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Energetic valorization of waste tires

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ABSTRACT

Significant high levels of available waste tires in Brazil, which reached approximately 473 thousand tons in 2015, offer an attractive potential for their use as fuel in advanced thermal conversion processes. Technologies for energetic valorization of waste tires were reviewed and two alternatives based on updraft gasification in a modified reactor design were proposed. First of all, a large-scale updraft gasifier on IGCC (Integrated Gasification Combined Cycle) was considered for the gasification of the derived fuel from waste tires, capable to produce between 10.8 and 16.1 MJ of electric energy per kg of derived fuel from waste tires fed to the reactor. The second alternative considered a small-scale updraft gasifier feeding an internal combustion engine, coupled to an electricity generator for the production of up to 8.2 MJ of electric energy per kg of derived fuel from waste tires fed to the reactor. Implementation of these technologies will allow energetic valorization of waste tires in Brazil, solving their disposal problems, creating jobs, reducing negative disposal environmental impacts in landfills, and increasing distributed generation of electricity.

1. Introduction

Environmental concerns, oil price instability, economical and geopolitical issues motivate the development of new energy generation technologies. Sustainable use of energy resources is necessary for the proper management of the planet's natural resources and reduction of environmental pollution. Thus, obtainment of renewable fuels is an issue among current challenges. This should be done at affordable costs with economically feasible applications, in order to reduce pollutant emissions, including NO_x, CO_2, particulate matter (PM), and C_xH_y.

Tire disposal is a worldwide problem, aggravated along with growing vehicle fleets. Tires must be properly disposed to reduce their impact on the environment; however, disposal occurs through incineration most of the time, which is the fastest and easiest discarding procedure. Tire incineration produces a large number of emissions, including a broad set of hydrocarbons, and halogen-chlorinated compounds (chlorinated methanes, dioxins, and PCBs -polychlorinated biphenyl) [1]. This also produces pyrolytic oil, which contains toxic chemicals and heavy metal compounds capable of causing adverse health effects.

Studies stated that water pollution caused by runoff derived from tire fires can last up to 100 years [2]. In addition, toxic incineration exhausts from waste tires are far more mutagenic than from well-designed and properly operated coal-fired plants emissions [3].

Disposal of tires in landfills is environmentally harmful, since they tend to return to the surface and break layer covers, damaging the land settlement in the long term and their rehabilitation [3].

Estimates regarding the number of waste tires annually generated in Brazil range between 17 and 20 million units, 6 million only in the state of São Paulo state; the number of accumulated units within inappropriate deposits is estimated to be at least 100 million [4]. According to CEMPRE [5]- Business Commitment for Recycling, non-passive tire recovery has negative value, i.e., waste tires carry costs for new tire dealers who eventually pay for residue disposal.

Concerns related to contamination associated with tire disposal led to the search for reuse technologies of discarded tires. Thus, energetic valorization of tires began along with the introduction of their use as a raw material in building construction, in asphalt surfacing processing, and in the footwear industry, among other applications [6].

2. Tire production and waste tire disposal

The estimate growth for the worldwide tires demand, about 4.3 percent per year, reached 2.9 billion units in 2017, while waste tire disposal in 2015 reached nearly 1 billion units [7].

According to the Brazilian Pneumatic Industry Association [3], production of tires in 2014 by the Brazilian industry totaled 70.8 million units, which was a small reduction compared to 2013, a year in which the historical record was achieved by the sector. In addition, 12.4 million units were exported in 2013, a slight growth of 0.6% in total manufactured tires; and 7.0 million tires were imported. Table 1 presents the number of tires produced in the 2006-2014 period.

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Table 1
Number of tires produced in Brazil in the 2006–2014 period [3,8].

	Production by Categories (Million of units)								
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Cargo	6.9	7.3	7.3	6	7.7	7.448	7.138	8.231	7.894
Van	5.9	6	5.8	5.6	7.9	8.470	8.267	9.904	8.860
Drive car	28.9	28.8	29.6	27.5	33.8	32.568	30.406	32.554	33.266
Motorcycle	11.4	13.8	15.2	13	15.2	16.078	14.519	15.041	15.642
Agricultural	0.688	0.83	0.903	0.679	0.917	0.793	0.807	0.928	0.873
Others	*n.a*	*n.a*	*n.a*	*n.a*	*n.a*	0.109	0.107	0.103	0.118
Industrial	0.508	0.462	0.716	0.963	1.6	1.396	1.360	2.072	2.069
Airplane	0.051	0.061	0.047	0.0418	0.06	0.060	0.054	0.052	0.050
Total	54.347	57.253	59.566	53.783	67.177	68.933	64.670	70.898	70.786

n.a: not available.

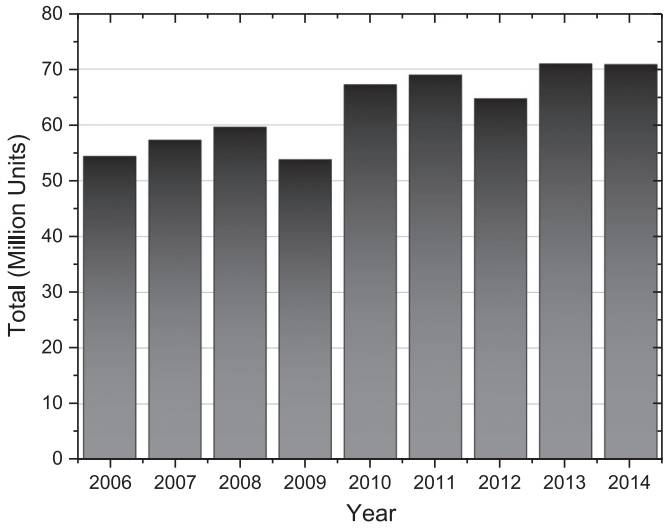

Fig. 1. Behavior of the Brazilian tire production in the 2006–2014 period [3,8].

Main export destinations included Argentina, United States, Colombia, and Mexico. Due to a competitiveness loss regarding Brazilian products and reduction of imports from MERCOSUR, direct exports from tire factories have been reduced by an average of 3% per year since 2010, ranging from 25.1% of total Brazilian production in January 2010 to 18.0% in 2014. Fig. 1 shows the behavior of the Brazilian tire production in the 2006-2014 period.

The observed behavior regarding Brazilian tire production presented a sustained increase, except in 2009 and 2012. A significant reduction of tire production in those years was a reflection of the global economic crisis [9–11].

2.1. Waste tire generation and disposal

The tire life cycle generally consists of five main stages, comprising of raw materials extraction, production, consumption (use), waste tire collection, and processing for recycling or disposal, depending on local conditions of each country or region where they are produced or sold [12].

Waste tire generation in 2013 by region was: USA, 4.4 million metric tons [13]; Europe, 3.4 million metric tons [17]; Japan, 1.02 million metric tons [14], Russian Federation, 1 million metric ton [15], and Brazil, 365 thousand tons [3,16], with 3.31 million metric tons produced in the rest of the world. Fig. 2 shows the volume distribution of waste tire generated in 2013 worldwide.

The Brazilian Pneumatic Industry Association [3] invested R$ 105 million in 2015 to recycle tires from 834 collection points across the country. This value was higher than the amount spent in 2014 (R$ 99 million), when 89 million units were collected. 445 thousand tons of waste tires were collected in 2014, which was in amount 10.1% higher in comparison to that collected in 2013. Since the waste tire collection by manufacturers began in 1999, 3.11 million tons of waste tires were collected and disposed of properly, which was the equivalent of 623 million passenger tires. Tire manufacturers have already invested R$ 724 million in the program until March 2015, equivalent to US$ 207 million. Fig. 3 shows the mass of waste tires recycled in Brazil, in the 2000-2015 period.

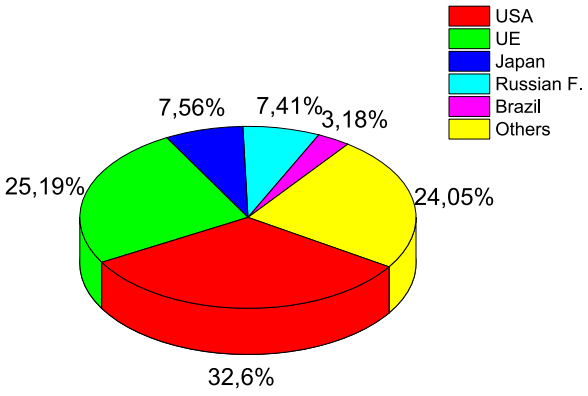

Fig. 2. Waste tire volume generation worldwide in 2013 [12–14,20].

The recollected waste tire amount increased steadily during the last 5 years, but it remained below 85% of the total waste tire generated.

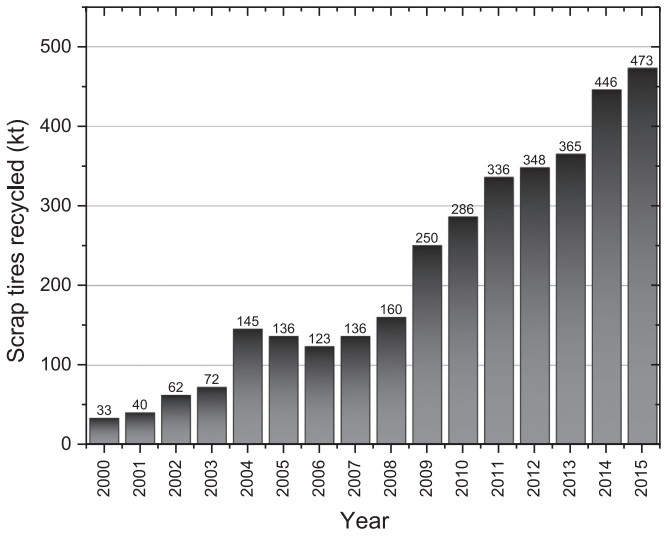

Fig. 3. Waste tires recycled in Brazil in the 2000 to 2015 period [3,8].