Fuel 106 (2013) 401–409

Contents lists available at SciVerse ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Advanced thermal treatment of auto shredder residue and refuse derived fuel

Richard Taylor *, Ruby Ray, Chris Chapman

Advanced Plasma Power (APP), Unit B2, Marston Gate, South Marston Business Park, Stirling Road, Swindon, UK

HIGHLIGHTS

- The Gasplasma® process combines a fluidised bed gasifier and plasma treatment.
- The process can be used to treat auto shredder residue and refused derived fuel.
- The clean syngas is suitable for power generation or as a chemical precursor.
- Conversion efficiencies >97% for carbon and >85% for energy.
- Net electrical efficiency is constantly above 25% for the prepared waste.

ARTICLE INFO

Article history:
Received 5 April 2012
Received in revised form 27 August 2012
Accepted 22 November 2012
Available online 10 January 2013

Keywords:
Gasification plasma
ASR
Oxy-steam
Vitrification

ABSTRACT

The disposal of End-of-Life Vehicles (ELVs) results in a highly heterogeneous polymeric waste stream of Automobile shredder residue (ASR). Within Europe, strict legislation, such as the End-of-Life Vehicle Directive and the Landfill Directive, has imposed targets for reducing this waste stream and diverting the material away from landfill. One pathway open to recyclers is to thermally process these wastes, but the presence of chlorine and metallic species can present challenges to traditional incineration technologies. This paper discusses the use of Gasplasma®, an advanced thermal treatment technology, comprising fluidised bed oxy-steam gasification followed by plasma treatment, for ASR, refuse derived fuel (RDF) and blends of ASR and RDF wastes.

The work demonstrates the ability to process these highly heterogeneous materials achieving high energy conversion (87–94%) and virtually complete carbon conversion, producing a calorific synthetic gas (syngas) capable of being used for power generation or as a chemical feedstock. The actual conversion efficiency achieved is dependent on feed chemistry and properties. The study also shows that ash components of the feed material can be transformed into an environmentally stable vitrified product.

1. Introduction

When an automobile reaches the end-of its useful life, it can be seen as a valuable source of materials that are recovered, recycled or re-used. Indeed, within the European Union a car may be composed of amongst others 57.5% ferrous metals, 10% non-ferrous metals (including aluminium, zinc, copper, lead and magnesium species), 7.5% plastics, 7.3% textiles, 2.9% rubber, and 5.2% glass [1]. To encourage reuse, recycling and recovery of a used automobile, the European Commission enacted the End-of-Life Vehicle (ELV) Directive [2]. This legislation not only banned the use of certain hazardous substances, such as lead, cadmium and mercury in certain applications in new automobiles, but it also progressively raised the recycling and recovery targets of ELVs, requiring 95% by 2015.

When an automobile is disposed of, potentially polluting materials such as automotive fluids and batteries are removed, and then economically valuable components are recovered (including tyres which are often used as a fuel or as source of raw materials [3]), with the remaining bulk being sent for shredding. At this stage, ferrous and non-ferrous metals are separated from lighter fractions. These lighter fractions are interchangeably termed automotive shredder residues (ASRs), auto fluff or auto shredder fluff. These residues may be divided into heavy, light, middling, and dust fractions which contain varying quantities of glass, fibre, rubber, automobile liquids, plastics, dirt, and mix of ferrous and non-ferrous (mainly alloys of copper and aluminium) metal components. ASR still contains potentially recovered materials using technologies such as heavy media separation, froth flotation, jigging, magnetic separation, air knives, air classification etc. Markets and prices of recovered components are controlled by the ability for these mate-

* Corresponding author. Address: Advanced Plasma Power (APP), Unit B2, Marston Gate, South Marston Business Park, Stirling Road, Swindon, UK. Tel.: +44 1793238506.

E-mail address: richard.taylor@app-uk.com (R. Taylor).

0016-2361/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.fuel.2012.11.071

rials to meet relevant materials specifications [4]. This makes the potential value of recovery of materials from ASR relatively low. This issue is exacerbated by the potential for residual contamination of recyclates with oils or other automotive fluids, some of which are considered hazardous in nature.

ASR materials may account for 25% of the total mass of ELVs, which in the UK accounts for around 450,000 tpa of landfill or 0.1% of the total waste arising [5]. However, within Europe around 14 million End-Of-Life Vehicles (ELVs) arise annually, whilst a further 9–11 million is generated in the USA [6,7]. As such, the quantities of ASR sent to landfill is still large, and the shrinking of available landfill capacity and the rising cost of their use has led to an increased focus on the processing of these ASR materials [8]. In some countries ASR has been considered as a building material [9], while their relatively high calorific value has prompted investigation as use in cement kilns or for power generation using pyrolysis, gasification, and incineration process. However, ASRs present challenges for efficient heat recovery from many technologies due to the presence of high levels of ash, residual metals, and usually relatively high chlorine content [10].

Thermal processing of ASR also offers the opportunity to increase recovery of metals and inert components, while generating energy. It is reported [8] that air-based gasification of ASR wastes in Japan, allowed 40% of the material fed to the system to be recovered either as metals within the gasification process or glass granulates at the subsequent combustion process, whilst 50% of the feed is converted into thermal energy and power.

Similarly, the total volume of Municipal Solid Waste (MSW) waste produced within the EU 27 countries alone amounted to 262.4 million tonnes in 2007 and this is forecast to increase to around 338 million tonnes by 2020, with landfill remaining the main method of waste treatment, currently accounting for around 41% of the EU 27 total [11]. While the composition of MSW is seasonal and varies with geography, MSW from developed countries contains plastics, metals, glass and other components that can be recovered and recycled. Residues produced from this recovery process, often term refuse derived fuel (RDF) or solids recovered fuel (SRF), represent a valuable source of fuel for renewable energy generation as they typically have a biogenic content in the range 60–65% [12].

Advanced thermal conversions (ATCs) technologies, which encompass gasification and pyrolysis, are increasingly being considered as the preferred choice for thermal processing of wastes. The main reasons are that these renewable processes reduce dependency on fossil fuels and lower green house gas emissions, move away from the more polluting practice of disposal to landfill and are considered to manage wastes in a more sustainable way making them publically more acceptable [13,14].

Gasplasma® technology developed by Advanced Plasma Power, is an advanced thermal conversion (ATC) technology consists of a bubbling fluidised bed gasifier (BFBG) followed by a single carbon electrode plasma converter. This ATC technology allows processing of a broad range of wastes, including ASR and RDF as individual feed or in combination with each other. The process provides high conversion efficiencies using waste feed, and is designed specifically to cope with ash components and problem species (e.g. PVC) found in ASR, while allowing enhanced materials recovery (e.g. metals, glass, etc.) from process feeds. The plasma converter plays a major role in reducing impurity in syngas and therefore the load on downstream gas clean-up technologies by both transforming tars, chars and large organic molecules into syngas components (mainly H_2, CO, CO_2, H_2O and CH_4) and immobilising inorganic materials (particulates and heavy metals components) into the vitrified material generated within the plasma converter [15]. The plasma converter vitrifies the feed ash which otherwise posses disposal problems for most other gasification or combustion process and yields a environmentally stable and non-leachable product with a variety of uses [16].

2. Materials and methods

2.1. Gasplasma® technology

The Gasplasma® process, which comprises a bubbling fluidised bed gasifier (BFBG) and plasma converter, is designed specifically for steam/oxygen gasification. The Gasplasma® system is shown schematically in Fig. 1.

The gasifier contains a bed of nominally 1 mm mullite ($3Al_2O_3\cdot 2SiO_2$) particles, and is fed with a supply of steam and oxygen as the gasification medium. The fluidised bed is maintained at a temperature of between 700 and 800 °C, with the actual operating condition depending on fuel characteristics and desired reaction profiles. The flows of steam and oxygen are finely controlled to maintain the bed temperature, good fluidization (25% higher than minimum fluidization velocity) of the gasifier bed and also to obtain the required syngas quality (low residual tar and char levels with high calorific values). The fluidised bed gasifier permits the process to accept a broader range of feedstock types and physical properties (both in terms of particle size and density), while maintaining good isothermal conditions within the bed through the enhanced heat transfer caused by the mixing, leading to a more consistent syngas generation and high conversion efficiencies.

The waste is thermally decomposed within the gasifier to produce a crude syngas, containing residual tars, unconverted char and entrained ash particles. This crude syngas enters the side of the converter chamber above the slag level and circulates around the periphery of the chamber allowing the gas to increase in temperature while receiving maximum exposure to the intense ultra violet light within the converter, aiding cracking of tar substances and conversion of the residual char [17]. The converter is also designed to capture the particulate materials entrained in the syngas flow from the gasifier and convert these into slag. The base of the converter chamber contains a layer of molten slag. The plasma power is controlled to provide a syngas temperature of 1000–1200 °C from the plasma converter and destruction of the residual tars and chars contained within the crude syngas.

Data reported and discussed in this paper are generated from the demonstration Gasplasma® plant which is in Swindon, UK. The demonstration plant has maximum feed capacity of 100 kg/h whereas the generic full scale plant has been designed for 12 t/h feed basis. The core principal of the gasifier and the plasma converter described above is applied for both full scale and demonstration plant. In the demonstration plant, the hot syngas from the plasma converter is cooled through a thermal fluid heat exchanger, reducing the syngas temperatures to around 200 °C whereas in full scale plant, this sensible heat would be recovered to generate steam, which would then be used for power generation via steam turbine. The cooled syngas is further cleaned to remove fine particulate and acid gases (e.g. HCl, H_2S etc.) in the gas cleaning system which is a combination of dry and wet cleaning processes. The syngas composition is constantly monitored to provide guidance on the adjustment of process parameters to achieve consistent high quality syngas which is subsequently used for power generation via gas engine.

2.2. Materials

Two separate waste streams were used in the experimental study, Automotive Shredder Residue and Refuse Derived Fuel. The prepared RDF comes from a number of waste treatment facilities in floc form. Similarly, automotive shredder residue for the demonstration plant arrives from facilities where ELV are mechanically broken down to facilitate the recovery of components and metal scrap. The waste feed is metered into the gasifier under controlled conditions, using a variable speed screw feeder at