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METHOD OF PRODUCING SHRINK-FREE KNITTED FABRIC HAVING CHARACTERISTICS OF ELASTIC RESTORABILITY

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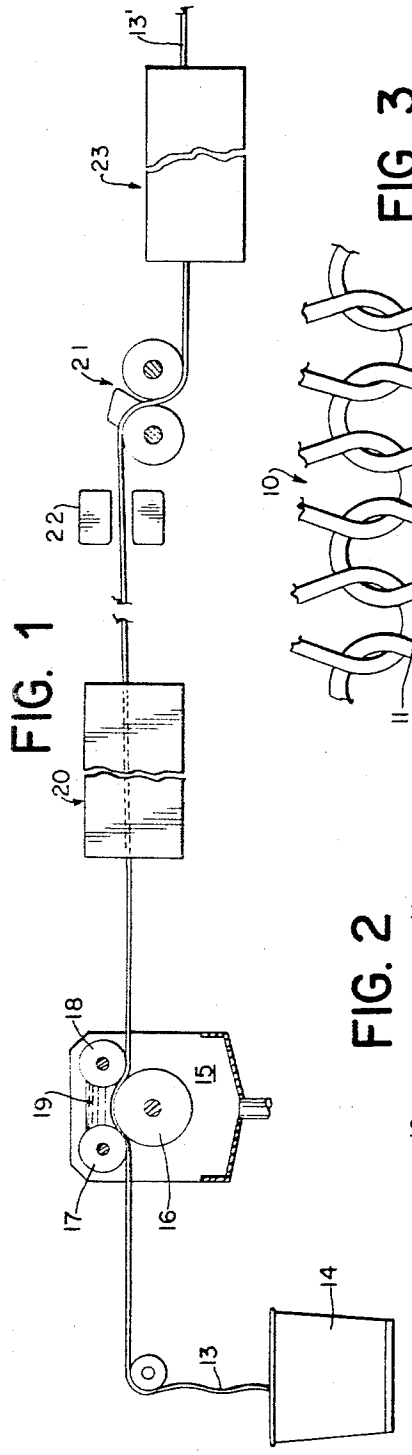


FIG. 1

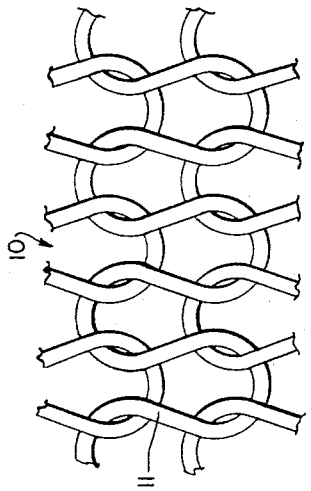


FIG. 3

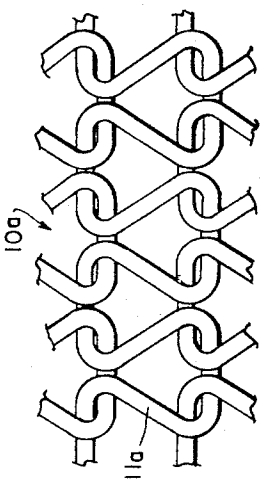


FIG. 5

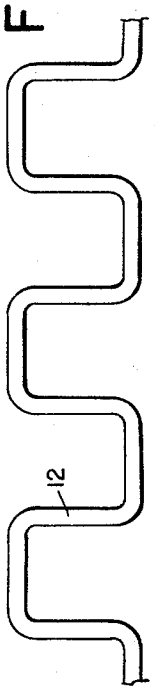


FIG. 6

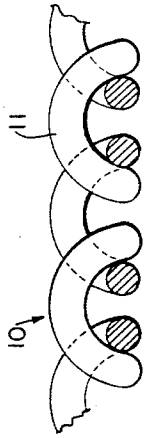


FIG. 2

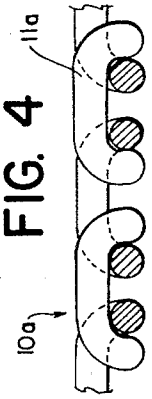


FIG. 4

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3,438,106

METHOD OF PRODUCING SHRINK-FREE KNITTED FABRIC HAVING CHARACTERISTICS OF ELASTIC RESTORABILITY

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Continuation-in-part of application Ser. No. 427,292, Jan. 22, 1965. This application Aug. 17, 1966, Ser. No. 573,039

Int. Cl. D06c 21/00

U.S. Cl. 28—74 3 Claims

ABSTRACT OF THE DISCLOSURE

The invention relates to the production of shrink-free, elastic knitted fabrics. The invention provides a novel method for producing shrink-free elastic knitted fabrics which includes impregnating the fabric with a stabilizing resin and mechanically compressing the knitted fabric an amount more than necessary to provide shrinkage control but less than that amount which results in discernible pleats. The stabilizing resin is subsequently cured to provide the finished product.

This application is a continuation-in-part of application Ser. No. 427,292, filed Jan. 22, 1965 and now abandoned.

The present invention relates to knitted fabrics, and is directed more specifically to the treatment of knitted fabrics to stabilize them in a shrink-free condition and to impart thereto characteristics of elastic restorability. In more specific aspects, the invention relates to a fabric treated in accordance with the invention and to a yarn derived from the fabric.

In a knitted fabric, as distinguished from a woven fabric, the fabric is constructed in both its widthwise and lengthwise directions by a series of interlocked loops formed by a continuous yarn or a series of continuous yarns. As a result, a knitted fabric has a substantial interdependency of its length and width dimensions, and it is also easily distortable. These characteristics have made the knitted fabric a desirable material for many articles of clothing, because of the ability of a garment, formed of knitted fabric, to conform and to change its shape to accommodate body movements, etc.

Because of the inherently distortable nature of knitted fabrics, and because of the distortions inevitably imparted to the fabric during its construction and processing shrinkage of knitted fabric, particularly in a lengthwise direction, has always been a significant problem. Many of the problems related to such knit fabric shrinkage have been alleviated by certain important inventions of the recent past, including particularly those described and claimed in United States Letters Patent No. 3,015,145 and No. 3,015,146, granted Jan. 2, 1962, to Eugene Cohn et al., and United States Letters Patent No. 3,083,435, granted Apr. 2, 1963, to Eugene Cohn et al. These and related inventions have, for the first time, enabled knitted fabric processors to treat knitted fabric, on a commercial scale, in a manner to impart initially to the fabric an artificial lengthwise compression, or compaction, corresponding in overall extent to the amount of inherent lengthwise shrinkage in the fabric, with due regard for the necessary handling of the fabric during its manufacture into garments, etc. For the first time, these inventions have enabled knitted fabric and garments made from knitted fabric to be marketed on a large scale with a guarantee of less than 1 percent lengthwise shrinkage, as had been a conventional business practice for many years in connection with fabrics of woven construction.

Although the ability to mechanically impart longitudinal compressive shrinkage to knitted fabrics, to an extent enabling them to be sold with a guarantee of less than 1 percent shrinkage, represented an advance of extraordinary significance in the field of knitwear, and greatly increased the desirability and usefulness of knitted fabrics and garments made therefrom, utilization of compressively preshrunk knitted fabric has been to a large degree, limited to such garments as underwear, sleepers, polo shirts, and the like, and was not widely accepted for such applications as women's outerwear, for example. In this respect, conventional fabrics (i.e., fabrics containing or formed entirely of cotton or other natural fibers, cellulosic fibers, etc., referred to herein as "ordinary" fibers) even when mechanically compressively preshrunk to a guaranteed shrinkage level of less than 1 percent could be distorted and drawn out of shape, at least until laundered on one or more occasions to become finally relatively stabilized. While this is not particularly a disadvantage with respect to T-shirts, polo shirts, underwear items, sleepers, and like items, it would represent a disadvantage with respect to higher fashion outerwear, where precise form and fit of the garment are significant. This has largely limited the fashion outerwear field to knitted fabrics of expensive construction, utilizing special yarns, such as special thermoplastics, spandex elastic yarns, and the like.

In accordance with the present invention, further fundamental improvements have been made in the processing of knitted fabrics, containing or formed entirely of ordinary fibers, which enable shrink-free knitted fabric to be desirably and advantageously utilized in such demanding applications as fashion outerwear, for example. To this end, the process of the invention provides for the compressive shrinking of the fabric by mechanical means to a predetermined and controlled extent, and the stabilization of the fabric in such compressively pre-shrunk condition, in a manner which imparts characteristics of elastic restorability to the fabric. The extent of the mechanical compressive shrinkage is critical to the process, as is the manner in which the stabilization of the fabric is effected. Fabric treated in accordance with the invention may be merchandised with a firm guarantee of lengthwise shrinkage of less than 1 percent, under the severe conditions of washing and tumble drying, and yet is most desirably suited to such demanding applications as fashion outerwear, because of the ability of the treated fabric to conform, to acommodate the stresses and the distortions of body movements, and to return to and retain its initial form and shape.

As a more specific aspect, the process of the invention involves carrying out the mechanical compressive shrinking operation to impart a precisely controlled amount of compressive shrinkage to the knitted fabric prior to its stabilization. The minimum level of compressive shrinkage imparted to the fabric is that which at least slightly exceeds the inherent residual shrinkage of the raw fabric when subjected to wash and tumble dry testing. This critical minimum will vary from one fabric to another, as a function of fabric construction, previous processing and the like, but can be readily determined with respect to any fabric by measuring its length before and after washing and tumble drying in accordance with a standard procedure.

In the construction and preliminary processing of knitted fabric, significant tensions and lengthwise elongations are introduced into the fabric (e.g., at least 15–20 percent elongation is very common), and controlling and eliminating the effect of these tensions and elongations

represents a profound challenge to the processor of knitted fabric. The processor of woven fabric, on the other hand, while faced with problems of a somewhat related nature, is able to deal with them at an entirely different order of magnitude, to such an extent that the problems are in reality different in kind as well as different in amount. Thus, in virtually all situations contemplated by the invention, the minimum mechanical compressive shrinkage required to be imparted to the knitted fabric to exceed its inherent residual shrinkage will be at least 15 percent, which is grossly in excess of anything contemplated for the treatment of woven fabrics and, indeed, far beyond the capacity of most equipment and processes to deal with.

The maximum amount of mechanical compressive shrinkage tolerated by the process is that amount at which crimping or pleat formation appears and becomes noticeable to the eye. The maximum amount of mechanical compressive shrinkage tolerated by the process will vary from one fabric to another but, again, is readily determinable with respect to any given fabric by progressively increasing the amount of compressive shrinkage until the undesirable crimp or pleat formations become apparent. In virtually all cases contemplated by the invention, the maximum amount of mechanical compressive shrinkage tolerated will not be significantly in excess of 30 percent.

Although it is contemplated that the invention may be practiced with compressive shrinkage equipment of more than one type, significantly superior results are achieved with the equipment and processes of the beforementioned patents of Eugene Cohn et al., which readily accommodate the compressive shrinkage of knitted fabrics over the full operative range of from about 15 percent, minimum, to not significantly in excess of 30 percent, maximum. Compressive shrinkage systems which are incapable of imparting at least 15 percent compressive shrinkage would, of course, be wholly inoperable in the process. Systems capable of inducing up to, say, 20 percent compressive shrinkage could be utilized in the practice of the process, but would be limited with respect to the range of fabrics capable of being handled and the variety of fabrics characteristics capable of being achieved.

Stabilization of the compressively treated fabric is effected, in accordance with the process of the invention, by impregnating the knitted fabric, prior to compressive shrinkage treatment, with a wash-and-wear type stabilizing resin. The resin characteristics are chosen to enable the impregnated fabric to be dried, if necessary, and exposed to such heat and manipulation as is appropriate to the compressive shrinkage operation, without causing the resin to become set or cured. After compressive shrinkage has been imparted to the impregnated fabric, it is then heated sufficiently to cure and set the resin and impart substantial permanence and elastic restorability to the fabric.

The process of the invention represents a significant advance in the knitwear field, in that stability of the fabric and its ability to elastically restore itself to its stabilized form can be imparted to the fabric through the treatment of the so-called ordinary fibers. Heretofore, it has been necessary to utilize synthetic stretch yarns, such as spandex and other expensive yarns in the construction of the fabric in order to achive the desired stability and restoreability.

In processing a knitted fabric in accordance with the invention, appropriate balance is maintained or established between the elastic restorability of the fabric in both its lengthwise and widthwise directions, unless other characteristics are specifically desired in the finished product.

A more specific facet of the invention involves the preparation of special purpose yarns by first treating knitted fabric in accordance with the process principles outlined above to provide a shrink-free, stabilized fabric, and then "de-knitting" the fabric to derive individual yarns having advantageous characteristics and configurations. By reason of the substantial mechanical compressive shrinkage imparted to the fabric in accordance with the process, the individual knitted loops of yarn are reformed into a highly angular configuration, and are subsequently stabilized in such configuration by curing of the stabilizing resin. When such fabric is "de-knitted" the derived yarns retain an angular, sinuous configuration and have a desirable degree of lengtthwise elasticity. Special and desirable effects can be achieved by subsequently utilizing these elastic yarns in the construction of other fabrics.

For a better understandinng of the invention, reference should be made to the following detailed description and to the accompanying drawings, in which:

FIG. 1 is a simplified, schematic representation of a processing line advantageously utilized in carrying out procedures according to the invention;

FIG. 2 is an enlarged, fragmentary, cross-sectional view of a conventional untreated jersey knit fabric;

FIG. 3 is an enlarged, fragmentary, plan view of the untreated fabric shown in FIG. 2;

FIG. 4 is an enlarged, fragmentary, cross-sectional view of the fabric of FIG. 3 after treatment in accordance with the invention;

FIG. 5 is an enlarged, fragmentary, plan view of the treated fabric of FIG. 4; and

FIG. 6 is an enlarged illustration of a stretch yarn after the removal from the treated fabric of FIG. 5.

Referring now to the drawings, and initially to FIGS. 2 and 3 thereof, there is illustrated a typical plain jersey knitted fabric **10**, which comprises a plurality of transverse courses of knitted loops **11**, so arranged that the loops of one course interlock with the loops of adjacent courses. In their "normal" condition, the individual loops of the fabric are more or less rounded in form, and by reason of such rounded form the knitted loops can accommodate a certain amount of elastic distortion in both widthwise and lengthwise fabric directions. The nature and extent of the normal elastic distortion is a wide variable, depending upon such fabric construction features as the size and nature of the yarns, tightness and looseness of the knit, the knitted structure itself, etc.

The knitted fabric of the invention may advantageously be formed of 100 percent cotton or other natural fibers, or may be partly of natural fibers and partly of ordinary man-made fibers. It is conceivable, in fact, that the proportion of ordinary fibers (natural and/or man-made) could be in the minority, it being understood, however, that in the finished product, the important characteristics of the treated fabric are derived primarily from the treated ordinary fibers and yarns, and not from heat setting or other treatment of special man-made fibers such as thermoplastic fibers, etc.

In accordance with the procedure of the invention, the knitted fabric, typically and advantageously in tubular form, but also in flat, open-width form in appropriate cases, is thoroughly impregnated with a liquid solution of a heat-curable "wash-and-wear" type resin. A specific, advantageous resin for this purpose is a solution of Permafresh (TM) Reactant 183, as made available as of Jan. 22, 1965 by the Chemical Products Division of Sun Chemical Corporation, Wood River Junction, R.I. This resin is indicated by the manufacturer to be a methylol imidazolidone type, which is covered by a United States Patent No. 3,049,446. A desirable and advantageous solution of the designated resin for the purpose intended includes about 25 pounds of the Permafresh Reactant 183, as designated above, in a water-diluted 20 gallon mixture. Additives, such as fiber lubricants, catalysts and wetting agents, also are utilized.

The above-described resin has particular advantages in that, after impregnation of the fabric, the resin remains stable for a considerable period of time, until subsequently set in a heat-curing operation. Thus, impregnated fabric may, where appropriate and desired, be stored,

transported, or given other processing treatments between an impregnating stage and a curing stage. It will be understood, of course, that the present invention is not limited to the particular resin specified above, but can utilize a variety of similar resins, which may be designated for convenience as yarn fixing resins.

In the case of the specified resin, incorporating Permafresh Reactant 183, and other resins applied from a liquid solution, it is desirable to reduce the moisture content to a desired level for the compressive shrinkage operation. The precise moisture level, after the drying stage, will be a function of the particular type of compressive shrinkage operation utilized, inasmuch as certain compressive shrinkage procedures in current use advantageously utilize essentially dry fabric (less than 10 percent moisture), whereas others utilize relatively moist fabric (e.g., around 20 percent). In any event, where the resin is a heat-curing resin, the heat of the dryer should be maintained at a level which will not promote curing. In the case of the specified Permafresh Reactant 183, which is heat-curable in a temperature range of from about 300° F. to 350° F., drying should be carried out at a temperature below 300° F. and more advantageously at a temperature in the range of 200° F. to 260° F. The final moisture content of the fabric may be regulated by controlling the total drying time, which is generally more preferable than varying the drying temperature.

In a continuous process, the fabric may be conveyed directly from the dryer to a compressive shrinking apparatus, although it is possible with many deferred curing resins, and in particular with the specified Permafresh Reactant 183, to store the dried, impregnated fabric for a period of time and even to perform certain other operations, such as stripe matching, on the fabric, if desired. In either case, the fabric ultimately is distended laterally to predetermined uniform width, perhaps steamed, and then directed into a compressive shrinkage apparatus, which most advantageously is of the type illustrated, described and claimed in the before-mentioned Eugene Cohn et al., United States Patents No. 3,015,145, No. 3,015,146, and No. 3,083,435, but may be of other design as will appear. The compressive shrinkage apparatus receives the impregnated fabric in flat form and at a uniform, distended width and causes the fabric to be fed into compressive shrinking zone at a first predetermined speed and to be controllably released from said zone at a second predetermined and substantially slower speed, such that the fabric is substantially shortened in length within the compressive shrinking zone. As will be understood, such reduction in length is not necessarily accompanied by corresponding alteration in fabric width, as usually would be the case by reason of the length-width interdependency of knitted fabrics. By means of heat and/or pressure applied to the compressively shrunk fabric, within or upon leaving the zone, the fabric is temporarily "set" in its shortened, laterally distended condition. As will be understood, the shortening of the knitted fabric is brought about by readjustment of the fabric stitches relative to each other and also by reformation of the stitches themselves. The arrangement is such that the fabric, as it emerges from the compressive shrinkage apparatus, actually has an altered structure, at least with reference to the form of the knitted stitches or loops.

The above-described alteration of fabric structure may be better understood by reference to the plain jersey knitted cotton fabric illustrated in FIGS. 2–5. Thus, FIGS. 2 and 3 are representative of a jersey knitted fabric **10** in its "normal" condition, in which the courses of knitted loops **11** are rounded and fully formed. In FIGS. 4 and 5, the fabric **10***a* is shown after compressive shrinkage treatment to the extent contemplated by the invention, and the interlocked stitches **11***a* are more angular and substantially shortened in the lengthwise direction, without significant change in the widthwise spacing of the stitches, so that the fabric is structurally shortened.

The specific procedures to be carried out between impregnation of the fabric and compressive shrinkage thereof will vary according to the specific nature of the compressive shrinkage treatment. In a typical treatment utilizing apparatus of the before-mentioned Eugene Cohn et al. United States patents, the fabric is dried after impregnation, and then steamed slightly immediately before compressive shrinkage to impart a controllably uniform and small amount of moisture to the fabric to assist the actual compressive shrinkage operation. In the case of so-called "wet" processes, such as with apparatus according to the Chatfield United States Patent No. 2,522,663, granted Sept. 19, 1950, the fabric may be conveyed directly from the impregnating equipment to the compressive shrinkage equipment or it may be dried slightly, if necessary to reduce the moisture level to about 20 percent. In the case of so-called "wet" treatments, the fabric will be dried after the compressive shrinkage operation.

In accordance with one of the significant aspects of the invention, the impregnated fabric is treated in the compressive shrinkage stage so as to emerge therefrom with a predetermined amount of imparted compressive shrinkage, within a precise and critical range. The minimum amount of compressive shrinkage acceptable in carrying out the process of the invention is that amount which will at least slightly exceed the inherent residual lengthwise shrinkage of the raw fabric. This minimum level of compressive shrinkage may be determined readily, with respect to any piece of fabric, by subjecting a sample of the fabric to standard wash and tumble dry testing procedures, and comparing the length of the fabric before and after the testing procedures. If, for example, the fabric sample measured 80% of its initial length after undergoing the wash and tumble dry procedures, the compressive shrinkage operation would be adjusted to impart 20% or more compressive shrinkage to the incoming fabric. In virtually all instances, the inherent residual shrinkage of a knitted fabric is such that at least 15% lengthwise compressive shrinkage is required to be imparted thereto, in order to exceed the inherent residual shrinkage.

The maximum amount of compressive shrinkage tolerated in the practice of the invention is that amount at which the fabric becomes crimped or pleated to an extent which is apparent to the unaided eye. Experience indicates that, for a given fabric, this maximum level of compressive shrinkage is readily ascertainable by a test procedure in which the amount of compressive shrinkage is gradually increased. As the amount of shrinkage reaches the maximum acceptable level for the fabric, a definite and detrimental change in the appearance of the fabric is readily noticeable. In virtually all instances, the maximum acceptable level of compressive shrinkage will not significantly exceed 30%.

After compressive shrinkage to an extent contemplated by the invention, the unstabilized fabric, when subjected to standard wash testing (wash and tumble dry, as described hereinafter) would tend to "grow" or increase slightly in length.

A reliable wash and tumble dry test procedure suitable for the purposes of the invention involves first washing the fabric sample in a conventional home-type automatic washer, using a "hot" wash cycle of approximately 30 minutes, with a "medium" load for the machine, and using a standard, commercially available home laundry detergent. The washing cycle should be followed by two rinse cycles and a standard spin cycle for the machine. Subsequent to the foregoing washing procedure, the fabric sample should be dried in a conventional automatic home-type tumble dryer, operated at the manufacturer's recommended temperature for the fabric, but not less than 120° F., until the sample feels dry to the hand. The machine should be operated at its normal tumble speed un-

der medium load specified for the machine. Measurement of fabric dimensions is made by placing permanent marks on the fabric samples and measuring the distance between them before and after the wash and tumble dry procedure. The fabric should be reasonably free of wrinkles and distortions during the taking of measurements, but should not be ironed. Preferably, the samples should be conditioned by being directly exposed to a standard atmosphere of about 65% relative humidity and 70° F. for a period of at least ½ hour and preferably about 3 hours.

Although it is possible to perform the processes of the invention with several different types of mechanical compressive shrinkage apparatus, the systems of the beforementioned Eugene Cohn et al. Patents No. 3,015,145, No. 3,015,146, and No. 3,083,435 are significantly advantageous over all other known systems, because of the ability of the patented system to accommodate the entire critical range of compressive shrinkage for a wide variety of knitted fabrics. In this respect, the system of the before-mentioned Eugene Cohn et al. patents is readily able to impart to a fabric compressive shrinkage in amounts up to and somewhat exceeding 30% without forming detrimental pleats, and the apparatus is easily controllable over the entire critical range from about 15% compressive shrinkage to not significantly in excess of 30%. Other commercially available forms of compressive shrinkage apparatus, which are able to impart a maximum of, say, 20% compressive shrinkage without forming detrimental pleats would be capable of utilization in the practice of the invention but would be limited to the processing of a limited range of fabrics which would not require extensive compressive shrinkage in order to achieve the results sought for and required by the process. By way of example only, and not of limitation, it is envisioned that it might be possible to usefully employ to a limited extent in the process of this present invention compressive shrinkage apparatus such as illustrated in the Chatfield Patent No. 2,522,663, granted Sept. 19, 1950, and the Wrigley et al. United States Patent No. 2,263,712, granted Nov. 25, 1941, as well as so-called "microcreping" apparatus (which shortens fabric by introducing small, undiscernible pleat formations therein).

In the preferred and advantageous procedure of the invention, in which the compressive shrinkage apparatus is in accordance with the beforementioned Eugene Cohn et al. patents, a temporary set may be imparted to the fabric by the application of heat and pressure as the fabric exits from a short compressive shrinkage zone of the equipment, but the nature and extent of the heat set need not be such as will advance the resin to its cured condition. As may be better understood upon reference to the before-mentioned Cohn et al. Patent No. 3,015,145, the compressive shrinkage apparatus includes a pair of nip-forming rollers, and at least one of these may be supplied with an internal heating medium in the form of steam, heated oil, or the like.

Prior to compressive shrinkage operation, the fabric is laterally distended in a controlled manner to a predetermined uniform width, and the fabric is directed into the compressive shrinkage operation while such predetermined width is maintained. In addition to providing for necessary uniformity of fabric presentation to the compressive shrinkage operation, the lateral distention of the fabric can be so controlled in extent as to enable a desired balance to be maintained between lengthwise and widthwise shrinkage and elastic restorability in the finished product. It will be understood, in this respect, that a knitted fabric may have varying degrees of inherent widthwise elasticity, depending upon its knitted construction as well as upon the various treatments to which the fabric has been subjected. Most advantageously, fabric processed in accordance with the invention will have a maximum shrinkage characteristic of 1% in length and 5% in width and a maximum growth characteristic of 5% in length and 1% in width, by standard wash and tumble dry test.

After compressive shrinking, the fabric, while being maintained in a condition free of lengthwise and other tensions, is conveyed through a heating chamber in which the impregnated resin is permanently cured. In the case of the specified resin mixture, including Permafresh Reactant 183, final curing may be carried out by heating the fabric to a temperature in the range of 300° F. to 350° F. and advantageously by heating it for about one and one-half to five minutes at a temperature of around 325° F. This serves to permanently but elastically set the fabric structure in a compressively shrunk form such as illustrated, in the case of plain jersey knit fabric, in FIGS. 4 and 5. The individual yarns of the fabric also assume permanently set but elastically distortable characteristic forms related to the original loop structure of the knitted fabric but typically of more angular nature. Thus, in the case of plain jersey knitted cotton fabric, the individual yarns **12** (FIG. 6), when separated from the fabric body and thereby freed of the influence of adjacent, interlocked yarns, assume a characteristic form remarkably similar to a square wave.

A particularly advantageous processing line for carrying out one of the procedures of the invention is reflected diagrammatically in FIG. 1, in which knitted fabric **13**, advantageously but not necessarily in tubular form and including af least a significant amount of natural or ordinary man-made fibers, is taken from a supply container **14** and directed to an impregnating apparatus generally designated by the reference numeral **15**. Most advantgeously, the impregnating apparatus is constructed generally in accordance with the Samuel Cohn et al. United States Patent No. 3,207,616, granted Sept. 21, 1965. In general, such an impregnating apparatus includes three rollers **16**, **17**, **18** arranged in triangular configuration and forming among them a reservoir **19** for the impregnating resin solution.

Fabric leaving the impregnating apparatus is directed to a dryer, generally designated by the reference numeral **20**, which advantageously is constructed in accordance with the Samuel Cohn et al. United States Patent No. 3,102,006, granted Aug. 27, 1963, and the Samuel Cohn et al. United States Patent No. 3,065,551, granted Nov. 27, 1962. A dryer constructed in accordance with the beforementioned patents assures uniform, controlled drying of the fabric while maintaining it free of tensions and distortions. Where a wet process is utilized during compressive shrinkage, however, the dryer **20** may be used to a lesser degree or, possibly, eliminated altogether. At this stage, other processing operations may be performed on the fabric, as may be appropriate, such as stripe matching, stitch line straightening, etc.

After drying, the fabric may be stored or otherwise processed, if desired, or it may be conveyed directly to a compressive shrinking operation. At this stage the resin impregnant contained in the fabric is in a water soluble form.

Whether directly or after interruption, the impregnated fabric is eventually advanced from the drying stage to a compressive shrinkage apparatus, designated generally by the reference numeral **21**. As previously mentioned, the compressive shrinkage apparatus is most advantageously in accordance with the Eugene Cohn et al. Patents Nos. 3,015,145, 3,015,146, and 3,083,435.

In the schematic illustration of FIG. 1, which incorporates a "dry" process compressive shrinkage apparatus, it may be advantageous to provide steamers **22** directly in advance of the compressive shrinking apparatus, for imparting a desired, uniform moisture content to the fabric as it enters the compressive shrinking zone. Steaming facilities would be particularly desirable in cases where there is a substantial interruption between drying of the fabric and subsequent compressive shrinking, in order to provide uniform heat and moisture conditions to the fabric immediately before compressive shrinking.

Typically and advantageously, the compressive shrink-

age apparatus includes facilities for bringing the fabric to an elevated temperature. This may be desirable for a number of reasons, including imparting a temperature "set" to the fabric in its compressively shrunk condition. In the apparatus of the Eugene Cohn et al. Patent No. 3,015,145, for example, heat exchange medium is supplied to at least one of a pair of processing rollers, and advantageously also to a confining shoe which acts upon the fabric during compressive shrinkage. However, the fabric advantageously is not, at this stage, heated to such a temperature and for such a duration as to bring about substantial curing of the impregnated resin.

After the compressive shrinkage operation, the fabric is conveyed, by suitable means which maintain it free of tensions, particularly in the lengthwise direction, into a curing chamber, designated generally by reference numeral **23**. The curing chamber may be in the form of a dryer and, like the dryer **20**, advantageously is construced in accordance with the principles of the beforementioned S. Cohn et al. Patents Nos. 3,102,006 and 3,065,551. In the curing dryer **23**, the fabric is maintained in a relaxed state, and brought up to the curing temperature of the resin, so that the completed fabric **13'**, emerging from the exit side of the curing chamber **23**, is permanently set.

In appropriate cases, where interrupted procedures are employed, the same physical unit may serve in the capacity of a dryer **20** and a curing chamber **23**, it being understood that the unit will be operated at a lower temperature (e.g., 200° F. to 260° F.) for drying purposes and at a higher temperature (e.g., 300° F. to 350° F.) for curing purposes.

In accordance with a further and specific aspect of the invention, a fabric treated in accordance with the process previously described may be utilized to advantage in some cases as an intermediate product, which is disassembled or "de-knitted" to yield individual elastic yarns suitable for incorporation in other fabric constructions. To this end, the initial fabric, to be processed as a source of stretch yarns, would be a circular knitted fabric and would be processed throughout in its circular or tubular form so as to avoid discontinuities in the individual yarns. After processing of the tubular knitted fabric, by resin impregnation, compressive shrinkage and curing to produce a stretch fabric, the stretch fabric is disassembled or "de-knitted" to yield a stretch yarn substantially of the order illustrated in FIG. 6. The de-knitted stretch yarn has permanently set loops corresponding in position to the interconnected loops of the knitted fabric, but usually rendered relatively more sharp and angular by reason of the compressive shrinkage procedure.

Plain jersey knit fabric may be utilized for the production of stretch yarns in the manner described above, inasmuch as the jersey construction incorporates an uninterrupted and evenly spaced series of knitted loops. Some of the other knitted constructions, in which spaces are provided between some of the loops of a given yarn, would be desirable for the production of stretch yarns to be used to produce textured effects.

A stretch yarn produced in accordance with the present invention by disassembly of plain jersey knit stretch fabric processed in accordance with the invention, has a unique and unusual appearance in that the individual loop formations, which are usually more or less rounded in form, become quite angular during processing of the fabric, and the de-knitted yarn has a form very much resembling a square wave.

The stretch yarns produced in accordance with the invention may be subsequently incorporated in other knit fabrics, along with other non-stretch yarns, or they may be incorporated entirely or in conjunction with other yarns in the manufacture of specialty fabrics including fabrics of other than knitted construction.

The method of the invention has significant utility in connection with the treatment of fabrics formed 100 percent of ordinary fibers, such as cotton. However, as will be understood, the treated fabric may incorporate any lesser quantity of ordinary fibers, and the treatment of the invention will be particularly applicable to the ordinary fiber content. It is even possible that a fabric, advantageously treated in accordance with the process of the invention with respect to its ordinary fiber content, might also incorporate spandex and other special purpose yarns.

Fabric treated in accordance with the invention has especially advantageous utility in connection with the manufacture of knitted outerwear garments, where proper form and fit are significant requirements. The treated fabric can be fully stabilized against excessive shrinkage or growth resulting from machine washing and tumble drying, as would be experienced in the most severe normal uses of the fabric, and at the same time the fabric has an extraordinary and highly advantageous degree of elastic restorability. Elastic restorability is particularly important in connection with outerwear garments, for example, because a garment may be repeatedly stretched and distorted during use, by normal body movements, and it is important that the fabric quickly return to its initial dimensions so as to avoid giving the garment a baggy appearance.

The process of the invention requires that the fabric impregnated with uncured resin, be mechanically compressively preshrunk in the lengthwise direction to a predetermined, critical extent, the lower limit of which is that amount of compressive shrinkage which will slightly exceed the inherent resilient shrinkage of the raw fabric, and the maximum limit of which is that amount of compressive shrinkage which will induce pleat formations giving the processed fabric a detrimental appearance. Typically and advantageously, it is desired to approach the maximum limit of the critical compressive shrinkage range. Because of the significant amount of mechanical compressive shrinkage imparted to the fabric in accordance with the process, the fabric after curing typically will have a significantly improved stretch characteristic, relative to untreated fabric. By way of example, fabric treated in accordance with the invention may have an extendability as much as 100–200 percent greater than untreated fabric. The improved extendability of the fabric, coupled with its elastic restorability, gives the fabric remarkable and highly desirable properties for its use in connection with the manufacture of outerwear garments.

It will be understood that the specific form of the invention herein illustrated and described is intended to be representative only, as certain changes may be made therein without departing from the clear teachings of the disclosure.

What is claimed is:

1. The method of treating knitted fabric containing ordinary fibers, to provide a substantially shrink-free knitted fabric free of discernible pleats and having substantial elastic restorability, which comprises:
   (a) impregnating at least the ordinary fibers of the knitted fabric with a subsequently curable stabilizing resin,
   (b) thereafter mechanically compacting said knitted fabric in a lengthwise direction an amount greater than that required for shrinkage control,
   (c) said amount of compacting being not less than 15% nor significantly more than about 30%,
   (d) said compacting step reorienting the loops of the knitted fabric structure relative to each other and reforming the geometrical configuration of the individual knitted loops,
   (e) thereafter curing the stabilizing resin without significantly imparing the imparted mechanical compressive shrinkage, whereby the fabric retains significant elastic restorability.

2. The method of treating knitted fabric containing

ordinary fibers, to provide a substantially shrink-free knitted fabric free of discernible pleats and having substantial elastic restorability, which comprises

(a) impregnating at least the ordinary fibers of the knitted fabric with a subsequently curable stabilizing resin,

(b) thereafter mechanically compressively shrinking said knitted fabric in a lengthwise direction to an extent not less than a predetermined minimum and not more than a predetermined maximum,

(c) said predetermined minimum being greater than the amount of inherent residual shrinkage in the unstabilized fabric,

(d) said predetermined maximum being that amount of compressive shrinkage which will impart a detrimental appearance to the fabric through the formation of pleats,

(e) said compressively shrinking step reorienting the loops of the knitted fabric structure relative to each other and reforming the geometrical configuration of the individual knitted loops, and

(f) thereafter curing the stabilizing resin,

(g) whereby the treated fabric retains significant elastic restorability.

3. The method of claim 2, wherein:

(a) said knitted fabric is shortened approximately 15% to 30% in a lengthwise direction by said mechanically compressively shrinking step.

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