BENDING PROPERTIES OF A LIGHTWEIGHT SUITING FABRIC AS AFFECTED BY A FUSIBLE AND A NONFUSIBLE INTERFACING

by

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(ABSTRACT)

Garment construction is based on converting a fashion fabric into a wearable structure. Interfacings are attached to the fashion fabric in enclosed seams to provide support and stiffness for the seam area. Interfacings affect how the fashion fabric can bend. Therefore, it is the purpose of this study to determine the effect fusible and nonfusible nonwoven interfacings have on three bending properties of a lightweight suiting fabric. These three properties are flexural rigidity, crease recovery, and seam head size.

A lightweight suiting fabric, a nonwoven fusible interfacing, and a nonwoven nonfusible interfacing were selected for the study. The flexural rigidity and crease recovery were measured for the component pieces of fashion fabric, nonfusible interfacing, and fusible interfacing and for the fusible and nonfusible composites. The flexural rigidity and crease recovery for the composites were recorded for the composite bent with the interfacing side up and with the interfacing side down. Seam head size was measured for en-

closed seams with no interfacing (control), fusible interfacing, and nonfusible interfacing. Cross-sections of the enclosed seams were photographed against a ruler with hundredths of an inch increments. The seam head size was read from each of the photographic slides.

Seven null hypotheses were tested. The hypotheses pertained to bending resistance and crease recovery of composites and their components, interfacing side up and down when bending and creasing, and fusible and nonfusible composites; and to seam head sizes of composites of the three selected fabrics.

It was found that it did not make a difference which interfacing type is used (fusible or nonfusible) with respect to crease recovery and seam head size. It did make a difference which interfacing type was used with respect to flexural rigidity. The fusible composite was 2.47 times stiffer than the nonfusible, however.

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CHAPTER I. INTRODUCTION.

Garment construction is the process of converting a flat fabric into a wearable structure for the human form. Most garments share the common characteristic of being formed by seaming fabric sections together. Seams are placed in strategic locations in order to create different garment styles or structures. The most common method used for constructing seams is stitching with needle and thread.

Different types of seams have been identified and specified by the United States government (United States Government, Sections 1 and 2, 1965). Two common seam types used in producing garments are the superimposed seam and the enclosed seam. The superimposed seam is one in which two pieces of fabric are laid one atop the other and stitched. The enclosed seam is one in which two or more fabric layers are stitched together and then the fabric is folded back upon itself to enclose or encase the seam allowance.

Seams may affect the way in which the fabric of a garment bends and drapes. For example, if a superimposed seam is constructed, the fabric bending resistance may increase depending on whether the fabric is bent parallel or perpendicular to the seam. If the fabric is bent parallel to or along the stitching line, the seam will act as a hinge. A seam parallel to the bending axis has a small effect on the bending rigidity of the fabric. A seamed fabric, when bent parallel to the seam, has a slightly higher bending resistance than that of a single layer of the same fabric when bent with no seam present. Therefore, a seam will introduce some rigidity to the fabric. If the fabric is bent perpendicular to the superimposed seam, the bending resistance will be much higher than in a specimen bent parallel to the seam because the seam itself resists bending (Dhingra and Postle, 1980).

In comparing layers of fabric with no seams, Dhingra and Postle (1980) found that a double layer of fabric has a bending resistance 10-12 times greater than that of a single layer. Fabric layers near the bending axis in a double layer specimen lack the freedom to bend independently. Thus, increased bending resistance results when seams or additional layers of fabric are added.

The crease recovery of a fabric is the ability of the fabric to return to its original form after having been creased under a weight. The recovery is dependent on the fibers' and yarns' ability to recover from the strain placed on them by the weight (Abbott, Coplan, & Platt, 1960). The creasing of a fabric has been found to be related to the lack of recoverability of the fibers (imperfect elasticity). Creasing involves large strains placed on the fibers within a fabric. When the creasing force is removed, the fibers will only partially recover (Treloar, 1977).

In an enclosed seam, the fabric is forced to bend back upon itself in order to encase the seam allowances. Mechanical and physical properties of the fabric may cause a seamline to appear distorted. Although the design line of a garment is planned to coincide with the marked seamline on a pattern, the resulting effect may be that the fabric fold does not fall directly on the seamline (stitching line) but instead beside it (Moore, 1984). The area between the fold of the fabric and the stitching line is called the seam head (Moore, 1984; Moore, Gurel, & Marshall, 1986; Solinger, 1980).

Distortion of the intended design line occurs because the fabric's bending properties are not considered. Lanier (1980) and Moore (1984) postulate that distortion produces a concave appearance parallel to the enclosed seam in areas such as collars, lapels, welt pockets, and bound buttonholes. The folded edge of the enclosed seam becomes taut thus causing the concave appearance. According to Lanier (1980), in order for the fabric to fold on the intended design line, the stitching line must be moved away from the design line toward the cut edge of the garment segment.

Interfacings were first used in the mid to late 1700s when collars and lapels were introduced in men's fashions (Mini-History, 1979). Women's fashions soon afterward included the lapel.

Interfacings are used to provide support, stiffness, or stabilization in certain areas of garments and are often found in areas where enclosed seams exist (Bendel, 1984; Brumbaugh and Mowat, 1977; Cross, 1985; Kalka, 1982; Kartun, 1974; Lawrence and Yurick, 1977; Shishoo et al., 1971). When interfacing fabric is combined with fashion fabric, the bending properties of both fabrics are altered. The type of interfacing as well as the treatment given to the interfacing may affect the size of the seam head in an enclosed seam area. Oftentimes, the interfacing is trimmed away from the enclosed seam allowance in order to reduce bulk and thereby reduce the size of the seam head (Lawrence and Yurick, 1977).

Several types of interfacings are available for use in garments. Woven, sew-in interfacings were the only types available until the early 1900s. The nonfusible, or sew-in, interfacings may have either woven or nonwoven structures. They also come in a variety of weights, thicknesses, hands, and structures.

Fusible interfacings are those that have a thermoplastic dot coating on one side that, when heated, adheres the interfacing to the fashion fabric. Fusible interfacings were first patented in the early 1900s (Kartun, 1974) and are used extensively in garment construction (Bendel, 1984; Cross, 1985). The fusible interfacings also come in a wide variety of weights, thicknesses, hands, and structures.

Little research has been published on seam head size, bending properties of fusible and nonfusible interfacings, and the effect on bending of interfacing treatment in seam allowance areas. Therefore, the purposes of this study are (1) to compare the effect of fusible and nonfusible interfacings on the flexural rigidity, crease recovery, and seam head size of a lightweight suiting fabric and (2) to compare the flexural rigidity and crease recovery of interfacing/fashion fabric composites and components.

The objectives of this research are to determine certain physical characteristics of the fashion fabric and the interfacings; to analyze the flexural rigidity of the components and the composites; to analyze the crease recovery for the components and the composites; and to analyze seam head size for the composites and a control specimen with no interfacing.

The results of this research should be important in helping the home sewer and the apparel manufacturer to choose the type of interfacing best suited for enclosed seam areas when using lightweight suiting fabrics.

CHAPTER II. REVIEW OF LITERATURE.

The review of literature is presented in three sections. The first section will focus on bending properties of fashion fabrics and of fashion fabric/interfacing composites and subjective and objective measurements of fabric hand. The second section will deal with the characteristics of fusible and nonfusible interfacings. The final section will pertain to design line distortion in enclosed seam areas.

BENDING PROPERTIES

Moore (1984) contends that fabric must be capable of molding to the body if it is to be constructed into a garment and worn. Furthermore, the bending properties of fashion fabrics, interfacing fabrics, and composites of the two both aid and hinder the construction process of clothing. Dhingra et al. (1981) point out that fabrics are expected to adjust to movements the body makes as a garment is worn. The mechanical properties of fabrics are studied in order to predict how a fabric will behave once it is woven or knitted. In this way, fabrics can be designed to meet desired characteristics for specific end uses (Grosberg, 1970).

Bending and Creasing Properties of Fashion Fabrics

Types of fabric deformations and/or mechanical properties include creasing, bending, and shear. These fabric mechanical properties relate directly to the fabric's drape, hand, tailorability, creasing, wrinkling, and shape retention. The fabric's thickness, weight, weave, crimp, and yarn density also influence the bending behavior (Dhingra et al., 1981). Bending behavior, which includes creasing and crease resistance, is a bulk mechanical property. Other bulk properties include compression, shear, and dimensional stability. In normal use, fabrics are subjected to bending deformation (Hearle et al., 1969).

Bending properties of fabrics can be divided into two categories. The first is bending with a large radius of curvature, normally a large gentle bend. The second type is one with a small radius of curvature or a sharp bend. A large radius of curvature represents the fabric properties of handle, drape, and possibly wrinkle resistance. A small radius of curvature represents the crease resistance of a fabric. In fabrics that bend sharply, some deformation will be retained even after a period of recovery. The fibers in the yarns tend to buckle (Grosberg, 1970).

Grosberg, in analyzing bending properties, found that the bending rigidity of a fabric was greater than the sum of the bending rigidities of the individual yarns within the fabric. According to his findings, yarns are not free to bend where they come in contact with other yarns, thus interyarn friction exists.

The bending of the fabric puts stress on both fibers and yarns which often results in a resistance to further bending. The bending resistance of fabric has been found to be greater than the sum of the bending resistances of the yarns used to construct the fabric. This may be due to the fabric construction process because the yarns support each other and make the structure stiffer and more resistant to bending (Grosberg, 1966). When a fabric is bent, the yarns crossing the crease or bend are subjected to pressures in addition to those incurred in weaving. Yarns with low twist tend to flatten and compact at the location of the crease. The yarn deformation may occur by intrayarn fiber movement, allowing the individual fibers to avoid the high strain and also improving the fabric's ability to recover. If the fibers can move to avoid the strain, however, a permanent crease which is desired in pleats will not be possible. If the fibers cannot move, as in yarns with high twist, the fibers and the yarns will be deformed (Hearle et al., 1969).

When a fabric is severely distorted, the fibers in the yarns may be deformed as well as displaced depending on the amount of twist in the yarn. When the fabric is bent, bending strains are imposed on the fibers. The amount of strain on the fibers and the ability of the fibers to recover from the strain influence how the fabric reacts to bending (Abbott et al., 1960; Treloar, 1977). The flexibility of a fiber increases as the diameter of the fiber decreases. Woven fabrics are often constructed in such a way that the strength and flexibility of the fibers are preserved (Dhingra et al., 1981).

When a yarn is deformed, the fibers within the yarns initially move in order to minimize the strain on the fibers themselves. The amount of movement that the fibers can have depends on the amount of friction within and between the yarns. The fibers tend to cluster together when the fabric bends, instead of bending individually. This clustering tends to increase the flexural rigidity of the yarn and the fabric. Therefore, the flexural rigidity of the yarn would be greater than the sum of the flexural rigidities of the fibers that constitute the yarn (Abbott et al., 1960).

Each fiber bends with a different radius of curvature depending on its position in the yarn. The fibers closest to the inside curve of a bent yarn have the smallest radii of curvature or sharpest bend, and therefore have the greatest amount of strain. The fibers toward the outside of the curve of the yarn have larger radii of curvature, or a more gentle curve, thus smaller amounts of strain exist. The inner fibers have the least amounts of recovery while the outer fibers have the most recovery (Abbott et al., 1960).

Interfiber friction helps determine how well a fiber will recover from bending. Fibers can be prevented from returning to their original positions because of this friction. Sometimes, if the fabric is shaken, the frictional forces may release the fibers and the fibers in a previously creased area will recover from bending more completely (Abbott et al., 1960).

Recovery of fabric from bending is dependent on the recovery ability of the fibers and the yarns present in the fabric. When yarns are woven into a fabric, they restrict the movement of the yarns with which they come in contact. The restriction will increase the flexural rigidity of the fabric. Fibers affect how the yarns within the fabric will recover from creasing. If the fibers do not recover completely due to a permanent set formed in creasing, the yarn's ability to recover from creasing is reduced. When the fibers are under increased strain, the ability of the yarns to recover decreases. When a fabric is bent or creased, some fibers move from their original positions. Upon release of the bending force, these fibers cannot return to their original position and can interfere with other fibers which are trying to return to their original places (Abbott et al., 1960).

Dhingra and Postle (1980) compared the bending behavior of fabric that had two different widths of seams to that of fabric with no seams. They found that it was easier to bend a fabric when the seamed specimen was bent along an axis parallel to the seam than when the specimen was bent on an axis perpendicular to the seam.

For the specimens bent along an axis parallel to the seam, a seam allowance of 1 mm had little effect on the bending resistance. When a single layer of fabric was bent, the seam aided the bending by acting as a hinge at the stitching line. As the width of the seam allowance increased to 2.5 mm and above, a double layer of fabric was being bent because the seam allowance was caught in the clamps holding the fabric as it was bent. The bending resistance of the specimen with a 2.5 mm seam allowance was higher than that in the specimen with a 1 mm seam allowance because only a single layer was being bent in the 1 mm specimen and a double layer was being bent in the 2.5 mm specimen (Dhingra and Postle, 1980).

For the specimens bent perpendicular to the seam (i.e., crossing the seam), the seam resisted bending and had a greater bending resistance than the specimens bent parallel to the seam. The specimens bent non-uniformly due to the seam being more rigid than the adjacent fabric areas. When comparing fabric specimens with no seams, the bending resistance of a double layer of a fabric was 10-12 times higher than that of a single layer of fabric. Stitching the layers together also increased the bending resistance (Dhingra and Postle, 1980).

Solinger (1980) described the property of seam head as it was related to a 'butterfly seam', similar to the enclosed seam but with only one layer of the fabric folded back over the seam allowances. Solinger defined the seam head as the distance from the fold of the fabric to the nearest stitching line. There are three dimensions of seam head size. First, there is seam depth, the total thickness of the two or more layers of fabric sewn together. The second dimension is seam length, the length of the seam sewn which is dependent on the size of the fabric piece being sewn. The third dimension is seam width which is the size of the seam allowance. Solinger, however, made no mention of the effect of a fabric's bending resistance on the seam head size.

Moore (1984) studied the effects of certain physical and mechanical fabric properties on the seam head size in wool and wool/polyester blend fabrics. Six fabrics were included in the study. The thickness, bending length, weight, fabric count, flexural rigidity, and cover factor were measured for each fabric. Yarn properties also were measured, including yarn number, twist, yarn diameter, and twist factor.

Fifteen 50 x 150 mm enclosed seams were constructed for each fabric. Five warp, five filling, and five bias seams were constructed for each of the six fabrics. A total of 90 enclosed seams were constructed. Cross-sections of the seams were photographed against a ruler with increments of one hundredth of an inch. The photographic slides were magnified and the seam head size for each specimen was recorded. The data were analyzed to determine if fiber content, thickness, grain direction, and flexural rigidity had significant effects on the seam head size. The seam head size was significantly larger for the wool/polyester blends. Grain direction had no significant effect on the seam head size. Fabric thickness was found to have a significant effect on seam head size. Flexural rigidity was positively correlated to the seam head size.

Fabric Hand Properties

Studies have been done to develop objective measures of several aspects of fabric hand. Fabric stiffness is one of the properties of hand. Objective measurements of flexural rigidity, crease recovery, and drapeability already exist for the measurement of fabric stiffness.

A study by Howorth (1964), compared objective measurements of fabric weight, thickness, stiffness, and hardness to subjective rankings made by judges. The researcher studied suiting, lingerie, and dress fabrics. Smoothness, stiffness, and thickness accounted for the differences noted by the judges in the hand of fabrics.

Elder et al. (1984) looked at the relationship between subjective assessments of hand and physical measurements of properties related to hand. The fabrics studied were bent by the judges with their hands and a number was assigned for the stiffness of a fabric. A value of 12 was assigned to a standard fabric, against which all other fabrics were compared. Values greater than 12 denoted stiff fabrics while values of less than 12 denoted less stiff fabrics. The fabrics were also bent using a Shirley Cyclic Bending Tester. An analysis of variance on the results indicated that the judges could discriminate between the different levels of stiffness measured objectively for the fabrics. The results were significant at $p < .001$.

The Kawabata System has been developed to give an objective measure of fabric hand. By using verbal expressions of hand, such as stiff, smooth, soft, and crisp, a panel of 10 experts from the textile industry evaluated 200 fabrics. Numerical values were given for the verbal expressions. These evaluations provided a standard for comparing other fabrics. Dr. Kawabata developed equations to calculate the Total Hand Value by using ratings given by the experts. Specific mechanical properties which relate to hand were measured, including tensile and shearing properties, pure bending properties, compression properties, surface smoothness and frictional properties. There was high correlation between the mechanical properties and the Total Hand Value scores. The Kawabata system is currently being used in Japan, Europe, and the U. S. (Fortess et al., 1982).

Bending Properties of Fashion Fabric/Interfacing Fabric Composites

Various conditions will affect the bending of fabric. One is the introduction of interfacing. A primary reason for using interfacings is to stiffen design details such as in collars and cuffs (Dhingra and Postle, 1980; Kartun, 1974; Shishoo et al., 1971). Since there are various weights of interfacings available, a variety of changes in stiffness of the fashion fabric will occur depending on the thickness and stiffness of the interfacing used (Bendel, 1984; Kozlosky, 1981).

Nonwoven fabrics have different bending properties than woven fabrics. Nonwoven fabrics have a higher bending rigidity than woven fabrics due to the bonding of the fibers to form the fiber mat. The yarns and fibers in a woven fabric have the ability to shift thus reducing the strain put on them. Nonwoven fabrics, depending on the method used to bind the fibers together, may lack the ability for yarns and fibers to shift to reduce the strain. This immobility is the reason for the higher flexural rigidity of some nonwoven fabrics. The mechanically bonded nonwovens have the ability for the fibers to shift when under strain. Fabrics in which fiber intersections are bonded together have the ability to move as far as the bond will elongate. Laminated fabrics lack the ability for the fibers to move (Krcma, 1971).

Shishoo, Klevmar, Cednas, and Olofsson (1971) studied the bending resistances of composites of fusible interfacing and fashion fabric. They found that fusible interfacing with a random pattern of thermoplastic dots was stiffer than fusible interfacing coated in a regular thermoplastic dot arrangement. The regular-dot coated interfacing had more space, on average, between the dots than did the randomly coated interfacings, and these spaces allowed the composite to bend more easily. There was little stiffening observed for interfacings in which the adhesive dots were spaced widely apart. The distance between these dots was not recorded, however.

Shishoo et al. (1971) found that the bending resistances of fashion fabric/interfacing composites were 4-10 times greater than the summed bending resistances of the respective component parts. This was most likely due to the fusing action. Also, the bending resistance measured for the composite differed depending on whether the fashion fabric side or the interfacing side was placed up when bending. Shiloh (1972) determined that the fusing process increased the flexural rigidity (bending resistance) considerably. The composite constructed with a dot coated interfacing was found to be more flexible than a laminated or sheet bonded structure. According to Shiloh, it is claimed that a dot coated fusible interfacing composite is as flexible as a nonfusible interfacing composite.

In a study by Dhingra and Postle (1980), the bending resistance of a fashion fabric/fusible interfacing composite was found to be 4-7 times more than the average bending resistance of the components. This was partly due to a double layer of fabric being bent and partly because of the fusing action. They also found that the greater the difference between the bending resistances of the components, the greater the bending resistance of the composite.

Dhingra and Postle also analyzed the bending behavior of fused interfacings. They found that it was more difficult to bend the fabric when the interfacing side of the composite was up or bending in a convex manner than when it was down or being bent in a concave manner.

Shishoo et al. (1971) found that, even though the fashion fabric was several times stiffer than the interfacing when bending resistance was measured prior to fusing, the interfacing was the major determinant of the stiffness of the composite after fusing. This most likely was due to the fusing. It was also found that the interfacing had the greatest stiffness in the lengthwise direction. Thus, the composites were the stiffest when bent perpendicular to the lengthwise direction of the interfacing. When the specimens were bent along the bias of the interfacing, the stiffness was lower than in the composites bent in the lengthwise or widthwise direction. Shishoo et al. also found that the amount and distributional pattern of the adhesive on the fusible interfacing influenced the bending rigidity of the composite of interfacing and fashion fabric.

More research has been done on fusible interfacings than on nonfusibles because it has been thought that fusibles had more effect on the bending behavior of fashion fabric. However, according to some researchers, fusible interfacings are as flexible, and sometimes even more so than the nonfusible interfacings when the interfacings are combined with a fashion fabric (Shiloh, 1972).

A study by Shiloh (1972) utilized a fusible interfacing fused to six different apparel fabrics. The lengthwise direction of the base fabric of the interfacing followed the warp direction of the apparel fabric. Wrinkling of the composites and of the unfused components was analyzed by using a Sivim Wrinkle-Meter. It was found that the composites had more severe wrinkling, which was due to the fabric areas around the fused areas being fixed and unable to bend and shear. Fusing increased the bending length and the flexural rigidity of the fabrics. Since drapability is linearly related to bending length, it was determined that the fusing would also increase the stiffness and thus decrease the fabrics' ability to drape. Shiloh found, as Shishoo et al. had, that the bending and wrinkling of a composite were affected more by the interfacing properties than by the fashion fabric properties.

Multon (1985) compared preshrunk and nonshrunk fabrics which were fused to interfacings. Four cotton/polyester shirt weight fabrics and three types of fusible nonwoven interfacings were used. Half of the fashion fabric specimens were prewashed prior to attaching the interfacing. After fusing, the composites were laundered and compared after the first, fifth, tenth, and twenty-fifth launderings. Flexural rigidity, bond strength, and dimensional stability of the composites were compared. It was found that preshrinking the fabric affected the flexural rigidity of the composites since those composites were more rigid than the composites without the prewash treatment. Each fabric and interfacing type resulted in a different amount of bond strength of the composite. Prewashing gave a lower dimensional stability in the weft direction of the fabric in all cases. The warp direction was unaffected.

Koenig and Kadolph (1983) compared three performance characteristics of seven types of fusible interfacings. The characteristics studied included durability to laundering (dimensional stability, delamination, and appearance); wrinkle recovery, and drape. The same fashion fabric, a cotton/polyester broadcloth, was treated with each of the seven interfacing types. The interfacings included a plain weave, a tricot warp knit, a weft-insertion tricot warp knit, a random web--a dry laid nonwoven, an oriented web--a dry laid nonwoven, a spunlaced nonwoven, and a spunbonded nonwoven. All of the seven composites shrank in the warp and weft directions after five laundering treatments. However, none of the composites shrank more than 2.5% which was the allowable amount of shrinkage. Therefore, all the interfacings were acceptable with respect to shrinkage. The seven composites exhibited separation in a few areas after the first laundering. Thus, all the interfacings were unacceptable with respect to delamination. For appearance ratings, none of the composites were rated equal to or above the 4.0 acceptable rating. None of the composites showed acceptable recovery from wrinkling. The drape coefficient of the composites differed significantly from the drape coefficient of the control of fashion fabric with no interfacing. This would be expected since a primary reason for using interfacings is for stiffening. Thus, according to Koenig and Kadolph, fusible interfacings do not give desirable results with respect to wrinkle recovery, delamination, and appearance after laundering, but they do with dimensional stability.

In 1983 and 1984, Britton et al. described the development and implementation of a computer program that simulates the mechanical properties of nonwoven fabrics. The method of simulation, bond breakage, and fabric failure were included in the studies.

The first article dealt with how the simulation model was set up, given the decision to focus on individual bond sites. Initially, data on fiber properties, web geometry, and binder properties were recorded into the main computer program. When the fabric was strained, static equilibrium had to be reached before the new positions of a bond could be recorded. The coordinates of the bond sites were recorded after each step to form a data base of bond movements so mechanical properties could be calculated. To model the fabric on the computer, bond sites were randomly placed in a specified area and then connected by lines. The fabric model was then studied under varying amounts of strain to determine the extent to which the bond sites would move or shift (Britton et al., 1983).

The second article dealt with a fabric model with bonds at fiber intersections. The simulated fabric was depicted in an unstrained position; then depicted in a new position under a known amount of strain. Each bond site moved in the direction of the force when the fabric was placed under the strain. A critical force value (the amount of force applied to cause bond breakage) was established. The force amounts for each bond were determined mathematically. If the force of a fiber on a bond exceeded the critical force value, the bond was considered broken (Britton et al., 1984a).

The third article dealt with fabric failure. A model fabric was constructed with specific dimensions and representing a more realistic fabric. The fabric was strained until the fabric broke into two pieces. The number of bonds broken at each percentage of strain was recorded. The last fiber strand broke at 166% strain (Britton et al., 1984b).

In summary, little research has been conducted on seam head size and the effect of fusible and nonfusible interfacings on the seam head size. Information available that is relevant to this area is mainly on the bending behavior of composites incorporating fusible interfacings and the bending behavior of superimposed seams, yarns, fibers, and double layers of fabrics.

INTERFACINGS--FUSIBLE/NONFUSIBLE AND WOVEN/NONWOVEN

Garments often have been designed with some sort of object-- bustles, whalebones, and countless others-- to impart desired shapes. During the 1700s, collars and lapels became popular fashion details in men's garments and prompted the need for interfacings to give the desired stiffness and shape in the area (Mini-History, 1970; Multon, 1985). An interfacing is a fabric which is placed between the outer garment layer and the facing or lining to stiffen, support, and give body to a certain area (Kartun, 1974). A variety of woven fabrics was used as interfacings including horse hair, starched cotton, or linen fabrics, self-fabric, flannel, burlap, and buckram (Mini-History, 1979). Nonwoven interfacings were introduced in 1942 and utilized the manmade fibers that had recently been developed (Multon, 1985). In

1952, Pellon Ⓡ was developed and sold. It was a blend of cotton, rayon, and nylon bonded with a nitrile rubber formulation. It provided excellent strength and stability and was lightweight (Marler, 1977).

In 1912, Frederick Hansing developed the first fusible interfacings. Patents for fusible interfacings were first issued in the early 1900s although fusibles were not used commercially until the 1950s. In 1951, Sydney Morgan and Harold Rose developed and marketed a fusible interfacing which they called Stayflex Ⓡ (Cross, 1985; Kartun, 1974; Marler, 1977; Multon, 1985). This interfacing was made of a woven cotton base fabric and had a continuous coating of adhesive on one side. By the 1960s, these "iron-ons" were available in both woven and nonwoven structures. The thermoplastic resin was applied to one side of the base fabric and tended to form a boardy and stiff composite (Kartun, 1974; Multon, 1985; Zisk, 1974). This type of interfacing was still being used in the 1970s, but its apparel applications were limited because of the stiffness. During the 1950s, a new coating method for adhesives was developed which softened the hand of the composite. This method was called sinter coating. In this process, a powdered adhesive was spread onto a base fabric and then partially melted onto the surface of the base fabric. This type of interfacing still gave a firmer hand than was desired (Zisk, 1974). Improvements in fusibles occurred during the 1970s with the invention of the dot-coated and random-coated adhesives. These adhesive processes tremendously improved the hand obtainable with the fusible interfacings (Kozlosky, 1981; Shiloh, 1972).

In 1964, a heat sensitive substance was printed onto a base fabric in known amounts and in predetermined locations. Only 17% of the base fabric was covered with the adhesive allowing the fabric to move freely between the attached areas after fusing. A softer hand and more flexible fabric resulted. In 1966, a second generation of fusible interfacings was developed. This consisted of a preplanned pattern of dots made of heat sensitive material applied to a base fabric. There were about 725,000 dots per square yard. The dots in a square yard weighed only one half ounce. Each dot had a diameter of approximately .5 mm and a height of .2 mm. These interfacings cost more than the sinter coated fusibles, but they could be applied to fabrics with a wider variety of fiber contents (Potts, 1976).

Nonfusible Interfacings

Prior to nonwoven interfacing fabrics, self fabric was a common type of interfacing used. Nonfusible interfacings come in woven, nonwoven, and knitted structures and in a variety of weights and thicknesses. Basically, a nonfusible interfacing is a fabric which is sewn onto the inside of a garment area such as a collar or cuff to stiffen and support that area (Lawrence and Yurick, 1977).

The application of the nonfusible interfacing is time consuming. It requires that the interfacing be placed over the fashion fabric and sewn in place by machine and/or hand. Some textbook instructions suggest that once the interfacing is sewn in place, the interfacing seam allowance should be trimmed to 1/8 inch to reduce bulk in the seam area (Lawrence and Yurick, 1977).

Nonfusibles have the advantages that their application does not change the outward appearance of the fashion fabric and that they are easily removed if a mistake is made. Since nonfusibles are applied with stitches, they permit greater control in shaping garment sections as is needed in tailoring garments (Bendel, 1984). Disadvantages are that their application requires more skill and time than does the application of a fusible (Bendel, 1984; Fusing Effectiveness, 1982; Shiloh, 1972). Also, differential shrinkage may occur when the interfacing and fashion fabric shrink at different rates. Another disadvantage is that the nonfusible introduces bulk at seams because in most cases it must be included in the seam (Lawrence and Yurick, 1977).

Fusible Interfacings

Fusible interfacings are available in many weights and structures, with more structural variety than with the nonfusibles. Fusibles are made in woven, nonwoven, knitted and a combination of knitted and woven base fabrics.

Fusible interfacings are applied to fashion fabrics by means of heat, pressure, moisture, and time. Manufacturers test their interfacings to determine the proper fusing conditions to create a permanent bond and provide users with application instructions (Cohen, 1978; Multon, 1985; Russell, 1978; Shiloh, 1972; Shishoo et al., 1971; Worthington, 1980).

It is recommended that the seam allowance of the interfacing be trimmed away prior to fusing in order to reduce bulk in the seam area. Some sources suggest trimming off the entire seam allowance of the interfacing, while others suggest trimming off only 1/2 inch so that the interfacing will be caught in the seam to prevent slippage if delamination occurs (Lawrence and Yurick, 1977; Multon, 1985).

There are both advantages and disadvantages of fusible interfacings. Some advantages are the decreased time and skill necessary for application (Brumbaugh and Mowat, 1977; Shishoo et al., 1971). Thus, apparel manufacturers find it cheaper to construct garments with fusibles because less time and less skilled workers are needed. Fusibles also help stabilize the fashion fabric after application and help prevent stretching (Fusing Effectiveness, 1982; Potts, 1976). After fusing, the interfacing and fashion fabric can be treated as one (Lawrence and Yurick, 1977).

A disadvantage of fusibles is that interfacings which require a high temperature for fusing cannot be used on delicate, heat sensitive fabrics. Another common problem is strike back which occurs when the resins in the adhesive dots melt and travel back through the interfacing fabric towards the warm iron. The strength of the resulting bond is reduced when strikeback occurs (Kozlosky, 1981). Strike through also may occur when the adhesives flow to the outside of the fashion fabric (Potts, 1976). When strike through occurs, the fashion fabric color is affected. Delamination is another problem with the fusibles. It results when a permanent bond is not made when heat is applied. Delamination reduces the degree to which the interfacing supports or stiffens the fashion fabric (Kozlosky, 1981). Sometimes the interfacing and fashion fabric shrink at different rates causing bubbles or puckers to occur (Kozlosky, 1981). Also, fusibles are difficult to remove if the need arises (Potts, 1976).

Woven Interfacings

Woven interfacings are typically constructed in a plain weave and have lengthwise and crosswise grain. They are found in both fusible and nonfusible forms. Generally, woven interfacings sections are cut in the same grain direction as the garment section to be interfaced. Self fabric is often used to interface woven fashion fabric garment sections. This helps eliminate the problem of differential shrinkage and/or color change in the fashion fabric.

Nonwoven Interfacings

Nonwoven interfacings are constructed in various manners such as dry-laid webs, wet process webs, and spunbonded webs (Casper, 1975; Depoe, 1974; Gillies, 1979; McDonald, 1971)

The dry-laid webs are constructed by randomly arranging a layer of fibers, by means of a fluid force, onto a conveyor belt. Fibers two to four inches in length are used. Longer fibers tend to become entangled with shorter ones which helps hold the mat together. The web is then bonded by spraying it with a resin, by mechanical means such as needle punching, or by melting the fibers to fuse them together. The fiber contents generally used for dry-laid webs are rayon, polyester, or nylon (Casper, 1975; Depoe, 1974). The advantages of the dry process include the following. A variety of textile fibers as well as variety of fiber denier, length, crimp, and binders can be used. The type of fiber and binder can also be easily changed on the production line which makes shorter runs possible. The final advantage is that the machinery needed for producing dry-laid webs is readily available to manufacturers (Depoe, 1974).

Three types of nonwoven fabrics are produced by this method. The first type is the stable or multidirectional web. Fibers are laid in a random web by the means of air. The fabric does not stretch in any direction and has excellent strength in all directions (Depoe, 1974; Multon, 1985).

The second type is the stretchable or unidirectional web, also called an oriented web. Fibers are laid parallel to the length of the fabric by using wool or cotton cards. The web has good strength in the lengthwise direction and very low strength and high elongation in the widthwise direction. There is very poor recovery in the widthwise direction, however (Depoe, 1974; Multon, 1985).

The final type of dry-laid webs is the all bias which has good stretch and recovery in all directions. The fabrics are designed to be used with knits and lightweight wovens. Fibers are crosslaid in order to achieve the stretch (Depoe, 1974; Multon, 1985).

Wet process webs are constructed by using a modified paper making technique. The nonwoven fabric is made by preparing a suspension of staple fibers and a binder in water. A mat is prepared from this slurry and heated until the binder is activated. The mat is thus bonded at the fiber intersections. The fiber content generally used for these nonwovens is polyester, rayon, or nylon (Casper, 1975; Depoe, 1974). The advantages of wet-processed nonwovens are that the web has excellent uniformity and fibers with varying amounts of crimp can be used to produce bias stretch (Depoe, 1974).

Spunbonded nonwovens are produced by extruding hot filaments onto a moving conveyor belt. The filaments are allowed to fall and entangle randomly. The filaments bond to each other under pressure before they cool so no additional binder is necessary. This type of nonwoven usually is made from nylon fibers. The fabric has excellent strength in all directions (Casper, 1975; Depoe, 1974; Gillies, 1979). The advantages of spunbonded interfacings are that they have high tensile and tear strengths and low bulk (Depoe, 1974).

There are many advantages of nonwoven interfacings. These include the following. The nonwoven has no selvages, snags, or knots. The interfacing can easily be marked for cutting. The nonwovens are easily cut and are stable during cutting. The web will not ravel so there is a smooth edge for stitching. The web maintains its shape and hand after laundering. Some nonwovens have good bulk properties with low weight. Finally, nonwovens cost less than other types of interfacing structures (Depoe, 1974).

Other Interfacing Structures

The final types of interfacing base fabrics are the knitted tricot interfacing and the combination knitted and woven interfacing (weft insertion). In a weft insertion type during the knitting process separate yarns are laid across the entire fabric width and woven between the knit loops (Multon, 1985).

Selection of Fusible and Nonfusible Interfacings

Selection of both fusible and nonfusible interfacings must be done carefully to produce a satisfactory composite with the face fabric. When choosing interfacings, the face fabric always must be considered as well as the desired design features of the garment. For nonfusibles, the fabric and interfacing can be draped one atop the other to determine if the firmness is what is desired (Bendel, 1984; Kalka, 1982; Lawrence and Yurick, 1977). For fusibles, however, draping is not enough since the fusing process will change the hand. Therefore, it is suggested that a supply of various weights and structures of fusibles be kept on hand so different types can be fused to a fabric to determine which produces the most desirable results (Bendel, 1984; Stern, 1978).

There are many different constructions and weights of both fusible and nonfusible interfacings to choose from. Both fusibles and nonfusibles have advantages and disadvantages so that it is often a matter of preference or guesswork when choosing which type to use.

DESIGN LINE DISTORTION

When a garment is constructed, a displacement of the design line often occurs. The stitching line and design line are intended to be in the same place but in enclosed seams this may not happen (Moore, 1984). This displacement is due to the fabric not having room to turn or move in the encased seam area so the fabric becomes taut and distorted along that design line (Lanier, 1980). The stress on the fabric of an enclosed seam causes the fabric to fold beside the seam, not on top of it. This results in a larger seam head which is the distance from the fold to the stitches. The seam head is equal to the amount of design line distortion that occurs in the garment seam area (Moore, 1984).

Lanier (1980) measured design line distortion of enclosed seams and suggested a solution to decrease the amount of distortion. Lanier analyzed the effect of decreasing the seam allowance by .5 mm, 1 mm, and 2 mm. A sample of home sewers constructed and evaluated the appearance of each of these corrections on the enclosed seams of 27 jacket fronts.

Four construction points were evaluated including the collar ends, the point where the collar and the lapel were joined, the point where the jacket hem joined the facing on a curved jacket front, and a welt pocket. It was found that appearance improved in all cases in which the seam allowance was decreased. This decrease in seam allowance allowed room for the fabric to turn and, therefore, the fold of the enclosed seam fell on the true design line. Thus, design line distortion was eliminated.

There is still limited information available on design line distortion in enclosed seams. Several books published for clothing construction teachers and home sewers have mentioned possible solutions to this distortion. However, no mention was made regarding design line distortion resulting from the introduction of interfacing in a seam. One method used when sewing upper and under collars was to stop stitching 1/16 inch from the dot on the pattern where the collar stops and the lapel begins (the collar termination point). Also, the stitching line for the ends of the collar was moved 1/16 inch toward the cut edge. The lapel also was stitched to within 1/16 inch of the collar termination point. Thus, there was a 1/8 inch section not stitched at the collar termination point. Several authors suggested that this technique would reduce puckering in that area (Bane, 1974; Lanier, 1980; Moore, 1984).

Stitching lines for darts are also modified to prevent puckering at the tip and to reduce bulk. In this method, the small pointed end of the dart is stitched with a slight curve toward the fold of the dart. This creates a smoother line on the dart (Kraak, 1977; Lanier, 1980; Margolis, 1978; Moore, 1985). A curved stitching line also could be applied to a lapel at the collar termination area producing a straighter edge for the lapel (Lanier, 1980; Moore, 1985; Schwebke, 1960). This method of curving the stitching line also works for welt pockets. Cabrera and Meyers (1983) suggested that the stitching lines of a welt pocket curve could be moved inward toward the slash in the pocket. This improves the visible appearance of the pocket opening by making the lines smoother and straighter.

In summary, design line distortion in enclosed seams occurs when there is not enough fabric allowed for the turning of an enclosed seam. Therefore, the design line and stitching line fail to coincide. This can be corrected by decreasing the seam allowances and allowing more fabric for the turning of the enclosed seam.

CHAPTER III. STATEMENT OF THE PROBLEM.

There is evidence from the review of literature that little attention has been given to comparing the bending properties of interfacing and fashion fabrics. Flexural rigidity, crease recovery, and seam head size of fusible and nonfusible interfacings in combination with lightweight suiting fabrics warrant further study.

PURPOSE

The purpose of this research is to compare the effect of a fusible and a nonfusible nonwoven interfacing on the flexural rigidity, crease recovery, and seam head size of a lightweight suiting fabric. Bending resistances of the interfacing/fashion fabric composite and the respective components and the bending resistances of the composite when the interfacing side is on top and with the interfacing side down for each interfacing type are compared. Comparisons also are analyzed for the angle of crease recovery of the interfacing/fashion fabric composite and the respective components and for the crease recovery of the composite when the interfacing side is on top when creased and the composite with the interfacing side down for each interfacing type.

OPERATIONAL DEFINITIONS

For purposes of this research, the following definitions are used:

Fashion Fabric: A woven lightweight suiting fabric.

Base Fabric: A nonwoven structure which is used in the construction of nonfusible and fusible interfacings.

Nonfusible Interfacing: A nonwoven fabric structure consisting of only a base fabric that is used to stiffen areas of garments. The interfacing is applied by sewing it to the fashion fabric.

Fusible Interfacing: A nonwoven fabric structure consisting of a base fabric with thermoplastic dots adhered to one side, that is used to stiffen certain areas of garments. The interfacing is applied using a specified temperature, time, and pressure to melt the thermoplastic dots and cause them to attach to the fashion fabric.

Thermoplastic Dots or Adhesive Dots: The dots adhered to the base fabric of an interfacing which melt with heat and moisture to fuse the interfacing to a fashion fabric.

Flexural Rigidity or bending resistance: A fabric's resistance to bending under its own weight.

Encased Seam or Enclosed Seam: A seam in which the fabric on each side of the seam is bent back over and covers the seam allowances.

Seam Head: The distance from the fold in an enclosed seam to the stitching line which forms the seam.

Composite: A structure consisting of a combination of a fashion fabric and an interfacing (fusible or nonfusible).

Nonfusible Composite (nonfusible interfacing/fashion fabric composite): A composite consisting of a nonfusible interfacing attached to a fashion fabric by friction between the fibers of the two fabrics or by stitching in a seam.

Fusible Composite (fusible interfacing/fashion fabric composite): A composite consisting of a fusible interfacing fused to a fashion fabric.

OBJECTIVES

Nine objectives were identified and used to guide the researcher in conducting this study. They are as follows:

Objective I: To determine specific physical characteristics of the lightweight suiting fabric and of each nonwoven interfacing:

A. Weight

B. Thickness

C. Fabric count for fashion fabric

D. Count of adhesive dots per inch for fusible interfacing

E. Structure of the nonwoven interfacings and fashion fabric

Objective II: To compare the sum of the bending resistances of the components of the composite to the bending resistance of the composite for each of the interfacing/fashion fabric combinations.

Objective III: To compare the bending resistance of the composite with the fashion fabric side up to the bending resistance of the composite with the interfacing side up for each of the interfacing/fashion fabric combinations.

Objective IV: To compare the average angle of crease recovery of the components of the composite to the average angle of crease recovery of the composite for each of the interfacing/fashion fabric combinations.

Objective V: To compare the angle of crease recovery of the composite with the fashion fabric side up to the angle of crease recovery of the composite with the interfacing side up for each of the interfacing/fashion fabric combinations.

Objective VI: To compare the bending resistances of the fusible composite and the nonfusible composite.

Objective VII: To compare the crease recovery of the fusible composite and the nonfusible composite.

Objective VIII: To measure the seam head size in the enclosed seams when the fashion fabric is combined with the following interfacings:

A. No Interfacing (Control Specimen)

B. Fusible Interfacing

C. Nonfusible Interfacing

Objective IX: To compare the seam head size of the following interfacing/fashion fabric combinations:

A. Fusible interfacing with control specimen

B. Nonfusible interfacing with control specimen

C. Fusible interfacing with nonfusible interfacing

RESEARCH HYPOTHESES

Certain results were expected from this study. Therefore, seven research hypotheses were set up. The research hypotheses are as follows:

Hypothesis 1: The average bending resistance of the composite will be greater than the average sum of the bending resistance of its component pieces for each interfacing/fashion fabric combination.

Hypothesis 2: The average bending resistance of the composite with interfacing side up will be greater than the average bending resistance of the composite with interfacing side down.

Hypothesis 3: The average bending resistance of the fusible composite will be greater than the average bending resistance of the nonfusible composite.

Hypothesis 4: The average angle of crease recovery for the composite will be greater than the average angle of crease recovery for the components.

Hypothesis 5: The average angle of crease recovery for the composite with interfacing side up will be greater than the average angle of crease recovery for the composite with interfacing side down.

Hypothesis 6: The average angle of crease recovery for the fusible composite will be greater than the average angle of crease recovery for the nonfusible composite.

Hypothesis 7: The seam head size for the fusible composite will be greater than the seam head size of the nonfusible composite which in turn will be greater than the seam head size of the control with no interfacing.

ASSUMPTIONS

In this study, it is assumed that the cantilever stiffness test, crease recovery, and thickness tests are valid measures of stiffness, crease recovery, and thickness respectively. It is also assumed that the photographic process for measuring seam head size is a valid and reliable measure.

LIMITATIONS

There were various limitations in this study including the following:

1. Only one fashion fabric was used for the study.

2. Only nonfusible and fusible nonwoven interfacings produced by the same company and labeled as featherweight were used.
3. All seams were sewn with the same thread, tension, stitch length, and seam allowance.
4. The fashion fabric seam allowances were not graded or trimmed after the seam was sewn. The fashion fabric seam allowance was left 15 mm wide.
5. The interfacings were trimmed by 10 mm prior to construction of the seams.
6. Due to the limited number of specimens and the destructiveness of the seam head specimens, no comparisons were made among the values of flexural rigidity, crease recovery, and seam head size.

CHAPTER IV. METHODS AND MATERIALS

Interfacings have been used since the early 1700s as a way of supporting and stiffening a fashion fabric to create a specific design or strengthen the fashion fabric. There are differing opinions as to whether fusible or nonfusible interfacings are the most desirable in garment construction. Research has shown that the flexural rigidity of a fabric increases significantly when a fusible interfacing is applied, therefore affecting the appearance of the garment section.

The preceding review of literature discussed the lack of published information and research on the bending behavior of nonfusible interfacings and on the effect of interfacings, both fusible and nonfusible, on the seam head size of an enclosed seam constructed in a lightweight suiting fabric.

The following research procedures were used to analyze bending behaviors of fusible and nonfusible interfacings and composites made from these interfacings and a lightweight suiting fabric and to determine the effect of these interfacings on the seam head size of a lightweight suiting fabric.

FABRIC SELECTION

The fashion fabric used in this research was a lightweight suiting fabric readily available to home sewers and manufacturers for use in constructing women's lightweight suits. The selected fabric was a blend of 35% polyester, 35% acrylic, 18% rayon, and 12% other fibers constructed in a herringbone twill weave.

Two nonwoven interfacings, one nonfusible and one fusible, were selected for use in this study. Both were constructed of 100% polyester fibers, labeled as featherweight, and produced by the same manufacturer. The suiting fabric and the interfacings were bought at a local fabric store in Blacksburg, Virginia.

FABRIC CHARACTERIZATION

Five fabric properties were measured to characterize the fabrics used for this study. These properties were weight, thickness, fabric count for the fashion fabric, count of adhesive dots per inch in fusible interfacing, and the structure of the nonwoven interfacings and the fashion fabric.

Weight and thickness were measured using standard conditions of 70 ± 2 ° F and 65 ± 2% relative humidity (ASTM Standards, 1974)

Weight

The weight of the fabric was measured as mass per unit area using ASTM D-3776, Option B--full width sample (ASTM Standards, 1974). The crosswise cut ends of the fabric were recut so that they were perpendicular to the selvage. Five length and width measurements in centimeters were taken across each of the fabrics to establish the area. The five length measurements were averaged to obtain a length measurement for each fabric. The same was done for the width measurements of each fabric. The measurements were converted to yards. The weight was measured in grams on an Ohaus 1500D scale and then was converted to ounces. The fabric weight in ounces per yard squared was calculated from the average length, average width, and weight measurements.

$$\text{Ounces per yard squared} = \frac{\text{Weight (oz)}}{\text{Length (yd)} \times \text{Width (yd)}}$$

Thickness

Fabric thickness was measured in thousandths of an inch using a thickness testing instrument made by Custom Scientific Instruments, Inc. of Kearny, New Jersey. Ten 100 x 150 mm specimens were used for the fashion fabric and for each of the interfacings. The ten cut specimens for seam head size were used for the thickness measurements. Each specimen was measured once in the center using ASTM D-1777 (ASTM

Standards, 1974). Ten readings were taken for each of the three fabrics. The ten readings for each fabric were averaged to obtain the average thickness of the fabric.

Fabric Count For Fashion Fabric

Fabric count, the number of yarns per inch was measured according to ASTM D-3775 (ASTM Standards, 1974). Five measurements in the warp and filling directions were taken at different locations throughout the fabric. Five warp and five filling measurements were averaged separately to determine fabric count for each direction.

Adhesive Dot Count For Fusible Interfacing

No standard procedure was available for counting the adhesive dots per inch. Therefore, the following method was developed by the researcher. The number of adhesive dots per square inch was counted at five separate locations on the fusible interfacing. No magnification was necessary. Five one square-inch sections were ruled, and as the total number of dots in a section was counted, the dots in the section were marked with a red pen to prevent counting each dot more than once. The five one square-inch measurements were averaged to obtain a measurement of adhesive dots per inch for the fusible interfacing.

Fabric Structure

The interfacing fabrics were magnified (10x) using a Fisher Scientific microscope. The microscopic analysis was done to determine if the two interfacings had random or oriented web structures. The fashion fabric was viewed with the naked eye to determine the weave.

FLEXURAL RIGIDITY MEASUREMENT

Flexural rigidity was measured using ASTM D-1388, the cantilever stiffness test (ASTM Standards, 1974). Measurements were taken on the fashion fabric, fusible interfacing, nonfusible interfacing, fusible composite, and nonfusible composite.

Twenty 2.54 x 15.24 cm specimens of each interfacing and thirty specimens of the same size of fashion fabric were cut with the length of each specimen following the crosswise direction of the fabric. Ten specimens of each of the interfacings and of the fashion fabric were used for measuring the flexural rigidity of these fabrics alone. Ten fusible composites and ten nonfusible composites were constructed using the remainder of the specimens.

One 20.32 x 40.64 cm press cloth was cut from plain unbleached muslin. The press cloth was soaked in distilled water for 5 minutes, then run through a wringer with 40 of pounds pressure per square inch. The cloth was placed in a plastic bag with a zipper closure to keep it damp until used for constructing the fusible composites. A dry Elnapress with a 10 sec timer was used for fusing. The wool setting, recommended by the manufacturers for fusing the interfacing, was used. The fusible interfacing was placed on the back side of the fashion fabric. The specimens were placed on the padded table of the Elnapress with the interfacing side facing the heating plate. The damp press cloth was placed over the specimens and the press lid was locked in place over the specimens. After ten seconds, the specimens were removed and allowed to recondition for 24 hours.

The nonfusible composite was constructed by placing the interfacing on the back of the fashion fabric only. The interfacing was adhered to the fashion fabric only by the friction between the fibers of the two fabrics.

To measure bending length an FRL Cantilever Bending Tester was used. Four overhang measurements were taken for each of the ten specimens for each component and composite. The overhang, measured in centimeters, extended until the fabric bent 41.5°. One measurement was taken from each end of the fabric with the face up and again with the back up. For the composites, the measurements were taken from each end of the fabric with interfacing side up and interfacing side down and recorded separately. The four measurements taken for the component pieces were then averaged together to calculate the bending length for the components. For the composites, the two measurements taken for each side (interfacing up and interfacing down) were averaged together to obtain measurement for bending length for the composite as a whole. Bending length (C) was equal to one half the average overhang (O).

$$C = O/2$$

Weight in milligrams was taken for each specimen using a Mettler AC100 scale. Weight per centimeter squared (W) was calculated by dividing the weight in milligrams by the area of the specimens (38.7 cm^2).

$$W = \frac{\text{weight (mg)}}{38.7\ cm^2}$$

Flexural rigidity (G) was calculated by multiplying weight per centimeter squared (W) by the bending length (C) cubed. Flexural rigidity was recorded in mg-cm.

$$G = W \times C^3$$

Flexural rigidity was determined for the three components and the two composites. Measurements for the composites were recorded for flexural rigidity with the interfacing side up when bending and with the interfacing side down.

The flexural rigidity measurements were used to determine the bending resistances of the components and the composites.

CREASE RECOVERY MEASUREMENT

The angle to which a specimen recovers after creasing is the measure of crease recovery. Crease recovery was measured following AATCC 66-1978, Wrinkle Resistance--Recovery Angle Method (Technical Manual of AATCC, 1983). Thirty-six 15 x 40 mm specimens of each interfacing and sixty 15 x 40 mm specimens of fashion fabric were cut using a die. The specimens were cut with the length of the specimens going in the crosswise direction of the fabric. Twelve specimens of each of the interfacings and the fashion fabric were left uncombined. Twenty-four fusible and twenty-four nonfusible composites were constructed with the remaining samples.

The fusible composite samples used for measuring crease recovery were constructed using the same method for constructing the fusible composites for flexural rigidity.

The nonfusible composites were constructed by placing the interfacing on the back of the fashion fabric. These fabrics were held together only by the friction of the fibers between the fabrics.

Twelve specimens of each of the three fabrics and of the two composites were die cut to 15 x 40 mm. To measure crease recovery, a Monsanto wrinkle recovery tester was used. Crease recovery was measured following guidelines set up in AATCC 66-1978--The Recovery Angle Method. the specimens were placed in a metal clip and bent in half 20 mm parallel to the

15 mm edge. The metal clip was placed in a plastic holder. A 500 gm weight was placed on top of the holder for five minutes. After the five minutes, the metal clip was removed from the plastic holder and specimens were allowed to recover for 5 minutes while one side of the crease hung perpendicular to the table. After five minutes of recovery, the angle of recovery was recorded.

The crease recovery was measured for the two interfacings, the fashion fabric, and the two composite types. For each composite, the angle of recovery was measured for the composite creased with the interfacing side up and the interfacing side down, and the data for each side were recorded separately. The data were not averaged for the statistical analysis.

When the nonfusible composite was allowed to recover after creasing, the component pieces recovered different amounts. The angle of recovery for both components of the composite were recorded and averaged together to obtain a value for the crease recovery of the composite.

ENCLOSED SEAM CONSTRUCTION

Thirty 100 x 150 mm specimens of the fashion fabric and twenty 100 x 150 mm specimens of each interfacing were cut with the longer dimension parallel to the lengthwise fabric direction. Each specimen was cut in half to form specimens measuring 50 x 150 mm. The halves of each 100 x 150 mm specimen were kept together. The interfacing specimens each had 10 mm trimmed from one lengthwise side, making each 50 x 140 mm.

The seams were constructed using a Bernina Sport home sewing machine Model 802. Stitch length was set at 2.5 mm and a seam allowance of 15 mm was used. The thread tension was balanced by a sewing sample seam and removing a few inches of stitches, and adjusting the tension until the bobbin and upper thread tails were equal in length. The seams were constructed at standard conditions of 70 ± 2 ° F and 65 ± 2% relative humidity.

Ten seams each were constructed for the fashion fabric with no interfacing, for the fusible composites, and for the nonfusible composites. The fusible interfacing was attached to the back of the fashion fabric by pressing it with a dry Elnapress. Three 20.32 x 40.64 cm press cloths were cut for fusing the interfacing to the fashion fabric. The press cloths were soaked in distilled water for 5 minutes and fed through a 40 pound wringer. The cloths were stored in plastic bags with zipper closures until used. The fusible interfacing was laid on the back of the fashion fabric so that the trimmed edge of the fusible interfacing was 10 mm from one long edge of the fashion fabric. Each press cloth was used for preparing six or seven specimens at one time. The specimens were pressed using the wool setting. The

Elnapress was closed and locked for 10 sec. After the 10 sec timer sounded, the specimens were removed.

To sew the seams, the face sides of the fashion fabric were laid together and stitched. The nonfusible interfacing was placed on both back sides of the fashion fabric with the trimmed edge of the interfacing 10 mm away from the cut edge of the fabric. The seams were sewn using a contrasting color of thread. The seam was stitched 15 mm from the long side on which the trimmed edge of the interfacing was placed.

The seams were pressed open using the dry Elnapress. Ten specimens were pressed simultaneously. Ten 20.32 x 20.32 cm press cloths were cut from unbleached muslin. Each press cloth was used three times. The cloth was weighed, soaked in distilled water, fed through a 40 pound wringer, and reweighed prior to each use. Each cloth was stored in a plastic bag with a zipper closure until use. Each seam was held open while the damp press cloth was laid on top of it. The seams were pressed for 10 sec using the wool setting.

Three 20.32 x 40.64 cm press cloths were constructed of unbleached muslin for pressing the enclosed seams. They were prepared the same way as the 20.32 x 20.32 cm press cloths. The amount of water in grams picked up by the press cloths was calculated to determine if there was a difference in moisture pickup for each use. A Kruskal-Wallis test was used to determine if there were statistically significant differences among the three uses of the 30 smaller press cloths.

The test was not significant at the .05 level. A Wilcoxon Rank Sum test was used to determine if there were differences between the two uses of the larger press cloths (Hollander and Wolfe, 1973). Again, the test was not significant at the .05 level. Therefore, the amount of water pickup for each press cloth use was not significantly different, and the amount of water pickup by the press cloths for the enclosed seams did not create an additional variable that could affect the seam head size. Five enclosed seams were pressed at a time. After pressing the seams open, the fabric was folded over to enclose the seam allowances. The press cloth was laid over the seams and the seams were pressed on the wool setting for ten seconds. The seams were then turned over and pressed again with the same press cloth without rewetting.

The unsewn 150 mm edges of each seam were basted together to hold the seams secure while measuring the seam head. One half of this edge was basted twice as an aid for identifying the specimens as the left or right side of the seam for the photographic analysis.

SEAM HEAD MEASUREMENT

The Instrument

The instrument used to measure size of seam heads was developed by Moore (1985). The instrument allows a cross-section of an enclosed seam to be held under and against a ruler while a photographic slide is taken.

The instrument consisted of a platform on which a one to one reproduction of a clear ruler with hundredths of an inch increments was mounted. A low tension clip mounted on a wooden stand was used to hold a cross-section of the enclosed seam in place. The exposed thread of the stitching line was placed on the zero point of the ruler. The fabric was placed in the clip so it was flush with the ruler. The platform was placed on a light box with an opaque glass surface so that a 3200 Kelvin light would shine from under the specimen and ruler to allow the increment marking on the ruler to be distinctly visible. The 3200 Kelvin lamp was color balanced for Ektachrome ASA 160 Tungsten film. The lightbox and platform were placed on a Bencher copy stand. Four additional high intensity lights were used from above the platform. These were Tensor dual lamp 60 watt lights. A 35 mm camera body with one adapter ring, a reducing ring to allow for one to one reproductions, and a 55 mm lens were used. The exposure setting was an F-stop of 4 with a shutter speed of 1/8 sec. The specimens were photographed with the described set up in a darkened room in order to prevent overexposure. The data were read from the slides using a Singer Caramate Slide projector with self-contained, back-lighted screen in a darkened room.

The Specimens

Two specimens were cut perpendicular to the seam from each enclosed seam specimen 25 mm from each end to form two cross-sections. The specimens were labeled according to the type of seam (Control, Fusible, or Nonfusible), the end from which the specimen came (single basted or double basted), and the identifying number within each group (1-10). The type of seam was labeled by using the letters X--Control, Y--Fusible, and Z--Nonfusible. The end from which the specimen came was labeled as A--Single basted and B--Double basted.

Each specimen was mounted in the low tension clip and placed under the ruler so that the stitching thread was at the zero mark. A typed label indicating the specimen type, end, and number was placed in the lower right corner of the area to be photographed. An example of a label would be 2AY. This would indicate that it was the second specimen (2) of the fusible (Y) enclosed seams cut from the side of the specimen that was single basted (A).

Data

The slides of the cross-sections were projected onto a self-contained, back-lighted screen. The specimens were thus magnified for ease of reading. Three readers recorded the observed seam head size of each specimen to establish the reliability of the instrument. A Kruskal-Wallis test was run to see if there were statistically significant differences among the three readers (Hollander and Wolfe, 1973). A nonsignificant H value of .2 was found at the .05 level for the three readers for the control specimens. A nonsignificant H value of .36 was found for the fusible readings and a nonsignificant H value of 3.84 was found for the nonfusible readings at the .05 level. Therefore, there were no statistically significant differences among the three readers. The three values recorded for each seam head specimen by the readers were averaged together to give a single value for each specimen. These averaged values were used to test the hypothesis for seam head size.

Data Analysis

The research hypotheses were tested in the null form. Hypotheses 1-6 were tested using a Wilcoxon Rank Sum test. All were tested at the .05 significance level. For hypotheses 1-3, the test was set up for 10 occurrences. The data for each hypothesis were recorded in two columns. For example, in hypothesis 1, the first column contained 10 sums each obtained by adding an interfacing bending resistance value and a fashion fabric bending resistance value. The second column contained the 10 bending resistances found for the composite (the average of the bending resistances of the composite with interfacing side up and interfacing side down). The 20 values recorded under the two columns were ranked in order from smallest to largest by placing a number from 1 to 20 beside each value in the two columns. After ranking, the ranks given for the data values in each column were added together within the column. The column with the smaller rank sum was used to test the hypothesis. This was the W Value. Hypotheses 1 and 3 were two tailed tests and hypothesis 2 was a one tailed test. For the two tailed test, the critical value was obtained by a formula given for the test. If the smaller rank sum was less than the critical value, the hypothesis was rejected. For the one tailed test, the critical value was obtained from a table of critical values for the Wilcoxon Rank Sum test (Hollander and Wolfe, 1973).

To test hypotheses 4-6, a Wilcoxon Rank Sum test for 12 observations was used. The columns were constructed as in the 10 observation tests. The smaller rank sum was the W* value and was compared to the critical value. The critical values for the two tailed tests (hypotheses 4 and 6) and for the one tailed test (hypothesis 5) were obtained from the normal tables (Hollander and Wolfe, 1973).

Hypothesis 7 was tested using a Kruskal Wallis test with a significance level of .05 for three groups of 20 observations each. The 60 observations were ranked as in the Wilcoxon Rank Sum test and the 20 ranks for each of the three groups were added together. An H value was calculated using the formula specified in the test method. The critical value was obtained from the X^2 tables. For a two tailed test, the critical value was 5.991. The null hypothesis was rejected if the calculated H value was greater than or equal to the critical value. A nonparametric multiple comparison for a one way analysis of variance (ANOVA) was used to determine which variables differed within the Kruskal Wallis test. Significance levels of .1, .05, and .01 were used to establish the range of significance for each variable. A value was calculated for each seam head type (control, fusible interfacing, and nonfusible interfacing) by dividing the rank sum for each seam head type by the number of observations in each group (20). The values for the three types of seams were subtracted as follows: control minus fusible, control minus nonfusible, and fusible minus nonfusible. The values obtained from the subtractions were compared to critical values calculated using a formula specified in the test method (Hollander and Wolfe, 1973).

CHAPTER V. FINDINGS AND DISCUSSION

Interfacings have been used to support or stiffen fashion fabrics since the 1700s. Few studies have compared nonfusible and fusible interfacings or determined seam head size. This study compares the effects of fusible and nonfusible nonwoven interfacings on the flexural rigidity, crease recovery, and seam head size of a lightweight suiting fabric.

FABRIC CHARACTERISTICS

The fashion fabric used in this study was a lightweight suiting fabric with a fiber content of 35% polyester, 35% acrylic, 18% rayon, and 12% other fibers. The two interfacings used were 100% polyester. The fashion fabric was constructed in a twill weave and the two interfacings were of random web structure.

Specific fabric characteristics were determined to more fully describe the fabrics. These characteristics were fabric count for the fashion fabric, adhesive dots per square inch for the fusible interfacing, the structure of the fashion fabric and the nonwoven interfacings, weight, and thickness. Table 1 lists the characteristics for each fabric.

Table 1: Fabric Description

Characteristic	Fashion Fabric	Fusible Interfacing	Nonfusible Interfacing
Fabric Count (Yarns/inch) Warp	35	---	---
Weft	39	---	---
Adhesive Dots (#/in^2)	---	182	---
Structure	Herringbone Twill weave	Random web	Random web
Weight (oz/yd^2)	6.69	1.41	1.34
Thickness (in)	.026	.018	.007

STATISTICAL ANALYSIS OF HYPOTHESES

Null hypotheses 1-6 were tested using Wilcoxan Rank Sum tests at a significance level of .05. Hypotheses 1, 3, 4, and 6 were two tailed tests and hypotheses 2 and 5 were one tailed. Hypothesis 7 was tested using a Kruskal-Wallis test at a significance level of .05.

Hypothesis 1 stated that there would be no difference between the average sum of the bending resistances of the components of a composite and the average bending resistance of that composite for each of the interfacing/fashion fabric combinations. The alternative hypothesis stated that the sum of the bending resistances of the components would not equal the bending resistance of the composite. For both the fusible and nonfusible interfacing combinations, the null hypothesis was rejected. Therefore, it was concluded that the average sum of the bending resistance of the components may not equal the average bending resistance of the composite (Table 2). Table 2 lists the rank sums for the two groups tested, the W values, and the critical values. For the nonfusible interfacing/fashion fabric components and composite, the bending resistance of the nonfusible composite was 1.27 times greater than the sum of the bending resistances of the components of nonfusible interfacing and fashion fabric. This is not a large difference. Thus, the bending

Table 2: Hypothesis 1: Bending resistances of components and composite.

	Fusible Interfacing	Nonfusible Interfacing
Rank sum for sum of components	55	57
Rank sum for Composite	155	154
W Value	55**	57**
Critical Value	79	79

W value-- n = 10
** significant (.05 level)

resistances of the nonfusible composites and its summed component pieces are practically equal. For the fusible interfacing components and composite, the bending resistance of the fusible composite was 3.14 times greater than the sum of the bending resistances of the components of the composite.

Research hypothesis 1 was, therefore, supported because the bending resistance of the composite is greater than the bending resistance of its component pieces. This is true for both interfacing/fashion fabric combinations.

Null hypothesis 2 stated that there would be no difference in the bending resistance of the composite with interfacing side up and with interfacing side down while bending for each interfacing combination. The alternative hypothesis stated that the bending resistance of the composite with the interfacing side up would be greater than the bending resistance with the interfacing side down.

For the nonfusible composite, it was found that there was no significant difference between the bending resistances with interfacing side up and interfacing side down. For the fusible composite, it was also found that there was no significant difference between the bending resistances with interfacing side up and with interfacing side down (Table 3).

Table 3: Hypothesis 2: Bending resistance with interfacing side up and down.

	Fusible Interfacing	Nonfusible Interfacing
Rank Sum For Interfacing Up	87	85.5
Rank Sum For Interfacing Down	121	109.5
W Value	87	85.5
Critical Value	127	125

W value-- n = 10

By looking at the rank sums, however, it appeared that there is a difference as to which side is up when bent. The bending resistance with interfacing side down was 1.39 times greater than with interfacing side up for the fusible composite. For the nonfusible composite, the bending resistance with interfacing side down was 1.28 times greater than with interfacing side up.

Therefore, research hypothesis 2 was unsupported. The research hypothesis stated that the bending resistance of the composite with interfacing side up would be greater than the bending resistance with interfacing side down. The research hypothesis was unsupported for both the fusible and nonfusible composites.

Null hypothesis 3 stated that there would be no difference between the bending resistances of the fusible composite and the nonfusible composite. The alternative hypothesis stated that the bending resistance of the fusible composite would not equal the bending resistance of the nonfusible composite. The hypothesis was not rejected. It was found that there was a significant difference between the bending resistances of the fusible composite and the nonfusible composite (Table 4). The average bending resistance of the fusible composite was 2.47 times greater than the average bending resistance of the nonfusible composite.

Table 4: Hypothesis 3: Bending resistances of fusible and nonfusible composites

	Fusible Interfacing	Nonfusible Interfacing
Rank sum of Bending Resistance	155	55
W Value	55**	
Critical Value	79	

W value-- n = 10
** significant (.05 level)

Thus, research hypothesis 3 was supported. The average bending resistance of the fusible composite was greater than the average bending resistance of the nonfusible composite.

According to null hypothesis 4, there would be no difference between the average angle of crease recovery of the components of the composite and the average angle of crease recovery of the corresponding composite for both of the interfacing/fashion fabric combinations. The alternative hypothesis stated that the average angle of crease recovery for the components would not equal the crease recovery of the composite.

For the fusible interfacing/fashion fabric components and composite, the hypothesis was rejected. It was found that there was a statistically significant difference between the average angle of crease recovery of the components and the crease recovery of the composite (Table 5). The angle of crease recovery for the components was 1.04 times greater than the crease recovery of the fusible composite. This was not a great difference, thus the crease recoveries of the components and the composite were practically equal. Also listed in Table 5, it was found that the hypothesis for the nonfusible components and composite was not rejected. Thus, there was no significant difference.

Table 5: Hypothesis 4: Crease recovery of components and composites

	Fusible Interfacing	Nonfusible Interfacing
Rank sum for sum of components	193.5	156
Rank sum for composites	106.5	144
W* Value	-2.51**	-0.346
Critical Value	±1.96	±1.96

W* Value-- n = 12
** significant (.05 level)

The research hypothesis corresponding to null hypothesis 4 was unsupported. The research hypothesis stated that the average angle of crease recovery of the composite would be greater than the average angles of crease recovery of the components. For the fusible composite and components, the average angle of crease recovery of the components was slightly greater than the angle of crease recovery for the composite. For the nonfusible composite and components, there was no difference.

Null hypothesis 5 stated that there would be no difference between the angle of crease recovery with the interfacing side of the composite up and with the interfacing side down when creased. The alternative hypothesis was that the angle of crease recovery with the interfacing side up when creased would be greater than the angle of crease recovery with the interfacing side down when creased.

For the fusible composite, the null hypothesis was rejected; there was a statistically significant difference between the crease recoveries with the interfacing side up and the interfacing side down when creasing (Table 6). The average angle of crease recovery for the composite creased with interfacing side up was 1.09 times greater than the average angle of crease recovery with the interfacing side down when creased. This was not a big difference. In all practicality, it may not matter which side is up when creased for the

Table 6: Hypothesis 5: Crease recovery with interfacing side up and down.

	Fusible Interfacing	Nonfusible Interfacing
Rank sum for interfacing up	212.5	156
Rank sum for interfacing down	87.5	144
W* Value	-3.609**	-0.346
Critical Value	-1.645	-1.645

W* value-- n = 12
** significant (.05 level)

fusible. For the nonfusible composite, there was no statistically significant difference between the angle of crease recovery for the composite creased with the interfacing side up and with the interfacing side down.

Therefore, research hypothesis 5 was supported for the fusible composite but not for the nonfusible composite. The research hypothesis stated that the crease recovery with interfacing side up would be greater than the crease recovery with interfacing side down.

According to null hypothesis 6, there would be no difference between the angles of crease recovery for the fusible composite and the nonfusible composite. The alternative hypothesis stated that the angles of crease recovery for the fusible composite and the nonfusible composite would not be equal. The hypothesis was not rejected; there was no significant difference between the two composites (Table 7).

Therefore, the research hypothesis which corresponded to null hypothesis 6 was unsupported. The research hypothesis stated that the average angle of crease recovery of the fusible composite would be greater than the average angle of crease recovery for the nonfusible composite.

Table 7: Hypothesis 6: Crease recovery for fusible and nonfusible composites.

	Fusible Interfacing	Nonfusible Interfacing
Rank sum for crease recovery	144.5	155.5
W* Value	-0.318	
Critical Value	±1.96	

W* value-- n = 12

The final hypothesis, hypothesis 7, stated that there would be no difference in the seam head size of the enclosed seams with no interfacing (the control), fusible interfacing and nonfusible interfacing. Hypothesis 7 was rejected; there was a statistically significant difference among the three types of enclosed seams with respect to seam head size.

A nonparametric multiple comparison for a one-way ANOVA was done to see which types of seam heads differed (Table 8). It was found that the control seams differed significantly from the seams containing the fusible interfacing ($.05 < p < .10$). The control also differed significantly from the seams containing the nonfusible interfacing ($p < .01$). The seams containing the fusible interfacing and the seams with the nonfusible interfacing did not differ significantly.

Since there was no difference between the fusible and nonfusible seam head sizes, research hypothesis 7 was unsupported. The research hypothesis stated that the seam head of the fusible composite would be greater than the seam head of the nonfusible composite which would in turn be greater than the seam head of the control seam.

Table 8: Hypothesis 7: Seam head measurement

	Control	Fusible	Nonfusible
Rank Sum	391.5	625.5	813
n	20	20	20
Rank Sum/n	19.55	31.28	40.65
Control-Fusible	11.73**		
Fusible-Nonfusible	9.37		
Control-Nonfusible	21.1***		

** significant (.05 < p < .10)

*** significant (p < .01)

DISCUSSION

Information found in this study can be used for the selection of interfacing type with respect to how the interfacing affects the bending of a fashion fabric.

Results indicate that for flexural rigidity, the resistance of a fabric to bend under its own weight, the composite of interfacing/fashion fabric resists bending more than the composite's respective components. This was true for both types of interfacing, fusible and nonfusible. The results show that interfacing does stiffen the fabric area where it is applied. This is, of course, a primary reason for using interfacing. These findings are similar to the findings of Dhingra and Postle (1980) and Shishoo et al. (1971) who also found that the bending resistance of a composite of fusible interfacing/wool fashion fabric was 4-10 times greater than the average bending resistance of the components. In this study the difference between the bending resistance of the components was not as great as Dhingra and Postle and Shishoo et al. found. This is due to a difference in fabric types used in this study and the other studies and the difference in thickness of the fabrics in this study and in the other studies. Wool fabrics were used in the studies by Dhingra and Postle and Shishoo et al. The bending resistance of the nonfusible composite was only 1.27 times greater than the average bending resistance of its component pieces. This was not much of a difference. The fusible composite had a bending resistance 3.14 times greater than the average bending resistance of its components. Thus, a double layer of fabric such as a composite was stiffer than a single layer such as a component. This difference from prior findings may be due also to the improved adhesives used on the fusible interfacing which allow the fusible composite to bend more easily than the fusible composites seven to ten years ago. Neither Shishoo et al. nor Dhingra and Postle studied the nonfusible interfacing/fashion fabric composites or components.

It was found in this research that it does not matter, with respect to flexural rigidity, if the fabric composite for either interfacing type is bent with the interfacing side up or down. According to Shishoo et al., the bending resistance of a composite would differ depending on whether the interfacing side was up or down when bending. Dhingra and Postle stated that it was more difficult to bend the composite with the interfacing side up. In this study, it was found that there was no significant difference between the bending resistance of a composite bent with interfacing side up or down. Again, this may have been due to improved interfacing and fashion fabrics and also because different fiber contents and thicknesses of fabrics were used for the three studies. Therefore, in a garment area such as a lapel, which is interfaced on both the upper and lower lapels, there should be no difference in the bending resistance of that area between the upper section of the lapel which is bent with the interfacing side down and the lower section of the lapel which is bent with the interfacing side up. Improved technology of interfacing design and structure over the last ten years no doubt contributed to this.

When comparing the flexural rigidities of the fusible and nonfusible composites, it was found that there was a significant difference. The fusible composite had a bending resistance 2.47 times greater than that of the nonfusible composite. Therefore, it does make a difference which type of interfacing is used in a garment when studying bending resistances. This difference is most likely due to the fusing process undergone by the fusible interfacing. Also, the difference in thickness of the fusible interfacing and the nonfusible interfacing may have contributed to this difference. However, with the method of thickness measurement used, it was not possible to tell if there was a difference in the thickness of the base fabrics or if the thickness difference was only attributed to the thickness of the adhesive dots. Therefore if a stiffer area, which has a greater resistance to bending, is desirable when considering interfacing of this weight and structure, the fusible interfacing would be the better choice.

With respect to the crease recovery of the composites, it was found that there was a slight difference between the average angle of recovery of the components of fusible interfacing and fashion fabric and the composite made from these components. The difference was not large enough to state that the components recovered more than the composite. The components had an average recovery only 1.04 times greater than the corresponding composite's angle of recovery. Therefore, the components would recover slightly more than the composite but not enough to make a noteable difference. In other words, the fusing of the interfacing to the fashion fabric slightly reduced the ability of both fabrics to recover from creasing. This would be an advantage in the construction of enclosed seams. It is desirable for the seam to lie flat. Therefore a lower crease recovery would be desirable because the seam would be less likely to try to recover from its pressed condition and thus deleteriously affect the appearance of the seamed area.

There was no difference between the average angle of recovery for the components of nonfusible interfacing and fashion fabric and the angle of recovery of the composite of those two fabrics. The fact that the fabrics were not permanently adhered to each other may have contributed to this.

It was also found through testing Hypothesis 5 that there was a significant difference between creasing the fusible composite with the interfacing side up and interfacing side down. This difference was not large enough to be considered a major finding for this study. The crease recovery for the composite creased with interfacing side up was only 1.09 times greater than was the crease recovery with interfacing side down. Therefore, the crease recoveries were practically equal. The composite recovers only slightly more from creasing when the interfacing side is up. For an encased seam, in which the fabric is creased with the interfacing side down, the seam would have a tendency to lie flatter. An area such as a lapel where the composite is creased with the interfacing up and down, there should be no major difference between the upper and lower lapel areas.

For the nonfusible composite, there was no significant difference between the two up and down interfacing conditions for crease recovery. This also may be due to the interfacing not being adhered to the fashion fabric. Therefore, there should not be a difference in how the areas of a garment recover because of the way in which the composite is creased.

It was found that there was no significant difference in the crease recoveries of the fusible and nonfusible composites. This means that it would make no difference in a garment, with respect to crease recovery, if a fusible interfacing or a nonfusible interfacing was used. Therefore, both of the interfacings should produce the same crease recovery results.

There has been little research reported comparing the crease recoveries of interfacing composites and components. The results from this research could be used to show that it does not make a difference which interfacing type is used with respect to crease recovery if using a lightweight suiting fashion fabric.

When comparing seam head sizes of the enclosed seams in the control and composite samples, it was found that there was a significant difference between the control and the fusible and nonfusible composites. There was no significant difference between the seam head size of the enclosed seams with either interfacing type.

It was expected that the enclosed seams with interfacing would be different from the control with no interfacing because one of the purposes of interfacing is to stiffen or add body to the fashion fabric.

Since there is no difference in seam head sizes of the enclosed seams with either of the interfacings, it does not make a difference which type of interfacing is used in an enclosed seam area when looking at seam head size.

Moore (1985) did not study the seam head sizes of enclosed seams with interfacings. Her findings dealt with the effect of various fabric properties such as fiber content, thickness, and flexural rigidity on the seam head size of wool and wool/polyester fabrics. No other research on the seam head size of enclosed seams has been found.

It is not possible to relate the values of crease recovery, flexural rigidity, and seam head size in this study because the three tests were not run using the same specimens containing the exact same yarns. This would not be possible because of the specimen size and the destruction of the specimens in measuring seam head size.

For this study, each test was compared between the two interfacing types. This described the difference between nonfusible and fusible composites for each of the three tests. It was found that the two composite types did not differ with respect to crease recovery and seam head size. The composite types did differ in flexural rigidity.

CHAPTER VI. SUMMARY.

Clothing is constructed by joining fabric sections to make a wearable structure. Garment sections are joined by seams. The most common method of constructing seams is with needle and thread.

Interfacings have been used since the mid 1700s for adding support, stiffness, and stability to garment areas. There are many structures used for interfacings such as nonwovens, wovens, knits, and knitted-woven combinations. One of the common structures in use is the nonwoven. Interfacings can be either fusible or nonfusible. Both are commonly used, but there are differing opinions as to which type of interfacing is better.

Previously, fusible interfacings were stiff and boardy due to the type of adhesives used and the density of the adhesive applied to the base fabric. Fusible interfacings have the adhesive placed in a random or preplanned dot pattern. The unfused areas between the dots allow for flexibility, thus a fabric composite has the ability to bend. This allows a fusible composite to behave more like a nonfusible composite.

There are many different types of seams used for garment construction. One type of seam used in garments is the enclosed seam, constructed by laying two fabric sections one atop the other and stitching a specified distance from the cut edge. The fabric is then folded back to enclose or encase the seam allowance.

Because of the mechanical and physical properties of the fabric, the fabric in an enclosed seam area may not be able to fold directly on the stitching line of the seam. The distance from the fold to the stitching line is called the seam head size. Apparel designers usually design a garment so the intended design line falls on the stitching line. The size of a seam head in an enclosed seam is a reflection of the amount of design line distortion. The distortion is the distance of the fabric fold from the stitching line or, in other words, the seam head size.

Few studies have been found that specifically look at the bending of interfacing/fabric composites. One study done on the bending properties of fusible interfacing/fashion fabric components and composites by Shishoo et al. (1971) found that the bending resistance of a composite of fashion fabric/fusible interfacing was 4-10 times greater than the sum of the bending resistances of the components of fashion fabric and fusible interfacing.

Another study by Dhingra and Postle (1980), found that the bending resistance of a composite of fusible interfacing/fashion fabric was 4-7 times more than the average bending resistance of the components. They also found that it was more difficult to bend a fusible interfacing/fashion fabric composite with the interfacing side of the composite up than with the interfacing side down.

Moore (1984) and Moore et al. (1986) studied the effects of specific physical and mechanical properties of fabrics on the seam head size of enclosed seams constructed from those fabrics. Fabric thickness, flexural rigidity, and fiber content was found to affect the seam head size of enclosed seams of wool and wool/polyester suiting fabrics.

Lanier (1980) studied design line distortion of enclosed seam areas such as welt pockets, lapels, hem edges near the front facing, and bound buttonholes. She found that if the stitching line was moved away from the design line toward the cut edge, the fabric would fold along the design line. Shifting the stitching line compensates for the mechanical properties of the fabric that would otherwise prevent the fabric from bending on the design line (stitching line).

There is little information on the effect of interfacings, both fusible and nonfusible, on the bending properties of fashion fabrics. Thus, the purpose of this research was to compare the effect of a fusible and a nonfusible interfacing on the flexural rigidity, crease recovery, and seam head size of a lightweight suiting fabric. In addition, comparisons were made between the bending resistance of the interfacing/fashion fabric composite and the respective components and between the bending resistances of the composite bent with the interfacing side on top and with the interfacing side down for each interfacing type. Also, comparisons were made between the angle of crease recovery of the interfacing/fashion fabric composite and the respective components and between the crease recovery of the composite with the interfacing side on top when creased and the composite with the interfacing side down for each interfacing type.

The fabrics used were a lightweight suiting fabric of 35% polyester, 35% acrylic, 18% rayon, and 12% other fibers; a 100% polyester nonwoven fusible interfacing labeled as featherweight; and a 100% polyester nonwoven nonfusible interfacing also labeled as featherweight.

Seven research hypotheses were written for this study. Hypothesis 1 stated that the bending resistance of the composite of interfacing/fashion fabric would be greater than the average summed bending resistance of component pieces. This hypothesis was tested in the null form. The research hypothesis was supported.

Hypothesis 2 stated that the average bending resistance of a composite with interfacing side up would be greater than the average bending resistance with interfacing side down. This hypothesis, when tested in the null form, was unsupported.

Hypothesis 3 stated the average bending resistance of the fusible composite would be greater than the average bending resistance of the nonfusible composite. When tested in the null form, the hypothesis was supported.

Hypothesis 4 stated that the average angle of crease recovery of the composite would be greater than the average angle of crease recovery of the components. The hypothesis was unsupported for both of the interfacing/fashion fabric combinations.

Hypothesis 5 stated that the average angle of crease recovery of the composite with interfacing side up would be greater than the average angle of crease recovery with the interfacing side down. The hypothesis was supported for the fusible composite but not for the nonfusible composite.

Hypothesis 6 stated that the average angle of crease recovery of the fusible composite would be greater than the average angle of crease recovery of the nonfusible composite. The hypothesis was unsupported.

Hypothesis 7 stated that the seam head size of the enclosed seams with fusible interfacing would be greater than the seam head size of the enclosed seams with nonfusible interfacing which would in turn be greater than the seam head size of the enclosed seam with no interfacing (the control). The hypothesis was unsupported because there was no difference between the fusible and nonfusible seam head sizes.

The findings of this study support in part the findings of Dhingra and Postle and Shishoo et al. This study was different from the other two studies in the type of fabrics used. It was found than the average bending resistance of a composite was greater than the average of the summed bending resistances of its component pieces. The difference was not as great as previous studies which may be due to improved fusible interfacings and is most likely due to the different fabrics used. Another finding of this study was that it did not matter with respect to flexural rigidity, whether the interfacing/fashion fabric composite was bent with interfacing side up or down, contrary to what was found in previous studies. Again, improved interfacings and fashion fabrics and the lighter weight fabrics used in this study lessened the difference. It was found that it did make a difference which type of interfacing was used (fusible or nonfusible) with respect to flexural rigidity. The fusible interfacing gives a stiffer composite than the nonfusible interfacing.

Another finding was that the fusible composite had a slightly lower crease recovery than its component pieces, which is desirable in an interfaced area, such as a lapel, so the area will lie flat. This difference was not large enough to make a noteable difference. This was not the case for the fusible composite. Its crease recovery did not differ significantly from the crease recovery of its components. For the fusible composite, it may make a slight difference whether the composite was creased with interfacing side up or down. The difference again was not large enough to be considered a major finding. The composite recovered more when the interfacing side was up. In a garment area in which the interfacing is up when creased, such as in the underside of a lapel, the garment section would tend to resist lying flat. There was no difference between the crease recovery of the fusible composite and that of the nonfusible composite. Therefore, either interfacing type can be used with successful and similar results in a lightweight fashion fabric.

With respect to seam head size, there was no difference between the fusible and nonfusible composites. Either interfacing type would give similar results.

These interfacings produced similar composites, but the fusible composite was 2.47 times stiffer than the nonfusible composite. Information from this study could be used for interfacing selection by home sewers and manufacturers and as evidence that fusible and nonfusible interfacings may not differ as much as opinion has suggested.

CHAPTER VII. RECOMMENDATIONS FOR FUTURE RESEARCH.

This study was done to provide information for home sewers and manufacturers about the effects of a nonfusible and a fusible nonwoven interfacing on three bending properties of a lightweight suiting fabric. Selection of interfacing type is basically a matter of preference. Little information is available which compares nonfusible and fusible interfacings. Studies comparing these two interfacing types are needed to provide a basis for interfacing selection by manufacturers and home sewers.

The results of this research indicated no difference between the fusible composite and the nonfusible composite with respect to crease recovery and seam head size. The two interfacing composite types did differ significantly from each other with respect to flexural rigidity.

Further research could be done in this area to provide information about interfacings and their effects on fabric properties. Studies could be done using different interfacing structures such as woven, knitted, and weft insertion (a combination of knitting and weaving). These structures could be studied individually or compared to each other.

Different fashion fabrics could be studied using the same tests and interfacing types as this study. This would allow a study of the relationship of flexural rigidity, crease recovery, and seam head size to be done.

Research could be conducted to compare interfacings which have 1/2 inch trimmed from the seam allowance and those without trimming from the seam allowance with respect to bending resistance, crease recovery, and seam head size. Several authors of garment construction books suggest that the interfacings be trimmed from the seam allowance to reduce bulk. The suggested research would show whether trimming is as beneficial as the books suggest.

Studies should be done on the effect of interfacing on the draping of fabrics. This information, in conjunction with studies on flexural rigidity and crease recovery, would be beneficial to designers and quality control managers in the apparel industry.

More research is needed on options for correcting design line distortions created by seam heads. These studies could include interfacings. Recommendations should be given as to how far the stitching line should be moved to correct the design line distortion for various types of fabrics and fabric/interfacing composites. This information should be available to home sewers in garment pattern directions and to manufacturers.

The present research could be repeated using enclosed seams with interfacing on only one side of the seam. Comparisons could be made between each side of the enclosed seam to study the effect of the interfacing on the seam head size.

Analyses could be done on the mechanical properties, such as buckling, shearing, and compression-extension, which may play a role when an interfacing is bent in an enclosed seam. Equipment which would magnify the cross-section would be needed to study these properties.

Finally, different instruments could be developed to measure seam head size. One possiblity would be to use a load analyzer and digitizer in which a slide is projected onto a screen where a fixed cursor is used to record length of lines, area, and define points on the X and Y axes. Computer software could be developed to measure the amount of curvature and the angle of bending. Such a procedure would reduce the subjectiveness of the analysis.

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