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Newman

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[54] NONWOVEN FABRICS

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[22] Filed: **Jan. 25, 1971**

[21] Appl. No.: **109,645**

Related U.S. Application Data

[60] Division of Ser. No. 863,273, Oct. 2, 1969, Pat. No. 3,622,422, Continuation-in-part of Ser. No. 563,238, July 6, 1966, abandoned, which is a continuation-in-part of Ser. No. 530,734, Feb. 28, 1966, abandoned, which is a continuation-in-part of Ser. No. 514,079, Dec. 15, 1965, abandoned.

[52] **U.S. Cl.** **161/151**, 156/306, 161/159, 161/170

[51] **Int. Cl.**.....**C09j 5/00**, C09j 7/04

[58] **Field of Search** 161/159, 151, 170; 156/306

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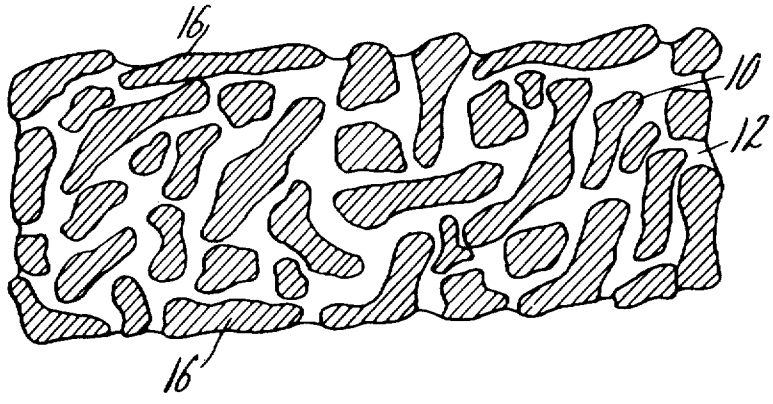
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[57] **ABSTRACT**

A major portion by weight of an unbonded fibrous fleece is combined by heat and pressure with a minor portion of a thermoplastic film to form soft, conformable, air-permeable nonwoven fabrics suitable for use as disposable clothing.

6 Claims, 7 Drawing Figures



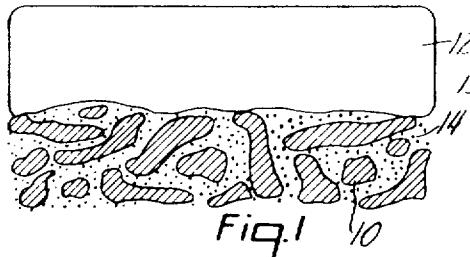


Fig. 1

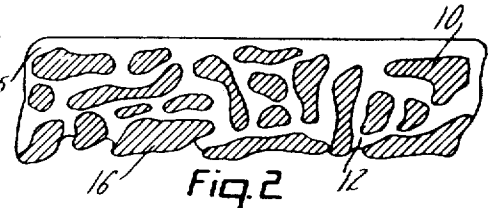


Fig. 2

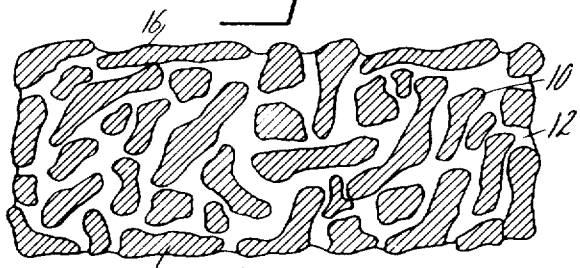


Fig. 3

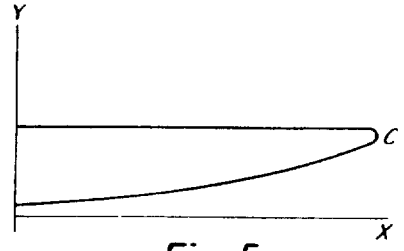


Fig. 5

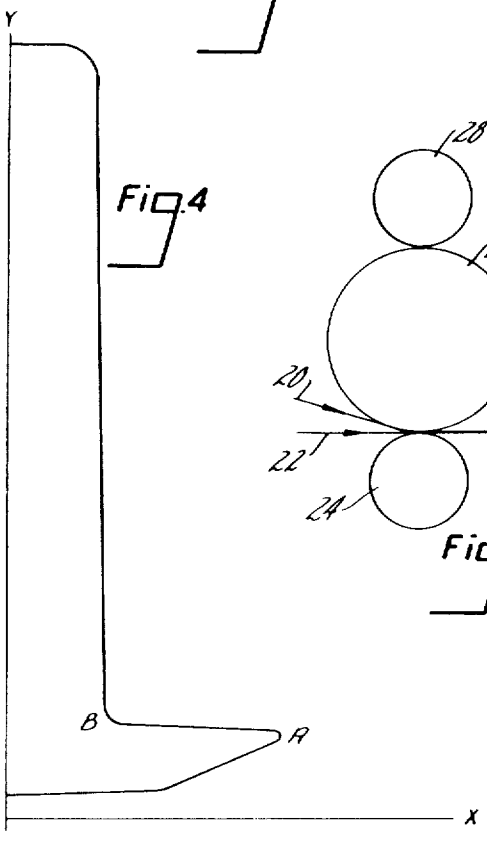


Fig. 4

Fig. 6

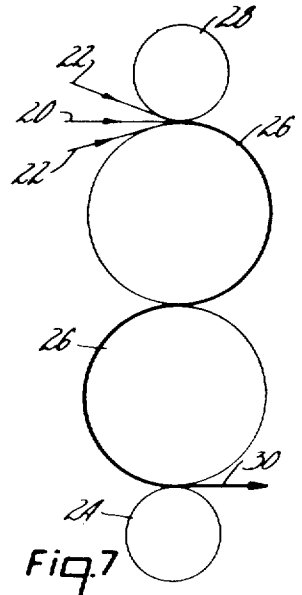


Fig. 7

NONWOVEN FABRICS AND PROCESS THEREFOR

This is a division of my copending application Ser. No. 863,273, filed Oct. 2, 1969, now U.S Pat. No. 3,622,422 said application being a continuation-in-part of my application Ser. No. 563,238, filed July 6, 1966, which is a continuation-in-part of my application Ser. No. 530,734, filed Feb. 28, 1966, which in turn is a continuation-in-part of my application Ser. No. 514,079, filed Dec. 15, 1965; Ser. Nos. 563,238, 530,734, and 514,079 being now abandoned.

This invention relates to a process for the manufacture of air-permeable nonwoven fabrics suitable for use as disposable clothing and allied uses, and to certain products of said process. More specifically, it relates to a process for combining an organic polymeric film which is unoriented and which may be heated without undergoing substantial shrinkage with an unbonded fleece of textile length fibers.

It is known to combine polymeric films with various substrates such as paper, cloth, and nonwoven fabrics, the latter being either adhesively bonded or needled to provide handling strength. Such a combination may be brought about the use of adhesives, or by the use of heat and pressure. These combinations, however, partake of the nature of laminations, in that the tensile properties of the film and the tensile properties of the substrate are individually distinguishable, as explained below, on a stress-strain diagram. Prior art film-to-substrate combinations of the layered or laminate type do not develop the maximum strength possible considering the potential tensile strength which the combination of components is capable of developing in accordance with the present invention. Additionally, it has been found particularly difficult in the past to develop fiber-film combinations which were air-permeable — i.e., breathable, as desired for such uses as for comfortable interlinings and disposable clothing. So far as I am aware, the preparation of such air-permeable materials has been accomplished mainly by dusting a particular binder onto a fibrous web, by the incomplete consolidation of an impregnating latex, by stretching or otherwise manipulating a fiber-film combination, or by swelling or dissolving some of the fibers from such a combination. It is an important element of the present invention that an air-permeable product can be made from a fibrous web and an impermeable thermoplastic film by a simple process.

In addition, prior art laminations made from such substrates, where the various yarns or fibers of the substrate are interconnected and incapable of free and independent movement, suffer from what may be called planar instability. That is, the elongation strains set up in the film and in the substrate during processing, and the recoveries after processing, are different for the two species, with the result that such laminates tend to curl markedly at the edges. This curling, which is very undesirable in many applications, is even accentuated by humidity changes, because although the film and the substrate are adherent to each other, each of these elements reacts more or less independently to humidity changes, and each tries to react in its characteristic fashion because each is present essentially in a continuous phase.

It is also known to combine fibers and film substance to make substitutes for artificial leather, weighing up to a pound or more per square yard and 20 to 40 mils thick. Examination of such products fails to reveal the widespread and uniform dispersion of fibers through film substance which is characteristic of the product of this invention. In general, the nonwoven clothing fabrics of the present invention are realized with combinations of fiber and film which do not weigh in excess of 50 to 70 grams per square yard, and which are not over 5 or 6 mils thick in final form.

It is therefore a primary object of this invention to develop breathable and conformable nonwoven fabrics of improved tensile strength and an improved degree of planar stability. It is a further object of this invention to prepare such nonwoven fabrics from a thermoplastic film, as defined below, and an unbonded array of textile-length fibers.

It is an additional object of this invention to prepare nonwoven fabrics from a thermoplastic film and an unbonded array of textile-length fibers in which the stress-strain curve is characterized by a low elongation and a single inflection point.

A further object of this invention is to prepare air-permeable nonwoven fabrics of the above type from an impermeable polymeric continuous film and an unbonded array of textile-length fibers.

Other objects of the invention will appear more fully from the following description and drawings, in which:

FIG. 1 is a cross-sectional view of a prior art laminate comprising a film and a nonwoven fabric.

FIG. 2 is a cross-sectional view of another prior art product, both FIGS. 1 and 2 representing air-impermeable products.

FIG. 3 is a cross-sectional view of a typical product of this invention.

FIG. 4 is a stress-strain diagram of the prior art laminate of FIG. 1.

FIG. 5 is a stress-strain diagram of the product of FIG. 3, on a scale which is three-fourths of the scale of FIG. 4.

FIG. 6 is a schematic representation of an apparatus suitable for carrying out the process of this invention.

FIG. 7 is a schematic representation of an alternative apparatus suitable for carrying out the process of this invention.

The principal embodiment of my invention is a nonwoven fabric comprising fibers and a bonding film, the bonding film being present in continuous phase, with substantially all of said fibers embedded in said bonding film in discontinuous phase and distributed substantially throughout the entire body of said film, said nonwoven fabric deriving its integrity essentially from said film. The term "continuous phase" does not herein signify that the film substance is impermeable. Actually, the film has sufficient air porosity to render it breathable and comfortable when the fabrics fashioned into disposable garments. The term "continuous" signifies that the film is not dispersed into disconnected particles or fragments, and that if the fiber substance were to be dissolved out of the combined product, a unitary and manipulatable film would remain. In the products of my invention the fibers are held in position essentially by the softened and resolidified film substance. The starting fibrous array should be so open, and the fibers so free to move with relation to each other, that the film-bonding material can penetrate between and

surround substantially all of the fibers. In the preferred form of my invention, the fibrous array component which is used as a starting material has little or no integrity before combination with the film bonding material component and the fibers are not felted, interengaged or bonded to more than a casual degree so that there is minimal interference with the bonding of fibers to film substance which it is desired to develop.

The products of this invention differ from most prior art combinations in several important ways. First, the fibrous substrate is not a needled or otherwise bonded nonwoven fabric, but is an unbonded array of intermingled textile fibers such as is delivered by a card, garnett, air-lay machine, or the like, in which the only restraint to the free movement of the fibers is the casual frictional contact of one fiber with another. Therefore, the eventual bond between fibers and film substance, after the process of the invention has been carried out, is the operative bond in the product, and is not obscured or altered by any prebonding residing in the substrate.

This has the dual advantage of allowing the maximum amount of cooperative bonding between film and fibers, and of producing a final product in which film and fibers coact as a unitary reinforced material with a stress-strain diagram which is not characteristic of either component tested separately or combined in a normal laminating procedure.

It has been found that a desirable degree of air porosity, ranging from about 10 to as high as over 90 cubic feet of air per minute at 0.5 inch pressure drop (Frazier Tester) can be realized if the film portion of the product does not constitute more than 10 to about 45 percent of the total assembly, by weight, and if the process is so conducted that the fibers are distributed substantially uniformly throughout the film substance, from one face to the other. It has been found that if the film portion constitutes 50 percent or more of the weight of the product, and especially if the fibers are distributed in a non-uniform manner, impermeable products are liable to result.

The process of this invention involves a combination of heat and pressure applied to the film-substrate combination sufficient to cause the heat-softened film to penetrate substantially uniformly through the entire depth of the unbonded fibrous substrate, as explained more fully below.

Referring to FIG. 1, representing in cross-section a prior art film-nonwoven fabric laminate, an array of textile fibers **10** is shown as bonded by an adhesive binder **14** to form a nonwoven fabric, which in turn has been laminated by heat and pressure to a thermoplastic film **12**. The film **12** may extend to a slightly greater depth into the nonwoven substrate than shown, particularly if the inter-fiber spaces in the substrate are incompletely filled with binder, but essentially the product is a two-component laminate of film and substrate.

The two-component nature of such prior art products is illustrated by the stress-strain diagram of FIG. **5**, representing the typical behavior of such products when tested on an Instron machine, using a one-inch wide strip on the 50 pound scale with the cross-head speed and chart speed both 12 inches per minute. From the initiation of the extension to the point B, the tensile properties of the nonwoven substrate are being tested, and are found to reach a maximum of 11.7 pounds at point **4**. From point B on, the long vertical extension of the curve represents the elongation of the film portion **12** of the laminate. The stress-strain diagram of a product of this type, therefore, is a composite curve, indicating that the nonwoven fabric substrate and the film, although superficially unified, really act independently when the laminate is subjected to tensile stress.

Apparatus suitable for carrying out the process of the invention is shown at FIGS. **6** and **7**. A convenient source of heat and pressure for continuous production of the product of FIG. **2** is represented in FIG. **6** by a three-roll calender, with a cotton, husk, or fiber-filled roll **26** mounted between two steel rolls **24** and **28**, the steel rolls being capable of being heated, as by gas-fired burners mounted axially therein. The calender should be capable of operating at a pressure of at least 500 pounds per inch of nip width through pressure loading on the journals, said pressure devices and journals being conventional and not shown.

A continuous sheet of film **20**, together with a fibrous web **22**, from any desired source such as card, garnett, air-lay machine or the like, not shown, is fed to the nip formed by the lower and heated steel roll **24** and the cotton roll **26**. The temperature and pressure requirements of the process will vary with the nature of the film, as set forth in the discussion below. For utmost penetration of the film substance into and amalgamation with the fibrous web, to produce the product of FIG. **3**, it is convenient to have the film contact the heated steel roll directly. Alternatively, the product of FIG. **3** may be made by employing a four-roll calender, consisting of two cotton rolls **26,26**, mounted between heated steel rolls **24** and **28**, the calender being equipped with pressurized journals, not shown. In the preferred routing shown in FIG. **7**, a continuous sheet of film **20** is sandwiched between two fibrous webs **22—22** and is subjected to heat and pressure first in the nip formed by heated steel roll **28** and a cotton roll **26**, and then in the nip formed by the bottom heated steel roll **24** and the lower cotton roll, heat thus being applied to alternate surfaces of the combination.

As films suitable for the practice of this invention I have found that it is preferable to utilize cast or flat-extruded films, because of the lower degree of shrinkage which such films undergo during heating in comparison with uniaxially or biaxially oriented films of the same chemical composition. Although the latter types of film have higher strength, their utilization in this invention necessitates special tensioning devices to hold the film to full width as it passes through the hot nip. Films made from acrylic polymers, polyethylene, polypropylene, polyvinyl chloride and the like are characteristic thermoplastic films suitable for use in this invention, with polypropylene particularly preferred.

A wide variety of textile fibers may be used in this process, the selection of a particular fiber or blend of fibers depending on the particular tensile and elongation characteristics desired in the final product. Fibers which are substantially straight yield products with a total elongation of 15 to 25 percent; fibers of similar chemical composition, but highly crimped, yield products with a total elongation of around 30 to 70 per-

cent. Cotton, rayon, (including polynosics), acetate, polyester fibers, polyacrylic and modified polyacrylic fibers, and a variety of other natural and synthetic fibers may be used.

Operating conditions during the calendering operation will vary with the particular film employed, a general guide being that the temperature should be high enough to soften, but not to melt, the film. In general, this means that the process is carried out with the steel roll or rolls heated to the softening temperature of the film, but preferentially below the melting point of the film. In the case of polyethylene, the temperature range between softening point and melting point is rather narrow, and calendering temperatures are critical. For this reason, when a fiber-reinforced polyolefine film is desired, I prefer to use polypropylene, with a working range of around 40°F. between softening point and melting point. In the case of films where there is a wide range between softening point and melting point, considerably more latitude may be employed in calender temperatures.

The invention will be illustrated by the following examples.

EXAMPLE 1.

A soft, thermoplastic polymeric film was cast from a copolymer consisting of 95 parts of ethyl acrylate, 5 parts of butyl acrylate, 5 parts of acrylonitrile, and 2 parts of glycidyl acrylate. The dried film was about 1 mil thick and weighed about 15 grams per square yard.

A carded web, with the fibers predominantly oriented in the lengthwise direction, was prepared from a blend of 80 percent 3 denier nylon and 20 percent 3 denier viscose rayon. It weighed 20 grams per square yard, and had substantially no tensile strength, being less than 0.5 pounds per inch-wide strip in the machine direction.

The fibrous web was completely encapsulated into the film by passing the combination through the apparatus of FIG. 6, with the steel roll heated to 300°F. and the cotton roll to 200°F. by transfer of heat from the steel roll. The pressure was 800 pounds per inch of nip width.

After processing, the resultant nonwoven fabric had a strength of 18 pounds in the machine direction, 3 pounds in the cross direction. It was very soft and conformable, and had an air porosity of 95 cubic feet of air per minute per square foot of fabric at ½ inch hydrostatic head as measured on the Frazier Tester.

The rigidity of the fabric was measured according to Federal Specification CCCT-191b, Method 5206-2, on the Fabrics Research Laboratory Cantilever Tester. The flexural rigidity G, expressed in inch-pounds was 0.00005, or 58 milligram-centimeters. In general, the flexural rigidities, average of machine direction and cross direction, will range from 40 to 200 milligram centimeters.

By comparison, the flexural rigidity of prior art impermeable fiber-film combinations normally ranges from tenfold to several hundredfold greater.

EXAMPLE 2.

A random web of crimped nylon fibers, 3 denier and 1½ inches long, was prepared on a Rando-Webber machine. It weighed 25 grams per square yard.

The fibrous web was combined with a film of cast polypropylene 0.5 mils thick, weighing 10 grams per square yard, by passing both materials through the apparatus of FIG. 6, with the fiber layer next to the steel roll, heated to 350°F., and the film against the cotton roll, heated to 250°F. The pressure was 850 pounds per inch of nip.

The final product weighed 35 grams per square yard and consisted of 28 percent film substance and 72 percent fiber. It had an air-permeability of 82 cubic feet of air per minute per square foot of product at ½ inch hydrostatic head.

The products of the above examples of this invention have related to fibers combined with truly thermoplastic film — that is, films which can be repeatedly softened and resolidified without substantial degradation. There exists another class of films which have a temperature range within which they are tacky and adhesive, but which contain cross-linking reactants so that on heating or curing at elevated temperatures, the film becomes irreversibly set and cannot be reverted to a plastic condition. Such films at room temperature or slightly above partake of the nature of thermoplastic films, and are considered within the scope of thermoplastic films as defined in this invention.

One type of such films, particularly useful for the production of the fabrics of this invention, is a modified acrylic film supplied by Rohm and Haas under the name OROFORM. This film is soft and plastic at room temperature, flowing readily under modest heat and pressure. If heated to 300°F. or more, the film cross-links internally and becomes thermoset in nature. Subsequent to such a heat-setting or curing process, the film is quite thermostable, withstanding prolonged exposure to temperature of 300°F. and over. It will yellow slightly in 1 minute at 400°F., considerably at 500°F., but does not melt or decompose to an adverse degree at those temperatures.

In processing what will for convenience be herein termed transiently thermoplastic films, a single-nip process is generally used, similar to the apparatus of FIG. 6. If the acrylic film 20 is adhesive at room temperatures, it may be supplied on a roll of release paper, from which it is separated just prior to being combined with the chosen fibrous web 22. Interlinings for films of this sort, and devices for separating film and interlining, are well-known in the art and are not shown. In order to post-cure the film and convert it to a thermoset condition, any convenient secondary heating arrangement may be used, as an oven, heated dry cans, infra-red lamps, and the like.

The preparation of thermally-resistant air-permeable nonwoven fabrics will be illustrated by the following example.

EXAMPLE 3.

Using the apparatus of FIG. 6 and the general procedure of EXAMPLE 1, a random web of 3 denier Kodel 11 (Eastman polyester) fibers weighing 25 grams per square yard was combined with a 1 mil thick Oroform film (Rohm and Haas) type C-23. The calender pressure was 1,200 pounds per inch of nip width, with the steel roll heated to 255°F., and the cotton roll to 175°F. The material was then heated to 325°F. for one minute to complete the transformation

of the film to a thermoset condition. The product resembled the product of FIG. 3, and had a stress-strain curve resembling that of FIG. 5. The tensile strength of the product per inch-wide strip was 7.6 pounds machine direction, 7.7 pounds cross direction; elongations were between 40 percent and 50 percent in each direction. The air porosity was 19 cubic feet of air per minute on the Frazier Tester. The product, consisting of 67 percent fiber and 33 percent film, was soft and conformable, with a flexural rigidity G of 0.00007 inch pounds or 81 milligram-centimeters.

The above procedure was repeated using a web of Nomex (duPont's polyimide) fibers, weighing 25 grams per square yard. After calendering, the tensile strengths were 16.5 pounds in the machine direction, 6.6 pounds in the cross direction. The corresponding elongations were 34.6 percent and 76.3 percent. After heat-curing for 1 minute at 325°F., the figures were 17.5 pounds, 8.2 pounds, 24.8 percent and 27.2 percent respectively.

Both of the above products have a stress-strain curve characterized by a single inflection point, typical of the products of this invention, and were suitable for use as fabrics for use as disposable clothing and the like, particularly where high-temperature conditions need to be met.

If very high porosity is desired in such film-fiber combinations, one expedient method is to agitate the acrylic polymer solution while the film is being cast, so that air bubbles are incorporated into the cast film said bubbles collapsing during the cal-endering operation and leaving minute scattered discontinuities in the film.

In general, the products of this invention may be differentiated from prior art laminated or otherwise bonded nonwoven fabrics by their air-permeability, their enhanced planar stability, and their exceptionally low rigidity per unit weight of bonding film employed. Additionally, the ratio of wet strength to dry strength in the products of this invention is very high, reaching 90 percent or more. Since the film substance is in a continuous phase, the internal cohesive strength of the product is excellent, with no internal splitting or delamination.

The weight ratio of film to fiber will vary with the character-istics to be incorporated into the product. My preferred range is to have between 10 percent and 45 percent of the product composed of film substance, with the balance fiber. Below about 10 percent film substance, the product is liable to develop a fuzzy and essentially fibrous surface: above about 50 percent, the products are liable to be impermeable to air, and the synergistic effect of the fiberfilm combination becomes smaller.

Having thus described my invention, I claim:

1. A soft, thin, conformable, air-permeable nonwoven fabric of enhanced planar stability and suitable for fashioning into disposable garments comprising

an array of unspun and unwoven textile length fibers,

said fibers being bonded by a polymeric film in continuous phase,

said fibers being distributed substantially uniformly throughout the entire body of said film, in discontinuous phase,

the substance of said film being substantially the sole bonding medium serving to unite said fibers into said nonwoven fabric,

said film constituting not over 45% of the weight of said nonwoven fabric.

2. The product according to claim 1 in which the film is a thermoset acrylic film.

3. The product according to claim 1 in which the film is thermoplastic.

4. The product according to claim 2 wherein the product is characterized by a stress-strain curve possessing a single inflection point.

5. The product according to claim 3 in which the product has an air-permeability of at least 10 cubic feet of air per minute per square foot of product at one-half inch hydrostatic head.

6. The product according to claim 2 in which the thermoplastic film is polypropylene.

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