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3,226,796

METHOD OF MANUFACTURING ELASTIC FABRIC
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The present invention relates to the manufacture of elastic textile webs and is more particularly concerned with a novel method of manufacturing an elastic fabric or web having predetermined desirable properties of dimensional stability (i.e. resistance to wash shrinkage), weight and construction, together with a predetermined desired stretch.

Narrow elastic fabrics or webs presently available for use as waistbands or for other purposes in under garments and other wearing apparel are commonly manufactured to predetermined standards of weight per unit length, width, construction (ends and picks) and stretch, and to some degree shrinkage, which have been found best for particular end uses. After it is woven, finish (such as starch and optical bleach) is frequently applied to the web, and it is then dried by passage over conventional drying rolls and the web is ready for use. Control of the constructional characteristics and stretch other than shrinkage by appropriate adjustment of tension and other factors during yarn manufacture and the weaving process is well-known. The industry, so far as we are aware, has not found any satisfactory solution to the problem of residual shrinkage remaining in the finished narrow fabrics and which promptly manifests itself upon the first washing of the garment incorporating the same. Such wash shrinkage also disturbs the dimensions of the fabric, its stretch and very notably its appearance in an undesirable manner. Expedients so far attempted to overcome these difficulties have met with little or no success, finished webs currently on the market still having, on the average, a wash shrinkage of about 15%, with attendant secondary undesired adverse effects upon stretch and web dimension.

An apparently obvious solution to the problem turned out to be no solution at all. It was suggested that lengthwise mechanical compaction of the ordinary elastic web by say 15% following its manufacture, either before or after application of finish, should stabilize the fabric, so the wash shrinkage would be negligible since such fabrics originally have a wash shrinkage averaging about 15%. Unexpectedly, while the residual shrinkage was so reduced, the stretch was increased by a factor greatly exceeding 15%, and, at the same time, the weight and closeness of construction of the fabric were undesirably increased, and the end product turned out to be unusable primarily because of the resultant excessive stretch. Thus, mere mechanical compaction of existing fabrics was found not by any means to be a solution to the problem.

We have discovered that in order to produce a narrow elastic fabric with satisfactory properties of stretch and constructional characteristics and which has been rendered shrink-proof or shrink-resistant to a predetermined degree by mechanical lengthwise compaction, it is necessary to modify substantially the construction of the initial fabric prior to compaction, both as to its closeness of construction and its initial stretch. The present invention

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provides a new method of manufacturing an elastic fabric having the desired properties mentioned above.

In further describing the invention it will be found helpful to refer to the following definitions of some of the terms used:

"Stretch" refers to the percentage the fabric may be elongated by tension from a relaxed condition to its maximum length from which it will still return to approximately its original length and without rupture or substantial impairment of its characteristics.

"Closeness of Construction" means, generally speaking, the density of the fabric due to the crimping of warp threads and the frequency per unit of length of picks. Since it is a function of change of length of a given fabric it will be considered primarily in that connection in the present specification.

"Shrinkage" or "Wash Shrinkage" means the percentage contraction of a given fabric when subjected to a normal first washing and tumble drying not under tension.

"Mechanical Compaction" (sometimes called "compressive shrinking") refers to increasing the closeness of construction of the fabric by the application of external physical forces exerted lengthwise of the fabric, as, for example, by the method and apparatus of U.S. Patents 2,765,513 and 2,765,514.

C denotes the percentage the fabric is compacted by mechanical compaction;

S_i refers to the stretch of the initial fabric prior to compaction;

S_c refers to the stretch of the fabric after compaction; S_d refers to the stretch of the compacted fabric after drying;

L_i is the length of any given piece of the initial fabric; L_c is the length of the same piece after compaction;

L_s is the length of the same piece after compaction and during stretch drying;

L_d is the length of the same piece after drying.

Stated in terms of the definitions just given, the problem solved by the present invention is to provide a method of producing a novel elastic fabric or webbing product which when finished has a closeness of construction satisfactory for its intended use, good dimensional stability (i.e. a wash shrinkage which is close to zero), and a stretch which is also satisfactory for the intended use. We have discovered that to produce such a fabric requires, first, the manufacture, as by yarn making and weaving, of a dimensionally unstable initial fabric of initial predetermined different closeness of construction, wash shrinkage, and stretch, which, either in the greige state or if simply finished and dried in the usual way, would be unsatisfactory for the intended end use; second, the mechanical compaction thereof preferably in the presence of moisture, followed, if necessary, by drying, preferably while under tension. The special initial web may be compacted in the greige or, optionally, treated with a finish, with or without drying, prior to being mechanically compacted. If the finish is not applied before compaction it may be applied thereafter prior to stretch drying. The compacted fabric will have the desired closeness of construction, stretch and resistance to shrinkage if the initial fabric from which it is made has been properly constructed, as taught by the present invention. Finish may be applied to the fabric at the most convenient stage in the process prior to final drying.

According to the invention, we first produce elastic yarns of predetermined initial stretch, as, for example, by the method shown in British patent specification No. 461,938 (complete specification filed February 26, 1937). We then weave by known methods, as, for example, by the method disclosed in said British specification, and employing known apparatus (such as that disclosed in U.S. Patent 2,625,959 of Crompton & Knowles) a dimensionally unstable initial elastic textile fabric whose initial closeness of construction and initial stretch (S_i) are both less than desired in the processed fabric by the amounts given in the formulae hereinafter set forth and any given piece of which initial fabric is considered to have a length (L_i) when relaxed. The initial fabric comprises an upper series of picks and a lower series of picks (which may, for example, be of cotton), a plurality of inelastic warp threads (also cotton, for example) at least some of which are interwoven with at least some upper and some lower picks and some of which may be stuffer threads not interwoven, and a plurality of elastic warp threads (rubber, for example, spirally wrapped with a cotton cover as disclosed in said British specification 461,938) normally disposed between the upper series and the lower series of picks but not interwoven therewith. The weaving of the previously processed and selected yarns is conducted under controlled tension to produce in the initial fabric an initial closeness of construction (i.e. fewer picks) less than that present in the compacted fabric by the factor (C) which is substantially the normal wash shrinkage of the initial fabric, where

$$C = \frac{L_i - L_c}{L_i}$$

and also to provide an initial stretch (S_i) of the initial fabric which is less than the stretch (S_c) of the compacted fabric wherein the initial stretch (S_i) is determined by the formula

$$S_i = S_c \left(1 - \frac{C}{100} \right) - C$$

all values being expressed as percentages and then mechanically compacting the fabric lengthwise by the percentage C of L_i .

Further, in accordance with the invention, we preferably conduct the mechanical compaction in the presence of moisture and heat, as by applying steam to the fabric prior to and/or as it is being compacted, and follow these steps with drying the fabric while it is stretched to a length L_s greater than L_c and less than L_i , whereupon it will be found that the finished product will retract to a length L_d slightly less than L_c and have a stretch S_d slightly greater than S_c without impairing the stability imparted by the compaction and will have a more pleasing appearance and smoothness than would otherwise be present. Optionally, finish (such as starch and optical bleach) may be applied to the initial greige fabric prior to the compaction, and the fabric either dried or not prior to being compacted, or, alternatively, finishing may occur immediately after compaction and prior to stretch drying.

A more complete understanding of the invention may be had from the following detailed description taken in conjunction with the accompanying drawings setting forth and illustrating the best mode presently contemplated for carrying out the invention. In the drawings like numerals refer to like elements in the several views, and

FIG. 1 is a somewhat diagrammatic view in elevation with parts in section showing the principal working elements of apparatus useful for carrying out the compacting and drying steps of the novel method of the invention;

FIG. 2 is a plan view of a fragment of a narrow elastic unfinished initial fabric of the invention prior to compaction;

FIG. 3 is a longitudinal sectional view of the same taken on line 3—3 of FIG. 2;

FIG. 4 is a view similar to FIG. 3 of the same fabric after compaction, showing its increased closeness of construction due to increased frequency of picks and the crimping of the inelastic warp threads;

FIG. 5 is a plan view of a fragment of an elastic warp thread employed in the fabric of the invention, illustrating its spiral inelastic two-layer wrapper;

FIG. 6 is a plan view of a fragment of an inelastic warp thread employed in the fabric according to the invention showing its condition of crimp prior to compaction;

FIG. 7 is a similar view of the same fragment showing its condition after compaction, and

FIG. 8 is a chart illustrating the lengths assumed by any given piece of fabric during different stages of the novel process.

Referring to FIG. 1 the apparatus includes the working elements of a machine such as is disclosed in U.S. Patents 2,765,513 and 2,765,514 to which reference may be had for a more detailed description of the apparatus and method of compaction preferably employed in practicing the present invention. The narrow elastic greige fabric as it comes from the loom in its initial unstable and unfinished state is indicated by the symbol F_i . It is led over guide roll 10 optionally fed by rolls 12 and 14 to the steam shoe 16 and compacting blade 17. The shoe 16 is steam heated by chamber 19 and discharges steam from chamber 21 through a felt 23 mounted in the slot 25 into the passing fabric. The shoe 16 has a contoured forward surface 27 and the blade 17, located beneath the shoe, likewise has a contoured surface 28 both of which face the surface of the roll 18, the surface 28 constituting a continuation of the shoe surface 27. The driving roll 18 has a frictional web-gripping surface and is rotated at a predetermined peripheral speed greater than that of the retarding roll 20 whose surface is frictionally web-gripping to an even greater degree than that of roll 18. The fabric is led onto the roll 18 by the surfaces 27 and 28 which are so contoured and adjusted as to increase the arc of contact between the fabric and the roll 18 and thereby increase efficiency of the overall feed of the fabric by such roll and to exert a maximum feeding force on the fabric at the forward edge of the blade which is located so close to the nip of the rolls 18 and 20 that the column of fabric found between such forward edge and the nip is self-supporting against buckling. The yarns and fibers will be mechanically compacted to the desired degree by the great longitudinal forces exerted on the fabric as it passes from the nip formed by the blade and roll 18 to the retarding nip formed by the rolls 18 and 20.

The compacted web F_c may then, in accordance with the invention, be passed through a drier of known construction wherein it is dried under predetermined tension while being pressed by a travelling blanket 24 against a smooth heated drum 26. After leaving the drier the fabric may be folded or wound up in any suitable manner (not shown) for storage and/or transportation and subsequent use.

In accordance with the invention the initial fabric F_i is composed of such yarns and has been so woven as to possess predetermined physical properties of closeness of construction and stretch (S_i). It will also have an initial shrinkage (wash shrinkage) which will determine the degree of later compaction. The initial properties are established in accordance with the discoveries of the present invention. First, the general construction of the fabric will be discussed prior to considering in detail the phenomena and unexpected results which occur from compaction of the fabric.

As seen in FIGS. 2 and 3 a typical narrow elastic fabric according to the invention comprises an upper series of picks 30 and a lower series of picks 32, both of which are usually inelastic cotton threads. A plurality of inelastic warp threads 34 (cotton, for example) are interwoven with the wefts preferably in the manner shown, side by side inelastic warps passing over and under alter-

nate picks and intervening picks to produce a smooth web. Elastic warp threads 36 are disposed between the upper series and the lower series of picks and are not interwoven therewith. Nonelastic stuffer warped threads not interwoven with the picks may also be included. The elastic threads comprise the usual rubber threads, usually rectangular in cross section, covered by a tightly wrapped, spiral cover of cotton threads 38 (FIG. 5) which are so closely arranged with respect to each other when the rubber thread is contracted as substantially to hide the rubber thread from view. The covering threads 38 are in turn bound by an outer spirally wound thread 40 which, however, is wound in a direction opposite to that of the threads 38 and the turns of which are spaced further from one another. For a more detailed description of such elastic yarns reference may be had to The American Cotton Handbook, second revised edition, by G. R. Merrill, A. R. Macormac, and H. R. Mauersberger, published by Textile Book Publishers, Inc., New York, at page 373. For further particulars of the construction of elastic yarns and webbing of the type with which the present invention is concerned see British patent specification No. 461,938 accepted February 6, 1936.

The initial unstable greige fabric of the invention is woven on machinery and using techniques well known in the art. For example, looms disclosed and described in U.S. Patent 2,625,959 may be employed.

However, in accordance with the invention, this initial fabric is provided with special predetermined characteristics and properties so that upon mechanical compaction it will have the hitherto unattainable and desirable advantages of being shrinkproof to the desired degree while also having the desired stretch.

Accordingly, the initial fabric must have a closeness of construction, less than that of similar elastic webs presently on the market, such that the compacted fabric will have a satisfactory closeness of construction. It likewise must possess an initial stretch such that after compaction the final stretch will be of the desired magnitude. We have found that these two properties are not directly inter-related. It might be expected that an elastic web having a wash shrinkage of 15% and stretch of 95% would when compacted by 15% of its original length have a wash shrinkage of substantially zero and a stretch of about 110%. We have found that quite to the contrary the increase in stretch of some samples tested was to 125%, of the order of 30% instead of 15%. The following Table I shows the relationship found between initial and final stretch of a number of specimens compared with the amount of compaction, which is determined in each case by the wash shrinkage of the particular fabric.

Table I

Sample	Control shrinkage, percent	Original stretch (S _i), percent	Compaction (C), percent	Compacted stretch (S _c), percent
1	18	80	19	120
2	12.5	105	10	125
3	12.7	80	12.7	105
4	14.1	87.5	14	110
5	10.4	95	10.5	110
6	14	90	14	120
7	9.3	95	9.5	115
8	20	85	20	125
9	18	70	19.5	120

The explanation of the unexpected results and the reason why prior workers have apparently been unsuccessful in finding a way to manufacture a dimensionally stabilized elastic web lie at least in part in the peculiar reaction to compaction of the covered rubber threads employed as some of the warp threads in the fabric. From FIG. 5 it will be seen each rubber thread carries a tight inelastic spirally wound cover applied at a certain angle of twist. This cover is surmounted by another spirally but less closely wound thread which is wound in the opposite direction. The two-ply cover thus formed grips and in-

hibits the contraction of the rubber thread and since, in the normal course of manufacture the rubber thread is under predetermined tension, the initial fabric will have an initial stretch related not only to the tension and characteristics of the rubber itself but also to the tightness of its inelastic cover. We have found that compaction of a web containing elastic warp threads of the type just described tends to change the angle of twist of the spiral cover threads, and even a small change in such angle will have a pronounced effect on the future stretch and contraction of the rubber thread which is thereafter gripped less tightly by its cover and is more free to elongate as well as to contract, especially the latter. The stretch of the fabric also may well be affected by the increase in closeness of construction due not only to the bunching more closely together of the picks, as clearly appears from a comparison of FIG. 3 with FIG. 4, but also from the crimping of the inelastic warp threads. It will be seen that the warp thread shown in FIG. 6 before compaction is crimped to a substantially lesser degree than the same thread after compaction, as shown in FIG. 7.

What ever the explanation for the behavior of these elastic webs, we have found that the initial stretch which must be built into the initial fabric in order to produce a commercially satisfactory compacted fabric, rendered shrink-proof to a desired degree by mechanical compaction of the same order as its wash shrinkage, is capable of determination by the following formulae:

If the percentage of compaction C which equals substantially the normal wash shrinkage of the particular fabric prior to compaction is

$$C = \frac{L_i - L_o}{L_i}$$

then the required initial stretch S_i of the unstable unfinished initial fabric is

$$S_i = S_c \left(1 - \frac{C}{100} \right) - C$$

S_i, C_o and C being expressed as percentages.

When the fabric is then compacted lengthwise by C percent of L_i an elastic fabric shrink-free within commercially acceptable limits and having the proper closeness of construction and the commercially desired stretch will result. Having thus established the requisite initial stretch for the unstable initial fabric, it is possible by known methods to produce yarns and to weave such a fabric which, when compacted to the extent C will yield such desired end result within commercially tolerable limits.

While there is a wide variation among commercially sold elastic webs as to pick count, we have found that, as would be expected, the pick count of the special initial fabric of the invention will increase in proportion to the degree of compaction. Thus if C is 15% the pick frequency per unit of length will be increased 15% when the fabric is compacted. It follows that the initial fabric should be woven with a pick count of about 15% less than the desired count in the completed fabric. An example of one web, in accordance with the invention, was a narrow elastic fabric, manufactured to have the necessary initial stretch, where it was desired to have a pick count of 66 picks per inch in the finished fabric. The initial greige fabric was woven with a count of 58 picks per inch, a wash shrinkage of 15% and a stretch of 80%. After compaction wash shrinkage was substantially zero, stretch was increased to 115%, and the pick count had increased to about 66 picks per inch. This increase, while not precisely 15%, was within acceptable limits.

While the fabric as it emerges from the nip formed between the rolls 18 and 20 of the compacting machine shown in FIG. 1 will be found to be satisfactorily stabilized and to have proper stretch characteristics, it is moist and its appearance may not be acceptable. Tensionless drying but perhaps accompanied by ironing would normally be suggested as the proper next step to avoid removal of the compaction previously produced. We have

found, on the contrary and surprisingly, that heating and pressing the fabric while tensioned to a length L_s beyond length L_c but less than length L_1 , quite unexpectedly does not impair the work done by compaction, while at the same time improving the hand and appearance of the fabric to a remarkable degree. In other words, the fabric compacted in accordance with the invention possesses the unique property of being dimensionally stable even when subjected to tensions during drying.

This drying under tension is accomplished in known apparatus disclosed diagrammatically at the left of FIG. 1. The blanket 24 is run at sufficient speed so that the fabric F_c is tensioned as it enters between the blanket and the drum 26 and is held under such tension until discharged from the blanket and drum. The tension pulls it out to a length L_s greater than L_c but less than L_1 sufficient to present a flat fabric to the dryer. After drying, the relaxed fabric promptly contracts to a length L_d slightly less than L_c . The dimensional stability of the fabric is unimpaired and it retains the desired stretch and at the same time possesses the desired appearance.

Typical examples of length increments of the fabric processed according to the invention appear in FIG. 8. The length L of any given piece of fabric is shown on a logarithmic scale during different stages of processing. If L_1 is 100, L_c is 86; L_s during stretch drying is 92 and ultimate L_d in a relaxed condition after drying becomes 84.

We have found that the additional changes produced in the fabric by the drying step are not sufficiently substantial to require modification of the formula used to determine S_1 which will produce the desired S_c . In other words, the fact that drying under tension will permit the web to take up to a final L_d which is slightly less than L_c and will produce a corresponding slight change in the final stretch does not impair the validity of the formula based upon the values immediately before and immediately after compacting. Tests on a number of different samples of webs confirm this fact as indicated by the following Table II wherein the samples tested were woven to the predetermined S_1 , were treated with a finish after being woven and then conventionally dried on cans, prior to being run through the compacting and stretch drying devices:

Table II

Sample No.	Initial wash shrinkage, percent	Initial stretch (S_1), percent	Percentage compaction (C), percent	Final stretch (S_d), percent	Residual wash shrinkage, percent
1-----	12.7	80	12.7	105	0
2-----	14.1	87.5	14	110	1/2
3-----	14	90	14	120	0
4-----	9.3	95	9.5	115	0

For the compacted fabrics of the invention to be commercially salable they ordinarily must be treated with a finish comprising starch and an optical bleach during the course of manufacture. If this finish is applied to the specially constructed greige fabric and the latter dried in the usual way by passage over stacked drying cans the thus prepared fabric will be found entirely suitable for further processing in accordance with the invention. Weaving and application of finish may occur at one mill and the fabric shipped elsewhere for further processing.

If desired, the step of applying finish to the fabric may be included more directly in the process of the invention, thus permitting continuous manufacture of the novel fabric in a single operation at one location. For example, the greige web F_1 , specially woven, may flow directly from the loom to the compacting machine. Finish may be applied to the fabric by sprayer 42 (or in any other suitable manner) prior to entering between the shoe 16 and roll 13. Alternatively, finish may be applied to the web F_c as it leaves the nip of the rolls 18 and 20

prior to drying, as by means of the sprayer 22. The latter procedure may be preferable to avoid gumming of the shoe 16, blade 17, and rolls 18 and 20 with the finish material. While we have disclosed and described the invention in terms of a single end of narrow elastic fabric, it will nevertheless be understood that more than one end may be processed side by side simultaneously by using equipment of suitable width. Furthermore, the method of the invention is applicable to webs of widely varying widths which otherwise are constructed in accordance with the teachings of the invention.

While we have herein disclosed and described preferred methods and machines for carrying out our invention it will be understood that the invention may be practiced on other machines, and the invention is intended to be limited only by the proper scope to be afforded the appended claims.

We claim:

1. The method of making an elastic textile fabric which after processing has a predetermined closeness of construction, dimensional stability and stretch, which method comprises

first construction a dimensionally unstable initial textile fabric having an initial length L_1 of any given piece when relaxed, greater than L_c of said given piece after processing,

said initial fabric comprising an upper series of picks and a lower series of picks, a plurality of inelastic warp threads at least some of which are interwoven with at least some upper and some lower picks, and a plurality of elastic warp core threads each having a tight inelastic spirally wound cover thereon.

said initial fabric having

an initial closeness of construction which is less than that of the fabric after processing by the percentage C, where C is substantially the normal wash shrinkage of the initial fabric, and, an initial stretch S_1 which is less than the final stretch S_c of the fabric after processing wherein S_1 is determined by the formula:

$$S_1 = S_c \left(1 - \frac{C}{100} \right) - B$$

S_1 , S_c and C being expressed in percentages, and mechanically compacting said fabric lengthwise by C percent of L_1 to a length of L_c , the mechanical compaction changing the angle of the spiral cover of the composite warp core threads to reduce the grip on the elastic core threads thereof and increasing the closeness of construction to thereby provide increased longitudinal stretch in the fabric over that normally expected.

2. The method as defined in claim 1 wherein the step of mechanical compaction is performed in the presence of moisture and is followed by the step of drying the fabric.

3. The method as defined in claim 1 wherein finish is applied to the initial fabric prior to the step of mechanically compacting the same.

4. The method as defined in claim 1 wherein the step of mechanical compaction is performed in the presence of moisture and

is followed by the step of drying the fabric while stretched to a length less than L_1 but greater than L_c and

thereafter allowing the dried fabric to relax.

5. The method as defined in claim 4 wherein finish is applied to the initial fabric prior to the step of mechanically compacting the same.

6. The method as defined in claim 4 wherein finish is applied to the fabric after the step of mechanically compacting the same and in advance of the drying step.

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DONALD W. PARKER, *Primary Examiner*.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

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Kenneth R. Fox et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 40, for "C_c" read -- S_c --; column 8, line 23, for "construction" read -- constructing --; same column 8, lines 42 to 44, the formula should appear as shown below instead of as in the patent:

$$S_i = S_c \left(1 - \frac{C}{100}\right) - C$$

Signed and sealed this 27th day of December 1966.

(SEAL)

Attest:

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