JTATM
Journal of Textile and Apparel, Technology and Management
Volume 8, Issue 1, Spring 2013

Sewability of Air-jet Textured Sewing Threads in Denim

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ABSTRACT

Sewability of a fabric depends on the fabric low-stress mechanical properties, sewing thread properties and the sewing machine settings. This paper investigates the sewability of denim fabrics stitched with air-jet textured sewing thread. It was found that the fabric formability is dependent on the fabric weight. Fabric formability was higher for the heavyweight fabrics and lower for the lightweight fabrics. The overall bending rigidity was the lowest for the denim with the lowest formability and weight. Polyester air-jet textured sewing threads resulted in higher seam efficiency and seam pucker, but lower needle cutting index compared to Polyester/Viscose air-jet textured sewing thread. In weft direction the seam efficiency was higher, whereas in warp direction the needle cutting index was higher for all the fabrics.

Keywords: air-jet texturing, denim, low-stress properties, sewing thread, sewability

Introduction

Modern high-speed sewing machines require sewing threads of high quality for satisfactory performance. Although, polyester sewing threads have almost replaced cotton sewing threads due to the higher strength and durability, their thermoplastic nature makes them susceptible to change in the properties by the heat generated during sewing [i]. In this respect, the threads with sufficient bulk such as spun and air-jet textured threads are the ideal choice [ii]. The frictional properties of air-jet textured sewing threads are very similar to the spun threads, as the presence of numerous loops gives the effect of spun yarns [i]. In addition, air-jet textured sewing threads provide better locking in the fabric compared to the continuous filament threads [iii]. Air-jet textured sewing threads with variable overfeed in core and surface can be used as potential sewing threads [iv,v]. The strength of the sewing threads depend upon fibre and yarn properties [vi]; and load sharing between the constituent filaments [v]. Air-jet textured sewing threads are the ideal choice for value added garments where seam appearance and seam performance are very crucial.

The market share of denim has increased several folds in the last few decades. In denim garments, sewing threads possess a linear projection on the surface and are subjected to abrasion. Therefore, unless the sewing thread is strong enough, it may break before the denim [vii]. At present, mainly three types of sewing threads namely spun polyester thread, cotton-wrapped poly-core thread and poly-wrapped poly-core thread are used in sewing of denim garments. As the manufacturing processes of these threads are very costly, air-jet textured sewing threads are the economical option available to reduce the garment cost. The seam efficiency achieved by using air-jet textured threads is higher than cotton and it is very close to spun polyester thread. Uniformity characteristics of air-jet textured sewing threads are far superior to those of cotton and spun polyester threads [ii]. In the present paper, the sewability performance of two types of air-jet textured sewing threads in denim garments has been analyzed.

Experimental

Materials

Polyester and viscose parent yarns, having the properties as shown in Table 1, were selected to produce the air-jet textured yarns. These two yarns were blended during air-jet texturing by feeding four packages simultaneously to the jet. Initially, all four packages were of polyester yarn and then two polyester yarn packages were replaced by two viscose yarn packages to produce 100% polyester (PET) and 50:50 blends of polyester and viscose (PV) air-jet textured yarns respectively. Both the air-jet textured yarns were then doubled on a ring doubler with 8 twists/inch for the preparation of sewing threads.

Table 1. Properties of parent yarns

Yarn type	Yarn tex	No. of filaments	Tenacity (gm/tex)	Strain at break (%)	Modulus (gm/tex)
Viscose	8.4	24	26.74	12.44	560.4
Polyester	8.7	34	42.86	24.01	497.3

In order to cool the needle during sewing and hence minimize the thread breakage, a commercial spin finish of silicone base (Clearco 326) was applied on sewing threads with 3% concentration during winding. The details of PV (T1) and PET (T2) air-jet textured sewing threads are given in Table 2.

Table 2. Dimensional and tensile properties of air-jet textured sewing threads

Sewing thread code	Number of plies	Yarn tex	Tex ticket number	Tenacity (gm/tex)	Loop strength (gm/tex)	Knot strength (gm/tex)	Strain at break (%)	Modulus (gm/tex)
T1	2	102	90	23.75	38.98	17.61	16.29	280.1
T2	2	102	90	35.04	56.96	24.90	30.01	257.2

Six different denim fabrics produced by Pioneer Denim of India and commonly used constructional parameters for clothing were selected for the current study. The details of these fabrics are given in Table 3.

Table 3. Fabric constructional parameters and dimensional properties

Areal density (g/m^2) Nominal	Actual	Weave	Fabric code	Fabric sett E/cm	P/cm	Yarn count (Ne) Warp	Weft	Fabric thickness (mm)	Crimp (%) Warp	Weft	Cover factor Warp	Weft	Cloth
477	506	1/3 Twill	F1	28	18	7.3	6.4	1.16	29.9	9.6	26.6	17.8	27.5
317	361	1/2 Twill	F2	27	16	9.0	10.3	0.81	22.9	5.8	23.0	12.8	25.3
468	471	1/3 Twill	F3	24	19	6.8	5.7	0.84	19.8	11.4	23.4	20.1	26.7
452	439	1/3 Twill	F4	30	19	7.4	7.7	1.02	27.4	6.9	25.6	16.9	27.8
207	223	1/2 Twill	F5	33	19	17.3	18.7	0.52	23.1	11.3	20.4	11.1	23.4
207	192	1/2 Twill	F6	32	18	16.0	15.9	0.48	14.0	13.4	20.5	11.3	23.5

Methods

The yarn count and tex ticket number were measured as per ASTM-D 1059 and ASTM-D 3823 test methods respectively. The breaking strength and elongation, loop strength and knot strength were measured according to ASTM-D 204 method, on the Instron tensile tester. The gauge length was kept at 500 mm and a jaw traverse rate of 300 mm/min was used. The fabric thickness was measured according to ASTM-D 1777 method on the R & B cloth thickness tester. Fabric weight was measured with the help of a round cutter and an electronic weighing balance as per ASTM-D 3776. End and pick densities were measured by using ASTM-D 3775 method. Warp and weft crimps were measured by ASTM-D 3883 method. The fabric breaking load and elongation were measured according to the ASTM-DI683 method.

Measurement of Fabric Low-stress Mechanical Properties

The low-stress mechanical properties of the denim fabrics were tested on FAST (Fabric Assurance by Simple Testing) system. Surface thickness and released surface thickness were measured on FAST-1 at loads of 2 g/cm^2 and 100 g/cm^2 respectively. The bending rigidity of the fabrics was calculated on FAST-2. The extensibility in warp and weft direction was measured on FAST-3 at a load of 100 g/cm width. Fabric formability was calculated from the fabric extensibility values at low loads of 5 g/cm (E5) and 20 g/cm (E20) on FAST-3. The shear rigidity of the fabrics was calculated by using the fabric bias extensibility (45° to warp & weft direction) value on FAST-3 at a load of 5 g/cm width. The dimensional stability of fabrics was evaluated in terms of relaxation shrinkage and hygral expansion on FAST-4.

Sewing

A Singer industrial lockstitch sewing machine (Model 191 D 200AA) was used for stitching the denim samples with the following conditions:

Machine speed : 2500 stitches/min
Seam geometry : plain lock stitch seam
Stitch density : 8 stitches/inch
Seam allowance : 1 inch
Needle size (Singer system) : 16 and 18 for lighter and heavier denims respectively.

Evaluation of Sewability

The fabric sewability was evaluated by measuring seam parameters such as seam efficiency, seam slippage, seam pucker and needle cutting index. The seam efficiency was measured according to the ASTM-D 1683 test and it was calculated using the following formula:

$$Seam\ efficiency(\%) = \frac{Seam\ tensile\ strength}{Fabric\ tensile\ strength} \times 100$$

The seam slippage was tested as per ASTM-D1683 at a gauge length of 75 mm and traverse speed of 300 mm/min. The load-elongation curve of a fabric (Figure 1) without seam was superimposed over the load-elongation curve of the same fabric with a standard seam sewn parallel to the yarns being tested. The load at which both the load-elongation curves differ by a predetermined distance (6 mm for apparel fabrics) is the measure of resistance to seam slippage. Higher load indicates the fabric is more resistant to seam slippage.

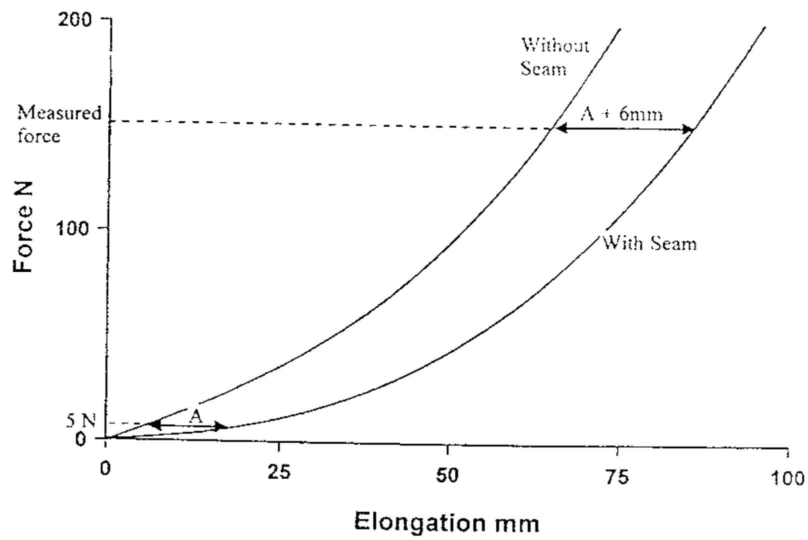

Figure1. **Load-elongation curve for seam slippage**

The seam pucker was determined by measuring the difference in fabric and seam thickness under a constant compressive load. The thickness strain was calculated by using the following formula:

$$Thickness\ strain(\%) = \frac{S - 2F}{2F} \times 100$$

Where S = Seam thickness and F = Fabric thickness.

The seam damage was measured according to ASTM-D 1908 method for needle related damage due to sewing in woven fabrics. The number of threads cut by the needle action was counted on Mitsubishi Micro Watcher with a magnification of 500. The needle cutting index was calculated by using the following formula:

$$Needle\ cutting\ index(\%) = \frac{Number\ of\ yarns\ cut/inch}{Number\ of\ yarns\ in\ fabric/inch} \times 100$$

Results and Discussion

Tensile Properties of Sewing Threads

Table 2 shows the tenacity, loop strength, knot strength, breaking strain and modulus of both air-jet textured sewing threads. It can be observed that PET sewing thread (T2) shows higher tenacity, loop strength, knot strength and breaking strain as compared to PV sewing thread (T1). This may be due to higher tenacity and extensibility of PET parent yarn as compared to PV parent yarn. It is also observed from the results that the modulus of PET air-jet textured sewing thread is lower than PV air-jet textured sewing thread. This is due to higher extensibility of PET air-jet textured sewing thread for a given load as compared to PV thread.

Fabric Tensile Properties

Fabric tensile properties such as breaking strength, breaking elongation and flexural rigidity are given in Table 4. The results show that the breaking strength and breaking elongation of the fabrics in the warp direction increases with the increase of fabric aerial density. In weft direction no specific trend has been observed. It may be also observed that all denim fabrics have high breaking strength and breaking extension in the warp direction as compared to weft direction. This may be due to higher warp crimp values as compared to weft crimp. The flexural rigidity increases with the increase of fabric aerial density and it is substantially higher for heavy weight fabric than the lightweight fabrics.

Table 4. Mechanical properties of fabrics

Fabric code	Areal density (g/m^2)	Breaking Strength (Kgf)		Breaking extension (%)		Flexural rigidity (µN.m)
		Warp	Weft	Warp	Weft	
F1	506	85.86	57.94	43.67	19.24	106.93
F2	361	55.07	29.77	34.71	11.31	51.75
F3	471	80.99	61.60	38.73	21.67	103.50
F4	439	79.73	42.70	36.40	11.91	90.96
F5	223	30.58	19.67	30.71	16.93	22.38
F6	192	28.04	14.10	14.53	16.27	11.21

Fabric Low-stress Mechanical Properties

In garment making process a fabric is deformed in a number of different ways such as bending, extension, longitudinal compression and shearing in the fabric plane at very low loads. These deformations are imposed to form the three-dimensional shapes that are required in most structured garments. The response of fabric to these stresses varies with the type of fabric, its construction and the methods used in finishing. These variables determine the fabric tailorability and the appearance of the garments in wear. FAST system measures the physical and dimensional properties of a fabric that can be used to predict performance in garment manufacture and the appearance of the garments in wear. The fabric physical and dimensional properties measured on FAST system are described in Table 5.

Table 5. Fabric low-stress mechanical properties measured on FAST system						
Property	Fabric samples					
	F1	F2	F3	F4	F5	F6
RS-1	0.80	0.80	0.40	0.40	0.80	0.80
RS-2	0.40	0.40	0.40	0.80	0.40	0.80
HE-1	0.80	0.80	0.40	0.40	0.40	0.80
HE-2	0.80	1.20	0.40	0.80	0.80	0.80
F-1	8.02	3.52	7.32	6.36	1.73	0.33
F-2	1.81	0.60	1.31	1.19	0.58	0.53
E100-1	3.80	2.10	2.00	2.40	3.10	2.00
E100-2	2.10	1.50	2.50	2.00	4.00	5.10
B-1	314.30	172.70	239.30	211.50	63.70	16.00
B-2	89.80	25.40	81.80	43.80	10.70	7.30
G	524.00	217.00	434.00	671.00	87.00	54.00
ST	0.291	0.226	0.279	0.278	0.186	0.209
STR	0.300	0.333	0.318	0.281	0.204	0.298

Relaxation Shrinkage (RS)

Relaxation shrinkage is the irreversible change in the fabric dimension associated with the release of extensional or compressional strains within a fabric that were not permanently set during finishing. Both excessive and insufficient values of relaxation shrinkage can create problems in tailoring [viii]. From Table 5, it may be observed that the overall relaxation shrinkage values are the lowest in denim F3 and highest in denim F6. The warp relaxation shrinkage (RS-1) is lowest in denims F3 and F4 and the weft relaxation shrinkage (RS-2) is highest in denims F4 and F6. In all the fabrics, different warp and weft relaxation shrinkage values have been observed and also no specific trend has been observed. This is due to differences in fabric constructional parameters and differences in recovery of fibers strained during fabric manufacturing. The results of FAST system suggest that the pleating of the fabric having low relaxation shrinkage value is difficult.

Hygral Expansion (HE)

Hygral expansion is the reversible change in fabric dimension associated with the absorption and desorption of water. The hygral expansion value depends on degree of fiber swelling due to humidity variations [viii]. A high value of hygral expansion can lead to loss of appearance in humid conditions as the fabric increase in dimensions under such conditions. The seam can also pucker in these conditions as the sewing thread prevents relative movement of the fabrics [ix]. It may be observed from the results that overall hygral expansion values are lowest in denim F3 and highest in denim F2. Among all the fabrics, the maximum value of hygral expansion has been observed in the weft direction of denim F2 (HE2). It may be also noticed that all fabrics have different warp and weft hygral expansion values and no specific trend has been observed. This may be due to different response of fabrics to moisture as a result of different constructional parameters.

Formability (F)

Fabric formability can be calculated by multiplying fabric extensibility and fabric bending rigidity. This parameter measures the degree of compression sustainable by a fabric in a certain direction before the fabric buckles. The lower is the formability the more is the seam pucker, as the fabric is unable to accommodate the small compression placed on the fabric by the sewing thread [x,xi]. From Table 5, the higher values of warp formability (F-1) and weft formability (F-2) have been observed in denim F1. The results also show that the value of overall formability is lowest in denim F6. It may be also noticed that formability is higher for heavyweight fabrics and lower for lightweight fabrics. This may be due to the fact that heavyweight fabrics have more rigidity, which increases the in-plane compressional resistance. Also it has been observed that the formability in warp direction is higher than that of weft direction which may be attributed to higher end density which helps to increase the in-plane compressional resistance.

Extensibility (E)

Extensibility is the measure of fabric extension at a given load. During garment making-up, in particular fabric shaping and sewing, the fabric needs to be stretched to a certain degree to confirm to the intended shape. In FAST system, the value of extension at a load of 100 gf/cm is used as the measure of extensibility. This ability of a fabric to stretch at low load is of major concern to tailors [viii]. From the results (Table 5) it may be observed that among all the fabrics, the value of overall extensibility is lowest in denim F2. The lowest values of warp extensibility (E100-1) have been observed in denims F3 and F6. Also the lowest values of weft extensibility (E100-2) have been observed in denims F2 and F4. The low extensibility can be attributed to the lower crimp in the fabric. The results of FAST system suggest that in case of fabrics with low warp extensibility, problems can arise with overfeed seams and also it is difficult to mold the fabric. These results further suggest that low weft extensibility can cause decreased fabric handle.

Bending Rigidity (B)

Bending rigidity is a measure of the couple required to bend the fabric. This fabric property is related quite closely to fabric weight and thickness. Heavier and thicker fabrics have higher bending rigidity. Fabrics with low bending rigidity may exhibit seam pucker and cause problems in cutting. They are difficult to handle on an automated production line. A fabric with a higher bending rigidity may be more manageable during sewing, resulting in a flat seam but may cause problems during molding [vii]. From Table 5, it may be observed that the overall bending rigidity is lowest in denim F6 due to its lowest formability and weight. The highest value of both warp and weft bending rigidity has been observed in denim F1. It can be attributed to the highest weight and thickness of the fabrics. The results of FAST system also suggest that except F6, molding of all denims may be difficult due to their higher bending rigidity.

Shear Rigidity (G)

The fabric shear rigidity is the ability of a two-dimensional fabric to form a three-dimensional garment, which can be estimated from the bias extensibility. Fabrics having lower shear rigidity values deform so easily that it may cause problems in handling, laying-up and sewing. The higher value of shear rigidity causes problems in molding and discomfort in wearing. It may be observed from Table 5 that denim F4 gives maximum shear rigidity value. This can be attributed to its highest fabric cover factor which prevents the rotation of the threads at crossover points with the low load applied during shear. The results of FAST system also suggest that except denim F6, molding of all denims may be difficult due to their high shear rigidity.

Surface Thickness (ST)

Surface thickness is the difference in thicknesses of a fabric measured at pressures of 2 gf/cm^2 (0.196 kPa) and 100 gf/cm^2 (9.81 kPa), respectively. This gives information about the hairiness or surface bulk of the fabric and can be used to check more closely the consistency of fabrics that have any type of surface treatment, e.g. brushing, milling, cropping or singeing. It has been observed from the results that surface thickness is highest for denim F1 and lowest for denim F5. The highest surface thickness value of denim F1 may be because of its highest weight and thickness.

Also this can be attributed to the higher amount of compressible fiber or pile on the surface of the fabric.

Released Surface Thickness (STR)

Released surface thickness is the measure of surface thickness after the fabric has been exposed to steam or water. It provides a measure of the stability of the finish on a fabric. The larger the values of released surface thickness, the less stable is the finish. This measurement is important in determining the extent of subsequent changes in appearance and handle of the fabric after garment pressing and can indicate the potential re-emergence of such things as running marks [xi]. It can be noticed from Table 5 that the value of released surface thickness is higher for denim F2 and lower for denim F5. No suggestion has been observed from the results of FAST system. However, higher values of released surface thickness of denim F2 can cause poor finish stability, poor appearance retention, re-emergence of running marks or cracking and distortion of fabric.

Sewability

Sewability is defined as the ability and ease with which fabric components can be qualitatively and quantitatively seamed together, to form a garment [xii]. The characteristics of a good quality seam are its strength, elasticity, stability and appearance. These qualities were measured by seam parameters such as seam efficiency, seam pucker, seam slippage and needle cutting index.

Seam Efficiency

The retention of strength in a seamed fabric after sewing with respect to the original fabric strength is measured in terms of seam efficiency. From the results (Table 6), it can be observed that seam efficiency decreases with the increase in fabric tensile strength in both warp and weft direction and incase of both the sewing threads. This is because seam efficiency is inversely proportional to fabric strength. In some lightweight denims the values of seam efficiency have been observed more than 100%. This is due to early occurrence of fabric failure than the seam. Lower seam efficiency has been observed in heavyweight denims as compared to lightweight denims as heavy weight fabrics have higher bending rigidity values, which causes increase in fabric strength and hence decrease in the seam efficiency. It may also be observed that warp and weft seam efficiency largely depend on the mass value or fabric cover in the respective direction. Among all fabrics, denim F1 has higher mass value in warp direction and F3 has highest mass value in weft direction, which gives lowest warp and weft seam efficiency respectively. It has been further observed that fabrics sewn with PET air-jet textured sewing thread (T2) have higher seam efficiency values as compared to fabrics sewn with PV air-jet textured sewing thread (T1). This is due to higher tenacity of PET air-jet textured sewing thread as compared to PV air-jet textured sewing thread.

Table 6. **Seam efficiency (%) of fabric samples**

Sewing Thread	Direction	Fabric samples F1	F2	F3	F4	F5	F6
T1	Warp	52.65	75.19	55.10	54.59	90.31	92.43
	Weft	79.93	93.96	70.88	91.99	98.25	114.57
T2	Warp	63.75	89.54	72.70	68.92	117.63	94.97
	Weft	90.54	100.09	87.13	96.77	104.78	110.99

Seam Slippage

Seam slippage is the partial or complete loss of seam integrity because of the yarn slippage parallel to stitch line. It is indicated by the load required to separate the seam by a certain distance. Higher load indicates the fabric is more resistant to seam slippage or the seam slippage is less. The results for seam slippage are given in Table 7. It may be observed from the results that denim F1 shows highest resistance to seam slippage with both the sewing threads. This may be due to better interlooping of the sewing thread with the fabric (F1) of higher weight and thickness. It has been also observed that the lighter denims F5 and F6 show less resistance to seam slippage. It may also be noticed that all denims are highly resistance to seam slippage (zero slippage) in warp direction when sewn with PV air-jet textured sewing thread (T1). This is due to higher warp cover factor of fabrics and lower extensibility of the sewing thread does not allow the yarns to slip. It can be observed that fabrics sewn with PET air-jet textured sewing thread (T2) in weft direction give less seam slippage (indicated by higher load) than the fabrics sewn with PV air-jet textured sewing thread. This is because of better compatibility of PET air-jet textured sewing thread in weft direction as compared to PV air-jet textured sewing thread.

Table 7. Seam slippage (Kgf) of fabric samples

Sewing Thread	Direction	Fabric samples F1	F2	F3	F4	F5	F6
T1	Warp	–	–	–	–	–	–
	Weft	–	21.84	–	–	14.09	8.85
T2	Warp	–	32.74	55.93	35.83	22.55	16.28
	Weft	38.59	23.4	36.39	32.6	17.26	11.56

– indicates no seam slippage at maximum load. Higher the load, more is the resistance to seam slippage.

Seam Pucker

Seam pucker refers to the gathering of the seam either just after sewing or after finishing/ laundering causing an unacceptable seam appearance. It is estimated by measuring the percentage increase in the thickness of a seamed fabric over the original fabric under a constant load. It may be observed from the results (Table 8) that the puckering consistently decreases with the increase in fabric weight and thickness. This may be due to the increase in in-plane compressional resistance and flexural rigidity of the fabrics with the increase in weight which helps in reducing the seam pucker. It may be also observed that the fabrics sewn with PET air-jet textured sewing thread (T2) give higher puckering values than the fabrics sewn with PV air-jet textured sewing thread (T1). This may be due to higher extensibility of PET air-jet textured sewing thread, compared to PV air-jet textured sewing thread which causes more differential shrinkage in the fabric and hence more puckering.

Table 8. **Seam pucker (%) of fabric samples**

Sewing Thread	Fabric samples F1	F2	F3	F4	F5	F6
T1	7.69	21.12	11.01	14.67	33.98	38.74
T2	14.34	25.14	15.16	20.80	35.04	39.37

Needle Cutting Index

Needle cutting index is the damage of warp and weft threads because of the needle action. It is objectionable in the fabric as it may result in reduced seam strength or poor appearance or both due to frayed yarns. The needle cutting index depends on the fabric weave, cover factor, stitch density, thread diameter and surface properties of the thread. The results for needle cutting index are shown in Table 9. It may be observed that damage along the warp direction is high as compared to weft direction due to higher warp cover. It may be further observed that the fabrics sewn with PV air-jet textured sewing thread give higher damages than the fabrics sewn with PET air-jet textured sewing thread. This may be due to low frictional surface of PV air-jet textured sewing thread as compared to PV air-jet textured sewing thread. No specific trend has been observed with fabric weight or fabric sett.

Table 9. Needle cutting index (%) of fabric samples

Sewing Thread	Direction	Fabric samples					
		F1	F2	F3	F4	F5	F6
T1	Warp	7.76	5.23	5.55	7.47	5.20	5.37
	Weft	5.37	4.38	3.78	3.39	4.19	3.62
T2	Warp	3.89	3.48	4.92	6.14	4.96	3.67
	Weft	2.95	4.07	3.39	2.11	3.35	2.25

Conclusions

This research investigated the sewing performance of air-jet textured sewing threads in denim. Fabric formability was higher for heavyweight fabrics and lower for lightweight fabrics. The overall bending rigidity was lowest in the denim with lowest formability and weight. The shear rigidity was highest for the fabric with higher cover factor while the surface thickness was highest for the fabrics with higher weight and thickness. Polyester air-jet textured sewing threads resulted in higher seam efficiency and seam pucker but lower needle cutting index compared to PV air-jet textured sewing threads. Seam efficiency was higher in weft direction while needle cutting index was higher in warp direction for all the fabrics. Seam efficiency was dependent upon the fabric strength, whereas seam slippage and seam pucker were dependent upon the weight and thickness; and the needle cutting index was dependent upon the fabric cover and surface friction of sewing threads.

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