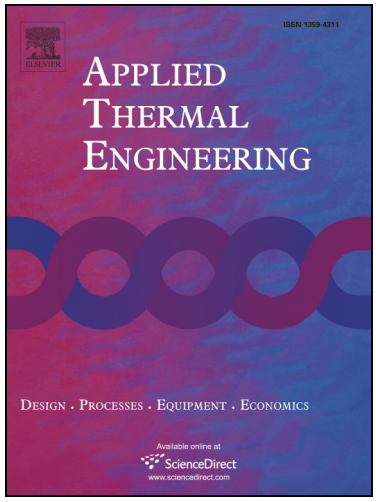

The deceleration mechanism and the critical extinction angle of downward flame spread over inclined cellulosic solids

Ying Zhang, Xiangfeng Chen, Yuhan Song, Xinjie Huang, Yi Niu, Jinhua Sun

PII: S1359-4311(17)32795-3
DOI: http://dx.doi.org/10.1016/j.applthermaleng.2017.04.125
Reference: ATE 10274

To appear in: *Applied Thermal Engineering*

Received Date: 7 September 2016
Revised Date: 29 March 2017
Accepted Date: 25 April 2017

Please cite this article as: Y. Zhang, X. Chen, Y. Song, X. Huang, Y. Niu, J. Sun, The deceleration mechanism and the critical extinction angle of downward flame spread over inclined cellulosic solids, *Applied Thermal Engineering* (2017), doi: http://dx.doi.org/10.1016/j.applthermaleng.2017.04.125

The deceleration mechanism and the critical extinction angle of downward flame spread over inclined cellulosic solids

Ying Zhang[a,b], Xiangfeng Chen[a], Yuhan Song[a], Xinjie Huang[c], Yi Niu[a], Jinhua Sun[d,*]

[a] *School of Natural Resource and Environment Engineering, Wuhan University of Technology, Wuhan 430070, China*

[b] *Faculty of Construction and Environment, the Hong Kong Polytechnic University, Hong Kong*

[c] *School of Building Engineering, Anhui University of Technology, Maanshan 243002, China*

[d] *State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei 230027, China*

*Corresponding Author Tel: +86 551 3606425 Email: sunjh@ustc.edu.cn (J.H. Sun)

Abstract

To investigate the behaviors of flame spread over inclined surfaces, a series of flame spread experiments over whitewood with various inclinations were carried out. The development characteristics of the pyrolysis front with time are discussed, and four different states of flame spreading were observed under different ranges of surface inclination, including the accelerating flame spread region ($\theta \geq 10°$), steady flame spread region ($-20° \leq \theta < 10°$), decelerating flame spread region ($-45° < \theta < -20°$) and extinction region ($\theta \leq -45°$). Among them, the decelerating state is a special flame spread behavior, and has never been reported in previous researches. Subsequently, the deceleration mechanisms of downward flame spread were explored in this study through a balance analysis of the heat and mass transfer between the solid pyrolysis and the gas combustion. An empirical formula of the critical extinction angle was established to predict the occurrence of extinction.

Keywords: flame spread, inclination effects, deceleration, extinction, critical angle

1. Introduction

A flame spreading over a solid surface is a common phenomenon, and the development of the flame spread determines the hazard posed in a potential accident [1-3]. Flame spread in an actual fire is complex and has many factors, of which the inclination of the solid surface is one of the most important. In the King's Cross fire in London in 1987, the 30° inclination of the escalator was a crucial factor in the rapid spread of the fire, causing a disaster [4, 5].

Since this accident, more attention has been given to the effect of the inclination of a solid surface on flame spread globally [6-9]. In their researches, the empirical relationships between flame spread rate and inclination angle were obtained. However, the transient effects of inclination on flame spread rate were neglected in these empirical relationships, and the rate was supposed to be constant. Although this hypothesis can bring some convenience to theoretical analysis, it results in incorrect estimates of the rate of flame spread. For example, the rate might increase with time along the upward surface due to the interaction between flame and the inclined surface [10-13]. Chen et al. [14] investigated the development of flame spread behaviors with various inclination angles, and their results are shown in Table 1. They found that flame spread behaviors showed different states with increasing inclinations: these are extinction, steady spread and acceleration. When the inclination angle is sufficiently large for upward flame spread, the flame propagation