EFFECT OF VARIOUS TYPES OF ABRASION ON THE BREAKING STRENGTH AND ELONGATION OF SELECTED COTTON AND NYLON FABRICS

by

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CHAPTER I

INTRODUCTION

Attempts to determine "wearability" of a fabric in the textile laboratory have led to the development of more types of abraders than any other textile testing apparatus. It is still not possible to predict accurately from laboratory data how a fabric will perform in actual wear because wear characteristics depend on end use and care of the fabric. Abrasion and wear cannot be used interchangeably. Abrasion is a rubbing action involving relative motion between one material and another. Wear is the effect of all types of deterioration (mechanical and chemical). Abrasion is just one factor affecting wear, but salvage (service-worn) studies show that abrasion is a major cause of failure (Kaswell, 13).

In actual wear a fabric is subjected to several types of abrasion, but the two most often encountered are flat and flex abrasion (McNally and McCord, 18). No one abrader can produce all types of abrasion encountered in wear. A more accurate measure of abrasion resistance of a fabric would be to abrade the same fabric on several different abraders, then evaluate the abraded fabric specimens for the same physical characteristics. Numerous studies have been conducted to observe physical characteristics of fabrics after one type of abrasion, but very little has been done in testing the same fabric on several different abraders. A study by Kaswell (14) on two types of abraders showed that no simple relationship existed between the two types of abrasion. It should not be said that X cycles on one abrader were equivalent to Y cycles on the other.

A wide variety of abrasion testers are found in textiles laboratories today. McNally and McCord (18) found those most commonly used are: Accelerotor, Schiefer, Stoll, Taber, U. S. Testing Company Abrader, and Wyzenbeck.

A common method for evaluating fabrics for damage after abrasion is through changes in breaking strength and elongation (Kaswell, 15). Both measures are reasonably sensitive and are proportional to the work done on the fabric (Hamburger, 12). By observing changes in breaking strength and elongation for different amounts of stress on the same instrument, and on different instruments, the effect of different types and amounts of abrasion on a fabric may be studied. Lack of recent research in the literature indicates there is a definite need for more study in this area. The objectives of this study were:

1. To determine the breaking strength and elongation of a cotton and a nylon fabric after various levels of abrasion with three types of abraders.
2. To observe the amount of stress necessary to produce a noticeable change in strength and elongation for each type of abrader.
3. To evaluate the changes in strength and elongation of a cotton and a nylon fabric after various levels of abrasion.

CHAPTER II

REVIEW OF LITERATURE

Abrasion resistance is the degree to which a fabric is able to withstand surface wear and rubbing (Kaswell, 15). The question of whether to evaluate a fabric on the results of laboratory abrasion or to try to imitate wear in order to predict the serviceability of a fabric is one which has frustrated textile scientists for many years. Because a fabric is subject to so many types of wear according to its end use, Ball (6) states that there is no such thing as a "standard wear test." For this reason, laboratory instruments are designed to reproduce the influences that are accountable for the major portion of total fabric destruction during wear. Abrasion is the most important single factor in wear, and textile scientists concern themselves mainly with abrasion in the laboratory (Kaswell, 15). There is a difference between performing tests to make predictions about a fabric and attempting to imitate actual wear in the laboratory. The purpose of laboratory testing is not to predict serviceability, but to determine and compare various fabric characteristics. Validity of abrasion results should not depend on their imitative accuracy, but on intelligent interpretation based on empirical comparisons with service wear (Pierce, 19).

McNally and McCord (18) cited several problems that must be considered in evaluating laboratory tests: (a) accelerated tests require that the rate of destruction be much higher than it would be in actual wear, (b) the nature of abrading action may not be what is actually encountered in wear. For example, the cutting action produced by abrasive paper is rarely found in wear, (c) abrasion is only one of a whole complex of factors involved in the wear of a fabric. Zook (27) pointed out that attempts to compare laboratory tests with actual wear are further complicated by many personal factors involved in service wear, such as extent of perspiration; size, weight, and occupation of the wearer; climate; cleaning methods; and an infinite number of mechanical factors.

Abrasion resistance in the laboratory is determined by recording the amount of action necessary to produce a certain amount of damage. The higher the ratio of abrading action to damage, the better the abrasion resistance of the fabric. In order to produce abraders that will give a valid indication of fabric performance, the factors affecting abrasion must first be determined. Although many studies have measured abrasion resistance of fabrics, attempts to find the basic causes of failure have been few. Backer and Tanenhaus (5) determined that abrasion resistance of a fabric depends on its energy absorbing and releasing qualities. When stress is applied to a fabric, the fabric will resist destruction only as long as it is able to absorb the energy imparted to it and release this energy upon removal of the stress. During its wear life, a fabric is not designed to resist a single stress application of high magnitude, but rather it is designed for long use, being subjected to repeated application and removal of low stresses. These may include bending, twisting, tension or compression. Physical properties of a fabric determine its ability to absorb and release energy. One of the basic properties for high abrasion resistance is good elasticity—that is, the ability of a fabric to return to its original configuration after being deformed by stress application (Hamburger, 12). Kaswell (15) agreed that good elasticity is one reason why nylon is so resistant to abrasion, and that cotton is less elastic, and has only moderate abrasion resistance.

The type of fiber is an inherent factor affecting abrasion. Yarn size, twist, diameter, fabric weave, yarn count are non-inherent qualities of a fabric that help determine its abrasion resistance. Kaswell (13) referred to those qualities as "form factors" that ultimately govern the elastic behavior of a fabric. Abrams and Whitten (2) showed that because of greater fiber cohesion, higher twist yarns and plyed yarns have greater abrasion resistance. Thicker yarns also have greater resistance, although this effect is more pronounced with flat than with flex abrasion (McNally and McCord, 18). Resistance usually is improved by increasing the threads per inch because of better distribution of the stresses, up to the point where the increased number of threads makes the fabric less flexible. Backer and Tanenhaus (5) explained that fabric weave has the effect of improving abrasion resistance as the crowns (intersection of warp and filling yarns) per square inch are increased, thus reducing the normal load per warp crown. This means if all other factors are equal, plain weave fabrics will have better resistance than twills or satins. Abrasion resistance can also be improved by equalizing crown heights in the warp and filling directions, giving a higher cover factor (more geometric area of contact between fabric and abradant).

A series of field service studies by the Quartermaster Corps (Stoll, 24) indicated that fabric destruction and disintegration may be roughly divided into: 30 per cent plane (flat), 20 per cent flex (bending), 20 per cent edge, 20 per cent tear, and 10 per cent other factors. The relative importance may be different because of individual fiber properties. Even microscopically it is sometimes difficult to decide exactly the factors contributing to any given wear.

The nature of the abrading surface and conditions determine how severe, and what type of damage is done in each situation. Abrasive action is determined by the cohesion between abrasive and fiber, between fibers, and between structural parts of each fiber. McNally and McCord (18) found that in flat abrasion the fabric may encounter: (a) frictional wear--rubbing against a smooth foreign surface, (b) cutting--when the projections on the abrading surface are small compared to the fiber diameter, and (c) plucking--when surface projections are large compared to the fiber diameter. Backer (4) stated that when fabrics are flexed (bent back and forth), abrasion is a result of internal friction--fiber against fiber and yarn against yarn.

With any type of laboratory abrasion, the results are sensitive to general test conditions, nature of motion between fabric and abradant, nature of abradant, pressure and tension on the specimen, removal of debris during testing, and method of evaluation of abrasion damage. Since abrasive power of most abradants decreases with use, a consistent pattern of changing abradants must also be considered (McNally and McCord, 18).

Both wear and abrasion studies have indicated that abrasion resistance measured on one specific abrader involving one type of abrading action is not sufficient for evaluation of a fabric. Because of the numerous and different abraders in use, there are no standard abrasion test specifications or minimum requirements for resistance to abrasion. Weiner and Pope (26) attempted to compare results on different abraders and set up correlation coefficients in order to make predictions about a fabric. Generally studies of this type have not met with much success, probably because of lack of standardization of the procedures used, and because different properties of the fabric are measured with each abrader (Zook, 27). Mann (17) used five different abraders on two knit fabrics and found that the fabric superior on one type of abrader was not necessarily superior on another type, depending on its mechanical action. Results also varied greatly depending on the direction and pressure of the rubbing action. Schiefer and Werntz (21) used the Schiefer abrader with two different abradants: (a) a spring steel abradant, and (b) a silicon carbide abrasive paper, on sixteen cotton fabrics. They found that the fabric rankings with the two abradants were quite different. This difference was attributed to the fact that the rate of destruction with one abradant was about ten times as rapid as that of the other. The authors suggested that this same discrepency occurs between accelerated laboratory tests and slow abrasion in actual wear.

Results using the same type of abrader in different laboratories have varied. A study conducted in seven laboratories using the Accelerotor abrader showed excellent agreement among laboratories in ranking three classes of cotton and rayon fabrics according to percentage weight loss after abrasion (Cooke, 7). It was pointed out in the Final Report on Interlaboratory Abrasion Tests (10) that in a study using nine different abraders, a wide variation in results occurred among the laboratories using the same abraders. The main cause of variation was probably because of different estimates of endpoint, both visual and physical. Also differences may have occurred with pressure, abrasive and fabric.

There is still not sufficient information about abrasion and wear to determine which type of abrasion testing to use in the laboratory. Until there is more evidence in favor of one type, a wide variety of abraders will continue to be used.

Types of Abraders

The Accelerotor, the Schiefer and the Stoll are among the most common abraders found in textile laboratories. They give different types of abrasion in various combinations of both flex and flat abrasion.

Accelerotor. This instrument is designed with a small chamber in which there is a metal impeller (rotor) revolving at high, controllable speeds ranging from 1000 to 8000 revolutions per minute. The fabric is tossed around inside the chamber, against the rotor, against the chamber wall and against itself, encountering both flat and flex abrasion. With this type of action the fabric is subject to shock, compression, tension, flexing, rubbing, scuffing and stretching--producing abrasion of fiber against fiber, yarn against yarn, fabric against metal or abradant. The rotor blades are pitched to cause the specimen to zig zag around the chamber. The fabric motion is random, meaning the sample is free to move in any direction (AATCC, 1). Steigler (23) believes the stresses and strains of the surface contact to which the fabric is subjected during abrasion are similar to those effects in end-use wear. The Accelerotor is versatile in that the action may be varied in several ways: changing rotor speed, varying the length of the rotor as well as its shape, and varying the amount of time a specimen is subjected to abrasion. Also, grit liners, which give a cutting or plucking action or no-grit liners, which give merely a frictional action, may be used in the Accelerotor.

Studies conducted with the Accelerotor (Cooke, 7 and Steigler, 23) have shown it to be simple to operate, speedy, accurate and reproducible. In Cooke's (7) study involving seven laboratories, tests were run on similar fabrics at both controlled and uncontrolled speeds for specified lengths of time, using both grit and no-grit liners. The results were in excellent agreement, with only one of the laboratories being significantly different from the other six in evaluating percentage weight loss after abrasion. They also found no significant difference in results when the fabrics were run in different order in the abrader, showing that the efficiency of the liners was not worn down with each successive test. The study by Steigler (23) on army trousers showed that after abrasion in the Accelerotor for 3-4 minutes, fabric specimen resembled army trousers worn for two years.

In addition to regular dry abrasion tests, the Accelerotor is designed to do wet abrasion, edge abrasion, and abrasion due to laundering. Various types of abrasion and flexing can produce with great rapidity and reproducibility the effects of slow-moving forces encountered in wear, laundering and dry cleaning over a long period of time. The tests can detect with good precision small differences in mechanical abrasion resistance among fabric samples (Cooke, 7).

Schiefer. The development of this abrader was based on a mathematical approach to abrasion. The action is produced by rotation of both abradant and specimen at slightly different angular velocities. These axes of rotation are separate but parallel, and the abradant surface is sufficiently larger than that of the specimen so that the entire surface of the specimen is in contact with some portion of the abradant at all times. The result is that with each rotation of the two surfaces, every point of the specimen is abraded equally in all directions, and comes in contact with a different portion of the abradant (ASTM, 3). Schiefer (20) stated that this eliminates the factor of non-uniformity of the abradant. A study by Schiefer and Werntz (21) using this abrader showed that not only is the abradant constant for each test, but the results are consistent even after several million revolutions with the same abradant.

The Schiefer abrader provides a sensitive means for studying the influence of factors involved in abrasion resistance with a flat, multidirectional action. The settings of the instrument, method of mounting the specimen, conditions of the test (dry, wet), and criteria to be used in evaluating abrasive wear depend on the nature of the specimen tested, and the use to be made of the results (Schiefer, 20). It clearly states in ASTM (3) that the abrasive action of this instrument is by no means meant to imitate any actual wear situation but is for research purposes only. However, results show that abrasion resistance of similar fabrics are often useful in evaluating fabric serviceability for a specific end use.

Stoll. Abrasion with the Stoll Inflated Diaphragm Abrader is flat and multidirectional, using an emery-type abradant with the grains of the emery smaller than the width of the fibers. Stoll (24) explained that this abradant has the tendency to break up the cohesion of the fibers rather than snag or cut them.

The fabric specimen is inflated over a rubber diaphragm under a specified pressure, controlled between 0 and 6.0 psi. A controlled air pressure in the diaphragm produces uniform contact between fabric and abradant by flattening the balloon-shaped inflated sample an equal amount each time. This balloon-shape also helps eliminate much of the problem of removal of debris during testing. The diaphragm moves back and forth as it turns slowly, giving the multidirectional action. Each double stroke of the abrader is a cycle, and the machine automatically counts these cycles on an attached counter. It also is equipped with a timer that stops the abrader after a certain set period of time. The end point may be determined by: (a) destruction of the fabric (forming a hole), (b) abrasion for a certain period of time, (c) abrasion for a set number of cycles (ASTM, 3). This abrader is also designed with a special apparatus to produce flex abrasion.

Studies by Stoll (24) of fabric before and after abrasion on the Stoll abrader have shown that surface appearance and microscopic appearance show damage similar to the damage of fabrics after abrasion during wear.

Evaluation of Abrasion

A major problem of laboratory abrasion is the interpretation of results. An accurate measure of abrasion depends greatly on how the resistance is evaluated. In deciding how best to evaluate a fabric after abrasion, possible end uses of the fabric must be taken into consideration. For example, in dressy, sheer fabrics, a visual evaluation might be the most meaningful; whereas for heavy cotton fabrics used in work clothes, tensile and tear tests would probably be better. Hamburger (12) stated that the method of evaluation must be sensitive to changes in the amount of abrasion, and should be proportional to the work done on the fabric.

There are many different ways in which a fabric can be evaluated for the effect of abrasion. Among the most commonly used are: end point destruction, surface appearance, changes in weight or thickness, air permeability, tear strength, breaking strength, and elongation. All of these methods of evaluation have some disadvantages but Kaswell (15) stated that most textile scientists agree that the least objectionable measure of change is breaking strength before and after abrasion. Zook (27) pointed out that selection of just one end point is undesirable since the rate at which a sample has proceeded to destruction cannot be determined. Also, this end point is often difficult to define or reproduce. By measuring the strength loss after various cycles or levels of abrasion, the rate of destruction can be depicted.

Breaking strength. This measurement (sometimes referred to as tensile strength) is the ability of fibers, yarns and fabrics to resist rupture by means of tension. Strength tests are useful as a measure of uniformity--since any physical or chemical change in a fabric nearly always will result in a change in strength. They are of no imitative value since in wear fabrics are not subject to steady increasing forces, but to a repeated series of abrasions and stresses (Kaswell, 15). Kaswell's (14) laboratory evaluation of military fabrics indicated that reduction in breaking strength provided the best and most accurate criterion for measuring extent of abrasive damage. Stout and Moseman (25) studied fifty-eight clothing fabrics before and after abrasion and found that nearly all the fabrics decreased in breaking strength with increasing abrasion.

The measure of strength is a measure of the weakest fibers of a fabric. For this reason there may be wide variation between high and low values reported, especially for the natural fibers where fiber quality is less controllable than with man-mades. Edelman (9) found that another cause of wide variation in the measurement of breaking strength might be in the skill of the operator. He found that operators who performed breaking strength tests daily obtained more consistent results than those who performed the test only occasionally. In relation to jaw breaks, he found no consistent differences between skilled and unskilled operators, possibly because this factor may depend on the tightness of the jaw, which even a skilled operator cannot always control.

Elongation. Another indicator of change in a fabric brought about by abrasion is elongation. It is the amount of deformation caused by a tensile force, expressed in terms of its original length, usually in per cent (ASTM, 3). Recorded jaw separation at the time of tensile testing is taken as a direct measure of the fabrics elongation. There may be slight elongation of the specimen held in each jaw called "jaw penetration," making the original gauge slightly higher, and the true elongation slightly less, but this error is negligible and usually is ignored in calculation (ASTM, 3).

Elongation is affected by fiber, yarn, and fabric structure. Fabrics with greater elasticity will have higher elongation. It also varies with physical test conditions (wet or dry) (Kaswell, 15). Physical or chemical changes in a fabric usually have a direct effect on fabric elongation. Stout and Moseman (25) found that elongation, along with breaking strength was a consistent indicator of changes in a fabric after abrasion and showed decreased elongation with few exceptions. They found that an increase or decrease in strength did not necessarily mean the same would happen with the elongation, even on the same specimen. Lohr (16) and Douglas (8) also found that cotton fabrics decreased in strength with increased abrasion, but at the same time, elongation increased with additional amounts of abrasion.

CHAPTER III

METHOD OF PROCEDURE

This study was part of the larger North Central Regional Project, NC 68, "Mechanisms of Fabric Stress Absorption and Performance." The cotton and nylon fabrics used were specially produced for that project by Testfabrics, Inc. to have similar weight, construction and yarn size. Both the cotton and nylon fabrics had a single filling yarn and a two-ply warp yarn. Both fabrics were plain weave, weighing about 3.9 oz/sq yd.

Sampling Plan

The sampling plan used for the NC 68 project was a randomized block. The blocks (numbered I-V) were each divided into six areas (A to F) and each area was divided into samples according to the size needed for testing on each type of abrader. The areas for Accelerotor abrasion were divided into sixteen 6 1/4 x 6 1/4 inch samples; for Schiefer abrasion the areas were divided into sixty-six 5- x 5-inch samples; for Stoll abrasion, there were forty-four 4- x 4-inch samples. These samples were cut from the areas avoiding slubs within the areas to be abraded. Assignment of abrasion levels and test to be done on a particular sample were obtained from an IBM randomized sheet sent to each abrading station. Warp breaking strength and elongation specimens were taken from areas A, C, and E; filling tests were taken from areas B, D, and F.

All samples were labeled on the fabric face with abrading station, fiber, block, area, sample number and abrasion level. For example a sample labeled: 4 C I B 15--3 was: Station 4, Cotton, Block I, Area B, Sample 15, Level 3.

Abrasion

All fabrics were abraded in standard atmosphere (70°F, 65% r.h.) at seven stations using three Accelerotor abraders (Stations 1--Indiana, 2--Ohio, and 3--Missouri), two Schiefer abraders (Stations 4--Kansas and 5--South Dakota), and two Stoll Inflated Diaphragm abraders (Stations 6--Minnesota and 7--Wisconsin). The fabrics were abraded at nine different levels from level one with almost no abrasion to level nine at near destruction. Intermediate levels of abrasion were established by varying amount of pressure, type of abradant, and abrasion time. Level zero was the unabraded fabric used for control. The amount of abrasion at each level for each type of abrader was determined in pilot work by the stations using the same type of abrader.

Such variables as atmospheric conditions, abrading procedures, end points for each level with a particular type of abrader, and the fabric itself were controlled as much as possible. Differences in abraders, natural differences in various parts of the fabric, and different techniques of the operators were variables that could not be controlled. By using the same procedures for like abraders, results could be compared for similarity. Since the fabrics were woven at the same place, the effects of different types and amounts of abrasion on each fabric could be analyzed.

Accelerotor. The accelerotor abrader was used according to the procedure outlined in AATCC Accelerotor Method 93-1959 (AATCC, 1). All samples were run at 3000 rpm using various combinations of rotation time and two different types of liners (plastic and #250 grit paper). Each liner was discarded after a total abrasion time of thirty minutes, reversing the collar from front to back after every fifteen minutes of abrasion. A four and one-half inch rotary blade with a 15^{o} pitch was used in the chamber. Fifteen 6-inch by 6-inch square specimens were abraded at each level as follows:

	COTTON		NYLON	
Level	Minutes	Liner	Minutes	Liner
1	1	plastic	1	plastic
2	3	plastic	3	plastic
3	10	plastic	30	plastic
4	30	plastic	1	#250 grit
5	1	#250 grit	3	#250 grit
6	2	#250 grit	7	#250 grit
7	3	#250 grit	15	#250 grit
8	7	#250 grit	30	#250 grit
9	15	#250 grit	45	#250 grit

Schiefer. Two stations used the Schiefer abrader according to Uniform Abrasion Testing Machine Method ASTM D 1175-E 64T, with the following exceptions: (1) A counter-weight was placed on the back of the tester to counter-balance the weights used, (2) No specimens were abraded to destruction, but rather to a specified number of revolutions at each level, as determined by the pilot work. Samples that reached destruction before the specified number of revolutions were discarded, and replacements were used. The samples were abraded with a spring steel abradant using various combinations of weight (one, three, five and ten pounds) and number of revolutions. The specimens were mounted with a template on a 1.5-inch plastic disc to insure equal tension on each specimen. Fifteen 3.8-inch circular specimens were abraded at each level as follows:

	COTTON		NYLON	
Level	Head Pressure in Pounds	Cycles	Head Pressure in Pounds	Cycles
1	1	25	1	1,000
2	1	300	1	5,000
3	3	50	3	5,000
4	3	500	3	10,000
5	5	100	5	10,000
6	5	300	5	15,000
7	5	500	10	10,000
8	5	700	10	15,000
9	5	1,000	10	20,000

Stoll. Two stations used the Stoll Inflated Diaphragm abrader according to Inflated Diaphraghm Method ASTM D 1175-64T. The mounted specimens were inflated over a diaphragm under a controlled pressure of 4 psi throughout the testing. A vertical load of one pound, using #0 emery paper was brought into contact with the inflated diaphragm and allowed to reach equilibrium before abrasion. Levels varied only according to number of cycles abraded. The circular specimen holder made a reciprocal of motion of 125 ± 5 double strokes per minute while completing one revolution in a maximum of 100 strokes--giving multidirectional abrasion on a circular abraded area one inch in diameter. Ten 4-inch circular specimens were abraded at each level as follows:

Level	COTTON Double Strokes	NYLON Double Strokes
1	10	20
2	20	40
3	30	60
4	40	80
5	50	100
6	60	150
7	70	200
8	80	300
9	90	400

Breaking Strength and Elongation

Breaking strength and elongation were used to evaluate changes in the fabrics after abrasion at each level. The abraded cotton and nylon samples were cut one and one-half inches wide and as long as the abraded specimen would allow. At the individual stations these strips were ravelled to one and one-fourth inches and sent to Kansas for breaking strength and elongation determinations. Here they were ravelled to one inch, and the threads counted on each sample to determine threads per inch. One-inch squares were drawn on each specimen marking the area to be broken.

Breaking strength testing was done according to the Ravelled Strip Method, ASTM D 1682-59T with the following exception: Because the abraded area of the Schiefer and Stoll abraders was not large enough for the standard three-inch clamp gauge, the clamps of the tensile tester were set only one-inch apart. The Scott Tester, Model J was used for evaluation of both breaking strength and elongation. Both were recorded on an accompanying chart which works with the movement of the clamps of the Scott Tester. Specimens were tested in both the warp and filling direction for all ten levels.

For comparative purposes an additional analysis was done on fifteen warp and fifteen filling unabraded samples of cotton and nylon, using the same method of procedure except that the distance between clamps on the Scott Tester was the standard three-inch width. Breaking strength was recorded in pounds, and elongation as percentage of the original length. Averages of breaking strength and elongation were calculated for each level of abrasion.

Analysis of Results

To make comparisons among the three types of abraders, it was first necessary to establish if the stations using the same type of abrader obtained similar results.

A three-way analysis of variance was done on the mean values at each level of abrasion for each station. The three sources of variance were station (seven factors), level (ten factors), and direction (two factors). Since all seven stations and both directions were analyzed together, it was necessary to run an additional two-way analysis of variance to obtain a pattern of breakdown of the stations by direction and level. The two fixed variables were: level (ten factors) and direction (two factors). Abrasion data for the warp and filling directions were not analyzed separately. These were analyzed only for general patterns of change in strength and elongation. All significant differences were determined at the five per cent level of probability (see Appendix, Tables I-V).

CHAPTER IV

RESULTS AND DISCUSSION

The effect of abrasion using three types of abraders on cotton and nylon fabrics was studied. The cotton and nylon fabrics were chosen because they are two fibers used in fabrics that are subject to many types of abrasion in wear. By abrading the fabrics at several different levels (amounts of stress), a pattern of breakdown in strength after abrasion was observed for each type of abrader. This study did not in any way attempt to equate individual levels of abrasion among the abraders, but only to compare patterns of breakdown among the three types of abraders.

Three Way Analysis of Variance

A three way analysis of variance was done to show statistically if the same types of abraders gave similar results. The fixed variables analyzed were: stations (seven factors), levels (ten factors), and direction (two factors). Four sets of determinations were analyzed for each of the seven stations. These were: cotton breaking strength, nylon breaking strength, cotton elongation, and nylon elongation. All of the values analyzed were means of fifteen determinations at each level of abrasion with the Schiefer and Accelerotor abraders, and ten at each level with the Stoll abraders. All significance was determined at the five per cent level. The variance values in Tables I-IV (Appendix, p. 41) represent the amount of change in strength and elongation; for example, a high variance value indicates there was a noticeable change from level one through level nine.

Cotton breaking strength (Table I, Appendix, p. 41). There were no significant differences between the Schiefer abraders or among the Accelerotor abraders. There was significant difference between the two Stoll abraders. Both Stoll abraders produced significantly lower values than all other abraders. There was no significant difference between the Schiefer and Accelerotor values. The least over-all reduction in breaking strength after abrasion occurred with Schiefer abrasion. Variance was lowest for the three Accelerotor abraders, and highest for the Stoll abraders.

Nylon breaking strength (Table II, Appendix, p. 41). Significant differences occurred between the two Schiefer abraders, between the first two and the third Accelerotor abrader, and between the two Stoll abraders. Differences in nylon breaking strength between like abraders were not very great, even where significance occurred, but differences among the three types of abraders were large. The Schiefer abrader was significantly higher than the other two, and the Stoll abrader was significantly lower than the Schiefer or the Accelerotor abraders. As with the cotton breaking strength, variance with the Stoll abraders was greatest. Variance for the Accelerotor and the Schiefer abraders was about the same.

Cotton elongation (Table III, Appendix, p. 42). Values for cotton elongation were similar for samples abraded by all instruments.

From the highest to the lowest values there was only a difference of 3.6 per cent. There were significant differences among the three Accelerotor abraders, and these values were all significantly higher than the values for Stoll and Schiefer abraders. There were no significant differences between the highest values for the Schiefer abrader and those for the two Stoll abraders, or between the values for the two Stoll abraders. Values for the two Schiefer abraders were significantly different from one another. Variance was highest for the Stoll abraders and lowest for the Accelerotor, but none of the values were high compared to those of breaking strength.

Nylon elongation (Table IV, Appendix, p. 42). Significant differences occurred between the two Schiefer abraders, between the highest and lowest Accelerotors, and between the two Stoll abraders. Differences among like abraders, even where significance occurred, were small compared to the differences among the three types of abraders. The Schiefer nylon elongation results were significantly higher than either of the other two, and the Stoll results were significantly lower. Variance was relatively small for all three types of abraders, especially for the Schiefer abraders. Variance was highest for the two Stoll abraders.

Two Way Analysis of Variance

A two way analysis of variance was done to study the effects of abrasion on breaking strength and elongation at each level of abrasion, and to observe an over-all pattern of breakdown for the fabrics.

Through this analysis, levels were grouped according to levels that were not significantly different from each other. This grouping was done for each of the seven stations individually on all four sets of determinations: cotton breaking strength, nylon breaking strength, cotton elongation, and nylon elongation. The values in Tables V-VIII (Appendix, p. 43) are mean values of warp and filling determinations. All significant difference was determined at the five per cent level of probability.

Accelerotor. The amount of stress at each level for the Accelerotor was varied by using two types of liners (plastic and grit) and by changing the amount of abrasion time, holding the rotor speed constant. The fabrics were subjected to a combination of flex and flat abrasion.

The first significant drop in cotton breaking strength occurred after level five (Table V, Appendix, p. 43). The first four levels were abraded with the plastic liner; level five was abraded for one minute with the grit liner. After level five, a steady downward trend was seen with a significant drop after level eight and again after level nine. Douglas (8) noticed a definite decrease in cotton breaking strength after changing from the plastic to the grit liner in the Accelerotor. She attributed this loss to the removal of fibers and decreased fiber cohesion in the remaining damaged ones. Combined warp and filling strength ranged from 67 pounds at the unabraded level to 26 pounds at level nine.

For nylon breaking strength, although there was no clear pattern of breakdown from level zero through level nine for the three stations as a whole, there was a steady decrease in strength after the first level of abrasion through to level nine. This decrease was significant at several levels for one or more of the stations. Station 1 showed a significant decrease after level five, and stations 2 and 3 after level four. Values for station 1 showed no significant decreases from level five through level nine. Stations 2 and 3 showed significant decreases in breaking strength after levels six, seven, and eight. The change from the plastic liner to the grit liner after level three had no noticeable effect on the nylon breaking strength (Table V, Appendix, p. 43).

Cotton elongation as a whole showed an increasing trend as abrasion increased. There was no pattern of change observed for the three stations. Station 1 had the highest elongation at level nine, but elongation was highest at level four for both stations 2 and 3. This was the last level at which the plastic liner was used indicating that elongation increased with the plastic liner, then decreased somewhat with the grit liner. The range of elongation from the highest level to the lowest was only 3.5 per cent (Table VI, Appendix, p. 44).

Nylon elongation with the Accelerotor showed a decreasing trend from level zero through level nine. The first significant drop occurred after level four, the first level at which the grit liner was used. Stations 1 and 2 showed another significant decrease after level seven, station 3 after level six. No further significant decrease was observed (Table VI, Appendix, p. 44). The range of nylon elongation after

Accelerotor abrasion was 70.5 per cent to 54.5 per cent.

Schiefer. Stress using the Schiefer abrader with a spring steel abradant was varied by changing the pounds of pressure on the specimen being abraded, and by varying the number of cycles the specimen ran. The action of the Schiefer was flat and multidirectional.

Cotton breaking strength did not significantly decrease until after level six (Table VII, Appendix, p. 45). This level of abrasion was 300 cycles at five pounds of pressure. The additional pressure at level five (the first level at which five pounds was used) did not significantly affect the cotton strength, but the increase of 200 cycles at level six did have an effect. The breaking strength continued to decrease after level six but not significantly.

The first significant drop in nylon breaking strength occurred after level seven for station 4 and after level eight for station 5 (Table VII, Appendix, p. 45). Level seven was the first level at which ten pounds of pressure was used. Another significant decrease occurred after level nine for both of the stations. The total decrease in strength from level zero to level nine was 15.5 pounds.

With cotton elongation after Schiefer abrasion there was a downward trend from level zero to level nine but no significant decrease after any one level of abrasion for station 4. There was a significant drop after level five for station 5. This is the first level at which five pounds of pressure was used in abrasion. The range of elongation was 16.0 per cent to 12.5 per cent (Table VIII, Appendix, p. 46).

There was no clear pattern of change in nylon elongation as a result of Schiefer abrasion (Table VIII, Appendix, p. 46). It fluctuated up and down from levels one to four, leveled off at levels five and six, then decreased somewhat after level six. Station 5 showed a significant decrease after level eight, and both stations showed a significant decrease after level nine. The effect of additional pressure with abrasion was not noticeable for the nylon elongation. The range of elongation was 73.0 per cent to 60.5 per cent.

Stoll. Damage to fabrics using the Stoll abrader was caused by a flat, multidirectional action with number zero emery paper. Stress was varied by changing the number of cycles that the fabric was abraded. Pressure on the specimens was held constant throughout.

Cotton breaking strength as a result of Stoll abrasion decreased steadily from level zero to level nine, with significance after every level to level four (Table IX, Appendix, p. 47). The strength decreased less rapidly after level four. The greatest decreases occurred after levels one and two, after very little abrasion was done on the fabric (10 and 20 cycles respectively).

With nylon breaking strength there was a significant decrease after almost every level of abrasion (Table IX, Appendix, p. 47). Stoll abrasion had an immediate effect on the nylon strength with the largest decrease occurring after the first level of abrasion, and a steady decrease continuing through level nine.

Cotton elongation changed little after Stoll abrasion, and no pattern was established with the degree of abrasion since the elongation fluctuated up and down from level to level. No significant differences occurred between any two consecutive levels for station 6 (Table X, Appendix, p. 48). With station 7 there were both significant increases and decreases from level to level, but no clear pattern related to the number of abrasion cycles.

Nylon elongation decreased with increasing abrasion except for a slight rise after level four and again after level seven (Table X, Appendix, p. 48). The decrease was most rapid after the first and second levels of abrasion for both stations. For station 6 the decreasing trend continued, but there were no significant drops through level nine. Station 7 showed significant decreases after levels three, four, six, and nine as well as one and two.

Warp and Filling Breaking Strength and Elongation

Although the two way analysis of variance used the mean of warp and filling values to group the levels not significantly different from one another in breaking strength and elongation, it did not indicate differences in the pattern of breakdown by direction. In some cases the patterns of breakdown of warp and filling were similar. In other instances, however, the changes were different for each direction. Patterns of change for warp and filling for each station are illustrated in the Appendix, Plates I-VIII.

Accelerotor. The trends in breakdown for cotton warp (Plate I, fig. 1, Appendix, p. 50) and filling (Plate II, fig. 1, Appendix, p. 51) breaking strength were similar. The warp strength decreased from 78 pounds at level zero to 28 pounds at level nine. The filling strength ranged from 58 pounds at level three to 23 pounds at level nine. The filling actually increased slightly from level zero to level three, then decreased steadily after level three.

Nylon breaking strength showed similar trends in the warp and filling direction, with the filling decreasing slightly more than the warp. Warp values ranged from 88 pounds at level zero to 75 pounds at level eight (Plate III, fig. 1, Appendix, p. 52). Filling values ranged from 88 pounds at level one to 64 pounds at level nine (Plate IV, fig. 1, Appendix, p. 53). Neither the change in liner nor increased abrasion had a definite effect on the nylon breaking strength results.

Cotton elongation after Accelerotor abrasion showed quite different patterns of change between warp and filling. With the warp (Plate V, fig. 1, Appendix, p. 54) there was a definite and consistent increasing trend from level zero (8 per cent) to level nine (15 per cent). Lohr (16) observed this trend for cotton elongation after Accelerotor abrasion, but gave no explanation for it. Douglas (8) found that elongation increased with the plastic liner, but decreased with the grit liner. There was no consistent trend of increase or decrease in filling elongation (Plate VI, fig. 1, Appendix, p. 55). It fluctuated up and down from level zero to level eight, finally increasing to level nine. One reason the change may be difficult to evaluate in the filling direction is that there was only a range of 4 per cent from the highest value (23 per cent) to the lowest (19 per cent).

The patterns of warp (Plate VII, fig. 1, Appendix, p. 56) and filling (Plate VIII, fig. 1, Appendix, p. 57) nylon elongation were similar except that in the filling direction the elongation increased slightly up to level three after the initial drop at level one. The highest warp elongation was 70 per cent at level zero and the lowest was 53 per cent at level nine. Filling values ranged from 72 to 55 per cent.

<u>Schiefer</u>. There was a definite directional effect with the cotton breaking strength. The warp strength (Plate I, fig. 2, Appendix, p. 50) varied little from level zero through level nine; the range was from 79 pounds at level zero to 72 pounds at level nine. The strength actually increased from level one through level five (81 pounds) before it began to decrease to level nine. Filling breaking strength (Plate II, fig. 2, Appendix, p. 51) decreased slowly from level zero (59 pounds) to level five (55 pounds). After level five the strength dropped rapidly to 20 pounds at level nine. Level five is the first level abraded using the maximum pressure of five pounds. It is possible that the filling crowns were higher, and the additional pressure caused more damage to them than to the warp.

There was considerable fluctuation in both the warp and filling nylon breaking strength. Warp values (Plate III, fig. 2, Appendix, p. 52) ranged from 92 pounds at level three to 78 pounds at level nine. Filling strength (Plate IV, fig. 2, Appendix, p. 53) ranged from 87 pounds at level zero to 67 pounds at level nine. There was almost a consistent decrease in strength in the filling direction due to abrasion, but warp strength remained almost the same throughout all levels, until level nine, where it decreased noticeably.

There was little change in cotton warp elongation as a result of Schiefer abrasion (Plate V, fig. 2, Appendix, p. 54). It ranged from 8 per cent to 10 per cent, with no logical pattern of fluctuation. In the filling direction (Plate VI, fig. 2, Appendix, p. 55) there was a definite decrease in elongation from 22 per cent at level zero to 15 per cent at level nine. The crown damage discussed with cotton breaking strength may have had the same effect of decreasing the filling elongation.

The patterns of change in warp (Plate VII, fig. 2, Appendix, p. 56) and filling (Plate VIII, fig. 2, Appendix, p. 57) nylon elongation were similar. Warp values ranged from 78 per cent at level four to 65 per cent at level nine. Filling elongation was highest at level two (79 per cent) and lowest at level nine (61 per cent). Both warp and filling values fluctuated up and down from level zero through level nine, with a slight over-all decrease in both.

Stoll. Cotton breaking strength decreased much more rapidly after the first level of abrasion in the filling direction (Plate I, fig. 3, Appendix, p. 50) than in the warp (Plate II, fig. 3, Appendix, p. 51). In the filling direction the greatest decrease in strength occurred between level zero and level four. After level four the filling strength decreased slightly through level nine. The decrease in the warp direction was more even and gradual from level one to level nine.

Stoll abrasion had a definite deteriorating effect on the nylon breaking strength in both the warp and filling direction. Warp breaking strength (Plate III, fig. 3, Appendix, p. 52) decreased from 88 pounds to 48 pounds. There was an even greater decrease in filling strength, from 88 pounds to 32 pounds (Plate IV, fig. 3, Appendix, p. 53). Both the warp and filling started decreasing after the first level of abrasion, and continued a steady decrease through level nine.

Cotton elongation fluctuated up and down more from level to level in the warp than it did in the filling, but neither direction showed any distinct pattern of change from level one through level nine. The range for warp elongation (Plate V, fig. 3, Appendix, p. 54) was 9 per cent to 7 per cent, and for filling (Plate VI, fig. 3, Appendix, p. 55) it was 21 per cent to 17 per cent.

Patterns of elongation in warp and filling were similar for the nylon after Stoll abrasion. Both showed a rapid decrease in elongation until after level three, where elongation began to decrease less rapidly through level nine. Warp elongation (Plate VII, fig. 3, Appendix, p. 56) ranged from 70 per cent at level zero to 46 per cent at level nine. Filling elongation ranged from 74 per cent at level zero to 41 per cent at level nine. Nylon elongation followed the trend of nylon breaking strength, decreasing with increasing levels of stress.

Breaking Strength and Elongation With the Three-Inch Gauge

In order to compare the unabraded cotton and nylon fabrics with the standard breaking strength and elongation test method according to ASTM (3), fifteen unabraded specimens of nylon and cotton, both warp and filling were tested using a three-inch clamp gauge on the Scott Tester, Model J.

Results for the cotton breaking strength and elongation were almost the same as with the one-inch clamp (Table XI). Both were slightly lower with the three-inch clamp. Nylon results, however, were noticeably lower with the three-inch clamp, especially the elongation, which was about fifteen per cent lower in both the warp and filling direction. On the basis of these results, no attempt was made to adjust any results obtained with the one-inch clamp gauge.

CHAPTER V

SUMMARY AND CONCLUSIONS

This investigation was done to study the effect of abrasion on a cotton and a nylon fabric with three types of abraders. Evaluation of breaking strength and elongation before abrasion and after nine levels of abrasion indicated what effect the three types of abrasion had on the two fabrics. As part of the North Central Regional Study, NC 68, "Mechanisms of Fabric Stress Absorption and Performance," these fabrics were abraded at seven different stations, using three Accelerotor, two Schiefer, and two Stoll abraders. The nine levels of abrasion were established by varying amount of pressure, type of abradant and abrasion time. All breaking strength and elongation determinations were done at one station by the same operator using a Model J Scott Tester—Ravelled Strip Method according to ASTM (3). A one-inch clamp gauge was used for all samples except one set of unabraded fabrics tested with the three-inch guage.

A three way analysis of variance using station, direction, and level as the fixed variables showed that results of like abraders were in egreement in most cases. Even where significant differences ($P < 0.05$) occurred they were not great. Patterns of change differed among the three types of abraders with variance highest for the Stoll abraders. This indicates that there was a greater decrease in strength and elongation from level one through level nine as a result of abrasion with the Stoll than with the other two types of abraders.

A two way analysis of variance of direction and level, grouped levels that were not significantly different ($P < 0.05$) from one another. Cotton breaking strength did not change significantly with Accelerotor abrasion until after level four, the first level using the grit liner; with Schiefer abrasion the first significant drop occurred after level six; with Stoll abrasion it decreased significantly after the first level and continued decreasing through level nine. Accelerotor abrasion caused a steady decreasing trend in nylon breaking strength, but no definite pattern of breakdown at any particular level was evident; Schiefer abrasion caused a significant decrease after levels six, seven, and eight; Stoll abrasion caused a significant decrease after level one and this decrease continued with significance after almost every level. There was a definite increase in cotton elongation from level one through level nine after Accelerotor abrasion, but no distinct pattern among the three stations was established; there was a slight decrease from level one through level nine after both Schiefer and Stoll abrasion but no pattern related to the amount of abrasion. Nylon elongation decreased with increased abrasion for all three types of abraders. Schiefer abrasion had the least effect on nylon elongation, and Stoll abrasion had the most.

Results of warp and filling strength and elongation showed the directional effect after abrasion. Patterns of breakdown were similar in cotton breaking strength, warp and filling, after Accelerotor abrasion, but Schiefer and Stoll abrasion both caused a greater decrease in the filling direction than in the warp. All three types of abraders showed similar patterns of warp and filling change in nylon breaking strength after abrasion. Cotton elongation increased noticeably in the warp direction after Accelerotor abrasion, but changed little after Schiefer or Stoll abrasion. In the filling direction, there was little change after Accelerotor abrasion, but both Schiefer and Stoll abrasion caused a noticeable decrease. Nylon elongation decreased in both the warp and filling direction for all three types of abraders.

No pattern of difference from the one-inch gauge was established when unabraded cotton and nylon specimens were tested with a three-inch clamp gauge. Only the nylon elongation showed a distinct difference with the three-inch gauge, being 15 to 20 per cent lower. A difference in tension on the three-inch specimens, or a greater effect from jaw penetration (ASTM, 3) may be the reason for this difference.

In conclusion, this study showed that patterns of breakdown in strength and elongation for the cotton and nylon fabrics evaluated were similar for like abraders, but different among the three types of abraders. It is not possible to equate the results of abrasion on one abrader with those on another on the basis of breaking strength and elongation. However, it is possible to compare results, and by evaluating a fabric under several sets of conditions, make more accurate statements about the fabric's performance.

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APPENDIX

TABLE I

MEANS OF ALL LEVELS OF COTTON BREAKING STRENGTH
FOR EACH ABRADING STATION

Station*	Abrader	Mean* (pounds)	Variance	LSD**
4	Schiefer	63.05	235.20	3.77
5	Schiefer	61.05	407.20	
1	Accelerotor	59.75	167.25	
3	Accelerotor	56.95	193.73	
2	Accelerotor	56.95	230.57	
6	Stoll	49.95	443.10	
7	Stoll	45.40	436.14	

* Station 1--Indiana, Station 2--Ohio, Station 3--Missouri, Station 4--Kansas, Station 5--South Dakota, Station 6--Minnesota, Station 7--Wisconsin.

TABLE II

MEANS OF ALL LEVELS OF NYLON BREAKING STRENGTH
FOR EACH ABRADING STATION

Station*	Abrader	Mean* (pounds)	Variance	LSD**
5	Schiefer	86.60	9.62	1.38
4	Schiefer	85.00	33.47	
2	Accelerotor	81.00	36.10	
1	Accelerotor	80.10	35.56	
3	Accelerotor	78.75	26.51	
7	Stoll	61.10	274.83	
6	Stoll	60.55	227.31	

* Ranked in descending order
** Least significant difference at the five per cent level

TABLE III

MEANS OF ALL LEVELS OF COTTON ELONGATION
FOR EACH ABRADING STATION

Station*	Abrader	Mean* (per cent)	Variance	LSD**
2	Accelerotor	16.95	25.69	0.63
1	Accelerotor	16.20	24.69	
3	Accelerotor	15.75	20.40	
4	Schiefer	14.55	27.41	
6	Stoll	14.45	40.05	
7	Stoll	13.95	29.71	
5	Schiefer	13.35	26.68	

TABLE IV

MEANS OF ALL LEVELS OF NYLON ELONGATION
FOR EACH ABRADING STATION

Station*	Abrader	Mean* (per cent)	Variance	LSD**
4	Schiefer	70.45	17.63	1.19
5	Schiefer	69.20	3.53	
2	Accelerotor	62.85	30.02	
3	Accelerotor	61.75	29.35	
1	Accelerotor	61.55	14.99	
6	Stoll	55.60	43.51	
7	Stoll	53.10	51.98	

* Ranked in descending order
** Least significant difference at the five per cent level

TABLE V

MEANS OF WARP AND FILLING BREAKING STRENGTH BEFORE AND AFTER ACCELEROTOR ABRASION

COTTON

Level*	Station 1 Breaking Strength (pounds)	LSD**	Level*	Station 2 Breaking Strength (pounds)	LSD**	Level*	Station 3 Breaking Strength (pounds)	LSD**
10	67.00	2.56	10	67.00	3.92	1	67.00	2.86
2	66.50		2	66.00		10	66.50	
3	66.00		1	65.50		2	66.00	
4	66.00		3	63.50		3	65.50	
1	64.50		5	62.50		5	64.00	
5	61.50		4	61.50		4	62.50	
6	59.50		6	59.00		6	60.50	
7	58.00		7	56.00		7	56.50	
8	51.00		8	42.50		8	46.00	
9	37.50		9	26.00		9	30.00	

NYLON

Level*	Station 1 Breaking Strength (pounds)	LSD**	Level*	Station 2 Breaking Strength (pounds)	LSD**	Level*	Station 3 Breaking Strength (pounds)	LSD**
2	85.50	2.59	1	88.00	1.71	10	85.50	1.09
3	85.50		10	87.50		1	82.50	
10	85.00		2	86.00		2	82.50	
1	84.50		3	85.00		4	81.00	
4	82.00		4	83.00		3	80.50	
5	80.50		5	80.00		5	79.00	
6	77.50		6	79.00		6	77.00	
7	76.00		7	76.50		7	75.50	
8	73.50		8	74.00		8	72.00	
9	71.00		9	71.00		9	72.00	

* Ranked in descending order

** Least significant difference at the five per cent level

TABLE VI

MEANS OF WARP AND FILLING ELONGATION BEFORE AND AFTER ACCELEROTOR ABRASION

COTTON

	Station 1			Station 2			Station 3	
Level*	Elongation (per cent)	LSD**	Level*	Elongation (per cent)	LSD**	Level*	Elongation (per cent)	LSD**
9	18.00	1.61	4	18.00	1.62	4	16.50	1.40
5	17.50		3	17.50		6	16.50	
6	17.50		9	17.50		7	16.50	
7	17.50		2	17.00		3	16.00	
8	17.50		6	17.00		5	16.00	
4	15.50		7	17.00		9	16.00	
3	15.00		1	16.50		8	15.50	
1	14.50		5	16.50		1	15.00	
2	14.50		8	16.50		2	15.00	
10	14.50		10	16.00		10	14.50	

NYLON

10	65.00		10	70.00	1.86	10	70.50	1.18
1	65.00		1	68.50		2	67.50	
3	65.00		3	68.00		1	66.00	
2	64.50		2	67.50		3	64.00	
4	64.50		4	62.50		4	63.00	
5	61.00		5	61.00		5	61.00	
6	60.00		6	60.00		6	59.00	
7	59.50		7	58.50		7	56.50	
8	57.50		8	56.50		8	55.50	
9	56.50		9	56.00		9	54.50	

* Ranked in descending order

** Least significant difference at the five per cent level

TABLE VII

MEANS OF WARP AND FILLING BREAKING STRENGTH BEFORE AND AFTER SCHIEFER ABRASION

COTTON

Station 4 Level*	Breaking Strength (pounds)	LSD**	Station 5 Level*	Breaking Strength (pounds)	LSD**
10	69.00	6.68	3	69.00	10.46
1	68.00		1	68.00	
4	68.00		2	67.50	
3	67.00		5	67.50	
5	66.50		10	67.50	
2	66.00		4	65.00	
6	62.00		6	56.00	
9	55.50		7	51.50	
7	55.00		8	50.00	
8	53.50		9	48.50	

NYLON

Station 4 Level*	Breaking Strength (pounds)	LSD**	Station 5 Level*	Breaking Strength (pounds)	LSD**
3	88.00	1.71	10	88.50	1.43
2	87.00		3	87.50	
4	87.00		6	87.50	
6	87.00		1	87.00	
10	87.00		5	87.00	
1	86.50		7	87.00	
5	86.50		2	86.50	
7	84.00		4	86.50	
8	84.00		8	85.50	
9	73.00		9	83.00	

* Ranked in descending order

** Least significant difference at the five per cent level

TABLE VIII

MEANS OF WARP AND FILLING ELONGATION BEFORE AND AFTER SCHIEFER ABRASION

COTTON

Level*	Station 4 Elongation (per cent)	LSD**	Level*	Station 5 Elongation (per cent)	LSD**
1	16.00	1.78	1	15.00	1.88
2	15.50		3	15.00	
3	15.50		4	15.00	
10	15.50		5	15.00	
4	15.00		2	14.50	
5	14.50		10	14.50	
6	14.00		6	13.00	
7	13.50		7	12.50	
8	13.00		8	12.50	
9	13.00		9	12.50	

NYLON

Level*	Station 4 Elongation (per cent)	LSD**	Level*	Station 5 Elongation (per cent)	LSD**
2	73.00	2.62	3	70.50	0.90
3	72.50		5	70.50	
4	72.50		4	70.00	
1	72.00		6	70.00	
5	72.00		10	70.00	
10	72.00		7	69.50	
6	71.50		2	69.00	
7	70.50		8	68.50	
8	68.00		1	67.00	
9	60.50		9	67.00	

* Ranked in descending order
**Least significant difference at the five per cent level

TABLE IX

MEANS OF WARP AND FILLING BREAKING STRENGTH
BEFORE AND AFTER STOLL ABRASION

COTTON

Level*	Station 6 Breaking Strength (pounds)	LSD**	Level*	Station 7 Breaking Strength (pounds)	LSD**
10	67.50	5.76	10	65.00	5.04
1	60.00		1	59.00	
2	54.00		2	52.00	
3	51.50		3	47.50	
4	50.00		4	44.50	
5	45.00		5	39.50	
6	45.00		6	39.00	
7	42.50		7	36.50	
8	42.50		8	35.50	
9	41.50		9	35.50	

NYLON

Level*	Station 6 Breaking Strength (pounds)	LSD**	Level*	Station 7 Breaking Strength (pounds)	LSD**
10	87.50	4.86	10	86.50	1.65
1	73.50		1	77.00	
2	68.50		2	73.50	
3	62.50		3	69.50	
4	61.00		4	65.50	
6	54.00		5	60.00	
5	53.50		6	51.50	
7	52.50		7	48.00	
8	48.50		8	42.00	
9	44.50		9	37.50	

* Ranked in descending order
** Least significant difference at the five per cent level

TABLE X

MEANS OF WARP AND FILLING ELONGATION BEFORE AND AFTER STOLL ABRASION

COTTON

Level*	Station 6 Elongation (per cent)	LSD**	Level*	Station 7 Elongation (per cent)	LSD**
5	15.00	0.58	2	14.50	0.50
2	14.50		10	14.50	
4	14.50		1	14.00	
6	14.50		4	13.50	
7	14.50		6	13.50	
8	14.50		3	13.00	
9	14.50		5	13.00	
10	14.50		7	12.50	
1	14.00		8	12.50	
3	14.00		9	12.50	

NYLON

Level*	Station 6 Elongation (per cent)	LSD**	Level*	Station 7 Elongation (per cent)	LSD**
10	72.00	2.94	10	68.50	1.77
1	59.00		1	60.00	
2	56.50		2	56.50	
4	55.50		3	54.50	
3	55.00		4	52.50	
5	53.00		5	51.00	
6	53.00		7	50.50	
7	52.50		6	48.00	
8	50.50		8	46.50	
9	49.00		9	43.00	

* Ranked in descending order

** Least significant difference at the five per cent level

TABLE XI

BREAKING STRENGTH AND ELONGATION OF UNABRADED COTTON AND NYLON

COTTON

Source	Warp Breaking Strength (pounds)	Warp Elongation (per cent)	Filling Breaking Strength (pounds)	Filling Elongation (per cent)
Station 4	79.00	9.00	59.00	22.00
Station 5	77.00	9.00	58.00	20.00
Station 6	77.00	8.00	58.00	21.00
Station 7	74.00	9.00	56.00	20.00
Station 1	77.00	9.00	57.00	20.00
Station 2	78.00	9.00	56.00	23.00
Station 3	76.00	8.00	57.00	21.00
3" gauge	70.00	8.00	57.00	19.00

NYLON

Source	Warp Breaking Strength (pounds)	Warp Elongation (per cent)	Filling Breaking Strength (pounds)	Filling Elongation (per cent)
Station 4	79.00	65.00	84.00	73.00
Station 5	90.00	69.00	87.00	71.00
Station 6	88.00	70.00	89.00	74.00
Station 7	89.00	68.00	84.00	69.00
Station 1	86.00	63.00	84.00	66.00
Station 2	88.00	70.00	87.00	70.00
Station 3	88.00	70.00	83.00	71.00
3" gauge	81.00	51.00	77.00	54.00

PLATE I

WARP BREAKING STRENGTH OF COTTON FABRIC BY STATIONS AFTER ABRASION WITH THREE TYPES OF ABRADERS

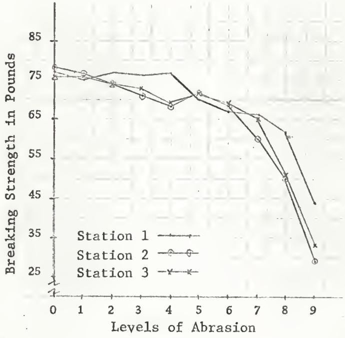

Fig. 1. Accelerotor

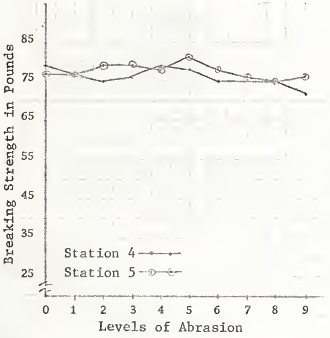

Fig. 2. Schiefer

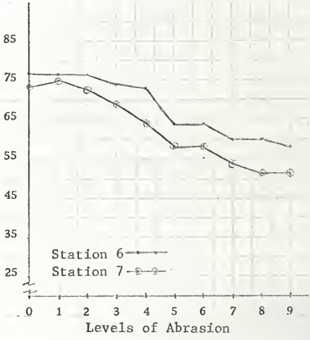

Fig. 3. Stoll

PLATE II

FILLING BREAKING STRENGTH OF COTTON FABRIC BY STATIONS
AFTER ABRASION WITH THREE TYPES OF ABRADERS

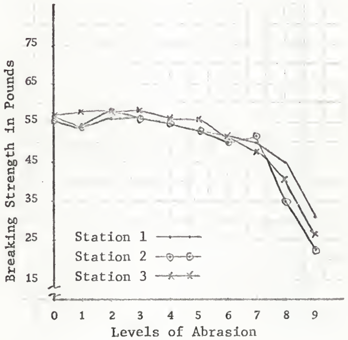

Fig. 1. Accelerotor

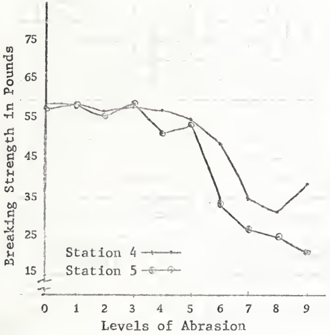

Fig. 2. Schiefer

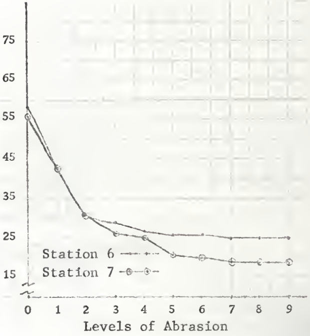

Fig. 2. Stoll

PLATE III

WARP BREAKING STRENGTH OF NYLON FABRIC BY STATIONS
AFTER ABRASION WITH THREE TYPES OF ABRADERS

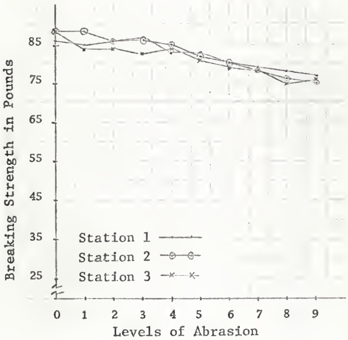

Fig. 1. Accelerotor

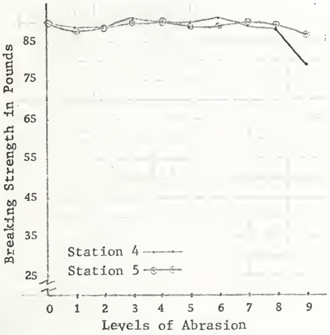

Fig. 2. Schiefer

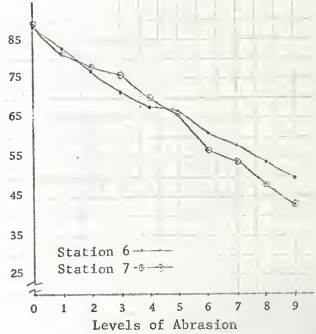

Fig. 3. Stoll

PLATE IV

FILLING BREAKING STRENGTH OF NYLON FABRIC BY STATIONS AFTER ABRASION WITH THREE TYPES OF ABRADERS

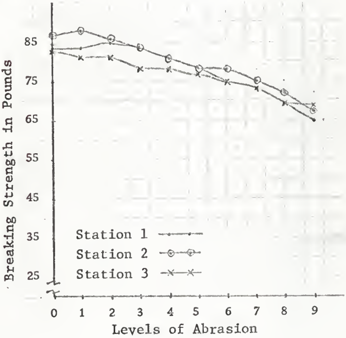

Fig. 1. Accelerotor

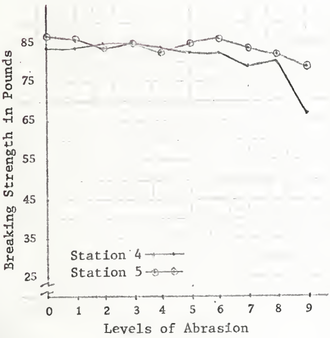

Fig. 2. Schiefer

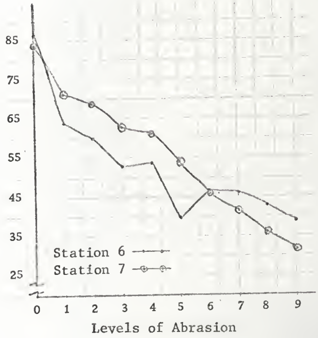

Fig. 3. Stoll

PLATE V

WARP ELONGATION OF COTTON FABRIC BY STATIONS
AFTER ABRASION WITH THREE TYPES OF ABRADERS

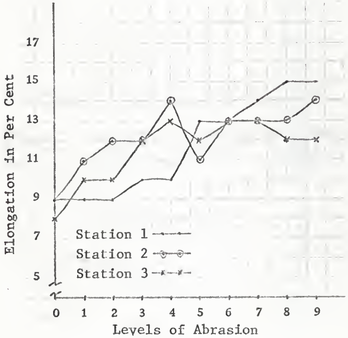

Fig. 1. Accelerotor

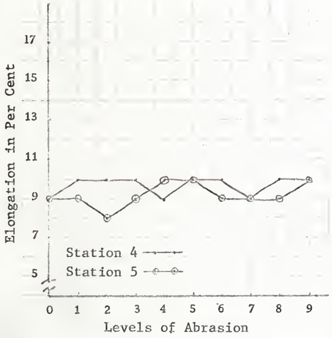

Fig. 2. Schiefer

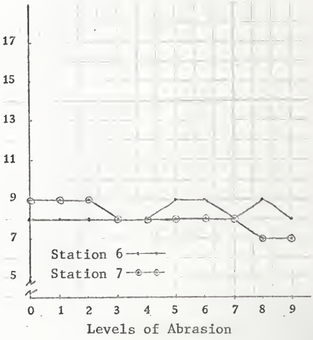

Fig. 3. Stoll

PLATE VI

FILLING ELONGATION OF COTTON FABRIC BY STATIONS AFTER ABRASION WITH THREE TYPES OF ABRADERS

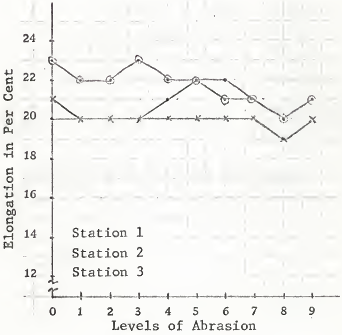

Fig. 1. Accelerotor

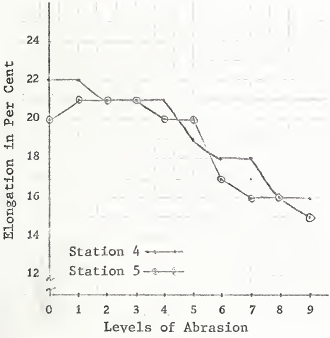

Fig. 2. Schiefer

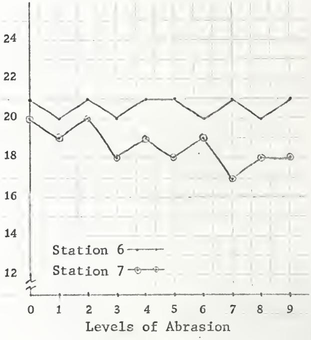

Fig. 3. Stoll

PLATE VII

WARP ELONGATION OF NYLON FABRIC BY STATIONS AFTER ABRASION WITH THREE TYPES OF ABRADERS

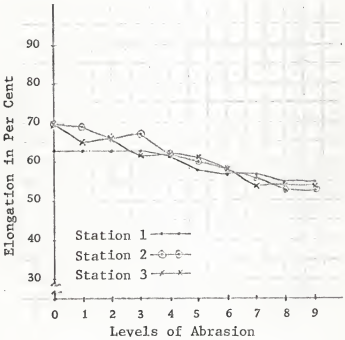

Fig. 1. Accelerotor

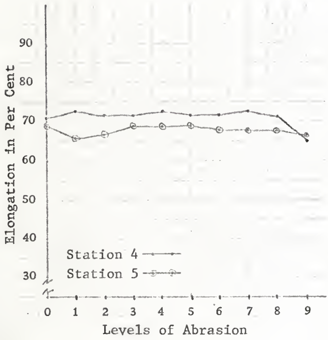

Fig. 2. Schiefer

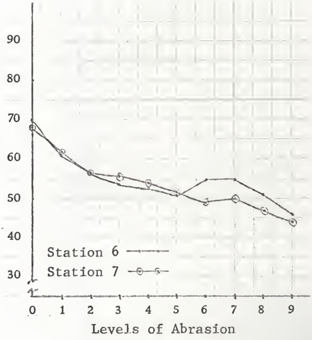

Fig. 3. Stoll

PLATE VIII

FILLING ELONGATION OF NYLON FABRIC BY STATIONS
AFTER ABRASION WITH THREE TYPES OF ABRADERS

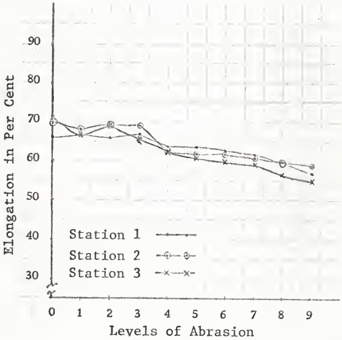

Fig. 1. Accelerotor

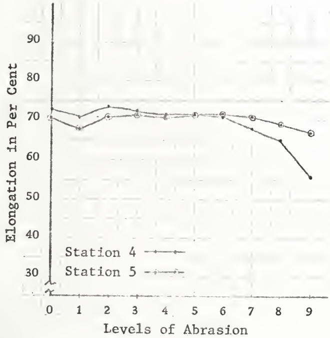

Fig. 2. Schiefer

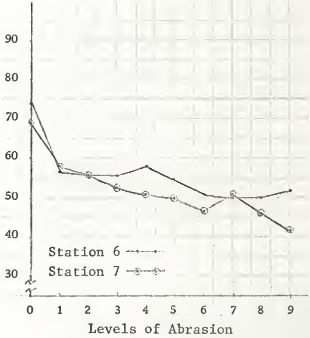

Fig. 3. Stoll

EFFECT OF VARIOUS TYPES OF ABRASION ON THE BREAKING STRENGTH AND ELONGATION OF SELECTED COTTON AND NYLON FABRICS

by

REBECCA ADELINE WALKER

B. S., Pennsylvania State University, 1966

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

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Manhattan, Kansas

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This investigation was designed to evaluate the effect of three types of abrasion on a cotton and a nylon fabric by studying the changes in breaking strength and elongation before and after abrasion. Seven stations in the North Central Region used three Accelerotor, two Schiefer, and two Stoll abraders. Levels of abrasion were established for each type of abrader by varying amounts of pressure, number of cycles and types of abradants on both the cotton and nylon fabric. A Scott Tester, Model J with clamps set one inch apart was used for Ravelled Strip (ASTM) breaking strength and elongation determinations.

A three way analysis of variance indicated that like abraders showed similar patterns of change in strength and elongation, and even where significant differences ($P < 0.05$) they were not great. However, patterns differed among the three types of abraders.

A two way analysis of variance of direction and level indicated that cotton breaking strength decreased significantly ($P < 0.05$) after level four with Accelerotor abrasion, after level six with Schiefer abrasion, and after level one with Stoll abrasion. Nylon breaking strength decreased consistently from level one through level nine with all three types of abraders, losing the least strength after Schiefer abrasion and the most after Stoll abrasion. Cotton elongation increased with Accelerotor abrasion from level one through level nine, but decreased with both Schiefer and Stoll abrasion. Nylon elongation decreased for all three types of abraders.

The cotton fabric showed a greater decrease in strength and elongation in the filling direction than in the warp. This was especially noticeable after Schiefer and Stoll abrasion. With nylon, the patterns of change in warp and filling were similar for all three types of abraders.