Case Studies in Thermal Engineering 8 (2016) 10–18

Contents lists available at ScienceDirect

Case Studies in Thermal Engineering

journal homepage: www.elsevier.com/locate/csite

Experimental studies on the effects of spacing on dripping behavior of thin polymethyl-methacrylate slab

Hui Zhu, Yunji Gao, Guoqing Zhu*

School of Safety Engineering, China University of Mining and Technology, Xuzhou, Jiangsu 221116, PR China

ARTICLE INFO

Article history:
Received 11 March 2016
Received in revised form
15 April 2016
Accepted 22 April 2016
Available online 23 April 2016

Keywords:
Dripping
Vertical burning
Spacing
Net heat flux
PMMA

ABSTRACT

Experiments were carried out to study the dripping behavior of vertical burning thermally thin polymethyl-methacrylate (PMMA) with different spacings parallel to the wall. With spacings of 7, 10, 13, 16, 19, 22, and 25 mm, the dripping behavior was studied by infrared video image analysis, and the mass retention was recorded by the load cells. As the spacing increased, the dripping time, dripping mass, and burnout growth distance first increased and then decreased. The minimum value was observed at the 13 mm case. The dripping behavior is assumed to correspond to the net heat flux to the surface, extensional viscosity, and gravitational force of melting PMMA. In this study, the dripping behavior was investigated using uniform PMMA samples with 200 mm height, 50 mm width, and 2 mm thickness.

1. Introduction

Thermoplastic polymethyl-methacrylate (PMMA), one of the best organic synthetic materials, has been widely used in interior decoration and insulation industries [1]. Therefore, many vertical walls are covered by large thermally thin PMMA materials, not only to beautify the environment, but also to ensure that the wall is not damaged. However, the potential hazards of these thermoplastics in fires are a matter of great concern. For instance, the dripping of burning polymers has been recognized as a great threat to the public, which can accelerate fire growth and spread fires between nonadjacent objects. When thermally thin PMMA materials are set in a vertical orientation, the molten materials drip because of the high mobility triggered by increasing temperature [2].

In the fire research community, many researchers [2–8] investigated the dripping behavior of burning thermoplastic materials. Wang et al. [2–4] carried out small-scale experiments for the dripping behavior of PMMA under the UL94 vertical test conditions [9]. The results indicate that flame spread and burning rate affect the dripping behavior of thermally thin PMMA materials. Under the UL94 vertical test conditions, the dripping behavior was categorized into two different types: small and uniform drops with a short first dripping time, and large and irregular drops with a long first dripping time. The activation energy of viscous flow and the ratio of the effective heat of combustion to the heat of gasification were also important properties of materials dominating the dripping types of polymers [2]. Regarding the factors influencing the dripping, it can be attributed to the reduction of viscosity not only due to physical melting, but also chemical degradation [2,3,7]. Xie et al. [5] demonstrated that a thinner thermoplastic sheet dropped faster and reached the peak heat release rate earlier than a thicker thermoplastic sheet. A thermally thick PMMA sheet exhibited softening, distortion, and surface

* Corresponding author.
E-mail address: zhuhui119@cumt.edu.cn (G. Zhu).

http://dx.doi.org/10.1016/j.csite.2016.04.004

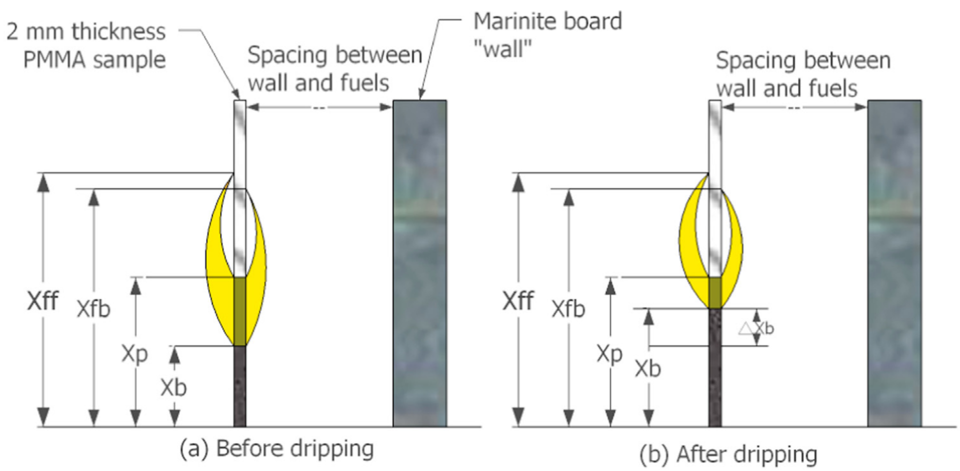

Fig. 1. Spacing effect on upward flame spread model.

bubbling; however, no dripping of the melted polymer was observed during the test by Zhang and Shields et al. [6]. Kandola et al. [8] established the relationships between the glass transition temperature and melt viscosity with the dripping behavior and burning intensity of PMMA.

All the studies mounted the polymer on a wall [5,6] or suspended [2,3,8] and subjected to a source of fire at the bottom during the tests. However, they did not consider the actual situation. Sometimes, the thin PMMA material is not completely attached to the wall, and a spacing exists between the wall and PMMA as shown in Fig. 1. When thermally thin PMMA materials in a vertical orientation were ignited at the bottom in this case, an upward flame spread was observed on the front side, and the back-side flame became one of the most important modes of parallel combustion between the back side of the sample and wall.

As the spacing between the wall and fuels increased, the physical picture gradually changed by the following effects [10]: A fraction of the net heat flux to the surface from the back flame increased, the scale of the turbulent eddies increased by the wall, and the flow of oxygen available for the combustion in the gap increased. Although these effects influenced the rate of fuel production by the wall, the net effect associated with dripping behavior of burning PMMA is not very clear.

As shown in Fig. 1, the front flame height of PMMA is X_{ff}, the back flame height is X_{fb}, the pyrolysis height is X_p, the burnout length is X_b, and the burnout growth distance ΔX_b. The length of the pyrolysis zone is $L_p(L_p = X_p - X_b)$. Fuel vapors are released from the pyrolysis surface and participated in the flame, which is confined to the buoyancy-induced boundary layer. The regions $(X_{ff} - X_p)$ and $(X_{fb} - X_p)$, where the flame extends beyond the pyrolysis length, are known as the combusting plume region, and the heat transferred from this region to the virgin fuel above X_p is responsible for the upward spread of the flame [11]. A thermally thin PMMA material was used as the sample to investigate the effects of spacing on the dripping behavior. Thermally thin materials have unique properties: Thermally thin flues are assumed to have no spatial and internal temperature gradients, and the physical thickness, d, should be less than the thermal penetration depth [12]:

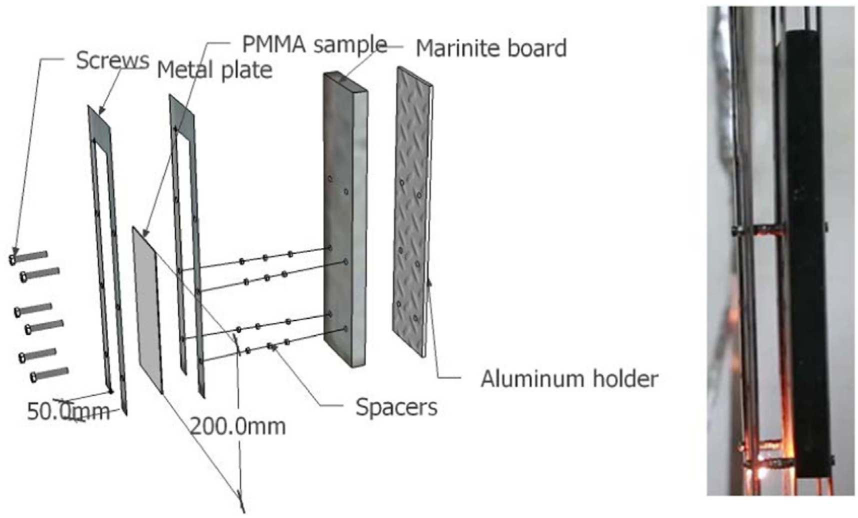

Fig. 2. Schematic of the experimental apparatus.