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**Review of the PhD Thesis of Zuhaib Ahmad, M.Sc.,
entitled "Structure and geometry of single and two layer stitched woven fabrics"**

Terminological remark

The thesis title in English language is "Structure and geometry of single and two layer stitched woven fabrics". As already clarified with the supervisor Prof. Brigita Kolcavova Sirkova, the topic covers woven fabrics based on single layer weaves or and interlaced two layer woven fabrics and the word "stitching" is used in this thesis as synonym for "interlacing" or "connecting" yarns.

a) Evaluation of the importance of the Ph.D. thesis for the given field

The investigation of the methods for mathematical description of the single and double layer woven fabrics is important research topic and there is no efficient solution for description of the fabrics geometry in this area. The problem is that the yarns relax at different places, depending on the weaving pattern, properties of the yarns and the parameters of the weaving process. The only one powerful numerical solution is the simulation of the complete weaving process with FEM software, where each yarn is represented with at least of 20-30 filaments. But this solution takes currently still few days for computations according the latest reports of colleagues (Stephen Hallett from Bristol, Damien Durville from Paris, during 602 Euromech Colloquium 2019) and my own experience. The software WiseTex solve the problem using minimisation of the potential energy of the yarns and works very fine for large class of structures, but it require special attention and preparation of the data for denser multilayer woven fabrics, too. For this reason, the development of parametric mathematical



method and numerical procedure for modelling of the geometry of the multilayer woven structures can speed up the design of such fabrics and optimisation of their properties. This thesis contributes to this area with a different method, which can be used for certain type of applications.

b) Problem-solving procedure, methods and achievement of the stated objective

The author selected Fourier series for approximation of the yarn axis. He recognize the different regions - single layer structure and connecting ("stitched") regions - and analyse these carefully. The identification of the yarn axis was done using modern image processing tool NIS after weaving, preparation, cutting and creating of microscopic images of seven different samples. The coefficients in the Fourier series are obtained using "theoretical FS analysis". How exactly the FFT is performed, remains not clear for me, but I can suppose, that the NIS software provides build in FFT analysis or any other computational tool, available today, was be used.

The selected procedures and methods for the achievement of the objective are not most flexible and the most powerful for this task, but their selection is reasonable and applicant demonstrate the ability to choice suitable modern tools and methods and apply them successfully for investigation of research problems.

c) Opinion on the results of the Ph.D. thesis and the importance of the author's specific contribution

The author demonstrate, that using image processing and analysing with Fourier methods is possible to represent effectively the yarn axis of multilayer woven fabrics. He succeed to apply the method for single and two connected layers and the developed method can be extended for automatic creation of 3D geometries based on the weaving pattern.

d) Other statements concerning mainly the evaluation of the method, clarity of structure, layout and the language level of the Ph.D. thesis

The structure of the thesis is clear. The language can be improved in several places, but is readable and understandable. I would expect to see more careful evaluation of the method for more complex pattern. The current evaluation of the quality of the approximation was based on few periods of the weaves and is mainly subjective (visual) and limited for few types of woven fabrics and materials. Any comparison to more simple approximation techniques like using "just splines" between the contact points is missing, but would be valuable, because it could demonstrate the advantages and problems of the single methods. Ideas for application of the obtained analytical functions are missing too –



these can be applied directly for computation of the crimp / yarn length and probably some more parameters of the structures analytically.

e) Comments on the student's publications

The student has 7 publication of good journals, 4 submitted publication in high impact journals under review and 7 publications in international conferences, all with the supervisor or different co-authors. This is very good publication record for the level of a PhD student.

f) The opponent's unambiguous statement whether he recommends the Ph.D. thesis for defence.

Based on the reading of the thesis and above short remarks, I would recommend to the Dean and the PhD Board to accept the thesis for defence.

Best regards



Prof. Dr.-Ing. habil. Yordan Kyosev

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Thesis title: Structure and geometry of single and two layer stitched woven fabrics

Student: Zuhaib Ahmad, M.Sc.

A. The thesis presents interesting topic and a comprehensive work of theoretical and experimental investigation of woven structures. This is an important field in the understanding of woven structures for applications in industrial materials including composites.

B. The objectives are clear. They are well defined and outlined. The thesis describes systematic methods of theoretical evaluation.

The experimental part is limited. The number of samples developed to validate the theoretical models is relatively small.

C. A variety of theoretical models starting from Pierce, Kemp and Olofsson are stated. Their specific application in special structural geometries are outlined. Extensive application of DFT (Discrete Fourier Transformation) is explored.

D. The method of evaluation is proven and correctly selected. Language is in good level.

E. The candidate has 1 publication in Journal of Textile Institute, 1 in Industria Textila, 1 in Vlakna and Textil and 1 in Material Science and Engg. For defence of PhD thesis this is quite sufficient. It must be outlined that in this area of research, it is relatively difficult to publish large number of articles. Other articles are under review and expected to be published in near future.

F. I would suggest the candidate to address to the following points during the defence.

1. What are the difficulties in modeling woven fabric structures using simple geometry?

2. The importance of computational tools (e.g. FEM, DFT etc.) to solve the structural problems should be highlighted. These tools make the solution of fabric geometry much simpler and user friendly.

3. What assumptions are necessary in modeling the fabric geometries with multifilament Basalt yarns/Tows? Especially with respect to the cross-sectional deformation?

4. What is the error of prediction with regard to the data obtained from real fabric samples? How does the candidate minimize such error in his models?

5. What can be application of composites made from such single layer and 2 layer structures?

The work has fulfilled requirements of PhD thesis and in view of the methodology adopted and obtained results, I recommend it for the Defence.



doc. Rajesh Mishra, PhD

26.03.2019