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THE INFLUENCE OF STITCH DENSITY ON THE STRENGTH, ELONGATION AND EFFICIENCY OF PLAIN SEAM IN A REAL WAX PRINTED FABRIC

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ABSTRACT
This paper studied the performance of seams in a real wax printed fabric. The purpose of this research was to find out the impact of three stitch densities on the strength, elongation and efficiency of plain seam in a Real Wax cotton print. Warp seams were used in the investigations. The stitch densities used ranged from 8-12 stitches per inch (SPI). A tensile testing machine (Hounsfield H5K-S) was used in the determination of the strength and elongation of fabric and seams. The thread used for the stitching was a Sunflag brand polyester thread, which is commonly used by Ghanaian seamstresses and tailors. Means, standard deviations and One-Way Analysis of Variance (at 0.05 alpha levels) were used in the analysis of the data. The outcome of the investigations indicated that differences existed between stitch densities used in the making of the plain seams on the Real Wax print chosen with regard to seam efficiency, strength and elongation. In all the parameters investigated, 12 stitches per inch had the highest values with 8 stitches per inch having the least values. It was also noted in the study that the fabric had higher strength than that of the seam stitched in 8 SPI, but for 10 and 12 SPIs the seams were stronger than the fabric. It is recommended that further research be conducted into the performance of threads on the Ghanaian market in seams and also the performance of seams in real wax prints after washing to determine how seams behave in wax prints during use.

Key words: *Strength; Stitch; Density; Efficiency; Elongation*

INTRODUCTION
The complex evaluation of the quality of a sewn product includes the evaluation of the construction, the pattern, the structure, the composition, and the properties of the used material. Seam quality is an important parameter deciding the performance of garments. According to Nassif (2013) in Cut and Sew Apparel Products, seams are formed when two or more pieces of fabrics are held together by stitches. He further stated that as a seam is one of the basic requirements in the construction of garments, seam quality has great significance in garments. The quality and performance of a sewn garment depends on various factors such as seam strength, efficiency, elongation, durability and appearance. Gaurav (2006) indicated that, for the perfect fit and look of a garment, seam appearance and its strength has to be proper. This will enhance the quality of the garment to meet its required end use.

Several variables interact to enable seams function effectively and perform as expected. According to American Society for Testing and Materials (ASTM) D6193-09 (1996), the characteristics of a properly constructed sewn seam are strength, durability, elasticity, security and appearance and these characteristics must be balanced with the properties of the material to be joined to form the optimum sewn seam. American and Efird Inc. (2009) stated that quality seam engineering relates to many areas of concern including seam strength and seam durability. Other variables involved in the achievement of seam quality include type of needle, seam type, and thread type and size. For example, American and Efird Inc. (2009) indicated five factors that determine the strength of a seam. The factors include fabric type and weight, thread fibre type, stitch and seam construction, stitches per inch and stitch balance. It was indicated that any one of these factors can adversely affect the performance of a sewn product depending on the end-use of the product.

The length of the machine stitches influences garment cost, appearance and durability. American and Efird, Inc. (2002) stated that generally the greater the number of stitches per inch in a seam, the greater the seam strength. However, American and Efird Inc., (2009) noted that on some fabrics (light and medium weight), too many stitches can cause damage to the fabric by cutting the yarns enough to weaken it and excessive stitches per inch can also contribute to seam puckering, and reduce the speed through the machine.

Stamper et al., (1991) stated that the fewer stitches per inch, the longer each is, and the faster the stitching progresses. Long stitches (5 to 8 per inch) are more attractive for topstitching than for regular stitching. In areas of stress especially, stitches that are too long allow the garment to gape 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. It is recommended that the stitch length should be regulated to correspond to fabric type and to the amount of stress the stitching will bear. Using the correct number of stitches per inch can greatly influence the strength, appearance and the overall performance of the seam for a given fabric type and application (American & Efird, 2002).

Mukhopadhyay et al., (2004) observed that the effect of stitch density on the tensile properties of seam is very significant. They noted that both seam strength and efficiency increased with increase in stitch density. Chowdhary and Poynor (2006) in their study on impact of stitch density on seam strength, seam elongation and seam efficiency also noted that seam efficiency did differ for three stitch densities. It was highest for 10-12 stitches per inch for both warp and weft directions and lowest for 6-8 stitches per inch. They also noted that significant differences existed between seam elongation and three stitch densities in both warp and weft directions with 14-16 SPI seams having the highest elongation in both directions. Meeting the requirements for SPI using the right type of thread for a particular fabric helps to achieve quality and enhance the apparel performance in use.

Brown and Rice (1998) (cited in Chowdhary and Poynor, 2006) identified fabric type and weight as the influencing factors that 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. Although short stitches were noted to increase the strength and durability of the seam, they do increase cost of production. Stamper et al. (1991)

also noted that 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 (Very lightweight**:** Less than 25 grams per square meter, Lightweight: 50 – 90 grams per square meter, Medium weight: 120 – 170 grams per square meter, Heavyweight: 215 – 260 grams per square meter, Very heavyweight: Over 350 grams per square meter, Pizzuto, 2012). In addition to these, American and Efird Inc. (2002) stated 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 is used in home sewing.

The Ghanaian market is filled with different Wax prints (a cloth printed by a wax or resin reservation process followed by dyeing with one or more colours added by a blocking process using wax for blocking) from both local and foreign companies. All the researches cited so far were not on real wax prints, which is a common fabric used in Ghana. These wax prints are used for the traditional wears like the "Kaba and Slit" and many other exquisite styles for all kinds of occasions. These Wax 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. Stitches and seams are part of the crucial elements of the construction of articles of clothing. They help create required fit for the wearer. The appearance of the seam forms part of the aesthetical properties of the sewn product and its quality contributes to better performance of the garment during use, in effect contributing to the overall quality of the sewn garment. Quality is one attribute that most consumers look out for in an apparel product. As indicated by Mehta and Bhardwaj (1998), if a product bought has a deficiency it cannot be used; therefore, failure of a seam makes a garment unusable even though the fabric may be in good condition.

Past studies in the area of clothing and textiles, however, have ignored performance attributes of seams used in African prints, which are used extensively in the Ghanaian community. General focus of research has been on textile testing with much emphasis on fibre, yarns, fabric (colour fastness, strength) than the sewn apparel. In other instances products are analysed based on visual inspection leaving the mechanical aspects, which involves seams properties. ASTM D6193-09 (1996) indicated 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 (such as thread type, seam type and stitch density). The improper selection of any one component can result in failure of the sewn junction and ultimately failure of the product manufactured.

When it comes to making sure the final garments are fit for the end use, tensile strength and seaming properties are key performance tests. 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).

A look at the performance of seams in Hitarget Real Wax prints which is produced by a company outside Ghana, but has become popular on the Ghanaian markets is, therefore, significant since it would help provide an empirical basis for existing choices and also help with interpretation of data for quality control.

The purpose of this paper was to investigate the performance of a plain seam on the basis of its elongation, strength, and efficiency with a particular thread type and variation of stitch density on Hitarget Real Wax print manufactured in China. This exploratory study was governed by the following research questions and hypotheses.

Research Questions

1. Is there any inequality between the fabric strength and seam strength of Hitarget Real Wax cotton printed fabric?
2. Is there any disparity between the fabric elongation and seam elongation of Hitarget Real Wax cotton printed fabric?
3. What is the difference between the efficiency of plain seam and stitch density of a Hitarget Real Wax cotton printed fabric?

Hypotheses

1. There is no significant difference between seam strength and stitch density of a plain seam in a Hitarget Real Wax cotton printed fabric.
2. There is no significant difference between seams elongation and stitch density of a plain seam in a Hitarget Real Wax cotton printed fabric.

METHODOLOGY

Materials

A Hitarget Wax printed fabric was bought from the market. Out of the fabric chosen a total number of 33 specimens were obtained for the experiments. Out of the 33 specimens 18 were used in testing for fabric weave, fabric strength, elongation, weight and thread count. Sunflag (100% polyester sewing thread), which is a brand of sewing thread and common on the Ghanaian market and mostly used by seamstresses in garment construction was bought from the market.

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. A tensile testing machine (Hounsfield H5K-S) was used in testing the tensile strength of fabric and seams. A magnifying glass was employed in determining the weave of the fabric. Weighing balance (Adam equipment) was used in determining the weight of the fabric. A pair of scissors was used in the cutting of threads and specimens and a sample cutter was used in cutting specimens for weighing. These instruments were obtained and used at the Ghana Standards Board (GSB) now Ghana Standards Authority (GSA) textile testing unit.

Experimental Procedures

Preparation of Specimens

The strip test method was employed in this study. Thirty-three specimens were prepared. Out of the 33 specimens 18 were not stitched. The unstitched ones were used in testing for fabric weave, fabric strength, elongation, weight and count. The fabric's weight, count, and fabric weave were read for the description of the fabric. Fabric weave used 1 specimen; tensile strength and elongation of fabric used 10 specimens (5 in warp direction and 5 in weft directions), which were

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randomly selected from the 2 yards of fabric purchased. Weight of fabric used 5 specimens and thread counts used 2 specimens and were also selected randomly.

Tensile strength and elongation of fabric

The specimens were in the weft and warp 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 (International Organization for Standardization (ISO) 13934-1 (1999) strip test method for fabric tensile properties).

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

The remaining 15 out of the 33 specimens were stitched with plain seams (301-SSa -1) at their centres. The stitched specimens were obtained by cutting 350mm × 700mm of fabric. This cut fabric was folded in half with the fold parallel to the longer dimension of 700mm and the seam was made in this direction as indicated by International Organization for Standardization 13935-1 (1999) for the strip test method (see Figure 1). Three specimens of 700mm× 350mm were stitched in each SPI and out of them the 15 specimens were obtained for testing for the seam strength and elongation.

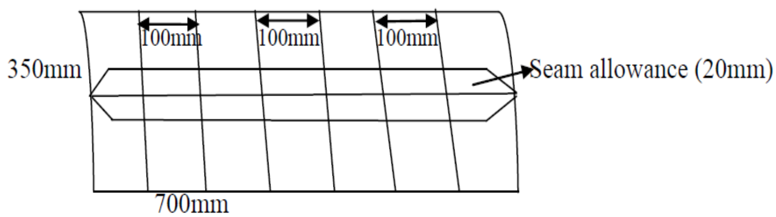

Figure 1. The piece of fabric from which 5 specimens were taken for each SPI

Preparation of final test specimen for seam strength and elongation

Out of the 700mm× 350mm stitched piece of fabric (Figure 1), five test specimens were cut of width 100mm × 350mm for each SPI (Figure 2). After obtaining the 100mm×350mm specimens, 4 cuts of 25mm length at 10mm distance from the seam as shown in Figure 2 were made.

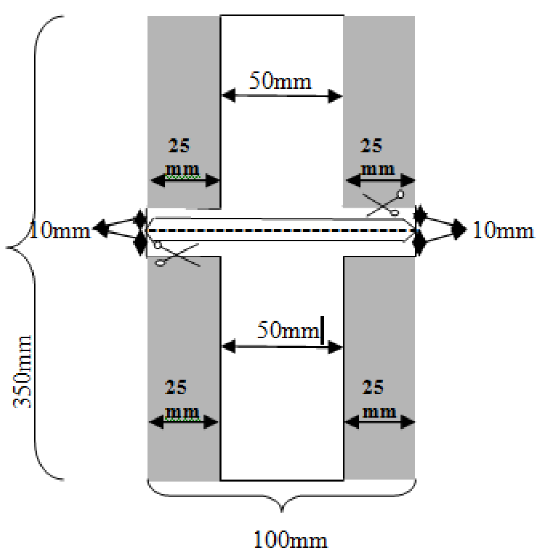

Figure 2. Determination of test specimen for seam strength and elongation

The area shaded and labeled 25mm (Figure 2) were frayed so that a final specimen width of 50mm was obtained for the investigations (see Figure 3).

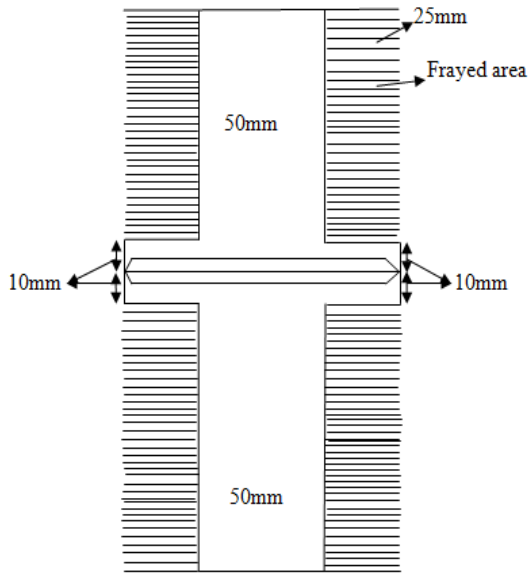

Figure 3. Final specimen for testing seam strength and elongation

The seams were sewn parallel to the warp direction. The International Organization for Standardization 13935-1 (1999) indicated that the seam can be sewn for testing parallel to the warp or weft direction, or both and the writers decided to use the warp direction. The plain open seams were made using the hand sewing machine with needle size 14 and the thread chosen (100% polyester Sunflag thread) was used as both upper and under threads in stitching all specimens. The 301 lock-stitches were used in the stitching. The 301 lockstitch seam as indicated by Olsen (2008) is the standard laboratory seam used in the testing of seam quality and is the most common seam used by seamstresses in Ghana.

Stitches were made in 8, 10 and 12 SPI's (stitch densities). The stitch densities 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 paper, and spot check of stitch densities used by seamstresses in Cape Coast in the central region of Ghana also indicated SPIs within this range. All specimens for the investigation were conditioned in moisture equilibrium with air having a temperature of 27ºC±2ºC and relative humidity of 65%±2% for 24 hours in a relaxed state as indicated by Ghana Standards Authority GS ISO 139 (2005) for tropical and subtropical countries. 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 Authority in carrying out the stated tests and the investigations were carried out at the Ghana Standards Authority textile laboratory.

Measuring breaking strength and elongation of fabric and seams

The specimens were tested for fabric strength and elongation and seam strength and elongation with the aid of the tensile testing machine (Universal Hounsfield) model H5K-S serial number

1058 at a speed of 100_{mm} / minute. Specimens were inserted into the testing machine vertically and carefully clamped to avoid slippage at the gauge length of 200mm±1mm. As the clamps moved, load between 1.0 and 3.0kg was applied on the strip. The breaking strength of the strip was recorded in kilogram force (kgf). The machine was capable of indicating the breaking strength as well as the produced elongation of the specimen. Fabric and seam elongations were recorded in millimeters and calculated using the formula below:

$$breakingelongation = \frac{elongation}{originallength} \times 100$$

All specimens for seam testing experienced rapture of stitching line as indicated in Figure 4. Seam efficiency was calculated using the formula that follows,

$$seam\ efficiency = \frac{seam\ strength}{fabric\ strength} \times 100$$ adopted from Chowdhary and Poynor (2006).

For interpretation purposes they indicated that if the percentage efficiency is greater than 100, the seam is stronger than the fabric. If it is less than 100%, the fabric is stronger than the seam.

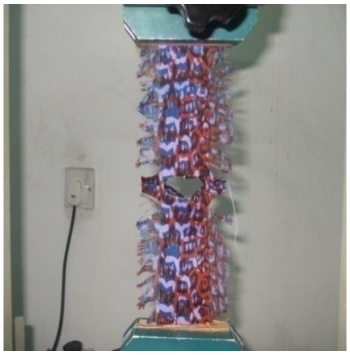

Figure 4: Rapture of stitching line

Data analysis

Readings were recorded for each of the tests identified from both stitched and unstitched specimens. The statistical software that was used in the analysis of the data was Statistical Package for the Social Science (SPSS) for windows version 17. The data acquired from the experiments were prepared and organized in SPSS setup and means, standard deviations and One-Way Analysis of Variance (at 0.05 alpha level) were the statistical tools used in the analysis of the data.

RESULTS AND DISCUSSION

The fabric was 100% cotton with a plain weave of 1×1 repeat in both directions. The fabric's attribute, thread count was determined and is presented in Table1.

Table 1: Fabric yarn count

Attribute	Value (thread count)
Fabric count	
Warp	93
Weft	72

In the warp direction the count was 93 whereas in the weft the count was 72 (see Table1). Means and standard deviations were used on other details for the selected structural and performance attributes of the fabric and is presented in Table 2.

Table 2: Means and standard deviations of fabric weight, tensile strength and elongation of fabric

Attribute	Number of specimens	Mean	Standard Deviation
Fabric weight	5	139.5g/m^2	1.55
Tensile strength			
Warp	5	59.6kgf	1.77
Weft	5	30.1kgf	4.22
Elongation			
Warp	5	5.7%	0.24
Weft	5	15.1%	1.46

The tensile strength of the fabric in the warp direction was higher (mean 59.6, standard deviation 1.77) than in the weft direction (mean 30.1, standard deviation 4.22), but for elongation, the weft direction (mean 15.1%, standard deviation 1.46) was higher than the warp direction (mean 5.7%, standard deviation 0.24) (see Table 2). This finding conforms to the general idea that the warp direction of fabrics is stronger than the weft and weft threads stretch more than warp threads.

To answer the research questions, and test the hypotheses, means, standard deviations and One-Way Analysis of Variance were employed and the results are presented in Tables 3 to 6.

Table 3: Comparisons between fabric strength and seam strength, Seam efficiency by three stitch densities and Comparisons between fabric elongation and seam elongation

Stitch Densities	Fabric Strength weft (n=5)	Seam Strength (kgf)	Seam Efficiency (%)	Fabric Elongation weft (n=5)	Seam Elongation (%)
	30.1			15.1	
8 (n=5)		27.9	92.5		6.3
10 (n=5)		36.5	121.0		7.0
12 (n=5)		38.9	128.9		7.2

n=number of specimens used, kgf= kilogram force

In other to answer research question 1, means were used. The results revealed that the fabric (mean 30.1) was stronger than the seams stitched in 8 SPI (mean 27.9). For the seams stitched in 10 (mean 36.5) and 12 (mean 38.9) SPIs, the seams were stronger than the fabric employed for the study (see Table 3). The result from the 8 SPI is in agreement with what Chowdhary and Poynor (2006) found out that the 100% cotton muslin with a plain weave they used was significantly stronger in both the warp and weft directions than the seams made with the stitch densities they employed in their study. With regard to seam efficiency, which answers research question 3, Table 3 indicates that, seam efficiency differs for the three stitch densities employed with 12 SPI (mean 128.9) having the highest efficiency and 8 SPI (mean 92.5) having the least (see Table 3). Seam efficiency increased with increase in stitch density (refer to Table 3). The finding is in concord with both Mukhopadhyay et al. (2004) and Chowdhary and Poynor (2006) who noted that both seam strength and efficiency increased with increase in stitch density. They indicated that Amoco Fabrics and Fibres Company reported that for most test fabrics, seam efficiency ranged between 60% and 90% for single stitched seams. For this study, the seam efficiency for 10 SPI and 12 SPI fell above the range given by the company, but the 8 SPI fell within (refer to Table 3). The results from the 10 and 12 SPIs with regard to seam efficiency show that the seams in these SPIs were actually stronger than the fabric. The foregoing shows that using 8 SPIs for plain seams in Hitarget Real Wax prints will perform satisfactorily in use in terms of strength. It should also be noted that generally seam efficiency more than 100% is not desirable in a garment. If a seam is stronger than the fabric it means that under stress the fabric will tear instead of the stitching, which will lead to a possible irreparable failure of the garment.

To answer the second research question, comparison was made between fabric elongation and seam elongation based on the SPIs used. The results indicated that the fabric (mean 15.4) had a greater percentage elongation than the seams in the three stitch densities used for the study (Table 3). The strength and elongation of the fabric in the weft direction was used for this analysis and that of research question 3. This was done because the seam was done parallel to the warp direction and so the pulling was done in the weft direction. This finding is contrary to what Chowdhary and Poynor (2006) found out in their study on the impact of stitch density on seam strength, efficiency and elongation on a 100% cotton muslin fabric; that the seams had significantly higher elongation than the fabric in both the warp and the weft directions for all the stitch densities they used which ranged from 6-16 SPIs. The differences between this experiment and that of Chowdhary and Poynor could be due to differences in the type of fabric and threads used.

To test hypothesis 1, One-Way Analysis of Variance was used and revealed that significant differences existed in the strength of the plain seam by the three stitch densities ($p=0.001$). The strength was higher with 12 SPI (mean 38.9, standard deviation 3.78) followed by 10 (mean 36.5, standard deviation 1.04) then 8 (mean 27.9, standard deviation 3.72) (see Table 4 for details).

Table 4: 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	17.16	0.001**
8	27.9	3.72			
10					
12	36.5	1.04			
	38.9	3.78			

***Significant $p\leq0.05$, M=Mean, SD=standard deviation, df= degree of freedom*

This result is not consistent with the null hypothesis and so was rejected. However, the finding is in agreement with what American and Efird Inc. (2002) stated that generally the greater the number of stitches per inch in a seam, the greater the seam strength. Further analysis to determine between group differences uncovered that differences were significant between all groups except for the differences between 10 and 12 SPIs which were not significant (see Table 5).

Table 5: Post hoc results for between-group variability for seam strength × stitch density

Fabric direction/stitch density	Mean difference	*p*-value
Warp		
8×10	15.2	0.002**
8×12	21.4	0.001**
10×12	6.1	0.467

***Significant p≤0.05*

Table 6: 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	3.89	0.050
8	6.3	0.39			
10					
12	7.0	0.53			
	7.2	0.73			

***Significant p≤0.05, M=Mean, SD=standard deviation, df= degree of freedom*

The Analysis of Variance results in Table 6 indicates some evidence of a significant difference between seam elongation and the three stitch densities employed for the study (p=0.050). A scrutiny of the mean statistics portrayed that seam elongation increased as stitch density increased, with 12 SPI (mean 7.2%, standard deviation 0.73) having the highest percentage elongation (Table 6). This is in line with the general performance of stitches with higher SPIs having higher elongation due to more inter looping of threads during stitching. The result is also in concord with what Chowdhary and Poynor (2006) noted that differences existed between seam elongation and three stitch densities in both warp and weft directions with the higher SPI having the highest elongation in both directions. Though the study was not done on a Wax print, it served as a literature with which other studies could be compared.

CONCLUSION AND RECOMMENDATIONS

Differences existed between stitch densities used in the making of the plain seams on the Hitarget Real Wax print chosen for the study with regard to seam efficiency, strength and elongation. As the stitch density increased, seam strength, efficiency and elongation increased with 12 SPI performing above 8 and 10 SPIs. For seam elongation, it was higher for the 12 SPI and lowest for 8 SPI. When it came to strength, 12 SPI came out to be the strongest and 8 SPI had the least strength. It was also noted in the study that fabric strength was higher than that of the seam stitched in 8 SPI, but for 10 and 12 SPIs the seams were stronger than the fabric.

However, the fabric had higher elongation in comparison with that of the seams stitched in all the three stitch densities.

From the results of this investigation, one might be tempted to propose that Ghanaian seamstresses be educated to use 8 SPI with Sunflag thread in the making of plain seams in Hitarget Real Wax prints. It should however be noted that the attributes of the fabric used for the study makes it a medium weight fabric for which stitch densities of 8 stitches per inch seems rather low and may result in gapping at the stitching line; when the garment is put under a resulting high stress as is found in some close fitting garments. This means that possibly the thread used for the study is too strong for the fabric employed for the study.

In the light of the above, further research should also be conducted into the performance of the threads on the Ghanaian market in seams and also the performance of seams in real wax prints during use. These will throw more light on not only the effects of the use environment on the performance of seams, but also the efficiency of the threads on the Ghanaian market in order to advice on the choice of threads and SPIs.

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