May 28, 1968 S. A. RANDS 3,384,915

MULTIPLE-COMPLIANT-BRISTLE BRUSH MEANS HAVING ENLARGED, ABRASIVELY COATED OUTER BRISTLE TIP ENDS OF MULTI-PHASE MATERIAL

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FIG. 1

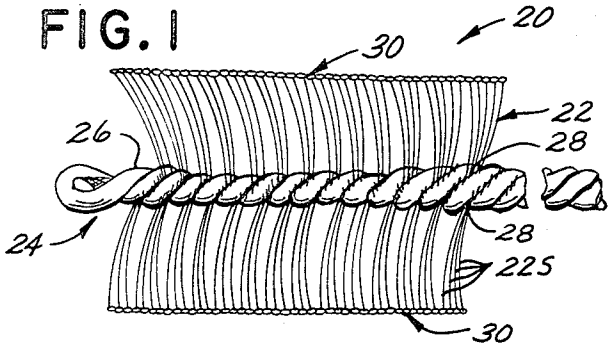
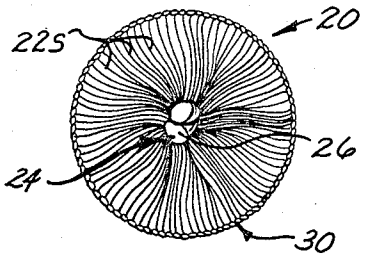


FIG. 2



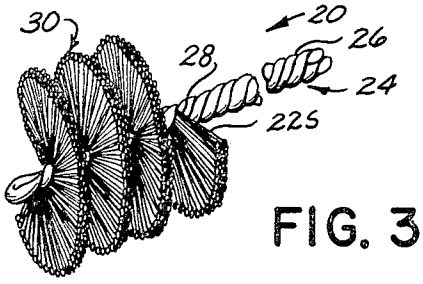


FIG. 3

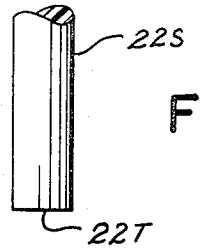


FIG. 4

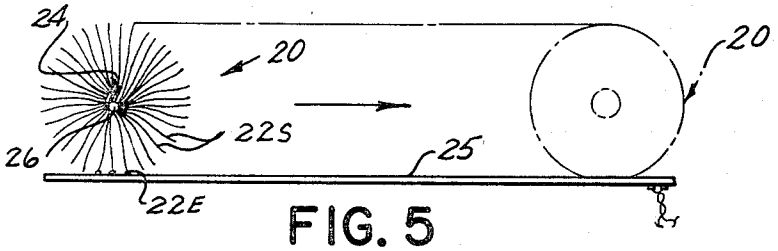


FIG. 5

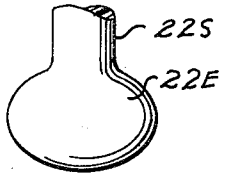


FIG. 6

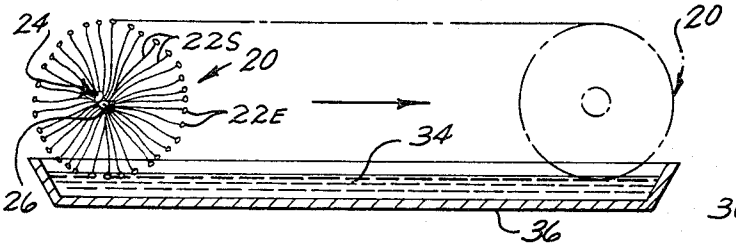


FIG. 7

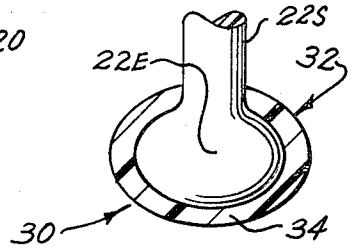


FIG. 8

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MULTIPLE-COMPLIANT-BRISTLE BRUSH MEANS HAVING ENLARGED, ABRASIVELY COATED OUTER BRISTLE TIP ENDS OF MULTI-PHASE MATERIAL

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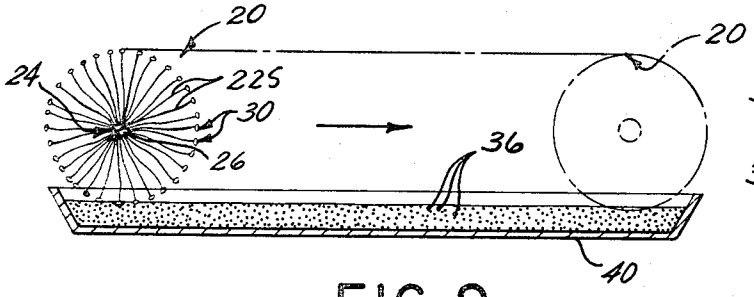

FIG. 9

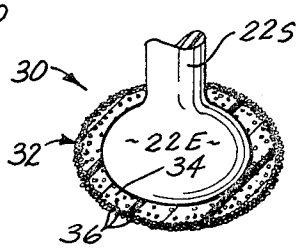

FIG. 10

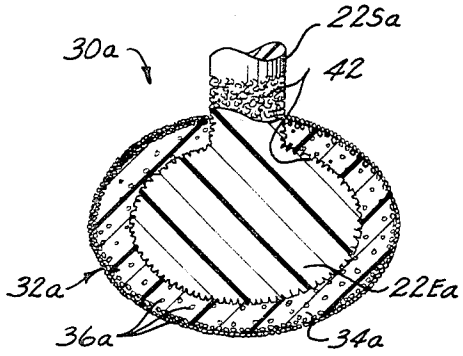

FIG. 11

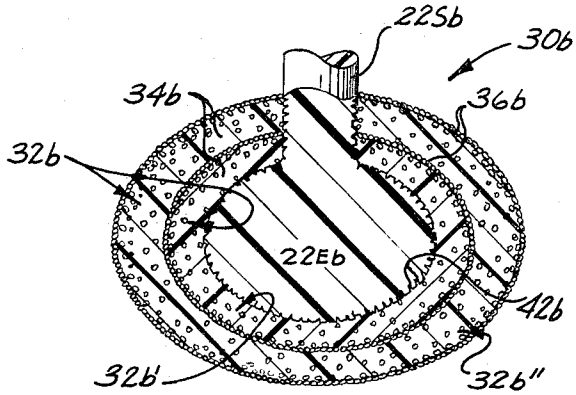

FIG. 12

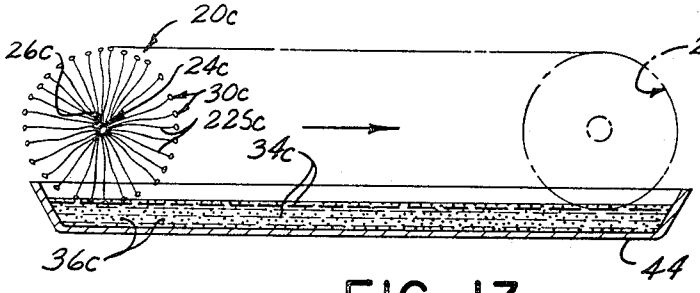

FIG. 13

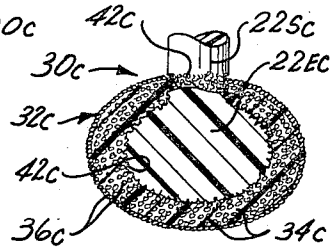

FIG. 14

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3,384,915

MULTIPLE-COMPLIANT-BRISTLE BRUSH MEANS HAVING ENLARGED, ABRASIVELY COATED OUTER BRISTLE TIP ENDS OF MULTI-PHASE MATERIAL

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Continuation-in-part of application Ser. No. 579,048, Sept. 13, 1966. This application June 30, 1967, Ser. No. 650,382

22 Claims. (Cl. 15—179)

ABSTRACT OF THE DISCLOSURE

An abrasive brush means being made up of a plurality of outwardly directed, non-metallic, extremely compliant and flexible material such as "Nylon" plastic, or other substantial equivalents, having corresponding exteriorly completely uncoated, flexible, compliant shaft portions completely made of said plastic, or substantially equivalent material, and having corresponding integral, laterally enlarged, free outer ends of the same material exteriorly provided with and adhesively carrying on the exterior thereof a desired type of outer coating means (usually a plastic adhesive bonding material and particles of extremely hard abrasive material) having desired physical characteristics and thus causing said laterally enlarged free outer bristle ends to effectively comprise two-phase material so as to present fresh, exteriorly protruding and projecting particles of abrasive material to the surface of a workpiece therein.

This application comprises a continuation-in-part of my copending application entitled "Abrasively-Coated Flexible Brush," Ser. No. 579,048, filed Sept. 13, 1966, now abandoned, which application comprises a continuation-in-part of my co-pending application entitled "A Coated Brush," Ser. No. 512,980, filed Dec. 10, 1965, now abandoned.

Generally speaking, the present invention relates to an improved form of the invention disclosed in the first above-identified parent application and disclosed and claimed more particularly in the second above-identified parent application, and comprises a multiple-compliant-bristle brush means having enlarged, abrasively coated, outer bristle tip ends of two-phase (or multi-phase) material, which may be generally referred to in shortened form as an abrasively coated, flexible, abrading brush which may be employed as a flexible grinding brush, a flexible honing brush, a flexible polishing brush, a flexible glaze-removing brush, or a brush intended for any of a great variety of generally similar purposes.

For example, one specific and highly desirable embodiment of the abrasively coated brush of the present invention is intended for use for the purpose of removing interior glaze frequently found on the cylinder walls of an internal combustion engine after it has been run for a considerable period of time. Such glaze is usually found when such an engine (usually an automobile, truck, or boat engine) is in a garage for a ring replacement and/or valve grinding job or other complete overhaul and has the head removed for replacement of piston rings and to facilitate the engine overhaul, etc. Such glaze is produced primarily from combustion and lubrication by-products present within each cylinder and, in particular, in the combustion chamber region thereof where such combustion and lubrication by-products are effectively deposited on adjacent wall portions and are effectively baked into what amounts to an extremely difficult-to-remove interior coating firmly adhering to adjacent inside

surfaces of each cylinder of the internal combustion engine as a result of the heat produced from the repeated combustion which occurs in each combustion chamber during each complete cycle of operation of the internal combustion engine.

The above-mentioned glaze, or other gummy or tarry deposits found in the combustion chamber and/or cylinder portions of internal combustion engines, has a number of undesirable effects such as interfering with free movement of the parts of the engine and undesirably affecting the sealing characteristics thereof, and various other undesirable effects.

One way to remove the glaze and other detrimental internal combustion engine deposits from within the cylinders of an internal combustion engine is to rebore the engine, which is usually done through the use of a very expensive special-purpose machine tool. However, this is a relatively costly job for a number of reasons. First, the special-purpose reboring tool is quite costly in itself. Second, the reboring job requires a skilled mechanic and can normally only be done at certain locations where proper equipment is available. Both of these factors cause the cost of such a reboring job to be rather substantial, to a degree such as to greatly reduce the number of instances where an owner of an automobile or truck with an engine in need of repair will have such a reboring job done. Incidentally, it should be noted that undesirable deposits on the engine valves or valve seats can be removed by a valve grinding operation, which is substantially simpler and cheaper to do than the engine reboring operation referred to above.

The novel abrasively coated grinding brush of the present invention lends itself ideally to removing such interior glaze and/or other undesirable and/or detrimental deposits from within the cylinders of an internal combustion engine when the head of the block of the internal combustion engine is removed and for doing so with a minimum expense involved in equipment and labor so that the complete operation will be very much less costly than an engine reboring job of the type referred to above.

It will be found that inserting a substantially cylindrical brush means of the present invention having a plurality of substantially radially outwardly directed flexible resilient bendable bristle means provided at their outer free ends only with, and adhesively carrying, enlarged abrasive globules, with the brush being of a size such that the enlarged abrasive globules are in resilient engagement with the glaze-coated inner surface of a cylinder of an internal combustion engine, and then power-rotating or otherwise moving the brush means (usually by way of a longitudinally centrally axially positioned bristle-mounting brush base means coupled to a power tool or power-driven element), will very quickly remove the glaze from within the cylinder and produce either a very slightly cross-hatched or a highly polished inner cylinder wall surface depending upon the nature of the abrasive particles carried by the outer free bristle ends of the brush means and also upon the rate of rotation of the brush means.

In other words, virtually any desired type of finished surface ranging from a slightly roughened finish to an extremely high-polish finish can be produced very quickly in each cylinder through the use of the apparatus of the present invention.

Of course, all of the glaze is completely removed, and it will be found that the operation has not enlarged the diameter of each cylinder to an extent such that a larger piston size is required, as is usually the case when an engine reboring job of the type referred to hereinbefore is done on an engine in need of repair. All that is necessary after the glaze-removing and deposit-removing oper-

ation of the novel flexible grinding brush means of the present invention for refinishing the interior surfaces of the cylinders of an internal combustion engine, is to use slightly oversized piston rings on the pistons. This will provide a virtually perfect seal between the freshly refinished cylinder wall portions and the oversized piston rings, and the engine will function in a manner substantially equivalent to the functioning of a brand-new engine, with high compression being maintained in the combustion chamber of each cylinder and with very little or virtually no fuel and/or lubricant by-passing of the engaged surfaces of the freshly refinished cylinder walls and the oversized piston rings occurring.

Of course, it should be noted that the novel abrasively coated grinding and/or honing brush means of the present invention may also be employed for removing any deposits from the pistons, valves, valve seats, and/or any other desired engine surfaces if such is believed necessary or desirable.

While the above-mentioned engine repairing function of the novel abrasively coated flexible grinding and/or honing brush of the present invention is one particularly advantageous form thereof, it should be noted that the invention is not specifically limited to such an embodiment or such a particular use, but may be employed for a variety of purposes where grinding, honing, polishing, or the like, is to be effected and where the resilient nature of each mounting bristle of the brush means can be advantageously employed for facilitating the grinding, honing, and/or polishing operation.

In other words, the novel device of the present invention may be said to comprise the functional equivalent of an abrasive grinding or honing wheel, or the like, but which is of a flexible or resilient nature so that when the enlarged abrasive globules carried by the free outer ends of the flexible bristles of the brush means come into contact with an effective obstruction (usually comprising a projecting portion of a workpiece which is to be abraded), the flexible resilient bristle shafts merely flex or give to whatever extent is required to allow the abrasive globules to pass the obstruction without fracturing in the undesirable manner of rigid prior art grinding wheels, and the like.

Indeed, in one preferred form of the invention, each of the bristle means is made of an extremely flexible, compliant, elastically bendable material which is usually plastic material, such as "Nylon" or other functional equivalent, having a modulus of elasticity of a sufficiently low value as to cause an intermediate uncoated shaft portion of said bristle means from an inner end thereof carried by a bristle-mounting brush base means to the enlarged abrasive globule at the outer end thereof to have a bending flexibility and compliance at least twice as great as that which would be provided if the coating means extended along substantially the complete length of said bristle shaft portion. It will be understood that this provides great compliance to the uncoated shaft portion and yet provides a maximized abrasive efficiency at the free outer end thereof in a manner which has not been achieved prior to the development of the present invention and which is incapable of achievement with prior art stiffer brush constructions or prior art resilient brush constructions not having the maximized abrasive characteristics of the enlarged two-phase (or multi-phase) material abrasive globule at the outer end of each bristle shaft, which has an inside mounting portion comprising an integral, enlarged end of the bristle shaft itself adhesively carrying the exterior coating means comprising both the adhesive bonding material (which is usually epoxy resin) and the finely divided, particulate, abrasive material. Thus, the present invention maximizes abrasive efficiency at the outer end of each bristle in a heretofore unmatched manner while maximizing flexibility and compliance in the uncoated bristle shaft portion in a heretofore unmatched manner, when considered in conjunction with the maximized abrasive efficiency of the novel type of enlarged abrasive globules carried at the outer ends of said extremely compliant, uncoated bristle shaft portions.

Additionally, in a preferred form of the invention, the exterior surface of each of the integral, laterally enlarged, free, outer bristle ends, which is usually made of "nylon" plastic material, or other functionally equivalent material, is effectively softened and rendered porous to a predetermined, inwardly directed extent by soaking same in a softening phenol solution, or by other equivalent treatment, whereby to comprise an outer-positioned, effectively softened, porous, adhesion-increasing junction interface layer having effective pores (which shall also means surface roughened portions) which are positionally penetrated by the inner surface of the outer layer of adhesion bonding material (which is usually an epoxy resin or other equivalent plastic resin adhesive material) in a manner which very greatly increases the effective adhesive junction strength therebetween or the strength of the adhesion of the inner surface of the adhesive bonding material and the softened, porous, adhesion-increasing junction interfacing outer layer of the integral, enlarged bristle end.

In one preferred exemplary form of the invention, the outer coating means carried by each of the integral, laterally enlarged, free outer bristle ends is of effectively laminated construction comprising two or more coating layers or laminae, with each individual such coating layer or lamina comprising a thin sheet of adhesive bonding material provided with and effectively carrying a plurality of particles of abrasive material (usually intermixed therewith, although in certain cases partially intermixed therewith and primarily attached to the outer surface thereof), although in certain forms of the invention certain of the coating layers or laminae may merely comprise adhesive bonding material positioned between coating layers or laminae which include both adhesive bonding material and abrasive particles.

In other words, the arrangement is such that two or more layers (usually a plurality of layers) which include adhesive bonding material and abrasive particles arranged in various desired manners, effectively produce a composite, laminated, complete outer coating means, which is the essence of this particular preferred embodiment of the invention.

The innermost coating layer or lamina is adhesively bonded to the effectively softened and porous outer surface of the innermost, integral, laterally enlarged, free end of the corresponding bristle in those forms where the outer surface has been softened and rendered porous in the manner referred to in the preceding paragraph and, in other forms of the invention, said innermost coating layer or lamina is adhesively bonded to the unsoftened outer surface of the integral, laterally enlarged, free end of the corresponding bristle, although this does not produce as good an adhesion as the preferred arrangement referred to immediately above. Each succeeding outwardly adjacent coating layer or lamina has the innermost surface of its adhesive bonding material adhesively joined to the exterior of the next inwardly adjacent coating layer or lamina, and in those forms where the abrasive particles thereof protrude outwardly, effectively adhesively interlocks with and engages with the protruding portions of the abrasive particles carried by the next inwardly adjacent coating layer or lamina.

The preferred arrangement referred to above produces a relatively large, composite, abrasive particle having an absolute maximum of abrasive efficiency for several reasons, including the fact that a large amount of particulate abrasive material is carried thereby, plus the fact that the abrasive particles are carried in successive, inwardly adjacent layers and thus, as the exterior of the abrasive globule wears away during grinding usage, there will always be a large number of fresh abrasive particles presented to the surface of the workpiece which is to be

abraded. Also, the novel, multi-layer laminated construction of the outer coating means referred to above, and the extremely strong junction thereof to the integral, laterally enlarged, free end of the corresponding bristle, particularly in those forms thereof having the effectively softened, porous, adhesion-increasing junction, interface layer on the exterior thereof, produces such a strongly adherent construction that there is virtually no likelihood whatsoever, despite the roughness of exterior contact of an abrading surface therewith, of any portion of the outer coating means being inadvertently disengaged from the remainder of the abrasive globule or the integral, laterally enlarged, free end of the corresponding bristle by breaking away or chipping away therefrom, which would have the effect of rapidly reducing the grinding efficiency of the corresponding abrasive globule.

The above-mentioned feature of the invention is vastly superior to, and unmatched by, prior art abrasive tipped bristle constructions and is an extremely important feature of the present invention.

Incidentally, it should be noted that, in one preferred form of the invention, after the application of each adhesive coating layer or lamina, it may be cured before the application of the next coating layer or lamina, which produces the most effective type of composite laminated multi-layer abrasive globule, although the invention is not specifically so limited and, in certain forms thereof, the final curing may be done after the multiple layers or laminae have been formed on the integral enlarged bristle end whereby to produce a cured, complete, abrasive globule in one curing operation.

Incidentally, it should be noted in connection with the above that the use throughout this application of the expression "two-phase" material in referring to the abrasive globule is intended primarily to refer to the inner, integral, laterally enlarged bristle end and to the complete, exterior coating means adhesively carried thereby, irrespective of whether the coating means is of a single layer or a multiple layer laminated type of construction. In other words, the integral, laterally enlarged bristle end is considered to be one material of the so-called "two-phase" material of each abrasive globule, while the exterior coating means adhesively carried thereby is considered to be a second material even though it may be of the multiple layer, laminated type referred to above and includes both adhesive bonding means and abrasive particles and thus might itself be referred to as a two-phase or multi-phase material. The expression "two-phase" is to be interpreted broadly in the light of the foregoing explanation.

The above-described extreme flexibility-in-response-to-opposition feature and the novel abrasive-maximizing outer enlarged abrasive globule bristle shaft end feature of the novel abrasively coated flexible grinding and/or honing brush of the present invention, in combination produces the major advantages of the present invention, since they effectively bring about the mounting of an absolutely maximized plurality of abrading elements in an extreme, compliant manner and with the abrading elements being of an attritionable nature such that they customarily present very effective outer abrading surfaces, consisting of a plurality of projecting, abrasive particle portions which extend substantially outwardly from the adhesive bonding material carrying same because of the fact that said adhesive bonding material is substantially softer than the material of a workpiece adapted to be abraded and thus wears away to an extent such as to allow the much harder, particulate, abrasive material to project outwardly therefrom in an abrasive efficiency maximizing manner.

The above-mentioned features produce the major advantages of the present invention, as referred to hereinbefore and hereinafter, and as implicit in virtually all applications and uses thereof. These features also make for a very long operating life in the novel, abrasively coated, flexible grinding and/or honing brush of the present invention as referred to above, and adapted for such grinding, honing, and/or polishing operations.

Additionally, it should be noted that the degree of resiliency and the degree of compliance of each of the bristles of the brush means, or of various different portions thereof, can be initially selected and, in certain cases, varied at different portions of the brush means, or, indeed, at different locations along the length of each bristle means if desired so as to be optimum for the particular purposes and uses for which the abrasively coated, flexible grinding and/or honing brush is intended.

As pointed out above, a major feature of the present invention is the fact that each bristle means carries a very large amount of abrasive material in the enlarged abrasive globule adhesively mounted on the integral, enlarged, free, outer end thereof so as to maximize abrasive efficiency and yet allow the remainder of each bristle shaft means to be substantially free of abrasive material, and of the adhesive bonding material, whereby to allow each bristle shaft portion to have substantial unaltered free flexibility and compliance characteristics having the advantages mentioned hereinbefore.

An extremely important feature of the invention is the fact that the enlarged, abrasive globule carried at the outer end of each of the flexible, compliant bristle means provides a maximum quantity of abrasive material at the precise location where it is needed for resiliently deflectable abrading contact with the workpiece which is to be abraded, honed, or polished.

Furthermore, each of the abrasive globules is of the attritionable nature referred to hereinbefore so as to present a fresh abrading surface to the workpiece at all times—said fresh abrading surface comprising projecting particles of abrasive material, such as silicon carbide, carborundum, or the like, carried by the more attritionable and abraded-away adhesive bonding material, such as epoxy resin or the like. This provides a flexible grinding, honing, or polishing brush having a very large quantity of the particulate abrasive material at an optimum, laterally outwardly maximized location and having all of the advantageous features referred to above which have been impossible to achieve in abrasive brush constructions having stiffer bristle shafts or in flexible brush constructions having less efficient mounting of abrasive means, either not in the form of enlarged, two-phase (or multi-phase) abrasive globules on integral, enlarged bristle shaft ends in the manner of the present invention or not having the attritionable feature of the present invention, in either case limiting the useful abrasive life thereof to a much shorter period of the working time than the maximum efficiency, abrasive globules of the present invention. Additionally, the form of the present invention having the previously mentioned adhesion-increasing junction interface layer on the exterior of the integral, enlarged outer bristle shaft ends provides increased efficiency of the adhesive means and, consequently, the prevention of excessively rapid wearing away or chipping away of the abrasive coating because of insufficient adhesion to the mounting end of the bristle shaft as has occurred in certain prior art constructions.

Thus, the improved device of the present invention will function as a very effective flexible grinding brush for a substantial period of time by reason of the fact that a large amount of the particulate abrasive material is carried at the radially outwardly maximized locations referred to above and in a manner where freely released quantities of the finely divided particulate material are continually presented to the adjacent surface of a workpiece which is being abraded—this latter function actually occurring during abrading operation of the apparatus.

With the above points in mind, it is an object of the present invention to provide an improved abrasively coated flexible grinding and/or honing brush having

bristle means provided with, and carrying at the free outer ends only, a plurality of enlarged abrasive globules.

It is a further object of the present invention to provide a device of the character referred to in the preceding object, wherein the laterally enlarged abrasive globules are firmly adhesively carried by, and are effectively bonded and joined to, the corresponding free outer ends only, of a corresponding plurality of bristles comprising a brush.

It is a further object of the present invention to provide a device of the character set forth in the preceding object, wherein the brush means is of a substantially cylindrical type having a plurality of substantially radially outwardly directed flexible resilient bendable bristle means provided with and carried by a substantially longitudinally centrally axially positioned bristle-mounting brush base means.

It is a further object of the present invention to provide a device of the character referred to hereinbefore wherein the effective surface roughness of a workpiece which will be produced by abrading contact therewith of the flexible grinding and/or honing brush of the present invention, is controlled by any or all of the factors referred to hereinafter. The first controlling factor is the number of bristles of the brush means per unit of outwardly directed circumferential brush area, which may be referred to as the bristle end or abrasive globule density factor. The second factor is the relative abrasive globule size. The third factor is the type of particulate abrasive material, and the particle size thereof, embodied in the abrasive globules. And the fourth factor comprises the speed and force with which the abrasive globules are applied to the surface of a workpiece during an abrading operation—in particular, when the brush means is power-rotated around a longitudinal axis thereof, since greater rotative speed produces greater outwardly directed centrifugal force acting on each of the abrasive globules, while lesser rotative speed produces reduced outwardly directed centrifugal force acting on each of the abrasive globules. Any or all of these factors can be selected or adjusted as desired to produce precisely the desired type of surface finish on the surface of the workpiece to be abraded, honed, and/or polished by the novel abrasively coated grinding and/or honing brush of the present invention.

It is a further object of the present invention to provide a device of the character set forth herein, wherein the abrasive globules comprise finely divided particulate material harder than the material of a workpiece which is to be abraded and also comprise adhesive bonding material softer than the material of the workpiece which is to be abraded, thus causing the adresive bonding material to be worn away by the surface of the workpiece during an abrading operation so that each abrasive globule will continually present fresh finely divided particulate abrasive material to the adjacent contact surface material of the workpiece during an abrading operation.

It is a further object of the present invention to provide a device of the character referred to herein wherein each laterally enlarged abrasive globule is carried only at the free outer end of the corresponding bristle means of the brush means so as to leave the major remaining portion of each bristle means substantially uncoated and unaltered with respect to the free flexibility and free compliance characteristics thereof.

It is a further object of the present invention to provide a device of the character referred to herein wherein the bristle means are made of a resilient, elastically bendable, flexible material such as "Nylon" plastic material, various other functionally equivalent plastic materials, pig bristles, or any other substantially functionally equivalent material.

It is a further object of the present invention to provide a device of the character referred to herein wherein the abrasive material comprises a finely divided particulate abrasive of a very great hardness, such as tungsten carbide, carborundum, silicon carbide, or the like, or other functionally equivalent abrasive materials having a hardness substantially greater than the material of a workpiece surface which is adapted to be abraded, ground, honed, and/or polished thereby.

It is a further object of the present invention to provide a device of the character referred to herein wherein the adhesive bonding means or material comprises a plastic material, which in one form of the invention is of a catalytically-initiated-curing or a heat-curing type such as an epoxy resin adhesive material or other substantial equivalent, capable of providing a very strong adhesive contact junction or bond of each of the laterally enlarged abrasive globules with respect to the free outer end of the corresponding bristle of the brush means whereby to positively and very firmly fasten same together. Furthermore, the bonding material, being softer than the surface of the workpiece to be abraded, will wear away during use so as to present to the surface of the worpkiece fresh particles of the abrasive material during an abrading operation.

It is a further object of the present invention to provide a device of the character referred to herein wherein the abrasive globules are of a multiple-layer, laminated type of construction including two or more coating layers or laminae of adhesive bonding material and finely divided particles of an extremely hard, abrasive material, either applied in sequence and individually cured between successive coating layer applications or applied in sequence and finally cured together, and either mounted directly on an integral, enlarged bristle end or on an effectively softened, porous, (and/or roughened) adhesion-increasing, junction, interface layer carried on the outer surface of such an enlarged, integral bristle end, which is usually made of "Nylon" plastic material or other substantial equivalent, while the adhesive bonding means is usually made of an epoxy resin adhesive material or other substantially equivalent material.

Further objects are implicit in the detailed description which follows hereinafter (which is to be considered as exemplary of, but not specifically limiting, the present invention), and said objects will be apparent to persons skilled in the art after a careful study of the detailed description which follows hereinafter.

For the purpose of clarifying the nature of the present invention, several exemplary embodiments of the invention, and several exemplary methods for manufacturing same, are illustrated in the hereinbelow-described figures of the accompanying single drawing sheet and are described in detail hereinafter.

FIG. 1 is a partially broken away, side elevational view of one exemplary embodiment of the invention wherein the device takes the form of a generally cylindrical brush or brush means made up of a plurality of bristle means, or bristle tuft means, having free outer bristle ends provided with, and adhesively carrying, a plurality of enlarged abrasive globules which, as further clarified in FIGS. 4–7, take the form of a radially outwardly maximized plurality of such enlarged abrasive globules compliantly carried by the corresponding uncoated major portions of each bristle means or bristle tuft means of the brush means whereby to provide a device ideally adapted for use in grinding, honing, and/or polishing a desired surface—in particular, an inside cylindrical surface such as a cylindrical bore, chamber, or the like, although not specifically so limited.

FIG. 2 is a right end elevational view of FIG. 1.

FIG. 3 is a greatly-reduced-size, fragmentary, partially broken away perspective view of the exemplary first embodiment of the invention as illustrated in FIGS. 1 and 2.

FIG. 4 is a greatly enlarged, fragmentary view of the conventional, initial, free outer end of an exemplary bristle of the plurality of bristles, or bristle tuft means,

comprising a complete brush similar to that shown in FIGS. 1–3 before treatment to produce the enlarged abrasive globules on the free outer bristle ends.

FIG. 5 is a reduced-size, somewhat diagrammatic view illustrating a first step in one exemplary method for producing from conventional, initial "Nylon" (or substantially equivalent) bristles such as shown in FIG. 4, the abrasive globules at the outer bristle ends of the brush means, which merely comprises the application of the outer bristle ends of the FIG. 4 type which, in the illustrated form, are of "Nylon," to a heated metallic surface whereby to melt the outer bristle ends and to produce integral, laterally enlarged, free, outer bristle ends such as the exemplary one illustrated in FIG. 6.

FIG. 6 is a greatly enlarged, fragmentary view, similar to FIG. 4, of an exemplary bristle which shows same after the initial bristle tip heating step of FIG. 5 has produced an integral, laterally enlarged, free bristle tip end on each of the bristles as exemplified by the single one shown fragmentarily in FIG. 6.

FIG. 7 is a reduced-size, somewhat diagrammatic view illustrating a second step in one exemplary method for producing the abrasive globules on the bristle ends of the brush means whereby to result in a brush of the type shown in FIGS. 1–3. This view shows the brush in end elevation but shows an underlying trough carrying the adhesive bonding liquid in section along a longitudinal vertical plane for purposes of maximizing the extent of the disclosure provided by this view.

FIG. 8 is a greatly enlarged, fragmentary view, partly broken away and partly in section, generally similar to FIGS. 4 and 6, and shows an exemplary outer portion of a bristle of the FIG. 6 type (which has had the laterally enlarged, integral free end formed thereon in the manner illustrated in FIG. 5) after it has been passed through the adhesive bonding liquid in the manner shown in FIG. 7.

FIG. 9 is a diagrammatic view similar in many respects to FIG. 7 but illustrates an exemplary third step in one exemplary method for producing the enlarged abrasive globules of the abrasively coated, flexible grinding and/or honing brush of FIGS. 1–3. This view is in end elevation with respect to the brush means but is in section along a longitudinal vertical plane with respect to the longitudinal tray or trough and the plurality of finely divided particles of abrasive material, such as tungsten carbide, carborundum, or the like, carried thereby and adapted to be adhesively picked up by the thin sheet of adhesive bonding material (usually epoxy resin) carried on the exterior of each integral, laterally enlarged, free bristle end as exemplified with respect to one of same in FIG. 8 as a result of the second method step illustrated diagrammatically in FIG. 7.

FIG. 10 is a view very similar to FIG. 8 but illustrates the complete abrasive globule (partly broken away and partly in section, however) carried on the integral, enlarged, free outer end of the single exemplary bristle and produced by the sequence of method steps illustrated in FIGS. 5, 7, and 9, and usually followed by appropriate curing of the bonding material, which may be catalytic curing, heat curing, or otherwise.

FIG. 11 is a greatly enlarged, fragmentary, sectional view very similar in many respects to FIG. 10, but illustrates a slight modification of the invention wherein the exterior surface of the integral, laterally enlarged free outer end of each of the bristles of the FIG. 6 type is effectively softened and rendered porous (or roughened) so as to provide an effectively softened, porous (or roughened) adhesion-increasing outer junction interface layer on the outer surface thereof, adapted to be partially penetrated by the inner surface of the outer layer of adhesive bonding material (usually epoxy resin) in a manner increasing the effective adhesive junction strength therebetween.

FIG. 12 is a greatly enlarged, fragmentary, cross-sectional view similar in many respects to FIGS. 10 and 11, but illustrates a modification thereof wherein the outer coating means is of a laminated construction comprising two (or more) coating layers or laminae, with all or any part of said multiple coating layers or laminae including adhesive bonding means and abrasive particles and with each such coating layer or laminae being successively applied either after an intervening cure or without same and followed by a cure of the composite laminated coating means.

FIG. 13 is a fragmentary view similar in many respects to a combination of FIGS. 7 and 9, with the abrasive particles being intermixed with the adhesive coating means at the time of application to the integral, laterally enlarged, free bristle ends of the FIG. 6 type.

FIG. 14 is a greatly enlarged, fragmentary, sectional view generally similar to FIG. 11, but illustrates a slight modification of the coating means produced by substituting the step illustrated in FIG. 13 for the two steps illustrated in FIGS. 7 and 9.

The exemplary first form of the invention illustrated comprises a brush means, such as is generally designated by the reference numeral **20**, which comprises a plurality of bristle means or bristle tuft means, such as generally designated by the reference numeral **22**, and a bristle-mounting brush base member or means such as is generally designated by the reference numeral **24**. It will be noted that in the exemplary first form of the invention illustrated, said brush means **20** is of substantially cylindrical configuration and the bristle means or bristle tuft means **22** are substantially radially outwardly directed and are carried by a bristle-mounting brush base means **24**, which is substantially longitudinally centrally axially positioned. Furthermore, it should be noted that the bristle means or bristle tuft means **22** are of flexible resilient bendable material of any of various kinds of material which will be referred to in greater detail hereinafter.

In the exemplary first form of the invention, the bristle-mounting brush base member or means **24** takes the form of a twisted wire **26** having the effective rear end portions **28** of each of the bristle means or bristle tuft means **22** positioned between adjacent helically twisted portions of said wire **26**, whereby to firmly lock each of the effective rear ends **28** of the bristle means or bristle tuft means **22** to said bristle-mounting brush base member or means **24**, and in a manner which generally defines a spiral or helical configuration as is most clearly shown in FIG. 3, although the invention is not specifically so limited in all forms thereof.

It should be noted that each of said effective rear bristle end or bristle tuft end portions may comprise an actual terminus of the corresponding bristle means or bristle tuft means **22** positioned within the twisted wire **26**, or may merely comprise an intermediate portion of a double length of bristle or bristle tuft means **22** which extends outwardly from the twisted wire **26** at another location whereby to effectively comprise another bristle or bristle tuft means **22**. Either type of mounting means may be employed, or various other types of mounting means within the broad scope of the present invention may be employed since the mounting of the bristle or bristle tuft means **22** does not touch upon, nor is an essential element of, the basic inventive concept of the present invention.

Each of the bristle or bristle tuft means **22** or each group of adjacent bristles may be said to comprise a plurality of individual bristles or bristle members, each of which is also designated by said reference numeral **22** and each of which comprises a flexible compliant bristle or bristle shaft, such as is specifically designated at **22S** in FIGS. 4, 6, 8, and 10, wherein each exemplary bristle member or bristle shaft member **22S** is shown fragmentarily and greatly enlarged.

It should be understood that each of the plurality of

bristle tuft means or groups of bristles **22** is made up of such bristles, bristle members, or bristle shaft members is the individual one specifically designated in FIGS. 4, 6, 8, and 10 at **22S**, although not specifically so identified in other figures because of the difficulty of so doing in view of the very small size of each individual bristle, bristle member, or bristle shaft member.

Each individual bristle member or bristle shaft member **22S** is initially of the form best shown fragmentarily in FIG. 4 in a conventional bristle shape with the free outer tip end **22T** being of substantially the same diameter as the rest of the bristle member, or bristle shaft member, **22S**.

However, each bristle member, or bristle shaft member, **22S** is intended to have an integral, laterally enlarged, free outer end such as is shown at **22E** in FIG. 6, and one method of forming same, where each of the bristle members **22S** is made of a thermoplastic material such as "Nylon" or substantially equivalent material, is to apply heat to the undeformed bristle tip **22T** of FIG. 4, which will have the effect of producing such an integral, laterally enlarged, free, outer bristle end as that shown at **22E** in FIG. 6.

While the above-described operation may be accomplished in any of several ways, FIG. 5 illustrates in somewhat diagrammatic form, one preferred exemplary arrangement for accomplishing this, which may be said to comprise a first method step in producing a brush of the type shown in FIGS. 1–3 wherein each bristle member **22S** has an enlarged abrasive globule, such as shown generally at **30** in FIGS. 1, 2, and 3, and shown in much larger and clearer form at **30** in FIG. 10. In FIG. 5, this is accomplished by applying the undeformed bristle tips **22T** of the bristle tuft means or groups of bristles **22** to the heated metal plate means **25**, which may be heated in any suitable manner and which effectively melts the bristle tips **22T** so that upon hardening they effectively comprise the integral, laterally enlarged, free outer ends **22E** such as is best shown in FIG. 6 with respect to a representative one of same.

After completion of the operation illustrated diagrammatically in FIG. 5, all of the bristle tuft means **22** and all of the individual bristle members, or bristle shaft members **22S** thereof, so treated will have integral, laterally enlarged, free outer ends similar to the one shown at **22E** in FIG. 6, which, when subsequently treated in the manner illustrated in the successive method steps shown in FIGS. 7 and 9 and usually appropriately cured, all of which will be described hereinafter, provides each so treated bristle shaft member **22S** with an enlarged abrasive globule similar to those referred to above and generally designated at **30** in FIGS. 1–3 and shown in somewhat greater detail at **30** in FIG. 10.

The plurality of bristles **22** each carrying at the outer end thereof an abrasive globule **30** comprises the assembly or group of abrasive globule means at the free outer ends of the bristle means **22** which is generally designated by the reference numeral **30** in FIGS. 1, 2, and 3.

It will be noted that the assembly or group of abrasive globules **30** caried by the laterally enlarged, integral, free outer ends **22E** of the plurality of bristle members or bristle shaft members **22S**, is arranged, in the exemplary first form of the invention illustrated, in a helical configuration as is perhaps best shown in FIG. 3 so as to be positioned at the extreme outer periphery of the complete brush means **20** for very effective abrading contact with the surface of any workpiece (not shown) which is to be abraded by the multiple-compliant-bristle brush means **20** having the enlarged, abrasively coated bristle tip ends comprising tthe assembly of abrasive globules **30**.

Each of the bristle members or bristle shaft members **22S** in the exemplary first form of the invention, is preferably made of a resilient, extremely compliant, and elastically bendable or deflectable material such as "Nylon" plastic material, polypropylene plastic material, or various other functionally equivalent materials having the desired elastically bendable and compliant characteristics and capable of having the integral, enlarged, free tip ends formed thereon whereby to be suitable for producing a very compliant brush having maximized abrasive means at the outer tip ends of each flexible, compliant bristle shaft and thereby having the advantages of the novel, abrasively coated, flexible, grinding and/or honing brush **20** of the present invention.

As pointed out above, the integral, laterally enlarged, free outer ends **22E** of each bristle member or bristle shaft member **22S** of the group of bristle means or bristle tuft means, generally designated at **22**, is provided with and very firmly and positively adhesively carries the corresponding and previously mentioned, laterally enlarged abrasive globule **30** which comprises a particulate abrasive material and an adhesive bonding material which provides a very strong adhesive junction thereof with respect to the integral, laterally enlarged bristle end **22E** but is not carried by the remainder of the corresponding bristle shaft member **22S** comprising the major portion of the length thereof from the bristle-mounting brush base means **24** all the way outwardly to the corresponding laterally enlarged abrasive globule **30**.

In other words, the arrangement is such as to cause each bristle member, or bristle shaft member, **22S** to have a major portion of the length thereof positioned inwardly of the corresponding laterally enlarged abrasive globule **30** (comprising the integral, laterally enlarged, free outer bristle end **22E** and the outer coating means indicated generally at **32** which, in the example illustrated, is shown as including the adhesive bonding material **34** and the finely divided, particulate, abrasive material **36** carried thereby) to be free of both the adhesive bonding material **34** and the abrasive material **36**, whereby to cause said major length portion of the bristle shaft member **22S** to have substantially unaltered, free flexibility and compliance characteristics and also whereby to provide a very substantial quantity of the abrasive material **36** in the attritionable adhesive bonding material **34** which together therewith comprises the outer coating means **32** carried on the enlarged, integral bristle end **22E** whereby to define the corresponding complete abrasive globule means indicated generally at **30**.

The substantial quantity of the abrasive material **36** carried in the attritionable complete abrasive globule **30** is at the extreme outer tip of each bristle shaft member **22S** and is, therefore, in an optimum position for abrading the inner surface of a concavely curved and often substantially cylindrical workpiece which is to be abraded, although the invention is not specifically so limited.

In the exemplary first form of the invention illustrated, each of the plurality of abrasive globules **30** is made up of the exterior adhesive bonding material **34**, in the form of a thin sheet thereof, and a quantity of the previously mentioned finely divided, particulate, abrasive material **36**, as is most clearly shown in FIG. 10 in completed form and as is also shown in the two method steps (actually, the second and third method steps, since FIG. 5 illustrates the first method step), indicated in sequence in FIGS. 7 and 8 with respect to the second method step and in FIGS. 9 and 10 with respect to the third method step.

The exemplary method for producing each of the abrasive globules **30**, as best illustrated in individual completed form in FIG. 10, includes the previously mentioned first step illustrated in FIG. 5 which converts each normal bristle tip, one of which is shown at **22T** in FIG. 4, into the integral, laterally enlarged bristle tip end, one of which is shown in FIG. 6 at **22E**, each of which is then dipped to just the extent of the enlarged bristle end portion **22E** in the liquid adhesive bonding material **34** carried in the extremely shallow tray **38** shown in FIG. 7. This is most easily accomplished by rolling the uncoated brush **20** along and through an extremely shallow layer of the liquid adhesive bonding material **34** in the shallow tray **38** from

the solid-line position shown at the left of FIG. 7 into the phantom line position shown at the right of FIG. 7 so that all of the integral, enlarged bristle shaft member ends **22E** are immersed to any desired extent within the liquid adhesive bonding material **34** without immersing the remainder of each bristle shaft portion **22S** therein. This is best accomplished by providing an extremely shallow depth to the tray **38** or by providing guide members (not shown) parallel to each side edge of the tray **38** and adapted to support the bristle mounting brush base member **26** at opposite ends thereof at a height such that only the integral, laterally enlarged bristle ends **22E** will be immersed to any desired extent in the adhesive bonding material liquid **34**. This operation should produce coated, enlarged bristle tip ends **22E** such as the exemplary one best shown in FIG. 8, wherein the integral, enlarged bristle end **22E** carries an exterior layer of the adhesive bonding material or liquid **34**, which is an epoxy resin in one preferred form of the invention.

The next or third step in the exemplary first method of the invention for producing abrasive globules, such as the exemplary one best shown at **30** in FIG. 10, is illustrated in FIGS. 9 and 10. The complete brush **20** which has the enlarged bristle ends **22E** coated with the adhesive bonding material **34** in the manner shown with respect to one of same in FIG. 8, is now placed at the left end of the tray **40** shown in FIG. 9 so that the adhesively coated, laterally enlarged, integral bristle ends **22E** are immersed to a desired depth (usually only a depth sufficient to immerse the coated enlarged bristle end **22E**) in the finely divided, particulate, abrasive material **36** positioned within the tray **40**, and the brush **20** is rolled from the solid-line position shown at the left of FIG. 9 to the phantom-line position shown at the right of FIG. 9, which will apply the particles of abrasive material **36** to the exterior of the still-liquid or semi-liquid adhesive bonding material **34** coating the exterior of the integral, laterally enlarged bristle ends **22E** in a manner such that said abrasive particles **34** will become firmly embedded therein to any desired extent of penetration whereby to produce a plurality of composite, enlarged, abrasive globules similar to the exemplary one best shown at **30** in FIG. 10 with respect to a single bristle shaft member **22S**.

Subsequently, the abrasive bonding material **34** will normally harden, set, or cure in a manner such as to form a very firm and positive bond between the outer coating means **32** and the integral, laterally enlarged bristle end **22E** of each bristle shaft member **22S** whereby to effectively comprise each such enlarged, abrasive globule **30**.

In the preferred form of the invention wherein the adhesive bonding material **34** comprises an epoxy resin, this hardening, setting, or curing may be catalytically induced or may be facilitated by curing at an elevated temperature for a predetermined period of time.

The above-described sequence of operations is true with respect to each of the so treated bristle shaft members **22S**, and the bond between the outer coating means **32** and the integral, laterally enlarged bristle end **22E** in each case will be sufficiently strong to prevent the abrasive particles **36** from becoming separating from the complete abrasive globule **30** until attrition or wearing away of the outer portion of the bonding material **34**, as a result of abrading contact with the surface of a workpiece to be abraded, occurs, and projectingly frees outer portions of outer elements of the particulate, finely divided, abrasive material **36** for direct abrading contact with the surface of the workpiece to be abraded.

In other words, the wear on the abrasive particles **36**, which are harder than the workpiece to be abraded, is very much less than the wear on the adhesive bonding material **34**, which usually comprises an epoxy resin **34**, and thus the epoxy resin wears away at a rate such that the abrasive particles **36** continue to protrude therefrom and outwardly present a very effective abrasive surface until such time as the outermost abrasive particles have actually been worn down and substantially worn away, at which time it will be found that additional abrasive particles **36** which were initially slightly closer to the center of the abrasive globule **30**, or spaced inwardly from the initial outer surface thereof, will now comprise the outermost surface of the partially worn away, abrasive globule **30** and will project from the softer, cured bonding material **34** and thus will continue to present a very effective abrasive surface at all times despite the amount of wear and attrition which occurs to each abrasive globule **30** as a result of long, continued and repeated use.

It will be noted that in the arrangement illustrated, virtually all of the abrasive material **36** is located at a radially maximized position relative to the axis of the bristle-mounting brush base means **24** for maximum abrading effect on a workpiece, and this is accomplished in a manner which does not unfavorably affect or modify the free flexibility and compliance characteristics of the bristle shaft members **22S** of the complete brush means **20**, which is extremely important for effective use of the abrasively coated grinding and/or honing brush **20**.

In order to provide a full understanding of the major advantages of the present invention, it is perhaps best to consider the problems which have been met and overcome with respect to prior art abrasive brush constructions and improvements thereon intended for, but not fully capable of, achieving the advantages of the present invention.

In connection with the above, it should be noted that one common type of abrasive brush which has been frequently used in the past and still widely used at present, is a metal brush consisting of a plruality of metal bristles provided with abrasive means. In some forms the metallic bristles may be coated with abrasive particles, usually held thereon by suitable adhesive means, extending along substantial portions of the shaft lengths of the metallic bristles and, in other forms, the metallic bristles may have a major portion of such abrasive material carried, usually by adhesive means or the like, adjacent to the outer tip end of the metallic bristles. The first point to note in connection with such metallic bristle abrasive brushes is that it is difficult, if not virtually impossible, to manufacture such metallic bristle brushes so that the bristles will have the optimum type of compliance and flexibility characteristics as provided by the novel, extremely flexible and compliant bristles of the present invention, which are usually made of "Nylon" plastic material or other substantial equivalent. Such metallic bristles, as found in wire brushes and the like, usually have compliance and flexibility characteristics which are not adequate for the purposes of the present invention—that is, they are not flexible and compliant enough to be capable of grinding, honing, and/or polishing inside cylindrical surfaces of various different diameters without interchanging the brush size, which can be readily accomplished with the novel abrasive brush of the present invention. Furthermore, this same lack of a proper degree of compliance and flexibility in such metallic bristle brushes has a similar detrimental effect on the use of such a brush, when abrasively coated, for grinding, honing, or polishing various surfaces of other contours and shapes which require the extreme flexibility and compliance characteristics of the novel "Nylon" bristle type of brush means employed in the present invention.

Also, it should be noted that such prior art metallic bristle or wire brushes usually have very little or virtually no damping present and, thus, during high-speed motor-driven operation of such a prior art metallic bristle brush, oscillation of the metallic bristles and resonance effects of an undesirable character are frequently encountered and tend to produce an effectively pulsating outer abrasive contact surface which is in engagement with a workpiece and which will, thus, tend to abrade the workpiece in a correspondingly pulsating, oscillating, undulating, or otherwise irregular manner, which is very likely to produce an irregular finished surface which may be wholly

unacceptable and which is not the usual intended end result of using such an abrasive brush. This type of effect is largely eliminated and overcome in and through the use of flexible, compliant plastic bristles such as "Nylon" bristles or other functional equivalents, as employed in the present invention because of the improved inherent damping and hysteretic characteristics thereof which virtually eliminate the undesired vibrating, pulsating, oscillating and resonance effects of prior art spring wire abrasively coated brushes as mentioned above, while still retaining the extreme compliance and flexibility characteristics required for achieving the purposes of the present invention as mentioned above.

Another problem which has existed with respect to such abrasive brushes is that of providing an adequate quantity of abrasive where it is needed—actually, at the outer tip ends of the bristles of the brush. In the case of both spring wire and plastic bristle brushes, it has been found difficult in the past to apply and retain a sufficient amount of abrasive material on a bristle tip end to provide a maximized abrasive efficiency and a long abrasive operating life. Where abrasive material has been applied to just a bristle tip end of either the spring wire bristle type or other type of bristle in the past, it has been found that only a relatively small amount of abrasive material can be caused to adhere to the bristle tip end, and if attempts are made to enlarge this beyond a certain extent, the end result usually is for any abrasive contact or impacting contact thereof with a hard surface such as that of a workpiece or the like, to cause chipping away or flaking away of large portions of the abrasive tip to occur and to thus quickly reduce and/or virtually eliminate the abrasive efficiency thereof.

If relatively small amounts of abrasive material are adhesively bonded to the tip of each bristle of such a prior art brush, whether the bristles are of the spring wire type or other type, the result has been found to be a very short operating life since the abrasive material is then found to be ground away rather rapidly and as soon as the abrasive tip has been so ground away, the remainder of the bristle has no abrasive effectiveness whatsoever.

Thus, one prior art attempted solution for this problem has been to attempt to provide abrasive material along either all or a very substantial portion of the length of each bristle of such an abrasive brush, either by adhering abrasive material to the exterior of each bristle brush along most of the length of the bristle shaft or in a few instances by providing a novel bristle having abrasive material provided along the length thereof at the time that the bristle is formed (usually by extrusion). This prior art attempt to provide abrasive material continuously has had unsatisfactory results for several reasons. First, it has been found that there is insufficient abrasive material at any particular location along each bristle shaft to provide maximum or even very adequate abrasive efficiency at the tip of the bristle during a grinding, honing, or polishing operation performed by the complete brush. This is because there is not enough abrasive material at the tip end. Also, another disadvantage of this prior art attempt to solve this problem arises from the fact that the abrasive material carried along the length of each such compliant, flexible bristle shaft, when it is of a flexible, compliant material characterized by greater flexibility and compliance than the relatively stiff spring wire type bristles, such as when made of extremely flexible, compliant plastic or the like, has the effect of substantially stiffening and changing the flexibility and compliance characteristics of the flexible plastic (or functionally equivalent) bristles to an extent such that most of the advantages provided by the present invention are not achieved.

The previously mentioned problem of chipping or flaking away of abrasive material applied to a plurality of bristle tip ends of such a brush because of inadequate junction or adhesion strength has been true with respect to prior art flexible, abrasively tipped brush constructions where the bristles have been of the spring wire metal type or of the extremely flexible plastic type. In other words, neither type of brush has apparently been able to mount a substantial quantity of abrasive material at the outer bristle ends (where the abrasive material is actually needed) in a manner such that it would remain in place for a long operating life and would not be chipped away or flaked off in the undesirable prior art manner mentioned above.

However, in the novel bristle construction of the present invention, as exemplified with respect to one of same in FIG. 10, the above-mentioned prior art problems are completely met and overcome, first of all because none of the adhesive bonding material **34** and also none of the abrasive material **36** adheres to the exterior of the major length portion of the bristle shaft **22S**, and thus the flexibility and compliance characteristics thereof remain unaltered and, indeed, in a preferred form of the invention, the extreme bending flexibility and/or compliance of such uncoated bristle shaft **22S** has a magnitude at least twice as great as that which would be provided by the two-phase or multiphase material if the coating means **32** extended along a major portion, or substantially the complete length, of the bristle shaft **22S**.

Also, the provision of the integral, laterally enlarged bristle ends **22E** provides a much larger adhesive contact surface area for the adhesive bonding material **34**, which is usually epoxy resin, to be adhesively joined to, and effectively cured in place with respect to, the large exterior surface area of the integral, laterally enlarged bristle end in each case. Thus, there is very little likelihood of the outer coating means **32** being inadvertently flaked or chipped off in large pieces as a result of abrading contact with a workpiece, as has frequently occurred in connection with prior art constructions in the manner referred to hereinabove.

In fact, this important advantage of the invention is even further enhanced in the slight modification of the invention illustrated in FIG. 11 as will be described in greater detail hereinafter.

The adhesive bonding material **34**, in one preferred form of the invention, comprises an epoxy resin as mentioned hereinbefore. However, in certain modifications of the invention it may comprise certain other types of thermosetting plastic material which are capable of being effectively cured so as to assume a hardened form thereof such as is shown at **34** in FIG. 10 as a result of setting or curing. In the event that the cure is not an elevated temperature cure or an air cure but is a catalytically induced cure, such a catalyst material may be added to the liquid bonding material **34** in the tray **38** immediately before the integral, laterally enlarged bristle tip ends **22E** of the brush means **20** are rolled therethrough, or immediately before a plurality of such brushes are to be so treated.

As an alternate, the catalyst material may be applied to the adhesive bonding material **34** coating the enlarged tip ends immediately after each of the enlarged bristle ends **22E** has had the adhesive bonding material **34** applied thereto as is best shown in FIG. 8. This subsequent application of the catalyst may be accomplished by dipping the integral, laterally enlarged bristle ends **22E** carrying the adhesive bonding coating **34** into such catalyst material, or may be accomplished by rolling same through a shallow tray containing such a catalyst in a manner substantially identical to the showing of FIG. 7, or this operation may be done by spraying a catalyst thereon, either before or after the admixture with the thin coating of bonding material **34**, or the application thereto, of the finely divided particulate, abrasive particles **36**. In fact, if desired, the adhesive bonding liquid **34** with or without a catalyst or curing agent, may be sprayed on the integral, laterally enlarged bristle ends **22E** or may be otherwise applied thereto to form the resultant, cured, abrasive globule **30** as best shown in FIG. 10.

On the other hand, the adhesive bonding material 34, in certain forms of the invention, may be of a non-thermosetting type and/or may not require curing of the type referred to above and/or may not require a catalyst of the type referred to above. In some forms of the invention, said adhesive bonding material 34 may be a thermoplastic material. In other words, the adhesive bonding material 34 is limited primarily to such a bonding material having the strongly adhesive and readily attritionable characteristics and other characteristics referred to hereinbefore and implicit in the description of the features and advantages of the abrasive globules 30 set forth herein.

It should be noted that the sequence of method steps illustrated in FIGS. 7–10 may produce abrasive globules having various different types of outer coating means 32. Said coating means may be of various thicknesses and may even be of a laminated, multiple-coating layer construction, one exemplary form of which is illustrated in FIG. 12, which will be described in greater detail hereinafter. Also, said coating means 32 may have various distributions of the abrasive particles 36. In one preferred arrangement, as is best shown with respect to one abrasive particle 30 in FIG. 10, the abrasive particles 36 are primarily applied to the exterior of the adhesive bonding sheet 34 so that the coating means 32 has a preponderance of adhesive particles 36 adjacent to the outer exterior thereof, with a considerable number thereof lying on the extreme outer surface of the coating means 32 and actually partially projecting outwardly therefrom whereby to provide a very effective exterior abrasive surface. However, the invention is not specifically so limited, and the abrasive particles 36 may be caused to penetrate the adhesive bonding layer or sheet 34 to a greater extent so as to be disseminated more evenly throughout same. This modification of the invention is shown with respect to a single abrasive globule in FIG. 14 and will be described in greater detail hereinafter.

FIG. 11 is a view very similar to FIG. 10, but illustrates a very slight modification of the form of abrasive globule shown in FIG. 10 and generally designated by the reference numeral 30 in FIG. 10. Because FIG. 11 does illustrate a modification, similar parts are designated by similar reference numerals, followed by the letter *a*, however.

In the FIG. 11 modification, it will be noted that the exterior surface of the integral, laterally enlarged end or bead 22E*a* carried by the bristle shaft 22S*a* is provided with an effectively softened and/or porous (which shall also be construed to mean "roughened"), adhesion-increasing junction interface layer 42 which is adapted to be partially penetrated by inner parts of the layer or sheet of adhesive bonding material 34*a* in a manner which greatly increases the effective adhesive junction strength which exists therebetween.

Otherwise, the modified abrasive globule 30*a* is similar to the abrasive globule 30 of the FIG. 10 form of the invention, and no further detailed description of other features thereof is thought necessary or desirable.

The important point to note in connection with the FIG. 11 modification of the invention is the fact that the junction of the coating means 32*a* to the adhesion-increasing junction interface layer 42 integrally carried by the exterior of the laterally enlarged bristle shaft end 22E*a* is so strong that it is virtually impossible to separate the outer coating means 32*a* from the enlarged bristle shaft 22E*a*. Thus, the advantages described hereinbefore with respect to the virtual elimination of any tendency for the abrasive coating to flake or chip off of the bristle during use is even more pronounced in the FIG. 11 modification of the invention than in the FIG. 10 form of the invention. This is extremely important since this has been one of the major disadvantages of earlier attempts to provide a similar structure.

FIG. 12 is another view generally similar to FIG. 11 and illustrates a further modification thereof. Because of the fact that it is a modification, similar parts shown in FIG. 12 are designated by similar reference numerals, followed by the letter *b*, however.

In the FIG. 12 modification, it will be noted that the outer coating means 32*b* is of an effectively laminated construction type comprising, in the example illustrated, two representative coating layers or laminae, the inner one of which is designated by the reference numeral 32*b'* and the outer one of which is designated by the reference numeral 32*b''*, with each such coating layer or lamina comprising a thin sheet of adhesive bonding material 34*b* provided with and effectively carrying a plurality of particles of the abrasive material 36*b* and with the innermost coating layer 32*b'* being adhesively bonded to the adhesion-increasing junction interface layer 42*b* having characteristics similar to that shown at 42 in FIG. 11 and previously described.

The outermost coating layer 32*b''* is subsequently adhesively bonded to the exterior of the innermost coating layer 32*b'* whereby to form the composite laminated complete coating layer generally designated by the reference numeral 32*b*.

Normally, the coating layers of FIG. 12, comprising adhesive material and abrasive material, are applied in sequence in a manner similar to that described hereinbefore and after each such application the coating layer or means is then cured in a manner similar to that described hereinbefore, although in certain forms of the invention the two or more coating layers may be sequentially applied and a composite cure effected thereafter.

In any event, the type of modified construction illustrated in FIG. 12 makes it possible to provide a cured-in-place, multiple-layer, laminated, abrasive globule construction such as is indicated at 30*b*, which may be made of any desired diameter and thus may have abrasive characteristics to any desired attritionable depth and, furthermore, this type of laminated construction provides an extremely strong construction which is incapable of being flaked or chipped off in an undesirable manner even when the composite laminated abrasive globule 30*b* is made quite large—much larger than would be possible without the multi-layer laminated construction and without the adhesion-increasing junction interface layer 42*b*.

As previously mentioned, it is also possible to make any of the forms of the invention such that the abrasive globule has the abrasive particles disseminated substantially throughout the outer coating means rather than having more of same near the exterior thereof than inwardly thereof. FIGS. 13 and 14 illustrate such a modified arrangement—FIG. 13 corresponding roughly to a combination of FIGS. 7 and 9 and showing both the adhesive bonding material 34*c* and the abrasive particles 36*c* combined in a shallow tray 44 so that the brush 20*c* can be rolled along the length of the tray 44 in a manner which will cause the integral, laterally enlarged bristle tip ends 22E*c* to be dipped into the mixture of the adhesive bonding liquid 34*c* and the abrasive particles 36*c*, which will result in a final abrasive globule 30*c*, after curing where such is needed, of the type illustrated in enlarged, fragmentary form in FIG. 14, where it will be noted that the abrasive particles 36*c* are very evenly disseminated throughout the adhesive bonding layer 34*c* so that the coating means 32*c* may be used for a substantially longer time than the coating means 32 of the FIG. 10 form of the invention.

In the FIG. 14 form of the invention, an adhesion-increasing junction interface layer 42*c* similar to that shown at 42 in the FIG. 11 modification of the invention is employed, although it may be modified to be equivalent to the FIG. 10 form of the invention in this respect. Also, in order to distinguish this modification from the other forms of the invention, similar parts are designated by similar reference numerals, followed by the letter *c*, however.

It should be noted for exemplary purposes that one par-

ticularly advantageous type of adhesive bonding material, such as shown at **34** in the first form of the invention, comprises an epoxy resin adhesive material such as that manufactured by the Epoxylite Corporation and identified by said company as "Epoxylite No. 8751," which comprises a dual liquid material wherein the liquids are mixed prior to use and wherein the adhesive bonding material **34** is adapted to be air-cooled at room temperature for a period of approximately 24 hours (room temperature being a minimum of approximately 77 degrees Fahrenheit for best results). For even higher strength, the adhesive bonding material **34** can be cured at an elevated temperature of between 200 and 250 degrees Fahrenheit for a period of approximately four hours. In the preferred form of the invention wherein the bristles such as shown at **22S** in the first form of the invention and, when provided with the globule on the end thereof, being generally designated by the reference numeral **22** in the first form of the invention, said bristles are made of "Nylon" plastic material and as described hereinbefore in connection with the FIG. 11 modification of the invention, each of the integral, laterally enlarged bristle ends **22E***a* may have the softened, effectively porous or roughened, adhesion-increasing junction interface layer **42** produced by pre-softening the exterior of the integral, laterally enlarged bristle end **22E***a* in a 15 to 20 percent solution of phenol or other functional equivalent. This provides a maximum junction bonding strength as previously described.

Additionally, it should be noted that the bristles, such as shown at **22S** in the first form of the invention, while being made of "Nylon" plastic material in a preferred form of the invention, may be made of various other functionally equivalent materials having the desired characteristics as described in great detail hereinbefore.

Also, it should be clearly understood that various types of adhesive bonding material substantially functionally equivalent to the preferred epoxy resin form of the invention described above may be used in lieu thereof. This is also true with respect to the finely divided particulate abrasive material such as shown at **36** in the first form of the invention, which may comprise, in a preferred form of the invention, particles of an abrasive material which is known in the art as "Norbide" grit, tungsten carbide particles, silicon carbide particles, particles of carborundum, or any other suitable abrasive material which may be of various different particle sizes as required for particular uses of the invention. In certain forms of the invention, said abrasive particles may be electrostatically or magnetically caused to be effectively erected or oriented in a desired positional or directional relationship prior to, or at the time of, junction thereof with the adhesive bonding means whereby to provide maximum abrasive efficiency.

It should be noted that the method illustrated in FIG. 5 of forming the integral, enlarged bristle ends such as the representative one shown at **22E** in FIG. 6, for example, may be modified in certain forms of the invention and may employ heat and/or pressure, or various combinations thereof, applied initially or subsequent to the formation of the bristle so as to produce an enlarged end or bead such as that shown at **22E** in FIG. 6, for example, which may be of flattened form, substantially spherical form, or may assume various different forms, shapes, or configurations which effectively comprise lateral enlargements as compared to the rest of the bristle shaft **22S**, and which provide a large exterior surface for adhesion with respect to the adhesive bonding means **34**.

It should be noted that the composite, laminated coating layer type of construction illustrated in FIG. 12 may include any desired number of coating layers or laminae, and all or any portion of said coating layers may be provided with the abrasive particles. Also, each coating layer or lamina may be cured after application and before the application of the next outermost coating layer or lamina, or the cure may comprise a composite cure of the various coating layers or lamina. Also, in some cases, it may be found desirable to exteriorly soften and/or treat the exterior surface of such a cured coating layer or lamina, such as by dipping in a softening phenol solution, or other medium providing the desired effect, prior to the application thereto of the next outermost coating layer.

It should be noted that the abrasively coated, flexible, compliant grinding and/or honing brush such as the exemplary first one shown in FIGS. 1–3 at **20**, may be provided with a suitable handle (not shown) for use in manually applying the abrasive brush **20** to a surface which is to be ground, honed, polished, de-glazed, or otherwise surface abraded, or a suitable coupling member (not shown) may be provided and be adapted for connection to a motor means (not shown) for longitudinally reciprocating or for rotating the brush **20** with respect to the longitudinal axis of the bristle-mounting brush base member **24** or for oscillating same in an orbital manner or with any other desired type of movement. In other words, the abrasively coated, flexible, compliant brush **20** may be moved in any of a variety of manners, either manually or power driven, with respect to a flat surface, a curved surface, the interior of a cylindrical surface, or, in fact, any desired surface, and will function as a very effective grinding brush, honing brush, polishing brush, de-glazing brush or the like having the advantages inherent in the unaltered, extremely flexible, compliant nature of the shaft portions of the bristles **22S** and having the advantages inherent in the provision of a very large amount of abrasive material in each abrasive globule **30** positioned at exactly the optimum location and so mounted as to be virtually inseparable, as by chipping or flaking off, or the like, from the corresponding bristle end. Furthermore, the brush **20** may have finish-producing characteristics depending upon the particulate surface of the abrasive material **36** and the rotation rate or rate of other type of movement of the complete brush **20** produced either manually or by a driving motor (not shown).

Incidentally, it should be noted that one of the major advantages of the present invention, in addition to those detailed hereinbefore, lies in the fact that a brush having the general exterior configuration shown in FIGS. 1–3 may be very effectively employed for grinding, honing, and/or polishing an inside cylindrical surface of any of several different sizes or diameters without requiring a change of the brush size. This is made possible by reason of the extremely flexible, effectively radially compressible, compliant nature of the bristle shaft members **22S**.

It should be noted that, while the cylindrical brush configuration illustrated in the figures of the drawing provides a particularly and peculiarly advantageous grinding, honing, and/or polishing brush especially well adapted for refinishing interior cylindrical surfaces when power-driven, the invention is not specifically so limited and the brush may assume a variety of different configurations adapted for, or particularly well suited for, various particular types of grinding, honing, and/or polishing usage, and all such are intended to be included and comprehended within the broad scope of the present invention.

It should be understood that the figures and the specific description thereof set forth in this application are for the purpose of illustrating the present invention and are not to be construed as limiting the present invention to the precise and detailed specific structure shown in the figures and specifically described hereinbefore. Rather, the real invention is intended to include substantially equivalent constructions embodying the basic teachings and inventive concept of the present invention.

I claim:

1. A multiple-compliant-bristle brush means having enlarged, abrasively coated outer bristle tip ends of multiphase material, comprising: a brush means having a plurality of outwardly directed, flexible, inwardly effectively compressible, resilient, bendable bristle means provided with and carried by a bristle-mounting brush base means,

said bristle means being made of non-metallic, extremely flexible, compliant, bendable plastic material having corresponding, exteriorly completely uncoated, flexible, compliant shaft portions completely made of said plastic material and having corresponding integral laterally enlarged, free outer ends of said plastic material exteriorly provided with and adhesively carrying on the exterior thereof a desired type of outer coating means having desired physical characteristics, thus causing said laterally enlarged free outer bristle ends to effectively comprise multi-phase material adapted to effectively and correspondingly alter the physical characteristics thereof, the laterally enlarged free outer ends of said bristle means integrally carried by corresponding shaft portions of said bristle means and said coating means adhesively carried therearound together comprising an enlarged, exteriorly abrasive globule of said multi-phase material with said adhesive coating means comprising a particulate abrasive material and a wear-attritionable adhesive bonding material providing a strong adhesive junction thereof with respect to the corresponding integral, laterally enlarged bristle end whereby to firmly fasten said outer coating means to said bristle end in a manner projecting outwardly therefrom, thus causing each bristle means to have a major portion of the length thereof positioned inwardly of the enlarged, exteriorly abrasive globule at the free outer end thereof substantially free of said abrasive material and said adhesive bonding material whereby to have substantially unaltered free flexibility and compliance characteristics and whereby to provide a substantial quantity of abrasive material in the attritionable adhesive bonding material of said enlarged, exteriorly abrasive globules carried at the free outer ends of said flexible, resilient, compliant bristle means for continually presenting an effective exterior abrading contract surface on the exterior of each of said enlarged exteriorly abrasive globules during continued or repeated abrading contact with the surface of a workpiece.

2. A brush as defined in claim 1, wherein each of said bristle means made of said extremely flexible, compliant, bendable plastic material has a modulus of elasticity of a sufficiently low value as to cause the intermediate uncoated shaft portion of said bristle means from an end thereof carried by said bristle-mounting brush base means to the integral laterally enlarged coated free outer bristle end thereof, effectively comprising said multi-phase material, to have a bending flexibility and compliance at least twice as great as that which would be provided by said multi-phase material if said coating means extended along substantially the complete length of said shaft portion.

3. A brush as defined in claim 1, wherein said particulate abrasive material and said adhesive bonding material are effectively intermixed whereby to cause said particulate abrasive material to be dispersed throughout said adhesive bonding material exteriorly carried by the corresponding integral, laterally enlarged, free outer end of the corresponding bristle means and together therewith comprising the corresponding enlarged, exteriorly abrasive globule.

4. A brush as defined in claim 1, wherein said outer coating means comprises an outer layer of said particulate abrasive material and an inner cementing and joining layer of said adhesive bonding material providing said strong adhesive junction of said outer coating means with respect to the corresponding integral, laterally enlarged free outer end of the corresponding bristle means whereby to firmly fasten them together.

5. A brush as defined in claim 1, wherein said particulate abrasive material comprises a finely divided material of a hardness substantially greater than that of a material of a workpiece adapted to be abraded thereby and said adhesive bonding material comprises an adhesive plastic epoxy resin material of a hardness substantially less than that of a material of a workpiece adapted to be abraded by said particulate abrasive material whereby to cause said bonding material at the outer surface of each of said enlarged, exteriorly abrasive globules to be abraded and worn away more easily than said abrasive material as a result of frictional contact with a surface of a workpiece adapted to be abraded thereby so as to present fresh, exteriorly protruding and projecting particles of abrasive material to an adjacent contact surface of a workpiece adapted to be abraded thereby.

6. A brush as defined in claim 2, wherein said particulate abrasive material comprises a finely divided material of a hardness substantially greater than that of a material of a workpiece adapted to be abraded thereby and said adhesive bonding material comprises an adhesive plastic epoxy resin material of a hardness substantially less than that of a material of a workpiece adapted to be abraded by said particulate abrasive material whereby to cause said bonding material at the outer surface of each of said enlarged, exteriorly abrasive globules to be abraded and worn away more easily than said abrasive material as a result of frictional contact with a surface of a workpiece adapted to be abraded thereby so as to present fresh, exteriorly protruding and projecting particles of abrasive material to an adjacent contact surface of a workpiece adapted to be abraded thereby.

7. A brush as defined in claim 3, wherein said particulate abrasive material comprises a finely divided material of a hardness substantially greater than that of a material of a workpiece adapted to be abraded thereby and said adhesive bonding material comprises an adhesive plastic epoxy resin material of a hardness substantially less than that of a material of a workpiece adapted to be abraded by said particulate abrasive material whereby to cause said bonding material at the outer surface of each of said enlarged, exteriorly abrasive globules to be abraded and worn away more easily than said abrasive material as a result of frictional contact with a surface of a workpiece adapted to be abraded thereby so as to present fresh, exteriorly protruding and projecting particles of abrasive material to an adjacent contact surface of a workpiece adapted to be abraded thereby.

8. A brush as defined in claim 4, wherein said particulate abrasive material comprises a finely divided material of a hardness substantially greater than that of a material of a workpiece adapted to be abraded thereby and said adhesive bonding material comprises an adhesive plastic epoxy resin material of a hardness substantially less than that of a material of a workpiece adapted to be abraded by said particulate abrasive material whereby to cause said bonding material at the outer surface of each of said enlarged, exteriorly abrasive globules to be abraded and worn away more easily than said abrasive material as a result of frictional contact with a surface of a workpiece adapted to be abraded thereby so as to present fresh, exteriorly protruding and projecting particles of abrasive material to an adjacent contact surface of a workpiece adapted to be abraded thereby.

9. A brush as defined in claim 1, wherein the exterior surface of each of said integral, laterally enlarged, free outer ends of corresponding ones of said bristle means of flexible, compliant, plastic material is effectively softened, porous, and roughened to a predetermined, inwardly directed extent whereby to comprise an effectively softened, porous, and roughened, adhesion-increasing junction interface layer partially penetrated by said outer coating means in a manner increasing the effective adhesive junction strength therebetween.

10. A brush as defined in claim 2, wherein the exterior surface of each of said integral, laterally enlarged, free outer ends of corresponding ones of said bristle means of flexible, compliant, plastic material is effectively softened, porous, and roughened to a predetermined, inwardly directed extent whereby to comprise an effectively softened, porous, roughened, adhesion-increasing junction interface layer partially penetrated by said adhesive bonding material of said outer coating means in a manner

increasing the effective adhesive junction strength therebetween.

11. A brush as defined in claim 3, wherein the exterior surface of each of said integral, laterally enlarged, free outer ends of corresponding ones of said bristle means of flexible, compliant, plastic material is effectively softened, porous, and roughened to a predetermined, inwardly directed extent whereby to comprise an effectively softened, porous, roughened, adhesion-increasing junction interface layer partially penetrated by said adhesive bonding material of said outer coating means in a manner increasing the effective adhesive junction strength therebetween.

12. A brush as defined in claim 4 wherein the exterior surface of each of said integral, laterally enlarged, free outer ends of corresponding ones of said bristle means of flexible, compliant, plastic material is effectively softened, porous, and roughened to a predetermined, inwardly directed extent whereby to comprise an effectively softened, porous, roughened, adhesion-increasing junction interface layer partially penetrated by said adhesive bonding material of said outer coating means in a manner increasing the effective adhesive junction strength therebetween.

13. A brush as defined in claim 5, wherein the exterior surface of each of said integral, laterally enlarged, free outer ends of corresponding ones of said bristle means of flexible, compliant, plastic material is effectively softened, porous, and roughened to a predetermined, inwardly directed extent whereby to comprise an effectively softened, porous, roughened, adhesion-increasing junction interface layer partially penetrated by said adhesive bonding material of said outer coating means in a manner increasing the effective adhesion junction strength therebetween.

14. A brush as defined in claim 6, wherein the exterior surface of each of said integral, laterally enlarged, free outer ends of corresponding ones of said bristle means of flexible, compliant, plastic material is effectively softened, porous, and roughened to a predetermined, inwardly directed extent whereby to comprise an effectively softened, porous, roughened, adhesion-increasing junction interface layer partially penetrated by said adhesive bonding material of said outer coating means in a manner increasing the effective adhesive junction strength therebetween.

15. A brush as defined in claim 7, wherein the exterior surface of each of said integral, laterally enlarged, free outer ends of corresponding ones of said bristle means of flexible, compliant, plastic mtaerial is effectively softened, porous, and roughened to a predetermined, inwardly directed extent whereby to comprise an effectively softened, porous, roughened, adhesion-increasing junction interface layer partially penetrated by said adhesive bonding material of said outer coating means in a manner increasing the effective adhesive junction strength therebetween.

16. A brush as defined in claim 8, wherein the exterior surface of each of said integral, laterally enlarged, free outer ends of corresponding ones of said bristle means of flexible, compliant, plastic material is effectively softened, porous, and roughened to a predetermined, inwardly directed extent whereby to comprise an effectively softened, porous, roughened, adhesion-increasing junction interface layer partially penetrated by said adhesive bonding material of said outer coating means in a manner increasing the effective adhesive junction strength therebetween.

17. A brush as defined in claim 1, wherein said outer coating means is of effectively laminated construction comprising at least two coating layers, with each such coating layer comprising a thin sheet of said adhesive bonding material provided with and effectively carrying a plurality of particles of said particulate abrasive material, with the innermost coating layer being adhesively bonded to the outer surface of said integral, laterally enlarged free end of a corresponding bristle, and with each succeeding outwardly adjacent coating layer having the innermost surface of the adhesive bonding material thereof adhesively joined to the exterior of the next inwardly adjacent coating layer whereby to form said laminated complete outer coating means.

18. A brush as defined in claim 17, wherein said adhesive bonding means of each of said coating layers comprises epoxy resin cured in place with said particulate abrasive material being carried and mounted in cured-in-place relationship by said epoxy resin of said coating layer.

19. A brush as defined in claim 18, wherein each of said bristle means made of said extremely flexible, compliant, bendable plastic material has a modulus of elasticity of a sufficiently low value as to cause the intermediate uncoated shaft portion of said bristle means from an end thereof carried by said bristle-mounting brush base means to the integral laterally enlarged coated free outer bristle end thereof, effectively comprising said multi-phase material, to have a bending flexibility and compliance at least twice as great as that which would be provided by said multi-phase material if said coating means extended along substantially the complete length of said shaft portion.

20. A brush as defined in claim 1, wherein said outer coating means is of effectively laminated construction comprising at least two coating layers, with each such coating layer comprising a thin sheet of said adhesive bonding material provided with and effectively carrying a plurality of particles of said particulate abrasive material, with the innermost coating layer being adhesively bonded to the effectively softened, porous and roughened outer surface of said integral, laterally enlarged free end of a corresponding bristle, and with each succeeding outwardly adjacent coating layer having the innermost surface of the adhesive bonding material thereof adhesively joined to the exterior of the next inwardly adjacent coating layer whereby to form said laminated complete outer coating means.

21. A brush as defined in claim 20, wherein said adhesive bonding means of each of said coating layers comprises epoxy resin cured in place with said particulate abrasive material being carried and mounted in cured-in-place relationship by said epoxy resin of said coating layer.

22. A brush as defined in claim 21, wherein each of said bristle means made of said extremely flexible, compliant, bendable plastic material has a modulus of elasticity of a sufficiently low value as to cause the intermediate uncoated shaft portion of said bristle means from an end thereof carried by said bristle-mounting brush base means to the integral laterally enlarged coated free outer bristle end thereof, effectively comprising said multi-phase material, to have a bending flexibility and compliance at least twice as great as that which would be provided by said multi-phase material if said coating means extended along substantially the complete length of said shaft portion.

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