



MECHANICAL PERFORMANCE OF SOLAR-PROTECTIVE FABRICS MANUFACTURED FROM VOLCANIC MINERAL- MODIFIED POLYESTER YARNS

Scientific paper
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ABSTRACT: The increasing demand for functional textiles has led to extensive research on the incorporation of mineral-based additives into synthetic fibers to enhance their performance characteristics. In this study, the effects of volcanic mineral additives on the mechanical properties of polyester yarns and woven fabrics intended for solar protection applications were investigated. Cerium oxide- and silicon oxide-based masterbatches were prepared using a PBT carrier and incorporated into polyester during the melt-spinning process to produce partially oriented yarns (POY). The POY yarns were subsequently textured to obtain draw textured yarns (DTY), which were then used in the production of curtain fabrics. The tensile properties, boiling shrinkage, and crimp contraction behaviour of the yarns were evaluated, while the mechanical performance of the woven fabrics was assessed through tensile strength and tear strength tests conducted in both warp and weft directions. The results demonstrated that the incorporation of volcanic mineral additives influenced the structural and mechanical behaviour of polyester yarns and fabrics. Fabric test results revealed that cerium oxide-added polyester fabrics exhibited higher breaking strength values than silicon oxide-added fabrics. Tear strength performance was affected by both fabric direction and additive type. While fabrics containing 2% silicon oxide showed lower tear strength in the warp direction, they exhibited higher tear strength in the weft direction. Overall, the findings demonstrate that volcanic mineral additives can be successfully incorporated into polyester yarn structures and significantly influence the resulting yarn and fabric properties.

Keywords: Polyester yarn, volcanic minerals, cerium oxide, silicon oxide, technical textiles, mechanical properties.



MEHANIČKE PERFORMANSE SOLARNO-ZAŠTITNIH TKANINA PROIZVEDENIH OD POLIESTARSKIH PREĐA MODIFIKOVANIH VULKANSKIM MINERALIMA

APSTRAKT: *Rastuća potražnja za funkcionalnim tekstilom dovela je do opsežnih istraživanja o ugradnji aditiva na bazi minerala u sintetička vlakna radi poboljšanja njihovih karakteristika performansi. U ovoj studiji ispitani su efekti aditiva vulkanskih minerala na mehanička svojstva poliestarskih pređa i tkanina namenjenih za primenu u zaštiti od sunca. Masterbačevi na bazi cerijum-oksida i silicijum-oksida pripremljeni su korišćenjem PBT nosača i ugrađeni u poliestar tokom procesa pređenja rastopa kako bi se proizvele delimično orijentisane pređe (POI). POI pređe su potom teksturirane da bi se dobile teksturirane pređe (DTI), koje su zatim korišćene u proizvodnji tkanina za zavese. Procenjena su svojstva zatezanja, skupljanje pri ključanju i karakteristike kovrdžavosti, dok su mehaničke performanse tkanina procenjene testovima zatezne čvrstoće i čvrstoće na kidanje sprovedenim u pravcu osnove i potke. Rezultati su pokazali da je ugradnja vulkanskih mineralnih aditiva uticala na strukturno i mehaničko ponašanje poliestarskih pređa i tkanina. Rezultati ispitivanja tkanina pokazali su da poliesterske tkanine sa dodatkom cerijum oksida pokazuju veće vrednosti čvrstoće na kidanje od tkanina sa dodatkom silicijum oksida. Na performanse čvrstoće na kidanje uticali su i smer tkanine i vrsta aditiva. Dok su tkanine koje sadrže 2% silicijum-oksida pokazale manju čvrstoću na kidanje u pravcu osnove, pokazale su veću čvrstoću na kidanje u pravcu potke. Generalno, nalazi pokazuju da se vulkanski mineralni aditivi mogu uspešno ugraditi u strukture poliestarskih pređa i značajno uticati na rezultujuća svojstva pređe i tkanine.*

Ključne reči: *Poliestarska pređa, vulkanski minerali, cerijum-oksid, silicijum-oksid, tehnički tekstil, mehanička svojstva.*

1. INTRODUCTION

The use of additives in polyester yarns is a widely adopted approach both to improve the processability of the polymer during production and to impart functional properties to the final product. In the textile industry, additives are extensively utilized to achieve multifunctional performance, including ultraviolet (UV) protection, thermal resistance, antibacterial activity, flame retardancy, antistatic behaviour, and improved mechanical properties. These additives are typically incorporated into the polymer matrix in masterbatch form and processed via the melt spinning technique, enabling uniform dispersion within the fiber structure. Additives used in polyester (PET) yarns can generally be classified into inorganic, organic, and hybrid (organic–inorganic) systems. Inorganic additives such as titanium dioxide (TiO₂), zinc oxide (ZnO), silicon dioxide (SiO₂), aluminum oxide (Al₂O₃), cerium oxide (CeO₂), and nanoclay structures are widely employed to enhance UV shielding, thermal stability, and abrasion resistance. These particles function primarily through UV absorption and scattering mechanisms, thereby improving the protective performance of textile materials. For instance, TiO₂ and ZnO



nanoparticles have been reported to enhance UV protection and opacity in polyester fibers, while nano-silica contributes to improved mechanical strength and surface hardness [1-5]. Organic additives generally include antibacterial agents, pigments, dyes, and organic flame-retardant compounds. Among these, silver-based antimicrobial systems (Ag^+ -containing structures) are particularly effective in inhibiting microbial growth on textile surfaces, thereby enhancing hygienic performance. Additionally, phosphorus-based flame retardants are commonly used to improve the combustion behaviour of polyester-based materials [4-7]. In recent years, nanoscale and hybrid additive systems have gained increasing attention due to their ability to enhance functional performance even at low loading levels. The high surface area of nanoparticles enables improved interaction with the polymer matrix, leading to synergistic effects in UV protection, thermal management, and mechanical reinforcement applications. However, the type and concentration of additives, together with fiber dispersion quality and spinning parameters, significantly influence the final performance of the resulting textile structures [3-6].

Solar protection properties in textiles can be achieved either through the use of functionalized yarns containing additives or through post-production surface finishing and coating techniques. However, the incorporation of functional materials directly into the fiber structure provides a more durable and long-lasting performance compared to surface treatments, which may degrade over time due to washing or environmental exposure. Several studies in the literature have investigated the effects of additives on the physical and mechanical properties of polyester fibers and fabrics. Previous research has demonstrated that the type, particle size, concentration, and dispersion quality of additives significantly affect tensile strength, elongation, stiffness, abrasion resistance, and thermal stability. However, studies specifically focusing on volcanic mineral-modified polyester yarns remain limited, particularly in the context of solar-protective technical fabrics. Therefore, further investigation is necessary to better understand the relationship between volcanic mineral incorporation and the mechanical performance of woven or knitted textile structures intended for outdoor applications [7-11]. In this study, volcanic mineral-added polyester yarns were used to produce curtain fabrics with inherent solar protection functionality. The aim of the study is to evaluate the mechanical properties of these technical fabrics in relation to different types and concentrations of mineral additives. It is expected that integrating volcanic minerals such as cerium oxide- and silicon-based compounds into the fiber structure will contribute to the development of advanced functional textiles with enhanced durability and solar protection performance.

2. MATERIAL AND METHOD

Granule-form masterbatches containing micro-materials with a PBT carrier were prepared by SETAŞ. The masterbatch preparation process was carried out using industrial production methods suitable for synthetic yarn manufacturing processes. In the first stage, granule-form masterbatches containing cerium oxide and silicon oxide micro materials were prepared separately. Subsequently, the obtained granule-form masterbatches and granule-form PET polymer were blended at various ratios and subjected to the extrusion



process. In this way, the production of a volcanic mineral-added composite masterbatch was targeted. One of the masterbatches was prepared with a composition of 10% cerium oxide and 90% PBT, while the other was prepared with a composition of 20% silicon oxide and 80% PBT. Partially oriented Volcanic Mineral added polyester yarns with were produced with different masterbatch ratios (%1, %2) where the fiber cross sections were selected as 'w' cross section. Polyester yarn production trials were carried out using a melt-spinning machine available at the yarn manufacturing facilities of Karesi Polyester A.Ş. POY polyesters were converted into draw textured yarns (DTY). The tensile properties for POY and DTY's were measured by using Uster Tensojet while boiling shrinkage (%), crimp contraction (%) results were obtained from Texturmat device. The experimental design of the produced Volcanic mineral added polyester POY and DTY is revealed in Table 1. Drapery woven fabrics produced from volcanic mineral additive yarns were exposed to fabric tensile and tearing strength test by using Titan Device according to EN ISO 13934-1 and EN ISO 13937-2 standards respectively. Fabric parameters are revealed in Table 2.

Table 1: Experimental Design

POY type	POY code	Masterbatch Ratio (%)	"Granule-form masterbatches containing volcanic minerals	DTY (Textured yarn code)
Conventional Polyester	P1	-	-	D1
Cerium Oxide Added Polyester	P2	1 %	10% Cerium Oxide 90 % PBT	D2
Silicon Oxide Added Polyester	P3	1 %	20% Silicon Oxide 80 % PBT	D3
Silicon Oxide Added Polyester	P4	2 %	20% Silicon Oxide 80 % PBT	D4

Table 2: Fabric parameters

Fabric code	Warp Yarn (denier/filament)	Weft Yarn (denier/filament)	Warp density (threads/cm)	Weft Density (threads/cm)	Fabric weight (g/m ²)
F1	100/36	300/36 polyester	90	30	273
F2	100/36 Cerium Oxide added polyester (0.001)	300/36 polyester	90	30	253
F3	100/36 Silicon Oxide added polyester (0.001)	300/36 polyester	80	30	227
F4	100/36 Silicon Oxide added polyester (0.002)	300/36 polyester	80	30	231



3. RESULTS AND DISCUSSIONS

Yarn Properties

The tensile properties, boiling shrinkage (%) and crimp contraction ratio (%) results of the POY and DTW (Draw textured yarns) are revealed in figure 1 and figure 2 respectively.

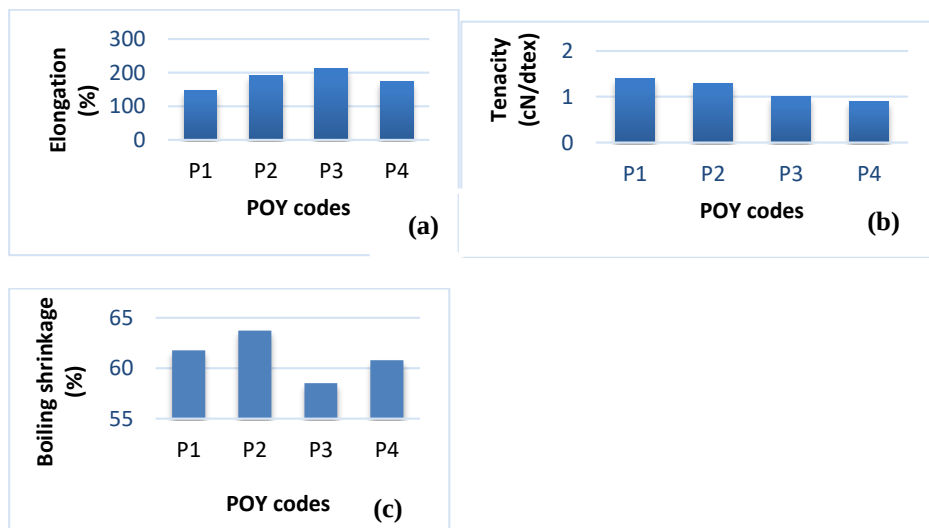
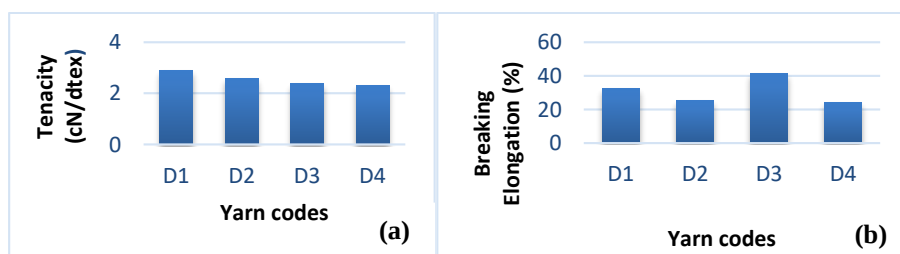


Figure 1. Elongation (a), tenacity (b) and boiling shrinkage (c) results of volcanic mineral added POYS.



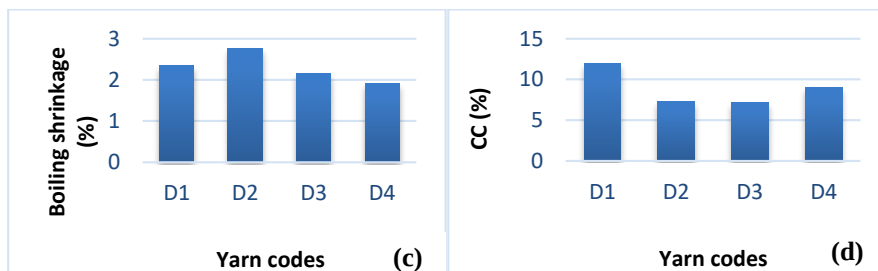


Figure 2: Tenacity (b), elongation (b), boiling shrinkage (c) and crimp contraction (d) results of volcanic mineral added textured yarns

When the Figure 2 is observed; The tensile strength values of the POY yarns tended to decrease with increasing cerium oxide concentration. This behaviour may be attributed to the disruption of polymer chain continuity and the formation of micro-scale stress concentration points caused by inorganic particles. Similar tendencies were observed in DTY yarns, although the texturing process partially altered the magnitude of the effect. Figure 2c presents the boiling shrinkage values of the DTY yarns produced with different additive concentrations. The highest boiling shrinkage was observed for sample D2 (approximately 2.75%), while the lowest value was obtained for D4 (approximately 1.90%). The results indicate that the additive concentration affects the dimensional stability of the textured yarns. While a moderate additive level appears to increase the residual internal stresses within the yarn structure, higher additive concentrations tend to reduce boiling shrinkage, suggesting improved structural stability and reduced molecular relaxation during thermal treatment. This behaviour may be associated with the interaction of cerium oxide particles with the polyester matrix and their influence on chain mobility and crystallization behaviour. When the crimp contraction of the yarns were observed (Figure 2d), the highest value was obtained from D1 coded yarns while minimum value was obtained from D2 coded yarns.

Fabric properties

The average breaking strength and tear strength values obtained from the tests conducted in both the warp and weft directions of the fabrics used in the study are presented in Figures 3 and 4 respectively. According to figure 3, breaking strength values in warp wise were generally higher than those in weft wise. Breaking strength of the fabrics produced from Cerium oxide added polyester yarns were higher than those produced from Silicon Oxide added polyester yarns. As figure 4 is analysed, it is understood that tear strength results were higher in weft wise among all samples. Fabrics produced from Silicon Oxide (2%) added polyester yarns (F4) revealed lower tear strength in warp wise but higher in weft wise.

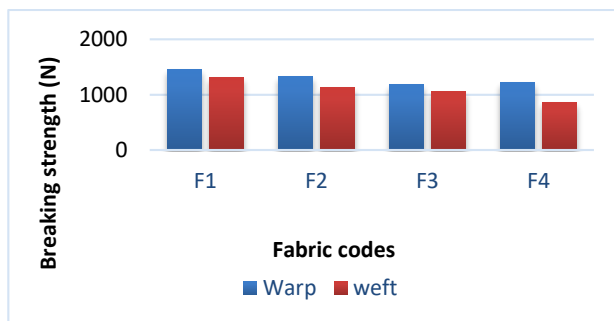


Figure 3: Breaking strength of fabrics

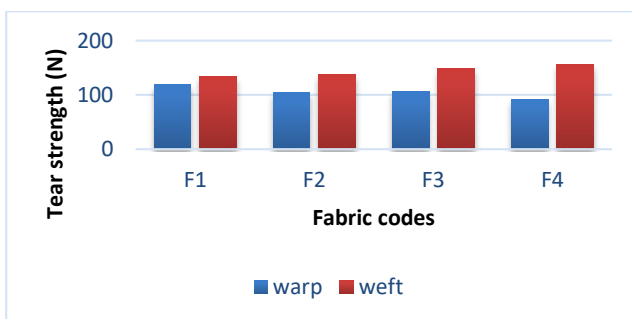


Figure 4: Tear strength of fabrics

3. CONCLUSION

In this study, the effects of cerium oxide and Silicon Oxide-based volcanic mineral additives on the properties of polyester yarns and woven fabrics were investigated. Volcanic mineral-added polyester POY yarns were successfully produced and subsequently converted into textured yarns. The tensile, and mechanical performance properties of both yarns and fabrics were evaluated.

The results showed that the incorporation of mineral additives affected the tensile and physical properties of polyester yarns. Compared to conventional polyester yarns, the addition of cerium oxide and silicon oxide particles generally caused a reduction in yarn tenacity, which may be attributed to the disruption of polymer chain continuity and the formation of stress concentration points within the fibre structure. Furthermore, the boiling shrinkage and crimp contraction values of textured yarns were influenced by both the type and concentration of the additives, indicating changes in molecular mobility and structural stability. Fabric test results revealed that fabrics produced from cerium oxide-added polyester yarns exhibited higher breaking strength values than those produced from silicon oxide-added polyester yarns. Tear strength performance varied depending on the fabric direction and additive type. While silicon oxide-added fabrics showed relatively lower tear strength in the warp direction, higher tear strength values were observed in the weft direction. Overall, the findings demonstrate that both cerium oxide and silicon oxide



additives can be successfully incorporated into polyester yarn structures and significantly influence the resulting yarn and fabric properties. The study provides a useful basis for the development of functional textile materials intended for solar protection and thermal comfort applications. Future studies will focus on evaluating the solar radiation transmission, UV protection performance, thermal insulation behaviour, and durability characteristics of fabrics produced from volcanic mineral-added polyester yarns.

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