Aug. 11, 1970 W. P. BOLEN ET AL 3,523,346

METHOD FOR MODIFYING THE SURFACE TEXTURING OF FABRICS

Original Filed May 13, 1966 2 Sheets-Sheet 1

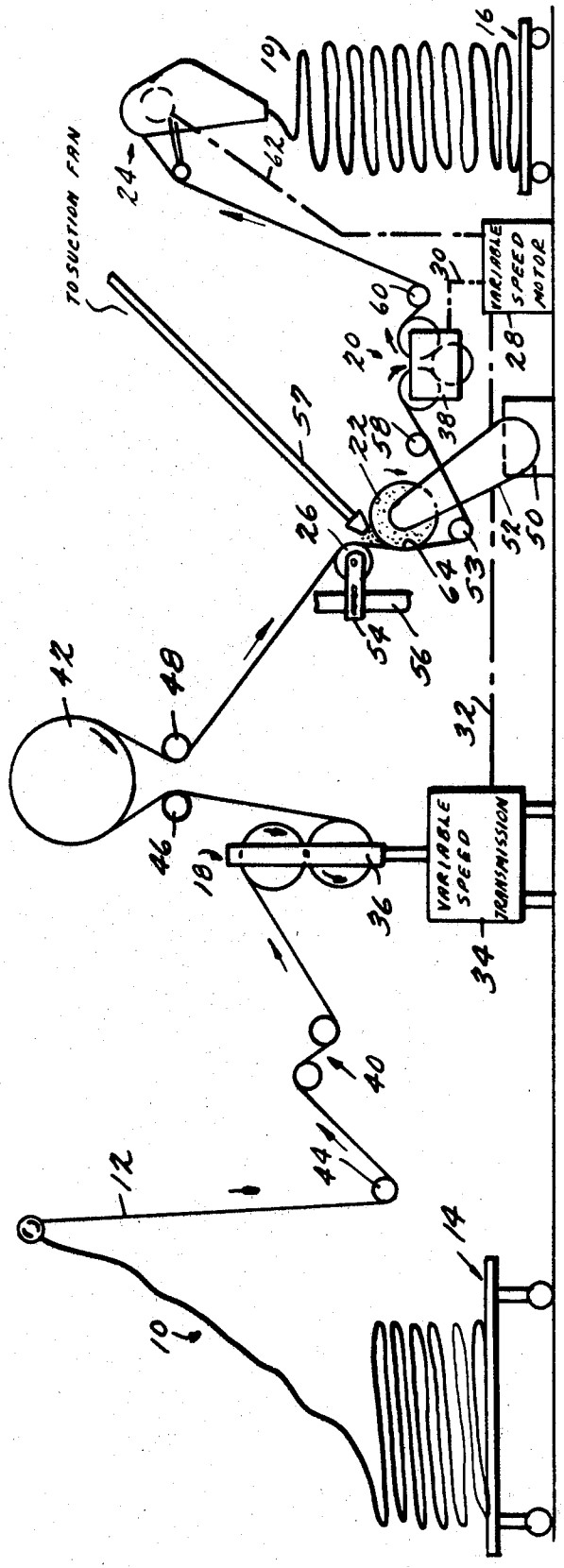

Fig. 1.

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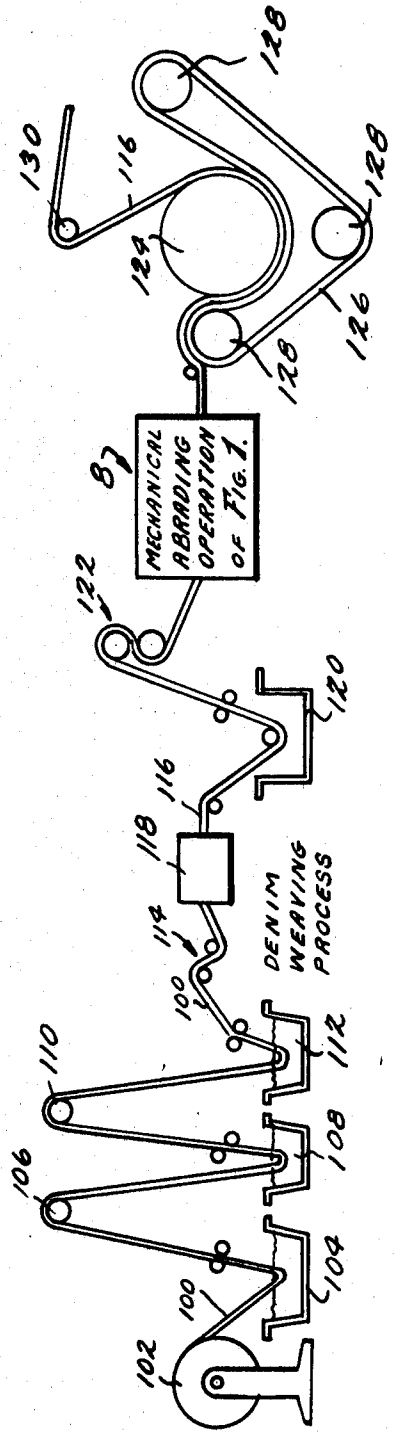
Fig. 2.



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METHOD FOR MODIFYING THE SURFACE TEXTURING OF FABRICS

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Int. Cl. D01d *11/06*; D02g *3/36*

U.S. Cl. 28—75 12 Claims

ABSTRACT OF THE DISCLOSURE

Fabrics containing irregularly dyed yarns are given a soft, velvety surface texture and a light mottled appearance by contacting a running length of the fabric with a rapidly rotating abrasive roller which mechanically loosens, breaks and removes an appreciable quantity of fibers from the face of the fabric and which simultaneously raises, fluffs and blends the remaining surface fibers.

This is a division of application Ser. No. 550,028, filed May 13, 1966, now abandoned which is a continuation-in-part of application Ser. No. 464,392, filed June 16, 1965, now abandoned.

This invention relates to fabrics having a modified surface texture of enhanced appearance and feel, to a process including a mechanical scrubbing, or grinding operation which imparts the modified texture to the fabric and to apparatus for carrying out the mechanical finishing operation.

The primary object of the present invention is the provision of a unique surface texture on the face of a fabric by means of a special mechanical grinding away of the fabric face, as contrasted with conventional napping or sueding, the special grinding being carried out by imparting relative motion between the fabric face and an abrasive surface. The unique surface texture almost invariably is characterized by a soft, slightly fluffy feel. The texture may also be characterized by a change in appearance due to the fluffy nature of the surface and due to the various effects of the grinding operation on different dyes, different fibers and different fabric constructions. The physical softness and the appearance of the abraded fabric has utility in a wide variety of fabrics, particularly fabrics for use in the manufacture of clothing, because of the pleasant warm feel, pliability and somewhat velvety nature of the surface.

It is a more specific object to produce the desired soft surface texture by passing the fabric in contact with an abrasive surface in a controlled manner and to provide apparatus for carrying out this operation. In the illustrative embodiments described more in detail hereinafter, a running length of the fabric is freed from all wrinkles and then a longitudinal portion thereof is placed under longitudinal tension to maintain it smooth and resistant to deflection. The tensioned portion is then passed in uniform contact with the surface of a rapidly rotating grinding roller having a harshly abrasive surface. The roller breaks and grinds away a significant amount of the fibers on the face of the fabric and lifts and blends the remaining surface fibers to produce a soft, slightly fluffy surface texture and, usually, a changed appearance. The grinding or scrubbing action is harsh, and special precautions both in the handling of the fabric and in the construction of the apparatus must be taken to assure that no part of the fabric becomes cut or torn by over-grinding.

It is a further object of the present invention to modify the appearance and feel of a fabric by a process which includes pretreatment of the yarn or fabric or both before the fabric is ground. According to the principles of this feature of the invention, the final surface texture is obtained by modifying or selecting one or more of the chemical or physical steps by which the initial yarn or fabric was produced so that the grinding action coacts with the special characteristics which have been imparted previously to the fabric. Specifically, the invention contemplates a dyeing process which reduces the normal penetration of the dye so that the subsequent grinding operation exposes undyed fibers, thus intensifying the mottled appearance which would be obtained by grinding alone.

It is another object to provide a yarn dyed woven fabric having warp and filling of different colors or yarns made up of different colored fibers, said fabric having a mechanically ground surface, as referred to above, so that the fabric takes on both a mottled or uneven shade and a soft, somewhat fluffy appearance and feel. Twill-woven yarn-dyed fabrics are particularly susceptible to the mechanical abrading process.

It is another specific object to provide an indigo denim fabric having, when new, a well-worn, broken-in appearance and feel. As is well known, conventional indigo denim is noticeably stiff and rough and of generally uniform color when new, but when it has been worn and laundered repeatedly, it fades unevenly, takes on a mottled appearance and becomes quite soft and flexible. These characteristics in broken-in denim clothing are desired by many persons from the standpoint of comfort and also because of the appeal of the seasoned, well-worn appearance.

According to the principles of the present invention, as it applies to the manufacture of new indigo denim having a broken-in appearance, the conventional indigo denim process is modified by subjecting the fabric to the special grinding operation which is the primary feature of the invention so that the fabric takes on a soft feel and an uneven color. In addition, it is generally desirable to first decrease the tenacity or penetration of the dye into the yarn in order to exaggerate or intensify the mottled appearance which is the primary characteristic of broken-in-denim.

The invention will be further understood from the following detailed discussion, taken with the drawings in which:

FIG. 1 is a simplified side elevational view of an apparatus for grinding the surface of a fabric according to the principles of the present invention; and

FIG. 2 is a schematic elevational view of equipment for producing a worn-look indigo denim in accordance with a specific object of the invention.

Production of enhanced fabric surface texture by grinding technique

Referring to FIG. 1 there is shown in schematic form an apparatus **8** for imparting a unique soft surface texture to one face of a continuously moving fabric **10**. For purposes of illustration the fabric **10** may be considered to be a yarn dyed, all-cotton twill having an upper face **12** which is predominantly warp ends of a different color from the filling. The fabric **10** is shown as being of a finite length which is fed as a running length to the apparatus from a cart **14** and which is delivered after being ground to another cart **16** whereby the ground length may be transported to another processing station.

The fabric **10** is moved through the apparatus **8** by two sets **18** and **20** of driven nip rollers which are hori-

zontally spaced from either side of a rotatably driven grinding roller **22**, the latter being the principal element of the illustrated apparatus. All of the other elements with the exception of a conventional cloth-folding device **24** are non-driven. It will be understood that suitable framing and supports, which are not shown, are provided for mounting the various elements in their respective positions. With the exception of a roller **26** for controlling the pressure of the fabric against the abrading roller **22** all the elements are fixed in position although, of course, provision for adjustment may be provided if desired. The nip rollers **18** and **20** may be of conventional rubber construction, and the various bars and idle rollers may be steel.

It is very important that the fabric **10** be rendered wrinkle-free and flat before it reaches the grinding roller **22**, and to this end the rear set of nip rollers **20** is driven at a higher peripheral speed than the forward nip rollers **18** in order to place the fabric **10** in tension in the direction of travel. As shown, there is provided a variable speed electric motor **28** which drives both sets of nip rollers through suitable drive connections illustrated at **30** and **32**. The drive connection **32** to the forward nip rollers **18** includes a variable speed transmission **34** whose output can be adjusted to provide the desired speed differential between the sets of rollers. The forward set of rollers **18** includes an upper and a lower roller both positively driven from the transmission **34** through a suitable gear connection **36**. The rear set of rollers **20** includes two upper rollers horizontally spaced a short distance from each other and a lower roller disposed below and in engagement with both the upper rollers. All three of the rollers are positively driven by the motor **28** through a suitable gear connection **38**.

As a further aid in removing wrinkles from the fabric **10** there is provided a pair of tension bars **40** in advance of the forward nip rollers **18** and a rotatable steam can **42** aft of the rollers **18**. As is known in the art, a steam can is a metal drum heated interiorly with steam and having a length equal to the width of the fabric.

An idle roller **44** is disposed ahead of the tension bars **40**, and two idle rollers **46** and **48** are disposed just below the steam can **42** for directing the fabric **10** to the can and receiving it from the can, respectively.

Aft of the steam can **42** are the pressure adjusting roller **26** and the grinding roller **22**. The latter is mounted in a fixed position and is driven at a constant high rate of speed in a direction opposite to the direction of fabric travel by an electric motor **50** and transmission **52**. The pressure adjusting roller **26** is disposed above and slightly forward of the abrading roller **22** and is adjustably mounted so as to be capable of varying the pressure of the fabric against the abrading roller **22**. In the construction which is illustrated the fabric **10** passes downwardly over the rear face of the pressure adjusting roller **26** over the forward face of the grinding roller **22** and then under an idle roller **53**. The roller **26** is therefore mounted for adjustment in a horizontal plane. In the interest of simplicity the adjustable mounting is illustrated in the form of a horizontally slotted arm **54** at each end of the roller **22**, the arms being secured to a fixed support **56** by bolts passing through the slots. In an actual installation it will usually be desirable to employ a more complex mounting which permits finer adjustment of the roller **22** and adjustment during operation. A suction hood **57** having an open lower end is disposed just ahead of the roller **22** to draw away the flock and dust removed from the fabric **10**.

From the idle roller **53** the fabric **10** passes under a tension bar **58**, through the nip of the rear nip rollers **20** to a rear idle roller **60** and thence to the conventional automatic folder **24**. The latter is driven from the variable speed motor **28** by a suitable drive connection illustrated at **62**.

In the illustrated embodiment the grinding roller **22** is a cylindrical body carrying abrasive particles at its surface and having high resistance to vibration and deflection during use. Typically the length of the cylinder will be equal to the width of the fabric although the cylinder may be separated into sections so as to produce ground stripes on the fabric. The abrasive particles may vary in size as desired or required to achieve the proper texture for a given fabric, and they may be embedded in the material of which the roller is constructed or provided in the form of a coating. For example, the roller **22** may be constructed of a solid abrasive which includes Carborundum or it may be a metal roller which carries the abrasive only on its surface. Good results have been obtained with a dynamically balanced, internally cooled 10-inch diameter steel cylinder of a length equal to the width of the fabric **10** and having a layer of heavy duty, 60-grit emery cloth **64** affixed to its surface.

In most cases it is important that the roller **22** be free of vibration and bowing or other distortion during operation, because the pressure of the fabric against the surface of the roller must be maintained uniformly with respect to both time and fabric dimensions. Vibration or deflection of the roller **22** will result in variations in the pressure, and this in turn will affect the grinding action. Since the grinding action must generally be harsh in order to obtain the desired soft fabric surface, variations in the pressure may result in over-grinding of portions of the fabric, thus cutting through or tearing the fabric.

It is important, therefore, that the roller **22** be dynamically balanced to eliminate vibration and distortion due to high rotational speed and that it be cooled to prevent thermal distortion resulting from the high friction of the grit with the fabric. It is known that the centrifugal forces set up in the material of construction during high speed rotation of a shaft or roller may create vibrations and distortion of the part. This comes about as a result of variations in density which in turn produce centrifugal forces which do not act in the same plane perpendicular to the axis of rotation. A shaft or roller which is dynamically balanced has been tested prior to use and modified, if necessary, so as to counterbalance these forces. With respect to cooling it is known that a shaft or roller may be made self cooling by constructing it as a hollow cylinder in which there is confined a mass of liquid.

Referring specifically to the operation of the grinding roller **22** on the warp face **12** of the fabric **10**, it should be understood that the grinding action contemplated by this invention is far more severe than conventional napping, sueding, or brushing techniques. While the grinding element, in some cases, might be constructed in the form of very stiff rotary brushes or stationary or reciprocating abrasive elements, the grinding action must always be so severe as to loosen, break and grind away an appreciable amount of the surface fibers thereby removing them in the form of extremely short fibers equivalent to flock. Simultaneously, the still-remaining surface fibers will be blended with each other and lifted thereby contributing to the production of a slightly fluffy surface having a soft warm feel and appearance. In addition, the ground surface of the yarn-dyed twill fabric **10** will take on a somewhat mottled appearance due to the grinding away of portions of the warp and the consequent exposure of the filling. A mottled appearance will also be obtained if the fabric or yarn has been dyed with a non-penetrating dye, because the grinding will remove some of the dye, thereby exposing undyed center portions of some of the yarns.

It will therefore be understood that the grinding away of an appreciable amount of the surface fibers of the fabric is critical for producing the texture and appearance contemplated by the present invention. In conventional napping or sueding operations special precautions are taken to avoid grinding with the result that the action of the napping brushes or other devices is limited to a teasing or

mild raising of the surface fibers. The absence of grinding action in the napping process results in little or no breaking of the surface fibers, and napping is therefore essentially a brushing operation which merely raises the surface fibers. Typically, napping and the like is carried out on fabrics having a soft filling, the operation being a raising of the fibers in the filling in preference to the fibers in the warp. On the other hand, some prior operations have subjected fabrics to abrasive rolls for the purpose of cutting the exposed thread surfaces to develop a cut pile or velvet effect on the fabric. Such operations have, however, carefully avoided the grinding away of the fabric surface.

With respect to the overall operation of the apparatus of FIG. 1 it has already been indicated that the fabric **10** is pulled through the apparatus by means of the sets of driven nip rollers **18** and **20** by being gripped between the upper and lower rollers of the forward set **18** and between the lower roller and each of the upper rollers of the rear set **20**. The rear set **20** is always driven at a higher peripheral speed than the forward set **18**. For example, the ratio of the output speed of the fabric to the input speed may be in the range of 1.02:1.00 to 1.04:1.00. The speed differential between the two sets, and thus the tension imparted to the fabric **10**, is controlled by changing the output speed of the transmission **34**. Since the folder **24** is driven from the common variable speed motor **28**, the folding operation is synchronized with the rate at which the fabric **10** is delivered from the rear roller set **20**.

It will be observed that the tension in the fabric is substantially independent of the pressure of the fabric against the grinding roller **22**, because it is the pressure-adjusting roller **26** which forces the fabric **10** against the roller **22**. This feature is desirable from the standpoint of flexibility of operation, because it permits a change in one variable without producing a corresponding change in the other variable. Generally, the tension will be adjusted first by reducing the speed of the rear nip rollers **20** to effect a wrinkle-free running length of fabric which is free of any appreciable sag. The speed of the fabric through the apparatus may be adjusted without changing the tension by varying the output speed of the motor **28**. Then the adjusting roller **26** is moved rearwardly to force the fabric against the rotating grinding roller **22** with sufficient pressure to effect the desired grinding. Ordinarily, the movement of the roller **26** is insufficient to produce any significant change in the tension.

It will thus be appreciated that the degree of grinding is affected not only by the nature of the fabric itself, but also by the tension, pressure of the fabric against the grinding roller **22**, peripheral speed of the grinding roller **22** and speed of the fabric past the grinding roller. The purpose of tensioning the fabric together with the steam can treatment is to remove all wrinkles and folds and to prevent the roller from distorting the fabric to an extent which would lead to over-grinding of portions of the fabric. The amount of tension which is to be applied will therefore depend on the nature of the fabric and will generally be arrived at by gradually increasing the tension until the fabric is taut and wrinkle-free.

Once a wrinkle-free fabric is obtained by proper tensioning the severity of the grinding action increases with an increase in the pressure of the fabric against the grinding roller **22** and with an increase in the peripheral speed of the roller **22** and with a decrease in the speed of the fabric past the roller. It is generally convenient to employ a constant speed grinding roller **22** and to utilize changes in pressure and fabric speed to control the process, although a variable speed grinding roller may be employed. The pressure and fabric speed to be employed will depend on the type of fabric being processed and on the kind of final fabric surface which is desired. Generally, a tough or thick fabric requires a higher pressure or lower fabric speed than a soft or thin fabric. It has been found that sufficient grinding action may be obtained by employing a range of fabric speed of about 20 yards per minute to 30 yards per minute, although higher speeds may be employed particularly when a more abrasive roller **22** is used. For most fabrics the pressure and fabric speed need not be related to each other in a predetermined manner. In the usual operation it will be convenient to first adjust the fabric speed by adjusting the output speed of the motor **28** and to then gradually increase the tension to the desired amount by lowering the output speed of the transmission **34**. The roller **26** may then be moved rearwardly to move the fabric into engagement with the grinding roller **22**. Subsequently, the fabric speed may be further adjusted either up or down by varying the output speed of the motor **28**.

While the apparatus is adapted to abrade only one face of a fabric, such as the warp face **12** of a twill-woven fabric, it will be understood that the invention is not limited to modifying only one face. If desired, the fabric **10** may be turned over and run through the apparatus again, or a second grinding roller and pressure adjusting roller may be added for grinding the lower face of the fabric **10**.

The grinding operation of the present invention is applicable to producing a unique surface texture on a wide variety of fabrics, the primary criterion for employing the process being whether or not the abraded fabric has an appearance and feel which is suitable and desirable for the intended purpose of the fabric. The final characteristics of a ground fabric result from the breaking, removal, raising and blending of the surface fibers, but as previously mentioned, the results obtained in each case will be affected by a number of characteristics of the fabric. These include the kind of fiber present, the physical arrangement of the yarns in the fabric, the type of dye and the type of dyeing process. In general it may be said that enhanced appearance and feel may be imparted to woven and knitted fabrics and to fabrics whose yarns are made of natural plant fibers, synthetic fibers, continuous filaments, some animal fibers and blends of any of these. When continuous filaments are present, very careful control of the grinding operation is required, because the abrading surface sometimes tends to catch a broken end of a filament and pull a length thereof out of the fabric causing puckering or other defects. Cotton yarns, synthetic yarns, and blend of cotton with 35%–65% polyester fiber or other synthetic fiber are admirably suited to the process, and the invention is therefore particularly concerned with fabrics made of these yarns.

Considering in more detail the effect of the fabric construction on the appearance and feel after abrasion, it may be said that, in general, the contrast between the ground and unground fabric is most pronounced when the fabric is a yarn-dyed woven fabric. One reason for this is that the grinding action, in breaking, removing and raising the fibers tends to blend some of the surface fibers of the warp and the filling. In addition, there is a selective grinding of those thread portions which contact the grinding surface to the greatest extent thereby removing parts of some threads while simultaneously exposing parts of other threads. Since yarn-dyed fabrics are typically woven with warp and filling of different colors, the abraded fabric tends to be uneven or mottled in color. In addition, the warp and filling may be different kinds of yarn in which case the fluffing of each may be different. The effect is more pronounced when there is a predominance of one group of yarns on the abraded face of the fabric or when ribs or cords have been woven in or otherwise formed. In this situation, the raised yarns receive more severe grinding thus becoming fluffed to a greater extent, and at the same time, a greater proportion of the fibers of the other yarns is exposed and blended with the fibers of the raised yarns.

Thus, fabrics woven with a twill weave or a satin weave are admirably suited to the abrading process, because the

grinding takes place preferentially on the raised yarns, usually the warp, of this kind of fabric. It has already been pointed out that a specific object of the invention is to apply the grinding process to a specific twill, denim, in order to produce a broken-in seasoned appearance and feel. In the case of stretch denim, which typically includes nylon in the filling, care must be taken to avoid "picking" of the nylon, as previously referred to. Picking of the nylon can be best avoided by selecting warp yarns of substantially greater diameter than the nylon yarns so that the latter are protected during grinding. In the case of blue denim, the blue warp prepared by an indigo dyeing process produces the added effect that the selective grinding action on the warp removes some of the dye thereby lightening the overall color of the fabric. This added effect results from the characteristic of indigo to deposit primarily on the surface of the fibers so that it is partially removed by the abrading process, thereby exposing the center portions of some of the yarns. Examples of fabrics having selectively raised groups of yarns, other than denim, are cotton flannel, duck, cotton gabardine, sateen and seersucker.

The fiber blending or smearing effect of the grinding operation has special significance when the individual yarns of which the fabric is made are formed of fibers of different colors. Preferably, the yarn is formed of all cotton fibers, all synthetic fibers or blends of cotton and synthetic fibers.

As examples of the invention, samples of conventionally prepared yarn-dyed, warp-faced, cranberry (red) and loden (green) denim of all-cotton construction and samples of yarn-dyed cranberry, blue, gray and loden denim of 50% cotton-50% polyester construction were passed through the above-described apparatus. In each case the initial samples, which were all woven with substantially white filling, presented a typical twill appearance and a rather rough surface texture. That is, the fabrics exhibited the conventional, sharply-defined diagonal ribs which characterize conventional denim. After grinding of the warp face, each of the fabrics was soft and fuzzy. In addition, diagonal ribs, while still visible, were no longer the predominant feature. Instead, the fabric took on the general overall color of the warp. The overall color was not uniform, however, because areas of light and dark shades of irregular size and shape were present. In addition, the actual direction of the filling yarns became apparent due to the presence of light and dark streaks running in the filling direction. Surprisingly, the overall color in the cranberry and loden fabrics appeared to be somewhat darker in shade than the overall color of the unground samples when viewed at arm's length. This evidently resulted from a combination of the fluffy surface texture with the smearing of the surface warp fibers with each other and with some of the filling fibers. The soft surface texture rendered the fabric less light-reflective and therefore tended to make it appear darker. The blending of the surface fibers tended to obliterate the portions of the white filling yarns which were clearly visible in the unground fabrics, and this effect combined with the reduced reflectance tended to give the appearance of a darker fabric. The individual warp yarns, of course, did not become darker, and, in fact, portions of some of them were lightened by the grinding action. The ground grey fabric appeared somewhat lighter in shade than the corresponding unground fabric.

Still another effect of the grinding on the above-described samples of denim was the removal of the small naps and the blurring of larger naps. Naps appear in conventional denim in the form of small tufts on the filling, the tufts resulting from the use of coarse-combed filling yarns.

In another example, a sample of piece-dyed, tightly-woven black twill of all cotton construction was ground by the apparatus. In this case, the ground sample was more flexible than the unground sample and was only slightly softer. The ground fabric was slightly lighter in shade but showed no mottled effect.

The grinding process is not, however, limited to twill-weave, satin-weave and corded fabrics because desirable effects can be produced on plain-woven fabrics as well. For example, the surface texture of fabrics, such as shantung and oxford, can be substantially altered by the process. In plain-woven fabrics having warp and filling of different colors, such as gingham and chambray, the surface appearance as well as the surface texture may be altered as a result of fiber mixing and the different action which may occur on the different yarns, as previously mentioned. This will be especially true if some of the yarns have been surface-dyed as discussed above, with respect to indigo denim.

The process is also applicable to undyed fabrics and to fabrics which are raw stock dyed and piece dyed. In the case of undyed fabrics, the removal of the surface fibers effects a cleaning action which often results in a significant lightening of the shade of an undyed fabric as well as a physical softening of the surface. The lightening effect is particularly apparent when the undyed fabric is a freshly-loomed, unfinished fabric, that is, one which is rough and full of blemishes and impurities which come either from the nature of the fibers or which were picked up in the manufacturing process. In this case, the grinding action removes not only the surface fibers but also the greater part of the visible trash, and this action, together with the fiber-blending action, produces a surface which is uniform in color and feel. In a specific example, a twill-woven, all-cotton fabric was produced in a conventional manner except that undyed yarn was employed. The ground fabric retained the diagonal ribs of the original sample but was very soft and of uniform off-white color. Only a very few, widely-spaced tiny flecks of dark trash remained.

When the fabric is a dyed fabric, the final effect of the grinding operation will depend in part on the nature of the dye and its method of application. In the case of a piece-dyed fabric, warp and filling are the same color, and the change in appearance is due primarily to the slightly fluffy look obtained by grinding. In the case of yarn-dyed fabrics, in which the warp and filling are typically of different colors, the change in appearance will generally be more pronounced.

With respect to the type of dye and the type of dye process, it is possible to select and control these variables so as to effect changes in the appearance of the final fabric. Broadly, this feature of the invention is aimed at intensifying the mottled appearance which can be obtained solely as a result of the grinding operation. The variables include (1) the use of dyes which inherently do not penetrate deeply into the fibers, (2) chemically treating the yarn or fabric prior to dyeing so as to reduce the tenacity of the dye or to reduce its penetration into the fibers, (3) adjusting the variables during dyeing with a penetrating type of dye so as to reduce penetration, and (4) chemically treating the yarn or fabric after dyeing to alter the normal tenacity or penetration of the dye. In each case, the object is to send to the grinding operation a fabric which will respond to the abrasion by becoming mottled and, usually, lighter in color.

As an example of the use of a dye which inherently does not penetrate deeply into the fibers, reference is made to conventional indigo which is employed in making one type of well known blue denim. Indigo is a dye which deposits during the dyeing process primarily on the surface of the fibers. As a result of this characteristic, the color of indigo dyed yarns in a fabric will be lightened when the fabric is ground by the process of the present invention due to the removal of some of the surface fibers. As already explained, the reduction in color will generally not be uniform as a result of the fiber intermingling

characteristic of the grinding operation and, in the special case of a twill weave, a very definite mottled appearance will result.

An example of a chemical before-dyeing treatment aimed at altering the tenacity of the dye is a special treatment of cotton yarn prior to being dyed by the indigo process, this treatment being described in detail hereinafter. Briefly stated, the special treatment consists of the elimination of a conventional chemical scouring bath for the yarn with the result that natural waxes and other substances remain in the yarn and make the deposition of the indigo dye uneven along the length of the yarn.

Adjustment of the variables in a dyeing process in order to limit dye penetration may be carried out in several different ways and may involve modification of the physical process steps or modification of the chemical nature of the dye baths or both. In order for the subsequent grinding operation to produce the desired mottled effect, the penetration of the dye must be controlled rather precisely so that the yarns have an undyed center and an outer layer of dyed fibers which is of generally uniform color and of generally uniform thickness. If the dye has not penetrated sufficiently, the fabric when ground will be too light in color and will lack the contrast necessary to produce the distinct mottled appearance which is desired. If the dye has penetrated too deeply, the grinding operation can produce the effects described hereinbefore, but the intensified mottling due to exposure of undyed yarn centers is not present. If the thickness of the layer of dyed fibers is non-uniform along the yarns, the ground fabric may show too much contrast between light and dark areas.

It has been found that uniform, limited penetration of a normally penetrating dye such as a hydron blue dye can be obtained by modification of the physical process steps while employing standard chemical procedures. Hydron blue is a well-known sulfide dye which is conventionally employed to dye cotton by a vat process. Broadly, the conventional process includes the steps of rendering the water-insoluble dye substance soluble by treatment with a reducing agent such as sodium hydrosulfite, impregnating the yarn or fabric with the solution and treating the impregnated fibers with an oxidizing agent to convert the soluble form of the dye back to the insoluble form. The following examples illustrate that relatively minor changes in the dyeing operation may be employed to obtain a yarn having the desired characteristics. In each example, a rope of all-cotton yarns was dyed, after being combed out flat and parallel, by a padding process employing a dye bath made up of 18 oz./gal. Denivat Everblue 57 (a hydron blue designated as Vat Blue 43 CI Number 53630) and 4 oz./gal. Denivat Everblack JHX. As is known, padding includes saturating the goods with the soluble dye solution, as by dipping a running length of the goods into a trough of the solution, and squeezing out the excess by passing the saturated goods between heavy squeeze rolls.

Example 1.—The yarns were dyed by padding at 190° F. (quick dip), steamed for 1 minute, washed in warm water, oxidized for 15 seconds with 1% hydrogen peroxide, washed in cold water and dried. Upon examination, the individual yarns were found to have an undyed core of very small diameter relative to the diameter of the yarn. The remainder was dark blue with intermittent longitudinal streaks of white. The yarns were unsatisfactory because penetration of the dye was too great to permit exposure of portions of the light core by the heretofore described grinding operation.

Example 2.—The yarns were dyed by padding at room temperature (quick dip), steamed for 1 minute, washed in warm water, oxidized for 15 seconds at 120° F. with 1% hydrogen peroxide, washed in cold water and dried. The yarns were unsatisfactory, because penetration of the dye was too slight.

Example 3.—The yarns were dyed by padding at 100° F. (immersed for 15 seconds), washed in warm water, oxidized for 15 seconds at 120° F. with 1% hydrogen peroxide, washed in cold water and dried. The yarns were unsatisfactory because penetration of the dye was too deep. Many of the yarns were dyed all the way through.

Example 4.—The yarns were dyed by padding at room temperature (quick dip), washed in warm water, oxidized at 120° F. with 1% hydrogen peroxide, washed in cold water and dried. The yarns were unsatisfactory because dye penetration was very slight and uneven.

Example 5.—The yarns were dyed by padding at 150° F. (quick dip), exposed to air for 15 seconds, washed in warm water, oxidized at 120° F. with 1% hydrogen peroxide, washed in cold water and dried. The yarns were satisfactory in that they had an undyed center surrounded by a dyed outer layer of substantially uniform thickness along their lengths. These yarns are suitable, for example, for making denim which may then be subjected to grinding to produce a broken-in denim, as described more in detail hereinafter.

An example of altering the effect of a dye after a dyeing process is a bleaching operation carried out on an indigo-dyed yarn, as more fully described hereinafter. The bleaching step lightens the shade of the yarn and, in the specific embodiment, cooperates with a non-uniform deposition of the dye on the fibers to aid in the production of a mottled appearance.

The abrading process is applicable to fabrics which have been given any of the conventional dry and wet finish treatments. Conventional dry finish treatments include various mechanical operations such as brushing, tentering and shearing. Conventional wet finish treatments include sizing processes and resin impregnation to impart crease-resistance. The resin treatment may be of either the pre-cure or post-cure type.

Production of enhanced surface texture and appearance by grinding technique in combination with prior operations

FIG. 2 ilustrates a process in which the previously described grinding operation cooperates with previously employed chemical operations to intensify the mottled surface appearance over that which would be obtained by grinding alone. While the illustrated process is directed toward producing an indigo denim fabric having a well-worn feel and appearance, it is described by way of example only and is not intended to limit the invention. That is, the chemical pre-dyeing and chemical post-dyeing steps which are described exemplify operations which may be employed to augment the effect of the grinding operation in a variety of processes, but they are not necessarily critical to obtaining a denim which is suitable as a broken-in denim.

Before considering the modified denim process, it will be helpful to review the conventional process. Conventionally, indigo denim manufacture begins with a chemical scouring operation during which raw cotton yarn is passed through a hot aqueous alkaline bath containing, for example, 0.7% lime, sodium carbonate and 1.0% caustic soda. It is well known that treatment of this type loosens and removes dirt naturally occuring waxes and oils present in the yarn. In conventional denim manufacture, as in almost all cotton fabric manufacture, a scouring process is considered necessary if a uniform color is to be obtained in subsequent dyeing or bleaching operations, because the presence of waxes and oils adversely affects these operations.

After scouring, the conventional indigo denim process includes a rinsing step and a yarn-dyeing step in which the yarn is dyed with an indigo blue dye. As is known, indigo blue dyes are vat type colors, that is, colors which are initially water insoluble and which are rendered soluble by chemical reaction prior to use. Conventionally, the insoluble indigo color is dispersed in water and caustic soda and a reducing agent, such as sodium hydrosulfite, are added to convert the color to a soluble chemical com-

plex. The yarn is then passed a number of times through a bath of the soluble complex, the absorbed complex being oxidized to the insoluble blue form after each pass. The oxidation may be carried out by passing the yarn through a suitable chemical oxidizing bath or by subjecting the yarn to atmospheric air for a period of time. After the last oxidation, the yarn is rinsed and dried, the drying operation being carried out for example, by passing the yarn over a series of heated drums.

Following dyeing, rinsing and drying, the yarn in the conventional indigo denim process is twill-woven with a white or gray filling yarn into a fabric having a predominantly blue upper, or warp face. The fabric, after a conventional brushing operation to remove loose foreign matter and dust, is then passed through a finishing bath where chemical additives are absorbed. The primary purpose of this operation is, broadly, to restore some of the softening or plasticizing substances to the fabric to effect more stiffness and to prepare the fabric for a subsequent compressive shrinking operation. A conventional finishing bath for denim is an aqueous bath containing a starch, a rewetting agent and a dispersion of an oil or wax, typical substances being palm oil, coconut oil, peanut oil, mineral oil or carnauba wax.

Following another drying step, the fabric in the conventional denim process is sprayed with a fine spray of water to provide a uniform moisture content and is passed through a compressive shrinking machine. As is known, shrinkage of a fabric in a compressive shrinkage machine is brought about by close contact of the fabric with an elastic or felt belt pasing under tension over a heated roll, the arrangement mechanically forcing the filling yarns of the fabric together. The fabric is substantially complete after this operation.

Referring specifically to FIG. 2, the raw yarn from which the fabric is to be made is illustrated at **100** as being in the form of bundles or chains wound on a suitable package **102**. The dry, unscoured yarn containing natural waxes and other substances is unwound from the package **102** and is passed directly through a first dye tank **104** containing a conventional chemically reduced solution of an indigo blue dye. The presence in the yarn of the natural oils and waxes and other naturally occurring substances effects an unbalanced or uneven absorption of the dye with the result that the dyed yarn is not uniform in color along its length or in its tendency to retain the dye. The yarn after dyeing may actually have a mottled appearance, or it may appear uniform when, in fact, the tenacity of the color may be non-uniform.

From the first dye tank **104**, the wet yarn moves upwardly over an elevated roller **106** to effect a long path of travel during which the soluble form of the dye is oxidized by atmospheric air to its insoluble blue form. This process is repeated by subsequently passing the yarn into a second dye tank **108** and up over an elevated roller **110**. The yarn is rinsed by passing it through a rinse bath **112** and is then dried as by passing it over heated drums **114**. Preferably, the yarn is dyed to a lighter shade of blue than is conventionally done so that both the lighter shade and the mottled appearance, or the tendency to become mottled, will contribute to the faded, uneven appearance of the final fabric. In the process illustrated, the yarn is passed through two dye tanks **104** and **108**, whereas in a conventional process employing the same equipment and materials, the yarn would be passed six times through the dye solution. The production of a lighter shade at this stage is not a strict requirement, however, inasmuch as the subsequent operations may be varied to produce the desired final shade. In some cases, the desired final result can be obtained even without eliminating the chemical scouring operation, although the mottled appearance is then not as noticeable.

After dyeing and drying, the yarn **100** is processed into a blue warp face denim fabric **116** by conventional procedures which are illustrated at **118**, including the twill weaving of the dyed yarn with white or grey filling yarn. The weaving and related operations are generally carried out completely separately from the dyeing, and it will be understood that the schematic drawing is intended to illustrate any and all conventional steps, including packaging and slashing before weaving and brushing after weaving, if desired.

At this stage, the denim is similar to conventional new denim in having a rather harsh, stiff feel and the typical well-defined diagonal stripes or ribs produced by the twill weave pattern and by the contrast between the blue warp and light filling. However, the fabric differs from conventional new denim in being of uneven shade when viewed, for example, at arm's length or further. That is, the fabric has light and dark areas of irregular size and shape which merge into each other. Upon close examination, it is found that the light areas result from the light color of portions of some of the warp yarns, this light color having resulted from uneven dyeing, as previously discussed.

From the weaving operation **118**, the fabric in the illustrated embodiment is passed through a bleaching bath **120** which may be, for example, an aqueous solution containing 1.0% soda ash and .05% sodium hypochlorite. Conveniently, the bath contains conventional finishing chemicals generally employed for denim production, although these may be provided in a separate bath if desired. In the illustrated embodiment, the bath **120**, in addition to the soda ash and sodium hypochlorite, contains a combination of peanut oil and auxiliaries in addition to a fatty base derivative used as a sewing lubricant. While a chlorine bleach is preferred from the standpoint of ease and economy, other bleaching agents, such as aqueous solutions containing chlorine dioxide or hydrogen peroxide, may be employed.

The effect of the bleaching bath **120** on the fabric is to reduce the cast of the blue color and to intensify or bring out a mottled uneven color which in the final fabric gives the well-worn or broken-in appearance. Conventional denim processing does not include bleaching of the fabric, because a dark, generally uniform color is desired.

The bleaching operation should not be regarded as critical to the success of the overall indigo denim process, because the grinding operation can usually be varied to produce much the same result due to the surface nature of the indigo color. The retention of natural waxes and oils in the indigo dyed yarn is generally desirable, however, because of the uneven color which results therefrom.

Aft of the bleaching bath **120** is a pair of heated drying drums **122** which evaporate substantially all the water from the fabric **116**. The warp face of the dried fabric is then mechanically scrubbed by the grinding apparatus **8** of FIG. 1, following which the fabric is subjected to a shrinkage operation. The latter is a conventional operation which is optional so far as the present invention is concerned.

As shown, the shrinkage operation is carried out by a compressive shrinking machine which includes a heated cylinder **124** and a thick, tensioned rubber belt **126** which is looped over three rollers **128** and held in contact with the cylinder **124**. As is known in the art, the arrangement and control is such that the fabric **116** in passing between the cylinder **124** and the belt **126** conforms to the compression of the latter and is mechanically shrunk by having its filling yarns forced together. From the belt **126** the fabric **116** passes over an idle roller **130** and thence to a packaging operation (not shown). If a compressive shrinkage step is employed, it must be employed subsequently to the abrading step, because the tension applied to the fabric during the latter step would tend to pull out the shrinkage.

The warp face of the indigo denim produced by the above process is characterized by the faded appearance and soft feel of conventional indigo denim which has been worn and laundered a number of times. More specifically, the fabric is overall quite light in shade and is mottled in that there are darker areas of irregular size and shape merging into lighter irregular areas with no well-defined boundary between adjacent areas. At the same time, the fabric is considerably more uniform in color than conventional new denim in that there is substantially no visible contrast between the blue warp and the light-colored filling. That is, the typical, sharply-defined twill appearance of conventional new denim is absent just as it is absent in well-worn, well-washed conventional denim. When the fabric is examined closely, it is found that those warp yarns which are exposed on the warp face vary in shade along their length, at times becoming almost white as a result of the uneven penetration of the dye and the subsequent grinding away of the unevenly-dyed surface fibers. It is also found that the exposed fibers of the raised warp yarns stand away from the yarns and present a soft, fuzzy feel. The filling yarns have a similar soft feel, although the effect is not as noticeable because the filling has been ground to a lesser extent than the warp. Further, it is found that the surface fibers of the exposed warp yarns are intermixed or blended with each other and with the raised fibers of the exposed filling. These fiber characteristics cooperate with each other to produce the previously-mentioned mottled effect and the previously-mentioned lack of contrast between warp and filling.

As previously indicated, broken-in denim may also be prepared by grinding denim which has been woven from the modified hydron blue yarn.

It will thus be appreciated that the present invention provides for the production of a unique fabric surface texture by (1) a special mechanical grinding of a fabric face or (2) the special grinding technique in combination with prior or subsequent operations including the use of surface dyes as distinguished from penetrating dyes and the use of chemical and physical treatments which affect the shade, tenacity, penetration and other characteristics of the dye. The invention is not restricted to specific kinds of fabrics or to specific apparatus, and the details given in the embodiments and examples are not intended to be limiting.

What is claimed is:

1. A method of producing a yarn-dyed woven fabric having an enhanced appearance and feel characterized by a mottled shade and a soft, pliable, slightly fluffy feel, said method comprising: dyeing a group of yarns to produce yarns, each of which has an undyed center surrounded by a layer of dyed fibers, the dyeing process including saturating the yarns with a solution of a normally deeply penetrating dye and limiting penetration of the dye so as to leave the centers of the yarns undyed;

weaving said dyed yarns with yarns of a different color to produce a fabric having warp yarn and filling yarn of different colors;

rendering the woven fabric flat and wrinkle-free; and

imparting a mottled shade and a soft pliable feel to a face of the wrinkle-free fabric by contacting said face with a highly abrasive surface and imparting relative motion between said face and said surface to loosen, break, and remove some of the fibers on said face, to raise a substantial portion of the fibers remaining on said face and to blend some of the surface fibers of the warp and filling, thereby selectively grinding portions of some yarns in preference to other yarns and thereby exposing portions of said undyed yarn centers.

2. A method as in claim **1** wherein the fabric is rendered wrinkle-free by applying tension thereto and wherein the step of breaking, removing and raising fibers includes passing the tensioned fabric in uniform contact with a rapidly rotating abrasive roller.

3. A method as in claim **1** wherein said dyed group of yarns are cotton-containing yarns, wherein said weaving operation produces a twill-woven fabric, said fabric showing marked contrast in color between warp and filling as a result of a preponderance of warp yarns exposed at one face and a preponderance of filling yarns at the other face, whereby selective abrading action takes place on those yarns which are in preponderance at the face which contacts said abrasive surface and whereby the blending of the fibers substantially eliminates the color contrast between warp and filling.

4. A method as in claim **3** where in cotton-containing yarns are dyed blue, wherein said weaving operation produces a blue denim fabric having a predominantly blue warp face, and wherein said blue warp face is contacted with said highly abrasive surface.

5. A method as in claim **4** wherein the step of irregularly dyeing the yarn along its length is carried out by employing cotton fiber which contains natural oils and waxes, said oils and waxes causing the dye to penetrate the yarns irregularly along their lengths.

6. A method of producing a blue denim fabric having a seasoned, well-worn appearance and feel characterized by a light mottled shade of color and a soft and pliable feel, said method comprising:

indigo dyeing cotton-containing yarn irregularly along the lengths of the yarn;

weaving said irregularly dyed yarn with yarn of lighter color to produce a blue warp-faced denim fabric;

grinding away an appreciable quantity of the fibers at the warp face of said fabric and raising and blending the remaining fibers so as to lighten the shade of said fabric, to substantially eliminate the contrast between individual blue and light yarns, to render the ground face soft and to impart to said ground face irregular areas of lighter shade which merge into adjacent irregular areas of a darker shade.

7. A method for producing blue denim fabric having a seasoned, well-worn appearance and feel comprising:

dyeing to a light indigo shade by the indigo process a cotton yarn having natural oils and waxes therein as a result of no previous scouring operation on the yarn after it has been spun, whereby the depth of penetration of the dye into the yarn varies irregularly;

weaving denim fabric from said dyed yarn by a twill weaving process;

subjecting said fabric to a mild bleaching treatment whereby some of the surface dye on said fabric is removed unevenly; and,

abrading the twill surface of said fabric to produce a soft feel.

8. A method as in claim **7** including subjecting the abraded fabric to a compression shrinking operation.

9. A method as in claim **7** wherein said bleaching treatment comprises passing the fabric through an aqueous solution of soda ash and chlorine.

10. A method as in claim **7** wherein the abrading of the twill surface of the fabric is obtained by passing the fabric in contact with the surface of a rapidly rotating roll, the surface of which is abrasive.

11. A method for producing a blue denim fabric having a seasoned, well-worn appearance and feel characterized by a light mottled shade of blue and a soft pliable feel, said method comprising: dyeing cotton yarn to a light indigo shade by the indigo process, said yarn having natural oils and waxes therein as a result of no previous scouring operation on the yarn after it has been spun whereby the depth of penetration of the dye into the yarn varies irregularly; producing denim fabric by twill weaving said light blue yarn with filling of a

lighter color to produce a denim fabric having a preponderance of the light blue yarn on the warp surface of said fabric; continuously moving a running length of said fabric through a treatment zone; rendering the portion of the fabric in said treatment zone flat and free of winkles by applying high tension to said portion; and simultaneously imparting to the warp face of said fabric portion a lighter, uneven shade of color and a soft warm feel characteristic of well-worn denim by mechanically abrading said warp face so as to remove some of the surface fibers from said blue yarns and to lift the remaining surface fibers, said abrading being carried out by passing said warp face in contact with an abrasive surface.

12. A method as in claim **11** wherein the abrading of the twill surface of the fabric is effected by passing the twill surface of the fabric in contact with the surface of a rapidly rotating roll disposed in said tension zone normal to the direction of fabric movement, said roll having a highly abrasive surface extending the width of the fabric.

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