

C92C3

Dimensional Stability, Aesthetic and Mechanical Properties of Micro-Fiber Blended Knitted Fabrics

PI(s): S. Rose Matic-Leigh

Relevance to NTC Goals:

The introduction of polyester finer (so called micro-denier fiber) fibers by the man-made fiber producer for use especially in apparel industry has created tremendous possibilities to achieve improved physical, mechanical, and aesthetic properties of apparel fabrics. It is well known that fiber fineness has profound **influence** on the physical, mechanical, and aesthetic including dyeing behavior of **fibers**. However, this relationship **is** strongly affected **by the yarn structure (both in woven and knitted fabrics) which in turn is dependent on the system of spinning and especially in blended** spun yarns. Our limited laboratory studies have shown that the fibers segregate, and this segregation **is** a function the geometric and mechanical properties of fiber, when spun on ring or open end spinning systems. Due to the development of new knit fabric **structures** it is the idea to determine the characteristics of the micro-fibers with and without other fibers in the blend. Influence of the micro-fiber properties on the yarn characteristics produced for the knitting purposes. Knitting efficiency, fabric performance and dimensional stability of micro-fiber knit structures. The generation of fundamental knowledge **will help** the knitting industry to go forward and retain primary position in the world competition, which are the basic NTC goals.

All the studies reported in the literature including the reports from our laboratories have been carried out on fibers that are no more **finer** than 1 - 2 denier. Studies on the effect of very fine denier polyester fibers of the order of **0.6-0.8** denier range in blends with cotton fibers of equal fineness need to be carried out if a better understanding of the role of yarn structure in influencing the processing dynamics and the physical and aesthetic properties of knitted fabrics is to be obtained. The distribution of fibers will influence the yarn and metal friction during knitting which in turn will affect the limited tension and consequently the machine efficiency and the fabric characteristics. Micro-fibers are opening new possibilities of application for spun and continuous **filament** yarns in different areas of textile production. This study will be performed to determine the effect of staple yarns **formed** of micro-fibers on knit fabric performance, dimensional stability, mechanical properties, and knitting efficiency. The concept is to use the micro-fiber blends with natural fibers to increase the production speed, lower the twist number, to add strength, improve hand, reduce harshness, achieve superior drape, and produce a stable knit structure.

Objectives:

1. To generate the characteristics of micro-fibers and their blends with natural fibers when spun on ring **open-end** (rotor), and **airjet** spinning systems. Generated data will be used for the accurate estimation of yarn properties when produced for knitting purposes. With the regard to the nature of the relationships between **fiber** and yarn properties, optimal yarns will be used for knitting.
2. To study the function between geometric and mechanical properties of micro-fibers, and their blends, as well as the yarns on knitting efficiency and knit fabric performance. To generate equations capable of accurately predicting influence of yarn characteristics on knit fabric behavior in use.
3. To understand and predict knit fabric characteristics for the known micro-fiber yarns and their blends. Blends with cotton and wool will provide fabrication of knit fabrics with better physical, mechanical and aesthetic properties which include better strength, improved hand, **reduced** harshness and good drape, and dimensional stability. It is dedicated to solve the problems of knitting manufacturing and achieving stable knit-goods properties.

4. To develop a mathematical model and a computer software for predicting the dimensions and characteristics of finished knit fabrics. This part is designed to collect such a data base using appropriate, reliable, and reproducible test methods to derive from it **a series of prediction equations which** would link the major manufacturing variables: yarn, knitting machine, average loop length, wet processing method for relaxed dimension of the finished micro-fiber knit fabrics. **Rheological** models will be the base for predicting dimensional behavior and establish parameter for dimensional stability of micro-fiber knits.

Structure Property Relation in Yarns for Knitting: Spun Yarns Made from PES Micro-Fibers and with Blends of Cotton on Ring, Rotor, and Airjet Systems

The micro-fibers for yarn production were received from Du Pont Different micromattique fibers were used to produce 100% microfiber yarns, as well as blends of polyester **microfibers** and cotton. Several groups of microfibers were used to produce different types of yarns.

Mechanical Properties of Knit Fabrics Using Ring Spun Yarns

Several ring spun yarns were used to establish regression equations between physical and mechanical characteristics of knit fabrics using geometrical and dimensional **parameters**. Regression equations for ring spun yarns in single jersey knit fabrics are shown in Table II. Developed regression equations **will** be used to establish mathematical models for predicting knit fabric characteristics. Correlation coefficients are showing good agreement with the experimental data Established relationships were developed from some ring **spun yarns used for knitting**.

TABLE I					
Item	Blend	Fiber Type	Denier Filament	Fiber Length (Inch)	Micronaire
I Group of Fibers (50/50 Cotton Polyester)					
1	Microfiber	D-919W	0.7	1.37	3.80
	Cotton	Upland	-	1.15	3.90
2	PES (reg)	D-216W	1.50	1.25	-
	Cotton	Upland	-	1.09	3.95
3	Microfiber	D-915W	0.7	1.37	3.80
	Cotton	Upland	-	1.15	3.90
II Group of Fibers (Micromattique fibers)					
1	Microfiber	D-919W	0.7	1.25	3.80
2	PES	T-40A	1.0	1.25	3.70
3	Microfiber	D-915W	0.7	1.50	3.80
III Group of Fibers (Micromattique)					
1	Microfiber	D-919W	0.7	1.50	3.80
2	PES	T-40A	1.0	1.25	3.70
3	PES	T-107W	1.0	1.50	3.90

Yarns produced from all the fibers and blends will be in several yarn counts single and plied using three spinning systems: (1) ring (2) rotor (3) airjet

TABLE IIRegression equations established for following relationship Coefficient of Determination

1.	Stitch Length (ℓ) + Fabric Thickness (D)		
	$D = 0.164 + 1.247 \cdot \text{Log}(\ell)$		$R^2 = 0.96$
		Correlation Coefficient	$R = 0.98$
2.	Stitch Length (ℓ) + Fabric Mass (M)		
	$M = 0.521 \times 10^{0.7\ell}$		$R^2 = 0.95$
		Correlation Coefficient	$R = 0.97$
3.	Stitch Length (ℓ) + Ball Burst Strength (B)		
	$B = 63.051 \times 10^{0.7\ell}$		$R^2 = 0.76$
		Correlation Coefficient	$R = 0.87$
4.	Knit Cover Factor (k) + Stitch Count (y)		
		a/courses (c)	
	$y_c = 31.335 \times 10^{-(9c + 2k)}$		$R^2 = 0.84$
			Correlation Coefficient $R = 0.92$
		b/wales (w)	
	$y_w = 14.778 \times 10^{-(5e + 2k)}$		$R^2 = 0.82$
			Correlation Coefficient $R = 0.91$
5.	Tightness Factor (TF) + Dimensional Parameters (k_c, k_w)		
		a/knit course constant (k_c)	
	$k_c = 28.25 - 1.65TF$		$R^2 = 0.76$
			Correlation Coefficient $R = 0.87$
		b/knit wale constant (k_w)	
	$k_w = 28.89 - 1.48TF$		$R^2 = 0.71$
			Correlation Coefficient $R = 0.84$
6.	Tightness Factor (TF) + Knit Fabric Constant ($k_{cw} = k_c/k_w$)-y		
	$k_{cw} = 2.12 \times 10^{-(3.8e + 2TF)}$		$R^2 = 0.67$
		Correlation Coefficient	$R = 0.82$

Physical and Mechanical **Properties** of Knit Fabric Made from Rotor Spun Yarns

Geometrical characteristics of circular single jersey knit fabrics produced of open-end (rotor) yarns which were produced and estimated from evaluated knit structures. Yarns used for formation of different knit structure-s were produced using a rotor spinning system. Yarns produced were:

Cotton/PES (regular) 50/50%
 Cotton/PES (microfiber-D919W) 50/50%
 PES (microfiber-D919W) 100%
 PES (microfiber-D915W) 100%

Yarn Type Open-End (Rotor)	YARN COUNT		Twist Mult. (TM)	FIBER TYPE	
	Cotton Count Ne _c	Direct Count tex		Cotton	PES
Cotton/PES (regular) 50/50%	22/1	27	3.5	Upland	D-216W
Cotton/PES (micro) 50/50%	20/1	30	3.5	Upland	D-919W
PES (micro) 0.7 den 100%	20/1	30	3.5	-	D-915W
PES (micro) 0.7 den 100%	36/2 (18)	33	3.5	-	D-919W

Single jersey fabrics were produced using rotor spun yarns with (4) different tightness factors and (4) designs. Using testing data from knit samples produced from blends of cotton with regular PES, Microfiber PES, and 100% Microfiber PES, rotor yarn relationships between geometrical, dimensional, physical, and mechanical characteristics was established. Geometrical characteristics of knit fabrics were: loop length (ℓ), yarn count (tex) cover factor (k), and stitch count ($c \times w$) and their effect on tensile properties of knit fabrics were studied. Dimensional parameters were: knit constants in course and wale direction (k_c and k_w), stitch density ($s = cw$), knit density constant (k_s) and knit fabric constant ($k_{cw} = k_c/k_w$) were calculated from geometrical characteristics. Equations used for the calculation of dimensional and geometrical parameters are as follows:

TABLE IV GEOMETRICAL CHARACTERISTICS OF KNIT FABRICS

1. $c = k_c / \ell; w = k_w / \ell$
2. $s = cw = k_s / \ell^2$
3. $k_{cw} = k_c / k_w$
4. $K = \sqrt{\text{tex}/\ell}$

Physical and mechanical characteristics of tested single jersey knit fabrics were dependent of knit fabric design, stitch length, and tightness factor. Physical and mechanical behavior of knit fabrics was **correlated** to geometrical and dimensional properties.

TABLE V

GEOMETRICAL CHARACTERISTICS OF MICROFIBER KNIT FABRICS

YARN TYPE	FABRIC DESIGN	YARN COUNT (tex)	1/ℓ	Stitch Length ℓ (cm)	STITCH COUNT		Cover Factor $K=\sqrt{\text{tex}/\ell}$	Stitch Density $S=k_v/\ell^2$	DIMENSIONAL PARAMETER			
					Courses per cm	Wales per cm			k_c	k_w	$k_s=k_c k_w$	$k_{cw} = \frac{k_c}{k_w}$
Cotton/PES PES (regular) Ne_c 22/1	Plain	27	5.21	0.192	6.3	4.7	27.08	29.76	1.21	0.91	1.10	1.33
	Lacoste	27	5.05	0.198	6.7	5.1	26.26	34.26	1.33	1.01	1.34	1.31
	Pintuck	27	4.85	0.206	7.1	5.5	25.24	39.06	1.46	1.14	1.66	1.29
	Weft Locknit	27	4.65	0.215	7.5	5.9	24.19	44.18	1.61	1.27	2.04	1.27
Cotton/PES PES (microfiber) 0.7 den Ne_c 20/1	Plain	30	4.26	0.285	5.5	4.3	23.32	23.87	1.30	1.02	1.32	1.27
	Lacoste	30	3.95	0.296	5.9	4.7	21.66	27.90	1.49	1.20	1.79	1.25
	Pintuck	30	3.50	0.310	6.3	5.1	19.16	32.24	1.80	1.46	2.64	1.23
	Weft Locknit	30	3.40	0.325	6.7	5.9	18.64	39.53	1.97	1.74	3.42	1.13
PES (microfiber) 0.7 den Ne_c 20/1	Plain	30	3.46	0.290	5.1	4.3	18.96	22.17	1.48	1.25	1.85	1.18
	Lacoste	30	3.28	0.305	5.5	4.7	17.97	26.04	1.68	1.44	2.42	1.17
	Pintuck	30	3.13	0.320	5.5	5.1	17.13	28.21	1.76	1.64	2.89	1.08
	Weft Locknit	30	2.98	0.336	5.9	5.5	16.31	32.55	1.98	1.85	3.67	1.07
PES (microfiber) 0.7 den Ne_c 36/2 (18)	Plain	33	3.08	0.325	4.7	3.9	17.66	18.60	1.54	1.28	1.96	1.20
	Lacoste	33	3.01	0.332	4.7	3.9	17.79	18.60	1.57	1.31	2.05	1.20
	Pintuck	33	2.87	0.348	5.1	4.3	16.50	22.17	1.78	1.51	2.68	1.18
	Weft Locknit	33	2.74	0.365	5.5	4.7	15.73	26.04	2.01	1.72	3.47	1.17

C92C3, Page 5

TABLE VI

PHYSICAL AND MECHANICAL PROPERTIES OF COTTON/MICROFIBER KNIT FABRICS

YARN TYPE	FABRIC DESIGN	YARN COUNT		Stitch length l (Inch)	STITCH COUNT		Mass (oz/sq. in)	Knit Fabric Thickness (mm)	Ball Burst (lb)	Stitch Density S=CPIxWPI	Mochnle Tightness Factor
		Ne _c	(tex)		Courses per In. CPI	Wales per In. WPI					
Cotton/PES PES (regular) Ne _c 22/1	Plain	22	27	0.076	16	12	4.22	0.17	68	29.76	10.70
	Lacoste	22	27	0.078	17	13	5.33	0.22	74	34.26	11.23
	Pintuck	22	27	0.081	18	14	5.56	0.26	75	39.06	11.63
	Weft Locknit	22	27	0.085	19	15	5.96	0.29	76	44.18	12.81
Cotton/PES PES (microfiber) 0.7 den Ne _c 20/1	Plain	20	30	0.093	14	11	4.98	0.20	75	23.87	10.65
	Lacoste	20	30	0.100	15	12	5.62	0.24	84	27.90	11.56
	Pintuck	20	30	0.113	16	13	5.98	0.29	88	32.24	11.74
	Weft Locknit	20	30	0.116	17	15	6.02	0.35	91	39.53	12.75
PES (microfiber) 0.7 den Ne _c 20/1	Plain	20	30	0.114	13	11	5.20	0.23	76	22.17	10.68
	Lacoste	20	30	0.120	14	12	5.43	0.29	82	26.04	11.54
	Pintuck	20	30	0.126	14	13	5.89	0.33	88	28.21	11.83
	Weft Locknit	20	30	0.132	15	14	6.27	0.39	93	32.55	12.69
PES (microfiber) 0.7 den Ne _c 36/2	Plain	18	33	0.128	12	10	5.86	0.35	85	18.60	10.63
	Lacoste	18	33	0.131	12	10	6.15	0.39	90	18.60	11.45
	Pintuck	18	33	0.137	13	11	6.47	0.45	96	22.17	11.83
	Weft Locknit	18	33	0.144	14	12	6.90	0.52	102	26.04	12.38

C92C3, Page 6

For **analysis** of fabric behavior, **several** knit fabric characteristics were taken into **consideration**: **fabric weight**, **ball burst**, **dimensional stability**, and **abrasion resistance**. During analyzing of knit fabric behavior, seven independent variables were **introduced** (**twist multiple, C, W, stitch length, yarn count, tightness factor, and yarn strength**) for developing a multiple regression model. For each fabric characteristic, the effective parameters are not really known. However, each p value indicates the significance of the effects by introducing the relative independent variable into the regression model. The lower p value has the most significant effect to the **regression** model and vice versa.

Since the more independent variables to be introducing to the model always come with a higher R-squared value, it is reasonable to use the technique of **stepwise** regression to decide the proper parameters to be introduced.

The results show that R-squared values for **fabric weight** and **ball burst** are always **high** and these indicate good multiple regression equations have been built.

Some results of the relationship between fabric weight and ball burst strength are shown in Figures 1-5. Other fabric characteristics varied very much and showed relatively low coefficient of correlation for used independent variables. Dimensional stability showed the most variation, so a different approach was established **to** solve the problem. Use of **rheological** models to solve the problem of dimensional stability of micro-denier knit fabrics was investigated.

When all mathematical equations are established, using all different **yarn** types, and knit' fabric structures, a mathematical model will be developed for a computer software to predict dimensions and some physical and mechanical characteristics of single jersey knit fabrics.

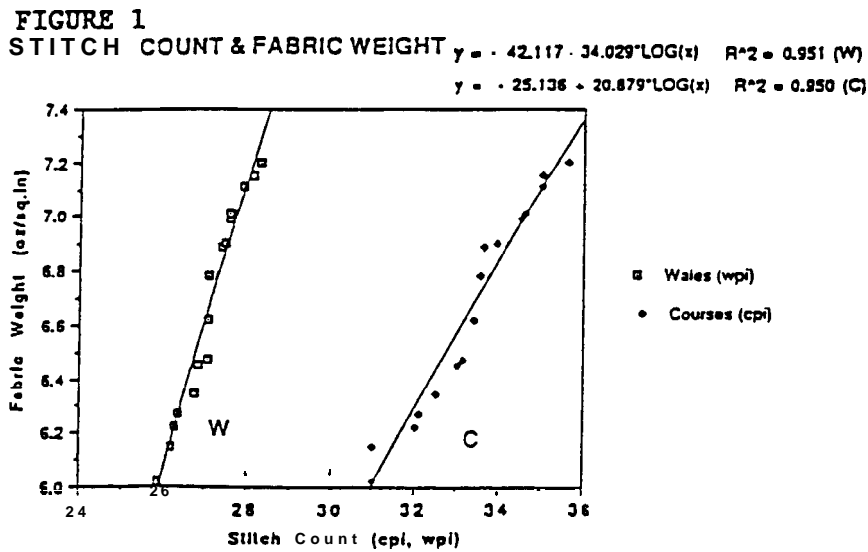


FIGURE 2
STITCH LENGTH & FABRIC WEIGHT

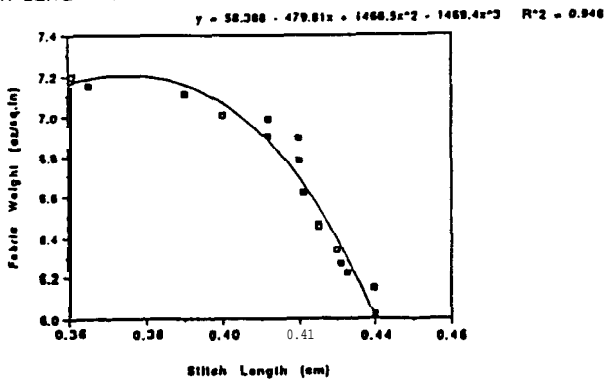


Figure 5
Scatterplot of Ball Burst vs Yarn Strength and Stitch Length

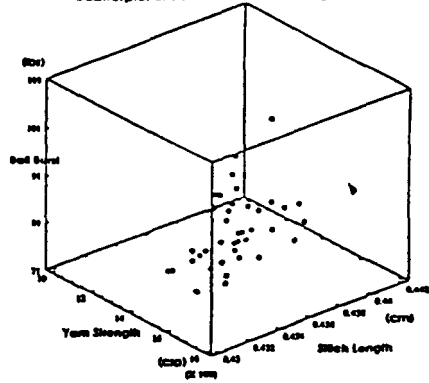


FIGURE 3
Scatterplot of Fabric Weight vs C and W

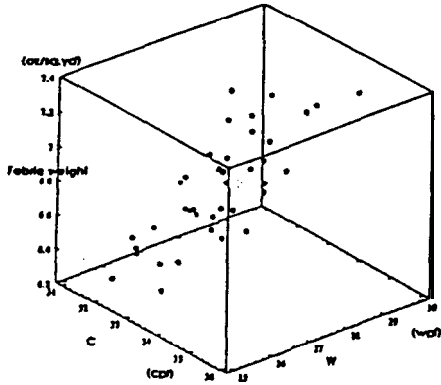
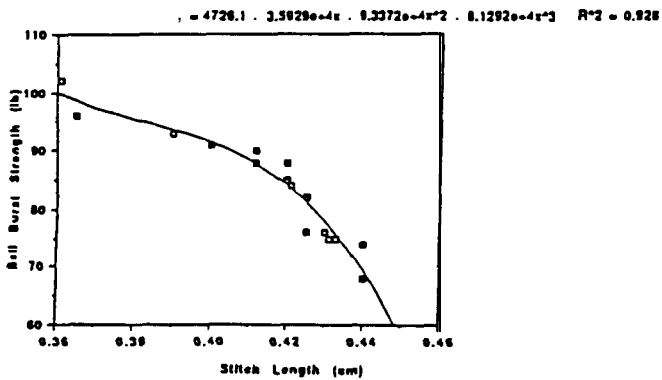


FIGURE 4
STITCH LENGTH AND BALL BURST STRENGTH



Conclusion:

The purpose of this research project is to generate the equations of the accurate estimation of dimensional stability and mechanical properties of knit goods produced of micro-fiber and their blends. The research activity in this project are focused on the development of a very simple and easy usable software which will be able to predict the micro-fiber knit fabrics in the fully relaxed (reference state). Computer software has to help the manufacturer to improve the consistency and reliability of the knit products while increasing the efficiency of the knitting operation by reducing time (higher production speed) and receiving better fabric performance as lower twist number, better strength, improved hand, reduced harshness, and superior drape. It is showing that in order to develop a **reasonably** accurate and **practical** prediction system, an extensive empirical data-base and actual measurements of fully relaxed dimensions of wide range of knit fabrics has to be collected.

Developed computer software will help knitting manufacturers to improve the **consistency** of their product, as well as to be able to predict in advance, the dimensions of single jersey knit fabrics.

Dimensional stability is approached and using rheological models to study the **influence** of load and deformation in **microfiber** knit fabrics is established. Application of rheological models were used to explain and predict deformation of knit fabrics under different loads. **Rheological** models can establish relationships between knitting process and knit fabric strain and predict the dimensional stability of knits produced of micro-fiber yarns and their blends. During manufacturing and use, knit fabrics are exposed to the effect of different forces that can be used to study behavior of knit fabrics during **strain**. Time dependence of strain on deformation, and time of deformation can be used to predict dimensional stability of micro-fiber knits using Rheology.

Fabric geometry will be the indicator of the knit fabric characteristics. To achieve the best fabric performance it is necessary to evaluate the geometry and mechanics of greige fabrics. It will be developed a system for measuring yam configuration and fabric geometry using image analysis system.

Knit fabric dimensional measurements will be collected using a new developed method of image analysis yarn **configuration** and knit fabric geometry measurements.

Literature Cited

1. Structural Mechanics Fibers, Yarns and Fabrics, J.W.S. **Hearle**, P. Grosberg, S. Backer. John Wiley Interscience, 1969
2. The Mechanics of Wool **Structures**, R. **Postle**, GA. Camaby. S. De Jong, John Wiley & Sons, 1988
3. **Boltz**, GJ., Needed--A Scientific Approach to Fabric Engineering, *Knitting Times* 56 (1), 23-24, **28-30** (1987)
4. Heap, S.A., Greenwood, P.F., **Leah R.D.**, Eaton, J.T., Stevens, J.C., and **Kfner**, P. Prediction of Finished Weight and Shrinkage of Cotton Knits--The Starfish Project Part I: Introduction and **General** Overview, *Textile Res. J.* 53 (2), 109-119 (1983)
5. Johnson, R.A., Wichem D.W., Applied Multivariate Statistical Analysis, Third Edition, Prentice-Hall Inc., New Jersey, 1992
6. **Matic**, S.R., Computer Produced Models for Knit Fabric Characteristics, *Knitting Times* 57 (2). 33-38 (1988)