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ANALYSIS OF POWER GENERATION POTENTIAL OF COAL MIXED BIOMASS

Shubham Singh[1], Anurag Srivastava[2]
Department of Mechanical Engineering
[1]M.Tech.(PE) Scholar, Mechanical Engineering department, S R Institute of Management & Technology, Lucknow
[2]Assistant Professor, Mechanical Engineering department, S R Institute of Management & Technology, Lucknow
Uttar Pradesh, India

***Abstract*— In view of energy and environmental problems associated with the use of fossil fuels (coal, petroleum and gas) in power generation, an increasing attention is being paid world-over by the scientists and technocrats for the utilisation of renewable energy sources in power generation, metallurgical industries etc. There are various type of renewable energy sources such as solar, wind, hydropower, biomass energy etc. out of these renewable energy sources, biomass is more economically viable for almost all the continents in the world. Biomass is a carbonaceous material and provides both the thermal energy and reduction for oxides, where as other renewable energy sources can meet our thermal need only. Amongst all the solid fuel like coal etc. biomass is the purest fuel consisting of very lesser amount of ash materials. The power generation potential data for renewable energy sources in India clearly indicates that the biomass has potential to generate more than 17000 MW of electricity per year in India. However, the country is locking in exploitation of biomass in power generation. Till date, India has been capable to generate only 2000 MW (approx.) of electricity per year in spite of declaration of several incentives by the govt. of India. Hence, there is an argent need to increase the utilization of biomass in power generation. The present project work is a positive step towards energy and environmental problems facing the world. The presently selected forestry biomass species has no any commercial use and are underutilized.**

Presently, co-firing (coal + biomass) has been proved to be more attractive and economically viable technique for power generation. In the present work, briquettes were prepared by mixing non-coking coal from Orissa mines and the related biomass species in different ratio (coal: biomass = 95:05, 90:10, 85:15, 80:20). The objectives have been to examine their energy values and power generation potential.

3rd chapter of this theses deal with the experimental work carried out in completion of this project work. The experimental works included determination of proximate analysis, energy value & ash fusion temperature (AFT) of different components of biomass, coal & there mixture.

The results & discussion of the experimental work have been outlined in chapter 3 of the thesis. The results has indicated that Cassia Tora biomass species has somewhat higher ash and lower fixed carbon contents then these of Gulmohar biomass species, energy values of Gulmohar biomass species were found to be little bit higher than that of Cassia Tora biomass. The proximate analysis results of studied coal proved it of F- grade.

As it is evident from result, an increase in biomass content (wood/leaf/nascent branch), in general, in the briquetted increases the energy values of the resulting briquettes. From Volatile Matter (VM) & Fixed Carbon result, it appears that the volatile matter contents is also playing significant role in affecting the energy value of the briquettes in addition to fixed carbon. Among the four AFTs (IDT, ST, HT & FT), softening temperature of ash is most important for boiler operation. The results have indicated that both biomass species have more or less same softening temperature but lower than that of coal. Increase in biomass content in the briquette on rang studied has slightly reduced the softening temperature. The softening temperature results of the briquettes also indicated that the boiler could be safely operated up to about 1100 0C with studied (Coal + Biomass) briquette.

The conclusion derived from present project work has been presented in Chapter 4 of this thesis.

***Index Terms*— proximate analysis, ash fusion temperature, electricity generation, energy content, non-woody biomass species.**

I. INTRODUCTION

A. INTRODUCTION

India being a developing nation, sustainable development is more important. Energy is a basic requirement for economic development. Every sector of Indian economy – agriculture, industry, transport, commercial and domestic – needs inputs of energy. Energy is an important factor for any developing country. Ever increasing consumption of fossil fuels and rapid depletion of known reserves are matters of serious concern in the country. This growing consumption of energy has also resulted in the country becoming increasingly dependent on fossil fuels such as coal and oil and gas. Rising prices of oil and gas and potential shortages in future lead to concerns about the security of energy supply needed to sustain our economic growth. Increased use of fossil fuels also causes environmental problems both locally and globally. Biomass has always been an important energy source for the country considering the benefits it offers. Biomass provides both, thermal energy as well as reduction for oxides. It is renewable, widely available, carbon-neutral and has the potential to provide significant employment in the rural areas. Biomass is also capable of providing firm energy. About 32% of the total primary energy use in the country is still derived from biomass. Ministry of New and Renewable Energy has realised the potential and role of biomass energy in the Indian context and hence has initiated a number of programmes for promotion of efficient technologies for its use in various sectors of the economy to ensure derivation of maximum benefits Biomass power generation in India is an industry that attracts investments of over Rs.600 crores every year, generating more than 5000 million units of electricity and yearly employment of more than 10 million man-days in the rural areas. For efficient utilization of biomass, bagasse based cogeneration in sugar mills and biomass power generation have been taken up under biomass power and cogeneration programme.

B. BIO-ENERGY TECHNOLOGIES FOR DECENTRALIZED POWER GENERATION

The advances in bio-energy technologies (BETs) over the last few decades have enabled a significant increase in the utilization of biomass for power generation. Key technologies available for promoting power generation from biomass in India are gasification, combustion, co-firing and bio-methanation.

1) Gasification

Biomass gasifiers are devices promoting thermo-chemical conversion of biomass into high energy combustible gas for burning in gas turbine (BIG / GT). Biomass, particularly woody biomass, can be converted to high-energy combustible gas for use in internal combustion engines for mechanical or electrical applications. Biomass gasifiers are devices performing thermo-chemical conversion of biomass through the process of oxidation and reduction under sub-stoichiometric conditions. Gasifiers are broadly classified into updraft, downdraft and cross draft (shown in Figs. 1.1 - 1.3) types depending on the direction of airflow. Gasifier systems with various capacities in the range of 1 kg/h to about 500 kg/h are presently in use. These systems are used to meet both power generation using reciprocating engines or for direct usage in heat application. The prime movers are diesel engines connected to alternators, where diesel savings up to 80% are possible. Among the biomass power options, small-scale gasifiers (of 20–500 kW) have the potential to meet all the rural electricity needs and leave a surplus to feed into the national grid. The total installed capacity of biomass gasifier systems as of 2011 is nearly 130 MW.

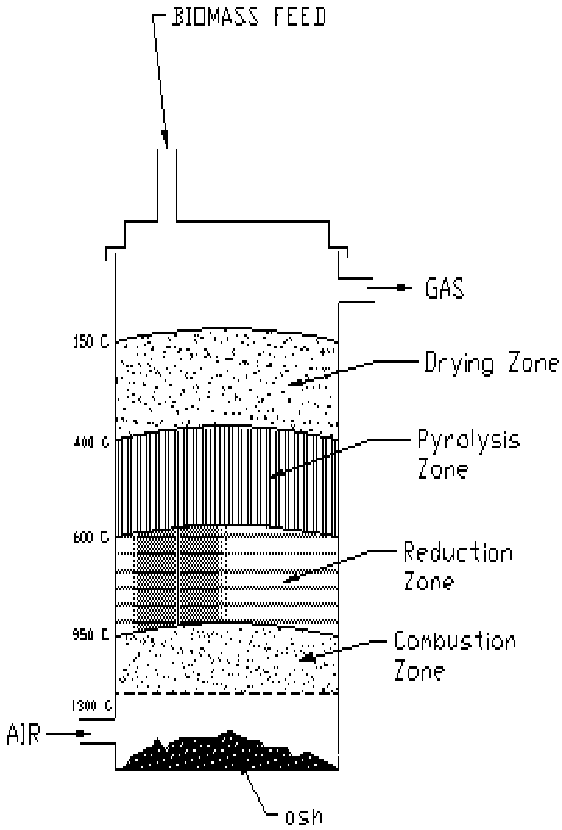


Fig.1.1: Updraft Gasifier

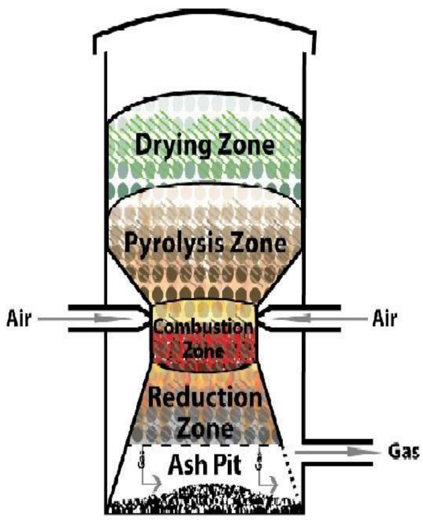


Fig.1.2: Downdraft Gasifier

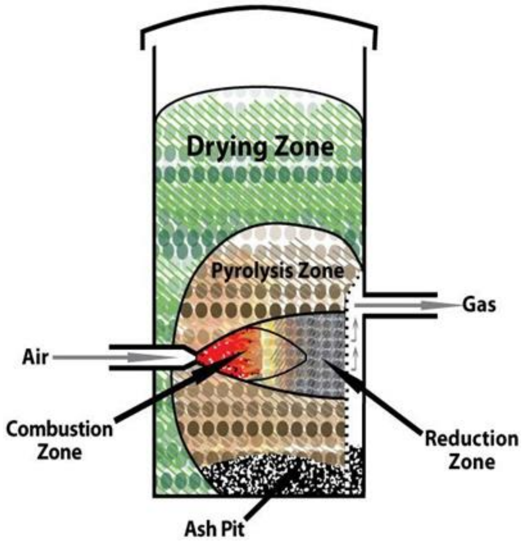


Fig.1.3: Crossdraft Gasifier

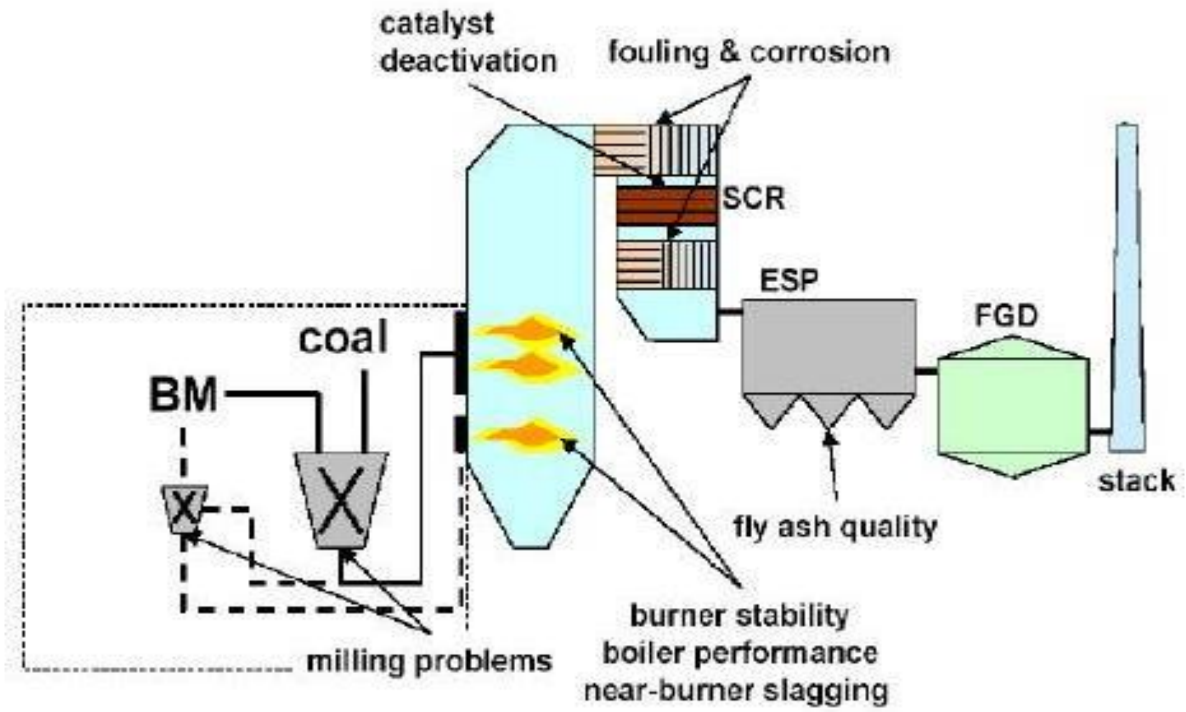


Fig. 1.4: Direct Co-firing System

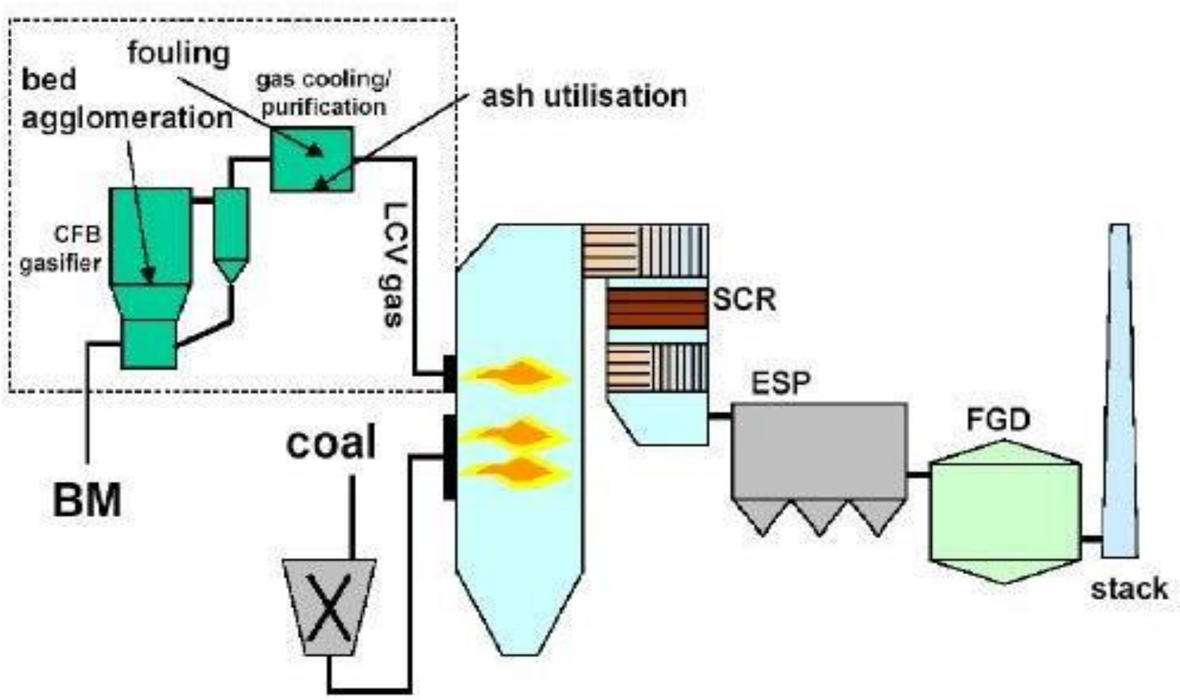


Fig.1.5: Indirect Co-firing System

2) Bio-methanation

It is the technology of biogas (a mixture of 60% methane and 40% carbon dioxide gas) production through anaerobic fermentation of cellulosic materials, such as animal dung, plant and vegetable wastes, etc. (Ravindranath and Balachandra, 2009) and combustion of this gas for electricity generation. The anaerobic digestion of waste has the disadvantages of large installation cost, longer reaction time, high amount of water requirement and large area for installing the plant. Except for a few demonstration projects, hardly any potential has been exploited till now in India.

C. FEEDSTOCK & PROCESSES

Biomass resources include woody, non- woody and animal manure, residues from food and paper industries, agricultural residues, wood wastes from industry and forestry, municipal wastes, sewage sludge, sugar crops (sugar cane, beet, sorghum), dedicated energy crops such as short-rotation (3-15 years) coppice (willow, eucalyptus, poplar), grasses (Miscanthus), oil crops (soy, sunflower, oilseed rape, jatropha, palm oil) and starch crops (corn, wheat). Residues and organic wastes have been the key biomass sources so far, but energy crops are achievement importance and market share. With re-planting, biomass combustion is a carbon-neutral process as the CO2 emitted has until that time been absorbed by the plants from the atmosphere. Residues, wastes, bagasse are primarily used for heat & power generation. Starch sugar, and oil crops are primarily used for fuel production. Cheap, high-quality biomass (e.g., wood waste) for power production may become limited as it is also used for heat production and in the paper industry and pulp industry. New resources based on energy crops have larger potential but are more costly. Technologies and cost of heat and power generation from biomass depend on availability feedstock quality, and transportation cost, power plant size, conversion into biogas (if any). If adequate biomass is available, bio power and CHP plants are a clean and reliable power source suitable for base- load service.

Fig.1.6 shows that different feedstock and different types of process for heat and power generation from biomass.

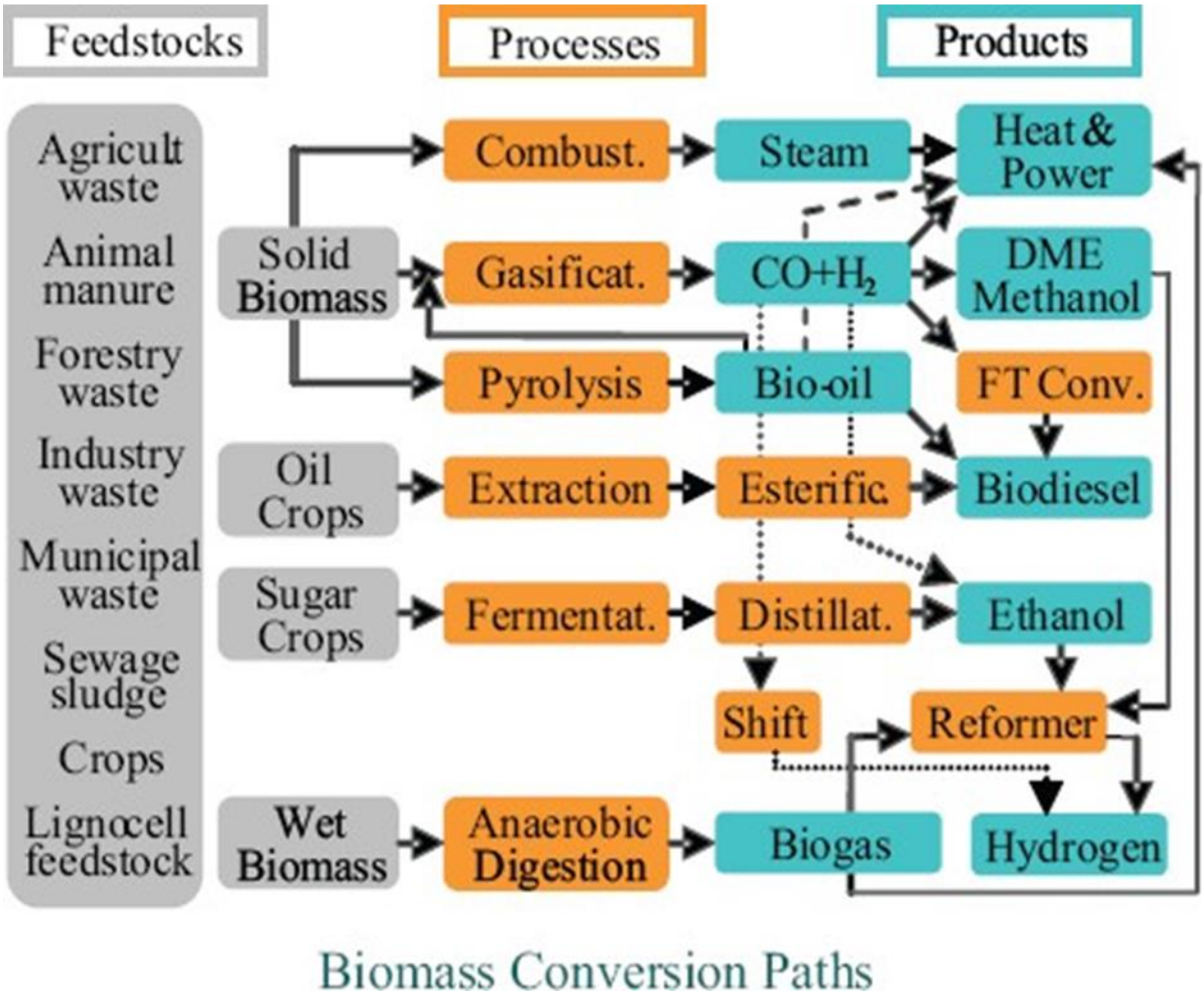


Fig.1.6: Feedstock & Processes

D. AIMS AND OBJECTIVES OF THE PRESENT PROJECT WORK

Following are the aims and objectives of the present investigation:

1. Selection of non-woody biomass species and estimation of their yield by field trial.
2. Determination of proximate analysis (% moisture, % volatile matter, % ash and % fixed carbon contents) of their different components, such as wood, leaf and nascent branch.
3. Mixed these biomass components separately with coal sample in different-different ratio.
4. Characterization of these biomass components for their energy values (calorific values).
5. Characterization of coal mixed biomass components for their energy values (calorific values).
6. Determination of ash fusion temperatures (IDT, ST, HT and FT) of ashes obtained from these biomass species and coal-biomass mixed sample.
7. Estimation of power generation potentials of these biomass species for a small thermal power plant on decentralized basis.
8. Comparative study of coal and mixed coal-biomass in different ratio of 95:05, 90:10, 85:15 and 80:20 with respect to selected biomass species.

II. LITERATURE REVIEW

Biomass-based energy devices developed in recent times (Mukunda et al, 1994). The need for this renewable energy for use in developing countries is first highlighted. Classification of biomass in terms of woody and powdery (pulverized) follows, along with comparison of its energetics with fossil fuels. The technologies involved, namely gasifier- combustor, gasifier-engine-alternator combinations, for generation of heat and electricity, are discussed for both woody biomass and powdery biomass in some detail. The importance of biomass to obtain high-grade heat through the use of pulverized biomass in cyclone combustors is emphasized. The techno economics is discussed to indicate the viability of these devices in the current world situation. The application packages where the devices will fit in and the circumstances favourable for their seeding are brought out. It is inferred that the important limitation for the use of biomass-based technologies stems from the lack of recognition of their true potential.

Calorific values of forest waste originating from forestry works such as woodland cleaning, reforestation and, all other silviculture tasks, were measured by static bomb calorimetry (Regueira et al, 2001). These waste materials, heretofore considered as useless refuse, are beginning to be used as alternative fuels in wide social sectors all over the world. Two of the main forest species, eucalyptus and pine existing in Galicia are included in this study. Some other parameters such as elementary chemical composition and heavy metal contents, moisture, density and ash percentage after combustion in the bomb, were also determined. The experimental results, with calorific values exceeding 20 000 kJ /kg make it advisable to use these materials as alternative fuel.

Proposed a method to evaluate and exploit the energetic resources contained in different forest formations (Regueira et al, 2004). This method is based on the use of a combustion bomb calorimeter to determine the calorific values of the different samples studied. These results were complemented with chemical analysis of the samples and with environmental and geomorphological studies of the zones, samples were taken.

Predicted ash fusion temperatures by using the chemical composition of the ash has previously been conducted only with linear correlations (Ozbayoglu and Ozbayoglu, 2005). In this study, a new technique is presented for predicting the fusibility temperatures of ash. Non-linear correlations are developed by using the chemical composition of ash (eight oxides) and coal parameters (ash content, specific gravity, Hardgrove index and mineral matter content). Regression analyses are conducted using information for Turkish lignites. Regression coefficients and variances of nonlinear and linear correlations are compared. The results show that the non-linear correlations are superior to linear correlations for estimating ash fusion temperatures.

III. EXPERIMENTAL WORK

A. SELECTION OF MATERIALS

In the present project work, two different types of non-woody biomass species Cassia Tora (Local Name: Chakunda) and gulmohar (Local name: Krishnachura) where procured from the local area. These biomass species were cut into different pieces and there different component like leaf, nascent branch and main branch were separation from each other. These biomass materials were air-dried in cross ventilator room for around 20 days. When the moisture contains of these air-dried biomass sample came in equilibrium with that of the air, they were crushed in mortar and pestle into powder of -72 mess size.

Coal sample for making the blend was collected from Lingaraj mines of Orissa. These materials were than processed for the determination their proximate analysis and Energy values.

Fig. 3.1: Sample of biomass component, component powder and coal powder

B. CALORIFIC VALUE DETERMINATION

The calorific values of these species (-72 mesh size) were measured by using an Oxygen bomb calorimeter (BIS, 1970, shown in Fig.3.3); 1 gm. of briquetted sample was taken in a nicron crucible. A 15 cm long cotton thread was placed over the sample in the crucible to facilitate in the ignition. Both the electrodes of the calorimeter were connected by a nicrom fuse wire. Oxygen gas was filled in the bomb at a pressure of around 25 to 30 atm. The water (2 lit.) taken in the bucket was continually starred to homogeneous the temperature. The sample was ignited by switching on the current through the fussed wire and the rise in temperature of water was automatically recorded. The following formula was used to determine the energy value of the sample.

Gross calorific value (GCV) = {(2500 $\times$ ΔT) / (Initial wt. of simple) — (heat released by cotton thread + Heat released by fused wire)}

Where, 2500 is the water equivalent water apparatus and DT in the maxim rising temperature.

Fig. 3.2: Briquetted sample Fig. 3.3: Oxygen Bomb Calorimeter (BIS, 1970)

C. ASH FUSION TEMPERATURE DETERMINATION

The ash fusion Temperature, softening Temperature, Hemispherical temperature and Flow temperature) of all the ash samples, obtained from the presently selected non-woody biomass species and coal-biomass (in ratio) mixed sample were determined by using Leitz Heating Microscope (LEICA shown in Fig.3.4) in Material Science Centre of the Institute. The appearance of ash samples at IDT, ST, HT and FT are shown in Fig. 3.5.

Fig. 3.4: Leitz Heating Microscope

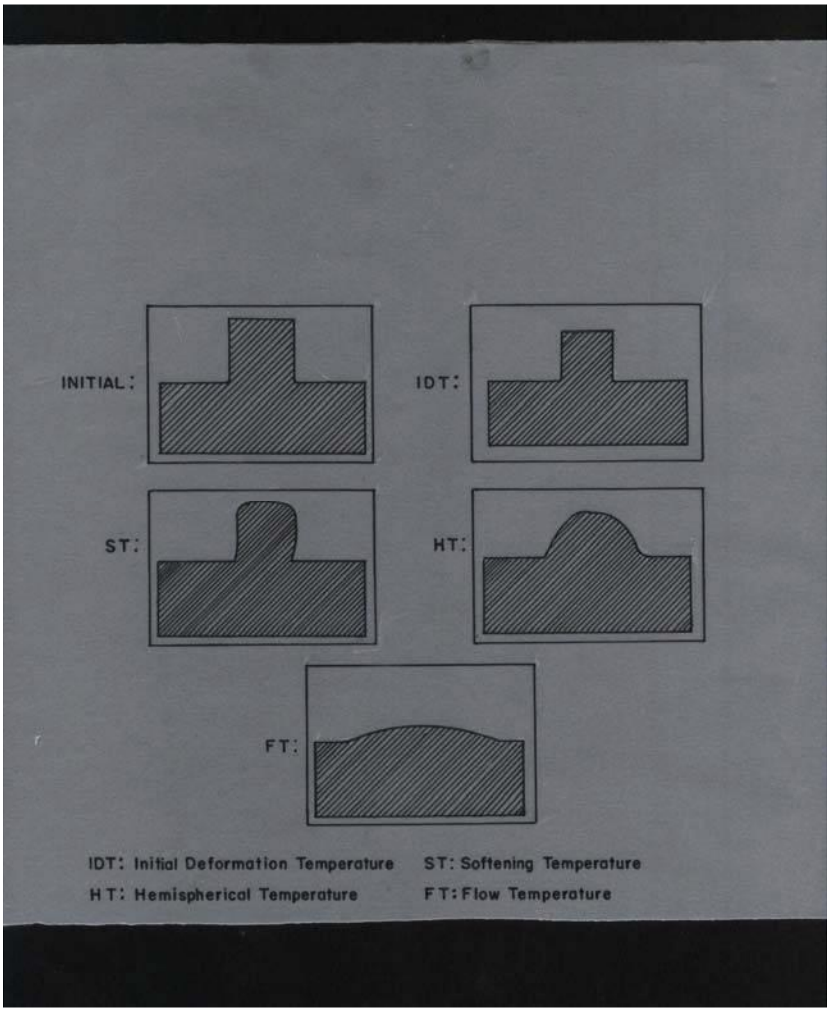


Fig. 3.5: Shapes of Ash Samples at Four Different Characteristics of Ash Fusion Temperature

IV. RESULTS AND DISCUSSION

A. PROXIMATE ANALYSIS OF PRESENTLY SELECTED NON-WOODY BIOMASS PLANT COMPONENTS AND COAL BIOMASS MIXED BRIQUETTES

The studies of the proximate analysis of fuels /energy sources are important because they give an approximate idea about the energy values and extent of pollutants emissions during combustion. The proximate analysis of different components of Gulmohar and Cassia Tora plant and these biomass species component briquettes with coal are presented in Tables 4.1 – 4.5. The data for proximate analysis of the components of these species are very close to each other and hence it is very difficult to draw a concrete conclusion. However, it appears from these tables that Cassia Tora biomass species has somewhat higher ash and lower fixed carbon contents than these of Gulmohar biomass species and the ash contents being more and volatile matter is less when 95% coal mixing with 5% biomass and 90% coal mixing with 10% biomass but when 85% coal mixing with 15% biomass and 80% coal mixing with 20% biomass then ash content is being less and volatile matter is more.

B. CALORIFIC VALUES OF PRESENTLY SELECTED NON-WOODY BIOMASS PLANT COMPONENTS

Calorific values data listed in Table 4.1 & 4.2 indicate that among all the studied biomass species, calorific values of wood component of both biomasses have higher in comparison to leaf and nascent branch. Gulmohar biomass species were found to be little bit higher than that of Cassia Tora biomass. Table 4.4 & 4.5 are shows that calorific value of coal mixed Gulmohar biomass (different component in different ratio) were found to be higher than that of coal mixed cassia tora biomass (different component in different ratio).

Amongst the four different ratios, ratio 80:20 gives the highest energy value in all mixed component and 85:15 also gives higher energy value except leaf component of both biomass in respect to other two ratios (95:05 and 90:10).

Comparison of data listed in Table 4.1-4.3 shows that in difference to coals included in the present study, both non-woody biomass materials have considerably higher calorific values and very lower ash contents. Table 4.4 & 4.5 indicates that calorific values of biomass species are something lower but ash content are also lower in compare to coal. This is definitely an benefit over fossil fuels. It is thus clear that these non-woody biomass resources will result in higher power production in the plant with slight emission of suspended particulate matters (SPM).

C. ASH FUSION TEMPERATURE OF PRESENTLY STUDIED NON-WOODY BIOMASS SPECIES

It also experimentally finds out the ash fusion temperatures to confirm its safe operation in the boiler. Ash fusion temperature of solid fuel is an important parameter affecting the operating temperature of boilers. Clinker creation in the boiler usually occurs due to low ash fusion temperature and this hampers the operation of the boiler. Hence the study of the ash fusion temperature of solid fuel is essential before its operation in the boiler. The four characteristic ash fusion temperatures were identified as: (i) initial deformation temperature (IDT) – first sign of change in shape; (ii) softening temperature (ST) – rounding of the corners of the cube and shrinkage; (iii) hemispherical temperature (HT) – deformation of cube to a hemispherical shape; and (iv) fluid temperature (FT) – flow of the fused mass in a nearly flat layer. The shapes of the initially taken cubic ash samples at IDT, ST, HT and FT are shown in Fig. 3.3. Identical shapes at these temperatures were obtained for all the studied non-woody biomass species like Gulmohar, cassia tora and coal mixed these biomass. Data for the ash fusion temperatures (IDT, ST, HT and FT) for have been listed in Table 4.6.

D. ELECTRICITY GENERATION SYSTEM

The biomass based electricity generation method is outlined in Figure 1.6 freshly cut wood holds a large amount of moisture, which must be removed to decrease the transportation cost and to increase the energy density (i.e. calorific value). The carbonization of biomass yields charcoal as main product and generates a large amount (approximately 65- 75 % of the weight of biomass) of volatile matter (pyrolytic gas). For the biomass energy system to be competitive and to increase energy conversion efficiency, technologies available for promoting power generation from biomass are gasification, combustion, co-combustion and bio-methanation. The pyrolytic gas should also be combusted to generate electricity. The ash obtained would be transported back to the plantation centre and used as a fertilizer, or it could be utilized as building material.

E. PROXIMATE ANALYSIS AND CALORIFIC VALUE OF DIFFERENT COMPONENTS OF NON-WOODY BIOMASS SPECIES AND COAL

The results obtained from proximate analysis and calorific value of non-woody biomass species, coal, coal-biomass mixed briquettes and Ash fusion temperatures of selected biomass species and coal- biomass mixed (in ratio) during the course of this project work have been summarized in Tables 4.1– 4.6 and presented graphically in Figs. 4.1-4.9.

Table 4.1: Proximate Analysis of Gulmohar (Local name: Krishnachura)

Component	Proximate Analysis (Wt. %, air-dried basis)				Gross CalorificValue (Kcal/ kg, Dried Basis)
	Moisture	Ash	VolatileMatter	Fixed Carbon	
Wood	9.00	3.00	72.68	15.00	4549
Leaf	8.90	7.20	70.11	15.00	3947
Nascent branch	9.80	4.20	70.05	14.22	4061

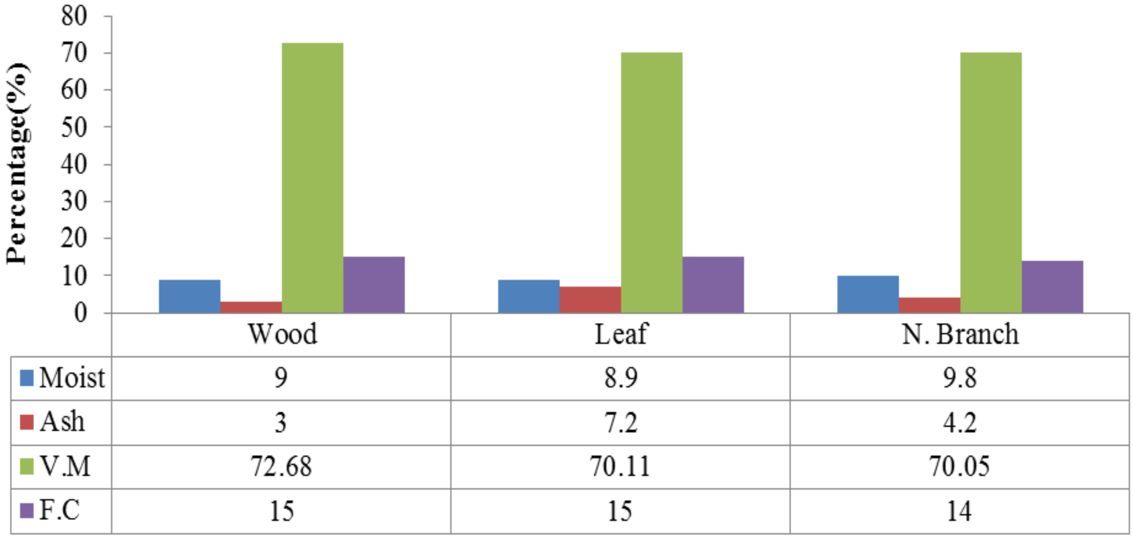


Fig. 4.1: Variation of Proximate Analysis of Gulmohar Biomass

Table 4.2: Proximate Analysis of Cassia Tora (local name: Chakunda)

Component	Proximate Analysis (Wt. %, air-dried basis)				Calorific Value(Kcal/ kg, Dried Basis)
	Moisture	Ash	VolatileMatter	Fixed Carbon	
Wood	11.00	7.80	68.50	12.00	4344
Leaf	11.50	7.40	69.00	14.00	4113
Nascent branch	10.00	5.20	70.00	14.00	3697

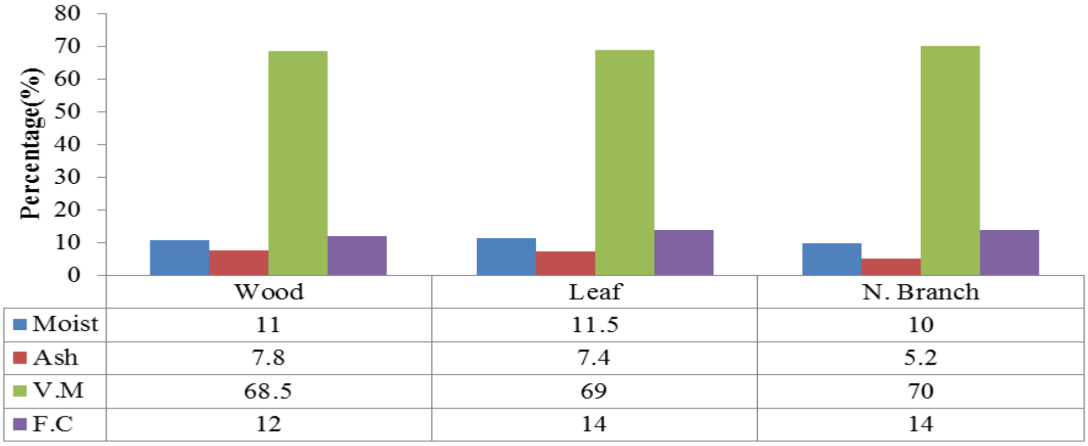


Fig.4.2: Variation of Proximate Analysis of Cassia Tora Biomass

Table 4.3: Proximate Analysis of Non-coking coal

Component	Proximate Analysis (Wt. %, air-dried basis)				Calorific Value (Kcal/kg, Dried Basis)
	Moisture	Ash	VolatileMatter	Fixed Carbon	
Lingaraj Mines	8.90	41.20	21.70	29	4237

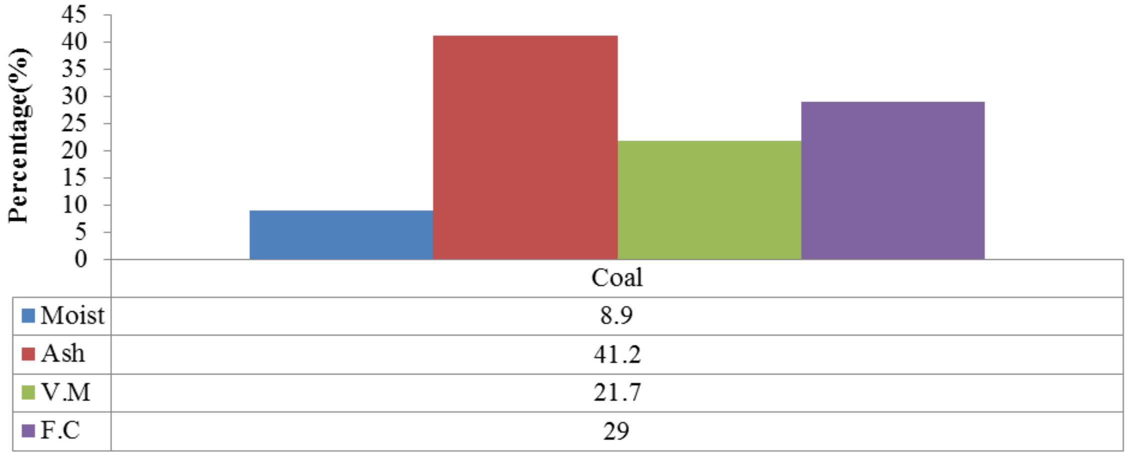


Fig. 4.3: Variation of Proximate Analysis of Non-coking Coal

Table 4.4: Coal: Gulmohar Biomass Different Component

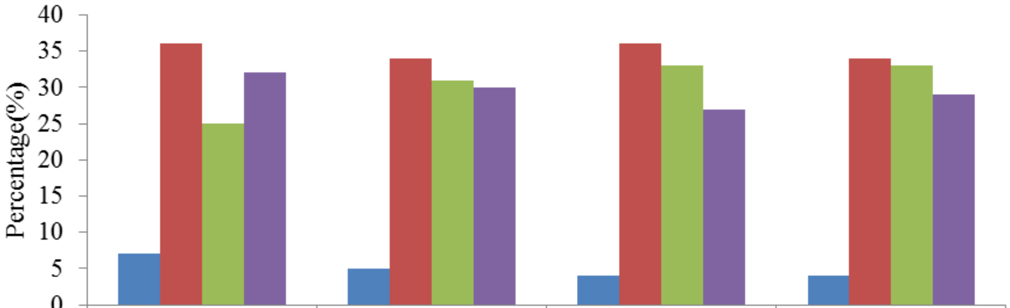
Ratio(Coal: Biomass)	Proximate Analysis (Wt. %, Air Dried Basis)				Calorific value (Kcal/ kg, Dried Basis)
	Moisture	Ash	VolatileMatter	Fixed Carbon	
Main wood					
95:05	7	36	25	32	3214
90:10	5	34	31	30	3497
85:15	4	36	33	27	3748
80:20	4	34	33	29	4087

Leaf

95:05	4	35	29	32	3422
90:10	4	36	31	29	3483
85:15	5	29	35	31	3077
80:20	6	31	33	30	3830

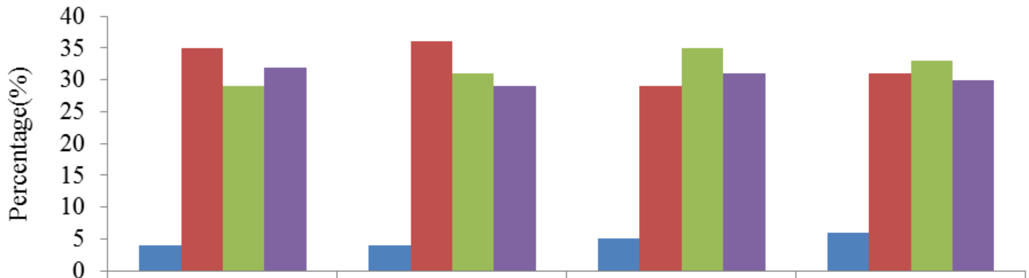
Nascent Branch

95:05	4	37	32	27	3584
90:10	3	33	35	29	3551
85:15	6	29	39	26	3557
80:20	7	30	42	21	3801



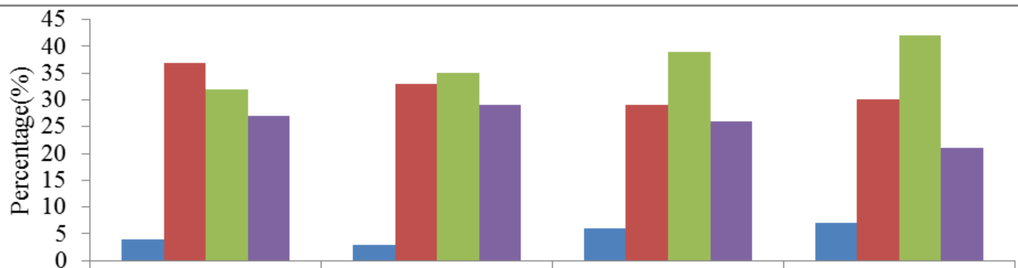
	95:05:00	90:10:00	85:15:00	80:20:00
Moist	7	5	4	4
Ash	36	34	36	34
V.M	25	31	33	33
F.C	32	30	27	29

Fig4.4: Variation of Mixture of Coal and Gulmohar Biomass(Wood)



	95:05:00	90:10:00	85:15:00	80:20:00
Moist	4	4	5	6
Ash	35	36	29	31
V.M	29	31	35	33
F.C	32	29	31	30

Fig.4.5: Variation of Mixture of Coal and Gulmohar Biomass(Leaf)



	95:05:00	90:10:00	85:15:00	80:20:00
Moist	4	3	6	7
Ash	37	33	29	30
V.M	32	35	39	42
F.C	27	29	26	21

Fig. 4.6: Variation of Mixture of Coal and Gulmohar Biomass(Nacent Branch)

Table 4.5: Coal: Cassia Tora Biomass Different Component

Ratio(Coal: Biomass)	Proximate Analysis (Wt. %, Air Dried Basis)				Calorific value (Kcal/ kg, Dried Basis)
	Moisture	Ash	VolatileMatter	Fixed Carbon	
Main wood					
95:05	3	36	36	25	3146
90:10	4	36	33	27	2980
85:15	4	37	39	20	3482

80:20	6	35	41	18	3454

Leaf

95:05	3	39	29	29	3275
90:10	4	39	29	28	3668
85:15	4	31	39	26	3051
80:20	4	33	34	29	4143

Nascent Branch

95:05	4	39	32	25	3471
90:10	7	37	29	27	3211
85:15	3	31	39	27	3675
80:20	3	36	39	22	3672

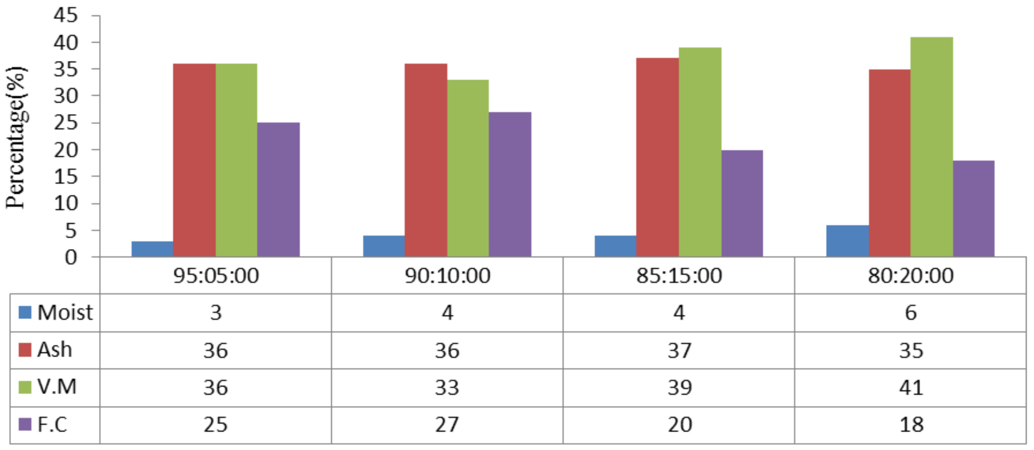


Fig. 4.7: Variation of Mixture of Coal and Cassia Tora(Wood)

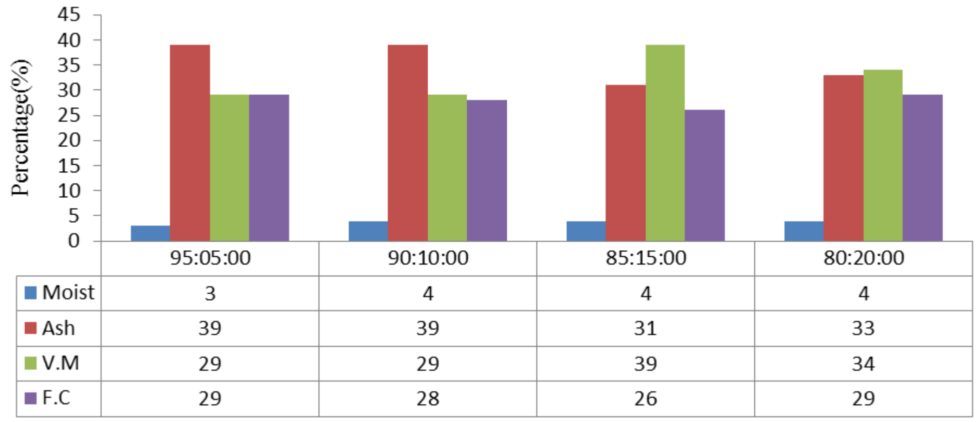


Fig.4.8: Variation of Mixture of Coal and Cassia Tora(Leaf))

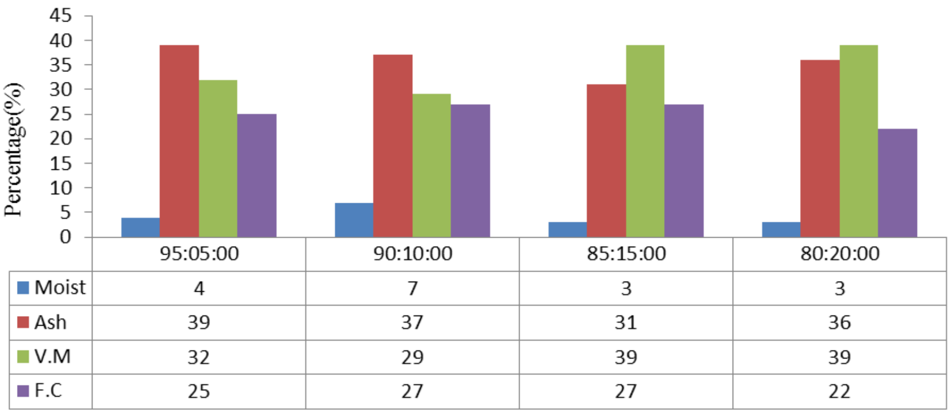


Fig. 4.9: Variation of Mixture of Coal and Cassia Tora(Nacent Branch)

Table 4.6: Ash Fusion Temperatures of Selected Biomass Species and Coal- Biomass Mixed Sample

Biomass Species / Coal-Biomass Mixed Ratio	Ash Fusion Temperatures(°C)			
	IDT	ST	HT	FT
Cassia Tora	893	1245	>1400	>1400
Gulmohar	1058	1249	>1400	>1400
Coal : Biomass(90:10)	1160	1297	>1400	>1400
Coal : Biomass(80:20)	1188	1298	>1400	>1400

IDT: Initial Deformation Temperature
ST: Softening Temperature
HT: Hemispherical Temperature
FT: Flow Temperature

F. CALCULATIONS

Table 4.7: Total Energy Contents and Power Generation Structure from 8 Months old (approx.), Gulmohar Plants

Component	Calorific Value (kcal/t, dry basis)	Biomass Production (t/ha, dry basis)	Energy Value(kcal/ha)
Main wood	4532×10^3	21.00	95172×10^3
Leaf	3907×10^3	7.00	27349×10^3
Nascent branch	3997×10^3	9.50	37971.5×10^3

* Data from filed studies (biomass production)

Energy Calculation:

On even dried basis, total energy from one hectare of land
= (95172+27349+37971.5) ×103
= 160492.5 ×103 kcal

It is assumed that conversion efficiency of wood fuelled thermal generators = 26 % and mechanical efficiency of the power plant = 85 %.

Energy value of the total functional biomass obtained from one hectare of land at 26% conversion efficiency of thermal power plant
= 160492.5 ×103 × 0.26
= 41728.05× 103
= 41728.05×103 ×4.186÷ 3600
= 48520.45 kWh

Power generation at 85 % mechanical efficiency
= 48520.45 ×0.85
= 41242.38 kWh/ha Land required to supply electricity for entire year
=73×105/ 41242.38
= 177 hectares

Table 4.8: Total Energy Contents and Power Generation Structure from 4 Months old (approx.), Cassia Tora Plants

Component	Calorific Value (kcal/t, dry basis)	Biomass Production (t/ha, dry basis)	Energy Value(kcal/ha)
Main wood	4344×10^3	4.00	17376×10^3
Leaf	4013×10^3	1.50	6019.5×10^3
Nascent branch	3672×10^3	2.50	9180×10^3

* Data from filed studies (biomass production)

Energy Calculation:

On even dried basis, total energy from one hectare of land
= (17376+6019.5+9180) ×103
= 32575 ×103 kcal

It is assumed that conversion efficiency of wood fuelled thermal generators = 26 % and mechanical efficiency of the power plant = 85 %.

Energy value of the total functional biomass obtained from one hectare of land at 26% conversion efficiency of thermal power plant
= 32575.5 ×103 × 0.26
= 8469.63×103 kcal
= 8467.29×103 ×4.186÷ 3600
= 9848.30 kWh

Power generation at 85 % mechanical efficiency
= 9848.30×0.85
= 8371.05 kWh/ha Land required to supply electricity for entire year
=73×105/ 8371.05
= 872.05 hectares

V. CONCLUSIONS

A. CONCLUSIONS

In the present work two non-woody biomass species Gulmohar and Cassia Tora were selected. Experiments to determine the proximate analysis, calorific values and ash fusion temperature was done on each of the components of the selected species such as main wood; leaf and nascent branch were performed. Estimation was done to analyse how much power can be generated in one hectare of land from each of these species. The following are the different conclusions drawn from the present work:

1. Both plant species (Gulmohar and Cassia tora) showed almost the similar proximate analysis results for their components, the ash contents being more in their leaves and volatile matter content less in Cassia tora wood and leaf.
2. Mixed ratio of Both biomass with coal(in four different ratio) also showed the same proximate analysis results, the ash contents being more when 95% coal mixing with 5% biomass and volatile matter is more when 80% coal mixing with 20% biomass.
3. The non-wood biomass species showed highest energy values for their branch, followed by wood, leaf and nascent branch.
4. Amongst the both biomass species Gulmohar has the highest energy value compared to Cassia tora.
5. Amongst the four different ratio, ratio 80:20 gives the highest energy value compared to 95:05, 90:10, 85:15.
6. Energy values of coal mixed Gulmohar biomass component were found to be little bit higher than that of coal mixed Cassia Tora biomass component.
7. Calculation results have established that nearly 177 and 872 hectares of land would be required for continuous generation of 41242.38 kWh per hectares from

Gulmohar and 8371.05 kWh per hectares from Cassia tora biomass species.

8. The ash fusion temperature of all the species are coming above the range of boiler operation, this would avoid clinker formation in the boiler.
9. This study could be positive in the exploitation of non-woody biomass species for power generation.

B. SCOPE FOR FUTURE WORK

The present study was concentrated on two non-woody biomass species such as Gulmohar and Cassia Tora. The following works are suggested to be carried out in future.

- Similar type of study need to be extended for another non-woody biomass species available in the local area.
- The biomass species may be mixed with cow dunk, sewage wastes, etc. in different ratios and the electricity generated potentials of the mixtures may be determined.
- Pilot plant study on laboratory scale may be carried out to generate electricity from biomass species.
- The powdered samples of these biomass species may be mixed with cow dunk and the electricity generated potential of the resultant mixed briquettes may be studied.
- New techniques of electricity generation from biomass species may be developed

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