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Technical assessment of discarded tires gasification as alternative technology for electricity generation

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ABSTRACT

Concern about contamination associated with the disposal of tires has led to the search for technologies to reuse discarded tires, which include the use of Tire Derived Fuel (TDF) as fuel in advanced thermal-conversion processes, this allows the energy use of these wastes at affordable costs and reduces the environmental impact on scrap tires disposal. A theoretical assessment of the technical viability of TDF gasification for electric and thermal power generation, from the producer gas combustion in an internal combustion engine and in a gas turbine, was performed. The combustion of producer gas derived from the gasification of TDF in an internal combustion engine driving a generator (ICE-G) appears as the more efficient route for electricity generation when compared with the efficiency obtained with the use of gas turbine (GT-G). A higher global efficiency, considering the electric and thermal generation efficiency can be expected with the use of TDF producer gas in GT-G, where is expected an overall efficiency of 77.49%. The assessment shows that is possible produces up to 7.67 MJ and 10.62 MJ of electric and thermal energy per kilogram of TDF gasified using an ICE-G and up to 6.06 MJ and 13.03 MJ of electric and thermal energy respectively per kilogram of gasified TDF using a GT-G.

1. Introduction

Tire disposal is a problem throughout the world that is aggravated as the vehicle fleet grows. The tire must have proper disposal procedure, to reduce their impact on the environment. However, most of the time, incineration becomes the disposal procedure, since it is the fastest and easiest way to discard it. Tire incineration forms hundreds of different combustion products, ranging from simple to complex hydrocarbons and halogechlorinated hydrocarbons (ranging from chlorinated methanes to the ultra-toxic dioxins and polychlorinated biphenyl (PCBs)) (Lew, 1990). Pyrolytic oil, is also produced which contains toxic chemicals and heavy metal compounds, capable to cause adverse health effects.

The estimated number of waste tires generated annually in Brazil rounds between 17 and 20 million units, from which 6 million units are generated in the state of São Paulo. The number of accumulated units in inappropriate deposits is estimated to be at least 100 million units (Andrade, 2007; ABRELPE, 2015).

Concern about contamination associated with the disposal of tires has led to the search for technologies to reuse discarded tires, which include energetic valorization, introduction as raw material in buildings construction, in the processing of asphalt surfacing and in the footwear industry, among others.

Due to its high calorific value, scrap tires are widely used as fuel in thermoelectric generation, in co-combustion coal-fired boilers and in the production of oils. Another major objective for uses of tires as fuel is to decrease the number of scrap tires disposed in landfills or stockpiles.

These applications however, are questioned due the pollutant emissions levels. According to United States Environmental Protection Agency (Marchiori, 2007), tire combustion emits approximately 6% of the burned fuel mass as solid particles and volatiles.

The use of Tire Derived Fuel (TDF) as fuel in advanced thermal-conversion processes with low contaminants emissions is a promising alternative in the market today, which allows the energy use of these wastes at affordable costs and reduces the environmental impact on the scrap tires disposal. Some experimental and theoretical studies on waste tires gasification at laboratory scale has been performed, mainly using plasma and steam gasification (Choi et al., 2016; Portofino et al., 2013; Galvagno et al., 2009; Xiao et al., 2008; Wang et al., 2016; Janajreh and Raza, 2014a), but with little information about the applicability of this route for electricity and heat production.

On this background, the main objective of this work is to perform a theoretical assessment of the technical viability of TDF

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Nomenclature

$\dot{m}_x$	mass flux of element x [kg/s]	LHW_x	lower heating value of element x [MJ/kg_{fuel}]
h_{fg}	water vaporization enthalpy [MJ/kg]	TDF	Tire Derived Fuel
Δh_x	enthalpy change of the element x [MJ/kg]	ICE-G	internal combustion engine driving an electric generator
Q_G	heat lost in the reactor [MW]	GT-G	gas turbine driving an electric generator
$\eta_{gasifier}$	reactor cold gas efficiency [%]	BFBG	Bubbling Fluidized Bed Gasifier
HHW_x	higher heating value of element x [MJ/kg_{fuel}]		

gasification for electric and thermal power generation, from the producer gas combustion in an internal combustion engine driving an electric generator (ICE-G) and in a gas turbine driving an electric generator (GT-G). This study provides a support for decision makers in order to select the correct technology for the desired applications from the energetic valorization of this waste.

2. Methodology for the technical analysis

The study evaluated the implementation of waste tires gasification for electricity generation using two different technology. In both cases, are performed the mass and energy balance in all components of the configuration. The generation efficiencies of electricity, heat and the overall efficiency were also determined. In the final stage, a comparison taking into account the thermodynamic efficiency of different cases was performed. Fig. 1 shows the technical analysis methodology for gasification of TDF for electric and thermal energy generation.

3. Waste tire gasification

The tire life cycle consists generally of five main stages, comprising the extraction of raw materials, production, consumption (use), waste tire collection and processing for recycling or disposal, depending on the local conditions of each country or region where they are produced or sold (Van Beukering and Janssen, 2001).

Tires have a mixed composition of carbon black, elastomer compounds, and steel cord, in addition to several other organic and inorganic components. Fig. 2 (ETRMA, 2014) shows a view of the tires average composition.

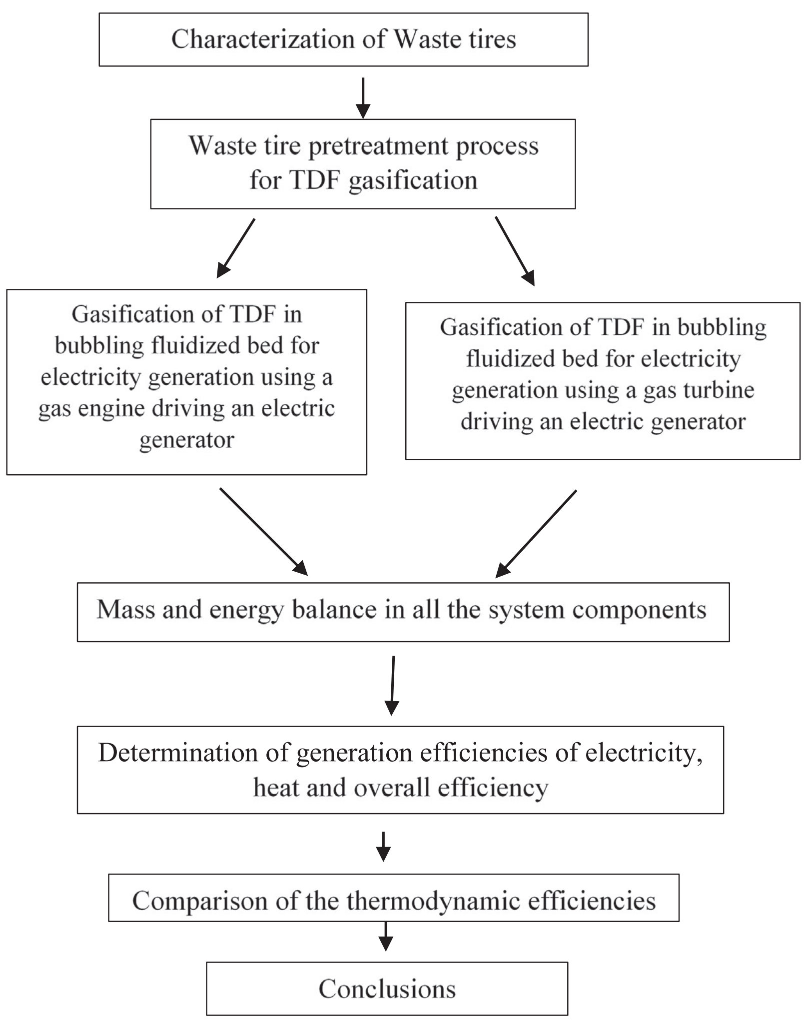

Fig. 1. Technical methodology for gasification of TDF for electric and thermal energy generation.