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Performance Analysis of Biofuel Fed Gas Turbine

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Abstract

The present paper deals with the study of the performance of a heavy-duty gas turbine running on biofuels. In particular, synthesis gas from glycerol steam reforming was used to feed the combustion turbine. Engine performances were compared with methane fed ones.

Therefore, a mathematical model of the gas turbine was implemented using GateCycle software. Model calibration was made using gas turbine on-design parameters, while performance test results were compared with experimental running data. The resulting analysis highlighted that the mathematical model is able to correctly simulate engine behaviour in different combustion turbine running conditions thus validating the mathematical model.

The combustion turbine studied was integrated with a syngas generator plant and overall efficiency was evaluated.

The analysis of the results confirms that using biofuels a reduction in engine performance occurs. On the contrary, integrating the gas turbine and syngas generator plant an overall efficiency increase was registered.

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Keywords:

1. Introduction

Emissions of CO_2, CO, SO_2 and NO_x from fossil-fuel combustion are the main causes of atmospheric pollution in both urban and extra-urban fields [1, 2]. Furthermore, in the last century world energy consumption has been increasing considerably. In the present scenario, bio-fuels have emerged as alternative sources of energy [3]. They

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can offer many benefits including sustainability, reduction of greenhouse gas emissions, rural development and security of supply.

The main aim of all biofuels is to replace fossil fuels reducing mainly the net amount of carbon dioxide emitted into the atmosphere. Most of gas turbines operate in high efficient combined cycle power plants and some of them use an integrated gasification section [4].

Gasification could be considered a serious alternative to produce synthetic fuels for gas turbines, replacing conventional fossil fuels. Burning these low LHV syngas allows using raw fuels that cannot be used in conventional gas turbines, due to technological considerations. Moreover it is possible to reduce greenhouse gas emissions thanks to an easier integration of pre-combustion carbon capture.

Syngas fuels are a mixture of gases with different fraction of hydrogen, methane, carbon monoxide, carbon dioxide, and hydrocarbons. Since the LHV of syngas is much lower than that of natural gas, which gas turbines are usually designed for, higher mass flows are required to reach similar rated power. That means fuel injectors and combustor in gas turbines need to be modified to make them suitable for the higher flows. All of the major OEM’s, including Siemens, General Electric, Mitsubishi Heavy Industries, Alstom [4, 5] have developed combustion system operating hydrogen rich fuels, such as syngas.

In the last decade the necessary to reduce greenhouse gas emission has led to an enormous growth of biodiesel production from vegetable oils. This process consists in a trans-esterification process using methanol, steam and electricity and some additional chemicals. A significant amount of glycerol is generated as waste co-product of biodiesel production in trans-esterification process.

Therefore the increase in biodiesel production by trans-esterification is leading to an excess of glycerol production as by-product. The glycerol is mostly used in medical, pharmaceutical and personal care applications. It also could be considered as matter for the synthesis gas (syngas) generation to feed many types of internal combustion engines (ICE) [6] or gas turbine [7]. The steam reforming is one of effective method to generate syngas from glycerol [8].

The present paper focuses on the analytical model development of an integrated gasification heavy-duty gas turbine burning different syngas fuels generated by a steam reforming process of glycerol. In particular, 48 different syngas compositions were considered to investigate the effect of syngas type on the operation and performance of the gas turbine as well as the overall efficiency of integrated system. The syngas composition types were produced using two steam to carbon ratio (S/C) values at different levels of reformer pressure and temperature. Moreover, the analysis examined the influences of water content in syngas on gas turbine performance.

Nomenclature

S/C	Steam to Carbon Ratio
GT	Gas Turbine
TIT	Turbine Inlet Temperature
RP	Reformer Pressure
RT	Reformer Temperature
ANGLE	Inlet Guided Valve Angular Position
VFC	Mass flow rate correction factor
VEC	Efficiency correction factor
CS	Corrected speed
A_{nozzle}	Minimum turbine nozzles’ area

2. Integrated Gasification Gas Turbine

The power plant studied in the present paper is an integrated gasification gas turbine. A schematic diagram of the plant is shown in Fig. 1.

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