Journal of Loss Prevention in the Process Industries 26 (2013) 1328–1334

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

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

Triboelectric charging behavior of wood particles during pellet handling processes

Lifeng Zhang [a,b], Jiangtian Hou [a], Xiaotao Bi [a,*]

[a] Clean Energy Research Center, Department of Chemical and Biological Engineering, University of British Columbia, Vancouver, Canada
[b] Department of Chemical and Biological Engineering, University of Saskatchewan, Saskatoon, Canada

ARTICLE INFO

Article history:
Received 17 May 2013
Received in revised form
6 August 2013
Accepted 7 August 2013

Keywords:
Biomass
Dust explosion
Electrostatic charge
Triboelectrification
Powder handling
Wood particles

ABSTRACT

Electrostatic charges accumulated on wood particles through triboelectrification during their transportation and handling processes can cause hazardous electrical discharge which may further trigger dust explosion. In this work, tribo-charging behavior of different kinds of wood particles was investigated by a vibrating plate charging method. It was found that reduction in the work function difference between contact bodies might contribute to the reduction of tribo-charge generation, while the reduction of electrical resistivity of wood pellets could effectively accelerate the charge dissipation. As the particle size decreases, accumulated charges increase significantly. In contrast, higher moisture content of wood particles leads to lower charge accumulation due to an accelerated charge dissipation rate. Tribo-charging behaviors of white pellets, torrefied pellet, steam treated pellets and dark pellets have also been investigated. Compared to the white pellets, they all have shown a reduction on charge accumulation to some extent. However, results suggested that all of them have nearly equivalent tribo-charge density as coal and wheat grains used as references in this study.

1. Introduction

Climate changes associated with the release of greenhouse gases to atmosphere from the combustion of fossil-fuels have called for the development of renewable, environment friendly and sustainable energy sources. As an abundant and renewable energy source, wood and agricultural residues are considered to be of great potential for replacing the solids fossil fuels.

Wood pellets are made from densification of bulky biomass residues. The densification process reduces the volume of raw biomass to provide a significantly higher energy density per unit volume, thus improving the efficiency of transportation, handling, and storage. Wood pellets have been widely used to substitute thermal coal in large power plants and district heating systems, as well as for home heating, especially in Europe. Canada's endowed forest resources make it becoming a major exporter of high quality wood products to U.S. and wood pellets to European countries. Given that wood pellet mills are located inland, pellets are usually transported by trains between pellet mills and seaports. After a period of storage, they are then loaded into the large ocean vessels in volumes of 7000–20,000 metric tonnes, shipped to destinations in great distance. During the entire supply chain, numerous handlings are involved within which the risk of dust explosion has become a safety issue in the past 10 years. Several incidents during wood pellets handling in various plants were reported[1], which were speculated to be related with electrostatic-induced dust explosion or self-heating caused spontaneous combustion. In the powder-handling operation, electrostatic charges are always present such as in transporting coal (Nifuku, Ishikawa, & Sasaki, 1989), malt grain (Nifuku & Enomoto, 2001), wood dust (Calle, Klaba, Thomas, Perrin, & Dufaud, 2005), and other powders handling

* Corresponding author. Tel.: +1604 822 4408; Fax: +1 604 8226003.
E-mail address: xbi@chbe.ubc.ca (X. Bi).

0950-4230/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jlp.2013.08.004

[1] On December 1st 2008, an explosion occurred at Atikokan power generation station (one of Ontario Power Generation's major coal-fired power station) while staffs were preparing for an all wood pellet test burn. Nobody was injured in this accident but the factory was seriously damaged (Source: http://www.opg.com/news/releases/Atikokan.pdf). In August 2009, another massive dust explosion occurred at a wood pellet production facility near Farmington, Maine, U.S. The pellet mill is owned by Geneva Wood Fuels LLC. A huge fireball was noticed by workers and the sound of explosion could be heard from about 10 miles away. No human injuries but the factory were damaged with an estimated loss of $8 million (Source: http://www.dailybulldog.com/db/features/pellet-mill-damaged-in-massive-explosion/). In December 2010, a dust explosion blew out a sheet metal wall at the Pacific BioEnergy plant in Prince George, BC. Canada, injuring no one but temporarily knocking production of wood pellets out of commission (Source: http://news.nationalpost.com/2012/04/28/fatal-sawdust-blast-in-b-c-comes-after-five-explsions-at-similar-plants-since-2009/).

industries (Amyotte & Eckhoff, 2010; Mehrani, Bi, & Grace, 2005), and there is always a danger for discharging ignited dust explosion, although there remains much to be investigated on the ignition mechanism (Nifuku & Katoh, 2001). Wood pellets tend to break up during their loading/unloading, pneumatic conveying and storage in deep silos, generating very fine wood dust. At the same time, pellets and fine dust particles can be charged by contacting each other and with the wall surfaces of handling equipment. When the charge level builds up to a certain level, dust explosion can be triggered by sparks or other ignition sources because of the low minimum ignition energy level of wood particles (Melin, 2012). In the current supply chain, pellets may be loaded, unloaded and conveyed several times before being fed into the combustor, generating electrostatically charged dust and creating safety concerns. Melin (2012) reported that the minimum ignition energy of wood particles was lower than that for coal particles. However, to the best of our knowledge, charging behaviors of wood pellets and dusts generated during handling and storage have not been reported in the literature. Therefore, the objective of the present study is to investigate charging behavior of different types of wood pellets and wood dusts in order to understand the dust explosion potential of pellets during their handling and transportation by comparing with two widely transported materials: coal and grain particles.

2. Experimental section

2.1. Test samples

Several types of wood pellets and two reference particles were used in this study. White pellets (WP, made from fibers) were obtained from Premium Pellet Ltd. Torrefied pellets (TP), steam treated pellets (STP), and dark pellets (DP made from wood barks) were obtained from the UBC Biomass and Bioenergy Research Group. The coal sample was obtained from the Mining Engineering Department of UBC, and the wheat grain samples (large flake oats, Rogers, Canada) were purchased from a local supermarket.

White pellets (WP) are the regular wood pellets produced in BC in large quantity, with a moisture content of about 6%. They are produced from nearly pure sawdust, shelving and wood chips, mostly pine with small portions of spruce and fir. Due to the low bark content in the raw material, it is a high quality pellet with very low ash content (<0.5%) and high ash melting temperature (>1300 °C).

Torrefied wood pellets (TWP) are also called the 2nd generation wood pellets made from torrefied (or mildly pyrolyzed) wood. Torrefaction can improve biomass quality such as energy density and hydrophobicity, which offers potential solutions to low energy content and low shelf life of regular pellets. Torrfied pellets samples were provided from the UBC Biomass and Bioenergy Research Group, prepared at a torrefaction temperature of 280 °C.

Steam explosion pretreatment is a chemical modification of the lignocellulosic material to improve its durability in terms of mechanical strength and hydrophobicity (Startsev & Salin, 2000). Steam exploded sawdust particles used in this work were treated at 220 °C with saturated steam at 250 psig over 10 min.

Dark pellets (DP) are made from woody materials that contain majority of wood bark. Because of the high mineral content in the bark, dark pellets used in this project have an average ash content of 3.5% by weight.

Coal and wheat grains were chosen as the references for comparison since they are widely transported and handled commodities and well-studied on their dust generation and explosion potentials. The charging behavior of these two reference particles enables us to compare the tribo-charging behavior of wood pellets so as to assess the potential for dust explosion.

Table 1
Prepared white pellet samples with different size distributions.

Groups	Particle sizes μm
A	500–595
B	425–500
C	355–425
D	212–355
E	106–212

2.2. Samples preparation

Selected wood pellets were crushed into different sizes, which were then hand sieved into different size ranges, by using US standard brass sieves (Dual MFG Co., USA). As shown in Table 1, white pellets were separated into test samples of different size ranges, while other test samples were prepared in one size range of 212–355 μm only. Prepared samples were stored in sealed plastic containers to keep their moisture contents stable.

The particle densities of test samples were determined from three discrete measurements on each test sample by an analytical balance (Sargent Welch, Model SWW400D, Buffalo, NY), and a multipycnometer (Quantachrome, Model MVP-6DC, Boynton Beach, FL).

The moisture contents of samples were determined by oven drying at 103 °C over 24 h using a Thermo Precision Oven (Thermo-Scientific, USA). All moisture contents reported in this work were on a dry basis.

Basic physical properties of test samples are provided in Table 2. Moisture contents of tested materials are also listed in this table except those samples prepared to examine the effect of moisture content.

2.3. Apparatus & procedure

The experimental apparatus is illustrated in Fig. 1.

As shown in Fig. 1, a vibratory feeder with a stainless steel tray (Eriez 15A, Eriez, USA) was utilized as the tribo-charger. Rubber discs on the inside of the vibratory attachment separate the tray from the vibratory base, at their point of contact, to minimize electrical discharges of the vibratory tray through the base. A Faraday cup, which consists of two brass cups isolated from each other by a Teflon spacer, was used. The inner cup is connected to an electrometer (Keithley Model 6514, Cleveland, OH), and the outer cup is grounded. In this work, each test was successively repeated by eight times and the average charge of each tested sample was obtained by averaging the eight repeated runs with the spreading indicated by the standard deviation.

Table 2
Physical properties of tested samples.

	Particle density (Kg/m^3)	Moisture content (%wt on dry basis)
White pellet (WP)	1426	6.32
Torrefied pellet (TP)	1420	3.02
Steam treated pellet (STP)	1428	3.78
Dark pellet	1414	7.93
Coal	2336	1.47
Wheat grain (WG)	1409	9.58