

March 31, 1959

W. J. RANKIN ET AL

2,880,080

REINFORCED ABRASIVE ARTICLES AND INTERMEDIATE PRODUCTS

Filed Nov. 7, 1955

FIG. 1

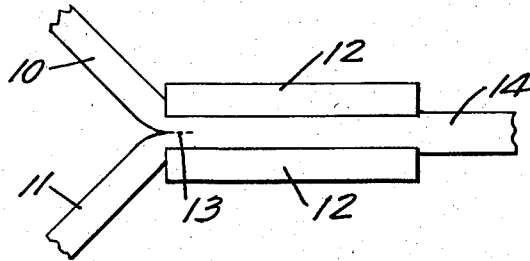


FIG. 2

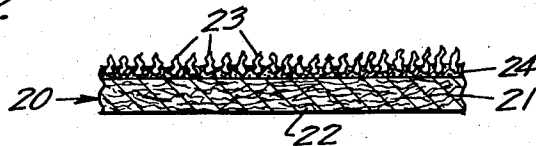
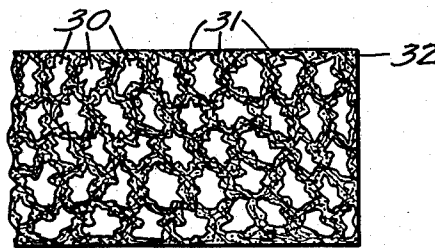


FIG. 3



INVENTORS
WALTER JAMES RANKIN
BARRY F. TUNGSETH
BY
Carpenter, Abbott, Coulter & Kinney
ATTORNEYS

1

2,880,080

REINFORCED ABRASIVE ARTICLES AND INTERMEDIATE PRODUCTS

Walter James Rankin and Barry F. Tungseth, St. Paul, Minn., assignors to Minnesota Mining & Manufacturing Company, St. Paul, Minn., a corporation of Delaware

Application November 7, 1955, Serial No. 545,193

11 Claims. (Cl. 51-297)

The present invention relates generally to reinforced resinous sheet materials. More particularly our invention relates to heavy-duty warp-resistant flexibly internally reinforced resinous coated abrasive sheet backing and abrasive articles formed therewith, rigid molded internally reinforced abrasive disc-wheels, and intermediate products produced in the manufacture of such articles.

It is often desirable, especially in heavy-duty abrading operations where high abrading pressures and stresses are encountered, to employ abrasive articles which have been strengthened with reinforcing materials. In coated abrasive sheets of this nature, the reinforcing material is generally contained internally of the backing sheet in the form of a mat or cloth embedded within a resinous plastic matrix or as an additional layer attached to the backing sheet and coextensive therewith. Abrasive disc-wheels of the type utilized as cut-off wheels or in portable abrading operations, which contain abrasive grains distributed throughout the body of the article, have been similarly reinforced. Without such reinforcing, such abrasive articles are incapable of withstanding the physical strain and stress to which they are continually subjected during heavy-duty abrading operations.

The proper selection of materials from which reinforced abrasive sheets and disc-wheels are to be manufactured has been a difficult problem in the abrasives industry. Greater uniformity in the resulting reinforced articles is attained with the use of reinforcing in handleable web form. However, materials which are readily woven or felted into a mat or cloth have heretofore had various disadvantages. For instance, cotton threads, sisal fibers, hemp fibers, jute fibers and similar materials can be felted into strong webs by air-laying. The webs can be impregnated with hardening resins and form strong sheets. However, such reinforcing materials absorb water and swell upon being subjected to moisture, causing the sheets to warp or ripple severely, or in the case of the coated abrasive disc to curl undesirably. Curled or warped edges catch and scar the workpiece or become torn. Warped abrasive disc-wheels become out of round and hence become imbalanced and difficult to handle or manipulate in operation. Since abrasive articles are often used in the presence of water in wet abrading operations and also are often stored for extended periods under humid conditions, reinforced abrasive sheets and disc-wheels which are so affected are unsatisfactory.

That abrasive discs employing moisture-swelling materials have not been entirely suited for use in wet abrading operations or storage under conditions of high humidity is evidenced by the many prior art patents which have attempted to solve the problem of moisture-effected curling in abrasive discs in various ways, such as by treating the non-abrasive surface of the article with a waterproof impregnant or covering in an effort to decrease or eliminate moisture absorption.

The suggestion has also been made of reinforcing abrasive disc backing and disc-wheels with high strength ma-

2

terials such as strands of glass fibers, which are not deleteriously affected by moisture.

Long glass strands are necessary to the formation of a handleable woven or non-woven reinforcing web where no binder resin is employed. In self-supporting mats formed of long strands, whether of a woven or non-woven nature, the general planes of the strands are parallel with that of the mat. Lamination of several layers of mat with subsequent resin impregnation and pressing serves only to squeeze the layers closely together. Little or no physical interconnection between the several adjacent layers results. Hence, homogeneity of strength across the several layers is never attained, as attested by the fact that structural failure occurs by delamination when the articles are subjected to ultimate flexural strength tests. Short glass strands or bundles exhibit notoriously poor felting characteristics. In fact, it is virtually impossible to form a mat or fabric of glass bundles without the use of a unifying binder material.

Handleable mats or webs may be formed from bundles of short glass fibers with the use of a small amount of binder resins; but uniformity of strength across a structure of several layers thereof is still not attained. The bundles lie flat in planes nearly parallel with the plane of the web. Thus when a plurality of the webs are laminated, little or no physical interlocking of fibers occurs to extinguish the weaker interface. The reinforcing material is always present as separate distinguishable layers.

A further disadvantage of resinous abrasive sheet backings reinforced entirely with fibrous glass material is that anchorage of abrasive grains bonded with an abrasive binder to the resinous abrasive disc backing is not sufficiently great to withstand heavy-duty abrading operations. The grains are rather easily stripped or shelled from the sheet by reason of delamination of the matrix resin from the reinforcing fibers adjacent the abrasive coating. Accordingly, the abrasive characteristics of such abrasive articles are deficient.

It is therefore an object of the present invention to provide a preformed handleable reinforcing material which, when impregnated and embedded within a hardened resinous matrix, renders the resulting articles high in strength but warp, curl and wrinkle resistant. It is a further object to provide reinforced sheet articles, notably abrasive sheets, discs and disc-wheels, which, although employing initially a plurality of layers of the reinforcing material, are homogeneous both in structure and in strength throughout the reinforced portion. It is a further object to attain the aforementioned objects while providing a reinforced abrasive sheet backing to which abrasive grains may be securely and lastingly bonded. It is a further object of the present invention to employ easily obtainable inexpensive components such as glass and cotton fibers and threads in our reinforcing material without encountering the disadvantages in the use thereof known to the prior art. Other objects and advantages of our invention will be apparent upon the reading of the specification and appended claims.

Combination of cotton and glass would be expected to provide sheets having intermediate properties of strength and warp resistance. Instead, by employing these and similar materials in the manner hereinafter set forth, there is obtained a handleable mat which when impregnated and embedded within a hardened resinous matrix has high strength, as good warp, wrinkle and curl resistance as the glass mat alone, and in addition shows no ply separation or lack of grain adhesion.

The present invention provides uniformly reinforced resinous articles having the desired properties of high strength, warp, wrinkle and curl resistance, stability under changes in humidity, resistance to delamination or flexing, as well as methods of making such articles,

In accordance with the principles of the invention, reinforcing is accomplished with a preformed felted fibrous mat which is self-supporting and may be impregnated with resins, and which is comprised of a substantial proportion of short impregnation resistant multiple-fiber cotton threads in combination with short glass filaments in the form of polymer-encased bundles of parallel filaments. The bundles of glass filaments, which are not themselves feltable, are held in mat form and supported in random orientation by the cotton thread segments. The mat is substantially non-laminar and uniform throughout its thickness. After a plurality of mat layers have been placed in superposition, pressed together and impregnated with suitable resins, the mat provides a high reinforcing and strengthening action. Delamination and warping are avoided. The reinforced resinous sheet provides a superior backing material for abrasive coated sheet products and molded abrasive disc-wheels, and has other uses and advantages.

In the accompanying drawings:

Figure 1 is a schematic sectional view showing effect of lamination under pressure of two layers of our novel reinforcing mat;

Figure 2 is a sectional view of a portion of a surface-coated abrasive sheet formed in accordance with the principles of the present invention; and

Figure 3 is a sectional view of a portion of an abrasive disc-wheel hereof.

In manufacturing the novel abrasive articles hereof, whether they be of the nature of coated abrasive sheets or discs or rigid abrasive disc-wheels, a handleable self-supporting fibrous reinforcing mat is first formed. This reinforcing mat, being self-supporting, is conveniently subjected to subsequent impregnating and/or coating operations designed according to the type of abrasive article to be formed.

As indicated in Figure 1, when a plurality of layers 10 and 11 of our reinforcing mat is placed between platens 12 under pressure and between carrier liners (not shown), not only is evidence of the former interface 13 of the contacting surfaces between adjacent layers removed but the identities of the several layers within the combined mat 14 cannot be restored by removing the pressure and attempting to peel the former layers back. This unique feature results from the interlocking characteristics of the mat components at the layer surfaces which mutually penetrate into adjacent layers and establish mechanical adhesion therewith. Thus, multiple layer reinforced articles cannot delaminate at layer interfaces, the existence of the interfaces having been completely removed during formation. As a result, the articles may be flexed, compressed or pulled apart under tensile stresses to the point of structural failure without delamination or indication of weakness at the former mat layer interfaces.

In making a reinforced backing sheet for surface-coated abrasive articles of the nature of sandpaper, the fibrous web is impregnated or filled with a liquid resinous material which is then hardened, preferably while the sheet is held under pressure. Single layers or multiple layers of the fibrous web may be employed. The resin, which is liquid at the temperature employed, is in amount sufficient to completely fill the voids between the threads and filament bundles. A strong, flexible, warp-resistant sheet results. To one or both sides of this sheet backing are applied the abrasive grains in a manner well known to the art, by coating the surface to which the abrasive grains are to be applied with a bonding adhesive, applying abrasive grains over the coating while the latter is in a tacky condition, and curing the adhesive to securely bond the grains to the backing.

The resulting abrasive structure is seen upon reference to Figure 2. The sheet backing 20 here consists of two layers of our preformed reinforcing mat 21 substantially surrounded by and embedded within the hard-

ened matrix resin 22. As indicated in the drawing, the two layers become indistinguishable in the completed backing. The many abrasive grains 23 are securely bonded to the sheet by means of the hardened adhesive bonding coat 24. If desired, a sizing coat of abrasive bonding adhesive may be applied over the abrasive-coated surface.

In abrasive disc-wheels, a molded structure is formed in which the abrasive grains are distributed internally throughout the reinforcing material and binder resin of the composite structure. The abrasive disc-wheels hereof may be manufactured by interspersing abrasive grains and matrix resin in a close fitting mold between several superposed layers of our reinforcing mat which have been previously cut or stamped to the desired shape. Pressure is applied to the mold contents whereby the abrasive grains become uniformly distributed amongst the reinforcing threads and filament bundles, and the matrix resin is then hardened.

Referring to Figure 3, the disc-wheel structure is seen to be comprised of abrasive grains 30 uniformly distributed throughout the fibrous components of several layers of the preformed reinforcing mat 31, the entire structure being unified by the hardened matrix resin 32 which substantially completely impregnates the reinforcing material and surrounds the abrasive grains.

Although the short glass fiber bundles of themselves are incapable of forming a self-supporting web without addition of a binder resin, we have found that they will readily form a uniform self-supporting mat when used in conjunction with a substantial amount of short fibrous components which of themselves are feltable. With reasonably careful handling, the glass fiber bundles are retained within the mat. Further, we have found that the moisture-swelling cotton threads may constitute up to approximately four-fifths of the total weight of reinforcing material in the hardened resin-impregnated backing material while still avoiding warping, rippling, or other deleterious moisture-effected deformation even upon repeated prolonged immersion in water and subsequent drying. This is a surprising result, particularly in view of the observed fact that a structure reinforced with an identically formed mat composed entirely of the moisture-swelling feltable threads becomes badly warped and rippled merely upon storage under humid conditions. These significant features are seen to be of high import upon consideration of the previously mentioned disadvantages of warping in abrasive articles.

We have found that the presence of the cotton in our reinforcing mat increases resistance to stripping or shelling of abrasive grains from the backing of the sheet materially over that of prior art sheets wherein the backing sheets employ glass fiber reinforcing entirely. For example, to obtain abrasive grain adhesion in the latter approximating that of our reinforced sheet backing, it is necessary to bond a substantially continuous surface, such as a layer of print cloth or cheesecloth, intermediate the surface of the backing sheet and the abrasive binder coat.

Having now generally described our invention, we will more specifically describe preferred embodiments of our reinforcing mat and procedures for making the same and by specific non-limitative examples illustrate the uses therefor.

FORMATION OF THE REINFORCING MAT

A web of untwisted or lightly twisted glass filament yarns drawn from a warp beam containing approximately 720 glass strands each containing about 204 individual loosely twisted filaments was led through aligning condensing combs and with the yarns in parallel aligned relation through a set of squeeze rolls where a rubbery butadiene-acrylonitrile copolymer latex dispersion in water of 30 percent solids by weight was applied at a dry coating

5

weight of 8-12 grams per hundred grams of glass. The aligned strands were then led over 200° F. hot cans protectively wrapped with cheesecloth, to unify the deposited rubbery particles into a non-tacky continuous protective sheath. The strands were then fed into a chopper where they were cut into bundles averaging about 1¼ inch in length. The sizing was seen upon microscopic examination to completely encase the bundles of fibers in a sheath of the rubbery copolymer and substantially completely impregnate the yarn and surround each individual filament.

A quantity of hard-cut (starch-sized) tightly twisted multiple-fiber cotton threads obtained as waste product from the cotton industry were similarly chopped to lengths averaging about 1¼ inch and intermixed with the sized glass fiber bundles in a tumbling blender at a ratio of 65 percent sized glass to 35 percent cotton by weight.

The blend was then felted into a random air-laid handleable self-supporting mat in a dry felting machine. In the present example, the felting apparatus employed was of a type sold by the Curlator Corporation under the trade name of "Rando-Webber." In that machine blended threads and bundles were evenly and uniformly distributed on a traveling belt which fed the material under a rotating knurled steel squeezing roll which pressed the components into a random uniform loosely formed non-handleable mat. The mat was then picked up by a traveling belt and fed into a venturi, through which a stream of air was rapidly passing. The threads and bundles in their blended relation were picked up by and suspended in the rapidly moving air and driven onto a relatively large rotating condensing roll which contained fine perforations through which the air was withdrawn from the suspension while filtering out the bundles and threads in the form of a handleable self-supporting mat. The formed web was then fed onto a liner and rolled up therewith for storage and subsequent use.

The resulting mat was uniform in relative distribution of threads and bundles. It had an uncompressed thickness of about ¼ inch and a weight of about 21 grams per square foot. The weight and density may be controlled as desired, within limits, by controlling the air velocity through the venturi, the rate of material feed, the speed of rotation of the condensing roll, etc. While our reinforcing mat was wound into storage rolls on a liner to prevent adjacent layers from becoming non-separably interconnected and interlocked, it was self-supporting and could be handled and lifted from the liner and cut or stamped into various desired shapes without substantial loss of bundles or threads and without breaking up or pulling apart.

Other film-forming materials may be employed in sizing the strands of glass filaments. The selection of the sizing material is, we have found, dictated principally by three factors, all of which relate to the matrix resin to be employed. Firstly, in order to permit the glass fibers of the bundles to exhibit the desired high degree of reinforcing characteristics, while imparting flexibility to the sheet, the sizing must be film-forming and substantially softer than the matrix resin. Thus, the embrittling matrix resin will not impregnate the bundles and the glass fibers are permitted to move within the sheath of sizing material relative to one another in response to stresses transmitted from the harder matrix resin, without displacement of the latter. Secondly, the sizing material should not be incompatible with the selected plastic matrix resin to the extent that there is no, or only a poor, adhesive bond formed therebetween. Lack of adhesion between sizing and matrix resin causes a decrease of flexural strength of the article as a result of the vulnerability to separation at the matrix resin sizing interface. Thirdly, where a heat-advancing or thermosetting resin is employed as the resinous matrix resin, the sizing should not decompose at the temperature at which the matrix resin is to be cured. Examples of other suitable sizing materials which

6

meet these several requirements include polyester and epoxide resins, natural and synthetic rubbers and other similar film-forming materials selected so as to be adhesively compatible with the matrix resin to be employed.

In the preceding example the rubbery sizing polymer was employed in an amount sufficient to substantially fully impregnate the glass fiber bundles as well as to substantially completely encase or ensheath the same. We have found it to be quite necessary that the bundles be at least substantially completely encased within a sheath of sizing material so as to maintain the unity of the strands after they are chopped into bundles and to prevent any substantial embrittling impregnation of the bundles by the matrix resin when the mat is later embedded therewithin.

The individual fibers of the bundles are thereby permitted to move relative to one another within bundles without displacement of resin when stresses are applied to the sheet. Thus a high degree of flexibility and resilience is attained.

We have devised a simple test whereby the sufficiency of the amount of sizing material applied to the strands prior to the chopping thereof into short bundles may be tested. After being sized, a sample strand of the sized glass is grasped between the hands. The hands are then pulled apart in the direction of the length of the strand, thus subjecting the individual monofiber filaments of the strand to tensile stresses, until the strand is broken. The degree of separation of the filaments at the broken ends of the strand (fibrillation) depends upon the amount and sufficiency of the sizing material present. If the strand has been properly sized, substantially no fibrillation will occur at the broken ends. On the other hand, should the sizing be inadequate, the individual filaments will separate along the strand and branch out at the broken ends in a sort of umbrella shape. We have found that if the fiber separation along the strands does not exceed a length of about ¼ inch sufficient bundle unity will be maintained during subsequent operations to provide a mat which is self-supporting and which when saturated with resin will provide a uniform flexible sheet. The test described applies to whatever material is employed as a sizing agent.

It is also necessary that the cotton likewise function as a group of fibers, rather than as individual fibers in our reinforced sheet to impart flexibility to the reinforced sheet material. Thus the matrix resin must be prevented from impregnating the threads to any substantial degree, similarly as in the case of the glass bundles. In the case of the chopped thread segments employed in the preceding example, the tight twist of the several fibers in the thread effectively prevents impregnation. The starch sizing used prevents the thread fibers from separating during the chopping operation and formation of the mat. We have successfully formed our mat using tightly twisted unsized cotton threads (soft-cut) with suitable results, although the resulting articles were seen to be somewhat less flexible due to fiber separation in some of the threads.

Where a loosely twisted thread is to be used a sizing of starch is inadequate. It is then necessary to size the threads in a manner similar to that of the glass strands in order to insure maintenance of the thread integrity and render the thread segments resistant to impregnation by the matrix resin. The selection of the sizing material is governed by the same requirements as above set forth for the glass component.

Although in the preceding description the length of the cotton threads and of the glass bundles was approximately 1¼ inch, it is to be understood that the lengths of either or both may vary somewhat from this. We have found, however, that a uniform reinforcing mat becomes increasingly difficult to form as the average length of either the bundles of glass fibers or the cotton threads approaches and exceeds about 2½ inches. Fur-

ther, the components of such a mat, being longer, tend to lay flatter, i.e., more parallel with the plane of the web, and thus homogeneity of strength across the thickness of a multi-layer reinforcing web is more difficult to attain.

On the other hand, where the average length of the glass bundles and/or the cotton threads is less than about $\frac{3}{4}$ of an inch, it is difficult to form a self-sustaining handleable mat. Thus, fabrication of reinforced articles therewith is correspondingly more difficult. Further, the flexibility of an article reinforced with such short lengths decreases, presumably due to tendency of the shorter fibers to function more as a filler than as reinforcing.

The ratio of the bundles of the glass fibers to the moisture-swellaible feltable threads may be varied widely within the scope of the present invention. The effect of such variation will be observed in the specific examples which follow. However, we have found that where less than about 20 percent by weight of the mat consists of the feltable threads, it is no longer possible to obtain a handleable self-supporting mat wherein substantially no loss of threads or bundles occurs during reasonably careful handling. Hence a substantial portion, at least about one-fifth by weight, of our reinforcing mat must consist of the moisture-swellaible feltable component. However, as will be hereinafter shown, at least about one-fifth of the reinforcing mat by weight must consist of the glass bundles in order to preserve the warp-resistance of the reinforced sheet.

Example 1

	Parts by weight
Polyester resin A (a solution, in 30 parts by weight of styrene monomer, of 70 parts of a polyester of stoichiometrically equivalent amounts of propylene glycol and a mixture of 4 mols of maleic anhydride and phthalic anhydride), e.g., Rohm & Haas Corp. "Paraplex P-43" -----	56
Polyester resin B (a solution, in 50 parts by weight of styrene monomer, of 50 parts of a polyester of stoichiometrically equivalent amounts of propylene glycol and a mixture of 1 mol of maleic anhydride and 4 mols of sebacic acid), e.g., Rohm & Haas Corp. "Paraplex P-13" -----	14
Styrene monomer -----	10
Benzoyl peroxide -----	1.4
Maleic anhydride -----	7
Powdered CaCO_3 filler -----	20

The polyester resins were initially blended. The benzoyl peroxide accelerator dissolved in the 10 parts styrene was added to the blend and intimately mixed therein. The solid maleic anhydride and filler were then separately stirred into the mixture.

Several sections of reinforcing mat containing ratios by weight of short sized glass-fiber bundles to hard-cut cotton thread segments of 80:20, 65:35, 30:70, 20:80, 10:90 and 0:100 were prepared on the "Rando-Webber" as hereinbefore described. The weight of the "65:35" mat, formed as previously described, was 21 grams per square foot. This weight determined the machine settings for the remaining mat sections, the weight of these varying slightly, due to the different proportions of components. It was found that a self-supporting web with mixtures containing less than about 20 percent of the cotton thread segments could not be successfully formed.

The mat sections were saturated and impregnated with the thermosetting polyester base resin matrix material and cured, the procedure being as follows: Two layers of the reinforcing mat were placed in superposed relation on a thin cellophane carrier sheet. The viscous polyester base resin was then poured over the mat sections at a coating weight of 63 grams per square foot. A second sheet of cellophane was placed over the impregnated mat and the entire structure was placed in a heated press of the platen type for three minutes where-

in the resin was cured to a hard firm state at a temperature of 220° F. and at a pressure of 33 pounds per square inch. The press was opened and the structure allowed to cool, at which time the cellophane sheets were stripped therefrom. The resulting cured reinforced resinous sheets had a thickness of 32-33 mils.

From each of the several sheets so prepared was cut one inch wide test strips. Samples of each type were tested under dry conditions for stiffness and tensile strength. Stiffness was determined on a standard Tabor stiffness tester (the stiffness being recorded in the units of force required to bend a one inch wide sample 15 degrees) and similarly for stiffness after immersion in water. The amount of warping or rippling, if any, was also visually observed after immersion. The results of the tests are seen from the following table:

TABLE

Ratio, glass/cotton	Scott Tensile (lb./in.)	Tabor stiffness (units)	After water immersion 30 hrs.	
			Tabor stiffness (units)	Warp
80:20-----	430	1,080	1,100	None.
65:35-----	375	1,050	985	None.
30:70-----	275	1,080	752	None.
20:80-----	245	1,060	650	None.
10:90-----	230	1,080	560	Rippled.
0:100-----	200	1,040	505	Rippled.

The tensile strength and stiffness (both before and after immersion) of the structures reinforced varied approximately with the ratio of sized glass bundles to cotton thread segments. However, although structures whose reinforcing contained 90 percent and 100 percent of cotton threads warped or rippled noticeably after immersion in water, the sheet containing 80 percent of the moisture-swellaible cotton did not warp or ripple appreciably. No warping whatsoever was apparent from any of the samples containing less than 80 percent cotton threads.

Upon microscopic inspection of edges of sample reinforced structures of the present example, which had been purposely torn, no evidence of a laminar type structure was seen. The non-laminar character of the torn edges signified that the strength of the sheet was substantially uniform across the entire thickness thereof.

Example 2

From each of the reinforced resinous sheets of the previous example were die-cut disc shapes to serve as abrasive disc backings. One surface of each of the backing discs was roughened slightly with a grit 120 abrasive sheet until reinforcing fibers were exposed. To the roughened surfaces of the discs was applied a coating of phenol-aldehyde resin abrasive binder. Abrasive grains were then distributed on the binder coated surfaces while the binder was in an uncured tacky state. The binder was then cured and a phenol-aldehyde resin sandsize coat was applied to the abrasive coated surfaces and cured.

The improved abrasive coated disc structures thus obtained were employed in weld removal operations on automobile doors. Those in which the reinforcing contained a substantial proportion of glass were tough and flexible and highly suited for edge grinding in crevices and corners without being torn or broken up. No delamination occurred. Moreover, those discs formed from the non-warping sheet backing of Example 1, i.e., those containing reinforcing comprised of at least about one-fifth by weight of sized glass bundles, were employed in wet abrading operations for the entire abrading life of the discs without any sign of becoming warped or curled or otherwise deleteriously affected by the moisture.

The reinforced resinous sheets were also coated on both surfaces to form improved light-duty non-warping

cutoff wheels. These were found to be highly satisfactory in all respects, e.g., rate of cut, disc-life, toughness, etc. Significantly, as the abrasive grains at the cutting edges were worn away through use, the bared backing sheets then were quickly ground away. Thus, as the edges slowly receded, fresh abrading edges were continuously provided.

We have found that abrasive grain adhesion to the disc backing is materially improved by roughening the surface of the backing to which the grains are to be applied. This serves to remove any thin film of unreacted resin matrix material present on the surface, as well as to expose reinforcing fibers at the surface, permitting a superior anchorage of the abrasive binder to the backing surface.

Example 3

	Parts by weight
Liquid epoxide resin (the reaction product of bisphenol A and epichlorohydrin; epoxy number approximately 192 grams per epoxide equivalent and hydroxy number approximately 80 grams per hydroxyl equivalent) -----	20
Liquid phenol-formaldehyde resin having a phenol to formaldehyde mol ratio of 1:2 -----	50
Diethylene triamine accelerator -----	3.5

The epoxide resin, presently marketed by the Bakelite Company under the tradename "Bakelite BR-18774," and the phenol-formaldehyde resin were intimately mixed and to such mixture was added the accelerator. The resulting liquid mixture, having a suitable pot life of approximately 20 minutes at normal room temperature, was immediately formed into a 28 mil thick continuous film on a polyethylene treated paper carrier and permitted to gel. Two layers of our reinforcing mat, prepared as hereinbefore described and having a sized glass fiber bundle to cotton ratio of 65:35, were next laid on the stable gelled film and a layer of cellophane placed thereover. The structure finally was placed in the laminating press and subjected to a temperature of 220° F. at a pressure of 33 pounds per square inch for about six minutes. Upon subjection to the heat and pressure of the press, the resin film flowed about and saturated the reinforcing mat and then cured to a hard firm state. The press was then opened and the sheet removed and permitted to cool, after which time the carrier sheets were stripped from the reinforced structure.

The resulting abrasive backing sheet was then coated with abrasive binder, abrasive grains and sandsize adhesive, as previously described. From the coated sheet were stamped several abrasive discs.

The properties of the discs of the present example were found to be substantially equivalent to those employing the aforesaid backing having a polyester resin base. Thus excellent heavy-duty abrasive discs having superior abrading characteristics were obtained. No curling or warping occurred upon prolonged storage under high humidity conditions or upon immersion in water, although the discs became somewhat less flexible upon aging for extended periods.

The ratio of phenolic to epoxide resin of the present example may be varied within wide ranges and still provide satisfactory abrasive sheet backing. Either of the two resins of the present example, or resins equivalent thereto, may be employed without the other.

Example 4

An abrasive disc was formed utilizing two layers of our reinforcing mat with the polyester base resin of Example 1, with the exception that 5 percent by weight of the polyester resins therein were replaced with a rubbery butadiene-acrylonitrile copolymer in a solution of 58 percent solids, the solvent being acetone. The sheet backing was then cured and coated with abrasive, as above described.

The coated abrasive article of the present example was seen to be fully equivalent to, but somewhat more flexible than, the identical structure not containing the copolymer. It was therefore particularly suitable for abrading operations where the workpiece contained crevices, irregularly shaped corners and other difficultly accessible surfaces.

Although in each of the preceding examples the structures described contained two layers of our reinforcing mat, it is apparent that reinforced articles may be similarly formed which contain less or more than this number. Where a thicker, tougher, less flexible article is desired several layers are employed, the flexibility generally decreasing and toughness and rigidity increasing with the use of additional layers.

Our reinforcing mat is also readily adapted to be employed in the continuous formation of reinforced sheet material. For example, the reinforcing mat may be directed from the mat forming machine onto a suitable carrier liner, such as cellophane, and thereon led under a resin addition station where liquid matrix resin is added in the desired amount. A second liner is then placed over the upper exposed surface of the saturated mat and the composite is continuously led through an oven and squeezed under pressure between opposed traveling belts, supported by a series of opposed rollers while the resin is hardened. The formed sheet and liners are then led from the oven and cooled under cooling sprays, after which the liners are continuously stripped from the surfaces of the sheet and separately wound in rolls for re-use while the resulting sheet material is similarly wound for storage.

When the reinforcing mat hereof is impregnated with resinous materials which are stable solids at one temperature and yet which are heat-curable, unique abrasive sheet backing results. This sheet material may be coated with abrasive grains and binder in flat sheet form on conventional coating equipment and later permanently formed into non-planer abrasive sheet articles, e.g., dome-shaped (concavo-convex) abrasive discs, roll cover sheets, etc., which find considerable use in the abrasive industry.

An example of such a backing material is formed by impregnating one or more layers of our mat material with the phenolic-epoxide resin composition of Example 3 during the initial liquid stage of the composition, and forming a sheet as above described. The pressing of the sheet is carried out at room temperature and continued until the resin composition has gelled to a tack-free solid state. The resulting stable heat-curable reinforced sheet material is then coated with abrasive binder after which abrasive grains are applied. However, the binder is not fully heat-cured. It is only solvent dried until tack-free under conditions insufficient to cure the resin of the backing sheet. Similarly, if desired, a sandsize coating is applied and solvent dried without being cured. Abrasive articles of desired size and configuration are then prior to use, molded under heat and pressure to the desired permanent shape, during which the resin of the backing sheet is fully cured. The abrasive binder and sandsize coats are simultaneously finally cured. During the molding and curing, it has been found desirable to place a layer of relatively soft material, such as drills cloth, between the abrasive surface of the article and the mold wall to prevent abrasive grains from being impressed into the backing sheet during the softening stage of the backing sheet resin.

As will readily be appreciated, the structure which we employ for our abrasive backing sheet containing one or more layers of our reinforcing mat has many other uses as well. These uses particularly extend to those in which a strong economical non-warping moisture-resistant sheet is desired. For example, our sheet materials are highly suitable as high dielectric electrical panels, suitcase paneling, table tops and other panel type reinforced structures where one or more of the characteristics of our sheet is

11

desirable. The stable heat-curable sheet materials above described are particularly advantageous for such uses in that they are readily molded and cured into irregular shapes.

Examples 1-4 have described the use of our reinforcing mat in abrasive sheet backing and products made therefrom. Where a reinforced rigid molded abrasive disc-wheel is desired, our novel reinforcing mat is equally suitable. The following examples will specifically illustrate the same:

Example 5

	Grams
Triallyl cyanurate monomer -----	56
Polyester resin A of Example 1 -----	56
Calcium carbonate filler -----	48
Grit 24 abrasive grains -----	220
Benzoyl peroxide -----	2.2

The reinforcing mat of the present example consisted of our sized glass fiber bundles and hard-cut cotton threads in a ratio of 60:40 by weight. Since abrasive grains are internally distributed within a molded disc-wheel, we prefer to employ a very lightweight reinforcing mat in order to facilitate distribution of the grains throughout the structure. Here the "Rando-Webber" control settings were adjusted such that the mat weight was 9 grams per square foot. From the resulting mat were cut discs weighing 4.2 grams, having a diameter of 7 inches and a center hole of $\frac{3}{8}$ inch diameter.

The monomer and polyester resin were intimately blended together and the filler and the benzoyl peroxide were separately added and mixed therein.

One layer of the preformed reinforcing mat disc was laid in a cylindrical mold having a diameter of 7 inches and a $\frac{3}{8}$ inch center port. Thereon was uniformly sprinkled 37.8 grams, or one-sixth, of the abrasive grains, the grains having been previously surface treated with a slurry of ceramic clay and dried at approximately 150° C. below the incipient fusion point of said clay. One-sixth of the resin mixture was then poured over the mat. A second layer was then placed within the mold in superposed position in the mold, and 37.8 grams of abrasive grains and an additional one-sixth of the resin added. The process was repeated until six layers of reinforcing mat had been placed in position and treated. A closure fitting adapted to cooperate with the mold and compress the contents was then inserted into the mold. The mold was placed in a heated hydraulic press and subjected to a pressure of 200 pounds per square inch at a temperature of 220° F. for ten minutes. The press was opened, the mold removed and allowed to cool, and the abrasive disc-wheel structure was removed. The disc-wheel was then given an additional post-cure without a mold for twenty hours at 300° F.

The resulting disc-wheel structure, having a diameter of 7 inches, a thickness of $\frac{1}{4}$ inch, and a center hole diameter of $\frac{3}{8}$ inch, was seen to demonstrate excellent abrasive qualities in all respects when employed in heavy-duty edge-grinding operations. Not only was the cured polyester modified triallyl cyanurate resin found to have all the requisite qualities of a good abrasive binder, e. g., toughness, excellent adhesion to abrasive grains, etc., but these characteristics were retained even under the high temperatures encountered in heavy-duty, high-pressure abrading operations. This latter feature was aided by the high temperature softening point (about 500° F.) of the binder resin employed. In portable abrading operations the disc-wheel was extremely smooth running and thus imparted a fine finish to the abraded workpiece.

No warping or wrinkling was observed in abrasive disc-wheels formed as described in the present example and reinforced with a mat containing up to about 80 percent of cotton after immersion in water for over forty-eight hours or after storage under highly humid conditions for over one year.

12

Example 6

The viscosity of highly fluid triallyl cyanurate monomer was increased by adding one part benzoyl peroxide to 200 parts of the monomer and heating the mixture to a temperature of 140° F. The mixture was constantly stirred under these conditions for approximately forty hours until the homopolymerization had increased the viscosity of the resin to a stage (approximately 3,000 centipoises) where the resin would not flow from the impregnated reinforcing mat during subsequent pressing operations. To 112 grams of the resulting viscous resin was added an additional 1.7 grams of benzoyl peroxide which was stirred therein. This resin binder material was then employed in the formation of a disc-wheel structure as described in Example 5. In this instance, however, the post-cure was thirty hours at 300° F.

The abrasive characteristics of the resulting disc-wheel were seen to be superior, in grain adhesion and high rate of stock removal under the extreme conditions of heavy-duty abrading operations, to that of the preceding example. This was attributable, at least in part, to the high heat softening point (530° F.) of the triallyl cyanurate polymer resin matrix employed. However, when employed in portable abrading operations, the disc-wheel of the present example tended to exhibit rougher running characteristics than the disc-wheel of the preceding example wherein the triallyl cyanurate resin was modified with a portion of polyester resin.

Upon being subjected to highly humid conditions and immersion in water for extended periods of time, the abrasive structure of the present example showed no tendency to warp, ripple or otherwise be adversely affected by moisture.

Not only may the triallyl cyanurate resin be modified by polyester resins in wide ranges, but other ethylenically unsaturated compounds may be employed as well. For example, highly satisfactory smooth-running abrasive disc-wheels have been prepared employing up to about 75 percent of monomeric styrene with the triallyl cyanurate monomer, the resin being cured in the presence of a peroxide or other equivalent accelerator.

Although other thermosetting resins are known which have high temperature softening points approximating those of cured triallyl cyanurate based resins, e. g., cured phenolic resins, applicants know of none which in addition provide the necessary moldability, soft chatterless running properties which are essential in manually operated portable operations, rigidity without brittleness, and other desired qualities. However, we have found it to be necessary that the triallyl cyanurate based resin be reinforced in abrasive disc-wheels before the described performance characteristics are attained.

Thus we have found that by forming abrasive disc-wheels employing a cured triallyl cyanurate resin reinforced with our novel reinforcing mat, abrasive disc-wheels are provided which have an abrading quality unequalled in prior art abrasive disc-wheels. That the combination disc-wheel is highly durable is shown by the fact that in merely attempting to dress down the edges of six disc-wheels of the type described in Example 5, two resinoid phenolic grinding wheels and one shellac grinding wheel were worn down, and one ceramic vitrified wheel was broken. However the same disc-wheels were extremely smooth running when employed in portable weld removal operations.

Example 7

	Grams
Epoxy resin ("Bakelite BR-18774") -----	67
Phenol-formaldehyde resin of Example 4 -----	67
Diethylene triamine accelerator -----	7
Grit 24 aluminum oxide abrasive grains -----	220

The two liquid resin components were mixed and to the mixture was added the accelerator. The resulting viscous matrix resin, which had a useful pot life of about 10-15

minutes at room temperature before gelling, was employed with layers of our reinforcing mat in the formation of an abrasive disc-wheel in the manner described in Example 5, the grains having a surface treatment as there described. The article was cured in the mold under 200 pounds per square inch pressure at 220° F. for 30 minutes and then post-cured without the mold for 20 hours at 210° F.

The resulting abrasive structure was adversely affected in no way upon subjection to high humidity and immersion in water. Although highly satisfactory for most portable grinding operations, the disc-wheel of the present example was somewhat less satisfactory under heavy-duty abrading operations at high abrasive pressures than triallyl cyanurate resin based disc-wheels (due presumably to the somewhat lower softening temperature of the resin matrix binder employed). However, the running characteristics were seen to be excellent, there being no tendency on the part of the structure to chatter when utilized in the abrasion of mild steels and weld joints.

Example 8

A disc-wheel structure was prepared according to Example 5 with the exception that the entire 112 grams of binder resin consisted of the polyester resin A there employed. The reinforcing mat used contained a ratio of sized glass fiber bundles to cotton threads of 30:70 by weight.

The abrasive grain distribution in the structure appeared to be slightly less uniform than that obtained in structures wherein the reinforcing mat contained a somewhat higher proportion of glass. This was due to the somewhat fluffier less dense characteristics of the reinforcing mat as a result of the higher percentage of lower density cotton employed.

The disc structure was highly satisfactory for light-duty abrading operations. However, upon being employed in heavy-duty operations where the frictional heat evolved was high, it became unsuitable due to decreased grain adhesion. This reduced adhesion at elevated temperatures was attributed in part to the softening at these temperatures of the matrix resin, the softening point thereof being about 250° F., more than 150 degrees lower than that of the cured triallyl cyanurate based resins employed in previous examples.

In the foregoing descriptions the abrasive disc-wheels hereof were formed by first stamping the reinforcing mat to the desired shape and then fabricating the abrasive article. It is apparent that the disc-wheels may also be manufactured by forming the structure in continuous sheets and subsequently stamping out the desired disc-wheel shaped articles therefrom. Although adhesion to the abrasive grains in the abrasive articles hereof is promoted by employing grains which have been surface treated (such as is disclosed in preceding examples), such treatments are not considered absolutely essential, the abrasive articles being useful, though somewhat less effective, when untreated abrasive grains are employed.

Inert fillers and/or extenders may be utilized in our disc-wheels or resin sheets in place of a portion of matrix binder. Other binder resins with or without the addition of fillers are suitable as the matrix resin in our novel reinforced articles. For example, acrylic and methacrylic polymers, vinyl chloride polymers, polyamides, copolymers of vinyl chloride and vinyl acetate and equivalents of these are suitable for use as the matrix resin in forming the reinforced sheet articles hereof. They are, however, somewhat less suitable in our abrasive disc-wheels than the triallyl cyanurate based matrix binders.

The weight of resin to be employed in impregnating and saturating a given weight of our reinforcing mat will vary somewhat with the particular resin chosen and the relative amount (volume) of abrasive grains, fillers or extenders, if any, employed. The resin content is just sufficient to substantially completely impregnate and satu-

rate the reinforcing mat without overflowing the same. Should a lesser amount of resin be used, some of the reinforcing threads and bundles are not surrounded by the matrix resin, leaving them free to rub against and shear one another, and not permitting them to exhibit their reinforcing qualities. On the other hand an excess of binder matrix, over that necessary to completely saturate the mat, will flow and be difficult to distribute uniformly over the structure and thus non-uniform thickness will result.

The use of abrasive structures employing our reinforcing mat in abrading operations necessarily results in some consumption or wearing down of the reinforced portion of the article. Reinforcing fibers are among the abrasive waste accruing during abrading operations. However, it is to be noted that even though our reinforcing mat contains a large proportion of glass fibers, we have found that substantially no irritating glass dust particles are present within the abrasive refuse, or in the surrounding air. The reason for this is felt to be because the bundle nature of the sized fibers is maintained even after the sheet material has been consumed, since upon microscopic examination of grindings from abrading operations much of the glass content was found to be in substantially unaltered bundle form.

Herein has been described a novel preformed handleable economical reinforcing mat and articles reinforced therewith which are strong, delamination-resistant and highly warp-resistant, even though containing a substantial proportion of moisture-swellaable fibers. The embodiments described are intended to be merely illustrative of our invention and accordingly we intend to be limited only by the scope of the appended claims.

What is claimed is as follows:

1. A self-supporting felted mat suitable for impregnation with a hardenable liquid resinous matrix resin in providing a strong reinforced warp-resistant resinous sheet material, said mat comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by weight of short moisture-swellaable impregnation resistant cotton thread segments.
2. A reinforced resinous sheet material comprising at least one layer of a preformed handleable self-supporting reinforcing mat substantially completely embedded within and surrounded by a solid water-resistant resinous matrix, said mat comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by weight of short moisture-swellaable impregnation resistant cotton thread segments.
3. A reinforced abrasive article comprising at least one layer of a preformed self-supporting felted reinforcing mat, abrasive grains uniformly associated with said mat and solid waterproof resinous binder material unifying said article, said mat being comprised of a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by weight of short moisture-swellaable impregnation resistant cotton thread segments.
4. An abrasive coated sheet material comprising: a backing including at least one layer of a preformed handleable self-supporting compressed reinforcing mat substantially completely embedded within and surrounded by a solid resinous matrix, said mat comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by

weight of short moisture-swella-ble impregnation resistant cotton thread segments; and abrasive grains adherently bonded to at least one surface of said backing by means of a water-resistant binder for bonding said grains.

5. A tough strong flexible highly warp-resistant coated abrasive sheet comprising: a backing including at least one layer of a preformed handleable self-supporting compressed reinforcing mat substantially completely embedded within and surrounded by a cured resinous matrix, said mat comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by weight of short moisture-swella-ble impregnation resistant cotton thread segments, said polymer sheath being substantially softer than said cured resinous matrix; and abrasive grains adherently bonded to at least one surface of said backing by means of a water-resistant binder for bonding said grains.

6. A tough strong highly warp-resistant homogeneous abrasive disc-wheel comprising abrasive grains uniformly distributed throughout at least one layer of a preformed handleable self-supporting compressed reinforcing mat, said grains and mat being substantially completely embedded within a cured resinous matrix binder, said mat comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by weight of short moisture-swella-ble impregnation resistant cotton thread segments, said polymer sheath being substantially softer than said cured resinous matrix binder.

7. A tough strong highly warp-resistant homogeneous abrasive disc-wheel comprising abrasive grains uniformly distributed throughout at least one layer of a preformed handleable self-supporting compressed reinforcing mat, said grains and mat being substantially completely embedded within a cured triallyl cyanurate based resinous matrix binder, said mat comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by weight of short moisture-swella-ble impregnation resistant cotton thread segments, said polymer sheath being substantially softer than said cured matrix binder.

8. A reinforced resinous sheet material including at least one layer of a preformed handleable self-supporting reinforcing mat substantially completely embedded within a solid water-resistant resinous matrix, said mat

comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by weight of moisture-swella-ble impregnation-resistant cotton thread segments, said polymer-encased bundles and segments being individually surrounded without substantial penetration by said resinous matrix.

9. A reinforced abrasive article comprising at least one layer of a preformed self-supporting felted reinforcing mat, abrasive grains uniformly associated with said mat and solid waterproof resinous binder material unifying said article, said mat being comprised of a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers encased in a sheath of flexible film-forming polymer and correspondingly 80-20 percent by weight of short moisture-swella-ble impregnation resistant cotton thread segments, said polymer sheath being resistant to liquid resin penetration with the fibers in each bundle upon flexure of said article being movable relative to one another.

10. A self-supporting felted mat suitable for impregnation with a hardenable liquid resinous matrix resin in providing a strong reinforced warp-resistant resinous sheet material, said mat comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of rubbery film-forming polymer and correspondingly 80-20 percent by weight of short moisture-swella-ble impregnation resistant cotton thread segments.

11. A self-supporting felted mat suitable for impregnation with a hardenable liquid resinous matrix resin in providing a strong reinforced warp-resistant resinous sheet material, said mat comprising a randomly oriented uniform mixture of 20-80 percent by weight of short bundles of aligned glass fibers substantially completely encased in a sheath of rubbery butadiene-acrylonitrile copolymer and correspondingly 80-20 percent by weight of short moisture-swella-ble impregnation resistant cotton thread segments.

References Cited in the file of this patent

UNITED STATES PATENTS

2,284,716	Benner et al.	June 2, 1942
2,356,866	Melton et al.	Aug. 29, 1944
2,682,735	Buckner	July 6, 1954
2,703,765	Osdal	Mar. 8, 1955
2,711,365	Price	June 21, 1955
2,779,668	Daniels	Jan. 29, 1957