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ANALYSIS OF THERMAL AGING EFFECT ON THE TENSILE STRENGTH OF TEXTILE MATERIALS INTENDED FOR THE REINFORCEMENT OF CONVEYOR BELT

Tsegaye Sh. Lemmi[1(*)], Marcin Barburski[1]

[1] Faculty of Material Technologies and Textile Design, Institute of Architecture of Textiles, Lodz University of Technology, 90-924 Lodz, Poland

[(*)] *Email:* tsegaye.lemmi@dokt.p.lodz.pl

ABSTRACT

Woven fabrics produced from high tenacity (HT) polyester/polyamide 66 yarns are most widely used to reinforce conveyor belts in the mechanical rubber goods industry. The tensile property of the conveyor belt is primarily dependent on the property of fabrics used to reinforce the belt. During the production process of the conveyor belt, the textile-rubber reinforcement undergoes a vulcanization process at high temperature to provide compulsory physio-mechanical properties of the belt by adhering the woven fabric with a rubber. Subjecting textile materials to high temperatures for the vulcanization process has an influence on the mechanical properties of the woven fabric. The main aim of this work was to investigate the effect of thermal aging on the tensile property of HT polyester yarn and woven fabric which is intended to reinforce conveyor belt. An extensive experiment on HT polyester yarn and the woven fabric was conducted by subjecting the textile materials to various aging temperatures. Additionally, the tensile property of fabrics after the vulcanization process of the conveyor belt was conducted to fully understand the effect of vulcanization temperature on the properties of woven fabric. The experimental test results of polyester yarn, woven fabric, and fabrics removed from the conveyor belt revealed that vulcanizing of the textile reinforced conveyor belt at high temperature(220 °C) can diminish the tensile strength and increase the elongation at break of the yarn and fabric.

KEYWORDS

Conveyor belt, yarn, elongation, fabric, tensile strength, thermal aging.

INTRODUCTION

Conveyor belts are used to transport general goods to continuous bulk materials in various industries. The invention of the conveyor belt is dated back to the late nineteenth century when Thomas Robbins designed the primitive conveyor belt system for Thomas Edison's Ore-Milling company to transport coal and ore. Subsequently, in 1905, mining engineer Richard Sutcliffe introduced the first underground conveyor belt made of cotton and rubber. Since then, many scholars have modified the design, properties, and materials used for conveyor belt production depending on the application areas. Nowadays, the increase in demand for transporting bulk materials in mining, construction, agriculture, and other industries with higher efficiency and affordable transportation costs accelerates conveyor belt technology improvement. Moreover, the invention of vulcanized rubber and thermoplastic fibers significantly contributed to the development of the textile reinforced conveyor belt sector. Thus, the use of textile materials for the reinforcement of heavy-duty conveyor belts is significantly increasing due to their light weightiness, high tensile property, energy efficiency, flexibility, and corrosion resistivity [1– 4].

During the vulcanization process, the reinforcement is subjected to a high temperature under pressure to adhere the textile fabric with rubber material in order to provide the necessary mechanical and physical properties of the conveyor belt required for the intended application. Hence, vulcanization temperature, time, and pressure are the most crucial parameters that determine the vulcanization process of the conveyor belt and the properties of the belt. The adhesion between the plies of the belt and the weave structure of the fabric substantially influences the belt's performance, safety, and durability [5], [6]. For the textile reinforced conveyor belt, the effect of these conditions is immense because most fabrics used for the carcass of conveyor belt are produced from polyester yarn in a warp and polyamide 66 in the weft direction, the property of these textile yarns are quickly diminished under high temperature [7]. The reliability of the entire conveyor belt system is dependent on the belt properties. Improper design and insufficient strength of a conveyor belt can cause its rupture and consequent downtime due to repair and replacement thereof. The rupture of a conveyor belt represents an unacceptable risk in the operation of a belt. Even though many researchers have conducted some prominent research in the field of conveyor belts, the effect of vulcanization process parameters on the textile carcass of the belt that determines the belt's tensile strength property has been left behind. This research aims to investigate the effect of thermal aging on the tensile strength and percentage elongation of the high tenacity polyester yarn and woven fabric intended for the reinforcement of heavy-duty conveyor belts.

MATERIALS AND METHODS

Materials

A woven fabric dipped in resorcinol–formaldehyde–latex (RFL) which was woven from a pre-activated high tenacity polyester in the warp and polyamide 66 yarn in the weft direction were supplied from Kordárna Plus a.s. company, Czech Republic. The detailed properties of the high tenacity polyester yarn and woven fabrics are provided in Table 1 and Table 2, respectively.

Table 6. Properties a pre-activated high tenacity (HT) polyester yarn [7].

Yarn Type	Property				
	Linear Density (tex)	Breaking Force (N)	Breaking Tenacity (cN/tex)	Elongation at Break (%)	Thermal Shrinkage @177.7°C for 2 min(%)
HT Polyester	110	89.90	81.00	13.50	5.50

Table 7. Properties of EP woven fabrics.

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-polyester yarn in the warp direction, P-polyamide 66 in the weft direction, 200-nominal strength of the fabric in kNm^{-1}.

Methodology

In order to analyze the effect of vulcanization parameters on the tensile strength of textile fabrics that are used to reinforce conveyor belts, the study was conducted on HT polyester yarns, and woven fabrics dipped in the RFL. First, HT polyester yarn and EP woven fabric were subjected to thermal aging under 140, 160 and 220 °C of aging temperature for thirty-five minutes of aging duration in an industrial oven. Following that, a multi-layer conveyor belt reinforced with textile fabric was produced under the same temperature and duration of time. Finally, textile layers were removed from the conveyor belt. The tensile property of yarns and fabrics pre-and post-thermal aging were tested in accordance with ISO 2062:2009 [8] and ISO 13934-1:2013 [9]. The tensile property of high tenacity polyester yarn was tested on a Zwick/Roell tensile testing machine of a 2.5 kN load cell with a constant rate of extension of crosshead speed of 250 mm/min and a gauge length of 250 mm, while the fabric's tensile strength was also tested on Zwick/Roell tensile testing machine of a 150 kN load cell with a mechanical extensometer and a testing speed of 100 mm/min under standard laboratory conditions. The specimens of 50 mm fabric width and 250 mm length between the clamps have been used to test the tensile strength of the fabric.

RESULTS AND DISCUSSION

High Tenacity Polyester Yarn Tensile Property Results

In the tenacity vs. percentage elongation curve shown in Figure 2, the result of HT polyester samples aged under different temperatures signifies that all yarn samples had shown similar characteristics in the curve's elastic range regardless of the aging temperature. However, in the plastic range, an increase in aging temperature has significantly incremented the elongation of the yarn and reduced the tenacity of the yarn. This indicates that the aging of polyester above its glass transition temperature can reduce the tenacity of the yarn while it increases the yarn's percentage elongation at break.

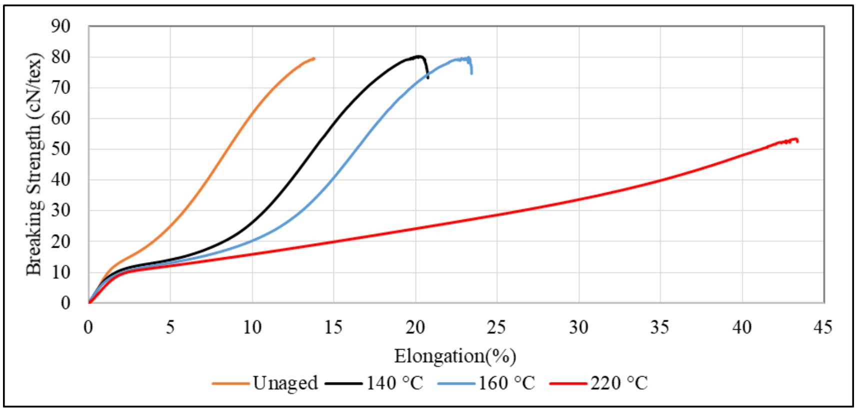

Figure 20. Stress-strain diagram of unaged and thermally aged 110 tex of high tenacity polyester yarn.

Tensile property of EP dipped fabric

The influence of thermal aging on the tensile strength and percentage elongation of woven fabric has shown in Figure 3. The results revealed that the increases in aging temperature decreased the tensile strength of the fabric. Moreover, the aging of the fabric at high temperature (220 °C) significantly decreased the tensile strength of the fabric. Nevertheless, the elongation of samples aged at 220 °C is 49.78% higher than the samples aged at 140 °C. From these results, it can be concluded that the mechanical properties of the EP fabric are dependent on the aging temperature and the fabric's fiber composition.

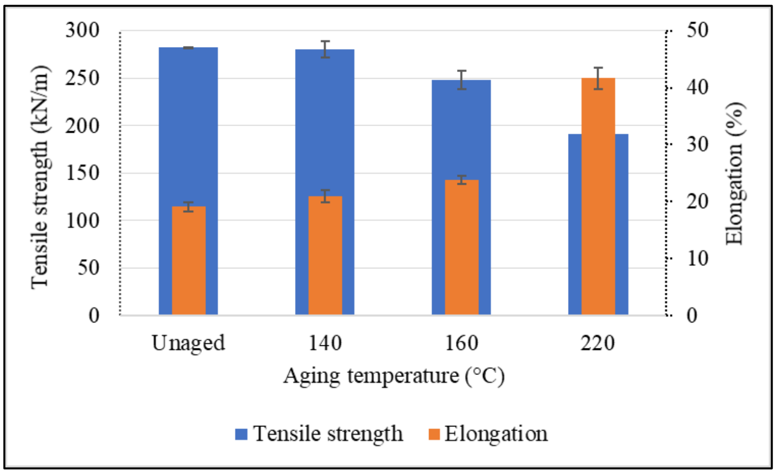

Figure 21. Effect of thermal aging on the tensile property of RFL-dipped EP woven fabric.

The effect of vulcanization temperature on the tensile properties of woven fabric has been analyzed by removing fabric ply from the conveyor belt post vulcanization process. As shown in Figure 3, the tensile strength and elongation of the fabric removed from the conveyor that was vulcanized at 220 °C were almost entirely destroyed. In comparison to the results of fabrics aged in an industrial oven (Figure 2), the tensile strength and elongation at break of the fabric vulcanized with the rubber were diminished. This arose from the fact that fabrics aged in the oven were aged under no pressure, but the fabric used as the carcass of the conveyor belt was subjected to thermal aging under high pressure; this influences the property of the vulcanized fabric.

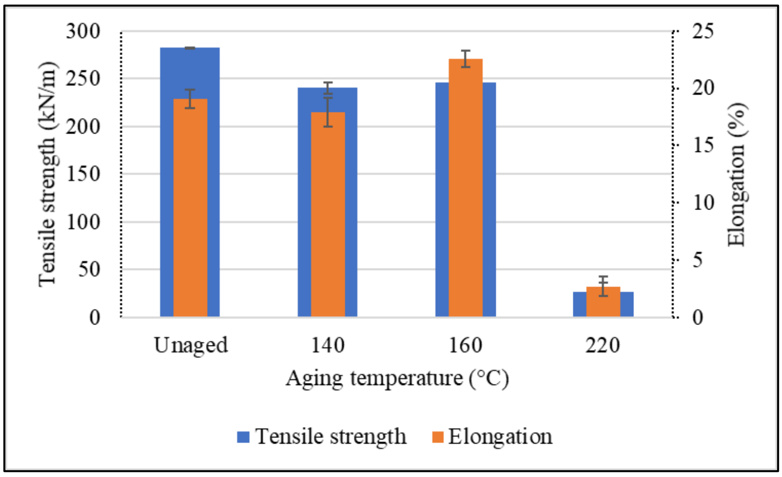

Figure 22. Tensile property of EP woven fabric removed from the conveyor belt.

CONCLUSION

In this work, the effect of aging temperature on the tensile property of textile material at yarn, fabric, and post vulcanization of conveyor belts was investigated. The study revealed that vulcanizing polyester/polyamide fabric [EP fabric] reinforced conveyor belt at 220 °C or above can destroy the tensile property of the conveyor belt, and this temperature cannot be recommended. However, the optimum tensile property of textile reinforced conveyor belts can be obtained by vulcanizing the reinforcement at 160 °C for 35 min.

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