of at least about 2 to 3 tons per square inch and thereafter the preliminary formed grinding wheel is cured at an elevated temperature. Alternatively, the mixture can be heated to an elevated temperature and thereafter is hot pressed providing partial curing of the resin in the mold followed thereafter by a final curing step.

In accordance with the displacement method disclosed in the aforementioned patent a differential pressure is created to cause substantially complete penetration and filling of the abrasive grain layer in which the reinforcing network is embedded which may comprise applying a differential pressure across the layer of bond material and abrasive grains or alternatively utilizing centrifugal force.

While it will be apparent that the preferred embodiments herein illustrated are well calculated to fulfill the objects above stated, it will be appreciated that the invention is susceptible to modification, variation, and change without departing from the proper scope or fair meaning of the subjoined claims.

What is claimed is:

1. A reinforced grinding wheel comprising abrasive grains, a bonding agent, and a reinforcing network embedded therein, said network comprising a circular element disposed in spaced substantially concentric relationship to the periphery of said wheel and a plurality of reinforcing elements disposed in a generally radially oriented pattern and positioned in the annular portion defined between said circular element and the periphery of said wheel, said reinforcing elements interconnected at their inner ends to said circular element and extending therefrom to a point contiguous to the periphery of said wheel, said circular element and said reinforcing elements consisting of a material of high tensile strength, said circular element of a cross sectional area substantially greater than the cross sectional area of each individual reinforcing element, and the tensile breaking load of said circular element and the combined tensile breaking load of said reinforcing elements each being of a magnitude at least equal to the tensile force developed in the body of said grinding wheel during rotation thereof.

2. A reinforced grinding wheel comprising abrasive grains, a bonding agent, and a reinforcing network embedded therein, said network comprising a circular element disposed in spaced substantially concentric relationship to the periphery of said wheel, and a plurality of reinforcing elements formed with an irregular surface contour disposed in a generally radially oriented pattern and positioned in the annular portion between said circular element and the periphery of said wheel, said reinforcing elements mechanically interlocked along their inner portions to said circular element and extending therefrom to a point contiguous to the periphery of said wheel, said circular element and said reinforcing elements consisting of a material of high tensile strength, said circular element of a cross sectional area substantially greater than the cross sectional area of each individual reinforcing element, and the tensile breaking load of said circular element and the combined tensile breaking load of said reinforcing elements each being of a magnitude at least equal to the tensile force developed in the body of said grinding wheel during rotation thereof.

3. A reinforced grinding wheel comprising abrasive grains, a bonding agent, and at least one reinforcing network embedded therein, said network comprises a ring disposed in spaced substantially concentric relationship to the periphery of said wheel, and a plurality of U-shaped reinforcing elements formed with an irregular surface contour mechanically interlocked at their bight portion to said ring and extending therefrom in substantially equal angular increments in a generally radially oriented pattern to a point contiguous to the periphery of said wheel, said ring and said reinforcing elements consisting

of a material of high tensile strength, said ring of a cross sectional area substantially greater than the cross sectional area of each individual reinforcing element, and the tensile breaking load of said ring and the combined tensile breaking load of said reinforcing elements each being of a magnitude at least equal to the tensile force developed in the body of said grinding wheel during rotation thereof.

4. The grinding wheel described in claim 3 wherein said ring comprises a coil of a plurality of high strength steel wire each having an ultimate tensile strength of at least about 200,000 p.s.i. and having a cross sectional area equivalent to a circular wire of a diameter ranging from about 0.030 to about 0.130 inch.

5. The grinding wheel described in claim 3 wherein said reinforcing elements are tenaciously adhered to said ring forming an integral network.

6. The grinding wheel described in claim 3 wherein said reinforcing elements comprise crimped high strength steel wire having a cross sectional area equivalent to a circular wire of a diameter ranging from about 0.030 to about 0.130 inch and an ultimate tensile strength of at least about 200,000 p.s.i.

7. The grinding wheel as described in claim 3 wherein said reinforcing elements comprise a fiber glass cord comprising a plurality of braided fiber glass rovings each of which comprises a plurality of fine sized continuous fiber glass filaments.

8. The grinding wheel described in claim 3 wherein the legs of said U-shaped reinforcing element extend radially outwardly in a substantially parabolic arcuate curvature in opposite directions approaching tangency with the periphery of said wheel.

9. A reinforced grinding wheel comprising abrasive grains, a bonding agent, and a reinforcing network embedded therein, said network comprising a circular steel rim disposed in spaced substantially concentric relationship to the periphery of said wheel and formed with a plurality of perforations therethrough, and a plurality of reinforcing elements formed with an irregular surface contour extending through said perforations and mechanically interlocked to said rim and extending therefrom outwardly in a generally radial pattern contiguous to the periphery of said wheel, said reinforcing elements consisting of a material of high tensile strength, said rim of a cross sectional area substantially greater than the cross sectional area of each individual reinforcing element, and the tensile breaking load of said rim and the combined tensile breaking load of said reinforcing elements each being of a magnitude at least equal to the tensile force developed in the body of said grinding wheel during rotation thereof.

10. A reinforced grinding wheel comprising abrasive grains, a bonding agent, and at least one reinforcing network embedded therein, said network comprising a high strength circular element disposed in spaced substantially concentric relationship to the periphery of said wheel, and a continuous reinforcing element formed with an irregular surface contour and comprising a plurality of overlapping loops disposed substantially in a plane perpendicular to the axis of rotation of said wheel and located in the annular portion between said circular element and extending contiguous to the periphery of said wheel, the inner portions of the loops of said continuous reinforcing element mechanically interlocked with said circular element, said circular element and said reinforcing element consisting of a material of high tensile strength, said circular element of a cross sectional area substantially greater than the cross sectional area of said continuous reinforcing element, and the tensile breaking load of said circular element and the combined tensile breaking load of said loops of said continuous reinforcing element, each being of a magnitude at least equal to the tensile force developed in the body of said grinding wheel during rotation thereof.

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11. A reinforced grinding wheel comprising abrasive grains, a bonding agent, and a reinforcing network embedded therein, said network comprising a circular element disposed in spaced substantially concentric relationship to the periphery of said wheel, and a reinforcing element formed with an irregular surface contour and wound in a spirally shaped configuration comprising a plurality of loops arranged wherein the plane of said loops are disposed substantially transversely to the plane of rotation of said wheel, said spirally shaped reinforcing element positioned in the annular portion between said circular element and extending contiguous to the periphery of said wheel, the inner portions of said loops of said spiral-shaped reinforcing element interlocked with said circular element, said circular element and said spirally-shaped reinforcing element consisting of a material of high tensile strength, said circular element of a cross sectional area substantially greater than the cross sectional area of said reinforcing element, and the tensile breaking load of said circular element and the combined tensile breaking load of said loops of said spirally-shaped

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reinforcing element as being of a magnitude at least equal to the tensile force developed in the body of said grinding wheel during rotation thereof.

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