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Desizing of Cotton Fabrics With Enzymes for Improved Performance

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Abstract

Desizing of cotton substrates with Amylase enzymes has been practiced since long time and is commercially successful. Amylases convert the water insoluble starches, used during sizing operation for enhancing the performance of the warp yarns, into water soluble products which are removed during subsequent washing. The use of enzymes for desizing is quite safe for the cotton substrates and do not cause any detrimental effect on the cotton cellulose unlike the oxidative and acid desizing operations. The performance of the desized fabric towards dyeing, printing and finishing is enhanced due to enzymatic desizing. Thus, desizing with enzymes is an effective substitutional approach for the chemical-based desizing processes.

Keywords: cotton, desizing, eco-friendly, efficiency, enzymes

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INTRODUCTION

The application of a sizing agent to warp yarns, prior to weaving, is essential for high weaving efficiency in the production of most fabrics because warp cotton yarns require a protective coating to improve the yarn strength and to reduce the yarn hairiness.[1] Sizing agents are selected on the basis of type of fabric, environmental friendliness, ease of removal, cost considerations, effluent treatment, etc. Starch, gelatin, oil, wax, and synthetic polymers such as polyvinyl alcohol, polystyrene, polyacrylic acid and polyacetates are usually employed as sizing ingredients. The size formulation covers the warp yarns and ultimately the fabric and the sized fabrics are less absorbent especially for dyes and chemicals; hence it may lead to uneven dyeing, printing or finishing if not completely removed from the substrate after weaving operation. The process of removal of size from the substrate is termed as 'desizing'. It can be carried out by prolonged cooking or by using strong chemicals such as acids, bases, oxidizing agents or suitable enzymes. The desizing operation is aimed to remove the size material from the warp yarns in woven fabrics and also to ensure the levelness of the dyestuff or printing ink applied during dyeing or printing. If the size is not taken out completely, it will also affect washing and rubbing fastness of the fabrics. The major desizing processes include rot steeping, oxidative desizing, acid desizing, enzymatic desizing of starches on cotton fabrics. Out of these methods, enzymatic desizing is commercially utilized in the process houses of textile industries for removal of starch from the sized cotton substrates.[2,3] The desizing of cotton with enzymes is an eco-friendly process which does not cause any harm to the cotton cellulose. The article gives an overview of

the enzymes used for desizing of cotton materials, along with their mechanism, application procedure, techniques for determining their effectiveness, and their benefits and limitations.

ENZYMES: THEIR SUITABILITY AND MODE OF ACTION

In the textile industry, one of the first areas which enzyme research opened up was in the field of desizing of textiles. It is estimated that approximately 15% of all commercial textile enzymes are used in desizing process. Enzymes are complex organic, soluble bio-catalysts, formed by living organisms that catalyze chemical reaction in biological processes. Enzymes are quite specific in their action on a particular substance. A small quantity of enzyme is able to decompose a large quantity of the substance it acts upon. Enzymes are usually named by the kind of substance degraded in the reaction it catalyzes.[4]

Enzymes have been used for desizing of cotton materials for more than a century. Amylase, malt extract, diastafor, rapidase, etc. enzymes have been used since long and are still used for the removal of starches and other sizes from cotton. Recently, amylopectic enzymes are commercially utilized by the industry on a large scale.[5]

For desizing starch, amylase (or carbohydrase) and maltase enzymes are generally used commercially. Amylase is a hydrolytic enzyme which catalyzes the breakdown of dietary starch to short chain sugars, dextrose and maltose. Amylase specifically hydrolyzes and reduces the molecular weight of amylose and amylopectin molecules in starch but does not affect cellulose. There are three types of amylases: bacterial, malt and pancreatic. These enzymes are produced by the fermentation process, which occurs when the starched fabric, stored in wet conditions at slightly elevated temperatures, i.e. warm temperature, becomes infected by micro-organisms. The function of these enzymes is to convert the insoluble starch into water-soluble starch known as 'Dextrin'. These Dextrins, being water-soluble, are easily removed by washing with water. The available product range of amylases (α-amylases, β-amylases, glucoamylase and isoamylase) allow desizing to be performed at a temperature ranging from 20 to 115°C.

The functioning of enzymes during desizing occurs by initial wetting of the substrate and pH buffering followed by swelling, penetration, cracking and de-stabilization of size layers; after which the attack of enzymes on the size layer takes place resulting in the conversion of water insoluble starches into water soluble products, which are finally removed during washing. The catalytic action of amylase enzyme resulting in the breakdown of starch into sugars is as shown in Figure 1.

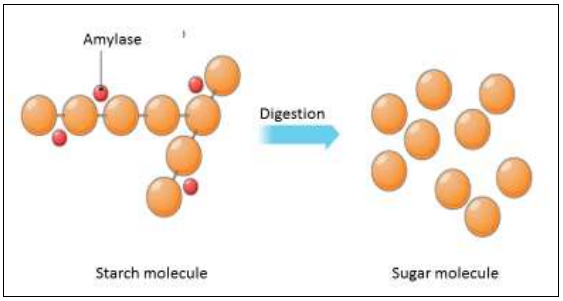

Fig. 1. *Conversion of Starch into Sugar Molecules by Amylase Enzyme.*

EFFECT OF VARIOUS PARAMETERS ON DESIZING

Effective enzymatic desizing requires strict control of pH, temperature, water hardness, electrolyte addition and choice of surfactant.[6] The summary of conditions, required for desizing with different types of enzymes, is given in Table 1.

The concentration of enzyme used for desizing varies according to its chemical nature and strength. However, the addition

of 0.5–3% enzyme (on the weight of the fabric) is quite sufficient for desizing.

Table 1. *Optimum Operational Conditions for Amylases.*

Amylase	Optimum pH	Optimum Temp. (°C)	Effect of NaCl	Effect of $CaCl_2$
Pancreas	6.8–7.0	40–55	+	+
Malt α	4.6–5.2	55–65	–	+
Malt β	4.6–6.2	40–50	–	–
Bacterial	5.0–7.0	60–70	0	+

'+' Indicates 'to Add', '–' Indicates 'Not to Add', '0' Indicates 'No Effect'.

Addition of a suitable stabilizer is essential to maintain the pH since a specific pH range is essential for the enzymes to become active.

Hard water should not be generally used for desizing purpose. If sequestering agents are required to be used, they must be tested before use because some sequestering agents may be harmful to the enzymes.

The activity of the enzymes is also affected by the presence of salts/electrolytes. Certain salts are used to enhance the temperature stability of enzymes. Pancreatic enzyme is completely ineffective in the absence of salts. For full activity, 1.7 g/L sodium chloride must be present in the desizing liquors. The presence of calcium chloride also activates the pancreatic enzyme. Malt (α) and bacterial enzymes require the presence of calcium salts for full activity.

Surfactants help to improve the wettability of the fabric and improve the size removal. The penetration of the enzyme as well as the wetting of the grey, untreated fabric is difficult and slow during desizing. Therefore, wetting agents are added to the desizing bath to accelerate wetting of the fabric and penetration of the enzyme. The selection of proper wetting agent in desizing is important because some wetting agents inactivate the enzymes. Non-ionic surfactants such as ethylene oxide condensates are the best suitable wetting agents for desizing with enzymes.

THE DESIZING PROCESS

In the actual desizing process, there are three important steps.

- saturation of the cloth with enzyme,
- reaction of the enzyme with the starch, and
- washing of the degraded products.

The cloth is passed, either in the rope form or in open width, through the enzyme solution, squeezed and piled in closed concrete pits. The desizing solution generally contains 0.5–3% enzyme and 2% common salt on the weight of the fabric. Required pH and temperature of the solution and concentration of enzyme are maintained in the bath. After 8 to 10 hours, or preferably overnight, the cloth is washed with water on a washing machine to remove the degraded starch products. If prior singeing is required, the cloth after singeing is passed through the enzyme solution in a continuous manner. The residual starch content, on the weight of the fabric, after desizing should be less than 1%.

Several application methods can be used for desizing, such as padding, jigger and continuous high speed processes. Most of the amylases are suitable for continuous (pad-steam) as well as discontinuous desizing (jigger, winch and pad-batch) processes.

Desizing on a jigger (Figure 2) is a simple batch method where the fabric from one roll is processed in a bath and re-wound on another roll. First, the sized fabric is washed in hot water at 80–95°C to gelatinize the starch. The desizing liquor is then adjusted to pH 5.5–7.5 and a

temperature of 60–80°C depending on the type of enzyme. The fabric then goes through an impregnation stage before the amylase is added. Degraded starch, in the form of dextrin, is then removed by washing at 90–95°C for two minutes.

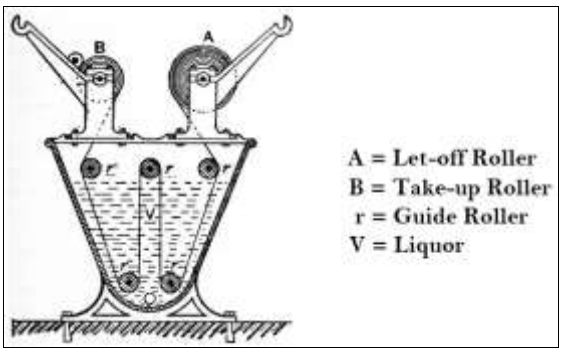

Fig. 2. *A Typical Jigger Machine.*

In the semi-continuous process of desizing, the use of pad-roll installation is quite popular.[7,8] The cloth in open-width form (Figure 3) is impregnated with the desizing liquor containing a suitable desizing agent and other ingredients, quickly preheated in a steam chamber or by infrared radiations, and then batched in a roll form in movable carriages and allowed to lie for 8–12 hours for digestion (conversion of starch into degraded products). During the storage period, the batched material is gently rotated to prevent uneven desizing due to drainage and the temperature in the storage chamber is maintained by slowly feeding steam into the chamber.[9]

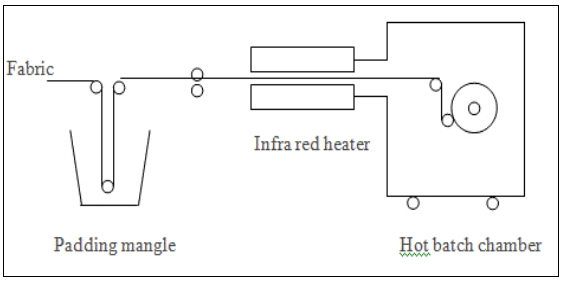

Fig. 3. *Schematic Layout of Pad-Batch Plant.*

With high-temperature amylases, desizing reactions can be performed in steam chambers at 95–100°C or even higher temperatures to allow a fully continuous process. A short open-width steaming may be operated at 95–100°C using saturated steam for 20–60 seconds. After completion of the operation, the desized fabric is washed in an open width washer to remove the water-soluble, short chain sugars. Various machines such as J Box (Figure 4), Vaporloc, Benninger, etc. are suitable for continuous desizing process.

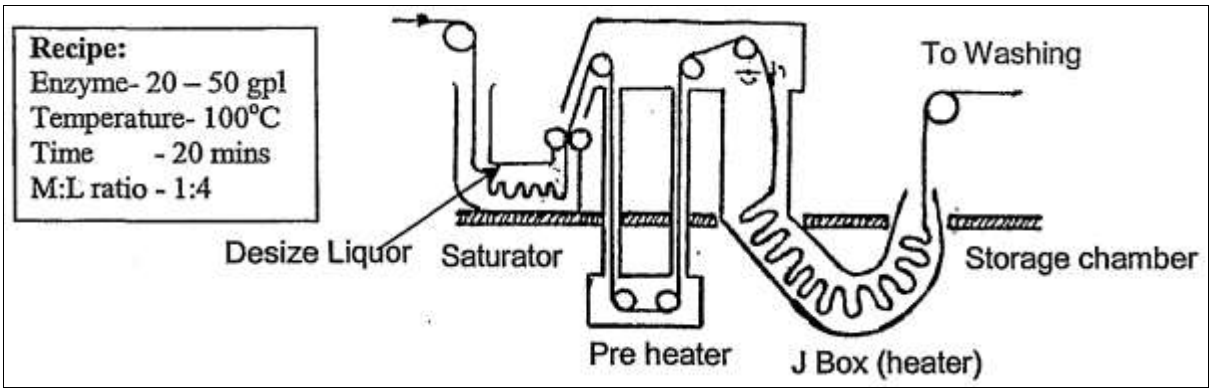

Fig. 4. *A Typical Continuous Desizing Operation Using J-Box System.*

ADVANTAGES AND DISADVANTAGES OF ENZYMATIC DESIZING

Desizing with enzymes has several advantages over other desizing processes, such as

- less chemicals are involved
- it is continuous process, so greater production can be achieved
- process is eco-friendly
- efficient in wide range of temperature

- no damage to cellulose fibers
- better strength retention
- softer feel

However, the main limitation of the enzymatic desizing process is that

- if the conditions of temperature, pH and time are not properly maintained, the desizing activity of the enzymes is destroyed.

DESIZING EFFICIENCY TEST

There are two methods to analyze the desizing efficiency. They are conventional method and TEGEWA method.

Conventional Method: In this method, the bone-dried weight loss (%) of the sample before and after desizing is calculated. First the sized fabric is weighed accurately and its weight is noted as W_1. Then the fabric is desized and dried and its weight is noted as W_2. The fabric is then treated with 3 g/l (35%) HCl at 70°C for 30 min., dried and weighed; the weight is recorded as W_3.

Total size = W_1–W_3
Residual size = W_2–W_3

The desizing efficiency (D.E.) is calculated as follows:

$$\text{D.E.}(\%) = \frac{(\text{Total size} - \text{Residual size})}{\text{Total size}} \times 100$$

TEGEVA rating test: This test is suitable for starch based sizes only. The TEGEVA rating scale is a scale, which consists of colors ranging from violet to white; white indicating complete removal of starch and excellent efficiency whereas different tones of violet representing different desizing efficiency – the deeper the depth of violet tone, the minimum is the removal of starch and inferior efficiency.

Reagent preparation: Potassium iodide [10 g of KI (100%)] is taken in 100 mL of water, and 0.6358 g of iodine (100%) is added to it. The solution is stirred until complete dissolution of iodine in KI solution has occurred. 800 mL of ethanol is added after this. The volume is adjusted to 1000 mL by adding water to the remaining solution.

Method of testing: One or two drops of the above solution is added on to a fabric and rubbed gently. The change in color is analyzed according to the Tegewa scale. The fabric should be cold and no residual alkalinity should be present before testing.

Assessment: A rating of 9 on TEGEVA scale indicates complete desizing of the fabric.

- No color change = No starch is present
- Pale blue to bluish violet = Presence of starch size or a blend of starch + synthetic size
- Brown = Presence of modified starch or a blend of starch/PVA size

CONCLUSION

The global awareness regarding ecological aspects had led the industries to design eco-friendly processes. Desizing of cotton with enzymes is one such process which has been successful on the commercial scale. It efficiently prepares the cotton fabric for further processes of pretreatment, viz. scouring and bleaching; as well as dyeing, printing and finishing.

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