Partially Oriented Yarn (POY) produced from semi-dull via melting spun using an extruder: Effect of die extruder temperature on elongation of the POY

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Abstract. Semi-Dull is a white and slightly opaque polyester type with 0.35 wt% of titanium dioxide (TiO2) content. Whereas, Partially Oriented Yarn (POY) is a type of yarn produced from polyester fibers derived from continuous filament using molten spinning. The used filament fibers have low strength with a very high percentage of elongation. This study aims to analyze the elongation properties of the yarn produced during molten spinning process of raw materials. The yarn produced has 165 denier 96 filaments Semi-Dull POY (i.e. POY 165/96 SDC). In this study, the used raw material is Semi-Dull, which then melted in the extruder machine and spun into Partially Oriented Yarn (POY). The temperatures of the extruder die was varied (i.e. 275, 280, 285°C) and controlled by using a commercial thermal fluid, i.e. DOWTHERM™. The POY samples prepared from the molten spinning process using extruder were then analyzed for their elongation at different extruder die temperatures. The elongation analysis results showed that the elongations of the POY were about 127.17; 137.85; 137.97 % at die temperatures of 275, 280, 285°C, respectively. From the results, it can be concluded that the die temperature has affected the elongation properties of the POY 165/96 SDC yarn.

1. Introduction
Polyester (PES) is one of important synthetic fibers. This synthetic fiber has several advantages e.g. good tenacity, resistance to the sunlight, easily to be processed and produced, widely used) [1]. One of the most frequently used process to produce synthetic polymers fibers is melt spinning. This process includes polymer melt extrusion through a small capillary die then pulled by winding the filament at high speed while solidified using cooled air. Particularly, for polyester filament produced at high winding speed, i.e. 2500-3500 m/min is called partially oriented yarn (POY), and then thermomechanically drawn to improve its physical properties [2, 3]. The processing conditions (e.g. extrusion temperature, cooling process) significantly affect the physical properties of yarns/threads produced [4]. For instance, textile materials used for sewing thread, rope, net should have high strength/tenacity of at least 7.5 g/d, while the ability to accept dyes, optical fiber is a secondary goal [5]. Additionally, there are several factors that affect the melt spinning process are momentum and heat transport processes, melt rheological, molten polymer orientation, glass transition, stress induced, ratio of crystallization [2, 4].
Semidull is a white and slightly opaque polyester type with 0.35% titanium dioxide (TiO2) content and disperse dyes is used in dyeing process. Semidull as a raw material is granulated and used as the basic material of polyester yarn making. In the next process semidull in the form of chips will melt then become polyester thread with the process of charging, melting and taking up. Polyester fiber is a polymer category consisting of Polyethylene Terephthalate (PET) and Monoethylene Glycol (MEG). The main use of Polyester in Textile is for making yarns, of which nearly 40% of the world's production of direct polyester is used to make Polyester Yarn. Polyesters in different forms are widely used in textile applications to make polyester (PET) resin and filament yarn such as partial mono filament yarn, Drawn Textured Yarn (DTY), Fully Drawn Yarn (FDY), Polyester Staple Fiber (PSF), Polyester Spun Yarn (PSY), and Partially Oriented Yarn (POY). POY is a yarn produced from polyester fibers spun with molten spinning and derived from long filament fibers or continuous filament. The filament fibers used have low strength with a very high percentage of elongation. POY threads are semi-finished threads made of melted chips PET and then through a spinning process. Polyester fibers spun with molten spinning generally produce POY yarns. These filaments are made from the melting of the polyester chip melt. In the spinning process, the speed of withdrawal affects the type of yarn produced, namely: a) At the speed of 500-1800 m/min produced the type of Un-Drawn Yarn (UDY) and Low Oriented Yarn (LOY); b) At the speed of 2600-4500 m/min generated type of Partially Oriented Yarn (POY); c) At speed 2500-5000 m/min (with integrated drawing) produced type Fully Drawn Yarn (FDY); d) At a speed of 5000-6000 m/min produced a type of superhigh-speed yarn [6]. In this study, partially oriented yarn (i.e. POY 165/96 SDC) was produced from semi-dull raw materials via molten spinning using an extruder. The number 165 shows the number of denier, and 65 shows the number of filaments. The objective of this study was to evaluate the effect of die extruder temperatures on the elongation of POY yarn produced.

2. Experimental
The materials used in this study were semi-dull, which was acquired Tivico, Jakarta. The temperature variation of the die extruder were 275, 280, 285°C. The yarn produced has specification of 165 denier 96 filaments Semi-Dull (i.e. POY 165/96 SDC). The textile test machine used in this study was Statimat ME+ manufactured by Textechno, which is shown in Fig.1a. Whereas, the schematic diagram of the melting spun is shown in Fig. 1b.

Fig. 1. a) Photograph of textile test machine (Statimat ME+); and b) Schematic diagram of melting spun
3. Results and discussion
In this study, three groups of POY samples produced from the melting spun of semi-dull (275 °C, 280 °C, and 285 °C) were tested for their elongation. Each of sample groups consisted of 6 POY thread samples. The elongation of those 6 samples were taken average for each of groups. The results showed that elongation for each groups, 275 °C, 280 °C, and 285 °C were 127.17 %, 132.87 %, 137.97 %, respectively. This results showed that the die extruder temperature significantly affect the elongation of POY thread produced via melting spun process of semi-dull material. Figure 2 below shows the plot of elongation of POY yarn produced versus the die extruder temperatures.

![Fig. 2. Effect of extruder die temperatures on the elongation of POY yarn produced](image)

Temperature contributes to the deformation process. The material is composed of vibrating particles. When the temperature is high then the vibration of the particles is stronger (dynamic) so that the material is more easily formed or deformed. Additionally, polymers commonly undergo changes in mechanical properties or behavior over a range of temperatures. In the temperature range of Tg – Tm, polymers change in behavior and structure from rigid, brittle, solid, like a glass to be flexible, soft, elastic, like fluid (visco-elastic). The relationship between mechanical properties (stiffness) and rise in temperature and changes in the structure of its molecular chains [7].

4. Conclusion
In this study, partially oriented yarn (POY) thread has been produced from semi-dull materials via melting spun process using an extruder. The effect of die extruder temperatures (275 °C, 280 °C, and 285 °C) on the elongation of the yarn produced have been investigated. The elongation tests have been carried out using a textile test machine, Statimat ME+. The test results showed that the increasing die temperature significantly increased the elongation of the yarn (i.e. POY) produced. The increases of elongation were 127.17 %, 132.87 %, 137.97 % for die extruder temperatures of 275 °C, 280 °C, and 285 °C, respectively.
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