MICROSCOPIC EVALUATION OF THE SURFACE OF SELECTED NYLON FABRIC BEFORE AND AFTER ABRASION

by

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CHAPTER I

INTRODUCTION

The terms abrasion and wear often are used interchangeably, but there is an important distinction between the two. Linton (13) has defined wear as the deterioration of a fabric or garment because of breaking, cutting or the wearing out or removal of the fibers or yarns. Skinkle (20) has defined abrasion as being produced by the friction of cloth on cloth, the friction of the cloth on external objects and the friction of the fibers on the dust or grit in the fabric. He included abrasion among the factors causing wear. Mann (14) similarly considered abrasion to be the most important single factor in wear. Many textile technologists therefore have simplified the problem of determining the wear qualities of fabrics by studying the resistance of fabrics to abrasion rather than to wear in general.

Both the manufacturer and the consumer are interested in the results of laboratory investigations concerning abrasion resistance of fabrics as it enables them to form a basis when attempting to predict the serviceability of fabrics. It should be noted, however, that it is only when the results of abrasive wear and service wear are correctly interpreted that the durability of a fabric can be predicted.

Clegg (6) stated that the failure of textiles in service is mainly attributed to a weakening of the structure caused by the mechanical breakdown of the individual fibers. McNally and McCord (12) attributed this breakdown to frictional wear, cutting and plucking of the fibers.

A microscopic examination can be used to determine the nature and extent of the yarn damage incurred on the textiles after progressive abrasion. To date, there have been few investigations done on the effect of varying intensities of abrasion, which include combinations of pressure and number of revolutions, on nylon fabric. Most of the work in this field has been on natural fibers rather than man-made fibers, and have dealt more with the effect of abrasion on individual fibers rather than on yarn and fabric structure.

A larger investigation, of which this study is a part, is currently being conducted by the North Central Region of the Agricultural Experiment Station to determine the effect of abrasion on physical properties of selected cotton and nylon fabrics.

This study had the following as its objectives:

1. To evaluate under the microscope, the type and extent of surface damage of unabraded and abraded specimens of selected nylon fabric.

2. To examine photomicrographs of representative areas from each group of unabraded and abraded specimens for the type and extent of surface damage.

3. To compare the type and extent of yarn and fabric damage of the unabraded specimens with the specimens abraded at varying intensities.

CHAPTER II

REVIEW OF LITERATURE

Wear has been defined by Booth (5) as the net result of a number of agencies that reduce the serviceability of an article. Some of the more important of these are bending and stretching, tearing, abrasion, laundering and cleaning. He similarly outlined abrasion to include three major types. Plane abrasion, which results from one flat surface rubbing against another, was found by Stoll (21) to be the most common as it contributed thirty per cent of the total wear of the fabric. This was followed by twenty per cent edge abrasion and twenty per cent flex abrasion. The remaining thirty per cent was attributed to tearing and other mechanical factors.

Skinkle (2) stated that the service life of a garment depended on such personal factors as size, weight, occupation of the wearer and on the climate around him as well as the mechanical details in the motion of the fabric while being worn. Gagliardi and Nuessle (9) found that in practical use a fabric is subjected to low stresses and strains whose cycles, on the average, are far apart so that there is always time available for stress and strain relaxation. However, with laboratory abrasion testing instruments these repeated stresses were not allowed to relax, thus subjecting the fibers to more severe abrasion than might be experienced in actual use.

Despite this criticism, laboratory abraders have been widely used for determining the abrasion resistance of fabrics. The American Society for Testing and Materials, Committee D-13 (1) has outlined various testing procedures and instruments commonly used to simulate abrasion. The Stoll Abrader subjects a specimen to unidirectional reciprocal rubbing and folding over a bar. Specimens also may be inflated over a rubber diaphragm and subjected to unidirectional or multidirectional rubbing action, thus making possible both plane and flex abrasion. The Taber Abrader subjects specimens to flat abrasion and uses rotary rubbing action. The Wyzenbeck Abrader measures flat abrasion with an oscillating cylinder. Flex abrasion is produced by the Accelerotor using a variety of abrasive surfaces at controllable speeds. The Schiefer Abrader produces uniform flat abrasion in every direction, using various pressures and number of revolutions.

Nature of Abrasion

In all cases, regardless of the type of instrument used, some type of stress is produced that has to be absorbed by the fabric. Hamburger (10) stated that abrasion is definitely a repeated stress application usually caused by forces of low magnitude that occur many times during the life expectancy of the material. To resist destruction, the specimen must be capable of absorbing the energy imparted to it upon these stress applications and of releasing this energy upon removal of the stress without the occurrence of failure. He stated that abrasion, or deformation under load, is governed by two major components--immediate elastic deflection and delayed deflection or creep. This delayed deflection was divided into primary creep, which is recoverable energy, and secondary creep, which is non-recoverable energy. Therefore, the primary and secondary creep, as well as the immediate elastic deflection, all contributed to the energy absorption capacity of a material.

Kaswell (11) pointed out that the lower the secondary creep the better the fiber in terms of wear, presuming that all other things were equal. This was supported by Hamburger's (10) theory that for a fabric to resist abrasion, energy must be released upon stress removal, but that secondary creep is non-recoverable energy; thus abrasion resistance is decreased when the secondary creep is high.

For a material to resist abrasion it must withstand many cycles of loading and unloading deformation. While secondary creep is an energy absorbing component of the total deflection, its contribution under repeated loadings is negligible, since it is removed in the course of the first few cycles. The immediate elastic deflection and the primary creep are recoverable upon load removal. They, therefore, contribute to the absorption and the return of energy necessary for proper performance under repeated stress.

With nylon, Meredith (16) found creep to be caused essentially by the breakdown of secondary bonds due to the combination of strain, energy and friction. He stated that one of the characteristics of nylon is its ability to recover almost completely from large strains, provided sufficient time is given for recovery to take place. Meredith (16) reported a study done by Abbott in 1951 who found that the extent to which a nylon filament recovered from creep under constant load depended on the total extension reached, the time under load and the time allowed for recovery. McNally and McCord (15) found elongation and elasticity more important than strength in a fabric's ability to absorb energy. The ability of nylon to resist abrasion was a combination of high strength, high elongation and excellent elasticity.

Morton (18) stated that abrasion produces a fabric unsatisfactory in two possible ways. It can render it so thin, so shiny, or so hairy that it becomes unsightly, or it produces a progressive detorioration in strength until a level is reached at which the fabric is no longer able to withstand the stress of usage without rupture. Chemical deterioration, fiber abrasion, and transverse cracking of the fibers were found by Clegg (6) to be factors causing the general breakdown of the fabric.

Morton (18) reported that there was a gradual breakdown of the powers of internal cohesion of the individual fibers, a gradual breakdown of the structural cohesion between the fibers or there could be a combination of these two during abrasion. McNally and McCord (15) attributed this mechanical breakdown of textiles to frictional wear, cutting, and plucking or snagging of fibers.

Factors Affecting Abrasion

The wearing quality of a fabric was found by Cranshaw, Morton and Brown (7) 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.

Backer and Tanenhaus (3) stated that the geometric area of contact between the cloth and the abradant surfaces determines the degree of pressures which occur under an abrasive load. These local pressures in turn determine the depth of penetration into the fabric structure by the abradant, and thus the true area of contact between the abradant and the specimen. This local penetration controls the amount of cutting and snagging damage while the true area of contact determines the amount of frictional damage which takes place in the form of fiber slippage and/or fatigue.

Labarthe (12) defined fatigue as the decrease of inherent resistance to wear, form and stability without causing actual fiber breakdown. It is produced by abrasion against smooth surfaces and internal abrasion by flexing, folding, stretching and compression.

The direction of the abrasion as related to the surface yarns was found by Backer and Tanenhaus (3) to effect the occurrence of the fabric breakdown. Abrasion along the yarns produced shearing or cutting of the fibers while abrasion across the yarns produced snagging.

Hamburger (10) stated that when the surface protuberance or crown height of the yarn was high as compared to the fiber diameter the forces between the abradant and the cloth planes were also high and thus the fiber was plucked. Similarly, Backer (2) found that an abrasive surface having sharp, small projections would cut individual fibers, eventually destroying the fabric structure.

The amount of plucking was also affected by the weave and twist of the yarns as evidenced by Hamburger (10). He found that fabrics with loose weaves and yarns with low twist did not hold the yarns and fibers tightly, allowing them to slip out of the fabric completely or to be displaced vertically.

In a study by Cranshaw, Morton and Brown (7) it was found that yarns having a high twist or a fabric with a tight weave had a good wearing quality. Both Backer (2) and Morton (18) agreed that it was better to have a tight weave and a lower twist. With the lower twist, the yarn could more readily flatten and present a larger surface of fibers to absorb the abrasive action.

McNally and McCord (15) found that such fiber dimensions as length, fineness, surface roughness of yarns and shape of microscopic cross sections influenced the abrasion resistance of fabrics because they affected fiber cohesion. Yarns made of filaments and long staple fibers showed less destruction as they were generally more difficult to remove or displace from the fabric than shorter fibers. Susich (22) found that the resistance to abrasion of spun yarns was always higher than that of the yarns made of multifilaments.

Fine fibers formed stronger yarns than coarse fibers, but coarse fibers improved abrasive wear within limits. Fibers which were too thin were easily ruptured because little abrasive force was needed to develop high stresses. However, if fibers were too coarse, fracture occurred more readily on bending because high strains developed in the outer layers of the bend. Heavier yarns containing more fibers than lighter ones permitted better distribution of stress for a given load and required rupture or displacement of a larger number of fibers before failure occurred.

McNally and McCord (15) stated that flat, elliptical or hollow fibers withstood abrasive wear better than round fibers because outer layers of round fibers must stretch over a greater distance, thus creating higher strains. Contrary to this, Du Bolt (8) found that the friction of a fiber was dependent on the shape of its cross section. Circular fibers had fewer points of contact between the fibers so the coefficient of friction was considerably decreased. Kaswell (11) found that friction between the fibers acted to control fiber slippage and thus reduce abrasive damage.

McNally and McCord (15) also found that such factors as yarn crimp and threads per inch affected abrasion resistance since they determined the yarn surface exposed to rubbing, fiber cohesion of yarns, distribution of warp and filling areas exposed to abrasion, and mobility of yarns and fibers needed to prevent damage from the impact of abrasive forces.

Finally, the degree of abrasive damage is influenced by the conditions under which abrasion is done. Labarthe (12) considered the following: (a) type of motion, (b) nature of the abradant, (c) pressure of abradant on sample, (d) tension on the sample, (e) completeness of lint removal, and (f) determination of end point or amount of abrasion.

The measurement of the relative amount of abrasion may also be affected by the method of evaluation and may be influenced by the judgment of the operator. In all abrasion testing devices the test specimen is rubbed in such a manner that the amount of rubbing can be measured and the resultant damage to the specimen recorded. Abrasion resistance is determined by noting the amount of abrading action needed to produce a given amount of damage or by comparing the amount of damage produced for a given abrading action. In either case, the higher the ratio of abrading action to amount of damage produced, the better the abrasion resistance.

Ball (4) suggested various measures to determine the abrasion resistance of a fabric. He included the changes produced in the tensile strength, thickness, weight, surface luster, air permeability, color, character of abraded materials and the appearance of the surface. The first six of these were measured by physical means while the last two were determined by use of the microscope, thus were subject to personal opinion.

Ball (4) found that changes in the above properties were not always in the same direction nor proportional to the amount of work expended.

As an example, some fabrics first increased in thickness with increasing rubs and then began to decrease as the abrasion was continued. This was attributed to the cutting and breakage of fibers, and the teasing of them out of the yarn, which resulted in a rough, fuzzy surface of greater thickness than the original. Further abrasion resulted to a point when these fibers were raised up and the thickness began to decrease.

Microscopic Examination

The microscope is used to produce a magnified image of an object or condition to reveal details invisible to the naked eye. Schwarz (19) stated that this instrument is of particular importance to the textile industry as it can be used to identify fiber, yarn and fabric structure. Skinkle (20) pointed out that advantages of microscopic evaluation, other than identification of fibers, are that only small samples are needed and that these samples are not destroyed by analysis. As individual fibers show a great deal of variation, photomicrographic records can be kept to assist in the identification of these details at a later date.

Schwarz (19) recommended microscopy as an effective means of reviewing the effects of abrasion as a result of test or of normal wear. Although evaluations of this nature may be biased by the examiner's perception of the area, they could be useful in determining the type and extent of abrasion.

CHAPTER III

METHOD OF PROCEDURE

Selection and Preparation of Specimens

The nylon fabric of this investigation was that used for Project 636, Kansas Agricultural Experiment Station, which is part of the North Central Regional Project--NC-68. It was constructed in a plain weave with a two-ply yarn in the warp direction and a single-ply yarn in the filling direction.

The fabric was divided into five blocks, designated as I, II, III, IV and V. There were six areas within each block, designated as A, B, C, D, E and F. These included specimens to be abraded at nine varying intensities, as well as an unabraded level to serve as the control. The number of specimens, sampling plan (Table I), and their position within these areas were determined by consulting the statistical design of the overall project (Table II). Surface analysis samples were taken from areas B and E of each block.

Specimens were cut from five inch square samples using a three and one-half inch die. The specimens were labeled with the following code:

fiber content.	N nylon
block number	I through V
area number.	A through F
sample number.	1 through 66
abrasion level	1 through 9--abraded 13--unabraded

For example, N III D 27-4 would be translated as nylon from block three, area D, sample number 27 from level four.

TABLE I

SAMPLING PLAN REPRESENTING ONE OF THE SIX AREAS
WITHIN EACH OF THE FIVE BLOCKS*

1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36
37	38	39	40	41	42
43	44	45	46	47	48
49	50	51	52	53	54
55	56	57	58	59	60
61	62	63	64	65	66

*In accordance with the experimental design of Project 636, Kansas Agricultural Experiment Station, North Central Regional Project NC-68.

TABLE II

RANDOM ASSIGNMENT OF SPECIMENS TO ABRASION LEVELS*

Abrasion Level	Block I	Block II	Block III	Block IV	Block V
		AREA B SPECIMENS			
1	20	16	39	8	48
2	30	41	38	21	51
3	23	29	3	22	64
4	4	3	32	25	5
5	63	14	55	36	38
6	37	37	59	60	62
7	48	35	58	31	30
8	58	38	19	57	21
9	25	62	44	6	59
13	12	46	56	48	49
		AREA E SPECIMENS			
1	19	14	7	54	65
2	58	13	32	56	32
3	14	2	25	22	55
4	15	9	10	64	64
5	6	40	11	18	63
6	46	27	58	37	33
7	62	10	56	61	52
8	23	8	46	60	59
9	31	32	17	15	37
13	47	28	39	8	45

*In accordance with the statistical design of Project 636, Kansas Agricultural Experiment Station, North Central Regional Project NC-68.

Abrasion

Specimens were abraded under standard conditions of 70° Fahrenheit and 65 per cent relative humidity on the Schiefer Abrader using a spring steel abradant. All specimens were mounted with the template, using a one and one-half inch plastic disc as the pressure foot in order to insure equal tension on each specimen. The two contacting plane surfaces, one the abradant and the other the specimen, rotated in the same direction at slightly different speeds. This difference allowed each point of the specimen to come into contact with a different portion of the abradant at each rotation. The entire specimen surface was in contact with some portion of the abradant at all times, thus insuring equal abrasion in all directions with each rotation of the two surfaces.

The abrader had weights of one, two, five and ten pounds that were interchanged and combined to give varying pressures. The abrasive action was stopped at a predetermined number of revolutions, but would have stopped automatically if the destruction point of the fabric were reached. The pressure and the number of revolutions used were in accordance with the overall NC-68 project following a pilot study (Table III).

The edge of the abrasion circle on each specimen was marked in four places so the abraded area could be identified easily. An area of approximately two and one-quarter by one and three-quarters inch that contained the one and one-half inch abraded circle was then cut from the rest of the sample with a wider margin left at the bottom than at the top for labeling. The code was then transferred to the sample just cut and the sample carefully centered on a slide. Time tape was used to hold the sample securely to the slide. The slides were placed vertically in a slide box so no compression or distortion would take place before evaluation.

TABLE III

ABRASION LEVELS*

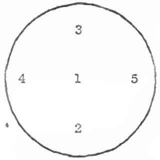
Level	Weight (pounds)	Revolutions
1	1	1,000
2	1	5,000
3	3	5,000
4	3	10,000
5	5	10,000
6	5	15,000
7	10	10,000
8	10	15,000
9	10	20,000
13	Unabraded	

*In accordance with the experimental design of Project 636, Kansas Agricultural Experiment Station, North Central Regional Project NC-68.

Surface Evaluation Using the Microscope

Microscopic analysis of the abraded and unabraded samples of nylon fabric was done with an American Optical Company Series 4 Microstar trinocular microscope. Ten power eye-pieces with a ten power objective were used for optical examination with surface lighting from two American Optical illuminators.

Slides were placed on the mechanical stage of the microscope and the surface of the fabric was evaluated in five areas in the order in which they are numbered below.



These areas were determined carefully in an effort to examine the same area, as nearly as possible, throughout all levels of abrasion. Readings for areas two, three, four and five were taken four millimeters from the outer edge, towards the center of the circle. The center position, number one, was determined by taking a point half the distance from positions four and five and a point half the distance from positions two and three. The place at which the two measurements intersected was taken as the center position.

The surface of each fabric specimen was evaluated for surface napping, yarn slippage and yarn erosion when four warp and four filling yarns were in focus.

The difference between the readings on the fine adjustment knob when the microscope was in focus on the loose fiber ends and when it was in focus on the surface of the fabric was noted as an indication of the extent of surface napping. The scale used for evaluating the surface nap is in Table IV.

Yarn slippage was determined by observing the degree to which the interstices between the yarns were filled with spreading yarns and fibers. The scale used for evaluating the degree of yarn slippage is in Table IV.

Yarn erosion was evaluated by observing the amount of tangling and the degree to which the yarns were losing their twist. The scale used for evaluating the amount of yarn slippage is in Table IV.

Surface Evaluation Using Photomicrographs

Photomicrographs were obtained using a 35 millimeter Kodak camera mounted on the vertical tube of the trinocular body of the microscope. Surface lighting from two American Optical illuminators was used for taking the photomicrographs. Three pictures were taken using the five power objective, which gave a magnification of 12.5 times; and three pictures using the ten power objective, which gave a magnification of 25 times. From the total of six pictures of each unabraded and abraded level, one picture at each magnification was selected that best represented the type and extent of damage.

Interpretation of Results

The mean of the degree of surface napping, yarn slippage and yarn erosion, as determined from the evaluation scales of Table IV, was calculated

TABLE IV

SCALE FOR SURFACE EVALUATION OF SURFACE NAPPING, YARN SLIPPAGE AND YARN EROSION*

Surface Nap

Scale		Number of revolutions of fine adjustment
12	Negligible	200-300
11		300-400
10		400-500
9	Slight	500-600
8		600-700
7		700-800
6	Moderate	800-900
5		900-1000
4		1000-1100
3	High	1100-1200
2		1200-1300
1		1300-1400

Yarn Slippage

Scale		
4	Negligible	Appear as original with some fibers in interstices
3	Slight	Yarn slightly spread
2	Moderate	Interstices half-filled with spreading yarns
1	High	Interstices filled

Yarn Erosion

Scale		
5	None	Yarn same as original, some loose fibers
4	1/4 worn	Damage from original to 1/4
3	1/2 worn	Losing twist and ends tangled
2	3/4 worn	Many loose fibers, badly tangled and damaged
1	Gone	Yarn completely worn away

*In accordance with the experimental design of Project 636, Kansas Agricultural Experiment Station, North Central Regional Project NC-68.

and recorded for each abrasion level. The degree of abrasive damage and the rate of progression of damage shown by the microscopic evaluation and the photomicrographs of the specimens were compared for each of the unabraded and abraded levels.

CHAPTER IV

RESULTS AND DISCUSSION

Specimens from progressive levels of abrasion were analyzed microscopically and photomicrographic records were kept of the type and extent of abrasive damage observed. A spun nylon fabric of a plain weave with a two-ply warp yarn and a single-ply filling yarn was used. Samples from each of the ten unabraded and abraded levels were evaluated and rated according to the amount of surface napping, yarn erosion and yarn slippage. The ratings given in the following discussion and in Table V are the means of the visual observations based on the scale in Table IV. Photomicrographs, using five power and ten power objectives, were taken of samples from each level to assist in recognizing the effect of varying abrasion intensities.

There was little detrius or lint removed from the nylon fabric during abrasion that otherwise would have intensified the stress of abrasion and caused early breakdown. Some difficulty was experienced in attempting to focus the microscope clearly on the yarn structure because of its thickness, twist and crimp. This problem was intensified as the amount of abrasion increased. In all cases, surface evaluation was made while the microscope was focused on the top of the crown rather than on the interlacing point.

According to the overall project, level thirteen was unabraded so it will be discussed first. Levels one and two; three and four; five and six; and seven, eight and nine are grouped for discussion according to the amount of pressure applied (Table III).

TABLE V

SURFACE EVALUATION OF UNABRADED AND ABRADED FABRICS*

Abrasion Level	Surface Napping	Yarn Slippage	Yarn Erosion
13	12.0	4.0	5.0
1	10.2	3.8	4.8
2	9.2	3.3	4.3
3	8.5	3.0	4.0
4	8.4	3.0	3.9
5	7.6	2.4	3.0
6	6.6	2.7	3.0
7	6.2	2.6	2.9
8	6.1	2.6	2.5
9	6.7	2.7	2.1

*Surface Evaluation Scale Table IV

Level Thirteen

There was considerable variation in the size of both the warp and the filling yarns as seen in the photomicrograph of the unabraded level (Plate I, Fig. 1). The filling appeared to be smaller in diameter and more tightly twisted than the warp. It had fewer loose fibers on the yarn surface and did not fill the interstices, or spaces between the yarns, to the extent of the warp yarns. The two-ply construction of the warp yarns was more visible in some instances than in others. The warp seemed to be in groups of two, making the interstices smaller between these than between the groups of such yarns (Plate I, Fig. 1; Plate I, Fig. 2). This may be attributed to the way in which the warp was set up in the loom.

The surface evaluation of the unabraded fabric was rated as negligible or none for surface napping, yarn slippage and yarn erosion. A few fiber ends were visible but most of the nap at this stage was attributed to raised fibers whose ends were not exposed. The size of the interstices varied considerably within the samples as some were partially filled with spreading yarns and loose fibers, while others had none. Yarn slippage was negligible as there were few spreading yarns in the interstices. The warp yarns tended to fill the interstices to a greater extent than the filling yarns (Plate I, Fig. 1). Yarn erosion was at a minimum as there were few loose or tangled fibers. The surface of the fabric exhibited no consistent pattern of location, concentration, length or direction of loose fibers.

Levels One and Two

Samples from level one (1 pound, 1,000 revolutions) and level two (1 pound, 5,000 revolutions) showed considerable increase in surface nap

EXPLANATION OF PLATE I

Photomicrographs of Unabraded Level Thirteen

Fig. 1. Magnification 12.5 times.

Fig. 2. Magnification 25 times.

PLATE I

Fig. 1

Fig. 2

over the unabraded level thirteen. The added pressure and revolutions applied to level one specimens showed proportionately a greater increase in surface nap than the same pressure, but added revolutions applied to level two. However, the surface nap of level one was rated 10.2 (negligible) as compared to 9.2 (slight) of level two.

The height of the nap varied considerably within the samples of both levels yet when averaged there was little difference noted between the samples. Although the height was increased, the nap consisted of few fibers so was quite thin, particularly in level one. It was noted that few fiber ends were exposed in level one; thus, surface nap was evaluated when the highest length of the raised fiber was in focus. This was less common in level two where more fiber ends were visible. The surface nap seemed to be in layers in several instances, thus readings were taken when the uppermost layer was reached.

There was a small amount of yarn slippage in level one but a considerable increase was noted in level two. Despite this difference, yarn slippage was slight as these levels had ratings of 3.8 and 3.3 respectively. A few more loose fibers were noted in the interstices but there were few spreading yarns (Plate II, Fig. 3; Plate II, Fig. 5). The majority of the loose fibers seemed to be displaced upwards, increasing the surface nap, rather than outwards into the interstices. The smaller spaces between two warp yarns were filled more than the spaces between the groups of warp yarns (Plate II, Fig. 3; Plate II, Fig. 4). There was little slippage noted with the filling yarns.

A corresponding proportion was noted in the yarn erosion evaluation of the two levels. Level one was rated 4.8 (one-quarter worn) and level two 4.3 (one-quarter worn). There was therefore a greater difference between

EXPLANATION OF PLATE II

Photomicrographs of Abraded Levels One and Two

Fig. 3. Abrasion Level 1. (Magnification 12.5 times)

Fig. 4. Abrasion Level 1. (Magnification 25 times)

Fig. 5. Abrasion Level 2. (Magnification 12.5 times)

Fig. 6. Abrasion Level 2. (Magnification 25 times)

PLATE II

Fig. 3

Fig. 4

Fig. 5

Fig. 6

level one and level two than between level thirteen and level one. Level one showed a slight increase in loose fibers that was intensified in level two. These loose fibers tended to be concentrated on top of the crown rather than on the interlacing. Tangling became noticeable in some areas of several samples as well as slight loss of twist as shown in the photomicrograph (Plate II, Fig. 5). The thicker yarns of the warp and some filling showed a tendency to be more damaged than the thinner yarns. The two-ply construction of the warp yarns was less visible in some instances (Plate II, Fig. 6).

It was noted that as the amount of yarn slippage increased so did the amount of yarn erosion. A possible explanation is that slippage decreased the cohesiveness of the fibers within the yarn, thus allowing more fibers to be displaced from the structure. Increased tangling and loss of twist were subsequently noted.

Levels Three and Four

Increased pressure resulted in additional damage to levels three (3 pounds, 5,000 revolutions) and four (3 pounds, 10,000 revolutions) specimens. However, there was a negligible difference between these levels as shown by their surface evaluation ratings.

Surface nap was evaluated slight in both levels as ratings were 8.5 and 8.4. Some areas of the specimens had moderate and high ratings but these were averaged to slight by areas having negligible surface nap. There was an increased concentration of loose fibers directly above the surface of the yarn structure making a thick nap. However, a few fibers did project farther up and it was these that were taken as an indication of the total nap height. The many loose fibers close to the surface in some areas made it more difficult to clearly discern the yarn structure as it gave it a "foggy" appearance. Layering was again noted in some instances.

Both levels had the same rating of 3.0 (slight) for yarn slippage. There was a small increase in the occurrence of yarn spreading and loose fibers filling the interstices, as seen in the photomicrographs (Plate III, Fig. 7; Plate III, Fig. 9). The spaces between the groups of two warp yarns had a tendency to be filled with spreading yarns and loose fibers (Plate III, Fig. 10). Warp yarns were spread more than filling (Plate III, Fig. 8). When the yarn slippage rating increased due to many loose fibers in the interstices, there was an increased tendency for these to tangle which in turn raised the yarn erosion rating.

Some areas appeared the same as the unabraded specimens in yarn erosion, while other areas had considerable loss of twist and tangled ends. The overall yarn erosion of levels three and four, however, was rated 4.0 and 3.9 (one-quarter worn) respectively.

Levels Five and Six

Surface napping, yarn slippage and yarn erosion increased in level five (5 pounds, 10,000 revolutions) and level six (5 pounds, 15,000 revolutions) with added pressure and number of revolutions.

The rating given surface nap of level five was 7.6 (slight) as compared to 6.6 (moderate) for level six. Considerable variation in nap height was noted between samples as well as areas within the samples. Increased thickness, particularly in level six, was noted but this was not necessarily accompanied by an increased nap height.

Yarn spreading, especially of the thicker yarns, increased in level five. The interstices were approximately half filled with spreading yarns and fibers (Plate IV, Fig. 11, Plate IV, Fig. 12). Yarn slippage decreased in level six as shown by its rating of 2.7 (moderate). There were many loose fibers but the interstices were not filled to the same extent (Plate IV, Fig. 13).

EXPLANATION OF PLATE III

Photomicrographs of Abraded Levels Three and Four

Fig. 7. Abrasion Level 3. (Magnification 12.5 times)

Fig. 8. Abrasion Level 3. (Magnification 25 times)

Fig. 9. Abrasion Level 4. (Magnification 12.5 times)

Fig. 10. Abrasion Level 4. (Magnification 25 times)

PLATE III

Fig. 7

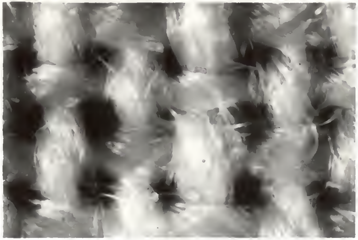


Fig. 8

Fig. 9

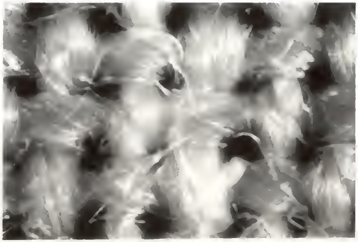


Fig. 10

EXPLANATION OF PLATE IV

Photomicrographs of Abraded Levels Five and Six

Fig. 11. Abrasion Level 5. (Magnification 12.5 times)

Fig. 12. Abrasion Level 5. (Magnification 25 times)

Fig. 13. Abrasion Level 6. (Magnification 12.5 times)

Fig. 14. Abrasion Level 6. (Magnification 25 times)

PLATE IV

Fig. 11

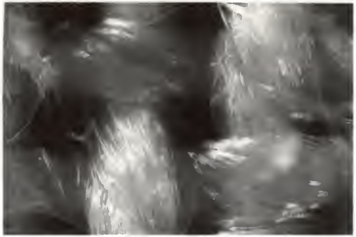


Fig. 12

Fig. 13

Fig. 14

Yarn erosion for both levels was rated 3.0 (one-half worn). There were considerably more fibers pulled loose which filled the interstices, increased the surface nap and increased the amount of tangling (Plate IV, Fig. 12; Plate IV, Fig. 14). Some yarns, particularly the warp, were losing their twist.

Some samples experienced greater damage than others. The samples that had more severe yarn slippage also tended to have more severe yarn erosion although the surface nap was not necessarily higher and/or thicker.

Levels Seven, Eight and Nine

Intensities added to level seven (10 pounds, 10,000 revolutions), level eight (10 pounds, 15,000 revolutions) and level nine (10 pounds, 20,000 revolutions) resulted in an increase in surface napping and yarn erosion. Little change was noted in the degree of yarn slippage.

The surface nap of levels seven and eight were similar as they had ratings of 6.2 and 6.1 (moderate) respectively. However, the height decreased in level nine as shown by its rating of 6.7 (moderate). In some instances the nap was thick and close to the surface while in others it was thin but tended to be spread out in layers giving height rather than thickness. When the nap was thick and close to the surface it was more difficult to identify the type and extent of yarn damage. There was considerable variation within the sample areas but the samples as a whole were quite consistent.

Yarn slippage remained at approximately 2.6 (moderate) for these three levels. There was some increase in yarn spreading and loose fibers in the interstices (Plate V, Fig. 17; Plate VI, Fig. 20). When yarn spread was more common than loose fibers, yarn erosion was less because there were fewer loose fibers to become tangled (Plate V, Fig. 16; Plate V, Fig. 17).

EXPLANATION OF PLATE V

Photomicrographs of Abraded Levels Seven and Eight

Fig. 15. Abrasion Level 7. (Magnification 12.5 times)

Fig. 16. Abrasion Level 7. (Magnification 25 times)

Fig. 17. Abrasion Level 8. (Magnification 12.5 times)

Fig. 18. Abrasion Level 8. (Magnification 25 times)

PLATE V

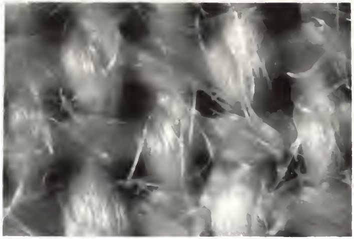


Fig. 15

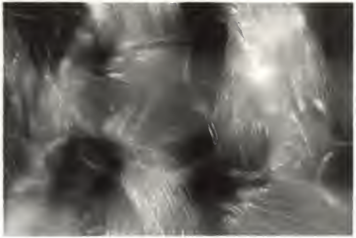


Fig. 16

Fig. 17

Fig. 18

EXPLANATION OF PLATE VI

Photomicrographs of Abraded Level Nine

Fig. 19. Magnification 12.5 times.

Fig. 20. Magnification 25 times.

PLATE VI

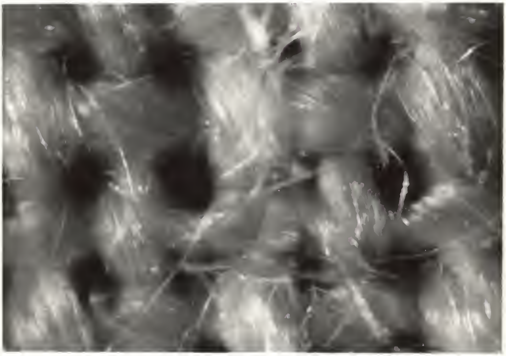


Fig. 19

Fig. 20

Considerable variation in yarn erosion was noted. Level seven was rated 2.9 (one-half worn), level eight 2.5 (approximately three-quarters worn) and level nine 2.1 (three-quarters worn). In level seven there was some loss of twist and the ply of the warp yarns became less distinctive (Plate V, Fig. 15). This was increased in level eight where many loose fibers, tangling and loss of twist were common (Plate V, Fig. 17; Plate V, Fig. 18). The amount of yarn erosion was increased in level nine but in no areas within the samples was the yarn completely worn away. There were many loose fibers, loss of twist and tangled ends noted yet the yarns were still intact (Plate VI, Fig. 19).

CHAPTER V

SUMMARY AND RECOMMENDATIONS

This study was designed to determine by microscopic analysis the effects of progressive abrasive action on selected nylon fabric. Abrasion levels were established by varying the amount of pressure and number of revolutions using the Schiefer Abrader. The surface of the specimens were evaluated according to a scale as to the degree of surface napping, yarn slippage, and yarn erosion. Photomicrographic records were kept to aid in determining the type and extent of abrasive damage observed.

Microscopic examination of the unabraded specimens revealed a variation in the diameter of the yarns and degree of twist. The warp yarns tended to be thicker and less tightly twisted than the filling yarns although discrepencies were noted here also. The interstices were slightly filled with loose fibers and spreading yarns, particularly those between the warp yarns. This may be the result of the difference in the amount of twist of the warp and the filling yarns.

As abrasion progressed, the outer layers of fibers from the yarns were loosened and pulled to the surface of the fabric which caused some difficulty when focusing the microscope on the yarn structure as the surface nap was high and thick. The greatest increase in surface nap height was experienced at level one when both pressure and number of revolutions were added to the specimens. It should be noted however, that the extent of surface napping at this point was still rated as slight despite this considerable increase. Generally there was a greater increase in surface nap with added revolutions although this was not true in all cases. Backer and Tanenhaus (3) suggested that added pressure increased the penetration of the abradant into the fabric resulting in cutting and slippage. However, increasing the number of revolutions also added to the stress produced. The long cycles prevented the specimens from recovering as easily from the added stress; thus, abrasion resistance decreased as the number of revolutions increased. As the extent of abrasion intensity increased to level nine there was a progressive increase in the height and thickness of the surface nap. However, at this point the height was decreased to the same as was noted in level six. A possible explanation for this is that the yarns packed with the increased pressure and revolutions thus preventing the fibers from being displaced as easily. Another explanation is that shearing of the fibers may have occurred which would account for the decreased surface nap.

Yarn slippage, identified by loose fibers and spreading yarns in the interstices, increased with added pressure and number of revolutions up to level five. At this point, the degree of slippage decreased and remained relatively constant up to and through level nine despite added pressure and increased number of revolutions. It would appear that the yarns could only spread to a certain extent after which they remained constant. Loose fibers were displaced to the surface of the fabric as indicated by the increased surface nap height and thickness.

Yarn erosion increased steadily throughout all levels of abrasion but was more affected by increased pressure than by increased number of revolutions. The explanation for this is the same as that given for the effect of increased pressure on surface napping. The loose fibers tended to tangle and the yarns began to lose their twist. This was most noticeable in the warp yarns which, as already stated, were less tightly twisted.

The abrasive intensities applied to the nylon fabric was the basis for evaluating the type and extent of yarn and fabric damage. Surface nap and yarn slippage were rated moderate, while yarn erosion evaluations of the fabric indicated that it was three-quarters worn.

A future study of the effect of varying abrasion intensities on the surface of this fabric could be done using an abrading instrument that combined flat, flex and edge abrasion. Color photomicrographs would be useful in illustrating fiber as well as fabric and yarn damage.

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MICROSCOPIC EVALUATION OF THE SURFACE OF SELECTED NYLON FABRIC BEFORE AND AFTER ABRASION

by

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B. Sc., University of Alberta, 1966

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

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Manhattan, Kansas

1967

This study was designed to determine the effects of flat abrasive wear on the surface of a selected nylon fabric by microscopic analysis, and to compare the type and extent of yarn and fabric damage of the unabraded specimens with the specimens abraded at varying intensities. Abrasion levels were established by combining different pressures and number of revolutions of the Schiefer Abrader. The surface of each specimen was examined under the microscope, and evaluated as to its degree of surface napping, yarn slippage and yarn erosion. Photomicrographs of representative areas from each group of specimens were taken to aid in determining the effects of progressive abrasion.

The degree of surface napping, yarn slippage and yarn erosion increased with added abrasive intensity. Increased pressure tended to cause more damage than increased number of revolutions. Surface nap height was raised to a rating of moderate after which it began to decrease. Yarn slippage increased to moderate at level six (5 pounds, 15,000 revolutions) and remained constant with added abrasion. The degree of yarn erosion increased steadily throughout all abrasion intensities.

The outer layers of fibers in the yarns loosened and pulled away from the yarns as abrasion progressed, resulting in an increased surface nap height that was often in layers. Yarn slippage increased if these fibers filled the interstices, rather than being raised to the surface, or if the yarns spread. Warp yarns, which were thicker and had less twist than the filling, spread more than the filling yarns. As the number of loose fibers increased there was a loss of twist, particularly of the warp yarns, and increased tangling on the surface of the yarns.

Although the overall extent of damage did increase with added abrasive intensity, at no point was the yarn structure completely destroyed. Further research is necessary to substantiate these findings.