



# Microturbine combustion and emission characterisation of waste polymer-derived fuels

Tine Seljak <sup>a, b, \*</sup>, Samuel Rodman Oprešnik <sup>a</sup>, Tomaž Katrašnik <sup>a</sup>

<sup>a</sup> Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia

<sup>b</sup> Center of Excellence PoliMat, Ljubljana, Slovenia

## ARTICLE INFO

### Article history:

Received 12 December 2013

Received in revised form

12 June 2014

Accepted 7 July 2014

Available online xxx

### Keywords:

Waste tire oil

Pyrolysis

Gas turbine

Liquefaction

Biomass

Glycerol

## ABSTRACT

The work presented here characterises the influences of different waste-derived fuels on the combustion process in a microturbine. The two most common types of solid waste are converted into liquids by liquefaction in polyhydric alcohols and by pyrolysis to produce the novel fuels LW (liquefied wood) and TPO (tire pyrolysis oil). Baseline results were obtained with diesel fuel and with raw polyhydric alcohols otherwise used in wood liquefaction process. The original contribution of this analysis is the in-depth comparison of the combustion and emission phenomena of LW and TPO under different operating conditions. The results revealed significantly higher CO (carbon monoxide) and THC (total hydrocarbons) emissions for LW due to its reduced atomisation ability and increased spray penetration in line with the physical and chemical properties of the fuel. The combustion properties of TPO resembled those of diesel fuel in terms of CO and THC. NO<sub>x</sub> (nitrous oxides) emissions reflected the elemental composition of the fuels. In addition, pronounced soot formation is observed when utilizing TPO, whereas for LW, the opacity measurements are surprisingly low. These results indicate that TPO can be exploited directly in gas turbines, whereas LW requires adaptations in the fuel supply system and a narrower range of operating conditions.

© 2014 Elsevier Ltd. All rights reserved.

## 1. Introduction

As the amount of human-derived waste is steadily increasing, multiple solutions are being developed to exploit the energy potential of that waste. Incineration, one of the most common techniques, is widely utilised to manage a wide portfolio of different types of waste. In 2010, approximately 512 kg of MSW (municipal solid waste) was generated per capita in the EU-27 countries, of which nearly 101 kg was incinerated, while another 118 kg was recycled and 89 kg composted [1]. Most of MSW consists of organic material, paper and plastics, although this ratio differs according to location and to the practice of other waste management techniques (i.e., composting, recycling, landfilling) [2]. Fig. 1 presents the distribution of MSW components in the EU-27.

While incineration for energy recovery is carried out by a variety of systems and processes, all exploit the residual heat in flue gasses

to produce hot air, hot water, steam or additional electricity. The process of energy recovery is thus limited to incineration plants supplying heat distribution networks that provide steam or hot water to urban districts and nearby industries. This process can be further upgraded with Rankine cycles to extract mechanical power.

For certain applications such as small decentralised heat and/or power production where waste can be efficiently converted into energy at the site of generation, more advanced techniques are required. Instead of incineration, these plants mainly rely on combustion in ICEs (internal combustion engines) due to their high efficiency, high availability and low purchasing and life cycle costs. The disadvantage of ICEs compared with larger steam turbines and other Rankine cycle engines that can be used in incineration plants is that ICEs require either liquid or gaseous fuels. The advantages of ICEs become particularly noticeable when aiming for decentralised CHP (combined heat and power) production with waste-derived fuels in small- or mid-size plants. Combining the availability, efficiency and lifecycle costs of ICEs with the possibility to convert waste into liquid or gaseous fuels, the choice is relatively straightforward when trying to exploit local waste materials for CHP production [4]. The high energy content of the two most widely available constituents of waste – natural polymers including

\* Corresponding author. Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia.

E-mail addresses: [tine.seljak@fs.uni-lj.si](mailto:tine.seljak@fs.uni-lj.si), [seljak@fs.uni-lj.si](mailto:seljak@fs.uni-lj.si) (T. Seljak), [samuel.rodman@fs.uni-lj.si](mailto:samuel.rodman@fs.uni-lj.si) (S. Rodman Oprešnik), [tomaz.katrasnik@fs.uni-lj.si](mailto:tomaz.katrasnik@fs.uni-lj.si) (T. Katrašnik).

**Abbreviations**

BSU	–	Bosch smoke unit
CHP	–	combined heat and power
CLD	–	chemiluminescence detector
CO	–	carbon monoxide
D2	–	diesel fuel
EQR, $\Phi$	–	equivalence ratio
FBN	–	fuel-bound nitrogen
FID	–	flame ionisation detector
GLY	–	glycols
HHV	–	higher heating value

ICE	–	internal combustion engine
LHV	–	lower heating value
LW	–	liquefied wood
MSW	–	municipal solid waste
NDIR	–	non-dispersive infrared
NO <sub>x</sub>	–	nitrous oxides
PAH	–	polyaromatic hydrocarbon
PEG	–	polyethylene glycol
p-TSA	–	para-toluenesulfonic acid
THC	–	total hydrocarbons
TIT	–	turbine inlet temperature
TPO	–	tire pyrolysis oil

biomass and paper and man-made polymeric materials such as tires and plastics [2] – makes them highly suitable substrates for energy recovery. Considering this fact and the goal of broadening the applicability of waste-derived products, several waste conversion processes have been developed, differing based on the waste composition and the technical and economic value of the end product. Conversion processes are predominantly based on the two similar thermochemical procedures of gasification [5] and pyrolysis [6]. However, biomass can also be efficiently converted into gaseous fuels by anaerobic biodegradation [7].

In the work presented here, two different liquid fuels derived from biomass waste (representing natural polymers) and waste tires (representing man-made polymers) will be systematically evaluated for the first time in the same experimental apparatus and compared based on the following criteria:

- gaseous exhaust emissions,
- smoke emissions,
- thermodynamic parameters.

The objectives of this study are:

- to explore the possibility of exploiting both fuels (LW (liquefied wood) and TPO (tire pyrolysis oil)) in an internally fired microturbine engine by providing insight into combustion and emission formation phenomena under typical conditions encountered in a microturbine,
- to analyse and elaborate the required adaptations of the fuel supply system that allow for stable, efficient and low

emissions operation while using the two alternative fuels analysed here,

- to analyse the performance of these two fuels in comparison to their closest relatives: D2 (diesel fuel) for TPO and GLY (1:1 mixture of diethylene glycol and glycerol) for LW as the mixture represents a basic solvent for producing LW.

These objectives are motivated by the following facts:

- The internally fired microturbine is tested here due to the several advantages of internally fired systems. Compared with externally fired gas turbines, internally fired systems are less complicated, are widely available in the lower power output range and are more efficient. The main reason for this increased efficiency is that the external working gas should be approximately 100 °C–200 °C higher than turbine inlet temperatures, often over 1000 °C [4]. This requires a high temperature heat exchanger, which significantly influences the overall efficiency of externally fired systems by increasing the pressure loss, reducing the heat transfer efficiency, limiting the maximum turbine inlet temperature and increasing the heat loss to the environment [8].
- Tested TPO fraction is obtained through distillation in the same temperature interval as diesel fuel (190 °C – 350 °C). Thus the hypothesis of similar combustion behaviour of TPO and diesel fuel needs to be assessed.
- LW is obtained through liquefaction of lignocellulosic biomass in a mixture of polyhydric alcohols (glycols). In the presented case these are diethylene glycol and glycerol in 1:1 ratio (GLY). As glycols used in LW production represent almost 75% of the reactants, the influence of added lignocellulosic waste on combustion behaviour of LW needs to be evaluated.

The experiments in this work are conducted in an experimental gas turbine at different TIT (turbine inlet temperatures) with high primary air temperatures, which refers to the temperature of the intake air in the combustion chamber in the range above 400 °C. High primary air temperatures are obtained through operation in regenerative cycle mode, in which the exhaust gasses are routed through the heat exchanger to heat the air discharged from the compressor. This was done to mimic the microturbine setups which are optimized for production of shaft power. For all operating points, comparative measurements are performed with D2 according to the EN 590:2009 standard and technical grade 1:1 mixture of glycerol and diethylene glycol to provide benchmark results. These results will be used to analyse the underlying mixture formation, combustion and emission formation phenomena occurring when different fuels are burned under various operating conditions.

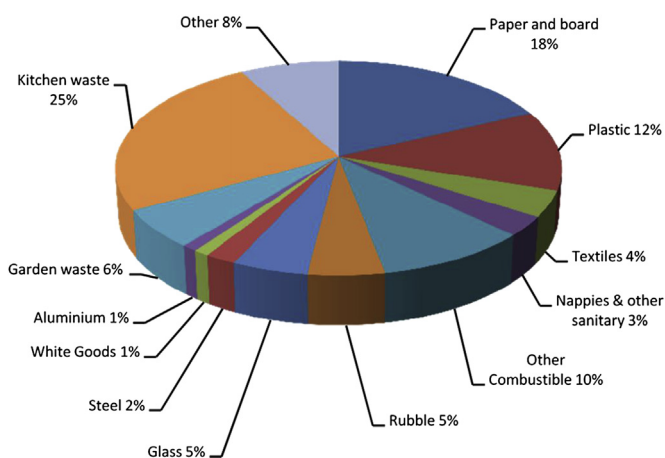


Fig. 1. Distribution of MSW in the EU-27 [3].

Download English Version:

<https://daneshyari.com/en/article/8076342>

Download Persian Version:

<https://daneshyari.com/article/8076342>

[Daneshyari.com](https://daneshyari.com)