Spontaneous Ignition Behavior of Cotton Fabric Having Different Amounts of Polyester

M. A. KHATTAB

Department of Materials Science, Institute of Graduate Studies and Research, Alexandria University, Alexandria, Egypt

SYNOPSIS

Measurements were made on a series of cotton/polyester blends having different compositions. The results showed that the time to ignition increased as the polyester contents of the fabric were increased. An explanation of this observation is given. Both the orientation of the fabric and the temperature of the furnace environment affect the time-to-ignition values. The time to ignition was found to be longer for the fabric loaded in horizontal position than that loaded in vertical position. This difference was attributed to the effect of the forced convection induced inside the furnace. © 1996 John Wiley & Sons, Inc.

INTRODUCTION

Spontaneous ignition does not account for a great number of fires; however it is a major problem when associated with certain conditions. Therefore, people should be aware of the causes and the effects of spontaneous ignition and the fire risks it may produce.

The simplest definition of spontaneous ignition is that it is a process wherein ignition of a material occurs without the intervention of an external flaming source (matches, cigarette, electrical spark, etc.) but due to radiation or convection of heat flux liberated from other sources. These could be hot plates, stoves, or the ovens which are still used in our villages.

In contrast, piloted ignition is distinguishable from the previous by the necessity of an external source of heat, in the form of a flame, to initiate the combustion process.

Unfortunately, polymeric materials, which play an important role in our modern life, are among the most common materials which may be spontaneously ignited. The most common polymers in the textile industry are cotton and polyester, used in our clothing, furniture, curtains, and beds.

Both spontaneous and piloted ignitions of a variety of fabrics were studied and it was concluded that a fabric's properties are essential to the prediction of its ignition behavior.[1-5]

Many different parameters related to the ignition character of cellulosic materials were studied.[6-8]

Two of the important parameters are the time to ignition (which is the minimum time needed for a material, when placed in certain environment, to ignite spontaneously) and the ignition temperature in a given environment. Our previous work showed that differential thermal analysis (DTA) could be used to determine, with good accuracy, the temperature at which the onset of spontaneous ignition occurs.[9]

In this paper the effect of fabric composition on the time required for ignition as well as the effect of the fabric orientation on the ignition character are discussed.

MATERIALS AND METHODS

Materials

Fabrics with the following different compositions were used: 100% cotton, 50 : 50 cotton/polyester, 35 : 65 cotton/polyester, 12.5 : 87.5 cotton/polyester, and 100% polyester. The fabrics were provided by Misr Spinning and Weaving Company via Misr Beida Dyers, Kafer EL Dawar-Egypt.

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Methods

Spontaneous Ignition Measurements

A specially designed furnace for spontaneous ignition measurements was used. Figure 1(a) illustrates a cross-sectional view of the furnace. The essential features of the furnace, similar to that used by Miller,[7] are

- A vertical steel cylindrical tube (8 cm in diameter, and 25 cm in length) surrounded by an electric heating coil. The temperature of the furnace is controlled by a temperature controller unit.
- An air pump to provide a flow of air through a glass tube that is mounted at the top of the furnace. The tube (or air) passes through the electric heating wire and down to the bottom of the furnace.
- A strip chart recorder which is used to monitor the output of a thermocouple located very near the sample.

Samples (2.5 × 3.5 cm) are attached to the sample holder and a chromel–alumel thermocouple is positioned 2 mm from the samples. The furnace temperature is adjusted to the desired level by means of the temperature controller. The samples were placed in the furnace by dropping the sample holder into a fixed position. The output of the sample thermocouple was recorded on a single channel recorder as a function of time. A typical output of the chart recorder is illustrated in Figure 1(b). The moment of insertion is represented by the first inflection point, and the moment of ignition is represented by the second inflection point on the curve. The time between these two inflection points is termed the "time to ignition" and measured in seconds. Each reported experimental value represents a mean average of five independent determinations of time to ignition.

Thermal Analysis

DTA was carried out on a Shimadzu thermal analysis instrument (DTA-30) fitted with a (Pt–Rh, Pt)

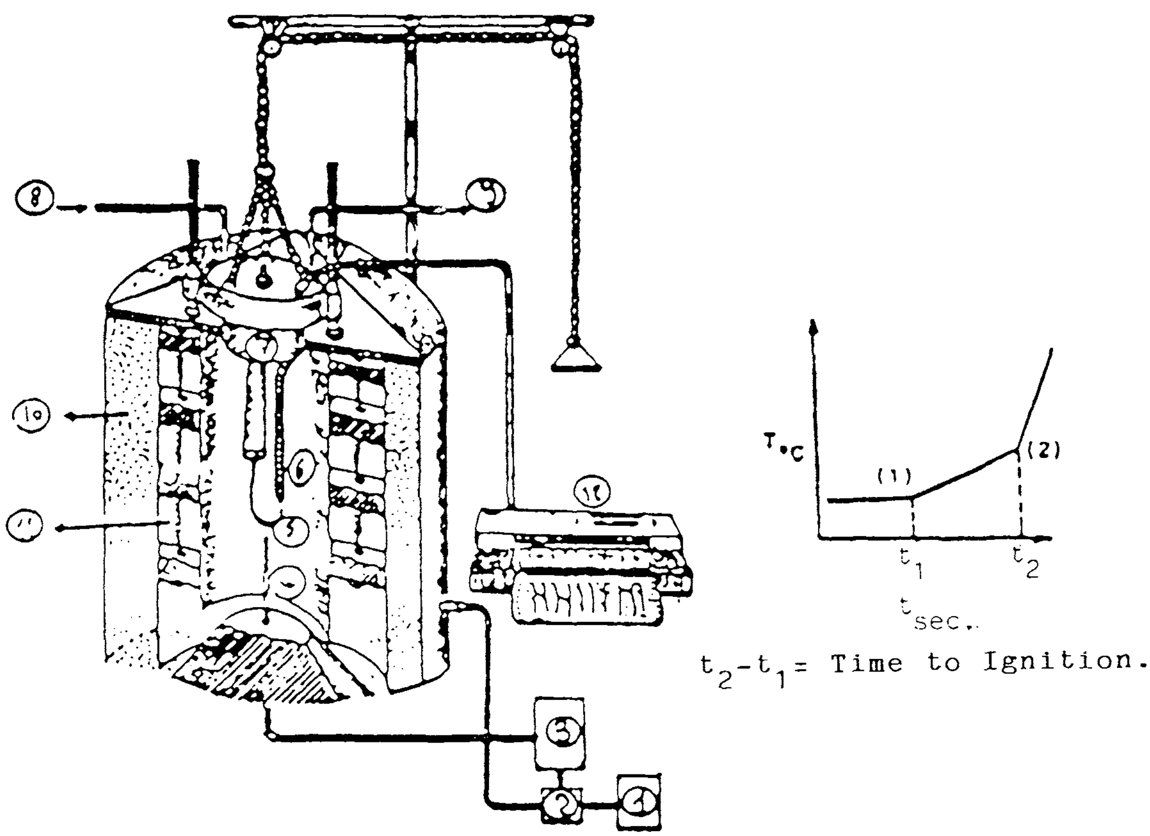

Figure 1 (a) Apparatus for spontaneous ignition studies: (1) power source; (2) relay; (3) temperature controller unit; (4) thermocouple to measure furnace temperature; (5) sample holder; (6) thermocouple to measure sample temperature; (7) insulating cover; (8) gas inlet; (9) gas outlet; (10) glass wool insulation; (11) heater; (12) single channel recorder. (b) Recorder output.

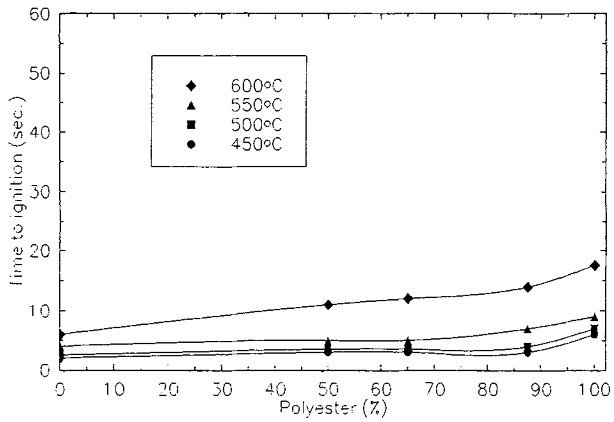

Figure 2 Effect of temperature and composition on the ignition of a series of cotton/polyester blends loaded vertically.

thermocouple. The conditions used were: sample weight of ca. 10 mg, heating rate of 20°C/min, and sensitivity of 50 mV. The samples were heated in a static air atmosphere.

RESULTS AND DISCUSSION

Figure 2 and Table I show the time to ignition for cotton fabrics having different polyester contents, at various fixed temperatures while loaded in a vertical position. For each fabric composition used, the time to ignition was found to decrease dramatically as the temperature was increased. Table I shows that at the lowest temperature used (e.g., 350°C) the pure cotton sample was found to be the only material ignited. The time to ignition at this temperature was found to be 18.5 s.

It is of interest to note that with increasing the polyester content in the fabric at a constant temperature, the required time to ignition either increases or has an infinite value, depending on the composition of the fabric used. For example, at a temperature of 350°C no ignition was observed for any fabric composition containing polyester (Table I). However, at the higher temperature of ca. 450°C, all the compositions of the polyester/cotton blend were ignited but the time to ignition recorded was found to increase as the polyester content increased. This agrees well with the results obtained by other workers,[3,10] despite the fact that they used a different technique from the one used here.

Table II and Figure 3 show a series of polyester/cotton blends heated at different temperatures and loaded in a horizontal position inside the furnace. The ignition characteristics obtained were similar to those observed when the materials were tested in the vertical position. However, the times to ignition for the materials, either pure cotton or blends, were much longer than those required for the same samples in the vertical position at the same temperature. For example, when a blend having a composition of 50 : 50 polyester/cotton was heated at 600°C, the recorded time to ignition was 3 s for the vertical orientation; however, when the materials were placed in the horizontal position, 11.5 s were needed for ignition. In addition, the lowest temperatures

Table II Effect of Temperature and Composition on the Time to Ignition of Series of Cotton/Polyester Blends (Horizontal Orientation)

Composition (%) (Cotton/Polyester)	Time to Ignition (s) at 500°C	550°C	600°C
100% Cotton	28	17.5	9
50 : 50	NI	22	11.5
35 : 65	NI	30	15.5
12.5 : 87.5	NI	42	25
100% Polyester	NI	60	38

NI, no ignition.

Table I Effect of Temperature and Composition on the Time to Ignition of Series of Cotton/Polyester Blends (Vertical Orientation)

Composition (%) (Cotton/Polyester)	Time to Ignition (s) at 350°C	375°C	400°C	450°C	500°C	550°C	600°C
100% Cotton	18.5	14	9	6	4	2.5	2
50 : 50	NI	NI	14	11	5	3.5	3
35 : 65	NI	NI	NI	12	5	3.5	3
12.5 : 87.5	NI	NI	NI	14	7	4	3
100% Polyester	NI	NI	NI	17.5	9	7	6

NI, no ignition.

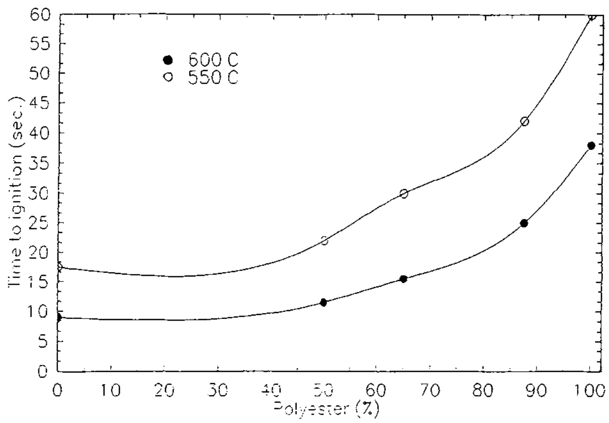

Figure 3 Effect of temperature and composition on the time to ignition of a series of cotton/polyester blends loaded horizontally.

for ignition of either pure cotton or blended fabrics are considerably higher than those used in the vertical position. For example, the lowest temperature required for ignition of cotton in the horizontal position was 150°C higher than that observed in the vertical position. This difference in ignition time and ignition temperature between the two orientations is expected (well documented) due to the direct fuel fed into the flame zone in the vertical position, as well as the forced convection directed upwards and easing the burning in a vertical position. Moreover, the induced blown and heated airflow rate is affected by the position of the sample causing a stream resistance within the furnace; as the sample in the horizontal position is directly facing the airstream, this leads to currents surrounding the cloth, which affects its temperature.

The vertical system represents much lower resistance to the airstream and the cooling effect is negligible in this case.

To reach a comprehensive understanding of the effect of polyester content on the ignition of the fabric, DTA was applied. Figure 4 shows the DTA curves for a series of cotton fabrics having different polyester contents. It is evident that cotton decomposes in three stages. The first stage is endothermic, occurs at about 110°C, and is characteristic of the evolution of water adsorbed. The second peak is exothermic in nature, appears at 370°C, and is characteristic of the decomposition of the cotton. The third peak, which occurs at 410°C, is probably due to the char oxidation.[11-12] The results also show that polyester melts at 250°C and decomposes at about 425°C, which is a higher temperature than the cotton decomposition. The thermal decomposition of cotton produces at least 70–80 volatile products; the most highly flammable product is levoglucosan which, when produced, decomposes and results in a large number of flammable products. One of the methods used to decrease the flammability of cotton is to change the rate by which the flammable gases are produced.[13]

Cotton decomposes thermally within a lower temperature range of 350–380°C (compared to that of polyester at 420–450°C) but whereas cotton maintains some structure integrity via char formations, polyester will melt and flow at temperatures above 250°C (Fig. 4). However, if the two fibers are blended and heated, the molten polyester wicks onto the cotton char, resulting in the so-called "scaffolding effect."

Thus the polyester melts ahead of the progressing flame front of the blend and coats the cotton fiber. This results in slowing the pyrolysis process of the cotton, i.e., affecting the pyrolysis rate by which the flammable gases are produced. This means that the polyester content in the blend is the controlling fac-

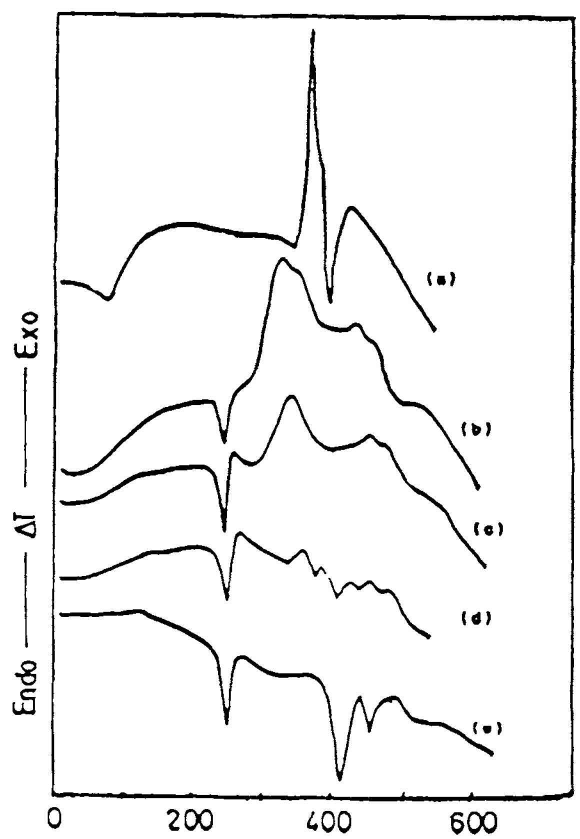

Figure 4 Differential thermal analysis curves for cotton fabric blended with different percentages of polyester: (a) 0% polyester; (b) 50% polyester; (c) 65% polyester; (d) 78.5% polyester; (e) 100% polyester.

tor which determines the rate of the overall fabric combustion.

In other words, time to ignition can be interpreted as a function of two sequential steps: (1) time needed to heat the cotton to its decomposition temperature, and (2) time required by the cotton to produce a mixture of flammable gases, reach an explosive level, and then ignite. Thus when the molten polyester covers the cotton portion it slows the pyrolysis by excluding the cotton from the oxygen atmosphere and trapping the pyrolysis products as they are formed. This contributes to increasing the time required for the cotton to reach its decomposition temperature, and consequently the overall time will be longer. This is probably the reason that as the polyester content of the blend increases, so does the time required for the material to ignite.

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