Available online at www.sciencedirect.com
ScienceDirect
Polymer Testing 25 (2006) 744–757
POLYMER TESTING
www.elsevier.com/locate/polytest

Material Behaviour

Effect of heat flux on the burning behaviour of foam and foam/Nomex III fabric combination in the cone calorimeter

T.M. Kotresh[a,b,*], R. Indushekar[a], M.S. Subbulakshmi[a], S.N. Vijayalakshmi[a], A.S. Krishna Prasad[a], V.C. Padaki[a], Ashwini K. Agrawal[b]

[a]Defence Bioengineering and Electromedical Laboratory, Post Box No. 9326, CV Raman Nagar, Bangalore - 560 093, India
[b]Indian Institute of Technology, Hauz Khas, New Delhi - 110 016, India

Received 22 March 2006; accepted 9 May 2006

Abstract

A comprehensive characterization of the burning behaviour of foam and foam/fabric combination has been carried out at different levels of heat flux varying from 10 to 70 kW/m^2 using cone calorimetry. Peak heat release rate (PHRR) was found to increase for foam and foam/fabric combination with increase in the level of heat flux. However, considerable reduction in PHRR was noted for foam/fabric combination vis-à-vis that of foam alone. Foam/fabric combination was found to exhibit two-step decomposition behaviour at heat flux levels of 50 kW/m^2 and above. Carbon dioxide and carbon monoxide yields were found to be lower for foam/fabric combination. Smoke toxicity, as indicated by the index of combustion completeness, was found to be lower for the foam/fabric combination.

Keywords: Cone calorimeter; Flammability; Heat flux; Heat release; Kevlar; Nomex III

1. Introduction

Foam and fabrics, either in combination or in their individual forms, have found a large number of applications in industry and in daily life. Foam and fabric combinations are widely used in many commercially established applications such as mattresses, automotive and furniture cushions, and carpet backing. Flexible polyurethane (PU) foams are extensively used due to their superior cushioning, ease of handling and physical properties. Seat cushion design of a military fighter aircraft is gaining importance in light of the sustained missions that may have the aircrew in their seats for more than 15 h [1]. Rate-dependent foam, either sandwiched between two layers of PU foam or above the PU foam, covered by the sheep skin or a thin cotton fabric is used in the military aircraft seat to come in contact with the ischial tuberosities of the seated pilot [1]. According to an estimate a total of 910 kg of foam and up to 100 kg of curtain fabric is used inside an interior of a civilian aircraft [2]. The use of foam certainly enhances the sitting comfort but this is coupled with the significant disadvantage of its flammability. The composition and weight of conventional seat materials used in

*Corresponding author. Defence Bioengineering and Electromedical Laboratory, Post Box No. 9326, CV Raman Nagar, Bangalore - 560 093, India. Tel.: +91 080 25058392; fax: +91 080 25282011.
E-mail address: tmkotresh@yahoo.co.in (T.M. Kotresh).

0142-9418/$ - see front matter
doi:10.1016/j.polymertesting.2006.05.009

public transport vehicles (passenger aircraft, trains, buses, etc.) contribute a major part of the hazards affecting passenger survival in fires [3]. As both fabric and foam are organic in nature, they ignite under the influence of a source of heat energy.

Recently, several research workers have reported the fire behaviour of foam alone [4–6] and foam/fabric combination [7–9]. The reported fabrics to cover the foam included treated and untreated cotton [7], Nomex [8] and 14 different varieties of polyester, nylon, polypropylene, acrylic, cotton, viscose rayon and their blends [9]. More emphasis is given on the combination testing as it has been recognized over a period of time that meaningful and more useful quantitative data can be generated by combination testing rather than tests carried out in isolation on individual components [7,10]. In the recently reported studies, foam/fabric combination testing has been carried out using a pre-determined heat flux of 35 [7,9] and 50 kW/m^2 [8]. However, from the search we found that there is lack of information on (a) the behaviour of foam/fabric combination at heat fluxes ranging from low to high levels and (b) the use of Nomex III as the fabric cover. In this paper, the burning behaviour of foam alone and foam/Nomex III fabric combination under the heat flux levels of 10 to 70 kW/m^2 in steps of 10 kW/m^2 will be reported.

2. Experimental

2.1. Materials

In the present study, commercially available polyurethane (PU) foam and inherently flame retardant Nomex III fabric were used. The details of PU foam and Nomex III fabric are given in Table 1.

2.2. Preparation of foam/fabric sample

Samples of size 100 mm × 100 mm × 25 mm and 200 mm × 200 mm were cut from the continuous sheets of PU foam and Nomex III fabric, respectively. The fabric cover was firmly wrapped over the foam and was secured by stapling at all the four corners. Adequate care was taken to ensure that the fabric cover was creased suitably at the edges for obtaining the tight packing of the foam inside the cover. A single layer of aluminium foil with its shiny side towards the sample was used to wrap the foam and foam/fabric combination sample. The wrapped sample was secured in the sample pan with a sufficient backing of ceramic wool blanket (60 kg/m^3 density) over the ceramic block. A retainer frame was placed around this assembly so that only 88 cm^2 of the top surface of the foam and the foam/fabric combination sample was exposed to the radiating conical heater. The optional wire grid was not used in the present study.

Table 1
Details of polyurethane(PU) foam and Nomex III fabric

PU Foam		Nomex III Fabric	
Density (kg/m^3)	Thickness (mm)	Area Density (g/m^2)	Thickness at 7 g/cm^2 (mm)
32–33	25	180	0.41

2.3. Cone calorimeter

A cone calorimeter that operates on the 'oxygen consumption' principle [11] and made by Fire Testing Technology Limited UK was used in the testing of samples as per ISO 5660. Foam and foam/fabric combination samples were tested at various levels of heat flux ranging from 10 to 70 kW/m^2 at intervals of 10 kW/m^2.

3. Results and discussion

3.1. Ignition time

The values of ignition time (t_{ig}) of the foam and the foam/fabric combinations at all the levels of heat flux considered in the present study are given in Table 2. It is seen that the ignition time for both the foam and foam/fabric combination decrease as the level of heat flux increases. This follows from the rate of heating to reach the ignition temperature increasing with increase of level of heat flux. It is also seen that at the heat flux level of 10 kW/m^2, the foam sample did not ignite, while the foam/fabric combination ignited only after an extended period of 200 s.

This behaviour could be attributed to the initial behaviour of the foam and foam/fabric combination on exposure to radiant heat. The foam on immediate exposure to radiant heat shrinks and melts concomitantly to form a black carbonaceous part that does not ignite even after extended period of exposure for almost 600 s, when the experiments were discontinued. The shrinking of the foam i.e.,