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Review report on the doctoral thesis

of **Tsegaye Shume Lemmi, M.Sc.** entitled: " **Influence of Vulcanization Process Parameters on the Physio-Mechanical Properties of Textile Materials Used for the Reinforcement of Rubber Goods** "
was prepared on the basis of invitation letter delivered on 17th May 2023
from chairman of the Council Barbara Blazejczyk-Okolewska, Council for Academic Degrees of the Lodz University of Technology.

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1. General summary of the doctoral thesis

The paper form of the doctoral thesis contains 114 pages, including 67 figures and 7 tables. The work is divided into seven main chapters, including the objective of thesis, definition of the statement of the problem as well as description of methodology for analyses of problem, including description of experimental parts, evaluation of results and list of references.

The first chapter was focused on definition of objective of thesis as well as hypothesis. Main part of the second chapter is focused on overview of the current state of the problem and a review of the scientific literature. The third chapter is focused on the definition of the parameters of materials utilized for the research. The chapter four is focused on definition of methodology for determination of the physio-mechanical properties of textiles and textile-reinforced conveyor belts. Chapter five is focused on the experimental testing where subsequently in chapter six the results and partial conclusions are discussed. The final conclusions of research work are presented in chapter seven.

2. The topicality of the doctoral thesis

The textile material-reinforced rubber goods pass through various processing stages, including the vulcanization process at high temperatures and pressure. Each processing stage has its own positive and negative impact on the properties of the reinforcement's constituent materials, such as yarns, fabrics, rubber, and the final product of the mechanical rubber good. The main goal of this thesis work was to investigate the influence of vulcanization process parameters on the physio-mechanical properties of textile materials utilized for the reinforcement of mechanical rubber products, mainly for conveyor belt reinforcement.

The main motivation of the research, as the author states, is the unexplored the problem in relation to vulcanization parameters on the components of the conveyor belt did not get attention from the researchers. In this work, the effect of vulcanization parameters on the carcass of textile-reinforced conveyor belts was taken as a main concern and investigated.

The research goal was to investigate the influence of vulcanization process parameters on the physio-mechanical properties of textile materials utilized for the reinforcement of mechanical rubber products, mainly for conveyor belt reinforcement; in accordance with the topic of research, the aim has been achieved. However, the scientific goal of the research has not been clearly shown. The aim of the dissertation is actual, important from the practical point of view in various sectors ranging from manufacturing to mining industries for transporting raw

materials and finished products. The dissertation topic is current and relevant in the context of up-to-date research in textile material engineering.

3. Methodology and Experimental part of the doctoral thesis

Experiments were designed to determine the physio-mechanical properties of textiles and textile-reinforced conveyor belts. The investigations were conducted on high tenacity polyester yarns, EP woven fabrics, and textile-reinforced conveyor belts under various processing parameters. To identify the effect of thermal aging on textile materials, high tenacity polyester yarns and fabrics were subjected to various experiments at different stages. Subsequently, the conveyor belt reinforced with the EP woven fabric was produced and subjected to mechanical property tests.

The student describes in detail and comprehensibly the methodology of measurement and analysis of selected experiments of the doctoral thesis. The measurement conditions and the expected behavior and hypotheses are described in detail. The thesis 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. 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.

4. Results, and Discussion, and Conclusions of the doctoral thesis

In these chapters, all experimental results have been presented clearly and in detail. 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 experimental part is quite extensive for the fact that it is a doctoral thesis.

The first part, is focused on the measurement of a selected set of input materials used for the production of woven reinforcement of conveyor belts. The outputs are statistically evaluated without deriving possible mutual theoretical relationships. From the point of view of the observed forces during testing, it would be appropriate to deal not only with the maximum force in the break, but with the forces corresponding to the load under real conditions of the conveyor belt. Belt operating conditions will never be in the area of maximum forces required for material rupture. In the case of studying the tensile curve, it would be appropriate to deal with the stiffness of the threads, corresponding to the initial modules that can be evaluated on the tensile curve.

I see shrinkage as one of the basic monitored properties. It is a reasonable choice due to the fact that heat is applied during the production of the final composite of the conveyor belt, which can lead to subsequent undesirable behavior in relation to the tenacity and elongation of the belt.

The second part, is focused on the measurement and evaluation of woven fabric samples for creation of final conveyor belt. The influence of Resorcinol-Formaldehyde-Latex (RFL) adhesive solution on the tensile property of EP woven was analyzed by conducting experiments on the greige and dipped woven fabric samples with different nominal tensile strengths. The tensile property analysis was compared, as shown in Figure 51(a-d), and the results are elaborated. Without adequate adhesion between the conveyor belt's constituent materials, achieving a conveyor belt that withstands the external force exerted on the belt from the conveyed materials is impractical. Therefore, the greige EP woven fabric undergoes a dipping process, where the curing is carried out at around 185 °C following the dipping process of the fabric in RFL solution. The investigation revealed that, besides imparting adhesion to the EP fabric, the dipping process could also cause mechanical and physical property changes to the woven fabric.

In Table 2 are selected basic construction parameters of woven fabric (greige as well dipped). Presumably the spatial geometry of fabrics was not investigated? After chemical treatment (dipped fabric) are the planar and spatial geometry parameters constant? The parameters of the woven fabric spatial geometry evaluate the waviness of threads, from which it is possible to derive the crimp of threads. From the presentation of the tension curves (Fig. 51), it is evident that the elongation depending on the change in warp yarn count changes? Is it possible to explain for what reason? Here, it would be appropriate to add the modulus of elasticity in tension (as the initial modulus determining the stiffness of the fabric). For the possibility of finding the relationships between greige and dipped fabrics, it would be appropriate to examine the tensile strength and elongation for both dipped and greige fabrics. I did not find results for greige fabrics at work. For the possibility of correlating the tenacity of yarn with the tensile strength of the fabric, it would be appropriate to indicate the tensile strength as "/one threads" not "/m", see Fig. 51-53.

The third part, is focused on the measurement and analysis of ep woven fabric reinforced conveyor belts. This part describes the effect of vulcanization parameters on the tensile strength and elongation of textile reinforced conveyor belts. Vulcanization is the crucial process of adhering the conveyor belt components under the application of temperature and pressure.

Therefore, the influence of vulcanization parameters, primarily vulcanization temperature and duration of vulcanization on the components of the conveyor belt was analyzed meticulously to understand how the tensile property of the fabrics used for the reinforcement can be affected by this process.

Which woven fabric sample from the experimental set of fabrics is presented in Fig. 56? What construction parameters does the fabric have? Perhaps it is mentioned in the text above, but it would be appropriate to add it to the text of the description of the image. With such an extensive experiment and presented data, orientation in the text is difficult for the reader.

Another monitored parameter in this section is effect of vulcanization parameters on the adhesion strength between plies of the textile reinforced conveyor belts. The images presented in Fig. 63 and 65 were not evaluated using image analysis? Using image analyses it is possible the woven fabric surfaces objectively quantified and after connect with the mechanical properties results.

The thesis work was aimed to contribute a novel insight into the field of textile-rubber reinforcement technologies with a primary focus on the conveyor belt carcass. Therefore, the objective of the thesis was to investigate the influence of vulcanization process parameters on the physio-mechanical properties of textile materials used in the reinforcement of mechanical rubber goods and establish an optimum vulcanization temperature and time for a specific type of conveyor belt.

The objectives of the assigned work were fulfilled.

5. Bibliography of the doctoral thesis

The bibliography in the dissertation is wide and actual. The references include 135 items. They are the articles as well as contributions published in scientific journals listed in the Web of Science database. The selection of references is adequate to the topic of the thesis.

REVIEW SUMMARY

Comments and review questions

1) What assumptions were used to define the shrinkage measurement time, see Table 7?

2) In figure 46 is a presentation of only the threads removed from the woven fabric marked dipped and greige? Or are there presented the tensile curves of the input materials - the polyester yarn used in weaving process?
3) Does the representation of the spatial geometry shown in Figure 47 correspond to any of the listed experimental fabrics?
4) Page 71: However, many researchers found that the tensile strength of warp yarn is degraded during a weaving process [128–130]. What is meant by that?

Conclusions of review

The author of the doctoral thesis has high scientific and research achievements. The results of the research have been presented in the journal publications (4+1under review) as well as on conferences (3) 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.

The doctoral thesis of Ms Tsegaye Shume Lemmi makes a significant contribution to the development of the scientific discipline of materials engineering at the same time meets the formal requirements for dissertations for the degree of doctor, in accordance with the regulations on scientific degrees and titles contained in the Law of July 20, 2018. Art.187 pt.1 and pt. 2 "Law on Higher Education and Science". I hereby request the Council of Disciplines of Materials Engineering of the Lodz University of technology of to admit the Author to further stages of the doctoral dissertation.

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