

AN EXPERIMENTAL STUDY ON THE FORMATION OF SMOKE LAYER IN COMPARTMENT FIRE

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ABSTRACT

Experiments have been performed to investigate the formation of smoke layer in case of several furniture fires such as trashcan, chair, carpet, sofa, mattress, and wardrobe in a residential room. As a result of the present investigation, the uniformly distributed fire of carpet showed that the ignition and the initial growth period were relatively short while the fully developed period was considerably long. The concentrated fires such as mattress and wardrobe showed that the ignition and the initial growth period were relatively long. The descending time of the interface heights was within 1-3 minutes to reach around 1m. However, the interface height was lowered to 0.25-0.75m above the floor at the time of the maximum temperature.

INTRODUCTION

The fire brings about the loss of life and property of a person. With the increasing possibility of the fire, it is becoming increasingly important to predict accurately the fire phenomena under various fire sources. In many countries, there have been continuous efforts to study the fire phenomena for the establishment of fire safety. Parker[1] studied the heat release rate by spending the oxygen. Lee[2] and Gottuk et al.[3] studied the monoxide concentration in bedroom fire and calculated the time of flashover. Yoon[4] studied concerning the structural vulnerability parts based on the full scale fire experiment in one of the apartment buildings. A number of studies[5-7] have therefore been carried out to obtain a deep understanding of the fire phenomena.

Although several studies have been already made on the fire phenomena in a compartment fire, no experiments appear to have been conducted on the formation of thermal stratification.

In this study, experiments have been performed using several furniture such as trashcan, chair, carpet, sofa, mattress, and wardrobe in a residential room to clarify the formation of the smoke layer

EXPERIMENTAL APPARATUS AND PROCEDURE

The experimental setup is shown in Fig. 1. The temperature sensors placed in the positions of ①, ②, ③, ④, ⑤, ⑥ and ⑦ and the equipment for gas analysis placed in the position of ⑧. The different fire sources are presented in table 1 and the room and door geometry are shown in table 2. The fire sources are positioned in the floor of the center in fire room. The experiment is performed under the closed conditions of all the windows and doors. The piloting source for the sofa, mattress and wardrobe is the circular trashcan contained 17 sheets of newspaper. The temperature is measured by the K-typed(chromel-alumel) thermocouples of 0.6mm size. During the experiment, all the above quantities are recorded by KAYE instruments(DIGISTRIP-4, 128 channel) once every 10 sec and datas are stored on hard disk in PC.

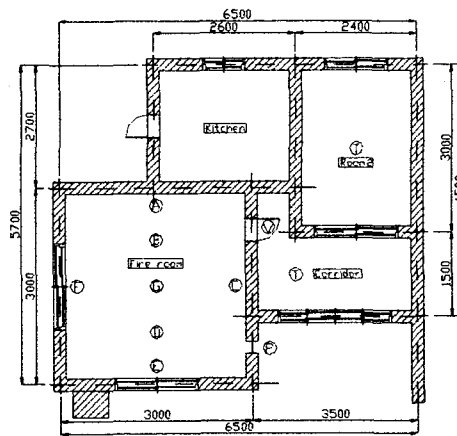


Fig. 1 Sketches of the test configuration with indications of the locations of instrument arrays

Table 1. Characteristics of various fire sources

name	size(cm)	material
trashcan	23×29×49	polyethylene
carpet	190×250	-
mattress	132×191×17	-
wardrobe	103×61×190	3mm veneer

Table 2. Room and door geometry

room name	room size(m)	door size(m)	window size(m)
fire room	2.6 _w ×2.6 _L ×2.9 _H	0.8 _w ×1.8 _H	1.5 _w ×1.2 _H
corridor	1.8 _w ×3.4 _L ×2.9 _H	1.5 _w ×1.8 _H	0.8 _w ×1.8 _H
room-2	2.3 _w ×2.5 _L ×2.9 _H	3.3 _w ×2.1 _H	1.2 _w ×1.1 _H

EXPERIMENTAL RESULTS

Fig. 2 shows the measured temperatures of the trashcan as a function of time at (A) position in the fire room. As will be seen from the figure, the temperatures of the floor and above the floor by 0.5m are low. The temperature above the floor by 1.0m is a gradual riser than the temperature above the floor by 0.5m. The temperatures above the floor from 1.5m to 2.7m are almost constant. The temperature above the floor by 2.9m is low because the heat is isolated by the false ceiling and the heat loss partly. The fire phenomena shows that the temperature of the initial growth increases rapidly to be the the highest point while that of the fully developed period decreases gradually to be the decay period.

Fig. 3 shows the temperatures of the chair at (A) position in the fire room. The temperatures of the ignition rise gradually to be the growth period and during the flashover period the temperature increases rapidly to be the maximum temperature and after the flashover the temperature decreases quickly. In the chair fire, there is two peaks in the temperature profile. The first peak is formed by the first burning of the frame, padding, and fabric. when the chair is collapsed by the burning of the legs, the scattered fire of the broken chair forms second peak.

Fig. 4 shows the measured temperatures of the carpet at (A) position. The range from the ignition to the growth period is relatively short in all the fire period. The fully developed period of the carpet is much longer than other fire sources like the trashcan and the chair and the temperature of the fully developed range is almost constant because the carpet is spreaded widely in the bottom and the carpet is burned constantly in all direction.

Fig. 5 shows the results for the sofa at (A) position. The sofa is located in the center of the fire room and the circular thrashcan is used by the fire starter. As shown in the figure, it takes 5 minutes to reach the growth period because the sofa is concentrated in the center of the fire room. The range of the flashover is short and the temperature of that increases rapidly to reach 700-800°C and after that the temperature decreases quickly to reach the decay period.

Fig. 6 shows the measured temperatures of the mattress at (A) position. The mattress is located above the floor by 0.3m in the center of the fire room and the circular thrashcan is used by the fire starter. It takes 10 minutes to reach the growth period. The range from the ignition to the growth period is relatively longer than that of other periods in all the fire range. There are two or three peaks in the mattress fire.

Fig. 7 shows the measured temperatures of the wardrobe at (A) position. The wardrobe is located in the center of the fire room and the circular thrashcan is also used by the fire starter. The growth period is very long and there are two peaks in the fire range.

Fig. 8-13 show the averaged temperatures of the upper and lower layer and the interface height of the two zones. The upper and lower layer is divided by the interface plane which is selected by the middle of the steepest slope as shown in those Fig. 14-15. The temperatures of the lower layer follow gently those of the upper layer, however, the temperatures increase

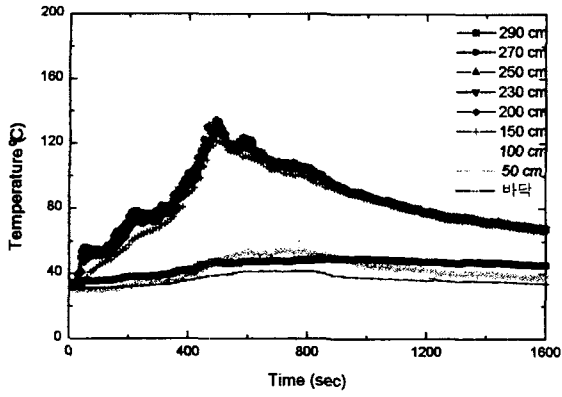


Fig. 2 Temperature profiles of A position in the trashcan fire

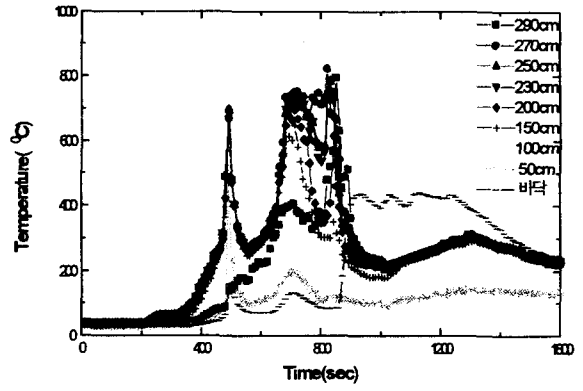


Fig. 5 Temperature profiles of A position in the sofa fire

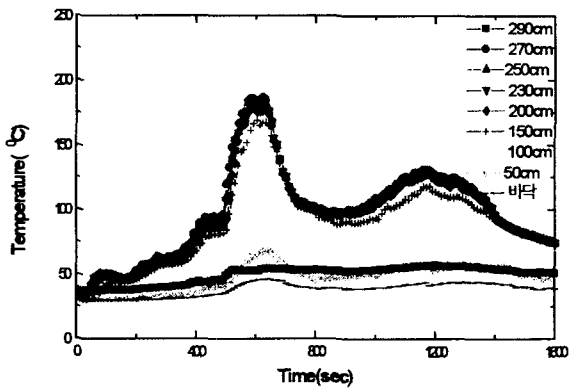


Fig. 3 Temperature profiles of A position in the chair fire

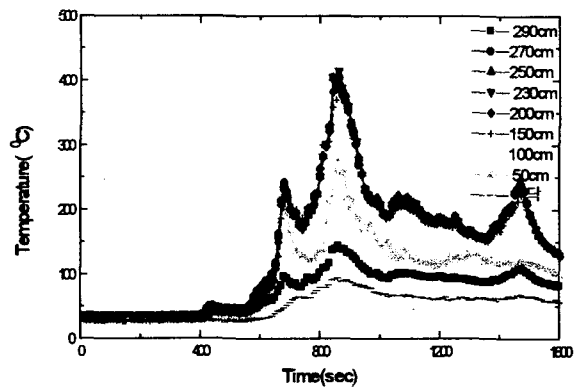


Fig. 6 Temperature profiles of A position in the mattress fire

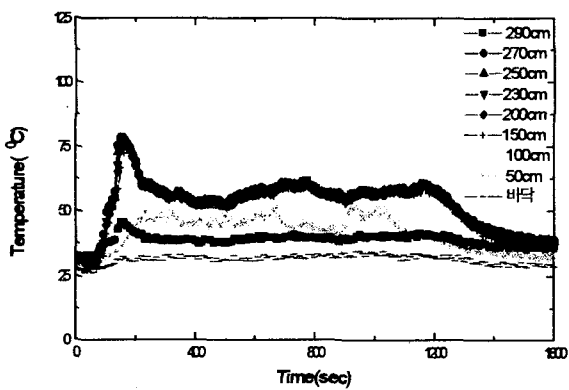


Fig. 4 Temperature profiles of A position in the carpet fire

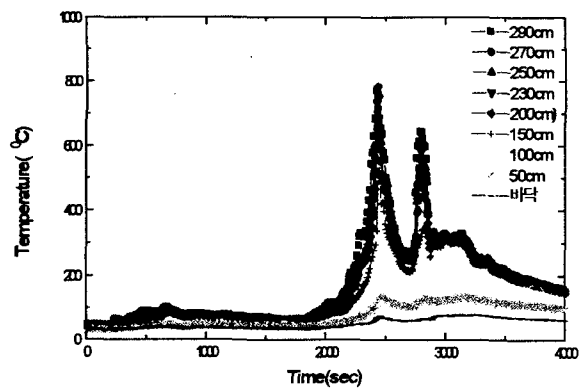


Fig. 7 Temperature profiles of A position in the wardrobe fire

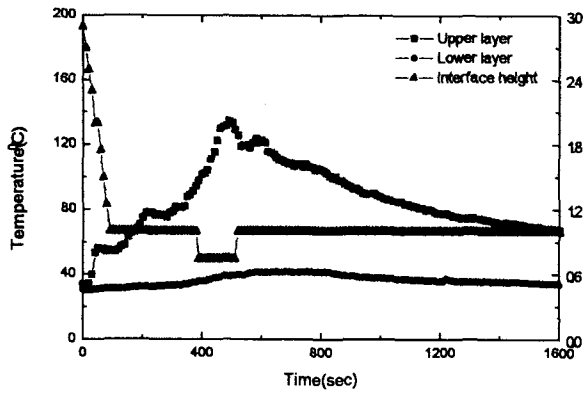


Fig. 8 Temperature profiles of the upper and lower layers and the interface height in the trashcan fire

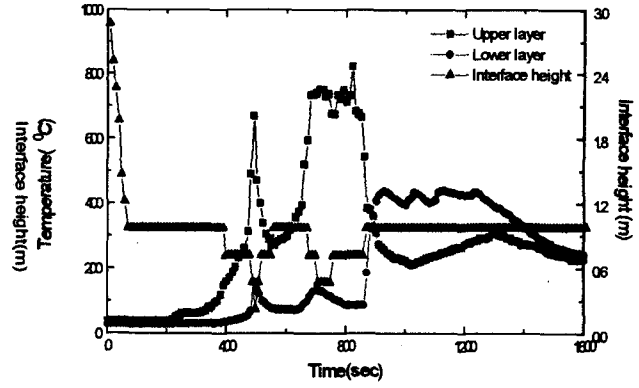


Fig. 11 Temperature profiles of the upper and lower layers and the interface height in the sofa fire

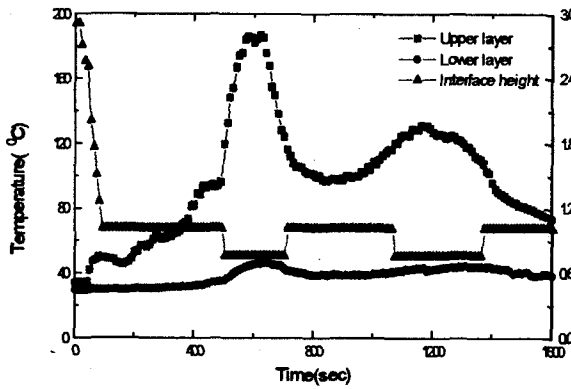


Fig. 9 Temperature profiles of the upper and lower layers and the interface height in the chair fire

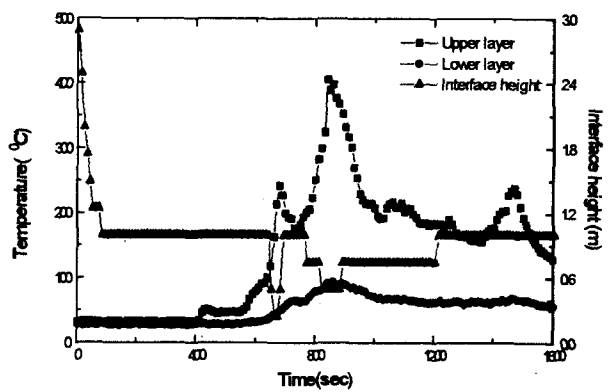


Fig. 12 Temperature profiles of the upper and lower layers and the interface height in the mattress fire

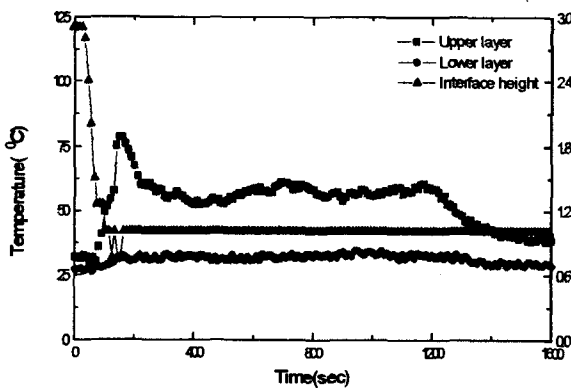


Fig. 10 Temperature profiles of the upper and lower layers and the interface height in the carpet fire

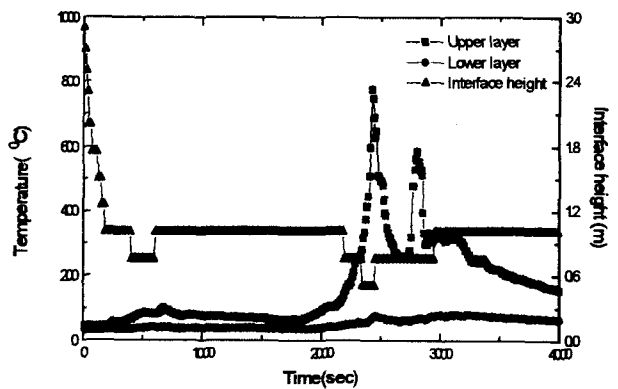


Fig. 13 Temperature profiles of the upper and lower layers and the interface height in the wardrobe fire

little at the maximum temperature of the upper layer and after the peak point the temperatures decrease slowly. The interface heights are around 1m as the steady state. However, the interface height of sofa, mattress and wardrobe are lowered to 0.25-0.75m from the floor at the time of maximum temperature of the upper layer.

Fig. 16-17 show the comparatives of the descending speed of the interface height. As shown in the figure, the descending time of the interface height was within 1-3 minutes to reach around 1m.

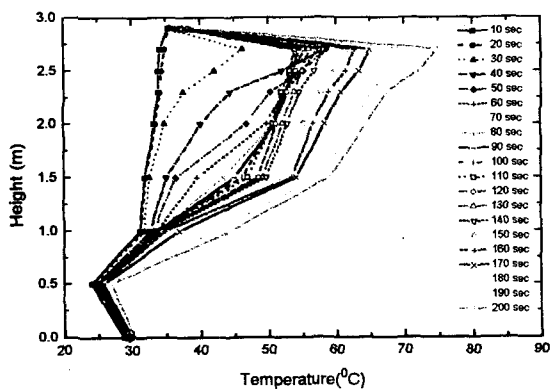


Fig. 14 Average temperature profiles of nine elevations from 10sec to 200sec in the trashcan fire

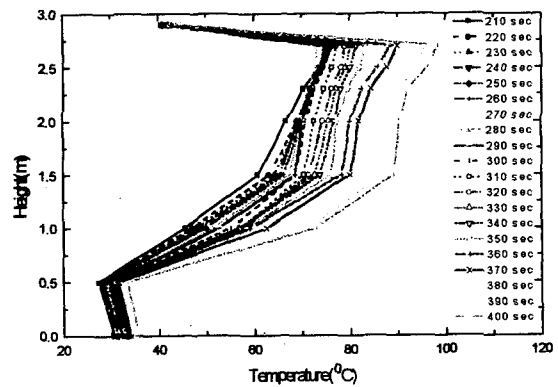


Fig. 15 Average temperature profiles of nine elevations from 210sec to 400sec in the trashcan fire

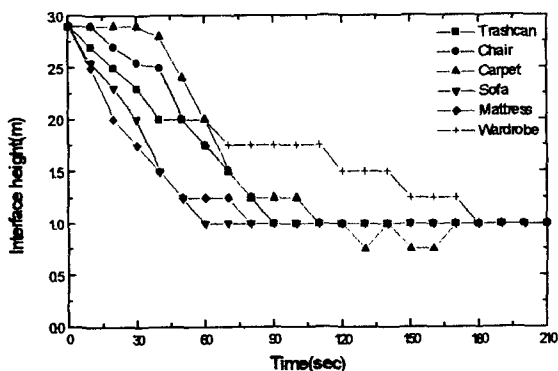


Fig. 16 Comparison of the interface heights from 0sec to 210sec in seven materials

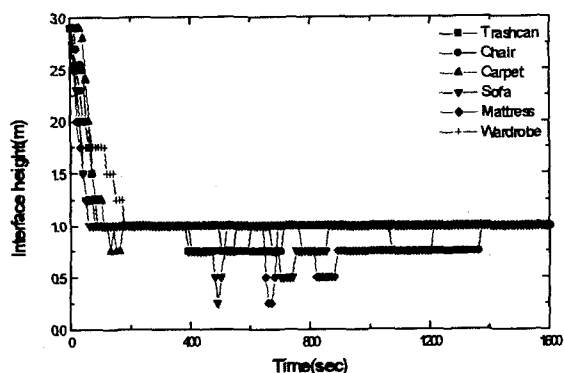


Fig. 17 Comparison of the interface heights from 0sec to 1600sec in seven materials

CONCLUSION

The resulting of the formations of smoke layer in case of several furniture fires such as trashcan, chair, carpet, sofa, mattress and wardrobe in a residential room are as follows:

First, in the uniformly distributed fire like carpet shows that the ignition and the initial growth period are relatively short while the fully developed period is considerably long. The ignitions and initial growth periods of the concentrated fires such as trashcan, mattress and wardrobe are relatively long.

Second, the descending time of the interface height is within 1-3 minutes to reach around 1m. The interface heights for the furniture fires are around 1m as the steady state. However, the interface height is lowered to 0.25-0.75m above the floor at the time of the maximum temperature.

Third, depending on the direction of the fire spread, one or more peaks appear in the temperature profiles.

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