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Experiment study of the altitude effects on spontaneous ignition characteristics of wood

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ABSTRACT

This paper has studied the influence of ambient pressure and oxygen content on spontaneous ignition of wood by conducting contrastive experiments with wood slab exposed to high temperature radiation at two different altitudes. The measurement of mass loss, time to ignition, and surface temperature of wood are carried out. Results show that mass loss rate of wood at high altitudes (3650 m) is higher than the one at low altitudes (50 m), while ignition delay time of the sample at high altitude is shorter. The surface temperatures at the time of ignition in the two different places are both close to each other, which indicates that the pressure did not affects the ignition temperature. The theoretical analysis on the phenomenon of different ignition behavior of wood in these two altitude environments has been presented.

1. Introduction

Ignition is the initiation and the most important stage of combustion, and the ignition of wood is a complex phenomenon, which consists of many physical and chemical processes. Ignition characteristics of charring materials, such as wood, exposed to radiation are of fundamental interest to the research on extracting energy by the burning of wood. Many researchers are attracted to study the basic theory of ignition of wood fuel. Several studies have been conducted on the ignition behavior of wood. There are some review papers on wood ignition [1–4]. Several models that deal with the ignition and pyrolysis of wood have been developed [5–12], discussing the chemical kinetics and physical processes involved in the burning process of wood, such as drying, charring layer reaction, and gas-phase reaction with integral or PDE method. Aspects of experimental researches on the ignition process of wood exposed to a heat resource have been conducted [13–19].

The characteristic of high altitude environment is that of which pressure and oxygen content are lower than those on plain. The influences of oxygen volume concentration on pyrolysis and ignition of wood have been investigated by some investigators. Weng [20] has proposed an integral model predicting the pyrolysis of wood in different ambient oxygen concentrations. Contrasted with the experimental data, the conclusion is that the mass loss rate decreases with the reduction of the ambient oxygen concentrations. Back III et al. [21] have concluded that the combustion of wood can not keep on when the volume concentration of oxygen is lower than 14%, which suggests that the 14% is a critical concentration of oxygen for wood combustion. Some researchers have indicated that the flow of pyrolysis gases in the charring solid relates to the Darcy's law, which shows that the pressure gradient presents in the porous structure of the wood under radiation [22,23]. However, there is little research on the ignition of charring materials at high altitudes, where the pressure and oxygen both are different from plain. The coupling influences of multi-factors introduced by the changing of altitude on ignition characteristics of wood have not been well known yet.

In this study, contrastive ignition experiments of wood at two altitudes have been conducted. The experiments have been conducted in Hefei (a city in the east of China, altitude is about 50 m) and Lhasa (a city in Qinghai–Tibet Plateau, altitude is about 3650 m), respectively. The ambient pressure and the partial pressure of oxygen of Lhasa are lower than Hefei, but the volume concentration of oxygen is same (21%) in these two cities (Table 1 describes the condition of the two cities). The aim of the experiments is to detect the effect of pressure and oxygen content on the ignition of wood. From the results of the two series of experiments, some ignition characteristics of charring materials under these two conditions are obtained, which can supply some suggestions for further research on the ignition, combustion and pyrolysis of wood.

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Nomenclature

E	activation energy (kJ mol^{-1})	μ	gas viscosity coefficient (N s m^{-2})
A	pre-exponential factor (s^{-1})	v	volume (m^3)
t	time (s)	M	molar mass of gas (g/mol)
T	temperature (K)		
k_D	Darcy's coefficient (m^3 s kg^{-1})	*Subscripts*	
u	velocity (m s^{-1})	0	initial condition
p	pressure (Pa)	∞	ambient
ρ	density (kg m^{-3})	g	gas
$\dot{m}''$	mass flux of volatiles material (kg m^{-2} s^{-1})	s	solid
R	gas content (8.314 J mol^{-1}K^{-1})	ig	at ignition time
ε	porosity		

2. Experimental system and procedure

2.1. Apparatus

It is used to research the ignition behavior of the materials exposed to a radiation and a general view of the experimental system is shown in Fig. 1, which consists of radiation source, weighting apparatus, heat flux meter, thermal couples, video camera, and data acquisition system.

2.1.1. Radiation source and main part

The dimension of the radiation source is 300 × 300 mm, which is made of six silicon carbide bars. The heat flux of radiation source can reach up to 50 kW/m^2 at the sample surface. A platform for holding samples is set under the radiation source, and the electronic scale for measuring weight loss of the sample during experiment is located at the bottom. Sample holder is a rectangle frame, which allows the insulating materials to be set between radiation source and scale for protecting the exact equipment. A ceramic fiber blanket is placed under the sample to make a thermal insulated boundary condition on the back. The distance between heat source and the sample surface is held at approximate 100 mm.

It is usually considered that there are two different ignition patterns: one is spontaneous ignition (unpiloted) and the other is piloted ignition. [2] However, this study just takes the former into account, thus there is no ignition pilot in the whole apparatus.

2.1.2. Heat flux meter

The heat flux meter, whose measurement range is from 0 to 100 kW/m^2, used in experiments is Schmidt–Boelter gauge, and it was calibrated by the first metrology and measurement institute of CASC. Heat flux is measured before every experiment with the meter, which is not shown on the schematic map.

Table 1
Ambient conditions in Hefei and Lhasa.

	Altitude (m)	Ambient pressure (kPa)	Oxygen density (g/m^2)	Relative concentration of oxygen (%)
Hefei	50	101	300	21
Lhasa	3650	65	195	21

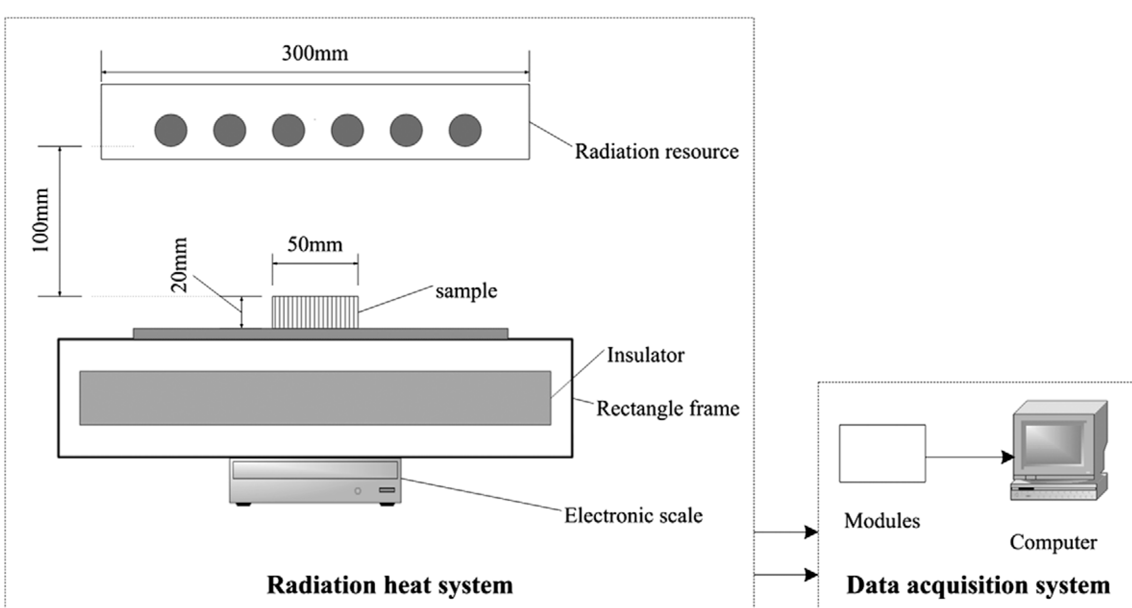

Fig. 1. Schematic of the experimental system.