PHOTOMICROGRAPHS OF UNSTAINED AND STAINED CROSS SECTIONS OF SELECTED COTTON AND NYLON FABRIC BEFORE AND AFTER ABRASION

by

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CHAPTER I

INTRODUCTION

Both the consumer and the manufacturer are interested in the wearing qualities of fabrics. Abrasion, one aspect of wear, has been a means of evaluating the acceptability of a fabric's wearing qualities in the laboratory. Studies have been made in an attempt to correlate the results of abrasion with the actual wear life of the fabric. Kaswell (16) stated that it was unnecessary for laboratory abrasion to actually reproduce service wear. If the wear produced by abrasion could be correlated with service wear and the results interpreted correctly, then the serviceability of the fabric could be predicted.

This study was designed to examine the fabric breakdown resulting from abrasion and not to predict the serviceability of the fabric. The purpose was to develop techniques for the study of cross sections of unstained and stained cotton and nylon fabrics through the use of photomicrographs.

The terms abrasion and wear have been used interchangeably, however, more recently a distinction has been made. Skinkle (25) defined abrasion as the friction of cloth on cloth, the friction of cloth on external objects, or the friction of the fibers on dust or grit in the fabric. Abrasion is only one factor of wear, but in most cases, it is the most important factor. Skinkle went on to define wear as the "amount of deterioration of a fabric due to breaking, cutting, or removal of the fibers."

Many of the previous studies have been empirical evaluations of abrasion resistance and have done little to explain the physical properties of the fibers which contribute to their resistance to abrasion. In an effort to explain the physical properties, a microscopic analysis has been used to study the damage to the fiber and fabric. Most of the photomicrographs have been of longitudinal sections with few studies reporting the effects of abrasion by use of cross sections. Staining the fabric has been done with both the longitudinal and cross sections to aid in the study of abrasion damage. The most widely accepted staining method for cotton is the Congo red test, as it shows the damage more clearly. Little work has been reported in the staining of nylon, but by use of stains which differentiate between the skin and core of the fibers, such as Lansayn Grey B L, the nylon skin could be studied.

The objectives of this study were: to observe any differences between the unstained and stained cross sections; to study, by photomicrographs of cross sections, the kind and degree of damage due to abrasion after varying lengths of time and pressure.

CHAPTER II

REVIEW OF LITERATURE

Abrasion has been determined as the commonly accepted way of ascertaining the service wear of a fabric. Mann (19) and Tait (29) cited abrasion as the most important single factor in wear. Zook (32) stated that for this reason, many textile technologists have simplified the problem by studying the resistance of fabrics to abrasion rather than to wear in general. As a result of the interest in trying to predict the service wear of a fabric or garment, many abrasion instruments have been developed. Some of the instruments and test methods designed to test for abrasion have been described by the American Society for Testing and Materials, Committee D-13 (1). Zook (32) reported that there does not appear to be any correlation between the results of the instruments therefore, there was a need for the standardization of abrasion test procedures. It was found that different results were obtained from the same abrasion instrument, when operated by various technicians. Because of this, each condition of wear became a separate problem and an analysis was necessary for each service condition to which the fabric was subjected.

Skinkle (25) explained that the service life of a garment depended on such personal factors as size, weight, and occupation of the wearer of a fabric, on the climate around him and on the laundry methods used together with the infinite variety of mechanical details involved in the motion of a fabric while being worn. Since no one test could resemble all of these elements, he cited six main factors affecting abrasion. They were: (1) character of motion, (2) nature of the abradant, (3) pressure of abradant on sample, (4) tension on sample, (5) removal of lint, (6) determination of end point or amount of abrasion. Stoll (26) suggested that the mechanical factors involved in normal wear could be assumed to be approximately thirty per cent plane abrasion, twenty per cent edge and projection abrasion, twenty per cent flexing and folding, twenty per cent tear, and ten per cent other mechanical action. Gagliardi and Nuessle (12) in a discussion of the life of a garment in relation to laboratory abrasion, stated:

> In the actual life of a garment in practical use, a fabric is subjected to relatively low abrasive forces, i.e., low stresses and strains, the cycles of which are, on the average, far apart, so that there is always time available for stress and strain relaxation. In spite of the precision and accuracy of laboratory abrasion machines, the general criticism that can be made against them is the rapid rate at which a specimen is destroyed by application of repeated stresses more severe than those commonly encountered in normal wearing of garments.

Gagliardi and Nuessle (12), Lomax (18), and Schiefer and Krashy (24) stated that the best way to evaluate the service wear of a fabric was to compare one fabric with another and rank them in the order of merit. In the work done by Backer (2), Kaswell (15), and Susich (27), all ranked nylon the highest in abrasion resistance. The position of the cotton fabric was found by Backer (2) and Susich (27) to be dependent upon whether the fabric was tested wet or dry.

Fabric Breakdown

Morton (22) stated that abrasion produced a fabric unsatisfactory in one of two ways:

> either rendering the fabric so thin, or so shiny, or so hairy, that it becomes unbearably unsightly, or it produces a progressive deterioration in strength until a level is reached at which the fabric is no longer able to withstand the stress of usuage without rupture.

Chemical deterioration, fiber abrasion, and transverse cracking of the fibers were found to be factors causing the general breakdown of the fabric by Clegg (8).

The structural compactness of the surface yarns and fabric and the direction of the abrasion as it related to the surface yarns have been found to affect the occurrence of the fabric breakdown. Backer and Tamenbaus (3) reported that abrasion directed along the yarns resulted in a great many sheared fibers, yet when abrasion was directed across the yarns, the fibers tended to snag. Clegg (8) also found that fibers held firmly by the fabric structure suffered a fairly intense abrasive action. The fibers on the surface which were held lightly suffered a gentle abrasive action.

The wearing quality of a fabric was found by Cranshaw et al. (9) to be very sensitive to the amount of yarn exposed on the surface. Only a little of the yarn surface needed to be removed before the bending forces holding the yarn together were set free. Zurek and Szemik (33) reported that in a plain woven cotton fabric, the loss in the area of the crown was considerable, although the change in the yarn mass as a whole was not so great. Damage to the fiber at the top of the crown varied with very gentle abrasion affecting the cuticle only, cross markings, transverse cracks, fibrillation, and bruising. Fibrillation, as defined by Clegg (8), involved, "the longitudinal disintegration of the fiber into a series of elements revealing the fibrillar structure." When the outermost portion of the primary wall of the cotton fiber was damaged, it had a bruised appearance which was attributed to a loosening, tearing, and partial or complete removal of the cuticle. Transverse cracking was cracks which occurred at right angles to the fiber axis.

Kaswell (15) reported that in fabric abrasion, the frictional forces were related to the damage which occurred through fiber tensile and bending fatigue and slippage. Friction between fibers also acted to control fiber slippage and thus reduced abrasive damage.

Frictional wear, cutting, and plucking were possible mechanisms contributing to mechanical breakdown of textiles during abrasion according to Backer and Tamenhaus (3) and Peirce (23). When deGrury et al. (10) used flat abrasion, they observed fiber surfaces which were snagged not only at the fiber ends where the break occurred, but throughout the length of the fiber. Thomson and Trail (30) reported that cracks, due to the breakdown by flexing, are more typical than flattening as the type of break that would occur in cotton.

DuBolt (11) presented the theory that the friction of a cotton fiber was dependent on the shape of its cross section. Swelling the cotton fiber decreased the coefficient of friction considerably for the swollen cross section of the fiber was more circular than before. This diminished the number of points of contact between the fibers.

According to Hamburger (13), "Resistance of a specimen to destruction resulting from stress application may be described as the absorption of energy imparted to the specimen without the occurrence of failure." Backer (2), Hamburger (13), and Peirce (23) theorized that fabric structures could absorb stresses by one yarn slipping across another, by yarn crimp being removed in the direction of stress, or by yarn extension. McNally and McCord (20) and Clegg (8) also discussed the fabric's need to absorb the punishment of repeated application of stress. Bending, tensioning, compressioning, and twisting were all forms of repeated stress application.

McNally and McCord (20) found elongation and elasticity to be more important than strength in a fabric's ability to absorb energy. They also reported the ability of nylon to resist abrasion was a combination of high strength, high elongation, and excellent elasticity while the low elongation of cotton fibers might account for some of its abrasion resistance.

During the wear life of a fabric, the manner by which the strength of a fabric was reduced was not the same for all fabrics as it was dependent on the nature of the warp and filling interlacement according to Cranshaw et al. (9). The yarns that had a high twist or a fabric with a tight weave were found to have a good wearing quality. Both Backer (2) and Morton (22) agreed that it was better to have a tight weave and a lower yarn twist. With the lower twist, the yarn could more readily flatten and present a larger surface of fibers to share in the resistance to the abrasive action.

Cranshaw et al. (9) and Morton (22) found it desirable to have a balance between the crimp in the warp and filling yarns. Then both yarns showed equally predominant on the surface of the cloth and could equally contribute to the total resistance of abrasion. Yarns that were highly crimped suffered greater abrasion damage in the study by McNally and McCord (20). Backer (2) observed that when yarns in one direction had a high crimp and the yarns in the other direction had a lower crimp, the lower crimp yarns were protected.

The resistance to abrasion of spun yarns, as reported by Susich (27) was always higher than that of the yarns made of multifilaments. The individual staple fibers protruded from the yarn surface and could be easily pulled out or cut through, causing a loosening and untwisting of the yarns.

Abrasive damage was dependent upon the finishes given a fabric or yarn, according to deGrury et al. (10). These finishes might be protective coatings, binding materials, crease proofing additives, and softeners. Damage was also dependent on the mechanical properties of the fiber, such as stiffness, elasticity, and toughness.

Measure Of Damage

The measurement of abrasive damage should be proportional to the work done to the specimen. Ball (4) and Skinkle (25) considered there to be eight measureable changes: (1) tensile strength, (2) thickness, (3) weight, (4) surface luster, (5) air permeability, (6) color, (7) character of abraded material, and (8) appearance of surface. Hamburger (13) stated that only the first four indicated possibilities of dependable quantitative results for the entire structure. He went on to say that strength is the most desirable criterion for measuring the extent of abrasion damage and not durability from the standpoint of strength. The change in thickness might be due to the increase in surface distortion as the fibers were cut, broken, and teased out of the yarn to form a rough, fuzzy surface reported Ball (4) and Hamburger (13). Ball (4) found an increase in weight in the first stages of abrasion, and with continued abrasion action, a decrease.

Through photomicrographs and microscopic examination of the fabric and longitudinal analysis of the fibers the researcher has been able to observe any damage that occurred and the type of damage that occurred when a fabric was abraded. An analysis of damaged cotton fabrics, done by Clegg (8), showed examples of fibrillation, transverse cracking, and compression. Through the use of the electron microscope, deGruy et al. (10) investigated the effects of abrasion and found bruising of the fibers, mashing, fragmentation, and fibrillation. In the study made by Wagner (31), abrasive damage was observed in the forms of fragmentation, fibrillation, transparency, cuts, chewed appearance, mashing, transverse folds, and cracks with fragmentation noticed more often than fibrillation.

Damaged fabrics have been treated with various chemicals or stains to aid in the study of the injured fiber. Some of the first microscopic work done in the study of damaged cotton hairs was by using the swelling test of Fleming and Taysen as a means of estimating the damage caused by micro-organisms. The undamaged cotton fibers showed bead-like swellings while the damaged cotton fibers were swollen uniformly and did not show the beads. It was then possible to count the number of damaged and undamaged fibers, and the per cent of damaged fibers could be calculated, according to Bright (6) and Skinkle (25). A modification of Simon's stain was used by deGrury et al. (10), on abraded cotton fabrics which rendered the damaged areas orange and the undamaged areas blue.

In 1926, Bright (6) reported Clegg to have found the use of the Congo red test as a means of studying damaged cotton. Clegg (7) gave further developments and applications of the test in 1940. When the Congo red test was used, the cotton fibers were not stained uniformly, but where the cuticle had been cut, loosened, or totally detached, the cellulose became deeply stained and gave the appearance of a bruise. This resulted in the cuticle staining only a faint pink while the exposed cellulose became a bright red which gave a means for detecting the damage to the cuticle.

Clegg (7) explained the reason for using sodium hydroxide in the Congo red test as a means of promoting a controlled amount of swelling. The first immersion of the fabric in the sodium hydroxide caused swelling which brought the fiber back almost to its original size before it collapsed. The collapse caused a shrinkage in the perimeter of the cross section and the thickness of the cell walls. Later in the test, the specimen was immersed in an eighteen per cent solution of sodium hydroxide to produce a final swelling which accentuated the color contrast.

Heyen (14) discussed cross sections of undamaged fibers stained with Congo red. He stated that:

> Fibers with normal cell wall thickness obtain cylindrical cross sections and become fairly red; fibers with thin walls obtain convolutions and stain faint pink; fibers show irregular stained patchs often as horizontal cracks or irregular spiral staining.

The Zinc-Chloride-Iodine stain, also known as Herzberg's stain, has been used in staining nylon, with the most recent publication of fiber identification methods by Morrison (21) giving this method. The cross section of the yarn was first swollen by zinc-chloride and then iodine was used to stain the skin. Both the skin and core were swollen with the zinc-chloride, which eventually disintegrates the nylon sections.

Berry (5) developed a method for staining nylon which differentiated between the skin and the core, but did not cause swelling or otherwise damage the yarn cross section. The dyes used were Kiton Pure Blue V, an acid dye, and Methyl Violet 2 B Supra I, a basic dye. The temperature and length of time the fiber remained in the stain were very important. The time was regulated in seconds and the temperature had to be kept constant at $70^{\circ}C$ for nylon 6 or the skin-core relationship would undergo considerable change.

One of the most recent methods of staining nylon was given by Kato (17). He stained the nylon fibers by use of Lansayn Grey B L, a type of neutral metal complex acid dye. This method was also developed to differentiate between the skin and the core of the fiber. Because the time and temperature were not crucial points in this method, there was less possibility of error.

There have been extensive investigations to determine the effects of abrasion on the physical properties of a fabric. A longitudinal examination was included in a number of the studies, but little work was found concerning cross sectional studies.

CHAPTER III

METHOD OF PROCEDURE

The cotton and nylon fabrics which were used by Wagner (31), were also utilized in this study. Cotton was chosen as one of the fabrics, because of its wide use today and its moderate resistance to abrasion. Nylon, recognized for its high resistance to abrasion, was used for a comparison. Both the cotton and the nylon were white fabrics, constructed of staple fibers, with similar weights, and without any applied finishes. The cotton fabric was a Sanforized bleached muslin and the nylon fabric was a spun nylon. Wagner (31) reported the weight of the cotton fabric as 3.2 ounces per square yard and the nylon fabric as 3.8 ounces per square yard. The cotton fabric appeared to be more closely woven than did the nylon fabric for the thread count of the cotton fabric was eighty-eight yarns per inch in the warp direction and eighty yarns per inch in the filling direction while in the nylon fabric there were sixty-seven yarns per inch in the warp direction and fifty-four yarns per inch in the filling direction. The structure of the yarns on the nylon fabric may account for this difference as the warp yarns were two-ply and the filling yarns were single while the cotton yarns were singles in both the warp and filling directions.

The cross sections were made from the unabraded and abraded specimens which had been measured for wrinkle recovery by Wagner (31). The fabrics had been abraded on the Schiefer Abrasion Testing Machine with a spring steel abradant using varying amounts of pressure and number of revolutions. The levels of abrasion established by Wagner, are in the Appendix A, Table I, varied from a light pressure, one pound, and short cycle (twenty-five revolutions) to a heavy pressure, ten pounds, and long cycle (five thousand revolutions). The cycles and pressures were designed to show varying degrees of damage from only slight to extensive damage, but all stopped short of total destruction, or rupture, as the breakdown of the fiber and fabric are not observable at this point.

The cross sectional investigation included both warp and filling specimens from the cotton and nylon fabrics at each level of abrasion. One warp and one filling specimen of the unabraded and abraded cotton and nylon fabrics at each level were left unstained and similar specimens were stained. After experimentation, it was determined best to stain the fabrics before they were imbedded.

Before staining, "Time Tape" was placed across the end of the specimens. With the use of a laundry marking pen, the code was written on the tape so it would be legible after staining. The following abbreviations were used in establishing a code for identifying each specimen:

Cotton - C
Nylon - N
Unstained - no mark
Stained - S
Warp - →
Filling - ↑
Unabraded specimen - 0
Abrasion levels - 1 through 12

"C S$\rightarrow$3" is an example of how the code would appear on a cotton fabric, stained, warp direction, and abrasion level 3. This code was used in denoting the specimens throughout the study.

The Congo red test was used to stain the cotton. The wet cotton specimens were immersed in an eleven per cent solution of sodium hydroxide, shaken, and allowed to stand for five minutes. The specimens were washed rapidly in distilled water, next placed in a saturated (two per cent) solution of Congo red and shaken at intervals for six minutes. When the specimens were withdrawn, they were rinsed in distilled water until no more dye came off, placed in an eighteen per cent solution of sodium hydroxide, removed, and then allowed to dry.

The nylon was stained with Lansayn Grey B L, in an aqueous solution. The specimens were placed in a suitable amount of the dye solution and gently heated at approximately 45°C for five minutes. After this the fabric was washed in distilled water to remove the excess dye, removed, and allowed to dry.

The specimens for imbedding were stapled to one and one-fourth by five-eighth inch cardboard frames and labeled at the bottom with a laundry marking pen. Each specimen was placed in a number eleven gelatin capsule, and dried in an oven for thirty minutes at 45°C. A Lucite solution, which forms a plastic substance, was used for imbedding the fabrics. The solution was prepared by mixing together 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 the oven at 45°C for twenty-four to forty-eight hours, until the solution hardened. The capsules were next dissolved in warm running water and dried. A raised portion with vertical sides about one-fourth by one-eighth inch was shaped around the imbedded 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 placed on a slide, a few drops of immersion oil were applied, and a cover glass was placed over them.

Although Wagner (31) examined the unabraded specimen and twelve levels of abrasion, the cross sectional microscopic analysis included only the unabraded and six levels of cotton and the unabraded and seven levels of nylon. Because the cotton fabric did not have as wide a range in the pressures applied as did the nylon fabric, more levels of nylon were studied in the cross sectional analysis. The lowest and the highest levels of abrasion under each variation in pressure (one, three, five, and ten pounds) were selected to be observed in detail. The levels of abrasion that were examined were the unabraded and levels 1, 6, 7, 10, 11, and 12 for the cotton fabric and the unabraded and levels 1, 3, 4, 7, 8, 11, and 12 for the nylon fabric (Appendix A, Table I). The microscopic analysis of the unstained and the stained cotton and nylon cross sections was done with an American Optical Company Series 4 Microstar trinocular microscope. The cross sections were studied with the ten and the forty-three power objectives, the ten power eyepieces, 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, two representative sections were selected to be photographed. Photomicrographs using both objectives were made of two of the 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 Kodak Plus X Pan Black and White Panchromatic film gave more satisfactory photomicrographs. A clearer picture was obtained and the glare cut down by using a blue filter.

By use of photomicrographs the specimens were compared to determine the effects of abrasion and the relationship between the degree of damage and the amount of abrasion. The unstained and stained cross sections were compared to determine the effects staining had on the fibers and if staining did help to show the damage more readily.

To aid in the comparison and study, a photomicrograph was taken of a millimeter scale. This could then be used in measuring the size of the yarns and the fibers and a comparison be made between levels and between the unstained and the stained.

CHAPTER IV

FINDINGS

The ten and the forty-three power objectives were used in making photomicrographs of the unstained and stained cotton and nylon fabrics. They were studied to determine evidence of abrasive damage and the effects of staining.

The area viewed through the eyepieces of the microscope was larger than the lens of the camera. This resulted in some of the photomicrographs having the cross section of the yarn off center. When making the plates, it was necessary to cut down the size of the photomicrographs. Because of this some items discussed, may not be observable in the printed photomicrograph.

The Lucite solution formed small bubbles on and next to the stained cotton fabric, but the bubbles did not appear on the unstained cotton and the unstained and stained nylon fabrics. Bubbles and streaks resulting from the oil immersion mounting appeared in some of the photomicrographs. Tears in the Lucite were noticeable by clear spaces in the yarn area.

Cotton Cross Sections

<u>Ten Power Objective Observations</u>

There was a difference in the size of the unstained and the stained cotton fibers with the stained fibers being the larger. The stain did not increase the fibers a consistent amount for the size of the fibers varied from 0.01 mm. to 0.06 mm. The measurement of the warp and filling yarns of the unstained and stained cross sections ranged from 0.01 mm. to 0.07 mm. with the average of 0.03 mm. The measurement of the interlacing fiber and yarn showed a greater difference for the range was 0.01 mm. to 0.12 mm. with an average of 0.08 mm. (Appendix B, Table II).

Both the unstained and stained cotton fibers had dark streaks. This made it difficult to determine whether the dark coloration was the normal streak or stain absorbed in the damaged area. The staining did not permit observations that showed how the damage occurred--break in the cell wall, partial removal of the cell wall, or complete removal of the cell wall.

There were many loose fibers in the unabraded warp and filling cross sections. In a surface evaluation, the loose fibers extending from the surface of the fabric were identified as the nap. The unstained warp yarns appeared more compact than the stained (Plate I, Figs. 1 and 2) while, the unstained filling yarns appeared less compact than the stained (Plate II, Figs. 1 and 2). The compactness of the fibers might be one explanation for the difference in the yarn diameters observed in longitudinal studies. In the stained warp yarn, places were observed where the fibers had separated and thus left a hole.

The unstained warp yarn at level 1 (1 pound, 25 revolutions) was found larger than the unabraded yarn; however the stained yarn and interlacing fibers were smaller than the unabraded (Plate I, Figs. 3

and 4). In the filling cross section, both the unstained and the stained yarns (Plate II, Figs. 3 and 4) were narrower than the unabraded when measured with the millimeter scale. The warp yarn appeared round and the filling yarn oval. In both the stained warp and filling yarns, there was an increase in the dark spots on the fibers over what had been present in the unabraded.

At level 6 (1 pound, 100 revolutions) the warp yarn still remained round, but the filling yarn was more flattened. The unstained warp yarn (Plate I, Fig. 5) showed a number of fibers beginning to pull away. The unstained filling yarn (Plate II, Fig. 5) had more loose fibers than level 1. It was observed in both the stained warp (Plate I, Fig. 6) and filling (Plate II, Fig. 6) that the whole yarn structure had pulled away from the interlacing yarn. The stained warp cross section showed fibers with an extensive separation into the yarn. In the stained filling cross section the warp interlacing fiber appeared to spread although in the warp cross section, it did not. There were a number of dark fibers both in the yarn and the loose fibers.

A difference in the size of the yarns was apparent in the unstained warp cross section at level 7 (Plate I, Fig. 7). This might have been a yarn with a smaller diameter originally or it might be the result of fibers being removed by increased abrasion. There were fewer loose fibers than at level 6, but there was an increase in the number of fibers being pulled from the yarns. An increased amount of damage was observed in both the stained warp (Plate I, Fig. 8) and

EXPLANATION OF PLATE I

Photomicrographs of Cross Sections Taken From the Warp of the Cotton 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 6 unstained

Fig. 6. Abrasion level 6 stained

Fig. 7. Abrasion level 7 unstained

Fig. 8. Abrasion level 7 stained

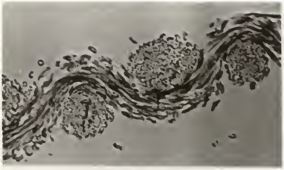
Fig. 1


Fig. 2


Fig. 3

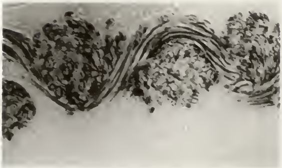
Fig. 4

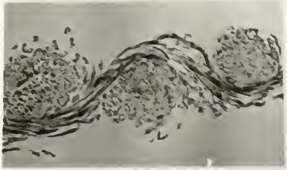
Fig. 5


Fig. 6

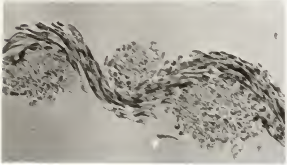
Fig. 7

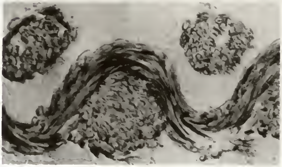
Fig. 8

PLATE I

EXPLANATION OF PLATE II

Photomicrographs of Cross Sections Taken From the Filling of the Cotton 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 6 unstained

Fig. 6. Abrasion level 6 stained

Fig. 7. Abrasion level 7 unstained

Fig. 8. Abrasion level 7 stained

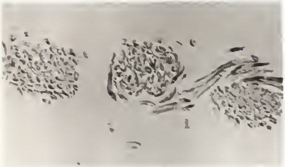

Fig. 1

Fig. 2

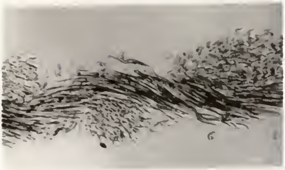

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

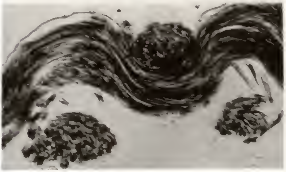

Fig. 8

PLATE II

filling yarns (Plate II, Fig. 8) by the increased dark coloration of the fibers and more stained yarns pulling from the interlacing yarn. It was also noted that some fibers were missing from the center of one of the stained warp yarn. The increased pressure (3 pounds, 100 revolutions) might have caused the stained filling yarns to have a rolled appearance.

Very few loose fibers were observed at level 10, but evidence was shown of fibers being pulled from the yarn both individually and by clusters. Longitudinal fibers that had been pulled from the yarn appeared in the unstained filling cross section (Plate IV, Fig. 1). The filling cross section showed the filling yarn to be flatter and the interlacing warp yarn to be spread more than at level 7 (Plate IV, Figs. 1 and 2). However, the warp cross section showed the warp yarns (Plate III, Figs. 1 and 2) to be smaller. In one of the stained warp yarns, a hole appeared which might have been caused by a loss of fibers since the yarn was also smaller.

Fibers being pulled from the yarn continued to be visible at level 11 (5 pounds, 100 revolutions). The unstained filling fibers appeared looser while the stained fibers appeared more compact (Plate IV, Figs. 3 and 4). Extensive damage was shown in the stained warp yarn (Plate III, Fig. 4) as a cluster of fibers were separated from the yarn, but there were few loose fibers.

The increased width of the warp yarn at level 12, probably resulted from more fibers being pulled from the edge of the yarn. The filling yarn appeared smaller than at lower levels (Plate IV, Figs. 5

EXPLANATION OF PLATE III

Photomicrographs of Cross Sections Taken From the Warp of the Cotton Fabric After Abrasion (magnification 25 times)

Fig. 1. Abrasion level 10 unstained

Fig. 2. Abrasion level 10 stained

Fig. 3. Abrasion level 11 unstained

Fig. 4. Abrasion level 11 stained

Fig. 5. Abrasion level 12 unstained

Fig. 6. Abrasion level 12 stained

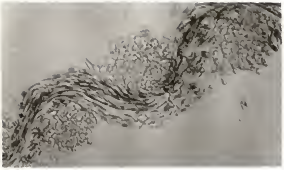

Fig. 1

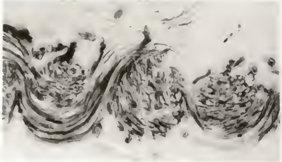

Fig. 2

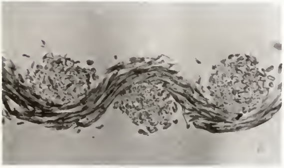

Fig. 3

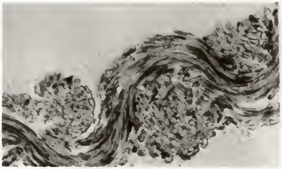

Fig. 4

Fig. 5

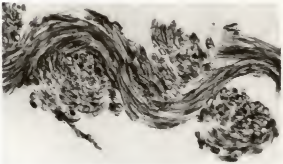

Fig. 6

PLATE III

EXPLANATION OF PLATE IV

Photomicrographs of Cross Sections Taken From the Filling of the Cotton Fabric After Abrasion (magnification 25 times)

Fig. 1. Abrasion level 10 unstained

Fig. 2. Abrasion level 10 stained

Fig. 3. Abrasion level 11 unstained

Fig. 4. Abrasion level 11 stained

Fig. 5. Abrasion level 12 unstained

Fig. 6. Abrasion level 12 stained

Fig. 1

Fig. 2

Fig. 3

Fig. 4

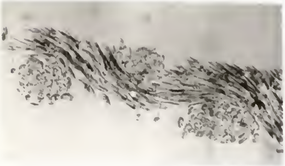

Fig. 5

Fig. 6

PLATE IV

and 6). The stained warp yarn (Plate III, Fig. 6) showed fibers and whole sections of the yarn pulled out. This resulted in a hole in the yarn and the yarn separating from the interlacing fibers. Both warp and filling yarns showed an increase in the amount of dark coloration with more solid dark spots.

Forty-three Power Objective Observations

Good pictures at this magnification were difficult to obtain because of the variation in the height of the fibers in a cross section and the high degree of precision required in focusing.

Both the stained and unstained fibers appeared more compact in the unabraded warp yarn (Plate V, Figs. 1 and 2) than the filling yarn (Plate VI, Figs. 1 and 2). Fibers pulling away were observed both now and in higher levels. Some of the fibers along the edge of the yarn had an elongated or drawn appearance as if they had been pulled. This was seen again at other levels.

Little change could be detected in the yarns at level 1. The large solid dark spot on the stained warp yarn (Plate V, Fig. 4) probably indicated damage, but the dark centers in the fibers were the lumen.

At level 6, fibers were pulled from the longitudinal yarn in the unstained filling (Plate VI, Fig. 5) and the stained warp (Plate V, Fig. 6). It was unknown what caused the dark spot in the unstained warp yarn (Plate V, Fig. 5), unless the fibers were burned. The dark stained warp fiber gave the appearance that the cell wall was pulling

EXPLANATION OF PLATE V

Photomicrographs of Cross Sections Taken From the Warp of the Cotton 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 6 unstained

Fig. 6. Abrasion level 6 stained

Fig. 7. Abrasion level 7 unstained

Fig. 8. Abrasion level 7 stained

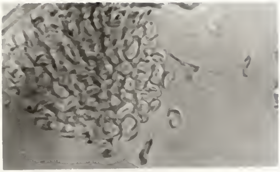

Fig. 1

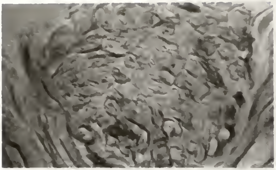

Fig. 2

Fig. 3

Fig. 4

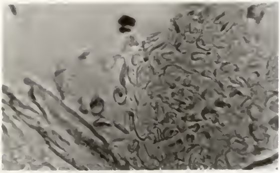

Fig. 5

Fig. 6

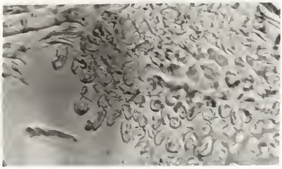

Fig. 7

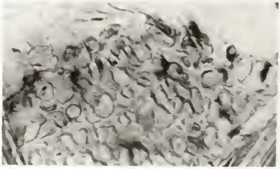

Fig. 8

PLATE V

EXPLANATION OF PLATE VI

Photomicrographs of Cross Sections Taken From the Filling

of the Cotton 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 6 unstained

Fig. 6. Abrasion level 6 stained

Fig. 7. Abrasion level 7 unstained

Fig. 8. Abrasion level 7 stained

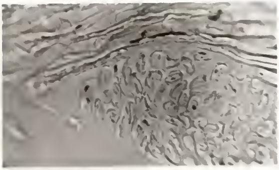

Fig. 1

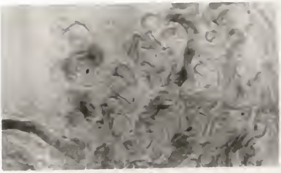

Fig. 2

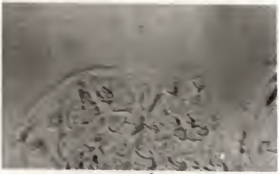

Fig. 3

Fig. 4

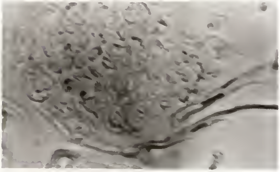

Fig. 5

Fig. 6

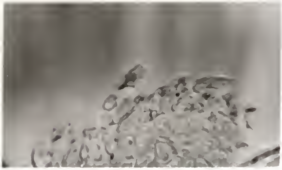

Fig. 7

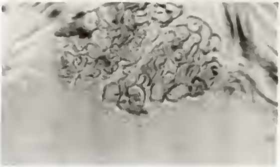

Fig. 8

PLATE VI

away. When the stained filling fiber (Plate VI, Fig. 6) had a dark spot from the edge to the center, it was assumed that the cell wall might have been broken in that area.

The stained filling yarn at level 7 had a division in the center of the yarn with the compact fibers to each side (Plate VI, Fig. 8). The filling yarn did not show as much damage as the warp yarn, although the ten power objective showed it to have more damage.

Little could be observed in the level 10 unstained warp or filling yarns (Plate VII, Fig. 1 and Plate VIII, Fig. 1). An example of fragmentation was seen in the longitudinal fiber surrounding the stained fibers of the warp yarn (Plate VII, Fig. 2). The stained filling yarn (Plate VIII, Fig. 2) had pulled away from the interlacing yarn which gave some of the fibers an elongated appearance.

In both the unstained warp and filling yarns (Plate VII, Fig. 3 and Plate VIII, Fig. 3) at level 11, a blur at the end of a number of the fibers could have been the cell wall pulling away. The center of the unstained warp yarns appeared compact with the outer fibers looser. The stained warp fibers (Plate VII, Fig. 1) appeared in clusters with space between and had definite staining.

At level 12 (5 pounds, 300 revolutions) the rippled edge of some of the outer fibers in the unstained warp yarn (Plate VII, Fig. 5) was assumed to be torn cell walls. The stained warp fibers (Plate VII, Fig. 6) also showed cell walls being pulled away with the outer edge of the yarn having more damage than the inner yarn. Both the stained warp and filling fibers were more irregularly spaced than at

EXPLANATION OF PLATE VII

Photomicrographs of Cross Sections Taken From the Warp of the Cotton Fabric After Abrasion

(magnification 107.5 times)

Fig. 1. Abrasion level 10 unstained

Fig. 2. Abrasion level 10 stained

Fig. 3. Abrasion level 11 unstained

Fig. 4. Abrasion level 11 stained

Fig. 5. Abrasion level 12 unstained

Fig. 6. Abrasion level 12 stained

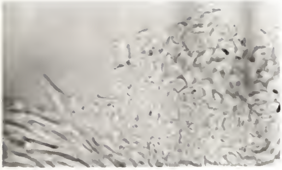

Fig. 1

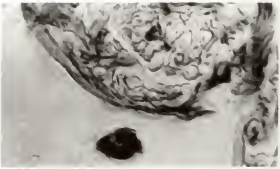

Fig. 2

Fig. 3

Fig. 4

Fig. 5

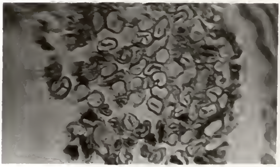

Fig. 6

PLATE VII

EXPLANATION OF PLATE VIII

Photomicrographs of Cross Sections Taken From the Filling of the Cotton Fabric After Abrasion (magnification 107.5 times)

Fig. 1. Abrasion level 10 unstained

Fig. 2. Abrasion level 10 stained

Fig. 3. Abrasion level 11 unstained

Fig. 4. Abrasion level 11 stained

Fig. 5. Abrasion level 12 unstained

Fig. 6. Abrasion level 12 stained

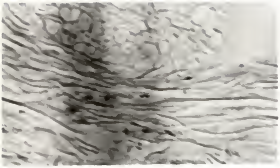

Fig. 1

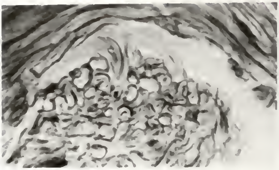

Fig. 2

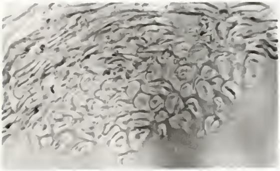

Fig. 3

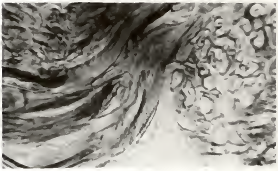

Fig. 4

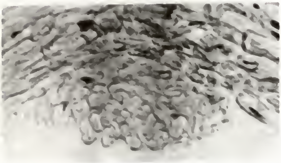

Fig. 5

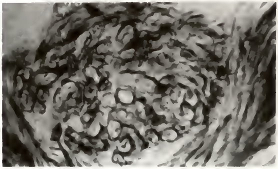

Fig. 6

PLATE VIII

lower levels.

Nylon Cross Sections

Ten Power Objective Observations

The nylon photomicrographs showed no difference in the size of the stained and unstained fibers (Appendix B, Table III). It was difficult to obtain a true measure of the warp yarn size because of the wide irregular spread of the yarn. The nylon fiber usually had a cylindrical shape with dark specks indicating the presence of delustrants.

Both plys of the warp yarn were visible in the unabraded yarn (Plate IX, Figs. 1 and 2). The warp yarn appeared spread with fibers extending away from the yarn while the filling yarn (Plate X, Figs. 1 and 2) was more circular. Loose fibers were observed in both the warp and filling yarns with the unstained loose fibers appearing farther from the yarn than those in the stained yarn.

Not as many loose fibers were observed at level 1 as in the unabraded yarn. The unstained filling yarn (Plate X, Fig. 3) and the stained warp yarn (Plate IX, Fig. 4) showed some fibers pulled away from the yarn. The stained filling yarns had a smoother edge than the unabraded (Plate X, Fig. 4).

At level 3 (1 pound, 500 revolutions), the unstained warp yarn (Plate IX, Fig. 5) was flattened and closer to the interlacing fibers which had spread. The unstained and stained filling yarns (Plate X, Figs. 5 and 6) were fuller which meant a higher crown as was evident

EXPLANATION OF PLATE IX

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 3 unstained

Fig. 6. Abrasion level 3 stained

Fig. 7. Abrasion level 4 unstained

Fig. 8. Abrasion level 4 stained

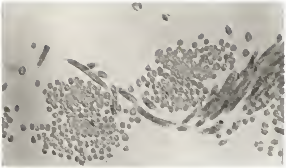

Fig. 1

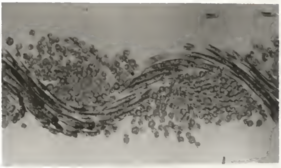

Fig. 2

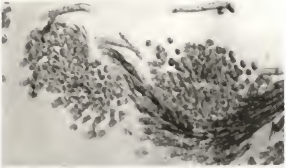

Fig. 3

Fig. 4

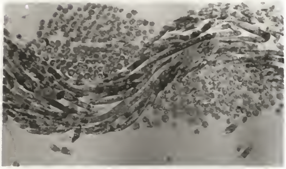

Fig. 5

Fig. 6

Fig. 7

Fig. 8

PLATE IX

EXPLANATION OF PLATE X

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 3 unstained

Fig. 6. Abrasion level 3 stained

Fig. 7. Abrasion level 4 unstained

Fig. 8. Abrasion level 4 stained

Fig. 1

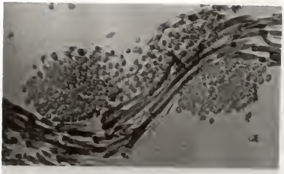

Fig. 2

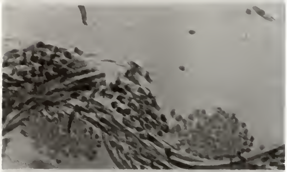

Fig. 3

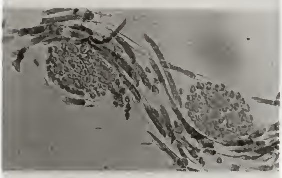

Fig. 4

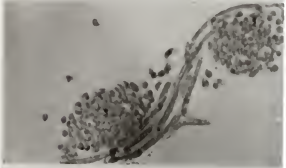

Fig. 5

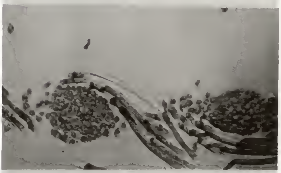

Fig. 6

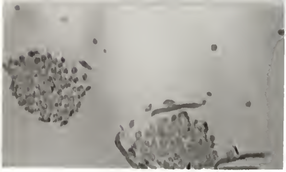

Fig. 7

Fig. 8

PLATE X

in the warp cross section where the interlacing fibers had spread. The stained warp yarns (Plate IX, Fig. 6) did appear more compact than at level 1.

The unstained warp yarn (Plate IX, Fig. 7) at level 4 showed more fibers pulling from the yarn which resulted in a more uneven surface and openings within the yarn. Little change was observed between level 3 and 4 in the unstained filling yarns (Plate X, Fig. 7). The stained filling yarn (Plate X, Fig. 8) appeared flatter and did not seem to contain as many fibers, but a count of the fibers would need to be made to substantiate this observation. The stained warp yarn (Plate IX, Fig. 8) appeared to be more compact and have a smoother surface yet it had more scattered fibers.

The fibers continued to pull from the yarn at level 7, but in the warp yarn (Plate XI, Figs. 1 and 2) this appeared as clusters rather than as single fibers. It was noted that in the unstained filling yarn (Plate XII, Fig. 1) the interlacing fibers were farther apart and there were more loose fibers than had appeared at the lower levels. It was unknown what caused the dark spot in the stained filling cross section (Plate XII, Fig. 2), but it might have been a burned fiber or the presence of detrius.

At level 8 (5 pounds, 100 revolutions), there was an increase in the loose fibers and fibers pulling from the warp yarn (Plate XI, Figs. 3 and 4). The unstained filling yarn (Plate XII, Fig. 3) showed a decrease in loose fibers and gave the appearance of missing fibers. The interlacing fibers appeared tangled and had a definite

EXPLANATION OF PLATE XI

Photomicrographs of Cross Sections Taken From the Warp of the Nylon Fabric After Abrasion

(magnification 25 times)

Fig. 1. Abrasion level 7 unstained

Fig. 2. Abrasion level 7 stained

Fig. 3. Abrasion level 8 unstained

Fig. 4. Abrasion level 8 stained

Fig. 5. Abrasion level 11 unstained

Fig. 6. Abrasion level 11 stained

Fig. 7. Abrasion level 12 unstained

Fig. 8. Abrasion level 12 stained

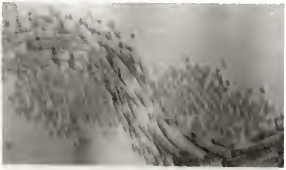

Fig. 1

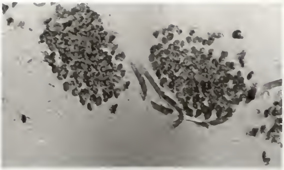

Fig. 2

Fig. 3

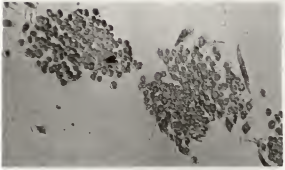

Fig. 4

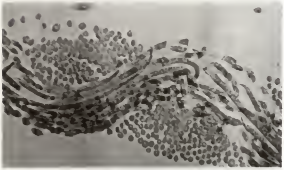

Fig. 5

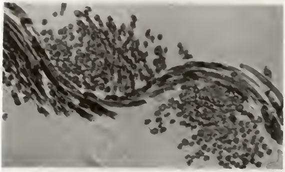

Fig. 6

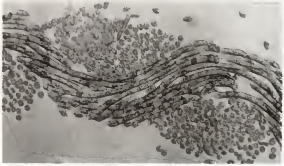

Fig. 7

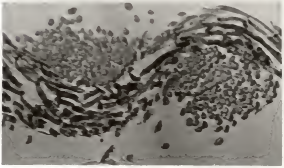

Fig. 8

PLATE XI

EXPLANATION OF PLATE XII

Photomicrographs of Cross Sections Taken From the Filling of the Nylon Fabric After Abrasion (magnification 25 times)

Fig. 1. Abrasion level 7 unstained

Fig. 2. Abrasion level 7 stained

Fig. 3. Abrasion level 8 unstained

Fig. 4. Abrasion level 8 stained

Fig. 5. Abrasion level 11 unstained

Fig. 6. Abrasion level 11 stained

Fig. 7. Abrasion level 12 unstained

Fig. 8. Abrasion level 12 stained

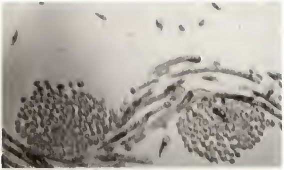

Fig. 1

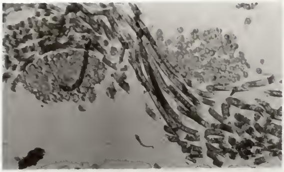

Fig. 2

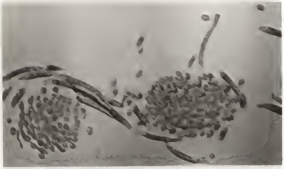

Fig. 3

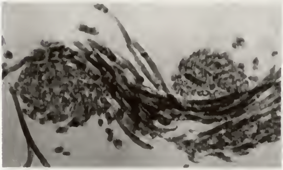

Fig. 4

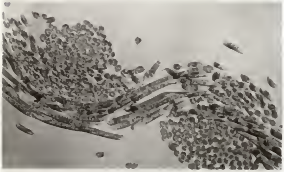

Fig. 5

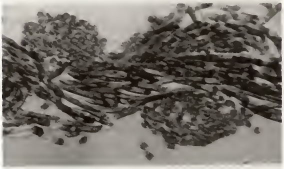

Fig. 6

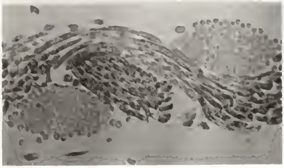

Fig. 7

Fig. 8

PLATE XII

outward pull.

At level 11, the warp yarns (Plate XI, Figs. 5 and 6) showed the beginning of a change in the yarn structure for there was a flattening of the fibers so that some of the yarns were even with the crown of the interlacing yarn while other yarns evidenced an increase in the number of fibers pulling out. The filling yarns (Plate XII, Figs. 5 and 6) also began to show signs of flattening and more completely filling in the space. There were more loose fibers than at the lower levels.

Both the warp and filling yarns at level 12 (10 pounds, 5,000 revolutions), showed greater damage. Fibers were pulled from the yarn which resulted in a hole in an unstained warp yarn (Plate XI, Fig. 7). There were many loose fibers in the unstained warp and stained filling yarn (Plate XII, Fig. 8).

Forty-three Power Objective Observations

The unabraded warp yarns (Plate XIII, Figs. 1 and 2) showed both plys. Because of the angle of the cross section slice and the angle of the fibers, one ply had an elongated appearance while the other one was circular. Since a dark spot appeared in both the unstained and stained yarns, it was not known whether it had been in the original yarn or was detrius. A good skin-core relationship was not shown in the stained yarn (Plate XIII, Fig. 2 and Plate XIV, Fig. 2). The warp yarn had a rough edge while the filling fibers were held in a circular cluster with an irregular spacing of the fibers.

The unstained warp yarn at level 1 appeared compact while the stained warp yarn showed more space between the fibers (Plate XIII, Figs. 3 and 4). An extension beyond the end of the unstained filling fiber (Plate XIV, Fig. 3) was observed both now and at higher levels. This could have been the length of the fiber or a sign of damage. Most of the fibers in both the warp and filling yarn were circular in shape, but a few had an oblong appearance.

In both the unstained and stained filling yarns at level 3 (Plate XIV, Figs. 5 and 6), a few fibers had more of a square or diamond shape rather than the normal circular appearance. A fiber that was away from the stained warp yarn (Plate XIII, Fig. 6) appeared to have a tail or be in the shape of a tear drop. This could have been the skin being separated from the core as would possibly have occurred in the bubbles that appeared in longitudinal observations.

There was little apparent difference between levels 3 and 4. A few of the stained warp fibers (Plate XII, Fig. 8) had a dark ring around them which could be the stained skin. If so, this was the first time it was observed.

The unstained filling yarn at level 7 (Plate XVI, Fig. 1) had more of an outward pull than was observed at lower levels. Some of the unstained warp fibers (Plate XV, Fig. 1) showed the clear portion to one side of the fiber and some of the filling fibers had the clear tail appearance. Irregular spacing of the fibers and the possible stained skin were noted in the stained filling yarns (Plate XVI, Fig. 2).

EXPLANATION OF PLATE XIII

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 3 unstained

Fig. 6. Abrasion level 3 stained

Fig. 7. Abrasion level 4 unstained

Fig. 8. Abrasion level 4 stained

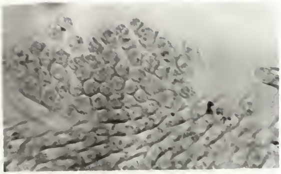

Fig. 1

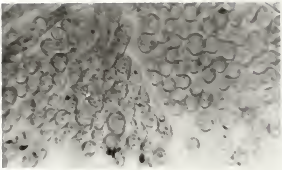

Fig. 2

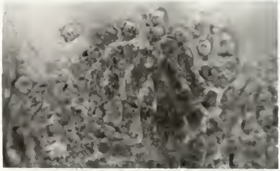

Fig. 3

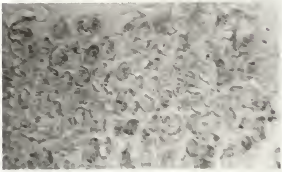

Fig. 4

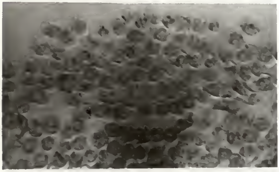

Fig. 5

Fig. 6

Fig. 7

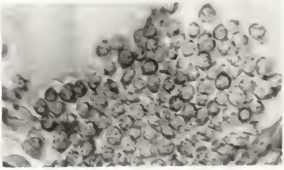

Fig. 8

PLATE XIII

EXPLANATION OF PLATE XIV

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 3 unstained

Fig. 6. Abrasion level 3 stained

Fig. 7. Abrasion level 4 unstained

Fig. 8. Abrasion level 4 stained

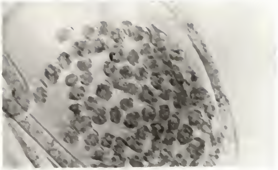

Fig. 1

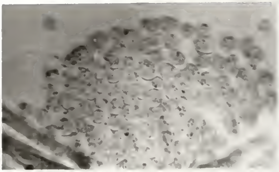

Fig. 2

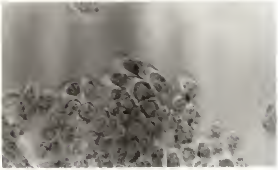

Fig. 3

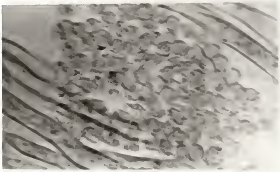

Fig. 4

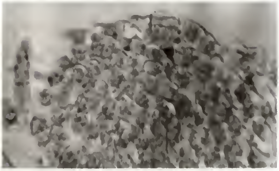

Fig. 5

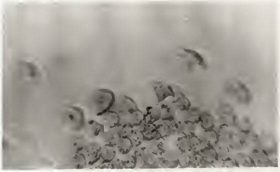

Fig. 6

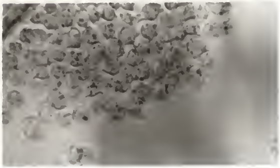

Fig. 7

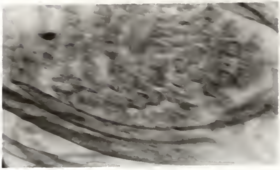

Fig. 8

PLATE XIV

Fibers continued to pull out from the yarn in both the warp and filling yarns at level 8 (5 pounds, 100 revolutions) with more space between the outer fibers of the stained filling yarn (Plate XVI, Fig. 4). The unstained filling yarns (Plate XVI, Fig. 3) had an increased number of oblong fibers and some of the stained warp fibers (Plate XV, Fig. 4) had the tear drop shape.

A flattened side was noted in some of the unstained warp fibers at level 11 and a dark streak at the end of some of the stained warp fibers (Plate XV, Figs. 5 and 6). Some of the unstained filling fibers were oblong and tear drop in shape and some of the stained filling fibers had the dark circles around them (Plate XVI, Figs. 5 and 6).

It was observed that at level 12 (10 pounds, 5,000 revolutions) the warp fibers (Plate XV, Figs. 7 and 8) were pulled from the yarn while the filling fibers (Plate XVI, Fig. 7 and 8) did not show this outward pull. The edge and loose fibers of the warp and filling yarn had an oblong and tear drop shape. Some of the warp fibers seemed to overlap. A longitudinal fiber, damaged at the bend, appeared on top of the cross section of the unstained filling yarn.

EXPLANATION OF PLATE XV

Photomicrographs of Cross Sections Taken From the Warp of the Nylon Fabric After Abrasion (magnification 107.5 times)

Fig. 1. Abrasion level 7 unstained

Fig. 2. Abrasion level 7 stained

Fig. 3. Abrasion level 8 unstained

Fig. 4. Abrasion level 8 stained

Fig. 5. Abrasion level 11 unstained

Fig. 6. Abrasion level 11 stained

Fig. 7. Abrasion level 12 unstained

Fig. 8. Abrasion level 12 stained


Fig. 1

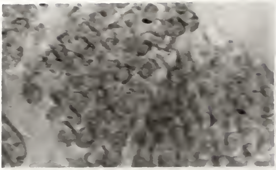
Fig. 2

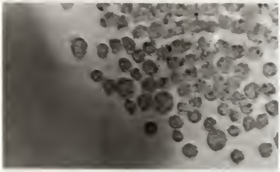
Fig. 3

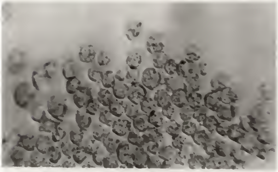
Fig. 4

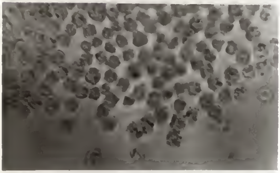
Fig. 5

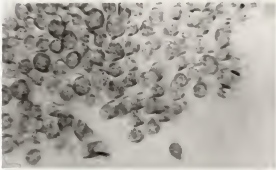
Fig. 6

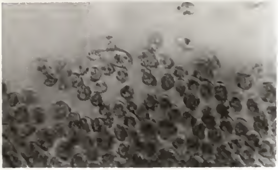
Fig. 7

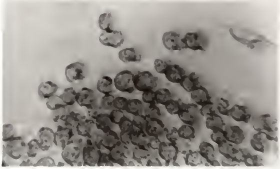
Fig. 8

PLATE XV

EXPLANATION OF PLATE XVI

Photomicrographs of Cross Sections Taken From the Filling of the Nylon Fabric After Abrasion

(magnification 107.5 times)

Fig. 1. Abrasion level 7 unstained

Fig. 2. Abrasion level 7 stained

Fig. 3. Abrasion level 8 unstained

Fig. 4. Abrasion level 8 stained

Fig. 5. Abrasion level 11 unstained

Fig. 6. Abrasion level 11 stained

Fig. 7. Abrasion level 12 unstained

Fig. 8. Abrasion level 12 stained

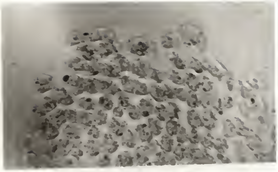

Fig. 1

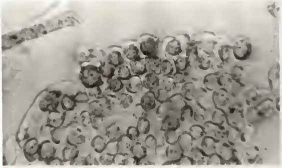

Fig. 2

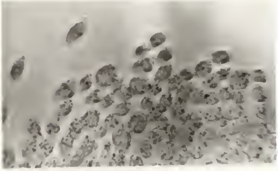

Fig. 3

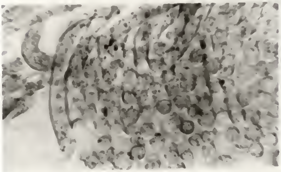

Fig. 4

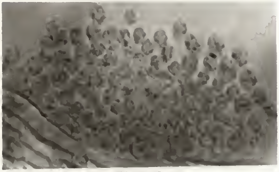

Fig. 5

Fig. 6

Fig. 7

Fig. 8

PLATE XVI

CHAPTER V

SUMMARY AND RECOMMENDATIONS

This study was designed to be exploratory and to develop techniques for studying unstained and stained cotton and nylon fabrics through the use of photomicrographs. The cotton and nylon fabrics which had been abraded by Wagner (31) were used for the cross sections. The cotton was stained with Congo red and the nylon was stained with Lansayn Grey B L. The specimens were imbedded in Lucite solution.

The cross sections were mounted with an oil immersion which resulted in some bubbles and streaks. Synnan (28) discussed the use of albuminized slides for mounting cross sections which reportedly allowed the researcher to stain the cross sections after mounting. Staining after mounting could not be done successfully in this study, but it might prove to give a better stained cross section.

The ten and the forty-three power objectives were used in studying the yarns and fibers at the selected levels of abrasion, which were the lowest and the highest revolutions under each variation in pressure. At each level, two cross sections were photographed which showed typical yarn and fiber structure or an unusual yarn structure.

Staining the cotton fibers caused swelling and the damaged area to absorb the stain. In the photomicrographs, the damage appeared as a dark coloration with the staining too dark to be able to distinguish how the damage occurred. It is suggested that colored photomicrographs might better show the damage, for then the stain could be distinguished from the normal dark streaks in the fibers. Possibly another stain which utilized two colors, one to stain the damaged area and the other the undamaged area, would aid in the study of the stained damaged fiber.

The nylon stain did not cause any difference in the size of the yarns and no consistent differences were observed. The Lansayn Grey B L stain for the nylon fabric did not give the distinct skin-core relationship desired and in most cases was unobservable. The writer would recommend that in further work another stain be tried, such as the one developed by Berry (5) which used two different colored stains, and possibly colored photomicrographs.

Damage to both the unstained and stained cotton was observed as the abrasion increased until extensive damage was apparent at the highest level. The warp yarn maintained a round appearance while the filling yarn showed a gradual, but progressive flattening with increased abrasion. At levels 6 and 10, the filling cross section showed the interlacing fiber spread while the warp cross section showed no change in width. At level 12, the fibers were pulled apart making the warp yarn wider which might be related to the increased abrasive action. The stained yarn pulled away from the interlacing yarn in both warp and filling cross sections at various levels, but with no consistent pattern. This was not observed in the unstained yarns. The number of fibers pulled from the yarn increased with successive levels and by level 10, the fibers were being pulled away in clusters as well as individually. The loose fibers observed in the unabraded specimen were not evident at level 1, but had increased at level 6, and then decreased in the higher levels. Throughout all the levels, the unstained yarn had such a slight crimp that it was practically flat while the stained warp yarn showed considerable crimp.

Nylon showed its high resistance to abrasion by the small changes that occurred as the amount of pressure and number of revolutions increased. No significant changes were observed until level 3 when the tail or tear drop shaped fibers first appeared and continued to appear at other levels. More research is needed to determine if they were the bubbles and burst ends observed in longitudinal analysis. At level 4, the dark ring first appeared around the fibers. The filling yarns at level 8 showed an important change when the fibers were drawn out. At level 11, damage could be observed by the change in the yarn structure and this continued at level 12. The nylon had more loose fibers a greater distance from the yarn than did the cotton. Fibers being pulled from the yarn were also observed. Higher levels of abrasion are needed in order to observe the nylon fabric breakdown comparable to that of the cotton.

A more extensive investigation is needed to determine if observations made in this study would be consistently noted if the sample size was larger and to clarify some of the observations. More work is also needed to be done with stains in order to find one that will aid in determining damage and the type of damage.

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APPENDIX A

TABLE I

LEVELS OF ABRASION ESTABLISHED BY WAGNER

Abrasion level	Weight	Number of revolutions
	Cotton	
1*	1 pound	25
2		50
3		100
4		300
5		500
6*		1,000
7*	3 pounds	100
8		300
9		500
10*		1,000
11*	5 pounds	100
12*		300
	Nylon	
1*	1 pound	100
2		300
3*		500
4*	3 pounds	100
5		300
6		500
7*		1,000
8*	5 pounds	100
9		300
10		500
11*		1,000
12*	10 pounds	5,000

*Levels of abrasion observed in detail for the cross sectional analysis.

APPENDIX B

TABLE II

MEASUREMENTS IN MILLIMETERS OF COTTON CROSS SECTIONS USING TEN POWER OBJECTIVES

Specimen	Unstained Yarns	Stained Yarns	Difference	Unstained Yarn and Crown	Stained Yarn and Crown	Difference	Unstained Loose Fibers	Stained Loose Fibers	Difference
Warp 0	0.12	0.19	0.07	0.21	0.31	0.10	0.05	0.08	0.03
Filling 0	.15	.16	.01		.27		.06	.20	.14
Warp 1	.16	.19	.03		.26		.04		
Filling 1	.12	.14	.02	.22	.24	.02	.13		
Warp 6	.17	.18	.01	.23	.31	.08	.02	.06	.04
Filling 6	.10	.14	.04	.19	.29	.10	.08		
Warp 7	.15	.21	.06	.22	.30	.08	.04		
Filling 7	.11	.14	.03	.20	.26	.06	.06		
Warp 10	.14	.17	.03	.22	.23	.01	.04	.04	.00
Filling 10	.10	.12	.02	.23	.32	.09	.05		
Warp 11	.13	.15	.02	.19	.30	.11	.07		
Filling 11	.11	.13	.02	.19	.25	.06	.06	.07	.01
Warp 12	.15	.17	.02	.22	.26	.04	.06	.01	.05
Filling 12	.10	.15	.05	.19	.24	.05	.04		

TABLE III

MEASUREMENTS IN MILLIMETERS OF NYLON CROSS SECTIONS USING TEN POWER OBJECTIVE

Specimen	Unstained Yarns	Stained Yarns	Difference	Unstained Yarn and Crown	Stained Yarn and Crown	Difference	Unstained Loose Fibers	Stained Loose Fibers	Difference
Warp 0	0.18	0.17	+0.01*	0.27	0.25	+0.02	0.10	0.06	+0.04
Filling 0	.14	.16	- .02*	.24	.31	- .07	.18	.10	+ .08
Warp 1	.19	.26	- .07	.30			.12	.07	+ .05
Filling 1	.13	.13	.00	.28	.22	+ .06		.16	
Warp 3	.18	.18	.00	.31			.07	.10	- .03
Filling 3	.15	.17	- .02	.20	.24	- .04	.10	.14	- .04
Warp 4	.23	.22	+ .01		.29		.08	.19	- .11
Filling 4	.15	.14	+ .01				.16	.12	+ .04
Warp 7	.17	.20	- .03	.32	.23	+ .09	.07	.17	- .10
Filling 7	.18	.13	+ .05	.28	.31	- .03	.16	.09	+ .07
Warp 8	.18	.22	- .04	.26			.10	.13	- .03
Filling 8	.17	.15	+ .02		.32		.12	.06	+ .06
Warp 11	.17	.21	- .04	.30	.30	.00	.10	.22	- .12
Filling 11	.14	.14	.00	.27	.35	- .08	.12	.14	- .02
Warp 12	.17	.17	.00	.28	.29	- .01	.06	.10	- .04
Filling 12	.14	.17	- .03	.29	.28	+ .01	.05	.16	+ .11

*+ used to indicate the unstained yarn was the larger while - was used to indicate the stained yarn was the larger.

PHOTOMICROGRAPHS OF UNSTAINED AND STAINED CROSS SECTIONS OF SELECTED COTTON AND NYLON FABRIC BEFORE AND AFTER ABRASION

by

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The purpose of this study was to develop techniques for studying cross sections of unstained and stained cotton and nylon fabrics through the use of photomicrographs. It was designed to observe any differences between the unstained and stained cross sections and to study the kind and degree of damage due to abrasion after varying lengths of time and pressure.

The cotton and nylon fabrics which had been abraded for longitudinal analysis were also used for the cross sections. The cotton was stained with Congo red and the nylon was stained with Lansayn Grey B L. The specimens were imbedded in Lucite solution. The cross sections were sliced with a thickness of fourteen microns at a 45° angle and mounted on a slide with oil immersion. The ten and the forty-three power objectives were used in studying the yarns and fibers at the selected levels of abrasion, the lowest and the highest revolutions under each variation in pressure. A photomicrographic record was made of cross sections at each level.

The Congo red caused the fibers to swell and the damaged areas to absorb the stain. The stain absorption was too dark to be able to identify how the damage occurred. The Lansayn Grey B L did not cause any difference in the size of the nylon yarns and no consistent differences were observed. The stain did not show a distinct skin-core relationship and in most cases was unobservable.

Damage to the cotton increased with abrasion until extensive damage was apparent at the highest level. The warp yarns maintained a round appearance while the filling yarns showed a gradual, but progressive flattening with the increased abrasion. The number of fibers pulled from the yarn increased with successive levels until they were pulled away in clusters as well as individually. Loose fibers were observed in the unabraded specimen and had increased at the level with one pound, one thousand revolutions, but then decreased with following levels.

Nylon showed its high resistance to abrasion by the small changes that occurred as the amount of pressure and number of revolutions increased. Higher levels of abrasion are needed in order to study the breakdown of nylon fabric comparable to that of the cotton. Tear drop shaped fibers were observed which were thought to be the skin pulled away from the core as would occur in bubbles. At the highest levels of abrasion, the yarn structure did change as the warp yarn flattened and became even with the crown of the interlacing yarn.

A more extensive investigation is needed in order to determine if observations made in this study would be consistently noted if the sample size was larger and to clarify some of the observations. More work also is needed done with stains in order to find one that will aid in determining damage and the type of damage.