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METHOD OF PRODUCING STABLE DRYER FABRICS

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This invention relates to methods and means for stabilizing dryer fabrics used in connection with paper-making machines.

Heretofore considerable difficulty has been encountered in the use of dryer fabrics produced in whole or in part from synthetic yarns, such as those formed from nylon, Dacron and the like. These difficulties have resulted from the fact that yarns of the character specified have a tendency to change in length as the dryer fabric produced therefrom passes from the hot-dry to the hot-wet conditions and is continuously subjected to repeated changes from one condition to the other. The synthetic yarns have a tendency to shrink upon the application of heat and have a tendency to grow or lengthen when subjected to moisture. As a result, the dryer fabrics formed of synthetic yarns have had a tendency to wrinkle and become flabby or loose along the running edges. This in turn tends to produce sheet cockle.

In accordance with the present invention, these difficulties are largely overcome by a special treatment to which the dryer fabric is subjected in the course of its production. Heretofore it has been customary to subject the fabric to tension in both the machine direction and in the cross machine direction in the course of treating it at elevated temperatures with one or more resins or other chemicals. It has been found that the difficulties referred to above can be greatly reduced, and substantially eliminated, if the treatment of the fabric is carried out under conditions not involving the usual, relatively high tension in the machine direction, and it can be further improved by reducing or eliminating tension in the cross machine direction. Treatment of the fabric under these conditions has been found to remove, or at least greatly reduce, the residual shrinkage present in the fabric as it is applied to a paper-making machine.

Insofar as the machine direction tension is concerned, it is not necessary or desirable to eliminate all tension; in fact it is desirable to apply sufficient tension to maintain the fabric belt in its extended condition as it is being subjected to the heat and resin or chemical treatment. Thus while it has been customary heretofore to apply to the fabric, in the course of its treatment, a tension of 5 pounds per linear inch or somewhat higher, in the machine direction, the present invention contemplates holding such tension down to a lower value, and in most instances down to about or below 3.2 pounds per linear inch. Thus a fabric having an initial width of, say, 114 inches should not be subjected to a machine direction tension above 350 pounds, unless the yarns and the weave employed permit a somewhat higher tension without preventing a substantial reduction in the residual shrinkage of the fabric. Another way of expressing the amount of tension is that it should not exceed about 0.04 gram per denier for the yarns used in weaving the fabric. This applies to both the warp direction and the filling or weft direction. If the tension tends to increase above the preselected value, as shown by a dynamometer, the attendant in charge of the treating procedure should immediately take steps to reduce the tension to the desired point. This, it will be appreciated, can readily be done by pressing a button on

the machine which will cause the tension roll to move inwardly to the required extent.

Tests have shown that as a dryer fabric passes through succesisve cycles of hot-wet and hot-dry conditions repeatedly the shrinkage or growth of the fabric is somewhat greater at the initial stages but then gradually levels off to a lower extent of shrinkage and growth in subsequent stages of wet to dry and dry to wet conditions. Also it may be stated that if a fabric is finished under a high tension there is a tendency to build residual shrinkage into the fabric, whereas if the fabric is finished at an extremely low tension there is a tendency to build into the fabric a growth characteristic. Accordingly, to stabilize the final fabric it is desirable to apply to it, in the course of the finishing treatment, an appropriate, intermediate amount of tension. This, as has been indicated, is preferably around 3 pounds per linear inch for greige fabrics of the type to be described. A more general way of expressing the amount of tension preferably imparted to the fabric in both the machine direction and the cross machine direction in the course of the finishing treatment, is that it should be kept below 0.04 gram per denier. This has been definitely established in relation to fabrics formed of conventional nylon, and no substantial departure from the indicated value is expected for other fabrics, regardless of their construction and the materials of which they are formed. In all cases the tension on the fabric, in both directions, should be such that the fabric being treated is permitted to shrink in both the warp and filling directions from the dimensions of the original fabric as woven on the loom.

A special nylon sold under the designation HT–1 nylon has no tendency to melt upon heating but chars when heated to too high a temperature. It is capable of withstanding temperatures for short periods of time up to 600° F. On the other hand, ordinary nylon of the Type 6 variety has a melting point around 425° F., while another nylon designated Type 66 melts at about 482° F. These ordinary nylons have been found to shrink to the extent of 7 percent to 11 percent when subjected to the heat encountered in the drying stage of a paper-making machine. On the other hand, HT–1 nylon, which may be characterized as high temperature nylon sold by E. I. du Pont de Nemours and Company under that designation, shrinks only about 1 percent. Such nylon may be used advantageously in accordance with the present invention. Other synthetic yarns than those specifically mentioned above may be used in the production of fabrics in accordance with the principles of the present invention, such fabrics having low residual shrinkage and also low wet to dry dimensional change because of the fibers selected. Such fibers may, for example, be formed of a wide variety of polyesters, including those sold under the tradenames Dacron, Vycron and Kodel. The removal of residual shrinkage and the selection of yarns having relatively low wet to dry dimensional change serves to provide a dimensionally stable dryer belt that is subject to unobjectionable changes in length due to heating and passage from hot-dry to hot-wet conditions in its use on a papermaking machine.

In the practice of the invention, the loop or section of fabric employed to form the dryer belt may be subjected to transverse or cross machine direction tension normally applied in the production of such belts, but here again it has been found desirable to reduce this tension to a substantial extent, or to eliminate it altogether. The residual shrinkage in the cross machine direction may thus be reduced to a desirable minimum or eliminated altogther. Finishing fabric at the tensions described has

been found to result in some bagginess in the edge portions of the belt that is objectionable, but this can be rectified by trimming off the edge portions of the fabric. In general it has been found that this bagginess has a tendency to extend inwardly from the free edges of the belt only to the extent of 2 to 18 inches. Therefore it is necessary to trim from each edge of the original fabric, after it has been treated with heat, chemicals or resins under the usual temperature conditions, only narrow bands having a width of 2 to 18 inches. The remaining fabric will be found suitable for use as a dryer fabric belt with satisfactory dimensional stability in both the machine direction and the cross machine direction to eliminate the objections hereinabove described.

It will be appreciated from the foregoing that the original woven fabric to be treated in accordance with the present invention should be formed of such length and width that it will have the desired dimensions after its lengthwise and transverse shrinkage and after the proper trimming of the edge portions.

In carrying out the present invention, apparatus of the type disclosed in the pending U.S. application of Christie et al., Serial No. 22,973, filed April 18, 1960, may be used, if the fabric is finished in endless belt form. However somewhat different apparatus is required if the fabric is treated while in flat, continuous form. Provision must then be made for passing flat fabric from a supply roll through the various treating zones and then winding it up in finished form on a storage roll. Sufficient lengths of the finished fabric may then be taken from the storage roll to form the desired dryer fabric belt.

While the apparatus disclosed in the Christie et al. application is directed primarily to the treatment of Fourdrinier fabrics, it may also be used for the treatment of other fabrics such as the dryer fabric with which the present invention is concerned. It will be understood that in that form of the invention which involves the application of no tension to the fabric in the cross machine direction, the tenter frame structures disclosed in the Christie et al. applications may be omitted. Briefly, the treatment described in the Christie et al. application involves the passage of an endles fabric, in belt form, for a number of cycles through the treating zone of the apparatus. The application of a desired tension to the fabric in the machine direction, as it is continuously advanced through its various cycles, is accomplished by the movement of one of the end rolls about which the belt is passed. By shifting the end roll in one direction its serves to impart a stretching or tensioning force to the belt, while shifting of the roll in the opposite direction will reduce or even eliminate the stretching or tensioning force applied to the belt. As explained above, the extent to which the end roll mentioned is shifted away from the roll at the opposite end of the belt will be such as to impart a much smaller tension force to the belt than is contemplated by the Christie et al. invention and is less than the tensioning force normally applied to the belt in the course of its use on a paper-making machine. This, as has been explained, is to reduce as far as possible the residual

shrinkage present in the belt in the lengthwise direction, as it is woven. Assuming that the fabric of which the belt is formed is woven in an endless fashion, the warps will extend crosswise of the belt and the wefts lengthwise. If the fabric is woven flat, in continuous form, the warps will extend lengthwise and the wefts or filling yarns crosswise of the belt, and the desired length then will be formed into a belt by fastening the free ends together by suitable clips, or the like.

In a manner similar to that disclosed in the above mentioned Christie et al. application, the dryer fabrics of the present invention will be subjected to treatments with one or more resinous materials as successive portions of the belt pass through a particular region, and the fabric will also be subjected to different temperature conditions. The resinous materials, which may be applied to the dryer fabrics in accordance with the present invention, may be of the same general character as those disclosed in the Beaumont et al. Patent No. 3,032,441, granted May 1, 1962, or they may be of any of a variety of other types adapted to adhere to the warp and weft yarns and to bond these together at their crossing points. Typical of such other resinous materials are Rhoplex having 50 percent solids and having one part of this material diluted with one part of water. The curing of this resin is preferably carried out at 400° F. Another suitable treating liquid is a 30 percent solution of Bendix phenolic resin V–108. This, after being dried, may also be cured at 400° F. Still another suitable treating solution is a 30 percent solution of Hycar 2600 X 91. The treating solution is formed by adding 60 parts of Hycar to 40 parts water. After such solution is applied to the fabric and dried, it is cured at 300° F. Yet another suitable treating solution is Bendix C–900 resin emulsion. This should be diluted to 25% solids and there should be added 10% hexamethylenetetramine, based on the resin solids, as a curing agent, or 20% of the V–108 resin may be used for this purpose. The curing temperature for the C–900 resin is 400° F. In general it may be said that resins of the expoxy family and polyurethanes may be used. In the foregoing treatment of the fabric, temperatures ranging from 190° F. to 480° F. may be used. The lower temperatures are used in the earlier stages, while the fabric is wet. During the total treatment the temperature is increased to at least 400° F. The maximum temperature should, of course, be below the melting point of the fibers used in the fabric and should not be so high as to bring about excessive degradation of the fibers.

The yarns used in the weaving of the dryer fabrics of the present invention may be any of those suggested for use in the production of Fourdrinier cloth in the patent to Holden et al. No. 2,903,021, granted September 8, 1959. As pointed out in that patent, the warps and wefts may be of the same construction or of different construction, and they may be in the form of multifilament yarns or monofilament yarns.

As typical examples of fabrics treated, fully or in part, in accordance with the present invention, those designated as Nos. 2131, 2208 and 2221 in the following table, which indicates the construction thereof, may be mentioned.

Table 1

Pc. No.	Type warp	Ends/ In.	Type filling	Picks/ In.	Weave
	(CD)		(MD)		
2131	140-10-300/3-ply, 25Z x 12½S nylon.	50	440-100-51/3-ply, 15Z x 8S Dacron.	29	Plain.
	(CD)		(MD)		
2208	140-10-300/3-ply, 25Z x 12½S nylon.	50	440-100-51/3-ply, 15Z x 8S Dacron.	29½	Do.
	(CD)		(MD)		
2221	520-34-300/3-ply, 16Z x 8S nylon.	25	1100-250-52/2-ply, 12Z x 6S Dacron.	20	Do.

In the foregoing table the first portion of the combined number, such as 140 in the number 140–10–300, means that the single raw yarns used have a denier size or weight of 140, expressed in grams per 9,000 meters of the yarn. The second portion, such as 10 in the number mentioned, means that there are 10 filaments in each raw yarn bundle. The third portion of the combined number, such as 300 in the number specified above, refers simply to a bright, high tenacity yarn to which that number is applied by its producer. As for the designation 25Z x 12½S, identified with piece No. 2131, this means that there are 25 turns per inch in the raw yarn in the Z direction, while there are 12½ turns per inch in the opposite or S direction when three plying the yarns entering into the warp thread used. With respect to the Dacron referred to in relation to the filling thread employed in the machine direction of the fabric, the numbers 51 and 52 identify types of Dacron. Type 52 is a bright, high tenacity yarn whereas 51 is another well-known type of Dacron yarn.

Fabric No. 2221 was woven 1½ feet longer than usual, to allow for lengthwise shrinkage during finishing, this fabric was subjected to lengthwise tension below 350 pounds at all times, over the 114 inch width, i.e., warp direction, of the fabric. Thus not more than 3 pounds per inch tension was applied to the fabric in the machine direction throughout the finishing operation. This contrasts sharply with the conventional treating method, in which a minimum tension of 5 pounds per inch is applied in the lengthwise or machine direction of the fabric. In the treatment of piece No. 2221 it was applied to the tenter pins of the finishing machine during treatment with the two solutions, thus maintaining it at a 114" width during such treatments. The length and width of the fabric was recorded during all of the cycles involved in the finishing treatment, with the following results being noted:

Table 2

Woven length	Length at start of cycle 99'	Length at end of cycle	Width
1st-1st solution	98'3"	98'0"	114"
2nd-1st solution	98'0"	97'11"	114"
Wet up	97'11"	97'10"	114"
1st-2nd solution	97'10"	97'10"	114"
2nd-2nd solution	97'10"	97'10"	114"
Cure	97'10"	95'7"	110"
Heat set	95'7"	94'9½"	110"
Dry inspection at 5 lb./linear inch tension.	94'10½"	94'10½"	

It will be noted that just prior to final cure the fabric had shrunk very little. During final cure and heat set it was necessary to bring the fabric in, in length, about every 10 to 30 seconds to prevent the tension from exceeding 350 pounds total on the dynamometer.

It has been found important not to allow the fabric length to fall below the desired finished length in the course of its finishing treatment. Fabric No. 2221 was found to conform with this requirement, without the necessity of allowing the tension in the machine direction to exceed about 3 pounds per inch or 350 pounds for the total width. On the other hand, in the treatment of piece No. 2208 under the same conditions described above it had a tendency to shrink below the desired finished length during the curing and heat setting steps. To offset such undesirable shrinkage, and pull the fabric back into desired length, the tension was permitted to rise during cure to between 2,500 and 2,800 pounds, and during heat setting the tension still remained quite high, i.e., 2,200–2,500 pounds. This was found to build back into the fabric an excessive amount of residual shrinkage, so that the intended stabilization of the fabric was not produced. This indicates the importance of weaving the original fabric to a sufficiently greater length than the desired finished length to avoid both the necessity of exceeding a tension which will prevent shrinkage in the course of finishing, and to eliminate the necessity of stretching the fabric after it has been treated with the resin solutions.

When fabric 2221 was given the wet up inspection, it was found that the edges of the top run of the fabric drooped about 2 inches and this dropping extended to a decreasing extent inwardly from the edge for a distance of about 8 inches. Accordingly after the fabric was dried, a strip was trimmed from each edge for a sufficient width to remove the drooping edge portions. This indicates the desirability of weaving the initial fabric to a width sufficiently greater than that of the desired finished width to permit trimming of a strip having a width between 2 inches and 18 inches from each edge of the fabric after completion of the finishing treatment. Such trimming of the treated fabric was found to completely remove any tendencies of the edge portions of the final fabric to droop. This was determined from dry inspection of the fabric under 5 pounds per linear inch tension without the employment of table rolls.

In the operation of the paper-making machine, the dryer can temperature usually does not exceed 325° F. Therefore the invention is concerned primarily with difficulties arising from changes in temperature of the dryer fabric up to that limit and from alternate changes in condition of the fabric from wet to dry and dry to wet. As the machine is started up, the temperature of the fabric will be raised from room temperature to a relatively high temperature determined by that of the dryer cans. So also when the paper web tears or breaks, and especially if the machine must be temporarily shut down to correct the difficulty, a quite high temperature difference occurs. On the other hand, in the normal course of operation of the machine, after the machine has been brought into its operating condition, the temperature of the dryer fabric does not vary over as wide a range. However it must be recognized that the temperature does vary to the extent of between 70° and 325° F. at rather frequent intervals.

One problem that arises in the operation of a paper-making machine, especially when it is first started up and also when a break occurs in the paper web, is that on these occasions a tail or leader of the web which is much narrower than the web being formed must be passed through the drying section of the machine. At these times the dryer fabric not only goes through wider temperature differences, but also it is subjected to wetting in only portions of its width, so that the expansion due to wetting is confined to only a portion of the fabric. This, in the use of conventional dryer fabrics, tends to produce serious difficulties in the way of shrinkage, variations in tension, guiding problems and creation of bulging or wrinkling. However when the fabric has had its residual shrinkage removed or greatly reduced, in accordance with the present invention, these difficulties are substantially overcome.

It may be mentioned that the increase in length of a fabric in going from a dry to a wet condition has been found to be above 2% for nylon and only about 0.118% for polyesters such as Dacron. A corresponding decrease in length occurs when the fabric goes from the wet to its dry condition. Changes in length of yarns formed of synthetic resins, such as nylon and Dacron, when not under tension has been found to be as much as 9% in going from room temperature to 212° F. This change, as has been explained, is a decrease in length. While the yarns only change about 7 to 11% in length in the course of such a temperature change, the change in length of the fabric, when not under tension, can be greater due to the development of crimps or undulations in the yarns in the course of such temperature changes. Of course when the fabric is under tension, say 5 lbs. per linear inch, testing it or using it on a paper machine, the actual change in length of the fabric which can be noted is much smaller, as indicated in the tables hereinafter provided. While reference has been made in the foregoing to changes in "length," it will be understood

that corresponding changes take place in the width of the fabric as it undergoes changes in moisture content and changes in temperature. Rather surprisingly, the substantial elimination of residual shrinkage of the fabric in the course of the finishing treatment, by the application of stretching forces substantially lower than those applied lengthwise of the fabric in its use on a paper machine, has been found to stabilize the dimensions of the fabric to such an extent that the objections encountered in the use of dryer fabrics produced heretofore are not encountered. As has been stated, the lengthwise tensioning forces applied to the fabrics dealt with, in the course of their treatment in accordance with the invention, has been held below 5 lbs., and preferably below 3.2 pounds per linear inch of width of the fabric. On the other hand, in the course of use of such fabrics they are subjected to a stretching force in the longitudinal direction of about 5 pounds per linear inch of width of the fabric. Expressing the tension applied to the yarn in another way it should not exceed 0.04 gram per denier for the yarns employed, in the course of treatment.

To determine the effectiveness of the present invention to improve the stability of fabric subjected to changes in temperature and moisture content in the course of use as a dryer fabric, numerous other tests have been conducted. Thus, four different types of fabric were subjected to the standard treatment described in the above-mentioned Christie-Schiff application Serial No. 22,973. These fabrics were of the following types:

(1) Endless all-nylon dryer fabric, with the wefts in the machine direction, having nylon of the conventional types, melting at temperatures of around 425° F. to 482° F.

(2) Flat woven all-nylon dryer fabric, with the warps in the machine direction, having nylon of the conventional type.

(3) A fabric like (1) above, but having HT–1 nylon in the machine direction.

(4) A fabric like (1) above, but having Dacron in the machine direction.

These fabrics when subjected to said standard treatment were found to show changes in length, percentagewise indicated by the following table:

Table 3

Percent change	1	2	3	4
Cold or base length	0	0	0	0
Hot-dry for 1 hr	−1.39	−1.33	−0.08	−0.97
Hot-wet for 1 hr	−0.58	+0.28	0	−0.83
Hot-dry for 1 hr	−2.97	−1.75	−0.38	−1
Hot-wet for 1 hr	−1.47	+.17	−0.19	−0.92
Hot-dry for 1 hr	−3.64	−1.92	−0.58	−1.06

As a further test conducted in the development of the invention, various sections of fabric No. 2131 woven in endless form with the wefts intended to extend in the machine direction, and which had been subjected to the standard, conventional finishing treatment, were heat tested under varying conditions on a sample finishing machine, with no tension being applied to the fabrics. One section, designated "Control," was not shrunk prior to the test, two other sections were tested after being subjected to heat shrinkage at 305° F. and 340° F., respectively. Each sample was caused to go alternately from hot-wet to hot-dry conditions over a period of four hours, after having been subjected for an hour to temperatures (designated "cold") increasing from room temperature up to the "hot" temperature encountered in the use of the fabric in the dryer section of a paper-making machine. The results of the shrinkage tests of the three different samples are indicated percentagewise in the following table:

Table 4

Test	Lapsed minutes	No. 2131 "control" (not shrunk)	No. 2131 heat shrunk 4 min. 305° F. pyrometer	No. 2131 heat shrunk 4 min. 340° F. pyrometer
Cold	0	0	0	0
Do	10	−0.25	−0.22	−0.17
Do	20	−0.25	−0.20	−0.17
Do	30	−0.28	−0.20	−0.17
Do	40	−0.31	−0.20	−0.17
Do	50	−0.31	−0.20	−0.17
Do	60	−0.31	−0.20	−0.17
Hot-Wet	10	−0.17	−0.028	0
Do	20	−0.17	−0.028	0
Do	30	−0.17	−0.028	0
Do	40	−0.17	−0.028	0
Do	50	−0.17	−0.028	0
Do	60	−0.17	−0.028	0
Hot-Dry	10	−0.25	−0.11	−0.06
Do	20	−0.28	−0.14	−0.06
Do	30	−0.28	−0.14	−0.08
Do	40	−0.31	−0.14	−0.08
Do	50	−0.31	−0.14	−0.08
Do	60	−0.31	−0.14	−0.08
Hot-Wet	10	−0.17	−0.028	−0.06
Do	20	−0.17	−0.028	−0.06
Do	30	−0.17	0	−0.06
Do	40	−0.17	0	−0.06
Do	50	−0.17	0	−0.06
Do	60	−0.17	0	−0.06
Hot-Dry	10	−0.25	−0.11	−0.03
Do	20	−0.28	−0.14	−0.03
Do	30	−0.28	−0.14	−0.03
Do	40	−0.31	−0.14	−0.06
Do	50	−0.31	−0.14	−0.06
Do	60	−0.31	−0.14	−0.06

It will be noted from the foregoing that the higher the temperature employed for heat shrinkage, the more stable the fabric became in going from wet to dry and dry to wet. Most of the residual shrinkage was removed at the higher temperature.

The advantages derived from the shrinkage imparted to fabric piece No. 2221, by maintaining the tension during treatment below 3.2 lbs. per inch of width, and the loss of this advantage in the subsequent stretching of the fabric, as in the case of piece 2208, is illustrated by the following table:

Table 5

Test	Lapsed minutes	2131 "Control" std. treatment	2208 Finished at minimum tension but taken out 5 in. after finishing	2221 Finished at 3.2 lbs./ linear inch tension or less to allow for shrinkage
Cold	0	0	0	0
Do	10	−0.25	−0.28	−0.20
Do	20	−0.25	−0.28	−0.20
Do	30	−0.28	−0.31	−0.22
Do	40	−0.31	−0.31	−0.22
Do	50	−0.31	−0.31	−0.22
Do	60	−0.31	−0.31	−0.22
Hot-Wet	10	−0.17	−0.20	−0.06
Do	20	−0.17	−0.20	−0.06
Do	30	−0.17	−0.20	−0.06
Do	40	−0.17	−0.20	−0.03
Do	50	−0.17	−0.20	−0.03
Do	60	−0.17	−0.20	−0.03
Hot-Dry	10	−0.25	−0.28	−0.11
Do	20	−0.28	−0.31	−0.14
Do	30	−0.28	−0.31	−0.14
Do	40	−0.31	−0.33	−0.14
Do	50	−0.31	−0.33	−0.14
Do	60	−0.31	−0.33	−0.14
Hot-Wet	10	−0.17	−0.22	0
Do	20	−0.17	−0.22	0
Do	30	−0.17	−0.22	0
Do	40	−0.17	−0.22	0
Do	50	−0.17	−0.22	0
Do	60	−0.17	−0.22	0
Hot-Dry	10	−0.25	−0.33	−0.08
Do	20	−0.28	−0.33	−0.11
Do	30	−0.28	−0.33	−0.11
Do	40	−0.31	−0.33	−0.11
Do	50	−0.31	−0.33	−0.11
Do	60	−0.31	−0.33	−0.11

The standard or conventional finishing treatment referred to herein, in relation to dryer fabrics, shall be understood to mean the treatment described in the above mentioned Christie et al. application Serial No. 22,973,

9. A method according to claim 7 in which no tension is applied to the fabric in the widthwise direction of the belt formed therefrom.

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