It is an object of the present invention to provide a unique method for increasing the physical properties, particularly the tensile strength and drapability of spray spun fiber structures of substantially continuous filament material, by orienting the filamentary material in a manner whereby increased stretch ratios are obtained in addition to a corresponding increase in tensile strength. Another object of the present invention is to provide a non-woven material of improved drapability and tensile strength per unit area per weight. It is yet a further object of the present invention to provide a method for increasing the speed at which the total elongation or stretching can be effected while lessening the danger of rupturing the fibrous sheet material. These and other objects will become apparent to those skilled in the art from a description of the invention which follows.

SUMMARY OF THE INVENTION

In accordance with the present invention, a process is provided for treating a spray spun fibrous sheet material, comprising stretching a spray spun sheet material having substantially continuous filamentary material therein, said filamentary material having before said stretching, a varying amount of orientation and being randomly thermally bonded to itself, at the time of spray spinning heat-relaxed stretching said fibrous sheet and subsequently again stretching said fibrous sheet thereby further orienting at least some of said filamentary material.

The present process is particularly advantageous because the filamentary material can now be drawn, stretched or elongated to a given area increase at a faster rate because the stretching is effected in at least two stages without attempting to obtain the maximum stretch in a single stage. If a maximum area increase is attempted in a single draw stage without rupturing the fibrous material, the overall rate of the draw is effected slower so as to not rupture the material in areas of weakness. However, in the present invention, the draw can be effected rapidly because the first draw is of less than the maximum and therefore can be carried out rapidly. After relaxation, the second draw can also be effected rapidly because, with the intermediate heat relaxation, the total draw which can then be effected is substantially increased over the original draw limit which may be only about 8 to 12 times, depending on the polymer, fibrous structure and the like. Thus, the present process provides a method for increasing the total draw while unexpectedly increasing the fibrous sheet materials strength as measured in force per unit area per weight.

DETAILS OF THE INVENTION

The spray spinning can be carried out by various known processes but it is preferably effected by the use of the techniques and apparatus disclosed in the pending patent application of Wagner et al., entitled, Method and Apparatus for Forming Fibrous Structures, Ser. No. 581,075, filed Sept. 21, 1966, now abandoned in favor of Ser. No. 740,913, filed June 28, 1968, now Pat. No. 3,543,332, which application is commonly assigned to the assignee of the present application. The disclosure of the noted patent application is hereby incorporated into the present application.

Basically, the spray spinning is preferably effected by extruding liquid fiber forming material, which may be either molten or plasticized in a solvent therefor through an orifice as a filamentary material. Preferably, attenuation of the incompletely hardened filament is effected by a plurality of high velocity gas streams issuing from gas passages spaced about the extrusion orifice and having passages that converge toward but do not intersect the extrusion orifice axis. The gas flow projects the filament away from the nozzle in a random pattern.
The filamentary material projected from the spinning zone has a combination of desirable characteristics which have been found to be particularly beneficial in the construction of nonwovens. Although the fiber is similar to conventionally spun fiber in the sense that it is in the form of a substantially continuous filament, it is characterized by random lengthwise variations in diameter and degree of orientation which result from random variations in the attenuating action of the gas streams acting on the filament. These variations in filament properties are of substantial magnitude. For example, in a typical embodiment the cross section of the largest filament portions is more than about ten times that of the smallest filament portions, with the mean being about 2½ times the cross section of the smallest filament portion. Thus, in a typical medium denier structure, the as spun denier per filament is about 12 to 18 with the average being about 15. After stretching in accordance with the present invention, the denier per filament is reduced to about 1.5 to 15 with the average being about 4. In heavier filament structures, the denier per filament tends to vary over a larger range, while in the lower denier per filament ranges, e.g., 0.5 to 15, the variance is normally over a smaller range. In a nonwoven structure embodying such filamentary material, the smaller diameter segments represent a larger proportion of surface area per unit volume, while the larger diameter segments are resist crushing of the nonwoven.

Preferably the as spun average denier per filament is in the range of about 3 to 30 and more preferably, 3 to 10. The most preferred stretched denier per filament averages about 0.25 to 3.

As the freshly spun filament is projected away from the spinning nozzle in a random pattern by the gas streams, a collection surface, such as the surface of a roller, a continuous belt, a screen or the like, is moved continuously in the path of the projected filamentary material to collect the filamentary material without destroying the random disposition of the filament sections. The movement of the collector surface serves to bring new portions of the surface into the path of the filamentary material continuously so that the collected fiber forms a web or sheet that is continuously removed from the collection zone. The extrusion rate and the speed of the collection surface are preferably so related to each other as to assure that the collected sheet will have the desired weight per unit length for the intended use of the nonwoven.

The present invention is used in the production of nonwoven spray fibrous structures which are synthetic, solid, high-molecular weight, fiber-forming polymers. All of the various organic polymers which can be melt or solution spun can be used in the present invention. Particularly, polyolefins such as polypropylene and polyethylene are used. In addition, cellulose acetate and triacetate, polyamides, polyeacetics, polyesters, acrylics and the like as well as conjugates thereof, can be used with correspondingly good results and certain particular advantages. It will be recognized that various combinations of two or more polymers can also be used whereby the polymers are extruded as conjugate materials or as separate distinct fibers using a plurality of extrusion means.

The collection of the nonwoven spray-spun fibrous material in sheet form can be controlled so as to produce a non-woven structure of almost any weight such as within the range of about 0.1 to about 50 ounces per square yard. The particular weight at which the nonwoven spray spun material is produced depends upon the end use for which it is intended. For instance, when the material is to be used as a carpet backing material, wherein the stretched product desirably has a weight of about 4 to 5 ounces per square yard, the spray-spun fibrous material may be originally collected in the weight range of about 10 to 20 ounces per square yard and, on subsequent drawing, the area increase greatly reduces the total weight per unit area such as between about 1 to 15 ounces per square yard. Weights of about 0.5 to 30 ounces per square yard or more are prepared in this manner.

In controlling the weight of the nonwoven, the degree of self bonding can also be controlled by varying the distance from the extrusion means to the collection surface so as to collect the fiber at a temperature whereby the residual heat and/or solvent retails the fibers sufficiently tacky to produce the desired self bonding. Of course it will be readily recognized that by placing the collection zone at a closer proximity to the extrusion orifice, an increase in bonding occurs whereas when the collection surface is further displaced, the amount of self bonding can be lessened. In certain applications, such as for high loft materials as contrasted with paper-like products, variations in bonding are often desired. Also, supplemental bonding means can be used such as by applying a suitable bonding material to the collector along with the filamentary material or by the subsequent application of a binder.

The drawing of the produced nonwoven can be effected either multiaxially or uniaxially depending on the particular characteristics desired in the end product. A multiaxial drawing, which is often effected biaxially, triaxially, etc., is often desired to obtain substantially equivalent tensile strength in a multitude of directions along the fibrous plane. In addition, the drape of the end product is also improved in all directions by multiaxial drawing. However, in certain instances, such as wherein the end use requires greater longitudinal strength than transverse strength or wherein drapability along the longitudinal direction is not as critical, uniaxial drawing may be preferred. Such uniaxial drawing is particularly desirable wherein two or more fibrous sheets are laminated together to produce an end product of high strength in a plurality of directions. Of course, the drawing can be effected in two or more stages wherein one longitudinal and one transverse draw is applied.

The drawing can be effected at temperatures which result in heating the sheet material, from room temperature (20 degrees centigrade) to just below the melting (tacky) temperature of the polymer. Preferably, the drawing is effected in the presence of heat such as by placing the fibrous sheet material over a heated shoe. Various drawing means can be used as well as various known heating means to produce correspondingly good results. Heating means such as radiant heating, gaseous heating, liquid heating, induction heating and the like are used. Typically, depending on the particular polymer used, the drawing is effected at a temperature of about 50 to 200 degrees centigrade or more and more preferably, in the temperature range of about 100 to 150 degrees centigrade.

The first elongation or stretching is preferably effected by stretching the fibrous sheet material about 25 to 85 percent and more preferably 30 to 80 percent of its maximum stretch as measured by the stretch required to rupture the fibrous structure. This stretch can be effected at high speeds because the maximum stretch is not being approached.

The maximum stretch on a single stage draw normally can be effected up to about 12 times the original length and under certain circumstances, depending on the fibrous structure, the polymer involved, the fiber denier, the nonwoven weight and the like. Higher and/or lower maximum stretches can be achieved. Various stages of stretching conducted multiaxially such as biaxially, the maximum stretch in both directions is normally in the range of about 3 to 5 times the original length and width, Thus, the total increase in the area of the nonwoven independent of the direction of stretch can be up to about 15 to 16 times or more than the original area. Again, exact area increase obtainable depends on the particular fiber characteristics and the like enumerated above.
Upon completion of the first stretching stage, the sheet material is then heat relaxed. The heat relaxation is affected at temperatures below the polymer melting point such as within the range of about 80 to 200 degrees centigrade, again depending upon the particular polymer involved. The heat relaxation is conducted in various heating mediums such as radiant heat, heated gases, liquids or the like. In a preferred method of heat relaxation, the heating is effected by heating the sheet material with superheated steam.

The heat relaxation time can be varied depending on the particular polymer utilized, the heat transfer efficiency and the time required to heat the sheet material to the desired temperature. Normally, the heat relaxation is affected in a matter of seconds to several minutes or more. In relaxations such as for polypropylene fibers using superheated steam, times of about 10 seconds to 45 seconds have been found to be suitable. The heat relaxation results in a slight shrinking which varies with the temperature used. Typically, shrinkages of about 5 to 15 percent in the drawn direction are incurred with the higher shrinkages occurring at the higher temperatures.

Upon completion of the heat relaxation, the fibrous structure is again subjected to stretching which is normally conducted in the same method as in the first stretching. However, the second stage stretching can be varied from the first stage. For instance, when the first stage stretching is effected substantially biaxially the second stage stretching may desirably be only uniaxially or vice versa as is desired for the particular end use.

It has been found that after heat relaxation, the maximum lengthening of the original fibrous structure is increased such that total elongations of up to about 18 times or more than the original length are now obtainable. This corresponds to area increases of up to about 20 times or more of that of the original area. In addition, such elongations further increase the strength of the fibrous material above what was previously attainable for corresponding area weights. Thus, the second drawing or stretching is effected to increase the area size of the fibrous material above the first stage stretch but may not necessarily increase the area size to the maximum, although this is often most desirable.

The present invention will be more fully described by reference to the examples which illustrate certain preferred embodiments of the present invention. Unless otherwise indicated, all temperatures are in degrees centigrade and all parts and percentages are by weight.

Example I

A polypropylene spray-spun, fibrous, nonwoven sheet material was produced in accordance with the aforementioned Wagner et al. apparatus and process to produce a spray-spun nonwoven sheet material having a weight of about 4 ounces per square yard. The polypropylene was spun at a melt temperature of 350 degrees centigrade through a 0.028 inch diameter nozzle of the geometric configuration described in the aforementioned Wagner et al. application. A sample of this spray-spun sheet having an average denier per filament of about 10, varying from about 3 to 18 denier per filament, was then stretched five times the steam relaxed length to obtain a total stretch at 124 degrees centigrade. The resulting sample was then divided into two parts. One part was steam relaxed in an autoclave at 121 degrees centigrade. The other part was not heat relaxed. Both the relaxed and unrelaxed sheet materials were then stretched two times in length to give a total stretch of 10 times the original length. A second proportion of the heat relaxed sheet was stretched 2 1/2 times the steam relaxed length to obtain a total stretch of 11 times the original length with a corresponding reduction in denier per filament.

Table I shows the results obtained as measured in tensile strength for the various samples tested.
duce correspondingly good results. Also, spray spun material produced using various other polymeric fiber-forming materials such as polyamides, polyesters, cellulose acetate, cellulose triacetate, acrylics, conjugates thereof and the like thermoplastic polymers are used with correspondingly good results.

The sheet-like structures of this invention may serve a variety of useful purposes. With suitable coating and/or laminations, they may serve in industrial applications, in the stead of conventional woven materials, films and papers. By incorporation of a suitable binder, with or without an additional embossing operation, cloth-like articles are produced. The nonwoven structures of this invention can serve in the preparation of felts, leather-like materials, and suede-like materials. They may be assembled into a layered structure which may then be needled to form a substrate which is suitable for use in poromeric materials. With high binder content and high pressure calendering, paper-like articles are produced. The present structures can serve as interlining or interfacing materials useful in imparting shape and/or stiffness to garments.

While there have been described various embodiments of the present invention, the methods and elements described herein are not intended to be understood as limiting the scope of the invention as it is realized that changes therein are possible. It is intended that each element, step, and the like of any of the following claims is to be understood as referring to all equivalent elements for accomplishing substantially the same results in substantially the same or equivalent manner. It is intended to cover the invention broadly in whatever form its principles may be utilized being limited only by the appended claims.

What is claimed is:

1. A process for treating a spray-spun fibrous nonwoven sheet material comprising stretching and simultaneously increasing the area of a spray-spun nonwoven sheet material having substantially continuous organic polymeric filamentary material therein, said stretching in an amount of about 25 to 85 percent of the maximum elongation, as measured by the stretch required to rupture the fibrous sheet material, said filamentary material having before said stretching a varying amount of orientation and being randomly bonded to itself at the time of spray-spinning, relaxing said fibrous sheet in presence of heat at a temperature within the range of about 80 to 200 degrees centigrade and subsequently again stretching in presence of heat at a temperature within the range of about 80 to 200 degrees centigrade and simultaneously increasing the area of said fibrous sheet, thereby further orienting at least some of said filamentary material, said stretching after said heat relaxation is to a total stretch greater than the maximum elongation prior to the first stretch.

2. The process of claim 1, wherein the stretching prior to the relaxation is in an amount of about 50 to 80 percent of the maximum elongation, as measured by the stretch required to rupture the fibrous sheet material.

3. The process of claim 1, wherein the stretching temperature is within the range of about 100 to 150 degrees centigrade.

4. The process of claim 1, wherein the relaxation is effected in the presence of superheated steam for about 10 to 45 seconds to effect a shrinkage of about 5 to 15 percent.

5. The process of claim 1, wherein the heat relaxation is effected in the presence of super-heated steam.

6. The process of claim 1, wherein the stretching both before and after relaxation is effected uniaxially.

7. The process of claim 1, wherein the stretching both before and after relaxation is effected multiaxially.

8. The process of claim 1, wherein the spray-spun fibrous nonwoven sheet material comprises polypropylene filamentary material.

9. The process of claim 1, wherein the organic polymeric filamentary material is selected from the group consisting of polyolefin, cellulose acetate, cellulose triacetate, polyamides, polycetals, polyesters and acrylics.

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PHILIP E. ANDERSON, Primary Examiner

U.S. Cl. X.R.

26—54, 60; 28—72 NW; 161—170, 402, 411; 264—115, 288, 289, 342 RE, DIG. 71, DIG. 73