THE PARTICLE SIZE EFFECT ON COMBUSTION BEHAVIOR OF CELLULOSE INSULATION

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ABSTRACT

The combustion of cellulose insulation treated with Borax, Boric acid and Aluminum Sulfate as combustion retardants is examined by candle type combustion tester. The cellulose fibers in cellulose insulation are classified by diameter as less than 0.2mm, 0.2mm-0.5mm, 0.5mm-2mm and more than 2mm. The burning behavior of cellulose insulation are studied by LOI (Limit Oxygen Index: Beginning point of smoldering), L-Point (Lower point of combustion transition from smoldering- flaming to flaming combustion). LOI, L-point and H-point rise with the increasing particle size of cellulose fibers because thermal decomposition rate of cellulose fiber decreases. The phenomena of combustion transition from smoldering to flaming combustion are determined by the generating rate of combustible gas and the formation rate of combustible gas mixture within the zone of cellulose fiber heated.

INTRODUCTION

Cellulose insulation is made from recycled newspaper. When property ground to a linear fiber form, such products become an excellent thermal insulation, commonly used in residential homes. The inherent combustibility of the cellulose material must be controlled. However, by the addition of combustion retardants. The combustion retardants of cellulose insulation used by boric acid and borax[1]-[5].

The article summarizes the last phase of a study of the smoldering combustion characteristics of cellulose insulation. In previous research smolder initiation[6][7][8] and smoldering propagation[9], transition to flaming combustion[10], smoldering smoke evolution in these materials have been investigated. The present study was undertaken to look a combustion behavior of cellulose insulation according to particle size of cellulose fiber.

EXPERIMENT

Unretarded insulation from a commercial manufacturer was fully conditioned to 50% relative humidity at 20°C. The cellulose fiber in cellulose insulation are classified by diameter as less than 0.2mm, 0.2-0.5mm and more than 2mm. The combustion retardants (mixture ratio——► Boric acid: Borax: Aluminum sulfate = 2:1:2) was usually reagent grade. In all cases, the material was through 200 mesh. It was mixed with insulation in sufficient quantity to give a final product that was 6,12,18,24 % by weight retardant. Uniform dispersion was achieved by two hours of mixing on a roller mill. ASTM C519 was employed to measure the density. The combustion behavior of cellulose insulation was used candle type flammability tester[8]. The detail method of experiment was described in previous paper[8][11].

RESULTS AND DISCUSSION

1. Combustion Behavior of Cellulose Combustion

The process description of combustion behavior of cellulose insulation is shown in Fig.1. At the oxygen concentration which is lower than LOI (Limit Oxygen Index), the cellulose insulation does not ignite with pilot flame because over the higher point of flammability limits, that is, the concentration of oxygen in the atmosphere does not meet the condition that causes the ignition of cellulose fiber. At the LOI point, the cellulose fiber begins smoldering combustion at the oxygen concentration exceeding the LOI point. As oxygen content increases, the smoldering phenomena are fully developed. During smoldering combustion of cellulose insulation, the smoldering combustion behavior is typically defined as smoke evolution burning without flame. The reason that causes smoldering combustion is the insufficient oxygen content in atmosphere and insufficient ignition heat produced by combustion of cellulose material in this study. In this case, smoke is the particularly serious hazard in real fire. At the L-point, the cellulose fiber begins combustion transition from smoldering to flaming combustion, which is described as two modes region. At the H-point, the cellulose fiber begins combustion with fully developed flame, which is described as flame spread region . In this region, the combustion behavior of cellulose insulation can be described as vigorous burning flame with small amount smoke. In this region, it is likely to reach flashover in real fire. The combustion behavior of cellulose insulation is studied by measurement of LOI, L-point and H-point.

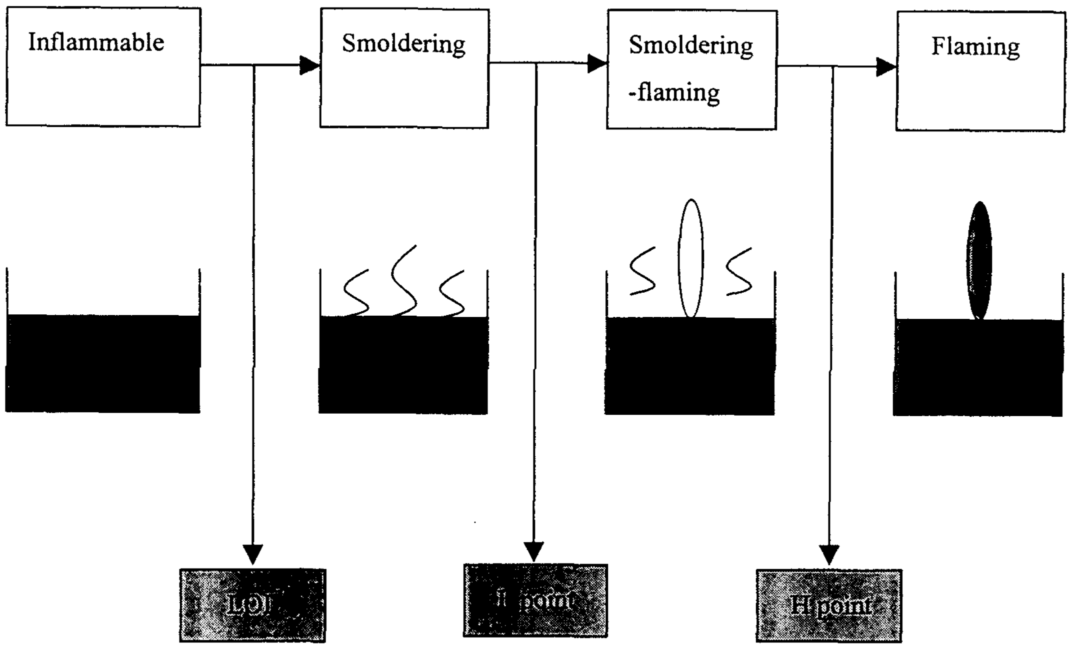

Fig. 1 Process Description of Combustion Phenomena

2. Effect of Particle Size on LOT, L-point and H-point

The effect of particle size of cellulose fiber on LOI, L-point and H-point are respectively shown in Fig.2, Fig.3 and Fig.4. LOI, L-point and H-point rise with increasing retardant contents of cellulose insulation because retardant material improves the flame resistance ability of cellulose material. But these three value decrease with increasing particle size of cellulose fiber because of thermal decomposition rate of cellulose fiber. The big surface area of cellulose fiber causes the reduction of thermal decomposition rate. Normally, with the increasing surface area of cellulose fiber, the formation rate of combustible gas mixture and the thermal transformation rate from ignition sources are raised. However, increase in particle size of cellulose insulation made the insulation ability decreased. Therefore, in the process of cellulose production, the particle size of cellulose fiber should be carefully considered, that is, the different cellulose fiber which has different particle size should be properly mixed. The particle size in final products of cellulose insulation must be controlled

3. Effect of Particle Size on Combustion region

The combustion regions of cellulose insulation with different particle size are shown in Fig.5 and Fig.6. With the increment in oxygen content of atmosphere, combustion mode changes as follows:

Non inflammable ⟶ LOI ⟶ Smoldering region ⟶ L-point
Two mode region ⟶ H-point ⟶ Flame spread region

With the increment of particle size of cellulose fiber, the whole regions and points appear at higher oxygen content. Besides, the area smoldering region and two mode region of larger particle size of cellulose fiber are more wider than that of small one. As the increasing of particle size of cellulose fiber, LOI and two mode region become larger. Therefore, at large particle size of cellulose fiber, the ability of fire proof is improved.

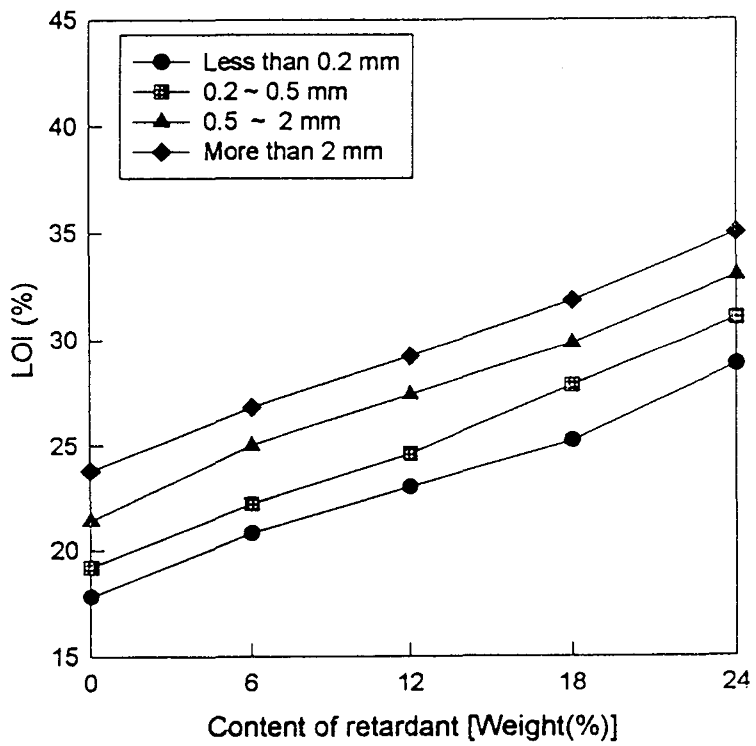

Fig. 2 Effect of treatment level on LOI of cellulose insulation treated with BA-B-AS system

4. The reason of this phenomena are explained by following:

I) At the large particle size, the thermal decomposition rate are raised by surface area increasing effect.

II) However, in spite of high generation rate of combustible gas, the ambient area of cellulose fibers is insufficient and oxygen rate is low. Thus the formation rate of combustible gas mixture are also low.

III) Therefore, at large particle size, the combustion behavior governed by the diffusion rate of combustible gas in the atmosphere.

IV) At small particle size, a part of heat energy transferred from ignition sources is released to atmosphere through the particle surface. Thus, the thermal decomposition rate is reduced by surface area decreasing effect.

V) However, in spite of low generation rate of combustible gas, the ambient area of cellulose fibers is sufficient, the formation rate of combustible gas mixture are relatively quick.

VI) Therefore, at small particle size, the combustible behavior governed by the generation rate of combustible gas coming from thermal decomposition of cellulose fiber.

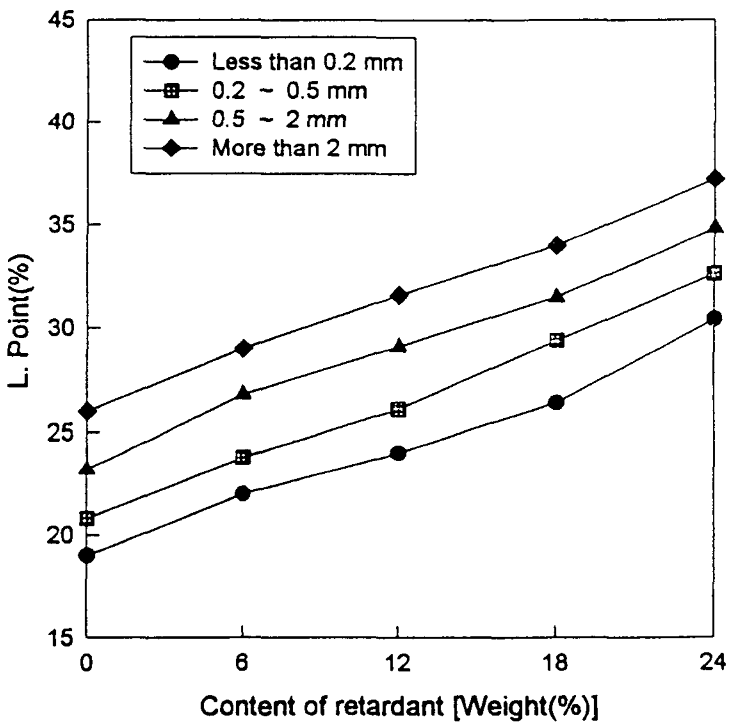

Fig. 3 Effect of treatment level on L.Point cellulose insulation treated with BA-B-AS system

CONCLUSION

The combustion behavior of cellulose fiber insulation was studied by different particle size. The conclusion are explained by followings:

1. LOI, L-point and H-point increase with the increment of particle size of cellulose fibers.
2. As the increasing of retardant concentration, the smoldering region, two mode region and flame spread region appear at higher oxygen content.
3. At large particle size of cellulose fiber, the ability of fire proof are improved by LOI and two mode region increasing effect.
4. At large particle size, the combustion behavior is determined by the diffusion rate of combustible gas, on the contrary, at small particle size, by the generating rate of combustible gas coming from thermal decomposition.
5. For the purpose of improvement of fire proof ability of cellulose insulation, the particle size of cellulose fiber must be mixed and controlled in process production.

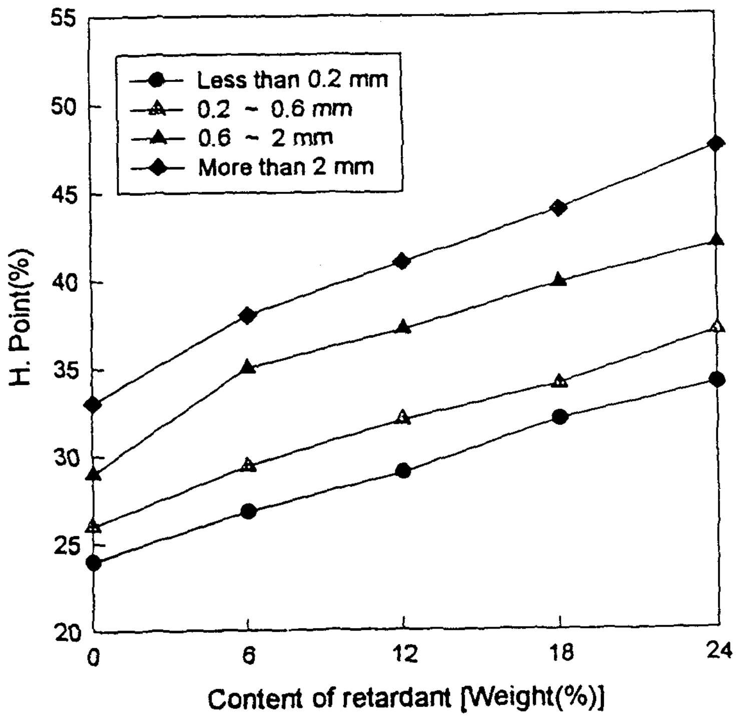

Fig.4 Effect of treatment level on H.Point of cellulose insulation treated with BA-B-AS system less than 0.2mm

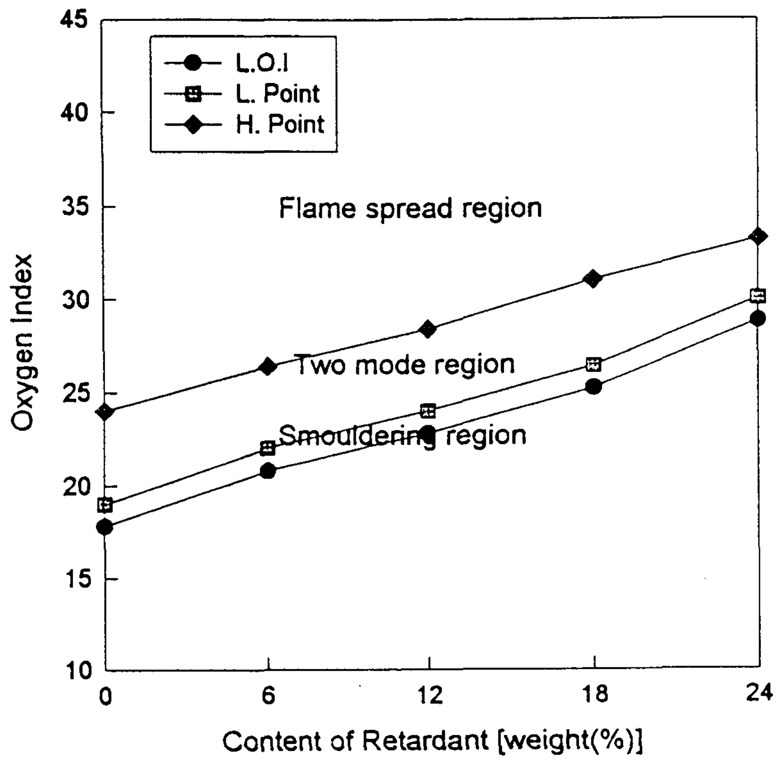

Fig.5 Effect of treatment level on combustion of cellulose insulation treated with BA-B-AS system less than 0.2mm

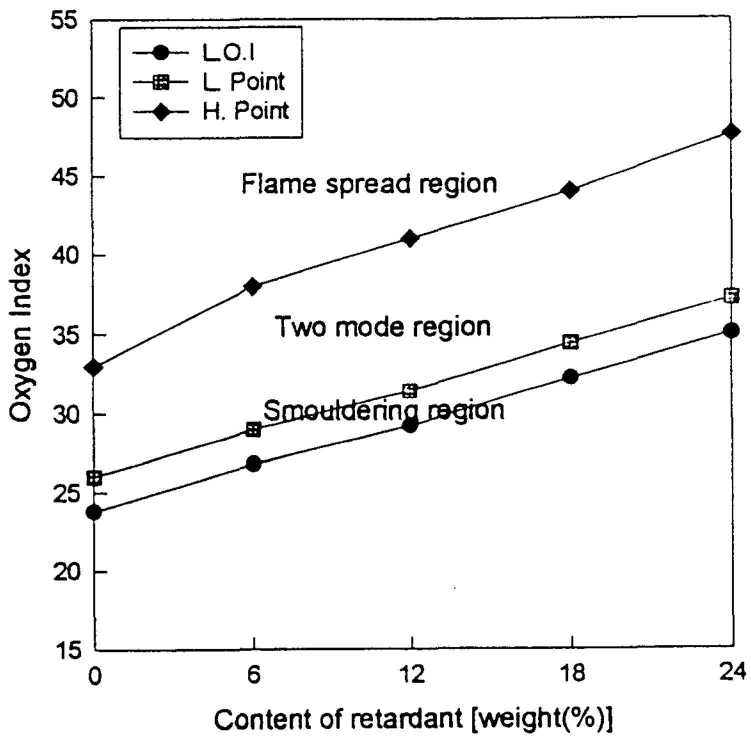

Fig.6 Effect of treatment level on combustion of cellulose insulation treated with BA-B-AS system more than 2mm

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