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FULL LENGTH ARTICLE

Evaluation of the flammability and thermal properties of a new flame retardant coating applied on polyester fabric

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Abstract The objective of this research was to investigate the effect of non-durable flame retardant (NDFR) coating of samples of polyester fabric untreated and treated with UV/Ozone for different periods. For this purpose, these samples were tested by Fourier transform infrared (FTIR) spectroscopy, thermal analysis tests as thermo-gravimetric analysis (TGA) and differential scanning calorimeter (DSC). The ignition test was applied using limiting oxygen index (LOI), flame chamber (UL/94). Results indicated that both AZ2 (dried at room temperature) and AZ8–12 (dried at 80 °C for 30 min after coating with non-durable fire retardant (NDFR) coating) polyester samples have significantly decreased the rate of burning and increased the limiting oxygen index.

1. Introduction

Polyester (PES) is one of the most important synthetic polymers. It can be used in two ways: as a raw material by itself or as a blend because of its wrinkle-resistant property and its ability to retain its shape [1]. The modification of polyester fiber was widely studied by several researchers. Many methods have been successfully used for modifying the physical and chemical properties of polyester fiber, such as blending with other polymers [2], coating with tetraethoxysilane for thermal property improvement [3] and modifying with inorganic materials [4]. PES is widely used in many fields such as textile, automotive industries, garments, pants, shirts, suits, and bed sheets either by itself or as a blend [1,5]. Conversely, it has various disadvantages such as highly flammable combined with dripping, smoking, shrinking effect, low dyeability, less wearing comfort, difficulties in finishing and insufficient washability associated with their hydrophobic nature [6,7]. For these reasons, it is necessary to improve the anti-dripping and fire retardant properties of PES. The ignition process depends on heat, fuel (such as Gasoline, acetone, ether, pentane), oxygen and free radical chain reaction. If a single angle in the fire triangle is missing the ignition can't take place.

Flame-retardant additives play an important role in saving lives and protecting property from damage. It can be added to polyester by three methods: additives to the polymer melt, flame-retardant co-polymers and topical finishes – which have all been used commercially to produce flame-retardant

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polyester textiles [8]. Non-durable fire retardant (NDFR) treatments involve water soluble chemicals that can be washed off with plain water. These treatments can withstand non-aqueous laundering with dry cleaning solvents. Non-durable chemical treatments as borax, boric acid, organophosphorous compounds can be added as fire-retardants [9]. These treatments can withstand non-aqueous laundering with dry cleaning solvents. The main advantage of the non-durable fire retardant coating has always been their relative low cost. Di-ammonium phosphate (DAP) is an effective intumescent fire retardant for several kinds of polymer-based materials [10–12]. It is a high molecular weight chain phosphate. Its efficiency is generally attributed to an increase in the char formation through a condensed phase reaction. The flame retardants can be classified into two types; the first one can be mixed with polymer and called additive flame retardants, while reactive flame retardant referred to add flame retardants by reaction [13]. A diagram of the current model of combustion of textile fibers is given in Fig. 1 [14]. Combustion is an exothermic process that requires three components, heat, oxygen and a suitable fuel. Combustion consists of the generation and emission of heat and light which makes the phenomenon visible. The emitted light color depends on the released amount of energy [15]. This work aimed to improve the ignition properties of the polyester by treating with NDFR coating. The effect of this new coating was examined by mechanical test (tensile and elongation), thermal analysis (DSC and TG), Fourier transform infrared (FTIR), and flammability tests (UL/94, LOI and small ignition tests).

2. Experimental

2.1. Materials

Mill bleached polyester fabric of weight 140 g/m^2, plain 1/1 weave was kindly supplied by the Misr Company for Spinning and Weaving, El-Mahala El-Kobra, Egypt. The fabric was washed with distilled water at 60 °C for 30 min and dried horizontally at ambient condition before testing.

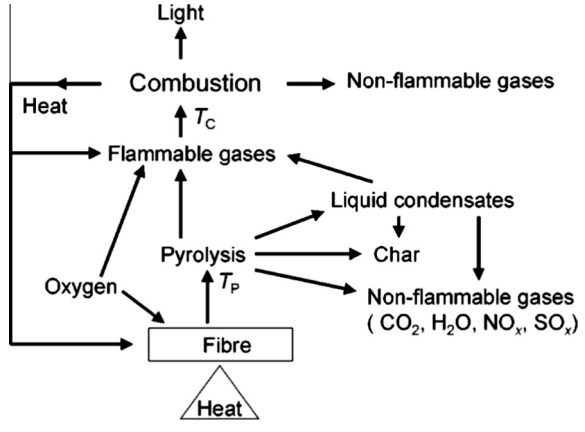

Figure 1 Combustion cycle for fibers, T_p is the pyrolysis temperature while, T_c; is the combustion temperature.

2.2. Synthesis of non-durable coating

The water based solution has been synthesised by adding di-ammonium phosphate ($(NH_4)_2HPO_4$, Merck chemical company, Germany), urea ($CO(NH_2)_2$, 99%, Fluka) and boric acid (H_3BO_4, 96%, Aldrich) to a round flask and stirring at ambient temperature for 2 h. Sodium borate ($Na_2B_4O_7{\cdot}10H_2O$, Aldrich) was then added slowly to the mixture, and stirred for 30 min until a white color appeared. The properties of the fire-retardant coating are tabulated in Table 1.

2.3. Prepared of the treated samples with final coating

Firstly, the polyester samples were exposed to UV/O_3 [16] for different irradiation times (0, 10, 20, 30, 40, 50 min) to excite the outer surface of the polyester sample then immersed in the freshly prepared non-durable coating for 10 min. Finally, the samples were removed from NDFR solution and padded under a constant pressure for 100% uptake and dried in an oven at 80 °C for 30 min [17].

2.4. Weight of polyester fabric

Five samples were cut to a specific area and weighed by Mettler Toledo of accuracy (0.1 mg). The weight was calculated for the square meter [18,19].

2.5. Mechanical properties

Tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. These important parameters obtained from the standard tensile testing are useful for the selection of engineering materials for any applications required. Fabric tensile strength test was conducted according to the ASTM method (1994), which is the standard method for breaking force and elongation of tensile fabrics [20] using H5KT Atlas instrument, USA.

Table 1 Characteristics of the NDFR coating.

Description	Non-durable fire retardant water based liquid
Appearance	Colorless, odorless liquid
Viscosity, ford cup No. 4	11 ± 1 s (at 25 °C)
Density, g/ml	1.1
Non-volatile,%	21.0 ± 0.5
Drying time	
Air drying	24 h
Oven drying at 85 °C	30 min
Limiting oxygen index (LOI)	24–26%
UL/94 (Horizontal)	Pass
Method of application	Dipping
Uses	It is used as a non-durable fire retardant solution for textiles, especially polyester