Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 216–223

Energy Procedia

www.elsevier.com/locate/procedia

9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

Exergy Analysis of Boiler Process Powered by Biogas Fuel in Ethanol Production Plant: a Preliminary Analysis

Nugroho Agung Pambudi[a,b]—, Ria Laurensia[a], Danar Susilo Wijayanto[a], Valiant Lukad Perdana[a], Maedanu Fasola[a], Muhammad Imran[c], Lip Huat Saw[d,e], Renanto Handogo[f]

[a] *Mechanical Engineering Education, Universitas Negeri Sebelas Maret, Jl. Ir. Sutami 36A, Surakarta 57126, Indonesia*
[b] *International Institute for Carbon-Neutral Reserch (WPI-I2CNER), Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan*
[c] *Department of Energy Engineering, School of Engineering, University of Management &and Technology, CII Johar Town Lahore, Pakistan.*
[d] *Department of Mechanical Engineering, Faculty of Engineering, National University of Singapore, Singapore -117576*
[e] *Lee Kong Chian Faculty of Engineering and Science, UTAR, Kajang, Malaysia – 43000.*
[f] *Department of Chemical Engineering, Faculty of Industry Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia*

Abstract

This paper investigates a fluidized bed boiler used in an ethanol production plant. The boiler uses biogas fuel produced by the waste system of the distillation unit within this ethanol plant. Using Engineering Equation Solver (EES), a mathematical model is developed by employing the exergy analysis. Before the study was undertaken, initial operating data of the components in the plant was collected. The results show that the boiler system has an overall efficiency of 68.238 %. The exergy efficiency in each component was also calculated. The evaporator and heat exchanger have the lowest efficiency at 45.97% and 28.96%, respectively. The efficiencies of the other components are 61.41% for the pump water pit, 54.42% for the soft water tank and 66.39% for the de-aerator.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

Keyword: Boiler; Exergy; Thermodynamic; ethanol; EES

1. Introduction

* Corresponding author. Tel.: +62-0271-718419; fax: +62-0271-718419
E-mail address: agung.pambudi@staff.uns.ac.id

1876-6102
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy .
10.1016/j.egypro.2017.12.035

Fossil fuels such as oil, natural gas and coal are limited and will be depleted in the near future. Researchers predict that crude oil reserves will be exhausted by the end of the 21st century. It is also expected that coal and natural gas reserves will be depleted in about 70 and 200 years, respectively [1]. The aforementioned fuels are not only getting scarce, but their use has been proven to have grave environmental consequences. Combustion of fossil fuels releases pollutants such as CO_2 and CH_4, which are now known to be major contributors to the global warming problem. This is evident in melting ice caps as well as higher tides and sea levels [2]. If left unchecked, these events are expected to eventually cause heavy flooding in low-lying cities, shores and islands. Fossil fuel prices are also unstable and it is expected that prices will rise sharply in the future. Although oil prices dropped considerably in 2015 in reaction to world events, it is expected that prices will appreciate as demand for fossil fuel increases. This price increase will mostly be felt by countries which have to rely on fossil fuel imports in order to meet energy demands.

Nomenclature

Symbols

ṁ	Mass flow (kg/s)
$\dot{Q}$	heat flow (kJ/s)
$\dot{W}$	Work flow (kJ/s)
ĖX	Exergy (kJ/s)
h	Enthalpy (kJ/kg)
g	gravity (m/s^2)
Z	elevation (m)
ex	specific exergy (kJ/kg)
I	irreversitility (kJ/s)
T	Temperature (K)
s	entropy (kJ/kg.K)

Subscript

CV	Control Volume
i	Inlet
o	Outlet
k	Specific stream
ke	Kinetik
po	Potential
ph	Phisical
ch	Chemical
p	Product

In commercial plants, including power generation plants and factories in the chemical industry, the problems associated with fossil fuels are well known. This has resulted in a gradual shift away from the use of fossil fuels to renewable energy sources. An ethanol plant in Indonesia have used biogas from the wastes produced by ethanol production as a complementary fuel to reduce energy costs as well as to reduce environmental problems. These plants are considering changing to renewable energy as the availability of residual oil in the domestic market is uncertain and its economic viability in the future is questionable. Once the biogas is used, the performance of whole ethanol production plant needs to be investigated. Exergy analysis by employing the second law of thermodynamics will be used to evaluate the performance of the system powered with biogas. This method has been widely used in studies to