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PROPERTIES OF STRETCHABLE COVER SPUN YARNS DEVELOPED FROM LYOCELL AND SPANDEX

Swati Sahu*, Alka Goel
* Research Scholar, G.B. Pant University of Agri. & Tech., Pantnagar
Professor G.B. Pant University of Agri. & Tech., Pantnagar

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ABSTRACT
Present paper reports the effect of change of spandex denier on the properties of stretchable lyocell-spandex cover spun yarn. The core component was spandex with 20D and 40D while sheath consisted of lyocell yarn; eco-friendly regenerated cellulosic yarns. The stretchable cover spun yarns were produced in a hollow spindle spinning frame. ANOVA was applied to study the significant effect of presence of spandex as well as effect of variation in denier of spandex was also noted. It was observed that yarn count, tenacity, breaking strength, elongation and imperfection of yarn was influenced due to presence of spandex. However, change in the denier of spandex affected all parameters except tenacity and unevenness.

KEYWORDS: Eco-Friendly Regenerated Cellulosic Fiber, Lyocell, Spandex, Cover Spun Yarn, Hollow spindle spinning frame.

INTRODUCTION
Pollution has detrimental effects not only on environment but also effects the health of human being. Production, manufacturing, utilization and non-decomposition of products are the main causes of pollution generation. Production of crops, manufacturing of fibers/fabrics, and utilization of coal in power generation and non-decomposition of polythene are the examples of various sectors causing pollution. Amid different sectors, textile is one of the largest polluting sector. Various researches and efforts have been made in direction to confiscate the tag of largest polluting sector from textile industry. Use of natural fibers, eco-friendly dyes, recyclable and non-hazardous chemicals are certain steps taken by producer/manufacturer to diminish pollution generation or to make the product eco-friendly.

Lyocell is one such eco-friendly regenerated cellulosic fiber developed by using chemicals which are 99.9% recyclable. It was manufactured by Acordis Cellulosic Fibers (Netherlands) and Lenzing (Austria) in 1989. Lyocell word is an amalgamation of Lyo and cell. Lyo letters comes from the Greek word lyein meaning dissolve and cell comes from cellulose. This name was recognized as the generic name by BISFA (International Bureau for the Standardization of Rayon and Synthetic Fibers, Brussels) and the Federal Trade Commission (USA). According to **Nergis and Beceren (2008)** it is different from other regenerated cellulosic fibers and conventional cellulosic fibers as it is only known standalone fiber which is eco-friendly. Apart from many similar properties of cellulosic fibers, it absorbs water perfectly and gives hygienic properties to textiles due to its cellulosic nature. After viscose and modal, lyocell is the third generation of man-made cellulosic fiber. It is designed to satisfy the need for a product that provides the comfort and luxury of a natural fiber, with the engineered finish of a man-made fiber.

The initial material for lyocell and viscose are the same, i.e. wood pulp, but their manufacturing processes are different. Lyocell fiber is manufactured by direct dissolving process using an organic cyclic polar solvent N-methyl morpholine-N- oxide (NMMO) whereas rayon is manufactured from a cellulose derivative that is chemically regenerated during the spinning process. In lyocell process the solvent is recycled eliminating the chemistry of the viscose process which uses caustic soda, carbon disulfide, and sulfuric acid to dissolve the pulp.

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According to **Borbely (2008)** Lyocell fibers are stronger than any other cellulosic fibers, especially when wet. These fibers are easy to spin in pure form or blended and capable of producing fine yarn. It absorbs more moisture at 20°C and 65% relative humidity. Fabrics developed from these fibers are benefited with high dimensional stability during washing and good thermally stability. It provides comfort in both psychological and physiological level. Good appearance, vibrant colour and unique drape make the fabric standalone among different regenerated cellulosic fibers. However despite having better properties than other cellulosic and regenerated fibers it lacks elasticity, like all the other cellulosic fibers.

Nowadays elasticity in fabrics is a prerequisite for fashionable apparel which provides better fitting, unhindered body movement and emphasis the body shape. Elasticity in fabrics can be achieved by incorporating elastomeric fibers viz. natural rubber, spandex, etc. According to **Boliek & Jensen (2009)** elastomeric fibers can be made from natural or synthetic polymeric materials that provide product with high elongation, low modulus, and good recovery from stretching. These fibers are made primarily from polyisoprenes (natural rubber) or polyurethanes and to a lesser extent, segmented polyesters. Among different elastomeric fibers, elastane fibers, better known under the trade name of lycra, spandex and dorlastan, reached the highest peak of consumption in textile industry. In-chemical terms, spandex is a synthetic linear macromolecule with a long chain of at least 85% of segmented polyurethane along with the alternating hard and soft segments linked by urethane bonds –NH-CO-O-. Soft chain are responsible for elasticity whereas hard chain provides intermolecular force and ensures a certain level of strength of fiber and long term stability.The bare spandex filaments are used in stretch fabrics, foundation garments, swim wears and hosiery. The stretchable yarns are produced by core sheath method using different spinning techniques like modified ring spinning, siro spinning, air jet spinning, hollow spindle spinning, friction spinning and rotor spinning. **(Das & Chakraborty, 2013).** Yarns developed through these spinning techniques are used in knitting, weaving and nonwovens of fabrics **(Goswami *et al*., 2005)**. Spandex filaments are compatible with different fibers like cotton, bamboo, viscose, wool, silk, polyester, etc.

In the present investigation hollow spindle spinning frame was used to cover spandex filament with lyocell sheath. High production speed and cost effectiveness of hollow spindle spinning frame were the main reasons for its selection. Hollow spindle spinning frame also provides the benefit of two yarns in a single yarn as it wrapped helically one yarn over the another, forming a composite yarn. Study was conducted with two deniers of spandex filament i.e. 20D and 40D in order to see the effect of count of core on the properties of developed yarns. The tested properties of pure lyocell yarn (Ly) and developed cover spun yarns were compard and discussed under heading of results and discussion. The Ly_{sp20} indicates cover spun yarn containing lyocell as sheath and 20D spandex as core whereas Ly_{sp40} have 40D spandex as core with lyocell yarn as sheath.

MATERIALS AND METHODS

Purchase of raw materials: Lyocell spun yarn of count 40/1 Ne was purchased @ Rs 340/kg from New Delhi. Spandex filaments were acquired from Kanpur @ ₹350/kg for 20 denier and ₹400/kg for 40 denier.

Parameters of hollow spindle wrapping machine: Cover spun yarns were produced using following hollow spindle machine setup which are given in the Table 1.

Table 1: Parameters of hollow spindle wrapping machine

S.No	Parameters	Hollow spindle wrapping machine
1	Spindle speed/wrapping speed (rpm)	6760
2	Take up speed (rpm)	67
3	Throwing speed (rpm)	32
4	Draft ratio	32/67
5	Stretch ratio of spandex	1:3 i.e 300%

Development of lyocell spandex cover spun yarns: The yarn used as sheath i.e lyocell yarn was first transferred from cone to double flange bobbin using reeling machine. The filament used as core was directly fed from cone under tension. Through different trials, a suitable spindle speed was decided on the basis of yarn strength and frequency of breakage of yarn during production. Filament was drawn off the upper end of the double flange bobbin and passed through nip rollers forming core-sheath type wrapped yarn. These yarns were transferred into cones using winding machines.

Testing of Developed Yarns: The developed cover spun yarns were subjected to evaluation with their respected properties like count, evenness, twist per inch, tenacity and elongation as per standard procedures.

Yarn count

Yarn count is a numerical expression, defines thickness/fineness, also known as linear density or yarn number. In the present investigation, a lea of 120 yards was made using wrap reel and weighed. The yarn count (Ne) was calculated using following formula:

$$\text{Yarn count (Ne)} = \frac{64.8}{\text{weight of a lea of 120 yards of yarn}}$$

Yarn evenness

Yarn evenness is defined as the variation in weight per unit length of the yarn or change in its thickness or degree of uniformity of a product like neps, thick and thin places. The unevenness and total imperfection of yarn samples were measured by Premier iQ2, India unevenness tester. Total ten readings were taken and an average was calculated by attached computer. Readings were expressed in percentage.

Twist per inch

The twist is usually expressed as turns per unit length i.e. turns per meter or turns per inch **(Saville, 1999)**. In the present investigation, yarn twist was determined by untwist and twist procedure as directed in ASTM D-1422: 99. The average twist per inch was calculated from 10 readings.

Yarn strength and elongation

The end use of any yarn is majorly determined by its strength. Yarn strength depends on various characteristics of fibers as well as manufacturing process viz staple length, fiber fineness, fiber strength, twist, evenness and finishes. The strength of yarn samples was measured by Uster Tensorapid 4 as directed in IS 1670-98:02 method and elongation was measured as per method in IS 1670-91:02. Ten readings were taken for each type of yarn tested and the average reading was calculated directly by the computer. Tenacity was recorded in g/den, elongation as a percentage and breaking force in grams.

Elastic content

Elastane content of the developed covered and core spun yarns was calculated by using following formula **(Agrawal, 2007).**

$$\text{Core content} = \frac{\text{Denier of elastane /draft of elastane}}{\text{Core or Covered Yarn Denier}} \times 100$$

Statistical analysis

Arithmetic mean and one way ANOVA were used to analyse the obtained readings. SPSS software was used for statistical analysis.

RESULTS AND DISCUSSION

Tested properties of pure yarn and developed yarns are given in Table 2 and discussed under given headings.

Table 2: Properties of developed cover spun yarn

S.No.	Yarn Properties	Ly	Ly_{sp20}	Ly_{sp40}
1	**Yarn count (Ne)**	40/1	38.51	31.63
2	**Twist per inch**	22.0	11.43	12.10
3	**Tenacity (g/den)**	2.05	1.55[a]	1.54[a]
4	**Breaking force (g)**	272[a]	214	260[a]
5	**Elongation (%)**	5.90	7.07	8.02
6	**% of core in yarn**	-	4.8	7.9
7	**Unevenness (%)**	10.66 [a]	9.56 [a]	9.67 [a]
8	**Total imperfection (per km of yarn)**	305.33	186.0	160.64

Ly: Pure lyocell yarn
Ly_{sp20}: Core-Spandex filament (20D), Sheath-Lyocell yarn
Ly_{sp40}: Core-Spandex filament (40D), Sheath-Lyocell yarn
a: Non-significant difference

Yarn count

It was clear from Table 2 that developed yarns were coarser as compared to pure lyocell yarn. The count of Ly_{sp20} and Ly_{sp40} was 38.51 Ne and 31. 63 Ne which was 3.27% and 20.92% (calculated) respectively less than the count of pure yarn. This decrease of yarn count was due to the presence of core component, as count of core decides the final count of the cover yarns. The results are well supported by **Gauri (2013)** who studied the effect of spandex draw ratio on the properties of stretchable silk yarns and fabrics and concluded that composite yarns containing spandex as core were coarser than control yarns.
In order to see the effect of core on yarn count statistical analysis was done. The statistical analysis (ANOVA) proved that core component of yarn had significant influence on yarn count at 5 per cent level of significance (Table 3).

Twist per inch

Tpi value of Ly_{sp20} and Ly_{sp40} was 11.43 and 12.10 respectively which were lower than the pure lyocell yarn (Table 2). Decrease in tpi provided greater bulkiness and softness to the respective yarns. **Das (2013)** stated that sheath securely wrapped the core when twist was increased in core-sheath yarn. He further stated that compact yarn structure resultant from high twist reduces the mobility of the elastane core.

Yarn breaking force, tenacity and elongation

It can be seen from the Table 2 that tenacity Ly, Ly_{sp20} and Ly_{sp40} yarns was 2.05 g/den, 1.55g/den and 1.54 g/den respectively. The developed yarns exhibited less tenacity as compared to pure yarn because of poor tenacity of spandex which was used as core. The results are in accordance with **Babaarslan (2001)** that tenacity and breaking force of composite yarn decreases when elastomeric filament is used as core. **Ortlek (2007)** studied effects of spandex and yarn counts on the properties of elastic core-spun yarns produced on murata vortex spinner and concluded that the various properties of elastic core-spun vortex yarns were significantly affected by spandex and yarn count. He further stated that core-spun vortex yarns containing spandex showed lower tenacity and higher breaking elongation values than vortex spun yarns. The liveliness of spandex affected the hairiness properties of core-spun vortex yarns. In the present study ANOVA showed significant difference between tenacity of developed yarns and the pure yarn at 5 per cent significance level (Table 3). Duncan post host analysis showed that Ly_{sp20} and Ly_{sp40} yarns have no significant difference between their tenacities.

It is evident from Table 2 that breaking force of Ly, Ly_{sp20} and Ly_{sp40} was 272, 214g and 260g respectively. Breaking force is directly proportional to tenacity of yarn thus higher breaking force means yarn acquired high tensile strength. The decrease in breaking force of developed yarns were because of their core i.e. spandex filament. It was calculated that Ly_{sp20} and Ly_{sp40} showed decrease of 21.32% and 4.41% breaking force compared to pure lyocell yarn. According to **Mankodi (2007)** core of cover yarns mainly contributes in yarn strength but sheath yarn also gives binding force to core yarn. Further, **Alagirusamy (2010)** stated that wrapping filament property and wrap density plays a major role in deciding tenacity of wrap yarn, apart from core filament/yarn tenacity and friction. The result can be supported by the existence of significant difference between breaking strength of lyocell, Ly_{sp20} and Ly_{sp40} at 5 percent level of significance (Table 3). It was revealed by post hoc test that pure lyocell yarn and Ly_{sp40} yarn have no significant difference.

It was found that elongation of Ly_{sp20} and Ly_{sp40} was 7.07% and 8.02% which was greater than the pure lyocell yarn i.e. 5.90%. The increased elongation of developed yarns was the result of their core filament i.e. spandex inherited with excellent elongation property. Ly_{sp40} exhibited 11.84% more elongation than Ly_{sp20} because of difference in spandex denier as well as content. **Quadir (2014)** stated that yarn elongation increases with increase in the denier of spandex at constant draw ratio of elastane. Significant difference was showed by ANOVA between developed yarns and the pure yarn at 5 per cent level of significance (Table 3).

Percentage of core content in developed yarns

Core content was calculated in percentage to find out the amount of core present in cover yarns. The properties of cover spun yarns is mainly affected by the core component therefore calculation of core content is essential to determine. Ly_{sp20} and Ly_{sp40} had 4.8% and 7.9% of spandex in their core respectively. The variation in core percentage at constant draw ratio was the reason for different percentage of elongation in developed yarns. The same result was stated by **Quadir (2014)** that at constant draw ratio, percentage of spandex in core of yarn changed by varying denier of spandex.

Yarn unevenness and total imperfection

It is depicted in Table 2 that unevenness percentage of Ly_{sp20} and Ly_{sp40} was 9.56 and 9.67 respectively whereas total imperfection was 186.0 and 160.64 respectively which were less than the total imperfection and unevenness of pure lyocell yarn (Table 2). It may be because fine yarn are less regular than the coarser yarn. This fact was also proved by **Tyagi (2003)** in his study of sheath-slippage resistance and other properties of polyester-viscose MJS core spun yarn. **Subramanium (1992)** cited the study of **Srinivasn (1986)** who pointed out that unevenness of wrap spun yarn is largely dependent on the sheath material of the yarn. Ly, Ly_{sp20} and Ly_{sp40} showed no significant difference in unevenness (Table 3) and significant difference in total imperfection at 5 per cent of significance level (Table 3).

Table 3: F and P value of properties of yarns

Properties	Yarn count (Ne)	Tenacity (g/den)	Breaking force (g)	Elongation (%)	Unevenness (%)	Imperfection (per km of yarn)
F value	281.4	53.6	11.7	24.4	1.3	1142.5
P Value	0.00*	0.00*	0.00*	0.00*	0.28	0.00*

CONCLUSION

The physical characteristics of stretchable cover spun yarns having eco-friendly regenerated cellulosic fiber as sheath and spandex as core are found to be significantly influenced by denier of spandex. It was noted that tenacity and unevenness of stretchable yarns were independent from the count of spandex. The amount of core present in the cover spun yarn, which also influences various properties of stretchable yarns, was found to be dependent on spandex denier i.e. higher the count of spandex more will be the percentage of core content. Significant difference was found between the properties viz. yarn count, tenacity, breaking strength, elongation and imperfection of pure lyocell yarn and stretchable yarns.

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