



Full Length Article

Steam exploded pine wood burning properties with particle size dependence



Muhammad Azam Saeed^{a,*}, Nieves Fernandez Anez^b, Gordon E. Andrews^a, Herodotos N. Phylaktou^a, Bernard M. Gibbs^a

^a School of Chemical and Process Engineering, University of Leeds, LS2 9JT Leeds, UK

^b Department of Energy and Fuels, Technical University of Madrid (UPM), Spain

ARTICLE INFO

Article history:

Received 1 October 2016

Received in revised form 29 December 2016

Accepted 5 January 2017

Available online 16 January 2017

Keywords:

Steam exploded biomass

Explosibility

Flame propagation

ABSTRACT

Power generation using waste material from the processing of agricultural crops can be a viable biomass energy source. However, there is scant data on their burning properties and this work presents measurements of the minimum explosion concentration (MEC), flame speed, deflagration index (K_{st}), and peak pressure for pulverised pine wood and steam exploded pine wood (SEPW). The ISO 1 m³ dust explosion vessel was used, modified to operate on relatively coarse particles, using a hemispherical dust disperser on the floor of the vessel and an external blast of 20 bar compressed air. The pulverized material was sieved into the size fractions <500 μm , <63 μm , 63–150 μm , 150–300 μm , 300–500 μm to study the coarse particles used in biomass power generation. The MEC (\emptyset) was measured to be leaner for finer size fraction with greater sensitivity of explosion. The measured peak K_{st} was 43–122 bar m/s and the maximum turbulent flame speeds \sim 1.4–5.4 m/s depending on the size distribution of the fraction. These results show that the steam exploded pine biomass was more reactive than the raw pine, due to the finer particle size for the steam exploded biomass.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Pulverised wood or pulverised agricultural waste biomass are effective substitutes for pulverised coal as low CO₂ fuels and hence can be used to reduce GHG emissions from coal fired power generation [1,2]. In the UK, pulverized woody biomass burning in existing coal fired power stations generated 5.7% of electricity in 2014 [3]. However, these raw biofuels have low bulk densities and low calorific values, making their handling and transportation a challenge. They are normally converted into compressed dried pellets at the biomass source and these increase the bulk density and reduce dust in transport [4]. The lower water content compared with the raw biomass reduces the transport costs per GJ of energy transported.

Adoption of further thermal pre-treatment such as torrefaction [5,6] or steam exploded biomass [7,8], further increases the bulk density and reduces the water content. Torrefied biomass involves heating at around 200–320 °C, then pulverisation and compression into pellets. Steam exploded biomass involves heating to similar temperatures as for torrefaction, with hot steam at high pressure

and then releasing this pressure so that the water absorbed in the biomass ‘explodes’ out, shattering the biomass. These thermal pretreatment processes of the raw biomass also makes the subsequent pellets stronger with less associated dust and less water absorption. The net result is a cost saving safe and cheap transportation compared to the thermal processing costs of the biomass. When delivered to the power station the thermally treated biomass can be milled alongside coal as the thermal treatment process makes the particles brittle. The thermal treatment creates a physical change in the structure of the fibrous biomass that makes the fibres brittle. This makes the thermally treated biomass more like coal and sometimes it is referred to as ‘biocoal’, although a precise definition of this term is lacking at present.

Thermally treated biomass using the steam exploded biomass process is investigated in the present work, using samples provided from an industrial scale pilot plant for this process. The authors [7] have previously investigated steam exploded biomass using the Hartmann dust explosion equipment and reported MEC data and flame speeds and compared them with the raw biomass. This work showed that steam exploded biomass was more reactive than the raw biomass, but this was mainly due to the particle size differences [7]. The steam exploded biomass had finer particles due to their brittle fibres breaking up more easily [6] during the steam

* Corresponding author.

E-mail addresses: azamsaeed86@hotmail.com (M.A. Saeed), profgeandrews@hotmail.com (G.E. Andrews).

explosion process. In the present work the same steam exploded biomass was investigated using the ISO 1 m³ dust explosion equipment. The emphasis is on the measurement of the reactivity of the same steam exploded and raw pine pulverized biomass by measuring the spherical turbulent flame speed and deriving the laminar flame speed and burning velocity. The peak pressure and the deflagration index, $K_{st} = \left(\frac{dp}{dt}\right)_{\max} V^{1/3}$, were also determined.

The physics of flame propagation in pulverized biomass/coal burners are identical to that which occurs in spherical flame propagating pulverised biomass flames in explosions [9], so that the present work is not just about explosion hazards but also about flame propagation in pulverized fuel burners. Biofuels carry fire/explosibility risks in their handling [10,11] and there is little published information on this as the standard 1 m³ explosion vessel with 'C' ring dust disperser does not work with fibrous biomass, which is why there was little data on biomass dusts. Lots of biomass fire/explosion incidents were reported in past [11] and it is of concern that there is a lack of reliable explosion protection for biomass dusts, which makes the design of protection equipment uncertain [9,10]. The reliable measurements of the reactivity parameters for these biofuels depend on multiple factors such as fuel properties and their size distribution [12].

Low temperature (~300 °C) thermal pre-treatment of biomass results in small chemical changes in their compositions but greater physical changes in the break-up of the structure of the fibres [10,12]. These thermally treated fuel pellets mill in a similar way to coal and can more easily be used to replace coal for the existing facilities than raw wood pellets. However, there is little known about the combustion characteristics of these thermally treated biofuels. It was found that coals become non-reactive for very coarse size due to their rigid thick structure delaying the efficient release of volatiles [13], whereas the biomass particles are porous with thin cell walls.

Slatter et al. [14] and Saeed et al. [2] showed that pine wood and bagasse samples respectively with particle size 300–500 µm would propagate a flame and Wong et al. [15] found that wood dust sizes up to 1200 µm could explode if they were dry. All these investigators found that biomass had a leaner MEC and higher values of K_{st} for finer particles, but that the peak overpressure was high for all sizes. Cashdollar [16], using 20 L dust explosion vessel, have shown that the reactivity of Pittsburgh coal dust decreases with increase in particle size. They also reported that beyond 200 µm particle diameter, the coal dust was non-explosible for narrow size range distribution. However, for broad size range particle fraction, they were explosive due to the presence of fine particles. Gao et al. [17] studied the effect of particle size distribution on the propagation of the flame using Octadecanol dust. The flame was visualized by high speed camera combined with band width filter. It was concluded that the flame developed by fines was regular shape and continuous due to high release of the volatiles whereas the flame developed by coarse particles was discrete and discontinuous due to less release of volatile and burning of the solid particles. Flame imaging revealed that the flame colour changed to blue as the particle size varied from fine to coarse. Worsfold et al. reviewed the explosion sensitivity and severity of non-traditional dusts with emphasis on the nano-size particles in comparison to the micro-size particles [18]. In this work the explosion characteristics and spherical turbulent flame speed of steam exploded pine wood were determined as a function of the particle size.

2. Experiments

2.1. Experimental materials

Pine wood with the 'steam explosion' thermal treatment was supplied by Zilkha Biomass Energy in the form of pellets. Around

20 kg of pellets were milled using Retch 100 ultrafine grinder to less than 500 µm and sieved for the following size fractions <63 µm (fine), 63–150 µm (moderate), 150–300 µm (coarse) and 300–500 µm (very coarse). There was insufficient raw biomass supplied to undertake tests in the ISO 1 m³ vessel, but the comparison with the raw pine wood and the steam exploded pine wood has been carried out using the Hartmann explosion equipment by Saeed et al. [7]. This showed that steam exploded pine wood was more reactive than raw pine wood in terms of a leaner MEC and higher flame speeds and initial rates of pressure rise in the Hartmann tube. However, this higher reactivity was due to the finer particle size for steam exploded biomass.

2.2. Chemical characterization of the raw pine wood in comparison to its steam exploded pine

Steam exploded pine wood was analysed for its elemental and proximate characterizations. Elemental analysis was performed using Flash 2000 thermoscientific analyser and proximate analysis using Shimadzu TA 50 [7]. By comparing raw pine wood and steam exploded pine (Table 1), elemental compositions were found to be similar, with a small increase in fixed carbon content and proportional reduction in volatiles in the steam exploded wood due to the previous thermal treatment. Steam exploded wood also had higher true density with less porosity as compared to raw pine wood sample.

Also particle size distributions of raw and steam exploded pine wood with different sieved sizes were defined (Fig. 1). The fineness of pine wood was increased after steam explosion treatment due to the shattering of structure and the increase in the brittleness of the particles. Also the increase in size fraction of this steam exploded pine wood (150–300 µm) approached to the same particle size distribution as that of raw pine wood.

2.3. Experimental methodology

Explosibility indices of the different studied fractions of steam exploded pine wood were determined with the modified ISO 1 m³ vessel (Fig. 2). This vessel has a design pressure of 25 bar g to withstand and it was designed based on ISO 6184/1 standard. Details of this modified vessel and experimental methodology had been explained in previous works [19–22], besides repeatability of the tests were checked periodically for different samples and were found to be within allowable limits [23]. Different explosibility characteristics like turbulent and laminar flame speed, pressure

Table 1

Chemical characterisation of raw pine wood in comparison to its steam exploded sample.

Chemical characterisation	Raw pine wood (YPW)	Steam exploded pine wood (SEPW)
% C (daf.)	51.0	52.8
% H (daf.)	6.1	5.8
% N (daf.)	0.0	0.4
% S (daf.)	0.0	0.0
% O (daf.)	42.9	41.1
% H ₂ O	5.4	4.4
% VM	77.5	73.0
% VM (daf.)	83.4	78.6
% FC	15.3	19.9
% Ash	1.7	2.7
CV (MJ/Kg)	19.9	19.5
CV (MJ/Kg) daf.	21.4	21.0
Stoich. A/F (g/g)	6.1	6.3
Actual stoich. conc. (g/m ³)	211.2	205
Bulk density (kg/m ³)	629.0	436.7
True/particle density (kg/m ³)	1678	1751.5

Download English Version:

<https://daneshyari.com/en/article/6475528>

Download Persian Version:

<https://daneshyari.com/article/6475528>

[Daneshyari.com](https://daneshyari.com)