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(54) Title: SMALL DIAMETER CUTTING TOOL

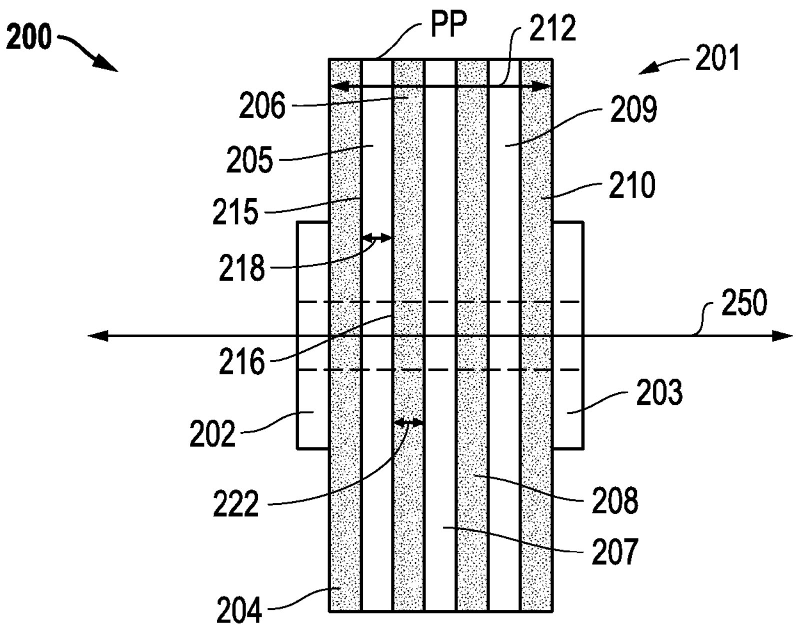

FIG. 2

(57) Abstract: An abrasive cutting tool has a body in the shape of a small diameter disk. The body has an outer diameter of not greater than about 100 centimeters, and an aspect ratio defined as a ratio of the outer diameter to an axial thickness of the body of at least about 10:1. The tool includes an abrasive portion having a bond material comprising abrasive particles and a resin having a normalized heat soak modulus of at least about 1.05.

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SMALL DIAMETER CUTTING TOOL

BACKGROUND OF THE INVENTION

The present invention relates in general to abrasive articles and, in particular, to a small diameter cutting tool.

DESCRIPTION OF THE RELATED ART

Abrasive wheels are typically used for cutting, abrading, and shaping of various materials, such as stone, metal, glass, plastics, among other materials. Generally, the abrasive wheels can have various phases of materials including abrasive grains, a bonding agent, and some porosity. Depending upon the intended application, the abrasive wheel can have various designs and configurations. For example, for applications directed to the finishing and cutting of metals, some abrasive wheels are fashioned such that they have a particularly thin profile for efficient cutting.

However, given the application of such wheels, the abrasive articles are subject to fatigue and failure. In fact, the wheels may have a limited time of use of less than a day depending upon the frequency of use. Accordingly, the industry continues to demand abrasive wheels capable of improved performance.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the features and advantages of the embodiments are attained and can be understood in more detail, a more particular description may be had by reference to the embodiments thereof that are illustrated in the appended drawings. However, the drawings illustrate only some embodiments and therefore are not to be considered limiting in scope as there may be other equally effective embodiments.

FIG. 1 includes an illustration of an abrasive tool in accordance with an embodiment.

FIG. 2 includes a cross-sectional illustration of a portion of an abrasive tool in accordance with an embodiment.

FIG. 3 includes a cross-sectional illustration of a portion of an abrasive tool in accordance with an embodiment.

FIG. 4 includes graphs comparing the normalized grinding and heak soak modulus performance for a conventional abrasive article and an embodiment of an abrasive article.

The use of the same reference symbols in different drawings indicates similar or identical items.

DETAILED DESCRIPTION

The following is directed to abrasive tools having abrasive particles contained within a bond material for cutting workpieces. Certain embodiments herein are directed to bonded abrasive wheels, including cut off wheels, that may be used for cutting metal workpieces, including metals of titanium or stainless steel. However, certain features of the embodiments herein may be applicable to other abrasive technologies, including for example, coated abrasives and the like.

The abrasive article can be made by forming a mixture of components or precursor components that may be part of the final abrasive article. For example, the mixture can include components of the final abrasive article, such as abrasive particles, bond material, filler, and a combination thereof. In one embodiment, the mixture can include a first type of abrasive particle. A type of abrasive particle can be defined by at least a composition, a mechanical property (e.g., hardness, friability, etc.), particle size, a method of making, and a combination thereof.

In some embodiments, the abrasive article may be formed by a method of bond batching, mixing abrasive with the bond, filling a mold, pressing the filled mold, baking or curing the pressed mold, removing the cured article, and then finishing, inspecting, speed testing, packing and shipping the abrasive article.

FIG. 1 includes an illustration of an abrasive tool in accordance with an embodiment. Notably, the abrasive tool 100 includes a body 101 having a generally circular shape as viewed in two dimensions. It will be appreciated, that in three-dimensions the tool has a certain thickness such that the body 101 has a disk-like or a cylindrical shape. As illustrated, the body can have an outer diameter 103 extending through the center of the tool, which can be relatively small, having a dimension of at least about 12 cm. Moreover, in certain other instances, the outer diameter can be greater, such as at least about 18 cm, or even at least about 20 cm. Still, in another non-limiting embodiment, the outer diameter can be not greater than about 100 cm, such as not greater than about 75 cm, or even not greater than 50 cm.

As further illustrated, the abrasive tool 100 can include a central opening 105 defined by an inner circular surface 102 about the center of the body 101. The central opening 105 can extend through the entire thickness of the body 101 such that the abrasive tool 100 can be mounted on a spindle or other machine for rotation of the abrasive tool 100 during operation.

FIG. 2 includes a cross-sectional illustration of a portion of an abrasive tool in accordance with an embodiment. The abrasive body 201 can be a composite article including a combination of portions of different types of material. In particular, the body 201 can include abrasive portions 204, 206, 208, and 210 and reinforcing members 205, 207, and 209. The abrasive tool 200 can be designed such that the reinforcing members 205, 207, and 209 can be placed within the body such that they are spaced apart from each other, and therein, separate each of the abrasive portions 204, 206, 208, and 210 from each other. That is, the abrasive tool 200 can be formed such that the reinforcing members 205, 207, and 209 are spaced apart from each other laterally through the thickness 212 of the body 201 and separated by abrasive portions 206 and 208. As will be appreciated, in such a design the abrasive portions 206 and 208 can be disposed between the reinforcing members 205, 207, and 209.

As further illustrated, the reinforcing members 205, 207, and 209 can be substantially planar members having first planar faces and second planar faces. For example, the reinforcing member 205 can be formed such that it is a planar member having a first major surface 215 and a second major surface 216. Moreover, the body 201 can have a design such that the abrasive portions 204, 206, 208, and 210 can overlie the major surface of the reinforcing members 205, 207, and 209. For example, the abrasive portion 204 can overlie the first major surface 215 of the reinforcing member 205 and the abrasive portion 206 overlies the second major surface 216 of the reinforcing member 205. In particular instances, the body 201 can be formed such that the abrasive portions 204 and 206 cover essentially the entire surface area of the first major surface 215 and second major surface 216, respectively. Accordingly, the abrasive portions 204 and 206 can directly contact (i.e. abut) the reinforcing member 205 on either sides at the first and second major surfaces 215 and 216.

Notably, the abrasive body 201 can be designed such that the reinforcing members 205, 207, and 209 can extend through a majority of the diameter 103 of the body 201. In particular instances, the reinforcing members 205, 207, and 209 can be formed such that they extend through at least about 75%, such as at least about 80%, or even the entire diameter 103 of the body 201.

In accordance with an embodiment, the body 201 is formed such that it can have an average thickness 212 measured in a direction parallel to the axial axis 250 extending through the center of the central opening 105. The average thickness 212 of the body 201 can be particularly thin such that it is suitable for cutting metal workpieces. For example, the average thickness of the body 201 can be not greater than about 3 centimeters. In other embodiments, the average thickness 212 of the body 201 can be not greater than about 2.5 centimeters, such as not greater than about 2 centimeters, or even not greater than about 1.5 centimeters. Still, certain embodiments may utilize an average thickness 212 within a range between about 0.5 centimeters and about 3 centimeters, such as between about 0.5 centimeters and about 2 centimeters.

The abrasive articles of the embodiments herein can have a particular aspect ratio defined as the ratio between the outer diameter 103 to the average thickness 212 of the body 201. According to certain designs, the aspect ratio is at least about 10:1, such as at least about 20:1, at least about 50:1, or even at least about 75:1. Certain embodiments utilize an aspect ratio within a range between about 10:1 and about 125:1, such as between about 20:1 and about 125:1.

In further reference to the reinforcing members 205, 207, and 209, such members can be made of an organic material, inorganic material, and a combination thereof. For example, the reinforcing members 205, 207, and 209 can be made of an inorganic material, such as a ceramic, a glass, quartz, or a combination thereof. Particularly suitable materials for use as the reinforcing members 205, 207, and 209 can include glass materials, incorporating fibers of glass materials, which may include oxide-based glass materials.

Some suitable organic materials for use in the reinforcing members 205, 207, and 209 can include phenolic resin, polyimides, polyamides, polyesters, aramids, and a combination thereof. For example, in one particular embodiment, the reinforcing members 205, 207, and 209 can include Kevlar™, a particular type of aramid.

Additionally, the reinforcing members 205, 207, and 209 can include a fibrous material having a coating overlying and bonded directly to the external surfaces of the fibers. The coating can be an organic material, inorganic material, or a combination thereof. Certain abrasive tools can use reinforcing members 205, 207, and 209 utilizing fibers having a coating of an organic material, which may be a natural organic material or a synthetic organic material, such as a polymer, which may aid bonding between the reinforcing member and the abrasive portion. Some suitable organic coating materials can include resins, which may be thermosets, thermoplastics, or a combination thereof. Particularly suitable resins can include phenolics, epoxies, polyesters, cyanate esters, shellacs, polyurethanes, and a combination thereof. In one particular instance, the abrasive tool incorporates a reinforcing member comprising phenolic resin-coated glass fibers.

The reinforcing members 205, 207, and 209 can include a plurality of fibers that are woven together. The fibers can be woven or stitched together in a variety of manners. In certain instances, the reinforcing members can be woven together such that a patterns is formed, including fibers extending primarily in two perpendicular directions.

The reinforcing members 205, 207, and 209 can have an average thickness 218 that is defined as the distance between the first major surface 215 and the second major surface 216 of the reinforcing member 205. The average thickness 218 can be less than 0.6 centimeters, such as less than 0.6 centimeters, or even less than 0.4 centimeters.

In relative percentages, depending upon the design of the abrasive article, the reinforcing members can be formed to have certain dimensions such that they compose a certain percentage of the total average thickness of the body. For example, the reinforcing member 205 can have an average thickness 218 that is at least about 3% of the total average thickness 212 of the body 201. In other instances, the reinforcing member 205 can have an average thickness 218 that is at least about 5%, such as at least about 8%, or even at least about 10% of the total average thickness 212 of the body 201. Certain reinforcing members can have an average thickness 218 that is within a range between about 3% and about 15% of the total average thickness 212 of the body 201.

In accordance with embodiments herein, the abrasive tool 200 is formed such that the body 201 includes abrasive portions 204, 206, 208, and 210. Reference will be made in the following paragraphs to the abrasive portion 204, however it will be appreciated that all of the identified abrasive portions can include the same features. The abrasive portion 204 can be a composite material having abrasive grains contained within a matrix material and further comprising a particular composition and type of porosity.

The abrasive grains can include a particularly hard material suitable for abrading and material removal applications. For example, the abrasive grains can have a Vickers hardness of at least about 5 GPa. The hardness of the abrasive grains can be greater in some tools, such that the abrasive grains have a Vickers hardness of at least about 10 GPa, at least about 20 GPa, at least about 30 GPa, or even at least about 50 GPa.

As further illustrated in FIG. 2, the body can be formed such that it incorporates reinforcing members 202 and 203 that abut the outer surfaces of the abrasive portions 204 and 210 about the central opening 105. In certain designs, the reinforcing members 202 and 203 can extend for a portion of the outer diameter 103, such as half the outer diameter 103 of the abrasive body 201. Provision of the reinforcing members 202 and 203 about the central opening 105 facilitates reinforcement of the body 201 at a location where the abrasive tool 200 is intended to be affixed to a spindle or machine. As will be appreciated, the reinforcing members 202 and 203 can have the same features as the reinforcing members 205, 207, and 209.

FIG. 3 includes a cross-sectional illustration of a portion of an abrasive tool in accordance with an embodiment. The portion of the illustrated abrasive tool 300 includes an outer circumference of an abrasive tool formed in accordance with an embodiment. Particularly, the portion of the abrasive tool 300 can have a body 201 including abrasive portions 204, 206, 208, and 210 previously described. Moreover, the abrasive body 201 includes reinforcing members 205, 207, and 209 disposed between the abrasive portions 204, 206, 208, and 210 as previously described.

Notably, the body 201 is formed such that it has a flat region 301 proximate to the center of the wheel and surrounding the central opening 105, and a tapered region 303 at the outer edge of the body 201. As illustrated, the tapered region 303 is formed such that it has an average thickness 312 measured at the outer diameter of the body 201 that is significantly greater than the average thickness 311 of the body 201 within the flat region 301. The formation of the tapered region 303 is facilitated by the extension of a tapered edge 305 of the abrasive portion 210 that extends at an angle to the external surface308 of the flat region 301 of the abrasive portion 210. The tapered region 303 is further defined by a tapered surface 306 of the abrasive portion 204, which extends at an angle to the surfaces 310 of the abrasive portion 204. As illustrated, the tapered region 303 can form a rim around the outer diameter of the wheel, wherein the tapered surfaces 305 and 306 extend at an angle axially outward from the surfaces 308 and 310, respectively. The tapered surfaces 305 and 306 can extend at an angle to a radius extending from the center of the body substantially parallel to the surfaces 308 and 310, and moreover, the tapered surfaces 305 and 306 can extend at an angle to an axial axis 250 extending through the center of the body 201.

According to some embodiments, the tapered region 303 can extend circumferentially around a portion of a periphery of the body 201. Certain designs may utilize a tapered region 303 that extends throughout the entire circumference of the body 201. While reference is made herein to abrasive articles incorporating a tapered region 303, it will be appreciated, that a tapered region 303 may not necessarily be present for certain abrasive articles.

As illustrated, the tapered region 303 can extend radially from the flat region 301 of the body 201. Embodiments herein may form a tapered region 303 having a length 330, as measured in a direction parallel to a radius extending from the center of the body 201, which can be a particular percentage of the dimension of the outer diameter 103 of the body 201. For example, the tapered region 303 can have a length 330 that is at least about 5% of the dimension of the outer diameter 103. In other cases, depending upon the intended application, the body 201 can have a tapered region 303 having a length 330 of at least about 10%, such as at least about 15%, at least about 20%, at least about 30%, or even at least about 35%, of the dimension of the outer diameter 103. Particular embodiments can utilize a tapered region 303 wherein the length 330 is within a range between about 5% and about 50%, and particularly between about 5% and about 35%, or even more particularly between about 5% and about 20% of the outer diameter 103.

In other terms, the length 330 of the tapered region can be at least about 10 centimeters. In some embodiments, the length 330 of the tapered region 303 can be greater, such as at least about 13 centimeters, at least about 15 centimeters, or even at least about 20 centimeters. Still, particular embodiments herein can utilize a tapered region 303 having a length 330 within a range between about 10 centimeters and about 30 centimeters, such as between about 10 centimeters and about 20 centimeters.

In a particular embodiment, an abrasive cutting tool may comprise a body in a shape of a small diameter disk. The small diameter disk may have an outer diameter of not greater than about 100 centimeters. In other embodiments, the outer diameter of the body may be at least about 12 centimeters. Moreover, in certain other instances, the outer diameter can be greater, such as at least about 18 centimeters, or even at least about 20 centimeters. Still, in another non-limiting embodiment, the outer diameter can be not greater than about 75 cm, such as not greater than about 50 centimeters. The body can have an outer diameter within a range between any of the minimum and maximum values noted above.

In addition, the body of the small diameter disk may have an aspect ratio (D:T) defined as a ratio of the outer diameter (D) to an axial thickness (T) of the body of at least about 10:1. The outer diameter (D) of the wheel is a measurement in a radial direction from one peripheral point to an opposite peripheral point for a line extending through the center of the wheel. The axial thickness (T) extends axially through the body defined as the dimension between a first major surface and second major surface of the body.

According to one particular embodiment, the aspect ratio (D:T) of the body may be at least about 20:1. Moreover, in certain other instances, the aspect ratio can be greater, such as at least about 50:1, at least about 75:1, or even at least about 100:1. Still, in another non-limiting embodiment, the aspect ratio can be not greater than about 1000:1, such as not greater than about 500:1, or even not greater than about 150:1. The body can have an aspect ratio within a range between any of the minimum and maximum values noted above.

The body also may comprise an abrasive portion having a bond material comprising a resin. The resin may have a normalized heat soak modulus of at least about 1.05, such as at least about 1.10. Alternatively, the resin may have an increasing high temperature flexural modulus.

In some embodiments, the resin used in the bond material may comprise an organic resin. In other embodiments, the resin may comprise a phenolic resin. In still other embodiments, the phenolic resin may be modified with a curing or cross-linking agent, such as hexamethylene tetramine. At temperatures in excess of about 90°C, some examples of the hexamethylene tetramine may form crosslinks to form methylene and dimethylene amino bridges that help cure the resin. The hexamethylene tetramine may be uniformly dispersed within the resin. More particularly, hexamethylene tetramine may be uniformly dispersed within resin regions as a cross-linking agent. Even more particularly, the phenolic resin may contain resin regions with cross-linked domains having a sub-micron average size.

In other embodiments, the resin can include at least about 40 vol% of a total volume of the bond material. Moreover, in certain other instances, the resin content can be greater, such as at least about 50 vol%, at least about 60 vol%, or even at least about 70 vol%. Still, in another non-limiting embodiment, the content of resin in the bond material can be not greater than about 90 vol%, not greater than about 80 vol%, not greater than about 70 vol%, not greater than about 60 vol%, or even not greater than about 50 vol%. The bond material can have a resin content within a range between any of the minimum and maximum values noted above. Increasing the total resin content can increase the amount of flow exhibited by the resin.

The abrasive portion also may comprise one or more fillers. The filler may comprise, for example, one or more powders, granules, spheres, fibers or a combination thereof. The filler also may comprise an inorganic material, an organic material or a combination thereof. Examples of fillers may include sand, bubble alumina, bauxite, chromites, magnesite, dolomites, bubble mullite, borides, titanium dioxide, carbon products (e.g., carbon black, coke or graphite), silicon carbide, wood flour, clay, talc, hexagonal boron nitride, molybdenum disulfide, feldspar, nepheline syenite, glass spheres, glass fibers, CaF_2, KBF_4, Cryolite (Na_3AlF_6), potassium Cryolite (K_3AlF_6), pyrites, ZnS, copper sulfide, mineral oil, fluorides, carbonates, calcium carbonate or a combination thereof. The filler may comprise a material consisting of an antistatic agent, a lubricant, a porosity inducer, coloring agent or a combination thereof. The filler also may be particulate material. The filler may be distinct from the abrasive particles. Alternatively, the filler may be significantly smaller in average particle size than the abrasive particles of any type.

According to one particular embodiment, the total content of fillers may be at least about 15 vol% of a total volume of the bond material. Moreover, in certain instances, the filler content may be greater, such as at least about 20 vol%, or even at least about 25 vol%. Still, in another non-limiting embodiment, the filler content can be not greater than about 60 vol%, such as not greater than about 50 vol%, or even not greater than about 45 vol%. The bond material can have a filler content within a range between any of the minimum and maximum values noted above.

According to a particular embodiment, the bond material can include a particular formulation of fillers. For example, the abrasive portion can include a first filler comprising iron and sulfur. In particular, the first filler may comprise pyrite (FeS_2), and more particularly, the first filler may consist essentially of pyrite.

In a particular embodiment, the first filler may be at least about 40 vol% of a total volume of the fillers within the abrasive portion. In certain instances, the filler content may be greater, such as at least about 45 vol%, or even at least about 50 vol%. In another non-limiting embodiment, the filler content can be not greater than about 70 vol% of the total volume of the fillers within the abrasive portion, such as not greater than about 65 vol%, or even not greater than about 60 vol%. The abrasive portion can have a filler content within a range between any of the minimum and maximum values noted above.

In some embodiments, the average particle size of the first filler can be not greater than about 30 microns. In some examples, the average particle size of the first filler can be not greater than about 20 microns, such as not greater than about 15 microns, not greater than about 10 microns, or even not greater than about 8 microns. In other non-limiting embodiments, the first filler average particle size can be at least about 1 micron, such as at least about 2 microns, or even at least about 3 microns. The average particle size of the first filler can be within a range between any of the minimum and maximum values noted above.

In other embodiments, the abrasive portion may comprise a second filler different than the first filler. The second filler may comprise potassium. The second filler may further comprise aluminum and/or fluoride. The second filler may further comprise a compound including potassium, aluminum, and fluoride. The second filler may consist essentially of $KAlF_4$.

In some embodiments, the abrasive portion may comprise a greater content of the first filler (vol%) as compared to a content of the second filler (vol%). The abrasive portion may comprise a ratio (V1/V2) of at least about 1, wherein V1 represents a content of the first filler (vol%) within the abrasive portion and V2 represents a content of the second filler (vol%) within the abrasive portion. In other examples, the ratio (V1/V2) may be at least about 1.5, or even at least about 2. In other non-limiting embodiments, the ratio (V1/V2) may be not greater than about 4, such as not greater than about 3.5, not greater than about 3, or even not greater than about 2.8, not greater than about 2.6. The ratio (V1/V2) can be within a range between any of the minimum and maximum values noted above.

In a particular embodiment, the second filler can be at least about 5 vol% of a total volume of the fillers. For example, the second filler can be at least about 10 vol% of the total volume of the fillers, such as at least about 15 vol%, or even at least about 20 vol%. In certain non-limiting examples, the second filler can be not greater than about 40 vol% of the total volume of the fillers, such as not greater than about 35 vol%, not greater than about 30 vol%, or even not greater than about 25 vol%. The second filler content can be within a range between any of the minimum and maximum values noted above.

In some instances, the second filler may comprise an average particle size of not greater than about 75 microns. For example, the average particle size of the second filler can be not greater than about 65 microns, such as not greater than about 55 microns, or even not greater than about 45 microns. In other non-limiting embodiments, the average particle size of the second filler can be at least about 5 microns, such as at least about 15 microns, or even at least about 25 microns. The second filler average particle size can be within a range between any of the minimum and maximum values noted above.

In other embodiments, the abrasive portion may include a third filler different than the first filler and the second filler. The third filler may include calcium. The third filler may further include oxygen, or a compound including calcium and oxygen. The third filler may consist essentially of CaO.

Examples of the third filler may comprise an average particle size of not greater than about 75 microns. In particular instances, the third filler average particle size can be not greater than about 65 microns, such as not greater than about 55 microns. Non-limiting embodiments may include a third filler having an average particle size of at least about 15 microns, such as at least about 25 microns, or even at least about 35 microns. The third filler average particle size can be within a range between any of the minimum and maximum values noted above.

The abrasive portion also may comprise a greater content of the first filler (vol%) as compared to the content of the third filler (vol%). The abrasive portion may include a ratio (V1/V3) of at least about 10, wherein V1 represents a content of the first filler (vol%) within the abrasive portion, and V3 represents a content of the third filler (vol%) within the abrasive portion. In other examples the ratio (V1/V3) may be at least about 15, such as at least about 20, or even at least about 22. In other non-limiting embodiments, the ratio (V1/V3) can be not greater than about 40, such as not greater than about 35, not greater than about 30, not greater than about 29, or even not greater than about 28. The ratio (V1/V3) can be within a range between any of the minimum and maximum values noted above.

Still, in other embodiments of the abrasive portion may comprise a greater content of a second filler (vol%) as compared to a content of the third filler (vol%). The abrasive portion may include a ratio (V2/V3) of at least about 5, wherein V2 represents a content of the second filler (vol%) within the abrasive portion and V3 represents a content of the third filler (vol%) within the abrasive portion. In some examples, the ratio (V2/V3) can be at least about 7, such as at least about 9. Non-limiting examples may include the ratio (V2/V3) at not greater than about 25, such as not greater than about 20, not greater than about 15, not greater than about 14, or even not greater than about 13. The ratio (V2/V3) can be within a range between any of the minimum and maximum values noted above.

In a particular embodiment, the third filler can be at least about 0.5 vol% of a total volume of the fillers. In certain instances, the third filler can be greater, such as at least about 1 vol%, or even at least about 1.5 vol%. In another non-limiting embodiment, the third filler can be not greater than about 5 vol% of the total volume of the fillers, such as not greater than about 4 vol%, not greater than about 3 vol%, or even not greater than about 2.5 vol%. The abrasive portion can have a third filler content within a range between any of the minimum and maximum values noted above.

In other embodiments, the abrasive portion may comprise a fourth filler different than the first, second and third fillers. In other examples, the fourth filler may comprise an aggregate, cement, Portland cement, or calcium silicates.

Embodiments of the fourth filler may comprise an average particle size of not greater than about 40 microns. For example, the fourth filler average particle size may be not greater than about 30 microns, or even not greater than about 20 microns. Non-limiting examples of the fourth filler average particle size can be at least about 1 micron, such as at least about 5 microns, or even least about 10 microns. The fourth filler average particle size may be within a range between any of the minimum and maximum values noted above.

Other examples of the abrasive portion may comprise a greater content of the first filler (vol%) as compared to a content of the fourth filler (vol%). The abrasive portion may include a ratio (V1/V4) of at least about 5, wherein V1 represents a content of the first filler (vol%) within the abrasive portion and V4 represents a content of the fourth filler (vol%) within the abrasive portion. Alternatively, the ratio (V1/V4) can be at least about 10, such as at least about 15. Other non-limiting embodiments of the ratio (V1/V4) can be not greater than about 30, such as not greater than about 25, not greater than about 20, or even not greater than about 19. The ratio (V1/V4) can be within a range between any of the minimum and maximum values noted above.

Examples of the abrasive portion may comprise a greater content of a second filler (vol%) as compared to a content of the fourth filler (vol%). The abrasive portion may comprise a ratio (V2/V4) of at least about 1, wherein V2 represents a content of the second filler (vol%) within the abrasive portion and V4 represents a content of the fourth filler (vol%) within the abrasive portion. In a particular embodiment, the ratio (V2/V4) can be at least about 3, such as at least about 5. According to one non-limiting example, the ratio (V2/V4) can be not greater than about 15, such as not greater than about 12, not greater than about 10, not greater than about 9, or even not greater than about 8. The ratio (V2/V4) can be within a range between any of the minimum and maximum values noted above.

In still another embodiment, the abrasive portion may comprise a greater content of the fourth filler (vol%) as compared to a content of a third filler (vol%). The abrasive portion may comprise a ratio (V3/V4) of at least about 0.1, wherein V3 represents a content of the third filler (vol%) within the abrasive portion and V4 represents a content of the fourth filler (vol%) within the abrasive portion. Other examples of the ratio (V3/V4) can be at least about 0.3, such as at least about 0.5, or even at least about 0.6. Other non-limiting embodiments of the ratio (V3/V4) can be not greater than about 3, such as not greater than about 2.5, not greater than about 2, or even not greater than about 1. The ratio (V3/V4) can be within a range between any of the minimum and maximum values noted above.

Examples of the fourth filler can be at least about 1 vol% of a total volume of the fillers. Alternatively, the fourth filler can be at least about 1.5 vol% of the total volume of the fillers, such as at least about 2 vol%. According to one non-limiting embodiment, the fourth filler can be not greater than about 5 vol% of the total volume of the fillers, such as not greater than about 4.5 vol%, not greater than about 4 vol%, or even not greater than about 3.5 vol%. The content of the fourth filler in the total volume of the fillers can be within a range between any of the minimum and maximum values noted above.

Other embodiments herein may utilize an abrasive portion including a fifth filler different than the first, second, third and fourth fillers. The fifth filler may comprise sodium. The fifth filler may further comprise aluminum, fluoride, sodium, and a combination thereof. In one particular instance, the fifth filler may consist essentially of Na_3AlF_6.

In a particular embodiment, the abrasive portion may comprise a greater content of the first filler (vol%) as compared to a content of the fifth filler (vol%). The abrasive portion may include a ratio (V1/V5) of at least about 1, wherein V1 represents a content of the first filler (vol%) within the abrasive portion and V5 represents a content of the fifth filler (vol%) within the abrasive portion. Embodiments of the ratio (V1/V5) can be at least about 1.5, such as at least about 2. Still, in another non-limiting example, the ratio (V1/V5) can be not greater than about 10, such as not greater than about 7, not greater than about 5, or even not greater than about 3. The ratio (V1/V5) can be within a range between any of the minimum and maximum values noted above.

Another particular embodiment of the abrasive portion may comprise a greater content of a second filler (vol%) as compared to a content of the fifth filler (vol%). The abrasive portion may comprise about a same content of the second filler (vol%) as compared to the content of the fifth filler (vol%). The abrasive portion may comprise a ratio (V2/V5) of at least about 0.1, wherein V2 represents a content of the second filler (vol%) within the abrasive portion and V5 represents a content of the fifth filler (vol%) within the abrasive portion. In other embodiments, the ratio (V2/V5) can be at least about 0.3, such as at least about 0.5, or even at least about 0.8. According to a non-limiting embodiment, the ratio (V2/V5) can be not greater than about 5, such as not greater than about 4, not greater than about 3, not greater than about 2, or even not greater than about 1.5. The ratio (V2/V5) can be within a range between any of the minimum and maximum values noted above.

Still, in another embodiment, the abrasive portion may comprise a greater content of the fifth filler (vol%) as compared to a content of a third filler (vol%). The abrasive portion may include a ratio (V3/V5) of at least about 0.01, wherein V3 represents a content of the third filler (vol%) within the abrasive portion and V5 represents a content of the fifth filler (vol%) within the abrasive portion. Other examples of the ratio (V3/V5) can be at least about 0.05, such as at least about 0.06, or even at least about 0.07. According to a non-limiting embodiment, the ratio (V3/V5) can be not greater than about 1, such as not greater than about 0.5, or even not greater than about 0.1. The ratio (V3/V5) can be within a range between any of the minimum and maximum values noted above.

Yet other embodiments of the abrasive portion may comprise a greater content of the fifth filler (vol%) as compared to a content of a fourth filler (vol%). The abrasive portion may include a ratio (V4/V5) of at least about 0.01, wherein V4 represents a content of the fourth filler (vol%) within the abrasive portion and V5 represents a content of the fifth filler (vol%) within the abrasive portion. Other examples of the ratio (V4/V5) can be at least about 0.05, such as at least about 0.10, or even at least about 0.12. In still another non-limiting embodiment, the ratio (V4/V5) can be not greater than about 1, such as not greater than about 0.5, or even not greater than about 0.2. The ratio (V4/V5) can be within a range between any of the minimum and maximum values noted above.

In a particular embodiment, the fifth filler can be at least about 5 vol% of a total volume of the fillers. In other instances, the first filler can be at least about 10 vol% of the total volume of the fillers, such as at least about 15 vol%, or even at least about 20 vol%. Other non-limiting embodiments of the fifth filler can be not greater than about 40 vol% of the total volume of the fillers, such as not greater than about 35 vol%, not greater than about 30 vol%, or even not greater than about 25 vol%. The fifth filler content can be within a range between any of the minimum and maximum values noted above.

In an embodiment, the abrasive portion may comprise a combination of the first filler, the second filler, the third filler, the fourth filler and the fifth filler. The abrasive portion may comprise a total content of the first filler, second filler, third filler, fourth filler and fifth filler of at least about 10 vol% for a total volume of the abrasive portion. In other examples, the total content of the first filler, second filler, third filler, fourth filler and fifth filler can be at least about 15 vol% of the total volume of the abrasive portion, such as at least about 20 vol%, at least about 22 vol%, or even at least about 25 vol%. Non-limiting embodiments of the total content of the first filler, second filler, third filler, fourth filler and fifth filler can be not greater than about 60 vol% of the total volume of the abrasive portion, such as not greater than about 55 vol%, not greater than about 50 vol%, or even not greater than about 45 vol%. The total content of the first, second, third, fourth and filler fillers relative to the total volume of the abrasive portion can be within a range between any of the minimum and maximum values noted above.

In other embodiments, the abrasive portion may comprise a wetting liquid remnant. The wetting liquid remnant can include an aliphatic chain, such as an aliphatic chain from tridodecyl alcohol (TDA). Alternatively, the abrasive portion may comprise a wetting liquid remnant including cyclic organic molecules, such as from highly chlorinated wax, furfurol or Chloro 40.

According to one particular embodiment, the bond material of the abrasive portion can include at least about 20 vol% of a total volume of the abrasive portion. Moreover, in certain other instances, the bond material content can be greater, such as at least about 30 vol%, at least about 40 vol%, or even at least about 42 vol%. Still, in another non-limiting embodiment, the content of bond material in the abrasive portion can be not greater than about 70 vol%, not greater than about 65 vol%, not greater than about 60 vol%, not greater than about 56 vol%, not greater than about 52 vol%, or even not greater than about 50 vol%. The abrasive portion can have a bond material content within a range between any of the minimum and maximum values noted above.

In addition, the abrasive portion may further include abrasive particles contained within the bond material. In some embodiments, the abrasive particles may comprise an inorganic material. For example, the abrasive particles may comprise one or more oxides, carbides, borides, nitrides, oxycarbides, oxynitrides, or a combination thereof. In other embodiments, the abrasive particles may consist essentially of oxides. In a particular instance, the abrasive particles may comprise an oxide material such as alumina, zirconia, silica, or a combination thereof. In still another instance, the abrasive particles may consist of superabrasive material. Such superabrasive particles may comprise diamond, cubic boron nitride, or a combination thereof. For example, the abrasive particles may consist essentially of diamond.

In some embodiments, the abrasive particles can be at least about 30 vol% of a total volume of the abrasive portion. Moreover, in certain other instances, the abrasive particles can be at least about 35 vol% of the total volume of the abrasive portion, such as at least about 40 vol%, at least about 41 vol%, or even at least about 42 vol%. Still, in another non-limiting embodiment, the abrasive particles can be not greater than about 70 vol% of the total volume of the abrasive portion, such as not greater than about 60 vol%, not greater than about 55 vol%, not greater than about 52 vol%, or even not greater than about 50 vol%. The total volume of the abrasive portion can have an abrasive particle content within a range between any of the minimum and maximum values noted above.

In other embodiments, the abrasive portion may comprise pores. For example, the pores can be at least about 0.5 vol% of a total volume of the abrasive portion. Moreover, in certain other instances, the pores can be at least about 1 vol% of the total volume of the abrasive portion, such as at least about 2 vol%. Still, in another non-limiting embodiment, the pores can be not greater than about 30 vol% of the total volume of the abrasive portion, such as not greater than about 25 vol%, or even not greater than about 22 vol%. The total volume of the abrasive portion can have a pore content within a range between any of the minimum and maximum values noted above.

In some embodiments, the first type of abrasive particle comprises brown fused alumina (BFA), or may consist essentially of BFA. The abrasive particles may comprise a coating. The coating may comprise, for example, a ceramic, a metal, a transition metal element, iron, an oxide, a metal oxide or iron oxide.

For example, the first type of particle may comprise Treibacher BFA. BFA may comprise oxides, such as BaO, CaO, Na_2O, P_2O_5, and a combination thereof. For example, BFA may comprise about 1360 to about 1560 PPM BaO. BFA also may comprise about 4940 to about 5140 PPM CaO. BFA also may comprise about 820 to about 1020 PPM Na_2O. BFA also may comprise less than about 50 PPM P_2O_5.

In some examples of the abrasive cutting tool, the BFA may comprise not greater than about 99 vol% Al_2O_3. In other examples, the BFA may comprise not greater than about 98 vol% Al_2O_3, such as not greater than about 97 vol% Al_2O_3. In other non-limiting examples, the BFA may be at least about 80 vol% Al_2O_3, such as at least about 85 vol% Al_2O_3, or even at least about 90 vol% Al_2O_3. The BFA of the abrasive cutting tool can have a Al_2O_3 content within a range between any of the minimum and maximum values noted above.

In an alternate embodiment of the abrasive cutting tool, the BFA may comprise not greater than about 20 vol% ZrO_2. For example, the BFA may be not greater than about 15 vol% ZrO_2, such as not greater than about 10 vol% ZrO_2, not greater than about 5 vol% ZrO_2, or even not greater than about 1 vol% ZrO_2. Other non-limiting embodiments of the BFA may have at least about 0.01 vol% ZrO_2, such as at least about 0.05 vol% ZrO_2, or even at least about 0.10 vol% ZrO_2. The BFA of the abrasive cutting tool can have a ZrO_2 content within a range between any of the minimum and maximum values noted above.

In another particular instance, the BFA may have a hardness not greater than about 20 GPa. For example, the BFA may have a hardness of not greater than about 19 GPa, such as not greater than about 18 GPa, or even not greater than about 17 GPa. Alternate non-limiting embodiments may include the BFA having a hardness of at least about 15.5 GPa, such as at least about 15.8 GPa, or even at least about 16 GPa. The BFA of the abrasive cutting tool can have a hardness within a range between any of the minimum and maximum values noted above.

In an example of a test for hardness, the sample grains are mounted in epoxy and then polished. Once the grains are mounted and polished a desired load is selected on the hardness tester for indentation. The load typically selected is 500g, but a load of 1kg also may be selected depending on the strength of the grains. Once the indent is done, a diamond-shaped indent appears and measurements are made to determine hardness.

Friability may be defined by the relative breakdown of a sample compared to a standard. Typically friability may be measured by ball milling grain for a given time, which is the same time used to ball mill a standard grain. After milling the residual grain/powder is screened and the amount of grain that has broken down is weighed. These measurements are compared to the starting amount of grain and then compared to the breakdown of the standard. This allows relative comparison of grain durability.

For example, ball mill friability may be measured by putting a given amount of grain in a ball mill container with media (e.g., tunsten carbide) and milling for a set time. Typically the time is dependent on when the standard or baseline grain reaches about 50% breakdown. This means 50% of the starting weight of the grain can pass through a small opening screen.

The standard for friability may be chosen based on the grain being tested. For example if a very friable grain (i.e., it breaks down more easily) is being considered, a standard would be chosen with like-friability. For BFA samples a more durable alumina standard may be chosen. The standard chosen also depends on the application to determine relevance of the standard.

Embodiments of the BFA also may have a friability of not greater than about 70% of the standard. For example, the BFA may have a friability of not greater than about 65%, such as not greater than about 60%. Non-limiting embodiments of the BFA may have a friability of at least about 20%, such as at least about 30%, at least about 40%, or even at least about 50%. The BFA of the abrasive cutting tool can have a friability within a range between any of the minimum and maximum values noted above. The classic alundum grain can be 70% more friable than the blue fired alumina.

The abrasive particles of the mixture and the final-formed abrasive article may include more than one type of abrasive particle. For example, the mixture can include a second type of abrasive particle different than the first type of abrasive particle. The second type of abrasive particle can differ from the first type of abrasive particle by any one of a composition, a mechanical property (e.g., hardness, friability, etc.), particle size, a method of making, or a combination thereof.

For example, the second type of abrasive particle may comprise alumina, zirconia or alumina and zirconia. The second type of abrasive particle may comprise essentially alumina and zirconia.

The second type of particle may comprise blue fired alumina (BLFA). For example, the second type of particle may comprise Treibacher blue fired alumina.

In some examples of the abrasive cutting tool, the BLFA may comprise not greater than about 95.3 vol% Al_2O_3. In other examples, the BLFA may comprise not greater than about 95.2 vol% Al_2O_3, such as not greater than about 95.1 vol% Al_2O_3. In other non-limiting examples, the BLFA may be at least about 80 vol% Al_2O_3, such as at least about 85 vol% Al_2O_3, or even at least about 90 vol% Al_2O_3. The BLFA of the abrasive cutting tool can have a Al_2O_3 content within a range between any of the minimum and maximum values noted above.

In an alternate embodiment of the abrasive cutting tool, the BLFA may comprise not greater than about 20 vol% ZrO_2. For example, the BLFA may be not greater than about 15 vol% ZrO_2, such as not greater than about 10 vol% ZrO_2, not greater than about 5 vol% ZrO_2, or even not greater than about 1 vol% ZrO_2. Other non-limiting embodiments of the BLFA may have at least about 0.16 vol% ZrO_2, such as at least about 0.17 vol% ZrO_2, or even at least about 0.18 vol% ZrO_2. The BLFA of the abrasive cutting tool can have a ZrO_2 content within a range between any of the minimum and maximum values noted above.

BLFA may comprise oxides, such as BaO, CaO, Na_2O, P_2O_5, and a combination thereof. For example, BLFA may include not greater than about 1200 PPM BaO, such as not greater than about 800 PPM BaO, not greater than about 400 PPM BaO, or even not greater than about 200 PPM BaO.

Embodiments of BLFA also may include not greater than about 4000 PPM CaO. For example, BLFA can be not greater than about 3000 PPM CaO, such as not greater than about 2000 PPM CaO.

Other embodiments of BLFA also may include not greater than about 800 PPM Na_2O. For example, BLFA can be not greater than about 400 PPM Na_2O, such as not greater than about 200 PPM Na_2O.

Still other embodiments of BLFA may include greater than about 50 PPM P_2O_5. For example, BLFA can be greater than about 100 PPM P_2O_5, such as greater than about 500 PPM P_2O_5, or even greater than about 1000 PPM P_2O_5.

In contrast to BLFA, embodiments of BFA may contain very different amounts of oxides described above for BLFA. For example, BFA may include at least about 200 PPM BaO, such as at least about 500 PPM BaO, or even at least about 1000 PPM BaO.

Embodiments of BFA also may include greater than about 2000 PPM CaO. For example, BFA can be greater than about 3000 PPM CaO, such as greater than about 4000 PPM CaO.

Other embodiments of BFA also may include greater than about 200 PPM Na_2O. For example, BFA can be greater than about 400 PPM Na_2O, such as greater than about 800 PPM Na_2O.

Still other embodiments of BFA may include not greater than about 50 PPM P_2O_5. For example, BFA can be not greater than about 40 PPM P_2O_5, such as not greater than about 30 PPM P_2O_5, or even not greater than about 20 PPM P_2O_5.

In other embodiments, the second type of abrasive particle may include not greater than about 90 vol% Al_2O_3. For example, the second type of abrasive particle may not be greater than about 85 vol% Al_2O_3, such as not greater than about 80 vol% Al_2O_3. Non-limiting embodiments of the second type of abrasive particle may be at least about 70 vol% Al_2O_3, such as at least about 65 vol% Al_2O_3, or even at least about 60 vol% Al_2O_3. The second type of abrasive particle can have a Al_2O_3 content within a range between any of the minimum and maximum values noted above.

In another embodiment, the second type of abrasive particle may comprise not greater than about 40 vol% ZrO_2. Other examples of the second type of abrasive particle may include not greater than about 35 vol% ZrO_2, such as not greater than about 30 vol% ZrO_2, or even not greater than about 25 vol% ZrO_2. Non-limiting examples of the second type of abrasive particle may be at least about 10 vol% ZrO_2, such as at least about 15 vol% ZrO_2, or even at least about 20 vol% ZrO_2. The second type of abrasive particle can have a ZrO_2 content within a range between any of the minimum and maximum values noted above.

Other embodiments of the second type of abrasive particle may have a hardness not greater than about 20 GPa. For example, the second type of abrasive particle may have a hardness not greater than about 18 GPa, such as not greater than about 17 GPa, or even not greater than about 16 GPa. Non-limiting examples of the second type of abrasive particle may have a hardness of at least about 14 GPa, such as at least about 14.5 GPa, or even at least about 15 GPa. The second type of abrasive particle can have a hardness within a range between any of the minimum and maximum values noted above.

In another example, the second type of abrasive particle may have a friability of not greater than about 20% of the standard. In a particular instance, the second type of abrasive particle may have a friability of not greater than about 15%, such as not greater than about 10%. Non-limiting embodiments of the second type of abrasive particle may have a hardness of at least about 2%, such as at least about 4%, at least about 5%, or even at least about 6%. The second type of abrasive particle can have a friability within a range between any of the minimum and maximum values noted above.

The abrasive cutting tool may further comprise a reinforcing member in the body. The reinforcing member may be at least about 1 vol% of a total volume of the body. In an embodiment, the reinforcing member may be at least about 2 vol% of the total volume of the body, such as at least about 3 vol%, at least about 4 vol%, at least about 5 vol%, or even at least about 6 vol%. Non-limiting embodiments of the abrasive cutting tool may comprise the reinforcing member being no greater than about 15 vol% of the total volume of the body, such as no greater than about 14 vol%, no greater than about 13 vol%, or even no greater than about 12 vol%. The body may comprise a reinforcing member content within a range between any of the minimum and maximum values noted above.

Embodiments of the body of the abrasive cutting tool may comprise a first reinforcing member. The first reinforcing member may abut the abrasive portion. The first reinforcing member may be disposed within the abrasive portion. The first reinforcing member may define an external surface of the body. Alternatively, the first reinforcing member may be disposed internally within the body.

Examples of the first reinforcing member may comprise an organic material. For example, the first reinforcing member also may comprise a polyimide, polyamide, polyester, aramid, and a combination thereof. Other embodiments of the first reinforcing member may comprise an inorganic material. The first reinforcing member may comprise an inorganic material such as ceramic materials, glass materials, glass-ceramic materials, or a combination thereof. The first reinforcing member may comprise glass fibers, such as phenolic resin-coated glass fibers.

In still other embodiments, the first reinforcing member may extend through an entire diameter of the body. The first reinforcing member may comprise a planar member comprising a first major surface and a second major surface. The abrasive portion may overlie the first major surface. The abrasive portion may be in direct contact with the first major surface of the first reinforcing member.

In a particular embodiment, the body may comprise a first reinforcing member and a second reinforcing member. The first reinforcing member and the second reinforcing member may be spaced apart from each other within the body. At least a portion of the abrasive portion may be disposed between the first reinforcing member and the second reinforcing member.

In some embodiments, the first reinforcing member may be at least about 3% of an average thickness of the body. In other examples, the first reinforcing member may be at least about 5% of the average thickness of the body, such as at least about 8%, or even at least about 10%. Non-limiting embodiments of the first reinforcing member may be not greater than about 18% of the average thickness of the body, such as not greater than about 15%, or even not greater than about 12%.

The first reinforcing member can have an average thickness of the body within a range between any of the minimum and maximum values noted above.

The abrasive particles of any type may have an elongated shaped. In a particular instance, the abrasive particles may have an aspect ratio, defined as a ratio of the length:width, of at least about 2:1, wherein the length is the longest dimension of the particle and the width is the second longest dimension of the particle (or diameter) perpendicular to the dimension of the length as viewed in two dimensions. In other embodiments, the aspect ratio of the abrasive particles can be at least about 2.5:1, such as at least about 3:1, at least about 4:1, at least about 5:1, or even at least about 10:1. In one non-limiting embodiment, the abrasive particles may have an aspect ratio of not greater than about 5000:1. Still, it will be appreciated, that in other embodiments, the abrasive particles of any type can be generally equiaxed having an aspect ratio of substantially 1:1. In yet another embodiment, the abrasive particles of any type can have an irregular shape.

In at least one embodiment, the abrasive particles (of any type) can have a particular cross-sectional shape as viewed in two dimensions. For example, the abrasive particles can have an ellipsoidal cross-sectional shape. An ellipsoidal shape can include circles, ellipses, and any other curvilinear shapes. Alternatively, in other instances, the abrasive particles can have a polygonal cross-sectional shape. Some suitable, non-limiting, examples of polygonal cross-sectional shapes include triangular, rectangular, pentagonal, hexagonal, septagonal, octagonal, and the like.

As described herein, in addition to the abrasive particles, the mixture may also include other components or precursors to facilitate formation of the abrasive article. For example, the mixture may include a bond material. According to one embodiment, the bond material may include a material selected from the group consisting of an organic material, an organic precursor material, an inorganic material, an inorganic precursor material, a natural material, and a combination thereof.

According to another embodiment, the mixture may include an organic material, or a precursor of an organic material, suitable for formation of an organic bond material during further processing. Such an organic material may include one or more natural organic materials, synthetic organic materials, and a combination thereof. In particular instances, the organic material can be made of a resin, which may include a thermoset, a thermoplastic, and a combination thereof. For example, some suitable resins can include phenolics, epoxies, polyesters, cyanate esters, shellacs, polyurethanes, rubber, and a combination thereof. In one particular embodiment, the mixture includes an uncured resin material configured to form a phenolic resin bond material through further processing.

Embodiments of the body may comprise at least about 5 vol% bond material for a total volume of the body. In other embodiments, the body may comprise at least about 10 vol% for the total volume of the body, at least about 15 vol%, at least about 20 vol%, at least about 25 vol%, at least about 30 vol%, at least about 35 vol%, at least about 40 vol%, at least about 45 vol%, at least about 50 vol%, or even at least about 55 vol% for the total volume of the body. In other examples, the body may comprise not greater than about 90 vol% for the total volume of the body. Still other examples of the body may comprise not greater than about 85 vol% for the total volume of the body, not greater than about 80 vol%, not greater than about 75 vol%, not greater than about 70 vol%, not greater than about 65 vol%, not greater than about 60 vol%, not greater than about 55 vol%, not greater than about 50 vol%, not greater than about 45 vol%, or even not greater than about 40 vol% for the total volume of the body. It will be appreciated that the body may have a bond material within a range between any of the above noted minimum and maximum values.

Embodiments of the body may comprise not greater than about 10 vol% porosity for a total volume of the body. In other examples, the body may comprise not greater than about 5 vol% porosity for the total volume of the body, not greater than about 3 vol%, not greater than about 2.5 vol%, not greater than about 2 vol%, not greater than about 1.5 vol%, not greater than about 1 vol%, not greater than about 0.8 vol%, not greater than about 0.5 vol%, not greater than about 0.4 vol%, or even not greater than about 0.3 vol% porosity for the total volume of the body. In still other embodiments the body may comprise at least about 0.01 vol% porosity for the total volume of the body, or even at least about 0.05 vol% porosity for the total volume of the body. It will be appreciated that the body may have a porosity within a range between any of the above noted minimum and maximum values.

EXAMPLE

Two samples were prepared and tested for heat soak modulus, and grinding performance. The samples were identical except for the resins used to form their abrasive bonds. The first sample is a conventional abrasive article with a standard resin 29-722, supplied from Durez-North America. The second sample is an embodiment as described herein comprising HAP resin (34-279), also supplied from Durez-North America. Each sample was rectangular with dimensions of 4x1x0.235 inches, and contained two internal, symmetrically located fiberglass webs known as #57 glass and supplied from IPAC. Each sample had 46 vol% abrasive, standard brown fused alundum with iron oxide coating, 40 vol% bond, 30 vol% resin, 4.9 vol% iron pyrite, 3.5 vol% potassium aluminum fluoride, 1.1 vol% lime, 0.5 vol% polymer microspheres, and 14 vol% pores.

The samples were heated at 400 °C for 30 minutes, cooled to room temperature, and then broken in a three-point bending test on a 2-inch span (per ASTM D790) to examine the effective degradation of strength and modulus due to exposure to 400°C. As shown in FIG. 4, the heat soak modulus of the conventional sample was normalized to 1.0. The heat soak modulus of the HAP sample was 1.13. Thus, the HAP sample outperformed the conventional sample by 13% with regard to heat soak modulus, which means that the HAP sample had a normalized heat soak modulus of 1.13. Similarly, with regard to grinding performance, the HAP sample outperformed the conventional sample by 9%.

According to one embodiment, the abrasive article may be particularly suited for cutting workpieces. Certain suitable workpieces can include inorganic materials, and more particularly workpieces made of a metal or metal alloy. According to one embodiment, the abrasive article may be particularly suited to cut materials such as metal alloys or titanium.

According to another embodiment, the abrasive particles can be shaped abrasive particles. Shaped abrasive particles can have a well-defined and regular arrangement (i.e., non-random) of edges and sides, thus defining an identifiable shape. For example, a shaped abrasive particle may have a polygonal shape as viewed in a plane defined by any two dimensions of length, width, and height. Some exemplary polygonal shapes can be triangular, quadrilateral (e.g., rectangular, square, trapezoidal, parallelogram), a pentagon, a hexagon, a heptagon, an octagon, a nonagon, a decagon, and the like. Additionally, the shaped abrasive particle can have a three-dimensional shape defined by a polyhedral shape, such as a prismatic shape or the like. Further, the shaped abrasive particles may have curved edges and/or surfaces, such that the shaped abrasive particles can have convex, concave, ellipsoidal shapes. In addition, rod and cylinder shaped abrasive particles may be provided, as well as bumpy-shaped grains, such as rod-like pretzel shapes with salt-like bumps.

The shaped abrasive particles can be in the form of any alphanumeric character, e.g., 1, 2, 3, etc., A, B, C. etc. Further, the shaped abrasive particles can be in the form of a character selected from the Greek alphabet, the modern Latin alphabet, the ancient Latin alphabet, the Russian alphabet, any other alphabet (e.g., Kanji characters), and any combination thereof.

The shaped abrasive particle can have a body defining a length (l), a height (h), and a width (w), wherein the length is greater than or equal to the height, and the height is greater than or equal to the width. Further, in a particular aspect, the body may include a primary aspect ratio defined by the ratio of length:height of at least about 1:1. The body may also include an upright orientation probability of at least about 50%.

In another aspect, the shaped abrasive particle can have a body having a length (l), a width (w), and a height (h), wherein the length, width, and height may correspond to a longitudinal axis, a lateral axis, and a vertical axis, respectively, and the longitudinal axis, lateral axis, and vertical axis may define three perpendicular planes. In this aspect, the body may include an asymmetric geometry with respect to any of the three perpendicular planes.

In yet another aspect, the shaped abrasive particle may include a body having a complex three-dimensional geometry including 3-fold symmetry in three perpendicular planes defined by a longitudinal axis, a lateral axis, and a vertical axis. Further, the body may include an opening that extends through the entire interior of the body along one of the longitudinal axis, lateral axis, or vertical axis.

In still another aspect, the shaped abrasive particle may include a body having a complex three-dimensional geometry defined by a length (l), a width (w), and a height (h). The body may also include a center of mass and a geometric midpoint. The center of mass may be displaced from the geometric midpoint by a distance (Dh) of at least about 0.05(h) along a vertical axis of the body defining the height.

In another aspect, the shaped abrasive particle may include a body that defines a length (l), a width (w), and a height (h). The body may include a base surface and an upper surface. Further, the base surface comprises a different cross-sectional shape than a cross-sectional shape of the upper surface.

In still another aspect, the shaped abrasive particle may include a body that has a generally flat bottom and a dome shaped top extending from the generally flat bottom.

In another aspect, the shaped abrasive particle may include a body comprising a length (l), a width (w), and a height (h). The length, width, and height may correspond to a longitudinal axis, a lateral axis, and a vertical axis, respectively. Further, the body may include a twist along a longitudinal axis defining the length of the body such that a base surface is rotated with respect to an upper surface to establish a twist angle.

In yet another aspect, the shaped abrasive particle may include a body having a first end face and a second end face a, at least three adjacent side faces extending between the first end face and the second end face, and an edge structure established between each pair of adjacent side faces.

In another aspect, the shaped abrasive particle may include a body having a central portion and at least three radial arms extending outwardly from the central portion along the entire length of the central portion.

The abrasive articles and processes disclosed herein represent a departure from the state-of-the-art. Abrasive articles herein can utilize a combination of features, such as abrasive particles having certain features, including but limited to, composition, average porosity, average grain size, grain ratio, and a combination thereof. Moreover, the abrasive articles may utilize additional features such as bond material, content of bond material, content of abrasive particles, fillers, and the like. While not entirely understood, the combination of features facilitates the formation of abrasive articles that have demonstrated unexpected and remarkably improved performance.

This written description uses examples to disclose the embodiments, including the best mode, and also to enable those of ordinary skill in the art to make and use the invention. The patentable scope is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Note that not all of the activities described above in the general description or the examples are required, that a portion of a specific activity may not be required, and that one or more further activities may be performed in addition to those described. Still further, the order in which activities are listed are not necessarily the order in which they are performed.

In the foregoing specification, the concepts have been described with reference to specific embodiments. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the invention as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of invention.

As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of features is not necessarily limited only to those features but may include other features not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive-or and not to an exclusive-or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

Also, the use of “a” or “an” are employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature of any or all the claims.

After reading the specification, skilled artisans will appreciate that certain features are, for clarity, described herein in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any subcombination. Further, references to values stated in ranges include each and every value within that range.

The abstract of the disclosure is provided to comply with patent law and is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing detailed description, various features may be grouped together or described in a single embodiment for the purpose of streamlining the disclosure. This disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter may be directed to less than all features of any of the disclosed embodiments. Thus, the following claims are incorporated into the detailed description, with each claim standing on its own as defining separately claimed subject matter.

WHAT IS CLAIMED IS:

1. An abrasive cutting tool, comprising:

a body in a shape of a small diameter disk having:

an outer diameter of not greater than about 100 centimeters,

an aspect ratio defined as a ratio (D:T) of the outer diameter to an axial thickness of the body of at least about 10:1,

an abrasive portion having:

a bond material comprising a resin having a normalized heat soak modulus of at least about 1.05; and

abrasive particles contained within the bond material.

2. The abrasive cutting tool of claim 1, wherein the normalized heat soak modulus is at least about 1.10.

3. The abrasive cutting tool of claim 1 or 2, wherein the abrasive portion comprises a filler comprising pyrite (FeS_2).

4. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive portion comprises a filler comprising $KAlF_4$.

5. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive portion comprises a filler comprising CaO.

6. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive portion comprises a filler comprising calcium silicate.

7. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive portion comprises a filler comprising Na_3AlF_6.

8. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive portion comprises a combination of fillers, a total content of the fillers is at

least about 10 vol% of a total volume of the abrasive portion, and not greater than about 60 vol% of the total volume of the abrasive portion.

9. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive portion comprises a wetting liquid remnant including at least one of an aliphatic chain and cyclic organic molecules.

10. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive particles comprise a first type of abrasive particle and a second type of abrasive particle different than the first type, and the second type of abrasive particle comprises alumina and zirconia.

11. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive particles comprise a first type of abrasive particle and a second type of abrasive particle different than the first type, the first type of abrasive particle comprises brown fused alumina (BFA), and the abrasive particles comprise a coating comprising iron oxide.

12. The abrasive cutting tool of any one of the preceding claims, wherein the abrasive portion comprises at least about 30 vol% and not greater than about 65 vol% abrasive particles of a total volume of the abrasive portion.

13. The abrasive cutting tool of claim 11, wherein the BFA comprises not greater than about 99 vol% Al_2O_3, and at least about 80 vol% Al_2O_3.

14. The abrasive cutting tool of claim 11, wherein the BFA comprises not greater than about 20 vol% ZrO_2, and at least about 0.01 vol% ZrO_2.

15. The abrasive cutting tool of claim 10 or 11, wherein the second type of abrasive particle comprises not greater than about 90 vol% Al_2O_3, at least about 60 vol% Al_2O_3, not greater than about 40 vol% ZrO_2, and at least about 10 vol% ZrO_2.

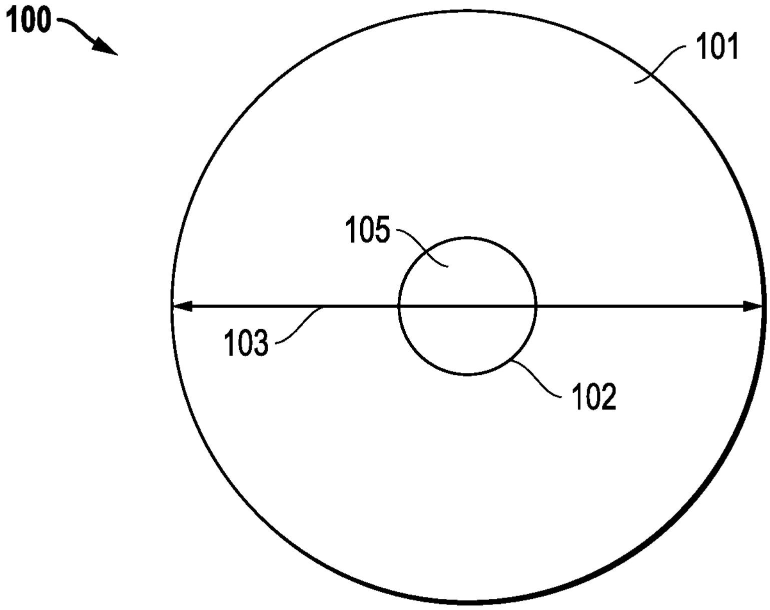
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FIG. 1

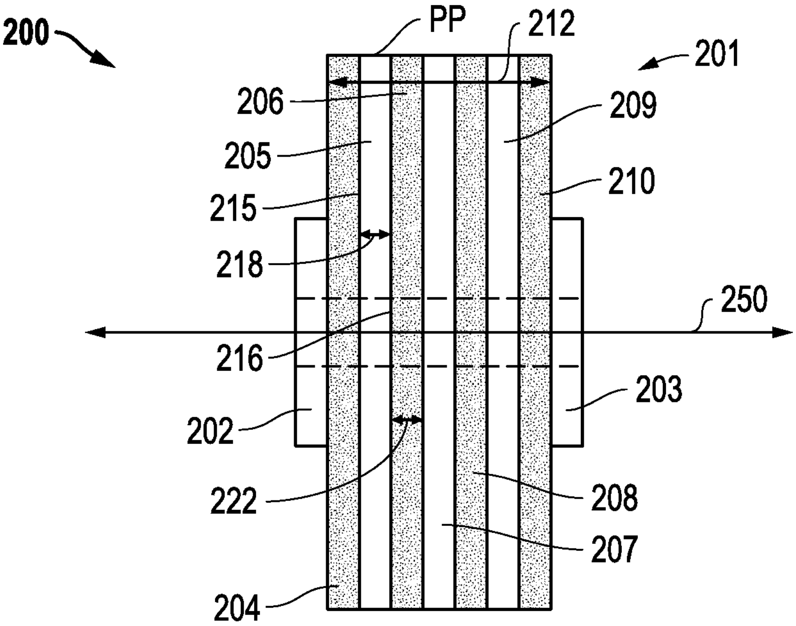
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FIG. 2

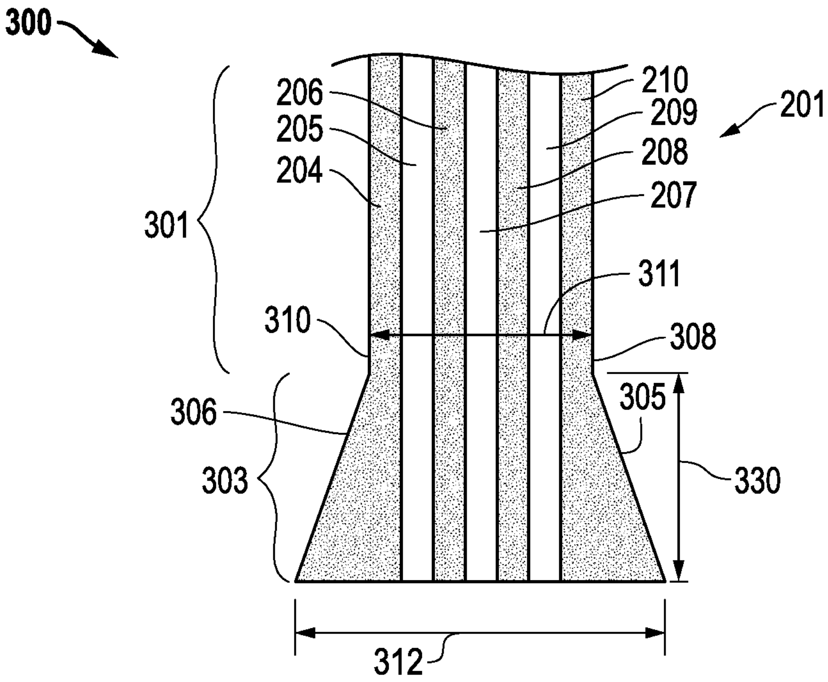
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FIG. 3

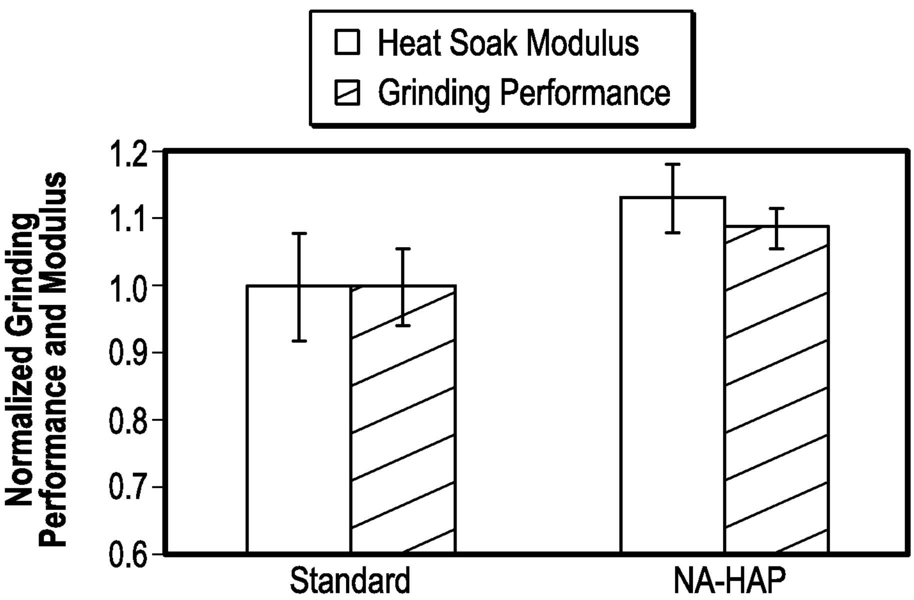
Heat Soak Modulus
Grinding Performance
Normalized Grinding Performance and Modulus
1.2
1.1
1.0
0.9
0.8
0.7
0.6
Standard
NA-HAP

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/044439

A. CLASSIFICATION OF SUBJECT MATTER

B24D 5/12(2006.01)i, B26D 1/143(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B24D 5/12; B24B 27/00; B24D 3/02; B24D 3/00; B32B 3/26; B24D 3/28; B26D 1/143

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: abrasive, cutting tool, aspect ratio, and resin

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2003-191170 A (FUJI GRINDING WHEEL CO., LTD) 08 July 2003 See abstract, paragraphs [0019]-[0025],[0039] and figure 1.	1-8,10,12
A		9,11,13-15
A	US 2011-0111678 A1 (ZHANG, HAN et al.) 12 May 2011 See claims 1-8 and figure 1.	1-15
A	JP 11-028669 A (MITSUBISHI MATERIALS CORP.) 02 February 1999 See abstract and figure 1.	1-15
A	JP 2002-283239 A (MIYAGI PREFECTURE et al.) 03 October 2002 See abstract and figure 1.	1-15
A	US 2011-0027564 A1 (FRANCOIS, EMMANUEL C. et al.) 03 February 2011 See abstract, paragraphs [0021]-[0043] and figures 1,2.	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 September 2013 (03.09.2013)	**04 September 2013 (04.09.2013)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/044439

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		EP 2461943 A2	13/06/2012
		WO 2011-017356 A2	10/02/2011
		WO 2011-017356 A3	05/05/2011