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T. E. C. KNEE

3,272,898

PROCESS FOR PRODUCING A NONWOVEN WEB

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FIG. 1

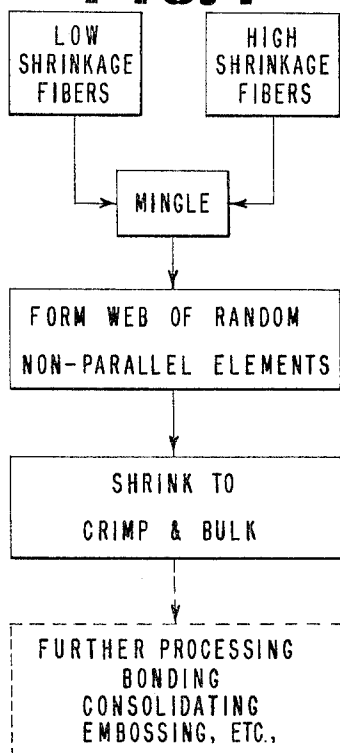


FIG. 2

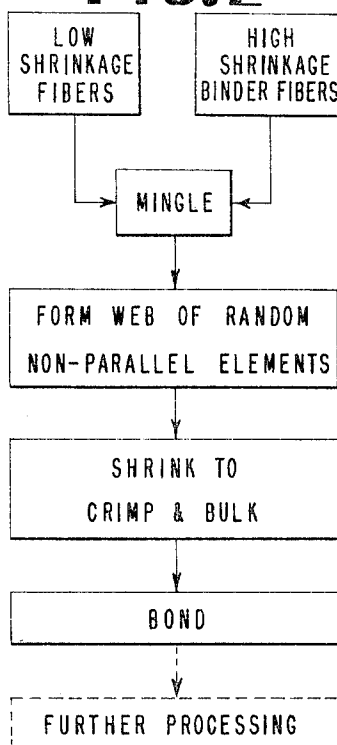
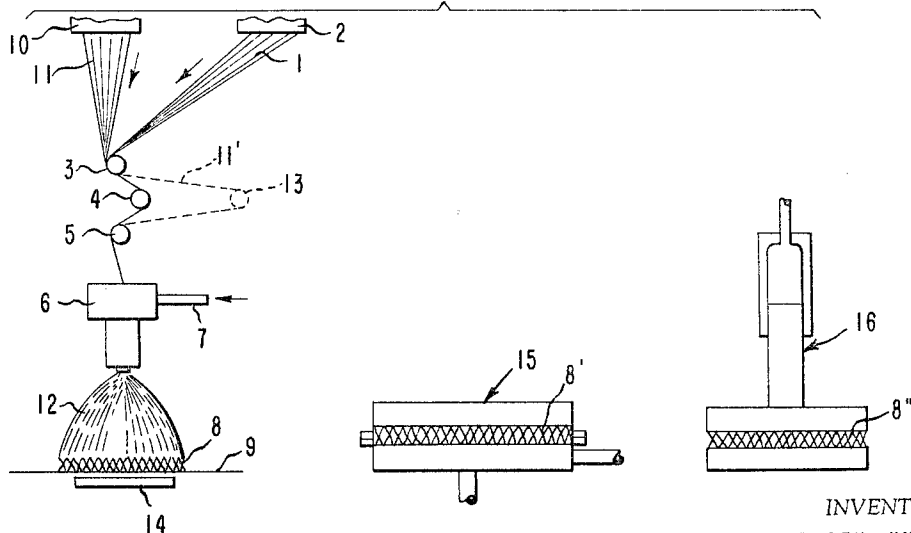


FIG. 3



INVENTOR
TERENCE EDWARD CREASEY KNEE

BY *Harry C. Braddock*
ATTORNEY

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PROCESS FOR PRODUCING A NONWOVEN WEB
Terence Edward Creasey Knee, Wilmington, Del., assignor
to E. I. du Pont de Nemours and Company, Wilmington,
Del., a corporation of Delaware
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6 Claims. (Cl. 264-119)

This application is a continuation-in-part of copending application Serial No. 156,348, filed on December 1, 1961, now abandoned.

This invention relates in general to nonwoven webs of continuous filaments and, more particularly, to an improved method for producing such nonwoven webs having superior properties.

In the production of nonwoven webs of fibrous elements, a number of basic problems exists with respect to fiber distribution, retention of structural integrity, and attainment of desired properties in terms of end-use function and aesthetics. These problems are especially acute when dealing with continuous filaments. It has been the experience of those skilled in the art that the parameters in their desirable ranges, more often than not, are mutually exclusive. Attaining one object in full often seems to require missing another object completely. As a result, the nonwoven structures known in the present state of the art are the result of compromises in balancing one set of objects against another.

It is desirable to produce nonwoven structures from a multiplicity of continuous filaments of synthetic organic polymeric materials, thereby taking advantage of the reduced manufacturing costs inherent in such a procedure as well as producing structures of greatly increased strength and having other useful and distinctive properties. British Patent 932,482 sets forth a process of distributing continuous filaments to form a web composed of filaments disposed in random nonparallel arrangement. To impart certain appropriate aesthetic properties to nonwoven structures, notably soft hand and good drape, it has been found desirable to highly crimp the individual filaments as set forth in Guandique et al., U.S. Patent 3,117,055. However, it also has been found that imparting the desired high crimp to the individual filaments prior to distribution in the web interferes with such distribution and, while processes for producing in situ the desired crimp level have been found, the instant invention represents an alternative method of crimping and bulking the filaments in situ in a web, which method is simple, effective, and inexpensive.

It has now been found that the majority of the filaments in a web composed of continuous filaments arrayed in random nonparallel order may indeed be crimped and the web bulked by the use of the instant invention employing differential shrinkage between these filaments and a few percent of filaments with a higher shrinkage level.

It is an object of the present invention to provide an improved process for treating a nonwoven web of uncrimped continuous filaments to produce a nonwoven structure of uniformly highly crimped filaments, the structure having soft hand and good drape. Furthermore, it is an object to treat such a web by simple, inexpensive means. It is a further object to employ as such a bulking and crimping physical means, the differential shrinkage of a minor portion of the total structure. Additionally, it is an object to crimp in situ and to a relatively high level of crimp and to impart substantial bulkiness to the majority of the continuous filaments in a nonwoven web of randomly distributed uncrimped continuous filaments of synthetic organic polymeric material to produce a high and uniform level of crimp in situ and a substantial increase in bulk. It is another object of this invention to

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provide an arrangement for treating a nonwoven web of randomly distributed uncrimped continuous filaments of synthetic organic polymeric material, said web having bonding material therein to produce a bonded nonwoven structure of highly crimped filaments. It is still another object of this invention to provide such an arrangement wherein the bonding material acts as the crimping and bulk-imparting material as well. Further objects and advantages will be apparent from the description herein-after.

In accordance with this invention, the objects are attained by a process for producing a bulked nonwoven structure of continuous filaments of synthetic organic polymeric materials comprising laying down a nonwoven web composed of filaments disposed in random nonparallel arrangement with a major portion of the filaments having a shrinkage when subjected to shrinkage conditions not exceeding 15% and preferably less, and a minor portion of the filaments having a substantially greater shrinkage under the same shrinkage conditions, being of the order of 40% to 50% or greater, with both said portions randomly and thoroughly admixed therein, and subsequently subjecting the unbonded web to the suitable shrinkage conditions, as by steam, hot air or the like, under conditions of no restraint so that on an area basis a 20% or more over-all shrinkage of the web is obtained. By this process, a bulked nonwoven web wherein the major portion of filaments is twisted and convoluted or crimped is obtained. Preferably, the minor portion of shrinkable filaments comprises between 5 and 25% by weight of the total web. A web so produced may then be subjected to further processing, as to bond by known means such as granular binders or by latex dispersion and may further be subjected to embossing or similar working treatments to impart additional aesthetic properties, the properties of the final product being a result of the filament properties and the crimping and bulking treatment in combination with the nature of the bonding and embossing treatments as is known. Still more preferably, the minor portion of highly shrinkable filaments may be composed of filaments capable of acting as the bonding element as may be accomplished in a process wherein the shrinkable filaments have lower melting points than the relatively unshrinkable filaments and the crimped and bulked web is raised to a temperature intermediate of the two melting points to accomplish bonding.

It is only through the use of continuous filaments, the use of an unbonded web and the use of no restraint, that is, no pressure on the web surfaces, during the shrinkage step, that all of the advantages of the process of this invention can be obtained. The use of continuous filaments permits the minor portion of high-shrinkage filaments to be effective for imparting crimp to the major portion of low-shrinkage filaments, thereby imparting bulk to the web. The use of small amounts of the shrinkable component is especially desirable when that component is to be used as the binder, since it is necessary to keep the binder at a lower level when soft, drapable nonwoven structures are desired.

In order for the minor portion of high-shrinkable filaments to be effective, it is also necessary for the web to be unbonded. This is particularly true when the shrinkable filaments have a low shrinkage force, as is the case when high-shrinkage binder filaments of a polyester such as a poly(ethylene terephthalate)/poly(ethylene isophthalate) copolymer are used as the shrinkable filaments. By unbonded is meant the absence of adhesive bonds, mechanical entanglements such as are obtained by needling techniques, or entanglements due to felting, as can be obtained by known techniques with feltable fibers such as wool. The synthetic organic filaments used in the process of this

invention are nonfelting and thus do not give rise to this type of bonding. The webs used in the process of this invention can be consolidated, however, by light pressure at room temperature to give them sufficient strength to be conveyed to the shrinkage operation.

In order to obtain the desired increase in bulk of the nonwoven structure and the twisting and convoluting of the major portion of continuous filaments into a crimped configuration, the web must be under no restraint so that it can shrink at least 20% on an area basis. Such shrinkage and the accompanying bulking cannot be obtained if the web is subjected to compressive condition, for example between pressure plates, during the shrinkage and crimping step.

The present invention is described in further detail below in connection with the accompanying drawings in which:

FIGURE 1 is a flow sheet of a preferred process according to the invention,

FIGURE 2 is a flow sheet of an optionally preferred process according to the invention, and

FIGURE 3 is a schematic representation of apparatus employed in the working of examples according to the invention.

Referring to FIGURE 1, a major proportion of low-shrinkage filaments is randomly combined or mingled with a minor proportion of high-shrinkage filaments to form a web of random nonparallel elements. This web is then subjected to an area shrinking treatment to crimp the majority of the low-shrinkage filaments and to impart bulk to the web itself. This crimped and bulked web may then be subjected to further processing as indicated in the figure, such as bonding by means of granular binders or by being subjected to a dip-bonding technique such as dipping in a latex dispersion, and may be processed still further between calender rolls or embossed between rolls having suitable patterns upon the surfaces thereof with pressure applied to form indentations upon the surfaces of the web and to impart additional aesthetic and useful properties. In practicing the aforesaid process, a great many variables will be apparent to those skilled in the art. For example, instead of performing the bonding and embossing under high pressure, the web may be bonded between heated rolls with only slight compression to yield an extremely soft product. Furthermore, the resultant product is dependent for its final properties upon the initial choice of organic filaments and upon the physical condition of these filaments when deposited to form the web, for it is well known that the properties of filaments of synthetic organic materials are dependent upon their past history with specific regard to strain, time, and thermal conditions. For example, a random web may be formed of 90% continuous filaments of poly(ethylene terephthalate) prepared according to known practice, such as subjecting the filaments to a high draw ratio so that these filaments have 10% or less resultant shrinkage in steam, and 10% continuous filaments of poly(ethylene terephthalate) prepared according to known treatments to have extremely high shrinkage, about 50% or greater in steam. A random web of nonparallel continuous filaments may be laid down according to the teachings in the aforementioned British patent. The web so prepared is then shrunk by being subjected to steam in an enclosed chamber under no restraint so that a gross area shrinkage of at least 20% occurs. It is then found that the 90% filaments with low shrinkage have been distorted or crimped, appearing twisted and convoluted, and also that the web has been bulked by a significant proportion, its original thickness having increased several times. In polyester structures, the crimp is largely elastic and locked in only by the shortened highly-shrunk filaments. This crimp, of course, may be set by appropriate and known post heat treatments.

Nylon may be used, poly(hexamethylene adipamide) or polycapraamide or the like. Because most polyamides

crystallize during processing, they do not ordinarily attain the desired residual shrinkage. Copolymers and terpolymers are known which do have the required high shrinkage and can be used. Other filaments, both for the high- and low-shrinkage portions, are suitable as will be apparent to those skilled in the art.

Referring to FIGURE 2, a similar process to that of FIGURE 1 is followed. By a suitable choice of starting synthetic polymeric materials, and by regulating the physical properties of the filaments formed therefrom, for example, the draw ratio to which the continuous filaments are subjected, it is possible to make the minor proportion of high-shrinkage filaments act as binder filaments. It has been found possible to accomplish this in nonwoven structures resembling both felts and loose fabrics. Thus, low-shrinkage filaments comprising about 90% by weight of the total may be prepared as previously described, while the about 10% of high-shrinkage filaments may be prepared as before except that a suitable choice is made from a polymeric material having a substantially lower melting point than that of the low-shrinkage filaments.

In the aforementioned British patent the use of binder filaments of an 85/15 copolymer of poly(ethylene terephthalate)/poly(ethylene isophthalate) (2GT/2GI) is taught and by suitably limiting the draw ratio of this component of the web, it may be laid down as the high-shrinkage component. The process is to shrink under conditions of no restraint and then bond, and may be carried on to further processing steps as previously described.

Preferred binder fibers for use with poly(hexamethylene adipamide) include polycapraamide copolymers, melt blends, etc., thereof with poly(hexamethylene adipamide). preferred binder filaments for use with poly(ethylene terephthalate) include the isophthalate copolymers thereof or merely poly(ethylene terephthalate) filaments of reduced orientation as taught in Piccard and Signaigo, U.S. Patent 2,836,576. Other binders include polypropylene and polyethylene.

The following examples illustrate specific embodiments of this invention that are not intended to be limiting but are illustrative of the working of the invention to produce highly useful products.

Example 1

A web is prepared with 10% binder filaments comprising an 80/20 copolyester of ethylene glycol with terephthalic and isophthalic acids (2GT/2GI). A filament of this type has a molecular structure nearly totally amorphous and, as a result of the absence of crystallinity in any considerable amount, despite drawing, will have a relatively low melting point. The method of spinning used is that described in the aforementioned British patent and is illustrated in FIGURE 3. The binder filaments 1 are melt spun from spinneret 2, other parts of the spinning equipment not being shown, and passed over triboelectric bars 3, 4, and 5, in sequence, being charged thereby to a level sufficient to provide adequate separating forces to the filaments which are then passed through draw jet 6, supplied with air from source 7. The filaments are then laid down as a web 8 on collecting surface 9, electrostatically attractive target 14 being beneath surface 9. The binder filaments of this sort are capable of 50% linear shrinkage when later shrunk in steam as will be seen. The remaining 90% by weight of web 8 is similarly melt spun from spinneret 10 and mingled with binder filaments 1 on triboelectric bar 3 and then passed in mixture therewith through the sequence previously described. This portion of the filaments is designated as 11 and in this example is made of poly(ethylene terephthalate) filaments (2GT) having approximately 5% linear shrinkage in steam. Such filaments have typical tenacities of 3.9 g.p.d. with an elongation of 50% and an initial modulus of about 60 g.p.d. The random and nearly homogeneous mixture of filaments 1 and 11 issues from air jet 6 in lay-down pattern 12

to form web 8. In this example, the collecting surface 9 is a sheet of kraft paper which is moved on an oscillating table, not shown, to produce a 1-yard square sample having a fabric weight of about 2.5 oz./yd.². This sample is consolidated in a platen press 16 between screens at a pressure of 100 p.s.i. for 30 seconds at room temperature. The sample 8' of the web, removed from the paper, is subjected under conditions of no restraint to 50% area shrinkage in steam chest 15, this step being carried out for a period of 30 seconds using atmospheric steam at 100° C. The resultant thick felt-like material (indicated as 8'' in the figure) derived from the shrinkage treatment is bonded by again being treated in platen press 16 at low pressure, about 3 pounds per square inch, at a temperature of 220° C. for about 3 minutes. The properties of the resultant web are: fabric weight, 5.75 oz./yd.²; strip tensile, 6.1 lb./in./oz./yd.²; elongation at break, 95%; tongue tear, 2.9 lb./oz./yd.²; thickness, 0.029 in.; and vibration modulus, 660 p.s.i.

Vibration modulus is a measure of web stiffness. It is determined in a dynamic test involving measurement of the resonance frequency of a strip of the material when subjected to a forced vibration. The sample is clamped at one end to a sinusoidally oscillating support and the frequency in cycles per second at maximum amplitude of vibration is measured either by an oscillograph or some counting device. The modulus is then calculated from the formula:

$$V.M_1 = \frac{224PC^2L^4}{t^2}$$

where $V.M_1$ is the vibration modulus in pounds per square inch, P is the density in grams per cubic centimeter, C is the observed frequency at resonance in cycles per second, L is the sample length in inches, and t is the sample thickness in mils. The lower the modulus, the more flexible is the sample.

Example II

A web is produced in a manner similar to Example I, except that 11% binder is used. This web is subjected to area shrinkage of 38% under conditions of no restraint. Bonding is carried out in a manner similar to Example I except that a time of 2 minutes is used and shims are placed between the platens of the press to limit the amount of compression. These shims are 0.020 in. thick. The properties of the final bonded web are as follows: fabric weight, 2.6 oz./yd.²; thickness, 0.018 in.; strip tensile, 7 lb./in./oz./yd.²; tongue tear, 2.6 lb./oz./yd.²; elongation at break, 53%; vibration modulus, 550 p.s.i.

Example III

A web is prepared from 12% of poly(ethylene terephthalate) as the high-shrinkage filaments and 88% of poly(ethylene terephthalate) as the low-shrinkage filaments. This is accomplished by using separate snubbing arrangements in which the high-shrinkage filaments are passed around a greater total included angle of wrap than the low-shrinkage filaments. In FIGURE 3, this is indicated by the dotted lines 11' passing about triboelectric bar 13. The portion represented by numeral 11' is the bundle from the minor portion of the total filaments. During spinning, an additional 20% by weight of particulate binder is incorporated in the web. This is added in the draw jet and is composed of a 55/45 copolymer of poly(ethylene terephthalate)/poly(ethylene isophthalate). The web is subjected under conditions of no restraint to shrinking treatment in steam chest 15 to a resultant condition of 45% area shrinkage and is bonded in platen press 16 at a temperature of 200° C. for 2.5 minutes. Only contact pressure is used between the platens of press 16, this pressure being so low as not to be measurable on the instrumentation then available. The resultant product has the following properties: fabric weight, 4.4 oz./yd.²; thickness, 0.054 in.; strip

tensile, 7.2 lb./in./oz./yd.²; standard Mullen Burst test, (ASTM D76-53), 110 p.s.i.; and air porosity, according to the Frazier Method (S. W. Frazier Co., Washington, D.C.), 72 ft.³/ft.²/min. at 0.5 in. of water.

The continuous filaments making up the major and minor components of the nonwoven web provided by the process of this invention must have shrinkage values of less than about 15% and greater than about 40%, respectively. By the term "shrinkage value" is meant the percentage decrease in the length of a continuous filament when exposed to a temperature above the glass transition temperature.

The implications of this improvement in the nonwoven art will be immediately apparent to those skilled in the practice. It is clear that by a suitable choice of filaments and of the processing conditions to which those filaments are subjected prior to distribution in a web, and to the type of treatment accorded to that web in the further processing after bulking and crimping by means of the differential shrinkage technique, a great variety of highly useful products may be prepared at a cost previously sought but not attained. Experience in practicing the instant invention has shown that the products that may be prepared by suitable variation of the parameters range from a felt-like nonwoven having a bulk density of approximately 3 pounds per cubic foot to a nonwoven fabric of high density approaching 20 pounds per cubic foot. Thus, by suitable manipulation it is apparent that products having utilities of such varying types as substrates for coated fabrics used in commercial upholstery trades to insulating pads may be produced. Filters may be made as can be tents and tarpaulins. The superior crimped and bulked product of the invention may be employed in apparel end uses when conditions are adjusted to produce appropriate nonwoven fabrics. Similarly, many other useful products will occur to those skilled in the art.

It is thought that the invention and its many advantages will be understood from the foregoing description and particular examples which should not be considered limiting but merely illustrative of the practice of the invention, and it will be apparent that various changes may be made in the form, construction, and arrangement of the apparatus employed herein without departing from the spirit and scope of the invention, the scope of which is described in the following claims.

What is claimed is:

1. A process for producing a bulked nonwoven structure of continuous filaments of synthetic organic polymeric composition comprising (1) forming an unbonded nonwoven web composed of continuous filaments of synthetic, organic polymeric composition with a major portion of said continuous filaments having a shrinkage value of less than about 15%, and a minor portion of said continuous filaments having a shrinkage value of at least about 40%, said forming characterized by the process conditions necessary to form the said continuous filaments having the said shrinkage values, said major and minor portions of said continuous filaments being randomly and thoroughly admixed with one another, and then (2) subjecting said unbonded nonwoven web to shrinkage conditions while in an unrestrained state in order to cause said minor portion of said continuous filaments to draw together the major portion of said continuous filaments into twisted, convoluted, crimped configurations, and cause bulking of said nonwoven web as well as a reduction in area of said nonwoven web of at least about 20%.

2. The process of claim 1 wherein the resultant nonwoven structure has a density of from about 3 to about 20 pounds per cubic feet.

3. The process of claim 1 wherein said continuous filaments are of poly(ethylene terephthalate).

4. The process of claim 1 wherein said major portion of said continuous filaments are filaments of poly(ethyl-

ene terephthalate) and said minor portion are filaments of a copolymer of poly(ethylene terephthalate) and poly(ethylene isophthalate).

5. The process of claim 1 wherein said minor portion of said continuous filaments is present to the extent of from about 5% to about 25% by weight of said non-woven web.

6. The process of claim 1 wherein said shrinking is accomplished by steam.

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ROBERT F. WHITE, *Primary Examiner*.

J. R. HALL, *Assistant Examiner*.