Safety Characteristics of Biomass Waste after Gasification Using the 20-L Dust Explosion Vessel

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Introduction

Biomass is a renewable energy source with great potential worldwide and in the European Union as described by Tzelepi et al. (2020). However, safety characterization is necessary to turn many types of waste biomass into a tradable commodity that has the potential to replace coal in power plants without significant modifications to firing systems. The 20-L dust explosion vessel was used, with a modified and calibrated dust dispersion system that could cope with very coarse particles. As described by Eckhoff (2021), the deflagration index, Kst, was higher for the biomass waste sample. The peak flame speeds were similar for both samples, reaching 1 m/s. The peak P_{max}/P_i was between 6 and 7 bar for both untreated and biomass. The mechanism for coarse particle combustion is considered to be influenced by the explosion-induced wind blowing the finer fractions ahead of the flame, which burns first, subsequently devolatilizing the coarser fractions.

Characterization of Feedstock and Product

Coarse wood particles (less than 3 mm) were the fuel used in this work. Biomass came from wood processing, originating from three different kinds of wood: Spruce (S), Pine (P), and Fir (F). These three wood species were mixed in roughly equal proportions during wood processing, and it was not possible to separate each species. The untreated sample is a typical example of residues from wood processing in the UK. Two samples were investigated: the raw coarse ground biomass, marked as Spruce-Pine-Fir Raw (SPFR), and the biomass, marked as Spruce-Pine-Fir (SPFT) across the manuscript. Their properties are summarized in Table 1 for their elemental composition and their volatile, fixed carbon, and ash content. Table 1 shows that gasification produced an increase of elemental carbon with a reduction in the % oxygen. This produced a 10% increase in the stoichiometric A/F. The calorific value on a dry basis was increased by 9%, as shown in Table 1.

Table 1. Proximate and ultimate analysis of the samples.

Biomass	%C	%H	%N	%O	%H_2O	%VM	%FC	%Ash	HHV (MJ/kg)	LHV (MJ/kg)	Stoich A/F (g/g)	Stoich. F/A (g/m^3)
	Dry Ash-Free (daf)				As Received (ar)				Dry	ar	daf	Actual
SPFR	50.4	6.9	1.2	41.4	7.8	73.4	16.2	2.6	19.9	17.8	6.4	187
SPFR residue	51.1	6.3	1.2	41.4	6.8	72.2	17.5	3.5	19.8	17.8	6.3	212
SPFT	54.7	6.9	1.1	37.4	4	74.6	18.1	3.2	21.7	20.1	7.05	183
SPFT residue	57.9	6.2	1.4	34.5	4.2	65.2	22.7	7.8	21.3	18.7	7.3	187

Particle Size Distribution

The raw and gasified biomass samples were of the coarse particle size distribution of less than 3 mm that were sieved to less than 1 mm for the present work. The sample particle size was analyzed by a Particle Sizer. The particle size distributions for the raw and gasified samples are summarised in Table 2.

Table 2. Size distribution in µm of the raw and gasified biomass.

Biomass	d_{10}, µm	d_{50}, µm	d_{90}, µm	d_{smd} or d_{32}, µm	Fines (Particles < 100 µm), %
SPFR	91	451	866	184	15.4
Post-explosion SPFR residue	69	288	747	124	17
SPFT	73	347	785	151	14.5
Post-explosion SPFT residue	78	343	781	164	14

The Modified 20-L Dust Explosion Vessel for Coarse Biomass Powders

The modified 20-L vessel, shown in Figure 1, was used for the determination of the flammability and explosion characteristics of biomass samples. The standard C-ring particle injector was found to be incapable of dispersing the pulverized coarse woody biomass, as the particles were compressed and blocked the flow in the delivery C ring. This occurred even when the woody biomass was sieved to less than 500 µm.

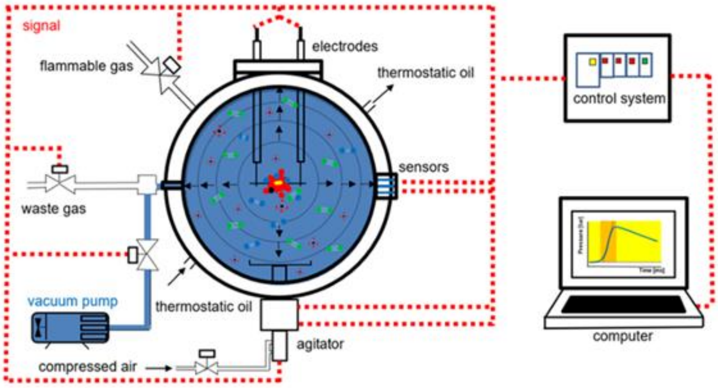

Figure 2. Modified 20-L vessel.

The Deflagration Index, K_{st}, as a function of the Equivalence Ratio, Ø, is shown in Figure 2. The peak K_{st} was measured in bar·m/s for raw and gasified wood mixture, respectively.

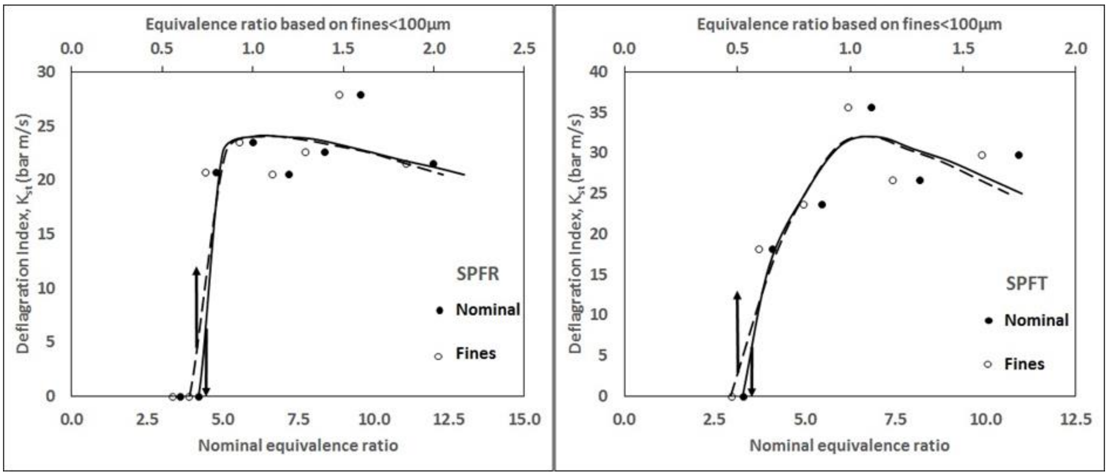

Figure 2. Deflagration Index (K_{st}) vs. Equivalence ratio (Ø) for raw SPF (SPFR) and torrefied SPF wood mixture.

Refereces

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