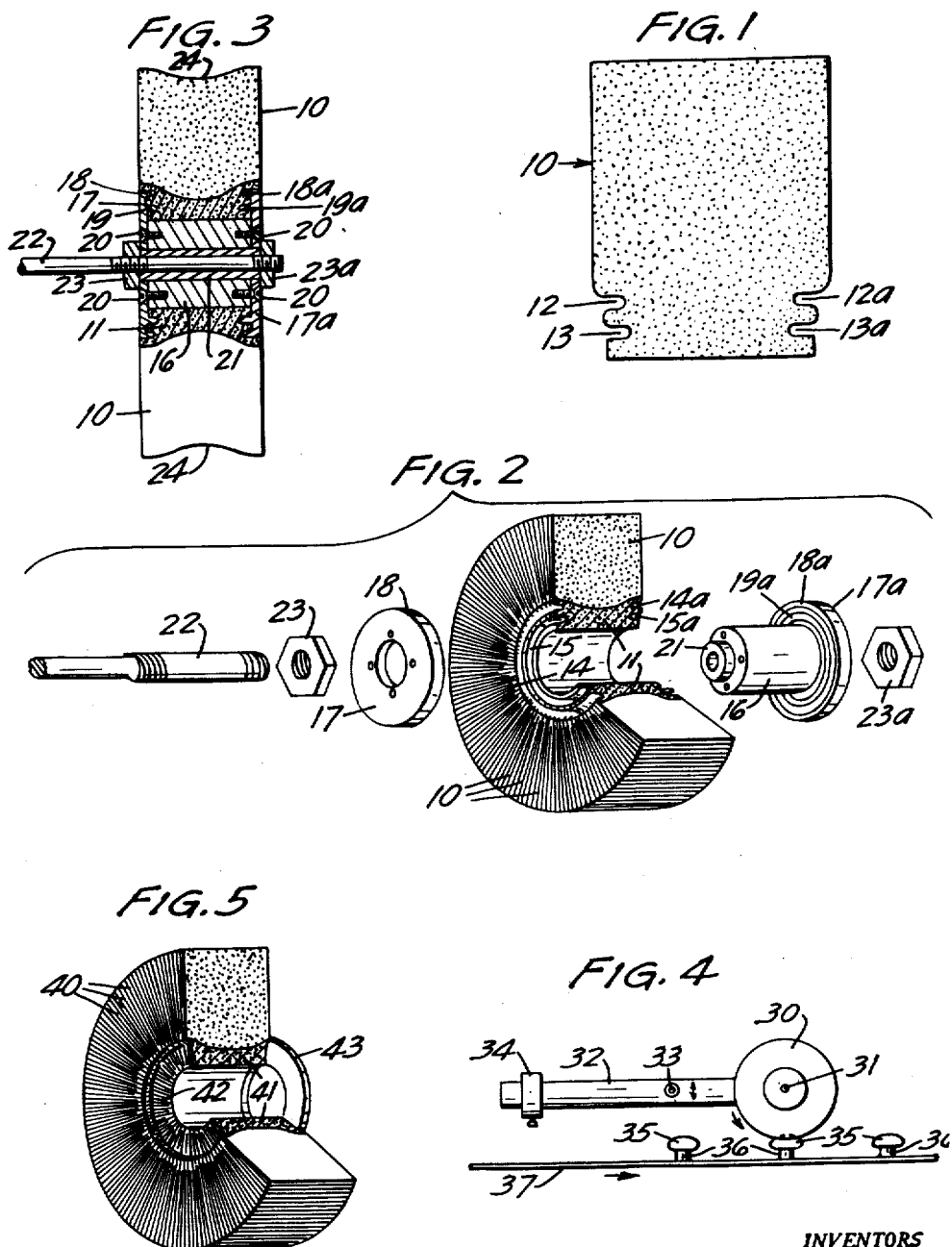


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METHODS OF MAKING NON-RIGID ROTATIVE
ABRASIVE STRUCTURES
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2,843,469

METHODS OF MAKING NON-RIGID ROTATIVE ABRASIVE STRUCTURES

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3 Claims. (Cl. 51—297)

The present invention relates to new and improved rotative abrasive structures comprised of an annulus of radially extending juxtaposed flat sections of abrasive sheet material, to methods of manufacturing the same and to novel methods by which these structures are employed in abrading and finishing operations. This application is a division of our copending application Serial No. 545,390, filed November 7, 1955 and now abandoned.

In the grinding and finishing of metal articles of curved or irregularly shaped surfaces, such as automobile accessories, preparatory to the plating or painting thereof, several different abrasive articles and procedures have heretofore been employed. For example, abrasive set-up wheels, abrasive belts and sisal buffs have all been used. Of these, the first named has seen widest use. Each has particular advantages rendering it suitable in abrading and finishing operations; yet each is endowed with one or more disadvantages which limit its practical utility.

Abrasive belts have seen extended use in operations where it is desirable to remove stock rapidly, particularly where flat or nearly flat surfaces are being abraded. By their very nature, however, abrasive belts are not very satisfactory where workpieces have extreme curved surfaces. Where surfaces of slight curvature are being abraded, belts are occasionally used in conjunction with contact or back up wheels having special irregular peripheral shapes. However, such use necessitates a specially shaped contact wheel for each type of article abraded. Belts are further disadvantageous where employed to abrade workpieces which have wide curved surfaces. The belt edges have a tendency to gouge and scar the workpiece making special finishing operations necessary to insure that gouge or scar marks which would appear after the article has been plated, painted, etc., are removed.

In most operations where articles of curved irregular contours are being abraded and finished, abrasive set-up wheels are most generally employed followed by a buffing operation. Set-up wheels are cloth buffing wheels to the peripheral surfaces of which have been bonded abrasive grains. The grains are bonded to the surface of the cloth by means of an adhesive binder which has been hardened or "set-up." A wheel having a hard rigid surface results. However, just prior to being used the abrasive coat is hammered to break up the surface into discontinuous clumps of abrasive and binder adhered to the cloth so as to render the abrasive coating somewhat resilient and yieldable to the contours of the workpieces. As can be readily seen, the hammering or breaking up of the abrasive coated surface to render the wheel suitable also reduces the useful life of the wheel. In fact, in typical abrading operations such set-up wheels must be replaced every 30–40 minutes. Costly work-stoppage and down time results which raises substantially the cost of abrading and finishing operations employing such wheels.

The use of sisal buffs, cloth buffing wheels containing layers of rope fibers, is also not uncommon. When sisal

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buffs are employed, abrasive compounds are added to the surfaces of the buffs during the operations, and serve as the primary abrasive component. Such operations are inconvenient, costly in that special equipment is required to handle the abrasive compounds, inefficient and extremely messy.

The present invention provides novel improved structures which obviate disadvantages heretofore known in the abrading and finishing art. It provides structures which accurately rapidly abrade workpieces having extreme curved irregular surface contours while effecting fine finishes thereto, irrespective of workpiece dimensions. Yet the structures hereof are also convenient to handle, install and replace and are operated without need of special operating equipment. In addition, the abrasive structures have long useful abrading lives so as to decrease to a minimum the necessary costly down time in abrading operations. Our invention further provides novel methods whereby our abrasive structures may be utilized to the peak of their efficiencies, and also provides methods whereby the novel structures may be manufactured uniformly, accurately and economically.

Our invention will now be more fully described in connection with the description of the accompanying illustrative drawings, wherein like character references refer to corresponding parts in the several views, and in which:

Figure 1 is a plan view of an abrasive wheel flap section employed in an abrasive wheel structure of the present invention;

Figure 2 is an exploded view in perspective showing the manner in which an abrasive wheel structure of the present invention, shown partly in section, is mounted for operation;

Figure 3 is a mid-section view of the assembly of Figure 2 which has been employed in an abrading and finishing operation;

Figure 4 is a schematic view of a portion of an automatic abrading and finishing operation employing an abrasive wheel structure of the present invention; and

Figure 5 is a perspective view, partially cutaway, of an alternative abrasive wheel structure embodied in the present invention.

Referring now generally to Figures 1–3, a unitary abrasive wheel structure is formed, in a manner hereinafter to be described, of an annulus of many radially extending juxtaposed flap sections 10 previously die-cut in the configuration shown in Figure 1 from coated abrasive sheet material. Adjacent flap sections 10 in the annulus are firmly rigidified and adhesively bonded together over a substantial area 11 at the radially inner portions thereof, which area extends across the entire width of the sheet and for a substantial distance, at least about ¼ inch, radially outward from the inner edge of the sections. Thus, the annulus is provided with a strong rigid reinforced inner rim. The several flap sections 10 are positioned such that the abrasive surfaces thereof extend in the same direction around the wheel structure with the abrasive surface of one section facing the back surface of the adjacent section.

The generally rectangular flap sections 10 each have a pair of opposed notches 12 and 12a (Figure 1) extending inwardly from the lateral edges near one end thereof. A second pair of opposed notches 13 and 13a extends inwardly from the lateral edges of the flap section adjacent the first mentioned notches 12 and 12a, respectively, to a depth somewhat greater than that of the latter. The portions of the flap sections extending between the notches 12 and 13 and between notch 13 and the end of the section terminate identically short of an extension line of the lateral edge of the flap section. Correspondingly, the similar protrusions on the opposite edge of the flap section terminate short of the lateral

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edge extension. The notches 12 and 12a of the several flap sections 10 align to define opposed outer circular grooves 14 and 14a, respectively, in the lateral surface of the annular structure near the inner periphery thereof; notches 13 and 13a similarly align to define inner circular grooves 15 and 15a, respectively.

The abrasive wheel structure is conveniently mounted for rotation on and with a shaft as shown particularly in Figure 3. A cylindrical hub 16, having an outer diameter slightly smaller than the inner peripheral diameter of the abrasive annulus and a width equal to the width of the latter at its inner periphery, is inserted into the center hole of the annulus. A flange 17, having a ring 18 extending laterally from the side surface at the outer edge thereof and a ring 19 of smaller diameter than and concentric with ring 18 extending laterally from said surface, is affixed one end of the hub 16 by means of bolts 20, the rings 18 and 19 extending into and being snugly received by the grooves 14 and 15, respectively, of the abrasive wheel structure. The said rings prevent radial expansion of the annulus during rotation due to centrifugal forces. Similarly, flange 17a, having laterally extending rings 18a and 19a is affixed the other end of hub 16 with the said rings being snugly received by the grooves 14a and 15a, respectively. When flanges 17 and 17a are in position, their exposed side surfaces fit approximately flush with the lateral surfaces of the abrasive wheel due to the previously noted configuration of the flaps 10.

In order to minimize stress concentrations in the structure during operation, the grooves in the structure, as defined by the notches in the individual flap sections 10, and, correspondingly, the rings of the flanges 17 and 17a are rounded out.

A cylindrical bushing 21 extends through the flanges 17 and 17a and the hub 16 and terminates flush with the exposed surfaces of the flanges. The bushing 21 receives a partially threaded shaft 22, the entire wheel assembly being affixed thereon by means of a pair of internally threaded hexagonal-head nuts 23 and 23a which are turned onto the shaft 22 and brought up tight against the flanges 17 and 17a.

A specific abrasive structure like that described is comprised of 850 abrasive sheet flap sections having a width of 4 inches and a length of 5 inches, the notches being positioned in the end one inch of the flaps. The abrasive sheet material consists of grit 180 coated abrasive sheet material in which the abrasive particles are adhered to a drills-cloth backing sheet by cured phenol-aldehyde bond and sandsize adhesive coatings. The annulus of radially extending flap sections has an outer diameter of 16 inches and an inner diameter of 6 inches. Each of the several flap sections is rigidified at the inner end and rigidly and firmly adhered to adjacent sections with a cured epoxide resin composition consisting of the reaction product of Bis-phenol "A" and epichlorohydrin, having an epoxy number of approximately 192 grams per epoxide equivalent and a hydroxy number of 80 grams per hydroxy equivalent (sold under the trade name of Bakelite BR-18774), accelerated with diethylene triamine, the ratio of resin to accelerator being 10:1. An area of the entire width of each flap section on each surface thereof was covered with the adhesive for a distance of at least $\frac{5}{16}$ inch from the radially inner end.

It has been found that the abrading action in our abrasive structure occurs principally at the tips of the individual flap sections, particularly when operated at advanced speed as described hereinafter, rather than on the surface of bent over or flexed flap sections. The tip-edge of the individual flaps contact the workpiece surface while the flaps are at right angles thereto. It would be expected that in such case the rate of stock removal would be extremely low, it being well known that in highly efficient coated abrasive belt operations the belt passes in parallel contact with the workpiece surface. On the contrary, however, our novel structures demonstrate ex-

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tremely high rates of stock removal. Moreover, when the structures hereof are employed to abrade and finish indentically shaped articles, such as occurs in automatic abrading operations, the peripheral surface actually takes the contour of the articles being abraded. This feature permits large areas of irregularly shaped workpieces to be evenly abraded in a single pass. In Figure 3, the abrasive flap sections 10 of the abrasive structure are seen to have taken the contour 24 of a workpiece during an abrading and finishing operation.

Due to the unique tip-grinding characteristics of our novel abrasive wheel structures the flap sections wear only at the tip-ends thereof. Thus, a fresh abrading surface is continually presented to the workpiece; yet abrading life of our structures is remarkably long, as will be specifically shown presently. Moreover, the wheels are usable until worn down to the rigid inner rim portions without substantial change in abrading characteristics.

One application in which the structures hereof have seen extended use is shown in Figure 4, the automatic abrading and finishing of the broad side surfaces of automobile bumperguards being illustrated. An abrasive wheel assembly, or abrasive head 30, is mounted on a shaft 31, the latter being rotatably affixed the end of platform 32 and driven in the direction of the arrow by suitable means such as an attached electric motor, or a motor and belt assembly (not shown). Platform 32 is pivotally mounted about an axis 33 permitting the abrasive head to be raised and lowered. Since the weight of the abrasive head 30 is considerably more than the abrading force to be exerted, a counterweight 34 slidably attached to the other end of the platform 32 decreases the force exerted by the abrading head due to its own weight against workpieces, here bumperguards 35, which pass under and in contact therewith. The abrading force may be varied by sliding the counterweight 34 on the platform 32. Supports 36 carried by a conveyor 37, which travels in the direction shown by the arrow, support and retain the bumperguards 35 in position during the operation. In passing into contact with, under and beyond the abrasive head 30, the forward edge of bumperguards 35 engage the rotating wheel, and as the bumperguards 35 advance, the wheel is raised, platform 32 being pivoted about axis 33, due to the upward force exerted thereagainst by the advancing increasing height of the bumperguard surface. As the article passes under and beyond the abrasive head 30, the latter is lowered again. A suitable stop, not shown, supports the platform with the head 30 in position for the next cycle. Thus, the bumperguard 35 is contacted by the abrasive wheel over substantially its entire length.

The 16 inch diameter, 4 inch wide wheel structure above described was assembled, the flanges being 8 inches in diameter, and employed with similar structures in the above described bumperguard abrading and finishing operation. The counterweight 34 was adjusted such that the force exerted by the wheel against the bumperguards was 12 pounds. Conveyor speed was such that bumperguards passed under the abrasive head at the rate of 600 per hour. Preliminarily, several bumperguards were passed under the new wheel structure rotating at 1850 R. P. M. in order to impart the surface contour of the bumperguards thereto. After about 5 minutes' time, during which about 50 articles passed in contact with the wheel, the wheel periphery had taken the contour of the guards such that nearly the entire side surfaces of the bumperguards were abraded in a single pass.

When rotated at a speed of about 1850 R. P. M., the abrading life of the contoured abrasive wheel structures was found to be about 3000-4000 bumperguards. That is, after abrading about this number, the flap sections on the wheel were worn down nearly to the rigid inner rim portion of the wheel. This necessitated about 5 minutes down time every 5-6.7 hours for replacement of the wheel. Such an abrading life is highly satisfactory com-

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pared to the 10 minutes' down time required every 40-45 minutes for set-up abrasive wheels in identical operations. Yet, surprisingly, we found that upon increasing the rotative speed of our abrasive structures about 20 percent, or to about 2200 R. P. M., where it would be expected that abrading life would decrease slightly, the useful life of each wheel structure increased many-fold—to about 10,000-12,000 bumperguards. Replacement of a wheel was then required only every 17-20 hours. Moreover, the finish imparted to the bumperguards was seen to have been improved considerably; at the advanced speed the finish imparted by the grit 150 wheel approximated that of a grit 180 abrasive belt whereas at the lower rotative speed the finish was similar to that imparted by a grit 150 abrasive belt. Rate of stock removal was found to be extremely high, three of our structures effectively replacing in many instances four prior art abrasive set-up wheels of like abrasive grade.

The rotative speed range at which the abrading life of the structures increased so remarkably could be visually ascertained. At the 1850 R. P. M. speed, the abrasive articles were seen to emit threads and pieces of the abrasive sheet flap sections of which the wheel structures were composed. This shredding of the individual flap sections occurred particularly as the bumperguards initially contacted the wheels. However, when the rotative speed was increased the shredding gradually diminished and at 2200 R. P. M. and beyond, no direct visual evidence of shredding could be seen.

Although the above specific example demonstrates abrasive wheel structures hereof of particular dimensions and shows them being employed in a particular use, the dimensions of our articles need not be confined to those above shown. Nor are the uses in which spectacular results are exhibited limited to that above shown. In fact, the abrasive articles of the present invention have been employed with similar success in many abrading and finishing operations. For example, they have been employed in grinding and polishing of jet aircraft engine blades in which extremely high precision is necessary, in the removing of rough scale resulting on iron and steel pieces from rough forging and particularly on flat plates (which, incidentally, is accomplished only poorly or not at all with abrasive belts), in the polishing of glass and for many other applications.

The rotative speed range at which the abrading life of these abrasive structures increases so surprisingly, varies according to the materials of which the abrasive structure is formed, e. g., stiffness of the abrasive sheets, wheel dimensions, the extent to which the flap sections are rigidified in the radial direction and adhered to adjacent flaps, etc., and the abrading conditions in which they are employed. Generally, it can be stated that the critical range is lower in a given operation where a large wheel with a relatively large inner diameter is employed and/or where relatively stiff abrasive sections are employed than in the converse case. However, in each instance the range at which the characteristics undergo the change may be visually determined by the wheel shredding observed. Where rapid wear by shredding may be observed at rotative speeds below the transition range, particularly where a workpiece is initially forced against the wheel in a nonradial direction such as occurs in automatic operations, no such shredding is seen at rotative speeds above the transition range. The transition does not occur instantaneously. It does, however, occur over a relatively slight increase in rotative speed, generally over an increase in rotative speed by only a few hundred R. P. M.

The use of our novel structures has permitted extreme economic savings in the abrading and finishing industry, primarily in the abrading and finishing of automotive parts and accessories and in similar types of operations. For the first time commercially has been provided a rotative abrasive article capable of quickly rapidly and

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accurately abrading workpieces of irregular contour while imparting a fine superior finish thereto, yet which has an abrading life many times that of abrasive articles previously employed for such operations.

We are aware, in pointing out our invention, that abrasive wheels formed of radially extending flap sections of abrasive sheet material have been known for many years, indeed since before the turn of the century. More recently, Leggett Patents Nos. 2,651,894 and 2,678,523 have been issued, covering modified forms of abrasive flap wheels. Such wheels have proven effective under the conditions and for the purposes for which they were designed. Significantly, however, they have not been made available in widths much, if any, beyond one or two inches; they are restricted to use at relatively low rotative speeds; and they do not provide the novel type of contourable tip-abrading now made possible with the novel structures of the present invention.

The 16 inch diameter wheel structure containing 850 flap sections (grit 150) previously described was prepared as follows: The previously die-cut flap sections 10 were assembled in face-to-back relation in an elongate channel member of U-shaped cross section. The flap sections were arranged with the ends adjacent the notches extending upwardly. The row of flaps was then compressed together. The compressive force was then released somewhat permitting the flap sections to spread apart slightly and a one-half inch wide strip of pressure sensitive adhesive coated masking tape was applied along each edge of the top surface of the block of slightly spread sections. Approximately 2-3 ounces of the previously prepared syrupy liquid epoxide resinous adhesive with accelerator blended in, having a useful pot-life of about 15-20 minutes, was then applied uniformly to the exposed surface of the block between the tape strips and allowed to penetrate between the individual flap sections. The block of sheets was then compressed under a pneumatic ram force of 700 pounds. Excess resin was wiped from the surface of the compressed block of flap sections. The strips of tape were then removed leaving edge surfaces which had not been adhesively wet. A pair of strips of the masking tape, the adhesive surfaces of which had been coated with a rubber based air-drying cement, were then positioned where the former strips had been. The block of flap sections was retained under the compressive force for about 10-15 minutes to permit the cement to dry at which time the pressure was released.

The block of flap sections was then removed from the channel, the individual flap being adhered to and bound by the tape strips, and manipulated into an annulus by bringing the end flap sections together with the tape strips on the inside. An 8 inch diameter steel forming ring was then temporarily driven into the radially outer lateral groove on each side of the structure to perfect the uniform annular shape thereof and compress the radially inner portions of the flap sections together. The two strips of tape were then removed from the inner peripheral surface. While the annulus was laid on a side, additional adhesive resin was poured into the radially inner groove on the exposed surface to insure adhesive impregnation entirely across the structure. Simultaneously, adhesive resin was painted over the entire inner peripheral surface. After the resin poured in the groove had penetrated between the flap sections and disappeared from view, the structure was inverted and the adhesive application repeated on the other side. About 2-3 ounces of additional adhesive resin was utilized in these latter applications, making the amount of adhesive employed in the structure total about 5 ounces. The wheel was then stored at room temperature for 12 hours while the adhesive resin cured to rigidly unify the structure and adhere adjacent flap sections in a rigid reinforced inner rim portion. The temporary steel forming rings were then removed, the grooves were cleaned out with coated abrasive paper to remove excess resin and

permit close fit of the flanges 17, 17a, and the article was boxed ready for shipping as a unitary article of commerce to be later mounted for operation on a hub assembly.

The amount of adhesive resin employed was sufficient to adequately bond the flap sections without having adhesive excess flow from the structure during application. However, the amount of adhesive necessary to adequately bond the flap sections and form the rigid inner rim portion without adhesive excess will vary for structures of different dimensions, abrasive grit size, etc., the five ounce quantity shown being merely that required in the specific illustrative example.

The rigid inner structure provided in the structures hereof by the unifying adhesive is particularly important in preventing flap sections from being axially buckled or compressed upon subjection to severe working stresses. As was previously mentioned, the unifying adhesive extended radially at least about $\frac{5}{16}$ inch from the inner periphery and continuously across the width of the wheel structure of the preceding specific example. Near the wheel sides, penetration was somewhat greater than $\frac{5}{16}$ inch due to that adhesive resin which had been added from lateral grooves as is shown in Figures 2 and 3. We have found that the minimum radial depth to which the unifying adhesive must penetrate in order to sufficiently rigidify the structure is about $\frac{1}{4}$ inch. Where the penetration is less than about this depth a weak spot exists in the structure at which point individual flap sections can buckle during operation causing failure of the structure. This is particularly important where wide wheel structures, that is, two inches wide and wider, are to be employed. Where each flap section is rigidified as above stated by the adhesive, the necessary rigidity is present in the inner rim portion of the assembled wheel even though a few flap sections are not adhered to adjacent sections on both surfaces thereof, in which event the wheel structure is in more than a single unitary segment. For example, even where a structure has been broken into one or more segments in transmit it may be assembled on a shaft (the centripetally reinforcing side members, e. g., ring containing flanges, holding the segments together) and safely operated at high speeds.

The rigid inner rim portion of our abrasive wheel structures may be still further rigidified by adhesively imbedding one or more annular reinforcing inserts, made, for example, of glass fiber reinforced plastic, in the interior of the inner rim portion. This may be done by forming identically positioned small notches in the individual flap sections at the flap ends which will become the inner periphery of the wheel structures. The notches align to define a groove into which the annular reinforcing insert is positioned as the structure is formed into an annulus. When firmly rigidly adhered in position, the reinforcing insert structurally cooperates with the rigid inner rim portion to even more firmly rigidify our wheel structures. It is to be understood, however, that such inserts are to be used only in conjunction with, not as a substitute for, the rigid inner rim portion formed of adhesively rigidified adhered flap sections. During the initial adhesive resin application, such end grooves may be filled with resin and thus serve the additional function of facilitating deep penetration of the resin around the grooves.

Other rigidifying and unifying resins than cured epoxide resin compositions may be employed in the abrasive structure hereof. For example, resins which cure to a strong rigid adherent state from a liquid stage such as polyester resins, alkyd resins, phenolic resins and other similar adhesive materials well known to the art are also useful.

It is not necessary that two grooves be present on the lateral surface of our abrasive wheel structures in order to provide means for the prevention of radial expansion due to centrifugal forces. Lesser or greater numbers of

grooves may be employed; in fact, no grooves need be present at all. In Figure 5, a wheel structure is shown having no lateral grooves. The annulus formed of radially extending juxtaposed abrasive flap sections 40 rigidified and adherently bonded together into a rigid inner rim section by rigid unifying adhesive 41 is provided with a depression 42 at the inner portion of each lateral surface. Centripetal reinforcing washers 43 (only one shown) which may consist of glass reinforced plastic, metal or other substance of high tensile strength, are adhered to the lateral surfaces of the inner rim portion in the depression 42 by means of an adhesive of high shear strength. The structure is then mounted on a hub assembly and placed, either singly or multiply, on a shaft for rotation. Any suitable adhesive is employed, in many instances this adhesive being the same as that employed for the rigid unifying adhesive 41.

Having now fully described our invention, it is to be understood that the various specific examples shown are for the purpose of illustration, not limitation, and that the scope of the invention is intended to be limited only by the disclosure as a whole, including the appended claims.

We claim:

1. In the method of forming an abrasive wheel comprised of an annulus of juxtaposed radially extending flap sections of abrasive sheet material having opposed notches therein which align to define opposed lateral grooves adjacent the inner periphery of said annulus and wherein adjacent flap sections are rigidified and firmly rigidly adhesively bonded together over a substantial inner end area to form a rigid reinforced inner rim portion in said structure, the steps comprising manipulating into an annulus a block of said notched flap sections arranged in superposed face-to-back relation, said block being temporarily bound together at the end portions of said flap sections forming the inner peripheral portion of said annulus by a flexible holding member which is affixed to said block, inserting a circular forming member into a groove in each of said lateral surfaces to perfect the shape of said annulus, said sections each being provided with a coating of a liquid curable adhesive resin on each side over a substantial area adjacent the radially inner ends thereof, and curing said resin to a hard firm state.

2. In the method of forming an abrasive wheel comprised of an annulus of juxtaposed radially extending flap sections of abrasive sheet material wherein adjacent flap sections are rigidified and firmly rigidly adhesively bonded together over a substantial inner end area to form a rigid reinforced inner rim portion in said structure, the steps comprising manipulating into an annulus a block of superimposed identically shaped flap sections of abrasive sheet material temporarily bound together in face-to-back relationship by a flexible tape strip adhered to one end of said sections, said sections each having a coating of a liquid curable adhesive resin on each side thereof over a substantial area adjacent said end and further having opposed notches in the lateral edges thereof adjacent said end which align to form opposed circular grooves in the lateral surfaces of said annulus, temporarily inserting a circular forming ring into a groove in each of said lateral surfaces to perfect the shape of said annulus, curing said resin to a rigid hard firm state and removing the rings.

3. A method of forming an abrasive wheel comprised of an annulus of many juxtaposed radially extending flap sections of abrasive sheet material wherein adjacent flap sections are rigidified and firmly rigidly adhesively bonded together over a substantial inner end area to form a rigid reinforced inner rim portion in said structure, said method comprising forming a loosely compacted block of superimposed identically shaped flap sections of abrasive sheet material each of which has two pair of opposed notches in its lateral edges near the upper end thereof, applying a liquid curable adhesive resin to the upper surface of said block and allowing said resin to penetrate

between individual flap sections, compacting said block, adhering a flexible tape strip along the upper surface of said block, manipulating the taped block with said tape on the inside into an annulus by bringing the end flap sections together, said annulus having two pair of opposed circular grooves in the lateral surfaces thereof defined by the alignment of said notches, temporarily inserting a circular forming ring into one of said grooves in each of said lateral surfaces to perfect the shape of said annulus, and flowing additional resin into the remaining grooves and allowing it to penetrate between individual sections to complete the resinous coating on said flaps over a substantial radial distance from the inner end thereof and

across the entire width of the sheet, curing said resin to a rigid hard firm state and removing the rings.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,843,469

July 15, 1958

Theodore J. Miller et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 24, for "he" read -- the --; column 5, line 51, for "radical" read -- radial --; column 7, line 67, for "structure" read -- structures --; column 8, line 70, for "compising" read -- comprising --.

Signed and sealed this 12th day of May 1959.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents