May 14, 1946. R. C. WHITMAN 2,400,182

UNIDIRECTIONAL-TWIST WOVEN FABRIC AND METHOD

Filed Nov. 29, 1943 2 Sheets-Sheet 1

Fig. 1

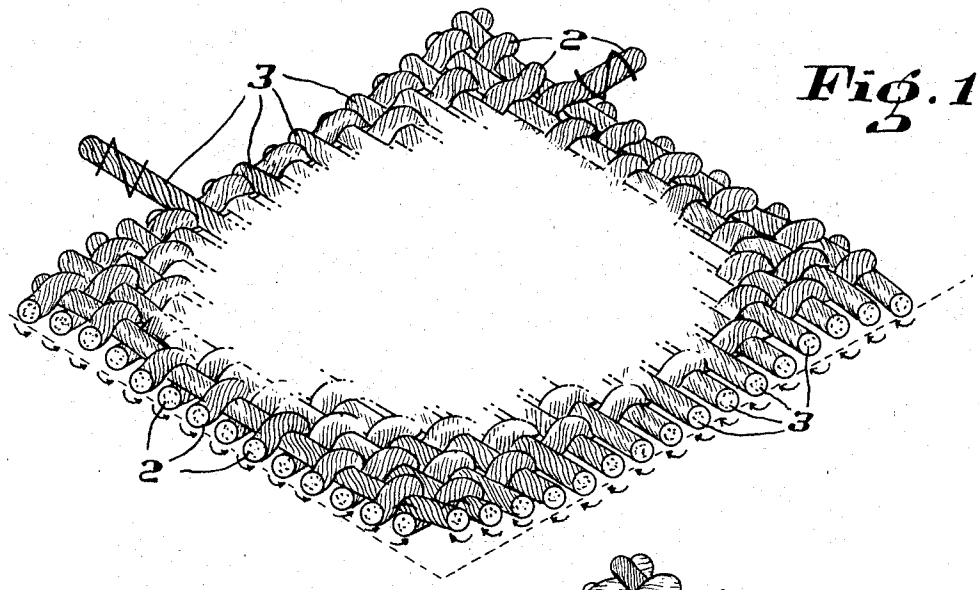


Fig. 2

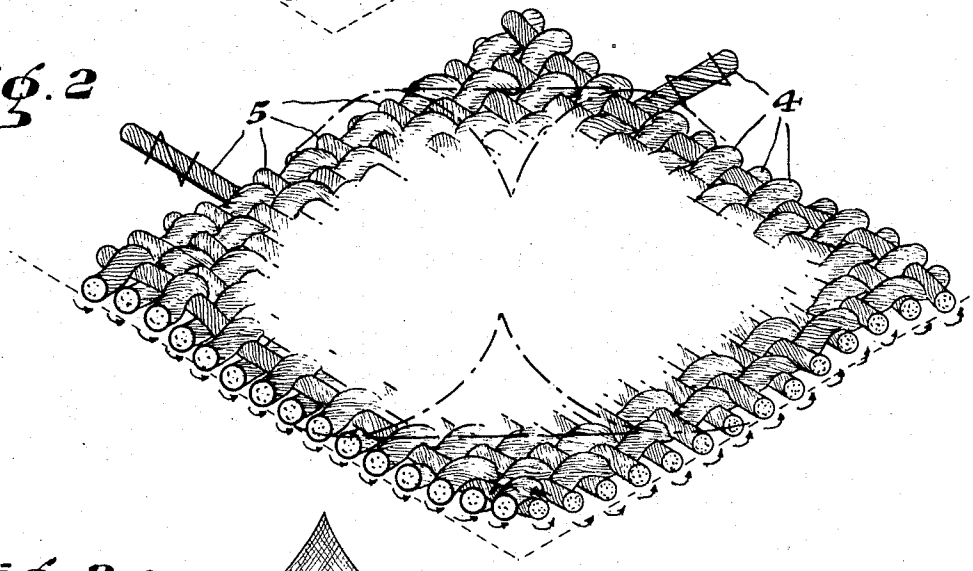
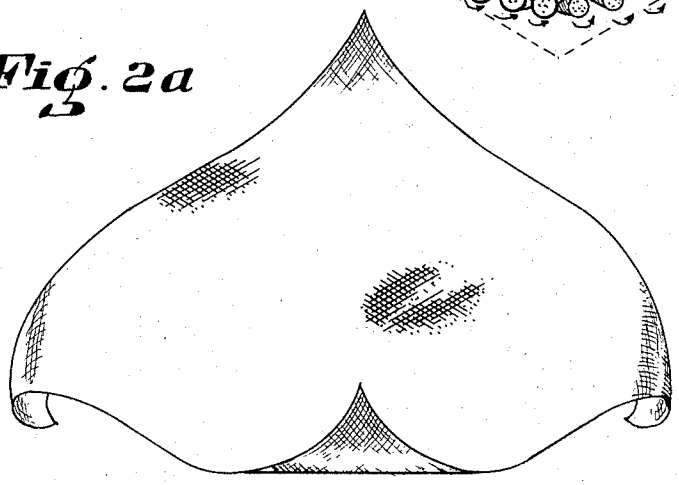


Fig. 2a



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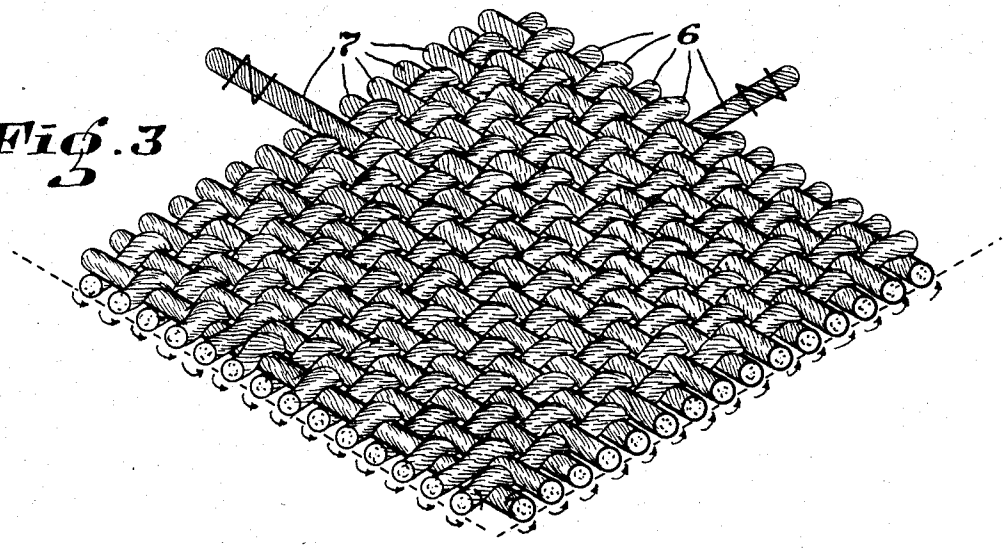
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May 14, 1946. R. C. WHITMAN 2,400,182

UNIDIRECTIONAL-TWIST WOVEN FABRIC AND METHOD

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Fig. 3



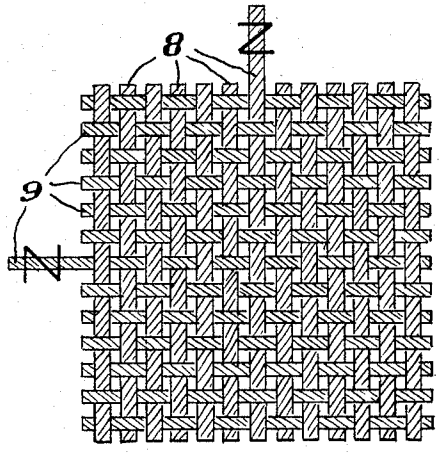


Fig. 4

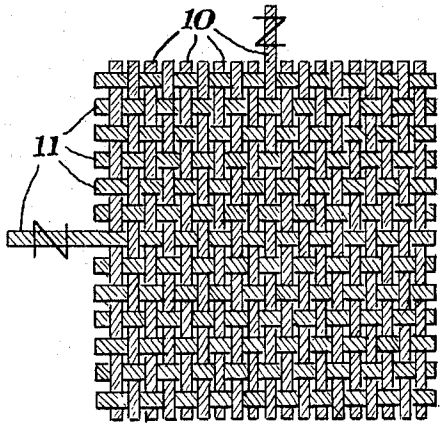


Fig. 5

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UNITED STATES PATENT OFFICE

2,400,182

UNIDIRECTIONAL-TWIST WOVEN FABRIC AND METHOD

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Application November 29, 1943, Serial No. 512,211

10 Claims. (Cl. 28—74)

This invention relates to woven textile fabrics and methods of making the same, and the object of the invention is to provide fabrics having substantially no tendency to curl which are woven using yarns twisted in the same direction in both warp and filling. The principal commercial applications of the invention are found in the field of stiffened woven fabrics to which the invention is particularly directed, though it is also useful in some unstiffened fabrics, principally narrow fabrics.

There are numerous uses for fabrics having little or no curling tendency, for instance, in dress goods, yard goods, curtain fabrics (e. g. organdies, lawns, voiles, marquisettes, fine muslins), uniform, and print cloths; in narrow fabrics including "slit" goods, tapes, ribbons and the like; and in various mechanical and industrial fabrics, both wide and narrow (e. g. muslins, drills, twills, sheetings) such as those used for radio spiders, condenser and insulating cloths, shoe linings, etc. Though most fabrics do not curl objectionably in the absence of a stiffening treatment, this is by no means universally true, particularly with respect to narrow and "slit" fabrics, and a considerable variety of commonly used fabrics, both stiffened and unstiffened, would be improved materially were it possible to determine and eliminate therefrom objectionable curling and so provide, as the present invention does, a satisfactory and certain basis for substantially eliminating such objectionable curling during not only cutting and fabrication into various articles of manufacture (which is sufficient for many purposes) but also during the utilization thereof—the latter particularly with respect to stiffened fabrics.

It has long been known in the textile art that many fabrics exhibit an undesirable degree of curl. For example, if a typical piece of a commercial light-weight stiff fabric, such as ordinary organdy, say about a foot square, is laid upon a flat surface, it will exhibit a curl such that diagonally opposite corners, for example, the top left-hand corner and lower right-hand corner, will lift from the flat surface and curl back over the central portion of the square of fabric so as to form a scroll. This tendency of certain fabrics to curl and roll up has been particularly troublesome to manufacturers and processers of fused fine fabrics, to manufacturers of tapes, and generally to manufacturers and users of resin-impregnated or otherwise stiffened woven textile products.

Numerous methods of overcoming this problem have been proposed including various chemical and mechanical finishing treatments of the yarns employed and/or of the body of the fabrics; special weaving or treatment of selvages; and special weaving of the body of the fabrics, such as weaving a fabric with right-hand (Z) and left-hand (S) twisted yarns arranged alternately in pairs in the warp and with unidirectionally twisted yarns in the filling, as in Schönholzer, U. S. Patent No. 2,215,938 (Fig. 2), or to use yarns in pairs of alternate twists both in the warp and in the filling (Fig. 3), only the latter of which achieves—at very considerable manufacturing expense because of requiring box looms—the non-curling stiffened fabric sought by Schönholzer. However, all of these methods have proven incapable of satisfactorily or uniformly solving the problem, or have been commercially unworkable or very expensive, if not prohibitively so (as in Schönholzer Fig. 3), because they involve the use of specialized equipment and extra operations.

The many conflicting proposals for the solution of the problem of fabric curl, particularly in stiffened fabrics, many of which proposals involve the use of opposing directions of twist of the component yarns, evidence both a failure to understand the significance of yarn twist to the phenomena of curl in fabrics and a complete failure to appreciate the presence and importance of other factors which also influence fabric curl as will now be described.

The present invention provides novel fabrics in which undesirable curl is overcome (or controlled or minimized to any desired degree), and provides a method of producing such fabrics without the use of special equipment and without substantial increase in manufacturing cost.

The general object of this invention is to provide textile fabrics both wide and narrow which exhibit substantially no tendency to curl. A particular object is to provide a fabric of such novel characteristics that it will not curl materially or objectionably upon being subjected to a fusing or other stiffening treatment. Further particular objects are to provide non-curling stiffened fabrics and a method of making the same.

The present invention was made only after very considerable study and experimental investigation in the course of which, in accomplishing the above objects, there were made several astonishing and unpredictable discoveries relating to the factors which influence fabric curl, namely, the discovery that yarn size of component yarns is the major factor though but one factor involved in the curl of fabrics and that the degree of yarn

twist and the number of yarn ends per inch of fabric in the warp and filling directions have an important effect as hereinafter appears. Fundamentally, it was discovered that the warp and filling yarns have a profound relationship and effect inter se and that the fabric curling or torque effect exerted by a given warp yarn can be and is neutralized or offset by the curling effect of a filling yarn of the same size and the same twist (same number of turns per inch and same direction of twist). Moreover, it was discovered that the curling effect of a set of warps can (in accordance with this invention) be neutralized by a set of fillings of the same direction of twist, even though the filling set differs from the set of warps in yarn size, in twist multiple, and in number of yarns per inch of fabric. The method of practising the invention by applying these discoveries in the manufacture of fabrics having substantially no tendency to curl is fully set forth hereinafter.

While the above discoveries are novel contributions to the art, there were also made other discoveries relating to the mechanism of curl of stiffened fabrics which are equally astonishing. My conception as to the true mechanism of fabric curl has been confirmed by study and dissection of numerous test specimens which show that soft unstiffened fabrics that tend to curl are caused so to do by the untwisting of certain dominant component yarns. Study of certain stiffened fabrics, however, resulted in the paradoxical discovery that in such fabrics the curl is caused by an increase in the twist (i. e. a twisting tighter) of the dominant component yarns. For example, when a foot square piece of a certain commercial broadcloth was laid upon a flat surface, it was observed to curl in that two of the diagonal corners lifted up somewhat from the flat surface and the other two diagonal corners attempted to curl downwardly. The curl here was caused by an untwisting of certain component yarns. However, upon subjecting said piece of fabric to the usual starch stiffening treatment and again laying it upon the table, it was observed that the diagonal corners which tended to curl upwardly before, then tended to curl strongly in the opposite direction, or downwardly, and that those corners which had curled downwardly before curled strongly in an upward direction. This was caused by the component yarns twisting tighter as the result of such stiffening treatment. This phenomena of reversal of direction of curl upon such stiffening has not been known and appreciated heretofore.

By properly applying these discoveries in yarn manufacture and selection, in weave layout and weaving of textile fabrics, one can produce a wide range of novel fabrics having warp and filling with the same direction of twist and which are characterized by a substantial absence of curl even though stiffened, or by a curl which is controlled to any desired small degree. Furthermore, one can produce the required yarns and such unidirectional twist fabrics on standard textile equipment and at no substantial increase in cost over the cost of otherwise similar common textile fabrics of equivalent weight.

In the drawings—

Figs. 1 and 2 are perspective views representing conventional fabrics, much enlarged, and illustrate the modus operandi of curling, Fig. 1 being an unstiffened fabric with warp and filling of opposite twists, respectively, and Fig. 2 being a stiffened fabric with warp and filling of unidirectional twist;

Fig. 2*a* is a perspective view representing typical curl of a small square of such conventional fabrics when wholly unrestrained;

Fig. 3 is a perspective view illustrating a non-curling fabric, much enlarged, of the present invention;

Fig. 4 is an enlarged diagrammatic view illustrating one preferred type of fabric of my invention; and

Fig. 5 is an enlarged diagrammatic view illustrating another preferred type of fabric of my invention.

Referring to the drawings, and particularly to Figs. 1 and 2, there are illustrated two portions of different conventional fabrics resting on flat horizontal surfaces (indicated by dashed lines). Fig. 1 represents an unstiffened fabric with warp yarns **2** and filling yarns **3** of opposite twists, respectively, the warp yarns **2** being of S-twist and the filling yarns **3** being of Z-twist. In Fig. 1 the warp yarns **2** tend to untwist (as indicated by the arrows) and, in turn, to lift the lower and diagonally opposite upper corners (as shown) of the fabric from the supporting surface, the two remaining diagonally opposite corners tending to bend in the opposite or downward direction, and the filling yarns **3** tend to untwist in the opposite direction (as indicated by the arrows), and also lift said corners so that the curling tendencies of the two sets of yarns augment each other in lifting said lower and upper corners, and try to bend the other two corners downwardly. If the fabric of Fig. 1 were stiffened, the diagonally opposite left and right corners would strongly curl upwardly, and the other corners downwardly.

Fig. 2 represents a stiffened fabric of unidirectional twist having warp yarns **4** and relatively smaller filling yarns **5**, both of Z-twist, in which both sets of yarns seek to twist tighter (as indicated by the arrows), the tendency of the relatively larger warp yarns **4** to lift the lower and diagonally opposite upper corners up to the positions shown by the dot and dash lines, being somewhat offset, though insufficiently, by the downward twisting tendency (see arrows at lower corner) of the smaller and less powerful yarns **5** so that said corners are lifted from the supporting surface by the warp yarns **4** despite the equally numerous filling yarns **5**. In order better to show the mechanism of curl, Fig. 2 illustrates it as more nearly flat rather than in the strongly curled position which it would normally assume, as indicated by the dot and dash lines.

Fig. 2*a* shows a curl typical of either of the conventional fabrics of either Fig. 1 or Fig. 2 when a piece of such fabric is wholly unrestrained and illustrates how such a fabric, if the curl continues, tends to form a scroll. In accordance with the earlier explanation, then, the curl of a textile fabric is due to the net curling effect of the two sets of yarns on each other, the twisting or curling effect of each set of yarns—twist direction being the same—depending upon the degree of twist (ordinarily expressed in terms of twist multiple) in each yarn, the size of each yarn, and the number of yarns per inch in the designated direction.

Fig. 3 illustrates a non-curling stiffened fabric of this invention resting on a flat horizontal support, with warp yarns **6** of smaller size than the filling yarns **7**, with the latter equal in number of ends but of lower degree (not shown) of unidirectional Z-twist, in which both sets of yarns tend

to twist tighter, the tendency of the warp yarns 6 to lift the lower and upper corners being neutralized by the filling yarns 7 so that the corners all lie flat and the fabric does not curl.

Fig. 4 illustrates diagrammatically a square weave stiffened fabric of unidirectional Z-twist in which the warp yarns 8 are of slightly larger relative size but a lesser degree of twist (not shown) than the filling yarns 9, the higher twist of any given number of filling yarns per inch being sufficient to offset the larger size (and hence greater curling tendency) of the same number of warp yarns per inch, thus providing a fabric having substantially no tendency to curl.

Fig. 5 illustrates diagrammatically a stiffened substantially non-curling fabric of unidirectional Z-twist having, say, 50% more warp yarns 10 than filling yarns 11, as in a 60x40 weave, in which the relatively larger size and degree of twist (not shown) of the filling yarns is sufficient to offset the curling tendency of the larger number of warp yarns of lesser size and relatively slacker twist. It will be evident that here the size and twist of the filling yarns are both increased, for the purpose of minimizing fabric curl, but in the practice of the invention it is found that such required changes to provide the non-curling fabric are not particularly noticeable from the standpoints of appearance and serviceability, and commonly are not even noticed in the trade. Most woven textile fabrics have as many or more warp yarns than filling yarns so that from the standpoint of end count nearly all of the typical applications of the invention fall in between the square weave of Fig. 4 (with its equal number of ends per inch of warp and filling yarns) and Fig. 5 (with its two-to-one ratio of warp to filling ends per inch). Also, for reasons of manufacture on modern spinning and weaving equipment nearly all fabrics, heretofore, particularly industrial fabrics, have larger warp yarns than filling yarns. For the same reasons, warp twist has been almost invariably higher than filling twist—in the trade "warp twist" is synonymous with high twist, and "filling twist" is synonymous with low twist.

The foregoing principles of the invention afforded a basis for my derivation of a mathematical equation which, as a practical matter, gives a general guide for successful application and use of the invention in the actual manufacture of non-curling fabrics. The equation is as follows:

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{\sqrt{N_w{}^3}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{\sqrt{N_f{}^3}}$$

where
M is twist multiple,
N is yarns number (size),
E is end count, and
w and f refer to warp and filling, respectively.

If either set of yarns includes yarns of different sizes or twist multiples, it will be necessary to consider each group of similar yarns of each set separately and add the results thereof together to obtain the total factor for each set. The twist multiple employed in this equation is the same as that employed in the textile art and equals twist turns per inch of yarn divided by the square root of the yarn number (cotton system), and for the purpose of the equation and in the specification and claims the size of all yarns is expressed on the cotton system, for example, 350 denier rayon yarns are classified approximately as number 15's; and the expression "end count" is to be taken as meaning the number of yarns per inch of fabric in the designated direction. In the application and use of the invention it is not necessary strictly to adhere to absolute equality as variations from the equality represented by the equation are necessarily encountered in practice, the ultimate test being whether any given fabric embodies the principles and features of the invention as herein described and claimed.

In the manufacture of stiffened fabrics to which this invention is principally directed, there are various means of stiffening which can be conveniently divided into three general groups. The first and most common involves the application of a water-soluble film or sizing to the surface of the base fabric. This group includes water-solutions of the starches, various common finishing gums, sugars, etc. The stiffening obtained with these products is removed when the fabric is laundered. The second method is to apply a water-carried water-insoluble substance to the base fabric. Various resins such as phenol formaldehyde, urea formaldehyde, casein formaldehyde, and the methacrylates are used for this purpose. Since these chemicals are water-insoluble when applied, or are rendered insoluble after application (by baking the fabric, usually), the stiffness obtained is not immediately or readily removed when the fabric is washed. Effects obtained with such water-insoluble materials as these are called "permanent finishes," although in a series of, say, 10 to 25 launderings, these resins are gradually dislodged from the fabric and their benefits disappear. The two methods may be applied to plain or mixed fabrics or yarns made of any textile fibres including staple or cut staple natural or synthetic cellulosic fibres or continuous filaments later referred to. There also may be included silk, wool or Aralac ("casein wool"), nylon, or other non-cellulosic synthetic fibres or filaments, such as vinyl acetate and vinyl chloride copolymers, and vinylidene chloride, for example, those sold under the respective names of Vinyon and Saran, or even inorganic fibres such as glass or asbestos, though in none of these non-cellulosic fibres does a water-swelling and stiffening with resultant reversal of curl occur.

The third method is employed only for stiffening base fabrics woven from or including yarns made up of, or which include mixed with other fibres, cotton or other natural cellulosic fibres such as sisal, ramie, hemp or jute, or synthetic cellulosic fibres such as viscose, cuprammonium and other regenerated cellulosic fibres (either cut staple or continuous filament), or cellulose ester fibres (either cut staple or continuous filament) such as cellulose acetate, cellulose butyrate, and cellulose propionate, or mixtures or copolymers of the same. This method involves the use of a chemical which swells and gelatinizes the cellulosic fibres themselves. When this chemical is neutralized or leached out, the cellulose is reprecipitated, the yarns or cellulosic fibres thereof are more or less stuck together, and the whole fabric is markedly stiffened, though not necessarily equally in both directions. Since the stiffening medium is in the cellulose itself, this stiffening method is usually the best so far as wash-fastness is concerned. For fusing agents a very considerable number of chemicals which are known and have been used in the textile art as fusing agents are available for this purpose, for example, in treating a cotton fabric, zinc chloride or fusing agents such as cuprammonium

(copper tetramine hydroxide) or sulphuric acid can be used. Other examples are "mixed acids" (nitric and sulphuric), phosphoric acid, a caustic soda solution at −10° C., calcium thiocyanate, and others. Naturally, no strongly alkaline fusing agent should be used on fabrics which include wool or Aralac type fibres. The action of fusing agents on cellulosic fibres, such as scoured cotton and rayon, is well known in the cloth-finishing trade and is referred to in the art as swelling, fusing, gelatinizing or parchmentizing, though herein usually termed "fusing." The methods or processes followed in using these various agents differ but the conditions have been thoroughly worked out for each of them and are well known to those experienced in the trade. For example, cellulosic fabrics fused with zinc chloride are exposed to treatment for a number of hours, whereas goods of a cellulosic composition processed with sulphuric acid are treated for only a few seconds. The reaction desired for the purpose of stiffening fabrics including cellulosic fibres and cellulosic yarns in the three types of treatments is a combined swelling and superficial solubilizing effect, producing some adhesion of the fibres to each other.

In ordinary textile fabrics the individual yarns have a desire to untwist somewhat. If the fabric is wet with water and the yarns are thus swollen, or are swollen by other liquid means, the desire of these yarns to untwist is increased. If the normal yarns could have their diameters decreased, the desire of these yarns to untwist would likewise be decreased, and might be decreased far enough so that they actually try to twist up tighter. This accounts for the fact that swollen and stiffened yarns in a textile fabric, upon drying, and accompanying decrease in diameter, attempt to twist tighter. The fibres of the yarns are stuck together so that they approximate monofilaments. In such coalesced yarns, two or three turns per inch will produce a considerable torsion, whereas in ordinary soft cotton yarn, two or three turns per inch do not produce any detectable torsion. When a yarn is fused, for example, with zinc chloride, it is swelled by the zinc chloride (strongly increasing its desire to untwist), the zinc chloride is then leached out coalescing and solidifying the yarns in a somewhat swollen state (as the zinc chloride is removed, the swelling in the yarn gradually decreases) and, finally, as the yarn is dried, its actual diameter is considerably decreased. It is during this drying process that the tendency of the yarn to untwist disappears and the tendency of the yarn to twist tighter becomes evident, the latter tendency, because of the coalescence, being much stronger than the former. This type of reversal of curl or reversal of twist tendency apparently results whenever a yarn is first swollen (either by water of solution or water of condensation), then stiffened or coalesced, and, upon drying, finally condensed, by "condensed" meaning that the diameter of the yarn is decreased, the density of the yarn being increased. For the purposes of applying the principles and the mathematical equation before referred to, the direction of twist in yarns so swollen and stiffened must be taken and regarded as in the direction of twisting more tightly. If stiffening takes place in the absence of swelling, however, yarns, so stiffened will untwist in the same way as they did before being stiffened.

Various stiffened fabrics may be made which include a substantial proportion of yarns in the warp, filling, or both, which are not swollen and stiffened so as to produce a reverse curl (yarns twisting tighter), in such fabrics the warp and filling each including 20% or more of swollen and stiffened yarns with their reverse fabric curling tendencies offset in general accordance with the foregoing disclosure. In such cases the proportion of yarns not so stiffened (as well as their direction of twist) may be safely disregarded as not significant in view of their relatively negligible effect upon curling as compared with that of the pronounced and very much greater curling effect of the swollen and stiffened warp and filling yarns of unidirectional twist. Similarly, if but a few soft yarns of opposite twist (than the dominant unidirectional warp and filling yarns) be inserted, as, for a pattern effect, for example, they may be disregarded since they do not significantly unbalance the equation.

In the practice of this invention it is essential to provide warp yarns and filling yarns that are spun with precision from uniform card sliver to definite sizes and twist multiples, and so woven that all areas of the body of the fabric are strictly uniform in construction since it is these factors, and their relation to each other, that are depended upon in arriving at the desired result. Even with the most modern equipment, and with carefully controlled spinning-room humidity, it is well known that considerable variation in the yarn size occurs as spinning proceeds. A spinning machine balanced and adjusted to product 30's yarns may, after a week or ten days' operation, be found to be delivering as fine as 35's or 36's, or as heavy as 27's or 26's, the shift toward lighter yarns usually proceeding faster and further than the shift towards heavier yarns. These variations are usually explained as resulting from humidity changes, temperature changes, stock changes, and machine wear, producing maladjustments.

Standard practice in modern textile mills calls for the analysis of yarns approximately every two weeks, and the readjustment of yarns size prescribed is made usually on the first roving frame, usually called the "slubber," or the second roving frame, known as the "first intermediate." This measure of control is satisfactory for ordinary fabric manufacture, but since it would permit "drifting" of yarn size to the extent mentioned above, it is obvious from the equation underlying this invention that it is entirely inadequate for the practice of the invention. Also, any change in yarn size produces a significant change in twist multiple since the spinning-frame delivers a fixed number of turns per inch to the yarn, rather than a fixed twist multiple. In the manufacture of fabrics of this invention it is recommended that yarn analyses and equipment adjustment as needed be made daily, usually at the second drawing frame rather than on any of the succeeding roving frames. In addition, special care should be taken in the control of spinning-room humidities, etc.

In making use of the equation, actual yarn sizes, as determined by analyses in the spinning-room, and actual twist multiples, as determined by well known formula involving spinning-frame gears, should be used rather than the "theoretical" or "standard" values. Similarly, actual end counts as reported by the weave room should be used. It is found that usually the slight changes in the end counts occasioned by variations in tension on the loom are not troublesome providing the

cloth tension is checked and adjusted daily in the usual way. For fabrics where a complete absence of curl is the requirement, as in radio spiders, it is found that the old style friction let-off on the loom is to be preferred to automatic positive let-off mechanism, such as the "Roper-Draper" or "Bartlett," which permit greater variations in end counts since they control tension with less precision, generally. Also, reasonable care should be taken to avoid any considerable distortion of the woven "neutralized" fabric in subsequent finishing processes. With fairly equal tensions therein so that the end count in the finished fabric is roughly equally higher or equally lower in both the warp and the filling, however, no trouble need be anticipated on this score.

Some examples of the invention are as follows:

Example I

A 60x52 cotton voile woven with 50's yarns in the warp and 55's yarns in the filling and designed for use as a curtain fabric was found to curl objectionably when stiffened with a urea formaldehyde-casein formaldehyde combination finish. In this fabric the warp twist multiple was 6.97 and the filling twist multiple was 6.0. The fabric lay-out was altered in substantial accordance with the equation to provide a substantially non-curling fabric by reducing the warp twist multiple from 6.97 to 6.51, by increasing the filling twist multiple from 6.00 to 6.25, by lightening up the warp yarns from 50's to 55.02's, and by heavying up the filling yarns from 55's to 50.81's. When these new values were substituted in the equation along with the actual filling end count 51.4, it was found that substantial balance as defined by the equation would be obtained if the warp end count were reduced to 57.6. A fabric woven to these new specifications is not significantly different in surface appearance from the original, but there is no material curl in the finished goods, though, according to the equation, the final fabric is out of absolute equality by 0.023 unit, the warp still predominating to this negligible extent.

Example II

A 64x60 print cloth designed for use in the manufacture of radio spiders was constructed using 34.42's cotton yarns in both warp and filling. The warp twist multiple was 4.05 and the filling twist multiple was 4.28, and the actual end count of the fabric 63.8x59.5. According to the equation, this fabric should not curl since it is out by only 0.007 unit, warp predominating, and when the fabric was impregnated with a phenol formaldehyde solution and stamped and formed into radio spiders, it produced spiders which were completely free from warp or curl regardless of the state of the resin when the final stamping, forming and heat-setting of the resin took place, or of the speed with which the spiders were withdrawn from the heated mold.

Example III

A partially fused 2.85 yds./lb. cotton sheeting designed for industrial use was made up with a total actual end count of 47.8x47.2. It is highly important to have this material substantially free from curl since small patterns are cut from it for use in the production of shoes. In order not to have this fabric too stiff and vapor impermeable, half of the warp yarns were boiled and bleached and half of the filling yarns were also so treated, the balance of the yarns in both warp and filling being natural grey cotton and hence unreactive to the fusing agent. After being woven, this fabric is stiffened with any one of the well-known fusing agents. The figures to be mentioned were derived by applying the equation to one-half of the filling yarns and one-half of the warp yarns, the rest of the yarns (which never were stiffened) being neglected as far as the equation is concerned. Using the equation, it was found that regular 14's yarns (actual 13.93) could be used in the warp and regular 16's (actual 15.72) in the filling, thus maintaining the usual finished weight of this fabric, and substantial balance can be still achieved by spinning the warp yarns with a twist multiple of 4.01 and the filling yarns with a twist multiple of 4.32. This will produce a fabric in which the warp predominates, according to the equation, by 0.20 unit, but which has substantially no curl.

Example IV

A leno fabric designed for use as a mosquito netting which will not curl after being stiffened with a well-known commercially available hydroxyethyl cellulose finish is made by weaving a 28x14 (actual 27.9x13.5) leno construction using 34.06's yarns in the warp and 27.10's yarns in the filling, the warp twist multiple being 4.02 and the filling twist multiple 5.21. This gives a substantially non-curling fabric, though it is slightly out of absolute balance in the warp, according to the equation, by 0.03 unit.

Example V

A very stiff, heavy interlining cotton fabric which does not curl after being stiffened with zinc chloride is made in accordance with the equation by weaving a construction of 48x44 (actual 48.1x43.8) using 12.25's yarns in the warp and 10.21's yarns in the filling. If the warp twist multiple is 4.00, the equation teaches that the filling twist multiple be 3.34 to produce a fabric with its sets of yarns almost exactly in curling balance inter se. After being woven, this fabric may be boiled and bleached to render it reactive to a concentrated solution of zinc chloride. The material is impregnated with this solution, batched for approximately two hours, and then thoroughly washed with water. After being swung dried, it will be found that the fabric is permanently stiff and shows no desire to curl.

Example VI

A loosely woven soft cotton fabric is commonly used for bunting and drapes. In this case it is frequently desirable to slit the material into long streamers which ideally will not turn when they are suspended in air. Such a material may be produced by weaving a 36x32 (actual 35.5x31.0) construction using 33.51's yarns in the warp and 35.12's yarns in the filling, the warp yarns having a twist multiple of 3.90 and the filling yarns having a twist multiple of 4.70. According to the equation, this fabric is exactly balanced to four decimal places. Such a material will show no tendency to curl even when a considerable length of it in narrow form is hung in the air.

Example VII

A novelty cotton-viscose staple rayon dress fabric which will not curl after being permanently stiffened with one of the well-known fusing agents, is made up as follows: The theoreti-

cal end count will be 64x60. The filling will consist of 90 denier viscose staple rayon yarns. For purposes of the equation, these are regarded as equivalent to 59's cotton yarns. The filling twist multiple will be 4.48 and the actual filling end count is 59.6. Of the ends per inch in the warp, approximately 30 will be grey cotton yarns or wool yarns. They will have a weight of 40's and their twist multiple will be 4.25, but since these yarns are not to be stiffened, they may be neglected as far as the equation is concerned. Only the rayon yarns are counted and employed in the equation. The actual end count of such rayon yarns is 33.9 per inch, consisting of 130 denier viscose staple rayon yarns. For use in the equation, these are equivalent to 40.89's cotton yarns. The twist multiple of these viscose yarns in the warp is 4.51. If the values for the rayon yarns are inserted in the equation, values for the grey cotton yarns (or woolen yarns) being omitted since they will not be affected by such a stiffening agent as zinc chloride, it will be found that this fabric is out in the warp by only 0.033 unit. Accordingly, it will not curl after being finished.

Example VIII

A non-curling fused Swiss Organdie can be made in accordance with the equation by weaving and fusing a 68x60 (actual 67.4x59.3) construction using 70.1's bleached cotton yarns in both warp and filling. In order to avoid material curl in the finished fabric the warp twist multiple is made 6.01 and the filling twist multiple 6.55, making an equation difference 0.009 in the warp.

The base or unstiffened fabrics made in accordance with this invention may conveniently be tested and compared from the standpoint of curl by cutting small five inch squares therefrom, impregnating such squares with a test solution (suitable for the character of the fibres and yarns to be stiffened therein), hot ironing the same, and then noting their deformation under standard conditions, for example, by noting the rise or elevation of any corner from a horizontal supporting surface—not to exceed 1½ inches. The preferred and most searching test for fabrics of cotton and/or viscose rayon is by first impregnating the fabric in a solution made up as follows:

	Parts
Bakelite solution (XR568, partially polymerized phenol formaldehyde solution, 40% Bakelite, 60% methyl alcohol)	4
Methyl alcohol	1
Water	5

The pick-up of the solution by the fabric may, for example, be from 125 to 150% by weight (on the weight of base fabric). The sample is then pressed between two heated metallic surfaces (net total pressure 10 lbs.) and a temperature of approximately 150° C., for 60 seconds in order to completely polymerize and set the resin. The sample is then at once removed and placed without restraint on a horizontal surface, such as a table, and promptly observed. Since this test is so searching, as a practical matter, fabrics so tested may be regarded as having substantially no tendency to curl if the sample remains substantially extended and no corner thereof rises more than 1 to 1½ inches above the supporting horizontal surface upon which it was placed. Fabrics made in accordance with the preferred practice of this invention are well within the amount mentioned. Most of the stiffening or fusing solutions hereinbefore referred to as employed in ordinary commercial applications as practiced in the cloth-finishing trade, will not cause the rise of a corner of a five inch square more than ½ to 1 inch above the supporting horizontal surface.

It will be clear from the foregoing that this invention provides novel fabrics and novel methods of making such products with equipment and materials commonly available, and that the nature of the invention is such that these goods can be produced at an entirely reasonable cost. While I have herein disclosed typical fabrics embodying this invention and suitable methods of making them, it will be understood that the invention is susceptible of embodiment in a great variety of forms within its spirit and scope, and that minor departures may be made from the methods above described while still following the essential teachings of the invention.

Having thus described my invention, what I desire to claim as new is:

1. A non-curling, stiffened mainly cellulosic woven fabric comprising warp and filling yarns, substantially all of unidirectional twist, uniformly dispersed throughout the body of the warp and filling of the fabric, the warp yarns being so related to the filling yarns with respect to twist multiple, yarn number and count as to produce substantially the equality represented by the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively.

2. A non-curling, stiffened mainly cellulosic woven fabric comprising warp and filling yarns, substantially all of unidirectional twist, uniformly dispersed throughout the body of the warp and filling of the fabric, the warp yarns being so related to the filling yarns with respect to twist multiple, yarn number and count as to produce substantially the equality represented by the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively, said fabric further including fused cellulosic yarns giving the fabric artificial stiffness.

3. A non-curling mainly cellulosic woven fabric comprising warp and filling yarns, substantially all of unidirectional twist, uniformly dispersed throughout the body of the warp and filling of the fabric, the warp yarns exceeding in number but being so related to the filling yarns with respect to twist multiple, yarn number and count as to produce substantially the equality represented by the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively, whereby the tendency of warp yarns to curl the fabric when stiffened by impregnation with a stiffening agent

characterized during drying and setting by the evolution of water is offset by the opposite fabric curling tendency of the filling yarns so that the fabric when stiffened remains in a substantially non-curling condition.

4. A non-curling stiffened, mainly cellulosic woven fabric comprising warp and filling yarns, substantially all of unidirectional twist, uniformly dispersed throughout the body of the warp and filling of the fabric, the warp yarns exceeding in number but being so related to the filling yarns with respect to twist multiple, yarn number and count as to produce substantially the equality represented by the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively.

5. The method of producing a non-curling, mainly cellulosic woven fabric for tapes and the like which comprises spinning, selecting, and weaving warp yarns and filling yarns which are substantially all of unidirectional twist, but with the twist multiple, yarn size and end count in the warp, and the twist multiple, yarn size and end count in the filling, all determined and the fabric woven in substantial conformity with the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarn size, E equals end count, and w and f refer to warp and filling, respectively, the different characteristics of yarn and yarn arrangement specified in the equation being adjusted to produce substantially the equality represented by the equation, said fabric having its respective warp and filling yarns uniformly dispersed and arranged throughout the body of the fabric.

6. The method of producing a non-curling, stiffened, mainly cellulosic woven fabric which comprises spinning, selecting, and weaving warp yarns and filling yarns which are substantially all of unidirectional twist, but with the twist multiple, yarn size, and end count in the warp, and the twist multiple, yarn size and end count in the filling all determined and the fabric woven in substantial conformity with the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarn size, E equals end count, and w and f refer to warp and filling, respectively, the different characteristics of yarn and yarn arrangement specified in the equation being adjusted to produce substantially the equality represented by the equation, said fabric having its warp and filling yarns uniformly dispersed and arranged throughout the body of the fabric, and then stiffening at least some of the fibres of at least some of said warp and filling yarns by impregnation with a stiffening agent characterized during drying and setting by the evolution of water and finally drying the same, thereby materially stiffening said fabric.

7. The method of producing a non-curling, stiffened, mainly cellulosic woven fabric which comprises spinning, selecting, and weaving warp yarns and filling yarns which are substantially all of unidirectional twist, but with the twist multiple, yarn size, and end count in the warp, and the twist multiple, yarn size and end count in the filling all determined and the fabric woven in substantial conformity with the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarn size, E equals end count, and w and f refer to warp and filling, respectively, the different characteristics of yarn and yarn arrangement specified in the equation being adjusted to produce substantially the equality represented by the equation, said fabric having its warp and filling yarns uniformly dispersed and arranged throughout the body of the fabric, and then fusing said warp and filling yarns, and finally drying the same, thereby materially stiffening said fabric.

8. A mainly cellulosic textile base fabric designed and adapted for stiffening purposes comprising a woven fabric composed essentially of sets of unidirectionally twisted warp and filling yarns uniformly dispersed throughout the body of the fabric, with the yarns of said sets so related in number, size, and degree of twist as to produce substantially the equality represented by the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling respectively, to offset and neutralize the fabric curling tendency of said sets of yarns, whereby the tendency of the warp yarns to curl the fabric when stiffened by impregnation with a stiffening agent characterized during drying and setting by the evolution of water is offset by the opposite fabric curling tendency of the filling yarns so that the fabric when stiffened remains in a substantially non-curling condition.

9. The method of producing a non-curling, mainly cellulosic woven fabric which comprises spinning, selecting, and weaving warp yarns and filling yarns which are substantially all of unidirectional twist, but with the twist multiple, yarn size and end count in the warp, and the twist multiple, yarn size and end count in the filling, all determined and the fabric woven in substantial conformity with the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarn size, E equals end count, and w and f refer to warp and filling, respectively, said fabric having its respective warp and filling yarns uniformly dispersed and arranged throughout the body of the fabric, the different characteristics of yarn and yarn arrangement specified in the equation being adjusted to produce substantially the equality represented by the equation, whereby the tendency of the warp to curl the fabric when stiffened by impregnation with a stiffening agent characterized during drying and setting by the evolution of water is offset by the opposite fabric curling tendency of the filling yarns so that the fabric when stiffened remains in a substantially non-curling condition.

10. A textile material of the type of tapes and the like comprising a relatively narrow woven cellulosic fabric having substantially no tendency to curl after hot ironing, composed essentially of unidirectionally twisted warp and filling yarns uniformly dispersed throughout the body of the fabric, with said filling yarns sufficient in number, size and degree of twist to offset and neutralize the fabric curling tendency of said warp yarns, and to produce substantially the equality represented by the equation

$$\frac{\left(M_w-\frac{N_w}{66}\right)E_w}{N_w^{3/2}}=\frac{\left(M_f-\frac{N_f}{66}\right)E_f}{N_f^{3/2}}$$

where M equals twist multiple, N equals yarns number, E equals end count, and w and f refer to warp and filling, respectively.

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