Comprehensive View on Garment Dyeing and Finishing

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Processing of garments offers many advantages compared to conventional route adopted in dyeing and finishing of fabrics. Many developments have taken place in the field of garment processing, especially in dyeing and finishing and easy care finishing has become synonymous with finishing of garments. Nevertheless stringent measures are required in the case of garment processing since any damage at this stage would result in value added losses. This paper discusses certain aspects related to dyeing and finishing of garments, in the selected area.

Keywords: Dyeing; Shrinkage; Stoneless wash; DP finish; Strength loss

INTRODUCTION

The benefits of garment processing revolve around quick response, improved inventory control and it is an obvious way to meet quick fashion changes also. During 20th century, most of the developmental works were aimed at enhancing the comfort properties of the fabrics and garments along with various functional finishes by improving 'use' value, enhancing 'esteem' value and imparting 'gimmick' values. There have been considerable concerns over the discomfort of wrinkle free garments due to hydrophobic nature of finish imparted to the fabrics in conventional treatments and reduced absorption properties. Washing of denim goods and the associated problems have a longer history and extended to other items such as chambrays and indigo dyed fabrics.

GARMENT DYEING AND DYEING MACHINES

The dyeing of the garments demands more care than fabrics due to the fact that the processing involves value added goods. The entire garment dyeing activities may be broken down into four categories, namely, fully fashioned garment dyeing, cut and sewn garment, dyeing of 100% cotton goods for boutique trades and processing of denims leading to stone wash, snow wash, over dyeing, stoneless washing and highlighting effects. A multi-colour splatter effect called 'splatter dyeing' has been made possible on denim garments due to the fact that the processing involves value added goods. The dyeing of the garments demands more care than fabrics due to the fact that the processing involves value added goods.

Unlike fabric dyeing machines where rollers and jets are commonly employed in moving the fabrics through the machine and liquor, garment dyeing machines require special arrangements to move garments with reduced tumbling actions. Salient features of drum type machines, extractors, paddle type and jet circulators have been discussed in the past by many authors as shown in Table 1. The attributes of ideal garment dyeing machine would include automatic controller for cycle repetition and optimization, shade consistency, centrifugal extraction, heating facility to make the cycle faster, cooling facility, lint filter to give cleaner look to the garments, sampling device for better shade management, addition tank, tilting mechanism for faster unloading of the garments, variable speed for processing different garments and volume level control for shade reproducibility.

Paddles are widely accepted for sweaters, loosely knitted goods due to their soft dyeing action, which avoids abrading and pilling the garments as shown in Figure 1 and Figure 2. For gentleness, the dyeing is carried out with an m:l ratio of 30:1 to 40:1, the blades of the paddle are either curved or rounded and the rotating speed of the paddle can be regulated from 1.5 rpm to 40 rpm. Overhead paddle, lateral paddle and high temperature paddle machines serve the needs of the entire range of the garments.

Dye extractors with multi-pocket designs have compartments to control garment movements, abrasion due to mechanical

Table 1 Garment dyeing machines and their principles

<table>
<thead>
<tr>
<th>Type of construction</th>
<th>Type of liquor and garment movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddling machine</td>
<td>Mechanical arrangements like paddle, drum</td>
</tr>
<tr>
<td>Drum machine</td>
<td>Hydrodynamic movement with adjustable jets</td>
</tr>
<tr>
<td>Washing-centrifuging machines</td>
<td>Hydrodynamic circulating dyeing machines with so called floating liquor circulation principle</td>
</tr>
<tr>
<td>Jet dyeing centrifuging</td>
<td>Jets and nozzles are used to facilitate movement of the garments</td>
</tr>
</tbody>
</table>

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action by carrying the garments through the dye liquor in the compartments. By making more compartments, the tumbling effects and the entanglements in the garments are reduced and also are the abrasions associated with it.

In drum type machines, a perforated drum is suspended lengthwise in a horizontal position, submerged in the dye liquor (Figure 3). The drums are divided into compartments and are capable of rotating in both the directions at 2 rpm to 20 rpm, when temperature varies up to 140° C. Drum dyeing-centrifuging machines are also called multipurpose drum machines or multi-rapid dyeing-centrifuging machines, since these machines can perform scouring, dyeing, centrifuging and conditioning successively with automated controls.

In jet machines, the dye liquor and goods are kept in circular motion by jet nozzles whose direction and force are adjustable. Turbulence nozzles at the bottom ensure liquor circulation, prevent goods from sinking and allow opening them. The machine capacity varies from 25 kg - 125 kg of dry weight with m:1 ratio of 1:25 to 1:40 and temperatures as high as up to 130° C.

FINISHING OF GARMENTS

Mechanical finishing of garments refers to the finishes, which are given to made-up textiles before they are ready for delivery. In most of the cases, the process consists of a steaming treatment, to remove creases or to relax the garments. Driers are often constructed using tumblers, made from perforated drum, equipped with heating unit, an air suction unit, circulation unit and a lint sieve device. The steam is blown outwards through the garment at low tension. Toppers are used for simultaneous steaming and stretching of trousers while pressing machines are used for pull-overs, jackets, sweatshirts, shirts etc., with dummies. Ironing is carried out after toppers, pressing dummy operation, in areas like collar, cuffs, pocket and button flaps, etc.

Earlier formaldehyde was originally used for improving the wet strength of the regenerated cellulosic fibres under acidic conditions and since then the applications have improved in various areas. Though the processes like wrinkle free, easy care, durable press finish employ similar chemicals, the results are varied.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-cure</th>
<th>Post-cure</th>
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</thead>
<tbody>
<tr>
<td>Curing</td>
<td>Flat state</td>
<td>Garment form</td>
</tr>
<tr>
<td>Benefits</td>
<td>Better smoothness</td>
<td>Smoothness</td>
</tr>
<tr>
<td></td>
<td>Dimensional stability</td>
<td>Dimensional stability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crease retention</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimum seam puckering</td>
</tr>
<tr>
<td>Drawbacks</td>
<td>No permanent crease</td>
<td>High cost</td>
</tr>
<tr>
<td></td>
<td>Seam puckering</td>
<td>Risk of premature setting</td>
</tr>
</tbody>
</table>

Table 2 Comparison of pre-cure and post-cure processes
type of application and the forms of the fabrics vary, to decide the required end uses. Novel washing techniques are also used to achieve faded and emerized effects. Different dyeing effects in the garments are obtained by treating one side of fabrics with cross linking agents while leaving the other side freely without modification, provides an approach for a smooth-drying-dyeable fabrics. Differential dyeing effects in the cotton fabrics are obtained by spraying the cross linking formulation and dyeing the fabrics subsequently with reactive dyes. Pre-cure, post-cure, garment dip processes, wet and damp cure, reversible cross linking treatments are, often, employed to achieve wider finish effects. The relative merits and demerits of both pre-cure and post-cure processes are shown in Table 2.

In the garment dip process, the garments are impregnated with a finish similar to the finish used in the conventional post-cure process, extracted, dried, pressed and cured. Softer hand in the garments can be achieved in this process compared to the conventional process.

It has been found that reaction of formaldehyde with the secondary hydroxyl groups and the cross links formed in such reactions are not favourable ones, in terms of stability, though they are kinetically preferred positions, in terms of reactivity. Proven relationship exists among various process variables like pH, curing temperature and time for a given fabric or garment. Two reactions take place under acidic conditions with cellulose including acid hydrolysis of cellulose and formation of methylene ether bridges between the molecules of formaldehyde, two hydroxyl groups of adjacent cellulosic chains. The formalization process takes place in a combination of fast reaction in the amorphous region and a slow diffusion in the crystalline regions.

Glyoxal itself can be used as a cross-linker but possibly breaks down during the curing operation and adversely affects the fabric strength and color. Attempts have been made to utilize various non-formaldehyde based chemicals including butane tetracarboxylic acid (BTCA), citric acid, liquid ammonia and various silicone based derivatives in finishing of garments. Phosphoric acid and polyphosphonic acids may also be used to impart wrinkle-resistant properties when used in combination with cyanamide. Finish effects from polycarboxylic acids are achieved through ester linkages while ether linkages are formed in N-methylolamide agents. BTCA treated cotton fabrics show similar properties as that of DMDHEU treated fabrics. The wrinkle recovery angle (WRA) of the BTCA treated fabrics is observed between 287°-298°C while the values have been found to be 264°-295°C for DMDHEU treated fabrics with the formaldehyde release up to 330 ppm - 450 ppm. The performance of citric acid treated fabrics is satisfactory in terms of durability and home laundering as compared to BTCA. In trifunctional citric acid hydroxyl groups hinder the esterification of acid with cellulose. Polymers of maleic acid esterify citric acid in-situ on cotton fabric under curing conditions which transforms citric acid into a compound with higher functionality and thus produce synergistic effect in the reaction. Incorporation of reactive polysiloxanes, with non-nitrogenous, non-formaldehyde cross linkers results in superior lubricating action between fibres, yarns and draping action, without loss of toughness and abrasion resistance.

Liquid ammonia treatment applied on cotton improves the wrinkle resistant performance, depending on the weight, construction of the fabric, and also the mode of handling. Grafting methods also have been attempted to graft glycidyl methacrylate on cotton using ultra violet radiation, where the extent of cross linking increases with type of catalyst used. Reaction of the methyl group with cellulose takes place followed by the reaction of acrylol groups (N-methylolacrylamide) from an aqueous solution by a base catalysed nuleophlic reaction or by a free radical initiated reaction with cellulose.

**STONELESS WASHING OF DENIM GARMENTS**

Though biopolishing of cotton fabrics employs cellulases, indigo dyed cotton fibres demand binding of enzymes on indigo dye molecules also in addition to the cellulose molecules, for effective wash down effects. It has been shown earlier that cellulases capable of binding cellulose molecules have a special domain called cellulose binding domain (CBD), while certain hydrophobic sites and other non-polar surfaces available in the cellulases bind the indigo molecules and act as an emulsifier, helping the dyes to float out of the cellulose fibers during hydrolysis. Besides CBDs, aromatic residues of the amino acids like tyrosine, tryptophan and phenylalanine also have been shown to play an active role in the protein-cellulose interactions. Binding of cellulase on highly ordered cotton fibres demand strict spatial conservation in the cellulase molecules like, CBD, while such conformational conservations are not required in the case of indigo particles and can be accomplished in the hydrophobic micro-environments.

Cellulases obtained from different sources exhibit varying degrees of binding capabilities, mainly controlled by the presence of certain hydrophobic residues and their locations on the outer surface of the enzyme globules. Cellulases produced by Trichoderma reesei, Chrysosporium lucknowense and Penicillium verruculosum, engineered EG I, EGII EGIII, EG V and CBH I, CBH II from Trichoderma reesei preparation and core domains of CBH I have been conventionally used to understand the mechanism of denim washing. Immobilized amino acids are also used to characterize the binding patterns of proteins on indigo. It shows that indigo molecules may indeed be bound to non-polar side chains of amino acids, which are enhanced by the presence of groups capable of forming hydrogen bonds. Typically protein loading of 0.5 mg/g to 3 mg/g fabric provides necessary abrasion effects on denim surface and final abrasive effect induced by the enzyme action on the surface of denim fabrics depends on the protein distribution between the substrate and bulk solution.
Laccases, a sub-class of oxidoreductases, are multi-copper oxidases that catalyse the oxidation of a wide range of phenols and other substrates with concomitant reduction of oxygen to water. Laccases, with certain low molecular weight organic mediators, can result in rapid decolourization and are also used in washing the denim garments though they are not effective by themselves in the process. In the presence of an aqueous medium, the laccases get oxidized and convert the mediator into free radicals which subsequently convert the indigo into isatin, isatic acid and anthranilic acid. The conjugated double bond between the two carbonyl groups in indigo is cleaved and the dye chromophore is destroyed proportionately to the dosage of the enzyme, which is considered to be the major advantage of laccases compared to conventional acid wash process.\(^8\)\(^9\)

### PRECAUTIONS IN GARMENTS PROCESSING

Processing of garments has come through a long way to reach the present prominent status. Though garment dyeing appears to be attractive, it calls for many stringent requirements related to panels, seams, elasticated areas, waist band, cuffs and problems often occur due to shrinkage behaviour, chafe marks/creases, accessories, sewing machines and in many occasions, garments are turned inside out and dyed with non-foaming lubricants. Tendency to entangle can be reduced by tacking and bagging the articles which in turn reduces the abrasion, wear and tear of interior metallic surface. Fibre type (natural / thermoplastic) fabric construction (tightly woven crease prone), loading (higher loading-higher creases), addition of lubricant (special lubricants reduces friction) are some of the parameters that influence chafe marks. Swollen cellulosic fibres are especially sensitive to mechanical friction, while thermoplastic synthetic fibres tend to form permanent creases.\(^6\)

For the garments prepared from the grey fabric, oxidative desize-scour-chemick-peroxide bleach sequence is used prior to processing. Residual hydrogen peroxide in the bleached materials can interfere with dyes and spoil the colour values. Uneven finish applications, curing conditions in the fabric state, prior to garmenting, results in panel to panel shade variation in the garment dyeing process.\(^3\)

In the case of reactive dyes, consistent shade replication depends on material to liquor ratio, alkali and salt concentration, heating rate, fixation time and temperature. The initial temperature of the textile substrate and process bath can influence the efficiency of the wetting process. Establishing the dyeing procedures for each garments style, dye system and set-controls can help to address the variations in load, water volume, temperature and cycle time. Garment to garment shade differences can be minimized with machine loads containing garments made from the same lot of fabric. Significant darkening of the fabrics occurs after subjecting it to calendering because of the increased optical contact and reduced light scattering power. Variations in shade among the garment panels, between garments can also occur due to treatments with optical brightening agents, mixing of panels from fabrics.

Processing problems related to the garment size control and appearance normally result from variations in yarn size/twist, ends/inch, picks/inch or courses/inch in the knitted fabrics. Tight seams in the garments become tighter, due to the shrinkage in a high temperature dyeing process, and prevent dye penetration on seams and underneath the stitches. Dimensionally stable thread with low elongation will help to minimize seam puckering after dyeing. In the case of knitted fabrics, pre-relaxation is employed to avoid the problems of seam pucker and garment distortion and such fabrics can also be used along with woven fabrics as fabric cut and sewn garment designs. Too much bulky or tight stitch must be avoided in elasticated areas, waist bands and cuffs. The various patterns present in the garments must be adjusted to compensate for shrinkage during dyeing process.\(^4\)

The physical condition of garments, process variables and their effects on garment finishing has been discussed in the past.\(^5\)\(^6\)\(^7\). Problems related to electrolysis of ionic processing solutions resulting from galvanic action of bimetallic garment accessories need special care. Anionic inhibitors are used to protect metal accessories, such as, button, zippers made of non-ferrous, white metals from oxidation and tarnishing.

The cross linking treatment of cotton fabrics and garments results many changes in physical properties of the fibres, yarn and fabrics depend on the extent of reactions. Excessive cross linking results in loss of the strength and abrasion resistance and while in adequate cross linking leads to poor shrinkage control, surface appearance, smoothness and crease retention. It has been shown that relatively low concentration of formaldehyde (2% OWF) produces more improvements in the crease recovery on cotton than rayon.\(^6\) Water spotting of the fabric, prior to curing, causes irreparable dye-resist spots on the garments. At higher temperature, increase in catalyst concentration decreases tear strength than at low temperature (165°C, 143°C) without any

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improvement in WRA. Fabrics and garments cured at low temperature shows lower tensile and tear strength loss than at high temperatures. Optimizations of wrinkle resistant treatments have been explored using suitable softeners treatments to increase abrasion resistance and tear strength; the softeners also act as sewing lubricant, protects threads from breaking and fusing, as the needle passes through. Without lubricant, an embrittled, resinated fabric would rapidly wear into holes at the elbows.

The release of formaldehyde in DMDHEU treated fabrics decreases with the addition of scavengers, substantially and not altered by the presence of various dyes. The cross linked fabrics show poor water absorption rates due to cross linking, application of hydrophobic softeners and tend to give warmer contact feeling. The surface friction increases in untreated fabrics after washing compared to the treated fabric, perhaps due to increased hairiness. Higher degree of cross linking in the amorphous regions is necessary for an increase in wrinkle recovery. The cross linking prevents irreversible slippage of adjacent cellulose chains during fibre extension thereby reducing permanent set and increasing elastic recovery. Good correlation exists between elastic recovery of single fibres and the crease recovery characteristics of fabrics made from them at moderate extension levels. Vapour phase formaldehyde in presence of sulphur dioxide catalyst produces a high level of crosslinking and produces fabric extremely resistant to wrinkling with crease recovery values of 300° C (W+F) for cotton and gives improvements in seams, collars, cuffs. Loss in tensile strength occurs as high as ~60% is observed in the cotton and fortisan fabric mostly as the result of the unavoidable acid hydrolytic degradation that accompanies the formaldehyde treatment.

CONCLUSION
Dyeing and finishing of garments, on outside, appear to be highly attractive but both the processes demand great deal of care in preparation and also during the processes, besides various accessories attached to them. Value added rejections arising out of these processes slow down the commercial acceptance of both the processes but the developments that take place in other branches of engineering could be used to control the process effectively and also to accommodate the necessary changes on account of the accessories involved in the garments.

REFERENCES