P- 1694

Computational Analysis of Combustion Chamber in Cogeneration Plant using Bagasse as a Fuel

P-1694

A Project Report

Submitted by

X.Lawrence - 71204402006

in partial fulfillment for the award of the degree
of

Master of Engineering
in
CAD/CAM

DEPARTMENT OF MECHANICAL ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

COIMBATORE – 641 006

ANNA UNIVERSITY:: CHENNAI 600 025

ANNA UNIVERSITY :: CHENNAI 600 025

BONAFIDE CERTIFICATE

Certified that this project report entitled **"Analysis of Fuel Flow in Fuel Cell for Efficient Power Generation"** is the bonafide work of

Mr. X.Lawrence - Register No. 71204402006

Who carried out the project work under my supervision.

(Signature of the HOD)

Dr. T. P. MANI
HEAD OF THE DEPARTMENT

(Signature of the supervisor)

Dr. V.VEL MURUGAN
ASSISTANT PROFESSOR

29/06/06
Internal Examiner

Dr. T.P. Mani
B.E., M.E. Ph.D., DML., MIE., MNIOR., MISTE.,
Dean & HoD / Dept. of Mech. Engg.
Kumaraguru College of Technology
Coimbatore - 641 006

29/6/06
External Examiner

DEPARTMENT OF MECHANICAL ENGINEERING
KUMARAGURU COLLEGE OF TECHNOLOGY

Sakthi Sugars Limited

Regd. Office & Factory : Sakthinagar - 638 315, Bhavani Taluk, Erode Dist.,Tamilnadu.
Phone : (04256) 246241 - 246244, 246341 - 246344. Fax : 04256 - 246442
E-mail : sakthi.unit1@rmy.sril.in

Admn /20-03/2006 April 26 , 2006

CERTIFICATE

This is to certify that Mr. X. Lawrence, Final year M.E (cad\cam) student from Kumaraguru College of technology, Coimbatore-641006. Has done a project work on "COMPUTATIONAL ANALYSIS OF A COMBUSTION CHAMBER IN A COGENERATION PLANT USING BAGASSE AS A FUEL" in our cogeneration plant, sakthinagar – 638315, Erode district. The results suggested were satisfactory and it is kept under consideration in order to implement in Future.

Yours faithfully,

FOR SAKTHI SUGARS LIMITED

T. Venkt

MANAGER - HRD

Head Office : 180, Race Course Road, Post Box No. 3775, Coimbatore - 641 018. Phone : 2221551, 5322222
Grams : "SUGARKING" Fax : 2220574, 5322488 E-mail : sakthi.corpoff@rmy.sril.in
Please visit us at : www.sakthisugars.com

THE GANDHIGRAM RURAL INSTITUTE – DEEMED UNIVERSITY

(Accredited with FIVE star status by NAAC)

GANDHIGRAM –624 302

DEPARTMENT OF MATHEMATICS

– SAP (DRS) NATIONAL CONFERENCE ON INTELLIGENT OPTIMIZATION MODELING

(NCIOM - 2006)

This is to certify that Dr./Shri./Ms. X. LAWRENCE, STUDENT, M.E (CAD/CAM) *of*

CT, COIMBATORE.

participated in the National Conference on Intelligent Optimization Modeling held during 03-04 March,

6 and presented a paper entitled "COMPUTATIONAL ANALYSIS OF A COMBUSTION

HAMBER USING BAGASSE AS A FUEL – A BIOMASS FUEL"

uthored by V. VELMURUGAN, R. PRAKASH

dhigram

March 2006

Dr. R. UTHAYAKUMAR

Convenor

Avinashi Road, NH-47, Kaniyur, Coimbatore-641659

Accredited by NBA*

A National Level Conference On

"Futuristic Trends In Aeronautics And Aerospace"

"A TRIBUTE TO J.R.D TATA & DEDICATED TO KALPANA CHAWLA"

CERTIFICATE OF MERIT

This is to certify that Mr./Ms. LAWRENCE . X

KUMARAGURU ENGG COLLEGE has

participated in the seminar under the topic of of a combus…

held at Park College of Engineering and Teknology on Feb-1…

CO-ORDINATOR

ABSTRACT

In the present scenario the amount of energy consumption by the people is increasing tremendously. This leads to exploitation of the fossil fuels, which in turns it suspected to unavailability of fuel for our future generation. Taken this factor in to the account bagasse as an alternative fuel in a furnace used in sugar industry is carried out in this work

Bagasse is a residual waste of sugar industry, which has very good combustion properties when used effectively because of this bagasse used in power generation. in this work first study of varies physical , chemical , combustion properties of bagasse were carried out and the analysis the temperature , velocity , and particle distribution at varies conditions using a simulation software (FLUENT)

In Order To Gain insight in to the operation and condition leading in stability due to varying input conditions, an extensive experimental program is carried out on an operating industry sakthi sugars in Appakudal .

Gas temperatures are recorded at various locations on the grate by using thermocouple and particle sample are collected at key points of interest. The experiment results are validation of the predicted results of fluent (CFD) software

The particle mostly gets burned in the rear end of the furnace near slope. These temperature contours are plotted for Bagasse flow of 6.7 Kg/s and particle size of 1638 micron. The above case is the optimum case for which the efficiency is very good compared to other cases. As the CFD model developed is validated, the optimized of operation condition were carried out and the results were presented

ஆய்வுச் சுருக்கம்

இன்றைய உலகில் மக்கள் தொகை நெருக்கடியில் நம்முடைய தேவைகள் எதிலும் அதிகமாகவே உள்ளது. இதனால் மக்கிப்போன பொருட்களிலிருந்து ஆற்றல் பெறப்படுகிறது. இன்று இயற்கை வனங்கள் அழிந்து கொண்டே வருகின்றன இதனால் நமது தலைமுறைகளுக்கு இவ்வரிய பொருட்கள் கிடைக்குமா என்பது சந்தேகம்தான் இதனை கருத்தில் கொண்டு என்னுடைய ஆய்வுக்கு கரும்புச்சக்கை மாற்று எரிபொருளாக எடுக்கப்பட்டது.

கரும்புச்சக்கை என்பது சர்க்கரைத் தொழிற்சாலைகளிலிருந்து வரும் மீதிப் பொருளாகும். இதனை தகுந்த முறையில் பயன்படுத்தினால் கணற்சி அதிகரிக்கும். ஆகையால் இதனை மின்உற்பத்திக்கு பயன்படுத்தலாம். இந்த ஆய்வில் முதலில் கரும்புச்சக்கையினை இயல்பு நிலை, இராசாயன மாற்றங்கள் மற்றும் கணற்சி நிலையயும் அறிந்தேன். பல்வேறு சூழ்நிலைகளில் வெப்பநிலை. திசைவேகம் துகள்களின் பரவல் CFD மென்பொருள் மூலம் ஆராயப்பட்டது.

வெப்ப மின் இரட்டையை உபயோகித்து நிலக்கரி தாங்கியின் பல்வேறு அமைவிடங்களில் வாய்வின் வெப்பநிலைகளானது பதிவு செய்யப்பட்டது மற்றும் துகள் மாதிரிகளானது. பல்வேறு இடங்களில் சேகரிக்கப்பட்டது. உலையின் நிலைப்பின்மையுடன் பல்வேறு நிகழ்ச்சிகள் கண்காணிக்கப்பட்டன. ஆய்வு முடிவுகளானது Fluent மென்பொருளின் முன்னறியப்பட்ட முடிவுகளை மதிப்பீடு செய்ய உதவுகிறது.

உருவாக்கப்படட CFD மாதிரியானது. மதிப்பீடு செய்யப்பட்டு போதுமான சார்புள்ள இயக்க காரணிகளானது தேர்ந்தெடுக்கப்பட்டது மற்றும் முடிவுகள் வெளிப்படுத்தப்பட்டன.

ACKNOWLEDGEMENT

The author grateful to his guide **Dr.V.VeL Murugan** , Assistant Professor, Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore for his excellent, utmost motivation, valuable advice, untiring support, timely suggestion, constant encouragement, enthusiasm, relentless patience, and inspiration throughout the study, holding in all the places.

The author expresses humble gratitude to **Dr.T.P.Mani**, Head of the Department, Mechanical Engineering, Kumaraguru College of Technology, Coimbatore for facilitating conditions for carrying out the work smoothly.

The author wish to express his deep sense of reverential gratitude to **Dr.K.K.Padmanabhan,** Principal, Kumaraguru College of Technology, Coimbatore, for providing the facilities to conduct this study.

The author deeply thanks to **Dr.S .Subramanium**, DGM of sakthi sugars limited in Appakudal and **Mr. R .Prakesh**, Director of radical technology in Coimbatore ,to guide me in technical aspect

The author expresses his heartfelt thanks to **Mr.N.Gunasekaran,** Professor, Department of mechanical engineering, Kumaraguru College of Technology, Coimbatore

The author also wish to thank **Mr.B.N.Sriharan**, and **Mr.N.Siva Kumar**, Lab Technicians, CAD Lab for being with him throughout this venture, right from the scratch and helping for completing the project successfully.

The author owes sincere thanks to all elders, parents, teachers and Lord Almighty who have bestowed upon their generous blessings in all endeavors.

CONTENTS

Title		Page No.
Certificate		i
Abstract		iv
Acknowledgement		vi
Contents		vii
List of Tables		x
List of Figures		xi
List of Symbols		xiii
CHAPTER 1	**INTRODUCTION**	1
1.1	Company profile	3
1.1.1	Various Systems in Cogenerations	3
1.1.2	Scheme of Air Flow System	4
1.1.3	Firing System	4
1.1.4	Fuel Air System	5
1.2	Cogeneration	7
1.2.1	Cogeneration Technologies	7
1.2.2	Cogeneration Benefits in General	8
1.2.3	Cogeneration Performance	9
1.2.4	Steam Turbine Systems	9
1.2.5	Gas turbine systems	10
1.2.6	Flue Gas Cleaning	11
1.2.7	Solid Residues	11
1.3	Bagasse as A Fuel	12
1.3.1	Economic Benefits Of Using Bagasse	13
1.3.2	Social benefits	14
1.3.3	Environmental Benefits	15
1.4	Introduction to C.F.D	17
1.4.1	what is cfd	17
1.4.2	Governing Equations	18
1.4.3	Program Structure	20

1.4.5	Uses Of Cfd	21
1.4.6	Procedure of Using Software	22
1.4.7	CFD Prediction	23
CHAPTER 2	**LITERATURE REVIEW**	24
CHAPTER 3	**COMPUTATIONAL ANALYSIS**	28
3.1	Analysis Of Bagasse Properties	29
3.1.1	Tests for Proximate Analysis	29
3.2	Mass Flow Rate	32
3.2.1	Stoichiometric Combustion Equation	32
3.3	Adiabatic Flame Temperature	33
3.3.1	Calculation of Adiabatic Flame Temperature	34
3.4	Thermo Gravimetric Analysis	35
3.4.1	Introduction	35
3.4.2	Use of TGA	36
3.4.3	Significance Of Tga	36
3.5	Calorific values of fuels	38
3.5.1	Introduction	38
3.5.2	Types of calorific value	38
3.5.2.1	Higher calorific value	39
3.5.2.2	Lower calorific value	39
3.6	Computational fluid dynamics	41
3.6.1	Gambit	41
3.6.2	Using flow boundary conditions	42
3.6.3	Define Various Input Parameters	45
3.6.3.1	Choosing a solver	45
3.6.4	The standard k-e model	47
3.6.5	Species	48
3.7	Validation of results	54
3.7.1	Experimental setup	54
3.8	Temperature measuring procedure	55
3.8.1	Grate level	55
3.8.2	Above the grate	56

LIST OF FIGURES

Figure	Title	Page No.
1.1	Scheme Of Air Flow System	4
1.2	Tangential Over Fire Air System	6
1.3	Separate Production Of Electricity And Heat	8
1.4	Steam Turbine Systems	10
1.5	Program Structure	20
1.6	Procedure of Using Software	22
3.1	Moisture Content 50%	37
3.2	Moisture Content 53%	37
3.3	Moisture Content 48%	38
3.4	Moisture Vs Caloric Value	40
3.5	Meshed Furnace	41
3.6	Reading Case File	45
3.7	Segregated Solver	46
3.8	Viscosity	47
3.9	Species Transport	49
3.10	Boundary Condition	50
3.11	Injection Points	
3.12	Iteration Curve	53
3.13	Thermocouple Setup	54
3.14	Temperature Measuring Procedures	55
3.15	Above The Grate	56
3.16	Measured grate temperature reading	56
3.17	Measured And Predicted Tangential Temperatures Reading	57
3.18	Grate Level Temperature Measurement	57
3.19	Spreader Plane Temperature Plane Measurements	59
4.1	Unsteady Distributor Combustion	61
4.2	Unsteady Grate Combustion	62
4.3	Combustion at different places lower value	63

LIST OF TABLES

Table	Title	Page No.
3.1	Proximate analysis of bagasse	30
3.2	Ultimate analysis of bagasse	30
3.3	Air Distribution For Bagasse Flow	32
3.4	Heat Capacity	34
3.5	Calorific Value Of Bagasse At Different Moisture Content	40
3.6	Boundary Condition Specified	43
3.7	Mass flow	50
3.8	For 0 injection	51
3.9	For 1 injection	52
3.10	For 2 injection	52
3.11	For 3 injection	52
3.12	For 4 injection	53
3.13	Thermocouple Details	54
4.1	Operating Conditions - Mass Flow Rate	67

3.9.1	Measured grate temperature reading	56
3.9.2	Measured and predicted temperature reading	57
3.10	Grade Level Temperature Measurement	57
3.11	Spreader plane temperature plane measurement	58
CHAPTER 4	**RESULT AND DISCUSSION**	60
4.1	Unsteady combustion	61
4.1.2	Grate plane	62
4.2	Sensitivity to boiler operating condition	63
4.2.1	Lower value of bagasse flow	63
4.2.2	Higher value of bagasse flow	64
4.2.3	Optimum value of bagasse flow	66
4.2.4	Selected range of flows for study	67
4.2.5	Optimum condition	67
4.3	Result obtained in fluent for optimum condition	69
4.3.1	Temperature distribution in distributor plane	69
4.3.2	Tangential Plane and Spreader plane temperature Contour	70
4.3.3	Particle trajectory	70
4.3.4	Distributor Plane	71
4.3.5	Tangential plane	71
4.3.6	Particle trajectory explanation	71
4.3.7	Species distribution	72
4.3.7.1	Bagasse volatile distribution	72
4.3.7.2	Oxygen distribution	72
4.4	Carbon dioxide distribution	73
CHAPTER 5	**CONCLUSIONS**	74
	REFERANCE	76

4.4	Higher Value of Bagasse Flow	64
4.5	Combustion at different planes optimum value	66
4.6	Temperature Distribution In Distributor Plane	69
4.7	Tangential plan	70
4.8	Injections	71
4.9	Distributor plane	72
4.10	Spreader plan	72
4.11	Spreader plan	73

LIST OF SYMBOLS

η	Total efficiency, %
Q_e	Gross electrical output, kw
Q_h	Useful heat output, kw
Q_h	Fuel energy input, kw
C	Atomic weight of carbon
H	Atomic weight of hydrogen
O	Atomic weight of oxygen
N	Atomic weight of nitrogen
M	Mass flow rate, kg/s
A	Area of input port ,m^2
V	Velocity of air, m/s
T	Adiabatic flame temperature, k
T_a	Ambient temperature, k
HCV	Higher calorific value, cal/g
LCV	Lower calorific value, cal/g

CHAPTER 1

INTRODUCTION

Increasing global concern about environmental pollution and the emission for green house gases are making biomass combustion a very real alternative to the more traditional coal-fired energy generation systems. Coal, its high carbon content, which initially made it so attractive, has become a global source of CO_2. As these environmental problems are steadily growing and the demand for energy is not decreasing, the industrialized world is being forced to seriously consider the alternatives. From this angle, any biomass fuels have some attractive qualities.

Bagasse is the cane residue, which is left over after the extraction of sugar Sugarcane has some of the most advantageous properties of biomass. It has benefited the environment by reducing the green house gases (GHGs) in the atmosphere in terms of its usage as fuel. It is a renewable source can play a major role in substituting fossil fuel for future power generation.

Computational Fluid Dynamics (CFD) is an increasingly used tool for solution of flow related engineering problems. The development and optimization of biomass grate furnaces via CFD analysis leads to a considerable reduction of investment and operating costs by a compact furnace design, by an increased availability of the plant, by reduced emissions as well as reduced air and flue gas fluxes in the furnace. This can be achieved by an appropriate design of the nozzles for air and flue gas injection as well as by adjusting the shape of the combustion chamber. In order to improve the mixing of unburned flue gas and air as well as the utilization of the furnace volume. CFD analysis helps to evaluate and avoid velocity and temperature peaks in furnace sections, which are of special relevance regarding material stress and deposit formation. CFD analysis helps to reduce the CO_2 emissions and temperature peaks due to optimized mixing conditions

CFD modeling is a non-intrusive tool that can provide insights into fluid flow problems that would be too costly or physically prohibitive to explore by experimental techniques alone, especially in some of the inhospitable environments found in power generation equipment. The insight and understanding that are gained from CFD simulations give added confidence to design proposals at reduced risk, avoiding the need to design by over sizing and over-specification.

1.1 COMPANY PROFILE

Sakthi Sugars Cogeneration Plant was started in the year 2001 in order to use the surplus waste bagasse from the sakthi sugar plant. It is located at Appakudal few kilometers from Sathyamangalam. Sakthi Cogeneration is having 35 MW TG & 120 TPH Boiler. Bagasse from Sugar Plant is the fuel for the boiler. The power generation is 35 MW of which 25 MW is exported to Grid. We call this as cogeneration since the fuel is taken from the sugar plant and in turn required steams, power are supplied to it. Here bagasses are used as the primary fuel and coal is used as the secondary fuel for burning.

Let us see various systems and various models that we have taken in to consideration in our project.

1.1.1 Various Systems in Cogenerations

- Water and steam circuit
- Air and flue gas circuit
- Auxiliaries
- Air compressor
- Electrical system
- Management information system

1.1.2 Scheme of Air Flow System

The figure 1.1 shows the air flow system in the cogeneration plant.

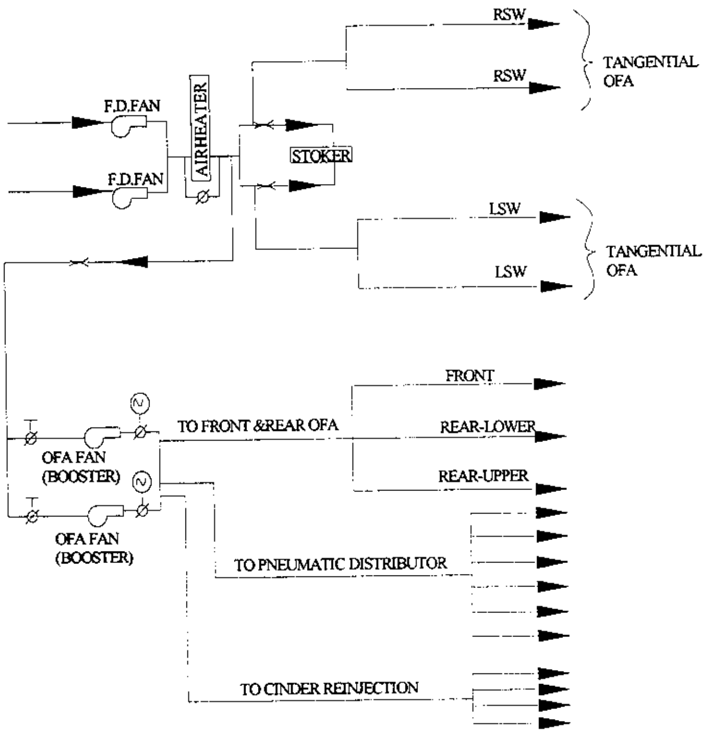


FIGURE -1.1 SCHEME OF AIR FLOW SYSTEM

1.1.3 Firing System

- Air system
- Bagasse firing
- Coal firing
- Air compartment

Air system

Airflow through the unit is handled by 2 no. Have forced draft fans (FD fans). FD fan Takes air from atmosphere (cold air). Before entering the furnace the air passed through turbulent air heater and gains the heat from the outgoing flue gas.

Bagasse firing

Approximately 60% - 65% of total combustion air (from Fd fans) flows through the stoker under grid 30% - 35% of the air through tangential over fire air registers, 5% - 10% of air flows through fuel distributors and cinder re injection nozzle after getting boosted by over fire air fans

Coal firing

Approximately 80%-85% of total combustion air flows through the stoker under grate, 15% - 20% of air flows through front and rear over fire air nozzles and cinder reinjection nozzle after getting boosted by over fire air fans.

Air compartment

The air plenum under the stoker under grate acts as air compartment. The uniform fuel distribution by fuel distribution permits minimum air zone regulation air from the forced draft duct enters the air box on both sides of the grate and then flows to the compartment through dampers

1.1.4 Fuel Air System

- Tangential Over fire Air for Bagasse
- Front and Rear over Fire Air for Coal
- Stoker under Grate Air
- Cinder Recovery System

Tangential Over fire Air for Bagasse

The tangential over fire air registers, which are located in the side walls, are directed to form an imaginary circle at the center as shown in the figure 1.2. It aids in burning the bagasse in suspension to a great extent, due to the turbulence created by air jets.

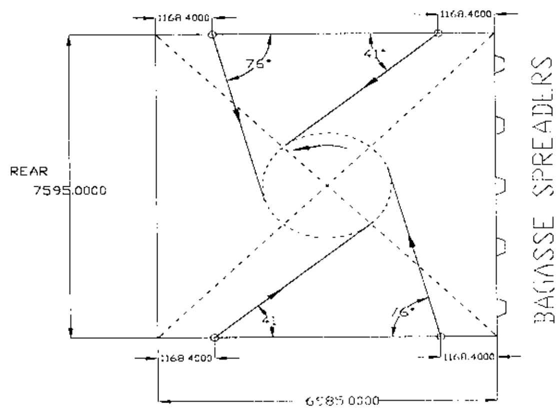


FIGURE -1.2 TANGENTIAL OVER FIRE AIR SYSTEM

Front and Rear over Fire Air for Coal

This over fire air system consists of nozzles arranged in the front and rear side of the boiler. High-pressure air (boosted by over fired air fans) is supplied to the nozzles, through the dustings.

The over fire air facilitates the combustion of the fines in suspension. It also provides some sort of agitation in the fuel bed to aid combustion of the bagasse / coal on the stoker grates bed. Necessary damper are provided for regulating the air.

Stoker under Grate Air

The stoker under grate air is supplied by F.D. fans . the air enters through the stoker wind box at both side of the boilers beneath the grate surface .

Cinder Recovery System

The cinder recovery system involves the return of the cinder (ash and carbon particles) to the furnace for re burning the larger portion of unburnt carbon particles in the fly ash enrooted to the stack.

The systems consist of nozzle at the bottom of the boiler second ash hopper after economizer. Where most of the unburnt carry over is collected. High-pressure air is taken from the over fire air fan for transporting the cinder in to the furnace. The necessary piping and discharge nozzle are provided in the system.

The discharge of the air and cinder mixture in to the furnace creates certain amount of turbulent, which is effective in aiding the combustion, particularity at high rating.

1.2 COGENERATION

This report presents the different aspects of the benefits of the cogeneration technology. Graphical illustrations support the descriptions of different cogeneration equipment configuration.

This report is the first part of a series of technical reports produced by COGEN. It is aiming at introducing appropriate technologies suitable to biomass, natural gas and clean coal fuel.

The report has been organized into two major sections. The first relates to Cogeneration. Technologies including performance parameters used to evaluate the benefits of cogeneration equipment as compared to other energy technologies.

The second section gives detailed descriptions of core and auxiliary equipment. Another useful document produced by COGEN 3 is the Cogeneration Project Development Guide which provides information and concepts that support investors in all activities related to project development, implementation and finance. This Project Development Guide is complementary to the technical reports.

1.2.1 Cogeneration Technologies

The definition of "Cogeneration", also known as "Combined Heat and Power" CHP), system is: The simultaneous generation of two useful forms of energy (such as power and heat) from the same plant using one single primary energy source In general, the heat generated for the process is a by-product of thermal power generation systems, where the primary source of fuel is biomass and fossil fuels. The amount of generated heat is dependent on the power generation process. The usefulness of the heat, defined as process steam, hot water or hot air, is dependent on the actual heat quality requirements in the system being served by the cogeneration plant. The temperature mainly defines the quality of the heat. Low heat temperature requirements will increase the amount of usable heat from the cogeneration system. Heat can be used for different types of heating purposes in industrial processes, residential heating and also for cooling processes.

1.2.2 Cogeneration Benefits in General

Cogeneration compared to separate generation of electricity and heat, results in fuel savings in the range of 25-30%, for the same amount of total electrical and heat generation difference is shown in figure 1.3 . Environmental benefits (i.e. CO2 mitigation and emission reduction)

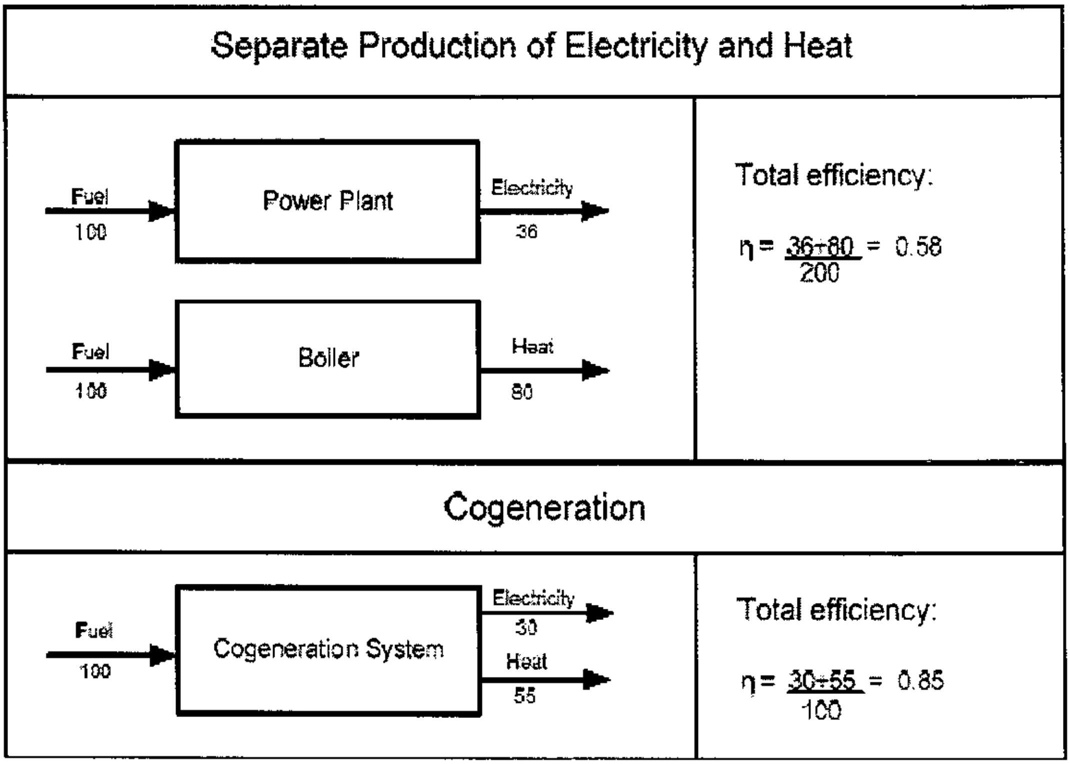


FIGURE -1.3 SEPARATE PRODUCTIONS OF ELECTRICITY AND HEAT

Cogeneration normally means decentralized power generation, which leads to Reduced grid losses (5-10%) – further fuel savings (see above) Increase power supply security Utilization of local fuels There are in principle two ways electricity generators can feed into the electricity supply system at the level of the high voltage transmission network, i.e. into the National Grid. This is what all large generators do. This is known as centralized generation. At the level of the lower voltage distribution network, i.e. directly into Regional Electricity Companies' networks. This is known as decentralized or embedded generation.

1.2.3 Cogeneration Performance

Cogeneration is by definition a process where two products are generated. The performance of a cogeneration system is hereby not unambiguous. The following are the typical parameters being used in measuring the performance of a cogeneration plant:

- Electrical efficiency çe = Qe / Qfuel
- Heat efficiency cheat = Qheat / Qfuel
- Overall efficiency çtot = (Qe+ Qheat)/ Qfuel
- Power-to-Heat Ratio á = Qe / Qheat

Qe = Gross electrical output, kWe

Qheat = Useful heat output, kWth

Qfuel = Fuel energy input

An economic optimization of the performance for a certain system will be dependent on the electricity, heat and fuel prices/values. An environmental optimization will be dependent on the actual system and the total system fuel savings.

The available heat utilization from a cogeneration system is dependent on the cogeneration technology but also on the heat quality (supply and return pressures and temperatures) requirements. Low temperature hot water systems (90/50 ^{0} C) could result in overall efficiencies > 90% (based on LHV), while steam supply (5 to 20 bar saturated) would lead to lower efficiency 60to 70%).

1.2.4 Steam Turbine Systems

The steam turbine system (Rankin process) is by far the most common power and cogeneration system. The system shown in figure1.4 is used from small units well below 1 MW to the largest power utility plants. Steam is generated in a boiler. The steam is expanded in the steam turbine connected to a generator. The expanded steam is cooled and condensed in a “heat exchanger” (condenser or a process cooling) where heat can be recovered and utilized. The temperature in the temperatures means extensive expansion and high electrical efficiency and vice versa.

The working media is normally water. Other fluids are possible for the Rankin cycle. A special group using ammonia and different types of hydrocarbons are called Organic Rankin cycles In condensing steam turbines the expansion can be maximized by using low temperature cooling water from the sea or wet cooling towers. This low temperature waste heat from the cooling is not utilized.

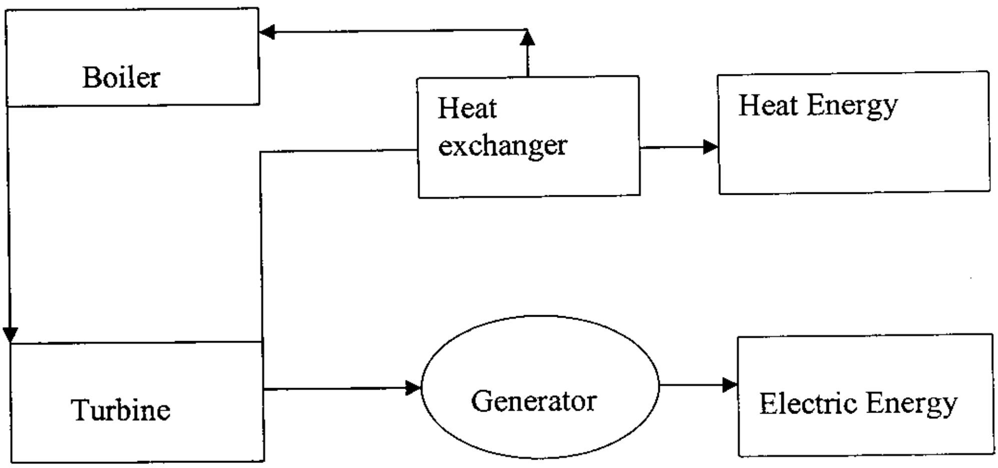


FIGURE -1.4 STEAM TURBINE SYSTEMS

1.2.5 Gas turbine systems

There are two groups of gas turbines on the market:

- Industrial gas turbines
- Aero-derivative gas turbines

Industrial gas turbines are designed for industrial applications, such as power generation and mechanical drive applications. Aero-derivative gas turbines are modified "gas generators" from aero engines, which have been connected to an industrial working turbine, with a generator.

A gas turbine cogeneration system includes a Heat Recovery Steam Generator (HRSG) in order to utilize the energy in the exhaust gas. The possible heat generation from gas turbines depends on the exhaust gas temperature. Aero-derivative gas turbines have typically high electrical efficiency and low exhaust temperature. Industrial gas turbines have typically higher exhaust temperature, which leads to relatively lower electrical efficiencies.

The moving grate or reciprocating grate is commonly used at capacities larger than 1-2 MW, but can be used even for lower capacity requirements. Since the fuel bed is mixed mechanically, moving grates are more fuel flexible than fixed grates. To minimize the risks like sintering of ash when fuels like straw and arable land residues, which contain high contents of ash, are combusted, a moving sloping grate is considered as the most optimal solution. Fuels with varying particle sizes also require a moving grate.

The most common fuels used in grate boilers are wood chips, but also mixtures of wood chips/peat, wood chips/shavings from saw-mills, briquettes. Residues from arable land are also sometimes used.

1.2.6 Flue Gas Cleaning

The most common equipment for removal of fly-ash are cyclones or multi-cyclones. The normal fly ash content after a cyclone is around 100 mg/m3 of flue gas. The prerequisites are better for dry fuel and a high degree of cleaning may be achieved with a good cyclone. Filters or precipitators provide high degree of purification but are expensive. Very low emissions of particles may be achieved by complementing the filters or precipitators with a flue gas condenser if this is possible (low temperature sink required). Implementing systems for achieving efficient combustion also contributes to reduce emissions significantly.

1.2.7 Solid Residues

Ash from biomass-fired boilers can be used as fertilizer. Rice husk can be sold to steel industries, generating additional revenue. This requires good combustion with relatively low unburnt carbon content in the ash. In fluidized bed combustion the ash is mixed with bed material, which must be considered as a possible use for ash. Extensive research has been performed in EU as regards the possible use of ashes and the possibility of recycling the ash back to forests or arable lands.

1.3 BAGASSE AS A FUEL

Cogeneration from sugarcane waste (bagasse) provides one of the best examples of renewable-based cogeneration yet it remains largely unexploited. The advantages of bagasse as a fuel for cogeneration are numerous, ranging from the environmental to the social and economic. Some advantages, such as increased security and diversity of supply or the furthering of aims of sustainable development even apply across these categories. The sugar industry is a major worldwide industry that currently faces many problems, as sugar prices are extremely volatile, with countries able to produce sugar most cheaply proving to be tough competition for those less able to do so. The sugar industry is also a large energy user. Most sugar mills already produce their own electricity to meet on-site needs, by burning bagasse or other fuels. This, however, is often not in cogeneration mode since, until very recently, there has been no incentive to produce electricity efficiently due to the unavailability of tariffs for electricity produced by IPPs and sold to the grid.

Much of the potential for energy generation has thus, so far, been wasted, as there was no requirement for it. With the introduction of biomass feed-in tariffs in countries such as Brazil and parts of India, there are now great opportunities for sugarcane-producing countries to learn from the best practices around the world. Until now, the potential for bagasse cogeneration has been largely un-quantified. This report was compiled to highlight the advantages and main issues of bagasse cogeneration and the potential it offers for electricity production.

Bagasse is the fibrous residue of cane stalk obtained after crushing and the extraction of juice. Each tones of sugarcane can yield 250kg of bagasse; the composition of bagasse varies with variety and maturity of sugarcane as well as with harvesting methods used and efficiency of the sugar mill in processing the sugarcane.

In the sugar industry, bagasse is usually combusted in furnaces to produce steam for power generation. It is also used as the raw material for production of paper and as feedstock for cattle. The value of bagasse as a fuel depends largely on its calorific value, which in turn is affected by its composition, especially with respect to water content and to the calorific value of the sugarcane crop, which depends mainly on its sucrose content. Every one-off sugar has an energy potential equivalent to those of 1.2 barrels of petroleum.

Bagasse cogeneration, especially in high-temperature and pressure configurations, could play an important role in encouraging much more efficient use of resources and ensuring widespread access to electricity services. Unfortunately, insufficient incentive to supply electricity to the grid because of low or inexistent buyback rates has meant that, until recently, around two thirds of harvested bagasse was wasted. This situation is now set to improve, with the introduction of more effective biomass feed-in tariffs in countries such as Brazil and India.

1.3.1 Economic Benefits of Using Bagasse

Benefits and advantages of bagasse cogeneration include:

- Increasing the viability of sugar mills
- Near-zero fuel costs, paid in local currency and valuation of bagasse as a waste product
- Increased fuel efficiency
- Increasing diversity and security of electricity supply
- Location at the point of energy demand, leading to minimal Transmission and distribution (T&D) costs.

Increasing the Viability of Sugar Mills

The long-term economic viability of sugar mills has become more vulnerable, mainly due to fiercely competitive domestic and global sugar markets the inherent energy inefficiency of design and operation as well as the industry's high energy requirements are also factors of growing importance. Appropriate remuneration of electricity from bagasse cogeneration would increase the added value to the alcohol and sugar sectors. This is especially valid as sugar-milling seasons often coincide with peak demand loads. In countries such as Brazil, where peak power can be up to ten times costlier that off-peak power, sugar mills can thus benefit immensely from the opportunity to sell electricity to the grid.

Fuel Costs

The capital costs of bagasse cogeneration plant are the lowest of all renewable forms of power generation, equal to those of biomass gasification projects, whilst generation costs, despite being higher than biomass gasification projects, small hydroelectric (HEP) and photovoltaic (PV), are on par with biomass power and lower than wind. Bagasse cogeneration projects also have short development periods, as the technologies used are proven and well established.

Diversity and Security of Supply

The use of a local fuel source guarantees a certain degree of security of energy supply, improving and increasing the trade balance with imported fuels. Onsite crop use ensures that delivery timeshare short and costs are kept low. Out of season, biomass co-firing with green wood or eucalyptus, for instance, is now possible in many cases, being factored into the design of new bagasse cogeneration plants. This enables bagasse cogeneration plants to operate beyond the crushing season for up to 300-330 days / year. The advantages of bagasse cogeneration in increasing security of power supply issues also include the capacity to generate during the dry season, when for example, HEP sites are not operational. Sugar mills that produce and export electricity also increase grid stability and reliability as well as decreasing the need for costly capital investments in grid upgrading in this area.

1.3.2 Social Benefits

The social benefits of onsite bagasse-fired cogeneration are:

- Greater employment for local populations
- More widespread availability of electricity
- More secure and reliable supply of electricity for existing consumers

Employment

Bagasse cogeneration has the potential to boost employment for neighboring populations, increasing income for farmers. It will also allow operational personnel to develop skills to use local equipment and technologies, improving the local socio-economy.

Availability of Electricity

As sugar mills tend to be located in rural areas, near sugarcane plantations, bagasse cogeneration will prove beneficial to local populations by contributing to expanding access to electricity supplies in areas otherwise distant from the grid. The advent of links to the network will facilitate the collection of electricity payments by electricity boards in rural areas whilst electricity boards will be able to better serve rural consumers through the upgrade of local and rural networks.

Quality of Electricity

The simultaneous increase in reliability and quality of power in the area will enhance quality of life whilst reducing voltage and frequency variation and the associated damages that these cause to network equipment. As it is a locally sourced fuel, bagasse will increase the reliability of electricity supply by diversifying sources and reducing fossil fuel dependence. This is particularly true of countries heavily dependent on HEP, such as Brazil, where bagasse cogeneration could reduce the risks of electricity shortages in dry years.

1.3.3 Environmental Benefits

As a biomass fuel, bagasse supplies a raw material for the production of natural, clean and renewable energy, enabling its use to further government targets for renewable energy use. In brief, the environmental advantages of bagasse cogeneration are:

- Low emission of particulates, SO2, NOx and CO2 compared to coal and other fossil fuels
- In GHG terms, bagasse combustion emits less than composting.
- Fuel efficiency.

Emissions

Bagasse combustion is environmentally friendly because it boasts low particulate and CO2 emissions. This is especially true where bagasse cogeneration replaces carbon-intensive fossil fuel generation. For instance, in India and China, bagasse could displace coal, which amongst other problems has very high levels of ash.

Combustion versus Composting

In terms of CO2 and other GHG, bagasse cogeneration would add no net emissions: bagasse is viewed as a waste product that needs to be disposed of – either by decomposition (composting) or combustion, both of which would release, as CO2, the carbon contained in bagasse.40 Besides, if the bagasse were to be composted, it would also release methane, a GHG 27 times more potent than CO2.41 These benefits will enable bagasse cogeneration to be a potentially significant player in international carbon credit markets in the future, with sugar industries reaping the social and financial benefits of the added revenues .

Fuel Efficiency

Cogeneration is a highly efficient energy conversion process. The same amount of bagasse will yield more power (heat as well as electricity) in cogeneration mode than in conventional combustion processes that do not recover heat. More efficient fuel uses can thus also further countries' sustainable development goals.

1.4 INTRODUCTION TO C.F.D

1.4.1 What is CFD

Computational Fluid Dynamics or simply CFD is concerned with obtaining numerical solution to fluid flow problems by using computers. The advent of high-speed and large-memory computers has enabled CFD to obtain solutions to many flow problems including those that are compressible or incompressible, laminar or turbulent, chemically reacting or non-reacting.

The equations governing the fluid flow problem are the continuity (conservation of mass), the Navier-Stokes (conservation of momentum), and the energy equations. These equations form a system of coupled non-linear partial differential equations (PDEs). Because of the non-linear terms in these PDEs, analytical methods can yield very few solutions. In general, closed form analytical solutions are possible only if these PDEs can be made linear, either because non-linear terms naturally drop out (e.g., fully developed flows in ducts and flows that are in viscose and irrotational everywhere) or because nonlinear terms are small compared to other terms so that they can be neglected (e.g., creeping flows, small amplitude sloshing of liquid etc.). If the non-linearity in the governing PDEs cannot be neglected, which is the situation for most engineering flows, and then numerical methods are needed to obtain solutions.

CFD is the art of replacing the deferential equation governing the Fluid Flow, with a set of algebraic equations (the process is called Discretisation), 1 which in turn can be solved with the aid of a digital computer to get an approximate solution. The well-known Discretisation methods used in CFD are Finite Deference Method (FDM), Finite Volume Method (FVM), Finite Element Method (FEM), and Boundary Element Method (BEM).

1.4.2 Governing Equations

The governing equations of fluid behavior are given in equations. These equations are given for compressible flow, but can be easily simplified for incompressible flow. In the Eulerian system, the particle derivative is described as follows

$$\frac{D}{Dt} = \frac{\partial}{\partial t} + \left(\overline{V}.\nabla\right) \qquad \text{----- (1.1)}$$

Where

$$\left(\overline{V}.\nabla\right) = d\overline{V} = \frac{\partial u}{\partial x} + \frac{\partial V}{\partial y} + \frac{\partial w}{\partial Z} \qquad \text{----- (1.2)}$$

This particle derivative will be used in the sections to follow to present the Navier-Stokes equations in conservative form.

Conservation of Mass

The equation for conservation of mass in conservative form is given as

$$\frac{\partial \rho}{\partial t} + \nabla . \left(\rho \overline{V}\right) \qquad \text{----- (1.3)}$$

Where ρ is the density and $\overline{V}$ is the vector velocity of the fluid.

Conservation of Momentum

The equations for conservation of momentum in the three Cartesian directions are presented.

$$\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial Z}$$
$$= \frac{\partial p}{\partial x} + \frac{\partial}{\partial x}\left(\lambda \nabla \overline{V} + 2\mu . \frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left[\mu\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)\right] + \frac{\partial}{\partial z}\left[\mu\left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}\right)\right] + \rho g_x$$

----- (1.4)

$$\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial Z}$$
$$= -\frac{\partial p}{\partial y} + \frac{\partial}{\partial y}\left(\lambda \nabla \overline{V} + 2\mu . \frac{\partial v}{\partial y}\right) + \frac{\partial}{\partial x}\left[\mu\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)\right] + \frac{\partial}{\partial z}\left[\mu\left(\frac{\partial w}{\partial y} + \frac{\partial v}{\partial z}\right)\right] + \rho g_y$$

$$\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho uw)}{\partial x}+\frac{\partial(\rho vw)}{\partial y}+\frac{\partial\left(\rho w^{2}\right)}{\partial Z}$$

$$=-\frac{\partial p}{\partial z}+\frac{\partial}{\partial x}\left[\mu\left(\frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}\right)\right]+\frac{\partial}{\partial y}\left[\mu\left(\frac{\partial w}{\partial x}+\frac{\partial v}{\partial z}\right)\right]+\frac{\partial}{\partial z}\left[\lambda\nabla.\overline{V}+2\mu\frac{\partial w}{\partial z}\right]+\rho g_{z}$$

----- (1.6)

These equations can be rewritten as a single vector equation using indicial notation:

$$\frac{D\rho\overline{V}}{Dt}=\rho\overline{g}-\Delta p+\frac{\partial}{\partial x_{j}}\left[\mu\left(\frac{\partial v}{\partial x_{j}}+\frac{\partial v_{j}}{\partial x_{i}}\right)+\delta_{ij}\lambda d\overline{V}\right] \quad \text{----- (1.7)}$$

The Energy Equation

The energy equation, which in essence is the first law of thermodynamics, is given in its most economic form as follows:

$$\rho\frac{D}{Dt}\left[e+\frac{p}{\rho}\right]-\frac{Dp}{Dt}+d\left(K\nabla T\right)+\tau_{ij}\frac{\partial u_{i}}{\partial x_{j}} \quad \text{----- (1.8)}$$

Where the viscous stresses are given by the stress tensor:

$$\tau_{ij}=\mu\left(\frac{\partial u_{i}}{\partial x_{j}}+\frac{\partial u_{j}}{\partial x_{i}}\right) \quad \text{----- (1.9)}$$

1.4.3 Program Structure

The figure 1.5 shows the programming structure of this part in detail

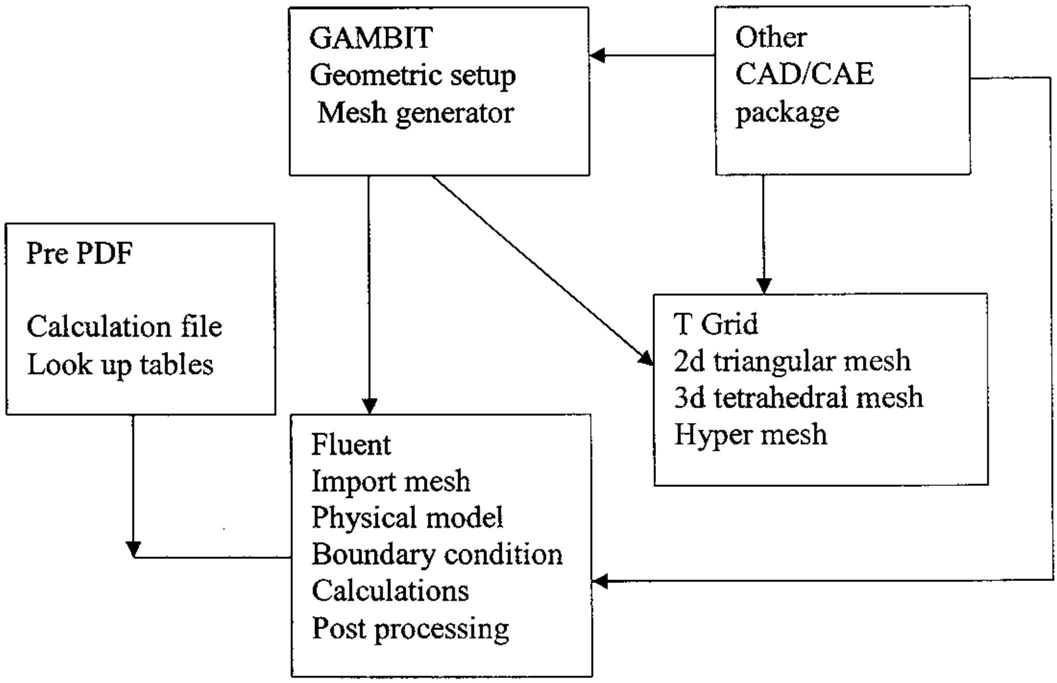


FIGURE-1.5 PROGRAM STRUCTURE

1.4.4 Applications of CFD

CFD is interdisciplinary cutting across fields of aerospace, mechanical, civil, chemical, electrical engineering as well as physics and chemistry. CFD has been widely used in industry in the past decade. It is certainly fun for fluids enthusiasts, but where exactly can CFD be applied - the following are areas of applications of CFD to date.

- Automobile and Engine
- Aerodynamics, Engines, Turbochargers, Intake/Exhaust Heating/Cooling
- Systems, Brakes etc.
- Industrial Manufacturing
- Aerospace, Aerodynamics. Gas Turbines, Rockets etc.
- Mechanical
- Pumps, Compressors, Heat Exchangers, Furnaces, Nuclear Reactors etc.
- Chemical Mixers (multiphase), Chemical Reactors, Separators, Boilers,

- Weather prediction, River and Tidal flows, Wind and Water-borne pollution,
- Fire and Smoke spread, Wind loading etc.
- Physiological
- Cardiovascular flows (Heart, major vessels), Flow in Lungs and breathing Passages etc.
- Naval Architecture, ship building etc.
- Others Glass, Steel and Textile manufacturing, Food processing etc.

1.4.5 Uses of CFD

The result of CFD analysis is relevant engineering data used in – conceptual Studies of new designs, detailed product development, trouble shooting, Redesign etc., Knowing how fluids will flow, and what will be their quantitative effects on the solids with which they are in contact, assists:-

- Building-services engineers and architects to provide comfortable and safe human environments.
- Power-plant designers to attain maximum efficiency, and reduce release of Pollutants.
- Chemical engineers to maximize the yields from their reactors and processing equipment
- Land-, air- and marine-vehicle designers to achieve maximum performance, at least cost.

1.4.6 Procedure of Using Software

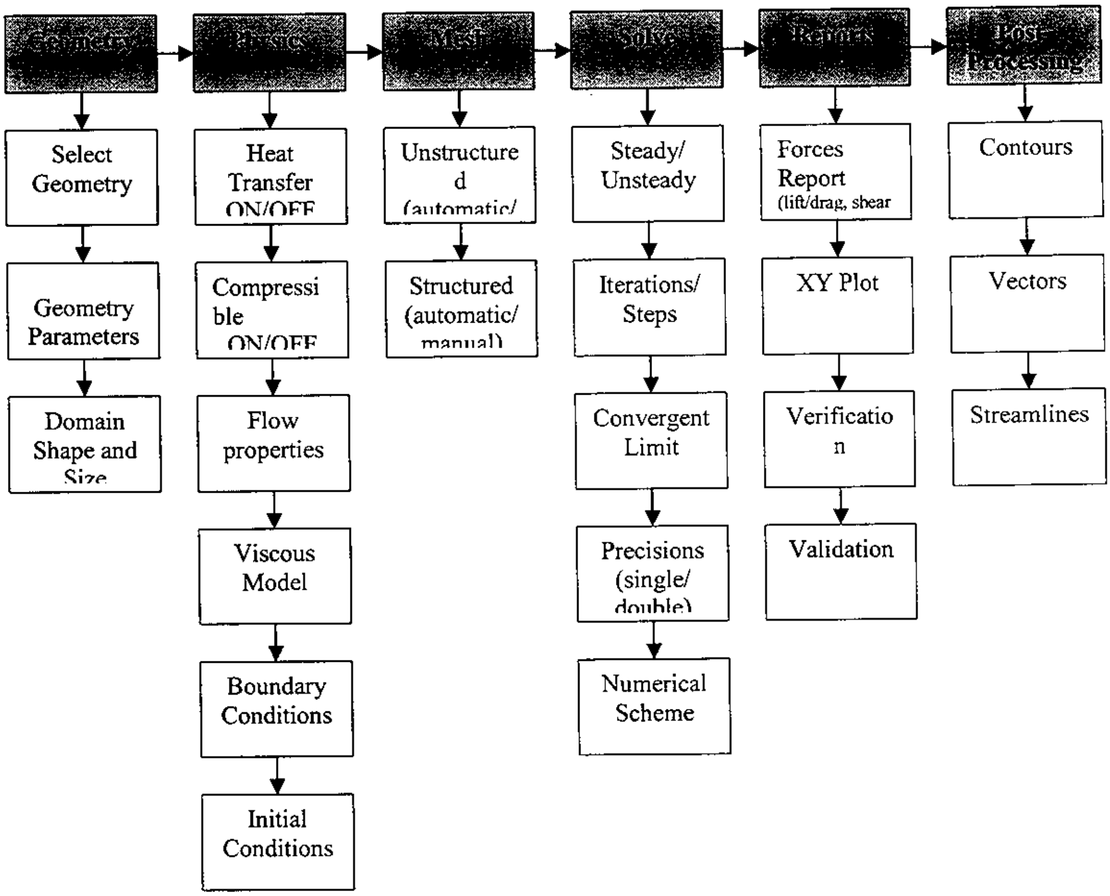


FIGURE-1.6 PROCEDURE OF USING SOFTWARE

Once you have determined the important features of the problem you want to solve, you will follow the basic procedural steps shown in figure 1.6.

- Create the model geometry and grid.
- Start the appropriate solver for 2D or 3D modeling.
- Import the grid.
- Check the grid.
- Select the solver formulation.
- Choose the basic equations to be solved: laminar or turbulent (or in viscid), chemical species or reaction, heat transfer models, etc. Identify additional models needed: fans, heat exchangers, porous.
- Specify the boundary conditions.
- Adjust the solution control parameters.

- Calculate a solution.
- Examine the results.
- Save the results.
- If necessary, renew the grid or consider revisions to the numerical or physical model.

1.4.7 CFD Prediction

CFD uses a computer to solve the relevant science-based mathematical equations Its components are: the human being who states the problem, scientific knowledge expressed mathematically, the computer code (ie software) which embodies this knowledge and expresses the stated problem in scientific terms, the computer hardware which performs the calculations dictated by the software, the human being who inspects and interprets their results.

CFD-based predictions are never 100%-reliable, because the input data may involve too much guesswork or imprecision the available computer power may be too all for high numerical accuracy the scientific knowledge base may be inadequate.

The reliability is greater:

- For laminar flows rather than turbulent ones
- For single-phase flows rather than multi-phase flows
- For chemically-inert rather than chemically-reactive materials
- For single chemical reactions rather than multiple ones
- For simple fluids rather than those of complex composition

CHAPTER 2

LITERATURE SURVEY

Sims E.H (2002), The Author says that the "Cogeneration", also known as "Combined Heat and Power" (CHP), system is The simultaneous generation of two useful forms of energy (such as power and heat) from the same plant using one single primary energy source In general, the heat generated for the process is a by-product of thermal power generation systems, where the primary source of fuel is biomass and fossil fuels. The amount of generated heat is dependent on the power generation process. The usefulness of the heat, defined as process steam, hot water or hot air, is dependent on the actual heat quality requirements in the system being served by the cogeneration plant. The temperature mainly defines the quality of the heat. Low heat temperature requirements will increase the amount of usable heat from the cogeneration system. Heat can be used for different types of heating purposes in industrial processes, residential heating and also for cooling processes.

Ayhan Demirbas (2003), In this paper the Biomass energy is one of humanity's earliest sources of energy particularly in rural areas where it is often the only accessible and affordable source of energy. Worldwide biomass ranks fourth as an energy resource, providing approximately 14% of the world's energy needs all human and industrial processes produce wastes, that is, normally unused and undesirable products of a specific process. Generation and recovery of solid wastes varies dramatically from country to country and deserves special mention. The burning velocity of pulverized biomass fuels is considerably higher than that of coals. The use of biomass fuels provides substantial benefits as far as the environment is concerned. Biomass absorbs carbon dioxide during growth, and emits it during combustion. Utilization of biomass as fuel for power production offers the advantage of a renewable and CO2-neutral fuel. Although the structural, proximate and ultimate analyses results of biomass and wastes differ considerably, some properties of the biomass samples such as the hydrogen content, the sulfur content and the ignition temperatures changed in a narrow interval.

Mozambique (2004), Cogeneration from sugarcane waste (bagasse) provides one of the best examples of renewable-based cogeneration yet it remains largely unexploited. The advantages of bagasse as a fuel for cogeneration are numerous, ranging from the environmental to the social and economic. Some advantages, such as increased security and diversity of supply or the furthering of aims of sustainable development even apply across these categories. The sugar industry is a major worldwide industry that currently faces many problems, as sugar prices are extremely volatile, with countries able to produce sugar most cheaply proving to be tough competition for those less able to do so. The sugar industry is also a large energy user. Most sugar mills already produce their own electricity to meet on-site needs, by burning bagasse or other fuels. This, however, is often not in cogeneration mode since, until very recently, there has been no incentive to produce electricity efficiently due to the unavailability of tariffs for electricity produced by IPPs and sold to the grid. Much of the potential for energy generation has thus, so far, been wasted, as there was no equirement for it. With the introduction of biomass feed-in tariffs in countries such as Brazil and parts of India, there are now great opportunities for sugarcane-producing countries to learn from the best practices around the world.

Michael Brown (2004), the economic development potential of bagasse cogeneration should not be under-estimated. Most cane producing countries are poor or extremely poor, with high unemployment and low rates of access to electricity supplies. If the measures recommended in this report can be implemented, there is substantial scope for the technology to accelerate social and economic development in some of the world's poorest regions. The amount of energy that can be extracted from bagasse is largely dependent on two main criteria: moisture content and the technology used for energy production. The output of electricity from bagasse cogeneration plants is fundamentally dependent on the prevailing electricity market rules – inadequate buyback prices paid to mill owners by the utility company create a substantial disincentive to size cogeneration plants to meet mill heat demand. Conversely, higher rates can incentivise owners to upgrade their energy facilities to enable maximum onsite efficiency. This is the key to enabling the potential for bagasse-based cogeneration to be achieved.

Renouf .M (2005), this paper presents the findings of a preliminary life-cycle assessment (LCA) of electricity generated from the combustion of sugarcane bagasse in Queensland sugar mills. The aim of the study was to determine if bagasse-derived electricity provides any environmental benefits over the existing dominant source of electricity in Queensland (electricity derived from black coal) .The study arose from the identification of the need for environmental information and methodologies for comparing energy alternatives on environmental grounds to provide guidance to a developing renewable energy market in Queensland and to substantiate 'green energy' claims. Results were generated using both an economic allocation method and a system expansion method. The results provided different results, highlighting the affect that methodology can have on the outcomes of a LCA study.

Ballester . J (2005), three p.f. Flames have been studied in a semi-industrial furnace, using different fuels: a bituminous coal, a lignite, and a biomass (oak sawdust). The operating conditions were exactly the same for the two coals, and verisimilar to those for the biomass flame. The objective of the study was to evaluate the impact of differences in fuel composition on flame characteristics, through measurement of the spatial distribution of the main parameters: temperature and concentrations of O2, CO, NO*x*, un burnt hydrocarbons, and N2O. The higher volatiles contenting the lignite lead to higher temperatures and more intense combustion than the bituminous coal. Nevertheless, as might be expected. The much higher volatiles content of the wood results in a more intense flame close to the burner, as indicated by visual observations and by concentrations of un burnt gases (CO and un burnt hydrocarbons) in that zone. It is remarkable that the combustion zone extends further for the biomass; while un burnt species were very low for the coals at an axial distance of 1 m, high values were detected for the pulverized oak. The measurements suggest that two stages can be distinguished in the biomass flame: a zone of intense combustion close to the burner, followed by a second region where the large biomass particles gradually devolatilize and are consumed.

CHAPTER 3

COMPUTATIONAL ANALYSIS

3.1 ANALYSIS OF BAGASSE PROPERTIES

Normally, the proximate analysis of air-dried bagasse is reported as follows .An air-dried bagasse sample is one, which is exposed to the atmosphere of a laboratory to bring it in equilibrium with the humidity conditions of the laboratory so that the sample does not gain or lose weight during analysis.

- **Moisture**

  Water expelled in its various forms when tested under specific conditions.

- **Volatile matter (VM)**

  Total loss in weight minus the moisture in bagasse when bagasse is heated in various conditions.

- **Mineral matter**

  Inorganic residue left over when bagasse is incinerated in air to constant eight under specified conditions. It is ordinarily referred to as ash.

- **Fixed Carbon (FC)**

  Obtained by subtracting from 100, the sum of the percentages by weight of moisture, VM and mineral matter. Ordinarily, percentage sulphur (by weight) does not form a part of the proximate analysis. However, due to harmful effects of sulphur dioxide and sulphur trioxide produced by burning sulphur to the environment, percentage sulphur (by weight) is also included when only proximate analysis is to be specified.

3.1.1 Tests for Proximate Analysis

The general procedures for the analysis is relating to proximate analysis is described below .For full details, the original standard may be referred to as shown in table 3.1 and table 3.2

- **Moisture**

  The moisture in the sample is determined by drying the known weight of the bagasse at 381 K ± 2 K (108°C ± 2 C).

- **Volatile Matter**

The method for the determination of VM consists of heating a Weighed quantity of air-dried sample at a temperature of 173K ± 10 K (900°C ± 10°C) for a period of seven minutes.

- **Mineral Matter (Ash)**

In this determination, the sample is heated in air up to 773 K (500°C) for 30 min, from 773 K to 1088 K (500°C to 815°C) for a further 30 to 60 min and maintained at this temperature Until the sample weight becomes Constant.

- **FC**

As explained earlier, FC is determined by deducting the moisture, VM and mineral matter (as weight %) from 100.The Bagasse is burnt in a sugar factory as in following composition.

TABLE 3.1 PROXIMATE ANALYSIS (WT. %) OF BAGASSE

Moisture	52.0%
Volatile matter	40.2%
Fixed carbon	6.1%
Ash	1.7%

TABLE 3.2 ULTIMATE ANALYSIS (WT. %) OF BAGASSE

Carbon	23.4%
Hydrogen (net)	2.8%
Sulphur	Traces
Nitrogen	Traces
Oxygen	20.1%
Moisture	52.0%
Ash	1.7%

3.2 MASS FLOW RATE

3.2.1 Stoichiometric Combustion Equation

$$\left[C_1H_{1.4973}\ O_{0.6395}\ + xO_2 + yN_2 * 3.76\ = aCO_2 + bH_2O + yN_2\right]$$

x = 1.054, y = 1.0545

$$C_1H_{1.4973}\ O_{0.6395}\ + 1.0545\ (O_2 + 3.76\ N_2) = CO_2 + 0.74865\ H_2O + 3.965\ N_2$$

Fuel Weight

C = 1 * 12 = 12

H = 1.4973 * 1 = 1.4973

O = 0.6395 * 16 = 10.232

Fuel = 23.72 units

Oxidizer Weight

O2 = 2.109 * 16 = 33.744

N2 = 55.5

Oxidizer = 89.244 units

Where,

C → Atomic weight of Carbon

H → Atomic weight of Hydrogen

O → Atomic weight of Oxygen

N → Atomic weight of Nitrogen

Where,

x = amount of oxygen needed for complete combustion

y = amount of nitrogen present in air supply

a = amount of carbon dioxide formed

b = amount of water vapor formed

Atomic wt of carbon = 12

Atomic wt of oxygen = 16

Atomic wt of hydrogen =1

Air - fuel ratio = 89.244/23.72 = 3.76: 1

Thus, air required for complete combustion of 1 kg of bagasse = 3.76 kg

2.2.2 Air Distribution for Bagasse Flow

TABLE 3.3 AIR DISTRIBUTION FOR BAGASSE FLOW

60% through	Under grate.
35% through	Tangential Nozzle
5% through	Bagasse spreaders or Distributors or Air Spreaders each under each Bagasse feeder

$$\mathbf{m = \rho \times A \times V}$$

Details from SSL

Where,

m is the mass flow rate of air in kg/s,

ρ is the density if air in kg/m^3,

A is the area of inlet port in m^2,

V is the velocity if air in m/s.

Total air flow rate = 150 tons/hr = 42 kg/s(base case)

Under grate – Air velocity

Length of under grate = 7595 mm

Breath of under grate = 5613 mm

Area of under grate, A = 5613 x 7595 = 42.6×10^6 mm^2

= 42.6 m^2

Density of air, ρ = 0.8 kg/m^3 at 469 K

Mass flow rate of air, m = 26 kg/s

→ m = ρ x A x V

26 = 0.8 x 42.6 x V

Velocity of air, V = 0.76 m/s

Nozzle Air

Length of the nozzle = 839 mm

Breadth of the nozzle = 254 mm

Area of one nozzle, A = 839 x 254 = 0.213 x 10^6 mm^2

= 0.213 m^2

Density of air, ρ = 0.8 kg/m^3 at 496 K

Mass flow rate of air, m = 15 kg/s = 15/4 = 3.75 kg/s

→ m = ρ x A x V = 3.75 = 0.8 x 0.213 x V

Velocity of air, v = 22 m/s of air at one nozzle

Spreader Air

Length of the spreader = 451 mm

Breadth of the spreader = 30 mm

Area of one spreader, A = 451 x 30 = 0.0135 x 10^6 mm^2 = 0.0135 m^2

Density of air, ρ = 0.8 kg/m^3 at 469 K

Mass flow rate of air, m = 2 kg/s = 2/5 = 0.4 kg/s at one spreader

→ m = ρ x A x V

0.4 = 0.8 x 0.0135 x V

Velocity of air, V = 37 m/s

3.3 ADIABATIC FLAME TEMPERATURE

Consider a combustion process that takes place adiabatically and with no work or changes in kinetic or potential energy. For such a process the temperature of product is referred to as Adiabatic Flame Temperature (AFT).This is the maximum temperature that can be achieved for the given reactants, because any heat transfer from reacting substances and any incomplete combustion would tend to lower the temperature of product. The AFT t_f can be controlled with the amount of excess gases that is used. AFT is ideal theoretical maximum temperature that can be obtained from given fuel and air mixture.

TABLE 3.4 HEAT CAPACITY EQUATION CONSTANTS FOR FLUE GAS OF BAGASSE FIRED BOILER

Heat capacity constant	Component				
	CO_2	O_2	N_2	H_2O	Total
N_i,Kmol	1.95	0.61	9.89	4.551	17.001
$(n_i.a_i)1$*	41.662	15.875	292.751	154.338	504.626
$(n_i.a_i)2$*	72.489	11.224	307.759	114.496	505.988
$(n_i.b_i)1*10^3$	125.354	7.171	-54.657	-13.719	64.149
$(n_i.b_i)2*10^3$	45.312	13.248	31.617	98.853	187.03
$(n_i.c_i)1*10^3$	-80.051	-1.430	137.059	69.166	124.744
$(n_i.c_i)2*10^3$	-14.389	-5.066	-4.007	-24.302	-47.764
$(n_i.d_i)1*10^3$	19.113	0.342	-52.173	-22.103	-54.821
$(n_i.d_i)2*10^3$	1.602	0.705	0.023	2.196	4.526

*1 & 2 refers to heat capacity data for temperature ranges 298-1500K and 1500-4000K

3.3.1 Calculation of Adiabatic Flame Temperature

T_a = 298k and

T = adiabatic flame temperature

Enthalpy of flue gas up to 1500K,

$H'_1 = 504.626 * (1500\text{-}298) + 64.149 * 10^{-3} (1500^2\text{-}298^2)/2$

$+ 124.744 * 10^{-6} * (1500^3\text{-}298^3)/3 - 54.821 * 10^{-9} * (1500^4\text{-}298^4)/4$

$= 606560 + 69319 + 139237 - 69275 = 745341$ kJ

Enthalpy of flue gas above 1500k,

$H'_2 = Q - H_1 = 851440 - 7458410 = 105559$ kJ

$=505.988 * (T\text{-}1500) + 187.03 * 10^{-3} * (T^2 - 1500^2)/2$

$-47.764 * 10^{-6} (T^3-1500^3)/3 + 4.526 * 10^{-9} * (T^4 - 1500^4)/4$

$= 505.988T + 93.515 * 10^{-3} T^2 - 15.921 * 10^{-6} T^3 + 1.132 * 10^{-9} T^4 - 921384$

$1.132 * 10^{-9} T^4 - 15.921 * 10^{-6} T^3 + 505.988 T$

$= 1026943$ kJ

Thus from the above equation we can find the value of T (Adiabatic Flame Temperature)

Adiabatic Flame Temperature of Bagasse T = 1650.8K (1377.8°C)

3.4 THERMO GRAVIMETRIC ANALYSIS

3.4.1 Introduction

Thermo gravimetric is one of the oldest thermal analytical procedures and has been used extensively in the study of polymeric systems. The technique involves monitoring the weight loss of the sample in a chosen atmosphere (usually nitrogen or air) as a function of temperature. The usefulness of TGA for analyzing complex systems such as rubber vulcanisates was greatly enhanced by the introduction of the ability to record simultaneously the first derivative of the weight loss. This is sometimes referred to as derivative thermo gravimetric analysis (DTA).

Thermo gravimetric analysis (TGA) is based on the measurement of the weight loss of the material as a function of temperature. TGA 2950 operates on a null-balance principle, using an electromechanical transducer coupled to a taut-band suspension system. The sensitivity of the balance is 0.1 mg. TGA curve provides information concerning the thermal stability of the initial sample, intermediate compounds that may be formed and of the residue if any. In addition to thermal stability, the weight losses observed in TGA can be quantified to predict the pathway of degradation or to obtain compositional information. The ability to vary atmosphere during the TGA evaluation, particularly from an inert to a reactive gas, provides additional information about a material composition and its stability. Our Simultaneous SDT 2960 analyzer can utilize the unique capability to perform TGA measurements concurrent with differential thermal analysis on the same sample. The experimental data offer more sophisticated understanding of reactions occurring at materials heating. SDT also provides evaluation of materials up to 1500°C. This ability to obtain measurements at higher temperatures is most useful for inorganic materials such as cements, clays, ceramics, superconductors and metals.

3.4.2 Use of TGA

It is a popular technique for the evaluation of the thermal decomposition kinetics of materials, e.g., polymers, rubbers and hence provides information on thermal stability and shelf life. However, it is probably best known for its ability to provide information on the bulk composition of compounds. The simultaneous TG/DTA system can be used for such applications as oxidation, heat resistance, and the amount of water, compositional analysis and the measurement of ash content in a sample.

3.4.3 Significance of TGA

From the below graph we can predict the rate of change mass of the bagasse particle on combustion.

Figure 3.1 is taken for 50% moisture level, which completely gets combusted in 499 C.

Figure 3.2 is taken for 53% moisture level, which completely gets combusted in 490 C.

Figure 3.3 is taken for 48% moisture level, which completely gets combusted in 516 C.

Thus this signifies that it is optimum to use bagasse of moisture 48%, which gives higher temperature.

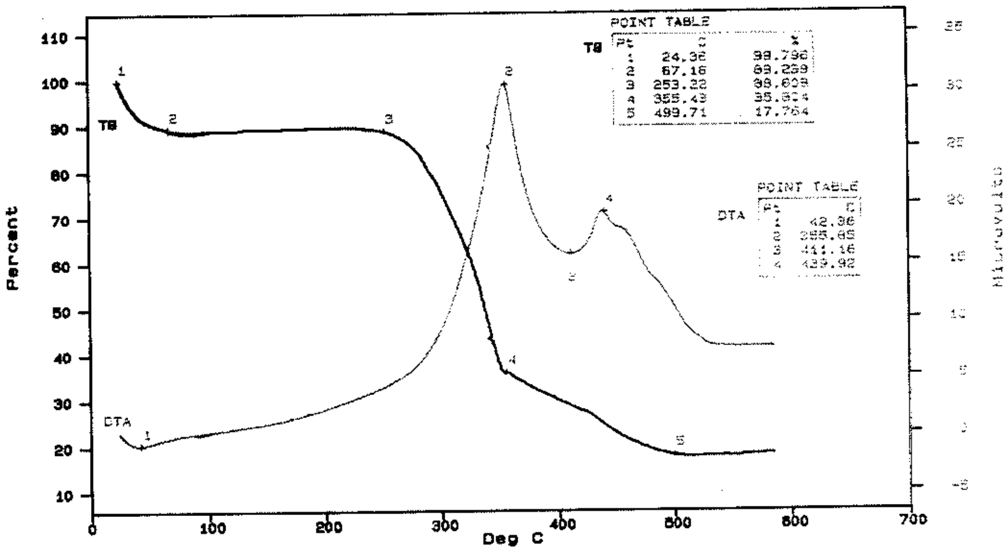


FIGURE-3.1 MOISTURE CONTENT 50%

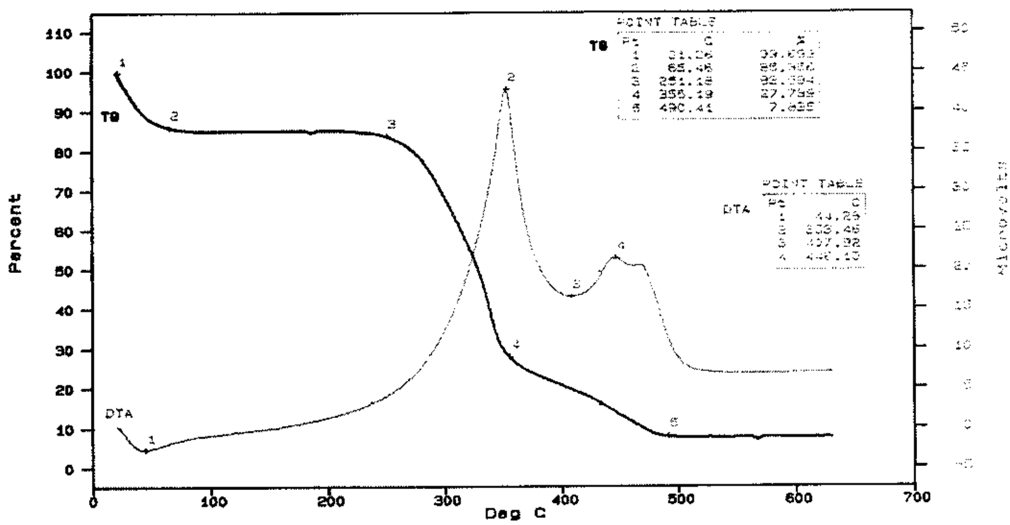


FIGURE-3.2 MOISTURE CONTENT 53%

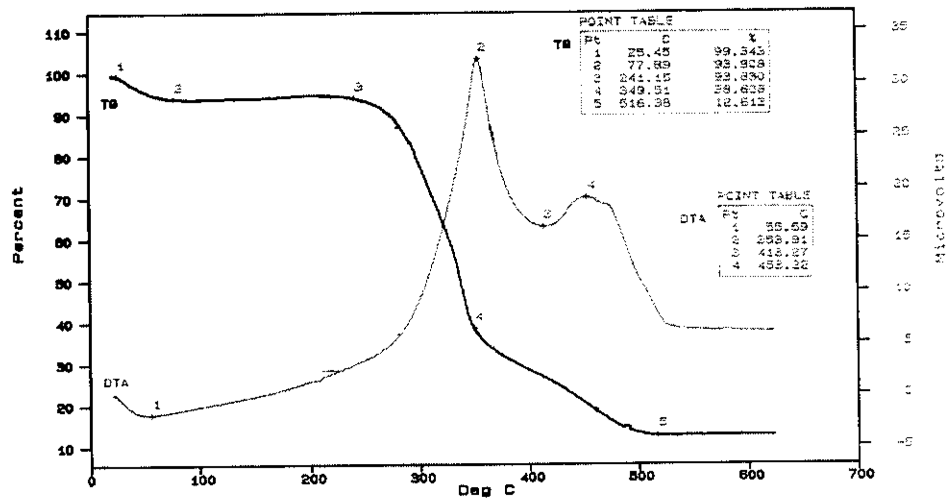


FIGURE-3.3 MOISTURE CONTENT 48%

3.5 CALORIFIC VALUES OF FUELS

3.5.1 Introduction

The calorific value of a fuel is nothing but the heat of combustion of the fuel. It is defined as the total heat produced when a unit mass of fuel is completely burnt with pure oxygen. It is expressed in kJ/kg for solid and liquid fuels and kJ/m^3 for gases. It is also said to be the heating value of the fuel. As discussed earlier, when a fuel is burnt, hydrogen combines with oxygen and gets converted into water. When water vapour is present in the flue gases, the latent heat of the vaporization is lost. Hence this quantity of heat is not available for any useful Purpose.

3.5.2 Types of Calorific Value

Fuels that contain hydrogen have two types of calorific value of fuels. They are:

- Higher Calorific Value of fuels (HCV) and
- Lower Calorific Value of fuels (LCV)

3.5.2.1 Higher Calorific Value (HCV)

The 'higher or gross calorific value' of the fuel is one indicated by a constant - volume calorimeter in which the steam is condensed and the heat of vapor is recovered.

3.5.2.2 Lower Calorific Value (LCV)

The lower or net calorific value is obtained by subtracting latent heat of water vapor from gross calorific value. In other words the relation between lower calorific value (HCV) and higher calorific value (LCV) can be expressed in the following way.

$$LCV = (HCV - 2465\, m_w)$$

Where m_w is the mass of water vapor produced by combustion of 1 kg of fuel and 2465 kJ/kg is the latent heat corresponding to standard temperature (saturation) of 15°C.

In MKS units

$$LCV = (HCV - 588.76\, m_w)$$

Where m_w is the mass of water vapor produced by combustion of 1 kg of fuel and 588.76 is the latent heat value in kcal as read from steam tables for 1 kg of water vapor.

The table 3.5 and figure 3.4 shows the calorific value at different moisture content

TABLE 3.5 CALORIFIC VALUE OF BAGASSE AT DIFFERENT MOISTURE CONTENT

Moisture %	Calorific value cal/g
8	4237.16
34	2885.17
40	2421.635
48	2536.667
51	2449.634
70	2132

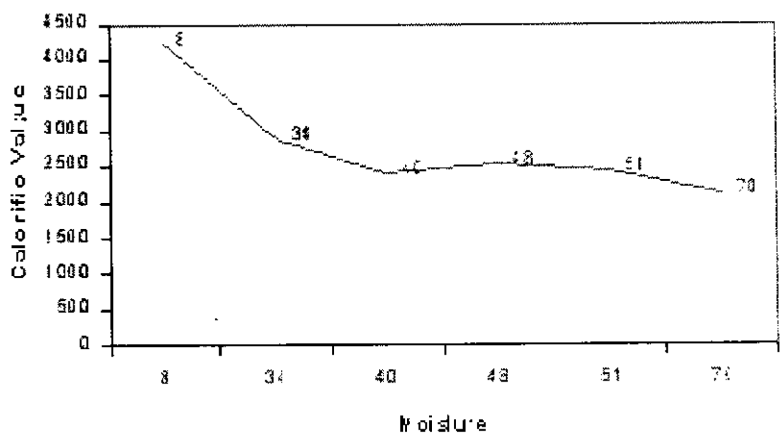


FIGURE - 3.4 MOISTURE VS CALORIC VALUE

3.6 COMPUTATIONAL FLUID DYNAMICS

Procedure for solving the non-premixed combustion problem

3.6.1 Gambit

It is a pre-processor with which the Furnace is built, meshed and boundary condition are specified

- Open Gambit software
- Build the model

Mesh the Furnace Model shown in figure 3.5 using tetrahedral type Mesh with fine node value (200mm per node)

Define the boundary conditions

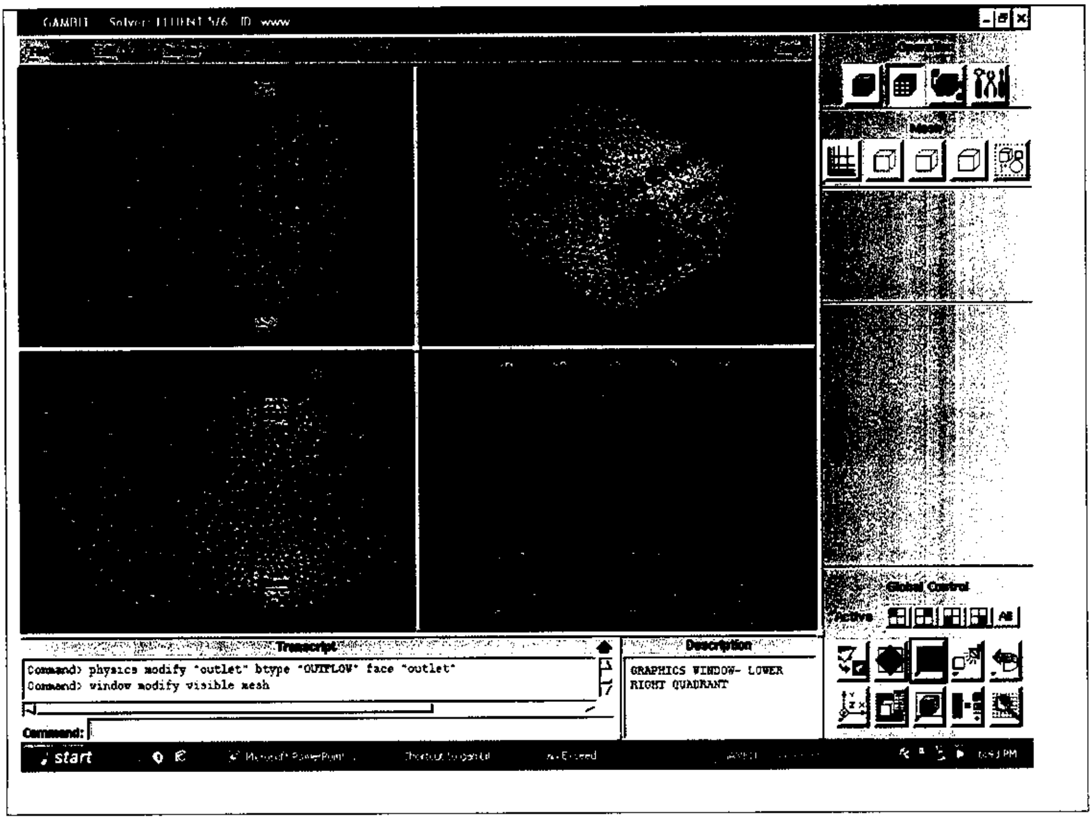


FIGURE – 3.5 MESHED FURNACE

3.6.2 Using Flow Boundary Conditions

This section provides an overview of flow boundaries in **FLUENT** and how to use them. **FLUENT** provides 10 types of boundary zone types for the specification of flow inlets and exits: velocity inlet, pressure inlet, mass flow inlet, pressure outlet, pressure far-field, outflow, inlet vent, intake fan, outlet vent, and exhaust fan.

The inlet and exit boundary condition options in **FLUENT** are as follows are explained and shown in table 3.6 .

Velocity inlet

Boundary conditions are used to define the velocity and scalar properties of the flow at inlet boundaries.

Pressure inlet

Boundary conditions are used to define the total pressure and other scalar quantities at flow inlets.

Mass flows inlet

Boundary conditions are used in compressible flows to prescribe a mass flow rate at an inlet. It is not necessary to use mass flow inlets in incompressible flows because when density is constant, velocity inlet boundary conditions will fix the mass flow.

Pressure outlet

Boundary conditions are used to define the static pressure at flow outlets (and also other scalar variables, in case of backflow). The use of a pressure outlet boundary condition instead of an outflow condition often results in a better rate of convergence when backflow occurs during iteration.

Outflow

Boundary conditions are used to model flow exits where the details of the flow velocity and pressure are not known prior to solution of the flow problem. They are appropriate where the exit flow is close to a fully developed condition, as the outflow boundary condition assumes a zero normal gradient for all flow variables except pressure. They are not appropriate for compressible flow calculations.

Inlet vent

Boundary conditions are used to model an inlet vent with a specified loss coefficient, flow direction, and ambient (inlet) total pressure and temperature.

Intake fan

Boundary conditions are used to model an external intake fan with a specified pressure jump, flow direction, and ambient (intake) total pressure and temperature.

Outlet vent

Boundary conditions are used to model an outlet vent with a specified loss coefficient and ambient (discharge) static pressure and temperature.

Exhaust fan

Boundary conditions are used to model an external exhaust fan with a specified pressure jump and ambient (discharge) static pressure.

TABLE 3.6 BOUNDARY CONDITION SPECIFIED

Boundary condition	**Boundary type**	**Number of Ports**
Under grate Inlet	Velocity Inlet	1
Bagasse Inlet	Velocity Inlet, Injections	5
Spreader Air	Velocity Inlet	5
Tangential air window	Velocity Inlet	4
Outlet	Outflow	1
Default Interior	Mixture	1

Outflow

No pressure or velocity information is required. Data at exit plane is extrapolated from interior and Mass balance correction is applied at boundary. Flow exiting Outflow boundary exhibits zero normal diffusive flux for all flow variables. Appropriate where exit flow is close to fully developed condition. Intended for incompressible flows, Cannot be used with a Pressure Inlet; must use velocity inlet. Combination does not uniquely set pressure gradient over whole domain. Cannot be used for unsteady flows with variable density.

Poor rate of convergence when back flow occurs during iteration. Cannot be used if back flow is expected in final solution as shown in figure 3.6 .

- Solver Fluent5/6 is incorporated.
- Save the file in .dbs format
- Export the Mesh File and save it as .msh format
- Close the Gambit File

Fluent Solving Steps

File →Read →Case → (Furnace.msh)

Grid → Check

Grid → Info → Size

Grid → Scale → Change the Units according to the usage

Thus we get 22990 Nodes

Now the model is ready for specifying its input values

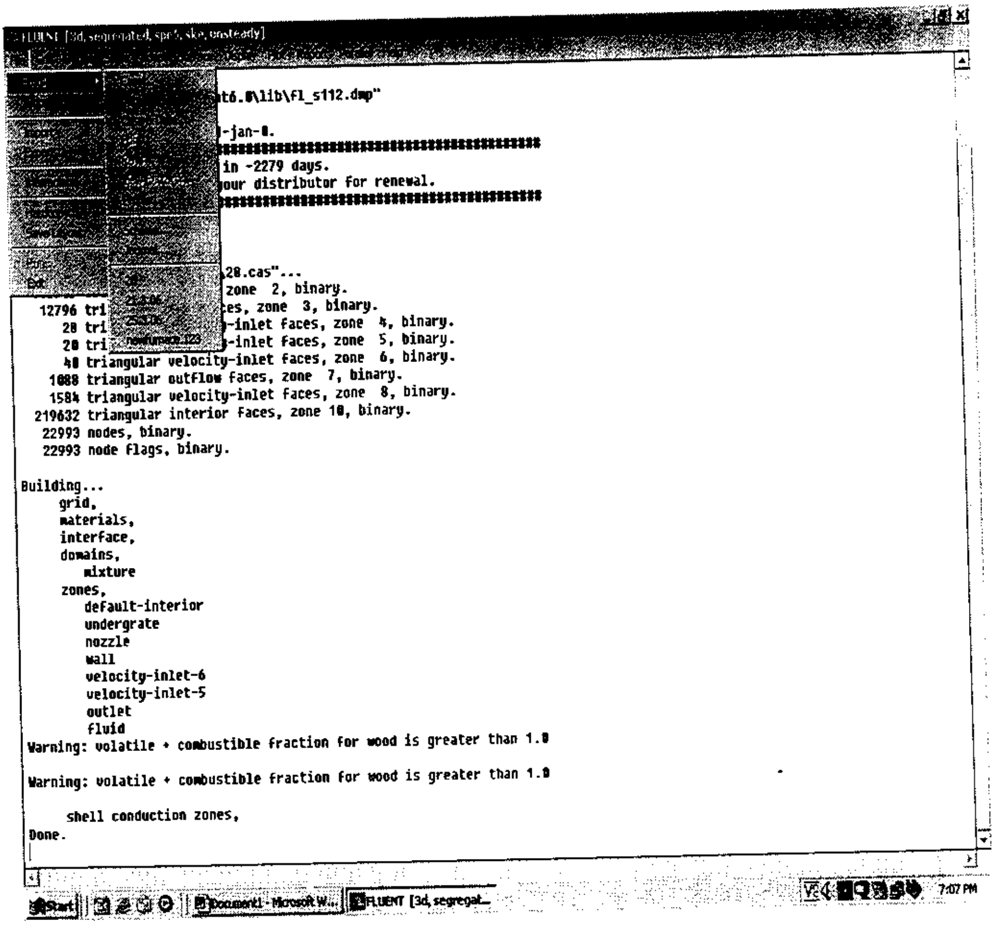


FIGURE-3.6 READING CASE FILE

3.6.3 Define Various Input Parameters

Define → Models → Solver Type → Segregated

3.6.3.1 Choosing a Solver

Choices are Coupled-Implicit, Coupled-Explicit, or Segregated (Implicit) The Coupled solvers are recommended if a strong inter-dependence exists between density, energy, momentum, and/or species as shown in figure 3.7

e.g., high speed compressible flow or finite-rate reaction modeled flows.

In general, the Coupled-Implicit solver is recommended over the coupled-explicit solver. Time required implicit solver runs roughly twice as fast. Memory equired: Implicit solver requires roughly twice as much memory as coupled-explicit or segregated-implicit solvers!

The Coupled-Explicit solver should only be used for unsteady flows when the characteristic time scale of problem is on same order as that of the acoustics. e.g., tracking transient shock wave

The Segregated (implicit) solver is preferred in all other cases. Lower memory requirements than coupled-implicit solver.

Segregated solver

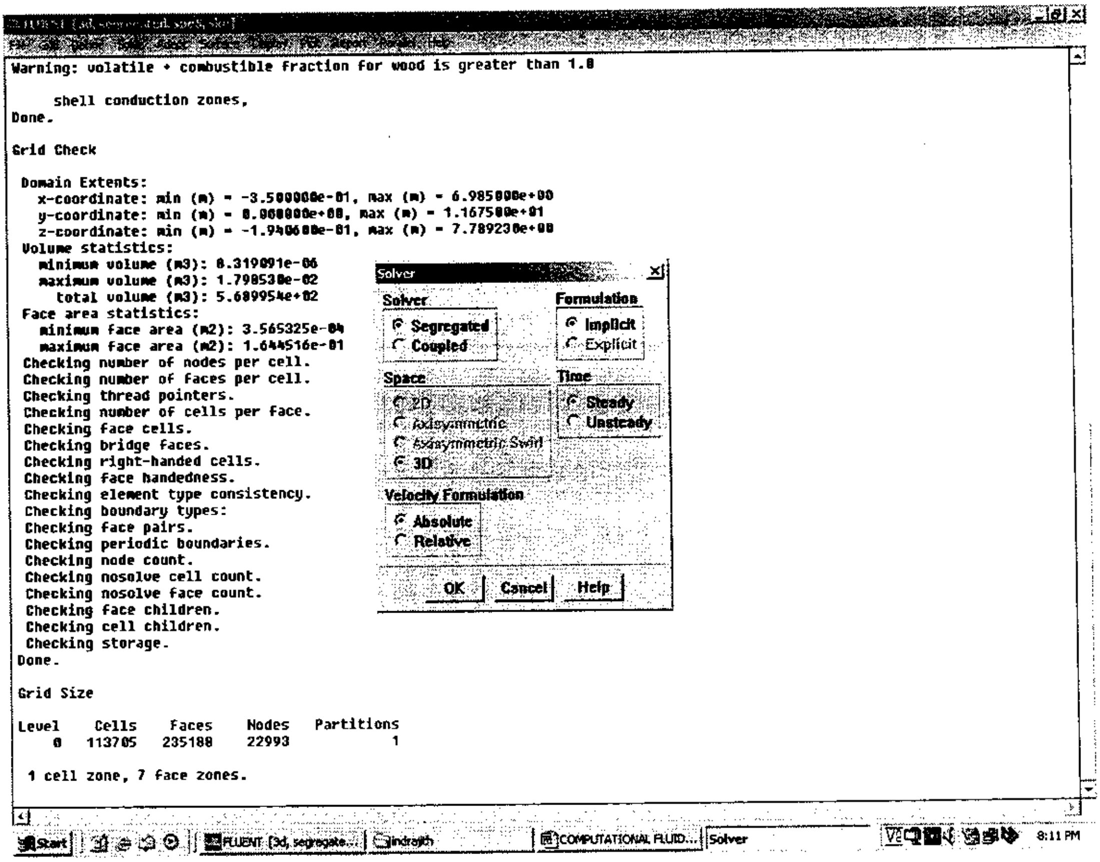


FIGURE – 3.7 SEGREGATED SOLVER

Viscosity

Define → Viscosity (We choose K-epsilon model)

3.6.4 The Standard k- € Model

Is a semi-empirical model based shown below in figure 3.8on model transport equations for the turbulence kinetic energy (k) and its dissipation rate (€). The model transport equation for k is derived from the exact equation, while the model transport equation for €was obtained using physical reasoning and bears little resemblance to its mathematically exact counterpart. In the derivation of the k- €model, it was assumed that the flow is fully turbulent, and the effects of molecular viscosity are negligible. The standard k- €model is therefore valid only for fully turbulent flows.

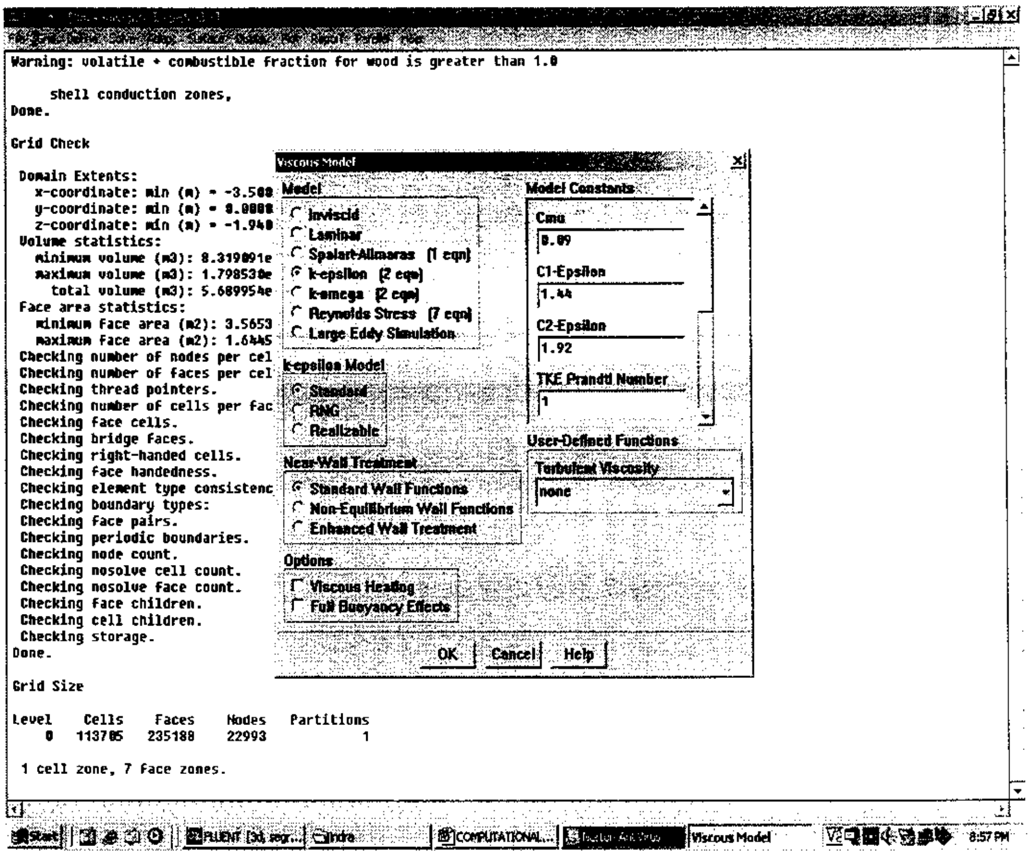


FIGURE – 3.8 VISCOSITY

Radiation

Energy → On

Define → Models →Radiation → P1

There are no solution parameters to be set for the P1, since it impacts the solution only through the energy equation.

The P-1 radiation model is the simplest case of the more general P-N model, which is based on the expansion of the radiation intensity I into an orthogonal series of spherical harmonics

Advantages of the P-1 Model

The P-1 model has several advantages over the DTRM. For the P-1 model which is easy to solve with little CPU demand. The model includes the effect of scattering. For combustion applications where the optical thickness is large, the P-1 model works reasonably well. In addition, the P-1 model can easily be applied to complicated geometries with curvilinear coordinates.

Limitations of the P-1 Model

You should be aware of the following limitations when using the P-1 radiation model:

The P-1 model assumes that all surfaces are diffuse. This means that the reflection of incident radiation at the surface is isotropic with respect to the solid angle. There may be a loss of accuracy, depending on the complexity of the geometry, if the optical thickness is small.

The P-1 model tends to over predict radiative fluxes from localized heat sources or sinks.

3.6.5 Species

Define →Models →Species...

- Enable Species Transport, select Volumetric and Wall Surface under Reactions, and specify the Mixture Material. See Section for details about this procedure, and Section for an explanation of the mixture material concept as shown in figure 3.9
- (Optional) If you want to model the heat release due to wall surface reactions, turn on the Heat of Surface Reactions option.
- (Optional) if you want to include the effect of surface mass transfer in the continuity equation, turn on the Mass Deposition Source option.

- (Optional) if you are using the segregated solver and you do not want to include species diffusion effects in the energy equation, turn off the Diffusion Energy source option.
- Specify mixture material as wood volatile by changing the properties which is corresponding to Bagasse properties.
- Specify Eddy dissipation rate for turbulence chemistry interaction.
- In this we can specify the no of products and reactants.

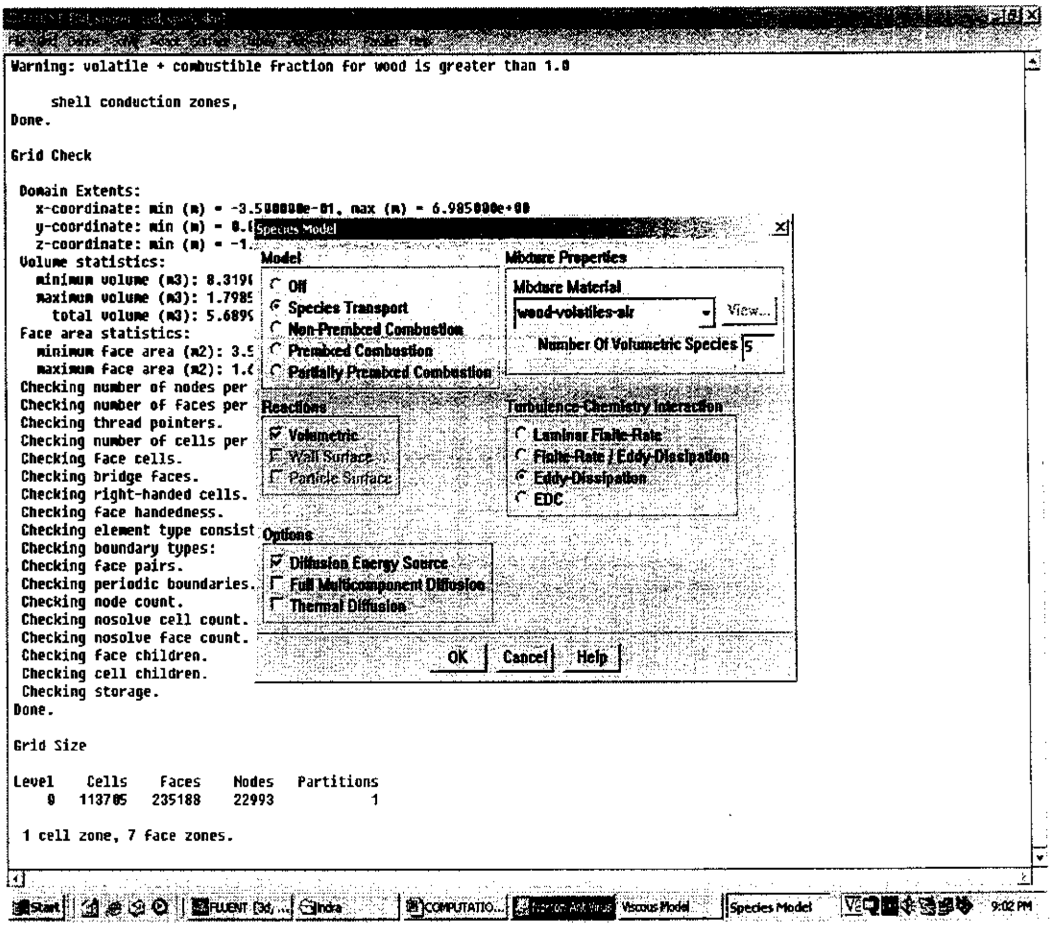


FIGURE-3.9 SPECIES TRANSPORT

Boundary condition

Define →boundary

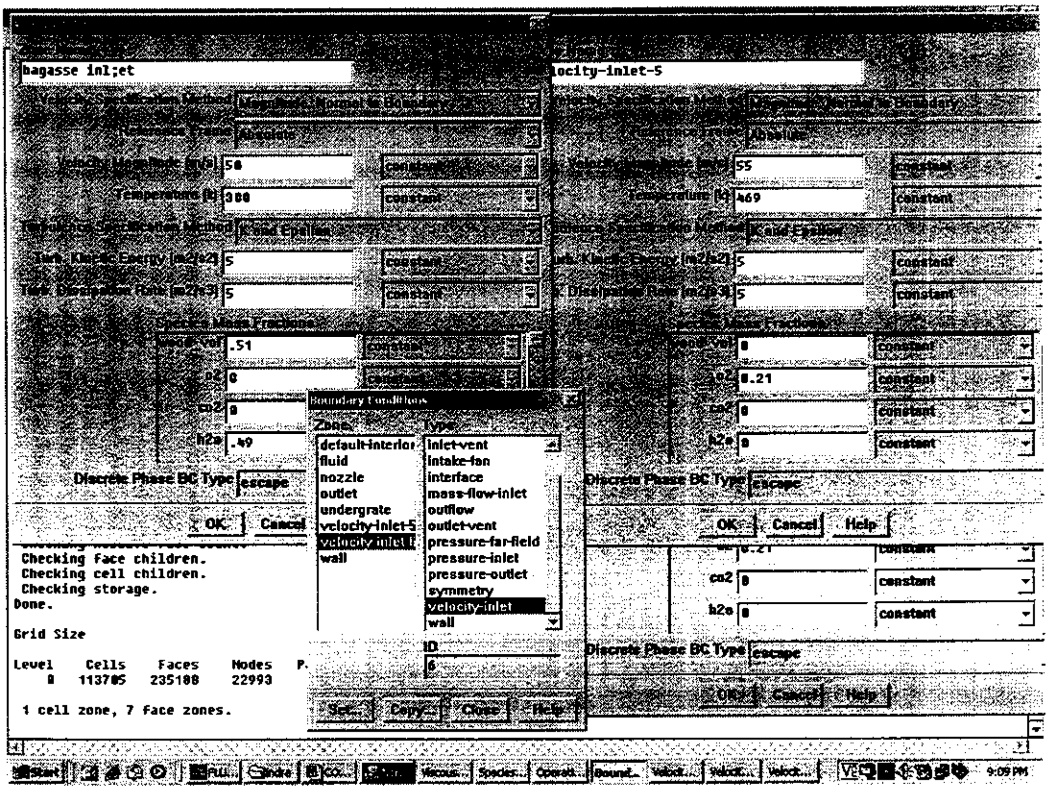


FIGURE-3.10 BOUNDARY CONDITION

In this dialog box we have to specify various boundary condition in table 3.7

TABLE 3.7 MASS FLOW

Boundary condition	Mass flow	Boundary type	Number of Ports
Under grate Inlet	60%	Velocity Inlet	1
Bagasse Inlet	4-15 kg/s	Velocity Inlet,Injections	5
Spreader Air	5%	Velocity Inlet	5
Tangential Nozzle	35%	Velocity Inlet	4
Outlet	------	Outflow	1
Default Interior	------	Mixture	1

Injection Points Specified

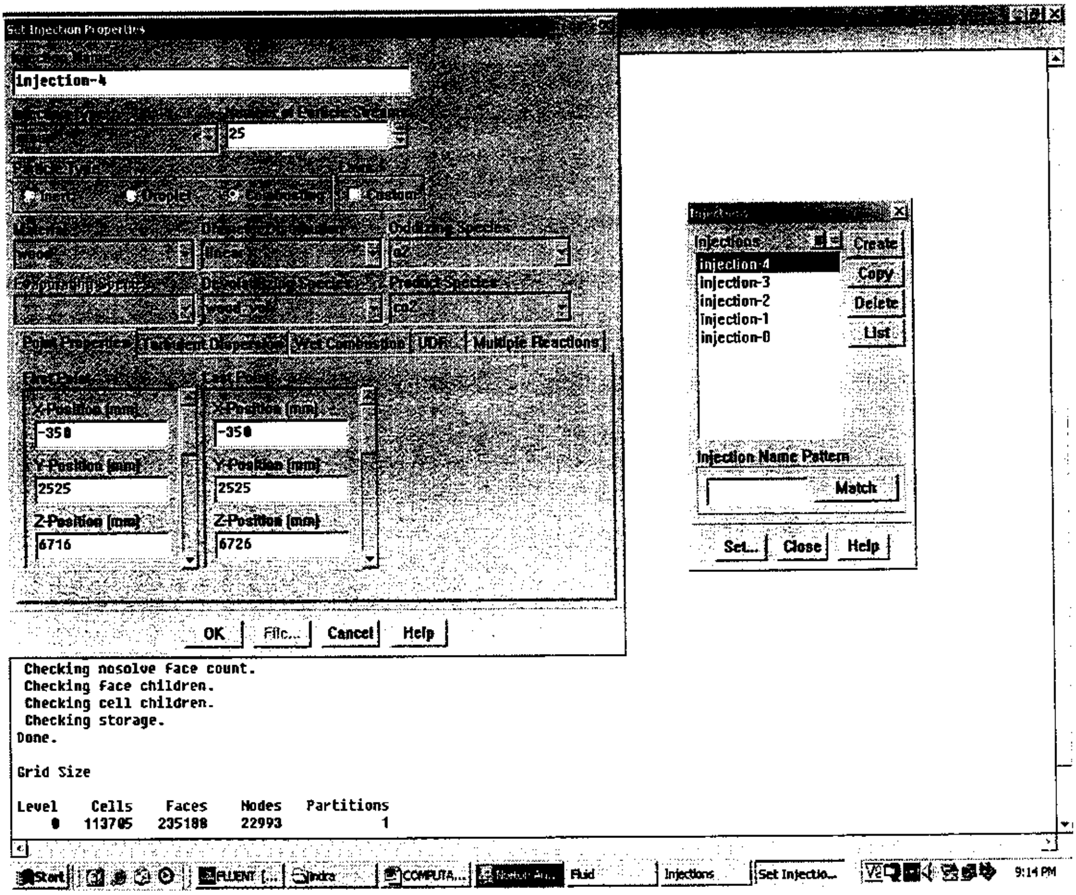


FIGURE-3.11 INJECTION POINTS

TABLE 3.8 FOR INJECTION 0

First Point	Metres	Last Point	metres
X Position	-350	X Position	-350
Y Position	2525	Y Position	2525
Z Position	845	Z Position	865

TABLE -3.9 FOR INJECTION 1

First Point	Metres	Last Point	metres
X Position	-350	X Position	-350
Y Position	2525	Y Position	2525
Z Position	2155	Z Position	2175

TABLE -3.10 FOR INJECTION 2

First Point	Meters	Last Point	meters
X Position	-350	X Position	-350
Y Position	2525	Y Position	2525
Z Position	3660	Z Position	3680

TABLE -3.11 FOR INJECTION 3

First Point	Meters	Last Point	meters
X Position	-350	X Position	-350
Y Position	2525	Y Position	2525
Z Position	5160	Z Position	5180

TABLE 3.12 FOR INJECTION 4

First Point	Meters	Last Point	meters
X Position	-350	X Position	-350
Y Position	2525	Y Position	2525
Z Position	6715	Z Position	6735

Thus after all the input parameters are given in to the fluent software we have to next initialize the value and solve for the convergence using iteration. This can be done by selecting the following options as shown in figure 3.12,

Solve → controls → Solutions

Solve → Monitors →Residual

Solve → Initialize →All zones

Solve → Iterate

Thus the value gets confirmed and various contours and vectors of various parameters such as Temperature, velocity, pressure, particle trajectory, species etc.

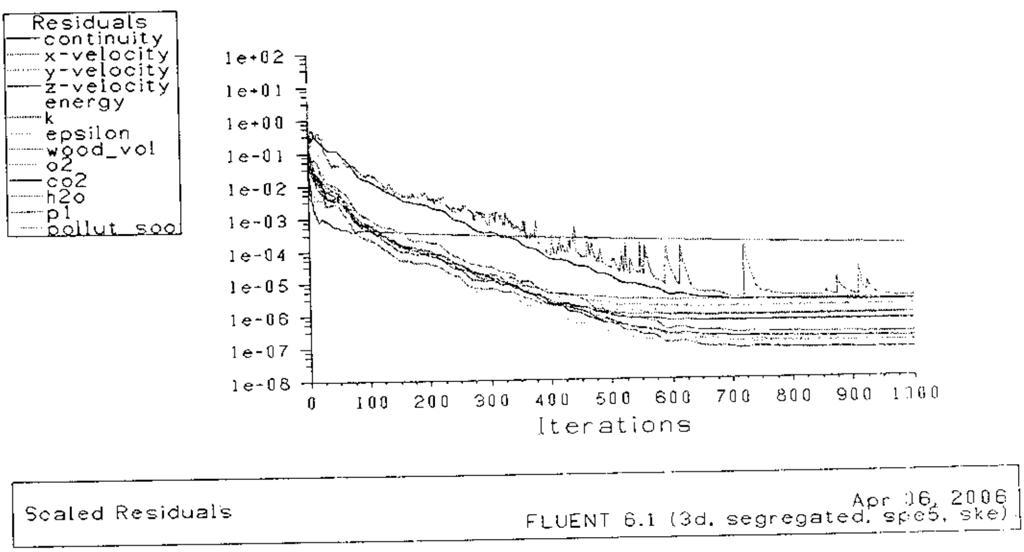


FIGURE – 3.12 ITERATION CURVE

3.7 VALIDATION OF RESULTS

3.7.1 Experimental Setup

The experimental setup used in the Sakthi sugars co-generation unit to determine the temperature at the various points inside the furnace is as shown below in figure 3.13.

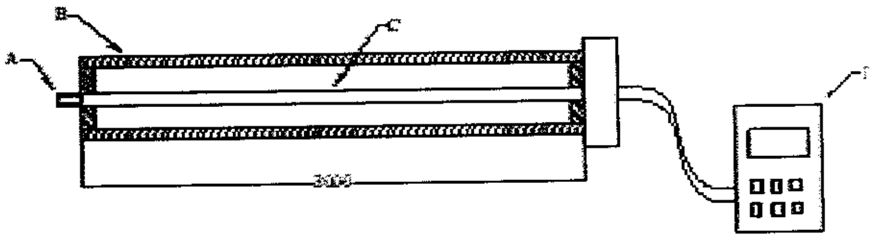


FIGURE – 3.13 THERMOCOUPLE SETUP

A – Temperature measuring tip

B - Galvanized Pipe (for support)

C - Thermo couple Wire

D – Digital Indicator

The setup uses K-type thermocouple to measure the temperature. It consists of a thermocouple well which is permanently fixed at a height of 3 m from the grate and is extended to a length of 3 m inside the combustion chamber. The thermocouple (K-type) can be inserted in to the weld section whenever necessary to a length of 0 to 3 m whose specifications are as given in the table 3.13.

TABLE 3.13 THERMOCOUPLE DETAILS

Type	K-type
Material	Chromel & Alumel (Ni – Cr & Ni – Al)
Temperature range	-270° to 1350°C
Applications	Inert and Oxidizing media

The temperature is measured along a horizontal and vertical line at a height of 1.5m and also along the grate surface. The values measured inside the furnace are given as a pictorial representation in fig 3.14 and 3.15

3.8 TEMPERATURE MEASURING PROCEDURE

3.8.1 Grate level

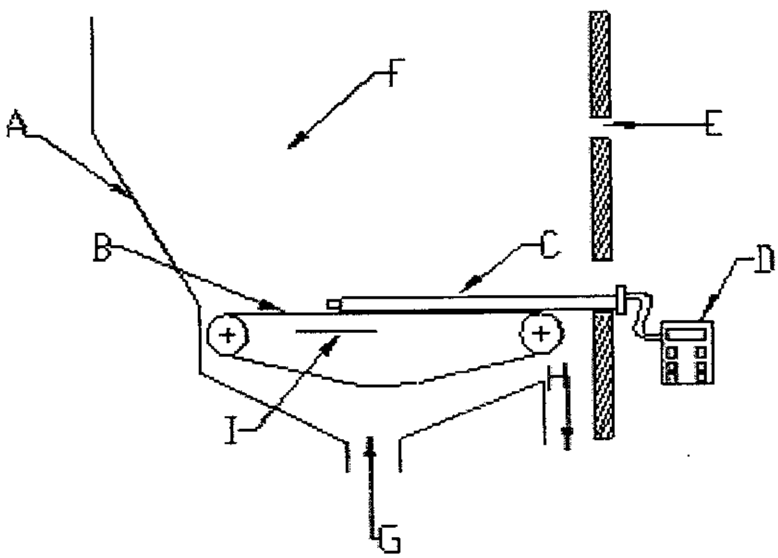


FIGURE – 3.14 TEMPERATURE MEASURING PROCEDURES

3.8.2 Above The Grate (1.27 M)

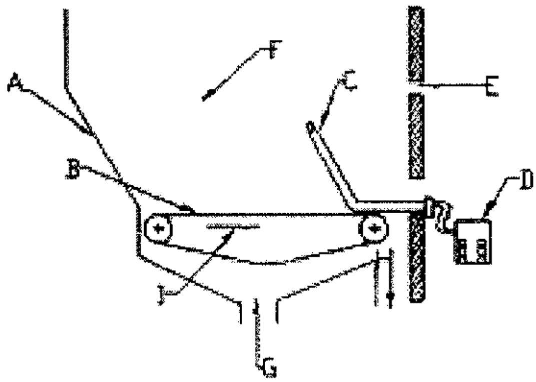


FIGURE – 3.15 ABOVE THE GRATE

A-Furnace Wall, B- Grate, F- Furnace, C- Thermocouple

D-Digital Indicator, G- Grate air opening, I – Air flow

3.9 EXPERIMENTED VS PREDICTED

3.9.1 Measured Grate Temperature Reading

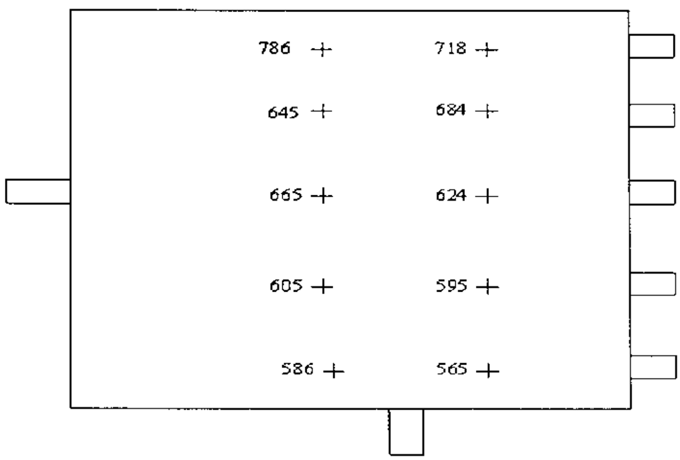


FIGURE – 3.16 MEASURED GRATE TEMPERATURE READING

3.9.2 Measured and Predicted Temperature reading

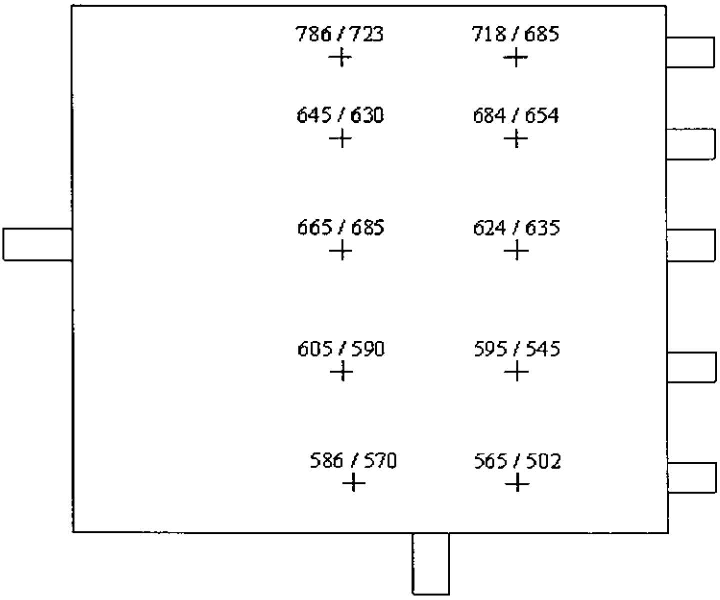
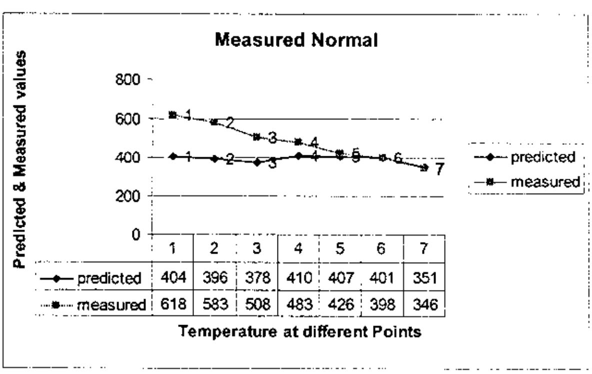


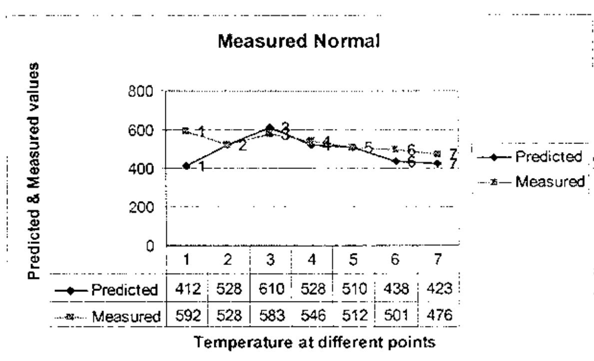
FIGURE – 3.17 MEASURED AND PREDICTED TANGENTIAL TEMPERATURES READING

3.10 GRATE LEVEL TEMPERATURE MEASUREMENT

Graph Measured (from SS) VS Predicted (CFD)



Grate 1m from the opening



Grate 2m from the opening

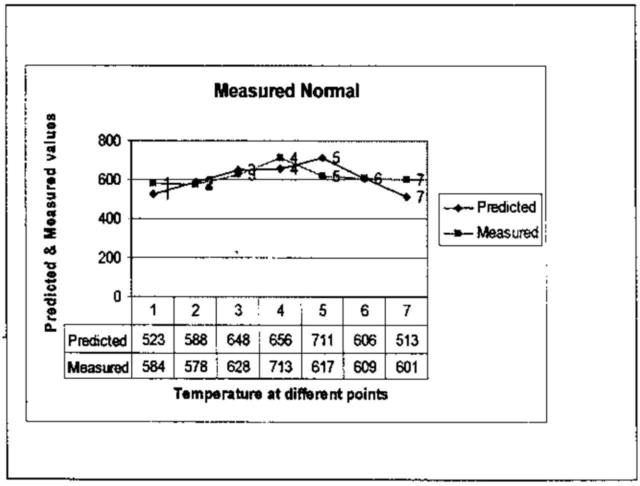
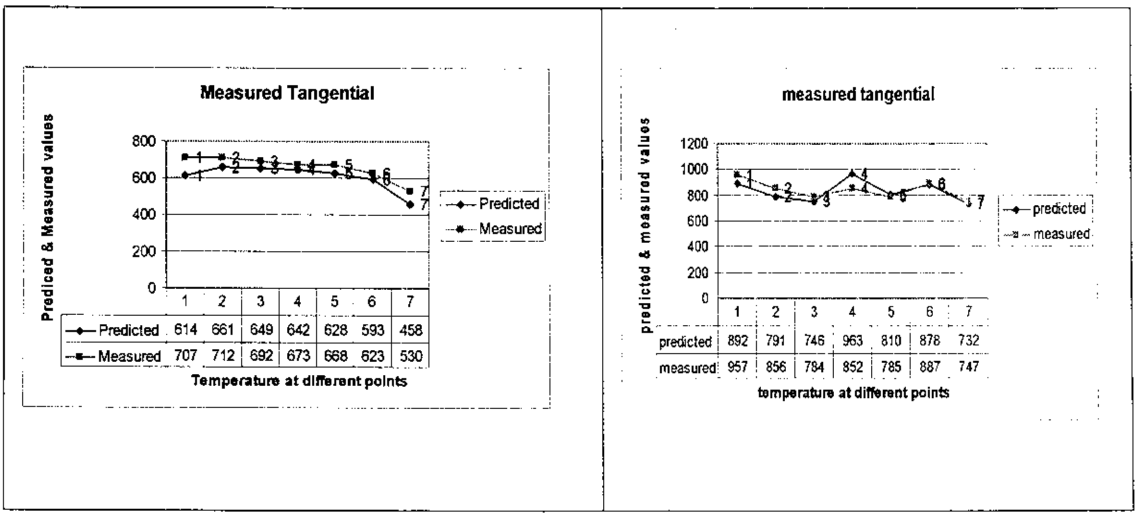


FIGURE-3.18 GRATE LEVEL TEMPERATURE MEASUREMENT

Thus the graphs 3.18 are drawn for the measured and predicted values and thus we are successfully getting the same matching values.

3.11 SPREADER PLANE TEMPERATURE PLANE MEASUREMENT

Graph Measured (from SS) VS Predicted (CFD)



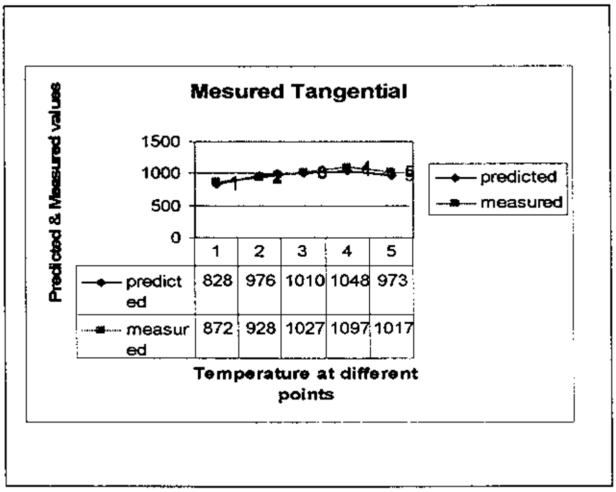


FIGURE – 3.19 SPREADER PLANE TEMPERATURE PLANE MEASUREMENTS

This part is done to validate my work using CFD.

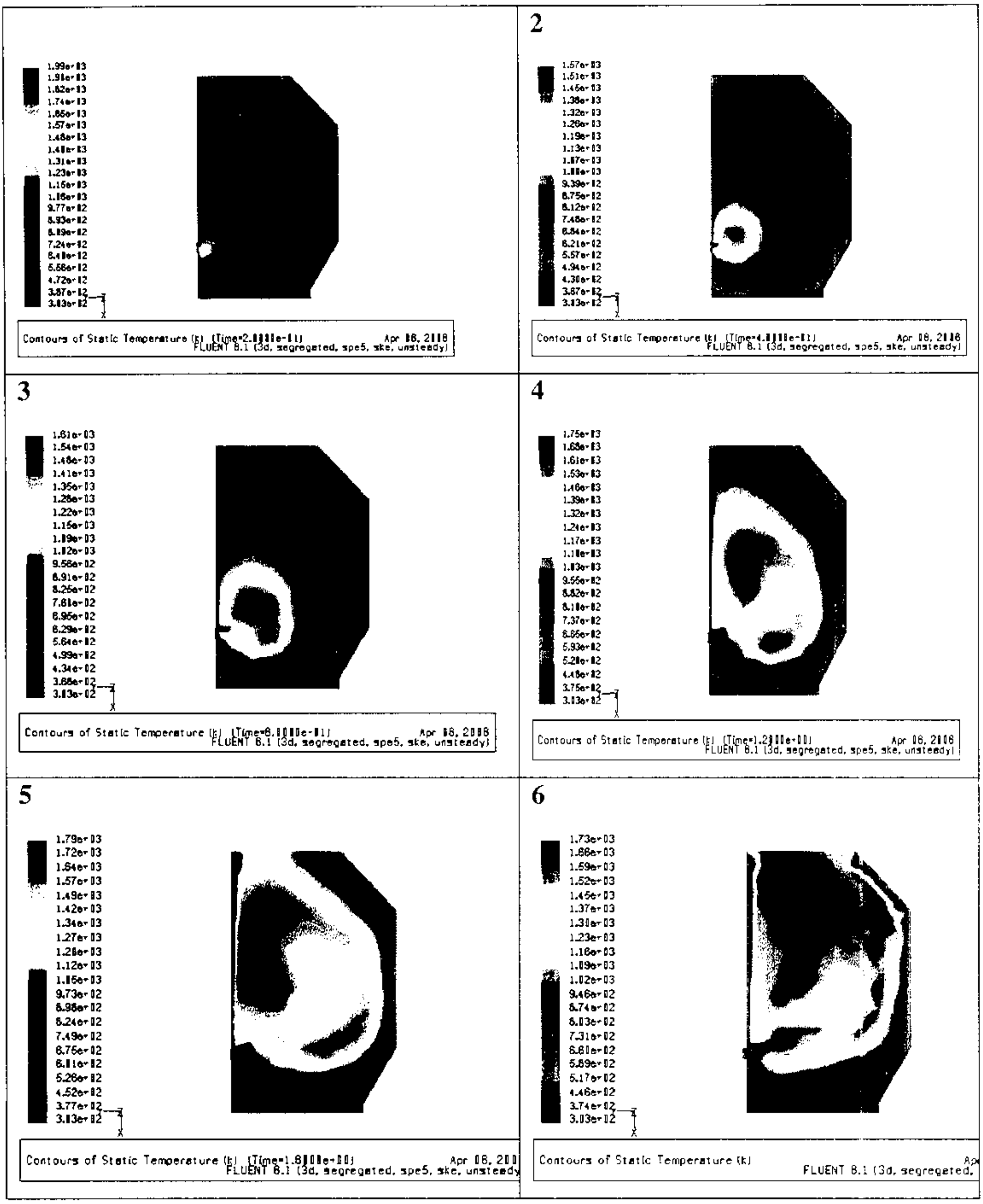
The above plot signifies the temperature distribution at various part of the grate CFD result and the experimented result are matching

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 UNSTEADY COMBUSTION

4.1.1 Distributor Plane



FIGUR -4.1 UNSTEADY DISTRIBUTOR COMBUSTION

4.1. 2 Grate Plane

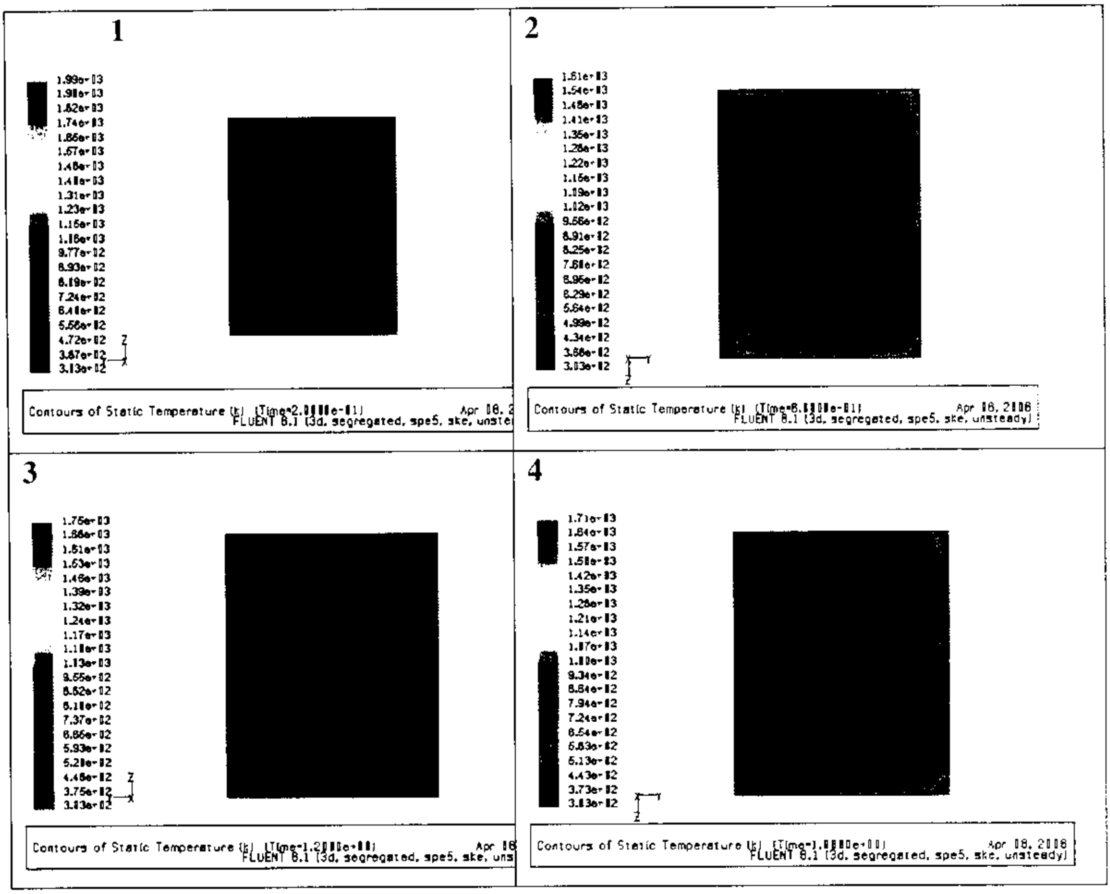


FIGURE - 4.2 UNSTEADY GRATE COMBUSTION

The above figure 4.1 and 4.2 contours shows the unsteady combustion with time step of 0.4 seconds. This explains that after few seconds of combustion the particles tends to fall on the grate and thus the figure proves by the temperature rise in each time step.

4.2 SENSITIVITY TO BOILER OPERATING CONDITION

4.2.1 Lower Value of Bagasse Flow (4.4 kg/s)

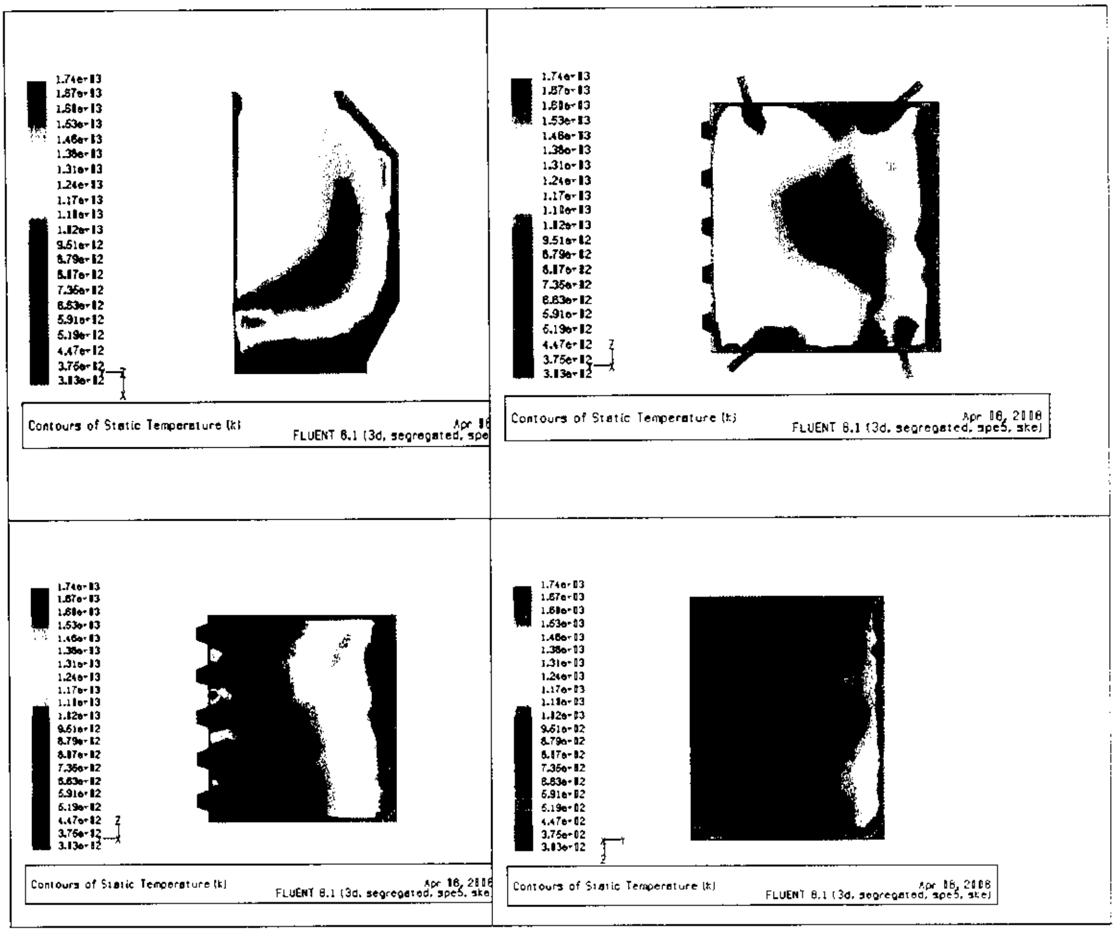


FIGURE -4.3 COMBUSTION AT DIFFERENT PLANES LOWER CALORIFIC VALUE

4.2.1 Bagasse (Lower mass flow rate) shwn in figure 4.3

Mass flow rate of bagasse for 5 spreaders = 15.9 ton/hr = 4.4 kg/s

Mass flow rate of bagasse for 1 spreader = 4.4/5 = 0.88 kg/s

Stochiometric air-fuel ratio for combustion = 1 : 3.76

As there is some amount of moisture present in the bagasse. So we can add excess amount of air for combustion as shown in figure 4.3 . Therefore.

Excess air-fuel ratio = 1 : 4.2

Air distribution for

Spreader	= 0.925 kg/s
Tangential	= 6.475 kg/s
Under grate	= 11.100 kg/s

From this value, corresponding velocities for

One spreader	= 17.12 m/s
One tangential	= 9.50 m/s
Under grate	= 0.34 m/s

4.2.2 Higher Value of Bagasse Flow (9.13 kg/s)

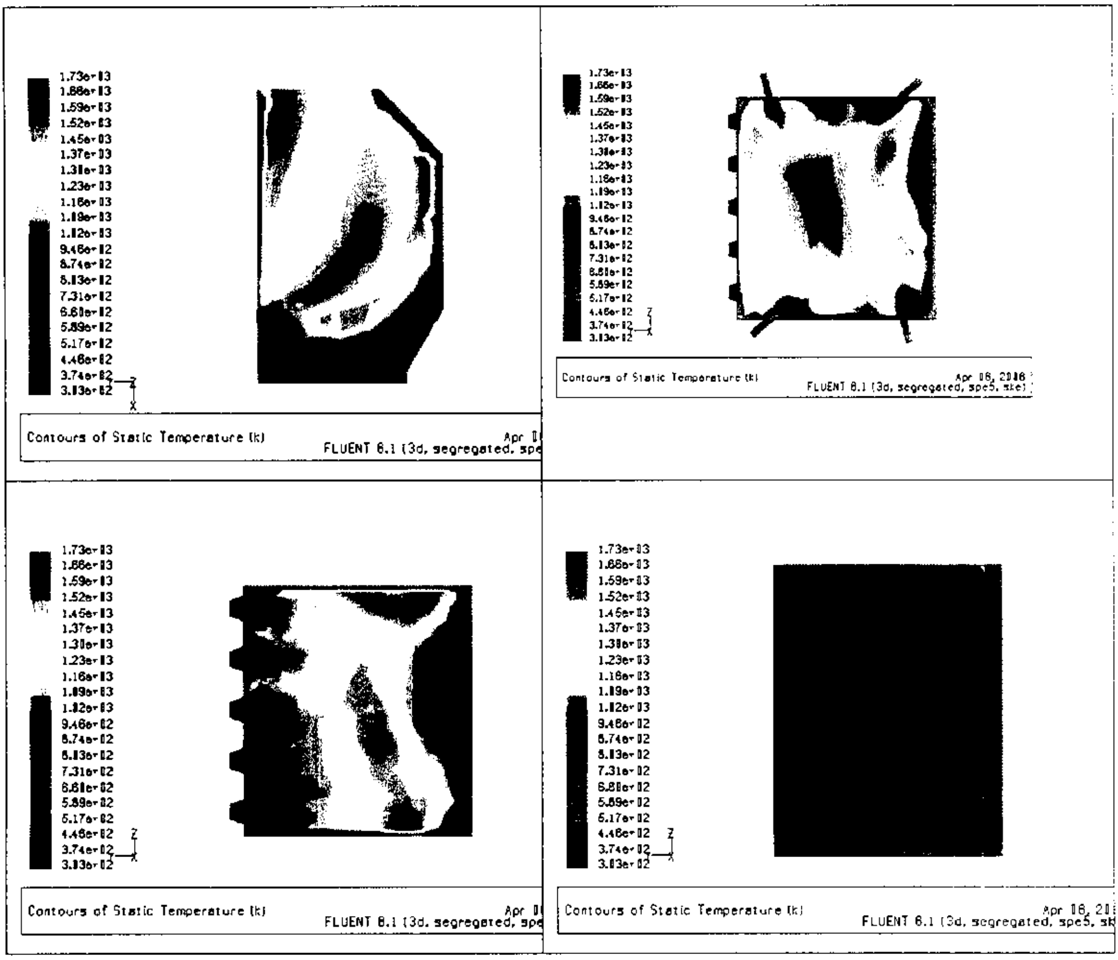


FIGURE - 4.4 COMBUSTION AT DIFFERENT PLANES HIGHER CALORIFIC VALUES

4.2.2.1 Bagasse (Higher mass flow rate)

Mass flow rate of bagasse for 5 spreaders = 32.9 ton/hr = 9.13 kg/s

Mass flow rate of bagasse for 1 spreader = 9.13/5 = 1.82 kg/s

Stoichiometric air-fuel ratio for combustion = 1 : 3.76

As there is some amount of moisture present in the bagasse. So we can add excess amount of air for combustion as shown in figure 4.4

Excess air-fuel ratio = 1: 4.2

Already, we know that

Air distribution for

Spreader = 1.90 kg/s

Tangential = 13.37 kg/s

Under grate = 22.90 kg/s

From this value, corresponding velocities for

One spreader = 35.0 m/s

One tangential = 19.6 m/s

Under grate = 0.67 m/s

4.2.3 Optimum Value of Bagasse Flow (6.17 kg/s)

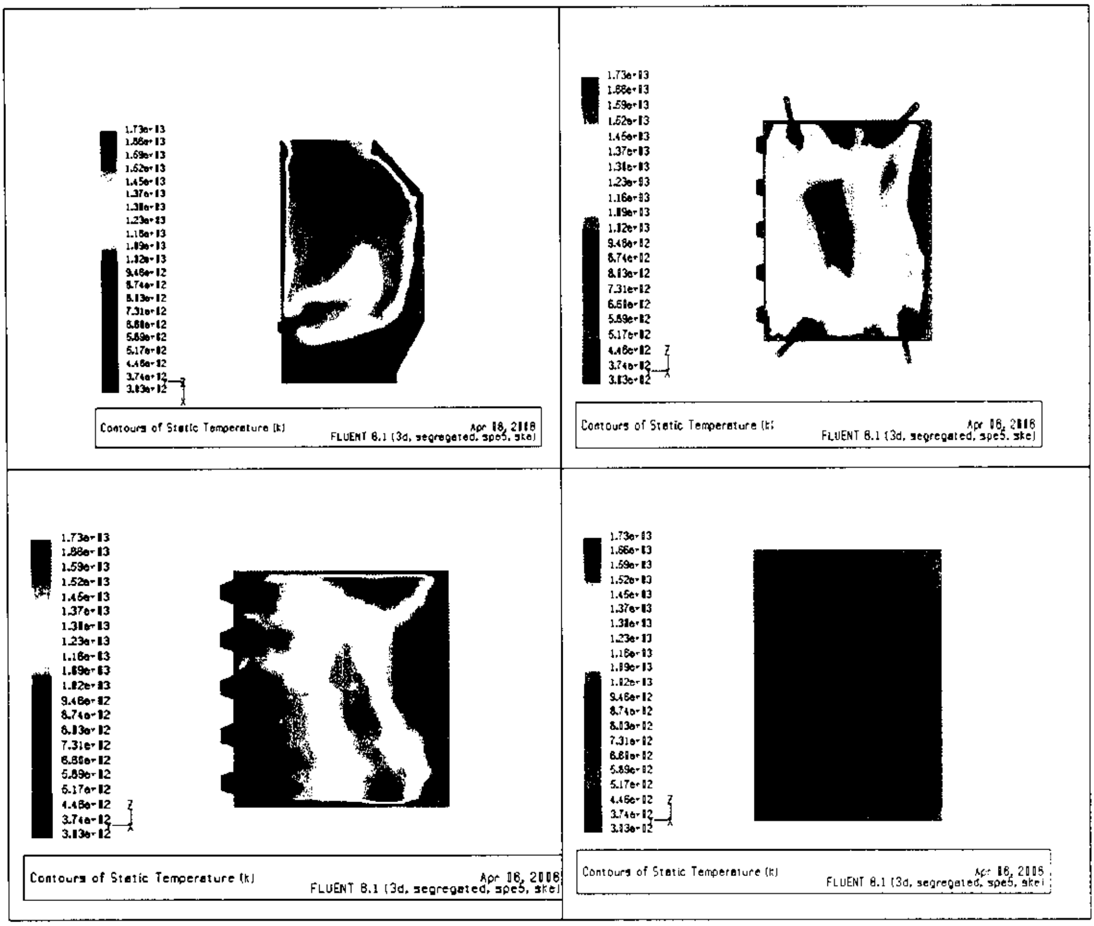


FIGURE-4.5 COMBUSTION AT DIFFERENT PLANES OPTIMUM VALUE

3.2.3.1 Bagasse (Medium flow rate)

Mass flow rate of bagasse for 5 spreaders = 24 ton/hr = 6.7 kg/s

Mass flow rate of bagasse for 1 spreader = 6.7/5 = 1.35 kg/s

Stochiometric air-fuel ratio for combustion = 1 : 3.76

As there is some amount of moisture present in the bagasse. So we can add excess amount of air for combustion as shown in figure 4.5

Excess air-fuel ratio = 1 : 4.2

Already, we know that

Air distribution for

Spreader = 1.4 kg/s

Tangential = 9.8 kg/s

Under grate = 16.8 kg/s

From this value, corresponding velocities for

One spreader = 26.0 m/s

One tangential = 14.3 m/s

Under grate = 0.5 m/s

4.2.4 Selected Range of Flows for Study

TABLE 4.1 OPERATING CONDITIONS - MASS FLOW RATE

	UNDERGRATE AIR (kg/s)	DISTRIBUTOR AIR (kg/s)	BAGASSE (kg/s)
Base Condition	16.8	1.4	6.7
Upper extreme	22.90	1.9	9.13
Lower extreme	11.2	0.925	4.4

4.2.5 Optimum Condition

Thus from the above plots explain that the optimum condition is the average or the mid value as shown in table 4.1

Optimum value

Mass flow rate of bagasse for 5 spreaders = 24 ton/hr = 6.7 kg/s

Air distribution for

Spreader = 1.4 kg/s

Tangential = 9.8 kg/s

Under grate = 16.8 kg/s

From this value, corresponding velocities for

One spreader	= 26.0 m/s
One tangential	= 14.3 m/s
Under grate	= 0.5 m/s

There is a smooth flow of Bagasse Particles in the correct trajectory so that there is an optimum residential time for complete combustion. As the velocity of various inlet ports are at optimum value and there is a proper turbulence created which in turn makes the particle to reside in the chamber for longer time.

More over in the higher flow value there is a incomplete combustion and these particles which are un burnt move out of the chamber along with the flue gas, thus causing environmental problems. In case of the lower value it is found that the combustion takes place at the lower part of the chamber and most of the particle fall down to the grate as the gravity force is predominant compared to the tangential velocity, this result in reduced efficiency.

4.3 RESULT OBTAINED IN FLUENT FOR OPTIMUM CONDITION

4.3.1 Temperature Distribution in Distributor Plane

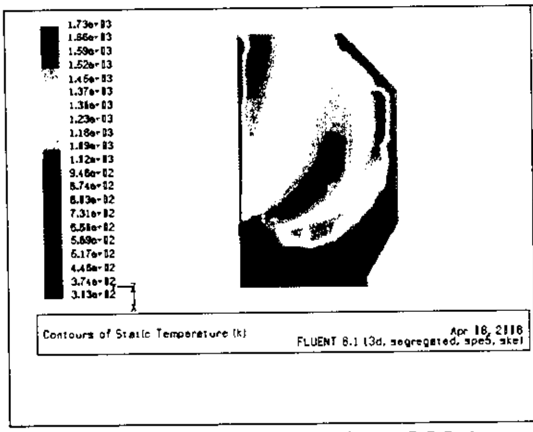


FIGURE 4.6 (A) – INJECTION 1

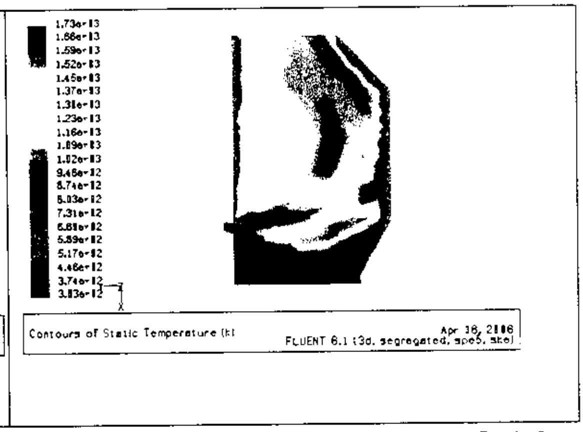


FIGURE 4.6 (B) – INJECTION 2

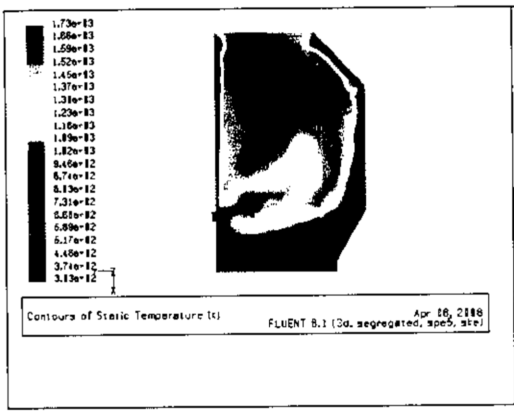


FIGURE 4.6 (C) –INJECTION 3

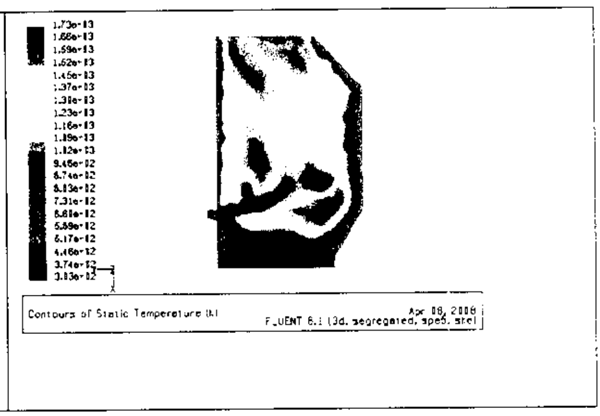


FIGURE 4.6 (D) – INJECTION 4

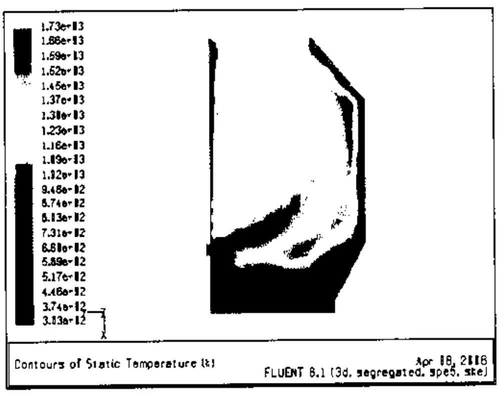


FIGURE 4.6 (E) – INJECTION 5

4.3.2 Tangential Plane and Spreader plane Temperature Contour

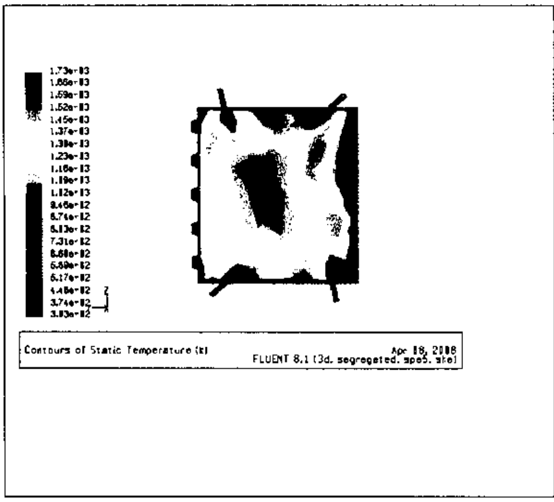


FIGURE - 4.7 (A) TANGENTIAL PLANE

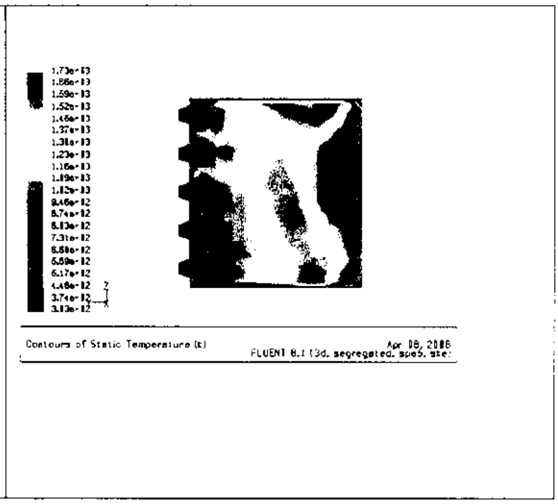


FIGURE - 4.7 (B) SPREADER PLANE

4.3.3 Particle Trajectory

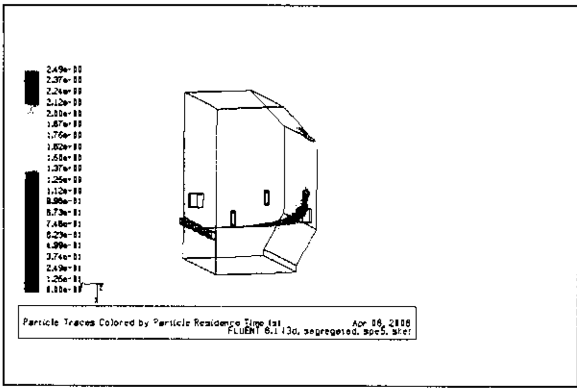


FIGURE – 4.8 (A) INJECTION 3

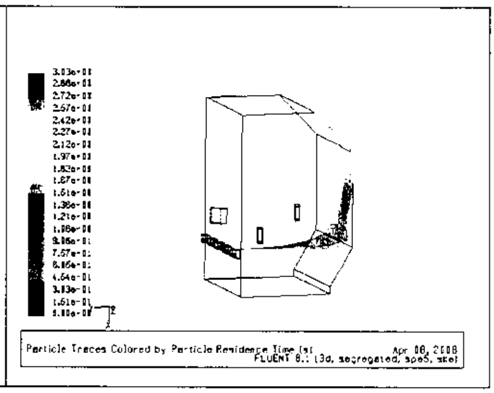


FIGURE – 4.8 (B) INJECTION 1

4.3.4 Distributor Planes

Explanation

Maximum temperature in the combustion chamber is 1730 k. The above plots explain about the temperature distribution in the furnace at different distributor planes. Tangential air that is above the distributor makes the Bagasse particle to move towards center of the furnace. Thus maximum combustion takes place in the mid injection point which can be seen in injection number 2 & 3 points. The particle mostly gets burned in the rear end of the furnace near slope. These temperature contours are plotted for Bagasse flow of 6.7 Kg/s and particle size of 1638 micron. The above case is the optimum case for which the efficiency is very good compared to other cases as shown in figure 4.7

4.3.5 Tangential Plane

Explanation

Above contour shows the Temperature distribution at two different plane such as tangential and spreader plane. This contour explains that temperature is maximum n the mid of the spreader plane, this happens due the tangential turbulence.

We can also see the circular formation of the particles due to tangential system. maximum efficiency before it falls in to the grate. Thus by varying the tangential velocity we can vary the particle residence time as shown figure 4.8

4.3.6 Particle Trajectory

Explanation

The above plots show the particle trajectory of the Bagasse particle at injections 1 & 3. In Injection 1 the particle travels long distance as the combustion takes place at slower rate. In Injection 3 the particle travels a distance shorter than the previous because the takes place at a faster rate due to tangential turbulence, which makes the particle to reside more time in the furnace. This particle trajectory varies due to particle size.

Higher the particle size then it tends to fall on the grate causing the incomplete combustion.

Lower the particle size then incombustible particle tends to move along with the flue gases causing pollution.

Thus this selected particle size seems to be optimum in which combustion takes place at its maximum rate.

4.3.7 Species Distribution

4.3.7.1 Bagasse Volatile Distribution

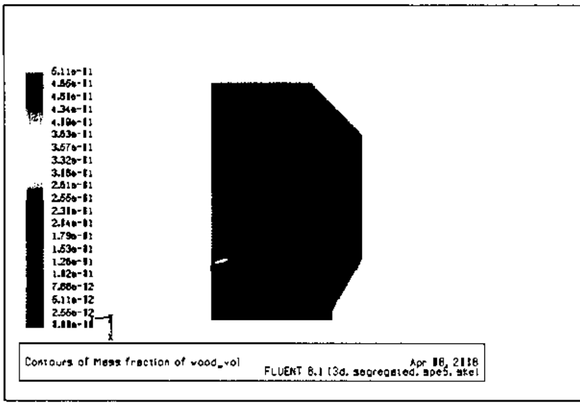


FIGURE-4.9(A) DISTRIBUTOR PLANE

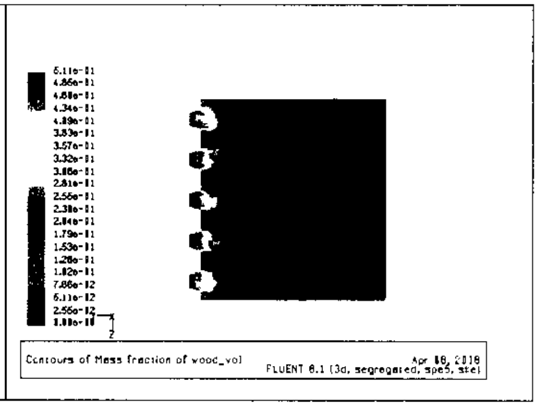


FIGURE - 4.9 (B) SPREADER PLANE

4.3.7.2 Oxygen Distribution

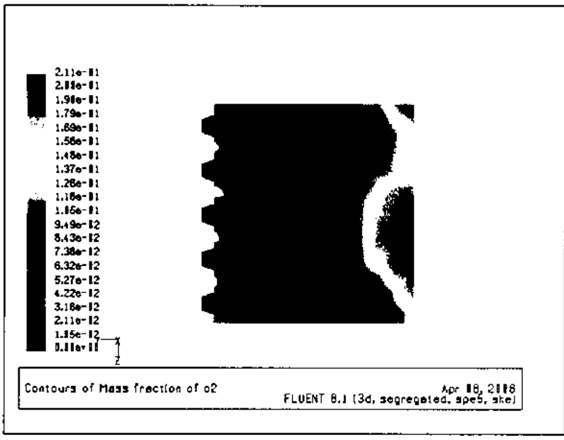


FIGURE - 4.10 (A) SPREADER PLANE

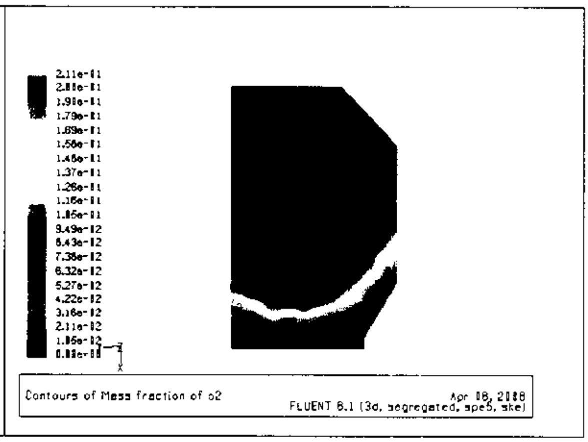
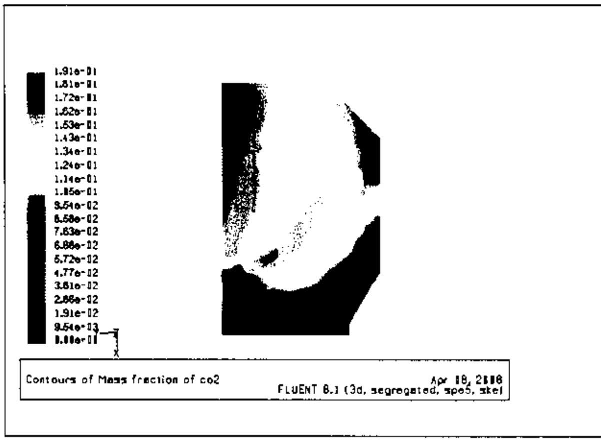


FIGURE-4.10 (B)DISTRIBUTOR PLANE

Oxygen is high were the combustion takes place and it is converted in to carbon dioxide after combustion figure 4.10. Thus the results are experimentally correct.

4.4 CARBON DIOXIDE DISTRIBUTION



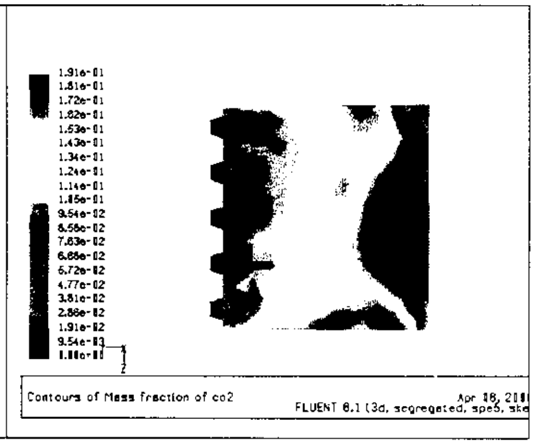


FIGURE - 4.11 (A) DISTRIBUTOR PLANE

FIGURE - 4.11 (B) SPREADER PLANE

This contour clearly explains that the carbon dioxide is more in the plane where combustion is completed and formation of co_2 can be visualized where combustion takes place.

CHAPTER 5

CONCLUSION

From the experiments carried out and subsequent analysis made by using FLUENT, a Computational Fluid Dynamics package, it was clear that the experimental results matched satisfactorily with the predictions of the software

From the above results and discussions, it is apparent that the boiler is sensitive to the flow parameters such as fuel flow rate, under grate flow rate, Tangential Air flow and fuel moisture. Tangential airflow velocity plays an important role, which helps in maintaining the turbulence in the furnace, which in turn helps in complete combustion of the fuel. So it is very important to control the flow parameters to have a stable and efficient furnace behavior for uninterrupted production of energy

Thus maximum combustion takes place in the mid injection point which can be seen in injection number 2 & 3 points. The particle mostly gets burned in the rear end of the furnace near slope. These temperature contours are plotted for Bagasse flow of 6.7 Kg/s and particle size of 1638 micron. The above case is the optimum case for which the efficiency is very good compared to other cases.

REFERENCE

1. Ballester J, Barroso J, Cerecedo L.M. and Ichaso R (2002) , Comparative Study Of Semi- Industrial-Scale Flames Of Pulverized Coals And Biomass ,*International Journal Of combustion And Flames*, 87, p.p. 204–215

2. Dixon T. F. (1983), Combustion characteristics of bagasse suspension boilers, *Proceedings of Australian Society of Sugar Cane Technologies*, 24, p.p.265-271

3. Drummond A.F. and Drummond L.W. (1996), Pyrolysis of sugar cane bagasse in a wire–mesh reactor, *Journal of Industrial engineering in chemical research*, 35, p.p.1263-1268

4. Hobson P. and Plaza F. (2003), Application of cfd in the sugar industry , *International conference on cfd in the mineral and process Industries* ,3 , p.p 77-87

5. Ingwald Obernberger D. (2005), Ash related problems in biomass combustion plants ,*International journal o f energy*, 24,2005

6. Luo M . and Stanmore B. R. (1984), Modeling combustion in a bagasse fired furnace formulation and testing of the model, *Journal of the institute of energy*, 67, p.p.128-135

7. Mann A.P. and And kent J.H. (1984), A computational study of heterogeneous char in a full-scale furnace, *Journal of combustion and flame*, 99. p.p.147-156

8. Nebra S.A. and Macedo I.C. (1988), Bagasse particles shape and size and their free-settling velocity, Journal of *institute of sugar journal*, 90, p.p.168-170

9. Pat DeLaquil M. (2003), Progress developing a sugar cane cogeneration industry, *International cane energy*, 46,221-254

10. Peter woodfield , John kent vasily novozhilov, and Terry Dixon, (1999), Prediction of unstable regimes in the operation of bagasse fired furnaces, *proceedings of second international conference on cfd in minerals and process industries Australia*,2, p.p.299-304

11. Schneider A . and Steven N ,(2003) ,CFD model development for sugar mill evaporations , *International conference on cfd in the mineral and process industries* ,3, p.p 105-110

12. Stubington J.F. and Aiman S. (1994), Pyrolysis kinetics of bagasse at high heating rates, International *journal of energy and fuels*, 8, p.p.194-203

13. Thomson T.L. and Clark N.N. (1991), A holistic approach to particle drag prediction, *Journal of powder technology*, 67, p.p.57-66

14. Woodfield P.L , kent J.H , and Dixon T.F. (1999), Computational modeling of combustion instability in bagasse fired furnaces, *The combustion institute, mediterranean combustion symposium*,41, p.p.813-824

11. Williams A . and Jones J.M. (1999), Combustion of pulverized coal and biomass, *Journal of progress in energy and combustion science*, 32, p.p.587-610