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Bagging Phenomenon on Jersey Knitted Fabrics

Feriel Bouatay and Adel Ghith
Department of Textiles
National Engineering School of Monastir
Tunisia
bouatay_feriel@hotmail.com

ABSTRACT

The aim of this paper is to study the influence of bagging deformations caused by stress on the characteristics of certain jersey knitted fabrics. We apply a multidirectional stress on some knitted samples varying in composition, in yarn counts and in some knit parameters. We are interested on the permanent maximum deformation and on the maximum permanent bagging height. Experiments are carried out and we found that the bagging volume depends on the fabric strength properties, yarns count and the knit density, whereas the permanent maximum deformation characterizing the bagging phenomenon decreases when the yarn linear density increase (yarn count decrease) and when the course count decrease. A rheological study shows that the generalized Maxwell model with four parameters fits (represents) the knitted fabric reaction after the application of the multidirectional stress. Also, the statistical study shows that the material composition is the most important parameter on the bagging phenomenon.

Keywords: jersey knitted fabrics, multidirectional stress, residual flexion, permanent deformation, strength properties, rheological model

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Introduction

Today we seek comfort, durability and low prices when he buys garments. Industrials should satisfy these exigencies with minimal cost. That’s why they should carries out some control quality tests in relation with the end use of his fabrics. In a daily use, knitted fabrics are submitted to some multidirectional stress especially in elbows and knees, these deformations reduce considerably the durability of the garment. So it is important to pay attention on this phenomenon.

Abghari et al (2004) were interested to the relation between the in-plan fabric tensile properties and the bagging behavior of woven fabrics by using a method based on a simulation of the bagging formation of a specified garment. The bagging procedure is based on the results of fabric tensile deformations in warp and weft directions. The experimental results show that the bagging behavior of woven fabrics can be predicted by the results of the biaxial tensile properties under low stress.

Nilgüm Özdil (2008) found that the augmentation of elasthan ratios increases the elongation rate of fabrics and the permanent deformation decreases due to the good recovery properties added by elasthan. She found that the bagging height and the permanent bagging volume decrease. She concluded that elasticity and the recovery of deformations in woven fabrics increase when elasthan is added.

Yokura et al (1986) had measured mechanical properties of some fabrics with KES-F system and had developed an empirical relationship to predict the residual bagging volume of fabrics from their dynamic creep and hysteresis behavior extracted from results on stress-strain, bending, and shearing deformations.

Yokura et al (1986) have used the volume of a bagged fabric as a measure of bagging properties and they give a model to predict it. In their study, the sample is placed and fixed on a device permitting to apply some loads (stress) for five hours. The shape of the distorted sample is measured with a topographic technique. The volume formed by the bagged fabric is used to evaluate the bagging properties.

Gurnewald and Zoll (1973) had investigated the fabric bagging mechanism. They used a device to have a motion similar to an arm bending to simulate the bagging phenomenon. They found a good correlation between simulated results and those observed in a daily use.

Zhang et al (1997) had applied on the woven fabric samples repeatedly stress by the use of a steel ball placed on an Instron Tensile tester to have a high bagging load. After five cycles they measured the bagging height and the bagging resistance. They found that these parameters depend on the results of the first cycle and the bagging fatigue.

Also, Zhang et al (1999) studied the mechanism of fabric bagging. They developed a testing procedure for simulating the bagging process to obtain psychological perceptual ratings. A series of photographs were taken from bagged fabric samples and compared with residual bagging height. Both ranking and rating scales were used as psychological degrees. They found that subjective perceptions of fabric bagging are largely based on fabric residual height. The residual bagging shape is a component of physical stimuli for a subjective perception of fabric bagging and it is related to the fabric anisotropy. They found a linear relationship between subjective perceptions and the measured residual bagging height. Also, they investigated the physical mechanism of fabric bagging by developing a model of the fatigue process in terms of internal energy.

Yeung et al (2002) had developed a method to evaluate the bagging phenomenon of fabrics. The method consists on capturing images and defining some criteria to identify the bagging volume. At a predetermined time and after the formation of bags the samples are photographed. They analyze pictures of the formed bags in warp and weft directions in order to show the anisotropy of the fabrics and eight criteria were extracted to characterize the bagging volume and the shapes after deformation. They found that the aspect of fabrics after bagging test can be estimated from the pictures criteria. Extensible fabrics having good recovery of the deformations were identified to prevent bagging tendency and the influence of the dimensional variations of various part of the body. During the last years, fabrics with elasthan are more and more used in knitted fabrics for their good recovery properties.

Merç B and Gürarda A (2002) studied the mechanical properties of fabrics containing elasthan and concluded that high elasthan ratio makes the yarn more flexible. The yarns with elasthan allow the fabric to move freely without any deformation in the fabric. Moreover, they have determined that the elasthan had an important influence on the tensile and tearing strengths of fabrics and these properties decrease with the increasing ratios of the elasthan in fabrics.

O. Jirsák et al (1993) had constructed a two-dimensional model of the mechanical properties of textiles, and had studied the relations between model parameters and model behavior. They described the influence of the number of bonding sites in the model on stress-strain curves, on the CPU time consumption, and on the stability of model outputs and they discussed the methodology of computer-simulation methods in the study of textile mechanics.

During bagging deformation, a fabric is subjected to a complex pattern of loading. Bagging force induces internal stress at multidirectional including shearing, tensile and bending (Karimarin et al, 2013). These repeated deformations decrease the lifetime of the clothing. In this regard, this research investigated the effects of fiber, yarn and fabric characteristics on the bagging behavior of single Jersey knitted fabrics.

Experimental

1. Yarns properties

1.1. Yarns composition

The knitted fabrics samples with different composition, yarn counts and different knit parameters are tested. In table 1 we present the characteristics of the yarns used in these samples.

Table 1. Yarns characteristics

Yarns	Composition	Metric count (Nm)	twist (lap/m)
1	Cotton	40	617
2	Cotton	60	678
3	Polyester	40	neglected
4	Polyester	60	neglected

1.2. Yarns strength properties

The yarns tensile properties are given from load - elongation curves and represented in figure 1.

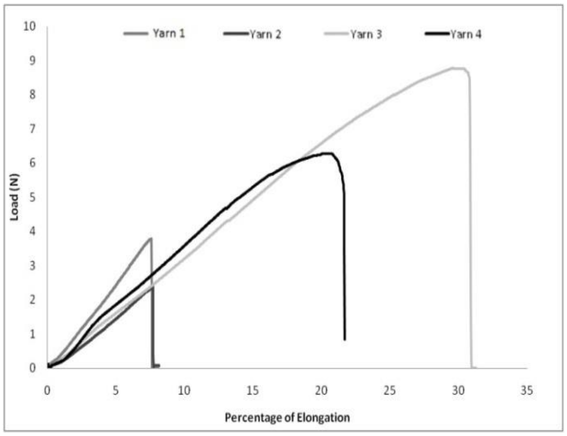


Figure 1. Yarns Load-percentage elongation curves

The polyester yarns are more resistant and more extensible than cotton ones. This result is essentially due to two principle facts; the first is that tenacity is much higher in polyester than in cotton and the second that polyester yarns are made up of multifilament whereas cotton yarns are obtained by conventional spinning process.

2. Knitted fabrics properties

2.1 Knitted fabrics composition

S. Ajeli et al (2009) had measured the bending rigidity of warp-knitted fabrics as a function of knit structure (underlaps length), density (wale and course spacing) and yarn bending properties. Experimental results show that there is a reasonable agreement between the calculated and measured values for both wale and course directions.

In this study, we use eight knitted fabrics presenting different characteristics. Table 2 presents the most important characteristics of these samples. These samples are knitted with two different yarn fineness and two different knit course counts. The variation of these parameters has an important influence on the samples properties as the variation of the length stitch, the thickness and the sample weight as shown in table 2.

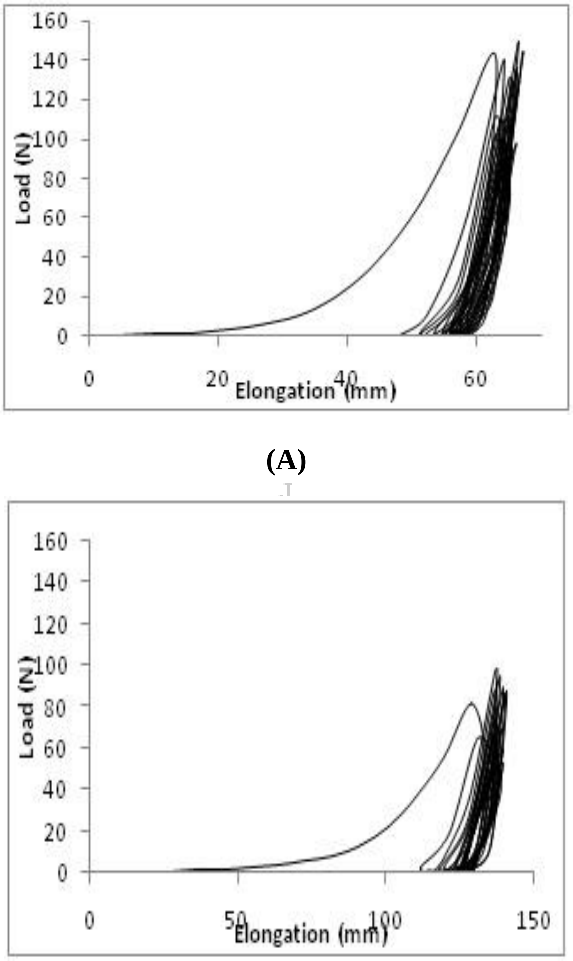
2.2 Strength properties study

The tensile properties of knitted samples are given in table 4. From the preceding table, we can see that the extensibility and the breaking tenacity are more important in the row direction than in the wale one. Also, we can note that the breaking strength in the wale direction is more important when we use a higher course count and a more fineness yarn. But, the increase of the course count and/or the yarn fineness leads to a decrease of the sample extensibility. These results are observed for cotton and also for Polyester samples. The polyester samples are more resistant and more extensible than those on cotton. So, we can predict that the permanent deformations of the bagging phenomenon shall be much more important in cotton samples than in polyester ones.

Bagging phenomenon is caused by a repetitive mechanical actions applied especially by elbows and knees. We studied in this paper the reaction of our samples with strength cyclic tests. The applied strength varies to 50% of the maximum supported strength, in the two directions (wale and row). When this strength is reached, the samples are relaxed (the stress is canceled) and the cycle is repeated twenty times. The obtained results are presented in figure 2.

Table 2. The knitted samples characteristics

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Composition	Cotton	Cotton	Cotton	Cotton	PES	PES	PES	PES
Nm	40	40	60	60	40	40	60	60
Course count	High	Low	High	Low	High	Low	High	Low
Stitch length (cm)	0,441	0,395	0,466	0,403	0,439	0,379	0,425	0,341
Thickness (mm)	0,837	0,866	0,617	0,631	0,816	0,897	0,643	0,756
weight (g/m²)	138,7	146,2	82,7	96,3	164,48	168,04	114,016	122,725



(A)

(B)

Figure 2. Cyclic tests curves of samples: (A) in wale and (B) in row direction

We note that the extensibility in the row direction is more important than in the wale direction, and the deformations increase with the number of the cycle. This result is due to the repetitive charges supported by the knitted fabric. Moreover the maximum deformation is reached from the 15th cycle and the deformation become stable. Also we can see from the curves a viscoelasticy reaction of the samples.

3. Device test

The bagging phenomenon is carried out by using a device presented in figure 3.

A 100 cm² squared shape samples are used and we apply on them a multidirectional stress by the conformator (1) until a fixed and constant maximum deformation is obtained. Then, the conformator is withdrawn, so the stress applied is cancelled and the samples are on a recovery period. The maximum permanent deformation is measured by the needle (2) as shown by figure 3. After, a multiple measurements and when a stabilization of the value is obtained, we took it as a definitive result.

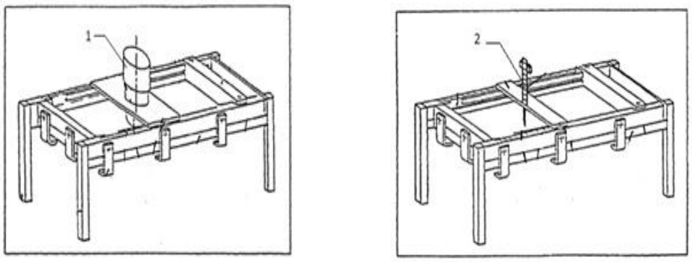


Figure 3. Bagging device: (1) conformator, (2) needle of measurement

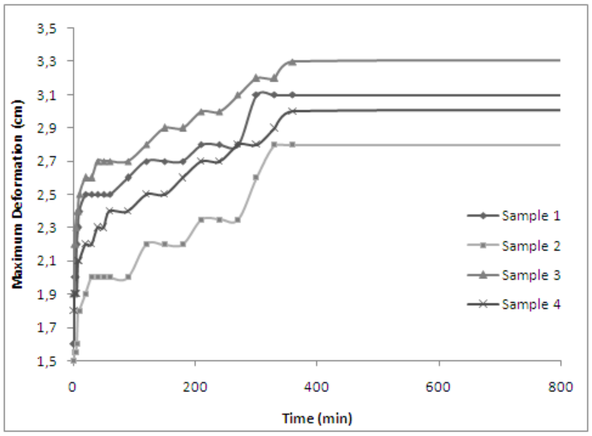
Result and discussion

1. Bagging properties

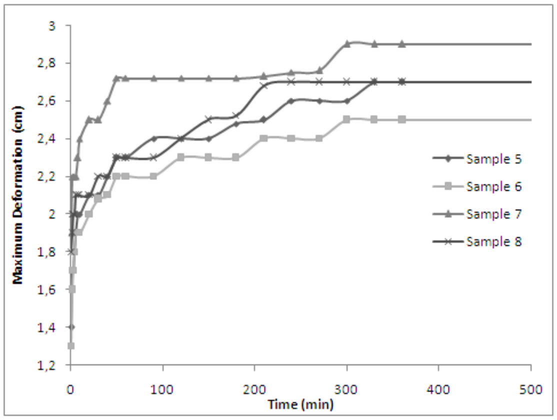
From the preceding strength properties we expect that the polyester knitted fabrics are more resistant to the bagging phenomenon than the cotton knitted fabrics. The deformations in the raw direction will be more important than the deformations in the wale direction.

1.1 Stressed mode

The results given according to the method detailed previously are represented by the figure 4.



(A)



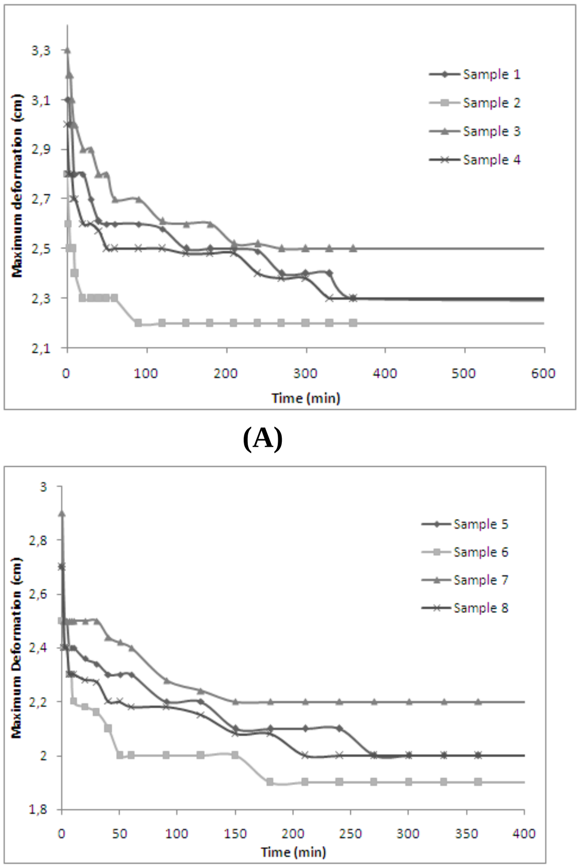
(B)

Figure 4. Variation of Maximum deformation during time: (A): cotton sample, (B): Polyester sample

We can remark that the most important permanent deformation is obtained for samples knitted with the fineness yarn and/or the highest course count. The use of a more fineness yarns generates the decrease of surface weight of the knitted samples having low resistance. However, the augmentation of the course count generates an increase of the stitch length and we obtain a less compact knitted fabric presenting low resistance. These results are checked for the two used materials. Also, we can see that, the deformations of cotton knitted fabrics are more important than those on polyester.

1.2 Recovery mode:

During the recovery period we measured the permanent maximum deformation for each sample. The results obtained are represented in figure 5.



(A)

(B)

Figure 5. Variation of Maximum deformation during recovery period: (A): cotton sample, (B): Polyester sample

We notice that the least weight and/or the least compact knitted fabrics present the most important permanent deformations even after a long period of recovering. Then the permanent deformations of cotton knitted fabrics are more important than those of polyester.

2. Modeling of bagging phenomenon

A model based on rheological study which fit the response of our samples to a multidirectional stress permits to predict the reactions of knit fabrics, choose the percentage of the added elasthan to avoid big permanent deformations. The rheological study shows that the generalized Maxwell model with 4 parameters fit very well the behavior of our samples when they support a multidirectional stress. The model is represented in the figure 6.

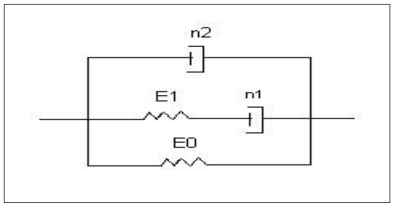


Figure 6. Generalized Maxwell model of 4 parameters

Table 4. The strength properties of the knitted fabrics

	Direction	Maximum Load (N)	Maximum Elongation (mm)	Maximum Elongation (%)	Maximum work (J)
S1	Wale	126,23	39,64	52,85	1,01
	Row	86,88	208,28	277,70	2,42
S2	Wale	165,69	60,89	81,18	2,02
	Row	115,02	147,69	196,92	2,86
S3	Wale	65,42	44,07	58,76	0,57
	Row	70,87	161,98	215,98	1,66
S4	Wale	103,46	50,44	67,25	1,00
	Row	88,55	147,38	196,51	1,98
S5	Wale	299,09	77,82	103,76	6,01
	Row	206,36	204,08	272,10	7,62
S6	Wale	317,70	68,06	90,75	6,48
	Row	188,36	152,36	203,15	6,63
S7	Wale	155,31	66,79	89,06	2,54
	Row	125,52	286,92	382,56	4,13
S8	Wale	195,30	70,85	94,47	2,76
	Row	167,34	170,23	226,98	4,40

Table 5. The model parameters and the linear deviation in the stressed mode

	a_0	a_1	a_2	α	β	Linear deviation
Sample 1	3,1	-5,1	2	2,2	0,05	0,32
Sample 2	2,8	-3,1	0,387	0,86	2,1	0,62
Sample 3	3,3	-1,995	-1,305	0,091	0,776	0,38
Sample 4	3	-1,24	-1,76	0,032	0,916	0,26
Sample 5	2,7	-1,9	-0,8	1,3	0,013	0,066
Sample 6	2,5	-1,8	-0,7	1,26	0,014	0,047
Sample 7	2,9	-2,3	-0,6	1,72	0,017	0,077
Sample 8	2,7	-2	-0,7	2,25	0,015	0,062

Table 6. The model parameters and the linear deviation in the recovery mode

	a_0	a_1	a_2	α	β	Linear deviation
Sample 1	2,3	-1	1,8	0,062	0,055	0,13
Sample 2	2,2	-3	3,6	0,09	0,1	0,24
Sample 3	2,5	-1,2	1,9	0,07	0,068	0,1
Sample 4	2,3	-1,6	2,3	0,068	0,07	0,23
Sample 5	2	-1,2	1,9	0,077	0,068	0,098
Sample 6	1,9	-1,2	1,8	0,077	0,068	0,046
Sample 7	2,2	-1,2	1,9	0,077	0,08	0,071
Sample 8	2	-1,2	1,9	0,077	0,08	0,097

The general equation of the knitted fabric behavior is:

$$\varepsilon(t) = a_0 + a_1.e^{-\alpha.t} + a_2.e^{-\beta.t}$$

a_0, a_1, a_2, α and β are constant expressed according to E_0, E_1, η_1, η_2 and σ_0 which are elasticity modulus, viscosity parameters of knitted samples and initial stress. We use the method of least squares to optimize the calculation of the model parameters and we give these parameters in the table 5 and 6.

3. The study of the influence of the stitch geometry

A study of the bagging phenomenon was carried out on the face and the back of knitted fabrics. With this intention we applied a multidirectional stress to the face and back sample and we calculate the variation of the maximum permanent deformation during time. The results are given by table 7.

Table 7. Maximum deformation in the back and upper faces of the knitted fabrics

	Maximum deformation	
	Back face	Upper face
Sample 1	3,1	3,2
Sample 2	2,8	2,9
Sample 3	3,3	3,6
Sample 4	3	3,4
Sample 5	2,7	2,9
Sample 6	2,5	2,7
Sample 7	2,9	3
Sample 8	2,7	2,8

The application of a multidirectional stress on the knitted fabric face generates more important deformation (the highest value of maximum flexion) than the knitted fabric back for the two types of raw material. The stitch geometry of single knit fabric (jersey) on the face and the back of samples cause this difference of deformations: on the face we observe the stitch wings and on the back we observe the stitch heads and the stitch feet, single knit fabric is rolled up towards the face in the raw direction and towards back in the wale direction.

After the recovery period we obtain the maximum permanent deformations presented in table 8.

According to this table we concluded that although the studied samples recovered a percentage of their deformation, but the maximum permanent deformation remained increasingly more important in the face than in the back. This result is observed for cotton and also for polyester fabrics. The stitch geometry is an important factor to minimize or to maximize permanent deformations in knitted fabrics.

Table 8. Maximum permenant deformation and the percentage of recovery deformation in the upper face and in the back face

Sample n°	Maximum permanent deformation (cm)		Percentage of recovery deformation	
	Back face	Upper face	Back face	Upper face
1	2,3	2,7	25,8%	15.62%
2	2,2	2,4	21.4%	17.24%
3	2,5	3,1	24.24%	13.88%
4	2,3	2,6	23,33%	23,52%
5	2	2,2	25,92%	24,13%
6	1,9	2	24%	25,92%
7	2,2	2,4	24,13%	20%
8	2	2,3	25,92%	17,85%

4. The study of the bagging phenomenon during short periods

The application of the multidirectional stress during 24 hours is not realistic in a daily use, so we decide to minimize the period of the stress application and we measure the deformations after 5 minutes, 15 minutes and 30 minutes. The results are given in table 9.

Table 9. Maximum deformation after short period of stress

	Maximum deformation		
	After 5 min	After 15 min	After 30 min
Sample1	1,4	1,7	1,9
sample 2	1	1,2	1,4
sample 3	2	2,2	2,4
sample 4	2	2,3	2,5
sample 5	1,5	1,6	1,8
sample 6	1,5	1,5	1,8
sample 7	1,9	2	2,2
sample 8	1,8	1,9	2

After 2 hours of a recovery period, the deformations decrease but even after a long period of recovery the permanent deformations obtained following a multidirectional stress during a short period are considered important and awkward for the user.

5. The influence of plating with elasthan

Four cotton/ elasthan and PES/ elasthan plated plain knitted fabrics were produced by using an industrial single jersey circular knitting machine (MV4-3.2 from Mayer & Cie, Diameter=30 inch, gauge=28, total number of feeders=96).

Plating yarn was a 22 dtex elasthan monofilament plated at 1:2 feeders using a Memminger elasthane feeder (MER) and a plating roll fixed on the ground yarn guide.

Elsthan yarn appears in the backside and cotton (PES) yarns in the front side of the plain knitted fabrics as shown in figure 7.

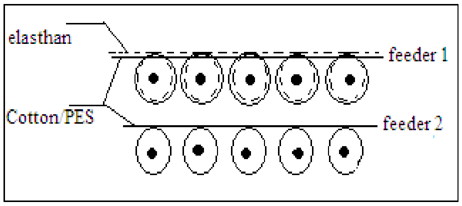
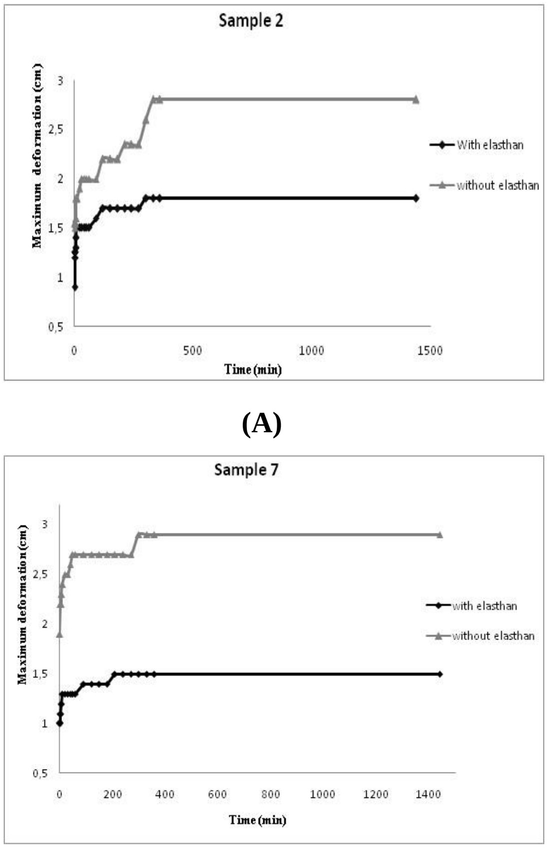


Figure 7. Elasthan plated plain knitted fabric

Elasthan is used in knitted fabrics to have more recovery and to minimize permanent deformations.

The figures 8 and 9 show the effect of elasthan on maximum permanent deformations and in the recovery period.

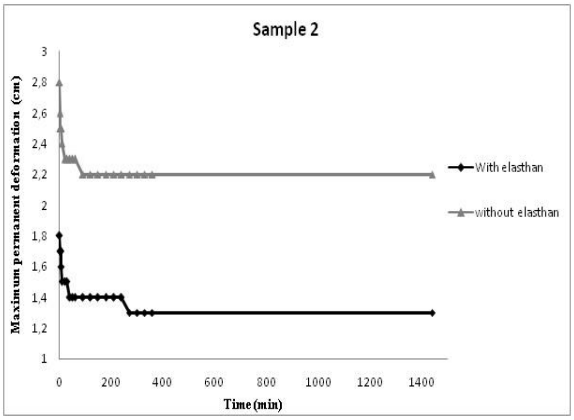


(A)

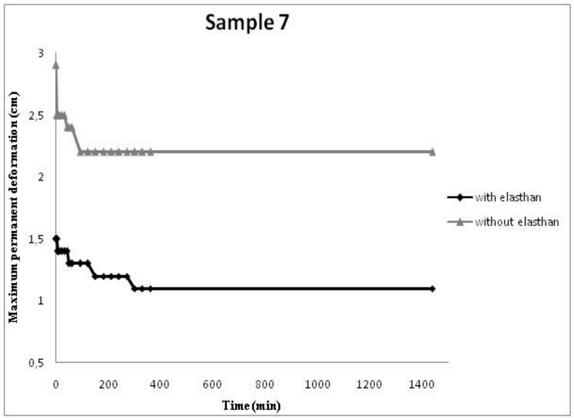
(B)

Figure 8. Variation of maximum deformation during time, (A): cotton sample, (B): Polyester sample during deformation

The results are significant, about 45% of deformations are removed.



(A)



(B)

Figure 9. Variation of the maximum permenant deformation during recovery mode (A): cotton sample, (B): Polyester sample

During recovery period:

About 70% of permanent deformations are canceled with the use of a few percentage of elasthan. The results show that the use of a percentage of elasthan decreases the residual deformation and the bagging volume and increases the knitted fabric recovery ability. Elasthan improves the elastic properties of the textile fabric.

D.L. Munden and Al (1956) shows that the use of the stretch yarn in the knitted constructions carries these properties one stages further, making possible the production of a knitted fabric of sufficiently high extensibility so that, by construction to one or two sizes only, a satisfactory fit over a complete range of sizes is possible. In addition, the relaxed size of the stretch fabric is everywhere smaller than the portion of the body on which it has to fit, thereby eliminating wrinkling at joints and ensuring a comfortable close-fitting garment.

Conclusions

The bagging phenomenon is very uncomfortable for the user, it appears on elbows and knees following the action of these articulations. These stress cause a multidirectional deformation.

In this paper the bagging phenomenon is characterized by two parameters: the maximum deformation and the maximum permanent deformation: the first is measured during deformation and the second is measured after a recovery period. We found a good correlation between the strength properties of the knitted fabric, the knitting parameters and the bagging phenomenon characteristics. We noted that the permanent deformation of the deformation obtained is tiny if the surface weight of the knitted fabric, the yarn count and the elasthan percentage are greater.

Moreover, the bagging volume is more important if we increase the course count of the knitting machine. Therefore the bagging phenomenon depends on the fibers properties and the yarn count. The Maxwell 4 parameters model represents the samples reaction following the application of the multidirectional stress during the deformation and recovery period with good correlations.

The uses of elasthan minimize permanent deformations and perform material recovering.

References

Abghari, R., Najar, S., Hagpanahi, M., Latifi, M. (2004).An improved analysis of bagging of textile fabrics: Part I: theoretical, International Journal of

Clothing Science and Technology, Vol. 16 (issue 5), pp 418-432

Ajeli, S., Ali, A., Jeddi, A., Rastgo, R., Gorga, E. (2009). An analysis of the bending rigidity of warp-knitted fabrics: a comparison of experimental results to a mechanical model, Journal of the Textile Institute, Vol. 100 (issue 6), pp 496-506.

Grunewald, K.N., Zoll, W. (1973). Practical Methods for Determining the Bagging Tendency in Textiles, International Textile Bull, No. 3, pp 273-275.

Jirsák, O., Lukáš, D., Charvát, R. (1993). A Two-dimensional Model of the Mechanical Properties of Textiles, Journal of Textile Institute, Vol. 84 (issue 1), pp 1-15

Karimian, M., Hasani, H., Ajeli, S. (2013). Analysing the Effect of Fiber, Yarn and Fabric Variables on Bagging Behavior of single Jersey Weft Knitted Fabrics, Journal of Engineered Fibers and Fabrics, Vol. 8 (issue 3), pp 1-9.

Merc, B., Gürarda, A. (2002). Proceeding of the XIIth Textile and leather, Romanian Conference, pp 17-19.

Munden,D.L., Fletcher, M. W. A. (1956).Processing and Properties of Knitted Stretch Fabrics, The Journal of the Textile Institute Proceedings, Vol. 47 (issue 8),pp. 638-669.

Nilgün, O. (2008). Stretch and Bagging properties of Denim Fabrics Containing Different Rates of Elastane, FIBRES & TEXTILES in Eastern Europe, Vol. 16 (issue 1), pp 63-67.

Yeung, K.W., Li, Y., Zhang, X., Yao, M. (2002). Evaluating and Predicting Fabric Bagging with Image Processing, Textile Research Journal, Vol. 72, pp 693-700

Youkura, H., Nagae, S., Niwa, M.(1986). Contributions of in-plane fabric tensile properties in woven fabric bagging behaviour using a new developed test method, Textile Research Journal, Vol. 56, pp. 748-754.

Zhang, X., Li, Y. Yeung, K.W., and Yao M. (1999), Textile Research Journal, Vol. 69 (issue 7), pp. 511-518.

Zhang, X., Li, Y., Yeung, K.W. and Yao M. (1999), Fabric Bagging. Part II: Objective Evaluation and Physical Mechanism, Textile Research Journal, Vol. 69 (issue 8), pp. 598-606.

Zhang, X., Yeung, K.W., Yao, M. and Li, Y. (1997), "Factors influencing bagging behavior of woven fabrics", Proc. the 4th Asian Conference, 24-26 June, pp. 512-517.