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DEDUSTING OIL COMPOSITIONS WITH ENHANCED HEAT RESISTANCE

Abstract

Dedusting oil compositions and binder compositions including such dedusting oil compositions for fiberglass are provided. Dedusting oil compositions are formed from a plant oil and a high activity aromatic amine. Binders may include polyacrylic acid polymers crosslinked with a polyol crosslinking agent and include a dedusting oil composition. Methods of making the binders and fiber-containing composites made with the binders are also provided.

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Background/Summary

FIELD OF THE DISCLOSURE

[0001] The present technology relates to dedusting oil compositions and binder compositions for fiberglass and to processes for making same. Binders include dedusting oil compositions that contain a plant oil and an aromatic amine.

BACKGROUND

[0002] Thermoset binders for fiberglass composite products such as fiberglass insulation are moving away from traditional formaldehyde-based compositions. Formaldehyde is considered a probable human carcinogen, as well as an irritant and allergen, and its use is increasingly restricted in building products, textiles, upholstery, and other materials. In response, binder compositions have been developed that do not use formaldehyde or decompose to generate formaldehyde. Such binder compositions require dust controlling agents to control particles formed from the breakdown of the fiberglass fibers. However, existing dust-controlling agents fail to exhibit the necessary temperature stability.

[0003] Thus, a need exists for dust-controlling agents having enhanced exotherm resistance. Additionally, the need exists for dust control agents having higher thermal stability. These and other issues are disclosed in the present specification.

BRIEF SUMMARY

[0004] The present technology is generally directed to dedusting oil compositions, binders including such dedusting oil compositions, and insulation products including such dedusting oil compositions. Dedusting oil compositions include a plant oil and a high activity aromatic amine. Dedusting oil compositions include where the high activity aromatic amine includes an aromatic amine having one or more active hydrogens attached to a nitrogen.

[0005] In embodiments, the aromatic amine includes an aniline, an alkylated aniline, a N-mono alkyl aniline, a diphenylamine, an alkylated diphenylamine, a phenylene diamine, a diphenyl-phenylene diamine, a N,N' dialkyl phenylene diamine, a hydroquinoline, an imidazole, a mercaptoimidazole, a mercaptothiazole, a hydroxybenzothiazole, a 4,4-bis(α,α -dimethylbenzyl) diphenylamine, derivatives thereof, metal salts thereof, or combinations thereof. Furthermore, in embodiments, the dedusting oil exhibits an exotherm onset temperature of greater than or about 190° C. In more embodiments, the dedusting oil exhibits an exotherm onset temperature of greater than or about 200° C. Additionally or alternatively, the high activity aromatic amine is present in the dedusting oil in an amount of about 0.1 wt. % to about 20 wt. %.

[0006] The present technology is also generally directed to binder compositions for fiberglass. Binder compositions include a polycarboxylic acid based binder, a formaldehyde-based binder, or a formaldehyde-free binder, and a dedusting oil composition, where the dedusting oil composition includes a plant oil and a high activity aromatic amine.

[0007] In embodiments, the aromatic amine includes an aniline, an alkylated aniline, a N-mono alkyl aniline, a diphenylamine, an alkylated diphenylamine, a phenylene diamine, a diphenyl-phenylene diamine, a N,N' dialkyl phenylene diamine, a hydroquinoline, an imidazole, a mercaptoimidazole, a mercaptothiazole, a hydroxybenzothiazole, a 4,4-bis(α,α -dimethylbenzyl) diphenylamine, derivatives thereof, metal salts thereof, or combinations thereof. Moreover, in embodiments, the crosslinking agent includes one or more polyol compounds. In more embodiments, the polyol includes sorbitol, triethanolamine, diethanolamine, polyvinyl alcohol, glycerol, propylene glycol, neopentyl glycol, trimethylolpropane, pentaerythritol, polyester polyol, acrylic polyols, carbohydrates, or combinations thereof. In yet further embodiments, the polycarboxylic acid includes a monomeric polycarboxylic acid, wherein the monomeric polycarboxylic acid comprises citric acid, itaconic acid, maleic acid, adipic acid, oxalic acid, trimellitic acid, butanetetracarboxylic acid, or combinations thereof or a homopolymer or copolymer formed at least in part from acrylic acid, methacrylic acid, butenedioic acid, methyl maleic acid, itaconic acid, crotonic acid, maleic anhydride, acrylic anhydride, methacrylic

anhydride, itaconic anhydride, maleic acid, fumaric acid, or a combination thereof. In embodiments, the plant oil includes soybean oil, linseed oil, safflower oil, sunflower oil, castor oil, corn oil, tall oil fatty acid, or a combination thereof. Embodiments include where the dedusting oil composition is present in the binder composition in an amount of less than or about 40 wt. %. Furthermore, in embodiments, the binder composition exhibits an exotherm onset temperature of greater than or about 185° C.

[0008] The present technology is also generally directed to methods of forming binder compositions for fiberglass. Methods include mixing a plant oil and a high activity aromatic amine, forming a dedusting oil, and mixing a polycarboxylic acid based binder, a formaldehyde-based binder, or a formaldehyde-free binder with the dedusting oil.

[0009] In embodiments, methods include curing the binder composition after mixing the resin composition and the dedusting oil. In more embodiments, methods include applying the binder composition to one or more woven or non-woven fibers prior to curing.

[0010] The present technology is also generally directed to fiber-containing composites.

Composites include woven or non-woven fibers consolidated with a cured binder, where the cured binder includes a polycarboxylic acid crosslinked by a crosslinking agent, a formaldehyde-based binder, or a formaldehyde-free binder, and a dedusting oil composition. Composites include where the dedusting oil composition includes a plant oil and a high activity aromatic amine.

[0011] In embodiments, the aromatic amine includes an aniline, an alkylated aniline, a N-mono alkyl aniline, a diphenylamine, an alkylated diphenylamine, a phenylene diamine, a diphenyl-phenylene diamine, a N,N' dialkyl phenylene diamine, a hydroquinoline, an imidazole, a mercaptoimidazole, a mercaptothiazole, a mercaptobenzothiazole, a 4,4'-bis(α,α -dimethylbenzyl) diphenylamine, a hydroxybenzothiazole, derivatives thereof, metal salts thereof, or combinations thereof. In more embodiments, the dedusting oil composition is present in the binder composition in an amount of less than or about 40 wt. %. Additionally or alternatively, in embodiments, the high activity aromatic amine is present in the dedusting oil in an amount of about 0.1 wt. % to about 20 wt. %. Furthermore, in embodiments, the fiber-containing composite comprises thermal insulation. In embodiments, the thermal insulation includes at least one of building insulation, pipe insulation, duct insulation or appliance insulation. In more embodiments, the fiber-containing composite includes acoustical insulation.

[0012] Additional embodiments and features are set forth in part in the description that follows, and in part will become apparent to those skilled in the art upon examination of the specification or may be learned by the practice of the invention. The features and advantages of the present technology may be realized and attained by means of the instrumentalities, combinations, and methods described in the specification.

Description

DETAILED DESCRIPTION

[0013] Various formaldehyde free binders for glass, mineral and organic fibers (natural and synthetic) have been described in the literature and used for many years. Formaldehyde-free binders refer to binder compositions with no added formaldehyde to the binder composition and which do not release formaldehyde during the manufacturing process and no detectable formaldehyde is released from the final product. One class of such binders is based on polyacrylic acid that is crosslinked with low molecular weight polyols such as triethanolamine, glycerol, or sorbitol. Other binders are based on condensation of low molecular weight polycarboxylic acids such as citric acid, polyacrylic acid, or triethanol amine (TEA) with polyols such as starch or maltodextrin. These polymers have been commercialized since late 1990s for the fiber glass insulation industry.

[0014] Although these polymers provide mechanical performance of the insulation products that are comparable with phenol-formaldehyde (PF) resins, hydrolytic stability (moisture resistance) and thermal resistance of these polymers are not comparable with PF resins, and tend to allow greater dust formation during manufacture. Dust, such as dust formed from normal fiber breakage, control of fibrous materials including fiberglass insulation can be achieved by addition of an external dedusting oil. These oils are conventionally either petroleum based with high-boiling points or based on oxidized/oligomerized plant oils and migrate to the surface of cured binder on the fibrous material, forming a thin layer of oil. These oils, however, can increase flammability particularly in curing ovens or if insufficiently cooled or cured.

[0015] In an effort to improve the thermal stability of dedusting oil compositions, phenolic antioxidant and functional triazine antioxidant compounds were incorporated as additives into the dedusting oil. However, the antioxidants failed to properly stabilize the dedusting oil. In addition, the existing dedusting oil compositions, such as those having phenolic or functional triazine antioxidant additives, have failed to provide adequate stabilization properties to the dedusting oil without requiring unacceptably high weight percentages of the antioxidant.

[0016] The present technology overcomes these and other problems by providing dedusting oil compositions with an increased exotherm onset temperature. The dedusting oil compositions according to the present technology include one or more high activity aromatic amines and a plant oil. It was found that the dedusting oil compositions according to the present technology exhibit exotherm onset temperatures greater than those achieved by phenolic or functionalized triazine containing compounds, which is surprisingly as phenolic and functionalized triazine compounds are considered to be more effective antioxidants. Without wishing to be bound by theory, it is believed that the high activity aromatic amines according to the present technology are able to donate an initial hydrogen, quenching one or more free radicals formed by decomposition of the plant oil. However, unlike phenolic compounds and functionalized triamines, which are very stable after initial donation, the high-activity amines of the present technology may be capable of rearrangement and partial decomposition, allowing donation of one or more further hydrogens. Thus, the dedusting oil compositions of the present technology may exhibit drastically improved exotherm onset temperature, as well as provide such a increased exotherm onset temperature to a resin binder composition, without requiring large amounts of amine or dedusting oil.

[0017] In embodiments, dedusting oil compositions according to the present technology include a plant oil and a high activity aromatic amine. Plant oils may include one or more long chain triglycerides, e.g., esters derived from glycerol and three fatty acids. In embodiments, the plant oil may be an soybean oil, linseed oil, safflower oil, sunflower oil, castor oil, corn oil, and tall oil fatty acid, as well as other plant oils as known in the art, and combinations thereof. As will be appreciated by those skilled in the art, many of these plant oils, and thus many of the corresponding plant oils, comprise a blend of many different compounds rather than one specific compound.

[0018] The fatty acids used to form the triglycerides may include one or more short-chain fatty acids (SCFA), e.g., fatty acids with aliphatic tails of 5 or fewer carbons (e.g. butyric acid), medium-chain fatty acids (MCFA) acids, e.g., fatty acids with aliphatic tails of 6 to 12 carbons, long-chain fatty acids (LCFA), e.g., fatty acids with aliphatic tails of 13 to 21 carbons, or very long chain fatty acids (VLCFA), e.g., fatty acids with aliphatic tails of 22 or more carbons. In terms of ranges, the fatty acids employed in forming the triglycerides optionally have an average chain length from 18 to 26, e.g., from 16 to 24, or from 14 to 22. Thus, the corresponding triglycerides used in forming the plant oils may similarly comprise carbon chains having any of these average chain lengths.

[0019] As discussed above, the present technology has surprisingly found that high activity aromatic amines may be utilized as the amine component of the dedusting oil in order to provide an increased exotherm onset temperature and improved stability. In embodiments, the high activity aromatic amine may be an aromatic amine having one or more active hydrogens attached to the nitrogen. In embodiments, suitable high activity aromatic amines may include an anilines, alkylated

anilines, N-mono alkyl aniline, a diphenylamine, such as 4,4'-bis(α,α -dimethylbenzyl) diphenylamine (VANOX® CDPA available from Vanderbilt Chemicals), a benzothiazole including a hydroxybenzothiazole, such as 1-or 2-OHBT, alkylated diphenyl amine, phenylene diamine, diphenyl-phenylene diamine and derivatives thereof, N,N' dialkyl phenylene diamine (para or meta), hydroquinolines including 1,2-dihydro-2,2,4-trimethyl quinoline and other alkyl substituted hydroquinolines, mercaptoimidazoles, an imidazole, a mercaptothiazole, such as 2-mercaptobenzothiazole (MBT), and metal salts thereof, and the like, as well as combinations thereof. However, it should be clear that other aromatic amines having one or more active hydrogens attached to the nitrogen are contemplated herein for use in dedusting oil compositions according to the present technology.

[0020] Regardless of the high activity aromatic amine and/or plant oil selected, the high activity aromatic amine may be present in the dedusting oil in an amount of less than or about 25 wt. %, based upon the weight of the plant oil and the high activity aromatic amine, such as less than or about 22.5 wt. %, such as less than or about 20 wt. %, such as less than or about 19 wt. %, such as less than or about 18 wt. %, such as less than or about 17 wt. %, such as less than or about 16 wt. %, such as less than or about 15 wt. %, such as less than or about 14 wt. %, such as less than or about 13 wt. %, such as less than or about 12 wt. %, such as less than or about 11 wt. %, such as less than or about 10 wt. %, such as less than or about 9 wt. %, such as less than or about 8 wt. %, such as less than or about 7 wt. %, such as less than or about 6 wt. %, such as less than or about 5 wt. %, such as less than or about 4 wt. %, such as less than or about 3 wt. %, such as less than or about 2 wt. %, such as less than or about 1 wt. %, such as less than or about 0.5 wt. %, or such as greater than or about 0.1 wt. %, greater than or about 0.5 wt. %, greater than or about 1 wt. %, such as greater than or about 2.5 wt. %, such as greater than or about 5 wt. %, such as greater than or about 6 wt. %, such as greater than or about 7 wt. %, such as greater than or about 8 wt. %, such as greater than or about 9 wt. %, such as greater than or about 10 wt. %, such as greater than or about 11 wt. %, such as greater than or about 12 wt. %, such as greater than or about 13 wt. %, such as greater than or about 14 wt. %, or any ranges or values therebetween.

[0021] Surprisingly, even at relatively low amounts of the high activity aromatic amine, an exotherm onset temperature ($^{\circ}$ C.) of dedusting oil compositions prepared according to the present technology may be greater than or about 10% higher than the plant oil alone, such as greater than or about 12.5%, such as greater than or about 15%, such as greater than or about 17.5%, such as greater than or about 20%, such as greater than or about 22.5%, such as greater than or about 25%, such as greater than or about 27.5%, such as greater than or about 30%, such as greater than or about 32.5%, such as greater than or about 35%, such as greater than or about 37.5%, such as greater than or about 40% higher than the plant oil un-modified with a high activity aromatic amine.

[0022] In embodiments, dedusting oil compositions according to the present technology may exhibit an exotherm onset temperature of greater than or about 180 $^{\circ}$ C., such as greater than or about 185 $^{\circ}$ C., such as greater than or about 190 $^{\circ}$ C., such as greater than or about 195 $^{\circ}$ C., such as greater than or about 200 $^{\circ}$ C., such as greater than or about 205 $^{\circ}$ C., such as greater than or about 210 $^{\circ}$ C., such as greater than or about 220 $^{\circ}$ C., such as greater than or about 230 $^{\circ}$ C., such as greater than or about 240 $^{\circ}$ C., such as greater than or about 250 $^{\circ}$ C., such as greater than or about 260 $^{\circ}$ C., such as greater than or about 270 $^{\circ}$ C., such as greater than or about 275 $^{\circ}$ C., such as up to about 300 $^{\circ}$ C. or less, or any ranges or values therebetween.

[0023] Furthermore, it was surprisingly found that the dedusting oils according to the present technology also exhibited a greatly increased lag phase when utilized in a binder. As used herein "lag phase" refers to the time period from the start of heat exposure to exotherm onset. The dedusting oils of the present technology exhibited a lag phase that is greater than or about 10% higher than the plant oil alone, such as greater than or about 12.5%, such as greater than or about 15%, such as greater than or about 17.5%, such as greater than or about 20%, such as greater than

or about 22.5%, such as greater than or about 25%, such as greater than or about 27.5%, such as greater than or about 30%, such as greater than or about 32.5%, such as greater than or about 35%, such as greater than or about 37.5%, such as greater than or about 40% higher, such as greater than or about 45%, such as greater than or about 50%, such as greater than or about 55%, such as greater than or about 60%, such as greater than or about 65%, such as greater than or about 70%, such as greater than or about 75%, such as greater than or about 80% higher than the plant oil un-modified with a high activity amine, or any ranges or values therebetween. Without wishing to be bound by theory, it is believed that a longer lag phase indicates a more efficient high activity amine.

[0024] Regardless of the method utilized to form the dedusting oils, the dedusting oil compositions discussed herein may be suitable for use in binder compositions, such as binder compositions for fiberglass that include a polycarboxylic acid such as polyacrylic acid and a crosslinking agent.

[0025] Also disclosed are fiber-containing composites containing binder compositions and methods of making binder compositions such fiber-containing composites. The embodiments disclosed herein advantageously provide improved thermal stability while controlling dust formation during the manufacture of fiber-containing composites. They also provide increased exotherm onset temperatures relative to conventional binder compositions, while maintaining and at times increasing desirable mechanical characteristics such as improved hydrolytic stability.

[0026] As used herein, the term “crosslinking agent” refers to a compound having the ability to form a covalent bond or a short sequence of bonds that link one polymer chain to another polymer chain upon curing, e.g., to link two polyacrylic acid polymers to one another. The term “dedusting agent” refers to a compound that is typically not crosslinked with a polymer, instead providing a surface coating to glass fibers for reducing dust formation during manufacture and handling of fiber-containing composites.

Binder Compositions

[0027] Disclosed are processes for making such binder compositions as well as the resulting binder compositions. In one embodiment, the method of forming a polyacrylic acid based binder composition for fiberglass includes mixing a polyacrylic acid with a polyol to form a crosslinkable polyacrylic/polyol resin and adding a dedusting oil compositions as discussed herein to form a binder composition.

[0028] The polymer to be crosslinked upon curing may include a polycarboxylic acid. Although the subject specification primarily refers to acrylic acid polymers, the polycarboxylic acids crosslinked according to the embodiments of the disclosure may include any polycarboxylic acid monomer, or any polycarboxylic acid homopolymer, and/or copolymer prepared from ethylenically unsaturated carboxylic acids including, but not limited to, acrylic acid, methacrylic acid, butenedioic acid (i.e., maleic acid and/or fumaric acid), methyl maleic acid, itaconic acid, and crotonic acid, among other carboxylic acids. The polycarboxylic acid polymer may also be prepared from ethylenically unsaturated acid anhydrides including, but not limited to, maleic anhydride, acrylic anhydride, methacrylic anhydride, itaconic anhydride, among other acid anhydrides.

[0029] Thus, in some aspects the polycarboxylic acid comprises a monomeric polycarboxylic acid selected, for example, from the group consisting of citric acid, itaconic acid, maleic acid, adipic acid, oxalic acid, trimellitic acid, and butanetetracarboxylic acid. In other aspects, the polycarboxylic acid may include a homopolymer or copolymer formed at least in part from acrylic acid, methacrylic acid, butenedioic acid, methyl maleic acid, itaconic acid, crotonic acid, maleic anhydride, acrylic anhydride, methacrylic anhydride, itaconic anhydride, maleic acid, or fumaric acid. Additionally, the polycarboxylic acid polymer of the present invention may be a copolymer of one or more of the aforementioned unsaturated carboxylic acids or acid anhydrides and one or more vinyl compounds including, but not limited to, styrenes, acrylates, methacrylates, acrylonitriles, methacrylonitriles, among other compounds. More specific examples of the polycarboxylic acid polymer may include copolymers of styrene and maleic anhydride, and its derivatives including its reaction products with ammonia and/or amines. For example, the

polycarboxylic acid polymer may be the polyamic acid formed by the reaction between the copolymer of styrene and maleic anhydride and ammonia.

[0030] The molecular weight of the polymer may vary depending on the specific polymer. For polyacrylic acid polymers, the molecular weight (Mw) optionally ranges from 1000-100,000 amu, e.g., from 1000 to 50,000 amu, from 1000 to 10,000 amu, from 2000 to 10,000 amu, or from 3000 to 5000.

[0031] The polymer compound may be a solution polymer that helps make a rigid thermoset binder when cured. In contrast, when the polymer compound is an emulsion polymer, the final binder compositions are usually less rigid (i.e., more flexible) at room temperature.

[0032] In some aspects, the polymer, e.g., acrylic acid polymer, may be crosslinked with a crosslinking agent. In this aspect, the crosslinking agent may be one or more polyols, such as one or more of sorbitol, triethanolamine, diethanolamine, monoethanolamine, polyvinyl alcohol, glycerol, propylene glycol, neopentyl glycol, trimethylol propane, pentaerythritol, polyester polyol, carbohydrates, and acrylic polyols. The crosslinking agent may include compounds containing at least two reactive functional groups including, but not limited to, hydroxyl, amine, aldehydes, isocyanate, and epoxide, among other functional groups. Examples of suitable crosslinking agent may include polyols, alkanol amines, polyamines, and other types of compounds with at least two functional groups that can undergo crosslinking with other binder ingredients, such as the polymer compound.

[0033] Specific examples of polyols suitable as a crosslinking agent include sorbitol, glycerol, ethylene glycol, propylene glycol, diethylene glycol, and triethylene glycol, maltodextrin, starch, and polyvinyl alcohol among other polyols. Specific examples of alkanol amines may include ethanolamine, diethanolamine, monoethanolamine, and triethanolamine, among other alkanol amines. Specific examples of polyamines may include ethylene diamine, hexane diamine, and triethylene diamine, phenylenediamine among other polyamines. Specific examples of epoxies may include bisphenol-A based epoxies, aliphatic epoxies, epoxidized oils, among other epoxy compounds.

[0034] The binder compositions may also optionally include a cure catalyst. Examples of cure catalysts may include phosphorous-containing compounds such as phosphorous oxyacids and their salts. For example, the cure catalyst may be an alkali metal hypophosphite salt like sodium hypophosphite (SHP). The cure catalyst may be added to expedite curing of the binder composition.

[0035] The binder compositions may also optionally include extenders. Examples of extenders may include starch, lignin, rosin, among other extenders.

[0036] The binder compositions may also optionally contain pH adjustment agents. For example, the present binder compositions and solution may include one or more acids or bases that maintain the pH between 2-8.

[0037] The dedusting oil compositions discussed herein may not be restricted to polycarboxylic acid based binders such as polyacrylic acid based binders, in embodiments. Instead, the dedusting oil compositions discussed herein having a plant oil modified with one or more high activity aromatic amines can replace traditional dedusting oil compositions used in traditional fiberglass binders such as formaldehyde-based binders, e.g., phenol-formaldehyde (PF), urea-formaldehyde (UF), melamine-formaldehyde (MF) binders, and combinations thereof, and formaldehyde-free binders such as polyesters, melanoidin-based binders, epoxy resin, acrylic resin, polyurethanes, and combinations thereof.

[0038] The dedusting oil compositions discussed herein can also be utilized to replace traditional dedusting oil compositions used in reducing sugar based melanoidin binders which include a reducing sugar, a Nitrogen-containing crosslinking compound and an ammonium salt of organic or inorganic acid as cure catalyst and its combinations thereof. Reducing sugars may include dextrose, fructose, or combinations thereof. Nitrogen-containing compounds can include urea,

hexamethylenediamine, a cyclic urea based on reaction product of urea & an aldehyde such as glyoxal or glutaraldehyde, amino-amide intermediates formed from reaction of an amine and a saturated or unsaturated reactant such as maleic anhydride, succinic anhydride, phthalic anhydride, tetrahydrophthalic anhydride, or combinations thereof. The cure catalysts can include ammonium sulfate, ammonium phosphate or ammonium salt of methanesulfonic acid, ammonium citrate and combinations thereof.

[0039] Thus, in embodiments, dedusting oil compositions as discussed herein may also be employed in formaldehyde-based binders and formaldehyde-free binders. For example, in one aspect a binder composition for fiberglass is disclosed that includes a formaldehyde-based binder, a crosslinking agent, and a dedusting oil according to the present disclosure. The formaldehyde-based binder optionally may be a phenol-formaldehyde based binder, a urea-formaldehyde based binder, a melamine-formaldehyde based binder, and any combination thereof.

[0040] Regardless of the method(s) utilized, dedusting oil compositions with one or more high activity amines according to the present technology may provide the improved stability and exotherm onset temperature benefits discussed herein, without requiring a larger percentage by weight of the binder composition to be formed from the dedusting oil(s) or stated differently, to be formed from the high activity amine. For instance, in embodiments, dedusting oil compositions may be present in the binder composition in an amount of less than or about 45 wt. %, based upon the weight of the binder composition, such as less than or about 40 wt. %, such as less than or about 39 wt. %, such as less than or about 38 wt. %, such as less than or about 37 wt. %, such as less than or about 36 wt. %, such as less than or about 35 wt. %, such as less than or about 34 wt. %, such as less than or about 33 wt. %, such as less than or about 32 wt. %, such as less than or about 31 wt. %, such as less than or about 30 wt. %, or such as greater than or about 5 wt. %, such as greater than or about 7.5 wt. %, such as greater than or about 10 wt. %, such as greater than or about 12.5 wt. %, such as greater than or about 15 wt. %, such as greater than or about 17.5 wt. %, such as greater than or about 20 wt. %, such as greater than or about 22.5 wt. %, such as greater than or about 25 wt. %, such as greater than or about 27.5 wt. %, or any ranges or values therebetween.

[0041] For instance, in embodiments, one or more high activity amines may be present in the binder composition in an amount of less than or about 4 wt. %, based upon the dry weight of the total solids in the binder composition, such as less than or about 3 wt. %, such as less than or about 2 wt. %, such as less than or about 1 wt. %, such as less than or about 0.5 wt. %, such as less than or about 0.25 wt. %, such as less than or about 0.1 wt. %, such as less than or about 0.05 wt. %, such as less than or about 0.01 wt. %, or such as greater than or about 0.01 wt. %, such as greater than or about 0.04 wt. %, such as greater than or about 0.08 wt. %, such as greater than or about 0.16 wt. %, such as greater than or about 0.32 wt. %, such as greater than or about 0.6 wt. %, such as greater than or about 1.1 wt. %, such as greater than or about 2.2 wt. %, such as greater than or about 3.3 wt. %, such as greater than or about 4 wt. %, or any ranges or values therebetween.

[0042] It was surprisingly found that the dedusting oil compositions discussed herein provide even greater exotherm onset temperature increases to a binder composition. In embodiments, even at relatively low amounts of the high activity amine and/or dedusting oil, an exotherm onset temperature ($^{\circ}$ C.) of binder compositions prepared utilizing dedusting oil compositions according to the present technology may be greater than or about 10% higher than a binder composition having a dedusting oil formed from the plant oil alone, such as greater than or about 20%, such as greater than or about 25%, such as greater than or about 30%, such as greater than or about 35%, such as greater than or about 40%, such as greater than or about 50%, such as greater than or about 60%, such as greater than or about 70%, such as greater than or about 80%, such as greater than or about 90%, such as greater than or about 95%, such as greater than or about 100% higher than a binder utilizing a dedusting oil formed from a plant oil un-modified with a high activity aromatic amine.

[0043] In embodiments, binder compositions according to the present technology may exhibit an exotherm onset temperature of greater than or about 180 $^{\circ}$ C., such as greater than or about 185 $^{\circ}$ C.,

such as greater than or about 190° C., such as greater than or about 195° C., such as greater than or about 200° C., such as up to about 250° C. or less, such as less than or about 225° C., such as less than or about 200° C., or any ranges or values therebetween

Methods of Making Fiber Composites

[0044] The present binder compositions may be used in methods of making fiber products. The methods may include applying a solution of the binder composition containing the dedusting oil along with the additive to fibers and curing the binder composition on the fibers to form the fiber product. The binder solution may be spray coated, spin coated, curtain coated, knife coated, or dip coated onto fibers. Once the liquid binder composition is applied, the binder and substrate may be heated to cure the binder composition and form a composite of cured binder and fibers that make up the fiber product.

[0045] The binder solution may be formed to have a viscosity in range that permits the efficient application of the solution to the fibers. For example, the viscosity may be about centipoises to about 1500 centipoises when the binder solution is at room temperature.

[0046] If the viscosity of the liquid binder applied to the substrate is too high, it may slow down the application process both at the release point for the binder as well as the rate of mixing and coverage of the binder on the substrate.

[0047] After application of the liquid binder composition on the substrate, the amalgam of liquid binder and substrate undergoes curing. In the curing process the polymer compound and the polyol may form covalently crosslinked bonds among each other to convert the amalgam into a thermoset composite. While, in embodiments, the dedusting oil may undergo limited crosslinking during curing, in embodiments, the dedusting oil discussed herein may undergo limited crosslinking, and may instead be present as a dedusting oil. When a thermal curing process is used, the amalgam may be subjected to an elevated temperature (e.g., up to 300° C.) to facilitate crosslinking in the binder. The peak curing temperature may depend on the specific formulation of the binder composition, the substrate, and whether a cure catalyst is used. The cured material typically includes about 0.5 wt % to about 50 wt % thermoset binder composition (e.g., about 1 wt. % to about 10 wt. %) with the substrate representing most of the remaining weight.

[0048] The binder composition may be a stable one-part composition that can be recycled during the application to the fibers and/or between applications on fibers. Thus, an unused portion of the binder solution that, for example, passes through the fibers may be captured and sent back to the supply of binder solution applied to the fibers. In some embodiments, the unused portion of the binder solution may be purified or otherwise treated before returning to the supply.

[0049] The reuse of the binder solution may not only reduce the amount of solution used, it may also reduce the amount of waste materials that must be treated and discarded. However, recycling unused binder solution requires that the solution remain stable for two or more application cycles. In many instances, two-part binder compositions that mix separated and highly reactive components immediately before their application will cure too rapidly to be recycled. One-part binder compositions may also be unsuitable if they do not have a sufficient pot life to remain relatively unreacted prior to use and during recycling. The present binder compositions include one-part binder compositions that are stable enough to be appropriate for binder solution recycling.

Fiber-Containing Composites

[0050] The present binder compositions may be added to fibers to produce fiber-containing composite products. The fibers may include organic fibers and/or inorganic fibers. Examples of the fibers may include polymer fibers and/or glass fibers, among other types of fibers. The fibers may be arranged as an insulation batt, woven mat, non-woven mat, or spunbond product, among other types of fiber substrate. Thus, in one embodiment the fiber-containing composite comprises (a) woven or non-woven fibers; and (b) a cured binder that holds the fibers together, where the binder may be any one or more of the binder compositions discussed above containing the dedusting oil of the present technology.

[0051] The present binder compositions may be used in fiber products to make insulation and fiber-reinforced composites, among other products. The products may include fibers (e.g., organic and/or inorganic fibers) contained in a cured thermoset binder prepared from a one-part binder solution of a polymer compound, the dedusting oil compositions, and crosslinking agent. The fibers may include glass fibers, carbon fibers, and organic polymer fibers, among other types of fibers. For example, the combination of the binder composition and glass fibers may be used to make fiberglass insulation products. Alternatively, when the fiberglass is a microglass-based substrate, the binder may be applied and cured to form printed circuit boards, battery separators, filter stock, and reinforcement scrim, among other articles.

[0052] The fiber-containing composites may take a variety of forms, for example construction materials including thermal insulation, piping insulation, duct boards (e.g., air duct boards), and building insulation, reinforcement scrim, and roofing membranes, acoustical insulation, among other construction materials. Additional examples may include loose-fill blown insulation, duct liner, duct wrap, flexible duct media, thermal insulation such as pipe insulation, tank insulation, building insulation, appliance insulation, and duct insulation, rigid plenum liner, textile duct liner insulation, equipment liner, oven insulation, elevated temperature board, elevated temperature wrap, elevated temperature panel, insulation batts and rolls, heavy density batt insulation, light density batt insulation, exterior foundation insulation board, and marine hull insulation, insulation board, duct board, elevated temperature board, acoustical insulation, such as HVAC insulation, appliance insulation or office interior board insulation, among other materials, as well as combinations thereof.

[0053] Fiber-containing composites prepared with the binder compositions of the present invention may have a density that range from about 5 kg/m.³ to about 100 kg/m.³. More specific density ranges may include about 5 kg/m.³ to about 20 kg/m.³; and about 10 kg/m.³ to about 80 kg/m.³, among other density ranges. Specific exemplary densities of a the fiber-containing composite may include about 5 kg/m.³; about 10 kg/m.³; about 15 kg/m.³; about 20 kg/m.³; about 25 kg/m.³; about 30 kg/m.³; about 35 kg/m.³; about 40 kg/m.³; about 45 kg/m.³; about 50 kg/m.³; about 55 kg/m.³; about 60 kg/m.³; about 65 kg/m.³; about 70 kg/m.³; about 75 kg/m.³; and about 80 kg/m.³, among other densities, as well as combinations and ranges therebetween. Densities for the fiber-containing composite may vary depending on the type of composite made. For example, when the fiber-containing composite is a thermal insulation batt, a density range of about 4 kg/m.³ to about 12 kg/m.³ may be common, although not the only density range. When the fiber-containing composite is duct board, a density range of about 30 kg/m.³ to about 100 kg/m.³ may be more typical, although again not the only density range.

[0054] The binder compositions may be formulated to impart a particular color to the fiber product when cured. For example, the concentration of reducing sugars in the binder compositions may be lowered to give the fiber product a white or off-white color when cured. Alternatively, a dye may be added to binder composition before, during, or after the curing stage to impart a particular color to the final fiber product (e.g., red, pink, orange, yellow, green, blue, indigo, violet, among many other colors).

EXAMPLES

[0055] The following Examples are presented to provide specific representative

[0056] embodiments of the present invention. The invention is not limited to the specific details as set forth in these Examples.

Example 1

[0057] 5 g of m-phenylenediamine were added to 95 g of commercially available plant-based dedusting oil. The mixture was heated at 90° C. for 1 hour with continuous stirring. A clear uniform liquid product was formed. The final dedusting oil composition had 5% phenylenediamine based on dry weight.

[0058] 5 g of diphenylamine was added to 95 g of commercially available high molecular weight plant-based dedusting oil. The mixture was heated at 90° C. for 1 hour with continuous stirring. A clear uniform liquid product was formed. The final dedusting oil composition had 5% diphenylamine based on dry weight.

[0059] In addition, MBT, OHBT, and CDPA were heated with commercially available dedusting oil, resulting in dedusting oils that contained from 5 to 10 wt. % high activity amine based on the weight of the dedusting oil.

[0060] As used herein, “exotherm onset temperature” is utilized to refer to the temperature at which the temperature of the dedusting oil or binder increases rapidly, “lag phase” refers to the time before reaching exotherm onset temperature.

Thermal Stability

[0061] The prepared dedusting oils of the present technology were evaluated for thermal stability using the exotherm test. The exotherm was evaluated by forming glass wads with 40% LOI. The glass-wad was sandwiched in R19 batts, compressed to a density of 2.8 pounds per cubic foot (44.9 kg/m.sup.3), and placed in an oven maintained at 475° F. (246° C.). Exotherm data was collected by use of a thermocouple to measure the temperature at the center of the glass-wads as a function of time. The exotherm resistance of a commercial polycarboxylic acid/polyol binder with 30% of the inventive dedusting oil was also evaluated.

[0062] Table 1 shows the exotherm onset temperature of glass wads of commercial dedusting oil, namely a high molecular weight plant oil, with various high activity amines according to the present technology as compared to exotherm of commercial dedusting oil without a high activity aromatic amine. As can be seen, addition of high activity aromatic amines as discussed herein greatly increased exotherm onset temperature compared to commercial dedusting oil alone.

TABLE-US-00001 TABLE 1 Oil Exotherm Onset (Mass Ratio of Oil:High Activity Amine)
Temperature ° C. Commercial dedusting oil 170 Commercial dedusting oil + diphenylamine (95-5) 200
Commercial dedusting oil + mPDA (95-5) 252 Commercial dedusting oil + MBT (95-5) 200
Commercial dedusting oil + 2-OHBT (90-10) 155 Commercial dedusting oil + CDPA (90-10) 228

[0063] Table 2 shows the exotherm onset temperature of glass wads made with a commercial polycarboxylic acid/polyol binder with 30% of the dedusting oil according to the present technology compared to polycarboxylic acid/polyol binder with 30% of commercial dedusting oil. As can be seen the inventive dedusting oil provides increased exotherm resistance.

TABLE-US-00002 TABLE 2 Binder + Oil (Mass Ratio of Oil:High Activity Exotherm Onset Amine) Temperature ° C. 70 wt. % Resin + 30 wt. % 180 Commercial dedusting oil 70 wt. % Resin + 30 wt. % 195 (Commercial dedusting oil- mPDA 95-5) 70 wt. % Resin + 30 wt. % 274 (Commercial dedusting oil- MBT 95-5) 70 wt. % Resin + 30 wt. % 290 (Commercial dedusting oil- 2- OHBT 95-5) 70 wt. % Resin + 30 wt. % 294 (Commercial dedusting oil- CDPA 90-10)

[0064] Table 3 illustrates the lag phase of glass wads made with a commercial polycarboxylic acid/polyol (“Resin”) binder with 30% of dedusting oils discussed herein. As can be seen, addition of a high activity amine as discussed herein greatly increased the lag phase compared to commercial dedusting oil.

TABLE-US-00003 TABLE 3 Binder + Oil (Mass Ratio of Oil:High Activity Amine) Lag phase (seconds) 70 wt. % Resin + 30 wt. % 1900 Commercial dedusting oil 70 wt. % Resin + 30 wt. % 4300 (Commercial dedusting oil- MBT 95-5) 70 wt. % Resin + 30 wt. % 3200 (Commercial dedusting oil- 2- OHBT 95-5) 70 wt. % Resin + 30 wt. % 4500 (Commercial dedusting oil- CDPA 90-10)

[0065] Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limits of that range is also specifically disclosed. Each smaller range between any stated value or intervening value in a stated range and any other stated or intervening value in that stated range is encompassed. The upper and lower limits of these smaller ranges may independently be

included or excluded in the range, and each range where either, neither or both limits are included in the smaller ranges is also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included.

[0066] As used herein and in the appended claims, the singular forms “a”, “an”, and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a process” includes a plurality of such processes, and so forth.

[0067] Also, the words “comprise,” “comprising,” “include,” “including,” and “includes” when used in this specification and in the following claims are intended to specify the presence of stated features, integers, components, or steps, but they do not preclude the presence or addition of one or more other features, integers, components, steps, acts, or groups.

Claims

1. A dedusting oil composition comprising: a plant oil; and a high activity aromatic amine; wherein the high activity aromatic amine comprises an aromatic amine having one or more active hydrogens attached to a nitrogen.
2. The composition of claim 1, wherein the aromatic amine comprises an aniline, an alkylated aniline, a N-mono alkyl aniline, a diphenylamine, an alkylated diphenylamine, a phenylene diamine, a diphenyl-phenylene diamine, a N,N' dialkyl phenylene diamine, a hydroquinoline, an imidazole, a mercaptoimidazole, a mercaptothiazole, a hydroxybenzothiazole, a 4,4-bis(α,α -dimethylbenzyl) diphenylamine, derivatives thereof, metal salts thereof, or combinations thereof.
3. The composition of claim 1, wherein the dedusting oil composition exhibits an exotherm onset temperature of greater than or about 190° C.
4. The composition of claim 3, wherein the dedusting oil composition exhibits an exotherm onset temperature of greater than or about 200° C.
5. The composition of claim 1, wherein the high activity aromatic amine is present in the dedusting oil composition in an amount of about 0.1 wt. % to about 20 wt. %.
6. A binder composition for fiberglass, comprising: a polycarboxylic acid based binder, a formaldehyde-based binder, or a formaldehyde-free binder, and a dedusting oil composition, wherein the dedusting oil composition comprises a plant oil and a high activity aromatic amine.
7. The composition of claim 6, wherein the aromatic amine comprises an aniline, an alkylated aniline, a N-mono alkyl aniline, a diphenylamine, an alkylated diphenylamine, a phenylene diamine, a diphenyl-phenylene diamine, a N,N' dialkyl phenylene diamine, a hydroquinoline, an imidazole, a mercaptoimidazole, a mercaptothiazole, a hydroxybenzothiazole, a 4,4-bis(α,α -dimethylbenzyl) diphenylamine, derivatives thereof, metal salts thereof, or combinations thereof.
8. The composition of claim 6, wherein the binder composition comprises the polycarboxylic acid based binder, and wherein the polycarboxylic acid based binder comprise a crosslinking agent, wherein the crosslinking agent comprises one or more polyol compounds.
9. The composition of claim 8, wherein the polyol comprises sorbitol, triethanolamine, diethanolamine, polyvinyl alcohol, glycerol, propylene glycol, neopentyl glycol, trimethylolpropane, pentaerythritol, polyester polyol, acrylic polyols, carbohydrates, or combinations thereof.
10. The composition of claim 6, wherein the polycarboxylic acid comprises a monomeric polycarboxylic acid, wherein the monomeric polycarboxylic acid comprises citric acid, itaconic acid, maleic acid, adipic acid, oxalic acid, trimellitic acid, butanetetracarboxylic acid, or combinations thereof or a homopolymer or copolymer formed at least in part from acrylic acid, methacrylic acid, butenedioic acid, methyl maleic acid, itaconic acid, crotonic acid, maleic anhydride, acrylic anhydride, methacrylic anhydride, itaconic anhydride, maleic acid, fumaric acid, or a combination thereof.

- 11.** The composition of claim 6, wherein the plant oil comprises soybean oil, linseed oil, safflower oil, sunflower oil, castor oil, corn oil, tall oil fatty acid, or a combination thereof.
 - 12.** The composition of claim 6, wherein the dedusting oil composition is present in the binder composition in an amount of less than or about 40 wt. %.
 - 13.** The composition of claim 6, wherein the binder composition exhibits an exotherm onset temperature of greater than or about 185° C.
 - 14.** A method of forming a binder composition for fiberglass, comprising: mixing a plant oil and a high activity aromatic amine, forming a dedusting oil composition, and mixing a polycarboxylic acid based binder, a formaldehyde-based binder, or a formaldehyde-free binder with the dedusting oil composition.
 - 15.** The method of claim 14, further comprising curing the binder composition after mixing the polycarboxylic acid based binder, formaldehyde-based binder, or formaldehyde-free binder and the dedusting oil composition.
 - 16.** The method of claim 14, further comprising applying the binder composition to one or more woven or non-woven fibers prior to curing.
 - 17.** A fiber-containing composite, comprising: woven or non-woven fibers consolidated with a cured binder; wherein the cured binder comprises the binder composition according to claim 6.
 - 18.** The fiber-containing composite of claim 17, wherein the high activity aromatic amine comprises an aniline, an alkylated aniline, a N-mono alkyl aniline, a diphenylamine, an alkylated diphenylamine, a phenylene diamine, a diphenyl-phenylene diamine, a N,N' dialkyl phenylene diamine, a hydroquinoline, an imidazole, a mercaptoimidazole, a mercaptothiazole, a mercaptobenzothiazole, a 4,4'-bis(α,α -dimethylbenzyl)diphenylamine, a hydroxybenzothiazole, derivatives thereof, metal salts thereof, or combinations thereof.
 - 19.** The fiber-containing composite of claim 17, wherein the dedusting oil composition is present in the binder composition in an amount of less than or about 40 wt. %.
 - 20.** The fiber-containing composite of claim 19, wherein the high activity aromatic amine is present in the dedusting oil in an amount of about 0.1 wt. % to about 20 wt. %.
 - 21.** The fiber-containing composite of claim 17, wherein the fiber-containing composite comprises thermal insulation.
 - 22.** The fiber-containing composite of claim 21, wherein the thermal insulation comprises at least one of building insulation, pipe insulation, duct insulation or appliance insulation.
 - 23.** The fiber-containing composite of claim 17, wherein the fiber-containing composite comprises acoustical insulation.
 - 24.** The fiber-containing composite of claim 23, wherein the acoustical insulation comprises at least one of HVAC insulation, appliance insulation or office interior board insulation.
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