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Steam gasification of waste tyre: Influence of process temperature on yield and product composition

Sabrina Portofino [a,*], Antonio Donatelli [b], Pierpaolo Iovane [b], Carolina Innella [b], Rocco Civita [b], Maria Martino [b], Domenico Antonio Matera [b], Antonio Russo [b], Giacinto Cornacchia [b], Sergio Galvagno [a]

[a] UTTP NANO – C.R. ENEA Portici, P.le E. Fermi, 1 Loc. Granatello, 80055 Portici (NA), Italy
[b] UTTTRI RIF – C.R. ENEA Trisaia, SS Jonica 106, km 419.5, 75026 Rotondella (MT), Italy

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ABSTRACT

An experimental survey of waste tyre gasification with steam as oxidizing agent has been conducted in a continuous bench scale reactor, with the aim of studying the influence of the process temperature on the yield and the composition of the products; the tests have been performed at three different temperatures, in the range of 850–1000 °C, holding all the other operational parameters (pressure, carrier gas flow, solid residence time). The experimental results show that the process seems promising in view of obtaining a good quality syngas, indicating that a higher temperature results in a higher syngas production (86 wt%) and a lower char yield, due to an enhancement of the solid–gas phase reactions with the temperature. Higher temperatures clearly result in higher hydrogen concentrations: the hydrogen content rapidly increases, attaining values higher than 65% v/v, while methane and ethylene gradually decrease over the range of the temperatures; carbon monoxide and dioxide instead, after an initial increase, show a nearly constant concentration at 1000 °C. Furthermore, in regards to the elemental composition of the synthesis gas, as the temperature increases, the carbon content continuously decreases, while the oxygen content increases; the hydrogen, being the main component of the gas fraction and having a small atomic weight, is responsible for the progressive reduction of the gas density at higher temperature.

1. Introduction

The disposal of waste tyres represents a relevant problem within the waste management strategy of the European Community: the world production amounts to 7 millions of tons (according to the European Tyre Recycling Association, Report 2008), 3 million of which are generated in Europe, that is 2% of total solid waste production, and even today the final destination of nearly 65–70% of such an amount is the landfill, with the consequent loss of high added value materials (Mui et al., 2004) and the relevant environmental impact.

Attempts on waste tyre reuse as solid fuel are largely documented: waste tyres have been used as principal or secondary fuel source in the production of steam, electricity, cement, lime, paper, steel and into the incineration of garbage; however these experiences have been severely limited by the scarce market demand and by the overall operational costs of the plants (Sharma et al., 1998). Anyway, it is well known that tyres possess high volatile and low ash contents with a heating value greater than that of coal and biomass. These properties make them an ideal material for thermal processes like pyrolysis and gasification (Kiran et al., 2000; Morris and Waldheim, 1998; Bridgwater, 2003), that, unlike combustion, convert the intrinsic chemical energy of a carbon-rich material in valuable by-products (Leung et al., 2002; Zabaniotou and Stavropoulos, 2003; Malkow, 2004). Among the thermal technologies, the gasification of waste tyres seems to be attractive since the gaseous fuel derived from the process can be stored, transported and easily fueled for existing boilers and combustors with little modifications (Belgiorno et al., 2003; Franco and Giannini, 2005). Another alternative consists in conveying the syngas in a fuel cell, thus improving the overall efficiency of the process (McKendry, 2002; Chaudhari et al., 2003); in a modern fuel cell, such as a molten carbonate type, a steady stream of hydrogen is required as fuel and for this reason the syngas must be adequately cleaned from trace contaminants and the composition must be properly upgraded (Lobachyov and Richter, 1998; Wu et al., 2006). In any case at moment the experiences are limited to bench or pilot scale studies (Galvagno et al., 2002; Donatelli et al., 2010).

Most part of the literature data on the waste tyre gasification are collected in fluidized bed reactors and using air as oxidizing agent, while data concerning other experimental designs are hardly found. Within this framework, the present study reports the results of an experimental survey of waste tyre gasification,

* Corresponding author. Tel.: +39 0817723579; fax: +39 0817723550.
E-mail address: sabrina.portofino@enea.it (S. Portofino).

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