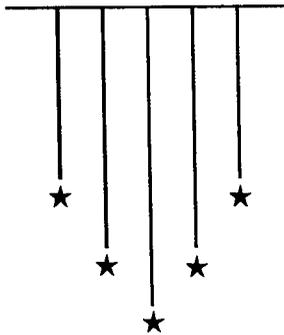
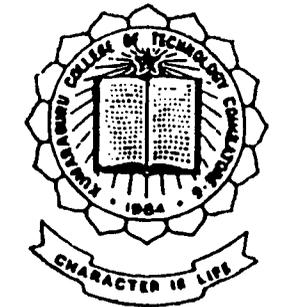


# CHEMOMETRIC APPROACH TO OPTIMIZE THE BIOWASHING OF 100% COTTON CARDED YARN



2000 - 2001

P-590



Submitted by

**B. ARUN KUMAR  
J. HARIHARAN  
RAGHU HARIHAR**

Guided by,

**Lecturer BHAARATHI DHURAI M.Tech**

In partial fulfillment of requirements  
For the award of the Degree of  
**Bachelor of Technology in Textile Technology**  
Of Bharathiar University, Coimbatore.

*Department of Textile Technology*  
**Kumaraguru College of Technology,**

*Department of Textile Technology*

**Kumaraguru College of Technology**

Coimbatore – 641 006

Project Work 2000 – 2001

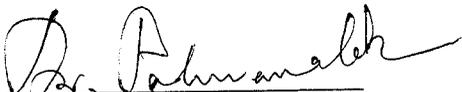
University Register No \_\_\_\_\_

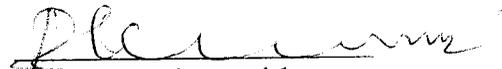
Name \_\_\_\_\_ Roll No \_\_\_\_\_

*Certified that this is Bonafide Record of the  
Project Work done by*

*Mr. \_\_\_\_\_*

*In the partial fulfillment for the degree of Bachelor  
of Technology  
in Textile Technology  
Branch of Bharathiar University*

  
Head of the department

  
Faculty guide

Place:

Date:

Submitted for the university examination held on \_\_\_\_\_

  
Internal examiner

  
External examiner

## ACKNOWLEDGEMENT

We would like to express our sincere thanks and gratitude to Dr. K. K. Padmanabhan, our Principal and Prof. A. R. Padmanabhan, Professor & Head of the Department of Textile Technology for their encouragement during the course of this work.

We would like to record our profound thanks and indebtedness to Mrs. Bhaarithi Dhurai, Lecturer, Department of Textile Technology for having taken strenuous efforts in guiding and perfecting this project.

Our special thanks to the Management and Staff of M/s Victus Dyeing, Tiruppur for supplying the samples free of cost. We would also like to thank Mr. Viswanathan GM and Mr. Valavi Victor Incharge YPD, The Lakshmi Mills Co. Ltd. for giving permission to do a part of the project work in their esteemed mill.

We record our thanks to Mr. P. R. Subramanian, Secretary SIMA, & Mr. Selvaraj, Joint Secretary SIMA for their valuable guidance and suggestions for completing this project work.

We would also like to thank the Management and Staff of M/s Premier Polytronics for allowing to do necessary tests at their Company.

We would also like to thank the entire faculty members and non-teaching staffs for their help and co-operation in the completion of this project work.

Finally we thank our parents for their great support in tough situations during this project work.

# CONTENTS

<u>TITLE</u>	<u>Page No.</u>
Abstract	2
I. Literature Survey	
1.1 Introduction to enzymes	3
1.2 Mode of Enzyme action	4
1.3 Fields where enzymes are used in Textile Industry	5
1.4 Factors Affecting the rate of Enzyme action	6
1.5 Effect of concentration on Substrate	7
1.6 Effect of temperature	7
1.7 Effect of pH	8
1.8 Abstracts from literature reviewed.	8
2. Methodology	
2.1 Materials Used	16
2.2 Fibre Properties	16
2.3 Yarn Properties	16
2.4 Enzyme Particulars	17
2.5 Brief summary of the Project work	19
2.6 Enzyme treatment	
i. Design of Experiment	21
ii. Drawing Surface plots for the Regression Equation	25
iii. Experimental Plan	25
iv. Experimental Procedure	27
3. Results and Discussions	
3.1 Test results	31(a)
3.2 Discussions on test results	31(b)
3.3 Effect of Enzyme treatment on Yarn Hairiness	31

3.4 Effect of Enzyme treatment on Yarn Strength	39
3.5 Effect of Enzyme treatment on Yarn Friction	48
3.6 Optimized Condition	57
4. Conclusion	58
5. Bibliography	59

## ABSTRACT

In a textile material the presence of hairiness will lead to generation of fluffs and flies in the industry. The presence of hairiness will also lead to the formation of small balls called pilling in the fabric. In recent past, attempts were made by treating cotton fabrics with enzymes by partial hydrolysis. In a similar way an attempt is made to improve the surface properties in the yarn stage itself by partial hydrolysis. The results have shown that the yarn properties can be improved by partial hydrolysis of the yarn by enzyme treatment. By this enzyme treatment, the properties of the yarn are changed. The yarn hairiness is reduced to a maximum of 21%. The strength loss occurred in this treatment is upto a maximum of 20%. And the yarn friction is reduced by 42%. By maintaining the concentration, temperature and time duration for processing the yarn the loss of strength, reduction in hairiness and improvement in friction properties can be controlled.

## LITERATURE SURVEY

### Introduction to Enzymes:

Enzymes are found in plants as well as in animals and microorganisms, where they play an important role in the function of cells. Enzymes have been used in the following areas,

- Breweries
- Wineries
- Food processing units
- Textile industry

Application of enzymes in industrial textile processes is concerned, began way back in 1857, when malt extract was used to remove amylaceous sizes from some textile materials before printing. Enzymes are naturally occurring high molecular weight protein capable of catalyzing specific chemical reaction of biological processes and hence are known as “**BIO – CATALYSTS**”. Chemically, enzyme is defined as a protein complex composed of about 200 – 250 amino acids. They are protein substances having a molecular weight ranging from 12,000 to over 1 million. Enzymes can bring about the following actions,

- Hydrolysis
- Oxidation
- Reduction
- Coagulation
- Decomposition

Enzymes are the most remarkable and highly specialized proteins. They have,

- Extraordinary catalytic power

Enzymes by its mere presence and without being consumed in the process can speed up chemical processes, such that the action of hydrolysis will be carried as a cyclic action. When an enzyme is used for hydrolysis action of cellulose, the same enzyme will be reused again without any huge loss in its activity.

- Higher degree of specific for their substrates

Enzymes can break down or synthesize the raw material, which is supplied in random manner or in a particular portion of the molecular structure of the raw material fed to it. Thus they can classify it as,

- Exo activity
- Endo activity

The above said activities will depend upon the type of enzyme we choose for the treatment.

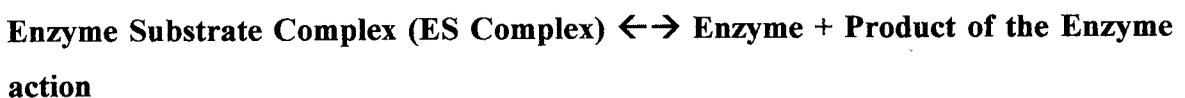
- They accelerate specific chemical constituents without formation of non-biodegradable by-products.

For most of the processing or finishing in an chemical processing industry, an Effluent treatment Plant is required for removal of toxic chemicals from the treatment liquor. In an enzyme treatment, for deactivation of the enzymes no toxic chemicals are required and hence the ETP is not required in most of the cases.

### Mode of Enzyme action:

No complete explanation is at hand to account for the mechanism of enzyme action. The most likely mechanism is the enzyme substrate complex theory, which is the widely accepted. As per the theory of distinguished feature of an enzyme catalyzed reaction is that which occurs with in the confines of the pocket on the enzyme called the active site. The molecule that is bounded by the active site and acted upon by the enzyme is called the substrate.

The following equation set forth the two phases of enzyme action according to the hypothesis:



It is the common fact that any reaction  $A \rightarrow B$  is associated with a certain amount of energetic barrier that represents the minimum amount of energy required for the reaction to proceed in the favorable direction and is known as the activation energy. In real practice whenever the active sites of the enzyme completely fits with the substrate known as the 'LOCK AND KEY' fashion, interaction between substrate and active site takes place resulting in a formation of a number of weak bonds including hydrogen bonds, Vander Waals interaction etc.

Formation of each weak interaction in the ES complex is associated by a small release free energy known as the binding energy. The binding energy is used as a major source of free energy used by enzymes to lower the activation energy of reactions so that the reaction proceeds at a much faster rate. It is to be noted here that no enzyme alters the equilibrium constant of any catalyzed reaction; it only provides a lower energy reaction path so that the rate is accelerated.

### Fields were the Enzymes used in the Textile Industry:

The enzymes have a wide range of applications in the Textile Industry, the places were they are used are listed below,

- **Desizing of Cotton**

Amylolytic enzymes in their natural form or modified state can destroy any type of starch turning it into water-soluble product without affecting the cellulose. E.g. Aquazim (Novo Nordisk )

- **Bio polishing**

It is the process of enzyme treatment where the fabric surface, handle and lustre are improved by removal of protruding fibres. During the enzymatic treatment, the surface of cellulosic fibre is partially hydrolyzed and the weakened fibres are removed by mechanical action by either fabric to fabric abrasion or between fabric & equipment.

- **Shrink proofing of wool**

The major property of the wool is its tendency to felt and then shrink. The presence of scales on its surface is the main reason for the shrinkage. By treatment with some enzymes from bacterium *Streptomyces fradiae*,

which is capable of attacking natural keratin, hydrolyzing some peptide linkages and the shrinkage can be reduced.

- Carbonization of wool

The process of removal of the vegetable materials from the wool fibre is called carbonization. Here by using some types of enzymes like hydrolases, will lead to an effective removal of vegetable wastes from the wool fibre.

- Desizing of Silk

Silk Desizing by enzymes require prior swelling of silk seracin by selected surfactant followed by treatment with serine protease enzyme combined with  $H_2O_2$  giving an efficient Desizing of sericin.

- Degumming of Silk

In the latest methods, the enzymes are used for degumming of silk. The ability of proteolytic enzymes to hydrolyse peptide bonds formed by specific amino acid has been effectively exploited to develop degumming processes. Proteolytic enzymes such as trypsin and papain have used for silk degumming. Degumming of silk with proteolytic enzyme like degummase improves the whiteness of the fabric with no adverse effect on the wetability and the strength.

- Used in Denim Washing

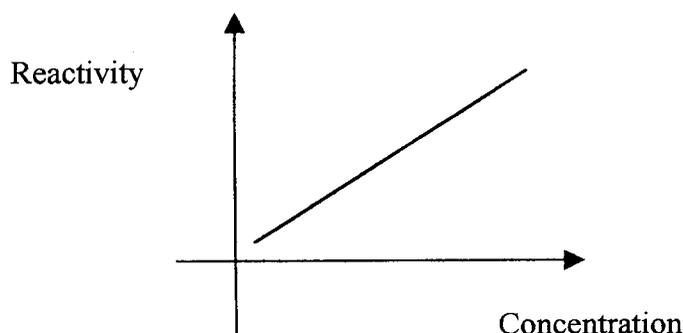
Cellulases have been used in denim washing purposes recently. The usage of pumice stones in denim washing in the olden days will lead to impartment of mechanical abrasion to the fabric, fibre and yarn damage and leads to a harsh feel. By using the enzymes in the denim washing, the mechanical abrasion is not imparted and the softness is imparted to the fabric.

### Factors affecting the rate of Enzyme action:

The major factors that affect the rate of enzyme action are given below,

1. Concentration of substrate
2. Temperature
3. pH

## Effect of Concentration of Substrate



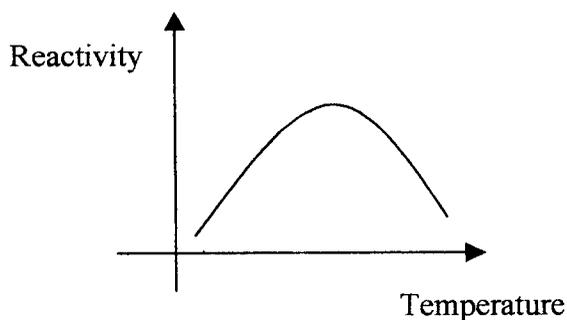
The concentration of the enzyme plays a vital role in the enzyme activity, the relation between the enzyme concentration and activity can be expressed as,

$$\text{Enzyme activity} \propto \text{Concentration}$$

From the above expression we can see that an increase in enzyme concentration will lead to the increase in the enzyme activity. Since there exists proportionality, we will get the graph as shown below,

## Effect of Temperature:

Similar to the most of the chemical reactions an increase in temperatures will lead to an increase in the chemical reaction. When a graph is drawn based on this reactivity we will get an inverted parabolic curve, meaning that an increase in the temperature will lead to increase in the chemical reactivity. On further heating as the temperature increases there will be decrease in the reactivity due to destruction of the molecules of the enzyme and lead to the formation of the parabolic curves.

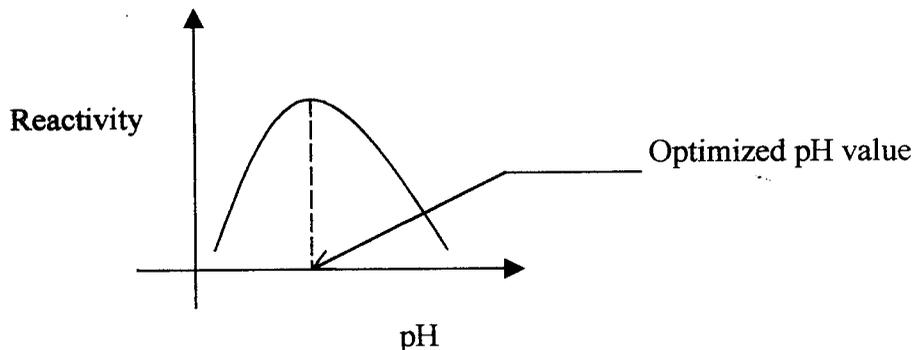


## Effect of pH

Any changes in the pH will directly affect the enzyme activity. Here there are 2 conditions,

- Decrease in pH will lead to poor reactivity of the enzyme.
- Increase in pH will lead to increase in activity to a certain extent, and above which will degradation of the enzyme itself.

The above property can be expressed in the graph, as the graph will be in the shape of the inverted parabola. An optimum range of the pH values is shown by the dotted line the graph. The graph is shown below,



## Abstracts from the Literatures reviewed

Mr. Sarkka P. et al<sup>1</sup>, shows in their paper “Bio finishing of Cellulose Fabrics” that bio finishing of cellulosic fabrics generally involves enzymatic treatment with cellulase and a mechanical treatment. The objective of bio finishing is to remove impurities and fibre ends that protrude from the fabric surface. Enzymatic hydrolysis weakens the fibre ends and mechanical treatment follows to remove the fibre ends and impurities. The major advantages of bio finishing are the reduction of pilling and fluff and the improvement of fabric cleanliness, hand, drape, and dyeing and hydrophilic properties. Although bio finishing can be carried out in batch or continuous processes, batch process are easier to control and use winces, jiggers, jet, or overflow machines. Optimally, bio finishing occurs after bleaching and before dyeing. It is critical to achieve

the objectives of bio finishing without compromising the tear strength of woven fabrics or the elasticity of knit fabrics.

A bulletin from the International Fabric Care Institute called "Fabric Care <sup>2</sup>" provides a brief introduction for dry cleaners on processing wrinkle resistant apparel made from cotton fabric. Most wrinkle resistant garments do not bear permanent tags or care labels that identify them as wrinkle resistant products. Guidelines are provided for identifying wrinkle resistant apparel, pre-cleaning inspections stain removal, and proper dry-cleaning and laundering procedures. Dark colored items should be laundered inside out with a cellulase enzyme detergent to reduce mechanical action and remove pills and fuzz. Wrinkle resistant treatments derive from cross-linking resins with cellulose molecules, and loss of elasticity to flexing and bending and lower abrasion resistance.

Mr. Shook D. B. et al <sup>3</sup>, in their paper "Detergents for Acid Cellulase Enzymes" explains the effect of various detergents on the activity of acid cellulase enzymes used in the stone washing of denim fabric. Evaluations focused on the appearance (abraded contrast, degree of back staining and spectro photometric reflectance) and physical condition (fabric weight and tear strength) of denim fabric samples. Trials involved six types of detergents. Results showed that nonlinear low molar ethoxylated surfactants, alkyl phenol ethoxylates, and tertiary amine nonionic surfactants all imparted poor contrast or caused dye re-deposition problems. Blends of ethoxylated alcohol and sulfonated alkanes yielded fair contrast. Detergents based on nonionic linear ethoxylated alcohol did not inhibit acid cellulase activity, limited dye re-deposition and imparted excellent color contrast.

Mr. Clarkson K. et al<sup>4</sup>, tells in their paper "Opportunities for use of Bio Chemicals in Textile Finishing" that, the cellulase enzymes depolymerize cellulose fibres into low molecular weight glucoses. Based on their role in cellulose hydrolysis, cellulases can be segregated into three types: exocellobiohydrolases, which chemically attack the ends of cellulose polymers and release cellobiose; endoglucanases, which hydrolyze polyglucoses into low molecular weight glucose. The review discusses such commonly used cellulase systems as that produced by the bacteria *Trichoderma reesei*, which comprises seven major enzymes (two exocellobiohydrolases, four endoglucanases, and

one beta-glucosidase). Such factors as pH and temperature exert dramatic effects on the activity of cellulases during the chemical finishing of cotton, flax and ramie fabrics.

Mr. Koo H. et al<sup>5</sup>, in their paper "Cellulase treatment of Cotton Fabrics" explains about the rate of catalytic hydrolysis of a cellulase enzyme in the presence of dyes on a cotton fabric. Reactive dyes and direct dyes on the fabric inhibited the enzyme's catalytic action. Vat dyes, however, did not inhibit the enzyme's catalytic action. When the cotton fabric was mercerized, the enzyme was more active than on non mercerized cotton fabrics. This could be a result of the lowering of crystallinity of cotton by mercerization. Treatment with the cellulase enzyme significantly decreased tear strength and dye uptake of the fabric. After multiple launderings, treated fabrics showed less color fading than untreated fabrics because the treatment prevented fuzziness on the fabric surface.

Mr. Khahorst S. et al<sup>6</sup>, in their paper "Optimization of Cellulase Enzymes" showed that, by varying processing parameters with acid and neutral cellulase treatments resulted in variations in the appearance of finished denim garments. Important parameters included treatment time and enzyme concentration. The goals were to treat in the shortest treatment time at the lowest chemical costs and to produce garments for a consistently high quality. Experiments indicated that liquid neutral cellulase required double the time to yield the same denim appearance as liquid acid cellulase. Reflectance values indicated more backstaining on fabrics treated with the liquid acid cellulase. Enzyme pH had an indirect effect on backstaining since it determined enzyme activity. Wash it several times when it is treated with using an acid cellulase. Neutral cellulase yielded fashion effects when treatments of over 60 minutes were required. In general the amount of enzyme used should be increased as the washing time decreases.

Mr. Koo H et al<sup>7</sup>, in their paper "Cellulase Treatment of cotton fabrics II: Inhibitory effect of Surfactants on Cellulases catalytic reaction." That the rate of catalytic hydrolysis in cotton fabrics by cellulase enzymes in the presence of surfactants. The surfactants were typical of those used in dyeing and finishing processes. Both anionic and cationic surfactants apparently inhibited the reaction, whereas the nonionic surfactants did not. The inhibitory actions of the surfactants were similar to those of some dyes. Electrostatic interactions between charged inhibitory compounds and the cellulase

enzyme both in solution and on the cotton fabric were probably responsible for these inhibitory actions.

David Bishop et al<sup>8</sup>, says in their paper “Hydrolysis of Cotton by Engineered Cellulases from *Trichoderma Reesei*”, that the enzyme activity mainly depends upon the extend of agitation. The enzyme activities towards cotton fabrics are influenced by ionic strength and absorbed ionic species as well as by temperature and pH. Adsorption and kinetic experiments confirm that increasing mechanical agitation favors Endoglucanases attack by greatly increasing the availability of sites for Endoglucanases absorption. The team says that the effect of enzyme hydrolysis on the material surface mainly depends upon the type of treatment given to the material before and also the type of fabric construction (in the case of fabrics) to which the material is subjected to Enzyme hydrolysis.

G. N. Sheth et al<sup>9</sup>, in their paper “Application of Enzyme treatment to cellulosic fabrics for imparting specific functional properties”, that the cellulase treatment or cotton fabrics brings about improvement in feel and handle accompanied by loss in weight, decrease in strength and reduction in abrasion resistance. Drape as well as crease recovery of treated fabric remains almost the same as that of original fabric. Improvement in air permeability is noticed in some cases. With neppy fabrics, treatment results in reduction in the number of neps. With respect to terry towel, improvement in absorbency is observed on enzyme treatment. In case of p/c blended fabric, enzyme treatment results in a decrease in the tendency to pill.

Mr. M. L. Gulrajani et al<sup>10</sup>, in their paper “Kawabata evaluation of enzyme treated cotton knitted fabric”, shows that there is a decrease in bending rigidity and shear rigidity when the fabric is treated with an enzyme. A decrease in the value of these properties indicates a softer fabric. Hence, it can be said that the enzyme treated fabrics are softer than the untreated ones. There is a weight loss in the material, which is the direct influence of the enzyme hydrolysis. The yarn tenacity is decreased due to the action of the enzyme. A decrease in the abrasion resistance indicates that there is reduction in the friction between the yarn to yarn and yarn to metal surface.

Mr Eun Kyung Choe et al<sup>11</sup>, shows in their paper “Effect of Pre-existing Dyes and Fabric Type on Cellulase Treatment of Cotton Fabrics”, that the weight loss

due to enzyme treatment is directly proportional to the enzyme concentration and to the time taken for treating the sample. The results show that they are in the form of multiples to the concentration and to the time taken. In their paper they have taken a comparative study between the mercerized and non-mercerized material and the results show that the weight loss value is more in the case of the mercerized ones. Similar case is also for the dyed ones, the extent of inhibition in the enzyme reactivity mainly depends upon the class and type of the dyes stuffs used for the sample before enzyme treatment.

Mr. M. L. Gulrajani et al<sup>12</sup>, shows in their paper “Chemometric approach to optimize cellulase treatment of cotton knits” that the weight loss due to enzyme treatment increases rapidly with the increase in enzyme concentration up-to 10% owf. Subsequently it levels off at higher concentration. Similarly, weight loss increases rapidly on increasing the treatment time up-to 45-min and then levels off. In the case of the bending length property there is a maximum decrease in the bending length property of about 36% at the highest level of enzyme concentration and at the highest level of treatment time (75min). As the enzyme concentration, an increase in the air permeability is seen in the process. Such a similar condition is also seen for an increase in treatment time. In the case of abrasion resistance, there is no much effect. By the above results they conclude that an improvement in the stiffness property, wetting, air permeability and also for the effect of the dye uptake.

Dr. Y. Kato et al<sup>13</sup>, shows in their paper “ Relationship between cellulase treatment and direct dye dyeing for cotton” that there is a weight loss in the fabrics and it will increase linearly with an increase in treating time with cellulase, at least up to 24hours. Weight loss obtained by the treatment for 4 and 24 hours was 4.2 and 17.7% respectively. In their experiment they have taken Congo Red and Chrysamine and Chrysophenine. These dyes are direct dyes and are dyed using the cotton fabrics. Then these fabrics are subjected to cellulase treatments. While treating with the cellulase the weight loss is seen lesser in the order of Congo red, Chrysamine and Chrysophenine at a given dye uptake. There fore it was concluded that cellulose molecules bound by the dyes, the affinity of which is larger, could be attacked by the cellulase with more difficulty. The chemical structure of cellulose does not change by dyeing with the direct dyes. It was considered that physical interactions such as hydrogen bonding, which was

formed between the direct dye and binding site, may block the hydrolysis of cellulose by cellulase, to the extent associated with the affinity of the dyes.

Mr. A B Kundu et al<sup>14</sup>, shows in their paper "Bio-polishing of jute-cotton union fabric" that the fabric is subjected to the cellulase treatment. By treating them with the cellulase the cellulose chains are partially hydrolyzed and as a consequence the fibres are weakened. Such weak fibres are separated from fabric by applying some mechanical stress to it. By the enzyme treatment there is an improvement in the appearance, smoothness and soft feel of the fabric and a loss in strength due to weakening of fibres constituting the fabric. Because of these opposing effects, the treatment should be carried out with such a concentration of enzyme that improves the soft feeling with out much loss in strength. It is evident that weight loss is less than 1.4% where as the strength loss increases upto 20% up with increasing in the enzyme concentration. By the enzyme treatment the smoothness of the fabric is improved. Since smoothness is directly related to fuzz, the fuzz concentration was measured through pill formation in fabric. The pill formation on the other hand is depended on the extent of rubbing, and the no of pills formed in each cycle was noted. The test results shows that there was a decrease in the pill formation.

Mr. A. B. Kundu et al<sup>15</sup>, in their paper "Improvement in properties of jute fibre by treatment with polysaccharide-degrading enzymes" shows that by enzyme treatment, the fibre fineness is increased by 11.5%. Apart from that the torsional rigidity of the fibres are also reduced by 12%. This would improve the spinning performance since reduced rigidity bears a strong positive correlation with spinnability. The increased bending angles of treated fibres are also indicates reduction in rigidity and thereby supports the above finding. It is evident from the results that bulk specific volume of fibres, which is a measure of handle softness, reduced by 14% on treatment with enzymes. The swelling property of the fibres is seen to be increased by 13.2%. This will lead to an increase in the absorption property or the wicking ability of the yarn made out of this enzyme treated fibre is improved.

Mr. Reiko Mori et al<sup>16</sup>, shows in their paper "Relationship between Cellulase Treatment and the Dyeability with a Direct Dye for various kinds of Cellulosic fibres" that, the cellulosic were dyed to equilibrium with Congo Red before and after

cellulase treatment. The fibres examined were rayon, polynosic, cupra, flax and cotton. It was found that the volume term  $V$  for dyeing was associated with weight loss caused by cellulase treatment, for the original fibres. Apparently affinity for dyeing for the cellulase treated fibres was calculated using a constant value of  $V$  obtained for each kind of the original fibres. The results led to the assumption that there would be two kinds of the regions that could be accessible to dye. One would be the region that was readily digested by the attack of cellulase. The previously dyed fibres were hydrolyzed by cellulase. It was formed that the physical bonding that formed between cellulose and Congo Red molecules would block the hydrolysis by cellulase for all the fibres examined. It was also assumed that there would be a region that could be accessible to cellulase but not entirely to Congo Red.

Mr. Oijusuoma Lea et al<sup>17</sup>, in their paper "Use of Cellulases in Treatment of Cotton Fabrics" shows that, they had carried out enzyme treatment using cellulases CBH I and EGII in Linitest and the mechanical action was provided by 10 steel disks. Enzyme treatments were carried out at pH 5 at 50 degree Celsius for 60 minutes. The liquor ratio was 1:10 and enzyme dosage was 0.2 to 5-mg/g substrate. After treatment the containers were immersed in boiling water for 5 minutes to terminate the enzyme action and the fabrics were washed subsequently with hot and cold water. The cotton fabrics were treated with different dosages of EG II and it resulted in higher weight loss and decreased tear strength as compared to CBH I treatment. Although the CBH I dosage was increased to 5 mg/g practically no effect was observed in the tear strength. Treatment with E.G. II resulted in improved pilling abrasion of the fabric, whereas the CBH I had less pronounced effect on pilling. Both enzymes improved the bending hysteresis from 0.44 to 0.38 gfc/cm. Thus individual cellulases have different modes of action which can be explored for various purposes. By installing the effect of purified cellulases and their defined mixtures novel information of the possibilities of cellulases can be obtained.

Mr. Achwal W. B. et al<sup>18</sup>, in their paper "Use of Cellulase Enzymes to improve Pretreatment of Cotton", that by pre-treating of cotton with enzymes leads to fibre swelling, which is enhanced by alkali boil. Enzyme systems containing pectinase show an increased uptake of red dye due to crystallization during the treatment process and an increased blue dye after alkali boil. Enzyme systems containing cellulase do not

need pectinase to produce high degrees of swelling. Using cellulase and energy needed for the conventional treatment process.

## METHODOLOGY

### Materials Used

The yarn, which is used for enzyme treatment, is 30s Carded Hosiery yarn. The characteristics of the fibre and yarn are given below.

### Fibre Properties:

<u>SL. No</u>	<u>FIBRE PARTICULARS</u>	<u>DETAILS</u>
1.	2.5% Span length	27.2mm
2.	50% Span length	13.7mm
3.	Uniformity ratio	50.3
4.	Micronaire value	3.4
5.	Bundle strength	19.5 g/Tex
6.	Trash	3.5%

### Yarn Properties:

<u>SL. No</u>	<u>YARN PARTICULARS</u>	<u>DETAILS</u>
1.	Count	30sK
2.	End use	Hosiery
3.	U%	13.0
4.	Thin places	30
5.	Thick places	200
6.	Neps	250

7.	Count CV%	2%
8.	Lea Strength (lbs)	72.0
9.	Strength CV%	5%
10.	CSP	2150
11.	Total Imperfections	2%

### Enzyme Particulars

The enzyme treatment on yarn is carried out using the enzyme named Bio Soft L+ supplied by Biocon India Ltd. The details of the enzyme are given below,

Biosoft L (+) is a technically advance enzyme system of the cotton fabric/garment finishing industry. The active ingredients of **BIOSOFT L (+)** are cellulolytic enzymes obtained by the fermentation of nonpathogenic moulds of the Asperigillus and Trichoderma species. **BIOSOFT L(+)** is also used in Tencel finishing to produce a range of stone washed effects with or without the inclusion of stones. Traditional stone washing is known to have a damaging effect on both the fabric as well as the equipment, which is eliminated with enzymatic “stone washing”.

### Advantages of using **BIOSOFT L (+)**

- High contrast look Biosoft L (+) reliably produces a low black stain, high contrast look. The contrast between blue and white yarns in denim stays high.
- High dose response Biosoft L (+) has a high dose response which provides the flexibility of varying dose, pH, temperature and time to achieve wide range of abrasion from light to heavy.
- Reduces stone requirement high levels of abrasion can be attained with fewer pumice stones which reduces fabric damage and machine wear, improves waste treatment and enhances garment load.

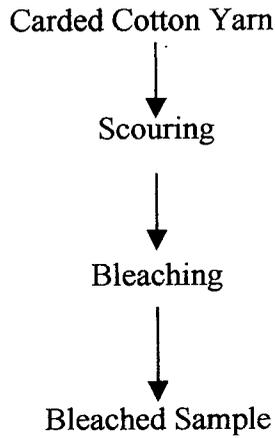
- Compatibility with auxiliary chemicals Biosoft L (+) is compatible with most other processing aids, including non-ionic surfactants, dispersing agents, pumice stones, abrasive powder, diatomaceous earth etc.

The processing parameters for the enzyme BIOSOFT L (+) supplied by the manufacturer for effective enzyme action are given below (This is mainly applicable for Industrial performances)

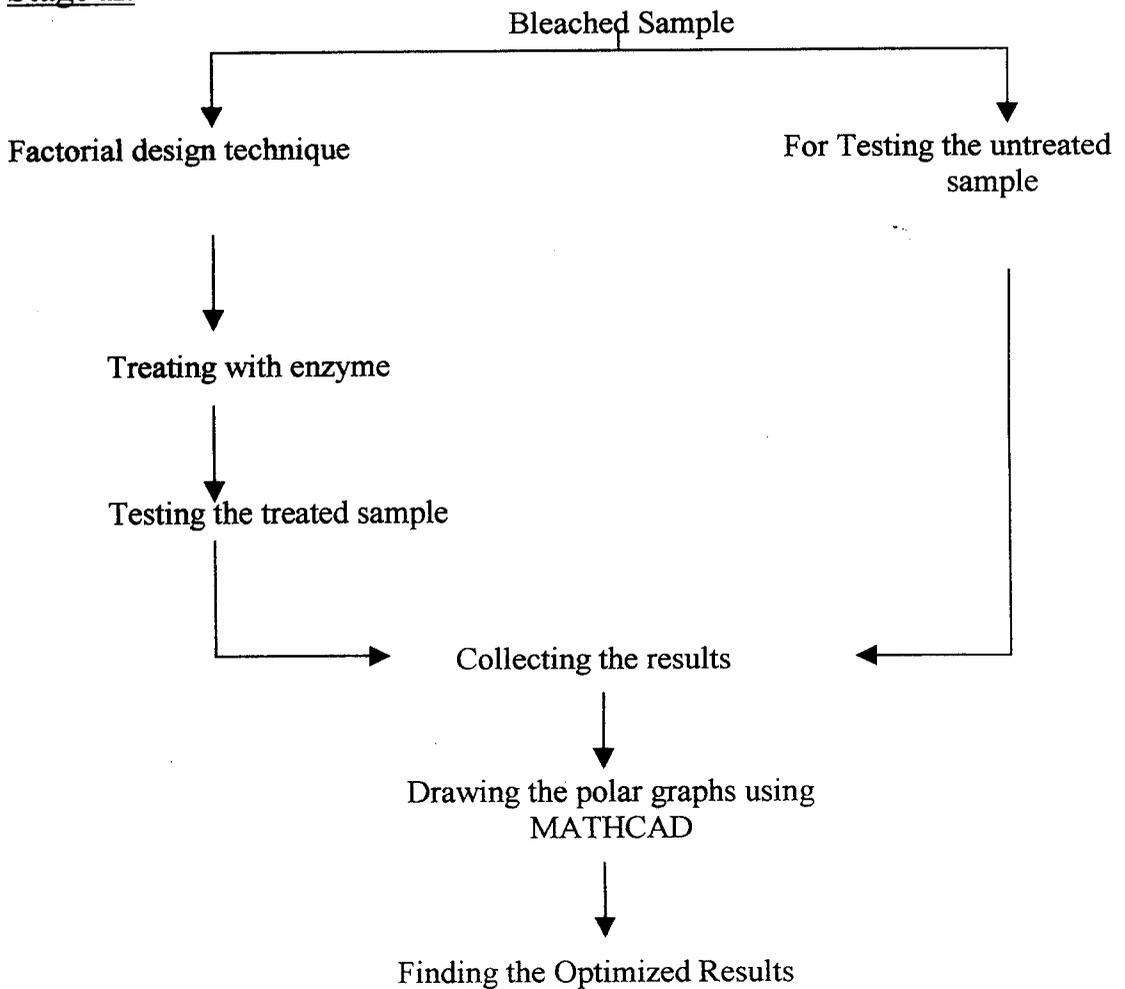
<b>Sl. No.</b>	<b><u>Parameters</u></b>	<b><u>Operational Ranges</u></b>
1.	Product	Cellulase
2.	Origin	Non pathogenic moulds of Asperigillus and Trichoderma
3.	Description	Cellulose hydrolysis
4.	Activity No.	50,000 – 75,000 CU/g <sup>19</sup>
5.	Temperature	50 – 55°C
6.	pH	4.5 – 5.5
7.	Dosage	4 – 8 gpl or 1 – 4% owm
8.	Time	10 – 20 minutes
9.	M:L ratio	1: 8 – 1:15

## BRIEF SUMMARY OF THE PROJECT WORK

### Stage I:



### Stage II:



<b><u>Scouring Particulars:</u></b>		
1.	Anionic detergents	0.1%
2.	NaOH	2.0%
3.	Na <sub>2</sub> CO <sub>3</sub>	2.0%
4.	Type of boiling	Kier boiling
5.	Neutralizing	With HCl

<b><u>Bleaching Particulars:</u></b>		
1.	H <sub>2</sub> O <sub>2</sub>	1%
2.	Anionic detergents	0.03%
3.	Type of wash	Cold wash
4.	Drying	Open air

## Enzyme Treatment

### Design of Experiment

The sampling plays a vital role in finding the exact property of the material to be tested. Hence a new technique called **FACTORIAL DESIGN TECHNIQUE** is used for sampling the yarns, which is used for Enzyme treatment. The method of Factorial Design technique, which we follow, is of **BOX AND BEHNKEN METHOD**. For an enzyme treatment, three important variables are,

- Temperature
- Concentration
- pH

Since there are 3 variables for a normal sampling, we require a lot of samples, which is much tedious and expensive too, hence by adopting the above said method (Factorial Design Technique) we can find the properties from 15 samples. The method of applying the factorial design technique is given below.

For a 3 variable sample the normal table for Sampling by Factorial Design Technique is given in the next page.

<u>Sl. No.</u>	<u>Variable 1</u>	<u>Variable 2</u>	<u>Variable 3</u>
1.	-1	-1	0
2.	1	-1	0
3.	-1	1	0
4.	1	1	0
5.	-1	0	-1
6.	1	0	-1
7.	-1	0	1
8.	1	0	1
9.	0	-1	-1
10.	0	1	-1
11.	0	-1	1
12.	0	1	1
13.	0	0	0
14.	0	0	0
15.	0	0	0

SL. No	$X_1$	$X_2$	$X_3$	$X_1^2$	$X_2^2$	$X_3^2$	$X_1X_2$	$X_1X_3$	$X_2X_3$
1.	-1	-1	0	1	1	0	1	0	0
2.	1	-1	0	1	1	0	-1	0	0
3.	-1	1	0	1	1	0	-1	0	0
4.	1	1	0	1	1	0	1	0	0
5.	-1	0	-1	1	0	1	0	1	0
6.	1	0	-1	1	0	1	0	-1	0
7.	-1	0	1	1	0	1	0	-1	0
8.	1	0	1	1	0	1	0	1	0
9.	0	-1	-1	1	1	1	0	0	1
10.	0	1	-1	1	1	1	0	0	-1
11.	0	-1	1	1	1	1	0	0	-1
12.	0	1	1	1	1	1	0	0	1
13.	0	0	0	0	0	0	0	0	0
14.	0	0	0	0	0	0	0	0	0
15.	0	0	0	0	0	0	0	0	0

In the above table the values -1, 0, +1 are the three ranges for each variable. Out of the 3 values in the range for a particular variable, the value '0' indicates the center value out of the given range and the '-1' and '+1' indicates the right and left extreme of the range respectively.

Out of the three ranges for each variable and for such three variables we will be finding each regression equation for each variable. The model of the regression equation is given below,

$$Y = b_0 + \sum b_i X_i + \sum b_{ii} X_i^2 + \sum b_{ij} X_i X_j$$

Where,

$b_0, b_i, b_{ii}, b_{ij}$  - are the coefficients of regression equation

$i, j$  - are the integers with  $i < j$

$Y$  - is the response or dependent variable

Three-dimensional surface plots were prepared to study the effect of variables on the responses. The optimum enzymatic conditions were selected from the predicted combinations and the experiments were repeated under these conditions to assess reproducibility.

The regression coefficients are obtained by calculating using the table given above. The procedure for calculating the regression coefficient is given below. By referring the table we can easily calculate the regression coefficients and directly substitute to the equation given above to get a regression equation to the respective property. In the tabular column given below shows the central composite rotatable design for 3 variables, where the 'x' indicates the variable of the design matrix.

<u>SL. No</u>	<u>Y values</u>	<u>Generalized form</u>
1.	$Y_0$	$\Sigma Y$
2.	$Y_1$	$\Sigma X_1$
3.	$Y_2$	$\Sigma X_2$
4.	$Y_3$	$\Sigma X_3$
5.	$Y_{11}$	$\Sigma X_{11}$
6.	$Y_{22}$	$\Sigma X_{22}$
7.	$Y_{33}$	$\Sigma X_{33}$
8.	$Y_{12}$	$\Sigma X_1 X_2$
9.	$Y_{13}$	$\Sigma X_1 X_3$
10.	$Y_{23}$	$\Sigma X_2 X_3$

The values of the regression coefficient can be found out using the above table and the following equation.

$$b_0 = 0.166338 (y_0) - 0.056791 \Sigma (y_{ii})$$

$$b_i = 0.073224 (y_i)$$

$$b_{ij} = 0.0625 (y_{ij}) + 0.006889 \Sigma (y_{ii}) - 0.056791 (y_0)$$

$$b_{ij} = 0.125 (y_{ij})$$

These regression coefficients are substituted to the equation to obtain the regression equation as shown below.

$$Y = b_0 + \Sigma b_i X_i + \Sigma b_{ii} X_i^2 + \Sigma b_{ij} X_i X_j$$

## Drawing Surface plots for the Regression Equation

The surface plots for the above regression equation can be drawn by using several softwares like MATLAB, MATHCAD etc. Here we will be using Mathcad for drawing the surface plots. The values are found for each respective conditions and then they are fed to a matrix. Then using a graphical representation option key, we can choose the required graph (surface plot or even we can have contour, bar charts etc). By choosing the required graph and by initializing the variable to the graph we will get the required surface plots.

### Experimental Plan

For the three variables as specified above, the ranges and the values of the 3 variables is indicated below,

<u>Sl. No</u>	<u>Variables</u>	<u>Ranges</u>
1.	Concentration	1%, 2%, 3%
2.	Temperature (°C)	46, 50, 54
3.	Time (minutes)	40, 50, 60

The fixed parameters are the following,

<u>Sl. No</u>	<u>Fixed parameters</u>	<u>Values</u>
1.	M : L	1 : 10
2.	pH	5
3.	Agitation rate (rpm)	4.5

Then according to the table given above, the Factorial design for the above 3 variables having the above respective ranges are given below,

<u>Sample No.</u>	<u>Variables</u>		
	<u>Concentration</u>	<u>Temperature</u>	<u>Time</u>
1	1	46	50
2	3	46	50
3	1	54	50
4	3	54	50
5	1	50	40
6	3	50	40
7	1	50	60
8	3	50	60
9	2	46	40
10	2	54	40
11	2	46	60
12	2	54	60
13	2	50	50
14	2	50	50
15	2	50	50

## Experimental Procedure:

The samples are taken from the lot. Then the samples are well conditioned in the condition chamber at 65%RH and at 27o C. The conditioned samples are then weighed in the electronic weighing instrument. The readings are noted individually. The total weight is calculated and then the required amount of water is taken according to the ratio given above (1:10). The water is then heated up-to the required temperature (depending upon the condition) which is performed. As we had previously discussed that for the enzyme treatment the pH level is important for this purpose acetic acid is used as the pH maintaining agent. After maintaining the pH, the enzyme is added. Here the pH level maintained is 5.0. An electronic pH meter is used for checking the pH value. Once the enzyme is added the solution is well stirred.

The mechanical agitation action is carried out using a microprocessor controlled washing fastness tester. There will be 10 bowls of capacity of 400ml (approx.). The solution is poured out into the bowl according to the individual sample weight. Then the yarn is put inside. For well mechanical agitation steel balls are added. The no of steel balls added will be 6 in each vessel. Then the agitation rate is set in the machine and also the time and temperature. The machine maintains constant temperature and accurate time and agitation rate. Then after the enzyme treatment a deactivation is to be carried out. For this the yarn is subjected to high temperature of  $>70^{\circ}\text{C}$  and  $\text{pH}>10$  is maintained and washed well and rinsed. During this treatment the enzymes will be degraded (“killed”) and further enzyme action will be inhibited. The yarn is then taken and well washed and rinsed and then it is dried out in hot air oven drying unit. The dried yarn is then properly handled out and packed well for rewinding and then for testing.

A sample data is given for the experimental procedure:

<b><u>Sample No: 4</u></b>		
<u>Sl. No</u>	<u>Details</u>	<u>Values</u>
1.	Material weight (grams)	199.5
2.	pH value	5.0

3.	Concentration of the enzyme used	3% = 5.98ml
4.	Temperature (Degree Celsius)	54
5.	Material : Liquor ratio	1 : 10
6.	Time (duration in minutes)	50

The enzyme treated yarn is tested for studying the following properties,

- yarn strength
- yarn hairiness
- yarn friction (yarn to metal)

The particulars of the testing instrument is given below,

## TENSOMAXX 7000

### Automatic Single Yarn Strength Tester

#### Technical Specifications

Make	:	Premier Polytronics Ltd.
Basic Installation	:	Tester, Display and control unit (PC), Printer (Colour), Automatic yarn changer (upto 20 cops) and creel
Accessories	:	Yarn Hook
Options	:	Clamps for lea and fabric testing
Measuring principle	:	Constant Rate of Elongation (CRE)
Testing speed	:	50 mm/min to 5000 mm/min
Test Length	:	150mm to 500mm
Pretension	:	0.5cN/Tex to 2.5cN/Tex Automatic between cop testing Automatic within cop testing (with rolling off arrangement)
Application Range	:	<b>Breaking Force</b> Single & Ply, Spun & Filament Yarn - 60g to 9000g Lea (Skein) and Woven Fabric Strip- 1.44kg to 90kg

#### Elongation

Upto 80% at 500mm test length

Upto 500%(or 750mm) at 150mm test length

**Accuracy 1%**

### **Outputs of the Product**

Numerical : Breaking Force( kgf, gf, lbf, mN, cN, N & KN), Breaking Elongation (%), Breaking Tenacity (cN/Tex, g/Tex, RKm), Time to Break (sec, min), Work Done , Partial Work Done, Modulus Characteristics, Statistical Block (Mean, Min, Max, CV% and Q95%)

## **PREMIER TESTER 7000**

### **Technical Specifications**

Make : Premier Polytronics Ltd.

Basic Installation : Tester, Display and control unit (PC), Printer (Colour), Automatic yarn changer (upto 20 cops) and creel

Options : Hairiness module, Cyros optical sensor for Fabric Simulation, Autocop, weighing balance for absolute count measurement

Principle : Photo electric principle.

Measurement range : From approx. 1 Tex to approx. 12 Ktex for fibre assemblies containing staple fibres 250, 50, 100, 200 or 400m/min or yd/min., switch selection. Slow start for delicate materials.

Evaluation time : 1, 2.5, 7.5, 10 or 20 minutes. Numerical result output on the monitor and via the printer.

Unevenness (U%) : Numerical determination of the unevenness in the range from U=0.15... 40%

CV% : Numerical determination of the unevenness in the range from U=0.5... 40%

Relative Count : Percentage count variations of the test material between

samples in a series of measurements with reference to the test length. Conversion of the mean value to 100%.

## **YARN FRICTION TESTER - LH**

### **Technical Specifications**

<b>Make</b>	:	Lawson Hemphill Corporation.
<b>Basic Installation</b>	:	Tester, Display and control unit (PC) with CTT basic unit. The YFT belongs to TYT accessories.
<b>Principle</b>	:	Kinematic Friction (Pin Friction type) Measures coefficient of friction over metal surface.
<b>Wrap angle</b>	:	90, 180, 360 (the wrap angle should not be less than 90°)
<b>Speed</b>	:	100 m/min.
<b>Range (<math>\mu</math>)</b>	:	0.1 to 0.5
<b>Count range</b>	:	7s Ne to 110 Ne

## Test Results

<u>Sample Number</u>	<u>Variables</u>			<u>Strength (g/Tex)</u>	<u>Hairiness (Index)</u>	<u>Friction (<math>\mu</math>)</u>
	<u>Concentration</u>	<u>Temperature</u>	<u>Time</u>			
1	1	46	50	13.83	5.98	0.12
2	3	46	50	13.91	6.26	0.11
3	1	54	50	10.96	6.47	0.12
4	3	54	50	14.53	5.98	0.14
5	1	50	40	13.59	6.06	0.22
6	3	50	40	13.37	6.01	0.16
7	1	50	60	14.30	5.79	0.19
8	3	50	60	14.32	5.61	0.14
9	2	46	40	13.76	5.79	0.21
10	2	54	40	13.83	6.14	0.26
11	2	46	60	13.47	5.93	0.32
12	2	54	60	13.18	5.53	0.12
13	2	50	50	13.72	5.24	0.25
14	2	50	50	13.65	6.48	0.28
15	2	50	50	13.81	5.97	0.24
Untreated	-	-	-	14.7	7.28	0.32

## DISCUSSIONS ON TEST RESULTS

From the literatures cited above, we came to know the following effect in the properties of the textile material.

- Decrease in hairiness
- Loss in Strength
- Decrease in yarn friction

A software was developed, and the experimental results were used for finding the values for plotting a graph (using MATHCAD), for each conditions. From those results the above trend is found out and each of them are analyzed in each detailed sessions. For each property, the surface plots are drawn using MATHCAD and shown below on each session.

### Effect of Enzyme treatment on yarn hairiness:

By enzyme treatment, the results show that the **hairiness** of the yarn is reduced ranging from 10 – 20%. The value of hairiness reduction depends upon the processing conditions i.e. it depends upon the variables. There are 3 graphs attached below, indicating the effect of enzyme treatment on yarn hairiness. The graph is displayed in the manner of % reduction of hairiness. The graphs has the following parameters,

- Time is fixed at each levels -1, 0, +1 i.e. 40, 50, 60 minutes respectively.
- The temperature is increased in the order of 1 degree Celsius.
- The concentration is also increased in the order of 1% as per the levels, -1, 0, +1, i.e. 1%, 2%, 3%.

The generalized regression equation is given below,

$$Y = 20.937 + 0.44x_1 - 0.153x_2 + 1.154x_3 - 3.925x_1^2 - 3.856x_2^2 - 2.809x_3^2 - 1.323x_1x_2 + 0.224x_1x_3 + 1.286x_2x_3$$

## Graph 1:

From the graph given here we can understand that as the temperature goes on increasing, there will be a gradual increase in %removal of hairiness and it falls down. The enzyme treatment is effected due to reaction with the cellulose of the fibre molecules and as the temperature increases the reaction rate is improved. As the temperature increases up the % removal of hairiness in the yarn falls down, mainly because the increase in temperature to a certain limit, will lead to destruction of enzymes. Due to this property the curve falls down. And also we can see there is an increase in the hairiness removal percentage as the concentration increases. For quick reference and for clear understanding a contour plot is drawn below.

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as -1.0 (i.e. 40 minutes).
- The value 'x' indicates the temperature.
- The value 'y' indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	9.093	10.751	11.297	12.621	12.833	12.563	11.811	10.577	8.861
-0.5	12.806	14.299	15.310	15.838	15.885	15.449	14.532	13.133	11.251
0.0	14.557	15.884	16.729	17.093	16.974	16.373	15.291	13.726	11.679
0.5	14.345	15.507	16.187	16.385	16.101	15.335	14.087	12.356	10.144
1.0	12.171	13.168	13.682	13.715	13.265	12.333	10.920	9.024	6.647

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the hairiness %. I.e. an increase followed by a decrease in values.

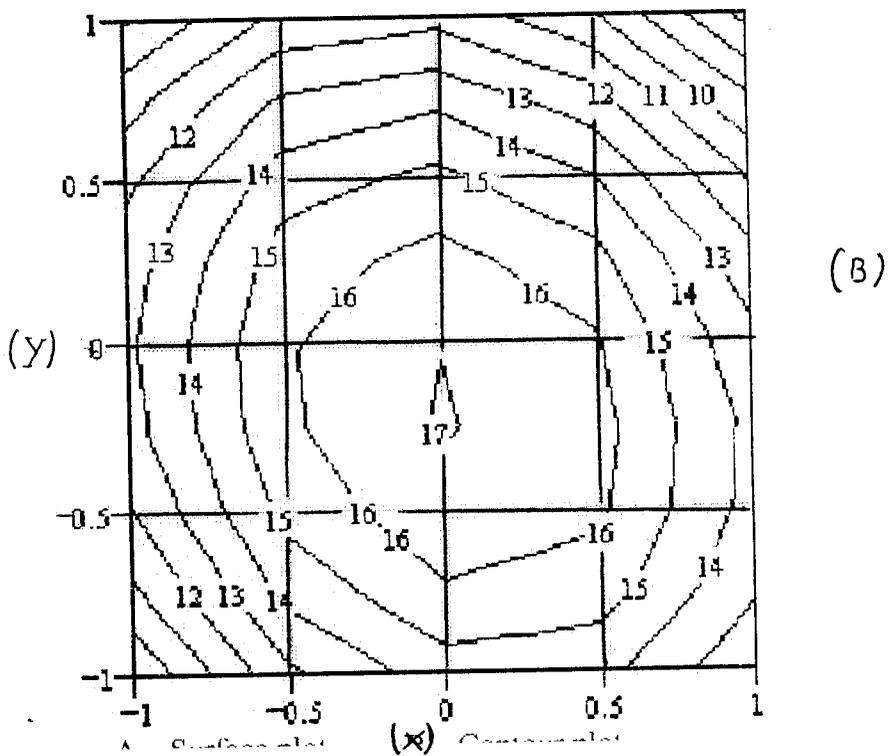
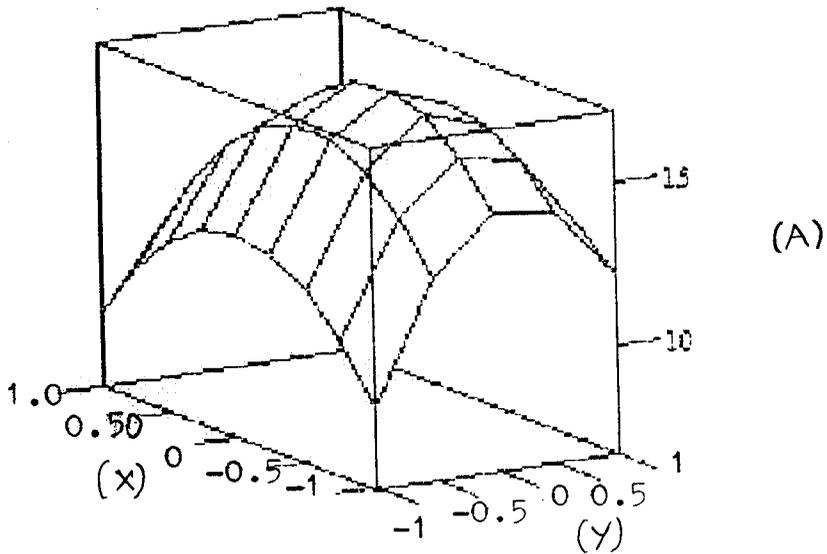
	-0.15	-0.10	-0.05	0.0	0.05	0.10	0.15	0.20
0.04	17.026	17.077	17.108	17.121	17.113	17.087	17.041	16.976
0.05	17.029	17.079	17.110	17.122	17.114	17.087	17.041	16.975
0.06	17.032	17.081	17.111	17.122	17.114	17.086	17.390	16.973
0.07	17.034	17.082	17.112	17.122	17.113	17.084	17.037	16.97
0.08	17.034	17.083	17.111	17.121	17.111	17.082	17.034	16.960

From the table above we can find one shaded portion which indicates the optimized value for the hairiness %. Here the following conditions are followed,

- The time is kept as constant = -1.0 (i.e. at 40 minutes)
- The temperature is increased as in the order of 0.2°C i.e. the values will be starting from 48.4, 48.6, 48.8, 50, 50.2, 50.4, 50.6, 50.8.
- The concentration is fixed in such a way that, the point at which the hairiness removal % increases and then decreases
- From the above table we can say that the optimum removal of hairiness occurs at the following conditions,

The optimized value for % maximum removal of hairiness is given below

<u>Sl No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	40 minutes
2.	Temperature	50 degrees
3.	Concentration	2.06%



A - Surface plot      B - Contour plot  
 Time - 40 minutes (yarn hairiness, graph 1)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

## Graph 2:

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as 0.0 (i.e. 50 minutes).
- The value 'x' indicates the temperature.
- The value 'y' indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	11.546	13.526	15.023	16.038	16.572	16.624	16.193	15.281	13.886
-0.5	15.371	17.185	18.517	19.368	19.736	19.622	19.026	17.948	16.388
0.0	17.234	18.883	20.049	20.734	20.937	20.658	19.896	18.653	16.928
0.5	17.134	18.618	19.619	20.138	20.176	19.731	18.805	17.396	15.505
1.0	15.072	16.390	17.226	17.580	17.452	16.842	15.750	14.176	12.120

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the hairiness %. I.e. an increase followed by a decrease in values.

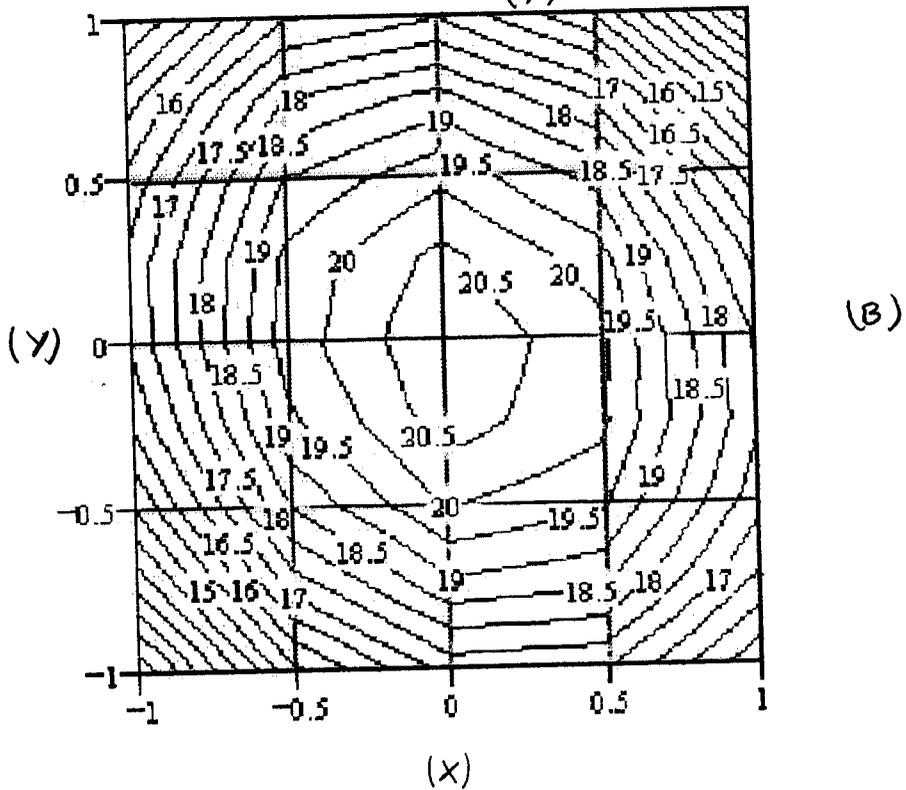
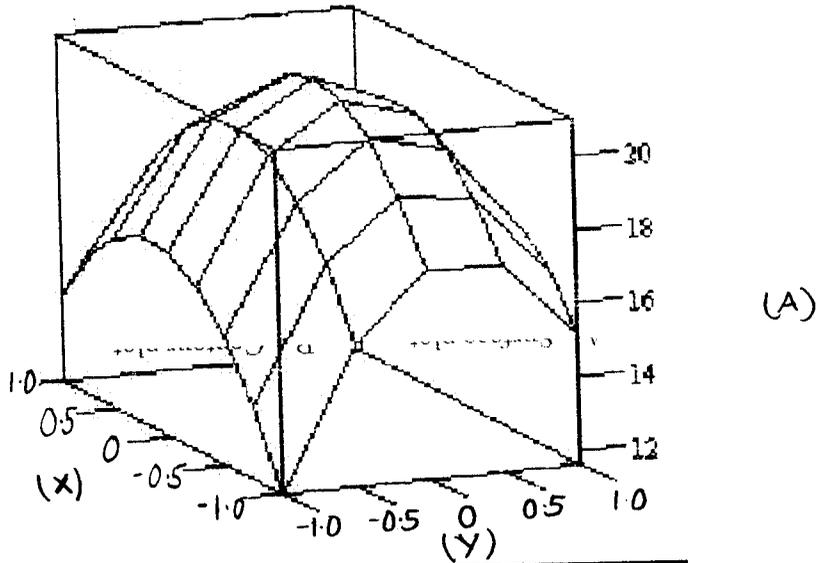
	-0.15	-0.10	-0.05	0.0	0.05	0.10	0.15	0.20
0.04	20.892	20.930	20.949	20.948	20.928	20.889	20.831	20.753
0.05	20.895	20.933	20.951	20.949	20.929	20.889	20.830	20.751
0.06	20.897	20.934	20.951	20.949	20.928	20.887	20.828	20.749
0.07	20.899	20.935	20.951	20.949	20.927	20.885	20.745	20.646
0.08	20.899	20.933	20.949	20.945	20.922	20.879	20.817	20.736

From the table above we can find one shaded portion which indicates the optimized value for the hairiness %. Here the following conditions are followed,

- The time is kept as constant = 0.0 (i.e. at 50 minutes)
- The temperature is increased as in the order of 0.2°C i.e. the values will be starting from 48.4, 48.6, 48.8, 50, 50.2, 50.4, 50.6, 50.8.
- The concentration is fixed in such a way that, the point at which the hairiness removal % increases and then decreases.
- From the above table we can say that the optimum removal of hairiness occurs at the following conditions,

The optimized value for % maximum removal of hairiness is given below

<u>Sl No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	50 minutes
2.	Temperature	50 degrees
3.	Concentration	2.06%



A - Surface plot      B - Contour plot  
 Time - 50 minutes (yarn hairiness, graph 2)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

### Graph 3:

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as 1.0 (i.e. 60 minutes).
- The value 'x' indicates the temperature.
- The value 'y' indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	8.381	10.682	12.501	13.838	14.693	15.066	14.957	14.366	13.293
-0.5	12.318	14.454	16.108	17.279	17.969	18.176	17.902	17.146	15.907
0.0	14.293	16.263	17.752	18.758	19.282	19.324	18.885	17.963	16.559
0.5	14.305	16.110	17.433	18.274	18.633	18.510	17.905	16.817	15.248
1.0	12.355	13.995	15.152	15.828	16.021	15.733	14.962	13.710	11.975

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the hairiness %. i.e. an increase followed by a decrease in values.

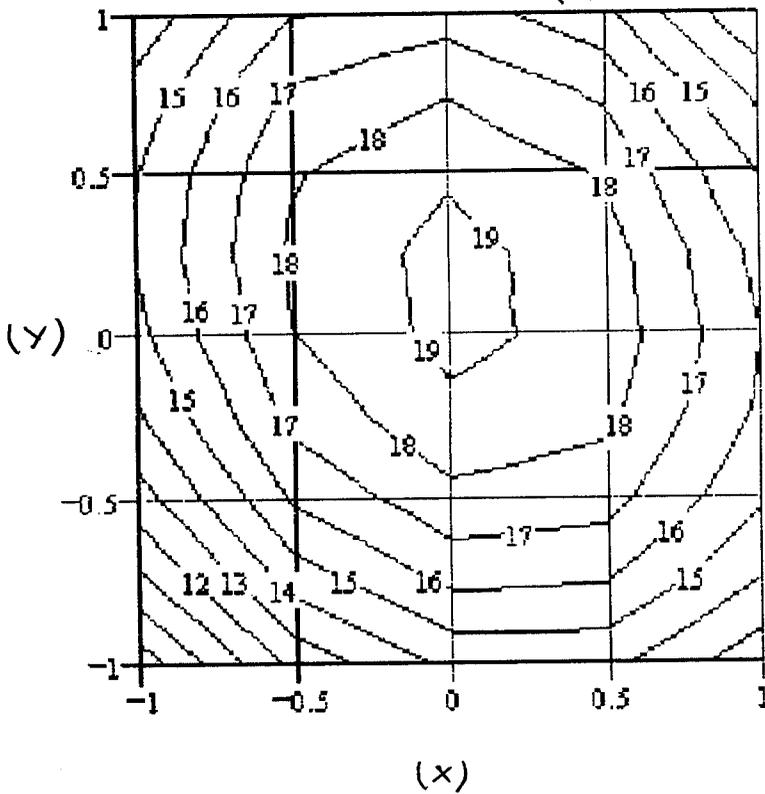
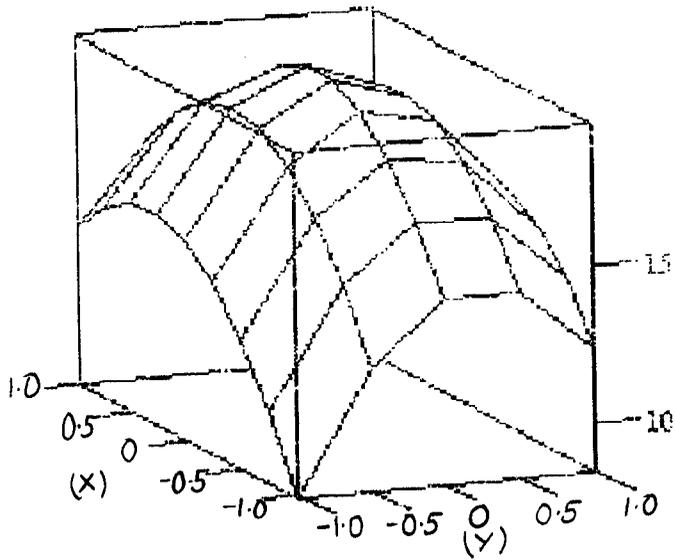
	-0.15	-0.10	-0.05	0.0	0.05	0.10	0.15	0.20
0.04	19.302	19.347	19.372	19.378	19.364	19.331	19.279	19.208
0.05	19.305	19.349	19.374	19.379	19.365	19.331	19.278	19.206
0.06	19.308	19.351	19.375	19.379	19.365	19.330	19.277	19.204
0.07	19.309	19.352	19.375	19.379	19.363	19.328	19.274	19.201
0.08	19.301	19.352	19.374	19.377	19.361	19.326	19.271	19.197

From the table above we can find one shaded portion which indicates the optimized value for the hairiness %. Here the following conditions are followed,

- The time is kept as constant = 1.0 (i.e. at 60 minutes)
- The temperature is increased, as in the order of 0.2°C i.e. the values will be starting from 48.4, 48.6, 48.8, 50, 50.2, 50.4, 50.6, and 50.8.
- The concentration is fixed in such a way that, the point at which the hairiness removal % increases and then decreases.
- From the above table we can say that the optimum removal of hairiness occurs at the following conditions,

The optimized value for % maximum removal of hairiness is given below

<u>Sl No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	60 minutes
2.	Temperature	50 degrees
3.	Concentration	2.06%



A - Surface plot      B - Contour plot  
 Time - 60 minutes (yarn hairiness, graph 3)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

## Effect of Enzyme treatment on yarn strength:

The enzyme treated yarns have a loss of strength of 5 – 20 %. The percentage loss of strength is mainly depended upon the processing conditions. There are three graphs attached below, indicating the effect of enzyme treatment on yarn strength. It can be easily understood from the graph, that as the temperature increases, there is an increase in the % loss of strength. The reason for such increase in the loss of strength % is that, the cellulose in the yarn is being hydrolyzed to glucose and fructose. This will lead to the reduction in yarn strength. The three graphs has the following parameters,

- Time is fixed at each levels –1, 0, +1 i.e. 40, 50, 60 minutes respectively.
- The temperature is increased in the order of 1 degree Celsius.
- The concentration is also increased in the order of 1% as per the levels, -1, 0, +1, i.e. 1%, 2%, 3%.

The generalized equation for strength is,

$$Y = 15.192 - 0.425x_1 + 5.366x_2 + 0.18x_3 - 1.154x_1^2 - 2.304x_2^2 - 0.837x_3^2 - 0.825x_1x_2 - 1.099x_1x_3 + 0.451x_2x_3$$

### Graph 1:

From the graph given here we can understand that as the temperature goes on increasing, there will be a gradual increase in % loss of strength. The enzyme treatment is effected due to reaction with the cellulose of the fibre molecules and as the temperature increases the reaction rate is improved. For quick reference and for clear understanding a contour plot is drawn below.

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as –1.0 (i.e. 40 minutes).
- The value ‘x’ indicates the temperature.
- The value ‘y’ indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	4.283	6.731	8.891	10.763	12.347	13.643	14.651	15.731	15.803
-0.5	5.898	8.243	10.300	12.069	13.550	14.742	15.647	16.624	16.593
0.0	6.936	9.178	11.132	12.797	14.175	15.265	16.066	16.580	16.806
0.5	7.397	9.536	11.386	12.949	14.224	15.210	15.909	16.319	16.442
1.0	7.281	9.317	11.064	12.524	13.695	14.579	15.174	15.482	15.501

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the hairiness %. i.e. an increase followed by a decrease in values.

	-1.0	-0.95	-0.90	-0.85	-0.80	-0.75	-0.70	-0.65
-1.0	4.283	4.796	5.297	5.786	6.264	6.731	7.186	7.630
-0.99	4.470	4.981	5.480	5.968	6.441	6.908	7.361	7.803
-0.9	4.652	5.161	5.658	6.143	6.617	7.080	7.530	7.970

From the table above we can find one shaded portion which indicates the optimized value for the minimum strength loss %. Here the following conditions are followed,

- The time is kept as constant = 40 (i.e. at 40 minutes)
- The temperature is increased as in the order of 0.2°C i.e. the values will be starting from 46, 46.2, 46.4, 46.6, 46.8, 47, 47.2.
- The concentration is fixed in such a way that, the point at which the strength loss % increases gradually.
- From the above table we can say that the optimum value for minimum strength loss %, occurs at the following conditions,

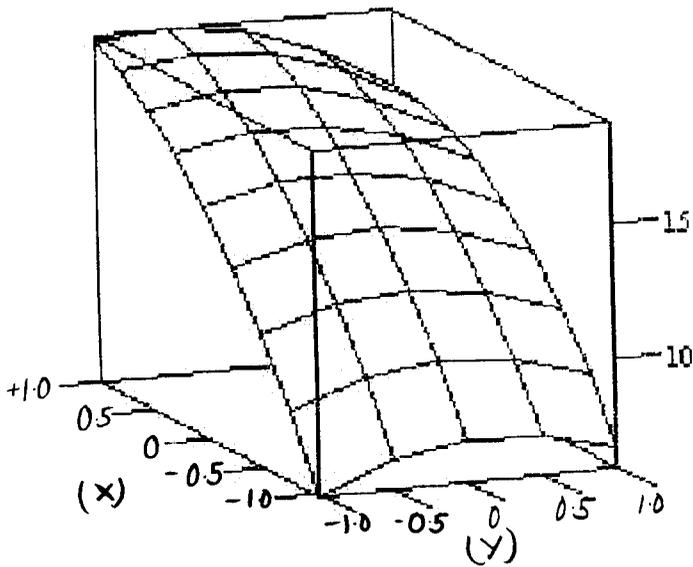
<u>Sl No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	40 minutes
2.	Temperature	46 degrees
3.	Concentration	1.0%

The above variables give an optimal minimum loss % of yarn strength. But at this value the hairiness removal % is extremely poor. Hence we cannot take this as the optimum value. The optimum value should be chosen in such a way that, the importance given to the hairiness is to be at the top. Hence the strength loss % at the following conditions should be noted,

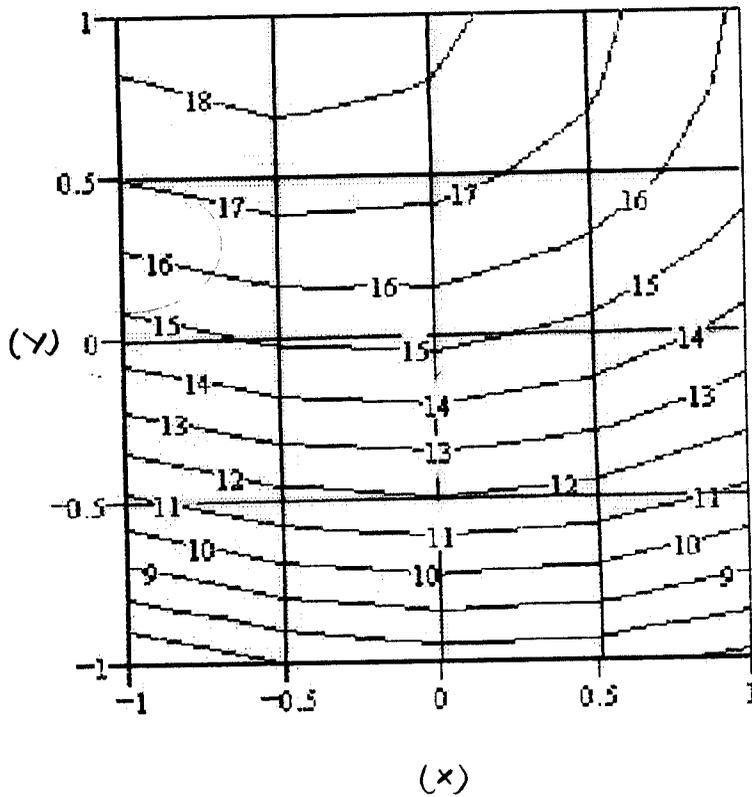
- Concentration → 2.06 %
- Temperature → 50 degrees
- Time → 40 minutes

Hence the strength loss % at these conditions is given below,

Parameters	Result
<ul style="list-style-type: none"> <li>• Concentration → 2.06</li> <li>• Temperature → 50 degrees</li> <li>• Time → 40 minutes</li> </ul>	14.211% loss in strength



(A)



(B)

A - Surface plot      B - Contour plot  
 Time - 40 minutes (yarn strength, graph 1)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

## Graph 2:

From the graph given here we can understand that as the temperature goes on increasing, there will be a gradual increase in % loss of strength. The enzyme treatment is effected due to reaction with the cellulose of the fibre molecules and as the temperature increases the reaction rate is improved. For quick reference and for clear understanding a contour plot is drawn below.

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as 0.0 (i.e. 50 minutes).
- The value 'x' indicates the temperature.
- The value 'y' indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	5.948	8.509	10.781	12.766	14.463	15.872	16.993	17.825	18.370
-0.5	7.014	9.471	11.641	13.522	15.116	16.422	17.439	18.169	18.611
0.0	7.502	9.857	11.923	13.701	15.192	16.395	17.309	17.936	18.274
0.5	7.414	9.665	11.628	13.304	14.691	15.790	16.602	17.125	17.361
1.0	6.748	8.896	10.757	12.329	13.613	14.609	15.318	15.738	15.870

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the hairiness %. i.e. an increase followed by a decrease in values.

	-1.0	-0.95	-0.90	-0.85	-0.80	-0.75	-0.70	-0.65
-1.0	5.948	6.483	7.007	7.519	8.020	8.509	8.986	9.452
-0.99	6.081	6.614	7.135	7.645	8.144	8.631	9.106	9.570
-0.9	6.207	6.738	7.258	7.766	8.262	8.747	9.221	9.683

From the table above we can find one shaded portion which indicates the optimized value for the minimum strength loss %. Here the following conditions are followed,

- The time is kept as constant = 0.0 (i.e. at 50 minutes)
- The temperature is increased as in the order of 0.2°C i.e. the values will be starting from 46, 46.2, 46.4, 46.6, 46.8, 47, 47.2.
- The concentration is fixed in such a way that, the point at which the strength loss % increases gradually.
- From the above table we can say that the optimum value for minimum strength loss %, occurs at the following conditions,

<u>Sl No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	50 minutes
2.	Temperature	46 degrees
3.	Concentration	1.0%

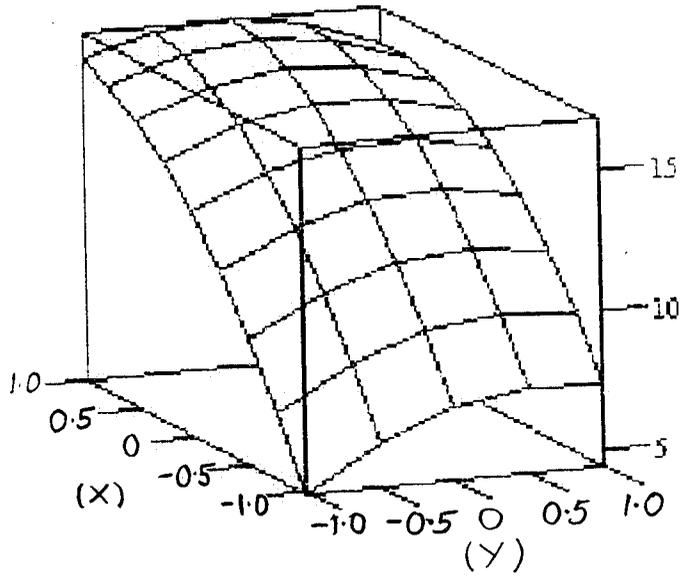
The above variables give an optimal minimum loss % of yarn strength. But at this value the hairiness removal % is extremely poor. Hence we cannot take this as the optimum value. The optimum value should be chosen in such a way that, the importance given to the hairiness is to be at the top. Hence the strength loss % at the following conditions should be noted,

- Concentration → 2.06 %

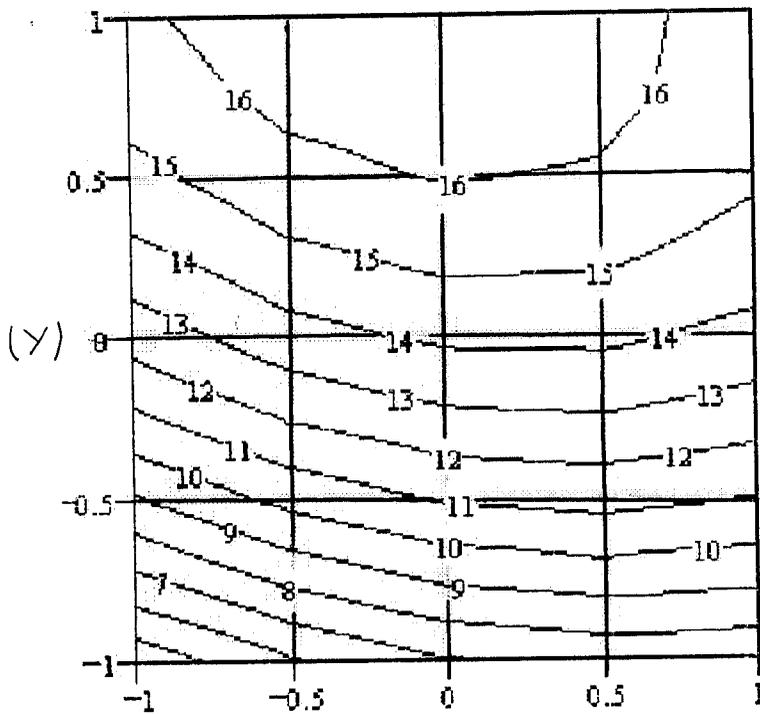
- Temperature → 50 degrees
- Time → 50 minutes

Hence the strength loss % at these conditions is given below,

Parameters	Result
<ul style="list-style-type: none"> <li>• Concentration → 2.06 %</li> <li>• Temperature → 50 degrees</li> <li>• Time → 50 minutes</li> </ul>	15.162% loss in strength



(A)



(B)

(X)

A - Surface plot      B - Contour plot  
Time - 50 minutes (yarn strength, graph 2)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

### Graph 3:

From the graph given here we can understand that as the temperature goes on increasing, there will be a gradual increase in % loss of strength. The enzyme treatment is effected due to reaction with the cellulose of the fibre molecules and as the temperature increases the reaction rate is improved. For quick reference and for clear understanding a contour plot is drawn below.

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as 1.0 (i.e. 60 minutes).
- The value 'x' indicates the temperature.
- The value 'y' indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	5.939	8.613	10.998	13.095	14.905	16.427	17.660	18.606	19.26
-0.5	6.455	9.025	11.308	13.302	15.009	16.427	17.557	18.400	18.95
0.0	6.394	8.861	11.041	12.932	14.535	15.850	16.878	17.617	18.06
0.5	5.756	8.120	10.196	11.984	13.484	14.697	15.621	16.257	16.60
1.0	4.541	6.802	8.775	10.460	11.857	12.966	13.787	14.320	14.56

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the hairiness %. i.e. an increase followed by a decrease in values.

	-1.0	-0.95	-0.90	-0.85	-0.80	-0.75	-0.70	-0.65
-1.0	5.939	6.497	7.043	7.578	8.101	8.613	9.113	9.601
-0.99	6.019	6.572	7.166	7.649	8.176	8.680	9.178	9.664
-0.9	6.088	6.642	7.184	7.715	8.234	8.741	9.237	9.722

From the table above we can find one shaded portion which indicates the optimized value for the minimum strength loss %. Here the following conditions are followed,

- The time is kept as constant = 1.0 (i.e. at 60 minutes)
- The temperature is increased as in the order of 0.2°C i.e. the values will be starting from 46, 46.2, 46.4, 46.6, 46.8, 47, 47.2.
- The concentration is fixed in such a way that, the point at which the strength loss % increases gradually.
- From the above table we can say that the optimum value for minimum strength loss %, occurs at the following conditions,

<u>Sl No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	60 minutes
2.	Temperature	46 degrees
3.	Concentration	1.0%

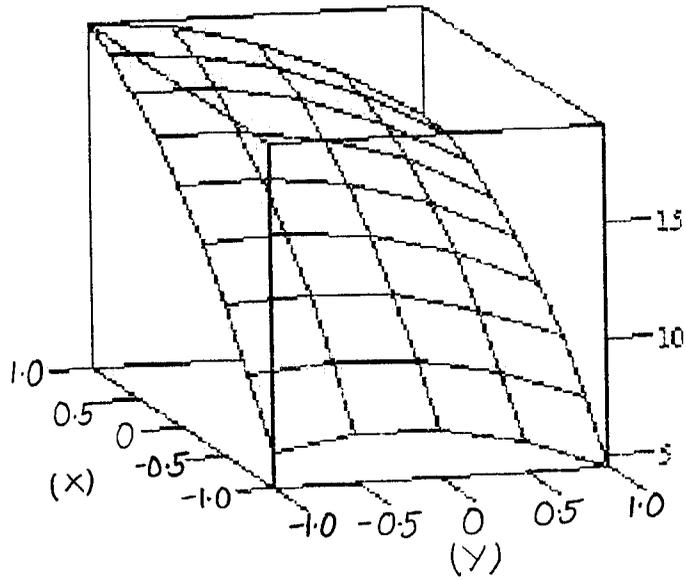
The above variables give an optimal minimum loss % of yarn strength. But at this value the hairiness removal % is extremely poor. Hence we cannot take this as the optimum value. The optimum value should be chosen in such a way that, the importance given to the hairiness is to be at the top. Hence the strength loss % at the following conditions should be noted,

- Concentration → 2.06 %
- Temperature → 50 degrees

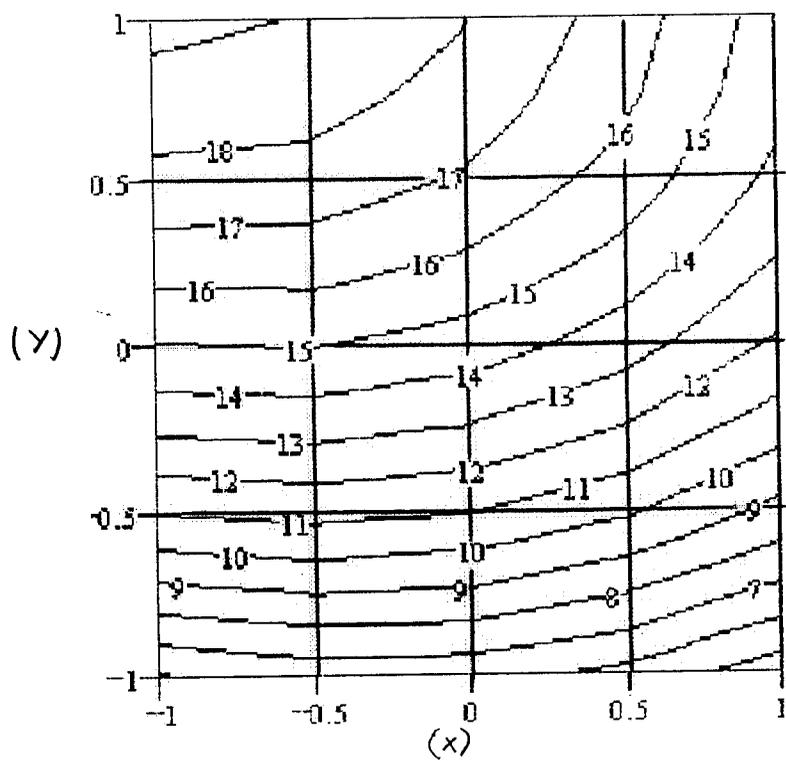
- Time → 60 minutes

Hence the strength loss % at these conditions is given below,

Parameters	Result
<ul style="list-style-type: none"><li>• Concentration → 2.06 %</li><li>• Temperature → 50 degrees</li><li>• Time → 60 minutes</li></ul>	14.439% loss in strength



(A)



(B)

A - Surface plot      B - Contour plot  
Time - 60 minutes (yarn strength, graph 3)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

## Effect of Enzyme treatment on Yarn Friction

The kinetic friction of an enzyme treated yarn is found out. The friction between yarn to steel is found out, as it is common in a textile industry, like garment sectors. By enzyme treatment, the results show that the yarn friction is reduced ranging from 15 – 50%. The reduction of yarn friction depends upon the processing conditions i.e. it depends upon the variables. There are 3 graphs attached below, indicating the effect of enzyme treatment in % reduction in yarn friction. The graph is displayed in the manner of % reduction of yarn friction. The graphs has the following parameters,

- Time is fixed at each levels -1, 0, +1 i.e. 40, 50, 60 minutes respectively.
- The temperature is increased in the order of 1 degree Celsius.
- The concentration is also increased in the order of 1% as per the levels, -1, 0, +1, i.e. 1%, 2%, 3%.

The regression equation for the yarn friction is,

$$Y = 40.586 + 2.251x_1 + 2.819x_2 + 1.678x_3 - 0.661x_1^2 - 4.366x_2^2 - 8.596x_3^2 - 1.249x_1x_2 - 0.214x_1x_3 + 9.469x_2x_3$$

### Graph 1:

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as -1.0 (i.e. 40 minutes).
- The value 'x' indicates the temperature.
- The value 'y' indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	17.419	20.679	23.394	25.563	27.186	28.263	28.795	28.781	28.221
-0.5	18.523	21.939	24.810	27.135	20.312	31.702	32.545	32.844	32.596
0.0	19.296	22.869	25.895	28.377	30.312	31.702	32.545	32.844	32.596
0.5	19.739	23.467	26.650	29.288	31.379	32.925	33.925	34.379	34.288
1.0	19.851	23.736	27.075	29.868	32.116	33.818	34.974	35.584	35.649

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the yarn friction %. I.e. an increase followed by a decrease in values.

	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.0
0.97	35.346	35.445	35.521	35.576	35.609	35.620	35.609	35.577
0.98	35.366	35.465	35.543	35.598	35.631	35.643	35.633	35.601
0.99	35.386	35.486	35.564	35.619	35.654	35.666	35.656	35.625
1.0	35.406	35.506	35.584	35.641	35.676	35.689	35.680	35.649

From the table above we can find one shaded portion which indicates the optimized value for the yarn friction %. Here the following conditions are followed,

- The time is kept as constant = -1.0 (i.e. at 40 minutes)
- The temperature is increased as in the order of 0.2°C i.e. the values will be starting from 52.6, 52.8, 53.0, 53.2, 53.4, 53.6, 53.8, 54.0.

- The concentration is fixed in such a way that, the point at which the yarn friction % increases and then decreases.
- From the above table we can say that the optimum decrease in yarn friction occurs at the following conditions,

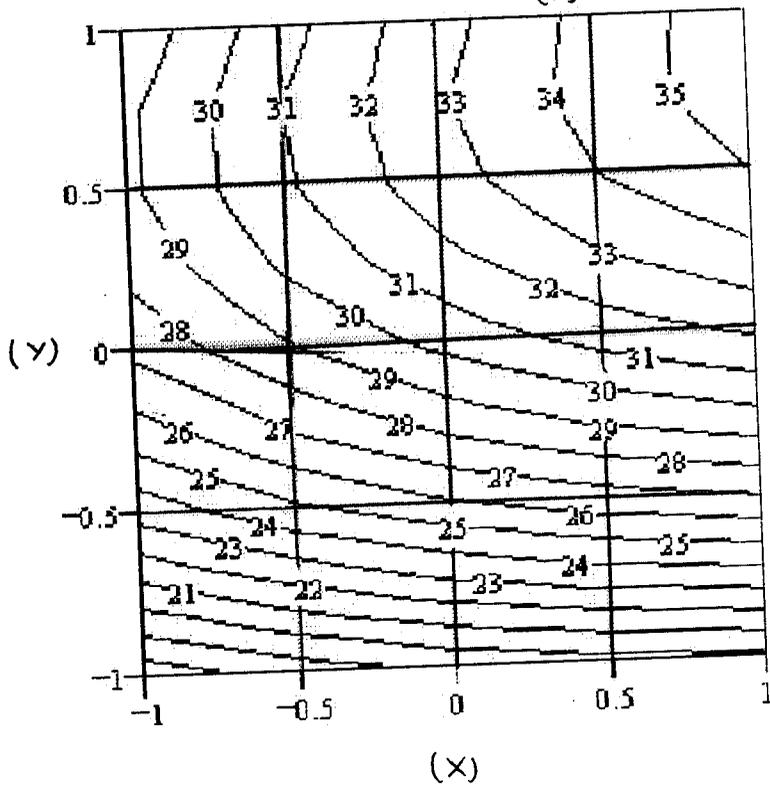
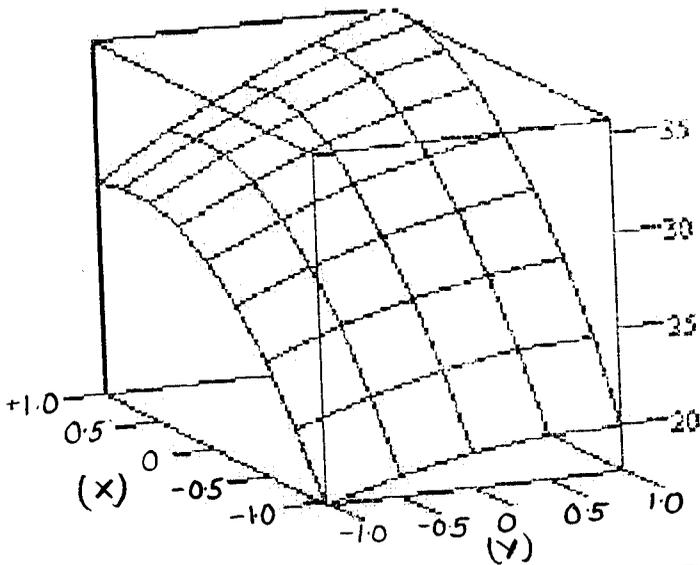
<u>SI No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	40 minutes
2.	Temperature	53.6 degrees
3.	Concentration	3%

The values of strength, hairiness, at optimized friction values are given below,

<u>SI No</u>	<u>Properties</u>	<u>Results</u>
1.	% decrease in yarn hairiness	7.656
2.	% loss in yarn strength	15.528

The values of strength, friction at optimized hairiness (17.122 %) values are given below,

<u>SI No</u>	<u>Properties</u>	<u>Results</u>
1.	% decrease in yarn friction	30.162
2.	% loss in yarn strength	14.211



A - Surface plot      B - Contour plot  
 Time - 40 minutes (yarn friction, graph 1)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

## Graph 2:

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as 0.0 (i.e. 50 minutes).
- The value 'x' indicates the temperature.
- The value 'y' indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	29.240	32.167	34.549	36.384	37.674	38.418	38.616	38.269	37.376
-0.5	31.486	34.257	36.482	38.161	39.295	39.883	39.925	39.422	38.373
0.0	33.401	36.016	38.085	39.608	40.586	41.018	40.904	40.244	39.039
0.5	34.986	37.444	39.357	40.725	41.546	41.822	41.552	40.736	39.375
1.0	36.240	38.543	40.299	41.511	42.176	42.296	41.869	40.898	39.380

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the yarn friction %. I.e. an increase followed by a decrease in values.

	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35
0.97	42.148	42.217	42.265	42.290	42.294	42.277	42.237	42.175
0.98	42.157	42.226	42.273	42.298	42.302	42.283	42.243	42.181
0.99	42.167	42.235	42.281	42.306	42.309	42.289	42.248	42.186
1.0	42.176	42.244	42.289	42.313	42.315	42.296	42.254	42.191

From the table above we can find one shaded portion which indicates the optimized value for the yarn friction %. Here the following conditions are followed,

- The time is kept as constant = 0.0 (i.e. at 50 minutes)
- The temperature is increased as in the order of 0.2°C i.e. the values will be starting from 50, 50.2, 50.4, 50.6, 50.8, 51.0, 51.2, 51.4.
- The concentration is fixed in such a way that, the point at which the yarn friction % increases and then decreases.
- From the above table we can say that the optimum removal of hairiness occurs at the following conditions,

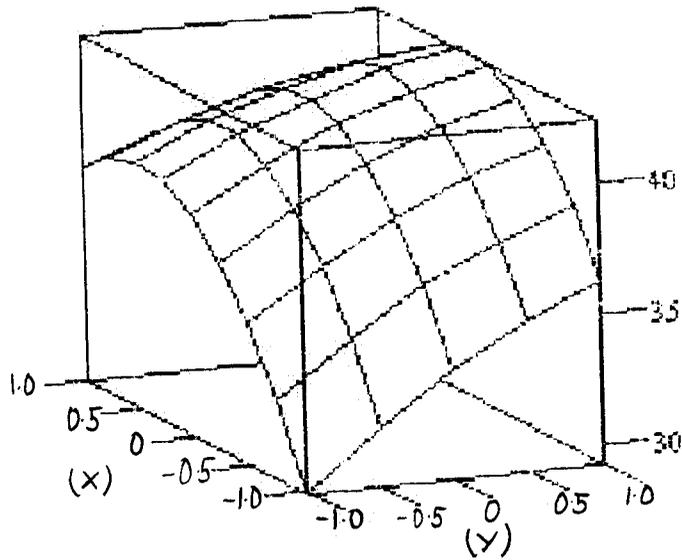
<u>Sl No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	50 minutes
2.	Temperature	50.8 degrees
3.	Concentration	3%

The values of strength, hairiness, at optimized friction values are given below,

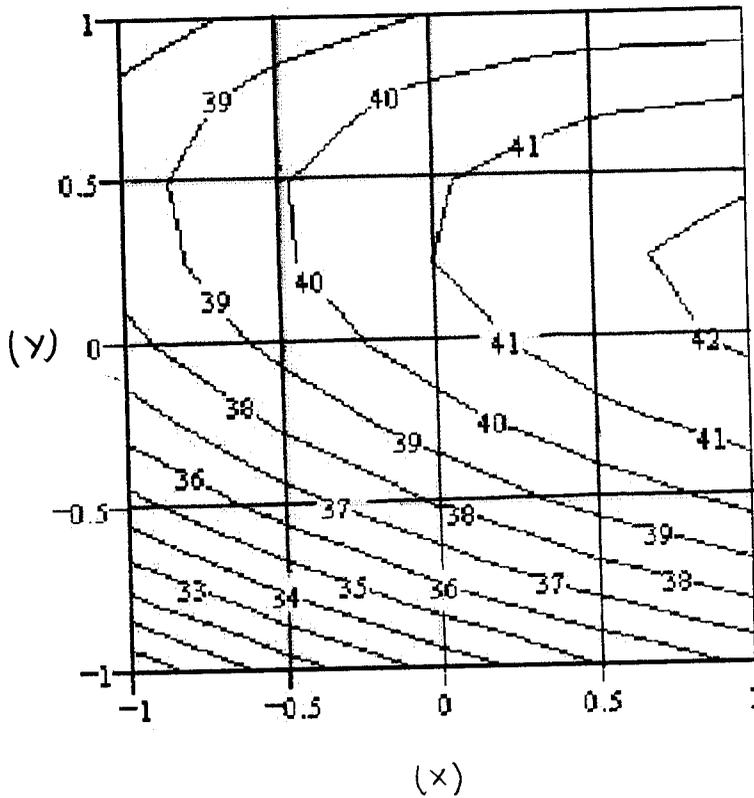
<u>Sl No</u>	<u>Properties</u>	<u>Results</u>
1.	% decrease in yarn hairiness	17.003
2.	% loss in yarn strength	14.433

The values of strength, friction, at optimized hairiness (20.949 %) values are given below,

<b><u>Sl No</u></b>	<b><u>Properties</u></b>	<b><u>Results</u></b>
1.	% decrease in yarn friction	40.719
2.	% loss in yarn strength	15.162



(A)



(B)

A - Surface plot      B - Contour plot  
 Time - 50 minutes (yarn friction, graph 2)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

### Graph 3:

The graph is obtained by plotting the following points as shown below.

- Here the time is maintained as 1.0 (i.e. 60 minutes).
- The value 'x' indicates the temperature.
- The value 'y' indicates the level of concentration.

The 'x' values indicates the following temperatures,

X=	-1.0	-0.75	-0.5	-0.25	0.0	0.25	0.5	0.75	1.0
Temp	46	47	48	49	50	51	52	53	54

The 'y' values indicates the %concentration maintained,

Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

The values for the above condition are,

	-1.0	-0.75	-0.50	-0.25	0.0	0.25	0.50	0.75	1.0
-1.0	13.067	18.361	23.110	27.313	30.970	34.081	36.647	38.667	40.141
-0.5	15.206	20.344	24.936	28.983	32.484	35.439	37.849	39.713	41.031
0.0	17.014	21.996	26.432	30.323	33.668	36.467	38.720	40.428	41.590
0.5	18.492	23.318	27.598	31.332	34.521	37.164	39.261	40.813	41.819
1.0	19.639	24.309	28.433	32.011	35.044	37.531	39.472	40.867	41.717

The optimized values for a specific condition can be found out the point or the condition at which there is a change in the yarn friction %. I.e. an increase followed by a decrease in values.

	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.0
0.57	40.294	40.578	40.841	41.081	41.300	41.496	41.671	41.824
0.58	40.299	40.582	40.844	41.084	41.302	41.498	41.672	41.825
0.59	40.303	40.586	40.847	41.086	41.304	41.499	41.673	41.825
0.60	40.308	40.590	40.850	41.089	41.306	41.501	41.674	41.825
0.61	40.312	40.594	40.853	41.091	41.307	41.502	41.674	41.825
0.62	40.316	40.597	40.856	41.094	41.309	41.503	41.674	41.824

From the table above we can find one shaded portion which indicates the optimized value for the yarn friction %. Here the following conditions are followed,

- The time is kept as constant = 1.0 (i.e. at 60 minutes)
- The temperature is increased as in the order of 0.2°C i.e. the values will be starting from 52.6, 52.8, 53.0, 53.2, 53.4, 53.6, 53.8, 54.0
- The concentration is fixed in such a way that, the point at which the yarn friction % increases and then decreases.
- From the above table we can say that the optimum decrease in yarn friction occurs at the following conditions,

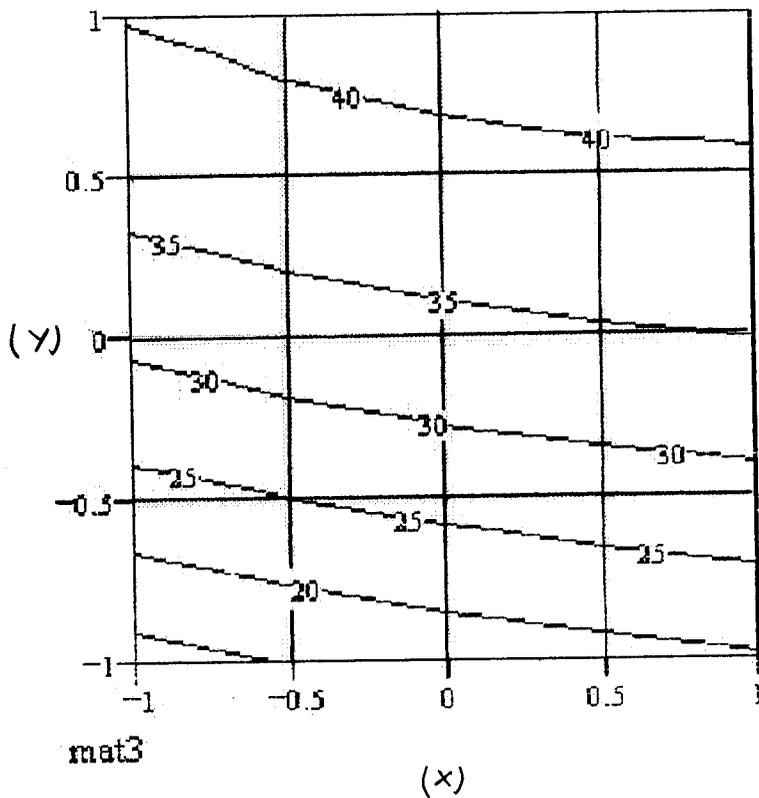
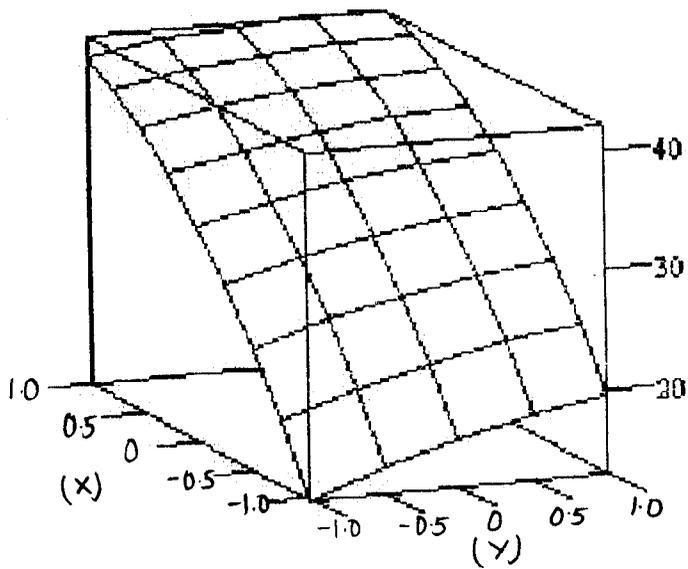
<u>Sl No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	60 minutes
2.	Temperature	54 degrees
3.	Concentration	2.61%

The values of strength, hairiness, at optimized friction values are given below,

<u>Sl No</u>	<u>Properties</u>	<u>Results</u>
1.	% decrease in yarn hairiness	9.543
2.	% loss in yarn strength	16.206

The values of strength, friction, at optimized hairiness (19.379 %) values are given below,

<b><u>Sl No</u></b>	<b><u>Properties</u></b>	<b><u>Results</u></b>
1.	% decrease in yarn friction	33.788
2.	% loss in yarn strength	14.439



mat3

A - Surface plot      B - Contour plot  
 Time - 60 minutes (yarn friction, graph 3)

X=	-1.0	-0.5	0.0	0.5	1.0
Temp	46	48	50	52	54
Y=	-1.0	-0.5	0.0	0.5	1.0
Conc	1%	1.5%	2%	2.5%	3%

### Optimized Condition:

The optimized condition is found out from the above results by noting the following points.

- % removal of yarn hairiness.
- % loss of yarn strength.
- % decrease in yarn friction.

Using the results, the optimized conditions are found out for 40, 50, 60 minutes.

For 40 minutes,

<u>SI No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	40 minutes
2.	Temperature	50 degrees
3.	Concentration	2.06%

For 50 minutes,

<u>SI No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	50 minutes
2.	Temperature	50.8 degrees
3.	Concentration	3%

For 60 minutes,

<u>SI No.</u>	<u>Parameter</u>	<u>Optimum value</u>
1.	Time	60 minutes
2.	Temperature	50 degrees
3.	Concentration	2.06%

## CONCLUSION

From the above results and its elaborate discussions, we can see that the property of the enzyme treated yarn mainly depends upon the no of variables chosen and its levels. The variables, which we have chosen, are the concentration, temperature, and time taken. With respect to the above variables, the yarn properties such as Strength, Hairiness, Friction for all the 15 samples are studied. For the above properties, the graphs are drawn. The graphs are drawn in such a way that, the time is kept constant and the effect of each property under variable concentration and temperature are studied. From the graphs we can see that, as the temperature increases for a particular concentration there is a trend in decrease of yarn strength. Similarly in the case of the yarn hairiness, there is an increase in hairiness removal percentage for an increase in the temperature under a particular concentration; and also there is an increase in hairiness removal percentage for an increase in concentration for a particular temperature. In the case of yarn friction, as the temperature increases the percentage decrease in yarn friction increases for a particular concentration. A similar decrease is also found for an increase in concentration at a particular temperature. Thus from the above conditions we can find an optimized condition based on “minimum % loss of strength, maximum % removal of hairiness and maximum % decrease in yarn friction”.

The optimized conditions for each time variable is given below,

For 40 minutes:

- Temperature – 50 °C
- Concentration – 2.06 %

For 50 minutes:

- Temperature – 50.8 °C
- Concentration – 3 %

For 60 minutes:

- Temperature – 50 °C
- Concentration - 2.06 %

## *Bibliography*

---

## BIBLIOGRAPHY

- \* Title "Enzyme application in Textiles", by Mr. Mrinal Thakur, Mr. Shailendra Singh, Mr. Subhendra Das, from "The Indian Textile Journal", page 27, Nov 2000.
- 1. Title "Bio finishing of Cellulose Fabrics", by Mr. Sarkka P, from "Internation Textile Bulletin", page no. 41, April 1995.
- 2. Title "Wrinkle Resistant Cottons" from the Journal "Fabric Care", page no. 24, 1995.
- 3. Title "Detergents for Acid Cellulase Enzymes", by Mr. Shook D. B., from AATCC Book of papers, page no. 34, 1994.
- 4. Title "Opportunities for use of Bio Chemicals in Textile Finishing", by Mr. Clarkson K., from AATCC Book of papers, page no. 319, 1994.
- 5. Title "Cellulase treatment of Cotton Fabrics", by Mr. Koo H., Mr. Waida T., Mr. Yoshimura Y., Mr. Igarashi T., from "Textile Research Journal", page no. 64, Feb 1994.
- 6. Title "Optimization of Cellulase Enzymes", by Mr. Khahorst S, Mr. Kumar A, Mr. Mullins M. M, from "Textile Chemist and Colorist", page no. 26, Feb 1994.
- 7. Title "Cellulase Treatment of cotton fabrics II: Inhibitory effect of Surfactants on Cellulases catalytic reaction.", by Mr. Koo H, Mr. Ueda, Mr. Wakida T., from "Textile Research Journal", page no. 615, Oct 1994.
- 8. Title "Hydrolysis of Cotton by Engineered Cellulases from *Trichoderam Reesei*", by Mr. David Bishop, Mr. Artur Cavaco-Paulo, Mr. Luis Almeida, from "Textile Research Journal", page no. 273, April 1998.
- 9. Title "Application of Enzyme treatment to cellulosic fabrics for imparting specific functional properties", by Mr. Sheth G. N., Mr. Mayboo C., Mr. Betrabet S. M., from SITRA, page no. 99, 1995.
- 10. Title "Kawabata evaluation of enzyme treated cotton knitted fabric", by Mr. Gulrajani L., Mr. Amit Dayal, Mr. Chakraborty M., from "Indian Journal of Fibre and Research", page no. 160, vol. 23 Sept 1998.
- 11. Title "Effect of Pre-existing Dyes and Fabric Type on Cellulase Treatment of Cotton Fabrics", by Mr. Eun Kyong Choe, Mr. Soon Young Park, Mr. Hee Cheol Cha, Mr. Byong Dae Jeon, from "Textile Research Journal", page no. 155, vol. 63 March 1997.

12. Title "Chemometric approach to optimize cellulase treatment of cotton knits", by Mr. Gulrajani L., Mr. Sanjeev Sinha, Mr. Banerjee P. K., from "Indian Journal of Fibre and Textile Research", page no. 30, vol. 22 March 1997.
13. Title "Relationship between cellulase treatment and direct dye dyeing for cotton", by Dr. Kato Y., from "Journal of Applied Polymer Science", vol. 45 1992.
14. Title "Bio-polishing of jute-cotton union fabric", by Mr. Kundu A., Mr. Ghosh B. S., Mr. Ghosh U. K., Mr. Sengupta S., Mr. Dutta A. K., Mr. Ghosn B. L., from "Indian Journal of Fibre and Textile Research", page no. 127, vol. 21 June 1996.
15. Title "Improvement in properties of jute fibre by treatment with polysaccharide-degrading enzymes", by by Mr. Kundu A., Mr. Ghosh B. S., Mr. Ghosh B. S., Mr. Ghosn B. L., Mr. Chakraborti K. S., from "Indian Journal of Fibre and Textile Research", page no. 101, vol. 18 June 1993.
16. Title "Relationship between Cellulase Treatment and the Dyeability with a Direct Dye for various kinds of Cellulosic fibres", by Mr. Reiko Mori, Mr. Toshio Haga, Mr. Toru Takagishi, from "Journal of Applied Polymer Science", page no. 1223, vol. 48 June 1993.
17. Title "Use of Cellulases in Treatment of Cotton Fabrics", by Mr. Oijusluoma Lea, Mr Cavaco-Paulo Artur, Mr. Siika-aco Matti, Mr. Buchert Johanna, from "Textile Research Journal", page no. 343, 1998.
18. Title "Use of Cellulase Enzymes to improve Pretreatment of Cotton", by Mr. Achwal W. B., from "Colourage", page no. 42, Aug 1995.
19. For enzyme activity no. and other details refer "[www.bio-cat.com](http://www.bio-cat.com)"