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ARTICLE

AN EFFICIENT DUAL FLUIDIZED BED BIOMASS GASIFICATION SYSTEM BASED ON FLUID PARTICLES VERTICITY

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ABSTRACT

A combined modelling of system is established for a dual fluidized bed (DFB) biomass gasifier and a rotary biomass dryer utilizing a grouping of built in unit and user defined operations. In the proposed method the idea of verticity is considered for compensating the excessive fuel and air supply in the fast fluidized bed (FFB) reactor in which with the rotating movement of air a single source of fire can flared up with no extra fuel supply. In order to achieve this the proposed methodology initially models the DFB gasification system based on the quasi equilibrium model. Then with the help of rotary drier model the moisture content with the biomass feedstock are eliminated and is fed to the gasification reactor. Next to introduce the verticity of the fluid particles, different air feeding angular fixtures are used in the FFB reactor. With this proposed model we can reduce the excessive air and fuel required in the FFB reactor considerably and also reduce the impact of energy efficiency of the system. The proposed method will be implemented on the MATLAB platform and the experimental results are validated based on the operation parameters such as feed air to the FFB reactor, gasification temperature, steam to biomass (S/B) ratio and initial moisture content of the feed biomass.

KEY WORDS
Dual fluidized bed gasifier; biomass gasification; biomass drying; verticity; fast fluidized bed (FFB).

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INTRODUCTION

Gasification could be a method that converts organic or fossil fuel based carbonic materials into monoxide, hydrogen and dioxide [1]. This is often achieved by reacting the fabric at high temperatures (>700 °C), while not combustion, with a controlled quantity of gas and/or steam. The ensuing gas mixture is termed syngas (from synthesis gas or artificial gas) or producer gas and is itself a fuel. The energy derived from chemical action and combustion of the resultant gas is taken into account to be a supply of renewable energy if the vaporized compounds were obtained from biomass. It's a thermochemical method, which means that the feedstock is heated to high temperatures, manufacturing gases which may bear chemical reactions to create a synthesis gas. This examination of technology for the chemical action of biomass and wastes 'syngas' in the main contains hydrogen and monoxide, and may then be accustomed turn out energy or a spread of chemicals, together with liquid and aerosolized transport fuels. Gasification could be a key technology for the utilization of biomass [2]. It delivers a high flexibility in utilizing different quite feedstock materials in addition as within the generation of various merchandise. In main, all differing types of biomass is regenerate by chemical action into syngas in the main comprising hydrogen, monoxide, dioxide and alkane series [3].

Biomass refers to all or any organic materials that are created from plants [4]. It's wide thought-about to be a significant potential fuel and natural resources for the longer term [5] [6]. Based on the resource size, there's the potential to supply a minimum of five hundredth of Europe's total energy demand, from purpose full-grown biomass mistreatment agricultural land now not needed for food, and from wastes and residues from agriculture, commerce and shoppers [7]. There are many completely different generic styles of gasification technology that are incontestable or developed for conversion of biomass feed stocks. Most of them are developed and commercialized for the assembly of heat and power from the syngas, instead of liquid fuel production. They're draft fastened bed, draught fastened bed, Entrained flow gasifiers (EF), Bubbling fluidized bed gasifiers (BFB), circulating fluidized bed gasifiers (CFB), dual Fluidized Bed and alternative steam blown, indirectly heated gasifiers and Plasma gasifiers [8].

Here, we tend to see concerning the DFB gasifier and its technologies. The DFB gasification process, offers varied benefits for biomass chemical change moreover because the utilization of different solid feed stocks [9]. This technology is eventual as a result of it yields high caloric product gas freed from N2 dilution even once air is employed to get the desired endoergic heat via in place combustion [10]. Indirect biomass gasification in a DFB system will be accustomed convert solid biomass into raw gas, which might be more upgraded to be used as substitute fossil fuel, city gas, liquid transport fuels or fuel in gas turbines [11]. DFB gasification advantages from the expertise gained with BFB and CFB, though square measure at associate in earlier stage of development than EF, BFB and CFB. DFB systems solely presently in operation in little scale heat [12] [13] and applications of power, and that they still got to be incontestable at pressure – but, if developed, these pressurized systems have the potential to supply low price, N free syngas.

The players concerned have a shorter log of expertise, however have with success operated plants at high availabilities, and a few have plans for liquid fuels production within the future. Twin systems have intermediate feedstock necessities, having the ability to just accept larger particle sizes and a wider vary of wetness contents [14]. The cluster of twin technologies even have many different attainable comes

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mentioned (such as Silva Gas for Process Energy, Taylor Biomass for Abengoa), and consequently the ECN MILENA 3.8odt/day pilot plant, operational since 2008, has fairly formidable scale-up goals (480odt/day by 2015). DFB gasifiers have had a scattered development within the past, however recent victorious demonstrations and interest in BTL applications are hopeful [15].

The organization of the paper is summarized as follows. Section 2 gives some of the recent research done in fluidized gasification system. In section 3, we explained our proposed methodology and the experimental results are shown in section 4 followed by conclusion in section 5.

RELATED WORKS

The very recent works related to the Fluidized Bed Biomass Gasification System are listed below:

A. Gomez-Barea and B. Leckner [16] have reviewed a Modeling of biomass chemical change in fluidized-bed (FB) reactors. Most of the modeling components from FB combustor models utilized in models of FB biomass chemical change (FBBG). There have been variations, although like within the mode of conversion of the char particles and within the quantity of heat transferred to surfaces. Char conversion was, in distinction, acknowledge however, revealed FBBG models haven't forbidden the offered info. The assorted approaches applied for reactor modeling, from black box models to machine fluid-dynamic models, were delineated, demonstrating their state of development and also the quality of every approach looking on the aim of the model. The fluidization model, wherever the fluid-dynamics of the FB was shortened by semi-empirical correlations, is that the commonest approach up thus far, utilized with major success. Most of the FB biomass chemical change models match moderately well experiments elite for validation, despite the assorted formulations and input file, additionally the validation of models with information from complete FB biomass chemical change units remains to be done.

Ion Iliuta et al. [17] have projected to investigate the new thought of all thermal cyclic multi-compartment BFB steam biomass gasifier. The active, one-dimensional, multi-component, non-isothermal model established for this idea accounts for elaborate solid and gas flow dynamics wherever upon chemical process or combustion reaction mechanics, thermal effects and freeboard-zone reactions were secured. Within the Multi-compartment effervescent fluidized bed (BFB) hybrid steam gasifier, all compartments were of rectangular cross-sections, contiguous and were divided by extremely thermally semiconducting sheets whereby an economical heat transfer happens. They showed that char combustion produces ample heat to sustain chemical process at warmth by tolerating up to twenty percentage heat losses. A non-diluted high hydrogen output and comparatively large hydrogen content may well be obtained from biomass chemical process in two-compartment effervescent fluidized-bed reactors. All thermal operation needed burning extra fuel so as to keep up a warmth within the combustor, and afterward within the gasifier itself, conjointly this operation may well be achieved with a switch periods of a moment supporting practicability of this new thought.

K. Goransson et al. [18] have conferred a preliminary check all thermal biomass gasifier at middle Kingdom of Sweden University (MIUN). The MIUN gasifier joined a fluidized bed gasifier and a CFB riser as a combustor with a style appropriate for in-built tar/CH_4 chemical process restructuring. The check was dispensed by 2 steps, fluid-dynamic study and measurements of gas composition and tar. These tests give basic data for temperature management within the combustor and also the gasifier by the bed material circulation rate. For the gas composition measurements, the syngas was drawn by an air pump through a gas acquisition stage and tested manually in a very gas sampling bag (Cali-5-bond) and examined off-line in a very parallel FID and TCD detection GC-system. The biomass chemical action technology at MIUN was straightforward, inexpensive, and dependable.

Thanh D.B. Nguyen et al. [19] have developed a three-stage steady state model (TSM) for biomass steam gasification during a DFB to compute the producer gas composition, carbon conversion, heat recovery, price potency, and heat demand required for the energy-absorbing gasification reactions. These models divided into 3 stages, the biomass shift to char and volatiles, the solid–gas reactions between biomass char and gasifying reagents (carbon oxide and steam) in fluidized- bed, and also the gas part reactions among the vaporized species within the free board of the gasifier. At every stage, associate degree empirical equation was calculable from experimental information to calculate carbon conversion and vaporized parts. It had been assumed that each unpersuaded char and extra fuel were fully combusted at 950°C within the combustor and also the heat needed for chemical change reactions was provided by the bed material. These have assessed the method performance of DFB that specialize in the electrical power generation, victimization the TSM. A completely unique procedure was initially mentioned there to search out effective in operation conditions of DFB on the idea of seven method performance criteria.

F. Miccio et al. [20] have planned the combined gasification of biomass and brown coal in an interior circulating fluidized bed (ICFB) for generating a valuable gas. The ICFB additionally also known as dual bed, had been practical to biomass gasification. The main advantage of this technology was the likelihood to hold out the method in two interconnected vessels, the primary operative beneath gasification conditions, whereas the other permits for partial combustion of the fuel and char burn-off. The heat and mass transfer between the vessels was delivered by the high bed circulation rate. The most advantage of associate degree ICFB gasifier was the assembly of gas with doubtless high heating price and made in flammable species, decreased dilution with element. The reliableness of the devices that enable the convective mass and warmth transfer between the combustor and also the gasifier ought to be improved to utterly mitigate leaks. The analysis of bed samples once utilization within the gasifier for over forty hours confirmed that a decrease of each the typical size and also the expanse occurred for the catalyst. Finding these ascribed to the mechanical stresses imparted by the sand at the high fluidization speed within the riser. These features were the main focus of their in progress investigations.

AfsinGungor Associate and UgurYildirim [21] have planned a 2-D model for an atmospheric circulating fluidized bed (CFB) biomass gasifier that utilized the particle based approach conjointly integrated and at the same time expected the hydraulics and gasification aspects. They separated the biomass gasification modeling into 3 classes, physical science equilibrium models, kinetic rate models and neural network models. These dimensional models self-addressed each hydraulics parameters and reaction kinetic modeling. The gasifier operation needed understanding of the result of assorted operational parameters on the performance of the system. The consequences of the operational parameters like gasifier temperature of an atmospheric biomass CFB gasifier valid with experimental knowledge within the literature for sensitivity analysis.

PROPOSED METHODOLOGY OF THE GASIFICATION SYSTEM

The energy demand of BFB reactor depends on the excessive fuel and air supply in FFB reactor to produce sufficient heat for gasification. Thus within the proposed methodology the thought of verticity is taken into account for compensating the excessive fuel and air supply within the FFB reactor during which with the rotating movement of air one supply of fireside will increasing up with no further fuel supply. So as to attain this the proposed methodology primarily models the DFB gasification system supported the quasi equilibrium model. Then rotary drier model is employed to get rid of the moisture content with the biomass feedstock and is fed to the gasification reactor. Next to introduce the verticity of the fluid particles, completely different air feeding angular fixtures area unit employed in the FFB reactor. The schematic diagram of the proposed methodology is shown in [Fig. 1].

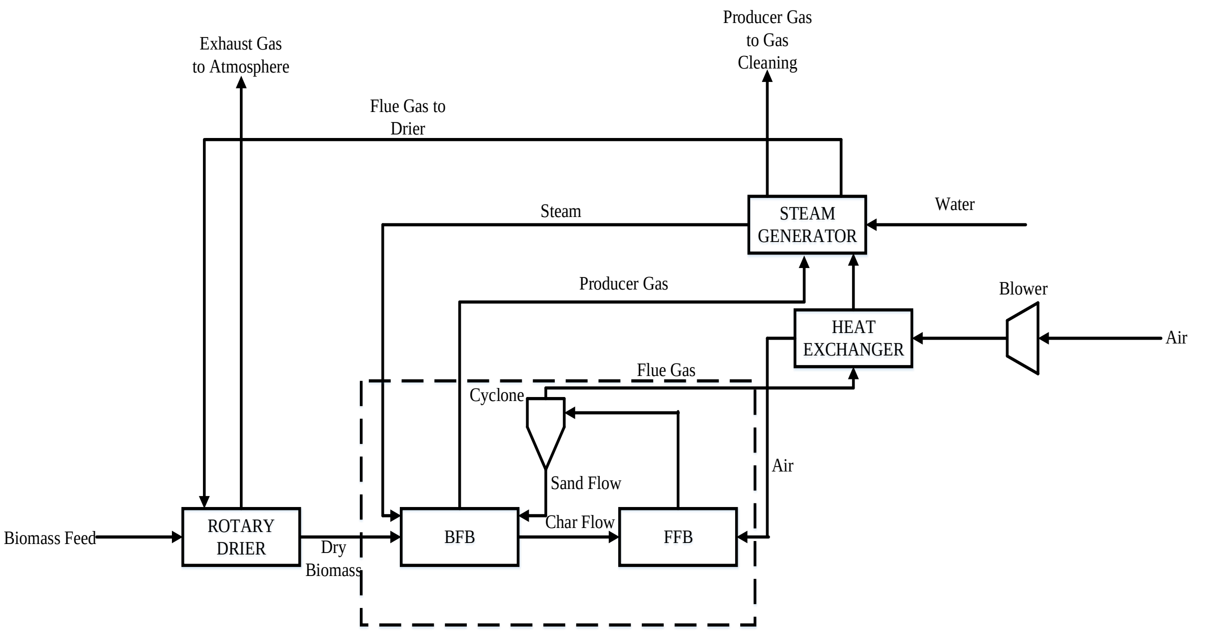

Fig. 1: Schematic diagram of proposed method

From [Fig. 1], the biomass first enter the rotary drier to diminish the moisture content. At that point, the dried biomass is given to the BFB reactor for steam gasification. The gasifier which provides the producer gas is chilled off to recoup for gas cleaning. The heat of the producer gas is recuperated for steam generation which is utilized in BFB reactor. The hot flue gas from FFB is utilized for preheating of air took after by generation of steam and toward the end for drying of biomass. If there should be an occurrence of typical operation, the FFB reactor temperature is higher than BFB reactor gasification temperature to convey the required heat with the end goal of gasification. The FFB reactor flue gas subsequent to preheating of air, generation of steam and drying of biomass is discharged to environment. Steam generation and air preheating are indirect procedure while biomass drying is direct procedure where biomass and flue gas are in direct contact. Thus, the exhaust gas water is from humidity of air, vaporization of food biomass moisture amid drying and excessive fuel ignition. The water imported to framework is utilized for source of steam produced in framework. The water present in the producer gas is acquired from the steam mixed to the BFB reactor, the water vaporized from gasification reactions and biomass.

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Characteristics of Biomass

In this proposed method, chips from Pinus radiata wood are utilized as feedstock in which the chemical formula is considered to be $C_{31}H_{45}O_{24.5}$ with proximate analysis and ultimate analysis shown in [Table 1] [22]. The LHV (Lower Heating Value) of biomass, ash free basis and water is computed by using the below correlation [23].

$$LHV_{BM} = 34835z_C + 93870z_H + 6280z_N + 10465z_S - 10800z_O \tag{1}$$

where is mass fraction of carbon (C), hydrogen (H), nitrogen (N), sulfur (S), and oxygen (O).

Table 1: Proximate analysis and ultimate analysis results of Pinus radiate

Proximate Analysis wt % (od)		Ultimate Analysis wt % (od)	
H_2O	0	C	51.2
Volatile	84	H	6.1
Fixed Carbon	15.6	O	42.3
Ash	0.4	N	0.2
-	-	S	0.02

The physical and thermal properties of Pinus radiata are calculated as a hypothetical compound. The feedstock heat formation is computed from reaction of the combustion, equation (2), and the capacity of heat of moisture free feedstock is computed using equation (3) [24].

$$C_{31}H_{45}O_{24.5} + 30O_2 \rightarrow 22.5H_2O + 31CO_2 \tag{2}$$

$$C_{P_{BM}} = 0.003867T + 0.1031 \tag{3}$$

where T is the temperature in Kelvin (K).

Rotary Drier Modelling

The modelling of the rotary drier's model is demonstrated in [Fig. 2]. The feedstock is thought to be from green log preparingor from forestresides, thusly, the moisturecontent is evaluated to be somewhere around 50-60%. A rotary drier was chosen for biomass drying in light of the fact that it is moderately straightforward and adaptable for utilizing distinctive types and sizes of biomass feedstock. Co-current design is received for the rotary drying, which avoids direct contact between dry biomass and thehot drying medium in this way lesser potential fire danger [30].

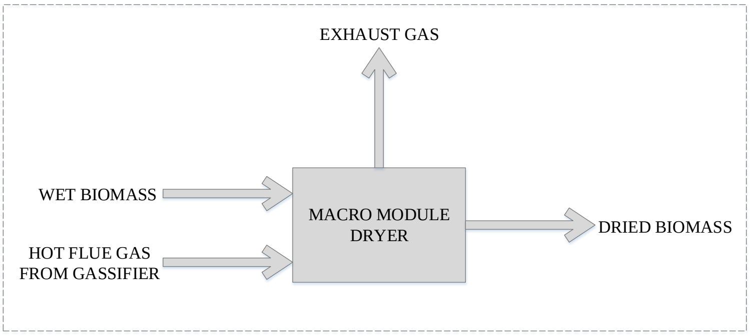

Fig. 2: Rotary dryer model

The computation of drying rate of actual biomass can be complex, which includes heat and mass transfer inside the solid biomass and among the surface of biomass and the drying medium. The absolute moisture content is relatively high, the rate of drying is still sensibly fast at drying end, and hence the process of drying is mainly controlled by the rate of heat transfer.

Mass Equilibrium of Water

The general mass equalization for the water over dryer is moderately basic on the grounds that there is no chemical reaction included in the process and the water is the main segment exchanging between stages. The water lost by the feed biomass is picked up by the gas stage, as is depicted in below equation

$$\dot{M}_{FG}(X_2 - X_1) = \dot{M}_{BM}(Y_1 - Y_2) \tag{4}$$

Where $\dot{M}_{FG}$ - rate of mass flow of flue gas (kg/s)

$\dot{M}_{FG}$ - Biomass on dry basis (kg/s)

$X_1 \& X_2$ - Flue gas humidity at inlet and outlet (kg/kg)

$Y_1 \& Y_2$ - Moisture content of biomass at inlet and outlet (kg/kg), which can be calculated by using the below equation

$$Y = MC/(100 - MC) \quad (5)$$

where MC indicates the moisture content of feed biomass. The humidity and rate of mass flow of inlet flue gas is calculated from operation of gasifier unit. Thus, if we know the target moisture content of the biomassandinlet, the outlet humidity of flue gas can be calculated from equation (4).

Energy Balance

The balance of energy for the drying system depends on the assumption that the provided heat by flue gas is equal to the gained heat by biomass for heat-up and vaporization of water plus the heat loss.

$$H = H_1 + H_2 + H_3 + H_4 + H_5 + H_L \quad (6)$$

In which

$$H = \left(\dot{M}_{FG} C_{P_{FG}} + \dot{M}_{FG} X_1 C_{P_{VW}}\right)\left(T_{FG} - T_{OUT}\right) \quad (7)$$

H_1 gives the heat for moist biomass to be heated to temperature of wet bulb which is given by

$$H_1 = \left(\dot{M}_{BM} C_{P_{BM}} + \dot{M}_{BM} Y_1 C_{P_{VW}}\right)\left(T_W - T_B\right) \quad (8)$$

H_2 gives the heat for vaporization of water at the temperature of wet bulb which is given by

$$H_2 = \dot{M}_{BM}(Y_1 - Y_2)\Delta Q_{VW} \quad (9)$$

H_3 gives the heat for biomass to be heated to the temperature of outlet temperature which is given by

$$H_3 = \left(\dot{M}_{BM} C_{P_{BM}}\right)\left(T_{OUT} - T_W\right) \quad (10)$$

H_4 is the heat utilized to heat moisture remaining in the biomass to the temperature at the outlet which is given by

$$H_4 = \left(\dot{M}_{BM} Y_2 C_{P_{LW}}\right)\left(T_{OUT} - T_W\right) \quad (11)$$

H_5 is the heat utilized to heat the water vapor to the temperature of outlet which is given by

$$H_5 = \dot{M}_{BM}(Y_1 - Y_2) C_{P_{VW}}\left(T_{OUT} - T_W\right) \quad (12)$$

H_L is the estimation of heat loss which is given by

$$H_L = 0.15H \quad (13)$$

In the above equations, is the latent heat of vaporization (kJ/kg), and are the inlet temperatures of biomass and flue gas, is the flue gas wet bulb temperature (0C), is the drier outlet temperature (0C), and and are the specific heat of biomass, flue gas, water, and liquid water (kJ/kg 0C) which are assigned as constants while drying.

Modeling Of DFB Gasification System

In this proposed method, DFB gasification system is modelled based on quasithree phase equilibrium model[19].Biomass steam gasification procedure is modeled in three phases including pyrolysis, char-gas reactions and reactions among gases. For modeling FFB reactor, a conversion reactor is described for combustion of unreacted char and unnecessary fuel. The DFB gasifier model developed is shown in [Fig. 3].

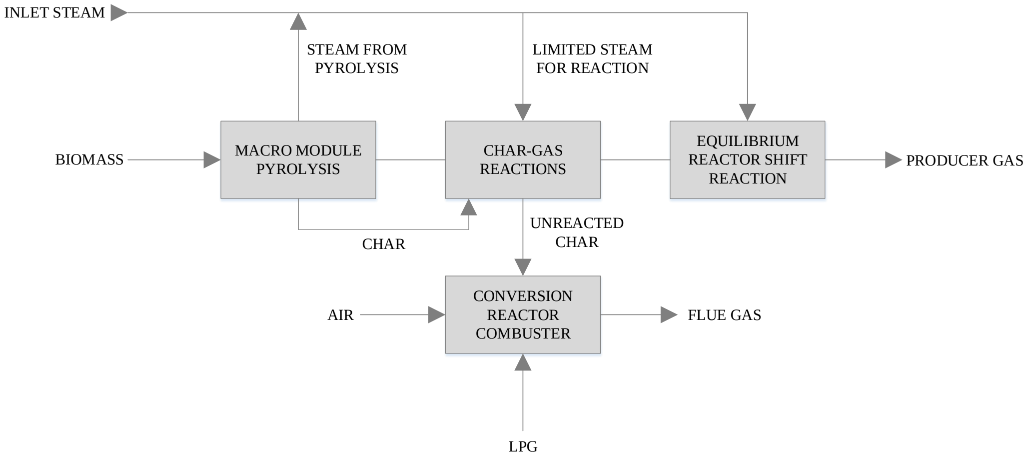

Fig. 3: DFB Gasification system model.

Pyrolysis Step Modelling

In Pyrolysis, biomass is transformed to char mixture and combustible gases. The exact prediction of the pyrolysis is considered as the most significant phase of the gasification [25]. Pyrolysis gas generally contains $H_2, CO_2, CO, H_2O, N_2, CH_4, H_2S, NH_3$ and tar vapors. Then by introduction of two empirical factors of molar ratio of CO/CO_2 (Φ_{CO}) and molar ratio of CH_4/H_2 (Φ_{CH_4}), five equations produced depends on elemental equilibrium of C, H and O components of biomass and gas to compute the concentration of five major elements of gas comprising of H_2, CO_2, CO, CH_4 and H_2O . In modelling, methane characterizes traces of other light hydro carbons and tar.

$$m_{CH_4} + m_{CO_2} + m_{CO} = m_C \qquad (14)$$

$$4m_{CH_4} + 2m_{H_2} + 2m_{H_2O} = m_H \qquad (15)$$

$$2m_{CO_2} + m_{CO} = m_O \qquad (16)$$

$$m_{CO} - \Phi_{CO} m_{CO_2} = 0 \qquad (17)$$

$$m_{CH_4} - \Phi_{CH_4} m_{H_2} = 0 \qquad (18)$$

where, m_i is molar flow rate of each element (kmol/s). Φ_{CH_4} and Φ_{CO} are computed by the subsequent correlations as a function of temperature.

$$\Phi_{CH_4} = 1.4 \times A_2 \times \exp\left(-{B_2}/{T_G}\right) \qquad (19)$$

$$\Phi_{CO} = A_1 \times \exp\left(-{B_1}/{T_G}\right) \qquad (20)$$

where T_G is gasification temperature (K), $A_1 = 4.7\times10^3, A_2 = 2.28\times10^{-3}, B_1 = 7163.6$ and $B_2 = 5404.85$ which were attained from curve fitting of experimental data [26]. The composition and amount of tar will change considerably from pyrolysis to final gasification. However, in this transition is ignored and the absolute tar content of producer gas were considered as function of gasification temperature, which has been taken from data in [27]. Then, composition of methane was altered by subtracting the hydrogen and carbon content of tar and its composition is given in [28].

$$Tar(wt\%) = -5.61\times10^{-3} \times T_G(K) + 6.95 \qquad (21)$$

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The other species concentration ($N_2, H_2S,$ and NH_3) are computed from fundamental balances for S and N and their reaction formation. The hydrogen composition is changed by subtracting the hydrogen content of hydrogen sulfide and ammonia.

Char Gas Reactions and Reactions among Gases Modelling

In this proposed method, boudouard, primary and secondary gas reactions were considered as char gas reactions whereas steam gas shift reaction was considered as steam gas reaction [29].

- Boudouard: $CO_2 + C \rightarrow 2CO$
- Primary Reaction: $H_2O + C \rightarrow H_2 + CO$
- Secondary Reaction: $2H_2O + C \rightarrow 2H_2 + CO_2$
- Shift Reaction: $H_2O + CO \rightarrow H_2 + CO_2$

It has been demonstrated that steam commitment to the primary and secondary reactions is restricted, along these lines, the steam commitment to reactions at balance can be computed utilizing a straightforward connection as follows [19].

$$\beta = \frac{m_{H_2O,CON}}{m_{H_2O}} = 51.4\exp\left(-75428 / T_G\right) \qquad (22)$$

Where $m_{H_2O,CON}$ is the moles of steam that contributes to the reactions, m_{H_2O} represents the total moles of steam and T_G represents gasification temperature.

The requirement of heat for BFB gasification reactor is given by the sum of requirement of heat of pyrolysis, char reactions and steam gas reactions. The requirement of heat at each part is computed from enthalpy balance. The produced char from biomass gasification and the FFB reactor excessive fuel are combusted with supplied air to deliver the required energy for BFB reactor. The excessive fuel to FFB is denoted by ratio of excessive supply of fuel energy to feed biomass energy.

$$\omega = \frac{\dot{M}_{FUEL} \times LHV_{FUEL}}{\dot{M}_{BM} \times LHV_{BM}} \qquad (23)$$

Where $\dot{M}_{BM}$ and $\dot{M}_{FUEL}$ are the mass flow of biomass and excessive fuel, and LHV_{BM} and LHV_{FUEL} are the equivalent lower heating values. The quantity of supplied air to FFB reactor is vital in design of DFB system. The need for supplying air to FFB reactor is for char oxidizing and excessive fuel as well as performing as fluidizing agent. The excessive factor for supplied air is defined as follows.

$$\lambda = \dot{M}_{AIR} / \dot{M}_{AIR,STOICH} \qquad (24)$$

where $\dot{M}_{AIR}$ is the mass flow rate of supplied air to FFB (kg/s), $\dot{M}_{AIR,STIOCH}$ is the mass flow rate of air at stoichiometric condition.

Biomass and air Feeding Angular Fixtures

In the proposed method, we have considered verticity for compensating the excessive fuel and air supply in the FFB reactor in which with the rotating movement of air from a single source of fire can flared up with no extra fuel supply. In order to achieve this we have designed the FFB reactor with different angular fixtures of biomass and secondary air inlet to study the effect of fluid particles in different characterized nature of verticity and their effects on axial temperature profiles for different angular fixtures of biomass and secondary air inlet in the fluidized bed zone. Four different angular (450,600,750and 900) biomass-feeding attachments are made and the required amount of biomass is filled in the hopper, which is connected to one end of the biomass feeding angular attachment. Similarly four angular (450,600,750and 900) air-feeding attachments and capacity blowers are connected to one end of the each air feeding angular attachment. Both attachments are fastened on the reactor chamber at maximum expandable bed height.

RESULTS & DISCUSSIONS

The proposed method is implemented on MATLAB working platform and the results obtained are given in this section. The results for the effects of temperature of gasification from 750 °C to 850 °C are shown in

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[Fig. 4] and for the S/B ratio effect from 0.6 to 1.2in [Fig. 5]. It can be seen in [Fig. 4 and [Fig. 5], with increase in temperature of gasification, the composition of H2 increases considerably while composition of CO decreases.

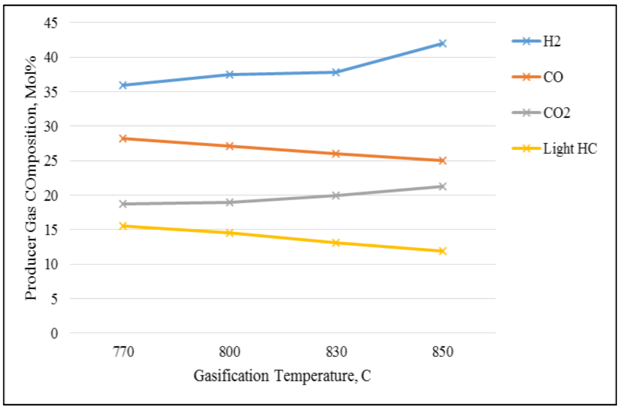

Fig. 4: Producer gas composition,*S/B* = 0.84

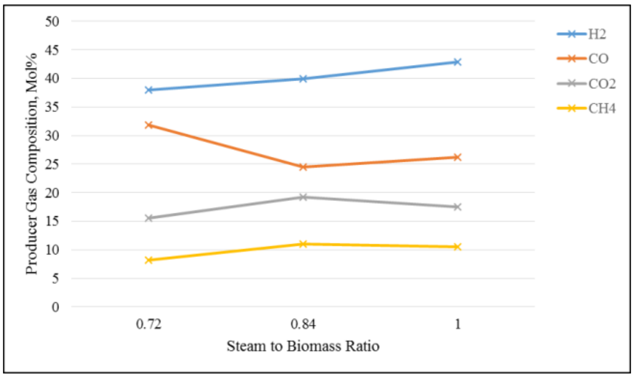

Fig. 5: Comparison of the producer gas composition, *T* = 850 °C

The effect of temperature of gasification and ratio of S/B on the performance of gasification has been observed utilizing the model established and the experimental results are presented in [Fig. 6] for the effect of gasification temperature and in [Fig. 7], for the effect of S/B ratio. From the Fig. 6 it can be observed that both the temperature of gasification and the S/B ratio have positive effects on gas output and ratio of H2/CO in the producer gas. The experimental results further more shows that the char output decreases with temperature of gasification and the ratio of S/B when more carbon is transformed to gas thereby more gas output. Though, as can be understood in [Fig. 6] and Fig. 7], the temperature of gasification has more important effect than the ratio of S/B on the gas output. For that reason, increasing the temperature is more efficient on reactions of char-gas than adding more steam to the system.

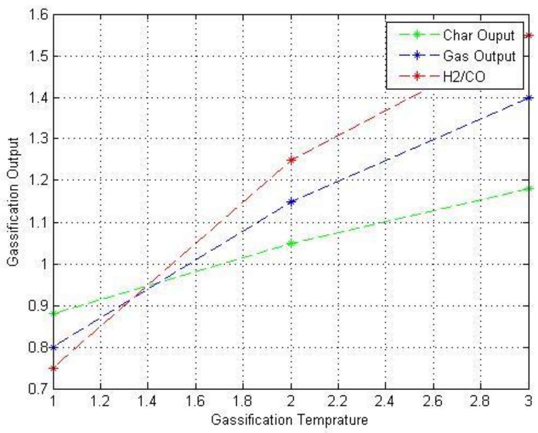

Fig. 6: The effect of gasification temperature on the system outputs, S/B = 0.80

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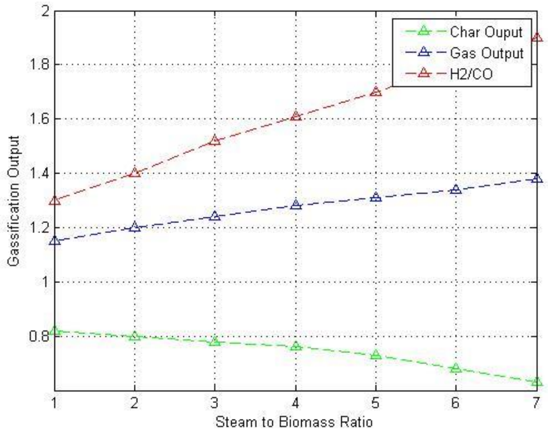

Fig. 7: The effect of steam to biomass ratio on the system outputs, T = 850 °C.

From [Fig. 7], it can also be understood that with rise in the ratio of S/B the gas output rises slightly but theratio of H2/CO of the produced gas rises more significantly. Both the temperature of gasification and ratio of S/B favor the steam-gas shift reaction near hydrogen production found according to the principle of Le Chatelier's, in which higher H_2/CO ratio results. The results obtained by different angular axis of biomass and Air feeding angular fixtures is shown in [Table 2] which gives the value of temperature, pressure drop and air velocity.

Table 2: Results of Biomass and Air feeding Attachment angle combination

Biomass and Air feeding Attachment angle combination	Temperature	Pressure Drop (N/m^2)	Air Velocity (m/s)	Mass Flow Air (Kg/s)
90^0-60^0	812	2901	0.023	0.0301
90^0-75^0	828	2845	0.020	0.0284
90^0-90^0	705	3470	0.047	0.0589
75^0-60^0	725	3345	0.042	0.0541
75^0-75^0	702	3478	0.048	0.0589
75^0-90^0	687	3712	0.051	0.0625
60^0-60^0	742	3648	0.044	0.0569
60^0-75^0	764	3601	0.035	0.0521
60^0-90^0	801	2941	0.020	0.0280

The effect of bed characteristics is another impact in the gasification system. The variation in the residence time with bed height is shown in [Fig. 8] in which the increase in bed height from 0.5 to 2.0D increased the residence time from 0.89 sec to 4.20 sec.

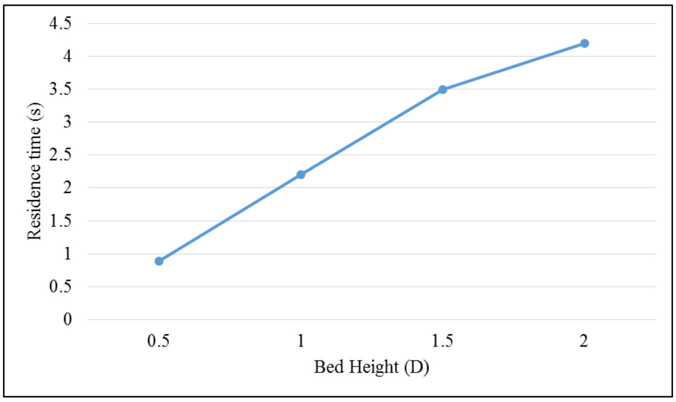

Fig. 8: Bed Height Characteristics with residence time

The impact of feed biomass moisture content by the exhaust gas on energy and exergy losses is shown in [Fig. 9]. As seen from the [Fig. 9], even though the exhaust gas energy loss rises intensely with rise in the content of feed biomass moisture, the exergy loss is not as much of exaggerated. The energy loss over exhaust gas rises with content of feed biomass moisture as its flow rate rises with more evaporation of

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water. Though, its exergy somewhat variate as its temperature is kept nearly constant with increase in content of feed biomass moisture. In the drying model, the inlet condition varies while temperature of exhaust gas and target biomass moisture content of are constant.

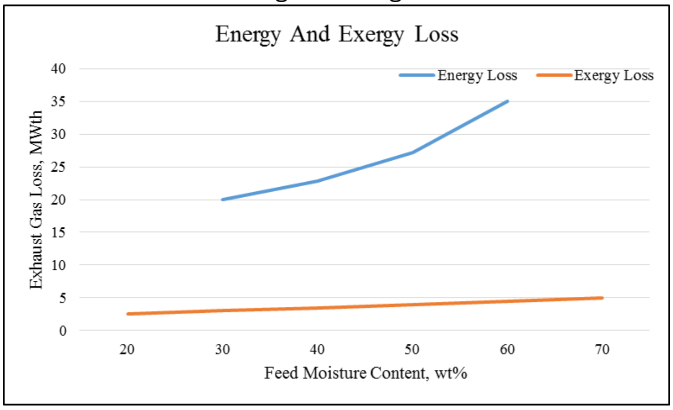

Fig. 9: The effect of feed moisture content on energy and exergy losses

The irreversibility of unit operations and the exhaust steam of flue gas are two sources of exergy loss though the irreversibility of dissimilar unit operations is the foremost contributor to the exergy loss of the system. The distribution of dissimilar unit operations in interior exergy loss of the system at different feed biomass moisture content is shown in [Fig. 10].

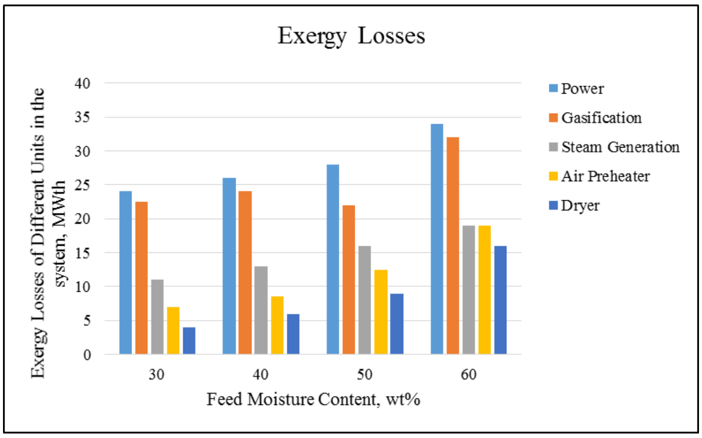

Fig. 10: The exergy losses of different unit operations in the system

The total exergy loss by the model rises considerably by increasing the moisture content of feed biomass. The exergy loss due to the drying is unimportant at low feed biomass moisture contents of below 30%. On the other hand, the exergy loss raises with feed biomass moisture contents intensely and the exergy loss from drying was higher than the gasification with feed biomass moisture content is at 50% or higher. Exergy loss due to steam generation falls significantly by the increase of the feed biomass moisture content.

CONCLUSION

The energy requirement of BFB reactor depends on the excessive fuel and air supply in FFB reactor to deliver sufficient heat for gasification. An integrated model system for DFB gasification and rotary dryer is established in mathematical modelling. Flue gas from the FFB reactor was employed for biomass drying. In the proposed model, the idea of verticity is considered for compensating the excessive fuel and air supply in the FFB reactor in which with the rotating movement of air from a particular source of fire can flared up with no extra fuel supply. The proposed method is implemented on the MATLAB platform and the experimental results are validated based on the operation parameters such as gasification temperature, feed air to the FFB reactor, S/B ratio and initial moisture content of the feed biomass.

CONFLICT OF INTEREST

There is no conflict of interest regarding the publication of this paper.

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