

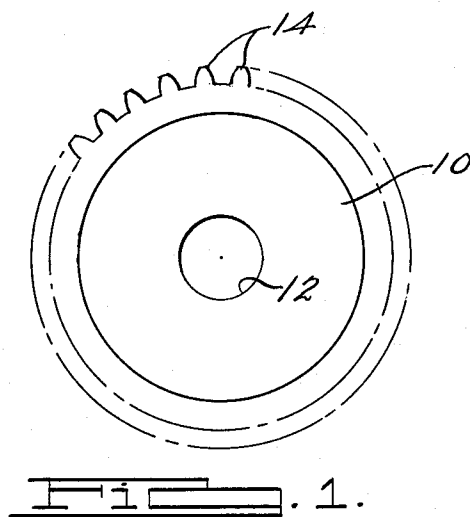
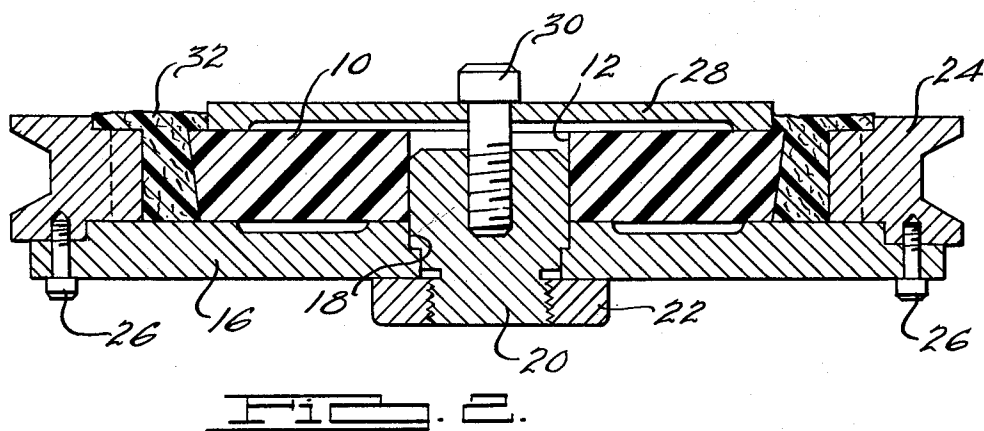
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POLYURETHANE GEAR FINISHING TOOL

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POLYURETHANE GEAR FINISHING TOOL

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The present invention broadly relates to abrasive articles and more particularly to an improved abrasive finishing tool comprising an abrasive matrix consisting of a plurality of abrasive particles tenaciously bonded to each other by a polyurethane resin bonding agent. More specifically, the present invention is directed to an improved gear-shaped abrasive finishing tool adapted to be disposed in meshing relationship with a hardened gear workpiece for imparting an improved surface finish to the faces of the tooth elements on the workpiece.

Gear-shaped abrasive finishing tools of the type comprising the present invention are in widespread use in industry for accurately finishing the surfaces of hardened tooth elements on workpieces such as gears, for example. The abrasive gear-shaped finishing tool is adapted to be mounted in a finishing machine wherein the finishing tool and a hardened gear to be finished are disposed in tight meshing relationship at crossed axes. The tool and workpiece are reciprocated longitudinally relative to each other during their rotation in meshing relationship whereby the full face width of each tooth of the gear to be finished is traversed by the abrasive teeth on the finishing tool. It is the conventional practice to reverse the direction of rotation of the finishing tool and workpiece each time the direction of traversing movement is reversed in order that both faces of each gear tooth are provided with an accurate surface finish. This finishing technique employing an abrasive gear-shaped finishing tool has been found to be eminently satisfactory to correct small dimensional inaccuracies such as tooth spacing, involute profile, lead, and runout caused during the heat treatment of the hardened gear. By virtue of the improved surface finish imparted to the gear teeth in addition to the correction of such small dimensional inaccuracies, improved contact patterns are obtained of mating teeth gears resulting in a significant reduction in the operating noise level of the finished gears and in most instances obviates the heretofore costly and time-consuming practice of matching and lapping gears in pairs.

In a typical finishing operation the abrasive gear-shaped finishing tool is rotatably mounted on a movable frame of a finishing machine and is moved thereby to and from a loading or inoperative position wherein the tool is disposed in loose meshing relationship with a gear to be finished and a finishing or operative position in which the tool is disposed in tight meshing relationship with a workpiece under a preselected tooth pressure. During the course of successively finishing a series of work gears, the abrasive teeth of the abrasive finishing tool become worn to the extent that the tool must be discarded and replaced with a new tool or, alternatively, the worn finishing tool must be removed from the machine and trimmed or dressed to restore it to the proper configuration and dimensional accuracy. While periodic trimming or dressing of the tool substantially prolongs its useful operating life, only a relatively few number of such trimmings can be made after which the tool must be scrapped. The increased emphasis on the use of automatic loading mechanisms on finishing machines of this general type has created the further problem of imposing shock loads on the tooth elements of the abrasive finishing tool which tend to cause fracture or breakage of one or more tooth elements thereon. The fracture of the tooth elements on the finishing tool materially reduces its useful operating life.

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It will be apparent from the foregoing that there is an increasing heretofore unfulfilled need for an expendable-type gear-shaped abrasive finishing tool which is of high strength and impact resistance, which effects rapid and efficient removal of metal from the surfaces of the workpieces in which the finishing tool is disposed in abrasive contact, which retains its dimensional stability during its manufacture and use, and which is of simple and economical manufacture.

It is, accordingly, a principal object of the present invention to provide an abrasive finishing tool which overcomes the disadvantages present in abrasive tools of similar type heretofore known.

Another object of the present invention is to provide an improved abrasive gear-shaped finishing tool which is of improved strength and impact resistance, which is of increased efficiency in the removal of metal from a workpiece being finished, which is itself of increased wear resistance providing for a longer operating life, which through its greater abrasive action enables the use of lower contact pressures to provide a comparable rate of material removal thereby providing for superior surface finishes, and which is of economical and simple manufacture and use.

The foregoing and other objects and advantages of the present invention are based on the discovery that by employing a polyurethane resin of a selected composition as a binding agent for a controlled proportion of abrasive particles, an abrasive matrix is formed suitable for use in gear-shaped finishing tools which possesses high strength and resiliency to absorb impact loads while concurrently providing for increased wear resistance thereby substantially prolonging the useful life of the tool. In addition to providing for a surprising increase in tool life the gear-shaped abrasive finishing tool comprising the present invention also increases the speed and efficiency of the finishing operation thereby providing for greater production efficiency and economy attending its use.

Other objects, features and advantages of the present invention will become apparent from the subsequent description and the appended claims, taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a side elevation view of a typical gear-shaped abrasive finishing tool of the type to which the present invention is applicable, and

FIG. 2 is a transverse vertical sectional view through a mold illustrating the manner by which the tool can be simply made to extremely accurate dimensional tolerances.

Referring now in detail to the drawings and as may be seen in FIGURE 1, an abrasive gear-shaped finishing tool constructed in accordance with the preferred practice of the present invention, comprises a central hub 10 having an arbor or bore 12 therethrough for rotatably mounting the finishing tool on a spindle by which it is rotated in meshing relationship with a workpiece to be finished. The peripheral portion of the finishing tool is formed with a plurality of teeth 14 which are comprised of an abrasive matrix consisting of a polyurethane resin bonding agent and a plurality of abrasive grains dispersed and tenaciously bonded therein. The abrasive matrix extends inwardly and is tenaciously bonded to the peripheral portion of the hub 10. The central hub 10 may be comprised of any suitable plastic or metal of sufficient strength to rigidly and integrally support the peripheral abrasive matrix.

It is important in order to achieve the benefits of the present invention that the abrasive matrix be comprised of a selected polyurethane resin which in admixture with the abrasive particles and additional filler materials if desired, provides a structure which possesses unique physical properties thereby providing for improved strength, wear resistance, and more efficient abrasive action. The poly-

urethane elastomer suitable for use in the invention comprises the reaction product between tolylene diisocyanate and a polyhydroxy ether compound with active hydroxyl groups thereon. The polyhydroxy ether constituent suitable for preparing the polyurethane resin consists of those having an average molecular weight ranging from about 1000 up to about 1500. The polyhydroxy ether compound and the diisocyanate compound can be employed separately and admixed together prior to molding or alternatively, a prepolymer can be formed containing a portion of the diisocyanate compound and all of the polyhydroxy ether constituent to which the excess diisocyanate compound is subsequently added at such time that the moldable abrasive mixture is to be prepared.

A prepolymer of the polyhydroxy ether and a portion of the diisocyanate constituent which has been found eminently satisfactory for the purposes of the present invention has a specific gravity ranging from about 1.41 to about 1.43 at 25° C. and is opaque having a natural buff color. The Brookfield viscosity expressed in centipoises taken at 77° F. with a model LVF spindle No. 4 is as follows: 6 r.p.m.—5000 to 6000 c.p.s.; 12 r.p.m.—3600 to 4500 c.p.s.; 30 r.p.m.—2480 to 3200 c.p.s.; and 60 r.p.m.—1950 to 2500 c.p.s. A prepolymer of the aforementioned type suitable for use in accordance with the present invention is commercially available from Reichhold Chemicals, Inc., and is designated as type 98-183. The tolylene diisocyanate constituent has a specific gravity at 25° C. of from 1.261 to 1.270 and a Brookfield viscosity at 77° F. of 2000 to 3000 c.p.s. at 60 r.p.m. employing a model LVS spindle No. 4. The polyisocyanate constituent is commercially available from Reichhold Chemicals, Inc. and is designated as type 34-625.

The prepolymer is admixed with the tolylene diisocyanate constituent in the proportions of about 100 parts by weight of prepolymer and about 26 parts per weight of the tolylene diisocyanate constituent corresponding to a percentage by weight of these constituents of 79% and 21%, respectively. The resultant cured polyurethane elastomer has a specific gravity taken at 25° C. of from about 1.378 to about 1.395; a density at 25° C. of from about 0.0498 to about 0.0502 pound per cubic inch, a Shore D hardness at 200° F. of from 40 to 45, at 77° of from 55 to 60 and at -13° F. of from 75 to 80; a tensile strength at 25° C. of from about 1500 to 2000 p.s.i.; a percent elongation at the 25° C. of about 65% to 75%; a compression load deformation under a load of 300 p.s.i. for a period of 24 hours at a temperature of 25° C. of from about 5.45% to about 5.75%; a compression set 30 minutes after load release at 25° C. of from 1.0% to 1.1%, and a shrinkage of about 0.001 to about 0.002 inch per inch during curing. The foregoing physical properties of the polyurethane elastomer are important to achieve the requisite structural characteristics when the abrasive particles are incorporated therein to achieve an abrasive gear-shaped finishing tool having a long useful operating life and improved abrasive finishing action.

The polyurethane resin constituent serves as the bonding agent of the abrasive particles and filler materials which may conventionally be employed in the proportions as set forth in the following table:

ABRASIVE MATRIX COMPOSITION

Ingredient	Usable Range, Percent by Weight	Preferred Range, Percent by Wt.
Polyurethane Resin.....	20-80	40-60
Abrasive Particles.....	20-80	30-50
Filler Materials.....	0-50	10-12

It is also contemplated within the scope of the present invention that the abrasive matrix may exclusively

comprise the polyurethane bonding agent in addition to some filler materials resulting in a finishing tool which is satisfactory for use in many polishing type finishing operations. Conventionally, however, the abrasive matrix incorporates at least about 20% by weight abrasive particles and preferably from about 30% up to about 50% abrasive based on the weight of the total abrasive mixture.

The abrasive material which is suitable for use in the manufacture of abrasive gear-shape finishing tools of the type comprising the present invention, can vary in composition and in grit size depending on the nature of the abrasive finishing action desired. The abrasive medium may be comprised of materials such as silicon carbide, aluminum oxide, diamonds, glass, silicon dioxide, etc., which may range in grit size from about 200 up to about 22 grit. The abrasive particles may also be blended to form mixtures of different compositions and grit sizes to provide the optimum finishing action consistent with the particular nature of the workpieces to be finished. Abrasive grains having a particle size of around 200 grit provide for an extremely fine degree of surface finish and act primarily as a filler for the resin constituent of the abrasive matrix. On the other hand grit sizes ranging from about 30 up to about 100 provide effective abrasive action suitable for removing the burrs and nicks on the tooth faces of hardened gear teeth. Conventionally, in the manufacture of a gear-shaped abrasive finishing tool for use in finishing hardened gear teeth, for example, it is preferred to employ a mixture of silicon carbide and aluminum oxide abrasive grains consisting of substantially equal proportions of 80 and 54 grit and a minor proportion of size 36 grit.

The filler materials which may be incorporated in the abrasive mixture in an amount up to the quantity set forth in the foregoing table serve primarily as extenders for the resin abrasive mixture and also contribute to the physical properties of the resultant gear-shaped finishing tool. Fillers of the non-wicking or non-absorbent type are preferred which facilitate achievement of homogeneity of the resultant gear-shaped finishing tool and also add weight and strength thereto. A filler material such as air borne silica which is thixotropic can be satisfactorily employed in the proportions indicated in the table which facilitates maintaining a substantially uniform suspension of the abrasive particles in the resin mixture during the curing of the bonding agent. Alternative filler materials of the types well known in the art including fiber glass, calcium phosphate, calcium sulphate, zinc oxide, carbon black, graphite, etc., can also be satisfactorily employed.

In preparing a moldable resin-abrasive mixture the resin constituent or prepolymer and the diisocyanate constituent comprising the polyurethane resin reaction mixture is preliminarily admixed together in a manner so as to minimize the entrapment of air bubbles in the mixture. Moreover, the resin and polyisocyanate constituents used are substantially water free so as to prevent the generation of carbon dioxide gas during the curing reaction which would promote the formation of a polyurethane cellular foam instead of a dense elastomer of the type required for tenaciously bonding the abrasive particles. The pot life of the uniformly blended polyurethane reaction mixture conventionally ranges from about 60 minutes to about 120 minutes.

The appropriate blend of abrasive grains also in a substantially moisture-free condition are thereafter uniformly admixed with the polyurethane reaction mixture which may be conveniently achieved by suitable or manual or mechanical stirring techniques. It is usually preferred to allow the blend of reaction mixture and abrasive grains to stand for a period of time after mixing and prior to molding to enable the escape of any entrapped air bubbles which may have been introduced in the mixture during the mixing operation. Alternatively, the

resin abrasive mixture can be subjected to a partial vacuum whereby the removal of any entrapped air bubbles is facilitated.

The resultant resin-abrasive mixture can thereafter be cast in a suitable mold and the polyurethane reaction mixture cured at a temperature ranging from about room temperature up to about 200° F. Since the reaction itself is exothermic, the heat generated during the curing of the polyurethane resin provides a source of heat which promotes complete curing of the resin without the use of exteriorly applied heat. It is usually preferred, in order to increase the rate of cure of the resin-abrasive mixture, to heat the mixture after casting to a temperature of about 100° F. This may suitably be achieved in an oven, preferably one which is pressure-tight enabling the imposition of a pressure of upwards of 100 pounds per square inch on the abrasive mixture minimizing the formation of large air bubbles in the reaction mass during curing. It has been found that by maintaining a reaction mixture containing abrasive grains therein at a temperature of about 100° F. under a pressure of 100 p.s.i. for a period of about 5 hours, a sufficient curing of the polyurethane bonding agent occurs to enable the mold to be removed from the oven and after standing at room temperature for an additional 7 hours or so the finishing tool can be stripped from the mold. Substantially complete curing of the polyurethane resin occurs during a post-cure or aging period conventionally comprising about 6 days during which the molded article standing at room temperature will attain its optimum physical characteristics.

It will be appreciated that variations in the curing cycle can be achieved by altering the time-temperature relationship to which the reaction mixture is exposed. While the resin-abrasive mixture can be heated to temperatures up to about 200° F., it is usually preferred to control the preliminary heating of the mixture to a temperature of about 100° F. The exotherm subsequently effects further heating of the resin-abrasive mixture further accelerating its curing action. Similarly while initial curing under a positive pressure is preferred, eminently satisfactory results have been obtained on cast gear-shaped finishing tools which were molded under atmospheric pressure conditions.

A typical mold suitable for casting a gear-shaped abrasive finishing tool of the type comprising the present invention is illustrated in FIGURE 2. The mold as shown in the drawing comprises a base plate 16 formed with a notched bore 18 in the center thereof in which a stud 20 is removably disposed and fastened by a clamping nut 22 threadably engaged on the threaded shank portion thereof. A ring mold 24 is removably secured to the base plate 16 by means of a series of circumferentially spaced attaching screws 26. The inner surface of the ring mold 24 is formed with a plurality of tooth elements thereon defining cavities corresponding to the involute abrasive tooth profile of the tooth elements desired to be formed on the abrasive finishing tool.

The central hub 10 which may be of a suitable pre-formed plastic or metallic material is centrally aligned in the mold by means of the bore 12 which is disposed in bearing contact around the stud 20. The central hub 10 is retained in appropriate position by means of a clamping plate 28 positioned in overlying clamping relationship on the hub section and retained in bearing relationship thereagainst by means of a clamping screw 30. With the mold in the assembled condition as shown in FIGURE 2, the resin-abrasive mixture indicated generally at 32 is poured in the annular space between the periphery of the hub section 10 and the inner surface of the ring mold 24 in an amount preferably in excess so as to assure a substantially complete filling of the annular space therebetween. The excess portion which overflows the annular space may thereafter be suitably trimmed off in a manner subsequently to be described.

In order to prevent tenacious adhesion between the resin abrasive mixture and the mold surfaces, a suitable mold release agent is employed which is applied to the surface of the base plate and to the inner surface of the ring mold exposed to contact with the resin-abrasive mixture during its curing reaction. Any one of a number of suitable mold release agents such as silicone fluids, polyethylene films, polyvinyl alcohol films, and polytetrafluoroethylene films, for example, can be satisfactorily employed for achieving the desired release characteristics of the cured abrasive gear-shaped finishing tool from the mold surface. At the completion of the curing of the resin-abrasive mixture or at least a sufficient partial curing thereof to retain its molded configuration, the mold is simply disassembled by removing the clamping screw 30 and clamping plate 28 and detaching the attaching screws 26 enabling the base plate 16 and stud 20 to be removed from the finishing gear by means of an arbor press, for example. The resultant gear-shaped finishing tool having the ring mold 24 around the periphery thereof can thereafter be simply separated by inverting the assembly and pressing the finishing gear from the ring mold. The excess resin-abrasive mixture on one side of the finishing tool can be simply removed such as by placing the finishing tool on a lathe spindle and removing the excess material by means of a suitable diamond-tipped tool such that the abrasive peripheral portion of the tool corresponds to the width of the hub section 10.

In order to further illustrate the improved abrasive finishing tool comprising the present invention, the following example is provided. It will be appreciated that the example is included for illustrative purposes and is not intended to be limiting of the scope of the invention as set forth in the subjoined claims.

Example 1

A resin-abrasive mixture was prepared comprising two parts by weight of an abrasive grit mixture and one part by weight of a polyurethane resin bonding agent. The abrasive grit comprised 10% by weight of a No. 36 silicon carbide grit, 40% by weight of a No. 80 silicon carbide grit, and 50% by weight of a No. 54 aluminum oxide grit. The resin constituent comprised 100 parts by weight of a prepolymer (Polylite 98-183), and 26.5 parts by weight of the polyisocyanate constituent (Polylite 34-625) available from Reichhold Chemicals, Inc.

The resin after being thoroughly mixed was thereafter blended with the abrasive grains forming a substantially uniform blend. The resulting resin-abrasive mixture was thereafter poured in a mold of the type illustrated in FIGURE 2 having a silicone release agent on the mold surfaces thereof. After the annular region of the mold was filled with the resin-abrasive mixture, the mold assembly was placed in a pressurized oven at a temperature of 100° F. and under a pressure of 100 p.s.i. for a period of 5 hours to effect preliminary curing of the polyurethane resin. At the completion of the 5 hour cure cycle under the aforementioned temperature and pressure, the mold was removed from the oven and allowed to stand at room temperature 7 additional hours. Thereafter, the substantially completely cured gear-shaped abrasive finishing tool was removed from the mold assembly and allowed post-cure or age at room temperature for an additional 6 day period.

A similar abrasive gear-shaped finishing tool was made employing an epoxy type resin of the types heretofore used in making finishing tools of similar type. After complete curing of both the polyurethane finishing tool and the epoxy finishing tool, each abrasive finishing tool was employed for finishing 25 surface hardened gears and 25 surface hardened pinions. The conditions and the

results of these tests for the polyurethane and epoxy finishing tools are set forth in the following table:

Condition	Polyurethane Finish Tool	Epoxy Finishing Tool
Dia. over 2 pins (.080 dia.) new-----	8.5220	8.5290
Dia. over 2 pins (.080 dia.) used-----	8.5205	8.5240
Number pieces finished (gear)-----	25	25
Number pieces finished (pinion)-----	25	25
Tooth clean-up (gear)-----percent-----	80-100	80-100
Tooth clean-up (pinion)-----do-----	70-100	70-100
Metal removal over pins (gear)-----	.0001/.0002	.0000/.0001
Metal removal over pins (pinion)-----	.0001/.0002	.0000/.0001
Finishing cycle time (gear and pinion) second-----	45	45
Transverse feed (gear and pinion) feet/minutes-----	4	4
Tool r.p.m. (gear)-----	200	200
Tool r.p.m. (pinion)-----	140	140

As will be noted in the foregoing table, a reduction in the diameter of the abrasive gear-shaped finishing tools as measured by the diametric distance between the outer surfaces of two 0.080 inch diameter pins disposed between adjacent tooth elements on opposite sides thereof revealed that a loss of only 0.0015 inch occurred in the polyurethane finishing tool whereas a wear of 0.0050 inch occurred in connection with the epoxy finishing tool. In addition to the improved wear resistance of the polyurethane finishing tool comprising the present invention, it will be further noted that the polyurethane tool had a substantially greater abrasive action as indicated by the quantity of material removed from both the work gears and pinions in comparison to that obtained under similar conditions by the use of the epoxy finishing tool. As indicated in the table, a decrease in the pin-to-pin diameter of the work gears of from 0.0001 to 0.0002 inch occurred in the case of the polyurethane finishing tool whereas a maximum material removal of up to 0.0001 inch was observed for both the pinions and work gears finished by the epoxy finishing tool.

In addition to the foregoing data, an examination of the tooth elements of the epoxy finishing tool revealed that at the completion of the twenty-second work gear, the abrasive tooth elements of the epoxy finishing tool began to crumble. No evidence of fracture or crumbling of the teeth of the polyurethane finishing tool was observed at the completion of the entire finishing operation.

The resulting data confirm that the polyurethane finishing tool removed 50% more metal in the same length of time as was removed by the epoxy finishing tool while the epoxy finishing tool wore down 30% faster than the polyurethane tool during the same length of time. The greater removal of metal by the polyurethane finishing tool was also accompanied by a better appearing surface finish. The foregoing data are believed to clearly estab-

lish the surprising superiority in the abrasive finishing action and durability of abrasive finishing tools made in accordance with the present invention.

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

10 What is claimed is:

1. An abrasive gear-shaped finishing tool comprising a cylindrical body having a plurality of tooth elements therearound at least the surfaces of which are comprised of an abrasive matrix comprising a polyurethane resin bonding agent and a plurality of abrasive grains tenaciously bonded therein, said bonding agent comprising the reaction product between tolylene diisocyanate and a polyhydroxy ether resin having a molecular weight ranging about 1000 up to about 1500, said bonding agent present in an amount ranging from about 20% to about 80% by weight of said abrasive matrix.

2. An abrasive gear-shaped finishing tool comprising a cylindrical body having a plurality of tooth elements therearound at least the surfaces of which are comprised of an abrasive matrix comprising a polyurethane resin bonding agent and a plurality of abrasive grains tenaciously bonded therein, said bonding agent comprising the reaction product between tolylene diisocyanate and a polyhydroxy ether resin having an average molecular weight of from about 1000 to about 1500, said bonding agent present in an amount of from about 40% to about 60% by weight of said abrasive matrix.

3. An abrasive gear-shaped finishing tool comprising a cylindrical body having a plurality of tooth elements therearound at least the surfaces of which are comprised of an abrasive matrix consisting of a polyurethane resin bonding agent and a plurality of abrasive grains tenaciously embedded therein, said bonding agent comprising the reaction product of about 100 parts by weight of a prepolymer consisting of tolylene diisocyanate and a polyhydroxy ether resin having a molecular weight ranging from about 1000 to about 1500 and a polyisocyanate constituent consisting of tolylene diisocyanate present in an amount of about 26.5% parts by weight, said bonding agent present in an amount ranging from about 20% to about 80% by weight of said abrasive matrix.

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