USE OF COLOR PHOTOMICROGRAPHS TO COMPARE UNSTAINED AND STAINED CROSS-SECTIONS OF A NYLON FABRIC BEFORE AND AFTER ABRASION

by

BOBBY JEAN EDMUNDSON

B. S., Texas Southern University, 1966

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

Approved by:

Esther M. Cormany
Major Professor

ACKNOWLEDGMENTS

Sincere appreciation is expressed to Miss Esther Cormany for the inspiration, encouragement, and the continuous guidance so generously and graciously given throughout this study. Grateful acknowledgment is also expressed to Dr. Dorothy L. Harrison and Dr. Maynard L. McDowell for their cooperation and thoughtful suggestions while serving on the writer's committee.

TABLE OF CONTENTS

LIST OF PLATES

LIST OF PLATES (Continued)

CHAPTER I

INTRODUCTION

The wearing qualities of fabrics are of major concern to both the consumer and the manufacturer. Though abrasion is only one aspect of wear, it is commonly considered an acceptable way of ascertaining the service wear of a fabric.

In the laboratory, abrasion of textiles can be measured by changes in the tensile strength, thickness, weight, surface luster, air permeability, color, character of abraded materials and appearance of the surface. According to Kaswell (8), the first six represent properties that it is possible to measure physically; however, the last two must be determined with the aid of a microscope.

The use of stains as a measure of damage is not new to the study of textiles, however, their use to help determine the kind and extent of damage caused by abrasion in fabrics is limited. Studies have been reported on nylon fabric that had been photodegraded (Kato, 10), in which stains were used on nylon to investigate the skin-core relationship.

There have been extensive investigations to determine the effects of abrasion on the physical properties of a fabric. Examination of the fiber shaft has been made in some studies but little work has been done concerning cross-sectional studies. Therefore, the objectives of this study were:

1. To compare by use of photomicrographs of cross-sections, the degree of damage on a fabric as influenced by the amount of abrasion.
2. To compare unstained and stained cross-sections to determine the effect staining had on the fibers and the degree to which staining helped to show the damage.

CHAPTER II

REVIEW OF LITERATURE

The Effect of Abrasion on Yarns and Fabric

According to the American Society for Testing Materials (1) abrasion may be defined as the wearing away of any part of a material by rubbing against another surface. Abrasion may be caused by friction of cloth on cloth, friction of the cloth on external objects, or, friction of the fibers on the dust or grit in the fabric (Lawrie, 13). Though abrasion is not the only factor in wear, generally it is considered the most important.

The geometric arrangement of fibers in yarns and yarns in fabric are important in designing fabrics with high abrasion resistance. The abrasion resistance of a yarn is a function of both the intrinsic abrasion resistance of the fibers composing the yarn and the geometry of the yarn structure (Kaswell, 9). Textiles are flexible and depending upon the end use repeated flexing as well as pure abrasion can contribute to product failure.

Backer and Tanenhaus (3) list the following factors as having an influence on fabric abrasion: geometric area of contact between fabric and abradant, local pressures or stress concentrations developing on specific yarn points or areas, threads per inch, crown height, yarn size, fabric thickness, yarn crimp, float length, yarn cohesiveness, and fabric structure.

According to Kaswell (8), crown may be defined as the elevation of one yarn over the other caused by the intersection of a warp and filling yarn. The extent to which this causes the crown to be displaced out of the fabric plane will depend upon the weave, yarn thickness, crimp, thread count and the interaction of these parameters between warp and filling. These crowns will bear the brunt of abrasive action, the resulting destruction being dependent upon the nature and direction of the abradant and the height and number of crowns. The greater the crowns, the less will be the stress concentration per crown (Kaswell, 8).

A low apparent bulk modulus or high over-all flexibility serves to bring as many yarn crowns in geometrical contact with the abrasive surface as is consistent with the fabric structure. The more numerous the crowns in contact and the more area per crown or projecting yarn float, the less will be the local load at a fiber point. As local load is reduced, the true area of contact at each point is also reduced and the protuberance will descend into the yarn structure to a lesser degree (Kaswell, 8). As a result, there will be less local frictional resistance to develop axial components of fiber stress, reduced surface cutting of the fibers and less fiber plucking, slippage and tensile fatigue.

Backer and Tanenhaus (3) revealed that when all other factors are held constant, the abrasion resistance of warp-flush fabric is improved by increasing the number of warp crowns per square inch of fabric, thus reducing the normal load per warp crown. This same trend is observed in fabrics varying in weave and yarn diameter.

The American Society for Testing Materials (1) defines yarn crimp as the difference in distance between two points on the fiber as it lies in an unstretched condition and the same two points when the fiber is straightened under specific tension, expressed as a percentage of the unstretched length. Yarn crimp distribution determines the relative vertical displacement of each set of yarns above and below the plane of the fabric.

Cohesion or the ability to cling may be obtained in the yarn form by increasing the twist, or in the fabric form through use of compact weaves or increased texture. Backer and Tanenhaus (3) considered it desirable to use the latter means of securing cohesion because it permits use of lower yarn twist, which leads to yarn flattening, presentation of greater surface and reduction of local loads.

The association of greater wear life with increased thickness of a given material has been reported many times, and implies a direct relationship between the decrease in thickness and the number of rubs in an abrasion machine. Increased fabric thickness and larger yarn diameters are generally related and provide marked improvement in the abrasion resistance of textile structures (Backer and Tanenhaus, 3).

There is sufficient evidence to demonstrate that knuckled fabrics closely woven from tightly twisted yarns possess low wear resistance.

This is caused by the inability of the surface fiber to translate and avoid the path of the abradant particle (Kaswell, 8).

The Effect of Abrasion on Fibers

The geometric area of contact of individual fibers with the abradant depends upon the normal load at the point of contact, the principal curvatures of the fiber, the contour of the fiber cross-section, and the fiber bulk modulus (Backer and Tanenhaus, 3).

It has been indicated that stresses along the fiber can develop from horizontal forces acting transversely to the fiber axis as a result of surface friction, shallow cutting, or actual snagging. Such stresses may cause fiber rupture or slippage in their first occurrence, or after numerous application, therefore, it is desirable to prevent their build-up or at least reduce their magnitude. Transmission of high stresses along the axes of surface fibers may be reduced markedly by having the fiber yield, until it can slip under the protuberance of the abradant. In addition, the fiber must return quickly upon release so as to be able to assist in carrying the horizontal load of the abradant surface. Backer (2) and Kaswell (9) have stressed the importance of fiber elongation as a requisite to high abrasion resistance in fabrics.

Microscopic Examination of Abrasion Damage on Fibers

Through microscopic examination and photomicrographs of the fabric and analysis of the fiber shaft, the researcher has been able to observe any damage that has occurred and the type of damage that occurred when a fabric was abraded. Clegg (6) furnished critical evidence of the complex nature of fiber rupture. Her observation of numerous fibrous structures points to the importance of fiber cracking and breaking along transverse cracks. Such cracks pass freely across fibrils and cell structure without regard to their orientation. Some fibers exhibit transverse cracks at intervals of about twenty microns along their entire length. Following rupture of a surface layer and formation of a small transverse crack, extremely high shear stresses are set up at the apex of the crack, but in the direction of the cleavage planes. As a result, the ruptured surface layer is separated from the next layer and peels from the fiber.

The use of cross-sections to study fabric breakdown is limited in the research that has been done. Wahrenbrock (16) in a study of cross-sections of nylon fabrics which had been abraded, reported that damage was observed in the forms of separation of skin from core, and conversion of the fiber contour from a circular shape to an oblong shape. She also revealed that higher levels of abrasion were needed in order to study the breakdown of nylon fabric comparable to that of cotton.

Staining Techniques for Nylon

Damaged fabrics have been treated with various chemicals or stains to aid in the study of the injured fiber. Studies have been reported in which stains were used on nylon to differentiate the skin-core relationship. One of the earliest was the Zinc-Chloro-Iodide stain also known as Herzberg's stain (Kato, 12). In this technique the yarn cross-section was first swollen in zinc chloride then the skin was stained with iodine. This type of staining leaves much to be desired, as far as an accurate determination of the amount of skin stained is concerned, since the zinc chloride chemically swells both the skin and core but possibly to different degrees, and too, continued treatment with the zinc chloride will ultimately disintegrate the nylon sections (Berry, 4).

Procion Black HGS, a reactive dye, has been used to stain nylon filaments that have been photodegraded. Kato (10) reported that the staining process is chemical in nature because of its fastness to thirty per cent pyridine water washing. Procion Black HGS used by itself was only found to be an effective stain for nylon filaments that had been photodegraded, however, Cannepin and J. Rayon (5) revealed that when used in conjunction with a iodine pretreatment of the specimen this dye would stain nylon 66.

Kato (11) developed a staining technique for nylon that utilized Lanasyn Grey BL, a kind of neutral metal-complex acid dye. The purpose of this stain was to distinguish the skin-core relationship of drawn and undrawn nylon filaments. Though primarily developed for nylon 6 yarns, it can also be applied to nylon 66 yarns, if slightly modified to compensate for their reduced stainability. Kato (11) further reported that neither the temperature of the staining solution nor the length of time of staining was necessarily critical for the results obtained. He attributed this to the relatively slow rate of diffusion of the dye employed. Wahrenbrock (16) used the Lanasyn Grey BL stain and reported that this stain did not aid in distinguishing the skin-core structure of nylon cross-sections nor did it help show the damage caused by abrasion more readily.

Recently Kato (12) developed another dye for differentiating between the skin-core structure of stretched and unstretched polyamide fibers. He found the Lanasyn Green BL (s) stain gave excellent and reproducible results without the severe swelling experienced in earlier methods. Application of this method to fibers that had been modified during or after spinning gave an interesting picture of the internal structure and helped to explain special characteristics, such as crease resistance.

Berry (4) found that by using a combination of two water soluble dyes, a satisfactory and reproducible staining technique for the skin-core structure of both nylon 6 and nylon 66 yarns was possible. The two dyes used were kiton Pure Blue V, an acid dye, and Methyl Violet 2B Supra I, a basic dye. Close regulation of the temperature of the dye baths and the staining time was important because of the speed with which the staining process occurred. Staining time for Kiton Blue was seven minutes while for Methyl Violet was fifty seconds. Though this technique uses a combination of a basic and an acid dye it is not a double staining technique. The selective skin staining depends on the dyes, especially Methyl Violet being taken up by the skin portion more quickly than by the core. Berry (4) found that sufficient contrast existed between the skin and core to make good photomicrographs without use of any light filter.

CHAPTER III

METHOD OF PROCEDURE

The fabric utilized in this study was a one-hundred per cent spun nylon that is being used in the North Central Regional Project NC-68. The Kansas Agricultural Experiment Station is one of the participating stations in this project. The nylon had a thread count of sixty-six in the warp direction and fifty-seven in the filling direction. The warp yarns were two-ply, while the filling yarns were single.

The fabric was divided into two blocks and each block into three areas, which were designated as A, C and E. From each area nine, five by five inch samples were drawn. The first six specimens were used for the various levels of abrasion, the seventh specimen was for control and the last two served as replacements. In sampling, the numbers one through nine were systematically arranged in each area of the two blocks so that none of the specimens for a given abrasion level contained the same warp or filling yarns (Appendix A).

A coding system was developed to designate the area from which each specimen was selected and the treatment it was to be given. A laundry marking pen was used to code the specimen. The abbreviations for the code were as follows:

Block I = I	Replacements = 8 and 9
Block II = II	Warp = ↑
Area A = A	Filling = →
Area C = C	Unstained = no mark
Area E = E	Stained = S
Abrasion level = 1 - 7	Bobby = B

For example, I-E-6-B↑S was a sample from Block I, area E, abrasion level 6, warp direction and to be stained. The "B" distinguished the specimens from the abrasion samples for NC-68.

The fabric was abraded on the Schiefer abrader with a spring steel abradant. The abrader allows the amount of pressure on a specimen to be varied by interchanging and combining one, two and five pound weights. The abrasive action can be stopped at any desired number of revolutions. A circular specimen, 3.815 inches in diameter, was cut with a die from each five by five inch specimen in preparation for mounting on the abrader. All specimens were mounted with the template, using a one and one-half inch plastic disc as the pressure foot, to insure equal tension on each specimen. When placed on the abrader and locked into position, the one and one-half inch diameter was the only area of the specimen to come into contact with the abradant. Seven levels of abrasion were used including a control (Appendix B). The levels varied from a light pressure, one pound and short cycle, (5,000 revolutions), to a heavy pressure, ten pounds, and a long cycle (20,000 revolutions). The selection of these levels was made on the basis of the results obtained by Wahrenbrock (16) who reported that higher levels of abrasion were needed to observe nylon breakdown comparable to that of cotton. Wahrenbrock's lowest level was one pound and 25 revolutions and her highest was ten pounds and 5,000 revolutions.

Cross-sectional investigations included both warp and filling specimens at each level. Three warp and three filling specimens of the unabraded and abraded nylon at each level were stained, and an equal number of specimens were left unstained.

Kiton Pure Blue V and Methyl Violet 2B Supra I were used for staining. An aqueous solution (1% by weight) of each of the dyes was prepared with distilled water. The two dye baths were placed on thermostatically controlled hot plates and heated to 90°C before insertion of the specimens. The staining time was seven minutes in the Kiton Blue, followed by rinsing in distilled water to remove excess dye, and a fifty minute treatment with the Methyl Violet solution. Again excess dye was removed by washing in distilled water.

Both warp and filling samples for embedding were cut from the unstained and stained specimens. These samples were mounted in cardboard frames one and one-fourth by five-eight inches and labeled at the bottom with a laundry marking pen (Appendix C). Though the bottom of each frame extended beyond the abraded area, the open portion of the frame contained abraded fabric. Each frame was placed in a number eleven gelatin capsule and dried in an oven for thirty mintues at 45°C. A Lucite solution, which forms a plastic substance, was used to embed the fabric for making cross-sections. The solution was prepared by mixing 300 ml. of methacrylate (with inhibitor), 170 ml. of di (n) butyl phthalate, and 2.5 gms. of benzoyl peroxide. The capsules were filled to within one-eighth of an inch of the top with lucite solution, tightly covered with the lids, and placed in an oven at 45°C for forty-eight hours, or until the solution hardened. The capsules were dissolved in warm running water leaving the embedded specimens in the Lucite. A raised portion with vertical sides about one-fourth by one-eighth inch was shaped around the embedded fabric by using an exacto knife. Six slices were cut from each specimen at a 45° angle with a thickness of fourteen microns using an American Optical Company sliding microtome. The cross-sections were mounted on slides in immersion oil and covered with a cover glass.

Microscopic analysis of the unstained and stained nylon cross-sections at each level was done with an American Optical Company Series 4 Microstar trinocular microscope. The cross-sections were studied with ten and forty-three power objectives, ten power eye-pieces and substage illumination. The ten power objective was used to obtain a view of the cross-section of the yarn and interlacing yarn. The forty-three power objective gave a closer view of the individual fibers within the yarn. After observing the six cross-sections on a slide, one representative section was selected to be photographed. Photomicrographs using both objectives were made of the selected unstained and stained cross-sections from the unabraded and abraded levels. A 35 mm. camera was attached to the vertical tube of the trinocular body of the microscope. It was found that Kodacolor X negative color film produced satisfactory photomicrographs. Color film was used so that the normal dark streaks in nylon could be distinguished from the stain. A blue filter was used to obtain a clear picture and cut down on the glare.

Photomicrographs of the specimens were compared to study the effect of abrasion and the relationship between the degree of damage and the amount of abrasion. The unstained and stained cross-sections were compared to study the effect staining had on the fibers and if staining helped show the damage.

CHAPTER IV

FINDINGS

The ten and forty-three power objectives were used in making photomicrographs of the unstained and stained cross-sections. The photomicrographs were compared to study the extent of abrasive damage and the effect of staining.

Ten Power Objective Observations

Examination of the unstained and stained cross-sections of the unabraded fabric revealed that the stain helped to show the fiber structure. The stained warp yarn (Plate I, Fig. 2) showed that the stain differentiated between the skin and core of the nylon fiber.

The plys of the warp yarn were visible in both the unstained and stained cross-sections)Plate I, Figs. 1 and 2) of the unabraded fabric. The warp and filling yarns appeared more compact in the unstained specimen than in the stained specimen. The fibers in the stained specimen were spread out with some extending away from the bundle. The same phenomena prevailed in the photomicrographs taken from the filling of the nylon fabric (Plate II, Figs. 1 and 2).

At abrasion level one (1 pound, 5,000 revolutions) more fibers had begun to spread from the unstained warp yarn and the filling yarn appeared sparse (Plate I, Fig. 3). The fibers in the warp yarn of the stained specimen (Plate I, Fig. 4) appeared fuller than they had in the unabraded specimens. Photomicrographs taken from the filling of the fabric revealed that more fibers pulled away from the warp and filling yarn (Plate II, Figs. 3 and 4) than was evident in the unabraded specimen.

Little change in appearance occurred at level two (3 pounds, 10,000 revolutions). The fibers of the unstained warp yarn (Plate I, Fig. 5) had spread further away from the bundle than they had in the unabraded and level one. The fibers in the filling yarn of the stained cross-section taken from the filling of the nylon fabric appeared more compact than the unabraded and level one.

It was noted at level three (5 pounds, 10,000 revolutions) that a portion of the fibers of the filling yarn in the unstained specimen (Plate I, Fig. 7) had been completely pulled out. This was the first time this type of damage was observed. Fibers continued to extend from the warp yarn. Fewer fibers extended from the filling yarn in the unstained specimen than in the stained (Plate II, Figs. 7 and 8). The stained warp yarn (Plate II, Fig. 8) appeared sparse due to pulled fibers.

More fibers had pulled from the filling yarn at level four (5 pounds, 15,000 revolutions). Fibers extending from the warp yarn were similar to the arrangement at level three, however, more fibers extended from the stained specimen than unstained (Plate III, Figs. 1 and 2). Fibers in one section of the two-ply warp yarn had been completely

EXPLANATION OF PLATE I

Ten Power Objective Photomicrographs of Cross-sections
Taken From the Warp of the Nylon Fabric
Before and After Abrasion
(magnification 25 times)

Fig. 1. Unabraded unstained

Fig. 2. Unabraded stained

Fig. 3. Abrasion level 1 unstained

Fig. 4. Abrasion level 1 stained

Fig. 5. Abrasion level 2 unstained

Fig. 6. Abrasion level 2 stained

Fig. 7. Abrasion level 3 unstained

Fig. 8. Abrasion level 3 stained

PLATE I

Fig. 1

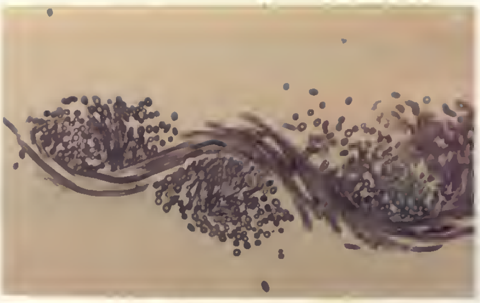


Fig. 2

Fig. 3

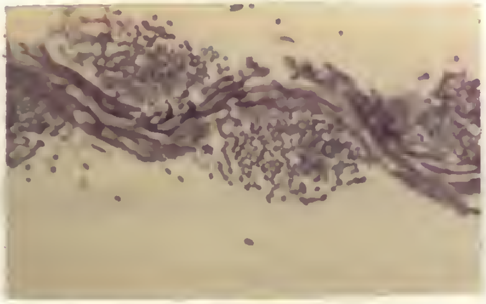


Fig. 4

Fig. 5

Fig. 6

Fig. 7

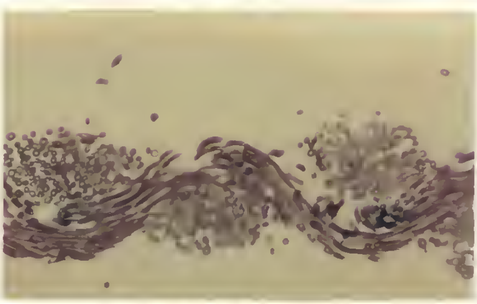


Fig. 8

EXPLANATION OF PLATE II

Ten Power Objective Photomicrographs of Cross-sections
Taken From the Filling of the Nylon Fabric
Before and After Abrasion
(magnification 25 times)

Fig. 1. Unabraded unstained

Fig. 2. Unabraded stained

Fig. 3. Abrasion level 1 unstained

Fig. 4. Abrasion level 1 stained

Fig. 5. Abrasion level 2 unstained

Fig. 6. Abrasion level 2 stained

Fig. 7. Abrasion level 3 unstained

Fig. 8. Abrasion level 3 stained

PLATE II

Fig. 1

Fig. 2

Fig. 3

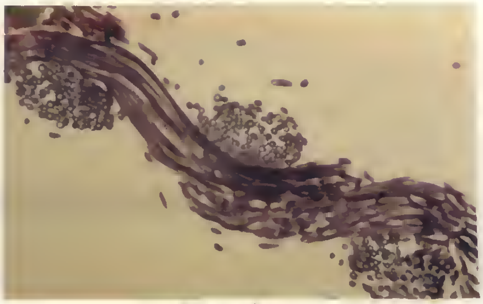


Fig. 4

Fig. 5

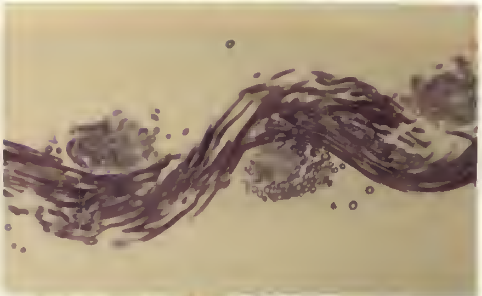


Fig. 6

Fig. 7

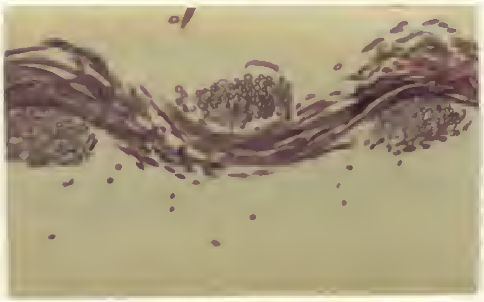


Fig. 8

EXPLANATION OF PLATE III

Ten Power Objective Photomicrographs of Cross-sections Taken From the Warp of the Nylon Fabric After Abrasion

(magnification 25 times)

Fig. 1. Abrasion level 4 unstained

Fig. 2. Abrasion level 4 stained

Fig. 3. Abrasion level 5 unstained

Fig. 4. Abrasion level 5 stained

Fig. 5. Abrasion level 6 unstained

Fig. 6. Abrasion level 6 stained

PLATE III

Fig. 1

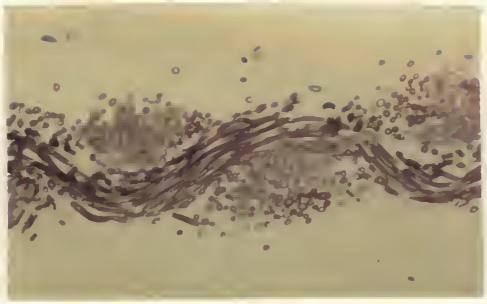


Fig. 2

Fig. 3

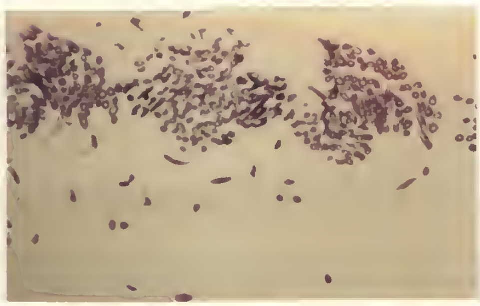


Fig. 4

Fig. 5

Fig. 6

pulled from between two adjacent filling yarns (Plate IV, Fig. 2). This was the first time this type of damage appeared in the warp yarn.

At level five (10 pounds, 15,000 revolutions) critical damage was observed. The fibers of the filling yarn (Plate III, Figs. 3 and 4) had completely worn away, while the warp yarn had fibers extending far from the bundle. The warp yarns (Plate IV, Figs. 3 and 4) of the cross-sections taken from the filling of the nylon fabric were sparse but still visible. The plys were not as obvious as they had been.

The damage observed at the level six (10 pounds, 20,000 revolutions) was similar to that of level five. A few fibers of the stained filling yarn (Plate III, Fig. 6) were still visible.

Forty-three Power Objective Observations

Detailed structures were not obvious in the unstained specimens (Plate V, Fig. 1 and Plate VI, Fig. 1). The stain helped show the skin-core relationship in the warp and filling fibers (Plate V, Fig. 2 and Plate VI, Fig. 2). Delustrants were visible in both the unstained and stained specimens. The fibers in the unabraded specimen were cylindrical in shape with a few appearing oblong. This could have been caused by the angle at which the fibers were cut, because some of the cut ends of the filling fibers (Plate V, Fig. 2) were oblong in shape. In the photomicrographs of the stained specimens some of the edge fibers appeared hazy. This could have been the result of the thickness of the cut fiber.

EXPLANATION OF PLATE IV

Ten Power Objective Photomicrographs of Cross-sections Taken From the Filling of the Nylon Fabric After Abrasion (magnification 25 times)

Fig. 1. Abrasion level 4 unstained

Fig. 2. Abrasion level 4 stained

Fig. 3. Abrasion level 5 unstained

Fig. 4. Abrasion level 5 stained

Fig. 5. Abrasion level 6 unstained

Fig. 6. Abrasion level 6 stained

PLATE IV

Fig. 1

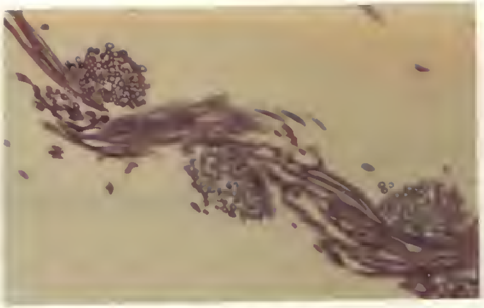


Fig. 2

Fig. 3

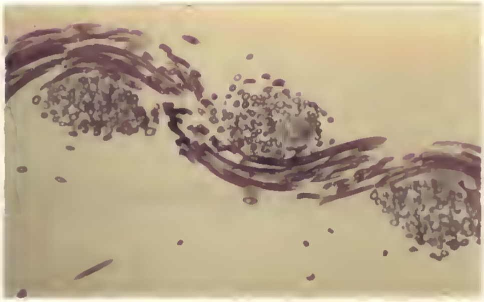


Fig. 4

Fig. 5

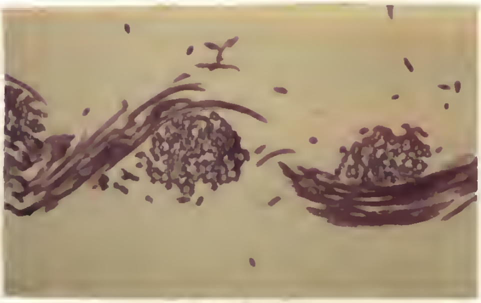


Fig. 6

EXPLANATION OF PLATE V

Forty-three Power Objective Photomicrographs of Cross-sections

Taken From the Warp of the Nylon Fabric

Before and After Abrasion

(magnification 107.5 times)

Fig. 1. Unabraded unstained

Fig. 2. Unabraded stained

Fig. 3. Abrasion level 1 unstained

Fig. 4. Abrasion level 1 stained

Fig. 5. Abrasion level 2 unstained

Fig. 6. Abrasion level 2 stained

Fig. 7. Abrasion level 3 unstained

Fig. 8. Abrasion level 3 stained

PLATE V

Fig. 1

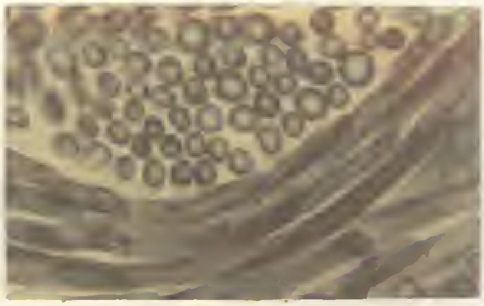


Fig. 2

Fig. 3

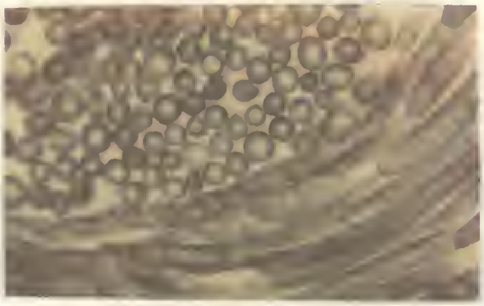


Fig. 4

Fig. 5

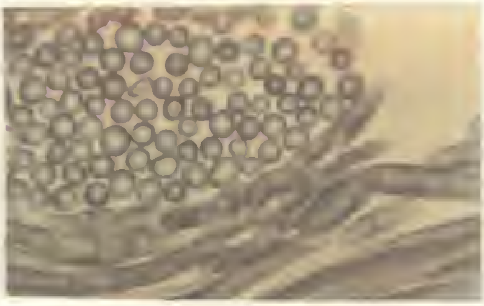


Fig. 6

Fig. 7

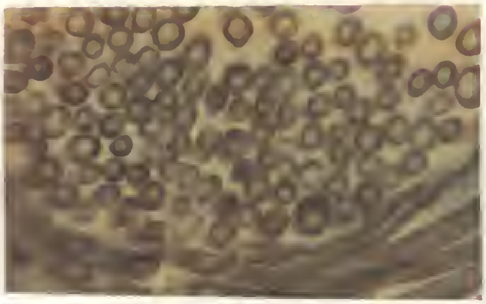


Fig. 8

EXPLANATION OF PLATE VI

Forty-three Power Objective Photomicrographs of Cross-sections

Taken From the Filling of the Nylon Fabric

Before and After Abrasion

(magnification 107.5 times)

Fig. 1. Unabraded unstained

Fig. 2. Unabraded stained

Fig. 3. Abrasion level 1 unstained

Fig. 4. Abrasion level 1 stained

Fig. 5. Abrasion level 2 unstained

Fig. 6. Abrasion level 2 stained

Fig. 7. Abrasion level 3 unstained

Fig. 8. Abrasion level 3 stained

PLATE VI

Fig. 1

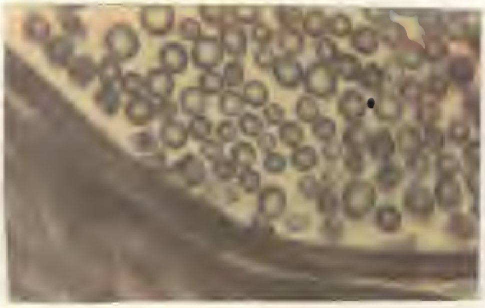


Fig. 2

Fig. 3

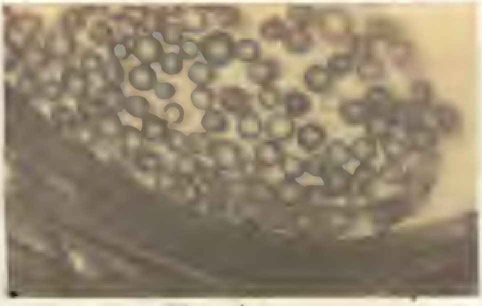


Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

There were few changes at abrasion level one (1 pound, 5,000 revolutions) in warp and filling yarn structure. More space appeared between the fibers of the warp and filling yarns (Plate V, Fig. 3 and Plate VI, Fig. 3).

At abrasion level two (3 pounds, 10,000 revolutions) the fibers of the warp yarn had begun to spread out (Plate V, Fig. 5). The filling yarn (Plate VI, Fig. 5) was still compact. Both plys of the warp yarn were visible in the stained specimen (Plate VI, Fig. 6).

At level three (5 pounds, 10,000 revolutions) the majority of the warp fibers were still circular in shape. In the stained specimen (Plate V, Fig. 8) some pear and oblong shaped fibers were visible. Black specks between the fibers were believed to be debris. No change in the structure of the filling yarn structure from that of level two was observed.

The unstained photomicrograph (Plate VII, Fig. 1) was not clean cut because there were tears in the Lucite. A break was noted in the skin of one of the stained warp fibers (Plate VII, Fig. 2) at level four. This was the first observation of this type of fiber damage.

Photomicrographs of the stained specimen at level five (10 pounds, 15,000 revolutions) revealed extensive damage, especially in the fibers of the warp yarn (Plate VII, Fig. 4). The skin had partially separated from the core of four fibers located at the lower edge of the bundle. The fibers were not circular, but were more diamond or square shaped (Plate VIII, Fig. 4).

EXPLANATION OF PLATE VII

Forty-three Power Objective Photomicrographs of Cross-sections Taken From the Warp of the Nylon Fabric After Abrasion

(magnification 107.5 times)

Fig. 1. Abrasion level 4 unstained

Fig. 2. Abrasion level 4 stained

Fig. 3. Abrasion level 5 unstained

Fig. 4. Abrasion level 3 stained

Fig. 5. Abrasion level 6 unstained

Fig. 6. Abrasion level 6 stained

PLATE VII

Fig. 1

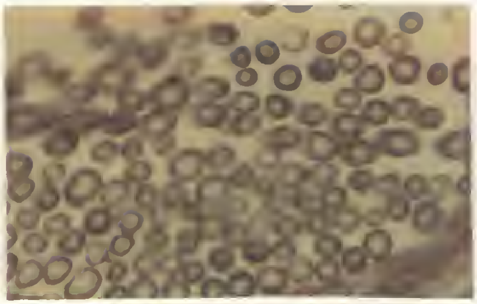


Fig. 2

Fig. 3

Fig. 4

Fig. 5

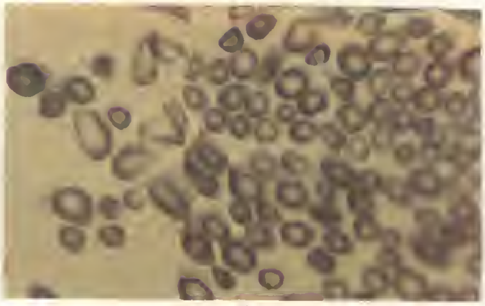


Fig. 6

EXPLANATION OF PLATE VIII

Forty-three Power Objective Photomicrographs of Cross-sections Taken From the Filling of the Nylon Fabric After Abrasion (magnification 107.5 times)

Fig. 1. Abrasion level 4 unstained

Fig. 2. Abrasion level 4 stained

Fig. 3. Abrasion level 5 unstained

Fig. 4. Abrasion level 5 stained

Fig. 5. Abrasion level 6 unstained

Fig. 6. Abrasion level 6 stained

PLATE VIII


Fig. 1


Fig. 2


Fig. 3

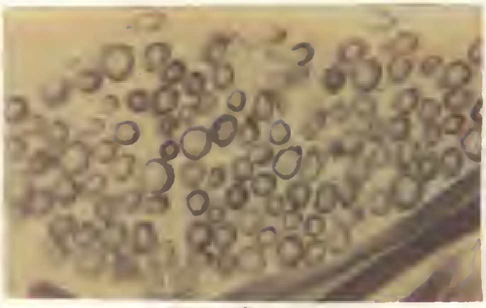


Fig. 4


Fig. 5

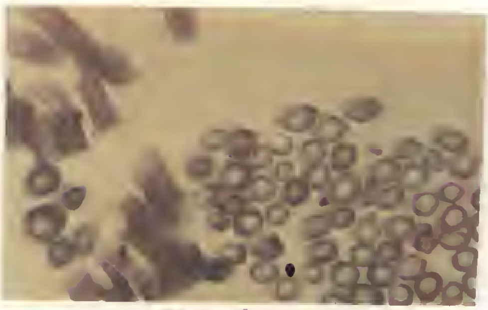


Fig. 6

Damage at level six (10 pounds, 20,000 revolutions) was similar to that for level five. Fibers of the warp yarn continued to extend from the bundle (Plate VII, Fig. 6). A short tear was visible in one oblong shaped fiber located at the left of the warp yarn. A number of the fibers appeared oblong in shape. Short pieces of the filling and warp yarns appeared in the stained specimens (Plate VII, Fig. 6 and Plate VIII, Fig. 6). Photomicrographs of the unstained specimen revealed a few oblong shaped fibers, however, a separation of skin and core could not be identified.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

This study was designed to evaluate the effect of a stain in ascertaining the extent of damage on a nylon fabric abraded for various levels of time and pressure. Stained and unstained cross-sections were prepared from a one hundred per cent spun nylon fabric, that is being used in the North Central Regional Project NC-68. The Kansas Agricultural Experiment Station is one of the participating stations in this project. The fabric was stained with Kiton Pure Blue V, an acid dye, and Methyl Violet 2B Supra I, a basic dye. The Methyl Violet was absorbed by the core of nylon faster than the Kiton Blue. The specimens were embedded in a Lucite solution that hardened into a plastic substance. Six slices, fourteen microns thick, were cut from each specimen at a 45° angle with an American Optical Company sliding microtome.

The cross-sections were mounted on slides in an oil immersion and covered with a cover glass. If a small amount of oil was spread on the slide and the specimen placed on top of it, and then a small amount of oil placed on top of the specimen, the formation of bubbles under the cover glass was kept at a minimum.

The ten and forty-three power objectives, ten power eye pieces and substage illumination were used in studying the cross-sections. A 35 mm camera mounted on the trinocular body of the microscope was used to make photomicrographs. One representative cross-section per slide was selected on the basis that it was typical of the yarn and fiber structure, or exhibited an unusual yarn and fiber structure. It was found that blue filter in a darkened room yielded good pictures.

The stains used, Kiton Pure Blue V and Methyl Violet 2B Supra I, were selected on the basis that they differentiated the skin and the core of nylon fibers that were evident in the photomicrographs. The skin stained a dark blue, while the core was a lighter blue. By using color photomicrographs it was possible to distinguish the normal dark streaks in nylon from the stain. Also, the presence of debris could be distinguished from yarn damage. Yarn damage was not easily identified in the unstained specimen.

Photomicrographs of the unabraded specimen revealed that warp and filling yarns of the unstained specimens were compact while the stained specimens had fibers extending away from the yarns. Extension of fibers from warp and filling yarns continued in the stained specimens at successive levels of abrasion, and first appeared in the unstained specimens at level one. Fibers in the unabraded specimens were cylindrical in shape with a few appearing oblong; this was found to be due to the angle at which the fibers were cut. At level three (5 pounds, 10,000 revolutions) a portion of the fibers in the filling yarn in the unstained specimen had completely worn away. This was the initial appearance of this type of damage. It was first observed in the warp yarn at level four (5 pounds, 15,000 revolutions). The majority of the fibers were still circular in shape with some few appearing pear or oblong. A break in the skin of one of the fibers in the stained warp yarn was first observed at level four. Drastic changes in yarn and fiber structure were observed at level five (10 pounds, 15,000 revolutions). The fibers of the filling yarn had completely worn away. The fibers in the warp yarn were sparse, but still visible. Separation of skin from core was evident in a number of the stained fibers. A number of the fibers appeared diamond or square shaped. This type of damage could not be identified in the unstained specimen. The highest level of abrasion, level six (10 pounds, 20,000 revolutions), exhibited damage similar to that of level five.

This study revealed that the most critical abrasive damage on nylon yarn and fiber structure first occurred at level five (10 pounds, 15,000 revolutions). Further study is needed to see if this would hold true for larger samples. Also, there are a number of other stains that could be tested. It would be interesting to study abrasion damage caused by other methods, such as actual wear or machine laundering.

REFERENCES CITED

1. American Society for Testing Material, Committee D-13. ASTM Standards on Textile Materials, American Society for Testing Materials, Philadelphia, 1964.

2. Backer, Stanley. "The Relationship Between the Structural Geometry of a Textile Fabric and Its Physical Properties, Part II: The Mechanics of Fabric Abrasion," Textile Research Journal, 21:453, 1951.

3. Backer, Stanley and S. J. Tanenhaus. "The Mechanics of Abrasion," Textile Research Journal, 21:635, 1951.

4. Berry, W. Rhett. "A New Staining Technique for Study of Skin and Core of Nylon Yarns," Textile Research Journal, 31:810-812, 1961.

5. Cannepin, A. and J. Rayon. "Effects of Iodine on Polyamides," Natural and Synthetic Fibers, pp. 519-27, 1963.

6. Clegg, Gladys G. "A Microscopical Examination of Worn Textile Articles," Journal of The Textile Institute, 40:T449-480, 1949.

7. Haven, George B. Mechanical Fabrics. John Wiley and Sons Inc., New York, pp. 298-304, 1932.

8. Kaswell, Ernest R. Textile Fibers, Yarns and Fabrics. Reinhold Publishing Corporation, New York, pp. 298-302, 1953.

9. ______________ Wellington-Sears Handbook of Industrial Textiles. Wellington Sear Co., New York, 1963.

10. Kato, Koichi. "Interpretation of Staining Results Obtained by the Procion Black HGS Procedure," Textile Research Journal, 30:540-42, 1960.

11. __________. "Skin and Core Staining of Nylon 6 Yarns," Textile Research Journal, 32:695-97, 1962.

12. __________. "Differentiation Between the Skin-Core Structure of Stretched and Unstretched Polyamide and Polyester Fibers," Journal of the Society of Dyers and Colourists, 81:343, 1965.

13. Lawrie, L. G. Textile Microscopy. Ernest Benn Limited, London, p. 105, 1928.

14. Skinkle, John H. Textile Testing. Chemical Publishing Co., New York, pp. 98-103, 1940.

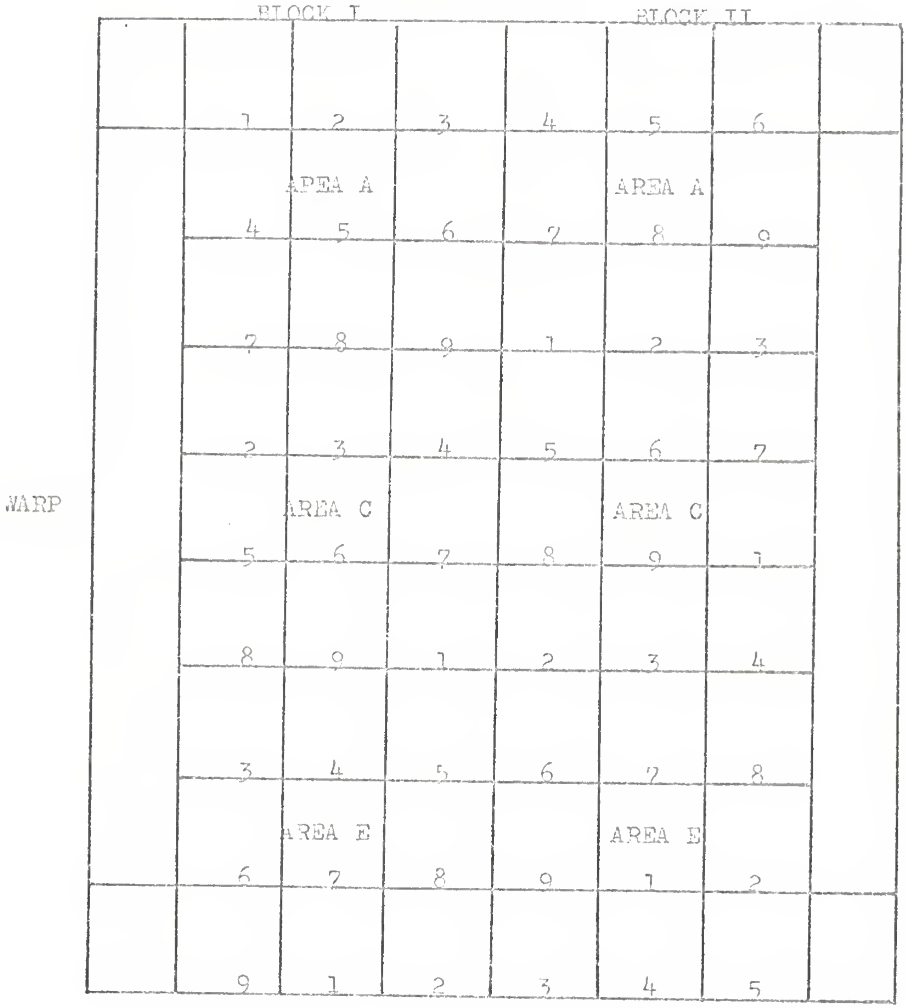
15. Susich, George. "Abrasion Damage of Textile Fibers," Textile Research Journal, 24:210-215, 1954.

16. Wahrenbrock, Mary A. "Photomicrographs of Unstained and Stained Cross Sections of Selected Cotton and Nylon Fabric Before and After Abrasion." Unpublished Master's Thesis, Kansas State University, 1966.

APPENDICES

APPENDIX A

SAMPLING PLAN



FILLING

Dimensions of Fabric: 38 inches wide x 1¼ yards long.

Scale: 1/8 inch = 1 inch

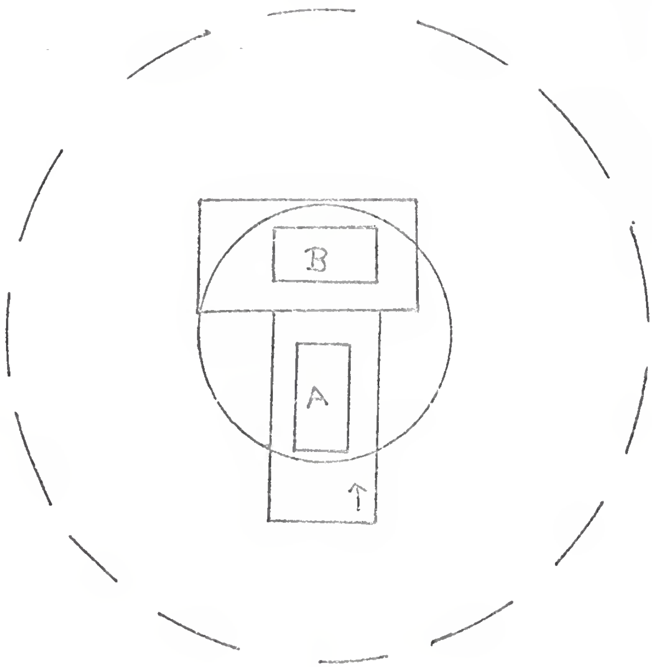
APPENDIX B

ABRASION LEVELS FOR NYLON

Abrasion level	Weight in pounds	Number of revolutions
1	1	5,000
2	3	10,000
3	5	10,000
4	5	15,000
5	10	15,000
6	10	20,000
7	0	0

APPENDIX C

DIAGRAM FOR CUTTING SPECIMENS TO BE EMBEDDED



○ .... One and one-half inch abraded area

▯ .... Cardboard frames

↑ .... Warp direction

A .... Warp specimen

B .... Filling specimen

USE OF COLOR PHOTOMICROGRAPHS TO COMPARE UNSTAINED AND STAINED CROSS-SECTIONS OF A NYLON FABRIC BEFORE AND AFTER ABRASION

by

BOBBY JEAN EDMUNDSON

B. S., Texas Southern University, 1966

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

The purpose of this study was to compare by use of photomicrographs of unstained and stained cross-sections, the extent of damage on a nylon fabric as influenced by the amount of abrasion. It was designed to observe any differences between the unstained and stained cross-sections.

The fabric used in this study was a one-hundred per cent spun nylon. The fabric was abraded on the Schiefer abrader at varying levels of intensity. The nylon was stained with Kiton Pure Blue V, an acid dye, and Methyl Violet 2B Supra I, a basic dye. The samples were embedded in a Lucite solution. The cross-sections were mounted in an oil immersion on slides. The ten and forty-three power objectives, ten power eyepieces and substage illumination were used to study the cross-sections from each of the abrasion levels. One representative cross-section per slide was photographed using Kodacolor negative film.

The Kiton Pure Blue V and Methyl Violet 2B Supra I stained the nylon fibers so that the skin and core was evident. The skin stained a dark blue, while the core appeared a light blue. It was possible to distinguish the type of damage that had occurred by the absorption of the stain. Detailed yarn and fiber structure were not as obvious in the unstained specimens.

The initial change in yarn and fiber structure after abrasion was a spreading out of fibers from the yarns. At abrasion levels three and four portions of the fibers of the filling and warp yarns had completely worn away. Fiber shapes that were initially circular became more pear, diamond or square shaped. The most critical abrasive damage on nylon yarn and fiber structure occurred at level five (10 pounds and 5,000 revolutions). Separation of skin from core appeared in a number of the stained specimen. The highest level of abrasion, 10 pounds pressure and 20,000 revolutions, exhibited damage similar to that of level five. Further study is needed to see if this would consistently hold true for larger samples.