

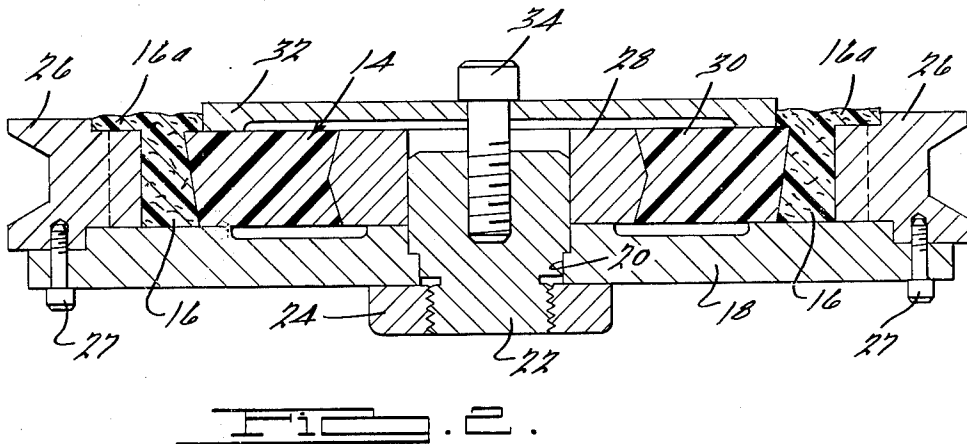
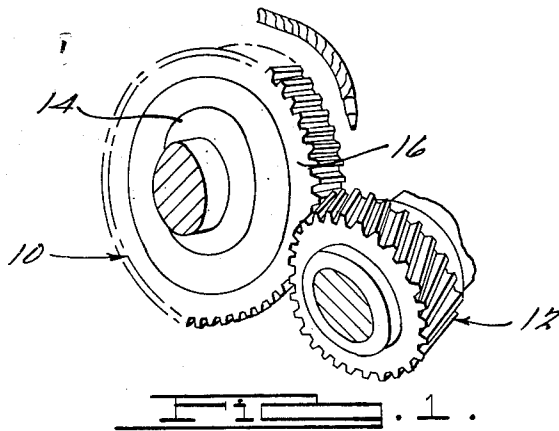
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TOOL FOR FINISHING TOOTHED ELEMENTS

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TOOL FOR FINISHING TOOTHED ELEMENTS

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The present invention broadly relates to resin-bonded abrasive articles and more particularly to a novel abrasive finishing tool employing a copolymerized polyamide-epoxy resin bonding agent providing for high strength and superior durability over abrasive tools of similar type heretofore known. More specifically, the present invention relates to resin-bonded gear-like finishing tools adapted for finishing the surfaces of workpieces having toothed elements thereon such as gear teeth, splines, serrations, and the like.

The abrasive articles comprising the present invention and more specifically, the gear-like abrasive finishing tools are used in industry for accurately finishing the surfaces of hardened tooth elements on workpieces such as gears, for example. The gear-like abrasive finishing tool is employed in finishing machines wherein the workpiece and finishing tool are rotated in tight meshing relationship at cross axes. The tool and workpiece are reciprocated longitudinally relative to each other whereby the full face width of each of the tooth elements on the workpiece is traversed by the finishing tool. The direction of rotation of the finishing tool and workpiece is conventionally reversed each time the direction of the traversing movement is reversed.

In accordance with the foregoing finishing technique, nicks and burrs on hardened gear teeth can be quickly removed. In addition, the finishing operation also serves to correct small dimensional inaccuracies such as tooth spacing, involute profile, lead, and runout caused during the heat treatment of the toothed workpieces. The correction of such dimensional inaccuracies and the smooth surface finish obtained provides for improved contact patterns of mating teeth of gears, for example, resulting in a material reduction in the noise level of the finished gears during use and in most instances, obviates the heretofore costly and time-consuming practice of matching and lapping gears in pairs.

The finishing tool is conventionally mounted on the finishing machine so that it is movable to and from a loading or inoperative position wherein it is disposed in loose meshing engagement with a workpiece to be finished, and a finishing position wherein it is disposed in tight meshing relationship with the workpiece at a preselected tooth pressure. The use of the finishing tool over a prolonged period of time for successively finishing toothed workpieces progressively causes the tool to become worn to the extent that it must be discarded and replaced with a new finishing tool or alternatively, the worn tool is removed from the machine and trimmed or dressed to restore it to the proper configuration and dimensional tolerances. After repeated dressings, however, the tool must eventually be discarded. In either case the replacement or dressing of the finishing tool necessitates an interruption of the finishing operation detracting from the overall production efficiency of the machine. A further problem arises in the use of automatic loading mechanisms on the finishing machines wherein some clashing between the toothed elements of the workpiece and the finishing tool is encountered during loading of the workpiece and movement of the tool to the finishing position causing shock loading of the tooth elements of the finishing tool which in some instances results in fracture or breakage thereof.

In view of the foregoing, a continuing need has been

presented for providing abrasive tools including gear-like finishing tools which are of high strength and impact resistance, which possess a long useful operating life, which effect rapid and efficient removal of material from the surfaces in which they are disposed in abrasive contact, which retain their dimensional stability during manufacture and use, and which are of simple and economical manufacture.

It is, accordingly, a principal object of the present invention to provide an improved abrasive tool and a simplified method of making the abrasive tool which overcomes the disadvantages of the abrasive tools and methods heretofore known providing greater efficiency in finishing operations, a longer tool life, and improved economy in manufacture and use.

Another object of the present invention is to provide an abrasive tool comprising a plurality of abrasive grains which are tenaciously bonded by a polyamide-epoxy resin bonding agent which markedly increases the wear resistance and useful life of the abrasive tool and, additionally, enables the tool to be employed at lower contact pressures to achieve the same rate of material removal providing for superior surface finishes.

Still another object of the present invention is to provide an improved simplified method of making abrasive gear-like finishing tools employing a polyamide-epoxy bonding agent which has a long pot life and which tenaciously bonds the abrasive particles impregnated therein through a self-sustaining exothermic reaction which can be initiated at room temperature without the necessity of employing special equipment and operating conditions.

The foregoing and other objects and advantages of the present invention are based on the discovery that by employing a controlled mixture of selected reactive polyamide and epoxy resins as a bonding agent for a controlled quantity of selected abrasive particles, an abrasive tool is obtained which possesses surprisingly superior tool life characteristics than abrasive tools of similar type heretofore known. For example, abrasive gear-like finishing tools made in accordance with the present invention and employed for finishing the surfaces of hardened gear teeth have been found to provide up to five times the useful operating life before necessitating a trimming or dressing thereof and up to eight times the total useful operating life in comparison to conventional epoxy bonded finishing tools under similar finishing conditions. This unexpected improvement, coupled with the superior strength and impact resistance of the polyamide-epoxy bonded abrasive tools, has resulted in substantial improvements in the efficiency and economy of finishing toothed elements of hardened workpieces.

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

FIGURE 1 is a fragmentary perspective view of a gear-like abrasive finishing tool disposed in meshing relationship at cross axes with a work gear to be finished; and

FIG. 2 is a vertical transverse sectional view taken through a mold for casting abrasive gear-like finishing tools in accordance with the preferred method of the present invention.

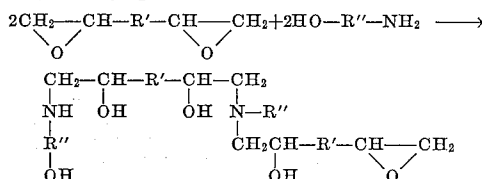
With reference to FIGURE 1 of the drawings, a typical abrasive gear-like finishing tool 10 is illustrated, having teeth thereon which are conjugate to and disposed in tight meshing relationship with a toothed workpiece such as a gear 12. The finishing tool 10 is generally comprised of an inner hub section 14 which may either be of a metallic or synthetic resin material and which is adapted to be rotatably mounted on a spindle of a finishing machine. The peripheral portion or working surface of

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the tool 10 comprises a resin-abrasive mixture 16 which is formed with a plurality of toothed elements therealong which on meshing sliding contact with the toothed elements of the work gear 12 produce the desired abrasive finishing action. The resin-abrasive mixture 16 comprising a matrix of the bonding agent in which the abrasive and filler particles are tenaciously bonded is bonded to the hub section 14 forming therewith an integral abrasive finishing tool.

In order to achieve the superior results of the abrasive tools made in accordance with the practice of the present invention, the proportions and the types of the polyamide resin and epoxy resin which are employed must be controlled within prescribed limits. A reactive polyamide resin or blend of polyamide resins is employed containing a controlled proportion of reactive amino groups which on blending with a selected epoxy resin undergoes a reaction or cure with the epoxy groups thereon resulting in a new thermosetting resin possessing properties unlike either of the resins alone and possessing new properties. The cured bonding agent is not merely a mixture of the polyamide and epoxy resins, but an entirely distinct chemical entity. After the curing reaction neither of the two resins is recoverable from the reactant mixture. The reaction between the active amino groups and the epoxy groups is exothermic and is instituted without the necessity of employing any catalysts or accelerator agents. The reaction can be carried out at room temperature and is self-sustaining through the exothermic heat evolved until a cured and hardened product possessing the desired physical properties is obtained.

The thermosetting reaction product obtained by the reaction of the reactive polyamide resin with the epoxy resin is believed to occur in accordance with the following simplified graphical illustration:



The foregoing reaction mechanism proceeds without the use of a catalyst resulting in the formation of a three-dimensional cross-linked thermosetting copolymer of the desired molecular weight having a high degree of impact resistance and the desired degree of resiliency and simultaneously providing tenacious bonding of the abrasive particles and miscellaneous filler materials into an integral and dimensionally stable mass.

The reactive polyamide resins usable in accordance with the practice of the present invention are those of the class derived from the condensation polymerization of dibasic acids obtained by the polymerization of unsaturated fatty acids, and polyamines. The polyamide resins are of low to moderate average molecular weight and possess reactive amino groups therein which react with the epoxy groups of the epoxy resin blended therewith. An indication of the degree of reactivity of the free amino group containing reactive polyamide resin is the amine value thereof which is indicative of the number of available reactive primary or secondary amino groups thereon. The amine value as herein employed is defined as the milligrams of potassium hydroxide equivalent to the amine alkalinity present in one gram of the resin. This value is conventionally determined by dissolving a weighed quantity of the polyamide resin in a solvent and titrating the solvated resin with .5 N hydrochloric acid. For the purposes of the present invention, reactive polyamide resins having amine values ranging from about 80 up to about 400 can be satisfactorily employed in formulating the bonding agent.

The polyamide resins are further characterized as being in a liquid form to facilitate blending with the epoxy

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resin constituent and may be thinned in viscosity by incorporating a controlled quantity of a suitable solvent such as, for example, alcohol or cellosolve. In the preferred practice of the present invention the polyamide resin is preferably selected of an average molecular weight to provide a sufficiently low viscosity to avoid use of solvents. Solvent containing polyamide resins are not preferred because volatilization of the solvent during the exothermic curing reaction has a tendency to form a slight degree of porosity in the resultant cured abrasive article and also increases the shrinkage of the molded article. When polyamide resins of a relatively high viscosity are employed, it is preferred that the resins are heated to an elevated temperature to achieve a viscosity decrease rather than incorporating a solvent therein.

The polyamide resins are conventionally made by the condensation of dimerized vegetable oil acids and suitable polyamine compounds. The initial reaction is carried out at low temperature in an autoclave followed by a progressive increase in the temperature to a point where the water of condensation is removed. Toward the completion of the reaction, a vacuum is applied and the temperature is raised in order that the reaction can be continued to an advanced degree of condensation polymerization to achieve the desired molecular weight.

The epoxy resins suitable for reaction with the polyamide resin to form the bonding agent comprise liquid epoxy polymers obtained by the additional polymerization of bisphenol A with epichlorohydrin resulting in a long chain molecule having ether linkages therein and reactive epoxy groups therealong which are reactive with the amino groups of the polyamide resin forming therewith a branched thermosetting copolymer. The epoxy resins may either be of the so-called pure type or of the modified type which are modified with reactive monomeric diluents which may contain a single epoxide group per molecule. The reactive monomeric diluents are generally classified as monoepoxides produced by the reaction of epichlorohydrin with such monohydroxol compounds as allyl alcohol, butyl alcohol, and phenol, to give allyl glycidyl ether, butyl glycidyl ether, and phenyl glycidyl ether, respectively. Styrene oxide can also be satisfactorily employed. The reactive diluents can be added in small proportions to the liquid epoxy resin in amounts up to about 15% and effect a reduction in the initial viscosity thereof without seriously impairing the properties of the resultant cured resin binding agent. However, an impairment in the strength of the resultant binding agent is obtained when concentration of the monomeric reactive diluent above about 15% are employed. In accordance with the preferred practice of the present invention, the so-called pure type epoxy resins are employed because of the superior physical properties of the resultant abrasive tool.

An indication of the reactive epoxy group content of the epoxy resin is conveniently expressed in terms of an epoxide equivalent value which represents the weight equivalent in grams of epoxy resin containing 1 gram equivalent of epoxide. The epoxide equivalent value is also indicative of the molecular weight of the epoxy resin employed. For the purposes of the present invention, epoxy resins having an epoxide equivalent value ranging from about 175 to about 200, and preferably from about 185 to about 195 can be satisfactorily employed.

The polyamide resin and epoxy resin of the type hereinabove set forth are employed in the bonding agent in proportions broadly ranging from about 15% up to about 65% by weight of the polyamide resin, and preferably from about 40% to about 60% of the polyamide resin and the balance epoxy resin. Because of the excellent pot life of the resin mixture which is generally in excess of 3 hours at room temperature, the two resins can be blended together directly after which suitable proportions of the abrasive particles or grit and other filler materials are added forming therewith a substantially

uniform mixture. The resultant blended resin-abrasive mixture can be thereafter cast into suitable molds of the appropriate configuration and subsequently cured forming a dimensionally stable, integral, homogeneous abrasive tool.

The composition of the resin-abrasive mixture which can be satisfactorily employed for forming abrasive tools in accordance with the practice of the present invention is set forth in the following table:

ABRASIVE TOOL FORMULATION

Ingredient	Usable Range, Percent by Weight	Preferred Range, Percent by Weight
Polyamide-epoxy resin mixture.....	20-80	40-60
Abrasive particles.....	20-80	30-50
Filler materials.....	0-50	10-12

The abrasive tool formulation as set forth in the foregoing table may exclusively comprise the resin mixture and some filler materials resulting in a tool which is satisfactory for use in some polishing-type finishing operations. Conventionally, however, at least 20% of the abrasive particles are employed, and preferably from about 30% to about 50% of abrasive particles based on the weight of the total mixture is used.

The abrasive particles suitable for use in the manufacture of abrasive tools can vary in grit size depending on the degree of abrasive finishing action desired. Abrasive particles such as silicon carbide, aluminum oxide, diamonds, glass silicon dioxide, etc., having a grit size ranging from about 200 grit up to about 22 grit as well as mixtures or blends thereof can be satisfactorily employed in the proportions indicated. 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 article. In the manufacture of abrasive finishing tools for finishing the hardened surfaces of tooth elements such as gear teeth, for example, it is generally preferred to employ a blend of abrasive grains such as silicon carbide and aluminum oxide comprising equal proportions of about 80 grit and 54 grit.

In addition to the resin constituent and the abrasive content, the abrasive tool formulation may also include varying proportions of suitable filler materials in amounts indicated in the foregoing table. The filler materials serve primarily as extenders for the resin-abrasive mixture and also contribute to the final physical properties of the resultant abrasive tool. Non-wicking or non-absorbent type filler materials are preferred which facilitate achievement of homogeneity of the resultant abrasive tool and add weight and strength thereto. A filler material such as airborne silica which is thixotropic can be satisfactorily employed in the proportions indicated and facilitates maintaining a substantially uniform suspension of the abrasive particles in the resin mixture during the setting and curing the resins. Alternate filler materials of the type well known in the art including fiberglass, calcium phosphate, calcium sulfate, zinc oxide, carbon black, graphite, etc. can also be satisfactorily employed.

The appropriate proportions of polyamide and epoxy resins are blended together employing a mixing technique which minimizes the introduction and entrapment of air bubbles therein. Thereafter, a suitable proportion of abrasive particles or mixture of abrasive particles and filler materials are added and blended into the resin mixture forming a substantially homogeneous blend. Mixing of the resin and abrasive particles in addition to the filler materials can satisfactorily be accomplished by calender rolling or by suitable manual or mechanical stirring techniques. The resultant blend can be thereafter readily cast into a mold of suitable configuration, the surfaces of which have been coated with a release agent

and cured into a solid mass. It is usually preferred to allow the resin-abrasive mixture to stand for a period of time such as about 15-30 minutes, for example, after mixing and prior to molding to enable escape of any entrapped air bubbles which may have been introduced during the mixing phase. Alternatively, the resin-abrasive mixture can be subjected to a partial vacuum wherein the removal of any entrapped air is facilitated.

As hereinbefore set forth, the curing of the resin-abrasive mixture can conventionally be achieved at room temperature without the use of any accelerating catalysts. The exothermic heat generated during the curing reaction of the resin, particularly when relatively thick sections are being cast as encountered in abrasive tools, generally provides for a self-sustaining reaction and the cure is substantially complete by allowing the cast article to cure overnight. It is possible, however, to employ heat either as a post-cure of a room-temperature cured abrasive tool or to initiate the curing cycle by heating the mold to a temperature of up to about 400° F. Molding of the resin-abrasive mixture can also be achieved under heat and pressure by placing the mold in a pressurized oven which is heated to an elevated temperature which effects both an increase in the rate of cure as well as a reduction in the potential porosity resulting from the entrapment of minute air bubbles in the liquid mix.

Further increases in the rate of cure can be achieved by incorporating suitable accelerators or catalysts in the resin-abrasive mixture. A variety of suitable accelerating compounds can be employed such as, for example, tertiary amines, boron trifluoride amine complexes, which are included in amounts generally ranging from about 5% up to about 15% of the polyamide resin content. The inclusion of such an accelerator compound is generally not preferred, however, in view of the substantially decreased pot life of the resin-abrasive mixture and the higher degree of shrinkage and distortion of the resultant cast article.

In view of the foregoing reasons and particularly in the case of casting gear-like abrasive finishing tools which must be maintained within relatively close dimensional tolerances, it is preferred that the curing reaction between the polyamide and epoxy resin is accomplished without the use of an accelerator and at a relatively low curing temperature which, if desired, can be followed by a moderately elevated post-curing temperature such as, for example, about 150° F. to assure substantially complete curing of the abrasive tool. The judicious selection of abrasive grains and filler materials blended with the resin in the appropriate proportion also reduces shrinkage of the cast article and provides for an increase in the dimensional stability thereof. Resin abrasive mixtures incorporating fillers therein in the amounts previously set forth which when cured at moderately low temperatures, have been observed to provide a shrinkage as low as about five ten thousandths of an inch which constitutes a further advantage of the composition and method of making abrasive articles in accordance with the present invention.

A typical mold suitable for casting abrasive gearlike finishing tools is illustrated in FIG. 2. The mold as shown in the drawing comprises a base plate 18 formed with a notched bore 20 in the center thereof in which a stud 22 is removably disposed and fastened by a clamping nut 24 threadably engaged on the threaded shank portion thereof. An internal master gear 26 is detachably secured along the periphery of the base plate 18 by means of a series of holding screws 27 and is disposed concentrically with the central stud 22. The hub section 14 is of a composite structure comprising an inner metallic sleeve 28 and a plastic rim 30 securely bonded thereto and extending radially therefrom to points spaced from the master gear 26. The composite construction of the hub section 14 is such that the metallic sleeve 28 is located adjacent to the spindle on which finishing tool is

placed and clamped thereon. The plastic rim 30 provides a lightweight extension of the hub section 14 resulting in a finishing tool which is of high strength and comparatively lightweight.

The hub section 14 is centrally aligned in the mold by the central stud 22 and is held in position by an overlying clamping plate 32 secured to the stud 22 by a clamping screw 34. With the mold and hub section in the assembled condition as shown in FIG. 2 the resin-abrasive mixture indicated at 16 is then poured in the annular space between the periphery of the hub section 14 and the inner surface of the master gear 26 in an amount preferably in excess to insure substantially complete filling of the annular region. The excess portion which overflows the annular space is indicated in FIG. 2 at 16a.

To avoid adhesion between the resin-abrasive mixture 16 and the surfaces of the base plate 18 and internal master gear 26 in contact therewith during the curing reaction, a suitable mold release agent is employed which is applied to the surfaces of the mold prior to casting of the resin-abrasive mixture. Any one of a number of suitable mold release agents such as a silicone fluid, polyethylene films, polyvinyl alcohol films, and Teflon films, for example, can be satisfactorily employed for achieving the desired release characteristics of the cured abrasive finishing tool from the mold.

The finishing tool on completion of the curing reaction can be simply removed from the mold by removing the clamping plate 32 and detaching the holding screws 27 enabling the base plate 18 and stud 22 to be removed by means of an arbor press, for example. The finishing tool with the internal gear 26 encircling the periphery thereof is thereafter inverted and pressed out of the master gear. The excess resin-abrasive mixture 16a can thereafter be simply removed by placing the finishing tool on a lathe spindle and machining the excess portion off with a diamond tipped tool so that the resultant edge of the finishing tool corresponds to the thickness of the plastic rim 30.

In order to provide a further understanding of the composition and methods as hereinbefore described, the following examples are provided which illustrate typical abrasive-resin mixtures which can be satisfactorily employed for casting abrasive finishing tools in accordance with the teachings of the present invention. It will be understood, however, that the following examples are provided by way of further illustration and are not intended to be limiting of the scope of the invention as set forth in the subjoined claims.

Example I

An abrasive gearlike finishing tool was made by preparing a resin-abrasive mixture having the following composition:

Ingredient:	Percent by weight
Polyamide resin -----	21.6
Epoxy resin -----	11.6
Abrasive—80 grit-SiC -----	33.4
Abrasive—54 grit-Al ₂ O ₃ -----	33.4
	100.0

The above formulation represents a resin mixture of the reactive polyamide resin and epoxy resin in the proportions of 65% by weight of the polyamide resin and 35% by weight of the epoxy resin. The polyamide resin employed comprises a reactive liquid polyamide resin derived from the condensation of dibasic polymerized fatty acids and suitable polyamines having a resultant amine value of about 377, a specific gravity of .97, a Brookfield viscosity of 5 poises at 75° C., and is commercially obtainable from General Mills, Inc., under the designation Versamid 140. The epoxy resin employed in the above formulation comprises solvent free unmodified liquid epoxy resin derived from the polymerization of bisphenol A and epichlorohydrin resulting in a

resin having an epoxide equivalent value 187-191, a Brookfield viscosity ranging from about 11,000-16,000 centipoises at 25° C., and a specific gravity of 1.18. An epoxy resin of this type is commercially available from General Mills, Inc., under the designation Genepoxy 190.

The appropriate proportions of the polyamide and the epoxy resins were blended by gentle mixing to avoid entrapment of air bubbles therein and the blended resin mixture was thereafter set aside during which time the appropriate proportions of the silicon carbide and aluminum oxide abrasive particles were weighed and blended. The resultant abrasive mixture was thereafter gently added to the resin mixture and blended therewith by agitation with a spatula until substantially uniform resin-abrasive mixture was obtained. The resultant resin-abrasive mixture was thereafter allowed to stand for a period of 20 minutes during which time the major portion of the entrapped air bubbles escaped from the surface of the mixture.

A mold of the general type shown in FIG. 2 was assembled and the surfaces thereof which were to be exposed to a resin-abrasive mixture were first coated with a mold release agent comprising 10% by volume of Dow-Corning Corporation silicon fluid No. 20, 10% by volume of toluene, and 80% by volume of isopropyl alcohol. The release agent was applied by means of a soft bristle brush and exposed to an air blast to remove the toluene and alcohol solvent therefrom leaving a residual film of the silicon fluid on the surfaces of the mold.

Thereafter an aliquot portion of the resin-abrasive mixture was poured in the annular space of the mold and allowed to stand and react at room temperature under atmospheric pressure for a period of about 12 hours during which time the resin-abrasive mixture was substantially completely cured. The resultant abrasive gearlike finishing tool was thereafter removed from the mold and the excess abrasive mixture trimmed from the topside thereof.

A second aliquot portion of the resin-abrasive mixture was poured into an assembled mold having a coating of release agent thereon and thereafter placed in a pressurized oven at a temperature of 150° F. and under a pressure of 100 p.s.i. and retained therein under these conditions for a period of about 5 hours. The mold was thereafter removed and the resin-abrasive mixture was substantially completely cured. The resultant abrasive finishing tool was thereafter removed from the mold and the excess thereof along the top portion was dressed.

The remaining portion of the resin-abrasive mixture was allowed to stand and was determined to have a pot life in excess of three hours.

Example II

A second resin-abrasive mixture was prepared using the same materials as previously described in Example I but wherein the percentage of polyamide resin and epoxy resin were changed to produce a resin mixture containing 60% by weight polyamide resin and 40% by weight epoxy resin with a resultant resin-abrasive composition as set forth below:

Ingredient:	Percent by weight
Polyamide resin -----	19.9
Epoxy resin -----	13.3
Abrasive—80 grit-SiC -----	33.4
Abrasive—54 grit-Al ₂ O ₃ -----	33.4
	100.0

The resin-abrasive mixture was prepared in accordance with the procedure set forth in the preceding example and thereafter cast in a mold and cured at room temperature under atmospheric pressure for a period of 12 hours.

Example III

A third resin-abrasive mixture was prepared employing the same ingredients as in the preceding examples but wherein the resin mixture was modified to consist of equal portions of the polyamide resin and epoxy resin resulting in an abrasive-resin mixture as follows:

Ingredient:	Percent by weight
Polyamide resin -----	16.6
Epoxy resin -----	16.6
Abrasive—80 grit-SiC -----	33.4
Abrasive—54 grit-Al ₂ O ₃ -----	33.4
	100.0

The resin-abrasive mixture was prepared and cast in accordance with the procedure as set forth in Example I and cured at room temperature under atmospheric pressure for a period of 12 hours.

Example IV

A fourth resin-abrasive mixture was prepared using the same ingredients as employed in the preceding example but wherein the proportion of polyamide resin and epoxy resin in the resin mixture was changed to consist of 40% by weight polyamide resin and 60% by weight epoxy resin and wherein the resultant resin-abrasive mixture had a composition as follows:

Ingredient:	Percent by weight
Polyamide resin -----	13.3
Epoxy resin -----	19.9
Abrasive—80 grit-SiC -----	33.4
Abrasive—54 grit-Al ₂ O ₃ -----	33.4
	100.0

The resin-abrasive mixture was prepared and cast in accordance with the procedure as set forth in Example I and cured at room temperature under atmospheric pressure for a period of 12 hours.

Example V

A fifth resin-abrasive mixture was prepared employing the same ingredients as in the preceding examples but wherein the ratio of the polyamide to epoxy resin in the resin mixture was changed so as to produce a mixture containing 20% by weight polyamide resin and 80% by weight epoxy resin with a resultant resin-abrasive composition as follows:

Ingredients:	Percent by weight
Polyamide resin -----	6.7
Epoxy resin -----	26.5
Abrasive—80 grit-SiC -----	33.4
Abrasive—54 grit-Al ₂ O ₃ -----	33.4
	100.0

The resin-abrasive mixture was prepared and cast in accordance with the procedure as described in Example I and cured at room temperature under atmospheric pressure for a period of 12 hours.

Example VI

A sixth resin-abrasive mixture was prepared employing a resin mixture comprising 35% by weight polyamide resin and 65% by weight epoxy resin and including a finely particulated aluminum oxide powder as a filler material resulting in a resin-abrasive mixture having a composition as follows:

Ingredients:	Percent by weight
Polyamide resin -----	21.9
Epoxy resin -----	11.6
Abrasive—36 grit-Al ₂ O ₃ -----	59.8
Filler—200 grit-Al ₂ O ₃ -----	6.7
	100.0

The finely particulated aluminum oxide filler constituent in the above formulation was blended with the abrasive particles and thereafter mixed with the resin mixture in accordance with the procedure set forth in Example I. The dispersion of the filler particles throughout the resin-abrasive mixture was observed to aid in suspending the relatively large sized abrasive grit during casting and curing of the resin-abrasive mixture which was accomplished at room temperature under atmospheric pressure for a period of 12 hours.

The abrasive gearlike finishing tools made in accordance with Examples I-VI were all observed to be of high strength, impact resistance and resiliency. Each of the finishing tools were run in meshing relationship with hardened work gears having gear teeth thereon conjugate to the teeth on the finishing tools. The finishing tools prepared in accordance with Examples I and V provided satisfactory results but did not provide as great a tool life as was obtained from the finishing tools produced in accordance with Examples II, III, IV and VI.

In order to evaluate the comparative tool life of the abrasive finishing tools made in accordance with the practice of the present invention in comparison to conventional epoxy bonded abrasive finishing tools a gearlike finishing tool was prepared for test employing an epoxy resin-abrasive mixture having the following formula:

Ingredients:	Percent by weight
Epoxy resin -----	24.2
Catalyst -----	9.7
Abrasive—80 grit-SiC -----	31.7
Abrasive—54 grit-Al ₂ O ₃ -----	34.4
	100.0

The epoxy resin constituent as set forth in the above formulation is commercially available from the Furane Chemical Company under the designation Furane Epocasp No. 1322 and comprises an epoxy resin incorporating a filler material therein. The catalyst is a conventional amine hardening agent and is commercially available from the Furane Chemical Company under the designation Furane amine hardener No. 963. The resin-abrasive mixture was prepared by blending the epoxy resin with the abrasive constituent forming a substantially homogeneous mixture after which the appropriate proportion of the amine catalyst was added. The resultant catalyzed resin-abrasive mixture was cast in a mold of the same type as shown in FIG. 2 and was cured in a pressurized oven which was heated to a temperature of 150° F. while maintained under a pressure of 100 p.s.i. The gearlike finishing tool after curing for a period of about five hours was removed from the mold and pressed therefrom.

The epoxy bonded abrasive tool and the abrasive finishing tool made in accordance with Example IV was thereafter employed for finishing hardened gear teeth on a commercial finishing machine. These tests indicated that the abrasive finishing tool made in accordance with Example IV had a tool life five times greater than the epoxy bonded finishing tool prior to requiring a dressing thereof and a total usable tool life of eight times as great as the corresponding epoxy bonded finishing tool.

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

What is claimed is:

1. An abrasive gear-like finishing tool having toothed elements thereon conjugate to the toothed elements on a workpiece to be finished, at least the working surfaces of said toothed elements of said tool comprised of an abrasive material including a matrix of a cured resin

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bonding agent having abrasive particles and fillers distributed therethrough and tenaciously bonded therein, said bonding agent consisting essentially of a copolymer consisting of the reaction product of a reactive polyamide resin having an amine value of from about 80 to about 400 and an epoxy resin having an epoxide equivalent value of from about 175 to about 200 and present in the proportions ranging from about 15% to about 65% by weight said polyamide resin and the balance said epoxy resin, said abrasive material comprising from about 20% to about 80% by weight said bonding agent, from about 20% to about 80% by weight said abrasive particles, and up to about 50% by weight of said fillers.

2. An abrasive gear-like finishing tool having toothed elements thereon conjugate to the toothed elements on a workpiece to be finished, at least the working surfaces of said toothed elements of said tool comprised of an abrasive material including a matrix of a cured resin bonding agent having abrasive particles and fillers distributed therethrough and tenaciously bonded therein, said bonding agent consisting essentially of a copolymer consisting of the reaction product of a reactive liquid polyamide resin having an amine value of from about 80 to about 400 and a liquid epoxy resin having an epoxide equivalent value of from about 175 to about 200 and present in the proportions ranging from about 40% to about 60% by weight said polyamide resin and the balance said epoxy resin, said abrasive material comprising from about 20% to about 80% by weight said bonding agent, from about 20% to about 80% by weight said abrasive particles, and up to about 50% by weight of said fillers.

3. An abrasive gear-like finishing tool having toothed elements thereon conjugate to the toothed elements on a workpiece to be finished, at least the working surfaces of said toothed elements of said tool comprised of an

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abrasive material including a matrix of a cured resin bonding agent having abrasive particles and fillers distributed therethrough and tenaciously bonded therein, said bonding agent consisting essentially of a copolymer consisting of the reaction product of a reactive liquid polyamide resin having an amine value of from about 80 to about 400 and a liquid epoxy resin having an epoxide equivalent value of from about 185 to about 195 and present in the proportions ranging from about 40% to about 60% by weight said polyamide resin and the balance said epoxy resin, said abrasive material comprising from about 20% to about 80% by weight said bonding agent, from about 20% to about 80% by weight said abrasive particles having a grit size ranging from about 200 up to about 22 grit, and up to about 50% by weight of said fillers.

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