ISSN : 2249 - 8877 Volume 4 Issue 1

Research & Reviews On Polymer

Trade Science Inc.

Full Paper

RRPL, 4(1), 2013 [20-26]

A study of the effect of stitch density on viscose knitted fabric made from vortex and airjet spun yarns

Kyatuheire Salome[1]*, Li Wei[1], Mwasiagi Igadwa Josphat[1,2]
[1]College of Textiles, Donghua University, Shanghai, (CHINA)
[2]School of Engineering, Moi University, Eldoret, (KENYA)
E-mail : kyatuheire6@yahoo.com

ABSTRACT

Viscose fiber provides fabrics with superior clothing comfort and appearance characteristics. Vortex and air jet spinning technology provides yarn with unique structures, which can be produced at a high production rates. The unique properties of viscose fibers on one hand and vortex and air jet spinning technology on the other hand have been exploited by many researchers to provide fabrics with superior clothing comfort. In this research work knitted fabrics were produced using viscose vortex and air jet yarns. The knit structure and stitch density were varied. Fabrics made from the vortex yarns were superior in terms of pilling and abrasion resistance. The study of the effect of stitch density on selected fabric characteristic revealed that pilling and abrasion resistance were positively correlated to stitch density. Air permeability was negatively correlated to stitch density.
© 2013 Trade Science Inc. - INDIA

KEYWORDS

Viscose;
Vortex;
Airjet;
Knit structure;
Stitch density.

INTRODUCTION

The airjet yarn can be classified as an open end spun yarn which consists of a core made up of nearly parallel fibers and a sheath of wrapper fibers. This structure is different from conventional yarn structures and hence imparts special properties to the yarn. The airjet yarn has some drawbacks, which include low level of yarn strength and limitation of the types of fibers which can be spun[27]. These drawbacks limited its application, and hence attracted the attention of several researchers, who reported that fiber type, preparatory process (like sliver drawing), and spinning parameters (main draft, air pressure, nozzle settings, etc) are some of the important parameters to be considered, so as to optimize airjet spinning[5,8,31,32]. Modifications of the airjet spinning process parameters led to the invention of the murata vortex spun (vortex yarn), which has more wrapper fibers. An increase in the number of wrapper fibers leads to the increase in vortex yarn strength[2]. The structure and properties of the vortex yarn are affected by several factors which include fiber properties[29], drafting ratio[13], air vortex flow process, nozzle structure[1,28] and plying of the yarn (single or double yarn)[3]. One of the important vortex spinning machine parts is the spindle. Ortlek et al[25] investigated the effect of spindle diameters on the yarn quality characteristics. The results indicated that the spindle diameter was directly proportional to yarn hairiness, but inversely proportional to yarn unevenness. In comparison to the ring and rotor spun yarns the vortex yarn structure exhibited lower hairiness, better abrasion resistance and superior pilling property[14,26]. A study of the factors affecting the hairiness of vortex polyester/viscose blended yarn indicated that drafting system is an influential factor. Other important factors included top roller, the back zone setting, the break draft, the yarn count and twist[21]. The advantages of fabrics made using vortex yarn are many. Apart from better hairiness and pilling resistance, fabric made from vortex yarns, when compared to those made from ring spun yarns, show better characteristics when factors such as absorbency, air and water permeability are considered[31]. These are some of the important factors which affect clothing comfort.

Apart from the spinning technology the type of fiber used is one of the important factors, which must be considered when designing a fabric. Textile fibers can be subdivided into two main classes; natural and man-made fibers. Man-made fibers are further subdivided into several groups which include regenerated, organic, inorganic and synthetic fibers. One of the oldest man-made fibers is viscose rayon (viscose). Viscose was originally developed as a cheap alternative to silk, and is considered as a biodegradable fiber since it is manufactured from wood pulp. Viscose fiber has a soft and comfortable feel, and produces fabrics with a unique drape. Viscose fiber is more absorbent when compared to cotton and can therefore be used to design fabrics which need to absorb perspiration from the human skin. The high absorbance properties allows for the dyeing of viscose using a wide range of dyes producing deep colors. Viscose fiber is suitable for various types of inner and outer knitwear products due to its comfort and visual characteristics[10]. However, one of the weaknesses of viscose fiber as reported by Busiliene, Lekeckas & Urbelis[7] is its comparatively higher tendency to pilling. This report was given after studying knitted jersey fabrics made from yarns spun using viscose, bamboo, cotton, polyester and polyamide fibers. As stated earlier on, vortex yarn spinning technology appears to overcome this problem[14]. In this context, use of vortex spun yarns, particularly when produced from viscose fibers, offers an opportunity for fabric designers to utilize the combination of viscose fiber and vortex spinning method for the production of fabrics where clothing comfort and appearance are priorities. While the combination of viscose fiber and vortex spinning can produce fabrics with superior clothing comfort characteristics, the choice of a fabric's manufacturing system has to be made.

Knitted fabrics have cut a niche above the other fabric forming systems in terms of fabric openness and elasticity. This enables them to find application in design of fabrics with special functionality such as clothing comfort. The characteristics of knitted fabrics are dependent on fiber types, yarn structure, fabric forming techniques and fabric treatment. Fabric porosity, one of the important factors which affect clothing comfort is dependent on fabric openness as illustrated using mathematical models developed by Ogulata & Marvuz[23]. Fabric openness has been reported to be dependent on the type of knit structures[12,22,24]. Structures with a higher level of openness allow easier movement of air and moisture, which will affect the heat balance of a human body, hence contributing to clothing comfort. For situations that require heat preservation, tighter structures are preferred since they provide less porosity, hence limiting the loss of warm air that is created between the fabric and the human body. Sometimes several layers of fabrics may be needed to provide optimum air and moisture flow to ensure the body temperature is maintained at a comfortable and health level[15]. Apart from fabric porosity, the knit structure also affects other quality characteristics which include loop length, fabric thickness, abrasion resistance, pilling resistance and bending behavior[11,12,30,33]. All the aforementioned factors also affect clothing comfort in one way or another. An intensive study covering the effect of fiber type, knitted structure characteristics and a host of several other factors, which have a significant impact on the clothing comfort of fabrics, reported that the fiber type and knitted structure, are some of the important factors to be considered[4]. The effect of the knit structure on the fabric characteristics cannot be overemphasized. In fact the manipulation of the knit structure is one of the important approaches to designing fabrics with a given clothing comfort functionality. This has been amply demonstrated by Chen et al[9], who used a novel approach to design knitted fabrics with improved water absorption and air resistance properties based on biometric double layered knitted structures with plant based branching system. In summary clothing comfort for a particular fabric will be affected by several factors which include fiber type, spinning method and knitting structure. The aim of this research paper was to study the effect of change of stitch density on selected fabric characteristics of viscose knitted fabrics made from vortex and airjet yarns.

MATERIALS AND METHODS

Yarn spinning and testing

Yarns were produced from viscose staple fibers whose length and fineness was 38 mm and 1.33 dtex respectively. The spinning process included carding and drawing processes to produce sliver of 3.5 ktex, and the spinning was done on a Murata air jet and vortex spinners. Except for unique machine settings on the two spinning systems, the spinning conditions were kept constant. The characteristics of the yarn samples produced were measured under standard conditions. Yarn unevenness was measured on YG133B/M yarn irregularity analyser. Hairiness values were measured using YG172 Hairiness tester.

Fabric knitting and testing

Fabrics were knitted on a flat knitting machine. The fabrics produced were; rib (RB), full cardigan (FC) and half cardigan (HC) structures, with every design having three different stitch densities designated as loose, medium and tight (TABLE 1). The samples were knitted in such a manner as to ensure the vortex and airjet yarns had similar stitch density for a given knitting pattern. From the knitting machine, fabrics were subjected to dry relaxation by laying them flat in a standard room condition (temperature of 21 ±2°C and relative humidity of 65± 2% RH) for one week. Samples to be tested were conditioned in the standard room conditions for 48 hours prior to testing.

TABLE 1 : Coding for fabric designs

Knit structure	Code	Loop Density	Code
Rib	RB	Loose	1
Full cardigan	FC	Medium	2
Half Cardigan	HC	Tight	3

The fabric thickness for the samples was measured using the procedure given in ASTM 1777-96 standards. Martindale pilling and abrasion tester was used to assess the pilling and abrasion values of the fabric samples according to ASTM 4970 and ASTM 4966 standards respectively. The degree of pilling was assessed visually by comparison with the standards. A lower number (for example 1) means the pilling resistance is low, (i.e. poor pilling resistance) and a higher number (e.g. 5) means the fabric shows lower tendency to pilling hence the pilling resistance is high. Abrasion resistance was assessed by rubbing the fabric samples until the end point or when a hole appeared in the specimen. A higher number of revolutions imply that the sample has a high level of abrasion resistance. The vice-versa is also true.

Air permeability was measured using the air permeability tester YG461E according to ASTM D 737 standards.

RESULTS AND DISCUSSIONS

Yarn quality characteristics

The quality characteristics of the vortex and airjet yarns are given in TABLE 2. The vortex yarn showed better yarn evenness due to the lower U%. The imperfections (Neps, thin and thick places) and hairiness of the vortex yarns are also lower, hence vortex yarn can be adjudged to have better quality characteristics. This is in agreement with the results obtained by Basal and Oxenham[2], when studying yarns made from polyester/cotton yarns.

Vortex spinning was an improvement of the airjet spinning technology whereby more than two air jets are used to create a three dimensional air vortex that not only increases the number of wrapping fibers but also increases the wrapping length of the wrapper fibers[27]. This leads to a yarn with better evenness.

TABLE 2 : Yarn quality characteristics

Parameter	Vortex yarn	Airjet yarn
U%	8	9.08
Thin places (-50%) per km	0	7
Thin places (-30%)per km	123	943
Thick places (+50%)per km	1	1
Neps (+200%)per km	51	863
Hairiness index (At 3mm)	0.13	6.84

Fabric quality characteristics

The fabrics quality characteristics were measured as explained in the materials and methods section. By counting the courses and wales per cm for the fabric samples the stitch density was determined as is given in TABLE 3. Other fabric characteristics measured included fabric thickness (FT), Fabric weight (FW) and Loop length (LL), whose results are given in TABLE 4.

TABLE 3 : Stitch density

Fabric Type	SD (CW/cm^2)	
	Vortex	Airjet
RB1	32.3	30.4
RB2	42.1	39.7
RB3	44.2	46.8
FC1	18.8	20.5
FC2	21.6	23.8
FC3	24.6	26.4
HC1	17.7	15.5
HC2	24.1	22.3
HC3	32.9	29.7

Analysing the stitch density data for difference of means revealed that for any given designed sample the vortex and airjet knitted fabric had approximately equal stitch density. In other words the differences in the stitch densities for the vortex and air jet yarn samples for any given knit design (say RB1) were not significantly different. Therefore a comparison of other fabric characteristics can be undertaken to investigate if the type of yarn and the change in stitch density had any effect on fabric characteristics. The fabric thickness for the knitted samples as shown in TABLE 4 indicated that for a given knit structure the fabric thickness decreased as the stitch density increased. This could be due to the fact that the loop length decreased as the stitch density increased. Despite the fact that the loop length decreased the increase in the number of stitches (loop) outweighed the decreasing length, leading to an increase in fabric weight.

Fabric comfort characteristics

Effect of stitch density on fabric pilling resistance

The results for fabric pilling are given in Figure 1. As explained in the material and methods section, the lower the grade the lower the pilling resistance, while the higher the grade the higher the pilling resistance. From the aforementioned diagram (Figure 1), pilling resistance for fabrics made from vortex yarns, increased as the stitch density increased for the rib structure. The other structures showed a mixture of little change or an increase of pilling resistance as stitch density increased. The samples made from airjet yarns, showed an increasing pilling resistance trend, as the stitch density increased. Considering that fabrics with higher stitch density exhibited lower fabric thickness and shorter loop length (TABLE 4), it can therefore be inferred that pilling resistance increased as fabric thickness and loop length decreased. Therefore pilling resistance is inversely proportional to fabric thickness and loop length. Comparing the fabric made from vortex and airjet yarn, the vortex yarn fabrics showed a higher resistance to pilling.

TABLE 4 : Fabric quality characteristics

Fabric Type	FT (mm)		FW (g/cm^2)		LL (cm)	
	Vortex	Airjet	Vortex	Airjet	Vortex	Airjet
RB1	1.83	1.94	0.034	0.032	1.33	1.35
RB2	1.77	1.91	0.037	0.037	1.18	1.22
RB3	1.76	1.84	0.041	0.042	1.05	1.07
FC1	2.65	2.72	0.037	0.037	1.15	1.08
FC2	2.52	2.5	0.042	0.042	1.1	0.96
FC3	2.3	2.31	0.043	0.043	0.94	0.91
HC1	2.37	2.71	0.034	0.034	1.28	1.31
HC2	2.32	2.61	0.036	0.036	1.07	1.18
HC3	2.22	2.38	0.037	0.037	1.02	1.04

Fabric pills are small knots or balls made from mixtures of wide varieties of small fibers. They accumulate at the surface of the fabric and get entangled by mild frictional action during processing or wearing. When the pilling level is high, the fabric may exhibit skin irritation, when worn next to the skin as an undergarment. It also affects both the handle and appearance of the fabrics thereby affecting the overall physiological comfort of the garment.

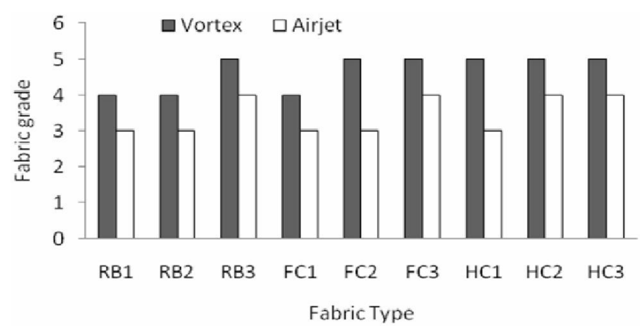

Figure 1 : Fabric pilling

As explained earlier on the degree of pilling was assessed visually by comparison with the standards. Fabrics made from vortex spun yarns exhibited comparatively better pilling resistance. This may be due to the fact that the wrapper yarns which are at the outer part of the yarn (sheath) are tightly held and have comparatively longer wrapping length[3,27]. This may leave comparatively much shorter fiber length available for pill formation (as shown by the better hairiness for vortex yarn (TABLE 2)) leading to higher resistance to pilling.

Effect of stitch density on fabric abrasion resistance

The investigation of fabric abrasion resistance which was undertaken using martindale fabric abrasion tester showed that the vortex yarn knitted fabrics samples took longer to get abraded, hence they have a better abrasion resistance (see TABLE 5). This could be due to that fact that the vortex yarn has a more compact structure when compared to the airjet yarn as discussed in the fabric pilling section earlier on. It can also be seen from the aforementioned table that the stitch density is positively correlated with fabric abrasion. Therefore it can be infered that abrasion resistance improved as the loop length and fabric thickness decreased. This is in agreement with Kane, Patil & Sudhakar[17] results. The higher level of abrasion resistance could be due to the tight packing of yarns in the samples with higher stitch densities.

TABLE 5 : Abrasion resistance

Fabric	Rotations (/1000 rubs)	
	Vortex	Airjet
RB1	85	50
RB2	90	70
RB3	105	100
FC1	90	65
FC2	90	75
FC3	95	75
HC1	60	50
HC2	65	60
HC3	65	60

Effect of stitch density on air permeability

Air permeability for the vortex and airjet yarn knitted fabric samples are given in Figure 2, which showed that, the fabrics made from airjet yarns allowed more air to pass through. The difference is however not significantly different. The figure also shows that the tighter the fabric (higher stitch density) the lower the air permeability. This is in line with the generally accepted fact that the air permeability of a fabric depends on the level of the fabrics openness[16,19,23].

Air permeability is the measure of the air that passes through a given area of fabric. It decreases as the stitch density decreases. Higher stitch density leads to more courses and wales which occupy more space, leading to smaller pores size. The decreased pores size leads to lower air permeability. Bivainyte & Mikucioniene[6] have established that this phenomenon holds true for fabrics made using the same design.

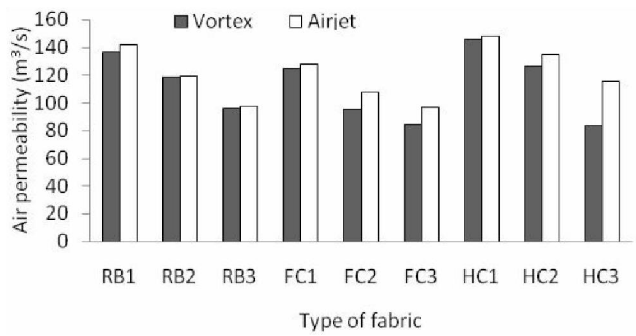

Figure 2 : Fabric air permeability

The difference between the air porosity for vortex and airjet knitted fabrics could indicate that air porosity is also affected by the compactness of the yarns. That is to say air porosity is not only due to air passing though the space that is created between the yarns but also the space that is created between the fibers. The vortex yarn has been proved to be more compact than the airjet yarn[27], therefore it is not surprising for the airjet yarn knitted fabric to exhibit higher air permeability. The air porosity of the airjet yarns fabrics could render them more suitable for situations where higher air permeability is needed. There are however other fabric applications that need less air permeability and the vortex yarn could therefore be more suitable.

To further investigate the air permeability of the knitted fabrics, the samples were laundered and the effect of the laundering process on air permeability investigated. The results obtained showed a similar trend to the one discussed above. A comparison of the air permeability results for the samples before laundering (BL) and after laundering (AL) showed that fabric air permeability decreased after laundering. This could have been caused by fabric shrinkage. Therefore, laundering procedures are critical when dealing with knitted fabrics.

TABLE 6 : Fabric air permeability

Fabric	Vortex yarn samples		Airjet yarn samples	
	BL (m^3/s)	AL (m^3/s)	BL (m^3/s)	AL (m^3/s)
RB1	136.5	88.6	141.9	98.8
RB2	118.6	51.2	119.4	75.3
RB3	96.6	33.6	98.2	37.9
FC1	124.8	63.04	128.1	47.4
FC2	95.6	54.9	108.3	30.6
FC3	85.01	30.4	96.7	29.8
HC1	146.2	68.8	148	82.1
HC2	126.9	51.3	135.2	68.4
HC3	84.2	34.5	115.7	47.7

CONCLUSION

Fabric samples were knitted on a flat knitting machine, using viscose yarns spun from vortex and airjet spinning systems. During knitting the fabric knit structure was varied at three levels (Rib, full cardigan and half cardigan). The stitch density was also varied at three levels (loose, medium and tight). The fabric characteristics indicated that fabrics knitted from vortex yarns showed superior pilling and abrasion resistance. Fabrics with lower stitch density, gave lower pilling resistance, higher air permeability and lower abrasion resistance. Considering loop length and fabric thickness; fabric abrasion resistance improved as the loop length and fabric thickness decreased, while air permeability decreased as the loop length and fabric thickness decreased.

REFERENCES

[1] G.Basal, W.Oxenham; Effects of some process parameters on the structure and properties of vortex spun yarn, Textile Research Journal, **76(6)**, 492-499 **(2006)**.

[2] G.Basal, W.Oxenham; Vortex spun yarn vs. air-jet spun yarn, Autex Research Journal, http://www.autexrj.org/No3-2003/0066.pdf, **3(3)**, 96-101 **(2003)**.

[3] Y.Beceren, B.U.Nergis; Comparison of the effects of cotton yarns produced by new, modified and conventional spinning systems on yarn and knitted fabric performance. Textile Research Journal, **78(4)**, 297-303 **(2008)**.

[4] G.Bedek, F.Salaun, Z.Martinkovska, E.Devaux, D.Dupont; Evaluation of thermal and moisture management properties on knitted fabrics and comparison with a physiological model in warm conditions. Applied Ergonomics, **42(6)**, 792-800 **(2011)**.

[5] M.Bhortakke, T.Nishimura, T.Matsuo; The structure of polyester/cotton blended air-jet Spun yarn, Textile Research Journal, **69(2)**, 84-89 **(1999)**.

[6] A.Bivainyte, D.Mikucioniene; Investigation on the air and water vapour permeability of double-layered weft knitted fabrics, Fibres & Textiles in Eastern Europe, http://www.fibtex.lodz.pl/article526.html, **19(3)**, 69-73 **(2011)**.

[7] G.Busiliene, K.Lekeckas, V.Urbelis; Pilling resistance of knitted fabrics, Materials Science (Medziagotyra), **17(3)**, 297-301 **(2011)**.

[8] R.J.Chasmawala, S.M.Hansen, S.Jayaraman; Structure and properties of air-jet spun yarns, Textile Research Journal, **60(2)**, 61-69 **(1990)**.

[9] Q.Chen, J.T.Fan, M.K.Sarkar, K.Bal; Plant-based biomimetic branching structures in knitted fabrics for improved comfort-related properties, Textile Research Journal, **81(10)**, 1039-1048 **(2011)**.

[10] X.-Q.Dai; Part III Material properties; Fibers, In Y.Li, X.-Q.Dai, (Eds); Biomechanical engineering of textiles and clothing, The textile Institute, Woodhead Publishing Limited, Abington Hall, Abington, Cambridge, England, 161-176 **(2006)**.

[11] R.A.M.A.El-Hady; The effect of aesthetic beauty design on the performance properties of jacquard weft knitted fabrics, Asian Journal of Textile, **1**, 74-86 **(2011)**.

[12] N.Emirhanova, Y.Kavusturan; Effects of knit structure on the dimensional and physical properties of winter outerwear knitted fabrics, Fibres and Textiles in Eastern Europe, http://www.fibtex.lodz.pl/article130.html, **16(2)**, 69-74 **(2008)**.

[13] N.Erdumlu, B.Ozipek; Effect of draft ratio on vortex spun yarn properties, Fibres & Textiles in Eastern Europe, http://www.fibtex.lodz.pl/article351.html, **8(3)**, 38-42 **(2010)**.

[14] N.Erdumlu, B.Ozipek, A.S.Oztuna, S.Cetinkaya; Investigation of vortex spun yarn properties in comparison with conventional ring and open-end rotor spun yarns. Textile Research Journal, **79(7)**, 585-59 **(2009)**.

[15] G.F.Fonseca, J.R.Breckenridge; Wind penetration through fabric systems. Part I, Textile Research Journal, **35(2)**, 95-103 **(1965)**.

[16] A.D.Gun; Dimensional, physical and thermal comfort properties of plain knitted fabrics made from modal viscose yarns having microfibers and conventional Fibers. Fibers and Polymers, **12(2)**, 258-267 **(2011)**.

[17] C.D.Kane, U.J.Patil, P.Sudhakar; Studies on the influence of knit structure and stitch length on ring and compact yarn single jersey fabric properties, Textile Research Journal, **77(8)**, 572-582 **(2007)**.

[18] P.V.Kadole, C.D.Kane, S.S.Aparaj, S.S.Burji; Migration of fibers in air-jet yarn. Textile Research Journal, **79(4)**, 360-364 **(2009)**.

[19] F.S.Kilinc, Y.Elmogahzy, B.Karaguzel, B.S.Gupta; Evaluation of porosity and comfort in knitted fabrics. Proceedings of Paper presented at Beltwide Cotton Conferences, New Orleans, Louisiana, http://www.cotton.org/beltwide/proceedings/2005-2012/index.htm, 2408-2430, January **(2005)**.

[20] H.W.Krause, H.A.Soliman; Theoretical study on the strength of single jet false twist spun yarns, Textile Research Journal, **60**, 309-318 **(1990)**.

[21] E.A.Haghighat, M.S.Johari, S.M.Etrati; A study of the hairiness of polyester-viscose blended yarns; Part I. Drafting system parameters, Fibres & Textiles in Eastern Europe, http://www.fibtex.lodz.pl/article125.html, **16(2)**, 41-44 **(2008)**.

[22] A.Majumdar, S.Mukhopadhyay, R.Yadav; Thermal properties of knitted fabrics made from cotton and regenerated bamboo cellulosic fibres, International Journal of Thermal Science, **49**, 2042-2048 **(2010)**.

[23] R.T.Ogulata, S.Mavruz; Investigation of porosity and air permeability values of plain knitted fabrics. Fibres & Textiles in Eastern Europe, http://www.fibtex.lodz.pl/article406.html, **18(5)**, 71-75 **(2010)**.

[24] E.Onofrei, A.M.Rocha, A.Catarino; The influence of knitted fabrics' structure on the thermal and moisture management properties. Journal of Engineered Fibers and Fabrics, http://www.jeffjournal.org/papers/Volume6/6.4.3Onofire.pdf, **6(4)**, 10-22 **(2011)**.

[25] H.G.Ortlek, F.Nair, R.Kilik, K.Guven; Effect of spindle diameter and spindle working period on the properties of 100% viscose MVS yarns. Fibres & Textiles in Eastern Europe, http://www.fibtex.lodz.pl/article161.html, **16(3)**, 17-20 **(2008)**.

[26] H.G.Ortlek, L.Onal; Comparative study on the characteristics of knitted fabrics made of vortex-spun viscose yarns. Fibers and Polymers, **9(2)**, 194-199 **(2008)**.

[27] W.Oxenham; Fasciated yarns- A revolutionary development? Journal of Textile and Apparel Technology Management, http://www.tx.ncsu.edu/jtatm/volume1issue2/articles/oxenham/oxenham_full.pdf, **1(2)**, 1-7 **(2001)**.

[28] Z.Pei, C.Yu; Investigation on the dynamic behavior of the fiber in the vortex spinning nozzle and effects of some nozzle structure parameters. Journal of Engineered Fibers and Fabrics, http://www.jeffjournal.org/papers/Volume6/6.2.3Pei.pdf, **6(2)**, 16-29 **(2011)**.

[29] C.Price, H.Senter, J.Foulk, G.Gamble, W.Meredith; Relationship of fiber properties to vortex yarn quality via partial least squares, Journal of Engineered Fibers and Fabrics, http://www.jeffjournal.org/papers/Volume4/4.4b5_Price.pdf, **4(4)**, 37-45 **(2009)**.

[30] B.Shahbaz, N.J.Jamil, S.Rafi; Shrinkage control of fleece knit fabrics by some yarn and knitting variables. Journal of Applied Sciences, **2**, 715-718 **(2002)**.

[31] G.K.Tyagi, G.Krishna, S.Bhattacharya, P.Kumar; Comfort aspects of finished polyester-cotton and polyester-viscose ring and MJS yarn fabrics. Indian Journal of Fibre & Textile Research, http://nopr.niscair.res.in/handle/123456789/4382, **34(June)**, 137-143 **(2009)**.

[32] G.K.Tyagi, S.Shaw; Structural and characteristic variations in viscose ring and air-jet spun yarns as a consequence of drawframe speed and its preparatory process. Indian Journal of Fibre &Textile Research, http://nopr.niscair.res.in/handle/123456789/13682, **37**, 27-33 **(2012)**.

[33] R.Zouari, M.Cheikhrouhou, M.Sahnoun; Statistical study of the influence of some knitting parameters variation on the fabrics quality. Journal of Applied Sciences, **8**, 3294-3297 **(2008)**.

[34] Z.Y.Zou, S.R.Liu, S.M.Zheng, L.D.Cheng; Numerical computation of a flow field affected by the process parameters of murata vortex spinning. Fibres & Textiles in Eastern Europe, http://www.fibtex.lodz.pl/article332.html, **18(2)**, 35-39 **(2010)**.