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METHOD OF HEAT STABILIZING POLYETHYLENE FABRIC COMPOSED OF FILAMENTS HAVING SPECIFIC RESIDUAL SHRINKAGE

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This invention relates to the production of textile fabrics from polyethylene polymer filaments. More particularly, the invention relates to a method for more economically producing finished polyethylene fabrics having improved qualities of shrink resistance, strength, appearance, construction, and other physical properties.

Greige or grey fabrics woven from polyethylene filaments usually are submitted to a finishing procedure in order to make the fabrics suitable for commercial purposes with regard to appearance, hand, smoothness of surface, regularity and firmness of construction, reduction or elimination of slippage of the individual filaments in the fabric, and also with regard to shrink resistance at higher temperatures. Such fabrics have a tendency to retract considerably upon being heated, the retraction occurring in both the warp and the filling direction. The retraction or shrinkage may occur even though the filaments from which the fabrics are made individually exhibit little or no retraction. It can be assumed that in the case of woven fabrics the retraction may be an effect of the weaving operation and/or the type of weaving construction, which may cause stresses and deformations of the filaments such that, after being woven, they tend to retract and relax if permitted to do so. The resulting shrinkage of the fabrics is undesirable in many instances.

Various methods and types of equipment have been devised and utilized to finish the greige fabrics, particularly to improve their shrink resistance, and most of these methods and apparatuses are based upon the principle of submitting the fabrics to a controlled limited shrinkage, or, in other words, a preshrinkage. Some of these methods, which hereinafter will be termed the conventional methods, treat the fabrics by pressing them between heated calender rolls, or treat them in hot water, steam or hot air, or use combinations of calendering and hot fluid treatment. The calender operation smooths the surface of the fabric under the influence of heat and pressure and forces the filaments into an interlaced construction, fixing them in their relative locations and positions. Under the influence of heat, whether from the calender rolls or from the hot fluid treatments, the fabrics retract in width and in length to a degree which is determined by their construction, by the equipment, and by the conditions of pressure, temperature, and duration of these conventional finishing methods. The finished fabrics are thus changed in their dimensions, due to shrinkage. The form and density of their constructions are also changed, due to calender pressure and shrinkage, and the calender pressure also changes the diameter and shape of their constituent filaments. With regard to the filaments, these are bent and folded in more or less sharp angles, and are flattened and thinned. Polyaxial stresses within the filaments are set up which, particularly at the angles, are known to initiate cracking of the plastic material and to accelerate

deterioration or aging under the influence of sunlight and weathering.

The foregoing disadvantages, particularly the reduction in dimensions of the finished fabrics, have had an effect on the manufacture of the greige fabrics. Wider looms have been used and greater yardage of fabrics woven in the greige so that a given desired width and length could be obtained for the finished fabrics.

One of the principal objects of the present invention is to provide a method for making finished polyethylene fabrics having improved characteristics while avoiding the necessity for producing increased yardage and avoiding the unfavorable effects, noted above, of conventional methods on the form and construction of the fabrics and on the form of the filaments. Other objects and advantages will become apparent hereinafter.

The invention, briefly stated, comprises processing oriented, polyethylene filaments by annealing them incompletely so as to leave in them a considerable ability to retract in length, i. e., a considerable residual shrinkage, then converting these filaments to greige fabric by a weaving, knitting, or braiding operation, and heating the greige fabric at a temperature close to but below the melting point of the polymer while simultaneously preventing any retraction of the fabric along both its length and width, thus producing a finished fabric. The filament annealing and greige treating steps are interconnected and the final results are dependent on their proper correlation.

Considering the invention in more detail, the polyethylene resin is extruded into filaments and oriented in the conventional way. Normally solid resin polymers are suitable, preferably those having a melting point in the range of about 110° C. to about 120° C., although polymers having lower and higher melting points are also contemplated. The oriented filaments are subjected to annealing which is incomplete and is so controlled as to leave in them a retractive power or residual shrinkage of not less than approximately 8% and not more than approximately 20% when the filaments are tested at 75° C. for 20 minutes. In this test the loose filaments are placed in water and their lengths are measured at the end of the test. It has been found that the filaments may be annealed as described by heating them to a temperature about 25 to 30° C. below the melting point of the polymer for not more than 1 to 5 seconds. The conditions of temperature and duration are dependent upon the specific polymer used and the diameter of the oriented filaments. The thinner the filament the shorter must be the time of heating, or the lower the temperature. For polymers melting in the range of 110 to 120° C., the heating of the filaments may be performed at about 80 to 90° C. for about 1 to 3 seconds. Heating may be carried out while the filaments are wound on a bobbin with the ends securely tied, as by placing the bobbin in an inert liquid heat exchange medium held at the proper temperature; or the filaments may be passed continuously through the bath or in heat exchange relation with a hot plate or over a heated roll without being allowed to retract in their axial direction.

The filaments are then converted into greige fabric as by weaving, knitting or braiding. The filaments in the greige fabric have the wavy or twisted form which the weaving, knitting or braiding operation imparts to them. This fact causes the greige fabric to be rough on its surface and more or less loose and slippery in its construction.

The greige fabric is then suitably held along both its length and width to prevent any retraction and subjected to a temperature of 20 to 3° C., preferably 15 to 5° C.,

below the melting range of the polymer and for a time ranging between about 10 seconds and about 10 minutes. The melting point of polyethylene polymers is rather sharply defined so that no fusion or joining of the filaments will occur, or should be allowed to occur, at the intercrossings. Any adequate mechanical device may be used for restraining the fabric during heating provided it is sufficiently strong to counteract the forces created by the tendency of the fabric to shrink in both directions and provided it is adjustable to preclude damage of the fabric. Tenter frames have been found to be suitable, using clamps or pins for attaching the fabric on all sides thereon. So-called pin tenters may be used for continuous operation. The fabric may be heated in any suitable way, as by circulating hot air, steam, or inert gas in contact with the fabric, or by means of radiation from any adequate source of heat, or by using infrared heaters. The heating means should permit the temperature to be precisely controlled as well as the duration of heating. As may be appreciated, the temperature to which the fabric is heated will depend on the duration of heating, higher temperatures being used for shorter times, and vice versa. Also, the diameter of the filaments and/or the thickness of the fabric will govern the heating, more heat being required for larger filaments or for thicker fabrics, and vice versa.

In one embodiment of this method, the fabric, suitably supported, is passed continuously in heat exchange relation with several pairs of radiant heating elements positioned both above and below the fabric. Each heater is somewhat greater in area than the fabric passing by it. The first heaters, or pair of heaters, which are encountered by the fabric are maintained at a temperature considerably higher than the maximum temperature desired for the fabric. The speed of the moving fabric is adjusted so that this maximum temperature is acquired and not exceeded by the fabric when it just reaches the far end of these heaters. The heaters are provided with electrical controls for decreasing or increasing the heat within a range not exceeding 3 to 5° C. As the fabric moves on, it encounters heaters which are adjusted to temperatures lower than the first pair so as to maintain the fabric at the desired temperature level within the necessary safety margin.

By heating the restrained fabric as described the annealing of the filaments within the fabric structure is completed and the breaking strength, shrink resistance and other characteristics are greatly improved while the fabric becomes stabilized in its initial greige dimensions. These characteristics and dimensions will be preserved when the fabric should later be subjected to elevated temperatures, much better than fabric that has been conventionally preshrunk.

Due to the internal stresses produced in the fabric filaments during the heating, the filaments straighten out as far as they are permitted to do so. Consequently, the surface of the fabric becomes smooth and its thickness is reduced. Heretofore, in this connection, in order to obtain a finished fabric of required properties, it had to be made in its greige form in a looser construction than desired for the finished goods and had to be calendered under pressure to smooth the surface and to reduce the thickness. These undesirable procedures are avoided by the present method because the fabric is not only made smoother but strengthened as well, as will later appear. Visual examination of the present fabric filaments shows a distinct difference over the filaments in calendered fabric. As noted above, calendering considerably changes the form of the individual filaments; in cross-section, the filaments, which in the greige were round, may take an elliptic shape or be flattened out to a thin ribbon; in the axial direction, the initial wavy form of the filaments in the greige becomes not only distinctly more accentuated but the waves are often changed into a broken form with sharpened angles. Filaments of the present fabric have the cross-sectional form they had in the greige fabric, but axially they are far less wavy, being substantially straightened.

The present finished fabric has substantially the same form and density of construction as had the greige cloth, but its construction is better stabilized and locked in its form, the slippage of the interlacing filaments being reduced to a minimum by their having been stretched. These changes help to increase the strength of the finished fabric.

Of substantial importance is the fact that the invention provides considerable economies in operation, as well as improvements in the cloth. Conventional preshrinkage causes a loss in length and in width of the greige fabric which may amount to ten percent or more in either direction, and as noted, made it necessary to weave or braid larger amounts of the greige fabric. The present method yields the same lengths and widths for the finished as for the greige goods and therefore reduces the yardage of fabrics to be woven, knitted, or braided. Or stating it another way, it is possible to produce fabrics of greater finished width than conventionally preshrunk fabric, using the same looms in both cases. In addition, the present method treats the greige fabric in one step, where some of the conventional procedures required several steps, including shrinkage and one or several calendering operations.

Another advantage of the invention is the improvement of the comparative aging performance of the finished fabric. All filaments, natural or synthetic, are subject to more or less pronounced deterioration when exposed to ultra-violet rays, especially at elevated temperatures. A study of this phenomenon has shown that conventionally finished fabrics usually deteriorate in a considerably shorter period of time than do the respective greige fabrics from which they are made when both are exposed to a source of ultra-violet rays. Apparently the shrinkage, and more so the calendering, of the greige fabrics are responsible for this increased deterioration. Fabrics finished according to the instant method, however, exhibited a reduced deterioration when tested with other fabrics under comparable conditions. In one example, three pieces of cloth originating from the same greige polyethylene fabric were submitted to artificial ultra-violet exposure under conditions simulating a six months' outdoor exposure to sunlight under southern (subtropical) conditions. One piece was in the original greige state; the second had been finished by conventional preshrinkage and calendering; and the third had been finished according to the present fabric heating step wherein the fabric is completely prevented from retracting. After exposure, the pieces were tested with regard to their breaking strength and it was found that the second piece had lost 11 percent of its breaking strength, whereas both the first and third pieces showed no apparent loss of strength. In a second example, using a very thin polyethylene fabric and an exposure simulating an eight months' outdoor influence under southern conditions, the greige fabric lost 21%, the conventionally finished fabric lost 26%, and the presently finished fabric lost 16% of its initial tensile strength.

The invention may be further illustrated by the following examples:

Example 1

Polyethylene resin having a melting point of about 117° C. was extruded to monofilaments which were then oriented by stretching them to a diameter of 380 microns. The residual shrinkage of these filaments was adjusted to 10%, when tested at 75° C. during 20 minutes, by running them under restraint through a water bath at 85° C. for one second. These filaments were woven into a fabric having 23 filaments per cm. as warps and 13 filaments per cm. as fillings. This fabric was attached on all four sides to a metallic frame by means of steel pins and then subjected to heat treatment between two infrared heaters

placed equidistantly from the two fabric surfaces which provided uniform heating over the entire surfaces. The temperature of the fabric was controlled by means of a thermocouple which was interlaced into the fabric. A temperature of 110° C. was reached in 9 seconds and this temperature was maintained over an additional period of 18 seconds. The results are tabulated as follows:

Fabric	Greige	Finished
Surface	Rough, slightly wavy	Smooth, straight.
Thickness	940 microns	830 microns.
Breaking strength:		
Warp direction	34 kg./cm.	37 kg./cm.
Filling direction	21 kg./cm.	23 kg./cm.
Shrinkage test at 75° C., 20 minutes:		
Warp direction	11.2%	1.4%.
Filling direction	8.4%	1.4%.

Example 2

A polyethylene resin melting at about 117° C. was extruded to monofilaments which were oriented by stretching them to a diameter of 500 microns. The filaments were annealed under the same conditions as in Example 1. A lenotype fabric was woven from them having an average of 5 filaments as warps and 4½ as fillings. This fabric was heat treated in a continuous oven of 30 meters length provided with hot air blowers on the upper and lower sides of the fabric to assure controlled temperatures over the entire length of the oven. The fabric was firmly attached on both sides on moving pin-tenters, which prevented shrinkage in width, and was held between pairs of closely fitting cylinders having roughened surfaces to prevent retraction in length. The temperature was adjusted to between 105° and 108° C. and the forward movement of the fabric so regulated that the heating time was 60 seconds. Surface improvement of the finished fabric was comparable to that obtained in Example 3. The following other results were obtained:

Fabric	Greige	Finished
Breaking strength:		
Warp direction, kg./cm.	13	20
Filling direction, kg./cm.	10	18
Shrinkage test at 75° C., 20 minutes:		
Warp direction, percent	10.1	0.9
Filling direction, do	6.1	0.9

Example 3

A fabric of a construction similar to the one described in Example 1, woven from oriented polyethylene filaments of 380 microns diameter and annealed as in Example 1, but of a melting point of about 120° C., was heated to a temperature level of 107–108° C. in a flow of hot air and maintained at this temperature over a period of 10 minutes. The fabric was firmly attached on all sides to a frame before and during the heating. Surface improvement of the finished fabric was as in Example 1. Other results are:

Fabric	Greige	Finished
Thickness, microns	940	820
Breaking strength:		
Warp direction, kg./cm.	48	48
Filling direction, kg./cm.	30	30
Shrinkage test at 100° C., over 5 min.:		
Warp direction, percent	28	6
Filling direction, do	24	14

Example 4

A polyethylene fabric prepared but not heated as described in Example 3, in which the polymer had a melting point of about 120° C., and the filaments a diameter of 340 microns, was attached on a metallic frame to prevent retraction and immersed in a bath of silicone fluid of the D. C. 200 type, the latter held at a constant temperature

of 110° C. and being inert to the fabric. The total time of immersion was 2 minutes. The fabric had the same finished appearance as had those treated according to Examples 1 to 3. The tests gave the following results:

Fabric	Greige	Finished
Thickness, microns	910	770
Breaking strength:		
Warp direction, kg./cm.	32	36
Filling direction, kg./cm.	23	23
Shrinkage test at 75° C., 20 minutes:		
Warp direction, percent	10.0	1.3
Filling direction, do	6.8	1.6
Shrinkage test at 93° C., 20 minutes:		
Warp direction, percent	26	6
Filling direction, do	21	5

It will be understood that finished fabrics may be produced according to the invention not only from polyethylene filaments but also from polyethylene yarns comprising a plurality of filaments or fibers. These yarns may be formed from oriented filaments that may or may not have been annealed, and if not, the yarns are subjected to the above-described annealing step before they are converted to fabric.

In some cases it is preferred to limit the heat applied to the fabric; and in this connection Example 3 may illustrate the point, the heating time being a full 10 minutes with no gain in breaking strength being acquired by the fabric, although, of course, the fabric was improved in other respects. Another useful precaution for smaller diameter filaments is to heat the fabric under substantially non-oxidizing conditions, as illustrated in Example 4 where the fabric was immersed in an inert heat exchange medium. Other suitable media are steam, nitrogen, oxygen-free gases, and various relatively high-boiling liquids inert to polyethylene at the processing temperatures used, such as salt solutions, of which a number are recorded in the technical literature. These media are also suitable for heating the filaments to anneal them.

By a "stabilized fabric," as used herein, it is intended to include a fabric improved as to its dimensional stability, its resistance to aging, and its firmness of construction or resistance against slippage of the filaments.

While the invention has been described in connection with selected embodiments of the same, it will be appreciated that it is capable of obvious variations.

In the light of the foregoing description, the following is claimed:

1. Method of producing stabilized finished fabric from oriented polyethylene filaments which comprises heating the polyethylene filaments to a temperature of about 25 to 30° C. below the melting point of the polyethylene polymer for about 1 to 5 seconds to leave in them a residual shrinkage between 8 and 20% when tested at 75° C. for 20 minutes, then converting the filaments to greige fabric in which the filaments assume a wavy form, heating said greige fabric to a strictly controlled temperature between 3 and 20° C. below the melting point of the polyethylene while simultaneously holding the fabric along both its length and width to prevent retraction thereof along said length and width, subjecting the fabric to said latter temperature for about 10 seconds to about 10 minutes, said time and temperature being coordinated so that the filaments straighten out by shrinking, said filaments having the capacity to shrink to the extent of their residual shrinkage, maintaining the fabric free from contact with compressing surfaces during said heating, and obtaining as a result of the foregoing steps a finished fabric which by comparison with said greige fabric has a smoother and flatter surface, has substantially the same surface area as said greige fabric, has improved stability, and exhibits breaking strength at least equal to said greige fabric.

2. Method of producing stabilized finished fabric from oriented polyethylene polymer filaments having a melting point of 110 to 120° C. which comprises annealing the

polyethylene filaments to leave in them a residual shrinkage of 8 to 20% when tested at 75° C. for 20 minutes, said annealing being carried out by heating the filaments to a temperature of about 25 to 30° C. below the melting point of the polymer for about 1 to 3 seconds, then converting the filaments to greige fabric in which the filaments assume a wavy form, heating the greige fabric to a temperature in the range of 15 to 5° C. below the melting point of the polymer while simultaneously holding the fabric along both its length and width to prevent retraction thereof along said length and width, subjecting the fabric to said latter temperature for about 10 seconds to about 10 minutes, said time and temperature being coordinated so that the filaments straighten out by shrinking, said filaments having the capacity to shrink to the extent of their residual shrinkage, maintaining the fabric free from contact with compressing surfaces during said heating, and obtaining as a result of the foregoing steps a finished fabric which by comparison with said greige fabric has a smoother and flatter surface, has substantially the same surface area as said greige fabric, and has improved stability and breaking strength.

3. Method of producing stabilized finished fabric from polyethylene greige fabric composed of oriented, polyethylene filaments, said filaments having been heated to a temperature of about 25 to 30° C. below the melting point of the polyethylene for about 1 to 5 seconds to leave in the filaments a residual shrinkage of between 8 and 20% when tested at 75° C. for 20 minutes, comprising heating the greige fabric to a strictly controlled temperature between 3 and 20° C. below the melting point of the polyethylene while simultaneously holding the fabric along both its length and width to prevent retraction thereof along said length and width, subjecting the fabric to said latter temperature for about 10 seconds to about 10 minutes, said time and temperature being coordinated so that the filaments straighten out by shrinking, said filaments having the capacity to shrink to the extent of their residual shrinkage, maintaining the fabric free from contact with compressing surfaces during said heating, and obtaining as a result of the foregoing steps a finished fabric which by comparison with said greige fabric has a smoother and flatter surface, has substantially the same surface area as said greige fabric, has improved stability, and exhibits breaking strength at least equal to said greige fabric.

4. The method of claim 3 in which the greige fabric is heated in an oxygen-free atmosphere.

5. The method of claim 3 in which the greige fabric is heated while immersed in a high-boiling liquid which is inert to the fabric.

6. The method of claim 3 in which the greige fabric is heated in air.

7. Method of producing stabilized finished fabric from oriented polyethylene polymer monofilaments having a melting point of 110 to 120° C. which comprises heating the polyethylene monofilaments under restraint to a temperature of about 80 to 90° C. for about 1 to 3 seconds, said filaments as a result of the heating having a residual shrinkage of 8 to 20% when tested at 75° C. for 20 minutes, then converting the monofilaments to greige fabric in which the filaments assume a wavy form, heating the greige fabric by means of infrared radiation to a temperature in the range of 20 to 5° C. below the melting point of the polymer while simultaneously holding the fabric along both its length and width to prevent retraction thereof, subjecting the fabric to said latter temperature for about 10 seconds to about 10 minutes, said time and temperature being coordinated so that the filaments straighten out by shrinking, said filaments having the capacity to shrink to the extent of their residual shrinkage, maintaining the fabric free from contact with compressing surfaces during said heating, and obtaining as a result of the foregoing steps a finished fabric whose constituent individual filaments are free of fusion connections to other filaments, said finished fabric by comparison with said greige fabric having a smoother and flatter surface, substantially the same surface area as said greige fabric, and improved stability and breaking strength.

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