STUDIES ON RICE HUSK PYROLYSIS AND GASIFICATION AND DEVELOPMENT OF A NOVEL CONFIGURATION FOR STEAM GASIFICATION OF RICE HUSK IN A CIRCULATING FLUIDIZED BED

by

VENU MADHAV SINGAMSETTI

Chemical Engineering Department

Submitted

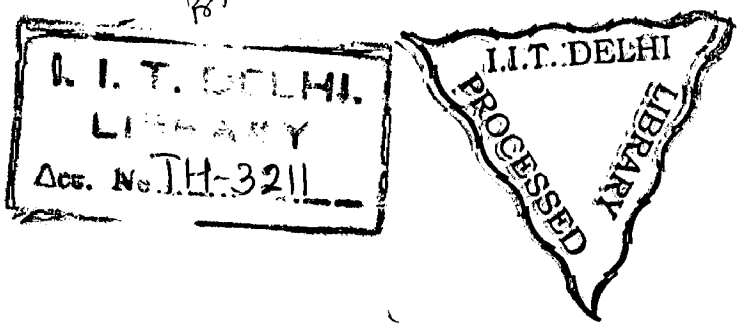
in fulfilment of the requirements of the degree of Doctor of Philosophy

to the

Indian Institute of Technology, Delhi

January 2005

Pyrolysis
Public health engineering
Biomass fuels - Pyrolysis & Gasification



CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON RICE HUSK PYROLYSIS AND GASIFICATION AND DEVELOPMENT OF A NOVEL CONFIGURATION FOR STEAM GASIFICATION OF RICE HUSK IN A CIRCULATING FLUIDIZED BED" being submitted by Mr. Venu Madhav Singamsetti to the Indian Institute of Technology, Delhi, for the award of the degree of "Doctor of Philosophy" is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

Prof. T. Rajeswara Rao
(Research Supervisor)
Chemical Engineering Department
Indian Institute of Technology, Delhi
New Delhi 110016
India

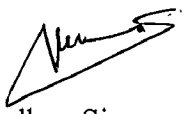
ACKNOWLEDGEMENTS

I am very grateful to my research supervisor, Prof. T. Rajeswara Rao, for his whole-hearted support, guidance, valuable suggestions and constant encouragement which enabled me to complete this research work. Despite his busy schedule, he spared his valuable time and provided all necessary help.

I would also like to convey my thanks to the staff of Biomass Lab, Mr. Badri Prasad Verma, Mr. Ramdev and Mr. Dilbagh Singh, for their efforts and being available whenever any help was required.

I am very thankful for the help and encouragement from all the faculty members of the Chemical Engineering Department. The help provided by the supporting staff is very much appreciated.

I would like to thank my wife, son, parents, in-laws and friends for their constant support throughout the period of this research work.



(Venu Madhav Singamsetti)

ABSTRACT

Rice husk is an abundantly available biomass resource. The efficient conversion of solid biomass to produce a gas for local use as well as transportation fuel would help in reducing pollution as gaseous fuels can be combusted more efficiently as compared to solid or liquid fuels. The emission of the greenhouse gas CO_2 is also reduced as the use of biomass is considered carbon-neutral. The utilization of biomass will also help in energy security. Fluidized bed gasification of rice husk with steam is a very efficient conversion process. In this conversion process, flash pyrolysis, which is a rapid reaction, yields volatile matter leaving char which gets converted to gas by a relatively slow reaction, gasification. In the present research work, pyrolysis and gasification of rice husk have been studied; and a novel configuration for steam gasification of rice husk in a Circulating Fluidized Bed (CFB) has been developed.

Pyrolysis of rice husk has been studied for determining the kinetic parameters. Isothermal experiments were carried out with rice husk grain sample in a silica tube reactor in nitrogen medium at 300, 350, 400, 450 and 500°C temperatures. Non-isothermal experiments were carried out both with grain sample as well as powdered sample in a Perkin-Elmer thermogravimetric balance at heating rates ranging from 5 to 100°C/min in nitrogen medium. Analysis of the isothermal data admitted the inference that the reaction follows second order kinetics; and the activation energy obtained is 53 kJ/mol. From the analysis of non-isothermal data, it is postulated that pyrolysis reaction exhibits a mutation through two distinct temperature zones. It is also significantly observed that the transition temperature depends on heating rate. A reaction order of 2 was judged as satisfying best fit criteria. The activation energy values obtained are in the range 75-119 kJ/mol in the lower temperature zone and 6-30 kJ/mol in the higher temperature zone. It is also premised that a kinetic compensation effect exists between the activation energy and frequency factors.

Experiments were conducted using a different experimental set-up, at 500, 600, 700, 750 and 800°C for determining the yield of gases during rice husk pyrolysis and their composition; and data analysis was done for determining the kinetics. Results indicate that the total volume of the gases increases rapidly upto a temperature of 750°C and then slows down with further increase in temperature. The moles of CH_4, CO and H_2 gases released increased almost linearly throughout with temperature upto 800°C. The data was analysed satisfactorily by 1st order kinetic rate equation. The activation energies for rice husk and its powder are 75.51 and 52.88 kJ/mol respectively. This analysis has been compared with analysis of published data on rice husk pyrolysis in a fluidized bed which showed that at any particular temperature, the rate constant is higher for pyrolysis in a fluidized bed as compared to that in a tube reactor.

In an experimental setup similar to that used for determining pyrolysis kinetic parameters, gasification reaction of rice husk char in steam was studied for determining the gasification kinetic parameters. The data has been analysed based on the volume reaction model and shrinking core model for slab type pellets. It is found that the volume reaction model with second order kinetics satisfactorily represents the experimental data. The activation energy obtained is 88.93 kJ/mol.

Cold fluidized beds of different configurations have been constructed and tested to determine the best configuration for steam gasification of rice husk. A stainless steel circulating fluidized bed has been constructed based on the chosen best configuration of the cold fluidized bed. The novel features of this configuration are a char/ash separator for separate char gasification in a bubbling fluidized bed and rice husk steam pyrolysis cum gasification in a circulating fluidized bed. Quartz tube windows have been used for measuring the solids circulation rate. The experiments led to the finding that the L-valve functions very well in a circulating fluidized bed having a single loop. However, for

operating two circulating fluidized beds in series, L-valves are not suitable as they are not able to maintain a proper seal between the riser and the downcomer leading to reverse flow of solids through the downcomer. Other non-mechanical solids flow devices such as seal pot, loop seal or V-valve have to be used to provide a seal between the riser and downcomer while absorbing the pressure fluctuations due to changes in the solids flow rates.

Residence time of rice husk in a cold circulating fluidized bed has been experimentally measured and also theoretically estimated. The experimentally measured and theoretically estimated residence time values are in the same range for low superficial gas velocity and high solids circulation rate, however at high superficial gas velocity and low solids circulation rate, there is a considerable difference between the experimental and theoretical values. The reason for this difference could be the idealized assumptions made for theoretical analysis of the phenomena occurring in a CFB riser.

CONTENTS