Optimization of the Macromolecular Structure in Poly(ethylene terephthalate) Filaments through Controlled Melt-Spinning Process Parameters for an Enhanced Drawability

Bénédicte Strich[1], Gregory Stoclet[2], François Caillou[3], François Rault[1] and Aurélie Cayla[1]

[1] Univ. Lille, ENSAIT, ULR 2461 - GEMTEX - Génie et Matériaux Textiles, F-59000 Lille, France, e-mail: benedicte.strich@ensait.fr
[2] Univ. Lille, CNRS, INRAE, Centrale Lille, UMR 8207 - UMET - Unité Matériaux et Transformations, F-59000 Lille,
[3] Concept Manufacturing, F-76190 Valliquerville, France

Abstract: Poly(ethylene terephtalate) (PET) is the most widely used polymer in textile industry as it represented 54% of the global textile fiber production in 2020 [1]. Their quality-price ratio is well-balanced, as they are produced at low costs thanks to the melt-spinning process, while developing sufficient mechanical properties for many applications [2]. During their manufacturing, PET filaments are usually drawn to achieve their desired mechanical properties as well as their targeted finenesses. Going even further in the drawing process allows higher finenesses to be achieved, down to less than 1 dTex, which corresponds to fine fibers or microfibers. The use of such fibers greatly increases the specific surface area available within textile structures, providing interesting properties for liquid absorption or particle retention in filtration applications [2]. Drawing is therefore a crucial stage that one may need to optimize to enhance its possibilities.

Semi-crystalline thermoplastic polymers have an inner drawing capacity, or drawability, that rely on the internal arrangement of their macromolecular chains [3]. Their theorical limiting drawability is determined by their molar mass, as it governs the extent to which the internal network can fully disentangle and expand [4]. However, this criterion alone is not sufficient to explain the drawing capacity of many polymers, PET being one of them, since the maximum drawing ratio achieved in practice are much lower than the theoretical ones [5].

The main objective of the work presented here was to identify in literature all structural factors that effectively promote PET filaments drawability. It has highlighted the importance of chain mobility that is limited by crystallinity or a too high chain entanglement level, as well as the importance of internal structure homogeneity to prevent premature breakage of filaments during drawing [6]. As melt-spinning exposes polymers to considerable stress at high temperature, the internal network of PET filaments is truly shaped during this process. One parameter to manage is spinline stress: when too high, it is responsible for strain-induced crystallization and therefore for a loss of chain mobility during the subsequent stretching process [4]. The concept of fine control of filament stress is also the key element in recent 'Superdrawing' techniques that aim to maximize filament drawability [2]. During melt-spinning, spinline stress is affected by controllable variables, such as spinning speed and polymer mass flow rate, both of which being responsible for increasing stress as they increase [7]. Other factors also need to be considered, such as the design of the spinnerets, as they help making the internal structure more homogeneous [6].

To supplement this knowledge, an experimental study has been carried out to determine the impact of process parameters of a conventional melt-spinning line on the organization of PET macromolecular chains. Each of these parameters combined induces a modification of the internal orientation within the different states of matter: in the molten state directly under the spinnerets, and in the rubbery state during drawing. The objective is therefore to modify them individually to obtain information on their impact on the internal structure of the filaments. For this purpose, various characterization methods have been used as X-Ray Diffraction (XRD), Differential Scanning Calorimetry (DSC) and Tensile Testing. Then, the results have been analyzed with regard to measured filament drawability. The objective of this work is then to acquire a better understanding of the structuration of PET during melt spinning, and to improve the control of the process with a focus on maximizing the drawability of the produced filaments.

Keywords: *Poly(Ethylene Terephtalate) Filaments, Melt-Spinning, Drawability.*

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