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Effect of Air Flow Velocity in Smoldering Combustion with Opposed Propagation on Cellulosic Material

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Abstract

Smoldering combustion is a phenomenon that is quite unique, because it is a flameless combustion. This smoldering phenomenon can be a hazard, because of it's characteristics. The characteristic of smoldering combustion is slow, low-temperature, flameless and sustained combustion. This phenomenon can occur on cellulose material both organic and non-organic. Smoldering combustion in organics material can cause a wildland fires, both in surface and inside the soil. This phenomenon in organics material was studied using tobacco material and found that ignition temperatures of 380-620^{o}C were observed. This reaserch was conducted in small scale, vertically oriented smoldering cylindrical apparatus, with varied air flow and from-up ignition (downward propagation). The oxidizer which contacted with the bottom surface of tobacco, was forced in certain volumetric flow rate. A constant power to igniter is applied until the temperature of tobacco 10mm from the igniter reached 500^{o}C. The main observation of this research is temperature distribution, mass loss rate and optical density from the resulting smoke. The temperature records in this research were measured by six type-K thermocouples. The mass loss rate of the tobacco in this research were masured by digital scale in real time. The optical density from the released smoke in this research were measured by opacity meter, which transmitted intensity value, converted into optical density value. Air flow variations used in this research were 1, 3, 5, 7, and 9 liter per minute (LPM). The result of this research showed that air flow is an important factor in the process of smoldering combustion. The ignition position and direction of air flow affect direction of propagation. In this research the propagation occured in two direction. In the first process, the propagation of smoldering front was in downward direction. Nevertheless, after the smoldering front reached the bottom surface of tobacco, heat released by ember were accumulated. The air flow from the bottom of the tube forced the combustible mixture to move upwards and then followed by the upward propagation of smoldering front.

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Keywords: Smoldering Combustion, Tobacco, Cylindrical Apparatus, Oxidizer, Temperature Distribution, Mass Loss Rate, Optical Density, Transmitted Intensity, Ignition, Upward, Downward, Propagation.

1. Introduction

Smoldering combustion is a phenomenon that is quite unique, because it is a flameless combustion [1]. This smoldering phenomenon can be a hazard, because of its characteristics. The characteristic of smoldering combustion is slow, low-temperature, flameless and sustained combustion. Smoldering combustion phenomenon in organics material was studied using tobacco material and found that ignition temperatures of 380-620^{o}C were observed [2]. This phenomenon can occur on cellulose material both organic and non-organic. Smoldering combustion in organics material can cause a wildland fires, both in surface and inside the soil [1,3]. This smoldering combustion can be hazardous, because after the combustion occured in surface of the soil, it could propagate inside the soil. The heat released then accumulated inside the soil. The accumulation of heat released could lead to smoldering combustion in extreem dry condition of land and forest floor. If it does occur, the smoldering combustion could propagate upward on to the surface of the soil and can cause wildland fire.

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Nugroho, Y.S., examined the wildland and urban fires situations in Indonesia and urged better understanding of fire phenomena in urban and wildland areas, and the needs of integrating wildland and urban fire risks in national and local development strategies in Indonesia [3]. Research conducted by Lei Yi and Liang Dong regarding upward and forward smoldering combustion, utilized an experiment apparatus of cylindrical tube with 42 mm of inner diameter and height of cylinder of 400 mm, with controlled oxidizer distributed from the bottom and the heat source located at the bottom, and several points of thermocouples placed in the experiment apparatus [4]. The research conducted by Lei Yi and Liang Dong is the basis of the author to design the experimental apparatus with different diameter (40 mm) and height (270 mm).

This research focused on the effect of air flow velocity in smoldering combustion with the heat source from the top of the tube, so the propagation of the smoldering is opposite of the air flow direction. The basis of heat source placed from the top of the tube and the air flow direction was the work of Torero, J.L [5].

2. The object of the study

A schematic of the experimental setup is shown in Fig. 1. The sample used in this experiment, tobacco, undergone a drying process before being placed in the aluminum cylinder. The apparatus design of this research is a cylindrical tube, filled with

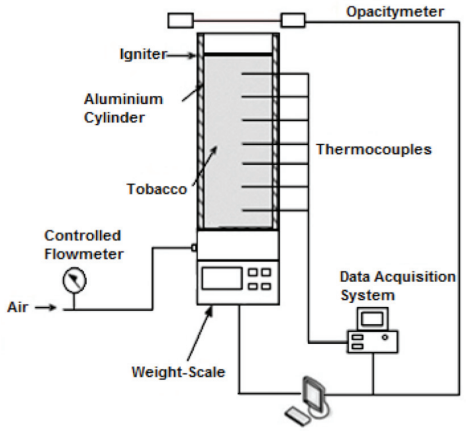

Fig. 1. Schematic of the experimental setup

tobacco material, with air flow distributed from the lower part of the apparatus. Six holes with pre-determined distances from the igniter (10, 40, 50, 130, 170, 210 mm) were used to place thermocouples to measure the temperature distribution during smoldering combustion. The whole cylindrical apparatus was placed on an electronic weight scale to measure the mass loss of sample material, and above the cylindrical apparatus, opacity meter was placed to measure smoke opacity.

The sample used in this research is pure white tobacco. Generally, the sample material used has fairly high moisture content. As previously said, before the experiment, the tobacco sample was dried beforehand by using an oven with the range of temperature 104-108^{o}C for 5 hours. Thus the value of moisture content of the tobacco decreased, and in this experiment the moisture content of the tobacco material decreased to 8%. So that at the time of the combustion test, the material can burn perfectly.

Table 1. Research Variables

Air Flow (LPM)	Material	Ignition Source
1	Dry Tobacco	Top
3	Dry Tobacco	Top
5	Dry Tobacco	Top
7	Dry Tobacco	Top
9	Dry Tobacco	Top

In this experiment the air flow was controlled by flowmeter, with the heat source placed above the sample, causing the smoldering propagation opposed of the air flow. With the variation of air flow is 1, 3, 5, 7, and 9 liter per minute as can be seen in Table 1. The main observation of this research is to observe the temperature distribution, mass loss rate and its smoke optical density. The temperature records in this research were measured by six Type-K thermocouples. The mass loss rate of the tobacco in this research were measured by digital scale in real time. The optical density from the released smoke in this research were measured by opacity meter, which transmitted intensity value, converted into optical density value.