THERMAL AGING EFFECT ON THE PHYSIO-MECHANICAL PROPERTIES OF TEXTILES USED FOR THE REINFORCEMENT OF CONVEYOR BELTS

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ABSTRACT

The use of textiles produced from high tenacity(HT) polyester yarns as a reinforcement material in the mechanical rubber goods industries, mainly in the conveyor belt, is extensively increasing due to their high tensile strength, flexibility, thermal stability, modulus of elasticity, and light weightiness. To achieve the desired property of a conveyor belt, the reinforcement components undergo various processing stages; among those stages vulcanizing the reinforcement materials under high temperatures is the crucial process that determines the physical and mechanical properties of the conveyor belt. The main aim of this work was to analyze the effect of vulcanization parameters on the physio-mechanical properties of high tenacity polyester yarns and fabrics that are utilized to reinforce a conveyor belt. An extensive experimental study was conducted on a pre-activated HT polyester yarn of different linear densities and woven fabrics produced for the purpose of conveyor belt reinforcement by subjecting the yarns and fabrics to various aging temperatures for a certain period of aging time. Following the experiments, a comprehensive study and analysis were conducted on the tensile property of the yarns and fabrics. The finding revealed that thermal aging has an immense impact on determining the tensile strength and elongation of the yarn and woven fabric, which also has a direct influence on the properties of the conveyor belt. The analysis of experimental test results of polyester yarns and woven fabrics revealed that vulcanizing textile-reinforced conveyor belt at high temperatures (220 °C) could deteriorate the tensile strength and increase the elongation at break of the yarn, fabric, or belt.

KEYWORDS

Polyester; Yarn; Woven fabric; Conveyor belt; Vulcanization; Tensile strength.

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INTRODUCTION

Nowadays, the demand for bulk materials transportation in mining, agriculture, construction, transport, power, and other industries with higher efficiency and reasonable transportation cost advances the revolution of conveyor belt technology. Thus, the requirement for lightweight conveyor belts in these sectors is immensely increasing, and textile-rubber reinforcement technology is coming to hand in modern heavy-duty transporting technology. In modern mechanical rubber reinforcement technology, primarily for conveyor belt reinforcement, textiles woven from a high tenacity polyester yarn in a warp direction and polyamide 66 in a weft direction are widely utilized. This is due to the fact that high-tenacity polyester yarn offers significant performance advantages over natural, regenerated, and other synthetic fibers. High warp modulus, which reduces fabric stretch and expansion under a load, superior tear resistance, and high tensile strength are some of these characteristics. Additionally, high-tenacity polyester is less sensitive to moisture and rot conditions; consequently, conveyor belt durability in these environmental circumstances is good [1].

The high demand of industries for lightweight conveyor belts draws the attention of many scholars to research how various processing parameters can influence the composition of the conveyor belt properties. Barburski et al. [2] investigated the impact of heat treatment on the woven fabrics used as a carcass of the conveyor belt at different production stages of the conveyor belt. The study revealed that fabric weave structure and duration of thermal treatment have an influence on the physical properties of the woven fabric. Amr et al. [3] also studied the effect of the number of plies of the reinforcing material, the speed, and the loading direction on the tensile property of textile-reinforced conveyor belts using the Taguchi method. Rudawska et al. [4] also analyzed the impact of temperature and humidity on the tensile property of textile-reinforced conveyor belts. Lemmi et al. [1] [5] in detail investigated the effects of thermal aging and vulcanization parameters on the tensile strength, elongation, and surface structure of the polyester yarn, EP woven fabric, and multi-ply conveyor belts. Also, different researchers provided fundamental information concerning the conveyor belt design and woven fabric structure used for the intent of conveyor belt reinforcement [6][7]. In previous works various scholars researched in the area of factors that affect the properties of conveyor belt [8-13]. However, the effect of vulcanization process on the mechanical properties of textiles used for the reinforcement of conveyor has been left behind. The main goal of this work was to analyze the effect of vulcanization parameters on the physio-mechanical properties of high tenacity polyester yarns and fabrics that are utilized to reinforce a conveyor belt.

MATERIALS AND METHODS

Materials

In order to analyze the thermal aging effect on the properties of textiles used for the reinforcement of mechanical rubber goods, especially conveyor belts, a comprehensive study was conducted on high tenacity polyester(poly(ethylene terephthalate)) yarn and technical fabrics woven from HT polyester yarn in a warp direction and polyamide 66 yarn in the weft direction. The yarn and fabric samples were supplied by Kordárna, A.s company, the Czech Republic. The detailed property of the yarns and fabrics used to conduct this work is provided in Tables 1 and 2, respectively.

Methods

Determining the impact of vulcanization process parameters on the tensile property of the conveyor belt carcass is difficult because of the complex structural composition of the conveyor belt. In this work, the following methods were employed to ascertain the effect of thermal aging on the properties of textile fabrics and yarns. High-tenacity polyester yarn and EP woven fabric samples were aged under the thermal aging temperature of 140, 160, and 220 °C for a duration of 35 minutes in an industrial oven. Following that, a multi-ply conveyor belt reinforced with a woven fabric of the same parameter was produced. The vulcanization temperature and duration used to vulcanize the conveyor belt was similar to the thermal aging used to age the fabric samples. Besides this, the samples used to reinforce the belt have the same property as the fabric samples on which the thermal aging investigation was conducted. Finally, the fabric samples were removed from the belt (Figure 1) to analyze the effect of the vulcanization process on the properties of the fabric used to reinforce the belt. The tensile property of the yarn and fabric samples pre-and post-thermal aging were tested in accordance with ISO 2062:2009 [14] and ISO 13934-1:2013 [15]. A Zwick/Roell tensile testing machine with a constant rate of extension, 2.5kN load cell, 250 mm/min crosshead speed, and a gauge length of 250mm was used to test the tensile property of the yarn samples. Also, for the tensile property testing of woven fabrics, the Zwick/Roell tensile testing machine of 150 kN load cell, testing the speed of 100 mm/min with a mechanical extensometer and the specimen width of 50 mm and 250 mm length between clamps were used. All experimental tests were conducted in standard laboratory conditions.

Table 1. Properties of High Tenacity Polyester Yarn sample [1].

Yarn type	Property				
	Linear density (tex)	Breaking force (N)	Breaking tenacity (cN/tex)	Elongation at break (%)	Hot air shrinkage (%)
High Tenacity Polyester	110	89.90	81.00	13.50	5.50

Table 2. Properties of Technical dipped woven fabric sample [1].

Fabric Type	Fabric Properties						
	Warp Yarn	Weft Yarn	Warp Count Ends/cm	Weft Count Picks/cm	Mass per unit Area (g/m2)	Crimp of Warp (%)	Weave Type
EP 200 - Dipped*	Polyester	PA 66	9.10 ± 0.25	4.50 ± 0.15	631 ± 10	2.50	Plain weave

* **E**-HT polyester yarn, **P**- Polyamide 66, **200** – nominal strength of the fabric sample in $kNm^{-1,}$ **Dipped**- the sample was dipped in resorcinol–formaldehyde–latex (RFL) solution to enhance the adhesiveness of the textile to rubber material.

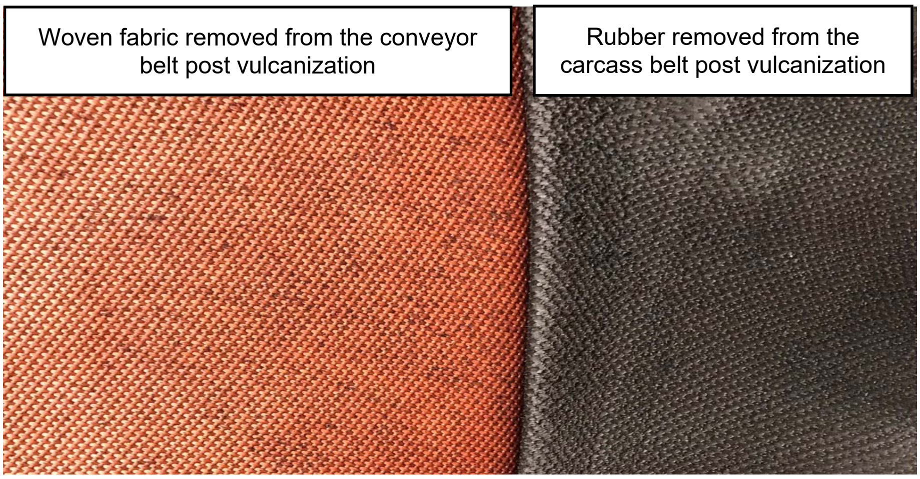

Figure 1. Woven fabric removed from conveyor belt reinforcement [1].

RESULTS AND DISCUSSION

The effect of thermal aging parameters on the tenacity and percentage elongation of high tenacity polyester yarn

By altering the aging temperatures, the impact of thermal aging factors on the tenacity of polyester yarn was studied. As shown in Figure 2, there were no considerable changes in the tenacity of the yarn samples aged at 160 °C and 200 °C compared to the tenacity of the unaged yarn.

However, compared to the tenacity of the unaged yarn samples, the tenacity of yarn samples aged at 220 °C was drastically decreased. This indicates that the aging of polyester yarns way above its glass transition temperature (≈180 ℃) and around the melting point (≈260 ℃) can degrade the tenacity of the yarn.

However, as shown in Figure 3, the aging of polyester yarns above the fiber's glass transition increases the yarn's percentage elongation. Unlike the tenacity, the percentage elongation of the yarn is incremented as the aging temperature approaches to the melting point of the yarn.

Influence of thermal aging parameters on the tensile strength of woven fabrics

In Figure 4, the impact of thermal aging on the woven fabrics aged in an industrial oven and the fabric removed from a conveyor belt post-vulcanization process were compared. Regardless of the thermal aging medium, the tensile strength of the fabric samples was degraded compared to the unaged fabric samples.

Nevertheless, severe deterioration of the fabric's tensile strength was observed for the samples aged at 220 °C in the case of both mediums of aging. Moreover, the samples removed from the vulcanized conveyor belt were almost destroyed at 220 °C; this discrepancy resulted from the fact that the fabrics aged in the oven were aged under no pressure, whereas the fabric used as the carcass of the conveyor belt was vulcanized under high pressure, which affects the tensile strength of the fabric. Therefore, vulcanizing of EP textile reinforced conveyor at or above 220 °C cannot be recommended regardless of the vulcanization duration.

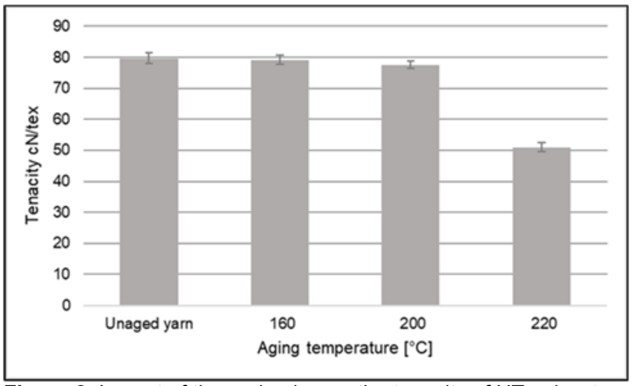

Figure 2. Impact of thermal aging on the tenacity of HT polyester yarn.

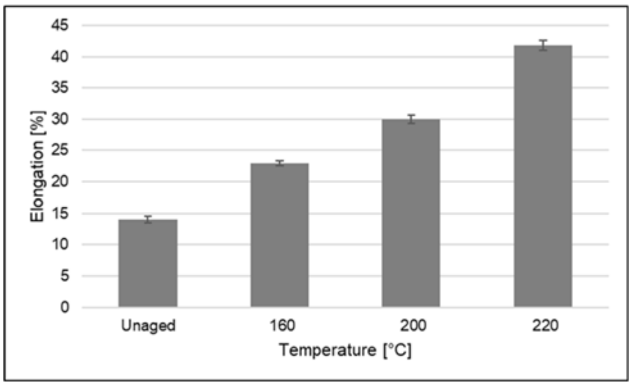

Figure 3. Effect of thermal aging on the percentage elongation of yarn.

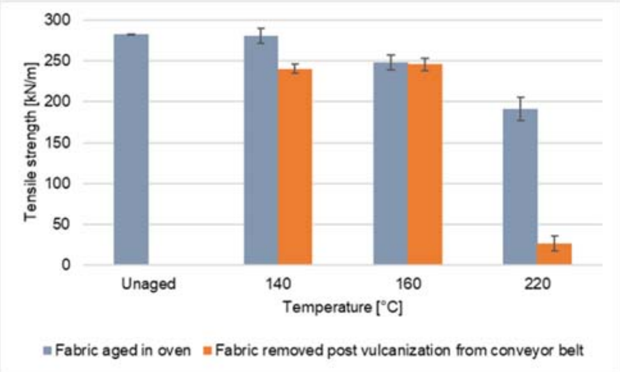

Figure 4. Effect of thermal aging on the tensile strength of the woven fabric.

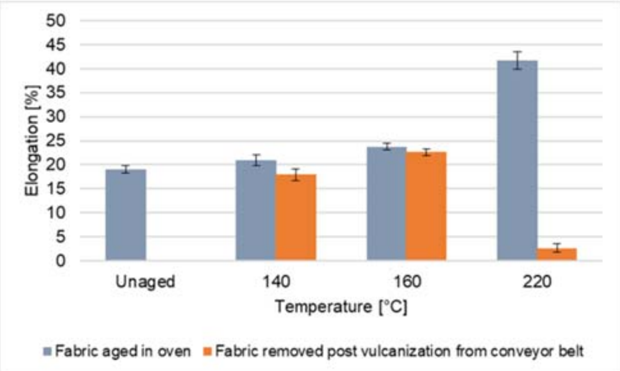

Figure 5. Effect of thermal aging on elongation of woven fabric.

Impact of thermal aging on the elongation of woven fabric

In determining the performance of the conveyor belt in varying stress levels, the percentage elongation of the conveyor belt has a significant impact. Hence, this property must be scrutinized during material choice for the reinforcement of the belt. As shown in Figure 5, the percentage elongation of the fabrics aged below Tg temperature of polyester (≈180 ℃) was around 5% higher compared to the unaged fabric. However, the fabric samples aged in an industrial oven at 220 °C were highly elongated, which is not recommended for the conveyor belt design. In order to reduce power fluctuation on the drive sharing of rollers, increase the service life of the belt and prevent the driving motor from burning out, always a conveyor belt with low percentage elongation is recommended. In addition, the elongation of the sample removed from the conveyor belt was fully deteriorated at 220 °C due to the fact that the sample was broken under a minor applied force.

CONCLUSIONS

The influence of aging temperature on the tensile properties of high tenacity polyester yarn and EP fabric was investigated by subjecting the yarn and fabric samples to different aging conditions used in the normal vulcanization process of conveyor belts. From the experimental results obtained, the tensile strength and percentage elongation of the polyester yarn and EP fabric is highly dependent on the aging temperature. Irrespective of the aging stage and medium of aging, the tensile strength of the samples subjected to thermal aging at 220 ℃ was decreased. However, the percentage elongation of yarn and Ep fabric samples aged in an industrial oven was shown higher percentage elongation, but the elongation of the sample removed from the conveyor belt vulcanized at 220 ℃ was lower than expected. Therefore, vulcanizing a conveyor belt reinforced by EP woven fabric at or above 220 ℃ is not recommended as it deteriorates the tensile property of the conveyor belt's constituent materials. Therefore, from the experimental analysis conducted, the optimum temperature to vulcanize EP reinforced conveyor belt is 160 ℃ for the duration of 35 minutes, depending on the number of plies of the conveyor belt.

***Acknowledgements**: The authors are grateful for the support provided by Sempertrans Bełchatów Sp. z o.o R&D department for providing the laboratory equipment needed to accomplish the goal of this work. This paper was completed while the first author was a Doctoral Candidate in the Interdisciplinary Doctoral School at the Lodz University of Technology, Poland*

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