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Oxy-biomass ignition in air and relevant oxy-combustion atmospheres for safe primary recycle and oxy-burner development

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Abstract

Results for ignition behaviour of pulverised biomass fuels in a 20 litre (L) spherical combustion chamber are presented and discussed. Four types of biomass currently used in UK utility pulverised fuel boilers have been tested for ignition behaviour in air, so at 21%v/v O_2, and also, to assess relative performance under oxy-fuel combustion conditions, in a 21%v/v O_2, balance carbon dioxide (CO_2) balance mixture (21Oxy) and a 25%v/v O_2 mixture (25Oxy) respectively. Peak pressures (Pmax) during constant volume ignition and combustion with 2500J and 5000J igniters were measured and recorded. The pressure ratios (P/R), defined as the ratio of the maximum pressure (Pmax) to the pressure at the start of ignition (P_0) for each test are reported. A P/R above a threshold of 2.5 is taken as an indication of positive ignition. All four biomass types ignited nearly as readily in 25Oxy as in air at a range of fuel concentrations. Ignition was much less readily achieved in 21Oxy for all fuel concentrations and peak pressures were also generally lower. Results were more erratic with 2500J igniters compared to 5000J igniters, suggesting a relatively stronger ignition source is required with these biomass samples than with pulverised coals previously tested; this is tentatively attributed to larger particle sizes and higher moisture contents. Implications for pulverised fuel oxy-fuel combustion applications are: 1) a primary recycle (PR) stream with 21%v/v O_2 would give improved pulverised fuel (PF) milling safety when compared to air firing but reduced ignitability in the burners; 2) a 25%v/v O_2 primary stream would approach air behaviour in mills and burners. These preliminary results suggest that approximately 25%v/v O_2 may give air-like performance in oxy-fuel pulverised coal plants using oxy-biomass.

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Keywords: Oxy-biomass; pulverised fuel; ignition; safety; burner.

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Nomenclature

21Oxy: 21 volume % oxygen in 79 volume % carbon dioxide.
25Oxy: 25 volume % oxygen in 75 volume % carbon dioxide.
30Oxy: 30 volume % oxygen in 70 volume % carbon dioxide.
40Oxy: 40 volume % oxygen in 60 volume % carbon dioxide.
304L: Grade of stainless steel similar to 304 type with low carbon content useful in corrosive environments.
ASU: Air separation unit .
bar: Pressure unit.
bar (a): Absolute pressure unit in bar.
$Ba(NO_3)_2$: Barium nitrate.
BaO_2: Barium peroxide.
CCS: Carbon capture and sequestration/storage.
CCT: Carbon capture technologies .
CO_2: Carbon dioxide.
CPU: Compression and purification unit used downstream in oxy-fuel combustion.
E: Energy, in the context of ignition energy, units J.
FNPT: Female National Pipe Thread.
IEA: International Energy Agency.
J: Joule, SI unit for energy.
kPa: kilo Pascal, 103 Pascal, pressure unit.
kPa (a): Absolute pressure unit in kPa.
Kst: Maximum rate of pressure rise of dust ignition assuming “cubic law”, st for “Staub” (dust in German), units in bar m/s or kPa m/s.
L: Litre, volume unit.
m^3: Cubic metre, SI unit for volume.
M48: Standard external Metric thread and fastener/bolt size.
N_2: Nitrogen.
O_2: Oxygen.
O_2/ CO_2: Oxygen and carbon dioxide mixtures used in oxy-fuel.
P_0: Pressure at start of ignition for pressure ratio calculation.
Pa: Pascal, SI unit for pressure.
PF: Pulverised fuel.
P_{max}: Maximum absolute pressure during dust ignition or peak pressure, bar or kPa.
Psig: Pound per square inch gauge, pressure unit.
PR: Primary recycle in oxy-fuel combustion.
P/R: Pressure ratio (dimensionless).
PTFE: Polytetrafluoroethylene, commercially Teflon.
R-20: 20 litre spherical ignition chamber designed and built at the University of Edinburgh.
rpm: Revolutions per minute, rotational speed unit.
T_0: Absolute temperature at the start of the experiment.
T_b: Absolute temperature of the burnt gas.
TWh: Terawatt-hour, 10^{12} watts per hour, electricity generation or electrical energy unit.
Zr: Zirconium.
%v/v: Volume per volume percentage concentration.