AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

GASEOUS FUEL GENERATION FROM WOOD PELLETS BY PARTIAL COMBUSTION IN AN UPDRAFT GASIFIER

By

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B.Sc. 1985 (Ain Shams University)

A Thesis

Submitted in partial fulfillment for the requirements of the Degree of M. Sc. in Mechanical Engineering (Energy)

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Cairo - 1988

بسم الله الرحمن الرحيم

" وعلمك ما لم تكن تعلم وكان فضل الله عليـــك

عظيمـــا "

صدق الله العظيم

بسم الله الرحمن الرحيم

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STATEMENT

This disseration is submitted to Ain Shams University for the degree of M. Sc.in Mechanical Engineering (Energy).

The work included in this thesis was carried out by the author in the department of Energy and Automotive Engineering, Ain Shams University, from / / 1985 to / / 1988.

No part of this thesis has been submitted for a degree or a qualification at any other university or institute.

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TO

MY BROTHER : AHMED

ABSTRACT

Gasification as a thermochemical conversion process of solid wastes and biomass into gaseous fuels has been considered in the present work. Partial Combustion gasification process was studied using an updraft, air blown, fixed bed gasifier. Set of experiments were carried out to study the effect of air flow rate and fuel particle size on the performance of the gasifier. The gasifier used in experiments was made up of a steel cylinder of 20 cm inner diameter, and 100 cm long resting on a preforated steel plate as a grate. The inner surface of this cylinder was coated by a clay layer of 1.5 cm thickness. Wood cubes of different cube sides (0.5, 1.0, 1.5, and 2.0 Cm) have been used as the material to be gasified. Experiments were carried out at four different air flow rates (430, 515, 735, and 1035 kg/ m2 h). To study the effect of the above two parameters on the gasifier performance, the calorific value of the produced gas and its composition were determined at different operating conditions. The calorific value was determined using Junikers calorimeter and was noticed to increase with the decrease of the particle size . The calorific value was found to increase also with the increase of the air flow rate to reach a maximum value at a certain point and starts deteriorating thereafter, This point was found to be at air flow rate of 735 kg / m2 hr. The calorific

value of the produced gas ranged between 3.2 to 4.8 MJ / nm3. Concentration of CO_2 in the produced gas was measured using infera red gas analyzer and was found to be ranged between 7.23 % to 9.88 %, while the concentration of CO was measured using Orsatt gas analyzer and was found to be in the range of 11.7% to 15.6%. The equivalence ratio for the gasification process was found to vary with the variation of either the air flow rate and the particle size or both. The efficiency of the gasification process was determined and was found to increase with the decrease of particle size, the increase of air flow rate, and consequintly the increase of the equivalence ratio. The optimum equivalence ratio for operating of an updraft gasifier for the gasification of wood pellets ranges between 0.25 to 0.31. The maximum cold gasification effeciency was 74 % at equivalence ratio of 0.31. The gasifier capacity was determined and was noticed to increase with the decrease of the pellet size and increase of air flow rate. The gasifier capacity during the present work was found to be on the range of 4 to 11.5 kW.

ACKNOWLEDGEMENTS

The author is deeply grateful to his supervisors, **Professor Dr. A. S. Gad El-Mawla** for his supervision of the research programme and his interest in the author welfare, and **Dr. M. R. Salem** for his sincer guidance, valuable advices and great assistance at all stages of the work.

Many thanks to **Y. H. El-Banhawy and Dr. A. M. Abdul-Aziz** for their continuous help and support throughout the research work. The author wishes also to acknowledge the help **offered** by the technical staff of the combustion laboratory. **Many** thanks to my colleagues and in particular to Eng. Amgad El-Gowainy.

Finally I would like to express my deepest gratitude to my family especially to my **mother** whom I owe a lot of the success in my life.

CONTENTS

NOMENCLATURE

A	Outer surface area of the pellets, m^2
Cp	Specific heat of water, kJ / kg.°K
C.V	Calorific value of the produced gas, kJ / nm^3
d	Particle diameter, m
E	Activation energy
ER	Equivalence ratio, dimensionless
K	Constant
Km	Mass transfere coefficient, kg / m^2 . hr
Ma	Air mass flow rate, kg / hr
Mg	Mass of the produced gas, kg / hr
Mw	Mass of water fed to Junikers calorimeter, kg
N	Constant drying rate
Pg	Produced gas pressure at the inlet of Junikers calorimeter, N / m^2
Ps	Standard pressure, N / m^2
R	Gas constant, J / kg. °K
SGR	Specific gasification rate, kg / m^2 . hr
T	Reaction temperature, °K
Tg	Produced gas temperature at the inlet of Junikers calorimeter, °K
Ts	Standard temperature, °K
t	Experiment period, min
V	Air velocity, m / sec

Va	Axial air velocity, m / sec
Vg	Volume of the produced gas fed to Junikers calorimeter, m^3
Vs	The corresponding value of Vg at standard temperature and pressure, m^3
Xo	Thickness of the combustion layer, m
ρ	Density, kg / m^3
η_c	Cold gasification efficiency, dimensionless
η_E	Engine efficiency, dimensionless

CHAPTER 1

INTRODUCTION

The energy crisis promoted an increase interest in alternatives and renewable sources of energy. The stored energy in the agricultural wastes and residues is one of the most important renewable energy sources. The use of the agricultural wastes and residues as an energy source provides an opportunity to reduce the current dependence on fossil fuels. This will evidently have strong implication to agricultural-based industries and farming projects which require either process steam and/or energy to run different machinery. This calls for the conversion of agricultural residues to a more convenient form, liquids or gaseous, before they could be used in existing machinery or devices. Significant developments have emerged during recent years, [1-3], in the technologies of converting low-value residues to high-value energy. Conversion of residues into energy can be accomplished by either biological or thermochemical processes. Biological, anaerobic fermentation, schemes are based on storing the wastes, with added materials, under controlled thermal and physical conditions to produce gaseous or liquid fuels. Thermochemical conversion processes involve heating the wastes to a temperature that causes the high molecular weight organic compounds to decompose into smaller molecules. The temperature and heating rates employed dictate whether the primary product is gaseous or liquid fuels. Thermochemical processes have inherent advantages when compared to the biological processes, [4]. Some of these advantages are :

- Thermochemical processes have residence time for conversion of the agricultural wastes into gaseous or liquid fuels on the order of minutes or seconds, while in the biological processes this residence time will be on the order of 5 to 10 days.

-thermochemical processes have a very high cellulosic conversion fraction compared to the biological processes if the temperature is sufficiently elevated. In some reactor systems it is possible to gasify in excess of 90 % by weight of the incoming organic matter.

- Thermochemical processes are not greatly affected by the changes in the composition of the feedstock, while biological processes are extremely susceptible to slight changes in the composition of the feedstock. However, when new feedstock is put in the reactor system, of a thermochemical process, careful tests must be made to ensure that coking or deposition tar on the equipment does not occur.

- storage of the feedstock will have a greater detrimental effect on biological processes than on thermal processes. If moisture is presented in the feedstock during storage, some