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Geometry of Weft Knitted Structures - Influence on Heat Resistance

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Abstract **-** The geometrical factors have important role to explain the differences between the heat transfer of weft knitted structures. In this paper are defined the basic geometrical parameters that describe the structure of weft knitted fabric. The measurement of heat resistance is carried out using the sweating guarded hotplate. The geometrical parameters of weft knitted structures are brought into the context of the heat resistance of weft structures and significant ones are outlined.

Keywords**:** Geometry, Weft, Knitting, Fibre, Heat resistance.

1. Introduction

Textile materials are discontinuous and produced from macroscopic sub-elements (finite length fibres or continuous filaments). The discrete nature of such materials means that they have void spaces or pores that contribute directly on some of the key properties of textiles, such as thermal characteristics and liquid absorption. It should be noted that the behaviour of fibrous materials is remarkably different from that of their constituent fibers. For example, the same wool fibre can be used both for the production of summer next-to-skin wear or winter coat. Therefore, the geometrical factors have to be included to explain the differences (Pan and Gibson, 2006).

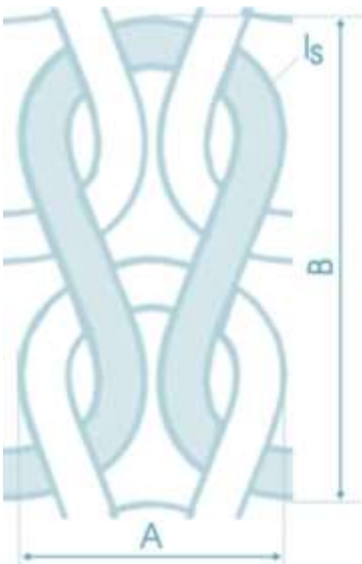
Overall, there is a limited number of studies related to the investigation of knitted fabrics. For example, the transfer of heat is measured through cotton and polypropylene underwear (Farnworth and Dolhan, 1985). Differences in transfer were recorded, but those, according to the authors, should not affect the human thermal comfort. Furthermore, different rib structures are investigated and it is noted that a decrease in rib number leads to a decrease in heat loss due to an increase of air amount entrapped between the loops (Ucar and Yilmaz, 2004).

Our previous investigations are mainly focused on the investigation of weft knitted fabrics. A number of single jersey fabrics were investigated using the sweating guarded hotplate in order to determine the influence of different parameters to the transfer. Regarding the raw material, it was shown that among different natural and syntetic fabrics, polyester with profiled cross section decreases the transfer of heat, while the knitwear produced from viscose enables the highest rate of transfer (Salopek et al., 2008). The fabrics with additional elastane yarn in the structure have rather higher values of heat resistance in comparison to the structures without elastane (Salopek and Skenderi, 2007). Among the yarn parameters that affect the transfer properties, the yarn count, thickness and variation of yarn mass should be pointed out, while among the fabric parameters, the moduli, cover factor, mass per unit area and porosity have biggest influence to the heat resistance (Salopek Cubric et al., 2012). Furthermore, the results indicated the decrease of heat resistance due to the fabric finishing process for up to 6% (Salopek Cubric and Skenderi, 2013).

In this paper are defined the basic geometrical parameters that describe the structure of weft knitted fabric. The parameters are brought into the context of the heat resistance of weft structures and significant ones are outlined.

2. Materials and Methods

For the investigation are designed and produced weft knitted structures using yarns of four different fineness and three raw materials. According to the raw material used, the produced fabrics are divided into three groups: A (100% cotton), B (100% viscose fibre) and C (100% lyocel fibre). After knitting, the fabrics are left to relax for 120 hours and then finished according to the same recipe. For each produced fabric are determined important parameters that describe geometry of a stich that forms weft structure. The parameters are described on Figure 1.



<u>Main parameters</u>

- Stitch width: A (mm)
- Stitch hight: B (mm)
- Stitch length (length of yarn in a stitch): l_s (mm)

$$l_s = 1{,}57A + d_y\pi + 2B \quad (1)$$

<u>Geometrical parameters</u>

- Stitch density: S_{df} (cm^{-2})

$$S_{df} = 10^2/(AxB) \quad (2)$$

- Munden constants for plain weft structures – k_c, k_w, k_s

$$k_c = c \times l \quad (3)$$

$$k_w = w \times l \quad (4)$$

$$k_s = S \times l^2 \quad (5)$$

- Fabric porosity: ε_f

$$\varepsilon_w = 1 - \rho_a \times \rho_b^{-1} \quad (6)$$

- Tightness factor TF

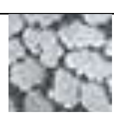
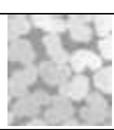
$$TF = Tt_y^{1/2} \times l_s^{-1} \ (tex^{1/2}\ mm^{-1}) \quad (7)$$

(ρ_a, ρ_b - fiber and yarn densities; Tt_y - yarn count)

Fig. 1. Geometrical parameters of weft knitted structures

The important parameters of used fiber (length and fineness), yarn (fineness, thickness, twist coefficient) and weft structure (stitch density, stitch length, porosity and tightness factor are shown in the Table 1.

Table 1. Parameters of fiber, yarn and produced weft structures

Group/nr.		Fiber			Yarn			Weft structure				
		Image	l_f	Tt_f	Tt_y	t_y	α_{tex}	S_{df}	l_s	k_s	ε_f	TF
Group A	1		28,1	1,5	12	0,14	3342	332	2,50	20,8	0,76	1,39
	2		28,1	1,5	14	0,15	3496	279	2,70	20,3	0,77	1,39
	3		28,1	1,5	17	0,16	3469	272	2,75	20,6	0,77	1,50
	4		28,1	1,5	20	0,18	3316	248	2,80	19,4	0,78	1,60
Group B	1		38,1	1,6	12	0,14	3287	341	2,40	19,7	0,80	1,44
	2		38,1	1,6	14	0,15	4303	323	2,40	18,6	0,77	1,56
	3		38,1	1,6	17	0,17	3320	304	2,45	18,2	0,76	1,68
	4		38,1	1,6	20	0,18	3584	286	2,55	18,6	0,75	1,75
Group C	1		40,8	1,2	12	0,14	3356	323	2,40	18,6	0,84	1,44
	2		40,8	1,2	14	0,15	3422	297	2,55	19,3	0,76	1,47
	3		40,8	1,2	17	0,17	3506	280	2,60	19,0	0,76	1,59
	4		40,8	1,2	20	0,18	3441	272	2,70	19,8	0,74	1,66

Legend: l_f – fiber length, mm; Tt_f – fiber fineness, dtex; Tt_y – yarn count, tex; t_y – yarn thickness, mm; α_{tex} - twist coefficient; S_{df} – stitch density in fabric, cm^{-2}; l_s - stitch length, mm; ε_w – weft structure porosity; TF – weft structure tightness

The heat resistance (R_{ct}) of knitted fabrics is determined as the quotient of the temperature difference between the measuring plate and the air (T_m - T_a) and the specific heat flux through the fabric sample

(H/A). The measurement is carried out using the sweating guarded hotplate. The environmental conditions were established as defined in the standard (ISO 11092, 1993): the air temperature of 20°C and relative humidity of 65%. The air velocity was kept constant during the measurements at 1 m/s.

3. Results and Discussion

The results of measured heat resistance for all investigated fabrics are given on the figure 2. The correlation matrix obtained in the multiple regression with dependent variable R_{ct} is given in the table 2.

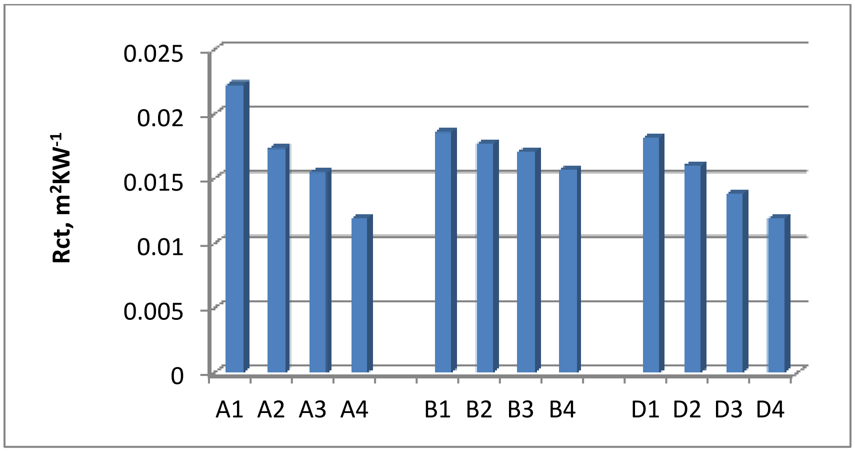


Fig. 2. Heat resistance of investigated fabrics.

The measured heat resistance of tested weft structures lies in the range 0.012 to 0.022 m^2 K W^{-1}. Comparing the measured results for the heat resistance of the weft structure and geometrical parameters, one can observe a stronger correlation between the heat resistance and stitch density (0,87). Among other geometrical parameters, the correlation with the loop length should be mentioned (R=0,77). The rest of the geometrical parameters, according to the carried test, do not affect the heat resistance. It should be bared in mind that this study is carried on a number of high porous weft structures (ε_f is in range 0,74-0,84), so the outcomes of the research using less porous weft structures (intended for the production of winter clothing) may point out at some other geometrical parameters.

Table 2. Matrix of fiber/yarn/fabric parameters and heat resistance

	Tt_f	l_f	Tt_y	α_{tex}	t_y	S_{df}	l_s	k_s	ε_f	t_f	R_{ct}
Tt_f	1,00	-0,48	0,00	0,22	-0,02	0,19	-0,13	0,03	-0,09	0,04	0,49
l_f		1,00	0,00	0,15	0,07	0,28	-0,54	-0,70	0,06	0,06	-0,63
Tt_y			1,00	-0,03	0,99	-0,82	0,64	-0,19	-0,56	0,99	0,51
α_{tex}				1,00	-0,04	0,13	-0,23	-0,28	-0,18	-0,02	-0,06
t_y					1,00	-0,78	0,57	-0,28	-0,57	0,98	0,44
S_{df}						1,00	-0,92	-0,11	0,41	-0,78	-0,87
l_s							1,00	0,49	-0,39	0,59	0,77
k_s								1,00	-0,16	-0,23	0,44
ε_f									1,00	-0,56	-0,37
t_f										1,00	0,47
R_{ct}											1,00

4. Conclusion

Quality characterization of the properties of each weft requires a systematic approach including measurements and calculations of a series of parameters in relation fiber – yarn – weft knitted structure – finishing – garment. In the present study, the whole process of production was controlled starting at the fiber level, in order to ensure that comparisons could be made. The performed tests indicate that certain geometrical parameters that affect the heat resistance of weft structures, i.e. stitch density in weft structure and loop length.

Presented results have expanded previous findings because they brought results that are focused geometrical parameters, instead of usual properties such as thickness or mass per unit area. There is a strong practical implication of the results, as the producers of weft fabrics will use the outcomes during the process of design in order to obtain the product with optimal heat resistance.

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