

Modeling of biomass reactor

A Major Thesis Submitted in

Partial fulfilment of the requirements for the award of the degree of

Master of Engineering

In

Thermal Engineering

By

N K Ram

ROLL NO.10233

(Session 2006-08)

Under the Guidance of

Dr. S Maji

Dr. B.B.ARORA



Department of Mechanical Engineering

Delhi College of Engineering

University of Delhi

Session 2006-08

Candidate's Declaration

I hereby declare that the work which being present in the minor thesis entitled “**CFD Modeling of biomass reactor**” in the partial fulfilment for the award of degree of MASTER in ENGINEERING with specialization in òTHERMAL ENGINEERINGö submitted to Delhi College of Engineering, University of Delhi, is an authentic record of my own work carried out under the supervisions of Dr. B.B.ARORA, and Dr. S Maji Department of Mechanical Engineering Delhi College of Engineering, University of Delhi. I have not submitted the matter in this dissertation for the award of any other Degree or Diploma or any other purpose what so ever.

N K Ram

College Roll No. 4-THR-2006

University Roll No: 10233

Certificate

This is to certify that the above statement made by N K RAM is true to the best of my knowledge and belief.

Dr. B B ARORA

Assistant Professor

Department of Mechanical Engineering

Delhi College of Engineering

Dr. S Maji

HOD & Professor

Department of Mechanical Engineering

Delhi College of Engineering



Acknowledgement

It is a great pleasure to have the opportunity to extend my heartiest felt gratitude to everybody who helped me throughout the project. It is distinct pleasure to express my deep sense of gratitude and indebtedness to my learned supervisor **Dr. B.B.ARORA**, Assistant professor, Department of Mechanical Engineering Delhi College of Engineering, for his invaluable guidance, encouragement and patient review. Their continuous inspiration only has made me complete this dissertation. .

I would also like to take this opportunity to present my sincere regards to my teachers for their kind support and encouragement.

I am thankful to my friends and classmates for their unconditional support and motivation for this dissertation.

N K Ram

04-THR-06

University Roll No. 10233

CONTENTS

Abstract	
Candidate's Declaration	ii
Acknowledgement	iii
Abstract	1
Contents	iv-vi
Lists of Figures	vii-viii
List of Tables	xi
Nomenclature	x
1. Energy scenario	2-6
Introduction	2
1.2 Primary and secondary energy	2
1.3 Commercial energy and non commercial energy	3
1.3.1 Commercial energy	3
1.3.2 Non-Commercial energy	3
1.4 Renewable and non-renewable energy	3
1.5 Global primary energy consumption	4
1.6 Energy distribution between developed and developing countries	5
2. Theory of gasification	7-25
2.1 Historical background	7
2.2 Basics of biomass gasification	9
2.3 Gasification approaches	9
2.4 Biomass energy conversion processes	10
2.4.1 Biological processing	10
2.4.2 Thermo-chemical processing to upgrade the bio-fuel	11
2.4.3 Chemistry	11
2.5. Direct Gasification	12
2.6 Indirect Gasification	13
2.7 Applications of Gasification	13
2.8 Types of reactors	14

	Updraft or Counter-current gasifier	14
	Updraft or Co-current gasifier	16
	2.8.3 Cross-draft gasifier	17
	2.8.4 Fluidized bed gasifier	17
	2.8.5 Rotary Kiln	19
	2.8.6 Spouted bed	19
	2.8.7 Entrained flow gasifiers	19
2.9	Chemical kinetics of gasification	
	2.9.1 Pre Heating	20
	2.9.2 Drying	20
	2.9.3 Devolatilization	20
	2.9.4 Gasification	20
	2.9.5 Miscellaneous processes	21
2.10	Chemical Reactions	21
2.11	Factors affecting gasification	23
	2.11.1 Energy content of Fuel	23
	2.11.2 Fuel Moisture content	23
	2.11.3 Size Distribution of the Fuel	24
	2.11.4 Temperature of the Reactor	24
3.	Mathematical modeling	26-38
	3.1 Physical Characteristics of the Problem and Assumptions Made	27
	3.2 Governing Equations	27
	3.3 Turbulence Model	28
	3.4 Radiation Model	33
	3.5 Combustion Model	33
	3.6 Boundary conditions	37
4	Solution methodology	39-43
	4.1. Pre-processing	39
	4.2. Processing	39
	4.3. Post processing	39
	4.4 Computational Grid	40
	4.5 Numerical Procedure	40



*Your complimentary
use period has ended.
Thank you for using
PDF Complete.*

[Click Here to upgrade to
Unlimited Pages and Expanded Features](#)

	Calculations	44-47
5.1	Calorific value of producer gas Calculation	44
5.2	Gasification efficiency	46
6	Results and discussion	48-51
7	Recommendations for future work	52
8	References	53-54
9	Figures	54-67

LIST OF FIGURES

	and Secondary Sources	2
Figure 1.2	Renewable and non renewable sources of energy	4
Figure 1.3	Global Primary Energy Consumption	4
Figure 1.4	Energy Distributions between Developed and Developing Countries (From BEE Brochure)	6
Figure 2.1	Chemistry of bio-mass gasification	12
Figure 2.2	Schematic of a Updraft Gasifier	15
Figure 2.3	Schematic of a Downdraft Gasifier	16
Figure 2.4	Fluidized Bed Gasifier	18
Figure 2.5	Shows the how the various physical and chemical reaction occur in a gasifier in a series and parallel system	22
Figure 3.1	Schematic of a down draft gasifier	26
Figure 6.1	Case 1 Temperature profile contours	53
Figure 6.2	Case 1 Mass fraction h_2 contours	53
Figure 6.3	Case 1 Grid	53
Figure 6.4	Case 1 Mass fraction Ch_4 contours	53
Figure 6.5	Case 1 Mass fraction CO contours	54
Figure 6.6	Case 1 Mass fraction $C(s)$ contours	54
Figure 6.7	Case 1 Mass fraction CO_2 contours	54
Figure 6.8	Case 1 Velocity contours	54
Figure 6.9	Case 2 Temperature profile contours	55
Figure 6.10	Case 2 Mass fraction h_2 contours	55
Figure 6.11	Case 2 Mass fraction Ch_4 contours	55
Figure 6.12	Case 2 Mass fraction CO contours	55
Figure 6.13	Case 2 Mass fraction CO_2 contours	56
Figure 6.14	Case 2 Mass fraction $C(s)$ contours	56
Figure 6.15	Case 2 Velocity contours	56
Figure 6.16	Case 3 Temperature profile contours	57
Figure 6.17	Case 3 Mass fraction h_2 contours	57
Figure 6.18	Case 3 Mass fraction Ch_4 contours	57
Figure 6.19	Case 3 Mass fraction CO contours	57
Figure 6.20	Case 3 Mass fraction CO_2 contours	58

	Reaction C(s) contours	58
	Velocity contours	58
Figure 6.23	Case 4 Temperature profile contours	59
Figure 6.24	Case 4 Mass fraction H_2 contours	59
Figure 6.25	Case 4 Mass fraction CH_4 contours	59
Figure 6.26	Case 4 Mass fraction CO contours	59
Figure 6.27	Case 4 Mass fraction CO_2 contours	60
Figure 6.28	Case 4 Mass fraction $C(s)$ contours	60
Figure 6.29	Case 4 Velocity contours	60
Figure 6.30	Mass fraction of Species (Graph E20)	61
Figure 6.31	Temperature gradient (E 0.20)	61
Figure 6.32	Mass fraction of Species (E0.25)	62
Figure 6.33	Temperature gradient (E 0.25)	62
Figure 6.34	Mass fraction of Species (E 0.30)	63
Figure 6.35	Temperature gradient (E 0.30)	63
Figure 6.36	Mass fraction of species (E 0.35)	64
Figure 6.37	Temperature gradient (E 0.35)	64
Figure 6.38	Comparison of Variation in Temperature gradient	65
Figure 6.39	Comparison of Variation in mass fraction of H_2	65
Figure 6.40	Comparison of Variation mass fraction of CH_4	66
Figure 6.41	Comparison of Variation mass fraction of CO	66
Figure 6.42	Comparison of Variation mass fraction of CO_2	67
Figure 6.43	Comparison of Variation mass fraction Species	67



Your complimentary
use period has ended.
Thank you for using
PDF Complete.

[Click Here to upgrade to
Unlimited Pages and Expanded Features](#)

LIST OF TABLES

Table 1.1 Primary energy consumption by fuel, 2003.....	5
Table 3.1 Flow and Boundary conditions	37
Table 5.2 Calorific value calculation table per m ³ of gas produced (Case 1)	45
Table 5.3 Shows Calorific value for all the four cases	45
Table 5.4 shows the gasification efficiencies for all the four cases	46.
Table 5.1 Mass Fraction of components per m ³ of gas produced.....	47

NOMENCLATURE

	ρ	density (kg/m ³)
	μ	dynamic viscosity (kg/m·s)
	ν	kinematic viscosity (m ² /s)
	c	concentration (mass/volume, moles/volume)
	c_p	heat capacity at constant pressure (J/kg·K)
	c_v	heat capacity at constant volume (J/kg·K)
	D	mass diffusion coefficient (m ² /s)
	D_H	hydraulic diameter (m)
	D_{ij}	mass diffusion coefficient (m ² /s)
	D_t	turbulent diffusivity (m ² /s)
	E	total energy (J)
	g	gravitational acceleration (m/s ²)
	G	incident radiation
	Gr	Grashof number ($L^3 \cdot \rho \cdot g \cdot \beta \cdot \Delta T / \mu^2$)
	H	total enthalpy (W/m ² ·K)
	h	species enthalpy (W/m ² ·K)
	J	mass flux; diffusion flux (kg/m ² ·s)
	k	turbulence kinetic energy (m ² /s ²)
	k	thermal conductivity (W/m·K)
	m	mass (kg)
	M_w	molecular weight (kg/kgmol)
	M	Mach number
	p	pressure (atm)
	Pr	Prandtl number ($\mu / \rho \cdot c_p$)
	q	heat flux
	q_r	radiation heat flux
	R	universal gas constant
	S	source term
	Sc	Schmidt number ($\mu / \rho \cdot D$)
	t	time (s)
	T	temperature (K)
	U	mean velocity (m/s)
	X	mole fraction (dimensionless)
	Y	mass fraction (dimensionless)

Greek letter

b	coefficient of thermal expansion (K ⁻¹)
e	turbulence dissipation (m ² /s ³)
e_w	wall emissivity
k	von Karman constant
m	dynamics viscosity (kg/m-s)
m_k	turbulent viscosity (kg/m-s)
ν	kinematic viscosity (m ² /s)
ν'	stoichiometric coefficient of reactant
ν''	stoichiometric coefficient of product
r	density (kg/m ³)
r_w	wall reflectivity
s	Stefan-Boltzmann constant
s_s	scattering coefficient
t	stress tensor (kg/m-s ²)

Subscript

i	reactant i
j	product j
r	reaction r