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Mathematical modelling of sawdust drying process for biomass pelleting

Paraschiv Lizica Simona[a], Paraschiv Spiru[a]*, Ion V. Ion[a]

[a]"Dunarea de Jos" University of Galati, Thermal Systems and Environmental Engineering Department, 47 Domneasca St., 800008, Galati, Romania

Abstract

The overall objective of this research is to conduct an analysis of biomass drying process. This paper investigates the effect of various drier inlet parameters such as sawdust moisture content, particle diameter and drying gas temperature on moisture content of dry sawdust and hot flue gases and their temperature profiles along the length of the dryer. Our simulations show that the overall drying rate increases when using sawdust with a more uniform particle size.

Keywords: biomass drying; pellet; sawdust; rotary dryer; biomass moisture;

1. Introduction

Wood pellets are a form of biomass fuel that is commonly used to produce heat, electricity or combined energy in micro-combined cooling, heating and power systems (mCCHP). Pelletizing has been widely used for mass and energy densification of biomass.

The use of biomass for energy production is becoming more popular because biomass is generally considered as a CO_2 neutral fuel. Wood is a major source of biomass energy and wood biofuels are particularly important in countries with high forest resources, but the main difference between biofuels and conventional fossil fuels is that they have higher and more varied moisture content [7, 8].

Wood biomass in its fresh form has a high moisture content of over 50%. Normally, in order to be burned, biomass has to be initially dried to optimize handling and storage, as well as to increase the energy efficiency of the conversion process and reduce pollutant emissions. The most used system for pre-treatment of biomass particles is the rotary dryer [9, 10].

Residues resulting from woodworking have minimal economic value and, in many cases, are processed to be used as a source of biomass energy. This is done by first grinding the material to achieve a more uniform particle size followed by drying the material. After drying, the material is introduced into a mold to produce pellets and forced to pass through it, forming compact cylinders. Under high pressure and temperatures, lignin naturally present in wood

* Corresponding author. Tel.: +4-072-132-0403.
E-mail address: sparaschiv@ugal.ro

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acts as a binder to help the particles to adhere each other. The newly formed cylinders are usually up to 6 mm in diameter and 12 mm long, have uniform moisture content, ready for use as fuel pellets.

Pellets have low moisture content about 7-8% and a high bulk density for an efficient transport. Wood pellets can be easily handled, transported and fed into boilers and ovens. Their manufacture involves intense drying, milling and granulation processes. The rotary dryer being analyzed has a triple pass and uses the hot combustion gases supplied by a burner for a direct drying process.

The moisture content of raw biomass is usually 30-60%. While the main purpose of wood drying is to reduce the moisture content to maximize the energy potential of the product, drying also offers other advantages such as improved combustion efficiency and control as well as boiler efficiency and low pollutant emissions. However, drying is an energy-intensive process.

2. Modeling of biomass drying process

Moisture content of biomass is very high, although it varies depending on several factors, such as tree species and the period of the year. The final moisture content of pellets from biomass is 7-8% and the biomass drying process improves the wood burning process and significantly reduces the final product volume, while maintaining the energy potential. As such, the drying process plays an essential role in producing an optimal fuel.

There are several different types of dryers that are available, but rotary dryers are most commonly used for drying biomass and have low maintenance costs [11]. They have a robust and simple construction, with high flexibility and reliability, which allows this type of dryer to operate under the most severe conditions and can handle a wide range of materials [1, 5].

Rotary dryers have proven to be the most cost-effective method for removing high volumes of water from biomass [3]. Although biomass has been ground, there are some variations in particle size distribution. Rotary dryers naturally allow variable residence times based on this variation size, resulting in a uniform moisture content of the material leaving the dryer, an ideal feature for a fuel. When the size of the sawdust grows, the drying time will increase, resulting in a significant increase in the size of the dryer and the cost of energy required for this process.

Table 1 presents the average elemental composition of the sawdust used into simulation.

Table 1. The average elemental composition of the sawdust.

Species	UM	Wet sawdust	Dry sawdust
Carbon, C	%	29,64	48,51
Hydrogen, H	%	3,5	5,73
Sulfur, S	%	0,0	0,0
Oxygen, O	%	19,9	32,56
Nitrogen, N	%	1,1	1,8
Moisture, W	%	45	10
Ash, A	%	0,86	1,4
Lower heating value	kJ/kg	-	16733

The process of rotary dryer is based on direct contact between the material to be dried and the drying gas. As the drum rotates, the flights raise and overturn the material through the drying gas to maximize the efficiency of the heat transfer process [2, 4, 6]. The rotary dryer analyzed is 3 m in diameter and 9 m in length. The rotary dryer has a slight horizontal slope to help gravitationally move the material through the drum. The speed of drying gases moving through the rotating drum, combined with this slope, naturally helps smaller particles move more quickly through the drum. This is ideal because it prevents over-drying of smaller and finer particles, while further drying of larger particles is carried out. When the sawdust reaches the discharge end of the drum, it is pneumatically discharged and separated from the drying gas in a cyclone.

The mass balances are written in terms of moisture content for the sawdust and hot flue gases rates.

The moisture content of sawdust on a wet basis are given by:

$$x_w = \frac{M_{ws} - M_{ds}}{M_{ws}} \tag{1}$$

$$g_w = \frac{M_{wg} - M_g}{M_{wg}} \tag{2}$$