

July 11, 1972

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3,676,288

LOW-DENSITY BONDED NONWOVEN FABRICS AND PROCESS THEREFOR

Filed May 4, 1970

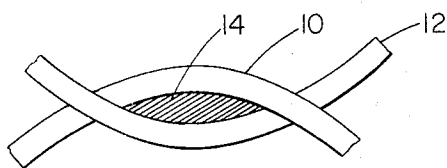


FIG 1

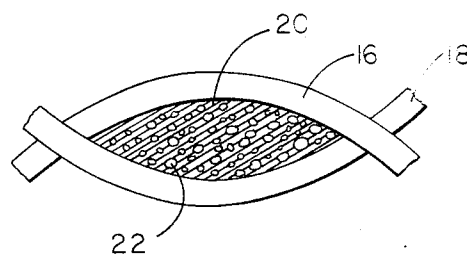


FIG 2

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**LOW-DENSITY BONDED NONWOVEN FABRICS
AND PROCESS THEREFOR**
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Filed May 4, 1970, Ser. No. 34,493
Int. Cl. B32b 5/02, 5/22
U.S. Cl. 161—158

7 Claims

ABSTRACT OF THE DISCLOSURE

Fibrous webs in which the fibers are free to move relative to each other are bonded with fluid polymeric binder solutions or dispersions containing a proportion of microspheric spheres of expandable plastic filled with an expandable low-boiling liquid or vapor. In drying the fluid from the binder, the microspheres are expanded in volume but not ruptured, leading to the formation of nonwoven fabrics with low density and high fluid absorbency.

This invention relates to a method for improving the insulating value, opacity, thickness, and absorbency of nonwoven fabrics. More specifically, it relates to a method of producing bonded nonwoven fabrics of exceptionally low density and high absorptive power, suited for use as surgical dressings, disposable dusters, wiping cloths, blankets, interlinings, and the like.

Nonwoven fabrics of various types are finding rapidly increasing usage as surgical dressings, dusting, cleaning, and polishing cloths, as fluid or paste applicators, and for a variety of allied uses. In such applications they are generally classified as disposable or limited use items, and are preferred over woven fabrics for reasons of convenience and economy. The majority of such fabrics are composed of rayon or cotton fibers, or mixtures thereof, carded or garnetted into a fleece and then bonded with an overall or a patterned application of a polymeric binder.

Such prior art products, however, are not ideal in all respects. In their behavior when folded or crumpled in use they are apt to be paper-like, lacking in the easy conformability of woven or knitted fabrics. Furthermore, the inter-fiber spacing is generally of small dimensions, the fibers being closer together and in a more compacted configuration than is desirable. Close fiber-to-fiber contact promotes high capillarity in an absorbent fibrous article, but decreases the potential total absorbency or pick-up. When it is desired that a nonwoven surgical dressing pick-up and retain large amounts of fluid, a fabric of low density, with substantial spaces or pores between fibers, is preferred. Similar considerations pertain when nonwoven fabrics are intended for use as dusters or wiping cloths, both for efficiency in pick-up and in case of shaking or washing the fabric clean after use.

Also, the insulating value of conventional nonwoven fabrics leaves something to be desired, since the close inter-fiber spacing minimizes the dead air space essential to proper insulation required for limited-use blankets, sleeping bag liners, and the like.

One possible reason for the undesirably high density of prior-art bonded nonwoven fabrics is that polymeric bonding agents are usually applied to fibrous webs in the form of aqueous emulsions or dispersions containing 15% to 25% solids. Although delivered as 40–50% solids content, the dispersions are too viscous in that form for application to delicate fibrous fleeces, and must be diluted.

The fluid binding material, held in between the fibers in the form of droplets, loses 75% to 85% of its volume during drying, with a consequent drawing together and compaction of the fibers and a decrease in the inter-fiber

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spacing. Loft and absorbency are sacrificed, and as an additional disadvantage, most bonded nonwoven fabrics have a translucency or semi-transparency that is undesirable in blankets, sheets, draperies, and the like.

It is with improvements in producing non-compacting polymeric binder systems that the present invention is concerned.

It is a primary object of this invention to provide a fluid-dispersed polymeric binder system for nonwoven fabrics in which the binder expands during the drying operation.

It is a further object of this invention to provide nonwoven fabrics of exceptionally low density and high opacity, suitable for use as surgical dressings, disposable dusters, all-purpose cleaning cloths, blankets, and the like.

The basis of this invention lies in the incorporation into a fluid-dispersed polymeric binder, such as a dilute aqueous latex, of a proportion of microspheres of expandable plastic, said spheres enclosing a heat-expandable fluid which increases drastically in volume at temperatures at which nonwoven fabrics are dried; impregnating a loose, unbonded fibrous fleece with such a mixture, said fleece comprising intermingled and overlapping fibers in casual mechanical engagement; and drying the impregnated fleece at a temperature sufficient to expand but not to rupture the plastic spheres, thus forming a closed-cell expanded binder system uniting the fibers.

One such type of microspheres, available commercially, is composed of minute spheres of a copolymer of vinylidene chloride and acrylonitrile or of an acrylic polymer enclosing a nucleus of isobutane, which is a gas at room temperature, with a boiling point of -10° C. The microspheres at room temperature are in the form of a fine dry powder, the individual particles of which average 6 to 8 microns in diameter. When heated to 190° F. or higher, however, the tendency of the isobutane nucleus to expand, coupled with the gradual softening of the plastic shell, forms expanded spheres with diameters averaging 25–30 microns, said spheres containing isobutane vapor. The expanded spheres therefore have a volume which is on the average over 60 times the volume which they occupied in unexpanded form. The particular temperature at which expansion occurs will vary with the nature of the plastic shell, a convenient working range being 190° F.– 250° F.

In the practice of this invention, two important criteria should be observed. First, the fibers in the fleece should be in only casual mechanical engagement, with maximum fiber mobility in all directions to move in compliance with the expanding binder-microsphere combination. Second, the drying or curing temperature of the saturated fleece should be such that the microspheres are expanded, but remain intact spheres and are not ruptured. By following these criteria, closed-cell structures are obtained, with three-fold to six-fold increases in thickness.

The invention will be more fully understood from the following description and drawings, in which:

FIG. 1 is an idealized view of segments of two interlaced fibers bonded by a prior-art polymeric binder.

FIG. 2 is a view of segments of two similar fibers bonded by the binder system of this invention.

Referring to FIG. 1, a pair of intercrossing fibers 10 and 12 are shown as bonded into a part of a nonwoven fabric by a bead 14 of dried polymeric bonding material. It should be appreciated that FIG. 1 is highly magnified, and simplified in the sense that a nonwoven fabric will show the fibers interlaced and entangled in a more complex fashion, although each fiber is still displaced with relative ease from its engagement with other fibers. It is nevertheless representative in that when a bead or droplet of aqueous polymeric binder is deposited between two or

more fibers, it comes to rest in a position where its tendency to spread by capillary action is equilibrated with surface tension forces resisting spread. Frequently this results in a lenticular bead of binder wetting a pair of fibers, as shown. As the web is dried, the volume of the bead of binder shrinks by loss of water, as explained above. The net result is a drawing or holding together of the fibers in a tightly compacted configuration, with a consequent loss of absorbency and an increase in density.

FIG. 2 is a similarly magnified view of a pair of fibers 16 and 18 held together by a bead of binder 20 which contains numerous expanded but intact gas-filled microspheres 22. Instead of the fibers 16 and 18 having been drawn together compactly in the drying process, the expanding tendency of the microspheres during the drying of the nonwoven fabric has increased the volume of the bead of binder. Such an expanded bead, although it still serves to bind the fibers together, is much more voluminous and of lower density than a normal bead of binder not containing microspheres.

As starting material in the practice of this invention there is employed a fleece of intermingled and overlapping fibers, preferably comprising a substantial proportion of fibers of textile length. By textile length is meant those fibers, usually averaging one-half inch in length or longer, which can be dry-assembled into a fleece or web by conventional textile fiber-separation devices such as cards, gannets, air-lay machines, and the like. For economy, and particularly where high water absorbency is desired, rayon or cotton fibers are the fibers of choice, although all of the synthetic fibers of commerce may be employed, such as nylon, acrylic, polyester, and polyolefin fibers. The textile-length fibers may for economy be blended with shorter fibers such as papermaking fibers or flock, such blends being amenable to dry-deposition processes.

Similarly, the particular polymeric bonding agent employed is not critical, being varied in accordance with the particular properties desired in the final product. Polymeric dispersions of acrylates or methacrylates are very often the choice where soft and absorbent nonwoven fabrics are to be produced: however, the invention is applicable to a variety of other polymeric binder dispersions such as polyvinyl acetate, copolymers of styrene-butadienes-acrylonitrile, natural rubber latices, and in general any polymeric dispersions which will wet out and adhere to the particular fibrous substrate being employed.

In practicing this invention, the desired proportion of microspheres in unexpanded form is mechanically stirred into the selected and diluted aqueous polymeric binder. In testing a number of different polymeric binder dispersions, no incompatibility or adverse affect has been noted, the microspheres being inert. The binder-microsphere dispersion is then applied by conventional means to a fleece of intermingled overlapping fibers, as by overall saturation, line bonding, spot bonding, or any known technique common in the art of producing bonded nonwoven fabrics. Drying of the wet fleece is accomplished by the application of heat, steam-heated dry cans being a convenient device. As might be expected, simple air-drying does not expand the microspheres, and the desired increases in thickness and absorbency of the nonwoven product are not realized.

Appreciable increases in thickness and absorbency of nonwoven fabrics are realized when microspheres are added to a polymeric binder in a proportion of 2 parts binder to one part microspheres. As the ratio is decreased to 1 to 1 or 1 to 2, greater expansion of the beads of binder is noted, and the thickness of the product is increased. Below a ratio of one part binder to two parts microspheres, the tensile strength of the end product decreases, although for special purposes a formulation of one part binder to four or even eight parts microspheres may be employed. A workable range is one part of polymeric bonding agent to from one-half to four parts of

microspheres, with a preferred range of one part polymeric bonding agent to one to two parts of microspheres.

Due to the low density of the microspheres (less than unity), they may tend to float or "cream" in dilute dispersions of latex binders. It has been found advisable as a general practice, therefore, to add to the binder-microsphere dispersion a small amount of a thickening or suspending agent. In the examples set forth below, for an aqueous binder solution containing 20% total solids (polymer plus microspheres) there was added in each instance 0.6%, based on solution weight, of a high viscosity, cold-water-soluble methyl cellulose.

The invention will be illustrated by the following examples.

EXAMPLE 1

To illustrate the need for an elevated drying temperature (generally 190° F. or over) to expand the microspheres, a carded fleece of 3 denier, 1 $\frac{1}{16}$ inch viscose rayon fibers weighing 26 grams per square yard was saturated with an aqueous binder formulation of 20% solids consisting of equal parts of an acrylic latex and polyvinylidene chloride-acrylonitrile-isobutane microspheres, from Dow Chemical Corporation, with a trace of methyl cellulose for thickening. The dry pickup was 35%, and the final product weighed 35 grams per square yard.

One portion of the above product was allowed to dry at room temperature. It was 18 mils thick when dry, thickness being measured by an Ames gauge with a pressor foot 1.5 inches in diameter. A similar portion was dried in an oven heated to 240° F. It was 60 mils thick, or 333% of the thickness of the air-dried sample. This increase in thickness was reflected in the relative absorbencies of the two products, being 566% in the case of the 18 mil air-dried product and 1140% in the case of the 60 mil steam-dried product. Absorbency was measured by immersing a weighed sample in water for five minutes, draining the sample for two minutes, weighing, and calculating the water-pickup (Absorbency test 4.41, U.S. Army Natick Laboratories, Limited Purchase Description, Chamois, Synthetic).

EXAMPLE 2

This example consists of a set of four samples, all based on a starting fleece of carded 3 denier, 1 $\frac{1}{16}$ inch viscose rayon fibers. All samples were bonded in an overall saturation and squeeze process.

Sample:	Web weight, gm. per sq. yd.	Binder, percent	Micro-spheres, percent	Wet pickup, percent
A-----	25	10	-----	253
B-----	29	10	10	150
C-----	23.6	5	10	246
D-----	22.6	2.5	10	208

The impregnant therefore varied from straight binder to 50% binder-50% microspheres, 33% binder-67% microspheres, and 20% binder-80% microspheres. All samples were dried in an oven at below 250° F. Physical data are presented in the following table.

Sample:	Weight, gm. per sq. yd.	Thickness, mils.	M.D. tensile	C.D. tensile	Percent water pickup
A-----	32	10	3.7	1.1	309
B-----	38	55	5.1	1.6	950
C-----	33	60	4.8	1.1	1300
D-----	28	55	3.5	0.4	925

NOTE.—M.D. and C.D. stand for machine direction and cross direction respectively, the figures in the table being pounds tensile strength per inch-wide strip, in the dry state. The percent water pickup is grams of water absorbed per gram of fabric, tested as in Example 1.

An additional and unexpected advantage of the process of the process of this invention is that when the fabrics

are tested wet, there is in general an 80% retention of tensile strength, versus a 40% retention of tensile strength shown by similar bonded fabrics not containing microspheres.

The actual percentage of binder, based on the weight of starting rayon fiber, was A, 25%; B, 15%; C, 12%; D, 5%.

Attempts to use microspheres alone, in aqueous suspension, as a binder for carded rayon fleeces resulted in products with no measurable tensile strength at the temperatures employed in this invention. Since microspheres alone do not bond fibers, the conclusion is that the retention of strength shown in the above table is due to a more efficient utilization of the actual binder material employed. As an illustration, a comparison of Samples A and C in the above table indicates that although C contains less than half as much actual binder as A, the tensile strength of C is equal to or superior to that of A. That is, by the process of this invention, a given weight of polymeric binder is increased in volume so that it effectively ties together more fibers, or longer lengths of fibers, or both. In general, as a nonwoven fabric binder is diluted with nonbonding microspheres up to a ratio of one part binder: four parts microspheres, the thickness of the resulting fabric is increased up to six-fold, with a three to five-fold increase in the water absorptive power of the fabric.

As mentioned above, the employment of microspheres in conjunction with a polymeric dispersion of binding agent for nonwoven fabrics leads to a very desirable increase in the opacity or covering power of the product. Opacity may be related to values measured by the Bausch and Lomb Opacimeter 33-88-12, as described in Textile Research Journal, volume 38, No. 1, January 1968, page 8. Therein, a value for 64 x 60 cotton sheeting is given as 0.63. For a nylon-rayon nonwoven fabric weighing 67 grams per square yard the given value is 0.44.

In a typical example, a carded fleece of viscose rayon fibers was bonded with an acrylic latex to give a nonwoven fabric weighing 56 grams per square yard, consisting of 80% fiber and 20% binder. The Bausch and Lomb opacity was 0.61. A similar fleece was bonded with the same bonding agent extended with microspheres to give a fabric weighing 58 grams per square yard, consisting of 76% fiber, 8% binder, and 16% microspheres. The opacity of the fabric containing microspheres was 0.91.

It might be expected that the process of this invention, expanding the fibrous structure and increasing the absorbency as it does, would lead to nonwoven fabrics of increased air permeability. Quite unexpectedly, this does not turn out to be the case. Air porosity or air permeability is lower in those products made with binder-microsphere combinations according to this invention than it is in those products made with binder alone, as described in Example 3.

EXAMPLE 3

A carded fleece of 1.5 denier, $1\frac{1}{16}$ inch viscose rayon fibers weighing 16 grams per square yard was saturated with a 20% aqueous dispersion of a commercial acrylic binder latex, squeezed to about 200% wet pickup, and dried on steam cans at below 250° F. The final weight was 21 grams per square yard; thickness 7 mils, air porosity 1120 cubic feet of air per minute per square foot of fabric at 0.5 inch hydrostatic head.

A comparable fleece was similarly bonded using a dispersion of one part acrylic binder to two parts of microspheres. The final weight was 21 grams per square yard; thickness 20 mils; air porosity 685 cubic feet of air per minute.

Repeated testing of other similarly paired fabrics confirmed the unexpected conclusion that the increased loft and absorbency associated with the use of microspheres was nevertheless accompanied by a decrease in air permeability and therefore an increase in the thermal insulating value (dead air space) of the fabric. Presumably this is

associated with the closed-cell nature of the expanded polymeric binder, and the fact that the non-porous binder fraction of the fabric has been expanded to occupy a proportionately larger fraction of the fabric volume.

Polymeric binders for nonwoven fabrics have, in general, a density greater than 1.0 gram per cubic centimeter in the form of a dried film after the associated water or solvent has been evaporated. By expanding the binder through the use of microspheres as set forth above, measurements on expanded binder films show densities of 0.6 gram per cubic centimeter or lower. This leads to the production of nonwoven fabrics with an apparent density of from 0.025 to 0.075 gram per cubic centimeter, compared with control fabrics made with unexpanded binder of a density of 0.15 gram per cubic centimeter and higher.

As discussed above, for the preservation of maximum loft and minimum density of the expanded binder mass, care should be taken to avoid exposure to temperatures at which the plastic binder spheres melt. If expanded spheres of polyvinylidene chloride-acrylonitrile are heated for any substantial time at 280° F., for example, the plastic spheres melt and the spongy nature of the expanded binder collapses, with a consequent thickening of the nonwoven fabric. When Sample B of Example 2 was heated to 280° F. for 2 minutes, the thickness of the fabric decreased from 55 mils to 25 mils, with a consequent decrease in absorbency and a substantially complete disappearance of the expanded microspheres.

Although the above description relates to products made by an overall saturation with binders containing microspheres, the process of this invention is equally adaptable to spot-bonding, line-bonding, and the application of binder material to discrete and spaced-apart web areas in general, with the creating of differentially-lofted and novel three-dimensional effects. A converse effect may be obtained by bonding a web with a conventional binder dispersion in a set of spaced-apart areas, drying the web, and then conducting a second bonding process, according to the principles set forth herein, using a microsphere-binder dispersion which on heating will expand only the previously unbonded portions of the web.

Having thus described my invention, I claim:

1. The process of producing bonded nonwoven fabrics of enhanced thickness, low density, enhanced opacity, and high water absorptive power which comprises

assembling an unspun and unwoven array of intermingled fibers comprising a substantial proportion of textile-length fibers, said fibers being in casual mechanical engagement only,

applying to a portion at least of said fibers a mixture of a fluid-dispersed polymeric binder containing admixed therewith a proportion of very fine plastic spheres,

said spheres comprising a thermoplastic heat-expandable generally spherical shell enclosing a heat-expandable low-boiling organic fluid,

drying the impregnated fibrous array at a temperature sufficient to cause said plastic shells to soften and become larger in diameter due to the expanding force of the fluid contained therein, but insufficient to cause rupture and collapse of said shells,

and cooling said impregnated fibrous array while maintaining said plastic spheres in permanently expanded condition.

2. The process according to claim 1 in which between one and two parts of plastic spheres are mixed with each part of polymeric binder.

3. The process according to claim 1 where the plastic spheres are formed from a polyvinylidene chloride-acrylonitrile shell enclosing a portion of isobutane, and the drying temperature is between 190° F. and 250° F.

4. The process according to claim 1 in which the polymeric binder is expanded to a density of not greater than 0.6 gram per cubic centimeter.

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5. A low-density nonwoven fabric of enhanced water absorptive power which comprises
an array of intermingled, unspun and unwoven fibers, comprising a substantial proportion of textile-length fibers, bonded by a polymeric binding agent,
said polymeric bonding agent having associated and admixed therewith a proportion of expanded and unruptured plastic spheres containing an expanded organic fluid in vapor form.
6. The product according to claim 5 in which the nonwoven fabric has an apparent density of between 0.025 and 0.075 gram per cubic centimeter.
7. The product according to claim 5 in which the plastic spheres average 25 to 30 microns in diameter.

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MORRIS SUSSMAN, Primary Examiner

U.S. Cl. X.R.

15 161—162; 156—77; 161—159; 117—140 A, 16