UNIVERSITY OF CAPE COAST

THE EFFECT OF THREAD TYPE, STITCH DENSITY AND WASHING

ON SEAM PERFORMANCE OF A GHANAIAN REAL WAX COTTON

PRINTED FABRIC

PATIENCE ASIEDUAH DANQUAH

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SEAM PERFORMANCE OF A GHANAIAN REAL WAX COTTON PRINTED

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BY

PATIENCE ASIEDUAH DANQUAH

Thesis submitted to the Department of Vocational and Technical Education of the

Faculty of Education, University of Cape Coast, in partial fulfilment of the

requirements for award of Master of Philosophy Degree in Home Economics

MAY 2010

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the results of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:......................... Date:.............................

Name: Patience Asieduah Danquah

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature........................ Date:.............................

Name: Ms Modesta Efua Gavor

Co-supervisor's Signature.............................. Date:.............................

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ABSTRACT

In a 2×3×3 factorial experiment, which included two brands of threads, three ranges of stitch density and three cycles of washing, the performance of plain seam in a Real Wax cotton printed fabric from Tex Styles Ghana Limited, formerly Ghana Textile Printing Company (GTP) was investigated. The performance properties investigated were strength, elongation and efficiency. Specimens were washed using the Standard Launder-Ometer (Gyrowash 315). Each washed specimen was dried in the sun and the specimens removed immediately they dried. The breaking strength and elongation of the fabric and the seams were determined using the tensile testing machine (Hounsfield H5K-S). Means and standard deviations and inferential statistics (Analysis of Variance and Independent Samples t-test at 0.05 alpha levels) were used for the analyses of the data.

Results in this study showed that differences existed between the two thread brands (OK, Sunflag) with regard to seam strength, elongation and efficiency, with Sunflag having higher values than OK. Also differences existed between the stitch densities used for the study, with seam strength, elongation and efficiency increasing as stitch density increased. Furthermore, differences existed between the washing cycles with regard to seam strength and elongation. On the other hand, in terms of efficiency, no difference existed between the washing cycles. In addition, the findings have brought to light the behaviour of seams in the different directions of the Wax printed fabric used for the study. The study showed that different Wax prints may require different types of threads at different stitch densities to provide desirable seams.

ACKNOWLEDGEMENTS

DEDICATION

I dedicate this thesis to my parents, Mr. and Mrs. Danquah.

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CHAPTER ONE

INTRODUCTION

Background to the Study

The wearing property of a sewn garment is greatly influenced by the quality of its seams, which form the basic structural element. A seam is the joint between two parts of a garment (Doshi, 2006). Seams in garments are to work efficiently by holding pieces of fabric firmly in place for the garment to be able to function properly to meet its required uses. Quality is one attribute that most consumers look out for in an apparel product; though it varies from individual to individual. Quality seams in sewn garments contribute to the overall performance of the garment in use. Poor quality seam makes a garment unusable even though the fabric may be in good condition. As indicated by Mehta and Bhardwaj (1998), if a product bought has a deficiency, it cannot be used, and poor quality of seams is a deficiency mostly encountered in the life of sewn garments.

The quality and performance of a sewn garment depend on various seaming factors such as seam strength, slippage, puckering, appearance and yarn severance (Carr & Latham, 1994; Dorkin & Chamberlain, 1961) (cited in

Mukhopadhyay, Sikka & Karmakar, 2004). For a perfect fitting and look of a garment, seam appearance and its strength have to be proper (Doshi, 2006). This enhances the quality of the garment to meet its required end use.

A number of studies reveal the interaction of various factors on seam performance. According to the American Society for Testing and Materials (ASTM) D6193-09 (2009), the characteristics of a properly constructed sewn seam are strength, elasticity, durability, security and appearance. These characteristics must be balanced with the properties of the material to be joined to form the optimum sewn seam. Other factors also influence the achievement of these characteristics in a properly constructed sewn seam. Such factors include type and weight of fabric, seam type, type of needle, thread type and size, and stitches per inch (stitch density).

Through stitches seams are formed, and other important construction processes are completed. Stamper, Sharp and Donnell (1986) asserts that once a fabric has been selected and cut for a particular apparel item, the next thing is to shape the flat fabric pieces to the desired three-dimensional form. Seams, darts, and dart equivalents are the means used to create that third dimension. Stamper et al. continued that thread stitching is the method used almost exclusively to secure shaping devices; therefore, the appearance and durability of any seam, dart or tuck depends on the stitches. The number of stitches per inch (SPI) can have direct influence on seam strength, stitch appearance and seam elasticity. Using the correct number of stitches per inch can greatly enhance the strength, appearance and the overall performance of the seam for a given fabric type and

application (American & Efird Inc., 1997). Chowdhary and Poynor (2006) noted that stitch density influenced both strength and elongation of seams. Mukhopadhyay et al. (2004) also observed that both seam strength and seam efficiency increased with increase in stitch density.

The length of machine stitches used may also influence garment cost, appearance and durability. The fewer the stitches per inch, the longer each stitch, and the faster the stitching progresses. Long stitches (five to eight per inch) are more attractive for topstitching than for regular stitching. In areas of stress, stitches that are too long create openings in the garment and pull away from the stitching. When a long stitch breaks, the result is a greater opening in the affected seam than could occur with shorter stitches (Stamper et al., 1986). Although short stitches are noted to increase the strength and durability of a seam, they do increase cost of production. Stamper et al. recommends that stitch lengths are regulated to correspond to fabric type and to the amount of stress the stitching will bear.

The type of thread used in stitching, its construction, size and finishing influence the seam strength of a garment (Doshi, 2006). Mukhopadhyay et al. (2004) observed in their study on the impact of laundering on the seam tensile properties of suiting fabric that, seam strength and efficiency of the fabric stitched with coarser yarn was higher than the fabric stitched with finer yarn. The range of sewing threads available on the market has recently increased significantly with sewing threads of cotton and polyester being the most commonly used in the manufacture of garments (Jonaitiene & Stanys, 2005).

However, the type of thread used depends on the fabric used (for example a silk fabric will take silk threads), but in some instances seamstresses do not pay much attention to the thread types and fabrics.

According to Gurarda (2008), the length of life of a seam in a garment should be as long as that of the other materials and both should be appropriate to the required end use of the garment. The seam can be considered to have failed in durability terms, if either the thread or the fabric in the seam fails at an early stage. For manufacturers to be able to select appropriate thread types and stitch densities to achieve quality in seams, conditions garments are exposed to during use must also be examined.

Garments do not only go through wear in the course of use, but also care, which include laundry and storage among others. As indicated by Mukhopadhyay et al. (2004), in the lifetime of a garment, both cloth and seam undergo repeated laundering, which may result in a change in the quality and performance of the sewn product. Seam performance after laundering is important in adjudging the suitability of a sewn product since seam quality is an important parameter deciding the performance of garments. For a garment's seam to be able to withstand the pressures from laundry processes, it will all depend on the stitch density and type of thread employed in the making of the seam. In a study by Mukhopadhyay et al., it was noted that seam strength and seam efficiency decreased after laundering with much reduction in coarser sewing threads, but no common trend in reduction was observed with the change in stitch densities employed.

Meeting the requirements for SPIs by using the right type of thread for a particular fabric helps to achieve quality and enhances the apparels' performance in use. An understanding of quality and performance of fabrics and apparel products will aid in achieving a vibrant industry. Brown and Rice (1998) (cited in Chowdhary & Poynor, 2006) identified fabric type and weight as the influencing factors to determine stitch density. They reported that lightweight and woven fabrics should be 15-18 SPI, medium weight fabrics 12-14 SPI and heavy-weight fabrics 6-10 SPI. Structural seams for jeans were recommended to have 8 SPI, and serged seams 14 SPI. The buttonhole should have 22 SPI, reinforcement should have 22 SPI, and leather and vinyl should be sewn with stitch density of 6-8 SPI. Stamper et al. (1986) also argue that high-count, thin and light-weight fabrics should use 15 SPI. Heavy and coarse fabrics with low count should have longer stitches. The number of stitches recommended for heavy fabrics was 8-10 SPI.

In addition to these, American and Efird Inc. (1997) recommends that for woven garments, such as casual shirts, the SPI should be 10-14, 7-8 for denim jeans, 8-10 SPI for children, 10-12 for dresses and trousers, and 14-20 for dress skirts or blouse. However, Chowdhary and Poynor (2006) stated that the conventional 10-12 SPI has been used in home sewing. An inquiry I made from a number of garment makers within the Cape Coast community indicated that the stitch densities used ranged from 7-12, with most of them using 8-10 SPIs.

Statement of the Problem

Ghanaians patronize African prints extensively. They are used almost on all occasions. In some cultures, traditional African Wax print is even included as part of the bride price. Among the major factories that produce African prints in Ghana are the Ghana Textiles Manufacturing Company (GTMC), Printex, Akosombo Textiles Limited (ATL) and Tex Styles Ghana Limited, formerly Ghana Textile Printing Company (GTP). The variations of textile prints produced include Java, Real Wax and Fancy. These prints, no matter how they are used to adorn the body, are stitched at one point or the other.

The line or shape of clothing depends largely on the way the sections are joined, that is seamed. Stitches and their resulting seams are part of the crucial elements of garments construction and the construction of other articles of clothing. The seams quality contributes to better performance of the garment during use, in effect contributing to the overall quality of the sewn garment. Although researches have been conducted on the performance of African prints, the performance of their seams have not received much attention. General focus of research has been on textile testing with much emphasis on fibre, yarns, fabrics (colour fastness, strength) than the sewn apparel. In other instances products are analysed based on visual inspection leaving the mechanical aspects, which involve seams properties.

ASTM D6193-09 (2009) asserted that, seam engineering, the determination of the best stitch type, seam configuration and thread type which should be used for a particular assembly requires a thorough knowledge of many variables. The

improper selection of any one component can result in failure of the sewn junction and ultimately failure of the product manufactured. The thorough knowledge of the variables that contribute to better seam performance can only be established through testing (AMANN Inc., 2009). In Ghana, clothes are usually made by custom and there are variations in the stitch densities employed by various garment makers. There is also the fact that there are wide varieties of threads on the market. Preliminary enquiries made revealed that some of the garment makers select stitch densities and sewing threads without paying attention to their effect on the overall performance of the apparel being made, in effect resulting in failure of the sewn junction during use and care. Meanwhile, Mehta and Bhardwaj (1998) stated that quality apparel must perform satisfactorily in normal use, meaning that a garment must be able to withstand normal wearing and care without seams coming apart, colour fading and fabric tearing.

As the garments made from African prints go through their cycle of use, they are exposed to conditions in wear and care such as laundry, which influences their overall performance. Researchers in the area of clothing and textiles have taken steps to identify the effects of some conditions, such as sunlight and washing, and have given their recommendations as to the fabrics use and care. For example, Fainu and Adams (1998) noted that washing per se and sunlight caused the colour of Real Wax, Real Java, and Batik fabrics to fade; and suggested that they are dried in the shade. Fianu, Sallah and Ayertey (2005) also found that sunlight caused loss of strength in Real Wax printed fabrics from

Ghana Tex Styles Ghana Limited with laundered specimens losing more strength. While these researches have gone on, most of their studies have been in the area of the textile print leaving the apparel itself, specifically the elements that form their basic structural composition (stitches and seams).

The parameters that contribute to success in seams discussed earlier are important elements that cannot be ignored in achieving quality seams in garments. An examination of the performance of seams in African prints by varying stitch density, sewing thread brands and washing would therefore help provide an empirical basis for existing choices, and in addition, help with interpretation of data for quality control.

Purpose of the Study

The purpose of this study was to investigate the impact of stitch density, brands of sewing threads and washing on seam strength, elongation and efficiency of plain seam, in a Ghanaian Real Wax cotton printed fabric.

Research Questions

The research questions were:

1. Is there any difference between the strength of a Ghanaian Real Wax cotton printed fabric and the strength of plain seam in the same fabric after three washing cycles?

2. Is there any disparity between a Ghanaian Real Wax cotton printed fabric's elongation and the elongation of plain seam in the same fabric after three washing cycles?

Hypotheses

HO$_1$: There is no significant difference between:

    a. Thread types

    b. Stitch densities and

    c. Washing cycles with regard to seam strength of a plain seam in a Ghanaian Real Wax cotton printed fabric.

HO$_2$: There is no significant difference between:

    a. Thread types

    b. Stitch densities and

    c. Washing cycles with regard to seam efficiency of a plain seam in a Ghanaian Real Wax cotton printed fabric.

HO$_3$: There is no significant difference between:

    a. Thread types

    b. Stitch densities and

    c. Washing cycles with regard to seam elongation of a plain seam in a Ghanaian Real Wax cotton printed fabric.

HO$_4$: Thread type, stitch density and washing cycle have no significant influence on the:

    a. Strength

    b. Elongation and

    c. Efficiency of plain seam in a Ghanaian Real Wax cotton printed fabric.

Significance of the Study

Consumers are concerned about the quality of items they purchase. Producers and retailers have the responsibility to know the consumer's conception of quality for product categories. When it comes to making sure the final garment is fit for the end use, tensile strength and seaming properties are key performance indicators. One of the major reasons for the consumer being dissatisfied with a garment, after poor colour fastness and stability, is when the seams in a garment fail due to seam breakdown (Olsen, 2008). This study will therefore help producers of garments and seamstress who use Ghanaian Real Wax cotton prints to know the appropriate thread type on the market to choose and stitch densities that would help achieve quality seams to meet consumers' desires in terms of seams.

Secondly, there is limited documented research on the performance of seams in garments made from the Ghanaian Real Wax cotton printed fabrics. This study has provided documentation on the influence that variation of washing, thread type and stitch density have on seam quality in garments made from Real Wax cotton printed fabrics.

Finally, the study would provide baseline information for teaching and research.

Delimitation

The scope of this study covered a Ghanaian Real Wax cotton printed fabric from Tex Styles Ghana Limited. Two different brands of sewing threads on the market were chosen. Three ranges of stitch densities were employed, specimens

were subjected to three washing cycles, and seam quality in terms of strength, efficiency and elongation were tested for.

Limitations

The limitations of the current study relates to the testing environment. This has got to do with the intensity of the sunlight used in drying the test specimens. Since the test specimens were not dried on the same day, a weather change that is possible variation in sunlight intensity might affect internal validity.

In addition, the current study had limitations related to the generalization of the findings. They include the one type of wax print from one company which was employed. It limits the possibility of generalizing the results to all wax prints. In addition, just two thread brands out of the several brands on the market were used which also add to the limitations regarding the generalization of the research findings.

Definition of Term

Plain seam: a superimposed seam (301-SSa-1) with the seam allowances pressed open.

Organization of the rest of the Study

The current study is divided into five chapters. The second chapter reviews literature relevant to the study. Chapter three discusses the methods used for the study, which include the research design, materials, instruments, sample and sample preparation, data collection procedures and the data analysis plan. Chapter four presents the findings and the discussion of the results of the study.

The last chapter, which is chapter five, provides the summary of the study, conclusions and recommendations.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

This research aimed at investigating the impact of stitch density, brands of sewing threads and washing on seam strength, elongation and efficiency of plain seam, in Ghanaian Real Wax cotton printed fabric.

This section reviews related literature on the factors and the properties that aid in the achievement of quality in seams. The literature is presented under the following headings in the chapter.

1. Theoretical framework

2. Conceptual base of the study

3. Quality assurance in the apparel industry

4. Testing seam performance

5. Seam performance and seam performance properties

    a. strength

    b. durability

    c. elongation

    d. efficiency

6. Factors that influence seam performance

     a. seam type

     b. threads

     c. stitches and stitch density

     d. fabric type

7. Effects of laundry on seam performance

Theoretical Framework

Deformation of Seams in Textile Fabrics

The study of the physical properties of seams in garments is important, because seam tensile behaviour is important from both theoretical and technical point of view. The stitch line plays an important role in the tensile behaviour of an assembly. The stitch line is prone to a longitudinal deformation which grows until its rupture. In fact, the deformation of the assembly is a mixture of the deformation of the fabric and that of the stitches. Consequently, tensile behaviour of the fabric, before its sewing, needs to be identified (Gribaa, Amar & Dogui, 2006). When textile materials are subjected to tensile force they undergo deformation (Baird, 1975).

Conceptual Base of the Study

The making of garments using textile products requires joining and the joined fabric should have similar strength at the point of joining as the original fabric (LaPere, 2006). This method of joining the fabric is commonly called seaming. AMANN Inc. (2009) indicated that seams are one of the essential connections in technical textiles. They make very flexible and safe connections

for producing complex two or three-dimensional products. LaPere (2006) also stated that seams are the basic elements that form the structure of any apparel, home- furnishing product and industrial textiles, and are the most important parameter to maintain product integrity.

It has been noted that the achievement of quality seams in garments, and for that matter apparel products, depends on several factors which in turn influence the properties of the seam. The factors which include thread type and size, fabric type and construction and seam type and the properties (efficiency, strength, durability, elongation and appearance) interact with the processes garments go through during use (for example, laundry) to affect the overall performance of the seams in the garment. This concept has been illustrated diagrammatically in Figure 1.

Factors   Seam properties

- Seam type   Elongation
- Fabric type/   Efficiency
  structure
                            Strength
- Stitch   Durability   → Overall seam performance
  density
  (SPI)
- Thread type
- Stitch type   Laundry
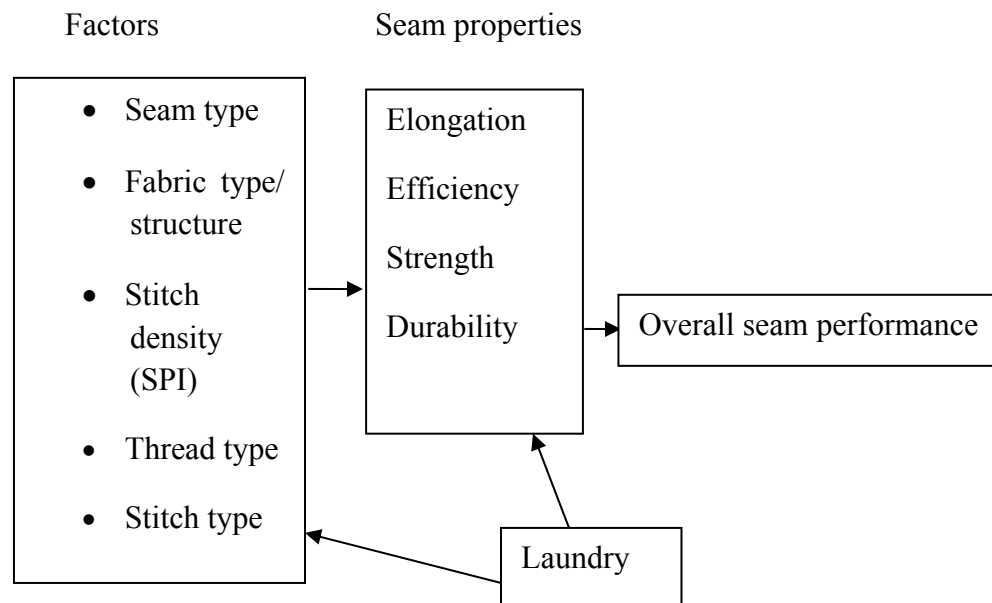
Figure 1. Factors and properties that influence seam performance in garments (developed by the author).

Quality Assurance in the Apparel Industry

For every industry or business, to get increased sales and better name among consumers and fellow companies, it is important to maintain a level of quality. In the garment industry, quality control is practiced right from the initial stage of sourcing raw materials, to the stage of final finished garment to assure consumers of product quality. For the textile and apparel industry, product quality is calculated in terms of quality and standards of fibres, yarns, fabric construction, colour fastness, surface designs and the final finished garment product. Studies have shown that there is direct correlation between fabric quality and apparel quality, and poor quality fabric results in excess cost of apparel manufacturing. There are a number of factors on which quality fitness of the garment industry is based. These include performance, reliability, durability, visual and perceived quality of the garment. Quality needs to be defined in terms of a particular quality certification, and international quality programmes like International Organisation for Standardization (ISO) 9000 series lay down the broad quality parameters based on which companies maintain export quality in the garment and apparel industry. Some of the main fabric properties that are taken into consideration for garment manufacturing for export basis are overall look of the garment, right formation of the garment, feel and fall of the garment, physical properties and colour fastness of the garment. Quality related problems in garment manufacturing like sewing defects such as open seams, wrong stitching techniques used, miss out of stitches in between, creasing of the garment and erroneous thread tension should not be overlooked (Doshi, 2006).

According to Chowdhary and Poynor (2006) quality control is an important aspect of the apparel manufacturing process because it affects manufacturers, retailers as well as consumers of apparel. While Merkel (1991) viewed quality as a synonym of excellence, Glock and Kunz (1990) viewed quality as a means to develop product differentiation that has a perceived value. However, quality attributes vary from individual to individual. As indicated by Mehta and Bhardwaj (1998) quality means different things to diffident people. The response of what quality is depends on peoples' perception of the value of a product or service under consideration, and their expectation of performance, durability, and reliability of that product or service. In this respect, Chowdhary and Poynor (2006) indicated that perceived apparel quality is a function of intrinsic and extrinsic cues. Intrinsic cues are an inherent part of the apparel product, and represent fit and style, sizing, the type of fashion and support fabrics, and the sewing process used to produce a quality garment for the intended purpose. In contrast, extrinsic cues to quality and performance include prices, brand names, retailers' reputation, visual display of the apparel product, and promotional strategies used to introduce and merchandise the product.

Chowdhary and Poynor (2006) pointed out that Rao's 'Total concept of quality' reflects commitment to excellence. The model stated that:

> The total concept of quality and quality management involves interaction, communication and performance of the work force. Intrinsic quality must be built into a garment. The entire merchandising, production-marketing

and operations and finance are involved in products of a predetermined level (p.561).

On the other hand, the definition of quality given by Taguchi as indicated by Balu, Gowri and Tharani (2009) is customer oriented. Taguchi defines quality in a negative manner "quality is the loss imparted to society from the time the product is shipped". This 'loss' would indicate the cost of customer dissatisfaction that leads to the loss of company reputation. This differs greatly from the traditional product-oriented definition, which includes the cost of rework, scrap, warranty and services cost as the measure of quality. The customer is the most important part of the process line, as quality products and services ensure the future return of the customer, hence improving reputation and increasing market share.

AMANN Inc. (2009) stated that in the sewing industry, product quality always means seam quality. There is no product quality without seam quality, and this applies for all applications and all the areas of the sewing industry. AMANN Inc. (2009) further stated that seams are always decisive for the product quality, since they contribute to the beauty and function of the apparel product. AMANN Inc. (2009) continued that in the area of home textiles, seam and product quality are linked closely. A broken seam on a sofa, a ripped seam on curtains or a weather-related torn seam on an awning ruins a product's quality as a whole. Reworking or replacing such problems is often time consuming and often very expensive as well. AMANN Inc. (2009) added that the importance of a seam's quality for the quality of the finished product is undoubted. Sometimes

even lives can depend on seams. For example, if a seam on a parachute or an airbag does not meet the requirements, life is in danger. Chowdhary and Poynor (2006) also asserted that selection of stitches and seams forms an integral part of producing a good quality garment. They indicated that stitch density is deemed to be an important attribute because it binds the textiles together. Glock and Kunz (1990) associated stitch length as an indicator of quality and speed of production. Anderson (2009) added that breaking stitches would result in a client that thinks less of one's apparel product quality.

Since quality is perceived differently by different individuals, it becomes difficult to ascertain what is accepted as quality across nations. Just-style.com (2001) reported that quality can be managed effectively across continents by setting clear expectations of what is acceptable and what is not by inspection, data collection and analysis of data and by addressing the root causes of less than desired quality. Quality means performance, condition, and properties, and if one wants to assess a seam under these aspects, a detailed requirement profile is needed. Yet, different seams demand different requirements. However, there are indicators such as seam stability (seam breaking strength and seam slippage), seam elasticity and appearance that are true for almost all seams. Their evaluation is the basis for assessing their quality (AMANN Inc., 2009). AMANN Inc. (2009) added that every seam analysis begins with the checking of these properties. In addition, there are individual quality criteria that must be worked out depending on the application and function.

According to Germanova–Krasteva and Petrov (2007), the appearance of the seam forms the aesthetical properties of the sewing product. It is inadmissible carving of the seam's line, poorly tightening of the seams ends leading to incompactly joining, torn threads or disturbing of the seam's wholeness and unevenness of its density. Figure 2 presents the describing factors contributing to seams quality summarised in a scheme by Germanova-Krasteva and Petrov.

ELASTICAL PROPERTIES	BRIGHT PROPERTIES	EXPLOITATIONAL PROPERTIES
Eveness of seam's line	Strength in cross direction	Friction resistance
Eveness of seam's density	Seam's elongation	Washing resistance
Completeness of the seam	Bending stiffness of the seam	Dry cleaning resistance
		Steadiness of natural agines
		Loosing of the seam
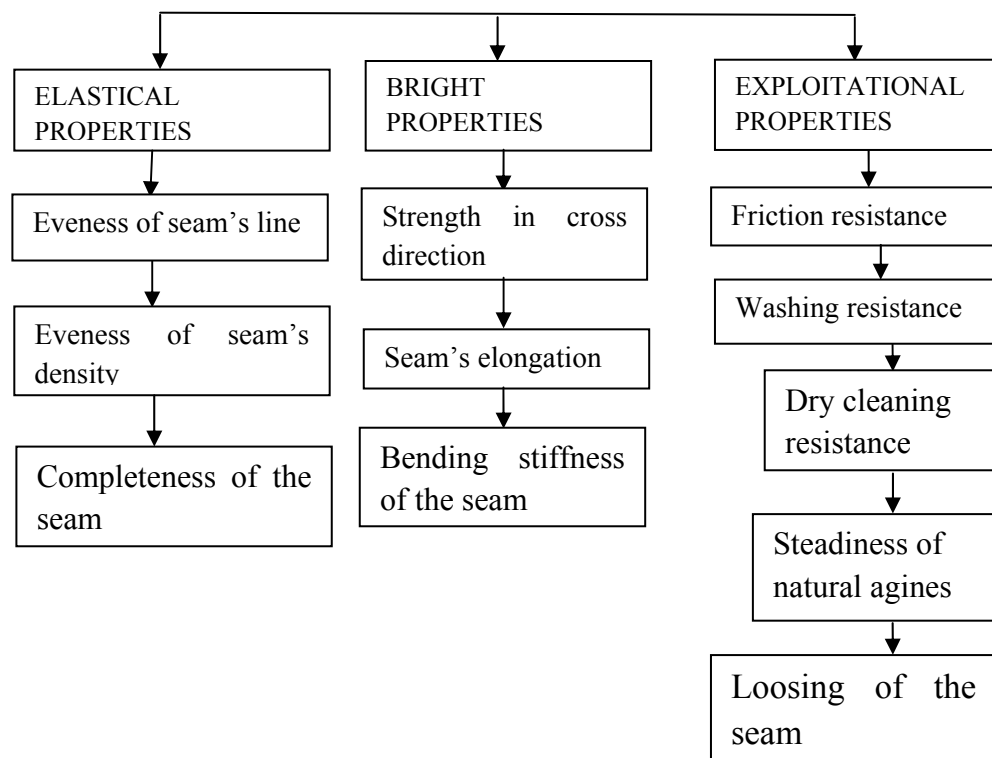
Figure 2. Describing factors contributing to seams quality (Germanova–Krasteva and Petrov, 2007).

In the view of Du (2009), the quality of a product may be obtained by testing a particular property of a material on different types of testing instrument. She argued that because textile products meet various physical, chemical and mechanical processes during pre-production and various stresses put on the

garment during post production, there is the need to test the product. Some measures that producers test at pre-production level include, colour fastness to laundry, colour fastness to light, dimensional stability of the fabric and strength (Du, 2009). For post-production, Du (2009) pointed out parameters like stitches per inch and concluded that quality control is a challenging job, because it satisfies buyer's requirement, seller's achievement and makers' fulfillment.

Testing Seam Performance

The key to managing quality effectively across the continents is consistently in quality procedures and practices (Just-style.com, 2001). This can be accomplished by having clear requirements (specifications) that the workforce understands, having uniformity in inspection, data collection and analysis. If all of these are in place, then performance of various plants can be compared and performance improvements addressed.

In order to attain quality across continents, standards are established for manufacturers to follow and quality control inspectors engage in testing and inspection to verify the quality of products. Mehta and Bhardwaj (1998) defined standards as something that is established by authority, custom or general consent as a model or example to be followed. They indicated, according to ISO, standards are documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose.

Standards facilitate communication and prevent misunderstanding, make parts interchangeability possible and as a result mass production is possible. Standards reduce cost and save money; these standards can be attained through testing. However, according to Mehta and Bhardwaj (1998), when one mentions testing to a garment manufacturer, usually, the manufacturer envisions a full fledge testing laboratory. Mehta and Bhardwaj (1998) pointed out that to effectively manage quality of garments, one does not need to have a full fledge testing laboratory. An effective testing programme can include only a pair of washer and dryer. It is amazing how much information can be gathered for decision making by only washing and drying an item of clothing.

According to Mehta and Bhardwaj (1998), a manufacturer lost $300,000 per year as a result of not testing a fabric before using it for production. In the apparel industry, in most cases, it is visual inspections that are made on garments by looking at the appearance of seams, which is just one of the properties, leaving other mechanical properties, which can be examined through testing. From Mehta and Bhardwaj (1998) it is clear that testing is a very important aspect of quality management. Testing, in itself, will not be of any help, but the interpretation of the numbers generated (test result) will help identify any problem areas.

Mehta and Bhardwaj (1998) asserted that fabric performance specifications for various properties for various end uses have been developed by bodies such as American Society for Testing and Materials (ASTM) and International Organisation for Standardization (ISO) for manufacturers to follow. Some retail

store chains and government agencies have their own standards for various clothing items and, the test methods to be used are indicated by them, making it easy for a garment manufacturer to interpret test results and come to a conclusion regarding the quality of the product. They continued that whenever such clear-cut guidelines are not available, the interpretation of test results can be based on comparative data or past experience, and sometimes it is a mater of intuitive judgments. Testing should be accomplished using some structured methods so that the test result can be compared. Examples of standards set by ISO for testing as indicated by Olsen (2008) include European Standards (EN) ISO 13934 – 1:1999 ravel strip strength, EN ISO 13934 – 2:1999 grab method for tensile strength, EN ISO 13935-1:1999 method for seam strength strip method and EN ISO 13935-2:1999 method for seam strength (grab method).

As time goes by test methods are modified to meet current trends of fabric properties or to produce more reliable results. As indicated by Olsen (2008), the four EN ISO standards stated in the previous paragraph are currently going through an amendment process to accommodate the vast range of fabrics with built-in stretch characteristics now being sold at the market place. Olsen (2008) pointed out that it is important that an individual used the appropriate method depending on the fabric type. Each of the standards set has test methods that have to be followed to achieve reliable results. Different fabric structures may require different test methods.

Olsen (2008) reported a seam testing procedure where standard fabric test specimens were prepared 400mmx100mm with a seam at one of the specimen.

The standard seam methods, she stated, relied on evaluating paired data taken from two tensile strength curves; the first curve is the tensile strength of the fabric and a second curve has a standard laboratory seam sewn across the centre. In this case, she indicated that the individual will pull on the same warp and weft threads with and without a seam. Olsen (2008) stated further that with stretch fabrics the specimens are 200mmx100mm with standard seam sewn across the middle of the specimen.

ASTM D1683 – 07 (2007) also indicated that Test Method D5034 shall be used to determine any characteristic in fabric that can be used to determine measurement of sewn seam strength. It indicated that the ASTM D1683-07 (2007) test method measures the sewn seam strength in woven fabrics by applying a force perpendicular to the seams. Sewn seams, it continued, can be obtained from a previously sewn article or seams sewn with fabric samples using either a specific seam assembly or production seam assemblies. It specified that the test method is used when a breaking force to rupture, a minimum elongation, or both are required to determine the sewn seam strength, seam slippage or seam intensity of a particular fabric for a specified end use. The test method is used in conjunction with test method D5034, which is used to measure breaking force and elongation of textile fabrics.

Researchers usually employ various standard methods to test performance of seams. According to Chowdhary and Poynor (2006), Mirafi (2001) tested efficiency of superimposed seams using ASTM D4632 for grab method and ASTM D4884 for wide-width method. While Chowdhary and Poynor (2006)

employed a modified grab test (ASTM D1683, 1994) for fabric and seam strength testing, Germanova–Krasteva and Petrov (2007) employed EN ISO 13935-01 for testing seam strength and -02 for seam's elongation. Gribaa et al. (2006) employed ISO 13935-1 (seam rupture using the strip method) and French norm NF G07119 (strip test method). Mukhopdhyay et al. (2004) employed ASTM standard (D1683-90a) for testing seam and fabrics tensile properties while Jonaitiene and Stanys (2005) employed EN ISO 13950, 1999 in carrying out tensile tests of seams.

Young and Lambert (1989) undertook a study to predict long term seam performance of seams under permanent pre-stress load as occurs with architectural fabric structures. They observed three primary test methods; the peel testing, tensile testing and dead load testing. In this study, the ISO 13935-1:1999(E) strip test method was employed for testing seam tensile properties and ISO 13934-1:19999(E) strip test method for fabric tensile properties. As the researchers use the methods and find defects in them, improvements and changes are made to make their results more accurate. Richardson (1989) reported that the stress-strain behaviour of highly structured nonwovens and composite geotextiles is significantly altered by confinement whereas woven geotextiles do not exhibit such a change. He continued that from the initial tests performed by Haliburton, it was apparent that the measured stress-strain behaviour of geotextiles was significantly influenced by details of the testing procedures. Such test details include the method of gripping the fabric, rate-of-strain, sample size/aspects ratio, initial preload, and fabric conditioning. He stated that beyond

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such mechanical details, the interpretation of the resulting load extension curves is a subject of controversy.

Seam testing requires specified methods to be followed, such as measurement to be used for specimens, speed of tensile testing machine, conditioning of specimens and much more. According to Richardson (1989), conventional tensile testing procedures assume a positive gripping mechanism that not only provides a secure load transfer, but also defines the gage length of the specimen.

Seam Performance and Seam Performance Properties

Seam is the basic structural element of a garment or household textile item. It is the means by which two pieces of fabric are joined together. Seams may be created with thread by hand or machine or with fusion through chemical bonding (Heaton, 2003).

Wikipedia (2009) described seams as the line where two or more layers of fabrics are held together by thread. According to LaPere (2006), the row of stitching joining two or more pieces of fabrics is known as the seam line. LaPere (2006) continued that the stitching comprising the seam line is usually parallel to the raw edge of the fabric and should be adequate for the durability of the home furnishing or apparel product. However, Heaton (2003) indicated that, unless otherwise stated, a seam is stitched 5/8 inch from the cut edge and the fabric from the stitching line to the cut edge is called a seam allowance. Desirable properties of a seam indicated by Balu et al. (2009) are, it must not be pulled apart under the stresses of service, it must not be cockle or tight, it must be

extensible as the fabric or as needed by the garment, the sewing stitches must not cut the fabric, and the seam must not break or crack on stretching.

Seams are meant to hold garment pieces in place for the life of the garment. Seam quality is therefore, an important parameter deciding the performance of garment (Mukhopadhyay et al., 2004). ASTM D6193-09 (2009) stated that the characteristics of a properly constructed sewn seam are strength, elasticity, durability, and appearance. It stated that the properties or characteristics must be balanced with the properties of the material to be joined to form the optimum sewn seam. In addition to the properties identified by ASTM D6193-09 (2009), Abdelkarim and Seif (2001) mentioned the interaction of seam strength and seam elongation as seam quality properties. Chowdhary and Poynor (2006) also observed the interaction of seam efficiency, strength and elongation as properties contributing to seam performance or quality seams in garments. These properties are influenced by seam type, stitch density, thread strength, needles and sewing machines. For example, American and Efird Inc. (2009) identified five factors that determine the strength of a seam. They factors are fabric type and weight, thread fibre type, construction, stitches per inch and stitch balance. American and Efird Inc. (2009) indicated that any one of these factors can adversely affect the performance of a sewn product depending on the end-use of the sewn product.

Seam Strength

Seam strength is one of the parameters that measure seam performance. According to Goyal (2006), it refers to the strength when a seam finally ruptures or when the fabric breaks. AMANN Inc. (2009) added that seam breaking

strength describes the resistance of seams to tensile stress on the seam, in crosswise direction. AMANN Inc. (2009) continued that if a seam's breaking strength is insufficient, the seam would tear during later use. They indicated further that the seam's breaking strength is determined by the fabric, the sewing thread and the sewing parameters. However, in the view of Goyal (2006) seam strength depends on stitch types, thread strength, stitches per inch, thread tension, seam type, and seam efficiency of the material. AMANN Inc. (2009) indicated that when choosing the sewing parameters, the stitch density, stitch type and the thread balance in the seam have a great influence on the seam's breaking strength. Increasing the stitch density by only one stitch per centimeter, for example, leads to a 25-30% increase of seam breaking strength. The type of thread and other parameters that will contribute to better seam strength can only be established through testing.

Tensile testing is usually used in testing seam strength. According to Germanova-Krasteva and Petrov (2007), tensile properties of a seam define the steadiness of products construction to deformation and are characterized through the strain strength in cross direction, elongation in direction of the seam and the bending stiffness. Seam strength testing is basically an examination of the amount of pressure required to tear or break the seam of the garment. Measurement of seam strength is a part of quality control procedure which is essential for garments (Doshi, 2006).

According to Richardson (1989), along with the tensile properties of geotextiles, seam strength is of growing importance to engineers. He continued

that for Geotechnical Engineers, ultimate seam strength is the most important performance parameter. American and Efird Inc. (2009) also indicated that when engineering seams, they recommend doing tensile tests on the fabric to determine its strength. They continued that an individual or manufacturer cannot specify seam strength requirements that are stronger than the fabric itself.

Since seam strength is one of the important parameters for seam performance, studies have been done to determine seam strength characteristics of certain fabrics with some of the parameters that contribute to seam strength. Chowdhary (2002) reported that antiqued and sandblasted jeans had higher tensile strength and elongation in warp direction than weft direction. For LS401 seams, fabric broke but seam did not. For SS 516, the seam strength was highest for the stone washed jeans followed by antiqued and sandblasted jeans. American and Efird Inc. (1997) observed increase in seam strength as stitch density increased. Chowdhary and Poynor (2006) also found differences in seam strength for three stitch densities in both warp and filling directions. Seam strength increased as stitch density increased. Contrary to the finding of American and Efird Inc. (1997) and Chowdhary and Poynor (2006), Wang, Chan and Hu (n.d) observed changing patterns of vibration cycle of tensile strength extensibility and stress withstand retention when stitch density was increased. Wang et al. (n.d) noted in their study on the influence of stitch density to stitches properties of knitted products that when stitch density was increased, the tensile strength at break of 301 lock stitch reduced. Mukhopadhyay (2008) noted increase in seam strength with increase in linear density of sewing thread.

Seam Durability

Gurarda (2008) asserted that seam durability is the third aspect of seam performance originally identified as necessary to satisfactory seaming. Seam durability relates to the length of life of a seam in a garment and its ability to withstand the end use required of the garment. ASTM D6193–09 (2009) indicated that the durability of a sewn seam depends largely upon its strength relative to the elasticity of the seam and the elasticity of the material. However, in less elastic, tightly woven or dense materials, there is a tendency for the plies to "work" or slide on each other. To form a durable sewn seam in these types of fabrics according to ASTM D6193-09 (2009), the thread size must be carefully chosen. The stitch density also needs to be carefully determined for the material so as not to cause excess tension which will unbalance the elasticity and cause puckering. It is also important to minimize abrasion and wear by contact with outside agencies to promote durability. Gurarda (2008) pointed out that a different problem of seam durability and abrasion can arise with denim jeans when they are subjected to stonewashing. In this process they are severely abraded to produce a worn and faded look. Careful thread selection is required to prevent damage to seams requiring immediate repair or damage which shortens the life of the garment.

Seam Elongation

Elongation according to ISO 13934-1:1999(E) (1999) is the ratio of the extension of a test specimen to its initial length, expressed as a percentage. It is the extension of the seam at break. ASTM D6193-09 (2009) indicated that the

elasticity (elongation) of a sewn seam should be slightly greater than that of the material which it joins. This will enable the material to support its share of the forces encountered for the intended end use of the sewn item. The elasticity of a sewn seam, ASTM D6193-09 (2009) stated, depends upon factors such as fabric type and strength, seam type, stitch type, thread elasticity and stitch density. Gurarda (2008) pointed out that with comfort stretch fabrics stretching up to 30 percent and action stretch fabrics stretching 100 percent or more, it would be necessary to create seams which would stretch and recover in excess of these percentages so that they do not restrict the flexibility of the garment or break at their limiting extension. Abdelkarim and Seif (2001) noted, in their study on the influence of sewing needle usage time on seam quality that, in terms of elongation, the long period of time of using the needle caused more extension on the seam.

Kadolph and Langford (2002) reported that fibre elongation for cotton is 3% to 7% but did not mention seam or fabric elongation. The reported study tested elongation for both fabric and seams. It was 12% for warp and 16% for filling yarns, with various seams ranging from 15% to 20% for warp, 17% to 22% for the filling direction. Obviously, the elongation for seams was higher than the fabric elongation. The finding of Kadolph and Langford (2002) is in agreement with the finding of Chowdhary and Poynor (2006). Chowdhary and Poynor (2006) found in their study on impact of stitch density on seam strength, seam elongation, and efficiency that the seams had significantly higher elongation than the fabric in both warp and weft directions for all stitch densities. They also

observed differences between seam elongation and three stitch densities in both warp and filling directions in a 100% muslin fabric.

Seam Efficiency

Seam efficiency is a function of compatibility between the fashion fabric, sewing thread, yarn size, needle, tension, seam type, and stitch density. It is a percentage representation of the ratio between the seam strength and the fabric strength (Chowdhary & Poynor, 2006). Chowdhary and Poynor (2006) indicated that, for interpretation purposes, if the percentage efficiency is more than 100%, the seam is stronger than the fabric. If it is less than 100%, the fabric is stronger than the seam. They continued that seam efficiency of 100% is required for a perfect seam. However, ASTM D6193 – 09 (2009) indicated that seam efficiency of the sewn seam should be as high as possible. This will produce sewn seam strength with a balanced construction that will withstand the forces encountered in the use of the sewn item. Mehta and Bhardwaj (1998) added that a fabric with higher seam efficiency would provide stronger seam than fabric with lower seam efficiency. Mehta and Bhardwaj (1998) continued that when woven fabrics are seamed, the absolute seam strength is not, in the majority of cases, of paramount importance, provided it is reasonably high. They concluded that a seam efficiency of about 60-70% indicates the seam will be commercially acceptable.

Chowdhary (2002) used seams from ready-to-wear garments in a study entitled, "Does price reflect emotional, structural or performance quality"?; and noted that seam efficiency of SS516 for the warp direction was 100% for stone

washed jeans, 91.94% for the antiqued jeans and 82.58% for sandblasted jeans. Chowdhary (2002) recommended extending the work on performance characteristics of textiles for other apparel items, weaves and fabrics. According to Chowdhary and Poynor (2006), some technical reports were found on seam efficiency for installing geotextiles for industrial purposes and the seam efficiency in that report ranged from 40% to 90%. Reports from Amaco Fabrics and Fibers Company indicated that, for most test fabrics, seam efficiency ranged between 60% and 90% for single stitched seams and 70% to 85% for the double rows of stitching (Chowdhary and Poynor, 2006).

Chowdhary and Poynor (2006) stated that a scholar of Geotextile Sewing Techniques reported that 90% to 100% seam efficiency is possible using grab test procedures. This confirms what Chowdhary and Poynor (2006) reported on what Mirafi (2001) found upon testing seam efficiency of superimposed seams using ASTM D4632 for grab method and wide-width method ASTM D4884. The findings revealed that seam efficiencies were higher with the grab test. Mirafi's Report noted that typical seam efficiencies ranged between 40% and 60 %. Chowdhary and Poynor (2006) revealed that the scholar on Geotextile Sewing Techniques noted that seam efficiency was 50% to 70% for polypropylene fabrics and 40% to 50% for woven polyester fabrics. Geotextile Sewing Techniques, according to Chowdhary and Poynor (2006) also reported that the normal stitch length for geotextiles was from 3 to 7 SPI. For sewing light weight materials, they used nylon, polypropylene, and polyester threads. However, for medium–weight fabrics, polyester thread was used. Kevlar thread

was used when seam strengths of 500lb/inch^2 were required. Seam stitch efficiency was higher for polypropylene threads (50% to70%) than the polyester threads (40 % to 50%).

Chowdhary and Poynor (2006) observed that seam efficiency differed for three stitch densities. It was highest for $10 - 12$ stitches per inch for both warp (61.29%) and filling direction (57.9%) and lowest for the $6 - 8$ stitches per inch 46.39% in the warp and 40.43% in the weft. They therefore, recommended that an attempt should be made to test each stitch length with a variety of thread types, yarn sizes, and yarn types used for both sewing thread as well as test fabric(s).

Factors that Influence Seam Performance

Seam Types

There are different types of seams with each performing separate functions. According to Integrated Publishing (2009), there are places where one seam will be better than others. Integrated Publishing (2009) continued that experience has shown that certain seams are best to serve a certain purpose. It indicated that these seams have been standardized so that people who do sewing can turn out the same type of work. Based on standardisation there are groupings for the various types of seams and Balu et al. (2009) and Doshi (2006) provided similar groupings. Balu et al. reported that the British standard BS3870 divides seam into 8 different classes. They are superimposed seam, lapped seam, bound seam, flat seam, decorative stitching, edge neatening with class 7 seams relating to the addition of separate items to the edge of a garment and class 8 involving only

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one piece of material. Doshi (2006) also indicated that the various types of seam constructions are the decorative seam, super imposed seam, applied seam, bound seam, edge neatening and lapped seam.

However, seam types in sewing, according to Wikipedia (2009), are categorised according to their structure. Each is classified by the abbreviated seam type. Based on this Wikipedia reported four different classes of seams which are superimposed seam (SS) with its variations, lapped seam (LS), bound seams (BS) and flat seam (FS). Garmento.org (2009) and Integrated Publishing (2009) pointed out that the seam or stitch formation is indicated by a symbol consisting of three parts; the first part denotes the class and consists of two uppercase letters; for example, SS. The second part denotes the type or the class of the seam or stitch formation and consists of one or more lowercase letters, for example, a. The third part denotes the number of rows of stitches used and consists of one or more Arabic numerals preceded by a dash; for example -1. The complete seam specification for the examples given becomes 301-SSa-1 with the 301 representing the class of stitch. Other examples are LSc-4, LSd-1 and LSak-2. It is noted that as the lower case letter increases the more complex and stronger the seam is. In this study the 301-SSa-1 seam type was employed.

Influence of seam type on the overall performance of seams.

Seam type is one of the factors that influence the properties of seams and further influence the overall performance of seams in apparel. As indicated by Stamper et al. (1986), the initial appearance of a garment, its durability, its comfort, its potential for alteration and its silhouette all depend on the seam types

and seam finishes selected for structuring the garment. Stamper et al. asserted that, a seam is used to effect a joint, when a garment's shaping and fitting requires that two or more pieces of fabric must be joined. Various types of fabrics and designs require different seams and seam techniques (Stamper et al., 1986). Stamper et al. indicated further that almost all of the subsequent major categories of apparel structures relate in some way to seams for their determining characteristics. Sleeves, waistbands and neckline treatments, for example, cannot be successful if the seams that are used to create them are of the wrong type, finished incorrectly and or made unskillfully.

American and Efird Inc. (2009) reported that stitch and seam construction or seam type influence seam strength and adversely affect the performance of a sewn product depending on the end-use of the sewn product. They indicated that many seam construction are more resistant to both stress and abrasion than other constructions. For example, they stated that felled seam is the strongest of all seams because the stress is shared by the fabric and the thread. AMANN Inc. (2009) added that the seam construction (seam and stitch type) influence the abrasion resistance. For example, lap seams for joining two material plies cause a more intense abrasion stress for the needle thread than inside positioned safety stitch. Thus, the bobbin thread in a double chain stitch is exposed to abrasion stress much stronger than in a lock stitch.

Crow and Malcolm (1985) undertook a study to find alternative seam types for Canadian forces combat clothing. They concluded that, based on minimum seam strength, the alternative seam which could be used instead of the double lap

seam in the lightweight combat fabric was the stitch and serge with topstitching. In the heavy weight combat fabric, they indicated, the safety stitch with or without topstitching and the stitch and serge with topstitching are suitable alternatives to the double-lap seam. Crow and Malcolm (1985) however found that no other seam type was strong enough for the twill fabric, although the stitch and serge with topstitching was almost sufficient.

LaPare (2006) also undertook a study on the effects of different fabric types and seam designs on the seams efficiency and noted that in terms of seam efficiency, there was no clear superiority of one seam type over the other seam for two fabric types (silk and cotton) but seam efficiency of the wool fabric was slightly higher for the SSn seam than the SSa seam. He noted that seam SSn appeared to produce a stronger joint in the wool fabrics. However, ASTM D6193-09 (2009) indicated that the end use of the item will govern the relative importance of the characteristics required in a properly sewn seam which are strength, durability, security and appearance. ASTM D6193-09 (2009) continued that the selection of the seam type and stitch type should be based upon these characteristics. In this study one seam type was selected and kept constant for all specimens involved to avoid the introduction of other variables into the study since seam type was not a major parameter in the study. The review was done on seam types to establish that depending on the type of seam employed in the construction process the resulting properties of the seam will differ.

Threads

The use of a suitable sewing thread is fundamental to ensure the desired properties for the assembly of garments (Gribaa et al., 2006). According to American and Efird Inc. (2009), thread only makes up a small percent of the cost of the finished product but shares 50% of the seam responsibility. Stamper et al. (1986) added that thread selection is a very important aspect of seam formation and can affect durability, appearance and even comfort. They indicated that one very important aspect of thread/fabric coordination is that the thread should be weaker than the fabric it joins but did not state how weak it should be. Broken stitches, Stamper et al. stated, can be repaired but if the thread is too strong, excessive stress will cause the fabric to split at the seam lines and there is no way to repair this type of damage and still maintain the garments original size and other aesthetic properties.

According to American and Efird Inc. (2004) the thread must be able to withstand the toughest wash and hold the seams together for the life of the garment. They argued further that in most cases, the repair costs in the laundry caused by using inferior thread will be far greater than the cost difference of using the right thread to begin with.

The range of sewing threads available on the market has increased significantly (Jonaitiene & Stanys, 2005). The development of new fibres, the development and improvement of new thread manufacturing processes as well as the continuously increasing demand from the industry to get various sewing threads designed for sewing a wide assortment of articles account for this

increase (Jonaitiene & Stanys, 2005). They indicated that about 70-80 percent of the sewing threads produced are used by the clothing industry and are required to have good satiability in laundering and ironing. Sewing threads of cotton and polyester (PES) are known to be the most commonly used in the manufacture of garments (Kalaoglu, 2001). Although they represent only a very small fraction of the cost of the garments, poor sewing threads can greatly increase production cost, as they cause frequent stoppages of sewing machines (Jonaitiene & Stanys, 2005).

During sewing, the elongation and the toughness of the thread reduce considerably. It was found that cotton threads exhibit higher strength loss than polyester threads (Sundaresan, Hari & Salhotra, 1997). Doshi (2006) stated that sewing thread's elasticity should match the elasticity of the fabric used, thus different fabrics require threads of different elasticity. For instance threads used for knitted, synthetic or woven fabrics are different. Gribaa et al. (2006) however, asserted that the type of thread determines the severity of abrasion (yarn-metal friction) which is crucial for seam durability. AMANN Inc. (2009) added that the seams abrasion resistance which is one of the performance properties of seams is primarily determined by sewing thread and in this regard mainly by the raw material which determines its general resistance to abrasion. AMANN Inc. (2009) continued that the sewing thread construction and its strength do have some influence too, but it is much lower than that of the raw material. Moreover, the core-spun threads feature a better abrasion resistance than other fibre threads. Multifilament threads are noted to be the best. Coarser

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threads, they noted, tend to be more resistant to abrasion than finer threads but indicated that this could be tricky too. This is because coarser threads are more prominent; thus increasing the abrasion stress which can even reverse the expected result. AMANN Inc. (2009) therefore, concluded that the sewing thread must correspond to the care requirements of the fabric regarding washing, bleaching, ironing, dry-cleaning or tumble-drying.

The type of the thread used, its construction, size and finishing influence the seam strength of a garment (AMANN Inc., 2009; Doshi, 2006). For American and Efird Inc. (2009) thread fibre type, construction and size have a definite effect on seam strength and polyester thread is more durable than cotton thread. Doshi (2006) pointed out that the type of thread used for garment construction depends upon the fabrics being used. For example, for silk fabrics silk thread is used. In the view of Gribaa et al. (2006), the finess of thread is expected to affect the strength of seam, the thicker thread provides a better seam strength, nevertheless it requires the use of a thicker needle which may damage the fabric.

Thread size plays important roles in the overall performance of seams in apparel. American and Efird Inc. (1997), for example indicated that to prevent seam puckering individuals should use the smallest thread size available that will maintain adequate seam strength and sewing performance. American and Efird Inc. (2009) reported that, given a specific fibre type and thread construction, the larger the thread size, the greater the seam strength. They stated, however, that in many cases, a smaller thread size will imbed itself in the seam making it less prone to surface abrasion. Doshi (2006) indicated that different thread sizes are

available in the market, but stated that finest threads are preferred more as longer length of finer threads can be wound around the lock stitch machine and do not acquire much space in the seam and this avoids seam puckering.

American and Efird Inc. (2009) indicated that in terms of fibre type of thread; some fibres are stronger than others and have greater loop strength contributing to greater seam strength. For example a 100% spun polyester thread will give greater seam strength than a 100% cotton thread of the same size. Synthetic fibres, like polyester and nylon, are much more resistant to abrasion and chemical degradation (such as bleach) than cellulosic fibres. Cellulosic fibres on the other hand have superior heat resistance. This view is in agreement with Jonaitiene and Stanys (2005), who reported that the types of fibres used in the manufacturing process, composition of threads and finishing impact on the quality of sewing threads. Glace or bond-finished threads are known to generally have superior abrasion resistance to soft-finished threads. Mercerised threads are stronger than soft cotton threads of the same fibre type and size.

Gurarda (2008) asserted that thread extensibility (elongation) has a part to play in achieving seam extensibility, but with conventional needle, thread is not an overriding factor. Cotton thread, she noted, typically have extensions at break of 6-8 percent, synthetics thread have 15-20 percent and higher for certain specialty threads for specific end uses. Junkindia.com (n.d) reported that the strength and the ductility (elongation) of sewing threads are essential. For example, when sewing heavy-weight fabrics, it is necessary to sew with sewing thread having high strength since thread breakage is apt to occur (Junkindia.com,

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n.d). It is the same when preventing thread breakage or puncture, when wearing the clothes. However, Junkindia.com (n.d) continued that, if ductility is excessive, it will cause seam puckering or stitch skipping and if it is too low, it may cause thread breakage.

In terms of thread construction, Doshi (2006) reported that core threads made with continuous filament polyester core, generally provide higher seam strength than spun and textured threads. For example, continuous filament polyester or nylon thread construction will provide greater resistance to abrasion and seam degradation. Some thread constructions according to Doshi (2006) are less subject to shearing or cutting each other when interloped together in the seam. Air entangled, textured and monochord thread constructions are known to exhibit the best loop strength characteristics.

Influence of threads on seam performance properties.

Jonaitiene and Stanys (2005) noted in their study on the analysis of seam strength characteristic of polyester-polytetrafluoroethylene (PES-PTFE) air-jet-textured sewing threads that, by changing the manufacturing parameters the properties of the thread; elongation at break, relative break force, absolute break, tensile tests of enervated sewing threads and seams strength varied within certain limits. However, Mukhopadhyay et al. (2004) found that initial and secant moduli of fabric sewn with finer yarn were lower as compared to the fabric sewn with coarser yarn. They explained that this occurred because the coarser yarn possesses higher moduli than finer yarn. They also observed that seam strength and elongation increased with yarn thickness, and work of rupture of seam was

higher for coarser yarn than that of finer yarn. In addition to the finding of Mukhopadhyay et al., Mukhopadhyay (2008) also noted that, in general with the change in thread linear density, greater improvement in seam strength, seam strain at break and work up to fracture were obtained in the case of chain stitched seam.

The appearance of a seam, which is one of the performance properties, is generally governed by the proper relationship between the size and type of thread, the stitch density and the texture and weight of the fabric (ASTMD6193-09, 2009). Gurarda (2008) stated that careful thread selection is required to prevent damage to seams requiring immediate repair which shortens the life of the garment.

Stitches

According to Gurarda (2008), apart from the thread, the type of stitch, needle and feed mechanism and the nature of the fabric sewn also determine the value of the properties of seams. A stitch is a single complete movement of a threaded needle in sewing (Answers.com, 2009). Whether the apparel item is casual or formal, the stitching in the garment accomplishes certain objectives, which according to Abernathy, Dunlop, Hammond and Weil (1999), include; joining individual pattern pieces, leaving no raw edges of fabric unravel and for decoration. Stitches actually form the basis of seams especially those made by stitching. There are various ways by which stitches are made in a garment. They can be done by the use of hand or machine. Glosson, Meek and Smock (1997) reported that early people used stone and bone needles and thread made from

animal sinews in stitching their garment pieces together. With the invention of the sewing machine, garment making became easier and other techniques could be employed.

Stitches influence the performance of seams in garments. Wang et al. (n.d), for example, indicated that the wearing property of knitted fabrics is greatly influenced by the stitch properties, such as strength, extensibility and stress-withstand retention. The stitch properties, they stated, in turn are related to stitch structure, stitch density and thread properties. Gurarda (2008) pointed out that the elementary basis of sewing is the stitch and a series of recurring stitches of one configuration are defined as a stitch type.

Stitch types.

Gurarda (2008) indicated that six different classes of stitch types have been defined by the British and American standards organizations. Similar numbering has been indicated by ISO standard number 4915 and British Standard BS3870 part 1:1991. The class of a stitch is indicated by a specification number. Garmento.org (2009) reported the following stitch classes: 100 class-single-thread chain stitch, 200 class-hand stitch, 300 class lock stitch, 400 class–chain stitch, 500 class-over edge stitch and 600 class-flat stitch. The four stitch types widely used for garment construction as indicated by Gurarda (2008) are class 300, 400, 500 and 600. In this study, a class 300 stitch was employed.

Influence of stitch type and density on seam performance properties.

Chowdhary and Poynor (2006) stated that the selection of stitches and seams is an integral part of producing good quality garments. They continued that stitch

type and stitch density influence the quality of seams in a garment. Poor choice can make the best fabric and related materials perform poorly and the reverse may be true when appropriate choices are made ahead of time. It must be noted that, the quality of a garment is a function of appropriate selection of textile materials and apparent production processes.

According to Gribaa et al. (2006), there are a wide variety of stitches by which the use depends on the function of the seam and the place where it appears in the clothing. The elongation and the strength of a sewn fabric can be affected by change in the form of seam because of the difference of the interlacement of thread with fabric for each stitch geometry. Gribaa et al. found that the deformation of seam increased as the stitch passed from lock stitch to double chain stitch. Gribaa et al. continued that what is in conformity with the characteristics of these two stitches are that the lock stitch pile up better seams whereas, double chain stitch gives more elasticity due to its way of formation.

Mukhopadhyay (2008) also undertook a study on the effect of two different types of stitches, lock stitch and chain stitch at the seat seam of a pair of trouser for military armed forces. He observed that performance of chain stitched seam was much better compared with lock stitched seam as regards lower value of force at low level of strain, higher value of force at break, strain at break and work of rapture.

American and Efird Inc. (2009) pointed out that generally, the more thread consumed in a stitch, the greater the seam strength, when they compared 301 lock stitch seams to 401 chain stitch seams. They explained that threads used in

301 lock stitch seams are more susceptible to sharing each other than 401 chain stitch and 504 over edge seams because of the way the threads are interlocked together rather than interloped together.

Gribaa et al. (2006) reported that the use of the most suitable stitch density depends on the material to be sewn and to the desired seam properties. Very high stitch densities they noted do not always give good results. American and Efird Inc. (1997) added that when writing garment specifications, the individual should always specify the proper number of stitches per inch (SPI) that should be used in the sewn products. Because the number of stitches per inch can have a direct influence on; the seam strength, the stitch appearance and the seam elasticity on stretch fabrics. American and Efird Inc. (1997) continued that the stitches per inch have a tremendous impact on the strength of the seam. It was indicated that, generally, the more stitches per inch, the greater the seam strength. There are rare cases where increasing stitches per inch can actually damage the fabric so that the seam is weakened, however, this only happens on specific fabrics that can be easily damaged by excessive needle penetrations.

Wang et al. (n.d) do not agree with American and Efird Inc. (1997) view that, generally, the more stitches per inch, the greater the seam strength. This can be noticed from what Wang et al. pointed out that, it is generally agreed that the strength, extensibility and stress withstand retention of the stitches increase as stitch density increases. However, in their experiments on the influence of stitch density to stitches properties of knitted products, Wang et al. found that the pattern of influence of stitch density on various stitches differs; even with the

same type of stitch the influences of stitch density on the stitch properties differ when the stitches are applied in different sewing directions. They noted that when stitch density was increased, the tensile strength at break of 301 lock stitch reduced; they stated that this finding goes against the norm that increase in stitch density leads to increase in strength. They also observed that when stitch density was increased, the tensile strength at break of 504 three thread over lock stitch increased gradually; 514 four thread over lock increased and reduced gradually. The greatest strength occurred at stitch density of 8 stitches per unit length. When stitch density was increased, the extensibility (elongation) at break of 301 lock stitch increased gradually for crosswise fabric samples but decreased gradually for lengthwise samples; 504 three thread over lock stitch increased gradually for both sewing directions; and 514 four thread over lock stitch increased and then decreased with the greatest rate at 8 stitches per unit length and when stitch density was increased, the rate of stress withstand of all three types of stitch was increased. Wang et al. noted that for 301 lock stitch, when the stitch density was increased the rate of extension at break increased for stitched samples at cross direction and was decreased for those stitched at warp direction. For 504 when the stitch density was increased, the breaking point of stitch extensibility for both warp and weft sample of fabric increased.

However, Chowdhary and Poynor (2006) found some patterns that confirm the American and Efird Inc. (1997) view that generally the more stitches per inch, the greater the seam strength. Chowdhary and Poynor (2006) noted that differences for seam strength were significant for three stitch densities in both

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warp and filling directions with strength increasing as stitch density increased. They found that seams with 10-12 SPI were the strongest in both directions. They also observed differences between seam elongation and three stitch densities in both directions. It was revealed that seams with 14-16 SPI had the highest elongation in both directions. Based on this, an additional analysis was taken by them to determine between group differences and it was noted that differences were significant between all three groups, except for the differences between 6 and 8 and 10-12 SPI in the warp direction. The groups were 6-8, 10-12 and 14-16 SPI. They also found that the fabric they employed in their study was significantly stronger than the seams in both warp and filling directions for all three stitch densities used for the study. For elongation they noted a significantly higher elongations in seams than the fabric in both warp and weft directions for all three stitch densities.

Gribaa et al.'s (2006) finding that very high stitch densities do not always give good results, is supported by Gurarda (2008) who indicated that increasing stitch density helps to increase seam stretch but only to a certain point. In lock stitch seams, he stated, an increase in stitch density actually reduces the proportion of thread lying on the surface of the fabric and available for direct extension with the seam, unless thread tension is adjusted at the same time as the stitch is shortened. With over edge stitches, Gurarda (2008) indicated that, increasing stitch density increases seam stretch but a limit is reached when the fabric becomes jammed between the crowded stitches. Too many stitches may also weaken the fabric and cause failure under transverse stresses. Gurarda

(2008) explained further that variations in stitch density affect seam strength and if other factors remain unchanged, then seam strength normally increases with increase in stitch density up to a point where the concentration of needle holes starts to weaken the fabric.

Gribaa et al. (2006) in their study on the influence of sewing parameters upon the tensile behaviour of textile assembly noted a correlation between certain parameters and assembly breakage. They found that when the stitch density level was low, rupture of thread after contracting of seam took place. When the stitch density level was high and the seam edge level was low assembly failure by tearing of sample occurred, whereas at the high level of both stitch density and the edge of seam, either assembly failure by tearing, breakage of sewing threads after seam slippage or damage of the fabric have been proved to happen. Gribaa et al. reported that when the stitch density has its minimal value, a rupture of the sewing thread is constantly noted; the weak friction between the sample and the seam caused the contraction of the seam. It was also noted that for a given force, seam is highly deformed at its low level density than at high level one.

Influence of Fabric Type on Seam Performance Properties

According to Abdelkarim and Seif (2001), the causes of sewing problems are very diverse, and can happen due to the machine, the fabric, the climate, the sewing thread or the sewing needle. American and Efird Inc. (2009) stated that fabric type and weight can affect seam performance depending on the fibre content (100% cotton, cotton/polyester blend, nylon), fabric construction (woven or knit) and type of weaves used (plain, twill, jersey, tricot); fill count, yarn type

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and size, pattern placement and seam direction and propensity of the yarns in the seam to shift or pull out of the seam. For example, American and Efird Inc. (2004) identified thread types and sizes that would optimise seam performance for denim garments.

Gurarda (2008) asserted that seams sewn in a densely woven or coated fabric cannot imbed in and are therefore more quickly abraded than those sewn into softer fabrics. The characteristics of the fabric are decisive for how flat or prominent a seam is, thus the seam having more and more exposure to the abrasion stress.

Gribaa et al. (2006) pointed out that during sewing process, the fabric is subjected to various mechanical solicitations (shear, compresion, extension), then fabric properties (composition, weave thickness, strength) will govern its "sew ability" and also seam performance. Stitch stability, they stated, depends on the rigidity of material; the deformation of sewing fabrics is a consequence of the internal frictions of fabric and of the relaxation process of cloth after the sewing process. Gribaa et al. indicated further that, it has been proven that fabric bending property is an important factor influencing puckering of the seam. In their study on the influence of sewing parameters on the tensile behaviour of textile assembly, they noted that results in warp direction proved some differences with weft direction in seam performance and stated that, the fabric construction affects the behaviour of sewn fabrics. Gribaa et al. observed that there were some differences which attested those influences of fabric

construction; the differences between yarns (twist, size, yarn fibre, density) affect the friction behaviour of seams (strength and slippage).

In the view of Stamper et al. (1986), fabric type and weight for example, determines a stitch density that should be selected. High count, thin, lightweight, soft fabrics usually require at least fifteen stitches per inch in order to be sewn securely. Heavy, coarse, low count fabrics, on the other hand, look better and are more durable when sewn with longer stitches. They argued that stitches that are too short might split the yarns of these fabrics and actually weaken the seam line. Eight to ten stitches per inch, or possibly even less in some cases, would be more appropriate for heavy fabrics. ASTM D1683-07 (2007) added that sewn seams in woven fabrics can fail due to rupture, slippage, or any combination thereof. ASTM D1683-07 (2007) continued that rupture can be further categorised as failure of fabric, or sewing thread or seam slippage.

In a study of impact of laundering on the seam tensile properties of suiting fabric by Mukhopadhyay et al. (2004), they found that coarser yarn had greater impact on seam properties of polyester-cotton fabric than cotton fabric. Both initial and secant moduli were reduced after laundering; the reduction being greater in polyester-cotton blended fabric. They explained that the observation indicates greater role of fabric composition influencing initial and secant moduli of seam, whereas impact of linear density of sewing threads on fabrics ultimate behaviour was large. In the current study real wax cotton printed fabric was employed.

Effects of Laundry on Seam Performance

Apparel comes under the impact of physical and chemical factors, such as abrasion, chemical products (for example, in laundry) and others during wear and care. As indicated by Germanova-Krasteva and Petrov (2007), the underwear and upper cloths are washed and overcoats proceed through dry-cleaning. Moris and Prata (1977) stated that as much as half of the wear on fabrics during use may occur in laundering. They indicated that, for example, abrasion may occur both in washing and in drying, and studies have shown that water quality, detergent type, and drying conditions are important variables affecting the amount of damage. The resistance of the product against washing and dry cleaning is a basic factor for evaluation of the exploitation properties of the seam in apparels (Germanova-Krasteva & Petrov, 2007). Mukhopadhyay et al. (2004) added that seam performance after laundry is important to adjudge the suitability of a sewn product.

Studies have been done to determine the impact of laundry on the performance properties of textile fabrics, but not much have been done on the impact on seams in garments. Mukhopadhyay et al. (2004) noted interaction of sewing parameters and laundry on the performance of seams. In their study on the impact of laundering on the seam textile properties of suiting fabric, they noted that the effect of stitch density, count of sewing threads, fabric composition and laundering on seam tensile properties of suiting fabric were very significant. Both initial and secant moduli were reduced after laundering; the reduction was greater in polyester-cotton blended fabric. Decrease in seam

strength and seam efficiency due to laundering was greater for coarser sewing threads. On the other hand seam strain at fracture was increased marginally, but work of rupture reduced after laundering.

In another study by Mukhopadhyay (2008) on the relative performance of lock stitch and chain stitch at the seat seam of military trouser, it was found that force at small strain and force at break increased on laundering, with the change being more in case of lock stitched fabric stitched with coarser sewing thread. However, strain at break decreased marginally on laundering in the case of both stitches.

Summary

As evident from the preceding information, sewing textile fabric is a very pointed operation which is governed by a broad spectrum of parameters like the stitch type, seam type and thread type. The adjustment of all sewing parameters will be a must to ensure quality. Nevertheless, the lack of understanding of the role of each factor and primarily of the interaction impact between factors limit the individual's ability to optimize the right selection of sewing parameters.

Current research works in the area of textiles and clothing have overlooked the study of the interaction of the factors and the properties of seams with laundry on African prints. Chowdhary (2002) used seams in ready to wear apparel, technical reports tested for industrial fabrics. LaPere (2006) used wool, cotton and silk fabrics, Chowdhary and Poynor (2006) employed 100% cotton muslin fabric, Mukhopadhyay et al. (2004) employed suiting fabric, Abdelkarim and Seif (2001) used 100% cotton fabric, Wang et al. (n.d) employed knitted

products, Germanova–Krasteva and Petrov (2007) used light fabrics and Gurarda (2008) employed Pet/Nylon-elastane woven fabrics.

None of the reviewed works reported on testing the factors (stitch density, thread type) in conjunction with the properties of seams (elongation, efficiency, strength) and laundry for Ghanaian Real Wax prints. Thus, this study looked at the influence caused by the interaction of these parameters on the performance of seams in terms of the stated properties in a Ghanaian Real Wax printed cotton fabric.

CHAPTER THREE

METHODOLOGY

This chapter describes the methods that were employed for the study. It explains how the investigations were carried out, why particular methods and techniques were employed. The chapter also provides an account of the materials, and procedures that were used for the study. The chapter ends with information on how data were analysed.

Research Design

This study is a quantitative experimental study because it investigated the impact of variation in stitch density, thread types and washing on seam strength, efficiency and elongation of plain seams in Real Wax cotton printed fabrics. The experimental type of research was chosen so that variables involved would be thoroughly examined. A 2×3×3 factorial design was employed for the study that included two brands of threads, three ranges of stitch density and three cycles of washing.

According to Ary, Jacobs and Razavieh (2002), a factorial design is an experimental design that investigates two or more independent variables at the same time, in order to study their effects singly and or in interaction with each other. They stated further that in a factorial design the researcher manipulates two

or more variables simultaneously in order to study the independent effect of each variable on the dependent variables as well as the effects caused by the interactions among the several variables. The three independent variables in this study were stitch density, thread type and washing. They were manipulated by combining them to evaluate their effects singly and in combination on the dependent variables seam strength, efficiency, and elongation.

Pre-testing

A piece of fabric measuring 700mm×350mm was cut from a Hitarget Real Wax cotton printed fabric. The cut piece of fabric was folded in half with the fold along the length and a plain seam with a seam allowance of 20mm made in this direction as indicated by ISO 13935-1:1999(E) (1999) for testing seam strength and elongation. A 301 lock stitch with stitch density of 12 was employed in stitching the seam. Five test specimens of width 100mm×350mm were cut from the 700mm×350mm piece of fabric with the seam. Five specimens are required in testing seam strength and elongation, where the mean of the five specimens is determined to arrive at the strength and elongation of the particular seam.

The pretesting was done using the same instruments as employed in the main study for testing seam strength and elongation. The pre-testing was carried out to determine the width of seam allowance at which the seam would break instead of slippage occurring, since the ISO standard 13935-1:1999 (E) (1999) indicated that the researcher or the group undertaking the study would have to decide on the seam allowance to use. With this intent 20mm seam allowance was used to prepare the specimens in the weft direction of the Hitarget Real Wax cotton printed fabric.

It was noted that with the 20mm seam allowance, breaking of stitches would occur without yarns in the fabric slipping through the seam allowance.

Materials

Twelve yards of Real Wax cotton printed fabric from Tex Styles Ghana Limited was bought from the market, since the company is perceived to produce good quality African prints. Two different brands of sewing threads, namely Sunflag and OK, were purchased from the market. These two brands of threads were chosen because they are common on the Ghanaian market and so mostly used by seamstresses in garment construction. Key soap, produced by Uniliver, Ghana limited, was purchased from the market and used for washing the specimens. The key soap was chosen for this study since it is a soap that has long been used in the Ghanaian community for washing clothes and still patronized by a good number of Ghanaians.

Sample and Sampling Procedure

The strip test method was employed by the researcher in this study. Out of the 12 yards of Tex Styles Ghana Limited Real Wax fabric bought, a total number of 295 specimens were obtained for the experiments. The specimens were selected using the simple random sampling method, where specimens were cut from different locations on the fabric in order to obtain a true representation of the various sections of the fabric (Figure 3). From the 295 specimens, 55 were not stitched. These were used in testing for fabric weave, fabric strength, elongation, weight, yarn linear density and count. Seam strength and elongation were tested for, using the remaining 240 specimens. Hundred strands of the threads used in the

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stitching of the specimens, were also cut with length 50cm for testing linear density, with each thread using 50 strands.

P	F	P	F	P	F	P	F	P	F
F	P	F	P	F	P	F	P	F	P
P	F	P	F	P	F	P	F	P	F
F	P	F	P	F	P	F	P	F	P
P	F	P	F	P	F	P	F	P	F
F	P	F	P	F	P	F	P	F	P
P	F	P	F	P	F	P	F	P	F
F	P	F	P	F	P	F	P	F	P

Figure 3. Random sampling of specimens in the warp and weft directions of the fabric (P= warp, F= weft).

Preparation of Specimens

Tensile strength and elongation of fabric.

The specimens were in both warp and weft directions and each measured 30cm×7cm. The 30cm×7cm specimens were frayed at both sides in their lengthwise directions to achieve the 30cm×5cm size required for testing. Tensile strength and elongation were tested using 40 specimens, where 30 of the specimens were washed before testing (15 in the warp direction, 15 in weft direction with 5 specimens from each direction used for each washing cycle).

Fabric weight, count and weave.

Five specimens, which were cut using the sample cutter, were used to determine the weight of the fabric. The area of each cut piece for testing for weight

was $0.015m^2$. Two specimens were used in testing yarn count (1 in the warp direction and the other in the weft) and 1 specimen was used for testing fabric weave.

Yarn linear density of fabric and threads.

Yarn linear density of the fabric was tested using a total of 350 strands of thread, which were removed from 7 rectangular strips cut from different sections of the fabric. Two rectangular strips were used for the warp direction, while the 5 of the rectangular strips representing different weft packages were used for the weft. All the strips were of the same length of 50cm and their width was 2.5cm. From the rectangular strips the 350 strands were removed, 100 for warp and 250 for weft as indicated by International standard 1SO 7211/5 (1984) (determination of linear density of yarn removed from fabric). To determine the linear density of the sewing threads, 50 strands were cut from each thread.

Seam strength and elongation.

The 301 lock-stitch was employed in the stitching. The 301 lock stitch seam as indicated by Olsen (2008) is the standard laboratory seam used for the testing of seam quality and is the most common stitch used by seamstresses in Ghana. Stitches were made in 8, 10 and 12 SPIs. Specimens were prepared from both warp and weft directions of the fabric and stitched with plain seams at their centres. The sewing threads (OK and Sunflag) were used as both upper and under threads in the stitching. Eighty specimens were used for each SPI, where each thread used 5 specimens in the warp direction and 5 in the weft direction for each testing. Twenty out of the 80 specimens served as controls, and the remaining 60

specimens for each SPI were used for the three washing cycles, with each cycle making use of 20 specimens. In all each brand of thread used 120 specimens (60 in the warp direction and 60 in the weft direction) making a total of 240 specimens in both warp and weft directions of the fabric.

The stitch densities that were employed for this study were selected based on the SPI's indicated by some researchers and authors for woven fabrics stated at the introductory part of this study, which ranges from 6-20 stitches per inch. The choices of SPIs were also informed by my observation of the SPI ranges commonly used by seamstresses in Cape Coast.

Preparation of seams and of test specimens for seam strength and elongation.

The 240 specimens were obtained by randomly cutting 350mm× 700mm pieces of fabric. The cut pieces of fabric were folded in half with the fold along the length and the plain seam with a seam allowance of 20mm made in this direction as indicated by ISO 13935-1:1999(E) (1999) for the strip test method (Figure 4). The seams were sewn parallel to both the warp and the weft directions, meaning both warp and weft seams were investigated. The ISO 13935-1:1999(E) (1999) indicated that a seam can be sewn parallel to the warp or weft direction or both for testing, and I decided to use both directions. It was also indicated that the researcher or the group undertaking the study would have to decide on the seam allowance to use hence the 20mm seam allowance chosen. Gribaa et al. (2006) stated that a yarn in a fabric can pull out of the seam from the edge. Proper selection of seam allowance is necessary to minimize or avoid seam slippage. Pre-

testing, which involved 5 specimens in the weft direction recorded that with the 20mm seam allowance, breaking of stitches will occur without yarns in the fabric slipping through the seam allowance.
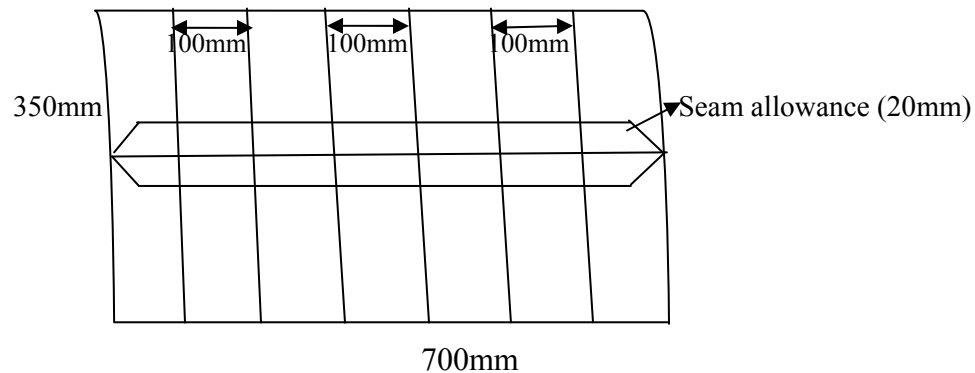
Figure 4. The piece of fabric from which 5 specimens were taken for each SPI.

Preparation of final test specimens for seam strength and elongation.

For each 700mm×350mm stitched piece of fabric, five test specimens of width 100mm×350mm were cut (Figure 4) to represent each SPI, direction (warp and weft), thread brand and washing cycle as well as the specimens that were not washed. In all 48 pieces of fabric of 700mm× 350mm for both directions (24 in warp, 24 in weft) were prepared. Out of the 48 fabric pieces, the 240 specimens of widths 100mm×350mm were obtained. After obtaining the 100mm×350mm specimens, 4 cuts of 25mm length at 10mm distance from the seam as shown in Figure 5 were made. The area shaded and labeled 25mm (Figure 5) were frayed so that a final specimen width of 50mm was obtained for the investigations (Figure 6). All specimens for the investigations were conditioned for 24 hours in a relaxed state as indicated by the ISO 13935-1:1999(E) (1999). All the procedures stated in

this text for the selection, preparation and testing were done according to the standard test methods employed by the Ghana Standards Board in carrying out the stated tests.
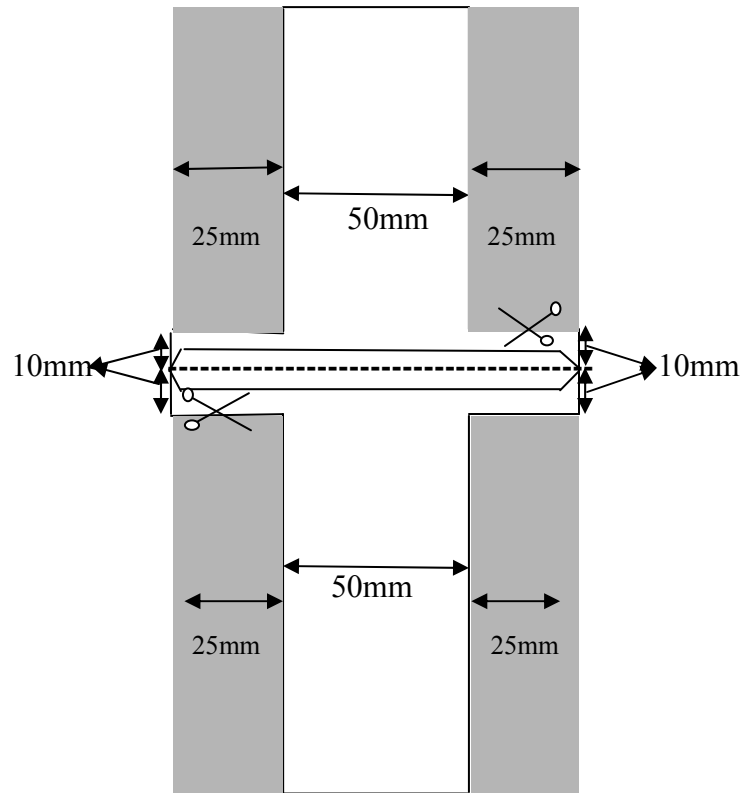
Figure 5. Determination of test specimen for seam strength and elongation.

Figure 6. Final specimen for testing seam strength and elongation.

Instruments

A Butterfly hand sewing machine with needle size 14 was used in the stitching of specimens. The hand sewing machine is mostly used among seamstresses and the 14 needle size is the type most of them employ in stitching.

The Standard Launder-Ometer (Gyrowash 315) was used in washing the specimens.

A tensile testing machine (Hounsfield H5K-S) was employed in testing the tensile strength and elongation of fabric and seams.

A magnifying glass was used in determining the weave of the fabric and fabric yarn count.

Weighing balance (Adams equipment) was used in determining the weight of the fabric and yarn linear density.

A pair of scissors was employed in the cutting of threads and specimens and a sample cutter was used in cutting specimens for weighing.

These instruments are used by the Ghana Standards Board (GSB) in testing for approval of textile prints and so were deemed reliable for use. Refer to Appendix for the pictures of the instruments used for the study.

Data Collection Procedure

Labelling of Specimens

The labelling of the specimens was done based on the direction of the specimen (warp, weft), the SPI and the number of washes the specimen had. For seam strength, all OK thread specimens were labelled OK and all Sunflag thread specimens were labelled SUN. Specimens stitched in 8 SPI were labelled 8, 10 SPI were labelled 10 and 12 SPI were labelled 12. All warp specimens were labeled 'P' and all weft specimens were labelled 'F'. Specimens washed once were labelled 1, two times were labelled 2 and three times were labelled 3. OKF81 and SUNF81 represented weft specimens that were washed once, OKF82 and SUNF82 represented weft specimens that were washed two times and OKF83 and SUNF83 represented weft specimens that were washed three times. This was done for the remaining two stitches per inch, which were 10 and 12 and the warp specimens. Specimens for testing fabric tensile strength and elongation were labelled as P, P1,

P2, and P3 for warp, F, F1, F2 and F3 for weft, with P and F representing specimens that were not washed (control). The labeling for weft specimens is presented in Figure 7.

Specimen label(seam strength /elongation)	Number of washing cycles
OKF8	0
SUNF8	0
OKF81	1
SUNF81	1
OKF82	2
SUNF82	2
OKF83	3
SUNF83	3
Fabric strength and elongation	
F	0
F1	1
F2	2
F3	3

Figure 7. Labeling of weft specimens for seam (strength and elongation, 8SPI) and fabric (strength and elongation).

Preparation of Soap Solution

A stock solution of the Key soap was prepared for washing the test specimens. The amount of soap solution used was obtained based on the weight of the specimens that were washed. It is noted that 1 gram of specimen weight takes 50ml of soap solution and 1L of water takes 5g of soap. For this study, two specimens weighed 6g and in one round of washing, 8 cylinders were used with each cylinder taking 2 specimens. The stock solution was therefore obtained by dissolving 12g of soap in 2.4L of water. The 2.4L of soap solution was enough to wash 16 specimens in one round of washing, with each cylinder taking 300ml of soap solution.

Washing of Specimens

The specimens to be washed were subjected to washing in the Standard Launder-Ometer (Gyrowash 315) with the solution made from the key soap. Ten steel balls were placed in each cylinder for agitation. The washing was done at 60^oC temperature for 30minutes and followed by rinsing and sun drying in the open space in each cycle of washing. The washed specimens were taken out of the sun immediately they dried. The specimens were not ironed. After drying, specimens were tested for fabric strength and elongation and seam strength and elongation.

Weighing of Fabric, Testing for Fabric Weave and Yarn Count

The five specimens were placed on the weighing balance (Adams equipment), one at a time, and their readings recorded. With the help of a magnifying glass, the fabric's weave and yarn counts were determined. For the yarn count, the number of yarns in the warp and weft directions of the fabric was counted 5 times and each recorded.

Testing Yarn Linear Density of Fabric and Sewing Threads

The 100 strands representing warp threads removed from the fabric were weighed together using the weighing balance (Adams equipment). For the 250 weft threads, they were weighed in a group of 50. The specimens for the threads were also weighed in a group of 50. Linear density was calculated from the mass of the strands prepared and the sum of the straightened lengths. The formula for calculating the linear density of the yarns as indicated by International standard 1SO 7211/5 (1984) (determination of linear density of yarn removed from fabric) is given as:

$$linear\ density\ in\ tex\ units = \frac{mass\ of\ threads\ taken\ from\ fabric\ in\ grams \times 1000}{total\ length\ of\ threads\ in\ meters},$$

where total length= mean straightened length× number of threads weighed.

Testing Fibre Type of Threads

Trichloroacetic acid and methalene chloride mixture used for testing polyester content of fabrics was employed in the determination of fibre content of the threads used in stitching the specimens. Pieces of the threads were cut and placed in different beakers containing the solution and shaken for 5 minutes. They dissolved completely indicating 100% polyester content. This testing was done to confirm the fibre content of the threads, which was written on them.

The fabric's weight, count, yarn linear density and fabric weave were read for the description of the fabric. Joseph (1986) stated that a woven textile fabric is described citing its average width, length, number of yarns per inch in warp and filling, yarn size and weight in grams. Yarn linear density and fibre type of the

threads used for the study were also determined to aid in the description of the threads.

Testing for Tensile Strength, Elongation of Fabric and Seams and Seam Efficiency

The tensile testing machine (Hounsfield H5K-S) was used for carrying out the testing for strength and elongation of fabric and seams. The gauge length of the tensile testing machine was set at 200mm ± 1mm and the rate of extension or the speed was set at 100mm/minute. The force at break and the extension at break of seams and fabric were recorded for each specimen in both the warp and the weft directions after each cycle of washing. These were done for the unwashed specimens serving as controls as well. Maximum forces at rupture were recorded in kilogram force (kgf). Fabric elongation was recorded in millimeters and calculated using the formula, viz:

$$breaking \quad elongation \quad = \frac{elongation}{original \quad length} \times 100 \cdot$$

Seam efficiency was calculated using the formula adopted from Chowdhary and Poynor (2006) and LaPere (2006):

$$seam\ efficiency = \frac{seam\ strength}{fabric\ strength} \times 100$$

I carried out the experimental procedures with the assistance of technicians at the Ghana Standards Board textile laboratory, from 19th of January, 2010 to 9th of February, 2010.

Data Analysis

Readings were recorded for each of the tests identified for stitched and unstitched, laundered and unlaundered specimens. The statistical means that was used in the analysis of the data collected was the Statistical Package and Service Solution (SPSS) for Windows version 17. Means and standard deviations were used to analyse the fabric's yarn linear density, yarn count, weight, strength and elongation. Means and standard deviations were also used to describe the deformation of the warp seams. Inferential statistics (Analysis of Variance and Independent *t*-test, at 0.05 alpha levels) were employed in testing the hypotheses since they are measures used in measuring differences, and the purpose of this study was to establish if any difference existed between and among the groups involved in the study.

To answer the two research questions, means and standard deviations were employed to determine if difference existed between the strength of the Tex Styles Ghana Limited Real Wax cotton printed fabric and the strength of plain seam in the same fabric after three washing cycles. Additionally, means and standard deviations were employed to determine if differences existed between the elongation of the Tex Styles Ghana Limited Real Wax cotton printed fabric and the elongation of plain seam in the same fabric after three washing cycles.

In testing hypotheses 1a, 2a and 3a, Independent t-test was used where thread type was taken against the dependent variables (seam strength, seam elongation and seam efficiency). For hypotheses 1(b, c), 2(b, c) and 3(b, c), One-Way ANOVA was employed where each independent variable (thread type, stitch

density and washing cycles) was taken against the dependent variables (seam strength, seam elongation and seam efficiency). In the case of hypotheses 4 a, b and c, which were to establish the combined effect of the independent variables on the dependent variables, 3-Way Analysis of Variance was used where the independent variables (thread type, stitch density and washing cycles) were taken against each dependent variable (seam strength, seam elongation and seam efficiency).

CHAPTER FOUR

RESULTS AND DISCUSSION

The purpose of this study was to investigate the impact of brands of sewing threads, stitch density, and washing on seam strength, elongation and efficiency of plain seam in a Ghanaian Real Wax cotton printed fabric.

In this chapter, the data obtained from the study are analysed and discussed. Readings were recorded for each of the tests identified from stitched, unstitched, washed and unwashed specimens. The Statistical Package and Service Solution (SPSS) for Windows version 17 was employed in analysing the data for the study. Means and standard deviations were used to report the details of selected structural and performance attributes of the fabric, the deformation of the warp seams and in answering the research questions. Inferential statistics (Analysis of Variance and Independent t-test at 0.05 alpha levels) were used in testing the hypotheses.

This chapter is presented under the following headings;

1. Structural and performance attributes of fabric and sewing threads

2. Deformation of seams in specimens

3. Difference between fabric tensile properties (strength and elongation) and seam tensile properties (strength and elongation)

4. Differences between thread types, stitch densities and washing cycles with regard to seam performance properties (strength, efficiency and elongation)

5. Influence of thread type, stitch density and washing cycle on seam performance properties (strength, efficiency and elongation).

Structural and Performance Attributes of Fabric and Sewing Threads

The details for selected structural and performance attributes of the fabric and the sewing threads were determined. The fabric was 100% cotton with a plain weave of 1x1 repeat in both directions. The sewing threads used for the investigations were OK and Sunflag. Sunflag had a higher linear density of 21 Tex as compared to OK with linear density of 15 Tex. From the linear density values of the two threads, it can be deduced that Sunflag is a thicker thread compared to OK thread. Both threads were 100% polyester. The results of the other details for the selected structural and performance attributes of the selected fabric are presented in Table 1.

Table 1 indicates that the fabric had higher yarn count in the warp direction (M= 80) than the weft (M= 69). It had higher linear density in the warp direction (M= 19 Tex) than in the weft direction (M= 17 Tex). The tensile strength of the fabric in the warp direction was higher (M= 40.04kgf) than in the weft direction (M= 27.70kgf), but for elongation the weft direction was greater (M= 21.73%) than the warp direction (M= 6.27%). These findings confirm the general accepted idea that the warp direction of fabrics is stronger than the weft, and weft threads stretch more than warp threads.

Table 1

Means and Standard Deviations of Selected Structural and Performance Attributes of Fabric

Attribute	N	M	SD
Fabric yarn count			
Warp	5	80	2.864
Weft	5	69	3.421
Fabric Weight	5	$111.34g/m^2$	1.027
Yarn linear density			
Warp	1	19Tex	
Weft	5	17Tex	0.482
Tensile strength			
Warp	5	40.04kgf	2.460
Weft	5	27.70kgf	1.826
Elongation			
Warp	5	6.27%	0.101
Weft	5	21.73%	0.677

N=Number of specimens; M=Mean; SD=Standard Deviation

Deformation of Seams in Specimens

In the process of taking data for the current study, it was observed that the directions of the specimens behaved differently in terms of deformation. Due to this, two types of deformations were observed and these were (i) rupture of stitching lines (sewing thread) labelled Type 1 (Figure 8) and (ii) damage of the fabric labeled Type 2 (Figure 9). This variation in the behaviour of the specimens in the current study is in concord with what Gribaa et al. (2006) observed in their study on the influence of sewing parameters on the tensile behaviour of textile assembly. In their study, Gribaa et al. noted three types of deformations which were (a) rupture of the sewing thread (b) damage of the fabric and (c) breakage of sewing thread after seam slippage. Moreover, Chowdhary (2002) reported that for LS401 seams, fabric broke but seam did not.

In this current study, while the weft seams experienced deformation Type 1, the warp seams, where the pulling was done on the weft threads of the fabric, suffered both types of deformations. Out of the 120 specimens for warp seams, 33 specimens had deformations where the stitching lines ruptured (Figure 8). The remaining 87 specimens had damage of the fabric without rupture of stitching line (Figure 9).
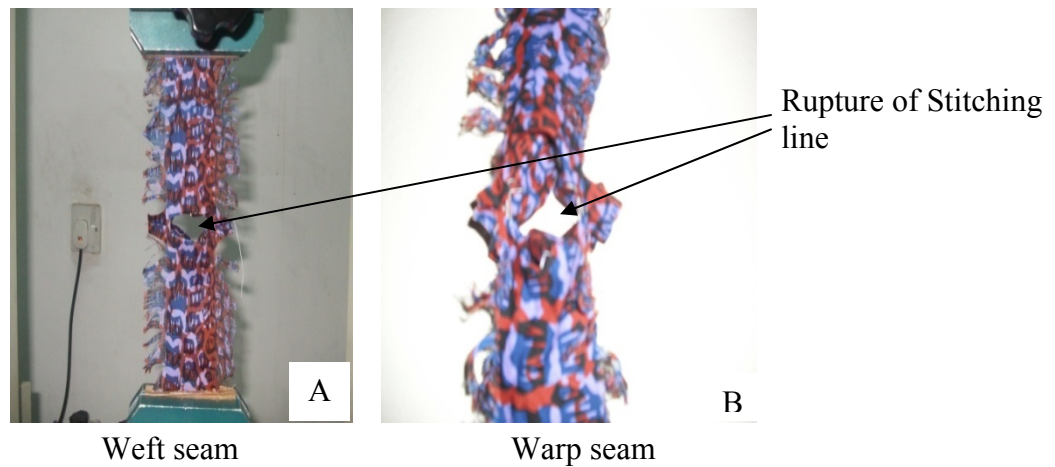
Figure 8. Deformation Type 1: Rupture of stitching line
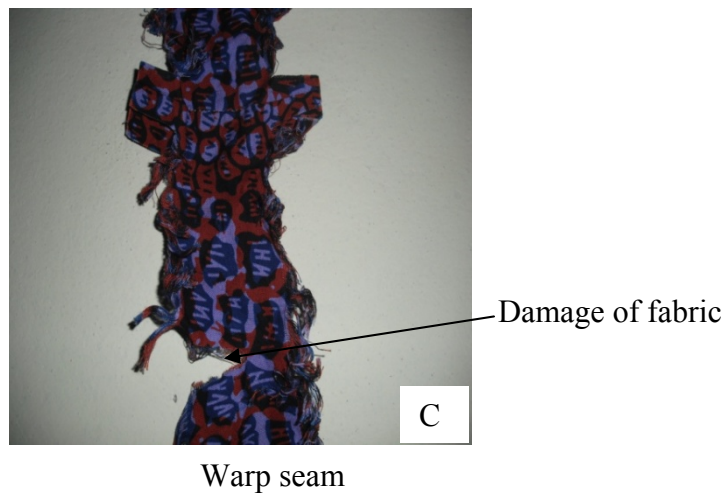
Figure 9. Deformation Type 2: Damage of fabric

Means and standard deviations were used to provide description of the number of specimens that experienced each type of deformation in the warp seams and are presented in Tables 2 and 3.

Table 2 shows that 8 stitches per inch for both Sunflag and OK threads experienced rupture of the stitching line (Type 1) when they were unwashed with

mean strengths of 22.06kgf and 20.76kgf, respectively. Their corresponding mean

elongations were 18.67% and 18.42%, respectively.

Table 2

Deformation of Warp Seams (Type 1)

		Strength		Elongation	
Thread Type/SPI/Washing	N(n)	M(kgf)	SD	M(%)	SD
OK8 unwashed	5(5)	20.76	1.544	18.42	1.211
Sun8 unwashed	5(5)	22.06	4.883	18.67	1.803
OK10 unwashed	5(3)	22.83	3.194	17.89	0.329
Sun10 unwashed	5(2)	24.90	0.141	15.72	1.491
OK12 unwashed	5(0)	0	0	0	0
Sun12 unwashed	5(0)	0	0	0	0
OK8 washed once	5(4)	18.80	1.807	21.85	1.361
Sun8 washed once	5(2)	22.70	0.566	24.81	1.829
OK10 washed once	5(1)	23.80	0	24.24	0
Sun10 washed once	5(0)	0	0	0	0
OK12 washed once	5(0)	0	0	0	0
Sun12 washed once	5(0)	0	0	0	0

N=Number of specimens; n=Number of specimens that had deformation Type1

Table 2 continued

Thread Type/SPI/Washing	N(n)	Strength M(kgf)	Strength SD	Elongation M(%)	Elongation SD
OK8 washed two times	5(4)	19.05	3.601	23.97	1.312
Sun8 washed two times	5(2)	28.80	2.687	27.08	1.839
OK10 washed two times	5(0)	0	0	0	0
Sun10 washed two times	5(0)	0	0	0	0
OK12 washed two times	5(0)	0	0	0	0
Sun12 washed two times	5(0)	0	0	0	0
OK8 washed three times	5(2)	19.80	3.960	20.55	1.434
Sun8 washed three times	5(2)	27.65	2.616	21.50	0.110
OK10 washed three times	5(1)	23.80	0	24.47	0
Sun10 washed three times	5(0)	0	0	0	0
OK12 washed three times	5(0)	0	0	0	0
Sun12 washed three times	5(0)	0	0	0	0

N= Number of specimens; n=Number of specimens that had deformation Type 1

When the warp seams were stitched in 10 SPI for both threads and unwashed, deformation Type 1 occurred for 3 specimens stitched in OK thread (M=22.83kgf, 17.89%) and 2 specimens stitched in Sunflag thread (M=24.90kgf, 15.72%). In a situation where both threads were stitched in 12 SPI and unwashed, none of the specimens experienced deformation Type 1. For the specimens that were washed once, OK stitched in 8 SPI had 4 specimens that experienced deformation Type 1

with mean strength of 18.80kgf and elongation of 21.85%, while Sunflag in 8 SPI had 2 specimens experiencing deformation Type 1 with mean strength and elongation as 22.70kgf and 24.81% respectively. Furthermore, OK stitched in 10 SPI had 1 specimen that experienced deformation Type 1 with mean strength of 23.80kgf and elongation of 24.24% (Table 2).

From Table 2, it can be noted that for the specimens that were washed twice, OK thread stitched in 8 SPI had 4 specimens that experienced deformation Type 1, with mean strength of 19.05kgf and elongation of 23.97%. Sunflag stitched in 8 SPI had 2 specimens, which experienced deformation Type 1, with an average strength of 28.80kgf and elongation of 27.08%. Again, Table 2 portrays that for the specimens that were washed three times; OK stitched in 8 SPI had 2 specimens that experienced rupture of stitching line, with mean strength and elongation of 19.80kgf and 20.55% respectively. Sunflag stitched in 8 SPI also had 2 specimens, which experienced deformation Type 1, with mean strength and elongation of 27.65kgf and 21.5% respectively. One specimen stitched in OK 10 SPI had deformation Type 1 with seam strength of 23.80kgf and elongation of 24.47%.

Table 3 indicates that when specimens were unwashed and stitched in 10 SPI, 2 specimens in OK and 3 specimens in Sunflag experienced deformation Type 2 with the former thread having mean strength and elongation of 18.10kgf and 17.63%. The latter thread had mean strength and elongation of 19.60kgf and 16.40% respectively. All specimens in 12 SPI of both threads experienced deformation Type 2. Their mean strengths and elongations at which the rupture occurred are provided in Table 3.

Table 3

Deformation of Warp Seams (Type 2)

		Strength		Elongation	
Thread Type/SPI/Washing	N(n)	M(kgf)	SD	M(%)	SD
OK8 unwashed	5(0)	0	0	0	0
Sun8 unwashed	5(0)	0	0	0	0
OK10 unwashed	5(2)	18.10	1.131	17.63	0.163
Sun10 unwashed	5(3)	19.60	1.900	16.40	1.580
OK12 unwashed	5(5)	21.92	5.002	18.81	1.005
Sun12 unwashed	5(5)	21.20	5.842	16.61	2.484
OK8 washed once	5(1)	16.10	0	20.35	0
Sun8 washed once	5(3)	19.60	4.351	24.40	0.931
OK10 washed once	5(4)	18.23	4.277	21.81	1.703
Sun10 washed once	5(5)	16.72	2.617	21.28	1.529
OK12 washed once	5(5)	20.14	4.282	21.89	1.133
Sun12 washed once	5(5)	21.28	4.130	22.17	1.852
OK8 washed two times	5(1)	13.90	0	22.19	0
Sun8 washed two times	5(3)	14.63	6.240	24.51	3.395
OK10 washed two times	5(5)	20.40	4.671	24.43	2.555
Sun10 washed two times	5(5)	16.88	5.598	22.02	1.939
OK12 washed two times	5(5)	20.46	3.105	24.07	0.951
Sun12 washed two times	5(5)	18.24	3.392	24.46	2.337

N=Number of specimens; n= Number of specimens that had deformation Type 2

Table 3 continued

Thread Type/SPI/Washing	N(n)	Strength		Elongation	
		M(kgf)	SD	M(%)	SD
OK8 washed three times	5(3)	12.63	1.815	20.75	1.270
Sun8 washed three times	5(3)	23.27	5.481	22.03	2.084
OK10 washed three times	5(4)	22.05	4.514	21.30	3.887
Sun10 washed three times	5(5)	21.10	3.737	22.68	1.950
OK12 washed three times	5(5)	17.70	3.748	20.00	2.060
Sun12 washed three times	5(5)	21.60	1.709	21.32	1.133

N=Number of specimens; n= Number of specimens that had deformation Type 2

Table 3 also depicts that for the specimens that were washed once, OK stitched in 8 SPI had 1 specimen which experienced deformation Type 2 at a force of 16.10kgf and extension of 20.35%. Sunflag stitched in 8 SPI had 3 specimens that experienced deformation Type 2 at an average force of 19.60kgf and elongation of 24.40%. OK thread stitched in 10 SPI had 4 specimens which experienced deformation Type 2 at an average force of 18.23kgf and elongation of 21.81%. All specimens stitched in 12 SPI for both threads and specimens stitched in 10 SPI for Sunflag experienced deformation Type 2, with the mean strengths and elongations at which the rupture occurred presented in Table 3.

Table 3 portrays that for the specimens that were washed twice, OK in 8 SPI had 1 specimen that experienced deformation Type 2 at the strength of 13.90kgf and elongation of 22.19%, whereas 8 SPI of Sunflag had 3 specimens that experienced deformation Type 2 with an average strength of 14.63kgf and

elongation of 24.51%. In addition, for the specimens that were washed twice, all specimens stitched in 10 and 12 SPIs for both threads experienced deformation Type 2, with their mean strengths and elongations provided in Table 3. For the specimens that were washed three times, both threads stitched in 8 SPI had 3 specimens that experienced deformation Type 2. Four specimens stitched in 10 SPI of OK thread also experienced deformation Type 2. Specimens in 12 SPI of both threads and 10 SPI in Sunflag thread experienced deformation Type 2 with, their average strengths and elongations provided in Table 3.

The findings from Tables 2 and 3 indicate that at the lowest stitch density, rupture of sewing thread (deformation Type 1) occurs, especially for the OK thread, where the number of specimens reduced after each washing cycle. At the higher number of stitch density for the OK and Sunflag threads in all the washing cycles, damage of the fabric (deformation Type 2) were mostly observed. In all, out of the 33 specimens that experienced deformation Type 1, Sunflag thread had 13 and OK had 20. On the other hand, out of the 87 specimens that experienced deformation Type 2, Sunflag had 47 and OK had 40. Though Gribaa et al. (2006) did not include washing cycle in their study on the influence of sewing parameters on the tensile behaviour of textile assembly, the results from this current study are in agreement with their outcome that at the low stitch density, rupture of the sewing thread occurred, whereas, at the high level of stitch density and edge of seam, deformation Type 2 was likely to occur.

The variation in the behaviour of the directions of the specimens in the current study, is also consistent with what Gribaa et al. (2006) noted. They observed

differences between the warp and weft directions in seam performance of a plain weave fabric, with the warp being polyester textured filament and the weft composed alternatively by cotton spun yarns and polyester spun yarns. They therefore, concluded that the fabric construction affects the behaviour of sewn fabrics. This shows that, indeed, fabric type/construction contributes to the performance of seams in garments. As indicated by American and Efird Inc. (2009) fabric type and weight can affect seam performance depending on the fibre content, fabric construction and type of weaves used, fill count, yarn type and size, pattern placement and seam direction.

In addition, the behaviour of the warp seams in this current study confirms the view of American and Efird Inc. (2009) that seam direction in a fabric contributes to its performance. This can be noted from the strength values of the different direction of the fabric, where the warp direction had greater strength than the weft direction. For the warp seams, the pulling was done on the weft direction of the fabric, which had weaker strength as compared to the warp direction. This could be a contributing factor to the behaviour of the warp seams, in that in this direction of the fabric, the seams were probably stronger than the fabric; thus causing the tearing of the fabric instead of the seam in most cases. Another factor that could contribute to the behaviour of the warp seams in this current study is the fabric count. As pointed out by American and Efird Inc. (2009) fabric construction (woven or knit) and type of weaves used (plain, twill, jersey, tricot) and fill count can influence seam performance. The fabric used for the current study had higher yarn count in the warp direction compared to the weft. For fabric direction that has

high number of yarns, the yarns are more packed and are able to withstand the forces applied to it than directions with low yarn count.

Differences between Fabric Tensile Properties (Strength and Elongation) and

Seam Tensile Properties (Strength and Elongation)

To establish if differences existed between seam strength and fabric strength after three washing cycles, which answered research question1, means and standard deviations were used and the outcome is presented in Tables 4 and 5.

When the specimens were unwashed, they had greater strength (M=40.04) than the OK thread stitched in 8 SPI unwashed (M=24.98); OK thread stitched in 10 SPI unwashed (M=28.32); OK thread stitched in 12 SPI unwashed (M=30.76) and Sunflag thread stitched in 8 SPI unwashed (M=31.16) (Table 4). For Sunflag stitched in 10 SPI and 12 SPI unwashed, the fabric had greater strength (M=40.04) than the seam stitched with Sunflag 10 SPI (39.46). Sunflag stitched in 12 SPI had greater strength (M=42.56) than the fabric used for the investigation.

In addition, when the fabric was washed once it had greater strength (M= 40.20), than OK thread stitched in 8 SPI washed once (M=24.76); OK stitched in 10 SPI washed once (M=27.98); OK thread stitched in 12 SPI washed once (M=31.26); Sunflag stitched in 8 SPI washed once (M=32.00) and Sunflag stitched in 10 SPI washed once. On the other hand, the seam in 12 SPI of Sunflag (M=43.46) had greater strength than the fabric (M=40.20) (Table 4).

Table 4

Comparisons between Fabric Strength (Warp) and Seam Strength (Weft Seams) after Washing

Fabric/Seam	Unwashed		1st wash		2nd wash		3rd wash	
	M(kgf)	SD	M(kgf)	SD	M(kgf)	SD	M(kgf)	SD
Fabric	40.04	2.460	40.20	1.927	31.18	2.158	33.24	3.450
OK 8	24.98	1.511	24.76	2.574	23.12	2.674	22.18	2.386
OK 10	28.32	5.053	27.98	2.465	27.46	2.642	24.04	3.535
OK 12	30.76	0.611	31.26	4.281	29.02	5.991	27.70	3.992
Sunflag 8	31.16	2.403	32.00	1.378	26.96	5.562	32.06	1.824
Sunflag 10	39.46	3.207	37.62	2.755	37.86	2.756	38.58	2.617
Sunflag 12	42.56	5.375	43.46	3.099	43.36	4.486	40.58	3.819

M=Mean, SD=Standard Deviation

Differences existed between the strength of the fabric and that of the seams when the specimens were washed twice. The fabric had greater strength (M=31.8) than the seams stitched in OK 8 SPI (M=23.12), OK 10 (M=27.46), OK 12 SPI (M=29.02) and Sunflag 8 SPI (M=26.96). For Sunflag stitched in 10 (M=37.86) and 12 (M=43.36) SPIs the seams had greater strength than the fabric (M=31.8).

When the specimens were washed three times, the fabric had greater strength (M=33.24) than seams in OK 8 SPI (M=23.12), OK 10 SPI (M=27.46), OK 12 SPI

(M=29.02) and Sunflag 8 SPI (M=26.96). In the case of the seams in Sunflag 10 (M=38.58) and12 (M=40.58) SPIs, a greater strength than that of the fabric (M=33.24) was observed (Table 4).

For the warp seams, because the majority of the specimens could not rupture at the seams, this analysis could not be done for all the specimens. It was only the specimens in 8 SPI unwashed that had all the specimens breaking at the seam and therefore, the analysis was done for those specimens. Table 5 contains the outcome.

Table 5

Comparisons between Fabric Strength (Weft) and Seam Strength (Warp Seams)

Washing/thread type/SPI	M (kgf)	SD
Fabric strength unwashed	27.64	1.919
unwashed OK 8	20.76	1.544
unwashed Sunflag 8	22.06	4.883

M=Mean, SD= Standard Deviation

Table 5 depicts that on the average there was difference between the strength of the specimens when unwashed (M=27.64) and the strength of the seams stitched in 8 SPI of both OK (M=20.76) and Sunflag (M=22.06) threads with the fabric having the greatest strength.

The findings from Tables 4 and 5 portray that, differences existed between fabric strength and seam strength. When the specimens were unwashed, the fabric on the average had higher strength than all the seams stitched in 8, 10 and 12 SPIs

of both OK and Sunflag threads apart from the seams stitched in 12 SPI of Sunflag thread. The findings also indicate that when the specimens were washed once, the fabric on the average had higher strength than all the seams stitched in 8, 10 and 12 SPIs of both OK and Sunflag threads apart from the seam stitched in 12 SPI of Sunflag thread. In addition, apart from the seams stitched in 10 and 12 SPIs of Sunflag thread, the fabric on the average had higher strength than all the seams stitched in 8, 10 and 12 SPIs of both OK and Sunflag threads when the specimens were washed twice. Finally, when the specimens were washed three times, the fabric on the average had higher strength than all the seams stitched in 8, 10 and 12 SPIs of both OK and Sunflag threads, except the seams stitched in 10 and12 SPIs of Sunflag thread.

The findings have added to Chowdhary and Poynor (2006) finding, that the fabric they used for their study had stronger strength than the seams in both warp and filling directions for all the three stitch densities they employed for their study.

To answer research question 2, which sought the differences between seam and fabric elongations, means and standard deviations were employed and the results are presented in Tables 6 and 7.

Table 6 indicates that there were differences between fabric elongation when unwashed and seam elongation. When the specimens were unwashed, the fabric had a higher percentage (M=6.27) elongation than OK thread stitched in 8 SPI (M=5.50). Contrary to this, all the specimens stitched in 10 (M=6.28) and 12 (M=6.96) SPIs of OK thread and 8 (M=6.41), 10 (M= 9.73), and 12 (M=7.99) SPIs of Sunflag thread had higher percentage elongations than the fabric (M=6.27). This

could be attributed to the fact that as stitch density increases more thread is consumed in the fabric making the stitch able to stretch better than when the stitch density is low. Another thing that could have contributed to this phenomenon is the sewing thread type; if the sewing thread has a better elongation, it will contribute to the elongation of the seam when used in making a seam.

Table 6

Comparisons between Fabric Elongation (Warp) and Seam Elongation (Weft Seams) after Washing

Fabric/Seam	Unwashed		1st wash		2nd wash		3rd wash	
	M(%)	SD	M(%)	SD	M(%)	SD	M(%)	SD
Fabric	6.27	0.101	7.26	0.447	6.46	0.463	7.28	0.270
OK 8	5.50	0.477	7.11	0.779	8.73	0.667	7.96	1.017
OK 10	6.28	0.799	6.87	0.378	8.97	0.309	8.87	0.835
OK 12	6.96	1.215	8.16	1.362	9.60	0.609	8.16	0.402
Sunflag 8	6.41	0.198	9.00	0.415	10.04	1.296	10.17	0.316
Sunflag 10	9.73	3.766	9.42	0.335	11.01	0.931	11.68	0.465
Sunflag 12	7.99	1.003	11.39	1.297	10.87	1.366	10.79	0.291

M=Mean, SD= Standard Deviation

Again there were differences between the elongation of the fabric and that of the seams when washed once. The specimens washed once showed that the fabric had higher elongation (M=7.26%) than the seams stitched with OK thread in 8 (M=7.11) and 10 (M=6.87) SPIs. However, the seams stitched in 12 (M=8.16) SPI of OK thread and seams in 8 (M=9.00%), 10 (M=9.42) and 12 (M=11.39) SPIs of Sunflag thread had higher percentage elongations than the fabric (M=7.26%). There was also differences between the elongation of the fabric and the elongation of all the seams in both threads (OK, Sunflag) in their respective stitch densities (8, 10 and 12) when washed twice. The mean elongations show that, on the average, all the seams stitched in OK and Sunflag threads in their respective stitch densities and washed twice had higher elongations compared to that of the fabric washed twice.

Table 6 further portrays that there were differences between the elongation of the fabric when washed three times and the elongation of all the seams in both threads (OK, Sunflag) in their respective stitch densities (8, 10 and 12) and washed three times. On the average, all the seams stitched in OK and Sunflag threads in their respective stitch densities and washed three times had higher elongations compared to that of the fabric when washed three times.

For the warp seams, because majority of the specimens could not rupture at the seams, this analysis could not be done for all the specimens. It was only the specimens in 8 SPI unwashed that had all the specimens breaking at the seam and therefore, the analysis was done for those specimens. Table 7 presents the outcome.

Table 7

Comparisons between Fabric Elongation (Weft) and Seam Elongation (Warp Seams)

Washing/thread type/SPI	M (%)	SD
Fabric strength unwashed	21.73	0.677
unwashed OK 8	18.42	1.211
unwashed Sunflag 8	18.67	1.803

M=Mean, SD=Standard Deviation

Table 7 shows that there were differences between fabric elongation when unwashed and the elongation of the seams both in OK and Sunflag threads stitched in 8 SPI and unwashed. The mean percentage elongations revealed that on the average the fabric when unwashed, had greater elongation than the seams in both OK and Sunflag in 8 SPI.

The findings from Tables 6 and 7 depict that when the specimens were unwashed, the weft seams on the average had higher elongation than the fabric except seams stitched in 8 SPI of OK thread. For the warp seams the fabric had higher elongation than the seams in 8 SPI of both threads. When the specimens were washed once, the weft seams on the average had higher elongations than the fabric apart from seams stitched in 8 and 10 SPIs of OK thread. In addition, when the specimens were washed twice, all the weft seams in 8, 10 and 12 SPIs of both threads on the average had higher elongations than the fabric. Finally, when the specimens were washed three times, all the weft seams in 8, 10 and 12 SPIs of both threads on the average had higher elongations than the fabric.

ASTM D6193-09 (2009) indicated that the elasticity (elongation) of a sewn seam should be slightly greater than that of the fabric which it joins. This will enable the fabric to support its share of the forces encountered for the intended end use of the sewn item. Based on this, the results of the current study, where the seams had greater elongation than the fabric are acceptable, since this will enable the fabric to support its share of the forces encountered for the intended end use of the sewn item. The findings are in agreement with what Kadolph and Langford (2002) also observed. They observed higher elongations for seams than fabric. The reported study tested elongation for both fabric and seams. It was 12% for warp and 16% for filling yarns, with various seams ranging from 15 to 20% for warp 17-22% for the filling direction. The findings are also similar to those of Chowdhary and Poynor (2006), who found that, seams had higher elongations than the fabric they used for their study in both warp and weft direction for all three stitch densities employed for their study.

Differences between Thread Types, Stitch Densities and Washing Cycles with regard to Seam Performance Properties (Strength, Efficiency and Elongation)

In order to compare seam performance properties with thread type, stitch density and washing cycle, which required testing of hypotheses 1(a, b, c), 2(a, b, c) and 3(a, b, c), inferential statistics was employed. The outcome is provided in Tables 8 to 21.

The results of the independent *t*-test used to evaluate the two threads and seam strength are presented in Table 8.

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Table 8

Means, Standard Deviations, *T*-values and *P*-values for Seam Strength by Two Thread Types

Fabric direction/thread type	M(kgf)	SD	df	*t*-value	*p*-value
Warp			91	1.227	0.223
OK	9.24	10.64			
Sunflag	6.49	10.93			
Weft			104.977	-10.825	0.001**
OK	26.79	4.215			
Sunflag	37.14	6.090			

**Significant p<0.05, M=Mean, SD=Standard Deviation

The results from Table 8 show that for the warp seams, there was no difference between OK and Sunflag threads in relation to seam strength (*t*=1.227, df=91, p=0.223). However, the mean strength values indicate that the OK thread seemed stronger than the Sunflag thread. The result from the warp seams is consistent with the null hypothesis that there is no significant difference between thread types with regard to seam strength of a plain seam in a Ghanaian Real Wax cotton printed fabric. Therefore this null hypothesis was retained. With regard to the weft seams, seam strength for Sunflag was stronger than OK (*t*=-10.825, df=104.977, p=0.001). This result is not consistent with the null hypothesis which states that there is no significant difference between thread types with regard to seam strength of a plain seam in a Ghanaian Real Wax cotton printed fabric; therefore, the null hypothesis was rejected.

The findings are consistent with AMANN Inc. (2009) and Doshi (2006) findings that, the type of the thread used in the construction of a garment, its construction, size and finishing influence the seam strength of the garment. In terms of the size of the threads, from their linear densities, Sunflag (21Tex) is a coarse and thick yarn, whereas OK (15Tex) is a fine yarn. This finding is also in agreement with what Mukhopadhyay (2008) also noted that seam strength increased with increase in linear density of sewing thread. Though his was in the case of chain stitched seam, same can be said of lock stitched seam based on the results of the weft seams of the current research.

The results from the weft seams of the current study is also in accordance with American and Efird Inc. (2009) view that, given a specific fibre type and thread construction, a larger thread size provides a greater seam strength. Furthermore, Gribaa et al. (2006) reported that, the finess of thread affects the strength of seam, with thicker threads providing a better seam strength.

To test hypothesis 1(b) that, there is no significant difference between stitch densities with regard to seam strength of a plain seam in a Ghanaian Real Wax cotton printed fabric, a one-way ANOVA was employed. The outcome is presented in Table 9.

Table 9

Means, Standard Deviations, F-values and *P*-values for Seam Strength by Three Stitch Densities

Fabric direction/SPI	M(kgf)	SD	df	F	*p*-value
Warp			2	96.083	0.001**
8	21.44	3.783			
10	6.28	10.88			
12	0	0			
Weft			2	19.701	0.001**
8	27.15	4.614			
10	32.65	6.628			
12	36.09	7.648			

***Significant p<0.05, M=Mean, SD=Standard Deviation*

The differences for seam strength were significant (p=0.001) for the three stitch densities used for the study in both warp and weft seams. Further analysis to determine between group variability revealed that differences were significant between all groups in both directions of the Tex Styles Ghana Limited fabric used for the study (Table 10). The results from the warp and the weft seams disagreed with the null hypothesis; therefore, the null hypothesis was rejected. Additionally, the findings are consistent with what American and Efird Inc. (1997) stated that the stitches per inch have tremendous impact on the strength of the seam.

Table 10

Post Hoc Results for Multiple Comparisons for Seam Strength × Stitch Densities

Fabric direction/stitch density	M	*p*-value
Warp		
8×10	15.165	0.001**
8×12	21.442	0.001**
10×12	6.278	0.001**
Weft		
10×8	5.498	0.001**
12×8	8.935	0.001**
12×10	3.438	0.048**

**Significant p<0.05, M=Mean difference

Mean statistics from Table 9 shows that, for seam strength in the weft direction of the Tex Styles Ghana Limited fabric, 12 SPI (M=36.09) on the average had the highest strength followed by 10 SPI (M=32.65) with 8 SPI (M=27.15) having the least strength. The mean scores from the warp seams in Table 9 however, indicate that 8 SPI (M=21.44) had the highest strength. This could mean that, as was noted in the deformation of the warp seams, whereas stitch density increased, damage of the fabric were observed; as stitch density increased the seam strength increased and made the fabric unable to withstand the seam thus, resulting in few seams in 10 SPI rupturing and none of the seams in 12 SPI rupturing.

The results from the warp seams are in consonance with what Wang et al. (n.d) also observed in their study on the influence of stitch density to stitches properties of knitted products. Wang et al. observed that the pattern of influence of stitch density on various stitches differs; even with the same type of stitch the influences of stitch density on the stitch properties differ when the stitches are applied in different sewing directions. They noted that when stitch density was increased, the tensile strength at break of 301 lock stitch reduced and the greatest strength occurred at stitch density of 8 stitches per unit length, which was at variance with the norm that increase in stitch density leads to increase in strength. Gribaa et al. (2006) reported that the use of the most suitable stitch density depends on the material to be sewn and to the desired seam properties. Very high stitch densities, they noted, do not always give good results. This is similar to the observation in the warp seams of the current study.

Additionally, the findings from the weft seams are in agreement with Chowdhary and Poynor (2006) findings that differences for seam strength were significant for three stitch densities in both warp and filling directions, and seams with 10-12 SPI were the strongest. American and Efird Inc. (2009) added that generally, the more thread consumed in a stitch, the greater the seam strength, and American and Efird Inc. (1997) observed increase in seam strength as stitch density increased. These findings are similar to the observation in the weft seams of the current study, where increase in stitch density resulted in increase in seam strength.

In order to test hypothesis 1(c), one-way Analysis of Variance was employed and the product is presented in Table 11.

Table 11

Means, Standard Deviations, F-values and *P*-values for Seam Strength by Washing Cycles

Fabric direction/washing	M(kgf)	SD	df	F	*p*-value
Warp			3	3.209	0.027**
unwashed	13.30	11.36			
washed once	6.60	9.979			
washed twice	5.15	9.944			
washed three times	5.77	10.41			
Weft			3	0.592	0.621
unwashed	32.86	7.024			
washed once	32.84	6.809			
washed twice	31.30	8.106			
washed three times	30.86	7.594			

**Significant p<0.05, M=Mean, SD=Standard deviation

For the warp seams, a slight difference was found between number of times of washing (washing cycle) and seam strength (F=3.209, df=3, p=0.027), but not in the weft seams (F=0.592, df=3, p=0.621). However, the mean strength values from Table 11 indicate that, the frequency of washing reduced the strength. On the average there was reduction in strength after each washing cycle in both directions where unwashed specimens of the weft specimens (M=32.86) had the highest

strength followed closely by first washing (M=32.84), with third washing (M=30.86) having the least strength. For the warp seams, unwashed specimens (M=13.30) had the highest strength, followed by washed once (M=6.60) and then washed twice (M=5.15), with washed three times specimens having a slight increase compared to washed twice specimens (M=5.77). Additional analysis to determine between group variability in the warp seams indicated that apart from the differences between unwashed and seams washed two times that were significant, differences were not significant between all the groups (Table 12).

Table 12

Post Hoc Results for Multiple Comparisons for Seam Strength × Washing Cycles

Fabric direction/stitch density	M	*p*-value
Warp		
unwashed × washed once	6.691	0.134
unwashed × washed twice	8.142	0.033**
unwashed × washed three times	7.531	0.084
washed once × washed twice	1.451	0.963
washed once × washed three times	0.840	0.994
washed three times × washed twice	0.611	0.997

***Significant p<0.05, M=Mean difference*

The finding for the warp seams was not consistent with the null hypothesis and so the null hypothesis was rejected, but the finding of the weft seams agreed with the null hypothesis, therefore the null hypothesis was retained. The findings are

consistent with the findings of Mukhopadhyay et al. (2004). In their study on the impact of laundering on the seam textile properties of suiting fabric, they noted that the effects of laundering on seam tensile properties of suiting fabric were significant. Also the finding from the warp seams, where strength increased after third washing compared to the second washing, agrees with Mukhopadhyay (2008). In his study on the relative performance of lock stitch and chain stitch at the seat seam of military trousers, he noted that, the force at break increased on laundering, with the change being more in the case of lock stitched seam stitched with coarser sewing thread. The current study also employed lock stitch seam. But it would be suitable if a further study is conducted on this current study where number of washing will be increased to determine the pattern of strength as the washing cycle increases.

In order to ascertain if differences existed between thread types with regard to seam efficiency of a plain seam in a Real Wax cotton printed fabric, which tests hypothesis 2(a), an Independent *t*-test was employed. Table 13 presents the results.

Table 13

Means, Standard Deviations, *T*-values and *P*-values for Seam Efficiency (Weft Seams) by Two Thread Types

Fabric direction/thread type	M (%)	SD	df	*t*-value	*p*-value
Weft			24.904	-6.054	0.001**
OK	73.14	8.731			
Sunflag	100.52	17.21			

**Significant p<0.05

Results from Table 13 reveal that, for the weft seams the difference between OK and Sunflag threads in relation to seam efficiency was significant (p=0.001). That is Sunflag (M=100.52%) had higher seam efficiency compared to OK (M=73.14%). The result was not in agreement with the null hypothesis which states that there is no significant difference between thread types with regard to seam efficiency of a plain seam in a Ghanaian Real Wax cotton printed fabric.

According to Chowdhary and Poynor (2006) if the percentage efficiency is more than 100%, the seam is stronger than the fabric and if less than 100%, the fabric is stronger than the seam. They continued that seam efficiency of 100% is required for a perfect seam. Therefore, it can be inferred that the seam produced by Sunflag thread is stronger than the fabric and slightly exceeds the 100% required for a perfect seam. On the other hand, the seam efficiency of the OK thread fell within the range provided by Mehta and Bhardwaj (1998). They stated that it is accepted that, with a seam efficiency of about 60-70 percent, the seam would be commercially acceptable. Chowdhary and Poynor (2006) added that Amaco Fabrics and Fibers Company reported that for most test fabrics, seam efficiency ranged between 60 and 90% for single stitched seams, within which the efficiency of the seam from OK thread also fell.

Furthermore, since the efficiency was less than 100%, the fabric was stronger than the seam. However, the result is at variance with what Geotextile Sewing Techniques as reported by Chowdhary and Poynor (2006), indicated that seam stitched efficiency was higher for polypropylene threads (50 -70%) than the polyester threads (40–50%). For sewing light weight materials, they used nylon,

polypropylene, and polyester threads and for medium–weight fabrics, polyester thread was used. The results from the current study is contrary to this since the threads used were both polyester and had efficiencies (OK=73.14, Sunflag=100.52%) that exceeded the range reported by Geotextile Sewing Techniques for polyester threads.

To test hypothesis 2(b), a one-way ANOVA was employed. The results are provided in Table 14.

Table 14

Means, Standard Deviations, F-value and *P*-value for Seam Efficiency (Weft Seams) by Three Stitch Densities

Fabric direction/SPI	M (%)	SD	df	F	p-value
Weft			2	6.499	0.004**
8	73.90	10.73			
10	88.57	18.35			
12	97.96	20.37			

***Significant p<0.05*

Table 14 shows that, statistically, differences for seam efficiency for weft seams were significant (p=0.004) for the three stitch densities used for the study. The result was not consistent with the null hypothesis; therefore, the null hypothesis was rejected. Further analysis of the data to determine between group differences, revealed that apart from the differences between seams stitched in stitch densities 8 and 12 that were significant; differences were not significant between all groups (Table15). The mean statistics indicates that on the average 12

SPI had the highest seam efficiency (M=97.96%), followed by 10 SPI (M=88.57%) with 8 SPI (M=73.90%) having the least efficiency.

Table 15

Post Hoc Results for Multiple Comparisons for Seam Efficiency (Weft Seams) by Stitch Densities

Fabric direction/stitch density	Mean difference	p-value
Weft		
10×8	14.662	0.090
12×8	24.054	0.003**
12×10	9.392	0.370

**Significant p<0.05

The findings portray that as stitch density increased seam efficiency increased (Table 14). Furthermore, the findings are consistent with what Chowdhary and Poynor (2006) found that seam efficiency differed for three stitch densities. It was highest for 10–12 stitches per inch for both warp (61.29%) and filling direction (57.9%) and lowest for the 6 – 8 stitches per inch 46.39% in the warp and 40.43% in the weft. In the current study, comparisons could not be made in terms of seam efficiency and stitch density for the warp seams, because not all specimens had rupture occurring at the stitching line for the various stitch densities employed for the study.

A one-way ANOVA was conducted to assess seam efficiency by washing cycles of a plain seam in a Ghanaian Real Wax cotton printed fabric (hypothesis 2c). The outcome is presented in Table 16.

Table 16

Means, Standard Deviations, F-value and *P*-value for Seam Efficiency (Weft Seams) by Washing Cycles

Fabric direction/washing	M(%)	SD	df	F	*p*-value
Weft			3	1.358	0.273
unwashed	82.10	16.07			
washed once	81.71	16.01			
washed twice	96.63	24.55			
washed three times	92.83	22.81			

**Significant p<0.05, M=Mean, SD=Standard Deviation

The results reveal that for the weft seams there was no difference between number of times of washing used for the study (washing cycle) and seam efficiency (p=0.273). The result agreed with the null hypothesis, therefore, the hypothesis was retained. However, seam efficiency was higher at the second and third washing. The seam efficiencies produced by the various washing cycles did not exceed 100% indicating that, the fabric was stronger than the seams (Chowdhary and Poynor 2006).

For the warp seams, Sunflag thread stitched in 8 SPI and unwashed had a higher seam efficiency of 79.64% than the OK in 8 SPI unwashed with efficiency of 74.95%. Seam efficiency could not be computed for the rest of the warp seams, because not all specimens broke at the seams for the various thread types, stitch densities and washing cycles.

To test hypothesis 3(a) which stated that there is no significant difference between thread types with regard to seam elongation of a plain seam in a Ghanaian Real Wax cotton printed fabric, an Independent *t*-test was used and the results presented in Table 17.

Statistically the difference for seam elongation of weft seams were significant for the two brands of thread employed for the study (p=0.001), but not for the warp seams (p=0.088). The result from the weft seams is in discord with the null hypothesis, while that of the warp seams is consistent with the null hypothesis. However, the mean statistics show that between the two threads used for the study, on the average Sunflag (M=9.88) had a higher percentage seam elongation compared to OK (M=7.76) for the weft seams. For the warp seams, OK (M=9.35) had a higher elongation compared to Sunflag (M=5.70).

Table 17

Means, Standard Deviations, *T*-values and *P*-values for Seam Elongation by Two Thread Types

Fabric direction/thread type	M (%)	SD	df	*t*-value	*p*-value
Warp			88.491	1.723	0.088
OK	9.37	10.75			
Sunflag	5.70	9.689			
Weft			118	-6.927	0.001**
OK	7.76	1.389			
Sunflag	9.88	1.908			

**Significant p<0.05, M=Mean, SD=Standard Deviation

One-Way Analysis of Variance was employed to test hypothesis 3(b) which stated that there is no difference between stitch densities with regard to seam elongation of a plain seam in a Ghanaian Real Wax cotton printed fabric. The results are presented in Table 18.

Table 18

Means, Standard Deviations, F-values and _P_-values for Seam Elongation by Three Stitch Densities

Fabric direction/SPI	M(%)	SD	df	F	_p_-value
Warp			2	153.300	0.001**
8	21.59	3.135			
10	4.96	8.727			
12	0	0			
Weft			2	4.111	0.019**
8	8.11	1.729			
10	9.11	2.190			
12	9.24	1.814			

**Significant p<0.05, M=Mean, SD=Standard Deviation

The results in Table 18 illustrates that statistically the difference for seam elongation were significant for the three stitch densities used for the study in both warp (p=0.001) and weft (p=0.019) seams. The results for both warp and weft seams disagree with the null hypothesis, therefore, the null hypothesis was rejected for both directions of the fabric used for the study. In addition, further analysis to establish between group differences uncovered that differences were significant

between all groups for the warp seams (Table 19). On the other hand, for the weft seams differences were not significant for all groups except for the differences between stitch densities 8 and 10 (Table 19).

Moreover, the results were consistent with what Chowdhary and Poynor (2006) observed in their study on the impact of stitch density on seam strength, elongation, and seam efficiency. They noted differences between seam elongation and three stitch densities in both directions of the fabric they used for their study. The mean statistics of the weft seams indicates that on the average 12 SPI (M=9.24) had the highest elongation with 8 SPI (M=8.11) having the least percentage elongation. For the warp seams, 8 SPI (M=21.59) had the highest elongation (Table 18).

Table 19

Post Hoc Results for Multiple Comparisons for Seam Elongation × Stitch Densities

Fabric direction/stitch density	M	p-value
Warp		
8×10	16.629	0.001**
8×12	21.585	0.001**
10×12	4.957	0.001**
Weft		
10×8	0.992	0.058
12×8	1.128	0.026**
12×10	0.136	0.946

**Significant p<0.05, M=Mean difference

The behavior of the stitch densities with regard to seam elongation in this current study is similar to the finding of Wang et al. (n.d) in their study on the influence of stitch density to stitches properties of knitted products. They found that for 301 lock stitch, when the stitch density was increased the rate of extension at break increased for stitched specimens at cross direction and was decreased for those stitched at warp direction. In addition, the result from the weft seams with regard to the stitch densities is in agreement with what Chowdhary and Poynor (2006) observed. They found increase in seam elongation as stitch density increased.

Analysis of Variance was employed to test hypothesis 3(c) that sought to establish if differences existed between washing cycles with regard to seam elongation of a plain seam in a Ghanaian Real Wax cotton printed fabric. The results are presented in Table 20.

The results depict that statistically the difference for seam elongation were significant for the washing cycles used for the study for the weft seams (p=0.001). For the warp seams no evidence was found of a difference between number of times of washing (washing cycle) and seam elongation (p=0.259). The mean statistics, however, shows that on the average, seam elongation of the weft seams increased after first washing (M=8.66) and second washing (M=9.87), but decreased slightly after third washing (M=9.61) compared to that of second washing. This occurrence is possibly due to the behaviour of the fabric. It may probably be due to shrinkage as the number of washing increased, which caused the yarns to become more compact, resulting in increase in elongation. In the case

of the warp seams, the elongation decreased after each washing cycle with seams

washed three times having the least elongation (M=5.53).

Table 20

Means, Standard Deviations, F-values and *P*-values for Seam Elongation by Washing Cycles

Fabric direction/washing	M (%)	SD	df	F	*p*-value
Warp			3	1.364	0.259
unwashed	10.82	9.098			
washed once	7.45	11.20			
washed twice	5.77	10.78			
washed three times	5.53	9.868			
Weft			3	16.222	0.001**
unwashed	7.14	2.096			
washed once	8.66	1.746			
washed twice	9.87	1.230			
washed three times	9.61	1.509			

**Significant p<0.05, M=Mean, SD= Standard Deviation

Table 21

Post Hoc Results for Multiple Comparisons for Seam Elongation by Washing Cycles

Fabric direction/stitch density	M	p-value
Weft		
washed once × unwashed	1.516	0.004**
washed twice × unwashed	2.727	0.001**
washed twice × washed once	1.211	0.030**
washed twice × washed three times	0.265	0.928
washed three times × unwashed	2.461	0.001**
washed three times × washed once	0.945	0.133

**Significant p<0.05, M=Mean difference

Additional analysis to establish between group differences in the weft seams revealed that only the difference between washed three times by unwashed, washed twice by washed once, washed twice by unwashed and washed once by unwashed were notable to be significant (Table 21).

Influence of Thread Type, Stitch Density and Washing Cycle on Seam

Performance Properties (Strength, Efficiency and Elongation)

To test hypotheses 4 a, b and c, a 3-Way Analysis of Variance was employed and the outcome is presented in Tables 22, 23 and 24.

Table 22

3-Way Analysis of Variance on the Influence of Thread Type × Stitch Density × Washing Cycle on Seam Strength

Source	Type III Sum of Squares	Df	Mean Square	F	*p*-value
Warp					
Thread type, stitch density and washing cycle	638.975	6	106.496	37.285	0.001**
Weft					
Thread type, stitch density and washing cycle	47.255	6	7.876	0.650	0.690

*Warp- R Squared= 0.982 (Adjusted R Squared= 0.976), Weft- R Squared= 0.820 (Adjusted R Squared= 0.777), **Significant p<0.05*

The 3-Way Analysis of Variance results from Table 22 depict that for the warp seams, thread type, stitch density and washing cycles had significant influence on seam strength of plain seam in the Tex Styles Ghana Limited Real Wax cotton printed fabric (p=0.001). The finding for the warp seams was not in agreement with the null hypothesis and therefore, the null hypothesis was rejected. The finding is consistent with Mukhopadhyay et al. (2004), findings that, effect of stitch density, count of sewing threads, fabric composition and laundering on seam tensile properties of suiting fabric were significant. For the weft seams, Table 22 shows no significant influence of thread type, stitch density and washing cycles on seam strength (p=0.690). This outcome is consistent with the null hypothesis and so the hypothesis was retained.

The variation in the results with regard to the warp and weft seams could be as a result of the differences in the tensile behaviour and the yarn linear density of the different directions of the fabric used for the study. The warp direction of the fabric had greater strength and linear density compared to the weft. For the warp seams the pulling was done on the weft threads of the fabric, which were weaker, compared to the warp threads. Since the fabric contributes to the performance of seams, it could probably mean that for the weft seams because the pulling was done on the strongest direction of the fabric, the sewing threads, stitch densities and washing cycles employed for the study could not influence them. Another occurrence that could probably contribute to the differences in the results in the warp and the weft seams is the variation in the deformation of the warp and the weft seams. For the warp seams, because majority of the specimens did not break at the stitching line, it could not provide a clear interaction of the independent variables.

In order to test hypothesis 4b, a 3-Way Analysis of Variance was used and the result is presented in Table 23.

The results from Table 23 show that for the warp seams, statistically thread type, stitch density and washing cycles had significant influence on the seam elongation of plain seam in Tex Styles Ghana Limited Real Wax cotton printed fabric (p=0.001). The findings are not in accordance with the null hypothesis and therefore, the null hypothesis was rejected.

Table 23

3-Way Analysis of Variance on the Influence of Thread Type × Stitch Density × Washing Cycle on Seam Elongation

Source	Type III Sum of Squares	Df	Mean Square	F	*p*-value
Warp					
Thread type, stitch density and washing cycle	494.908	6	82.485	128.156	0.001**
Weft					
Thread type, stitch density and washing cycle	7.393	6	1.232	0.994	0.434

*Warp- R Squared= 0.995 (Adjusted R Squared= 0.994), Weft- R Squared= 0.742 (Adjusted R Squared= 0.681), **Significant p<0.05*

For the weft seams, statistically thread type, stitch density and washing cycles had no significant influence on the seam elongation of plain seam in Tex Styles Ghana Limited Real Wax cotton printed fabric (p=0.434). This outcome was consistent with the null hypothesis and so the null hypothesis was retained. However, the variation in the deformation of the warp and the weft seams could probably be a contributing factor in the differences of the results from the warp and the weft seams. For the warp seams because majority of the specimens did not break at the stitching line, it could not provide clear interaction of the independent variables.

A 3-Way Analysis of Variance was conducted in order to test hypothesis, 4c and the result is presented in Table 24.

Table 24

3-Way Analysis of Variance on the Influence of Thread Type × Stitch Density × Washing Cycle on Seam Efficiency

Source	Type III Sum of Squares	Df	Mean Square	F	*p*-value
Weft					
Thread type, stitch density and washing cycle	10953.288	6	1825.548	8.418	0.001**

*R Squared= 0.622 (Adjusted R Squared= 0.541), **Significant p<0.05*

Table 24 portrays that there was significant influence of thread type, stitch density and washing cycles on seam efficiency of weft plain seams in the Tex Styles Ghana Limited Real Wax cotton printed fabric (p=0.001). This indicates that the results is in discord with the null hypothesis, which states that thread type, stitch density and washing cycle have no significant influence on the efficiency of plain seam in a Ghanaian Real Wax cotton printed fabric. None of the previous works compared these variables. This analysis could not be made for the warp seams because majority of the seams did not break at the stitching line.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Overview of Research Problem

Understanding quality and performance of apparel products is important for apparel merchandising and design majors (Chowdhary & Poynor, 2006). The performance of seams contributes to the quality of apparel products. It has been noted that the achievement of quality seams in garments and, for that, matter apparel products depends on several factors, which in turn, influence the properties of the seam. The factors and the properties interact with the processes garments go through during use (example, laundry) to affect the overall performance of the seams in the garment. Current published evidence in the area of clothing and textiles provide limited work that focuses on the performance of seams in sewn apparel products. It is in line with this that this research was undertaken to investigate the performance of seams in African prints by varying stitch density, sewing thread brands and washing cycles.

Summary of the Study

An experimental design was employed for the study which included two brands of threads, three ranges of stitch density and three cycles of washing. A

Real Wax cotton printed fabric from Tex Styles Ghana Limited was used for the investigation. The instruments used in the collection of the data included a Butterfly hand sewing machine, Standard Launder-Ometer (Gyrowash 315), tensile testing machine (Hounsfield H5K-S), magnifying glass, weighing balance (Adams equipment), a pair of scissors and sample cutter (see Appendix). The investigation was carried out at the Ghana Standards Board textile testing laboratory. The data analysis was done using means, standard deviations and inferential statistics.

Summary of the Findings

Two types of deformations were observed in the study and these were

i) rupture of the stitching line (sewing thread) labelled Type 1 and

ii) damage of the fabric labelled Type 2. The weft seams experienced deformation Type 1. The warp seams suffered both types, but majority of the specimens experienced deformation Type 2.

Increased stitch density led to deformation Type 2 in all the washing cycles irrespective of thread used. The smallest stitch density exhibited deformation Type 1 especially with OK thread and the number of specimens decreased after each washing.

After three washing cycles, fabric strength was greater than the majority of the stitched seams using both OK and Sunflag threads. However, after three washing cycles, the seams had higher elongations than the fabric.

It was found that, difference for seam strength was significant for the thread types (OK and Sunflag) used for weft seams, but not for warp seams. In the weft

seams, it was noted that Sunflag, on the average, had a higher strength value than its OK counterpart.

There were significant differences in seam strength with regard to the three stitch densities used. As the SPI increased, increase in strength was observed in the weft direction and the reverse was observed in the warp direction.

The differences for seam strength of plain seams in the warp direction were significant for the washing cycles used for the study, but not for the weft seams. However, it was observed that, on the average, with the weft seams, strength reduced after each washing cycle. For the warp seams, strength reduced after the first and second washes, but a slight increase after third washing was observed.

Furthermore, the findings of the study portrayed that thread type, stitch density and washing cycles have significant influence on the strength of plain seams in the warp, but not the weft seams.

In terms of efficiency, it was observed that differences for weft plain seams were significant for the thread types. Sunflag thread had a higher efficiency than OK. Differences for seam efficiency of weft plain seams were also significant for the stitch densities, with efficiency increasing as stitch density increased.

It was observed that differences for seam efficiency of weft plain seams were not significant for the washing cycles used for the study. However, it was noted that on the average efficiency reduced after the first washing, increased after second washing and reduced again after third washing, but not below the reduction experienced after the first washing. The findings from the current study

in addition, portrayed that for the weft seams thread type, stitch density and washing cycles had significant influence on efficiency.

With regard to the elongation of the plain seams in the Tex Styles Ghana Limited Real Wax cotton printed fabric, significant differences were noted in the weft seams for both threads, but Sunflag had a higher elongation than OK thread.

Differences were noted in seam elongation for the three stitch densities in both directions. Elongation increased in the weft seams as stitch density increased and the reverse was observed in the warp direction.

Additionally, differences in elongation were observed in the washing cycles in the weft but not in the warp direction. Warp seam elongation reduced after each washing cycle, but for the weft seams the elongation increased after the first and the second washing cycles and reduced after the third washing. It was also observed that thread type, stitch density and washing cycles had influence on warp seam elongation, but not weft seam.

Conclusions

The results of this current study led to the following basic conclusions. The overall performance of a seam in a garment depends on the seams direction in the fabric, its stitch density and the number of washes the garment will receive. Seam strength, elongation and efficiency may depend on the thread type and stitch density for various Wax prints. This is evident from what was observed in this study where Sunflag performed higher than its OK counterpart, in terms of seam strength, elongation and efficiency. It must however, be noted that the strength, elongation and efficiency produced by the Sunflag thread might not

turnout the best performance of seams when used in stitching particular stitch densities in a garment. This is because in the case of the warp seams for example, Sunflag in majority of the cases produced strengths that were stronger than the fabric; damaging the fabric instead of the stitching line breaking when force was applied. If the Sunflag thread is used in stitching lower stitch densities such as 8 in Tex Styles Ghana Limited Real Wax prints, there is the likelihood of it performing better than higher stitch densities. In terms of stitch density, all things being equal, as the stitch density increases seam performance in terms of strength, elongation and efficiency increases.

The current study offers scientific basis for the conventional practice (i.e., the use of different stitch densities and thread types in sewing different types of fabrics). It has also brought to light the behaviour of seams in the different directions of Tex Styles Ghana Limited Wax printed fabrics. The study has added to the previous knowledge that stitch density, fabric type and thread type have influence on the performance of seams in garments. In addition, it has provided knowledge that the different thread types in the Ghanaian market produce different seam performances. Finally, it has provided documentation on the interaction of stitch density, thread type and washing on the overall performance of seams in garments, which can serve as a basis for further research.

Recommendations

Based on the findings of the current study, it is recommended that seamstresses and tailors should be advised through outreach programmes,

seminars, workshops and conferences by Home Economics Departments and stakeholders in the garment industry in Ghana, to use appropriate stitch densities in the construction of garments; since some of the garment makers select stitch densities and sewing threads without paying attention to their effect on the overall performance of the apparel being made. They should also be particular about the type of sewing thread they choose in stitching garment pieces together since they can interact with the processes garments go through to influence their seam performance.

The Ghana Standards Board should also establish Standards with regard to the performance of sewing threads. The threads must be tested to ensure that they meet those standards before entering the Ghanaian market to enable consumers be assured of the quality of sewing threads in the market. This would help consumers achieve desired results from threads purchased.

In addition, it is recommended that an attempt should be made to investigate the performance of seams in other locally produced Wax prints by varying stitch density, thread brands and washing. This will give an overall picture of the performance of seams in locally produced Real Wax printed fabrics.

Again, it will also be in the right direction to test various stitch lengths with a variety of thread types on various fabrics in the Ghanaian Market. Testing other variables and publishing works on this relationship will offer future educators, scholars, students and garment manufacturers a solid foundation to make informed decisions regarding the use of sewing threads and stitch densities in clothing construction.

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APPENDIX

Weighing balance (Adams equipment)

Magnifying glass

Sample cutter

Washing machine (Standard Launder-Ometer, Gyrowash 315)

Tensile testing machine (Hounsfield H5K-S)