Title of dissertation: **Thermal absorptivity and other thermal comfort parameters of rib knitted fabrics**

Author: Asif Elahi Mangat, M.Sc

Examined by: Prof. Ing. Karel Adámek, CSc.

The presented work contains 100 pages, divided in several parts, as Introduction (7 p.), Review of the current state (32 p.), Porosity (5 p.), Evaluation and discussion of results (30 p.) and conclusion (4 p.). At the end author presents 85 references mentioned in the work and adequate number of 9 own publications and 6 conferences focused on the topic of the work.

Parameter of the thermal absorptivity was developed and defined at TUL in the 80's. This dissertation observes this parameter on set of 15 different anisotropic samples of knitted rib fabrics, in addition with different treatment of produced samples, really prepared, tested and discussed by the author.
Methods used by author are very complex, detailed, transparent and understandable – discussion of references, own theoretical and experimental procedures and comparison of their results.
The main topic of the dissertation – the thermal absorptivity of fabrics – is completed by observing of next thermal parameters influencing the comfort of clothing.

Schematic sample of ideal simulated surface – Fig. 2-16 and 2-17 (p. 40-41), taken over from study of image processing, seems to be ideal case for knitted rib after the Fig. 2-14 (p. 38), where the rib loops are very free. But the scheme of woven fabric after the Fig. 3-1 (p. 44), used for porosity definition, is very idealized. A real fabric is very deformed in both weft and warp directions (see for instance microscopic observation on TUL) and such simplification cannot be really used, I think.

Experimental data are really very extensive, so it could be useful to continue in evaluations. For instance, several bar diagrams, showing the values before and after treating, are not demonstrative enough. It should be better to create the correlation before/after and from received value of R^2 to state strong or feeble correlation for observed case. For instance, in the Fig. 5-5 the correlation is feeble, $R^2 = 0,3$, in the Fig. 5-6 the correlation is good, $R^2 = 0,8$ (both for quadratic function).
Similarly, to correlate the thermal conductivity and thermal absorptivity (Fig. 5-1, 5-3) p. 62 and 65, or to correlate the thermal resistance and relative water vapour permeability, Fig. 5-7 and Fig. 5-8 (p. 79) etc.

Some remarks or questions for discussion about the dissertation:
What about the model, mentioned in the Par. 1.2 (p. 5) as the aim No. 3?
White areas on the microscopic Fig. 4-12 (p. 57) are hollows in the low base or in the high ribs of knitted fabric? Relative contact area should characterize the ribs contacts, I think.
Water vapour permeability in the Tab. 5-13 (p. 77-78) is mentioned as the relative value, only. What about the absolute value.
Conventional versus "functional" fabric – I think that any clothing must be functional, otherwise is not usable – maybe a marketing term?

The defined goal – thermal absorptivity - is achieved, together with necessary focusing on many other parameters, influencing the comfort of clothing.
At the conclusion of my review I would state that presented dissertation fulfils all requirements of relevant internal rules of TUL and I do recommend the dissertation submitted by Mr. Asif Mangat for next procedure at the Faculty of textile engineering of the TUL.
In the case of the positive result of the defence of the dissertation I recommend to award the title of Ph.D.

Liberec, 25.11.2018
Karel Adámek

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Faculty of Textile Engineering

Review of doctoral thesis

Student: **Asif Elahi Mangat, M.Sc.**

Supervisor: prof. Luboš Hes, Dr.Sc., Dr.h.c.

Title of the thesis: **Thermal Absorptivity and Other Thermal Comfort Parameters of Rib Knitted Fabrics**

Field: Textile Technics and Materials Engineering
Working place: Department of Textile Evaluation, Faculty of Textile Engineering, Technical University of Liberec

This submitted doctoral thesis is devoted of studying of thermal absorptivity of rib knitted fabrics. Other thermal comfort parameters and properties of several different group of weft knitted samples including one group of woven fabric were also studied and mentioned.

The structure of thesis conforms to principles and requests to the structure of the scientific thesis. The topic of thesis is current and relevant in the context of up-to-date research in theory of thermal comfort parameters.

The author has performed good orientation and wide knowledge of the theory of thermal comfort considered in the thesis: theory of thermal absorptivity and heat transfer, as well as the thermo-physiological comfort are pointed the author's ability to perform the scientific work on the good level. It is evident that there are the theoretical knowledge and good view to the problem performed in this thesis, but only in the area of thermal comfort properties. The part of the structural yarn (multifil) properties and objectives as an input parameters which influenced the comfort properties of the produced knitted fabric – samples in submitted doctoral thesis are missing or are not very well discussed.

Chapters 1-2 are theoretical background of the research. In Chapter 2.16 *Knitted fabric structure and porosity,* the porosity is not mentioned and there were used knitted terminology with inaccuracy, i.e. terms:
Title of Figure 2 – 13 *Knitted fabric structure 1 x 1,* (both resources, original from prof. D.J. Spencer and other copied source, cited in this thesis, named that structure as Interlock). According author, this structure belongs to the rib knitted?
Is a term "*Rib loop*" the term for face (front) or reverse (back) loop/stitch?

Study of M.J. Pac (p.39) investigated the single jersey knitted fabric (36 tex, stitch length values 0,4 – 0,6 cm/stitch – totally different to the sample of this doctoral thesis) with the assumptions, and conclusions are not valid generally for all knitted structures. It is the same problem as the work of Semnani et all (p. 41) who mentioned 15 different knitted structures including single, double and interlock fabrics with different yarn count and different loop/cm^2, but they evaluated only two structure (double cross tuck and interlock with different structural parameters).

In Chapter 2.17 *Knitted rib and its structure* the "*rib stitch*" is described as "*blend of the two sides of the jersey stitch*". The sentences "*The rib stitch has the same appearance on both sides* ..."is not really correct. The knitted stitch is the basic unit of intermeshing, both side of that element has not same appearance and therefore we talk about face loop-side and reverse-loop side. If the term, which author used, „*the rib stitch*" consists of two loops (Fig. 2 -15, p. 40), the first element is reverse stitch and second is face stitch. When we turn the structure to the back side, the first element will be face and second will be reverse stitch. The appearance are not same.
The author mentioned (p. 39 and 40) that "*extensions of rib structures is about 140 %*" and advantage of rib stitch fabrics is "*fairly stable*". Those statements are in contrary.

The chapter 3.1 performed the porosity and its measurement for the textile fabric, but not knitted. The binding points of the stitch, the structure of rib knitted fabric which is not 2D, is totally different from the mentioned fabric (plain weave). There was written that the porosity was calculated by two methods, probably with using equations 3.9 and 3.11 (p.46).

The chapter 4 introduces the experimental part. It is the author's attempt to find firstly the connection between the structure (the geometrical parameters of knitted samples) and comfort prediction and secondly, the influence of the rib structures on the results from measuring of the properties with Alambeta, Permetest, Air Permeability Tester and Kawabata Evaluation System.

The part which deals with threads (yarns) only and their properties which influenced the knitted structures is still missing. We can find that the used material was "*100% pure polyester no blending with any other fibber...*" (p.47). This characterization is not enough for doctoral thesis. The knitting machine parameters and setting of working part (e.g. stitch cam, comb, take-off device) are still missed too. The author did not specify, which yarn count and which gauge were used for individual samples (the machine gauge is fixed by the producer, it is not possible to "*set from 8 to 12*" (p.48) or adjust) and other condition which is useful for anybody who will carry on the same experiment. The notice "*They were knit under normal tension force*" (p. 49) are insufficient.

The knitted samples are not deeply specified (i.e. course and wale spacing, loop length), the parameter „Stitch length per [cm]" for 15 types of rib structure (Table 4-1) was erased from previous thesis version. The standards or condition for measuring data from Table 4-1 are not mentioned. The contact area % was calculated according the equations 3.9 and 3.11 (p.46)? The input parameters for that equations are "*volume of the yarn*" and "*volume of the unit cell*" and they are not described. Why is the value "*contact area*" of rib structure 1 x 4 higher than in the structures 1 x 6, 1 x 3 and 1 x 2?

The elasticity and flexibility of the rib knitted fabrics (and author comments (p. 39) "*the extensions for rib structures up to 140 % can be achieved*") significantly influenced the methods of *painting technique* and afterwards the values of the "*contact area*".

An unanswered question from previous thesis version still remains. Why in equation (4.1) are mentioned area, but in the Figure 4-12 is showed the length (p. 57). With respect to the scale (length app. 2,2 mm) and 10 or more? readings we taken only the small area of that samples, it is not "*most*

precise way". In the case of longitudinal view into the yarn, researchers measure yarn diameter 100, 200 or 300 times. On the basis of this very inaccurately determined parameter – *"real contact area"*, further comfort properties are evaluated and discussed.

The Talysurf instrument and method for measuring were not specified (p.60).

Samples no 5 and 12 have the same rib type 2 x 1, but different *"contact area [%]"* in Table 5-1. Why? It is possible to produce the same structure with several different parameter of that area?

Other group of tested material were woven fabrics. In my opinion is not necessary to join that Chapter 5.4 to doctoral thesis (p. 65 – 69) with knitted fabrics topic.

The paired sample statistical procedure for thermal absorptivity of different knitted structure from different yarn material and linear density are not an appropriate tool for comparison and interpreting the measured results. Thermal absorptivity depends on type of fibres in case of the same knitted structure (i.e. see the single jersey 1, 8, 15, 17, 25, 26 and 31), but it is not discussed.

The group of fabric for KES measuring (Chapter 5.6) included 12 samples (Table 5-12) without described characteristics (sample 1, 2 are the same samples 5, 12 in Table 4-1?). Sample 6 (in Table 5-12) is the back-side of the sample 1 in Table 4-1? The discussion about the results are with mistakes of the values, because data – minimum and maximum are partly shifted (Table 5-12).

Other group of samples are mentioned in chapter 5.8. *Airflow direction and water vapour permeability* of samples 14 and 15 in Table 5-13 are not correspond with the Table 5-1. The new samples 16 – 18 are not described. We know nothing about the samples S No (Table 5-12), is it knitted?
Development of prediction of thermal absorptivity of rib knitted fabric based on porosity with the equation (5.1) is not described clearly. The parameter *"density of fabric"* (density of knitted rib are not written in previously mentioned tables) are measured or calculated (p.80)?
In Table 5 -16 the values of *"contact area assumed"* and *"measured"* (0,13 – 0.85 %) are very small and not correspond with the Figure 5-10, where relative contact areas reach values from 2 to 14 %.

I am afraid that it is necessary to deeply describe the rib structure and yarn structure before registration of patent application (Chapter 6.1), because in this experimental work it has been confirmed that one can produce the same rib structure 2 x 1 with different value of *"contact area"* (52 and 71 %).

With respect to the above mentioned comments, the doctoral thesis by Asif Elahi Mangat is not fulfils all the conditions for gaining the PhD. degree in Textile Technics and Materials Engineering; therefore it is not recommended.

Liberec, January 9, 2019

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Review of the doctoral Thesis Thermal Absorptivity and Other Thermal Comfort Parameters of Rib Knitted Fabrics by Asif Elahi Mangat.

The dissertation is re-written version of the dissertation submitted in 2017 under the same title.

The dissertation consists of six chapters in total with 100 pages including the list of references. First chapter defines objectives of the thesis and overview of methodologies. Chapters 2 to 4 describes theoretical principles, definitions of different phenomena linked with the Thesis topic and experimental facilities and instrumentation used for the experimental part of the thesis.

The main contribution and results of the experiments are in chapter 5.

Comparing with the previous version of the thesis, the newly submitted thesis was significantly improved, taking into account suggestions and comments of the previous review. Some formal mistakes remain that however don´t impact on the overall quality of the thesis. For example, there is still inconsistently used t and T for temperature, there is no explanation what is the characteristic dimension for natural convection on surfaces facing up and down – eq. 2.15 and 2.16 (it is definitely not the length in the direction of gravity as stated with the eq. 2.14), there is still a mistake in the eq. 2.5 and some other minor formal mistakes. However as said above, these formal errors don´t reduce the overall good level of the dissertation.

The work represents a good contribution in the field of textile characteristics and meets standards imposed on doctoral thesis. The dissertation presents very useful results that may fulfil a demand from textile industry. Research methods and individual steps undertaken in this study are based on the current knowledge in the field and proved to be appropriate for this kind of studies.

Mr. Mangat so far published a sufficient number of articles in journals ranked in WoS.

I therefore recommend the acceptance of the Thesis to the Faculty of Textile Engineering TU Liberec and after a successful defense to award a PhD degree.

In Brno, 11.2.2019

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Prof. ing. Miroslav Jícha, CSc

Odbor termomechaniky a techniky prostředí
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