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Characteristics of biomass in flameless combustion: A review

A.A.A. Abuelnuor [a,*], M.A. Wahid [a], Seyed Ehsan Hosseini [a], A. Saat [a], Khalid M. Saqr [b], Hani H. Sait [c], M. Osman [d]

[a] High-Speed Reacting Flow Laboratory, Faculty of Mechanical Engineering Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia
[b] Department of Mechanical Engineering, College of Engineering and Technology, Arab Academy for Science, Technology and Maritime Transport, P.O Box 1029, Abu Qir, Alexandria, Egypt
[c] Department of Mechanical Engineering, King Abdulaziz University-Rabigh, Saudi Arabia
[d] Sudan University of Science and Technology, Sudan

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ABSTRACT

The demands of energy and pollutant emissions reduction have motivated the combustion researchers to work on combustion improvement. Flameless combustion or high temperature air combustion has many features such as flame stability, low pollutant emission and uniform profiles of temperature compared to the other modes of combustion. Combustion of solid fuels likes biomass and wastes in flameless combustion conditions has not been investigated as comprehensive as combustion of gaseous fuels. The aim of using biomass in combustion is to reduce the pollutant emissions and to decrease the rate of fossil fuel consumption. In this review, combustion characteristics of biomass in flameless combustion are explained. The paper summarizes the research on the mass loss, ignition time, and NO_x emissions during biomass flameless combustion. These summaries show that biomass under flameless combustion gives low pollutant emissions, low mass loss and it decreases the ignition time.

Contents

1. Introduction

Energy supply is the basic request of humankind, for cooking, heating, manufacturing, electricity generation and transportation. Most of the energy demand of the world relies on the energy generation by combustion [1]. Improvement in the energy efficiency during the past few decades resulted in a reduction of the amount of energy required to generate a unit of gross domestic product (GDP) and hence, the rate of increase in global energy consumption has dropped significantly. Due to economic growth and population augmentation, the projection of global energy demands is about 80% of the world energy needs, and increases by 57% between the year 2004 and 2030. In 2030, fossil fuel combustion will fulfill about 80% of world energy needs. Fig. 1 illustrates the global energy consumption during the period 1980–2030 [2].

* Corresponding author. Tel.: +60 177353802.
E-mail address: abuelnuor99@yahoo.com (A.A.A. Abuelnuor).

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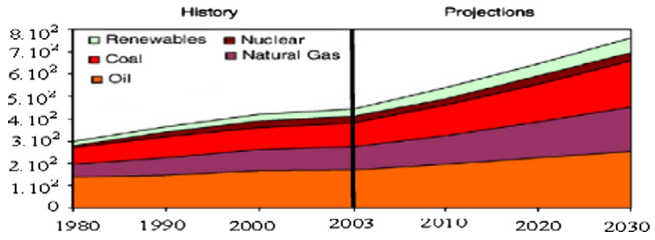

Fig. 1. Global energy consumption during the period 1980–2030 [2].

The term biomass stands for the waste from animal manure and/or for material derived from plants (i.e. wood, charcoal, or agriculture waste) and algae. The solar energy absorbed by plants, is used to the photosynthesis process which enables them to grow. This energy is called biomass energy, and it is stored in the plants and animals, or in the wastes. This energy could be recovered by using biomass as a fuel for combustion processes. Biomass energy could help to reduce the dependency on conventional fossil fuel products [3]. By some chemical, physical, and biological conversion processes, biomass could be transformed into liquid, gaseous, and solid forms, which can be easily burnt in combustion systems for power and thermal energy generation. Today, biomass contributes about 14% of the world total energy consumption, which is ranked as the fourth source of energy in the globe [4]. Biomass is the main source of energy for many developing countries. This is as high as 20% to 33%, but for the industrialized countries, biomass contributes about 9% to 14% of the total energy supplies. For some of the developing countries, biomass consumption reaches even over 50% to 90% of the total energy demand. In the poorer part of the inhabitants in developing countries, a large part of this biomass is used for cooking and heating and not for commercial purposes. Modern production of energy from biomass is applied for applications such as electricity generation, fuels for transportation and heat production for heavy industry in the industrialized countries. The energy demand from the biomass has strongly increased over the last decades in the developed countries such as the European Union [5]. The targeted ambitions of the European Union concerning the biomass usage are as high as 6000 PJ in the year 2010 (tripling the usage compared to the year 1999 levels), and possibly even more beyond the targets [6–8]. Today, pollutant emissions reduction from combustion process and saving energy are two common challenges for the researchers and industry [9,10]. The combustion researchers were exploring an alternative fuel and new regimes of combustion. Biomass is one of the alternative fuels in which its energy can be released in the combustion process. The term biomass stands for the waste from animal manure or for material derived from growing plants and all the organic materials derived from crops, trees, algae and plants [11]. The solar energy absorbed by plants, is used to the photosynthesis process which enables them to grow [12]. This energy is called biomass energy which is stored in the plants and animals, or in the wastes that they produce. This energy could be recovered by burning this biomass materials and use it as a fuel [13,64]. Biomass energy is considered to be one of the important parts of today's energy sources. This biomass energy could help the human to reduce their dependency on petroleum products, natural gas and coal. By some chemical, physical, and biological conversion processes the biomass could be transformed into liquid, gaseous, and solid fuels [14,15]. The transformation of biomass materials has a precise objective: to convert the carbonaceous solid material which is originally difficult to handle for bulky, and which is of low energy concentration, into the liquid fuels having physico-chemical characteristics that permit easy and economic storage and transferability through pumping systems [16]. The use of biomass products offers significant benefits as far as the environment issue is concerned. Biomass material absorbs carbon dioxide during growth and releases it during combustion. Therefore, biomass energy helps recycling the atmospheric carbon dioxide and does not contribute a net greenhouse effect. The biomass energy is mainly produced from wood and its wastes (64%), followed by municipal solid waste (24%), agricultural waste (5%), and landfill gases (5%) [13]. The process of producing biomass fuel is economically with negligible or even positive environmental effects through perennial crops. One of the oldest conversion methods to transform biomass into energy is the combustion due to its versatile character. In sequence to carry on to the latest conversion techniques, the combustion technology acquires constant improvements. The main advantages of this technology are already known in flameless combustion [17]. This technology has many names for examples high temperature air combustion (HTAC) [18], moderate or intense low oxygen dilution (MILD) combustion [19], Flameless Oxidation (FLOX) [20] and Colorless combustion [21]. In this paper, we referred to this technology by flameless combustion. The flameless combustion burner provides the following advantages; it reduces fuel consumption, reduces pollutant emission such as NO_x emission, stable and efficient combustion, enhanced heat transfer and low combustion noise [22–24]. Several studies have been conducted in the area of gaseous fuel combustion using flameless combustion facilities, but little attention was given on the behavior of solid biomass combustion in flameless condition. This paper will summarize the biomass behavior in the flameless combustion.

2. Biomass combustion

The process of the combustion is an overall exothermic set of reactions. The energy stored in the chemical bonds of a fuel is converted to heat energy and it can be used in different places such as heavy industry and a power plant to generate required steam for turbines that finally produce electricity and heat. In the case of the alternative fuel such as biomass, the combustion means burning of organic materials. In biomass combustion, wood is the most widely used fuel for burning. On the other hand, there is an increasing interest in other biomass types such as bark, tops and branches, straw, sawdust, waste wood or demolition wood, and energy crops (such as poplar and willow) [25–28]. The biomass combustion is a sequence of chemical reactions in which carbon is oxidized into carbon dioxide, and hydrogen is oxidized into the water. Incomplete combustion leads to formation of many unwanted products due to lack of oxygen [29]. The combustion air requirement depends on the physical and chemical characteristics of the fuel and the excess air is used to cool the systems. The excess air ratio is one of the main combustion parameters for high combustion efficiency. In most applications, the excess air ratio is far higher than the stoichiometric amount and the locally available combustion air. Biomass combustion depends on the following factors: the mass flow rate of fuel, the mass flow rate of combustion air for the complete combustion, the combustion products and the flame temperature. Due to high temperature, most reactions of the combustion are vapor phase reactions. During the normal combustion process, the flame burns efficiently when the oxygen is just enough to burn the existing fuel. Combustion could be maintained only if enough heat is present to raise the temperatures of unburned gases to necessary levels [30]. Generally, biomass combustion properties can be classified as microscopic and macroscopic. The microscopic examinations include thermal, chemical, kinetics, and mineral data. However, the macroscopic properties of biomass fuels are heating value, ultimate analysis,