



## Research paper

## Hydrophobic coatings for moisture stable wood pellets

J.M. Craven<sup>a</sup>, J. Swithenbank<sup>a</sup>, V.N. Sharifi<sup>a,\*</sup>, D. Peralta-Solorio<sup>b</sup>, G. Kelsall<sup>c</sup>, P. Sage<sup>c</sup><sup>a</sup> Energy and Environmental Engineering Research Group (EEERG), Department of Chemical and Biological Engineering, University of Sheffield, Mappin Street, Sheffield S1 3JD, UK<sup>b</sup> E.ON New Build and Technology Limited, Technology Centre, Ratcliffe-on-Soar, Nottingham NG11 0EE, UK<sup>c</sup> BF2RA, Gardner-Brown Limited, Calderwood House, 7 Montpellier Parade, Cheltenham GL50 1UA, UK

## ARTICLE INFO

## Article history:

Received 27 January 2014

Received in revised form

9 February 2015

Accepted 9 June 2015

Available online 19 June 2015

## Keywords:

Wood pellets

Hydrophobic coatings

Water resistant

Biomass treatment

## ABSTRACT

One of the key factors affecting the economic viability and safe deployment of wood pellet fired systems on a large scale is wood pellet stability. Wood pellets are extremely moisture unstable and present significant problems during the transportation, storage and handling stages of their lifetime. This study proposes an approach for creating moisture stable wood pellets through the addition of hydrophobic coatings. Pellets were treated with paraffin oil, castor oil, mineral oil and linseed oil and submerged in water for up to 1800 s. The strength of untreated pellets was found to decrease by around 94% after being submerged for 60 s, whereas no appreciable reduction in pellet strength was recorded after 1800 s in all of the oil treated cases. Treatment with oil was also found to reduce the formation of airborne fines and increase the energy density of wood pellets, increasing their HHV by up to 1.2 MJ kg<sup>-1</sup>.

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Introduction

The world wood pellet market has grown significantly in recent years and presents an exciting new prospect for the solid fuels market. Global production in 2012 was as high as 22.4 million tonnes, a level constituting an increase of more than 55% compared to production levels recorded in 2010, and pellet production capacity rose to a high of approximately 29.3 million tonnes per annum [1–4]. The European Union (EU) is currently the world wood pellet market leader and produces approximately 50% of the world's wood pellets, while it consumes around 67% of worldwide demand [1,2,4,5]. However, significant growth can be observed elsewhere across the globe. Increases in production capacity in the United States (US), Russia and Canada were recorded to be greater than any other competing European country between 2009 and 2010, and currently the US has the greatest production capacity worldwide [1]. Wood pellets are currently one of the largest internationally traded solid biomass fuels, and as capacity and production increases across the globe, international trading is set to increase even further [6].

However, where international shipments are necessitated,

logistical challenges are encountered. Although wood pellets present advantages over competing solid biomass fuels in terms of their moisture content and energy density, the handling of wood pellets requires care due to their low mechanical stability [6]. Wood pellets are well known for being moisture unstable and present significant problems during the transportation, storage and handling stages of their lifetime [8]. Due to their high hygroscopicity, wood pellets readily disintegrate when wetted. This disintegration and loss of mechanical stability is typically accompanied by a large increase in volume and can cause significant structural damage to transportation and storage devices [9]. Moisture uptake can also lead to increased rates of biological activity, rotting of the material and self-heating. Such processes act to decrease the heating value of the fuel and prompt the generation of combustible gases which pose a significant hazard when contained [9].

In addition to problems relating to hygroscopicity, wood pellets present a significant problem when they are in their dry state. Mechanical instability leads to the generation of fines during handling, and when combined with insufficiently ventilated areas, hot surfaces and/or electrical equipment, hazardous conditions prevail [9].

Previous work has explored the use of additives such as ligno-sulphonate, dolomite, starch, corn flour, potato flour and kraft lignin as binding agents to improve the characteristics of wood pellets [10–12]. However, such additives do not act to markedly improve the moisture stability of wood pellets. The aim of this

\* Corresponding author.

E-mail addresses: [james.craven@sheffield.ac.uk](mailto:james.craven@sheffield.ac.uk) (J.M. Craven), [v.n.sharifi@sheffield.ac.uk](mailto:v.n.sharifi@sheffield.ac.uk) (V.N. Sharifi).

study is to develop a treatment method to increase the hydrophobicity of wood pellets and in turn increase their overall mechanical stability through reducing their hygroscopicity. Pellets will be encapsulated using a range of oils and the effect such oils have on the hydrophobicity, grinding behaviour, heating value and combustion properties of wood pellets will be analysed.

## 2. Materials and methods

### 2.1. Materials

The wood pellets used in this study were procured from CPL Distribution Ltd and are certified according to ENplus A1. Pellets are 6 mm in diameter and are made from chemically untreated residues from the wood processing industry. An overview of the main parameters relating to the pellets used in this study is shown in Table 1.

In this study, the primary method of pellet encapsulation was treatment with oil. The oils used in this study were paraffin oil, castor oil, mineral oil and linseed oil, all of which were procured from Sigma–Aldrich UK Ltd. Table 2 provides an overview of each of the oils in terms of their density, viscosity and higher heating value (HHV).

### 2.2. Methods

#### 2.2.1. Pellet coating

Each oil was applied via two methods. When assessing individual pellet strength and the mass uptake of oil on a single pellet basis, single pellets were submerged in 100 cm<sup>3</sup> of oil at room temperature for up to 10 s to ensure saturation. Pellets were submerged in each of the oil samples at time intervals of 1 s, 2 s, 3 s, 5 s and 10 s in order to gauge the effect of time on oil absorption.

Pellets were then air dried for 24 h on a coarse mesh to allow excess oil to be removed via gravity. A total of ten samples were tested for each time increment and each oil treatment, and subsequent testing with the pellets was carried out immediately after the drying stage.

Treatment on a bulk basis for use in the milling tests was carried out in 0.14 kg batches. 5 cm<sup>3</sup> of oil was syringed into a volumetric beaker, the batch of wood pellets was then placed on top of the oil and then a further 5 cm<sup>3</sup> of oil was added on top of the pellets. Pellets were stirred for 300 s until evenly coated and air dried for

**Table 1**  
Overview of the main parameters relating to the wood pellets used in this study.

Parameter	Value	Unit	Relevant standard
Diameter	6	mm	–
Length	3.15 ≤ L ≤ 40	mm	–
Bulk density	651	Kg m <sup>-3</sup>	EN 15103
Net calorific value	18.4	MJ kg <sup>-1</sup>	EN 14918
Moisture content	≤10	wt%	EN 14774-1
Fines (<3.15 mm)	≤1	wt%	EN 15149-2
Mechanical durability	≥97.5	wt%	EN 15210-1
Ash content	≤0.7	wt%	EN 14775
Ash melting temperature	≥1473	K	EN 15370-1
Chlorine content	≤0.02	wt%	EN 15289
Sulphur content	≤0.03	wt%	EN 15289
Nitrogen content	≤0.3	wt%	EN 15104
Copper content	≤10	mg kg <sup>-1</sup>	EN 15297
Chromium content	≤1	mg kg <sup>-1</sup>	EN 15297
Arsenic content	≤0.5	mg kg <sup>-1</sup>	EN 15297
Cadmium content	≤0.1	mg kg <sup>-1</sup>	EN 15297
Mercury content	≤10	mg kg <sup>-1</sup>	EN 15297
Lead content	≤10	mg kg <sup>-1</sup>	EN 15297
Nickel content	≤100	mg kg <sup>-1</sup>	EN 15297

**Table 2**  
Density, viscosity and HHV of oils used for wood pellet treatment.

Oil	Density (kg m <sup>-3</sup> )	Viscosity, 25 °C (Pa s)	HHV (MJ kg <sup>-1</sup> )
Paraffin	870	0.12	44.7
Castor	965	0.91	35.9
Mineral	868	0.04	44.6
Linseed	957	0.03	37.7

24 h on 5 sheets of Kimberly–Clark industrial 2-ply cleaning towel to ensure any excess oil present on the pellets surface was absorbed and removed. A total of ten samples were prepared for each oil treatment.

Pellets treated on a bulk basis were used in conjunction with tests carried out to assess the milling properties of oil treated pellets and their respective HHV.

#### 2.2.2. Three point flexural testing

Three point flexural tests were used in lieu of the pellet test stated in BS EN 15210-1 which states the methods and apparatus required for the determination of mechanical durability of pellets. Three point flexural tests were used due to comparable results between untreated and oil treated pellets being unable to be generated using the apparatus stated in BS EN 15210-1. While comparable results between untreated and oil treated pellets are able to be determined when in their dry state, the equipment stated in BS EN 15210-1 is insufficient for untreated pellets after being submerged in water.

To provide comparable results between untreated and oil treated pellets, pellets were therefore subject to three point flexural tests in order to determine pellet strength. Pellet strength was assessed using a Zwick Roell Z050 tensile tester. Pellets sized between 26 mm and 28 mm were seated horizontally on a span measuring 20 mm. A 5000 N load cell was fitted to the tensile tester and a load was applied with an advancing speed of 8.3 μm s<sup>-1</sup>. A force was exerted and recorded at the midspan of the pellet until failure was recorded. Treated pellets were tested after being submerged for 180 s, 600 s, 1200 s and 1800 s, and untreated pellets were tested after being submerged for 30 s, 60 s and 180 s. A total of ten samples were prepared for each time increment and for each oil treatment.

#### 2.2.3. Milling and particle size analysis

Pellets were both milled as received and after treatment with oil. A Retsch PM100 planetary ball mill fitted with a 500 cm<sup>3</sup> stainless steel bowl and eight 30 mm diameter stainless steel balls was used for all of the milling tests. A rotational speed of 3.33 Hz (200 rpm) was maintained constant throughout, and the length of milling time was varied up to a maximum of 1800 s.

Initial work was carried out with untreated pellets in 0.05 kg batches, milling at time intervals of 60 s, 180 s, 300 s, 420 s and 600 s. However, such a mass per batch was found to be too low for work with pellets treated with oil. Milling was not found to take place with such a mass per batch, with the balls rotating freely and in turn not interacting with the material. Increasing the mass per batch of the oil treated pellets was found to have a favourable effect on the milling behaviour. Consequently, pellets treated with oil were milled in 0.145–0.15 kg batches at time intervals of 300 s, 600 s, 900 s, 1200 s and 1800 s. In all of the cases incorporating the treated pellets, the mass per batch corresponds to a starting mass of 0.14 kg of untreated pellets plus the additional mass of the oil used for treatment. Milling of the untreated pellets was examined with a mass per batch equal to that used for the treated pellets (0.14 kg); however, pellets were found to mill insufficiently compared to smaller batches.

Download English Version:

<https://daneshyari.com/en/article/7063867>

Download Persian Version:

<https://daneshyari.com/article/7063867>

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