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(54) Continuous process for producing composite sheet of fiber.

(57) A continuous process for producing composite fibrous sheets superior in strength, dimensional stability, flexibility, appearance, and feeling and additionally can be provided with electrical conductivity and hygroscopicity, which process comprises supplying a short-fibrous material in the form of liquid dispersion onto a continuously traveling fabric, romoving the liquid of the supplied dispersion to form a laminate of the fabric with a web of the short-fibrous material, followed by applying pressurized liquid jets onto the laminate to interlace filaments of the fabric with short filaments of the web.

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CONTINUOUS PROCESS FOR PRODUCING COMPOSITE SHEET OF FIBER

INDUSTRIAL APPLICATION FIELD

The present invention relates to a continuous process for producing composite sheets of fiber which have favorable properties such as mechanical strength, dimensional stability, and softness or flexibility, similar to common woven fabrics, knitted fabrics, or the like, and in addition combine suitably a variety of other properties such as a fur-like feel, hygroscopic property, electrical conductivity, flame retardance, and deodorizing function. These sheets are adaptable for vast fields of applications including apparel, bedding, interior cloth, bags, furniture spreads, packaging materials, various decorating cloths, base materials for shoes, automotive interior trims, filter cloths, wall coverings, etc.

PRIOR ART

As disclosed in U.S. Patent No. 4,147,574, No. 4,251,589, and No. 4,368,227, two sorts of techniques for producing composite fibrous sheets are known, one comprising laminating a woven, knitted, or nonwoven fabric with a short-fiber web previously formed, and applying pressurized liquid jets onto the short-fiber web to interlace short filaments of the web with filaments of the underlying fabric and the other comprising forming a short-fiber web directly on a base cloth in batchwise operation.

PROBLEMS TO SOLVE ACCORDING TO THE INVENTION

However, the above known techniques are complicated in production process and low in productivity. In particular, the technique comprising the previous formation of a short-fiber web involves such problems that drying of the web is accompanied by a large loss of energy and the temporary fixation of the web also much consumes a binder, which is dissolved and wasted in the laminating process. The primary object of the present invention is to provide a process which solves such problems in the prior art as noted above and permits producing uniform composite sheets very efficiently.

MEANS FOR SOLVING PROBLEMS

The present invention involves a continuous process for producing composite fibrous sheets which comprises supplying a short-fibrous material in the form of liquid dispersion onto a continuously traveling fabric, removing the liquid of the supplied dispersion to form a laminate of the fabric with a web of the short-fibrous material, followed by applying pressurized liquid jets onto the laminate to interlace short filaments of the web with filaments of the fabric.

That is to say, the process of the invention has been simplified in that a short-fibrous material which is a component of the intended composite is supplied in the form of liquid dispersion onto a continuously traveling fabric to form a laminate, which is then treated continuously with a pressurized liquid, thereby omitting the previous formation of a web from the short-fibrous material. The supply of the liquid dispersion of short-fibrous material, the lamination of the fabric therewith, and the treatment with pressurized liquid streams are carried out continuously by using a facility which can perform all of these operations.

The short-fibrous material used in the invention may be any of natural fibers and synthetic fibers, organic or inorganic, provided that it is dispersible in a suitable liquid. While fibers in fibril form can be used, it is advantageous to use short fibers like cut fibers when the fiber is required to disperse uniformly to the level of individual single filaments. The short fiber is chosen by considering collectively the dispersibility in a suitable liquid, the drainage of the liquid dispersion upon deposition on the fabric, the ability to be interlaced or entangled by treating with the pressurized liquid, and finally the performance and quality required for the end product to have. It is desirable to choose a fiber having a single filament denier of up to 30 d and a filament length of 1 to 30 mm.

Generally speaking, the proper range of short-fiber lengths, in the invention, varies with the single filament denier and the rigidity of fiber. For instance, the best suited range of filament lengths of an organic fiber of about 0.5 d is from 2 to 10 mm while that of an inorganic fiber of the same single filament denier is from 5 to 13 mm. In the case of an organic fiber with a larger single filament denier of about 10 d, the optimum range of this fiber lengths is from 7 to 20 mm, thus lying on the longer side. For the purpose of preventing the entanglement of fiber in the liquid dispersion medium, it is desirable to maintain the fiber itself in the non-crimped state as far as possible. When the fiber is strongly crimped, it is recommended to subject the fiber to a decrimping treatment before dispersing the fiber. The dispersion medium to use needs to be a liquid which does not decompose, degrade, or dissolve the short-fiberous material. Water is generally used.

The fiber concentration in the dispersion, though variable over the wide range of 0.001 to 0.5%, is preferably controlled within the higher concentration range of 0.06 to 0.5%, since lower fiber concentrations require a larger facility for preparation of the dispersion, this being industrially disadvantageous. In the higher-concentration range than 0.06%, the entanglement of filament with filament or defective dispersion tends to take place. In this case, a thickner is desirably added to give a dispersion viscosity of 10 to 100 cp, particularly 20 to 50 cp, and stirring is carried out by using a stirrer having rotary blades or the like, whereby a uniform dispersion state can be achieved. For further enhancing the degree of dispersion, a slight amount of surfactant may be added. However, no binder needs to be added for the purpose of the temporary web fixation because it is unnecessary to form a web previously from the short-fibrous material alone.

The short-fibrous material to be dispersed in a liquid may consist of one or more fibrous components. In the case of a single-component fiber of low dispersibility, for example, a carbon fiber or a ceramic fiber, a better and stable dispersion can be prepared from a mixture of this fiber with an organic fiber having a high dispersibility. Even an organic fiber, when it is high in denior, rigid, and non-crimped, is liable to fall off during the treatment with pressurized liquid streams. For the purpose of avoiding this, such a fiber is desirably combined with another organic fiber having a single filament denior of up to 1.5 d, particularly up to 1.0 d, whereby better results can be obtained.

When electroconductive composite sheets are produced according to the process of the invention, it is necessary to incorporate 0.05 - 30% of carbon fiber into the short-fibrous material. Less contents of carbon fiber than 0.05% will scarcely provide electroconductivity while higher contents than 30% will result in defective dispersion and provide product sheets of inferior quality.

Desirably, at least 20% of a very fine fiber of up to 1.5 d is incorporated into the short-fibrous material when it is intended to produce a composite sheet improved in flexibility, fineness in texture, and unity of carbon fiber with the base fabric.

For the purpose of fortifying the bond between the carbon fiber and other component fibers and further inhibiting the napping and falling-off of carbon fiber, it is desirable either to incorporate at least 10% of a heat-fusible fiber into the short-fibrous material and subject the formed composite sheet to heat-fusing treatment or to introduce a polymer binder, preferably a polymeric elastomer such as a polyurethane, into voids inside the composite sheet.

The liquid dispersion of short-fibrous material prepared as described above is supplied by means of a dispersion feeder onto a continuously traveling fabric with the feed width set to that of the fabric. A typical and best suited feed method is to flow down the dispersion in the form of thin film at an appropriate inclination to the fabric surface. From the thin film of liquid dispersion formed on the fabric, the liquid is increasingly removed as the fabric travels. This liquid removing process is closely related to the uniformity of the deposition distribution of fibrous material. Thus the control of liquid removal speed has important meaning. The liquid removal speed is controlled by the proper adjustment of the conditions of liquid-removal boxes installed under a moving fabric-support body in terms of the positions, sizes, number, and vacuum of these boxes.

The thus formed laminate in a wet state is then treated as such with jets of pressurized liquid to interlace component filaments into a single body texture.

This treatment with jets of pressurized liquid can be carried out by various known methods. Any pressurized liquid may be used provided that the liquid does not decompose, degrade, or dissolve the fibers to treat. In almost all cases, however, the use of pressurized water is suitable in the aspects of economy and handling performance. In the treatment with pressurized liquid, clogging of liquid-jetting nozzles, if any, will cause uneveness in the quality of the product sheet. In order to prevent this clogging, it is necessary to filter the pressurized liquid before feeding it.

In the invention, the composite sheet united by the interlacing treatment with pressurized liquid as stated above may be used further as a base material to produce another composite sheet by applying again a short-fibrous material in dispersed form to the upper or back side of the composite sheet and then repeating the above stated treatment. Thus, it is possible to produce composite sheets having higher volume proportions occupied by short-fibrous materials and diversified composite textures. In this case, the secondly fed and firstly fed short-fibrous materials may be of the same or different kinds. The number of laminations of the short-fibrous material is chosen as occasion demands.

After completion of the pressurized-liquid treatment, the composite sheet is dried to yield a final product.

In the process of the invention, a fabric having latent shrinkability can be used as a base material and the resulting composite sheet is treated under such conditions as to shrink and densify the fabric, thereby yielding a composite sheet having a united structure wherein a short-fibrous material is densely distributed and firmly fixed to the fabric. Suitable methods for shrinking treatment in this case include, for example, the treatment with a swelling agent, treatment with hot water, and treatment with hot air. In the case of the wet treatment, it can be carried out efficiently prior to the drying. Meanwhile it is advantageous that the hot-air treatment is carried out simultaneously with the drying.

According to the process of the invention, a wide variety of composite sheets thus can be produced by varying materials or process conditions as follows:

(1) Mechanical properties of product sheet, such as tensile strength and elongation, flexibility, drape-ability, and stiffness in flexture, can be controlled by choosing the base fabric material so as to fit the product for the end use thereof.

(2) The thickness of product sheet can be varied from about 0.2 mm to about 2.0 mm. In this case, the thickness of the base fabric is the first factor to control. This thickness is designed in consideration of the amount of short-fibrous material to be used and properties thereof.

(3) As to the appearance and surface state of product sheet, various types can be obtained including fur-like, suede-like, felt-like, and flannel-like types. These properties can be controlled by proper choice of the kind and such properties as single filament denier, cross-sectional shape, and filament length of the short-fibrous material and additionally by using compounded short-fibrous materials.

(4) Properties such as electrical conductivity, flame retardance, and deodorizing function are free to impart. It is effective to impart these properties by choice of the short-fibrous material. According to the invention, rigid fibers such as inorganic fibers can be used and various functions can be chosen and imparted alone or in combination. Function-imparting fibers can be obtained from general-purpose fibers or from blends thereof with other function-imparting fibers. In these cases, the invention exhibits its specificity. That is, the invention exhibits advantages such that high-function imparting effect can be achieved by using a small amount of expensive fiber as a component and that multifunctional composite sheets can be produced with ease, since short-fibrous materials are mixed together uniformly in the step of preparing the liquid dispersion and interlaced three-dimensionally with fiber of the base fabric throughout the surface of the composite sheet by the treatment with jets of pressurized liquid.

According to the invention, for instance, a process as shown later in Example 1 can provide a composite sheet wherein a carbon fiber is dispersed three-dimensionally and united with fiber of a base fabric. A less content of carbon fiber in such a sheet than in analogous sheets of the prior art achieves effects such as the effect of imparting high electrical conductivity.

Examples

The following examples illustrate the invention in more detail.

Example 1

A polyester fiber of 0.5 d in single filament denier and 5 mm in length and a carbon fiber of 0.6 d in single filament denier and 10 mm in length were put into water and then polyacrylamide was added to prepare an aqueous dispersion of short fibers (polyester fiber : carbon fiber weight ratio = 90 : 20, fiber concentration = 0.2 wt. %, polyacrylamide concentration = 0.05 wt. %). The dispersion in which the fibers were dispersed uniformly by stirring to separate into individual single filaments was passed through a flow box placed above the neighborhood of an inlet for a traveling fabric, while maintaining the flow rate constant by applying a hydrostatic pressure. The passed dispersion was allowed to flow down in film form along an inclined plate (45° inclined on the fabric-advance side from the plane perpendicular to the traveling fabric surface) attached to the flow box, thereby coating the traveling fabric of 110 g/m^2 basis weight made of a polyester filaments having latent shrinkability. Then, the applied dispersion was dehydrated to form a web of short fibers and at the same time the fabric was laminated with the web of short fibers. Water jets were applied continuously in three stages onto the short-fiber web side of the resulting laminate by using three sets of nozzles (orifice diameter 0.15 mm, interval between orifices 1 mm) at pressures of 20, 20, and 30 Kg/cm^{2}G for the respective sets.

The thus obtained primary composite sheet was turned upside down, that is, the fabric side was made upper, and this side was coated with the same dispersion of short fibers as stated above. Then, a dehydration, lamination, and treatment with pressurized water jets were carried out according to the above procedure.

The resulting secondary composite sheet, upon boiling in water and then hot-air drying, was 52% shrinked, thus yielding a composite sheet of 320 g/m² basis weight having electrical conductivity as good as 1 x 10²Ω/□ in surface resistivity and exhibiting a natural-leatherlike appearance and adequate stiffness in flexure.

Example 2

An ultra-flat type acrylic fiber of 10 d in single filament denier and 13 mm in length and a very fine acrylic fiber of 0.2 d in single filament denier and 3 mm in length were put into water and then polyacrylamide was added to prepare an aqueous dispersion of short fibers (ultra-flat acrylic fiber : very fine acrylic fiber weight ratio = 70 : 30, fiber concentration = 0.3 wt. %, polyacrylamide concentration = 0.05 wt. %). According to the dispersing and feeding procedure of Example 1, the dispersion was applied on a traveling fabric. This fabric was a polyester knitting of 50 g/m² basis weight having latent shrinkability.

Thereafter, dehydration, lamination, and treatment with pressurized water jets were conducted according to the procedure of Example 1. The back side of the thus obtained primary composite sheet was treated as stated above, thereby laminating a short-fiber layer on the back side. The resulting secondary composite sheet, upon boiling in water and then drying, was 45% shrinked, thus yielding a composite sheet of 256 g/m² basis weight having fur-like appearance and feeling.

Example 3

An aqueous dispersion (A) of short fiber was prepared which contained 0.2 wt. % of an a porous, hygroscopic acrylic fiber of 1.5 d in single filament denier and 7 mm in length and 0.05 wt. % of polyacrylamide. In addition, an aqueous dispersion (B) of short fiber was prepared which contained 0.2 wt. % of a very fine acrylic fiber of 0.1 d in single filament denier and 3 mm in length and 0.05 wt. % of polyacrylamide.

According to the dispersing and feeding procedure of Example 1, dispersion (A) was first applied on a traveling fabric. This fabric was the same as used in Example 1. Thereafter, the procedure of Example 1 was followed except that the treatment with pressurized water jets was conducted at pressures of 20, 30, and 30 Kg/cm²G to prepare a primary composite sheet. Subsequently, the back side of this sheet was treated according to the above procedure using dispersion (A) except that the treatment with pressurized water jets was conducted at pressures of 20, 30, and 40 Kg/cm²G, thereby preparing a secondary composite sheet. Further, the side treated for the secondary composite formation was coated with dispersion (B), and treated with pressurized water jets at pressures of 20, 40, and 40 Kg/cm²G to prepare a tertiary composite sheet. This sheet, upon boiling in water and then drying, was 54% shrinked, thus yielding a composite sheet. This composite sheet had a basis weight of 370 g/m² and hygroscopicity and the surface treated for the primary composite formation exhibited felt-like appearance and the opposite surface suede-like appearance.

Example 4

The following short fibers (i), (ii), and (iii) were put into water. A polyester fiber (i) of 0.5 d in single filament denier and 5 mm in length; a heat-fusible composite fiber of 2 d in single filament denier and 7 mm in length, each single filament thereof consisting of a polyester core and a polyethylene cladding; and a carbon fiber (iii) of 0.6 d in single filament denier and 10 mm in length. Then, polyacrylamide was added to prepare an aqueous dispersion of short fibers (very fine polyester fiber : heat-fusible fiber : carbon fiber weight ratio = 40 : 40 : 20, fiber concentration = 0.3 wt. %, polyacrylamide concentration = 0.075 wt. %). According to the dispersing and feeding procedure of Example 1, the resulting dispersion was applied on a traveling fabric. This fabric was a polyester knit of 50 g/m² basis weight having latent shrinkability.

Then, dehydration, lamination, and treatment with pressurized water jets were carried out according to the procedure of Example 1. Then, the back side of the resulting primary composite sheet was subjected to lamination with a short-fiber layer and interlacing of fibers, according to the above procedure.

The resulting secondary composite sheet was boiled in water, dried, and then calendered at 150°C. This sheet was 49% shrinked by the treatment with boiling water, thus yielding an electroconductive composite sheet of 189 g/m² basis weight, 0.34 mm in thickness, and 1.8 cm²/g in specific volume having a surface resistivity of 4 x 10¹ Ω/□. The carbon fiber was fixed firmly in the sheet. The surface of this sheet was smooth and the hand was rather rigid or stiff.

Example 5

An acrylic fiber of 0.2 d in single filament denier and 3 mm in length and a carbon fiber of 0.6 d in single filament denier and 6 mm in length were put into water and polyacrylamide was added to prepare an aqueous dispersion of short fibers (acrylic fiber : carbon fiber weight ratio = 97 : 3, fiber concentration = 0.2 wt. %, polyacrylamide concentration = 0.05 wt. %). According to the dispersing and feeding procedure of Example 1, the resulting dispersion was applied on a traveling fabric. This fabric was a non-shrinkable woven rayon stuff of 65 g/m^2 basis weight.

Thereafter, treatment was conducted according to the procedure of Example 1 to prepare a primary composite sheet. Further, the back side of this sheet was treated similarly to prepare a secondary composite sheet, which was then dried in hot air. Physical properties of the obtained composite sheet were as follows: Basis weight = 94 g/m^2, thickness = 0.47 mm, specific volume = 5.0 cm^3/g, and surface resistivity = $1 \times 10^3 - 1 \times 10^4$ Ω/□. The sheet showed high drapability and suede-like appearance and was soft to the touch.

Effect of the Invention

As described in detail hereinbefore, it is possible according to the process of the invention to produce composite sheets wherein short-fibrous materials and fabrics are united three-dimensionally, by simple continuous operation which can save energy, materials, and labor without being restricted with respect to materials. Therefore, it is possible, by the proper choice and combination of one or more short-fibrous materials with a base fabric, to provide composite sheets of high added value in a large volume at low costs which are superior in mechanical properties, dimensional stability, flexibility, etc. and have high-grade appearance and feeling such as those fur-like or natural leatherlike and additionally electrical conductivity, hygroscopicity, or other functional properties.

Claims

1. A continuous process for producing composite fibrous sheets which comprises supplying a short-fibrous material in the form of liquid dispersion onto a continuously traveling fabric, removing the liquid of the supplied dispersion to form a laminate of the fabric with a web of the short-fibrous material, followed by applying pressurized liquid jets onto the laminate to interlace filaments of the fabric with short filaments of the web.

2. The continuous process of Claim 1, wherein the liquid dispersion of short-fibrous material is supplied onto the fabric by allowing the dispersion to flow down in film form along a plate inclined on the fabric-advance side.

3. The continuous process of Claim 1, wherein the fiber concentration in the liquid dispersion of short-fibrous material is from 0.06 to 0.5% by weight.

4. The continuous process of Claim 1, wherein the short-fibrous material contains 0.05 - 30% by weight of carbon fiber.

5. The continuous process of Claim 1, wherein the short-fibrous material contains 0.05 - 30% by weight of carbon fiber and at least 20% by weight of a very fine fiber having a monofilament size of up to 1.5 deniers.

6. The continuous process of Claim 1, wherein the short-fibrous material contains 0.05 - 30% by weight of carbon fiber, at least 20% by weight of a very fine fiber having a single filament denier of up to 1.5 deniers, and at least 10% by weight of a heat-fusible fiber.

7. The continuous process of Claim 1, wherein a polymeric binder is provided to the laminate after interlacing treatment thereof.

8. A composite sheet produced according to the process of Claim 1.

9. A composite sheet produced according to the process of Claim 4.

10. A composite sheet produced according to the process of Claim 5.

11. A composite sheet produced according to the process of Claim 6.

12. A composite sheet produced according to the process of Claim 7.