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A novel conical combustor for thermal exploitation of vineyard pruning wastes

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HIGHLIGHTS

- ▶ Beds consisting on vine shoots are stable in a conical spouted bed combustor.
- ▶ Conical spouted beds are suitable to thermal exploitation of vineyard wastes.
- ▶ Previous drying of vine shoots improves combustion process.

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ABSTRACT

In order to determine the behavior of a new conical spouted bed combustor for the thermal exploitation of wastes of pruning of vineyards by combustion, a hydrodynamic study has been carried out with homogenous beds wastes of pruning of vineyards, the evolution of the different regimes and the stable operation conditions have been determined. Beds consisting of vine shoots have been dried for improving combustion. The success of the combustion of wastes of vineyards pruning in a conical spouted bed combustor has been proven based on combustion efficiency values.

1. Introduction

Biomass is the organic matter in trees, agricultural crops and other living plant material. The use of biomass for energy causes no net increase in carbon dioxide emissions to the atmosphere. That is, the use of biomass for energy does not increase carbon dioxide emissions and does not contribute to the risk of global climate change. In addition, using biomass to produce bioenergy is often a way to dispose of waste materials that otherwise would create environmental risks.

Vine is the main crop of the field cultivated by sweet fruit and vineyard in Spain, with 64.08% of the total area. In 2007 in Spain there was 1,169,000 ha of vineyards with a production of 5,420,700 ton of wastes [1]. In particular, the net amount of vineyard pruning wastes has been recently estimated in about one oven-dry tonne per hectare [2]. The vine shoots from the pruning of vine have low-average moisture content and a high cellulose and lignin content. Most of these wastes are burnt in the own exploitation after being retired from the land and in much smaller proportion are used as fuel in barbecues. In Spain, the application of these materials to the ground, previous fragmentation and crushed, as an organic wadding of slow decomposition or to superficial incorporation in the ground by means of the suitable farm work as alternative form it is being slowly implanted.

This new technology based in the spouted bed gas–solid contact in conical beds reduces power consumption, minimizes powder generation, and allows to avoid previous milling of agricultural wastes. Furthermore, with regard to construction and operation, this system is an easier and more economical alternative to other choices used for thermal valorization of wastes (such as moving bed dryers, rotary kilns, grate furnaces or fluidized bed combustors). Spouted beds have been used for thermal processing of wastes, both for combustion [3–14], for drying [15–23], for gasification [24–28] and for pyrolysis [29–41], but most of systems studied correspond to cylindrical units with a conical base.

In previous papers, the operativity of spouted bed technology has been proven for the treatment of coarse and sticky particles [42,43]; with a great particle distribution with low segregation [44] obtaining good results for biomass treatment [11,45], cork wastes [46] and sawdust and wood wastes [47]. In this work, a conical spouted bed reactor has been tuned up for the combustion of vine shoots wastes from Castile lands.

In this paper, a new conical spouted bed combustor for thermal exploitation of wastes of pruning of vineyards by combustion has

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Nomenclature

Ar Archimedes number, $gd_p^3\rho(\rho-\rho_s)/\mu^2$
D_b, D_c, D_i, D_o diameter of the top diameter of the stagnant bed, of the column, of the dryer bottom, and of the bed inlet, respectively, m
d_p particle diameter, m
$\overline{d_S}$ mean Sauter diameter, m
H_c, H_{cone}, H_o height of the cylindrical section of the combustor, of the conical section and of the stagnant bed, respectively, m
Q, Q_{air} feed flow of vine shoot and of air, m s^{-1}
$(\mathrm{Re_o})_{ms}$, $(\mathrm{Re_o})_{mj}$ Reynolds modulus correspondent to minimum spouting velocity and minimum dilute spouted bed (jet spouted bed) velocity, respectively
T temperature, °C
u, u_o gas velocity referred to D_i and to D_o, respectively, m s^{-1}
X moisture content (dry basis), wt.%
x_{steel}, x_{ins} thickness of the reactor wall and of the insulating, respectively, m

Greek Letters

γ angle of the conical combustor, deg
ρ_s, ρ_g density of solid and of the gas, respectively, kg/m^3
μ air viscosity, kg m^{-1} s^{-1}

been used with homogenous beds wastes of pruning of vineyards. The combustion of wastes of vineyards pruning in a combustor has been carried out in a conical spouted bed combustor in conditions to improve the environment, and the evolution of combustion gases has been analyzed. With this aim, the behavior has been analyzed by means of hydrodynamic and thermal studies in beds consisting of granular materials.

2. Experimental

The experimental unit design for this purpose on a pilot scale, Fig. 1, consists of two blowers connected in parallel that supply a maximum air flow rate of 500 Nm^3/h at a pressure of 15 kPa, two high efficiency cyclones in order to collect fine particles, a preheater to heat the gas at the inlet and thermocouples. The flow rate is measured by means of two mass flowmeters in the ranges of 50–300 and 0–100 m^3 h^{-1}, both being controlled by a computer. The accuracy of this control is ±0.5% of the measured flow rate [48].

The measurement of the bed pressure drop is sent to a differential pressure transducer (Siemens Teleperm), which quantifies these measurements within the 0–100% range [48]. This transducer sends the 4–20 mA signal to a data logger (Alhborn Almeno 2290-8), which is connected to a computer where the data are registered and processed by means of the software AMR-Control and their outputs are checked with U-type water manometer measurements. The software AMR-Control also registers and processes the air velocity data, which allows for the acquisition of continuous curves of pressure drop against air velocity.

The combustor, shown in Fig. 2, is made of AISI-310S heat-resistant stainless steel and is externally insulated. The optimal dimensions of the reactor are: cone angle, γ = 36°; of the bed base, D_i = 0.03 m; upper diameter of the cone, D_c = 0.14 m and height of the upper cylindrical section, H_c = 0.20 m and with different values of the contactor inlet diameter, D_o = 0.015, 0.02 and 0.03 m.

The temperatures of the air supplied by the blower before entering the contactor and at the exit are measured by two thermocouples located at the bed inlet and outlet. In addition, there are thermal conductivity detectors (Alhborn MT8636-HR6) for measuring air moisture content at both inlet and outlet. Temperature and air moisture contents are also stored in the Alhborn Almeno 2290-8 data logger, which allows monitoring of their evolution over time.

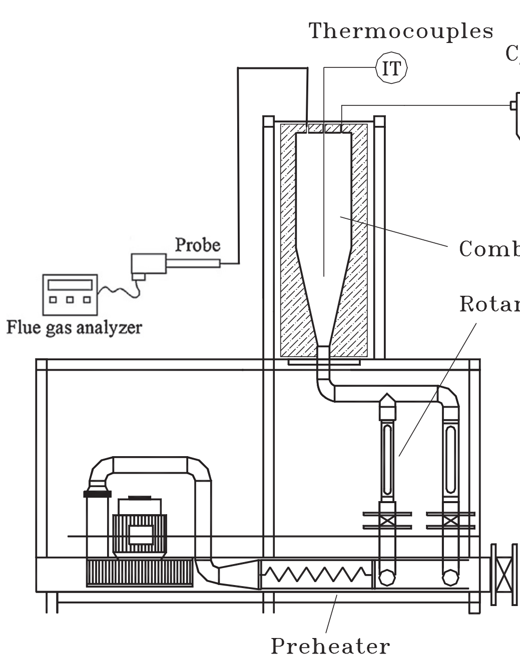

Fig. 1. Experimental equipment of pilot plant.

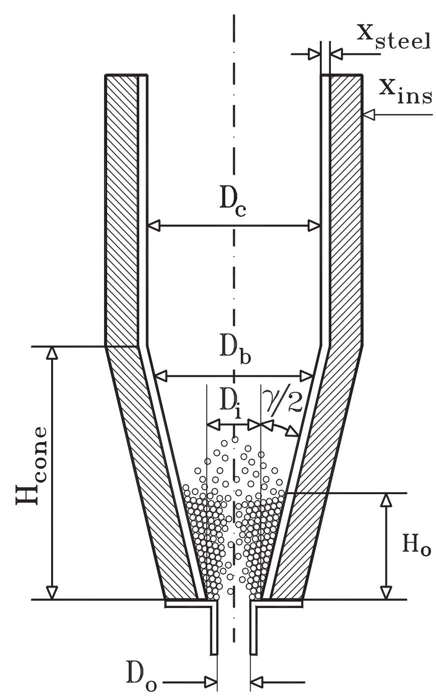

Fig. 2. Schematic diagram of the conical spouted bed combustor.