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Damage caused to fibres by the action of two types of heat

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Abstract

Research into the specific types of damage to textiles and singular textile fibres caused by contact with a heating plate at a given temperature and with the open flame of a gas burner is presented. Experiments were carried out using a selection of textiles (fabrics and knits) differing in colour, fibre composition and textile construction. The characteristic changes that occur in different kinds of textiles and fibres after thermal degradation were observed through microscopic examinations—optical and scanning electron microscopy (SEM).
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1. Introduction

The identification and differentiation of fibres and textiles often encompasses fibres that have been subjected to unusual conditions, e.g. high temperatures. Analytical material of this sort can derive, for example, from cases of arson, fire-raising, explosions or examination of the garments of people who have been involved in road accidents.

In cases involving the analysis of fibre products that come from these types of events, the expert is most often asked to ascertain their physicochemical makeup prior to undergoing thermal transformation. This most often involves questions like:

1. What kind of fibre product was destroyed (burnt, charred, etc.)?
2. Might this product have come from the victim or suspect?

Another area of investigation is that which shows whether or not the examined fibre product carries signs of the effects of high temperatures, fire, explosion, etc. This kind of information is useful in establishing the circumstances of the event.

Providing answers to such questions is difficult without conducting experiments to define the characteristic traits that occur in a thermally damaged fibre product. Consequently, conducting simulations of various thermal transmogrification processes of fibre products in laboratory conditions would seem appropriate.

The process of single fibre thermal degradation is different for various kinds of polymer of which the fibres are made [1,2]. Thermoplastic fibres, which include most synthetic fibres (e.g. polyamide, polyester and polyolefine), change primarily in terms of their physical state as temperature increases (contracting and melting), while chemical degradation (decomposition and burning) occurs only after their melting point has been exceeded. In the case of fibres that are thermosets, natural (vegetable and animal), regenerated cellulosic and protein and certain synthetic fibres (some acrylics), the primary effect of the action of high

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temperature in the course of heating is a change in the chemical structure of the polymer, whereas the progression of changes in their physical structure is less rapid.

The chemical structure of a fibre-forming polymer has a decisive influence on the thermal transformation process of a final fibre product. Other relevant factors that bear on this process are product parameters such as: the linear masses of a thread, thickness, tenacity, surface characteristics and plait.

A survey of literature, both from within the field of forensic science as well as beyond, provides insight into the behaviour of some fibres and textiles in different ‘‘high temperature scenarios’’.

The melting of fibre ends (nylon, polyester, acrylic and wool), as well as the effects of heat on cellulose fibres (viscose and cotton) were described [3], as observed in scanning electron microscopy (SEM) images.

Colourless, thermally altered fibres, i.e. melted, burnt or incinerated, were the subject of an identification study [4,5]. The authors [6,7] have previously investigated specific damage to coloured textiles from vapour cloud explosions.

The effects of flame-retardant coatings and heat on blended cotton/polyester and wool fabrics, as well as the study of a triple-blend fabric of cotton, polyester and wool treated for flame resistance are described [8,9].

The aim of the study was to ascertain whether contact with an open flame or heating plate might cause specific types of damage to textile products (garments) and their constituent fibres. This research was undertaken with the aim of providing information on the characteristics of coloured, popular textiles when subjected to the action of fire and high temperature, and to compare these results with those earlier obtained for the same types of material following degradation by a vapour cloud explosion.

2. Materials and methods

The subject of the research included textiles of the most popular colours and types, clothes and household garments differing in colour, fibre composition and textile construction. The same types of materials were used in earlier experiments that examined the effects of vapour cloud explosions [6,7].

All textile samples were subjected to contact with a heating plate at a given temperature, and with an open flame from a gas burner.

In the case of the latter, the products were placed under a microscope equipped with a temperature-adjustable plate, which was heated to 350 °C (margin of error = $\pm 5^{\circ}$). This temperature was established for the experiment so that it would exceed the melting point of all thermoplastic fibres included in the study. The heated products were weighed down with a metal disc, in order that the product maintains ideal contact with the surface of the heating plate. Most of the products were held to the heating plate for 30 s, whereas in the case of some (acrylic, polyester, silk and wool), this time was shortened to 15 s, due to the very rapid process of melting/charring that occurred with these fibres.

In the next phase, selected original fabrics and knits were placed in the flame of a gas burner until the point when the intensive process of their burning or melting began. Next, these products were removed from the flame and air-cooled.

Microscopic techniques were used to examine the thermal degradation in the textiles and single fibres, employing stereo and bright-field microscopy, while changes in singular fibres were observed using scanning electron microscopy. The surfaces of single fibres were observed at magnifications of 200–500×, using low energy secondary electron imaging (SEI).

3. Results and discussion

Changes in the colour and structure of the examined fabrics and knits were achieved as a basic result of the experiment. The initial sign of changes occurring in materials damaged by the heating plate, as well as those damaged by the flame, particularly in the case of products containing cellulose (cotton, viscose, etc.), acrylic and wool fibres, was a change in colour, with the products becoming yellowish and then brownish. A loosening of the structure of fabrics and knits was observed mainly in the case of cellulose textiles (Fig. 1). Wool and synthetic fibre products formed a hard crust (conglomerations of fibres) on the surface (Fig. 2). The changes were also observed throughout the entire mass of the fibres (e.g. polyester) (Fig. 3).

Examples of the results of changes in the morphological structure of fibres included in the study were presented taking the types of thermally altered fibres into consideration.

The first sets of SEM images show the fibres of a woollen pullover, altered by contact with a heating plate (Fig. 4) and an open flame (Fig. 5). Extensive degradation of the fibres was observed following contact with the heating plate. The ends of the wool fibres are almost invisible, having fused with the charred woollen mass. The results of gasses escaping in the process of the wool’s degradation can be observed throughout the length of the fibres, which become empty on the inside, while their ends form a bulbous structure.

Fig. 6 shows cotton textile fibres from a T-shirt following contact with a heating plate. A detailed observation shows a flattening and partial melting along the length of the fibres. Only small changes were observed in these fibres.

After contact with an open flame (Fig. 7), cotton fibres lose their typical appearance, taking on a lacelike, delicate, fragile charred consistency.

Figs. 8 and 9 show the effect of heat on fibres from a blouse made of cotton and viscose (50% Co, 50% CV). After contact with a heating plate, a softening, similar to melting, can be observed in viscose rayon and cotton fibres (Fig. 8).

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