Supervisor´s evaluation report on the PhD Thesis of Mr. Tariq Mansoor

"Thermal resistance prediction of wet socks and some other parameters of their comfort"

This systematic and original study deals with thermal comfort properties of socks in wet state. Socks are fabrics, where the absorbed moisture can strongly influence their thermal comfort properties, as a human foot could generate up to 50 grams of sweat per hour in a hot environment or at high physical activity. Due to this high sweat rates, thermal resistance may substantially decrease and can cause hypothermia. By means of the ALAMBETA fast working non-destructive tester, the candidate measured thermal resistance and thermal absorbtivity of 7 plain socks consisting of cotton, viscose, polyester, nylon, polypropylene, wool, and acrylic fibres, with same plaiting yarn polyester covered elastane, without any special finishing (commercial state). The selection of socks for his research was based on his previous experience in socks manufacturing company. The measurements were executed at up to 7 levels of the moisture content. Moreover, in his experiments, the candidate also respected the extension of the socks during their practical use, using his own additional device which made his experiments very realistic. The ALAMBETA testing corresponded well to the use of a socks inside a shoe (boundary conditions of first order).

In the next step, he focused on the development of a mathematical model for a prediction of thermal resistance of plain socks in the wet state, as he did not find any reliable model in the available literature except the last three. He has checked following models.

1. Mangat parallel/ series models
2. R.S Hollies model (parallel model)
3. S. Naka model (three parameters model series/ parallel)
4. Dias and Delkumburewatte (three parameters series model)
5. Fricke's model (100% Series)
6. Ju Wei model (considered polymer + air in parallel and air in series)
7. Baxter model (considered 21 % parallel+ 79% series)
8. Schuhmeister model (considered 30 % parallel+ 70% series)
9. Militky (considered 50 % parallel+ 50% series)
10. Maxwell Eucken-1 and Maxwell Euken-2(dispersed and continuous phases)

Above all models were compared with the experimental data. Unfortunately, none of these models was offering a good correlation with the experimental data from the wetted socks except Maxwell Euken-2, Schuhmeister and Militky's models. The solution was based on modifications of these models has done by adopting a combined approach of water and polymer components for determination of thermal conductivity and introduction of linear changes of the filling coefficient (volume ratio) with the increasing moisture we succeeded in predicting the thermal resistance of all samples at different moisture levels with the coefficient of determination R^2 ranging from 0.78 to 0.97. Based on the knowledge of the fibre composition (thermal conductivity of the used polymer), fabric areal density and thickness, these original models can predict the thermal resistance of the studied socks at any moisture level up to 70%. These models could be probably also applicable for other textile structures, but it should be verified first.

Besides thermal resistance of socks, the candidate also determined experimentally thermal absorbtivity of all the studied socks in wet state. Here, he also used the ALAMBETA tester. In his experiments, the candidate also respected the extension of the socks during their practical use, using his own additional device which made his experiments very realistic. The results were treated statistically and presented in diagrams. Very interesting results were also achieved by the candidate when measuring thermal resistance of socks subject to heat transfer by convection on their free surface, where the sock were worn free, not inside a shoe (boundary condition of 3rd order). He used a special thermal foot model installed in the laboratory of the Textile faculty in Zagreb (Croatia). The candidate discovered, that the gaps between the heated elements of this commercial device are a source of measuring errors. Consequently, he fixed a semi-permeable membrane on the foot model to avoid the turbulence effects. After this improvement, the candidate measured all his samples on this model with good reproducibility. Then he compared his results with the results achieved on the PERMETEST Skin model (which works in similar principle). Both devices now showed very good correlations. The results were discussed and commented.

He also measured the coefficient of friction between sock-insole interface at different moisture levels during his stay at ITM, Technical University of Dresden Germany. The results of the frictional characterization between the sock-insole interface as expected has positive correlation with the humidity levels. Furthermore, the models have been implemented in a programming language (FreeMat / Matlab) which potentially provides a software tool for textile designers and technologists to predict the thermal resistance of fabrics in a wet state for various applications.

As regards the possible plagiarism, the plagiarism detection system indicated the total plagiarism level of less than 1 %, which is excellent.

During the study, Mr. Mansoor showed full dedication to his research work, presented high creativity and original ideas, executed large number of systematic measurements and calculations when comparing various thermal resistance models. His results would surely contribute to the fundamental knowledge in the textile science and technology areas. He is an author or a co-author of 10 papers in impacted journals. I do recommend the submission of his Thesis for the defence at the Faculty of Textile Engineering of the Technical University of Liberec, Czech Republic.

In Liberec, on July 15th, 2020

Prof. Ing. Lubos Hes, DrSc