

# The Effect of Single and Dual-Core Yarns Produced with Different Core Materials on the Elasticity and Recovery Properties of Denim Fabrics

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## ABSTRACT

*Elastic structures are preferred for improving the elasticity and recovery of the fabrics. Bagging, which is a three-dimensional fabric deformation, is an undesirable appearance of fabrics. The lack of dimensional stability or recovery after pressure on the fabrics causes bagging deformation. In recent years, denim manufacturers prefer double-core yarns to cope with the problem of bagging. In this study, various types of weft yarns were produced by using different core materials in different combinations. Double-core and single-core ring-spun yarns (Ne 18,  $\alpha_e$  4,4) were used as weft yarns in weaving. Yarn and fabric samples were conditioned under standard atmospheric conditions and measured according to the related test standards. Yarns were tested and evaluated for important physical and mechanical properties such as evenness, imperfections, tenacity, breaking elongation, hairiness and yarn liveness. For denim fabric samples, all tests were performed after 3 consecutive domestic washing processes. Test results showed that there are significant differences between fabric properties depending on the weft yarn characteristics.*

*By using double-core weft yarns in denim fabric production, consumers can have stretch jeans for improving body movement comfort while exhibiting low growth and shrinkage values.*

## KEYWORDS

*Core yarns, double-core yarns, elasticity, recovery, bagging, denim*

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## INTRODUCTION

Consumers want to look good and feel comfortable in their clothes. The minimum elasticity requirements of the fabrics can be determined with the values of stretch that are encountered during sitting, bending or flexing of knees, hips and elbows. While body is standing at rest, the stretching value is zero and during different actions, back flex is 13-16%, elbow flex (lengthwise) is 35-40%, seat flex is 25-30% and knee flex (lengthwise) is about 35-45%. So, for improving body movement comfort in denim jeans, at least 10-35% elasticity is needed. The amount of extension depends on the end use of the fabric. The percentage of the stretch for loose fitting (comfort stretch) is 30% in course way - 15% in wale way while it is 60% in course way - 35% in wale way for form fitting (semi-support). This is generally accomplished by incorporating elastic fibres into the yarn structure [1]. Depending on body movements, the three-dimensional deformation

occurring in certain parts (knee, elbow etc.) of the garments, known as bagging, is an undesirable appearance [2]. The lack of dimensional instability or recovery after prolonged or repeated pressure on the fabrics causes bagging deformation [3]. In recent years, double-core yarns have begun to be produced, especially for denim jeans, to overcome the mentioned problem.

Core-spun yarns consist of two different components; a staple sheath and a filament core. If the core filament is an elastic polyurethane filament, it is known as "soft-core yarn" whereas if it is a rigid filament, yarns are known as "hard-core (rigid) yarn" on the market. In recent years, alternatively, multicomponent core-spun yarns, called double-core yarns, are developed in order to cope with the recovery problems of elastane. Double-core (dual-core) yarns are composed of three components; an elastic polyurethane filament (such as Lycra<sup>®</sup>, Creora<sup>®</sup> or Inviya<sup>®</sup> I-300) and a multifilament (such as Lycra<sup>®</sup> T400<sup>®</sup>) that are used in the core, which is then covered by a staple sheath. Double-core yarns are used for high quality denim fabrics [4]. Typically, as fabric stretch increases, the tendency for fabric growth or shrinkage increases as well. However, with double-core yarns, by combining elastane and multifilament, higher elasticity and recovery, lower growth and shrinkage values can be achieved [5]. Although it has high production costs compared to soft-core yarns, double-core spun yarns are preferred because of the high value-added denim jeans.

Many researchers have been focused on core-spun yarn properties [6-10]. Sarioğlu and Babaarslan investigated the effects of different filament fineness and yarn count on fatigue behavior of rigid core-spun yarns containing PET textured filament yarn [11]. Telli et al., focused on the usage of core and double-core yarns containing tungsten for electromagnetic shielding [12]. Akankwasa et al. focused on the mechanical properties of cotton/T400<sup>®</sup> knitted fabrics and reported that fabrics knitted from cotton/T400<sup>®</sup> yarns are advantageous in breaking elongation, bursting strength and air permeability compared to 100% cotton yarns [13]. Cataloglu stated that, alternative to elastane, using bi-component polyester fibres and poly butylene terephthalate (PBT) has inspired interest with regarding to higher strength due to better chemical resistance, better recovery, dimensional stability and elasticity properties [14]. Sarioğlu et al. analysed the effect of the false-twist textured polyester-filament yarns with different filament fineness, used as a core component of composite yarn on residual torque [15]. Denim fabrics were produced by using multifilament polyester yarns with different filament numbers and it was reported that yarns that have higher filament number might be problematic concerning elasticity, growth and elastic recovery [16]. Ertaş et al. analysed the effect of the density changes in the use of the double-core threads used in denim fabrics [17]. Bedez Ute analysed the mechanical and dimensional properties of the denim fabrics produced with double-core and core-spun weft yarns with different weft densities [18]. In another study, they investigated the effects of elastane linear density on the mechanical properties of double-core and single-core yarns, spun with different core materials [19].

Many researchers have examined the bagging properties of the fabrics. Ozdil evaluated stretch and bagging properties of denim fabrics containing different rates of elastane [20]. El-Ghezal et al. focused on the effect of elastane ratio and the finishing process on the elasticity of denim made of weft yarns that were cotton covered core-spun yarns containing elastane, having the same twist factor and various elastane ratios [21]. The performance of stretch denim fabrics under the effect of repeated home laundering practices was studied by Kan et al. [22]. Doustar et al. investigated the effect of weave design and fabric weft density on the bagging tendency of woven fabrics using FAST system [23].

In this study, the effects that weft yarn type (double-core, soft-core and hard-core) and core material have on the elasticity and recovery properties of the denim fabrics were investigated.

## EXPERIMENTAL

### Materials and Methods

With the aim of determining the effect of core material and core yarn production methods on the elasticity and recovery properties of denim fabrics, different types of weft yarns were produced. Double-core and core-spun yarns were used as weft yarns in weaving. Core-spun yarns were produced with two components; a staple sheath (cotton) and a filament core (EME, PES or elastan). Double-core (dual-core) yarns were produced from three components; elastane filament and a multifilament (EME or PES) used in the core, covered by a staple sheath (cotton) (Figure 1). The fineness of the first core (elastane) and the second core (PES or EME) are 44 dtex and 55 dtex, respectively. Their draft ratios are 3,4 and 1,06, respectively. 100% cotton Ne 10/1 Ring slub warp yarns were processed in a conventional denim process; which includes rope dyeing, rope opening, sizing etc.

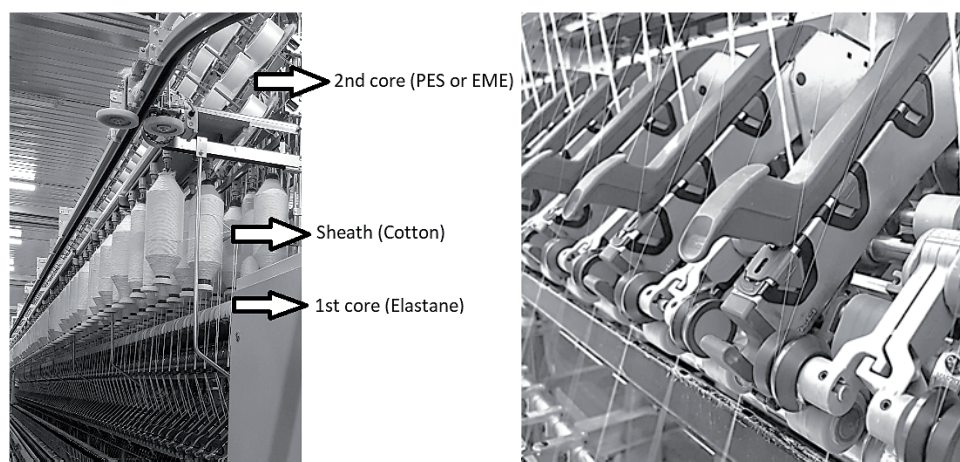


Figure 1. Double-core yarn spinning system

Table 1. Different weft yarns used in denim fabric production

Code	Yarn type	Core type	1 <sup>st</sup> core material	2 <sup>nd</sup> core material
D1	Soft core	Double core	Elastane	PES
D2	Soft core	Double core	Elastane	EME
C1	Soft core	Single core	Elastane	-
C2	Hard core	Single core	-	EME
C3	Hard core	Single core	-	PES

The weaving process was performed with five different weft yarns (Table 1) and the other production parameters were kept constant. Twill 3/1 woven fabrics were treated according to standard denim finishing procedures. Denim fabric production process parameters are given in Table 2.

Table 2. Denim fabric production parameters

Production parameter	Specifications
Warp yarn specifications	Ne 10/1 Ring slub warp yarn, $\alpha_e$ 4.3, 100% cotton Number of warp yarns: 4536
Weft yarn specifications	Ne 18 Ring double-core/ core weft yarn, $\alpha_e$ :4.4, Elastane draft ratio: 3.4 PES and EME draft ratio: 1,06 Sheath material: 100% cotton
Weave type	Twill 3/1 Z
Weft density	20 weft/cm
Reed type	60,8x4, ( The reed number is 60,8 dent/10cm, 4 end/ dent), Fabric width: 170 cm
Fabric finishing process	Washing-(desizing) (80°C with dispersing agent) –drying Finishing (50 g/l PE emulsion+15 g/l nonionic softener+2 gr citric acid for ph) Sanforizing (110°C ~10 sec)

Yarn and fabric samples were conditioned under standard atmospheric conditions ( $65 \pm 2\%$  RH,  $21 \pm 1^\circ\text{C}$ ) and measured according to the related test standards. Yarns were tested and evaluated for important physical and mechanical properties such as evenness, imperfections, tenacity, breaking elongation, hairiness and yarn liveness. Yarn uniformity, the IPI values and yarn hairiness were measured on Uster Tester 5, tensile properties were measured with Uster Tensorapid 4. Fabrics' weight, elasticity, growth and recovery properties were measured before and after three home laundering cycles [24]. Fabric test methods are given in Table 3.

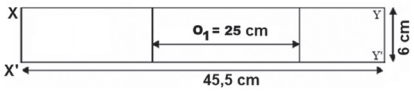
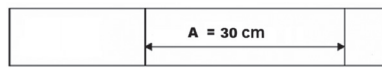
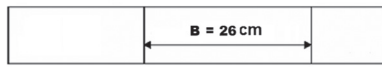
Table 3. Denim fabric tests and methods

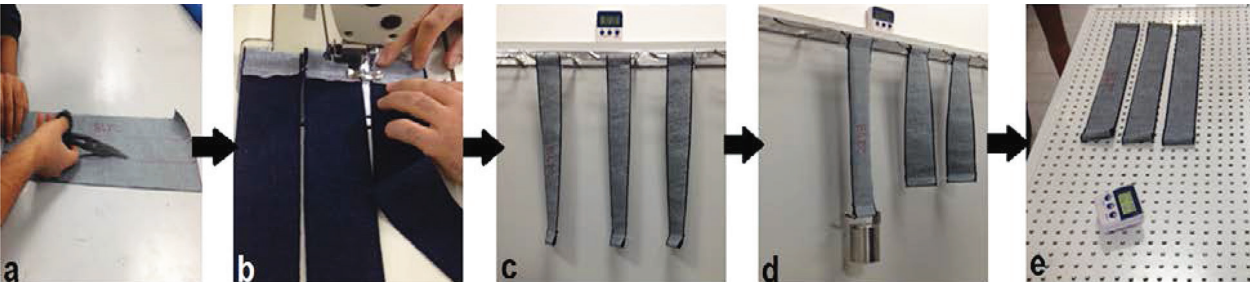
TEST NAME	TEST METHOD	UNWASHED / WASHED
Weight ( $\text{g}/\text{m}^2$ )	ASTM-D 3776-96	UNWASHED & WASHED(3HL)
Elasticity & Growth	ASTM-D 3107-Modified (Weight 3lb)	WASHED(3HL)
Recovery	ASTM-D 3107-Modified (Weight 5lb )	WASHED(3HL)
3 Home Laundry (3HL)	Based on AATCC-135 but Washed in 3*60C'	WASHED(3HL)

\*UW: Unwashed (before finishing treatment), W: Washed and finished

Fabric samples are prepared according to the test method, shown in Table 4, figures a and b. The apparatus used is a stretch testing instrument, which consists of a part with a fixed clamp at the top and a separate clamp to attach the weight at the bottom of the test sample. Two lines with the distance of 25 cm are marked on the sample (O1) and then stretched under tension for a certain time (Table 4, figure c). A mass of 3 lbs (1.35 kg) was used for applying tension to the denim fabric specimen so as to determine the fabric stretch and fabric growth after applying specific tension. Initially, the specimen is cycled three times to the fixed load with each cycle taking 5 s and then the load is hanged for 30 minutes (Table 4, figure d). After applying tension for 30 min (Table 4, figure e), the resulting distance between the lines is measured, which is A (mm). After the tension is removed and allowing 60 minutes for relaxation, fabric growth is found by measuring the relaxed distance between the lines: distance B (mm). Calculations are explained with an example in Table 4.

Table 4. The test method and calculations for measuring fabric stretch (elasticity) and growth

Calculations	An example
Fabric specimen	 $O_1 = 25 \text{ cm}$
Fabric stretch: 30 min after applying tension $e = \frac{100 \times (A - O_1)}{O_1} (\%)$	 $e = 20 \%$
Fabric growth (residual extension): 60 min after relaxation $l = \frac{100 \times (B - O_1)}{O_1} (\%)$	 $l = 4 \%$

## RESULTS AND DISCUSSION

The effects of the core material and weft yarn characteristics on the yarn evenness, yarn hairiness, breaking strength and elongation values, as well as the fabric test results, are given in Table 5 and Table 6. Weft and warp shrinkage values were measured after 3 home launderings.

Table 5. Physical and tensile properties of the weft yarns used in denim fabric production

Code	Thin places -40 %	Thick places +50 %	Number of neps	Uster H	Uster CV %	Tenacity cN/tex (CV %)	Breaking elongation % (CV %)
D1	2	17	17	5,72	8,5	16,73 (6,55)	9,52 (6,57)
D2		7	11	5,64	7,5	15,96 (5,61)	10,41 (5,43)
C1	4	6	11	5,79	8,4	16,47 (5,51)	8,84 (6,69)
C2		9	12	5,82	8,1	16,78 (8,26)	8,78 (16,04)
C3		20	17	5,69	8,6	16,5 (11,91)	8,12 (11,88)

Yarn strength, hairiness, evenness and IPI values of different weft yarns were close to each other and double-core spun yarns containing elastane & EME showed the lowest yarn unevenness, hairiness and strength but the highest breaking elongation values. Similar results were found in the previous studies [15].

Table 6. Denim fabric tests results

Code	Weft density/cm*		Warp density/cm		Fabric weight (gr/m <sup>2</sup> )		Weft shrinkage (%)	Warp shrinkage (%)	No of weft breaks/ 100.000 weft
	UW*	W*	UW*	W*	UW*	W*			
D1	19,7	22	26,8	30	257	307	-15,23	-1,23	1,2
D2	19,5	22	26,9	32,3	254	319	-12,53	-2,8	4
C1	20	22	27,3	33	256	312	-24,2	-3,2	1
C2	19,3	19,2	26,5	29	248	260	-0,0046	-9,8	3,1
C3	19,7	21,3	26,2	27,7	245	272	0,0043	-2,46	5

\*UW: Unwashed (before finishing treatment), W: Washed and finished

Weft and warp densities of the fabrics and fabric weight increased after washing. Denim fabrics' weight values, woven with different weft yarns, were close to each other before washing, but after washing, the fabrics containing EME had the lowest and the EME + elastane based double-core weft yarns had the highest values. As expected, due to higher weft shrinkage values, fabrics produced with weft yarns containing elastane have higher fabric weight and weft & warp densities than hard-core weft yarns. It is remarkable that in general more weft breaks were observed when hard-core weft yarns were used in the production of denim fabric.

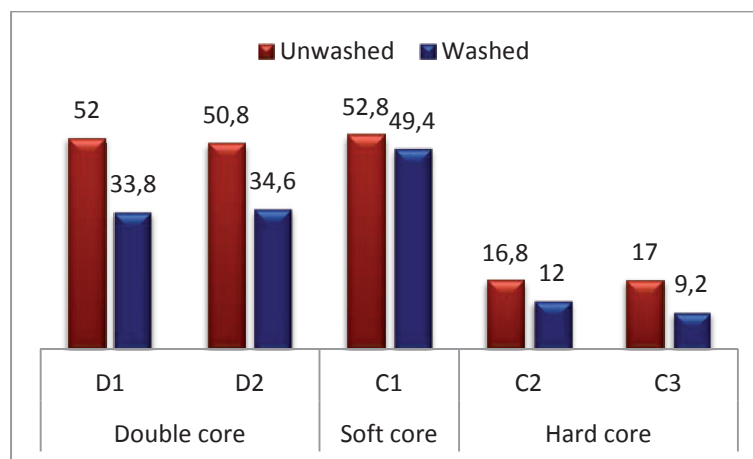


Figure 2. Elasticity (e %) values of the denim fabric produced with different weft yarns

Before washing, denim fabrics woven with weft yarns containing EME had the lowest fabric elasticity and soft-core weft yarns containing elastane had the highest fabric elasticity (Figure 2). After washing, elasticity values of all the samples decreased and again denim fabrics produced with soft-core yarns showed the highest elasticity values, whereas fabrics having core-spun weft yarns containing PES filament in the core showed the lowest values, as expected. The elasticity values of the denim fabrics woven with double-core yarns are found lower than the elasticity values of the fabrics woven with soft-core yarns, although higher than the elasticity values of the fabrics woven with hard-core weft yarns.

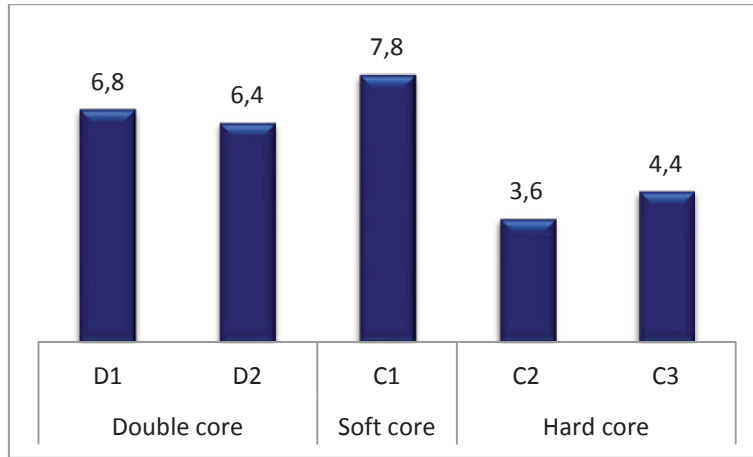


Figure 3. Growth (I/%) values of the denim fabric produced with different weft yarns

However, the high elasticity of the fabrics is not enough for customer satisfaction alone, growth values should also be at the desired level. The growth values of the denim fabrics woven with double-core yarns are found lower than the growth values of the fabrics woven with soft-core yarns. On the other hand, denim fabrics produced with hard-core weft yarns have lower growth values than the fabrics produced with double-core and soft-core weft yarns (Figure 3). Fabrics containing soft-core weft yarns showed the highest growth values whereas EME based core-spun weft yarns showed the lowest values.

## CONCLUSION

Modern consumers want to look good and feel comfortable in their clothes. For this reason, they expect them, especially denim jeans, to provide body movement comfort, allow freedom of movement, reduce burden and body shaping. The opposite is actually contrary to the spirit of denim jeans. In recent years, denim manufacturers prefer double-core yarns because they provide elasticity with the reduced bagging problem. In this study, the effects of weft yarn type (double-core, soft-core and hard-core) and core material on the elasticity and recovery properties of denim fabrics were investigated. It can be concluded that, by using double-core weft yarns in denim fabric production, consumers can have stretch jeans with improved body movement comfort (more than 30% stretch) that exhibit low growth and shrinkage values at the same time. Although double-core yarns have higher production costs compared to soft-core yarns, they are preferred in high quality denim jeans since they give satisfactory results in terms of both appearance and comfort.

### Acknowledgments

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