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(54) **LOW BINDER NONWOVEN FIBER MATS, LAMINATES CONTAINING FIBROUS MAT AND METHODS OF MAKING**

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(57) **ABSTRACT**

A nonwoven fibrous mat containing non-cellulosic fibers such as glass fibers, mixtures of glass fibers and synthetic polymer fibers, ceramic fibers, mixtures of glass fibers and natural fibers and mixtures thereof bound together with a water soluble, formaldehyde free binder, the binder content of the mat being in the range of about less than about 4 weight percent of the dry mat is particularly useful in making wood or wood product laminates. The mat can also contain limited amounts of cellulosic fibers. The low binder content produces mat manufacturing efficiencies and advantages in the wood laminate.

LOW BINDER NONWOVEN FIBER MATS, LAMINATES CONTAINING FIBROUS MAT AND METHODS OF MAKING

[0001] This application is a continuation of application Ser. No. 09/428,632, filed Oct. 27, 1999.

[0002] The present invention involves nonwoven mats having particular use in bonding to wood and wood products in making improved wood laminates and the method of making such mats and laminates. The mats produced according to this invention are useful as reinforcement and dimensional stabilizers for making a large number of products such as wood composites or laminates of all types, such as structural veneer plywood and hard faced wood products like laminated veneer lumber, plywood, and various boards like particle board, OSB, etc. for many uses. The mats are also useful as stabilizing and reinforcing substrates for various other wood products.

BACKGROUND

[0003] It is known to make reinforcing nonwoven mats from fibers and to use these mats as substrates in the manufacture of a large number of products. Methods of making nonwoven mats are known, such as the conventional wet laid processes described in U.S. Pat. Nos. 4,112,174, 4,681,802 and 4,810,576, the disclosures of which are hereby incorporated herein by reference. In these processes a slurry of glass fiber is made by adding fiber to a typical white water in a pulper to disperse the fiber in the white water forming a slurry having a fiber concentration of about 0.2-1.0 weight %, metering the slurry into a flow of white water to dilute the fiber concentration to 0.1 or below, and depositing this mixture on to a moving screen forming wire to dewater and form a wet nonwoven fibrous mat.

[0004] This wet nonwoven web of fiber is then transferred to a second moving screen and run through a binder application saturating station where an aqueous binder mixture, such as an aqueous urea formaldehyde (UF) resin based binder mixture, is applied to the mat in any one of several known ways. The binder saturated mat is then run over a suction section while still on the moving screen to remove excess binder. The wet mat is then transferred to a wire mesh moving belt and run through an oven to dry the wet mat and to cure (polymerize) the UF based resin binder which bonds the fibers together in the mat. Preferably, the aqueous binder solution is applied using a curtain coater or a dip and squeeze applicator, but other methods of application such as spraying are also known.

[0005] In the drying and curing oven the mat is subjected to temperatures up to 450 or 500 degrees F. or higher for periods of time usually not exceeding 1-2 minutes. Alternative forming methods for nonwoven fiber mats include the use of well known processes of cylinder forming, continuous strand mat forming which lays continuous strands of glass fibers in overlapping swirls, and "dry laying" using carding or random fiber distribution.

[0006] UF resins, usually modified with one or more of acrylic, styrene butadiene, or vinyl acetate resins, are most commonly used as a binder for fiber glass mats because of their suitability for the applications and their relatively low cost. Melamine formaldehyde resins are sometimes used for higher temperature and/or chemical resistant applications. To improve the toughness of the mats, a combination of higher mat tear strength and mat flexibility, which is needed to permit higher processing speeds on roofing product manufacturing lines and for maximum roofing product performance on the roofs and in other applications, it is common to modify or plasticize the UF resins as described above. The binder content of these finished mats typically are in the range of 15 to 25 weight percent or higher, based on the dry weight of the mat.

[0007] Mats made in the above described manner perform well in many applications, but do not provide the bonding strength desired for bonding to wood products.

SUMMARY OF THE INVENTION

[0008] The nonwoven mats of the present invention comprise fibers making up at least 90, preferably at least 95-weight percent or more of the mat, preferably with at least 80 weight percent of the fibers being glass or inorganic fibers. The fibers are bonded together with a very small amount of a resin binder containing essentially free of urea formaldehyde, phenol formaldehyde melamine formaldehyde or furfuryl alcohol formaldehyde resins. In this invention the presence of one or more of these conventional formaldehyde containing binders is not required and normally would not be present except as an impurity or trace amount. This is a substantial advantage in those areas where it is desirable to eliminate or minimize the presence of compounds containing formaldehyde from a product.

[0009] The resin binder is preferably a water soluble binder like polyvinyl alcohol, hydroxy ethyl cellulose, carboxy methyl cellulose, cellulose gums, polyvinyl pyrilidone, polyvinyl acetate homopolymer, and mixtures thereof. By a "small amount" is meant that the binder is no more than about five percent, preferably less than four percent, and most preferably less than three percent of the dry mat and usually is at least 0.3 weight percent, most preferably between about one to three weight percent. All percents used herein are weight percents unless otherwise stated.

[0010] The preferred fiber is glass fiber, but other fibers including synthetic fibers of all kinds such as polyester, nylon, polypropylene, etc., carbon fibers, ceramic fibers, metal fibers, etc., can be present in amounts up to 100 percent of the fibers. A minority of the fibers can be cellulosic fibers or fibers derived from a cellulosic derivative, i.e. less than half the total weight of fibers per unit area of mat. So called "binder fibers" can be used in lieu of liquid binder. These binder fibers are typically made of polyvinyl alcohol, polyvinyl chloride, polyolefins and their copolymers. Binder fibers can also be bi-component such as a polyester core covered with a sheath of polyethylene.

[0011] The mats of the present invention have lower physical properties initially like tensile strength, hot wet strength and tear strength than conventional mats, but the mats of the present invention surprisingly produce high bonding strength with wood. Most importantly, use of the inventive mat produces higher glass fiber loadings in the "glue line" of wood laminates and composites than prior art mats for this purpose have produced. The present invention is based in part on the discovery that limiting the binder content in the finished mat to a low level greatly improves the bond strength between the mat and wood, or a wood product, reduces the amount of undesired organic material in the nonwoven fiber reinforced glue lines in the resultant wood composite and increases the amount of desired wood bonding adhesive in nonwoven glass fiber reinforced glue lines. The low level of resin binder that is water soluble or water sensitive also allows for limited movement of the glass fiber network present in the mats of the invention, instead of rigid fracture during laminate forming, under high pressure which is characteristic of the thermosetting formaldehyde containing resin binders.

[0012] The mats of the present invention are particularly suited for use in the manufacture of wood composites or composites of wood products or mixtures of wood and wood products as well as wood veneer laminations. Herein, when wood composite is used it is intended to include all kinds of composites containing one or more wood layers, one or more wood product layers and one or more fibrous nonwoven mat layers. By wood products is meant products like hardboard, particle board, chip board, oriented strand board, laminated veneer lumber, gluelam timbers and the like, i.e. where the major portion of the material is wood in some form. The present invention also includes precursors of wood laminates or wood composites containing at least one layer of wood or wood product and one or more layers of the above described inventive mats.

[0013] By "formaldehyde free" it is meant containing essentially no formaldehyde, i.e. formaldehyde is not essential in the mats of the present invention, but might be present as an impurity in trace amounts. By "water soluble" is meant can be dissolved in water.

[0014] The present invention also includes a process of making the inventive nonwoven fiber mats described above from a slurry of fiber, preferably glass fiber, comprising forming a nonwoven web on a moving, permeable surface and thereafter saturating the fibrous web with an aqueous based binder, preferably water soluble such as polyvinyl alcohol binder with or without modification, removing excess aqueous binder and drying and curing the mat in an oven. The resultant mat is normally wound into rolls and packaged for shipment, and/or transported to a point of use.

[0015] The present invention also includes a process wherein one or more layers of the inventive mat are, after being impregnated with a normally used conventional wood adhesive, placed in contact with one or more layers of wood or wood product and the resulting laminate or precursor are then subjected to high pressure and sufficient heat to cure the adhesive.

[0016] The present invention also includes wood laminates, wood composites and veneered wood products containing one or more layers of mat of the present invention as an intermediate layer bonded between two or more layers of wood or wood veneer.

[0017] The inventive mats and glue lines of the wood laminates and composites of the present invention can also contain pigments, dyes, flame retardants, and other additives so long as they do not significantly reduce the ability of the mat to bond to a wood surface. The pigments or other additives can be included in the fiber slurry, the binder slurry or can be sprayed or otherwise coated onto the mat later using known techniques or included in the wood adhesive.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Mats of the present invention contain about 93-99.5, preferably about 96-99.5, weight percent fibers and about 0.5-4, preferably 0.75 to less than 3, weight percent binder or binder fiber, exclusive of any additives like pigments, etc. as described below. Binder contents in the dry mat in the range of 2-3 wt. percent are most preferred. The majority of the fibers are preferably glass fibers, but other fibers can be present. The glass fibers which can be used to make mats can have various fiber diameters and lengths dependent on the strength and other properties desired in the mat. It is preferred that the majority of the glass fibers have diameters in the range of about 6 up to about 23 microns, with the major portion of the fiber being preferably in the range of about 10 to 19 microns and most preferably in the range of about 13 to 17 microns, such as about 15-17 microns.

[0019] The glass fibers can be E glass, C glass, T glass, S glass or any known glass fiber of good strength and durability in the presence of moisture. Rotary made fibers of glass, basalt and slag can also be used, but are not preferred. Preferably, the glass fibers used are chopped continuous glass fibers, usually all having about the same target length, such as 0.25, 0.5, 0.75, 1 or 1.25 inch, but fibers of different lengths and different average diameters can also be used to get different characteristics in a known manner. Fibers up to about 3 inches in length can be used in a wet process for making fiber glass mats and even longer fibers can be used in some dry processes. Generally, the longer the fiber, the higher the tensile and tear strengths of the mat, but the poorer the fiber dispersion. Also, continuous strands containing a plurality of fibers can be introduced into the slurry of fibers just before forming the mat in a manner known in the wet laid mat forming industry to produce continuous reinforcement in the fibrous nonwoven mat.

[0020] While the majority of the fibers used in the present invention are glass fibers, a minor portion of non-glass fibers can also be used, such as cellulosic fibers including wood pulp of all kinds, cotton linters, cellulose derivatives such as cellulose triacetate, rayon, etc. Man-made organic synthetic polymer fibers such as nylon, polyester, polyethylene, polypropylene, etc. can also be used instead of cellulose fibers in any various blends with one or more cellulosic fibers.

[0021] The binders used to bond the fibers together are preferably resins that can be put into aqueous solution or emulsion latex and that are water soluble. Typical resin based binders meeting this description are polyvinyl alcohol, carboxy methyl cellulose, hydroxy ethyl cellulose, lignosulfonates, cellulose gums and other similar resins. Of these, polyvinyl alcohol resin is much preferred because of its water solubility and the good dry tensile strength it produces, its bonding strength to fibers, particularly glass fibers, its reduced levels of volatile organic compound (VOC) emissions, its phenol-free and formaldehyde-free nature and its stability in storage.

[0022] A particularly useful polyvinyl alcohol resin for use in this invention is AIRVOL™ 205 resin available from Air Products and Chemicals, Inc. of Allentown, Pa. AIRVOL™ 205 resin is partially hydrolyzed, highly reactive, water soluble and contains low levels of volatile components. It has a specific gravity of about 1.3 grams/cc and has a viscosity of about 5 cps at 4 percent concentration in water. AIRVOL™ 205 resin is fully compatible and redissolvable in numerous phenolic, urea and melamine resin based adhesives normally used in bonding layers of wood together.

[0023] A particularly useful carboxyl methyl cellulose resin for this invention is CMC AQUALON™ 7A available from Hercules, Inc. of Wilmington, Del. Another binder useful in the present invention are lignosulfonates, particularly the type used for foundry sand and ceramic products. Other suitable binders for the mat include resin based fiber sizings, so called "wet strength" non-formaldehyde resins used in the paper industry, non-crosslinked polyvinyl acetate homopolymer latex. Water sensitive or soluble binder fibers, usually made from PVOH, can also be used in lieu of resinous binders.

[0024] Processes for making nonwoven fiber glass mats are well known and some of them are described in U.S. Pat. Nos. 4,112,174, 4,681,802 and 4,810,576, which references are hereby incorporated into this disclosure by reference, but any known method of making nonwoven mats can be used. The preferred technique for the making of mats of the present invention is forming a dilute aqueous slurry of fibers and depositing the slurry onto an inclined moving screen forming wire to dewater the slurry and form a wet nonwoven fibrous mat, on machines like a Hydroformer™ manufactured by Voith-Sulzer of Appleton, WS, or a Deltaformer™ manufactured by Valmet/Sandy Hill of Glenns Falls, N.Y. The examples disclosed herein were made on a pilot scale model of a wet forming machine, binder applicator, and oven that produces a mat very similar to a mat that would be produced from the same slurry and binder on a production sized Voith-Sulzer Deltaformer™ with a curtain coater binder applicator and a flat bed, permeable conveyor type convection dryer.

[0025] After forming a web from the fibrous slurry, the wet, unbonded fibrous nonwoven web or mat is then transferred to a second moving screen running through a binder application saturating station where the binder, preferably resin based, in aqueous solution is applied to the mat. The excess binder is removed, and the wet mat is transferred to a moving permeable belt that runs through a convection oven where the unbonded, wet mat is dried and cured, bonding the fibers together in the mat. In production, the dry, cured mat is then usually wound into rolls and packaged such as by stretch or shrink wrapping or by putting into a plastic bag to keep out moisture and dirt, etc.

[0026] Preferably, the aqueous binder solution is applied using a curtain coater or a dip and squeeze applicator. In the drying and curing oven the mat is heated to temperatures of up to about 300 degrees F., but this can vary from about 220 degrees F. to as high as will not embrittle or deteriorate the binder, usually around 450 degrees F., for periods usually not exceeding 1 or 2 minutes and frequently less than 40 seconds, preferably significantly less than 30 seconds.

EXAMPLE 1

[0027] A fiber slurry was prepared in a well known manner by adding one inch long wet E type glass chopped fiber having fiber diameters averaging about 16 microns and cellulose fibers, standard bleached softwood kraft fibers, in a ratio of 80 weight percent glass fibers and 20 weight percent cellulose fibers. These fibers were added to a known cationic white water containing Natrosol™ thickening agent available from Hercules, Inc. and a cationic surfactant C-61, an ethoxylated tallow amine available from Cytec Industries, Inc. of Morristown, N.J., as a dispersing agent to form a fiber concentration of about 0.2 weight percent. After allowing the slurry to agitate for about 5-20 minutes to thoroughly disperse the fibers, the slurry was metered into a moving stream of the same whitewater to dilute the fiber concentration to a concentration averaging about 0.2 weight percent before pumping the diluted slurry to a headbox of a pilot sized machine similar to a Voith Hydroformer™ where a wet nonwoven mat was continuously formed.

[0028] The wet mat was removed from the forming wire and transferred to a Sandy Hill Curtain Coater where an aqueous hydroxy ethyl cellulose resin, NATRASOL™250 LR, available from Hercules, Inc., at 5 percent concentration was applied in an amount to provide a binder level in the cured mat of about 2-3 weight percent. The wet mat was then transferred to an oven belt and carried through an oven to dry the mat and at a temperature of about 350-degrees F. The basis weight of the mat produced was 1.5 pounds/100 square feet of mat. This mat is later referred to as A-1 mat.

EXAMPLE 2

[0029] Another mat was made exactly the same as the mat of Example 1, but only glass fibers were used producing a dry mat containing 97-98 wt. percent E glass fibers and 2-3 wt. percent of the HEC binder used in Example 1. This mat, referred to as A-2 mat, had a basis weight of 1.5 pounds/100 square feet.

EXAMPLE 3

[0030] A layer of A-2 dry mat and a layer of a conventional, commercial type 1.7 lb./100 sq. ft. dry fiber glass mat, referred to as A-3 mat, were used to make mat/particle board laminates. The A-3 dry mat was made in the same manner as A-1 mat, except the dry A-3 mat contained about 74 wt. percent 16 micron glass fibers and about 26 percent of a conventional, cured urea formaldehyde resin binder. The particle board used to made the laminates was ⅝ inch thick and had a density of 45 pounds per cubic foot.

[0031] To make the laminates, one surface of a piece of the particle board was coated with a conventional wood adhesive called 1701 RTU, a water based phenolic adhesive available from Neste Company of Springfield, Oreg., at an application level of 30 grams per square foot. A layer of mat was placed against the adhesive coated face such that there was one layer of mat in the glue line and these laminate precursors were then put under a pressure of 175 psi and a temperature of 330 degrees F. for seven minutes to dry and cure the adhesive. After releasing the pressure and cooling, the laminates and a piece of the particle board had the following properties in a conventional three point loading test.

TABLE

Type of Specimen	MOE*	MOR**
Particle Board alone	355,956	2,019
Particle Board/adhesive/A-3 mat	466,520	3,064
Particle Board/adhesive/A-2 mat	462,035	2,700

*Modulus of Elasticity in pounds/square inch.
**Modulus of Rupture in pounds/square inch.

[0032] These data show that adhering a nonwoven fiber glass mat to the surface of a wood product, in this case particle board, enhances the strength of the particle board. This also provides the particle board with a tougher surface, and if put on both surfaces, helps stabilize the board from warping due to temperature and/or humidity or moisture changes. These data also shows that similar and adequate strength is achieved in the laminate using a mat of the present invention containing a very low binder content, but having a substantial advantage of having much less non-adhesive organics in the glue line resulting in a more flame resistant laminate. Other advantages of the low binder mat is that it is less costly to manufacture because the binder is often more costly than the fiber and mat containing less binder can be dried and cured at a much faster line speed, with a substantially lower level of binder emissions during curing.

[0033] Any normally used water based wood adhesive can be used with the inventive mat to make inventive wood laminates. Another suitable adhesive is GP 5102 RESI-MIX™, a water based phenolic adhesive available from the Georgia Pacific Corporation of Atlanta, Ga. Also, the laminate can vary from one layer of wood, plywood, veneer, or other wood product with an inventive fiber mat bonded to one, two or all surfaces to provide a tough, reinforced surface(s) to multiple layers of wood, etc. having many glue lines with one or more layers of an inventive mat in one or more glue lines, with or without one or more reinforced surfaces.

[0034] It is not usually practical or economically possible for an inventor to determine the precise limitations of his invention because once an attractive result has been found, the effort and priority shifts to those things necessary to satisfy potential or actual customer needs with the invention. Therefore, when the word "about" is used herein to describe a numerical amount, it means the amount or range stated, or approximately the amount or range stated, so long as the amount that approximates the numerical amount or range produces the advantages disclosed for the invention.

[0035] Having the benefit of the above disclosure, many other modifications will be obvious to the skilled artisan, all of which are intended to be included in the scope of the following claims.

We claim:

1. A nonwoven fibrous mat comprising non-cellulosic fibers selected from the group consisting of glass fibers, mixtures of glass fibers and synthetic polymer fibers, ceramic fibers, mixtures of glass fibers and natural fibers and mixtures thereof bound together with a water soluble, formaldehyde free binder, the binder content of the mat being in the range of about 0.5-4 weight percent of the dry mat.

2. The mat of claim 1 wherein the binder content of the dry mat is within the range of about 1-3 percent.

3. The mat of claim 2 wherein the binder is selected from the group consisting of polyvinyl alcohol, carboxy methyl cellulose, ethoxy methyl cellulose and hydroxy ethyl cellulose.

4. A nonwoven fibrous mat comprising non-cellulosic fibers selected from the group consisting of glass fibers, mixtures of glass fibers and synthetic polymer fibers, ceramic fibers, mixtures of glass fibers and natural fibers and mixtures thereof, and cellulosic fibers, wherein the cellulosic fibers are present in an amount less than half the total weight fibers per unit area of mat, the fibers being bound together with a water soluble, formaldehyde free binder, the binder content of the mat being in the range of about 0.5-4 weight percent of the mat.

5. The mat of claim 2 wherein the mat contains cellulosic fibers in an amount less than half the total weight of fibers per unit area of mat.

6. The mat of claim 3 wherein the mat contains cellulosic fibers in an amount less than half the total weight of fibers per unit area of mat.

7. The mat of claim 1 wherein the non-cellulosic fibers are glass fibers.

8. The mat of claim 2 wherein the non-cellulosic fibers are glass fibers.

9. The mat of claim 3 wherein the non-cellulosic fibers are glass fibers and the binder is cellulosic.

10. The mat of claim 4 wherein the non-cellulosic fibers are glass fibers and the binder is cellulosic.

11. A method of making a nonwoven fiber mat comprising forming a web of fibers, applying an aqueous based, water soluble, formaldehyde free binder to the web of fibers, and drying the web and curing the binder to form a finished mat, the binder content being controlled such that the binder content of the finished mat is in the range of about 0.5-4 weight percent.

12. A method of making a wood or wood product laminate comprising placing a fiberous nonwoven mat containing glass fibers and having a formaldehyde free binder therein on a surface of a wood adhesive covered wood layer to form a laminate precursor and applying heat and pressure to the precursor to dry and cure the adhesive, the improvement comprising that the binder content of said fibrous mat is within the range of about 0.5-4.0 weight percent of the mat on a dry basis.

13. The method of claim 12 wherein the binder content is within the range of about 1-3 wt. percent.

14. A wood laminate or wood product made by the process of claim 12.

15. A wood laminate or wood product made by the process of claim 13

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