A hydropatterning apparatus and method conveys a sheet of fabric (12) through a patterning station (16) along a machine direction on a conveyor (24), preferably a drum, having a support surface (16, 60) formed with a pattern of raised or solid areas (16a) and lowered or void areas (16b), and has one or more manifolds (30) of hydrojet nozzles (32) disposed above the conveyor for directing a continuous curtain of fluid (40) downwardly to impact on the fabric so that properties of the fabric become altered in correspondence to the pattern of the support surface (16, 60). Fabric colored with a non-color-fast dye is hydropatterned by subtractive color removal to obtain a patterned washout effect. Alternatively, a support surface having raised or embossed areas is used to obtain a fiber displacement, lace-like effect in light fabrics. The disclosed hydropatterning technique is particularly suitable for producing a color washout effect in indigo dyed denim.
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APPARATUS AND METHOD FOR HYDROPATTERNING FABRIC

SPECIFICATION

Field of The Invention

This invention generally relates to a method and apparatus for producing a visual pattern or other patterned effect in fabric, and more particularly, for producing a pattern through treatment with water.

Background Of The Invention

It has become desirable to impart a visual pattern or other patterned effect on some types of fabrics. For example, it is desirable to produce a washed-out, distressed, or pre-worn effect on dyed denim fabrics. Dyeing and dye printing are normally additive processes where dyes or pigments are added to natural, white, or previously dyed fabrics. Creating distressed or pre-worn surface effects is generally a subtractive process of removing color from the dyed fabric. Several subtractive, dyed fabric treatment processes are known in the art, but have been found to be unsatisfactory for various reasons.

For example, discharge printing is a subtractive
printing process where fabric is piece-dyed and then printed with a paste of caustic soda and sodium hydrosulfite to destroy the color in the printed areas. The caustic paste used to remove the base color must be thoroughly washed out, or it can have a serious deteriorating effect on the fabric.

Acid washing is a chemically induced, subtractive process which removes color from fabric already cut and sewn into garments. Acid washed effects are achieved by soaking pumice stone in chlorine bleach, which are then added to a load of denim garments in an industrial washing machine without water. The load of stones and garments is agitated for a length of time based upon the degree of "frosting" or color removal desired, e.g. from one to several hours. The effect of the acid coupled with the abrasion caused by the stones is extremely detrimental to fabric strength and durability.

Stone washing is a mechanical, color subtractive process achieved by a combination of crocking, abrasion, and lack of color fastness to washing. Here denim garments are loaded into industrial washers along with water and pumice stones and agitated for a predetermined length of time. The degree of washout can be somewhat controlled by the length of the agitation cycle, however, the overall effect is the end result of substantially random processes. The fabric is subject to less abuse and deterioration in stone washing than in acid washing. However, for both stone and acid washing, the washout patterning of the fabric cannot be
precisely controlled and made repeatable from load to load. In both cases, the wash equipment is subjected to extremely hard beating caused by the tumbling and crumbling of the pumice stone.

Acid washing and other chemical treatment of fabrics generate large amounts of contaminated or caustic effluents which are discharged to the environment. It is highly desirable to find ways to reduce the amounts of polluted effluents that are discharged to the environment.

In order to overcome the disadvantages of the prior art, it is a principal object of the invention to provide an apparatus and related method for producing a visual pattern or other effect on fabric which minimizes abuse and deterioration of the process equipment, as well as the fabric being processed. In particular, it is a specific object to obtain subtractive color patterning of woven fabric by non-caustic fluid treatment which does not wear down and damage the process equipment and deteriorate the fabric. It is a further object to pattern fabric through a process which reduces the amounts of polluted effluents that are discharged to the environment.

Summary of The Invention

The present invention encompasses an hydropatterning apparatus comprising: a conveyor for conveying a sheet of fabric through a patterning station along a machine direction, the conveyor including a support surface formed
with a pattern of solid areas and void areas interspersed therein, wherein the fabric is placed flat in contact with the support surface as it is carried through the patterning station; hydrojet means disposed above the conveyor for directing a curtain of fluid downwardly to impact on the fabric as it is moved through the patterning station on the support surface, wherein said curtain of fluid is substantially continuous across the fabric and is controlled such that a visual property of the fabric become altered in correspondence to the pattern of solid areas and void areas of the support surface due to the impact of the fluid curtain on the fabric against the patterned support surface. The invention also includes a process for hydropatterning fabric as in the above-described apparatus, as well as the patterned fabric product produced by such process.

In the preferred form of the invention, the hydropatterning apparatus includes a plurality of manifolds mounted in parallel along the periphery of a conveyor drum forming a series of curtains of water under which the fabric is conveyed, each manifold including a plurality of nozzles, distributed in the cross direction perpendicular to the machine direction, which eject divergent, overlapping jets of water so that the water curtain impacts substantially evenly across the width of the fabric. The nozzles preferably have wide divergent openings so that they do not become clogged with fibers from the fabric and other debris, have angles of divergence in the range of 2 to 45 degrees, and are disposed
about 1 to 10 inches above the conveyor. Preferred results
are obtained using water pressures of about 1000 psi at
process speeds of 60 ft/min, and with energy of 0.4 to 2.0
hp-hr/sq-yd.

A specific application for the present invention is
the hydropatterning of dyed woven fabric obtained by washing
color from areas of the fabric in contact with the solid
areas of the patterned support surface. The support surface
is formed with a pattern of solid and void areas
corresponding to the washout pattern to be obtained on the
fabric. The void areas preferably occupy approximately 25
percent of the overall pattern area.

A further application for the present invention is
the hydropatterning of fabric obtained by displacement of
yarn or fiber in repeating patterns in the fabric. Light
density or loosely woven fabrics are subjected to the above-
described hydrojet treatment while in contact with a support
surface having a pattern of raised areas, such as domes, or
three-dimensionally embossed or relief-patterned woven
screens. Visual effects such as ribbing, wavy lines,
checkering, geometric or floral designs, or lacework can be
obtained. Hydropatterned fiber displacement can be applied
to dyed or undyed woven or knitted fabrics, as well as to
nonwoven and stitch-bonded fabrics.

Other objects, features, and advantages of the
present invention will become apparent from the following
detailed description of the best mode of practising the
invention when considered with reference to the drawings, as follows:

Brief Description of The Drawings

FIG. 1 is a schematic diagram of the process steps for hydropatterning fabric in accordance with the invention;

FIG. 2 is a perspective view illustrating one embodiment of hydropatterning apparatus for carrying out the invention;

FIG. 3 is a side schematic view of the hydropatterning apparatus illustrated in Fig. 2;

FIG. 4 is a side schematic view of another embodiment of the hydropatterning apparatus;

FIG. 5A is a sectional view showing a planar support surface for hydropatterning fabric which has a pattern of void and solid areas suitable for color washout effects, and Fig. 5B is a sectional view of a drum support surface which has a pattern of domes and depressed areas suitable for fiber displacement effects;

FIGS. 6A to 6K are photographs of support surface patterns and the resulting dye washout effects obtained in the fabric in accordance with the invention; and

FIGS. 7A to 7L are photographs of support surface patterns and the resulting fiber displacement effects obtained in the fabric.

Preferred Embodiments of The Invention
The hydropatterning apparatus and related method and products of the invention obtain a controllable and repeatable visual pattern in fabric by the application of a non-caustic fluid under pressure to the fabric carried in contact with a patterned support surface. The invention as described herein applies a continuous curtain of water to obtain a subtractive, color washout effect in dyed woven fabrics, such as in warp dyed denim with indigo dyestuff, and fiber displacement patterns in light density or loosely woven fabrics. However, it should be understood that the principles of the invention may be applied to other applications besides color washout and fiber displacement, may employ other non-caustic fluids besides water, and may be used with other types of fabrics, including nonwoven fabrics.

Referring to the general process steps of the invention as illustrated in Fig. 1, incoming fabric is subjected to any required pre-treatment, such as dyeing with dyestuff to obtain a base color level. The pre-treated fabric is then subjected to the hydropatterning treatment of the invention at a patterning station, which receives a supply of high pressure water from and returns recovered water to the associated water processing equipment. The patterned fabric from the patterning station is then subjected to any required post-treatment, such as drying under tension on conventional tenter frames, to obtain the final fabric product.

In the following description of one embodiment of the
hydropatterning apparatus, a continuous sheet of dyed woven fabric is subjected to hydropatterning treatment to produce a color washout effect. The dyeing of woven fabric is deemed to be well known to those skilled in the art. The type of dyestuff and method of dyeing plays an important role in the patterning effect to be obtained. For dyed denim, indigo dye is preferred for its surface or layered characteristic, i.e. not being fast to washing, which produces patterned effects by the removal of dye from the surface of the yarns in discrete areas. The indigo dye is typically applied by passing yarns from a warp beam through a series of 5 to 8 dye baths to form a number of dye coats on the surface of the fibers.

Referring now to one preferred form of hydropatterning apparatus shown in Fig. 2, the patterning station 10 includes an endless conveyor 24 driven by rollers 26, 28 for advancing the fabric 12 in a machine direction (arrow indicating a downstream direction). Preferred line speeds for the conveyor are in the range of 10 to 500 ft/min. The conveyor 24 presents a generally planar support surface 16 in the patterning zone which is formed with a plain weave pattern of solid (or raised) and void (or lowered) areas, e.g. grid, honeycomb, diamond, striated, etc. The fabric is supported in contact with the solid or raised areas of the pattern, while the void areas drain away the water applied to the fabric, as described further below. In the preferred embodiments, the void areas occupy approximately 25 percent
of the overall pattern area. The fabric 12 in Fig. 2 has a
different cross-hatching at the exit end 42 from the incoming
fabric at the entry end 38 to indicate that it has been
altered by the hydropatterning process.

Mounted above the conveyor 24 is an arrangement of
manifolds 30 spaced apart in parallel and aligned in a cross
direction of the fabric which is perpendicular to the machine
direction. The manifolds 30 are spaced approximately 4
inches apart, and are positioned at least 1.0 inch, and
preferably in the range of 1 to 10 inches above the conveyor.
Each manifold has a row of water jet nozzles 36, spaced along
the cross direction, which ejects a divergent fan jet 34 of
water downwardly on the fabric 12. The fan jets 34 overlap
to form a continuous curtain 40 of water which impacts
substantially evenly across the width of the fabric. This
produces an even pressure of water on the fabric against the
patterned support surface in order to avoid streaking or
otherwise uneven patterning.

The manifolds are designed to deliver fluid pressures
to the nozzles 36 in the range of 200 to 2500 psi. The
nozzles of the manifold are spaced approximately 1 inch apart
and are positioned 1 to 10 inches above the conveyor 24. The
fan jets 34 diverge in a fan-shape having an angle of
divergence in the cross direction relative to the nozzle axis
which is perpendicular to the conveyor surface. The angle of
divergence may be from 2 to 45 degrees, and experimentation
has shown that a divergence angle of about 18 degrees yields
an optimum fan shape and an even curtain of water pressure. The output energy of the curtain of water is preferably in the range of 0.4 to 2.0 hp-hr/sq-yd of fabric, and particularly 1.0 hp-hr/sq-yd. In the case of heavier fabrics such as denim, the energy applied to the surface of the fabric may be a surface effect and therefore independent of weight.

Preferred nozzles for use in the invention are of the type manufactured by Spraying Systems Co., distributed by J.W. Snowden & Associates, Manchester, New Hampshire, under product designation 0503-TC. This nozzle has a tungsten carbide spray tip which has been found effective for providing regulated pressure sprays. The ejection orifices in the nozzle have a non-circular shaped configuration. The preferred nozzle has an effective diameter of about 0.43 inches and flow rate of 1.5 gallons/min with an effective jet spray angle of approximately 18 degrees and 1000 psi.

As shown in Fig. 3, as the fabric is moved on the conveyor 24 through the series of water curtains 40, the water impacts on the fabric against the raised or solid areas of the patterned support surface. It is found that a dye which lacks a certain degree of color fastness, such as indigo dye, will wash out from the fabric in the raised or solid areas at least partially under the pressure of the water curtains. The water and carried-away dye is drained through the void areas of the support surface to a collecting tank 50 below the conveyor 24. A filter 52 is provided to
remove dislodged fibers and other debris, and a recirculating pump 54 returns the water under pressure to the manifolds 30. The washed out dye may be removed by the use of settling tanks.

A preferred conveyor structure is shown in Fig. 4 employing a cylindrical or drum conveyor 24 and patterned support surface 60. The manifolds 30 are arranged in close proximity at the upper part of the circumference of the support member. In its other aspects, the operation of this embodiment is similar to the first described embodiment, although the drum conveyor is found to provide preferred results. The water processing equipment in this embodiment includes a filtration system of the type manufactured by Dore Oliver Inc., Stamford, Connecticut, under product designation 120 DSM Screen. The DSM system has a dispensing nozzle 64 and filter screen 66 which directs fiber debris into discharge receptacle 70, while the filtered fluid is diverted to be recirculated through pump 72. A settling tank is used for dyestuff recovery, although it is not shown in the drawing.

In Fig. 5A, a side sectional view illustrates the washout patterning function of the water curtains 40 impacting downward on the fabric 12 carried on the support surface 16 (60). The support surface has a pattern of solid areas 16a and void areas 16b, such as may be produced by a honeycomb or evenly perforated pattern in a screen. The pressure of the water jets presses the fabric 12 against the
support surface so that portions of it are supported on the solid areas 16a and other portions are depressed into the void areas 16b. It is found that, for a dyed fabric, the dye tends to wash out from the raised portions supported on the solid areas 16a, and to drain into and to be retained in the depressed portions in the void areas 16b, thereby producing a color washout pattern corresponding to the pattern of the support surface.

In Figs. 6A to 6K, examples of several patterned support surfaces and the resulting pattern effect obtained on the fabric are shown. Generally, the support surface is formed out of fine wire mesh in which raised areas are formed in a repeating pattern, or from a metal plate in which void areas are perforated. In Fig. 6A the support surface was a perforated metal plate with round void areas, and the resulting fabric is shown in Fig. 6B having a stippled washout effect. The support surface in Fig. 6C is a wire mesh embossed with a repeating flower pattern, and the resulting patterned fabric is shown in Fig. 6D. The wire mesh employed a basket weave embossing in Fig. 6E, with the result in Fig. 6F, a plaid embossing in Fig. 6G, with the result in Fig. 6H, a lines/dots embossing in Fig. 6I, with the result in Fig. 6J. The patterned result of a wire mesh drum embossed with a honeycomb pattern is shown in Fig. 6K.

Besides retaining the washout pattern, the resulting fabrics can also retain a three-dimensional embossed effect corresponding to the pattern of the support surface due to
the pressure of the water at the hydropatternning station forcing the fabric into the open areas of the screen or plate. The patterned fabrics may be treated with sizing or other stiffeners or heat setting to make the embossed effect more permanent. The embossed effect can be obtained alone, without the washout effect, by using dyestuff which is more color fast than indigo or other vat dyes.

In Fig. 5B, a side sectional view illustrates the fiber displacement patternning function of the water curtains impacting downward on the fabric 12 carried on the drum support surface 16 (60). The drum support surface has a three-dimensionally embossed or woven relief pattern of raised or embossed areas 16a, such as in the shape of domes, and void areas 16b. The pressure of the water jets presses the fabric 12 against the support surface so that portions of it are forced against the domed areas 16a and other portions are depressed into the lowered or void areas 16b. The drum support surface is preferred for both color washout and fiber displacement effects. It is found that, for light density or loosely woven fabrics, the fibers are displaced by the action of the water and become entangled together at crossover points. The yarns are thus locked together, creating open areas or lace-like fabric with good cohesion and stability. The fabric also exhibits good drape and hand, because it is such an open fabric, yet has limited yarn slippage due to the locking together of the fibers during hydropatternning. The patternning is most effective in lightweight fabrics with fine
to moderate size yarns. Such patterns can include ribbing, wavy lines, checkering, geometric or floral designs, or lacework effects. The use of higher energy water curtains or treating the patterned fabrics with sizing can make the displacement effect more permanent.

Figs. 7A to 7L show samples of the displacement patterns obtained in fabrics with different patterned screens. In Fig. 7A, a blouse fabric made of polyester/rayon, having filament warp yarns of 76 ends/inch in the warp (machine) direction, and spun fill of 31 picks/inch in the cross direction, is patterned using the flower patterned screen shown in Fig. 7B. The photomicrograph of Fig. 7C shows a magnified view (16x) of the yarn displacement obtained. In Fig. 7D, a shirt fabric of 100% cotton, of 76 ends/inch by 68 picks/inch, is patterned using the woven mesh (20x20/inch) screen shown in Fig. 7E, with the displacement result shown magnified (16x) in Fig. 7F. In Fig. 7G, a seeded batiste fabric, composed of 92% polyester and 8% cotton fibers, of 90 ends/inch by 44 picks/inch, is obtained using the wavy lines/dots screen shown in Fig. 7H, with the displacement result shown magnified (16x) in Fig. 7I. Fig. 7J further shows the blouse fabric patterned with the wavy lines/dots screen of Fig. 7H, with the fiber displacement result shown magnified (16x) in Fig. 7K and (18x) in Fig. 7L.

Thus, the invention provides a method and apparatus for patterning fabrics by the use of one or more water
curtains under pressure against a patterned screen. The pattern can be regularly repeated in the fabric and controlled for the desired effect. A wide range of patterned designs and visual effects can be obtained. The hydropatterning technique of the invention produces minimal wear and tear on the process equipment and on the fabric being processed. Furthermore, the production of caustic or chemical wastes is minimized, thereby lessening the impact of such fabric treatment processes on the environment.

A wide range of other patterning effects can be achieved by using different dyes, colors, dyeing processes, water curtain configurations, screen patterns, fabrics, and fabric weaves. The water curtain can be generated by other types and arrangements of nozzles and pressure manifolds.

Woven, perforated, or expanded metal or plastic screens or other three-dimensional screens with raised and lowered areas can be used for the support surface to achieve the patterned effect. The hydrojet processing of the fabric can also employ additives, such as caustic agents and abrasives, if desired, and other types of fluids. Besides woven fabrics, other nonwoven, bonded, layered, gauze, or composite fabrics or laminates may be similarly hydropatterned in accordance with the principles of the invention.

Other modes of hydro-processing of fabrics may be devised in accordance with the principles of the invention disclosed herein. For example, columnar jets, offset manifolds, and other water curtain arrangements might be used.
with three-dimensional and other patterned support surfaces or with patterned stencils to obtain patterned visual effects in fabrics. A related example of hydroprocessing is PCT Application No. US/89/ , filed on April 14, 1989, by Veratec Inc., entitled "Apparatus and Method For Hydroenhancing Fabric Properties", disclosing the use of hydroprocessing of fabric to improve fabric properties such as uniformity of yarn distribution, enhanced bloom, wear-resistance, anti-cupping, and anti-torquing. Additions or modifications to the basic hydro-processing line might also be used, for example, incorporating mechanical brushing or abrading, chemical additives, and post-treatment processing such as bonding, binder padding, finish treatments, stiffening, etc.

Other variations of structures, materials, products, and processes may of course be devised. All such variations, additions, and modifications are nevertheless considered to be within the spirit and scope of the present invention, as defined in the claims appended hereto.
CLAIMS:

1. An apparatus for hydropatterning a sheet of fabric conveyed to a patterning station along a machine direction, characterized in that:
   the conveyor includes a support surface formed with a pattern of raised or solid areas and lowered or void areas interspersed therein, wherein the fabric is placed flat in contact with the support surface as it is carried through the patterning station; and
   hydrojet means are disposed above the conveyor for directing a curtain of fluid downwardly to impact on the fabric as it is moved through the patterning station on the support surface, wherein said fluid curtain is substantially continuous across the fabric and controlled such that a visual property of the fabric becomes altered in correspondence to the pattern of raised or solid areas and lowered or void areas of the support surface due to the impact of the fluid curtain on the fabric against the patterned support surface.

2. A method for hydropatterning a pattern in a sheet of fabric conveyed to a patterning station along a machine direction, characterized by the steps of:
   conveying the sheet of fabric supported flat in contact on a support surface formed with a pattern of raised
or solid areas and lowered or void areas interspersed therein; and

directing a curtain of fluid downwardly to impact on the fabric as it is conveyed on the support surface, wherein said fluid curtain is substantially continuous across the fabric and controlled such that a visual property of the fabric become altered in correspondence to the pattern of raised or solid areas and lowered or void areas of the support surface due to the impact of the curtain of fluid on the fabric against the support surface.

3. The invention according to Claims 1 or 2, wherein the conveyor is a belt conveyor driven on rollers, or a cylindrical drum.

4. The invention according to Claims 1 or 2, wherein the support surface has raised and lowered areas formed three-dimensionally therein.

5. The invention according to Claims 1 or 2, wherein the support surface is formed from a plate having void areas perforated therein.

6. The invention according to Claims 1 or 2, wherein the fluid curtain is provided by hydrojet means including a manifold extending in a cross direction perpendicular to the machine direction having a plurality of nozzles spaced in the cross direction which eject divergent, overlapping jets of water so that the resulting water curtain impacts substantially evenly across the fabric.

7. The invention according to Claim 6, wherein the
hydrojet means includes a plurality of manifolds arranged in parallel spaced apart in the machine direction over the fabric.

8. The invention according to Claims 1 or 2, wherein the conveyor and support surface include open areas for draining fluid downwardly therethrough, and recovery means are disposed below them for recovering and recirculating the fluid.

9. The invention according to Claims 1 or 2, wherein woven fabric dyed with a dye having a non-colorfast characteristic is hydropatterned by subtractive color removal of dye from the fabric by the fluid to obtain a color washout effect.

10. The invention according to Claims 1 or 2, wherein fabric is hydropatterned against a three-dimensionally patterned support surface to obtain a fiber displacement pattern in the fabric.
FIG. 1
**INTERNATIONAL SEARCH REPORT**

**I. CLASSIFICATION OF SUBJECT MATTER**

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL. (4): D04H 1/44  
US. CL: 28/104, 105; 428/131

**II. FIELDS SEARCHED**

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Documentation Searched other than Minimum Documentation to the extent that such documents are included in the fields searched.

**III. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>US, A, 3,537,945 (SUMMERS) 03 NOVEMBER 1970, ENTIRE DOCUMENT.</td>
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<tr>
<td>Y</td>
<td>US, A, 4,379,799 (HOLMES) 12 APRIL 1983, ENTIRE DOCUMENT.</td>
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* Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier document but published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered without it and cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more of the other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

**IV. CERTIFICATION**

Date of the Actual Completion of the International Search: 06 JUNE 1989  
Date of Mailing of this International Search Report: 30 JUN 1989

International Searching Authority: ISA/US  
Signature of Authorized Officer: W. J. VANBALEN