A new approach for predicting seam strength

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ABSTRACT – REZUMAT

A new approach for predicting seam strength

Owing to a high amount of stress, seam failure in workwear fabrics makes the fabric unsuitable although the fabric strength is high. It is therefore important to predict the seam strength to ascertain the performance of the garments during use and determine the required thread strength to match the required seam strength. An assembly is composed of a sewing thread and a fabric. The thread forming the seam undergoes several stresses during its passage from the sewing machine to the formation of the loop and when wearing the garment: these are mechanical stresses. Therefore, it is necessary to evaluate the strength of the seam. But, in the bibliography, most researchers have studied the strength of the seam concerning a single type of stitch. This work aimed to examine the seam's strength from the resistance to the loop of the thread for all types of stitches. In all of the earlier predictive equations, seam strength is predicted from thread loop strength with some multiplicative factors. The thread loop strength is measured without considering the stitch type. During the sewing process, threads loop differently from one stitch to another, therefore, the standard thread loop strength becomes unfit to predict the seam strength. In this paper, the effects of loop thread length and configuration are studied on thread loop strength and seam strength. The seam strengths predicted from the loop strength before and after considering the new loop configurations and the real seam strength are compared. So, new clamps for loop strength are configured and carried out. It is observed that there is a closer match between experimental and predicted seam strength with new loop configurations. The loop configuration has a significant effect on the thread loop strength and improves the accuracy of seam-strength prediction.

Keywords: *sewing thread, thread loop strength, seam strength, loop configuration, loop strength clamps*

O nouă abordare pentru preconizarea rezistenței asamblărilor prin coasere

Din cauza tensiunilor crescute, asamblările țesăturilor pentru îmbrăcămintea de lucru cedează, ceea ce face ca materialul să fie inadecvat, deși rezistența țesăturii este ridicată. Prin urmare, este important să se preconizeze rezistența asamblărilor prin coasere pentru a stabili performanța articolelor de îmbrăcăminte în timpul utilizării și pentru a determina rezistența necesară a firului, în concordanță cu rezistența necesară a cusăturii. Un ansamblu este compus dintr-un fir de cusut și o țesătură. Firul care formează cusătura suferă mai multe solicitări în timpul trecerii sale de la mașina de cusut până la formarea buclei și la purtarea îmbrăcămintei: acestea sunt solicitări mecanice. Prin urmare, este necesar să se evalueze rezistența asamblării prin coasere. Dar, în bibliografie, majoritatea cercetătorilor a studiat rezistența cusăturii în ceea ce priveşte un singur tip de cusătură. Scopul acestei lucrări a fost de a studia rezistența cusăturii de la rezistență la bucla firului pentru toate tipurile de cusături. În toate ecuațiile de predicție anterioare, rezistența cusăturii este preconizată din rezistența buclei de fir cu unii factori multiplicatori. Rezistența buclei firului este măsurată fără a lua în considerare tipul de cusătură. În timpul procesului de coasere, firele se desfășoară diferit de la o cusătură la alta, prin urmare, rezistența standard a buclei de fir devine inadecvată pentru a preconiza rezistența cusăturii. În această lucrare, influența lungimii și configurației buclei firului este studiată în ceea ce priveşte rezistența buclei firului și rezistența cusăturii. Se compară rezistența cusăturii estimată din rezistența buclei înainte și după luarea în considerare a noilor configurații de bucle și rezistența reală a cusăturii. Prin urmare, noi elemente de fixare pentru rezistența buclei sunt configurate și realizate. Se observă că este o concordanță mai strânsă între rezistența experimentală și cea preconizată a cusăturii cu noile configurații de bucle. Configurația buclei are o influență semnificativă asupra rezistenței buclei firului și îmbunătățește precizia predicției rezistenței cusăturii.

Cuvinte-cheie*: fir de cusut, rezistența buclei de fir, rezistența cusăturii, configurația buclei, elemente de fixare a rezistenței buclei*

INTRODUCTION

The seam performance and quality depend on various factors such as seam strength, seam slippage, seam puckering, seam appearance and yarn severance [1, 2]. Sewing needle penetration forces and fabric deformation during sewing are effective factors for seam performance, too [3–5]. The appearance and performance of the seam are dependent upon the quality of the sewing threads. One essential requirement of any thread is that it must be compatible with the needle size, various sewing machine settings (sewing speed, thread tension) and the fabric on which it is being sewn. Seam damage can be a serious cost problem, often showing only after the garment has been worn. The most important parameters that influence seam damage tendency are

Table 1

PHYSICAL CHARACTERISTICS OF FABRICS					
Fabric	**Weave**	**Yarn density**		**Weight (g/m²)**	**Thickness (mm)**
		warp (ends/cm)	**weft (picks/cm)**		
1	Plain	25	25	165	0.36
2	Twill 3/1	40	30	250	0.31
3	Twill 3/1	30	20	268	0.48
4	Twill 2/2	30	20	275	0.46
5	Twill 3/1	30	25	280	0.51
6	Twill 2/2	30	20	300	0.55
7	Twill 3/1	30	20	225	0.42
8	Twill 3/1	42	30	255	0.27
9	Twill 3/1	30	30	265	0.35

fabric construction, chemical treatments of the fabric, needle thickness and sewing machine settings with sewing thread. Fibre content, yarn construction, tightness and density are important parameters for fabric construction on seam damage. A large number of studies [6–9] have determined the seam strength according to ASTM 1683-04 standards, which express the value of seam strength in terms of maximum force (in Newton (N)) to cause a seam specimen to rupture [10].

The majority of thread breaks in a seam occur at a looped part of a stitch, and the loop strength of a thread is related more closely to stitch strength than linear tensile strength. Loop strength is the load required to break a length of thread that is looped through another thread of the same length; it is influenced by stiffness, fibre or filament type, ply and twist construction and the regularity of these factors. Many studies have predicted the seam strength from thread loop strength, stitch density and other factors [11–14]. The thread loop strength is measured without considering the stitch type. During the sewing process, threads loop differently from one stitch to another, therefore, the standard thread loop strength becomes unfit to predict the seam strength. In this paper, the effects of loop thread length and configuration are studied on thread loop strength and seam strength. The seam strengths predicted from the loop strength before and after considering the new loop configurations and the real seam strength are compared. So, new clamps for loop strength are configured and carried out.

MATERIALS AND METHODS

The detailed experimental procedure involved in carrying out this study is described in the following sections.

Fabric sample

Ten commercial samples of woven fabrics with different weaves and weights, commonly used for clothing, were prepared. Since denim fabrics are generally made of cotton or a mixture of cotton and elastane, the composition fabric chosen in this study is made of 100% cotton warp yarn and weft yarn in 95% cotton and 5% elastane. The physical characteristics of fabrics are shown in table 1. The fabric weight, thickness and yarn density were measured according to French Standards EN 12127. (1997) [15], ISO 5084. (1996) [16] and BS EN 1049-2 (1993) [17].

Sewing thread characteristics

A large variety of sewing threads is used in the clothing industry. The majority of the sewing threads used by the clothing industry are made from cotton and polyester fibre [18]. Three commercially sewing threads (60% PES, 40% CO) are used and chosen according to French Standard NF G 07-117 [19]. The thread characteristics are shown in table 2. The tensile proprieties were determined according to ISO 2062 (2009); the specimen was subjected to tension until break using a suitable tester (dynamometer type ‘LLOYD Instruments’ Lloyd LRX 2.5 K) [20].

Table 2

PHYSICAL CHARACTERISTICS OF SEWING THREADS			
Thread	**1**	**2**	**3**
Yarn count (tex)	25	30	40
Twist (tpm)	700	750	850
Twist direction	Z	Z	Z
Tenacity (cN/tex)	40.8	41.93	35.5

Measurement of tensile seam strength

To evaluate the seam strength, we have used two methods:

- the grab test: This test method can also be used to determine the seam strength in woven fabrics by applying a force perpendicular to the sewn seams according to ISO standard ISO 13935-1 [21]. The seam specimens are prepared with three different stitch densities.
- a prediction function for the theoretical calculation of the real seam strength [22]:

$$Ss = Sl * ds * ls * \alpha \quad (1)$$

Where Ss is the strength of the seam (N), Sl – loop strength of the thread (N), ds – density of the stitch (cm^{-1}), ls – length of the seam (cm) and α – coefficient of the seam between 0.8 and 1.1.

For the measure of loop strength, the thread samples were tested at 200 mm gauge length (L) at a constant time to break of 20±3 s on Lloyd LRX 2.5 K tensile tester as per French Standard NFG 07-310 [23]. (Laboratory of Textile Engineering LGTex, higher institute of scientific and technology studies, Ksar Hellal, Tunisia). The thread samples are looped as shown in figure 1.

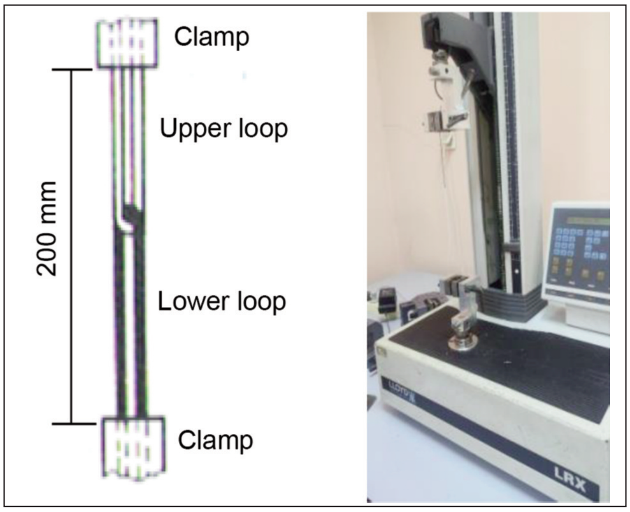


Fig. 1. Standard loop configuration (NFG 07-310)

To study the effect of the distribution of the length of the upper and lower loop on the loop strength and subsequently the seam strength, the loop strength is measured for three distributions ($L_{upper\ loop}$ = 1/2 L, $L_{upper\ loop}$ = 2/3 L, $L_{upper\ loop}$ = 3/4 L) in the new configuration corresponding the chain stitch type 401. This study is performed on thread 3.

Development of new loop configurations

The prediction function for the calculation of seam strength was developed basically for the lockstitch 301 the fact that the needle thread is looped through the bobbin thread of the same length as the standard loop configuration, however, it isn't the case for the other stitches. So, specific new configurations for each type of stitch were developed. For each stitch type, the behaviour of seam threads during a tensile test is determined. Therefore, two woven specimens (150 mm × 50 mm) are sewn by threads with different colours. Then these seam specimens are subjected to a constant maximum strain (tensile test). At this moment a photo (figure 2) is taken and analysed to develop the new loop configuration.

These configurations are developed for chain stitch type 401 and overedge stitch types 504, 514, 516, and 517. These stitches are mostly used in the apparel industry. To validate the new configurations, the real seam strength and the calculated seam strength for standard and new loop configurations are determined. Then, the coefficient α is calculated as follows:

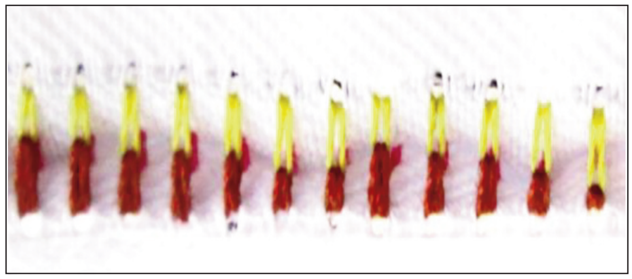


Fig. 2. Real seam behaviour to tensile test

$$\alpha = \frac{real\ seam\ strength\ (N)}{calculated\ seam\ strength\ (N)} \quad (2)$$

Conception and realization of news clamps for loop strength

The new clamps can be modelled as shown in figure 3.

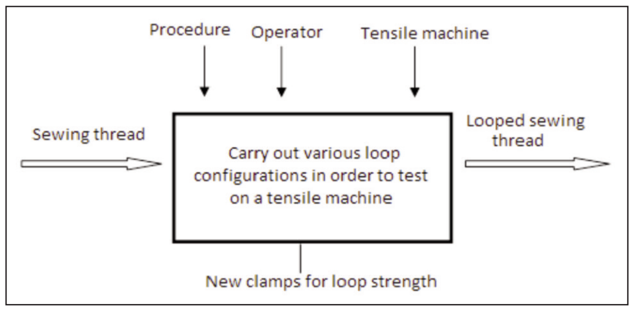


Fig. 3. New clamps modelling

The design of the clamps was performed on SolidWorks 2010 in a Windows environment.

RESULTS AND DISCUSSION

Thread loop strength

Table 3 shows that the size of the sewing thread is an important factor affecting loop strength. Higher sewing thread size leads to greater loop strength. This effect was proven by Sundaresan et al. who studied the effect of thread and fabric properties on sewing thread strength [24, 25].

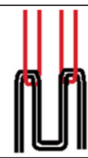
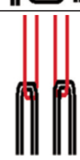
Table 3

SEWING THREADS LOOP STRENGTH			
Thread	Yarn count (tex)	Loop strength	
		Mean (N)	CV (%)
1	25	17.948	4.13
2	30	19.318	5.71
3	40	24.762	3.66

New loop configurations

Table 4 summarizes the standard and the new loop configurations for the studied stitches. The red loop is the upper loop(s) and the black one is the lower loop(s). The new loop configurations differ from the standard one, especially in several loops and several upper and lower yarns.

Table 4

STANDARD AND NEW LOOP CONFIGURATIONS		
Stitch type	**Standard loop configuration**	**New loop configuration**
Chain stitch 401		
Overedge stitch 504		
Overedge stitch 514		
Overedge stitch 516		
Overedge stitch 517		

New clamps

The new clamps can assemble and test several loops at once depending on the new configurations. These clamps contain three aligned cylinders donning (3), with a diameter of 3 mm, coated with a rubber material providing a good clamping of the yarns (figures 4, 5, 6).

Loop length effect on loop and seam strengths

The loop length distribution has an insignificant effect on the variation of the loop strength (table 5), but it minimizes the difference between the real seam strength and the calculated one (table 6). The minimum difference was visualized for the distribution Lupper loop = 3/4 *L*. This distribution is closer to the real configuration of chain stitch type 401. Stitch density was deemed to be an important attribute in seam quality because it assembles the fabric components. The change in stitch density exerts a great influence on seam strength (table 6).

The difference value is calculated per the following formula:

Table 5

EFFECT OF LOOP LENGTH DISTRIBUTION ON LOOP STRENGTH		
Loop length distribution	**Loop strength**	
	Mean (N)	**CV (%)**
$L_{upper\ loop}$ = 1/2 L	26.968	6.45
$L_{upper\ loop}$ = 2/3 L	26.959	11.17
$L_{upper\ loop}$ = 3/4 L	26.044	4.78

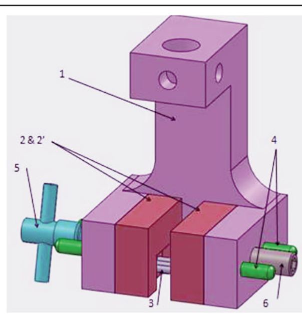


Fig. 4. 3-D view of a clamp: *1* – clamp; *2* and *2'* – two jaws; *3* – cylinders donning; *4* – pins; *5* – clamping screws; *6* – set screws

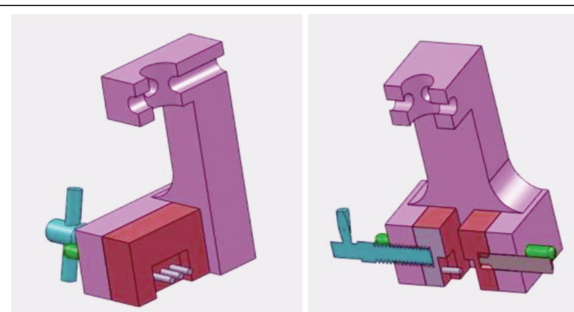


Fig. 5. Sectional view of a clamp

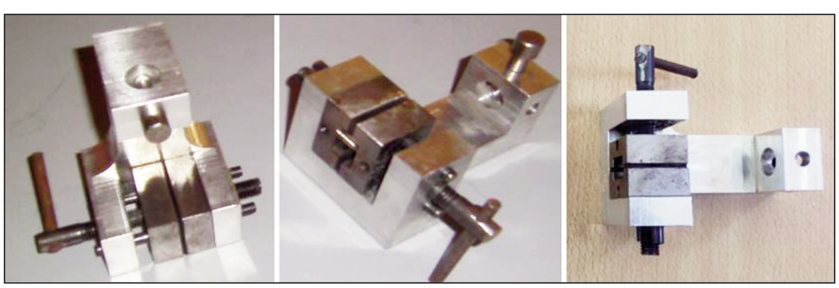


Fig. 6. Photos of carried clamps

Table 6

EFFECT OF LOOP LENGTH DISTRIBUTION ON SEAM STRENGTH				
Stitch density (cm^{-1})	**Real seam strength (N)**	**Difference (%)**		
		$L_{upper\ loop}$ = 1/2 L	**$L_{upper\ loop}$ = 2/3 L**	**$L_{upper\ loop}$ = 3/4 L**
2.5	291.380	3.95	3.92	0.55
3	315.840	13.2	13.2	10.16
4	386.273	10.47	20.39	17.6

$$Difference\ (\%) = \frac{Ss\ (calculated) - Ss\ (real)}{Ss\ (real)} \times 100 \quad (3)$$

New loop configuration effect

The difference between the loop strengths in the standard and new configurations for the chain stitch 401 is 8.77% against 48% for the overedge stitch 514 (table 7). These results show that the loop configuration has a very important effect on the loop strength. This can be explained by the fact that the new configurations for these stitches are very close to the standard ones. The difference value is calculated per the following formula:

$$Difference\ (\%) = \frac{Sl\ (new\ conf.) - Sl\ (standard\ conf.)}{Sl\ (standard\ conf.)} \times 100 \quad (4)$$

The overedge stitches are stronger than the chain stitch (table 8). The effect of stitch type on seam strength relates to the greater loss in strength that affects needle threads [4]. Variations in seam type can also affect seam strength with improved strength obtained in some of the lapped seams which have additional rows of stitching. Table 8 shows that the standard configuration gives values of α that exceed the limits given by the standard which are between 0.8 and 1.1 [1], except for the chain stitch 401. This can be explained by the fact that for this stitch, the loopback mode between the upper thread and lower thread is very close to the lockstitch 301. However, the loopback mode for the other stitches is very different. So the new loop configurations improve the accuracy of seam-strength prediction

CONCLUSION

In this study, the effects of loop thread length and configuration on thread loop strength and seam strength were investigated. The effect of the loop configuration on the accuracy of seam strength prediction is also studied. The results of this work are summarized below:

Table 7

EFFECT OF LOOP CONFIGURATION ON LOOP STRENGTH					
Stitch type	**Loop strength**				**Difference (%)**
	Standard configuration		**New configuration**		
	Mean (N)	**CV %**	**Mean (N)**	**CV %**	
401	24.793	5.12	26.968	6.45	8.77
504			26.968	6.45	8.77
514			36.811	8.15	48.73
516			46.247	10.20	86.53
517			42.442	10.80	71.18

Table 8

ASSOCIATIONS BETWEEN JOB STRAIN AND INDIVIDUAL AND ORGANIZATIONAL CHARACTERISTICS ACCORDING TO KARASEK'S MODEl					
Stitch type	**Calculated seam strength (N)**		**Real seam strength (N)**	**α**	
	S.C	**N.C**		**N.C**	**S.C**
401	371.460	404.52	368.66	0.91	0.99
504		404.52	450.63	1.11	1.21
514		552.165	436.85	0.79	1.17
516		693.705	516.35	0.744	1.39
517		636.63	458.33	0.719	1.23

Note: S.C – standard configuration; N.C – New configuration.

- New clamps for loop strength are configured and carried out.
- The effect of loop length distribution on the variation of the loop strength is not significant, but it minimizes the difference between the real seam strength and the calculated or predicted one (case of chain stitch 401).
- The loop configuration has a significant effect on the thread loop strength and improves the accuracy of seam strength prediction.
- The standard loop configuration gives values of α that exceed the limits given by the standard which are between 0.8 and 1.1, unlike the new loop configuration.

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