OPPONENT'S ASSESSMENT OF A DOCTORAL DISSERTATION

Author: Abdelhamid Rajab Ramadan Aboalasaad, M.Sc.

Title: Structure and Analysis of Woven Compression Bandages for Venous Leg Ulcers

Opponent: doc. Mgr. Irena Slamborova, Ph.D.

The submitted dissertation deals with the issue of the structure of compression bandages designed primarily for patients suffering from venous leg ulcers. These compression bandages are intended for patients as part of their treatment with the aim to reduce the swelling of their legs. As previously stated, the bandages are meant to be used particularly by patients suffering from venous leg ulcers. However, their application includes patients with lymphatic system disorders.

The proper manner of bandaging legs is challenging for many patients and, as a result, they are often unable to do it correctly. The bandage is either too tight or vice versa. Therefore, this is a truly current topic and has the potential to apply the research results in practical health care.

The dissertation, compiled through researching 168 bibliographical sources, analyses the topic extensively. The theoretical analysis is suitably complemented with the results of the author's own research.

In the practical section the author looks into the modification of the structure of a compression bandage made of 100% cotton by inserting an integrated tension sensor therein. I view the idea of the integrated tension sensor, which consists of threads distinguished in colour from the remaining structure of the bandage, as a breakthrough. The patient will very easily recognize the deformation of these coloured threads as tension (deformation) occurs in the bandage, thus eliminating the issue of the wrong mechanism of applying the bandage to legs and resulting in the degree of compression that is either too high or too low.

The newly designed bandage was subjected to a wide range of mechanical tests by the author in order to examine the relations between the deformation of a woven bandage, its porosity and its properties under tensile stress. The newly obtained results were compared to a commercially available 100% cotton yarn used to produce bandages. Except for cotton, other materials such as viscose – polyamide were used in the dissertation.

I really appreciate the author's viewpoint in terms of the antibacterial surface treatment of compression bandages. Bacterial contamination is found in most leg ulcers as is secretion, which is shown by fluid leakage through bandages and subsequent fouling of the bandage. This results in further microbial contamination. Therefore, zinc oxide nanoparticles and silver nanoparticles at various rates of concentration were applied to samples and the microbial activity of G+ and G- pathogenic bacteria was examined. The results of antibacterial efficiency are very good.

When evaluating the dissertation it is necessary to point out the research results which have become a basis for a number of publication outputs; that is, articles (11), conference presentations and seminars (9).

On the whole, the dissertation is carefully laid out, with chapters being logically linked and results subsequently summarised and discussed. The results achieved by the dissertation have a great deal of potential for practical application in health care.

A minor remark on my part – the names of bacteria strains are always italicized.

I have the following questions to ask the author:

1. How were the ZnO nanoparticles immobilised (anchored) on the surface of the material?

2. Was the size of the nanoparticles measured?

3. As the bandage containing immobilised nanoparticles will come into direct contact with human skin its harmlessness for health must be taken into consideration. What tests would the author propose to prove that the nanoparticles are not released from the material and the material is therefore non-toxic (harmless for health)?

4. What will be the life span of the newly designed compression bandages?

The Ph.D. candidate has demonstrated corresponding knowledge in the field. I **recommend** the dissertation submitted by Abdelhamid Rajab Ramadan Aboalasaad, M.Sc. **for a dissertation defence** and at the same time **recommend that the Ph.D. degree should be awarded.**

In Liberec, 23 July 2021

doc. Mgr. Irena Slamborova, Ph.D.

Lodz, 13th June 2021

DSc. Marcin Barburski, Associate Professor
Lodz University of Technology
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Review Report on Doctoral Dissertation

of **Abdelhamid Rajab Ramadan Aboalasaad, M.Eng.**
entitled: "**Structure and Analysis of Woven Compression Bandages for Venous Leg Ulcers** "
prepared based on invitation letter delivered on 14th May 2021
from Dean of Faculty of Textile Engineering doc. Ing. Vladimir Bajzik, Ph.D.

Supervisor:
Ing. Brigita Kolčavová Sirková, Ph.D.
Department of Technologies and Structures
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1. General description

The review has been performed on the basis of the Doctoral Dissertation in English.
The doctoral dissertation consists of 9 chapters, including an overview of the current state of the problem, description of experimental parts, evaluation of results and new findings and list of references. Additionally, a list of papers published by the author and a short Curriculum Vitae are included.
The material of the doctoral dissertation contains 102 pages, including 83 figures and 33 tables. The content of the dissertation presented is divided into nine individual chapters. In the beginning, the list of abbreviations and nomenclature used in the dissertation is presented.
The first chapter was an overview of the current state of the problem and a review of the scientific literature. The second chapter describes the purpose and aim of the thesis. The third chapter is focused on the comparison of different types of bandage existing on the market.
In chapter four, the characterization of yarns used in the bandage, the materials description, experimental techniques, research methodology and the experimental results are included.
Chapter five is the longest and most important chapter focused on the analysis of individual properties of woven compression bandages.
The summary of research work, evaluation of results and new findings are presented in chapter six. Finally, in the last chapter of the dissertation, 168 lists of references are included.

2. The topicality of the thesis

The main goal of the presented scientific work was to study the structure and behaviour of short-stretch cotton woven compression bandages (WCB). The thesis aims were focused on the definition of structure, then modification of construction and analysis of properties, and behaviour of WCBs. The author tries to create better condition during the application of

bandage by a patient, nurse, and athletic user and find a connection between structure and applied tension of bandage during static and dynamic applications. The motivation of this research was to investigate the optimum conditions for compression therapy using long- and short-stretch WCBs.
The research work combines textile aspects with very complex medical elements of the human circulatory system.
The research goal is an analysis of bandage; in accordance with the topic of research, the aim has been achieved. However, the scientific goal of the research has not been clearly shown. PhD candidate did not make any scientific hypotheses.
The aim of the dissertation is actual, very interesting and important from the practical point of view in medical applications, especially for the design and production of compression bandages.
Taking the above into consideration, I can state that the dissertation topic is current and relevant in the context of up-to-date research in textile material engineering.

3. Methodology

Investigations presented in the dissertation are based on three main topics:

1. Analysis of input staple twisted cotton yarn for producing 100% cotton bandages.
2. Analysis and modification of cotton woven bandage structure.
3. Evaluation of individual properties of woven bandages.

PhD candidate has measured the mechanical properties of cotton yarns and the modified surface of these yarns, then evaluated the structure of three basic types of WCBs and modified the construction of woven cotton bandage structure using an integrated tension sensor. The author also measured the bandage extension and porosity using a digital camera attached to the tensile testing device. Next, he made a comparison of pressure measured by Picopress with theoretical compression forces calculated by Laplace's law equation and evaluated the elastic recovery bandage on a mannequin and human leg at different positions and activities. In the end, the author studied the effect of compression bandages on lower leg muscles' performance using an eMotion wireless EMG system and thermal comfort properties using Alambeta and Permetest and finally validated the experimental results of thermal resistance and thermal foot manikin with three mathematical models. The characteristics of the tested yarns and fabrics were determined in accordance with the standards.
Chapter 5 presents many experiments and results with comments and analysis but lacks a summary and deeper analysis of why it is so and how these results solve the main scientific problem.
Experimental results confirmed the hypothesis, which is always true, that the type of yarns and structure of woven fabrics have significant effects on thermal resistance as well as the bandage tension and thickness of layers.
The dissertation includes results of experiments, but it is missing why some dependency exists and scientific analysis. This is because of the lack of a clear scientific hypothesis. The reader needs to conjecture it.
All applied experimental methods have been described clearly and in detail. In my opinion, the methodology is adequate to the problem which the author undertook to solve.

1. Results and discussion

All experimental results have been presented clearly and in detail. The figures, schemes, and tables are correct and supported to analyze the findings. Results have been commented on deeply, but they do not present why some results were observed and how measured parameters influenced the quality of bandage and users.

2. Conclusions

In this chapter, evaluation of results and new findings were presented with conclusions of the work. Conclusions are based on results. The conclusions take into consideration all findings of performed experiments.
The dissertation does not show the best solution for the design of a bandage. The dissertation presents test results, for example, "Wearing VI-PA bandage was associated with lower muscle activation by a percent of 8.42 % for FC muscle during the standardized activity and 14.82% during flexion-extension action". We do not know whether it is OK or not. What is the optimum? How should it be?
The most important conclusions of this work are the warp yarn tenacity should be greater than 15.5 cN/Tex, and its extension should be at least 12% to produce the highly stretched 100% Cotton WCB, and the optimum twist of warp yarns was ranged between 1800 - 2200 TPM for producing high extension Cotton WCBs.
PhD candidate design integrated tension sensor, which causes a change in the spacing of coloured threads during its deformation. The solution is sensors in the bandage in the form of a different colour pick from the other structure of the bandage. As a result, different colour picks with regular distance become visible due to deformation/stress in the bandage.
LSB has a higher resting pressure because of the elastane filaments; due to this, the patient should take off the LSB every day before sleep. Cyclic loading-unloading test confirmed that short-stretch WCB lost approximately 28.6% of its activity, whereas LSB lost only 10.05% after 5 days of application.
Experiment and simulation confirmed that wearing WCB improved the performance of muscles.

3. Bibliography

The bibliography in the dissertation is wide and actual. The references include 168 items. They are mostly the scientific articles published in world-renowned scientific journals and conference papers. The selection of references is adequate to the topic of the thesis.

4. Referee remarks, questions, and conclusions

Remarks
Figure 1.4 does not present a plain weave. This figure should be explained more deeply.

Table with List of Abbreviations and Nomenclature does not present all used Abbreviations.

In the reference, there are some mistakes. For example, the reference of figure 2.1 should be 52, not 53 and Mertová, et al. is not at position 33 etc.

The author should summarise each chapter because the reviewer needs to conjecture for what was analyzed.

In Figure 3.1, it is difficult to see the differences between the bandages.

Each chapter is well prepared, but it is difficult to understand the connection between them. It should be better explained because the reader needs to presume what is in the subsequent chapters. Please keep this in mind when you publish an article and during the defence.

Table 4.7 - 4.10 the produced yarn properties are presented, but without more profound comments on their purposes.

Questions
What do you mean by the "optimum elasticity of LSB"?

Please explain how adding the blue marks to the bandage structure could control the bandage tension as a function of the applied extension.

Please explain the methodology of optimization parameters to choose the best compression bandage.

Your present result confirmed the literature that increasing the plied yarn twist from 300 to 600 twist/m increases the yarn tenacity, then higher twist decreases tenacity, so why did you use linear trend line in figure 4.2?

From where on the images X-ray tomography (figure 5.37) has been detected gold on the surface of yarn?

What conclusions can be drawn from Figures 5.2 and 5.3?

What is new in using antibacterial finishing for a bandage? What scientific problem was solved?

Conclusions
The author of the dissertation has high scientific achievements. The results of the research have been presented in 12 scientific publications, at 9 conferences and workshops.
At the conclusion of my review, I would state that the presented dissertation fulfils all formal requirements and thesis conforms to principles and requests to the structure of scientific. Therefore, I recommend the dissertation submitted by Abdelhamid Rajab Ramadan Aboalasaad, M.Eng, for the next procedure at the Faculty of Textile Engineering of the TUL.
In case of positive results of the defence of the dissertation, I recommend awarding the title of Ph.D.

Marcin Barburski