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A Technological Progress and Influence of Operating Parameters In Bubbling Fluidized Bed Gasifiers

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Abstract

In recent years there has been an attempt to minimize our dependence on fossil fuels and exploits the other renewable sources. Biomass is one of the major resources with high convertibility through processes gasification. Among the two major routes: biochemical and thermochemical adopted for converting raw biomass feedstock into productgas,thepresentstudyfocusonadvancesinthermochemicalbasedbubblingfluidizedbedgasifiers(BFG). The paper aims at a compressive review on both solar assisted and conventional BFGs. Detailed insights are presented in terms of parameters like the effect of temperature, particle size, type of biomass, the feed rate of biomass, bed height, bed material on the energy conversion,heating value, gas yield,, tar conversion, gas compositionetc.

1. INTRODUCTION

The present era is an era of energy struggle, every nation is in need of energy as the sources of petroleum products are about to extinct, the primary worlds energy consumption has been drastically increased from the last 30 years[1]. Gasification is a thermochemical process that converts biomass into the usefull form of energy. This tremendous surge in the consumption of fossil fuels led to global warming and climate changes. Nature has gifted mankind the wonderfull natural resources with the least polluting agents, therefore, nature provides an option to switch to natural products from petroleum products which are at an alrming rate of extinction.There fore combining two natural energy sources that are biomass and solar energy is an alternative move to come out from the consumption of fossil fuels. Gasification of biomass converts the biomass into the usefull form of energy. The products of gasification are syngas, methane, which can be used for different purposes.

Gasification

It is a thermochemical process,itdiscusses to the conversion of carbonaceous material whether fossil or non fossil into gaseous fuel and chemicals[1]. Gasification requires a gasification medium so that reaction could occur. The gaseous medium could be gas(air, oxygen or supercritical steam. Nowadays non-fossil fuels are least used in gasification they are now replaced by fossil fuels like biomass. The final product of gasification is syngas or producer gas, which is a mixture of the corbon-monoxide and hydrogen.

The gasification is highly energy consuming process, and in order to commence the gasification process, it requires a very high temperature as it is a highly endothermic reaction and to attain the thermodynamic equilibrium. The temperature range so to occur the gasification process is about greater than 700◦c. Mainly 30% of energy is consumed from the initial feedstock of biomass to start the initial gasification in conventional autothermal reactors[2].In order to save this 30%energy from biomass resources concentrated solar energy power becomes handy and imparts the required amount of energy to start the gasification process,[3]. Besides this CSE provides and

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wide temperature range >1200◦c which gives the better yield and quality of syngas and low tar content [3].
The are other pathways of conversion of biomass into useful form those are listed belowin the fig [1]

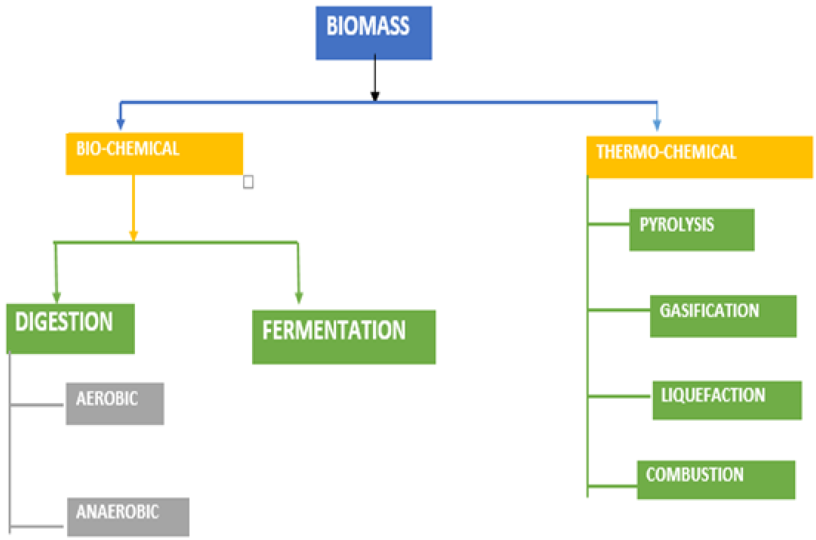

Fig1 Pathways of Conversion Of Biomass [1]

The gasification process requires the gasification agents because the biomass material contains the high molecular weight so to convert them into low molecular weight like CO and H_2. The different gasifying agents are mentioned below

- Air
- Oxygen
- Steam

Depending on the medium or agent used, as is the heating value and the composition of producer gas (Table[1]).

Table 2: Gasifying agents and heating values

Gasifying agent	Heating value (MJ/Nm^3)	Nature of product gas
Oxygen	12-28	CO &CO2
Steam	10-18	CO & H2
Air	4-7	CO

2. TYPES OF GASIFICATION

For the sake of comparison, gasification can be broadly classified in to two major categories shown in Fig 2.

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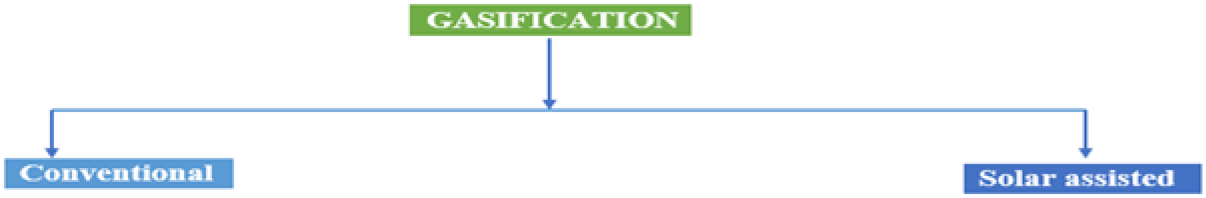

Fig 2 Major categories of gasification

2.1 Conventional gasification

Conventional gasification is referred as that type of gasification in which the gasification is initiated with the biomass, itself that is the ignition temperature is achieved by burning the biomass hence consuming the 30% energy of biomass. The conventional gasification is achieved through different gasifier those are listed below in fig 3.

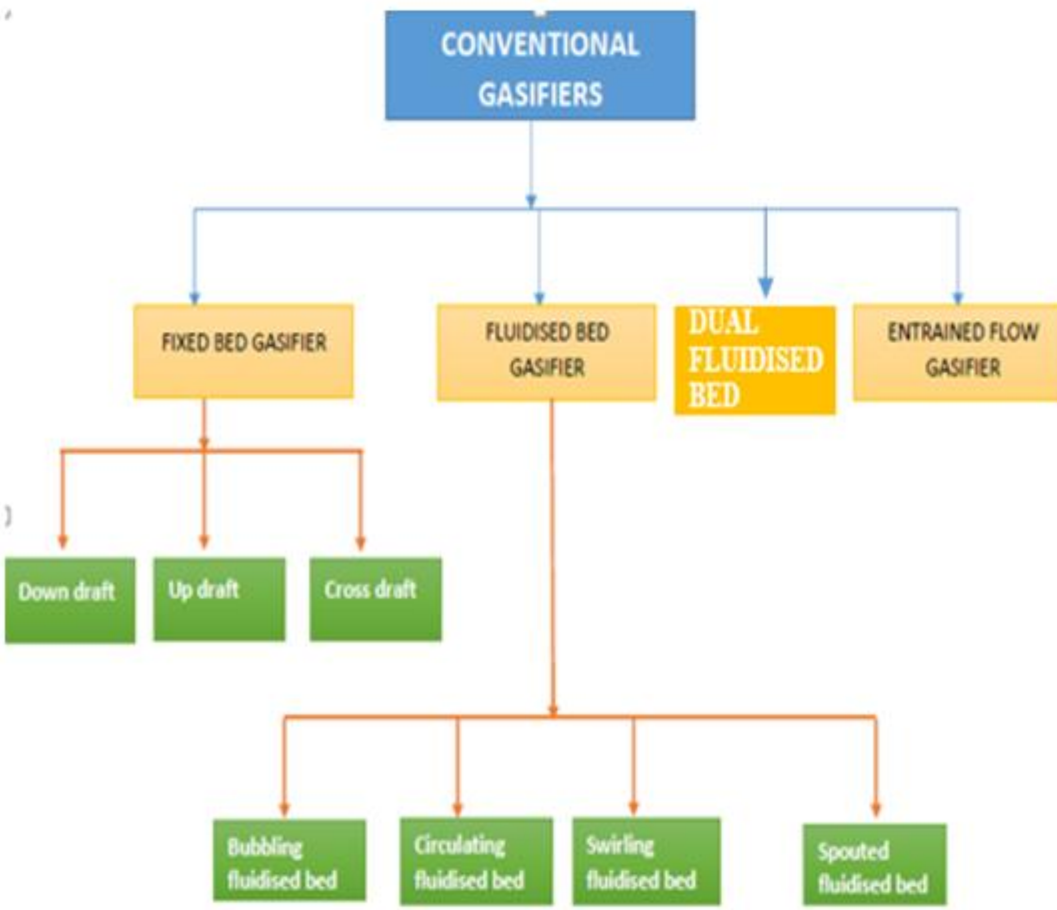

Fig 3 Types of Gasifier

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FIXED BED REACTOR*:*The fixed bed reactor is also known as a packed bed reactor, in this reactor, the fuel used for gasification is in solid form, these are made also in small sizes and they are economical to manufacture. Due to this reason, they are in use throughout the world. The fixed bed reactor is a cylindrical assembly with the fuel sustained at the bottom on the grate. The are different types of reactors depending upon the air feed[1]

i) Updraft Fixed Bed Gasifier

The updraft gasifier is also known as a counter-current gasifier, in this reactor, air is fed from the bottom and the feedstock is fed from the top, both are fed in the counter direction and the gas produced leaves the reactor from the upper side of the gasifier. The feedstock passes through different zones, the bottom zone is gasification zone which is at high temperature at which both the biomass and the gasifying medium react resulting in the char, product gas, and ash, the ash is collected at the bottom and the other products are collected at the top of the gasifier and the gas cleaning process is done to clean the gas**.**

ii) Down-draft fixed bed gasifier

The downdraft gasifier is the contrary of the updraft reactor, in the downdraft reactor the feedstock and the gasifying medium isfed from the top and sideways respectively. This gasifier was introduced to remove the tar production problem which was encountered in the up-draft gasifier**T**he downdraft gasifier has an advantage over the updraft gasifier, however this type is not suitable for the feedstock which has low ash fusion and high contents of ash and it results in the slag formation.

iii) Cross draft fixed bed gasifier

In this feedstock is fed from the top of the gasifier and gasifying agent is fed through the one side of the wall of the reactor and the gas leaves the reactor at the bottom. The cross-draft reactors are used in running engines and their tar production is very low also they are easy to manufacture but any change in moisture content of biomass and constituents in biomass leads to change in gasification [4]

FLUIDISED BED REACTOR

It's the type of reactor which works on the fluidization principle, which states that the biomass is suspended with velocity inside the reactor known as the minimum fluidization velocity and reacts like the fluid, the zones which appeared in the fixed bed reactor are not seen here the whole reactor has temperature uniformity. The reactor has bed known as the fluidized bed which is initially heated before feeding of the biomass, and then the biomass is mixed with bed material. There are different types of reactors of a fluidised bed which are given below [4].

i) Bubbling fluidised bed gasifier

This reactor was first created by Winkler in 1921,[1], this reactor is used for gasification of coal from many years. Depending on the use they can be developed as high temperature or low-temperature range gasifiers and their pressure range could be atmospheric or more than that.The bed is fed with gasifying medium and the reactor temperature is 900◦c at which the gasification occurs.

***ii)* Circulating fluidised bed gasifier**

The CFB is better than bubbling bed gasifier because of the reason that the biomass archives more reaction time in CFB than BFB gasifier. Because of the high reaction time of biomass, it is favored for high volatile fuels. [1]

The CFB has the following parts those are given below

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1. Riser
2. Cyclone
3. Solid recycle device

The riser acts as a reactor where the reaction takes place. The velocity through which the particles get suspended throughout the reactor is from 3.5 to 5.5 m/s whereas the velocity in BFB is 0.5 to 1 m/s.The solids which are collected outside the riser is the solid recycled are again fed to the base of the riser. In order to maintain the hydrodynamic condition of the riser the rate at which solids are collected back and the velocity (fluidization velocity) is enough.

iii) **Spouted fluidised bed gasifier**[4]

The different technique is used in this gasifier a fountain is created in the center of bed by the gasifying medium which provided by the large gape present at the base of the reactor and the extra air is used to make the whole bed cyclic and produces a spouted fluidizedbed.The gasifying medium could be air-steam or oxygen-steam, and various ranks of coal are used at high pressures. The particle size should be 1mm.

iv) Swirling fluidised bed gasifier[4]

The reactor consist of the bed particles which are granular and the reactor is a cylindrical column. The air is passed in to the reactor in two phases, the first phase, that is primary air is passed to the reactor through distributor plate from the bottom and the second phase that is secondary air through the sides of reactor at the freeboard zone, the primary air is supplied to make the system fluidized and the secondary air is provided to create a swirl and it provides good and enough time for mixing and the enough residence time . The swirl prevents the elimination of particles from the combustion chamber, this is mainly suitable for steam gasification.

v) **Entrained flow gasifier**[1]

The working of entrained flow gasifier is little different from the fixed and fluidized bed gasifier as its hydrodynamics is similar to pulverized coal boiler (PCB) but the oxygen required is in range of sub-stoichiometric but PCB requires a very high supply of oxygen and the geometry also varies. Thehigh-velocity jet is provided at the entry zone thus results in creating the recirculating zone.The feedstock fed from the top or sideways receives the heat from walls through radiative heat transfer and the downstream of hot gases and in the starts burning in the oxygen.The high amount of fuel through devolatlization is consumed at the entrance zone and the temperature may be as high as 2500◦c.Nearly the all oxygen supply is consumed in the combustion reaction and in theCO_2 and H_2O downstream environment zone the char undergoes gasification and these reactions comparatively slow than devolatilization so take much time in the conversion of char into gases therefore length of reactor is required .

Mostly all types are coal could be used except low-rank coal like ignite and biomass because of high moisture content. There are other reasons for the biomass is not used in entrained flow gasifier those are given below

1. The low residence time for the reaction of biomass in entrained flow gasifier
2. The high oxygen is required for biomass because biomass with calcium oxide and no alkali, the ash melting point is high,

The fuel needs to be very fine so to achieve that stage of the size of particles is very difficult The entrained flow gasifiers are known as a co-current plug flow reactor, here gas and fuel

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travel.Nearly 100% conversion of carbon is achieved low methane formation is observed, the tar content is nearly very low

vi) **Twin reactor or dual fluidised bed gasiifer**[1]

The system comprises of both the bubbling bed and the circulating fluidizedgasifier.The system is shown through the fig

The riser of CFB acts as the combustor and the BFB in the return leg acts as the gasifier, the superheated steam is used in the BFB and the pyrolysis and gasification takes place there. The non-mechanical valve is provided through which the unconverted tar and char moves to the riser and the air is used to fluidize the riser. In the combustion zone of riser, the tar and gas are produced during pyrolysis. The heat supplied for the endothermic reactions is gained from the particles which leave the riser those are collected at the riser exit and passed through stand pipe to BFB. The product gas is tar free as the tar is burned in the combustor,

Advantages of the dualfluidized bed are listed below

1. The combustor and gasifier both work on fluidization principle
2. The two chambers are given with different fluidization velocities as a result produces different bed densities
3. The beds have the same height but different hydrodynamic pressure at the bottom which makes the flow of biomass and sand possible from high pressure to low pressure creates a continuous circulation as like in a boiler. Hence results in a high residence time
4. The gasification yield is high due to proper mixing of biomass
5. The tar content in product gas is very low

2.2 Solar gasification

Solar gasification refers to the allothermal gasification of carbonaceous feedstock, in which the biomass is heated with the concentrated solar energy for the production of syngas, methane , applicable for generation of power in combined efficient cycles and fuel cells or for the production of liquid biofuels [6] [7]. Gasification of biomass in solar reactors is achieved in two ways, directly irradiated and indirectly irradiated solar reactors (fig 4)[2]. The exploration and evaluation of solar energy led the development of new designs of solar reactors like high flux solar simulator (HFSS), this system enables us to create the artificial sunlight required for laboratory experiments as it imitates the working of solar dishes or solar furnaces[8]. Argon and xenon short arc lamps are used in HFSS[9]. Studies on HFSS innovation began at the start of the 90′s[10].

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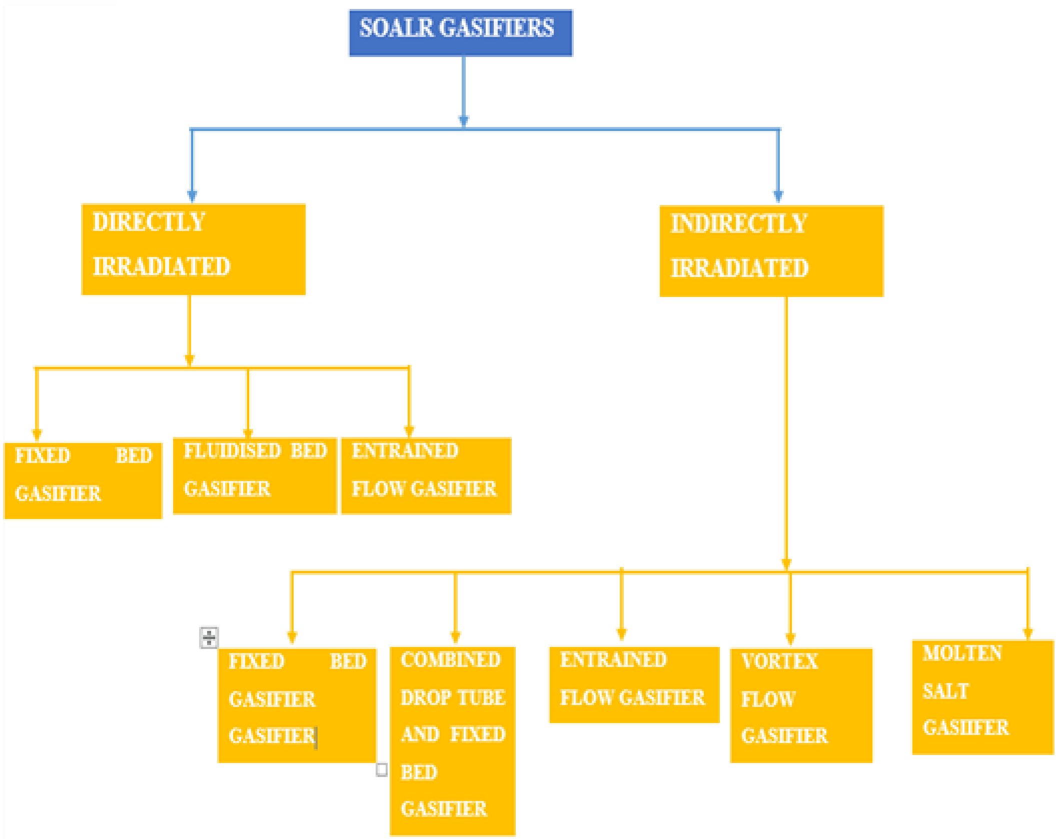

Fig 4 Types Of Solar Reactors[5]

i) **Directly Irradiated Solar Gasifier(DSIG)**

Irradiation refers to the process of exposing the material to the radiation so is the case in the directly irradiated solar gasifier.The DISG refers to the gasification of feedstock under solar radiation, the solar radiations are focused over a point through the window of the reactor in order to have a minimum loss of the energy and the gasification reaction should occur in a controlled manner. In DISG, there are the chances of the failure of the gasifier because with the gasification the tar and ash are produced, if the biomass is volatile in nature the tar and ash will get stick to the window and led to the failure

ii) **Indirectly Irradiated Solar Gasifier(IISG)**

In the IISG, the concentrated radiations are concentrated over the highly absorbing and conductive material and then concentrated over the feedstock to led the gasification reaction, there is no requirement of the window and encounters the problem of fouling as observed in DIR and keep safe from the failure of the [5]

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3. PROGRESS IN GASIFICATION

Table 1 Parameteric studiies on gasification

Year	Reference	Gasificatontype	Reactor Material	Dimensions		Biomass type	Major findings
				Diameter	Height		
1980	[14]	**Conventional** (bubbling fluidized bed)	-	-	-	Oak sawdust	• The air-steam mixture as the fluidizing agent • Comparison on gas yield, heating value, and the gas composition.
1980	[15]	**Conventional** (bubbling fluidized bed)	Stainless steel	0.15m diameter	0.12m height	-	• The granulation parameters on particle growth were established
1981	[16]	**Conventional** (bubbling fluidized bed)	310 Stainless steel	0.23m internal bed diameter, 0.4 expanded freeboard diameter	-	Waste tire	• Steam and air as fludizing agents • The operating temperature was 900-1100K • The gas yield decreased with reduction in temperature
1992	[17]	**Conventional** (bubbling fluidized bed)	40 Inconel 600 alloy	10.16 cm of the reactor section 15.24 cm of disengaging	55cm reactor zone 20 cm disengaging zone	Rice husk	• steam as a gasifying agent • comparison at 700°C and 800°C • gas compositions and carbon conversion with varies with temperatures.
1996	[18]	**Conventional** (bubbling fluidized bed)	-	6 cm	-	Sawdust (pine)	• effect of temperature • effect of H/C ratio • effect of the secondary air inlet.
1999	[19]	**Conventional** (bubbling fluidized bed)	Carbon steel	417mm bed diameter, 835mm disengaging zone,	4195mm total height, 686 mm bed height	Sugar cane bagasse	• air as a gasifying agent • air distributor plate was bubble cap type • parameters were measured as function of the air factor
2000	[20]	**Conventional** (bubbling fluidised bed)	-	60mm ID		Almond shells	• Comparison under two bed material olivine with dolomite • Effect on the tar content of producer gas.

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2002	[21]	**Solar** (bubbling fluidize)	Quartz tube	20mm ID,	20mm bed height 45mm freeboard	coal	• Biomass was directly exposed to solar radiation with the help of xenon beam reactor • with increasing intensity of radiations solar gasification increased maximum energy conversion was 8%, • the solar flux varied from 420 to 1270 kW/m^2
2003	[22]	**Conventional** (bubbling fluidized bed)	-	200mm internal diameter at the bottom and 300mm at the freeboard	-	Sub-bituminous coal	• Air and steam as gasifying agents • temperature was 880°C - 980°C
2003	[23]	**Conventional** (bubbling fluidized bed)	Stainless steel	100 mm	1m and 8cm	Waste tire powder	• air as a gasifying agent • parametric studies
2004	[24]	**Conventional** (bubbling fluidized bed)	-	-	-	Biomass slurry	• Supercritical water used as a gasifying agent • alumna used the bed particles
2005	[25]	Conventional (bubbling fluidized bed)	Stainless steel	29mm reactor 100 mm thermost at bed	-	Dried sewage sludge Car tires Bituminous coal Activated carbon	• Air as gasifying agent • sand as bed particles • compared the gasification rates of char and activated carbon in which it was observed sewage sludge has the highest reactivity and activated carbon has least reactivity
2006	[26]	**Conventional** (bubbling fluidised bed)	Stainless steel (1Cr18Ni19Ti)	100mm outer	1200mm	Mixed wood saw dust	demonstrates the tar-free gas with varying temperatures, the carbon conversion efficiency, and cold gas efficiency

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2007	[27]	**Conventional** (bubbling fluidised bed)	-	0.3 m	3m	Rice Husk	demonstrates the design of the fluidized bed gasification
2008	[28]	**Conventional** (bubbling fluidised bed)	-	a)not given b)800mm	a)6m b)11m and static bed height is 1.2m	-	Estimated the bed height using 2D cold models based on the axial pressure fluctuations
2008	[29]	**Conventional** (bubbling fluidised bed)	-	.192m internal	0.8 m	-	• A rotating distributor • effect of rotating distributor on the minimum fluidizationvelocity, bedheight was demonstrated
2009	[30]	**Conventional** (bubbling fluidised)	-	0.66m	1.8 m	-	• effect of diameters of bed particles on the fluidization velocity, • river sand, alumina sand and quartz sand
2010	[31]	**Conventional** (bubbling fluidised)	-	10.2 cm	106cm	Glass beads Ground walnut shells Ground corncob	• effect of the bed to height ratio • effect of superficial gas velocity on the hydrodynamics of the fluid
2011	[32]	**Conventional** (fluidized bed)	Mild steel	30cm ID	195cm	Rice Husk Sawdust Rice straw Mixed biomass	• effect of the parameters like feed rate, reaction time, fluidisationvelocity,etc. on the product gas. • demonstrates study of two models cold and hot model through mat lab

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2011	[33]	**Conventional** (bubbling fluidised bed)	Seam less stainless steel	200mm	1500mm	Saw dust	demonstrates combustion efficiency for different fuel feed rates or different values of excess air and particle size
2012	[34]	**Conventional** (bubbling fluidizedbed)	-	-	-	Chicken Litter	• demonstrates the study design of the gasifier • comparison of results from chicken litter, sawdust and rice husk with other others
2012	[35]	**Conventional** (bubbling fluidizedbed)	-	12cm	70 cm	-	demonstrates the design of fluidized bed for the application of the abatement of the fluoride from the industrial effluent gases
2013	[36]	**Conventional** (bubbling fluidizedbed)	-	94mm	360mm	-	Associates review of the published work models for the fluidization at the ambient conditions.
2013	[37]	**Conventional** (bubbling fluidizedbed)	-	82mm	-	Waste tire	• The air was used as the gasifying agent • The effect of different equivalent ratios, bed material, gasification temperature on the gas composition was studied
2015	[38]	**Conventional** (bubbling fluidizedbed)	-	-	-	Wheat straw	The mullite was used as the bed material, The equivalence ratio in the range of 0.1 to 0.65 and its effect on the lower heating value (LHV) of the producer gas was observed and its compatibility with the engine. The LHV was 3.6 MJ/m^3at the equivalence ratio of 0.165.

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2017	[39]	**Conventional** (bubbling fluidizedbed)	Stainless steel	83mm	1250 mm	Olive kernels, Date palm stones	Thethermogravimetricfluidized bed was designed, and the results were compared with the thermogravimetric fixed bed reactor, the effect of the temperature and the equivalence ratio were studied
2017	[40]	**Conventional** (bubbling fluidizedbed)	-	0.15m	2.5m	Coal	The proportion of mass flow rate of air was varied from 0.25 to 0.35, the ratio of mass flow rate of steam diverse from 0.15 to 0.25 and the effect of these variable ratios on the carbon conversion, cold gas efficiency, product gas heating value. The thermal output of gasifier was 100 kW.
2018	[41]	**Solar indirectly irradiated** (fluidizedbed)	Buster M-35(circula r zirconia), Stainless steel	42mm ID 52 mm OD	300mm	Charcoal Lignite Coal	This study is combined solar/autothermal gasification and the solar indirectly irradiated solar gasification. Carbon conversion, maximum cold gas ratio and solar to fuel ratio were studied. The effect of type of biomass on the performance of gasification wascalculated
2018	[42]	**Conventional** (bubbling fluidizedbed)	-	-	-	a) Rubber) wood c) Sawdust	• Dolomite and alumina sand as bed materialwere • 25% tar was reduced with dolomite. • The heating values were also compared.
2018	[43]	**Conventional** (bubbling fluidized bed	-	150 mm	2.3 m	a) Coffee husk b) Sawdust	The effect of agglomeration on the gasification separately of each biomass and gasification
2018	[44]	**Conventional** (bubbling fluidized bed	-	2000mm of one zone 800 mm of second zone	7773 mm	Rice Husk	• two-stage gasification concept • effect of the tar concentration on the product gas

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2019	[45]	**Conventional** (bubbling fluidized bed	-	78mm ID 102mm freeboard	1630mm	Beechwood Polyethene	• effect of bed material • effect of steam injection rate on the co-gasification of biomass

4. INFLUENCE OF DIFFERENT PARAMETERS

There are several parameters that affect the working of gasifier. These are summarised for both conventional and solar gasification process.

- Effect of Temperature on gas yield:
  Gas yield decreases as the gasification temperature decreases but heating value increases [16]
- Effect of Air Factor on Gas Lower Heating Value in Conventional Gasification:
  With air factor range in between 0.17 to 0.22 the heating value remained constant there was no effect on the heating value with changing air factor [19].
- Effect of Air Factor on The Cold and Hot Gas Efficiency in Conventional Gasification:
  The cold and hot gas efficiency increases with changing air factor [19]
- Effect on The Temperature of Bed Using Oxygen Indirectly Irradiated Solar Gasifier: The bed temperature increased on introducing oxygen in the reactor in indirectly irradiated solar gasifier [41].
- Effect of Biomass on Product Gas in Indirectly Irradiated Solar Gasifier:
  The total gas flow is less for the lignite coal but higher for the charcoal.[41].
- Effect of Bed Material on Tar Concentration in Conventional Gasification: -
  The concentration of tar is 25% less using dolomite as bed material as compared to the alumina sad used as the bed material produced.[42].
- Effect Of Equivalence Ratio On Different Parameters in Conventional Fluidised Bed:[18]
  - Effect of equivalence ratio on the gas composition in the range 0.20 to 0.40**: -**
  The gas composition (H, C, CO, CH_4) decreases on increasing the equivalence ratio
  - Effect of equivalence ratio on the tar content**: -**
  The tar content decreases on increasing the equivalence ratio until 0.45 but the heating value decreases.
  - Effect of equivalence ratio on the low heating value of gas: **-**
  The heating value of the gas decreases by increasing the equivalence ratio. At the ER=0.25 the LHV 5.2-7 MJ/Nm^3, but at the ER=0.45 the LHV= 3.45 to 4.5 MJ/Nm3
  - Effect of equivalence ratio on the gas yield**: -**
  The gas yield increases on increasing the equivalence ratio and the tar yield decreases but the heating value decreases.
- Effect Of The Freeboard Temperature On Tar Content:-[18]
  The tar content decreases on increasing the freeboard temperature up to 100°C. The tar decreased 2g/m^3 6g/m^3, but there is no impact on the gas composition
- Effect Of H/C On The Tar Content:-[18]
  The tar content decreases from 18 g/m^3 to 2 g/m^3 as the increase in the H/C ratio from 1.6 to 2.2

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- Effect Of The Equivalence Ratio On The Bed Temperature: -[37]
  The equivalence ratio has an impact on bed temperature. The bed temperature decreases below 700°C as the EQ is below the 0.28
- Effect Of The Equivalence Ratio On The Gas Composition in conventional gasification:[37]
  -The gas composition increases with a decrease in the equivalence ratio. The carbon monoxide and carbon dioxide concentration increase if the ER is in the range of 0.45 to 0.25. But below this range from 0.29 to 0.15 the concentration of CO decreases. The
  - Concurrently the concentrations of CH_4 and H_2 increase in the range of the ER 0.45 to 0.29 from 4% to 6% but in the ER 0.29 to 0.15 the percentage rather increases more from 6% to 12%
- Agglomeration Characteristics of biomass (coffee husk and sawdust) in conventional gasification:[43]
  -The coffee husk has been found prone to agglomeration whereas the sawdust is not prone to agglomeration.
  -The combination of both coffee husk and sawdust shows a less agglomeration.
  -The agglomeration is caused by the presence of the potassium in the biomass, coffee husk contains 55% potassium by weight while as sawdust has just 7%.
  -The mixture contains 29% only that's is the reason that co-gasification shows less accumulation of biomass.
- Effect of temperature on the producer gas in the conventional gasification:[17]
  - Effect of temperature on the gas yield:

The gas yield increases with the increase in the temperature, at the 700°C ,750°C,800°C the respective gas yields were 0.43m^3/kg, 0.63m^3/kg, 0.71m^3/kg.

- Effect of temperature on the heating value:

There is the inverse effect of the temperature on the gas heating value as the temperature increases the heating value decreases, at the temperature, 700°C ,750°C,800°C the respective heatng values are 12.1 MJ/m^3, 10.8Mj/m^3, 11.1MJ/m^3.

- Effect of temperature on the carbon conversion:

The carbon conversion increases as the temperature increases at the temperatures 700°C ,750°C ,800°C the respective carbon conversion obtained was 31.32%, 43.08%, 45.88%.

-Effect of temperature on the energy recovery*:*

The energy recovery increases as the temperatures increases at the temperatures 700°C, 750°C,800°C the respective recover was 37%, 50%, 55%.

- Effect of the bed material on the different parameters in conventional gasification :[20]
  The bed material has great effect on the heating value, tar content, gas yield, water conversion. the sand produces very high tar content while dolomite produces least and olivine has very less. Similarly, the heating value, gas yield change with bed material.

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Table 2 Effect of bed material on conventional gasification[20]

Bed material	Average Tar content (g/Nm^3)	Gasifying agent	Heating value (LHV) $kJ/N\ m^3$	Dry gas yield (g/Nm^3)	Water conversion (%)
Sand	43	Steam	13018	1.1	6
Dolomite	0.6	Steam	10935	1.9	39
Olivine	2.4	Steam	11369	1.7	27

- Effect of the bed material on cogasification in conventional gasification:[45]
  - Effect of bed material in gasification on Beachwood:

Table 3 Effect of Bed Material on Beechwood

Bed material	Energy production MJ/h	Cold gas efficiency (%)	Carbon conversion (%)
Silica sand	4.26	72.78	89.59
Olivine	4.25	72.56	92.08
Na-Y zeolite	4.44	75.79	90.65
ZSM- zeolite	4.89	83.57	98.20

- Effect of bed material in co-gasification of Beachwood and Polyethene

Table 4 Effect of Bed Material on Beechwood And Polyethene

Bed material	Energy production MJ/h	Cold gas efficiency (%)	Carbon conversion (%)
Silica sand	7.85	66.74	85.8
Olivine	7.19	61.12	84.2

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Na-Y zeolite	8.13	69.08	85.1
ZSM- zeolite	7.78	66.15	82.9

The energy production was increased in the cogasification but the carbon conversion was decreased also the cold gas efficiency was also decreased.

5. CONCLUSIONS

The following are the main conclusions:

1. **Tar content** reduces on increasing the temperature, tar content reduces on changing the bed material like dolomite, olivine. The tar content depends on the EQ as we increase the EQ up to certain value 0.45, but the heating value decreases. The tar content depends on the H/C ratio as the H/C ratio is increased tar content decreases in certain range (EQ=1.6 to 2.2)
2. **Gas yield** depends on the temperature as the temperature is increased the gas yield increases .The gas yield also depends on the bed material the dolomite has very high gas yield . The gas yield increase on increasing the EQ.
3. **Carbon conversion**depends on the temperature factor more is the temperature more is the carbon conversion it also depends on the bed material the most effective bed material remains dolomite in the bubbling bed fluidised gasifier
4. **Heating value**it decreases on increasing the temperature it has inverse relation with temperature. The heating value also depends on the bed material using sand as bed material the heating value is high of the gas butlower with dolomite and olivine. The heating value depends on the equivalence ratio also on increasing the ER the heating value decreases.
5. **Gas composition**it decreases as the increases in the EQ
   These all parameters showed a little dependency on each somewhere like heating value and tar content. So in order to get better results in the gasification the bed material must be taken in to the consideration, the temperature because on these variables many parameters like tar content, gas yield, heating value depend . There is role of EQ ratio also it also affects the product gas characteristics.

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