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The Influence of Heat Setting Conditions on Mechanical Properties of PTT Filaments

Ying Chen [a], Xin Ding [a,b,*], Yuling Li [a,b], Xueqian Zhao [a]

[a] *College of Textiles, Donghua University, Shanghai 201620, China*

[b] *Key Laboratory of Textile Science & Technology, Ministry of Education, Shanghai 201620, China*

Abstract

It is proposed that Poly(Trimethylene Terephthalate) (PTT) filaments are used for fabricating vascular prostheses instead of Poly(Ethylene Terephthalate) (PET) because of their lower Young's modulus and superior elastic recovery. The heat setting process is necessary to keep the stability of shape and mechanical properties as well as making the flattened tubular structures round. However, the best heat setting condition for keeping properties of lower Young's modulus and superior elastic recovery of PTT filaments is unknown. This paper studies the influence of different heat setting conditions to the change of Young's modulus and elastic recovery. The temperature range is chosen from 120 to 180 ℃ and time period is chosen from 30 s to 90 s. The heat setting of yarns is both done in the relaxation state and tension state. Results show that the best heat setting conditions to get lower modulus, higher elastic recovery and better creep property at the temperature of 160 ℃ under the tension state through 60 s. The tension or relaxation state has the biggest influence on elastic recovery and Young's modulus while time period has the least influence.

Keywords: Poly(Trimethylene Terephthalate); Heat Setting; Young's Modulus; Elastic Recovery; Temperature; Time Period

1 Introduction

PET is currently used for the fabrication of large and medium size woven arterial prostheses [1-4]. All grafts in general have lower compliance than those of host arteries and in particular the woven PET prosthesis has the lowest compliance [5]. To minimize compliance mismatch [1, 6, 7] between native artery and woven Dacron vascular prostheses and weave small diameter (<6 mm) [8] woven compliant prostheses, new polyester material Poly(Trimethylene Terephthalate) (PTT) have been used in manufacturing vascular prosthesis [9]. PTT which is manufactured with 1, 3-propanediol (PDO) and Terephthalic Acid (TPA) by polycondensation is a relatively novel thermoplastic polymer, and belongs to the aliphatic aromatic polyalkylene terephthalate family, which also includes the well-known and widely applied Poly(Ethylene Terephthalate) (PET) and

*Corresponding author.
Email address: xding@dhu.edu.cn (Xin Ding).

Poly(Butyleneterephthalate) (PBT) [10]. It was the difference in the number of methylene groups that resulted in the difference in physical properties among these aromatic polyester filaments [11]. PTT fibers have the resiliency and softness of nylon fibers and the chemical stability and stain resistance of Poly(Ethylene Terephthalate) (PET) fibers [12]. Both the Young's modulus and the breaking strength of the PTT filament were lower than those of PET filaments, whereas the breaking elongation was higher than those of PET filaments. PTT filaments had a high instantaneous elastic recovery even at a high elongation of 20%. The outstanding instantaneous elastic recovery of PTT filaments resulted from its helical conformation in crystal lattice, which responded immediately to the applied stress and deformed as though it was a coiled spring [11, 13]. So compared to PET, PTT filaments have favorable mechanical properties to weave compliance vascular prosthesis [9].

As-manufactured polymeric fibers are oriented semi-crystalline structures in which the macromolecules are rarely in their equilibrium state. Further instabilities are imparted when the fibers are converted to yarns and the yarns to fabrics. Heat setting is an important industrial process, since it rids them of their instabilities [14]. The importance of heat setting as a means for optimizing the structure and performance of oriented films and fibers has been well recognized. The morphological changes underlying the heat-setting process in Poly(Ethy1ene Terephthalate) (PET) and other semicrystalline polymers have been studied extensively over the past three decades by means of X-ray diffraction, IR spectroscopy, calorimetry, rheology, and other characterization techniques [15]. As for woven vascular prosthesis, the heat setting process is necessary to make the flattened tubular structures round and get optimum mechanical properties [5]. Heat setting will affect such important properties as stress–strain and recovery behavior, dye-uptake, optical properties, and thermal properties [14]. Most studies conclude that the increase in the crystalline fraction and the size of the crystalline domains during heat setting signinga qualitative change in the superstructure and morphology of the oriented matrix [15].

There were few studies about the heat setting process of PTT fibers. Liu carried out the heat setting process under a relaxed state for 30 seconds at the temperature of 150℃, and results showed that PTT filaments shrunk, breaking strength decreased and breaking elongation increased [16]. Dong studied the heat setting condition of PTT fibers during the temperature of 120 to 190℃ for 90 seconds. Results show that with the higher temperature, the crystallinity of fibers increased [17]. The study of Yin et al. showed that under pressure state the temperature of 160℃ is the best condition for the highest elastic recovery [18]. Yuan's study showed that the best heat setting temperature is lower than 160℃ and time period is lower than 60 seconds for knitted fabric under pressure state [19]. Liu studied the influence of temperature during the heat setting process on the knitted fabric and showed that with the increase of temperature the elastic recovery increased but the hand characteristics became worse. The better temperature for heat setting is lower than 160℃ [20].

However, the best heat setting condition for keeping properties of lower Young's modulus and superior elastic recovery is unknown. This paper designed the experiments and studies the influence of different heat setting conditions on mechanical properties, and especially on the change of Young's modulus and elastic recovery.

2 Experimental

70D/72f PTT filaments were used as heat setting samples. Time period is chosen from 30 s to