

Elastic High-Performance Covered Yarn: Fabrication, Characterization and Application

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Abstract

To increase the protective capacity of yarns while maintaining human wearing comfort, pure UHMWPE filament and Spandex were combined to fabricate an elastic high-performance covered yarn. The various wrapping process parameters were adjusted to prepare this single-lay-covered yarn with a perfect wrapping status, which also can achieve the balance of strength and elasticity. It was discovered that the wrapping process seriously affected the covered yarn's performance, and the new single-lay covered yarn showed desirable high strength and super elasticity. The strength of covered yarns shows three types of trend with the twist added, including first steep (300 t/m ~ 400 t/m), then gentle (500 t/m ~ 600 t/m) and last drastic (700 t/m ~ 800 t/m). The covered yarn twisted at 700 t/m shows the optimal coverage morphology, excellent elasticity, and high strength. Finally, an elastic cut-resistant fabric is practically knitted by this fabricated elastic cut-resistant composite yarn, and it presents good flexibility and protection with Level 2 cut resistance under standard testing. The fabricated elastic high-performance covered yarn is an ideal material for producing highly elastic protective textiles and is applied to manufacture high-quality flexible protective equipment.

Keywords: Elastic; High-performance; Covered Yarn; UHMWPE; Spandex

1 Introduction

Textiles for personal protection are vital to human survival and consistently play a significant part in social evolution [1]. Researching appropriate protective fabrics is essential since personal activities carry the potential of injury from knives and blunt objects, whether one is a soldier in wartime or a civilian in peacetime. High-performance yarns are a fundamental element of protective fabrics, and their research is important in both theory and practice [2]. Protective

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fabrics are usually made of high-performance fibres due to their special functionality [3], including ultra-high molecular weight polyethylene (UHMWPE), Kevlar, POB, glass fibre and carbon fibre. These fibres improve the fabric's resistance against cutting, stabbing, tearing, chopping, and sharp objects. For instance, the US patent "criminology" discusses using glass fibre as an effective material for cut resistance, providing excellent protection against sharp objects like knives and cones [4]. Tuba Alpyildiz designed a two-sided knitted fabric structure that utilises Kevlar 1414 fibre-covered yarns, significantly enhancing the fabric's cut resistance compared to the conventional weft-knitted fabric [5].

These strong fibres are not flawless, though. The short service life of Kevlar is caused by its ultra-low UV resistance [6]. Glass fibre has limited wear resistance and is fragile. Furthermore, it has been observed that PBO fibre may experience a drastic decrease in strength when exposed to water or continuous light sources [7]. The UHMWPE will melt when temperatures rise above 130 °C [8]. On the other hand, Kim et al. discovered that contact area and pressure should be considered when designing stab-resistant vests to enhance the wearer's comfort [9]. However, most protective fabrics lack elasticity, making them inappropriate for clothing and activities alone. Conversely, Spandex is a highly elastic chemical with an excellent elongation of 400% to 700% and a rebound rate of 95% to 99%. It is typically utilised in highly elastic, cosy clothing with a tight fit, such as sportswear and tights, and can withstand repeated stretching [10]. Based on the properties of high strength and elastic yarns, Huang created a fabric using UHMWPE as the sheath yarn to provide cut resistance and the Nylon/Spandex as the core to provide elasticity. Consequently, the glove possesses both elasticity and cut-resistant [11]. Nevertheless, UHMWPE's applicability is so broad that its capabilities do not align with what the general public wants. Otherwise, no single-ply covered yarn currently available offers the reported technology. Achieving a balance between high elasticity and strength for yarns is a considerable challenge.

An innovative solution was applied to solve this problem, which uses a core-sheath structure with UHMWPE as the sheath yarn wrapped around the Spandex. A single-ply cover and a high-strength yarn fineness of less than 100D have been effectively developed for a covered yarn. It has a high strength and flexibility tolerance. The wrapping effect can be changed by altering the process parameters, which can balance strength and elasticity for various conditions. The covered yarn has more remarkable performance qualities due to this technique. Furthermore, three knitted fabrics with French Terry structure have been fabricated using one of the covered yarns, which simultaneously exhibits remarkable elastic and cut resistance. Covered yarn, in the meantime, makes it possible to fabricate the ideal protective garments that combine high elasticity with superior protection.

2 Experiment

2.1 Materials

Spandex (70D, 105D) was supplied by Yantai Tayho Advanced Materials Co., Ltd (Shandong, China), and the pure UHMWPE filaments (50D, 75D, 100D) were provided by Zhejiang Jiayun New Materials Co., Ltd (Zhejiang, China).