ABRASIVE PARTICLES AND METHODS OF FORMING SAME

ABSTRACT

[0001] The following is directed to abrasive particles such as, abrasive particles including calcined alumina and ilmenite, and methods of forming such abrasive particles.

BACKGROUND

[0002] Abrasive particles and abrasive articles made from abrasive particles are useful for various material removal operations including grinding, finishing, and polishing. Depending upon the type of abrasive material, such abrasive particles can be useful in shaping or grinding a wide variety of materials and surfaces in the manufacturing of goods.

[0003] Due to its high level of hardness and high melting point, brown fused alumina is used in abrasive applications, such as blast finishing grains, lapping and polishing grains, abrasive grain fillers and in refractories as a raw material. Brown fused alumina is produced from the electric arc furnacing and refinement of bauxite ore to a purity of more than 95% aluminum oxide content. As bauxite is becoming increasingly scarce with increasing prices, there remains a need in the industry for creating a synthetic brown fused alumina using alternative materials to bauxite.

[0004] The publication discloses a method of producing abrasive particles wherein ilmenite is used as source for TiO_2 and mixed with calcined alumina. Ilmenite helps to disperse titanium uniformly in the crystal structure of alumina to achieve desirable properties for brown fused alumina. Abrasive articles made with the abrasive particles disclosed herein have a similar material removal rate and grinding life when compared to abrasive articles made with conventional brown fused alumina.

[0005] Some alternative materials are disclosed, for example, in U.S. Pat. No. 9163,128 B2 (Sachse) raw materials, which contain small quantities of contaminations, are thereby used chosen from the group consisting of calcined alumina, rutile, ilmenite and iron ore. In the article *Influence of the addition of niobium oxide on the properties of fused aluminum oxide used in abrasive tools* (https://doi.org/10.1590/0366-69132022683883357), (Passos et al.) calcined alumina and ilmenite are used for producing titanium oxide-containing aluminum oxide particles. However, Saches and Passos both fail to disclose a formulation that specifies the amount of calcined alumina and ilmenite to form a synthetic brown fused alumina. Saches only discloses that the formulation contains raw materials chosen from the group consisting of calcined alumina, rutile, ilmenite and iron ore in such quantities that titanium oxide containing aluminum oxide particles are produced having a chemical composition similar to that of brown fused alumina without any specificity as to which of the raw materials to use let

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alone the quantities of each of the raw materials that are used to create the claimed titanium oxide containing aluminum oxide particles. Passos, in the same way, only discloses the group of raw materials to be used without further specifying the amount to be used in production.

[0006] Beyond a general disclosure of raw materials, this publication discloses specific formulation of raw materials that produces abrasive particles having a composition similar to that of conventional brown fused alumina. For example, the final composition of abrasive particles disclosed herein can have a 94.97% Al_2O_3 weight content, substantially closer to the 95.78% Al_2O_3 weight content of a conventional brown fused alumina sample and a 2.43 % TiO_2 weight content, substantially close to the 2.47 % TiO_2 weight content of a conventional brown fused alumina sample. The abrasive particles disclosed in this publication have a chemical composition closer to that of conventional brown fused alumina when compared to the most relevant prior art.

DESCRIPTION

[0007] According to one aspect, a method of producing abrasive particles comprises melting a mixture of raw materials, the mixture comprising calcined alumina at least 0.1% to not greater than 4.5% by weight ilmenite for a total weight of the mixture, cooling the melted mixture to obtain a mass, comminuting and processing the mass of to obtain abrasive particles and wherein the abrasive particles comprise a body having a ratio of weight percent $Al2O_3$ to a weight percent TiO_2 of at least 30 and not greater than 65.

[0008] In another aspect, a mass of synthesized material comprises a body wherein the body comprises a mixture of raw materials, the mixture comprising calcined alumina and ilmenite, wherein the body comprises at least 90% to not greater than 97% by weight Al_2O_3 for a total weight of the body, at least 1.8% to not greater than 10% by weight TiO_2 for a total weight of the body and a ratio of weight percent Al_2O_3: weight percent TiO_2 is at least 30 and not greater than 65.

[0009] The following is directed to methods of forming a particulate material having certain compositions, including a particulate material in the form of abrasive particles, shaped abrasive particles, and the like. The particulate material may be used in various articles, such as abrasive articles, and more particularly, fixed abrasives, such as bonded abrasive articles, coated abrasive articles, non-woven abrasive articles, and the like. Still, in other instances, the particulate material may be used as a free abrasive material, wherein the particulate material is not necessarily attached to a substrate or incorporated into a matrix material.

[0010] The process can be initiated by melting a mixture of raw materials. In at least one embodiment, the mixture of raw materials can be a material selected from calcined alumina and ilmenite. In an embodiment, the mixture of raw materials consists essentially of calcined alumina and ilmenite. Melting the mixture of raw materials may include melting the raw materials in a fusion process in an electric arc furnace as known in the art.

[0011] In an embodiment, the mixture of raw materials may include a content of calcined alumina that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the mixture of raw materials may include at least 0.1% by weight ilmenite for a total weight of the mixture, or at least 0.2% or at least 0.3% or at least 0.4% or at least 0.5% or at least 0.6% or at least 0.7% or at least 0.8% or at least 0.9% or at least 1% or at least 1.1% or at least 1.2% or at least 1.3% or at least 1.4% or at least 1.5% or at least 1.6% or at least 1.7% or at least 1.8% or at least 1.9% or at least 2% or at least 2.1% or at least 2.2% or at least 2.3% or at least 2.4% or at least 2.5% or at least 2.6% or at least 2.7% or at least 2.8% or at least 2.9% or at least 3% or at least 3.1% or at least 3.2% or at least 3.3% or at least 3.4% or at least 3.5% or at least 3.6% or at least 3.7% or at least 3.8% or at least 3.9% or at least 4% or at least or at least 4.1% or at least 4.2% or at least 4.3% or at least 4.4% by weight ilmenite for a total weight of the mixture. In another aspect, the mixture of raw material may include not greater than 4.5% by weight ilmenite for a total weight of the mixture, or not greater than 4.4% or not greater than 4.3% or not greater than 4.2% or not greater than 4.1% or not greater than 4% or not greater than 3.9% or not greater than 3.8% or not greater than 3.7% or not greater than 3.6% or not greater than 3.5% or not greater than 3.4% or not greater than 3.3% or not greater than 3.2% or not greater than 3.1% or not greater than 3% by weight ilmenite for a total weight of the mixture. The mixture of raw materials may include a content of ilmenite that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.1% by weight ilmenite for a total weight of the mixture to not greater than 4.5% such as within a range from at least 1% to not greater than 4.5% or within a range from at least 3% to not greater than 4.5% by weight ilmenite for a total weight of the mixture.

[0012] In an embodiment, the mixture of raw materials may include a content of calcined alumina that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the mixture of raw materials may include at least 90% by weight calcined alumina for a total weight of the mixture, or at least 90.5% or at least 91% or at least 91.5% or at least 92% or at least 92.5% or at least 93% or at least 93.5% or at least 94% or at least 94.5% or at least 95% or at least 95.5% or at least 96% or at least 96.5% or at least 97% or at least 97.5% by weight calcined alumina for a total weight of the mixture. In another aspect, the mixture of raw material may include not greater than 98% by weight calcined alumina for a total weight of the mixture, or not greater than 97.5% or not greater than 97% or not greater than 96.5% or not greater than 96% or not greater than 95.5% by weight calcined alumina for a total weight of the mixture. The mixture of raw materials may include a content of calcined alumina that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 90% by weight calcined alumina for a total weight of the mixture to not greater than 98% such as within a range from at least 95.5% to not greater than 98% or within a range from at least 96% to not greater than 98% by weight calcined alumina for a total weight of the mixture.

[0013] The process continues by cooling the melted mixture to obtain a mass. The mass may include a body. The body may include a synthesized material. Cooling can include cooling the mass to room temperature.

[0014] In an embodiment, the mass may include a body having a content of Al_2O_3 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the body may include at least 90% by weight Al_2O_3 for a total weight of the body, or at least 90.5% or at least 91% or at least 91.5% or at least 92% or at least 92.5% or at least 93% or at least 93.5% or at least 94% or at least 94.5% or at least 95% or at least 95.5% or at least 96% or at least 96.5% Al_2O_3 for a total weight of the body. In still other embodiment, the body may include not greater than 97% by weight Al_2O_3 for a total weight of the body, or not greater than 96.5% or not greater than 96% or not greater than 95.5% by weight Al_2O_3 for a total weight of the body. The body may include a content of Al_2O_3 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 90% by weight Al_2O_3 for a total weight of the body to not greater than 97% such as within a range from at least 91% to not greater than 97% or within a range from at least 92% to not greater than 97% by weight Al_2O_3 for a total weight of the body.

[0015] In an embodiment, the mass may include a body having a content of TiO_2 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the body may include at least 1.8% by weight TiO_2 for a total weight of the body, or at least 1.9% or at least 2% or at least 2.1% or at least 2.2% or at least 2.3% or at least 2.4% or at least 2.5% TiO_2 for a total weight of the body. In still other embodiment, the body may include not greater than 10% by weight TiO_2 for a total weight of the body, or not greater than 9% or not greater than 8% or not greater than 7% or not greater than 6% or not greater than 5% or not greater than 4% or not greater than 3.5% or not greater than 3% or not greater than 2.5% by weight TiO_2 for a total weight of the body. The body may include a content of TiO_2 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 1.8% by weight TiO_2 for a total weight of the body to not greater than 10% such as within a range from at least 1.9% to not greater than 2.5%by weight TiO_2 for a total weight of the body.

[0016] In an embodiment, the mass may include a body having a ratio of a content of Al_2O_3 to a content of TiO_2 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the body includes a ratio of a weight percent of Al_2O_3 to a weight percent of TiO_2 of at least 30, or at least 31 or at least 32 or at least 33 or at least 34 or at least 35 or at least 36 or at least 37 or at least 38 or at least 39 or at least 40 or at least 41 or at least 42 or at least 43 or at least 44 or at least 45 or at least 46 or at least 47 or at least 48 or at least 49 or at least 50. In still other embodiment, the body includes a ratio of a weight percent of Al_2O_3 to a weight percent of TiO_2 of not greater than 65 or not greater than 64 or not greater than 63 or not greater than 62 or not greater than 61 or not greater than 60 or not greater than 59 or not greater than 58 or not greater than 57 or not greater than 56 or not greater than 55 or not greater than 54 or not greater than 53 or not greater than 52 or not greater than 51 or not greater than 50. The body may include a ratio of a weight percent of Al_2O_3 to a weight percent of TiO_2 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 30 to not greater than 65 such as within a range from at least 32 to not greater than 60.

[0017] In an embodiment, the mass may include a body having a content of Fe_2O_3 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the body may include at least 0.21% by weight Fe_2O_3 for a total weight of the body, or at least 0.22% or at least 0.23% or at least 0.24% or at least 0.25% or at least 0.26% or at least 0.27% or at least 0.28% or at least 0.29% or at least 0.3% or at least 0.31% or at least 0.32% or at least 0.33% or at least 0.34% or at least 0.35% or at least 0.36% or at least 0.37% or at least 0.38% or at least 0.39% or at least 0.4% or at least 0.41% or at least 0.42% or at least 0.43% or at least 0.44% or at least 0.45% or at least 0.46% or at least 0.47% or at least 0.48% or at least 0.49% or at least 0.5% Fe_2O_3 for a total weight of the body. In still other embodiment, the body may include not greater than 2.6% by weight Fe_2O_3 for a total weight of the body, or not greater than 2.5% or not greater than 2.4% or not greater than 2.3% or not greater than 2.2% or not greater than 2.1% or not greater than 2% or not greater than 1.9% or not greater than 1.8% or not greater than 1.7% or not greater than 1.6% or not greater than 1.5% or not greater than 1.4% or not greater than 1.3% or not greater than

1.2% or not greater than 1.1% or not greater than 1% or not greater than 0.9% or not greater than 0.8% or not greater than 0.7% or not greater than 0.6% or not greater than 0.5% by weight Fe_2O_3 for a total weight of the body. The body may include a content of Fe_2O_3 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.21% by weight Fe_2O_3 for a total weight of the body to not greater than 2.6% such as within a range from at least 0.21% to not greater than 0.5% by weight Fe_2O_3 for a total weight of the body.

[0018] In an embodiment, the mass may include a body having a content of Na_2O that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the body may include at least 0.01% Na_2O for a total weight of the body or at least 0.02% or at least 0.03% or at least 0.04% or at least 0.05% or at least 0.06% or at least 0.07% or at least 0.08%. In still other embodiment, the body may include not greater than 0.09% by weight Na_2O for a total weight of the body, or not greater than 0.08% or not greater than 0.07% or not greater than 0.06% or not greater than 0.05% or not greater than 0.04% by weight Na_2O for a total weight of the body. The body may include a content of Na_2O that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.01% by weight Na_2O for a total weight of the body to not greater than 0.09% such as within a range from at least 0.01% to not greater than 0.04% by weight Na_2O for a total weight of the body.

[0019] In an embodiment, the mass may include a body having a content of SiO_2 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the body may include at least 0.1% by weight SiO_2 for a total weight of the body, or at least 0.11% or at least 0.12% or at least 0.13% or at least 0.14% or at least 0.15% or at least 0.16% or at least 0.17% or at least 0.18% or at least 0.19% or at least 0.2% or at least 0.21% or at least 0.22% or at least 0.23% or at least 0.24% or at least 0.25% or at least 0.26% or at least 0.27% or at least 0.28% or at least 0.29% or at least 0.3% or at least 0.31% or at least 0.32% or at least 0.33% or at least 0.34% or at least 0.35% or at least 0.36% or at least 0.37% or at least 0.38% or at least 0.39% or at least 0.4% or at least 0.41% or at least 0.42% or at least 0.43% or at least 0.44% or at least 0.45% or at least 0.46% or at least 0.47% or at least 0.48% or at least 0.49% or at least 0.5% SiO_2 for a total weight of the body. In still other embodiment, the body may include not greater than 1.5% by weight SiO_2 for a total weight of the body, or not greater than 1.4% or not greater than 1.3% or not greater than 1.2% or not greater than 1.1% or not greater than 1% or not greater than 0.9% or not greater than 0.8% or not greater than 0.7% or not greater than 0.6% or not greater than 0.5% or not greater than 0.4% or not greater than 0.3% by weight SiO_2 for a total weight of the body. The body may include a content of SiO_2 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.1% by weight SiO_2 for a total weight of the body to not greater than 1.5% such as within a range from at least 0.1% to not greater than 0.5% by weight SiO_2 for a total weight of the body.

[0020] In an embodiment, the mass may include a body having a content of ZrO_2 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the body may include at least 0.01% ZrO_2 for a total weight of the body or at least 0.02% or at least 0.03% or at least 0.04% or at least 0.05%. In still another embodiment, the body may include not greater than 0.06% by weight ZrO_2 for a total weight of the body, or not greater than 0.05% or not greater than 0.04% by weight ZrO_2 for a total weight of the body. The body may include a content of ZrO_2 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.01% by weight ZrO_2 for a total weight of the body to not greater than 0.06% such as within a range from at least 0.01% to not greater than 0.04% by weight ZrO_2 for a total weight of the body.

[0021] In an embodiment, the mass may include a ratio of the sum of the percentages by weight of Fe_2O_3, SiO_2 and ZrO_2 to the percentage by weight of Na_2O that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the ratio of the sum of the percentages by weight of Fe_2O_3, SiO_2 and ZrO_2 to the percentage by weight of Na_2O may be at least 10 or at least 11 or at least 12 or at least 13 or at least 14 or at least 15. In still other embodiment, the body may include a ratio of the sum of the percentages by weight of Fe_2O_3, SiO_2 and ZrO_2 to the percentage by weight of Na_2O of not greater than 25 or not greater than 24 or not greater than 23 or not greater than 22 or not greater than 21 or not greater than 20 or not greater than 19 or not greater than 18 or not greater than 17 or not greater than 16. The ratio of the sum of the percentages by weight of Fe_2O_3, SiO_2 and ZrO_2 to the percentage by weight of Na_2O may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 10 to not greater than 25 such as within a range from at least 10 to not greater than 15. In an embodiment, the ratio is calculated by adding the weight percent of each of Fe_2O_3, SiO_2 and ZrO_2 and dividing the sum by the weight percent of Na_2O.

[0022] The process continues by comminuting and processing the mass to obtain abrasive particles. Comminuting can include crushing the mass via methods known in the art to obtain abrasive particles.

[0023] In an embodiment, the abrasive particles may include a body having a content of Al_2O_3 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the abrasive particles may include at least 90% by weight Al_2O_3 for a total weight of the body, or at least 90.5% or at least 91% or at least 91.5% or at least 92% or at least 92.5% or at least 93% or at least 93.5% or at least 94% or at least 94.5% or at least 95% or at least 95.5% or at least 96% or at least 96.5% Al_2O_3 for a total weight of the body. In still other embodiment, the abrasive particles may include not greater than 97% by weight Al_2O_3 for a total weight of the body, or not greater than 96.5% or not greater than 96% or not greater than 95.5% by weight Al_2O_3 for a total weight of the body. The abrasive particles may include a content of Al_2O_3 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 90% by weight Al_2O_3 for a total weight of the body to not greater than 97% such as within a range from at least 91% to not greater than 97% or within a range from at least 92% to not greater than 97% by weight Al_2O_3 for a total weight of the body.

[0024] In an embodiment, the abrasive particles may include a body having a content of TiO_2 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the abrasive particles may include at least 1.8% by weight TiO_2 for a total weight of the body, or at least 1.9% or at least 2% or at least 2.1% or at least 2.2% or at least 2.3% or at least 2.4% or at least 2.5% TiO_2 for a total weight of the body. In still other embodiment, the abrasive particles may include not greater than 10% by weight TiO_2 for a total weight of the body, or not greater than 9% or not greater than 8% or not greater than 7% or not greater than 6% or not greater than 5% or not greater than 4% or not greater than 3.5% or not greater than 3% or not greater than 2.5% by weight TiO_2 for a total weight of the body. The abrasive particles may include a content of TiO_2 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 1.8% by weight TiO_2 for a total weight of the body to not greater than 10% such as within a range from at least 1.9% to not greater than 2.5%by weight TiO_2 for a total weight of the body.

[0025] In an embodiment, the abrasive particles may include a body having a ratio of a content of Al_2O_3 to a content of TiO_2 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the abrasive particles include a ratio of a weight percent of Al_2O_3 to a weight percent of TiO_2 of at least 30, or at least 31 or at least 32 or at least 33 or at least 34 or at least 35 or at least 36 or at least 37 or at least 38 or at least 39 or at least 40 or at least 41 or at least 42 or at least 43 or at least 44 or at least 45 or at least 46 or at least 47 or at least 48 or at least 49 or at least 50. In still other embodiment, the abrasive particles include a ratio of a weight percent of Al_2O_3 to a weight percent of TiO_2 of not greater than 65 or not greater than 64 or not greater than 63 or not greater than 62 or not greater than 61 or not greater than 60 or not greater than 59 or not greater than 58 or not greater than 57 or not greater than 56 or not greater than 55 or not greater than 54 or not greater than 53 or not greater than 52 or not greater than 51 or not greater than 50. The abrasive particles may include a ratio of a weight percent of Al_2O_3 to a weight percent of TiO_2 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 30 to not greater than 65 such as within a range from at least 32 to not greater than 60.

[0026] In an embodiment, the abrasive particles may include a body having a content of Fe_2O_3 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the abrasive particles may include at least 0.21% by weight Fe_2O_3 for a total weight of the body, or at least 0.22% or at least 0.23% or at least 0.24% or at least 0.25% or at least 0.26% or at least 0.27% or at least 0.28% or at least 0.29% or at least 0.3% or at least 0.31% or at least 0.32% or at least 0.33% or at least 0.34% or at least 0.35% or at least 0.36% or at least 0.37% or at least 0.38% or at least 0.39% or at least 0.4% or at least 0.41% or at least 0.42% or at least 0.43% or at least 0.44% or at least 0.45% or at least 0.46% or at least 0.47% or at least 0.48% or at least 0.49% or at least 0.5% Fe_2O_3 for a total weight of the body. In still other embodiment, the abrasive particles may include not greater than 2.6% by weight Fe_2O_3 for a total weight of the body, or not greater than 2.5% or not greater than 2.4% or not greater than 2.3% or not greater than 2.2% or not greater than 2.1% or not greater than 2% or not greater than 1.9% or not greater than 1.8% or not greater than 1.7% or not greater than 1.6% or not greater than 1.5% or not greater than 1.4% or not greater than 1.3% or not greater than 1.2% or not greater than 1.1% or not greater than 1% or not greater than 0.9% or not greater than 0.8% or not greater than 0.7% or not greater than 0.6% or not greater than 0.5% by weight Fe_2O_3 for a total weight of the body. The abrasive particles may include a content of Fe_2O_3 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.21% by weight Fe_2O_3 for a total weight of the body to not greater than 2.6% such as within a range from at least 0.21% to not greater than 0.5% by weight Fe_2O_3 for a total weight of the body.

[0027] In an embodiment, the abrasive particles may include a body having a content of Na_2O that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the abrasive particles may include at least 0.01% Na_2O for a total weight of the body or at least 0.02% or at least 0.03% or at least 0.04% or at least 0.05% or at least 0.06% or at least 0.07% or at least 0.08% for a total weight of the body. In still other embodiment, the abrasive particles may include not greater than 0.09% by weight Na_2O for a total weight of the body, or not greater than 0.08% or not greater than 0.07% or not greater than 0.06% or not greater than 0.05% or not greater than 0.04% by weight Na_2O for a total weight of the body. The abrasive particles may include a content of Na_2O that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.01% by weight Na_2O for a total weight of the body to not greater than 0.09% such as within a range from at least 0.01% to not greater than 0.04% by weight Na_2O for a total weight of the body.

[0028] In an embodiment, the abrasive particles may include a body having a content of SiO_2 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the abrasive particles may include at least 0.1% by weight SiO_2 for a total weight of the body, or at least 0.11% or at least 0.12% or at least 0.13% or at least 0.14% or at least 0.15% or at least 0.16% or at least 0.17% or at least 0.18% or at least 0.19% or at least 0.2% or at least 0.21% or at least 0.22% or at least 0.23% or at least 0.24% or at least 0.25% or at least 0.26% or at least 0.27% or at least 0.28% or at least 0.29% or at least 0.3% or at least 0.31% or at least 0.32% or at least 0.33% or at least 0.34% or at least 0.35% or at least 0.36% or at least 0.37% or at least 0.38% or at least 0.39% or at least 0.4% or at least 0.41% or at least 0.42% or at least 0.43% or at least 0.44% or at least 0.45% or at least 0.46% or at least 0.47% or at least 0.48% or at least 0.49% or at least 0.5% SiO_2 for a total weight of the body. In still other embodiment, the abrasive particles may include not greater than 1.5% by weight SiO_2 for a total weight of the body, or not greater than 1.4% or not greater than 1.3% or not greater than 1.2% or not greater than 1.1% or not greater than 1% or not greater than 0.9% or not greater than 0.8% or not greater than 0.7% or not greater than 0.6% or not greater than 0.5% or not greater than 0.4% or not greater than 0.3% by weight SiO_2 for a total weight of the body. The abrasive particles may include a content of SiO_2 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.1% by weight SiO_2 for a total weight of the body to not greater than 1.5% such as within a range from at least 0.1% to not greater than 0.5% by weight SiO_2 for a total weight of the body.

[0029] In an embodiment, the abrasive particles may include a body having a content of ZrO_2 that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the abrasive particles may include at least 0.01% ZrO_2 for a total weight of the body or at least 0.02% or at least 0.03% or at least 0.04% or at least 0.05% for a total weight of the body. In still other embodiment, the abrasive particles may include not greater than 0.06% by weight ZrO_2 for a total weight of the body, or not greater than 0.05% or not greater than 0.04% by weight ZrO_2 for a total weight of the body. The abrasive particles may include a content of ZrO_2 that may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 0.01% by weight ZrO_2 for a total weight of the body to not greater than 0.06% such as within a range from at least 0.01% to not greater than 0.04% by weight ZrO_2 for a total weight of the body.

[0030] In an embodiment, the abrasive particles may include a ratio of the sum of the percentages by weight of Fe_2O_3, SiO_2 and ZrO_2 to the percentage by weight of Na_2O that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the ratio of the sum of the percentages by weight of Fe_2O_3, SiO_2 and ZrO_2 to the percentage by weight of Na_2O may be at least 10 or at least 11 or at least 12 or at least 13 or at least 14 or at least 15. In still other embodiment, the abrasive particles may include a ratio of the sum of the percentages by weight of Fe_2O_3, SiO_2 and ZrO_2 to the percentage by weight of Na_2O of not greater than 25 or not greater than 24 or not greater than 23 or not greater than 22 or not greater than 21 or not greater than 20 or not greater than 19 or not greater than 18 or not greater than 17 or not greater than 16. The ratio of the sum of the percentages by weight of Fe_2O_3, SiO_2 and ZrO_2 to the percentage by weight of Na_2O may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 10 to not greater than 25 such as within a range from at least 10 to not greater than 15. In an embodiment, the ratio is calculated by adding the weight percent of each of Fe_2O_3, SiO_2 and ZrO_2 and dividing the sum by the weight percent of Na_2O.

[0031] In an embodiment, the abrasive particles may have a particular particle size distribution that may facilitate improved manufacturing and/or performance of the abrasive particles. As used herein, the D50 value signifies the size value in the distribution, up to and including which, 50% of the total counts of abrasive particles defining the distribution are ‘contained’. For example, in a non-limiting example, if the D50 is 250 microns, 50% of the abrasive particles have a size of 250 microns or smaller. It will be appreciated that the D50 value may also be referred to as the median value of a sample. In one embodiment the average particle size (D50) of the abrasive particles can be at least 100 microns, such as at least 110 microns or at least 120 microns or at least 125 microns or at least 130 microns or at least 140 microns or at least 150 microns or at least 160 microns or at least 170 microns or at least 180 microns or at least 190 microns or at least 200 microns or at least 210 microns or at least 220 microns or at least 230 microns or at least 240 microns or at least 250 microns or at least 260 microns or at least 270 microns or at least 280 microns or at least 290 microns or at least 300 microns or at least 310 microns or at least 320 microns or at least 330 microns or at least 340 microns or at least 350 microns or at least 360 microns or at least 370 microns or at least 380 microns or at least 390 microns or at least 400 microns or at least 410 microns or at least 420 microns or at least 430 microns or at least 440 microns or at least 450 microns or at least 460 microns or at least 470 microns or at least 480 microns or at least 490 microns or at least 500 microns or at least 5-10 microns or at least 520 microns or at least 530 microns or at least 540 microns or at least 550 microns or at least 560 microns or at least 570 microns or at least 580 microns or at least 590 microns or at least 600 microns or at least 610 microns or at least 620 microns or at least 630 microns. In still another non-limiting embodiment, the average particle size D50 of the abrasive particles may be not greater than 1000 microns, such as not greater than 950 microns or not greater than 900 microns or not greater than 850 microns or not greater than 800 microns or not greater than 750 microns or not greater than 700 microns or not greater than 690 microns or not greater than 680 microns or not greater than 670 microns or not greater than 660 microns or not greater than 650 microns. The average particle size (D50) of the abrasive particles may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 100 microns to not greater than 1000 microns, such as within a range of at least 600 microns to not greater than 700 microns.

[0032] In still other embodiments, the abrasive particles may have a 90th percentile value (D90) that may facilitate improved manufacturing and/or performance of the abrasive particles. As used herein, the D90 value signifies the size value in the distribution, up to and including which, 90% of the total counts of abrasive particles defining the distribution are ‘contained’. For example, in a non-limiting example, if the D90 is 800 microns, 90% of the abrasive particles have a size of 800 microns or smaller. In a particular embodiment, the abrasive particles define a particle size distribution having a 90th percentile value (D90) of at least 100 microns, such as at least 150 microns or at least 200 microns or at least 250 microns or at least 300 or at least 350 microns or at least 400 microns or at least 450 microns or at least 500 microns or at least 550 microns or at least 600 microns or at least 650 microns or at least 700 microns or at least 750 microns or at least 800 microns. In another aspect, the 90th percentile value (D90) of the abrasive particles may be not greater than 1000 microns, such as not greater than 950 microns or not greater than 900 microns or not greater than 850 microns or not greater than 800 microns or not greater than 750 microns or not greater than 700 microns or not greater than 650 microns or not greater than 600 microns or not greater than 550 microns or not greater 500 microns or not greater than 450 microns or not greater than 440 microns or not greater than 430 microns or not greater than 420 microns or not greater than 410 microns or not greater than 400 microns or not greater than 390 microns or not greater than 380 microns or not greater than 370 microns or not greater than 360 microns or not greater than 350 microns. The 90th percentile value (D90) of the abrasive particles may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 100 microns to not greater than 1000 microns, such as within a range of at least 300 microns to not greater than 900 microns.

[0033] In still other embodiments, the abrasive particles may have a 10th percentile value (D10) that may facilitate improved manufacturing and/or performance of the abrasive particles. As used herein, the D10 value signifies the size value in the distribution, up to and including which, 10% of the total counts of abrasive particles defining the distribution are 'contained'. For example, in a non-limiting example, if the D10 is 400 microns, 10% of the abrasive particles have a size of 400 microns or smaller. In a particular embodiment, the abrasive particles define a particle size distribution having a 10th percentile value (D10) of at least 100 microns or at least 150 microns or at least 200 microns or at least 250 microns or at least 300 microns or at least 350 microns or at least 400 microns. In another aspect, the 10th percentile value (D10) of the abrasive particles may be not greater than 600 microns, such as not greater than 550 microns or not greater than 500 microns or not greater than 450 microns or not greater than 400 microns. The 10th percentile value (D10) of the abrasive particles may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 100 microns to not greater than 600 microns, such as within a range from at least 100 microns to not greater than 450 microns.

[0034] It will be appreciated that the D10, D50, and D90 values can be measured using the Malvern Zetasizer "Nano series" running the Zetasizer Software ver. 6.2. To run a sample of abrasive particles for particle size distribution, 40 mL of DI water can be poured into a beaker and 50ul of the abrasive particle sample (solids loading of 25 wt.% in water) can also be transferred into the beaker. The beaker is then placed on a jack stand in a soundproof box used for sonicating. Using the Mxsonix Touch-Screen S-4000 sonicator, an ultrasonic horn can then be placed through a hole at the top of the soundproof box and centered so that the bottom of the horn is approximately 0.25 inches from the bottom of the beaker. The sonicator can then be started for 30 seconds at amplitude 40. The sample can then be removed from the soundproof box and enough sample can be extracted into the sample cuvette until the cuvette is about ¼ full. The cuvette can then be placed into the sample holder of the Zetasizer and the Malvern software for Diamond material with a refractive index of 41-1.80i can be run on the sample. Intensity based D Values for D10, D50, and D90 are then generated by the Zetasizer software.

[0035] In still other embodiments, the abrasive particles may have a particular particle size distribution that may facilitate improved manufacturing and/or performance of the abrasive particles. In a particular embodiment, the abrasive particles can have a particle size distribution, wherein the difference between the 90th percentile value (D90) of the particle size and the 10th percentile value (D10) of the particle size, i.e., D90-D10, may be not greater than 450 microns such as not greater than 440 microns or not greater than 430 migrants or not greater than 420 microns or not greater than 410 microns or not greater than 400 microns or not greater than 390 microns or not greater than 380 microns or not greater than 370 microns or not greater than 360 microns or not greater than 350 microns or not greater than 330 microns or greater than 300 microns or not greater than 270 microns or not greater than 260 microns or not greater than 250 microns or not greater than 240 microns or not greater than 230 microns or not greater than 220 microns or not greater than 210 microns or not greater than 200 microns or not greater than 190 microns or not greater than 180 microns or not greater than 170 microns or not greater than 160 microns or not greater than 150 microns or not greater than 140 microns or not greater than 130 microns or not greater than 120 microns or not greater than 110 microns or not greater than 100 microns. In another embodiment, the abrasive particles can have a particle size distribution, wherein the difference between the 90th percentile value (D90) of the particle size and the 10th percentile value (D10) of the particle size, i.e., D90-D10, may be at least 25 microns, such as at least 50 microns or at least 60 microns or at least 70 microns or at least 80 microns or at least 90 microns or at least 100 microns or at least 110 microns or at least 120 microns or at least 130 microns or at least 140 microns or at least 150 microns or at least 160 microns or at least 170 microns or at least 180 microns or at least 200 microns or at least 220 microns or at least 240 microns or at least 260 microns or at least 280 microns or at least 300 microns or at least 320 microns or at least 340 microns or at least 360 microns or at least 380 microns or at least 400 microns. The difference between the 90th percentile value (D90) of the particle size and the 10th percentile value (D10) of the particle size, i.e., D90-D10 may be a value between any of the minimum and maximum values noted above, including for example, but not limited to within a range of at least 25 microns to not greater than 450 microns, such as within a range of at least 200 microns to not greater than 450 microns.

[0036] In still other embodiments, the abrasive particles may have a Friability Index that may facilitate improved manufacturing and/or performance of the abrasive particles. In an embodiment, the abrasive particles may have a Friability Index of at least 50% or at least 51% or at least 52% or at least 53 percent or at least 54% or at least 55% or at least 56% or at least 57% or at least 58% or at least 59% or at least 60%. In still other embodiments, the abrasive particles may have a Friability Index of not greater than 70% or not greater than 69% or not greater than 68% or not greater than 67% or not greater than 66% or not greater than 65% or not greater than 64%. The Friability Index may be a value between any of the minimum and maximum of values noted above, including for example, but not limited to within a range of at least 50% to not greater than 70%, such as within a range of at least 53% to not greater than 64%. To measure the Friability Index, nominal abrasive particles are collected by Ro-Tap of a standard graded grain sample. 100g of nominal grain is ball milled by rotating the mill having 2000+/- 15g of 0.75" diameter steel balls at 750+/- revolutions. The ball mill is emptied through a coarse screen to separate the balls. The mill is brushed to ensure complete recovery of the test sample. The sample is sieved on the Ro-Tap for 5 mins. using the following series of Grit Tyler Sieves:

1st Sieve	2nd Sieve	3rd Sieve	4th Sieve
12	9	10	12
14	10	12	14
16	12	14	16
20	14	16	20
24	20	24	28
30	24	28	32
36	28	32	35

The weight of the sample passing through the 3rd screen of the last sieve is recorded. Friability Index (FI)= 100 x (weight of sample passing through 3rd screen/weight of sample).

[0037] In still other embodiments, the abrasive particles may have a Vickers Hardness (Hv) that may facilitate improved manufacturing and/or performance of the abrasive particles. In an embodiment, the abrasive particles may have a Vickers Hardness (Hv) of at least 2000, such as at least 2010 or at least 2020 or at least 2030 or at least 2040 or at least 2050 or at least 2060 or at least 2070 or at least 2080 or at least 2090 or at least 2100 or at least 2110 or at least 2120 or at least 2130 or at least 2140 or at least 2150. In still other embodiments, the abrasive particles may have a Vickers Hardness (Hv) of not greater than 2300 or not greater than 2200 or not greater than 2190 or not greater than 2180 or not greater than 2170 or not greater than 2160 or not greater than 2150. The Vickers Hardness (Hv) may be a value between any of the minimum and maximum of values noted above, including for example, but not limited to within a range of at least 2000 to not greater than 2300, such as within a range of at least 2100 to not greater than 2200. The Vickers Hardness (Hv) may be measured by taking a sample of abrasive particles and measuring using the Akashi Mituoyo MVK-HO Hardness Tester.

[0038] As noted herein, the abrasive particles may be deployed in various manners for use in abrasive articles. For example, the abrasive particles may be part of a fixed abrasive article such as a coated abrasive article, bonded abrasive article, and a combination thereof. In particular instances, the abrasive particles can be coupled to a bond material, and further coupled to a backing or substrate via the bond material. The bond material may include compositions such as vitrified materials, ceramic materials, metal alloy, organic material, a resin, a polymer, and a combination thereof. In at least one instance, the abrasive particles can be part of a coated abrasive forming a single layer of abrasive particles coupled to a backing. In an alternative embodiment, the abrasive particles can be used as free abrasive particles.

EXAMPLES

Example 1

[0039] Three samples of a synthetic brown fused alumina were made according to the methods herein. The samples had the raw materials as described in Table 1. The raw materials were combined and melted in a fusion process in an electric arc furnace and the resulting mass of synthesized material was cooled to room temperature and comminuted to form abrasive particles.

Table 1

	Sample 1	Sample 2	Sample 3
Calcined Alumina (wt%)	95.83	97.01	95.75
Ilmenite (wt%)	4.17	-	4.17
Burnt Magnesia (wt%)	-	0.97	0.08
TiO2 (wt%)	-	2.9	

[0040] The particle sizes of the samples were measured according to the methods described herein and the results can be seen in Table 2.

Table 2

	Sample 1	Sample 2	Sample 3
D10 (microns)	494.1	386.9	494.1
D50 (microns)	657.9	636	657.9
D90 (microns)	819.6	818.9	819.6

[0041] The Friability Index and Vickers Hardness were measured according to the methods described herein for Samples 1 to 3 and can be seen in Table 3.

Table 3

	Sample 1	Sample 2	Sample 3
Friability Index (%)	63.2	68.6	73.9
Vickers Hardness (HV)	2122	2087	2021

[0042] The chemistry of each of the samples were measured via an XRF spectrometer. The results can be seen in Table 4.

Table 4

	Sample 1 (wt%)	Sample 2 (wt%)	Sample 3 (wt%)
Al_2O_3	94.97	97.02	91.42
TiO_2	2.43	1.58	2.37
AL_2O_3/TiO_2	39.08	61.41	38.57
Na_2O	0.03	0.04	0.098
Fe_2O_3	0.41	0.22	2.6
SiO_2	0.28	0.11	1.4
ZrO_2	0.04	0.01	0.059
Ratio $Fe_2O_3+SiO_2+ZrO_2/Na$	24.3	8.5	41.42
CaO	0.25	0.14	1.51
K_2O	1.3	0.01	

MgO	0.02	0.57	0.12
MnO	0.06	0.02	0.078
Cr_2O_3	0.03	0.04	0.036
P_2O_5	0.02	0.03	0.067
SO_3	0.02	0.06	0.039

Example 2

[0043] The abrasive particles of samples 1, 2 and 3 were each used to form abrasive sample wheel 4 (S4), abrasive sample wheel 5 (S5), and abrasive sample wheel 6 (S6), respectively. The abrasive wheels were formed according to the methods disclosed herein.

[0044] The abrasive wheel samples S4, S5, and S6 were evaluated in a grinding test at high power (HP) and low power (LP) against a comparative wheel sample 1 (CS1) using the parameters as disclosed in Table 4. Comparative wheel sample 1 (CS1) is available from Norton Abrasives as DXL85.

Table 5

Parameter	Specification
Work Material	IS2062 E250A- Structural Steel
Work Dimension	300(l) x 100 (w) x 10 (t) (mm)
Angle grinder	Bosch- Ø180mm- 2.6kW
Control Current (Amp)	LP: 7-8, HP: 8-9
Test mode	Surface grinding
Traverse rate	80 mm/s

[0045]

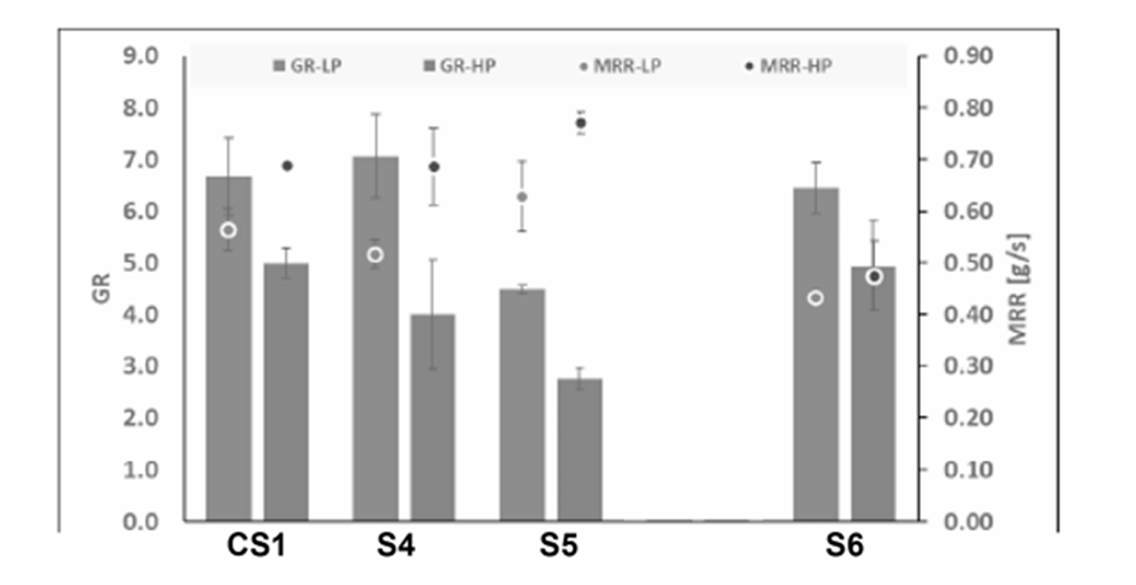

Fig. 1

FIG. 1 includes a plot of G-ratio and Material Removal Rate (MRR) for S4, S5, S6 and CS1. As illustrated, abrasive sample wheel S6 showed lower MRR in low power and high power conditions. Abrasive sample wheel S5 showed lower life, but high MRR. Abrasive sample wheel S4 showed performance closest to the comparative wheel sample 1 (CS1).

Keywords: abrasive particles, brown fused alumina, titanium dioxide, ilmenite, calcined aluminum, electric arc furnace.