Synthesis Gas Production from Catalytic Gasification of Saw Dust

Aly M. Radwan, Mohamed A. Hamad and Amr Moustafa Singedy

Chemical Engineering & Pilot Plant Department, National Research Center, Cairo, EGYPT
radwnnrc@hotmail.com; hamadnrc@hotmail.com

Abstract: Production of synthesis gas from gasification of saw dust with oxygen as a gasifying agent in bench scale batch fixed bed reactor was studied. A series of experiments were performed to investigate the effects of different operating parameters on the performance of the gasification process. These include, oxygen/fuel equivalence ratio, reaction temperature, reaction residence time, particle size of saw dust, particle size of the catalyst and the type of catalyst. The catalysts selected are, olivine, USY zeolite, granulated slag, dolomite, cement kiln dust, calcium oxide and house red brick. Over the range of the experimental conditions used, the results obtained indicate that the best operating conditions for a gasification process are: temperature 800°C, oxygen to fuel ratio 0.25, reaction time 90 minutes and calcined cement kiln dust as catalyst. The results also show that the product gas from gasification of saw dust with cement kiln dust has higher H_2 and CO concentrations.
[Aly M. Radwan, Mohamed A. Hamad and Amr Moustafa Singedy. **Synthesis Gas Production from Catalytic Gasification of Saw Dust.** *Life Sci J* 2015;12(7):104-118]. (ISSN:1097-8135). http://www.lifesciencesite.com. 12

Key Words: Gasification, saw dust, synthesis gas, catalysts

1. Introduction

Sustainable energy plays an important role in the world due to the increase in energy demand. Biomass is considered to have more potential as fuel for transportation. The biomass is more attractive as it is environment friendly with no net carbon dioxide to the atmosphere. Biomass is recognized as an important renewable energy source. The other reasons to use the renewable sources of energy is due to fast depletion of fossil fuels. It is well known that the thermo-chemical gasification is one of the most effective methods for obtaining energy from biomass [1-2].

Gasification of solid biomass convert it to gas often referred to as producer gas or synthesis gas which is mainly composed of CO, CO_2, CH_4 and H_2. The synthesis gas produced from gasification process are governed by operating conditions including the reaction temperature, pressure, gasifying agent, gasification reactor, type of the waste, type and amount of catalysts [3-24]. The significant parameters that affects the gas quality from gasification process is indeed the type of catalyst. Sutton et al have summarized the following criteria for assessing the effectiveness of the catalyst; effective tar removal, capability of generating suitable synthesis gas, resistance to the deactivation, simple in regeneration and low price [24].

A fixed bed gasifier is newly developed at National Research Center, EGYPT, to gasify fine biomass material such as saw dust for the purpose of power generation. Sawdust is chosen as the biomass feed in this study because compared to other materials saw dust is easily and abundantly available as waste and generally disposed in landfill areas, as a cheapest way to manage it. In addition, it is locally available at the surrounding areas of our institute. Saw dust is ready available in dry form which can be used directly in gasification processes.

In this work, the oxygen gasification of saw dust was performed in a batch fixed bed reactor. To achieve the maximum yield of synthesis gas from gasification of saw dust, the best operating parameters for saw dust gasification has to be determined. The low heating value of the fuel gas may indicate better utilization of the fuel. In this paper, the effects of operating parameters on the product gas yield and its heating value are determined and analysed

2. Material and methods

2.1. Biomass samples

Saw dust was obtained from saw mill in National Research Center, Giza Governorate, Egypt. Saw dust was used as a model biomass sample for the gasification experiments. They were screened as to neglect the particle size effect. The mean particle size diameter (d_{mp}) used for the gasification process is 90 µm. The proximate and ultimate analysis of saw dust wastes produced in Egypt are reported in Table (1).

2.2 Catalyst

Seven different types of catalysts were used in this work. These are, Olivine, CaO, house red bricks, USY zeolite, dolomite, granulated furnace slag and cement kiln dust. Cement kiln dust and granulated slag were brought from the Egyptian Cement company. Dolomite was brought from Ataka-Suez Gulf Region. Dry (purified) zinc chloride used was distributed by Lobachemiepvt. LTD, Mumbai, India. Calcium hydroxide pellets package used was distributed by BDH laboratory supplies Poole. BHIS LTD, England. Calcination of granulated of slag,

dolomite and cement kiln dust was carried at 850° C for 2 hrs. Chemical oxide analysis of catalysts is shown in Table 2.

Table 1.Proximate and ultimate analysis of saw dust (wt%)

Proximate analysis, based on dry basis (%)				Ultimate analysis (wt %)				Heating value
TVM %	FC%	%Ash	C	O	H	N	S	HHV,MJ/kg
82.0	17	1.0	47.2	46.0	6.5	0.3	0.0	19.5

2.3 Energy content of saw dust

The molecular formulas of the biomass wastes based on the ultimate analysis were estimated for saw dust as $CH_{1.65}O_{0.66}$. The higher heating value for saw dust was estimated based on the ultimate analysis by using the following empirical correlation equation 1. [25].

HHV in MJ/Kg = 34.91 C + 117.83 H – 10.34 O – 1.51 N + 10.05 S - 2.11 Ash… (1)

The higher heating value for saw dust was19.5 MJ/Kg.

2.4 Catalysts:

The catalysts which are used in this study include: Natural dolomite (calcium and magnesium carbonate), calcined dolomite, olivine, granulated slag, ultra stable zeolite (USY) zeolite, red house brick, calcium oxide and cement kiln dust. The cement kiln dust and granulated slag have been obtained from National Cement Company in HELWAN City.

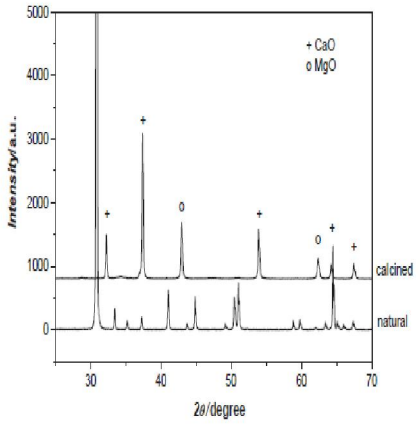
Catalyst properties:

Seven materials were used as catalysts as mentioned before. The calcined catalyst was prepared in muffle oven at 850 ºC for 2h. The properties of some of these catalysts are shown in Table (2).

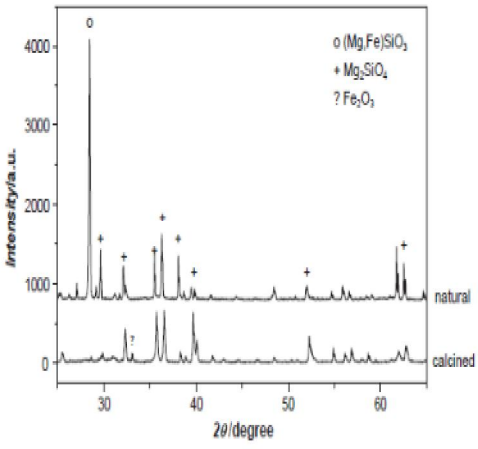
Table 2. Chemical component of catalysts, wt%.

Catalyst	MgO	SiO_2	CaO	Fe_2O_3	Cr_2O_3	Al_2O_3
Calcined dolomite	37.7	3.01	54.2	0.77	-	0..94
Olivine	51.8	36.5	0.73	9.1	0.6	0.57
Cement kiln dust	1.96	16.1	46.7	2.04	-	0.94
Granulated slag	3.4	39.9	26.3	2.56	-	13.7
Red house brick	1.3	74.8	1.25	5.04	-	14.08
USY zeolite	1.41	68.02	1.94	1.76	-	6.0

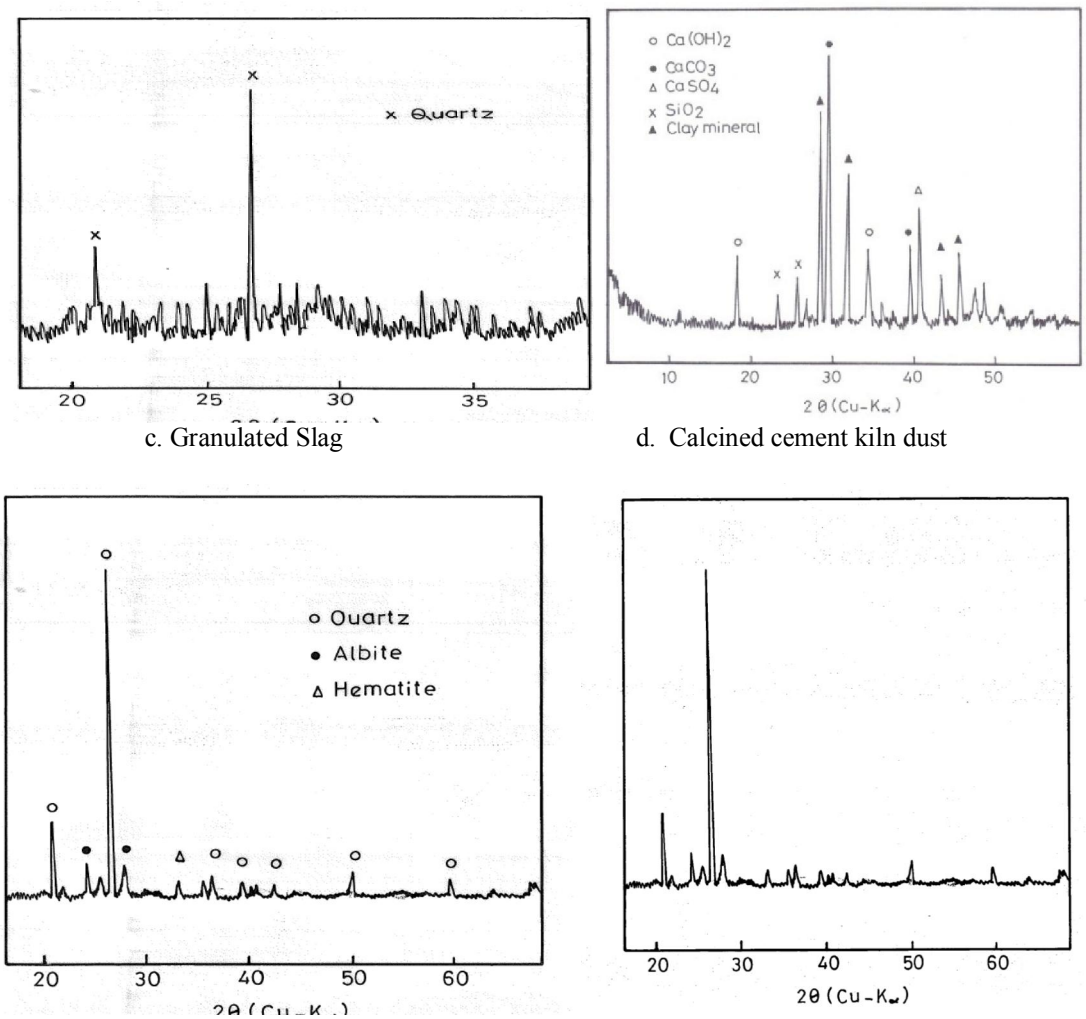
Calcined dolomite is a porous catalyst, its internal surface area and the presence of oxides in its matrix (CaO-MgO) make it an active catalyst with respect to the tar reduction. Olivine is a naturally occurring silicate mineral in which magnesium and iron are embedded in the silicate tetrahedral. X-ray diffraction (XRD) reveals that Olivine has an Orthombicstructure where as calcined dolomite has a simple cubic. Figure 1 (a, b, c, d, e, f) show typical X-ray diffractogram for calcined dolomite, Olivine, slag, red house brick and USY zeolite, respectively (Figure 1).



a. Olivine before and after calcinations



b. Dolomite before and after calcinations



c. Granulated Slag d. Calcined cement kiln dust

e. Red house bricks f. USY zeolite

Figure 1. XRD of different catalysts used in gasification of saw dust

2.4 Gasification system

Gasification of saw dust was carried out usinga bench scale fixed-bed reactor (SS 316, 0.98 mm ID). The total height of the reactor is 38 cm with total volume of 42 cm^3, externally heated by an electrical furnace. The reactor consists of three main parts, to be connected together during preparation for the experiments. The upper part includes 2 valves and pressure gauge to indicate the pressure during the experiment as shown in Fig.2. The biomass and any additives are added through the lower part. The upper and lower part are collected together through a middle fitting connection. In a typical test of gasification, 0. 2 g saw dust sample (with or without catalyst) was loaded into the reactor.

2.5 Gasification procedure.

Air in the reactor was purged for at least 5 min using the selected gasification agent (100% Oxygen). The loaded reactor was put into the furnace at selected reaction temperature where it takes 5-20 min to reach isothermal heating. The electrical furnace (60 cm long) with 7 cm ID and 20 cm OD and insulated with glass wool material is used to supply heat required to maintain the temperature of reaction for gasification of biomass. Also there is a temperature controller supplied with a thermocouple (type K) which exists beside the outer surface of the reactor to record and control the temperature inside the reactor. After a given reaction time, the reactor was taken out of the furnace to be cooled by an electrical fan. It takes about 15 min to cool down the reactor to room temperature. After that the producer gases are then measured and collected for analysis. Char and tar are also collected and weighted after opening the reactor (Figure 2).

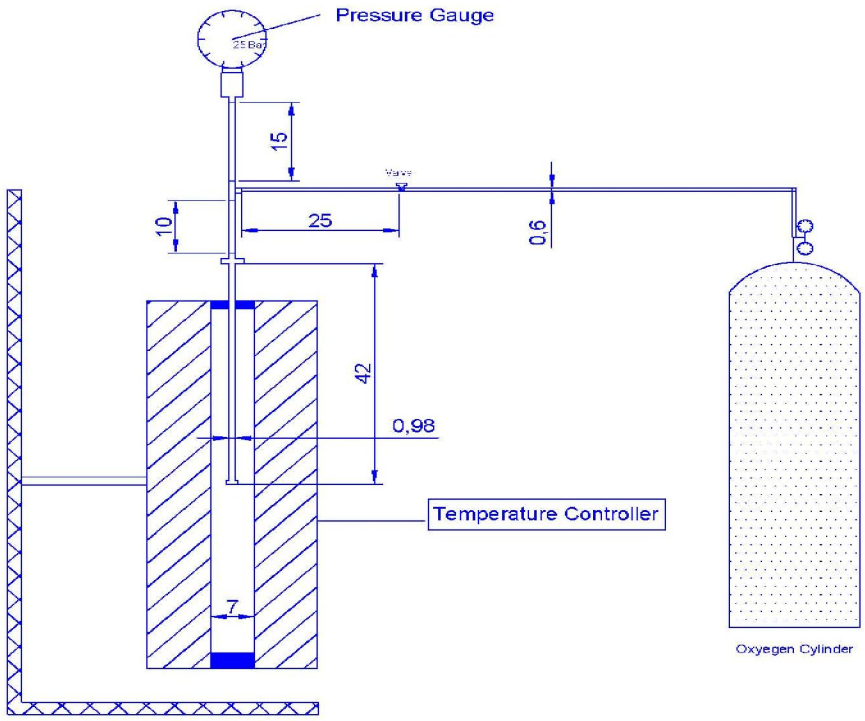


Figure 2. Reactor for gasification of saw dust (Dimensions in cm)

2.6Method of sampling and analysis

Gaseous products were analyzed by VARIAN model CP-3800 Gas Chromatograph at Egyptian Petroleum Research Institute (EPRI), Nasr city, Cairo.

The mass content of syngas constituents multiplied by their individual higher heating value (HHV) gave the overall higher heating HHV of the syngas as shown in eqn. (2). Gasification efficiency as defined in eqn. (3) is the percentage energy of biomass conserved in the form of fuel gas.

$HHV_{syngas} = x_{H2}\ HHV_{H2} + X_{CO}\ HHV_{CO} + X_{CH4}\ HHV_{CH4}$ (2)

Gasification efficiency = $(HHV_{syngas} * m_{syngas}/HHV_{biomass} * m_{biomass}) * 100$(3)

In above equations, HHV_{syngas} is the heating value of syngas, $m_{syngas}$is the weight of syngas, and $m_{biomass}$ is the weight of biomass, while HHV_i and x_i are higher heating value and weight fraction of syngas constituents (i=H_2, CO, CH_4).

The HHV of H_2, CO and CH_4 are 120.9 MJ/kg, 10.11 MJ/kg and 50.2 MJ/kg, respectively.

The heating value of the char was calculated from the elemental analysis.

HHV=0.34*C+1.4*H%-0.016*O%

The biomass char and tar samples extracted from the reactor at different conditions during gasification were analyzed by a variety of materials characterization techniques at Central Analytical Laboratories of National Research Centre, Egypt. Elemental analysis was done by CHNSO elemental (Vario EL III). Elemental analysis was useful to evaluate carbon conversion efficiency.

3. Results and discussions

3.1 Effect of operating parameters on the gasification processes

3.1. Effect of air/biomass equivalence ratio on gasification process

The appropriate equivalence ratio (ER) for the gasification of saw dust was varied by changing the weight of biomass and holding the other conditions constant. Figure 3 illustrates typical profile relation of temperature and pressure against time of the reaction during the gasification of saw dust for one of these groups of runs.

To study the effect of equivalence ratio on the producer gas yield, the experimental run at temperature of 700ºC for 90 min is illustrated in Figure 4. It was observed that the higher gas yield was obtained at 0.25 EQ for saw dust.

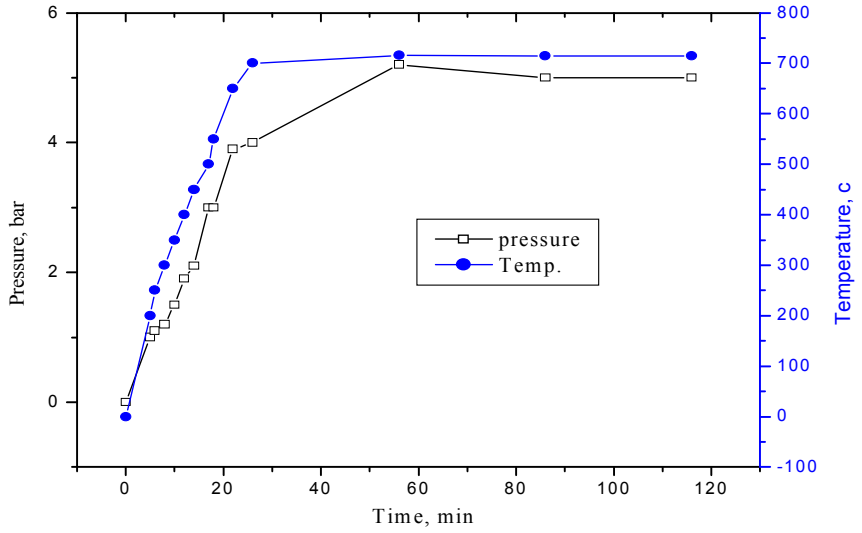


Figure 3. Profile of temperature, pressure against time of reaction during gasification

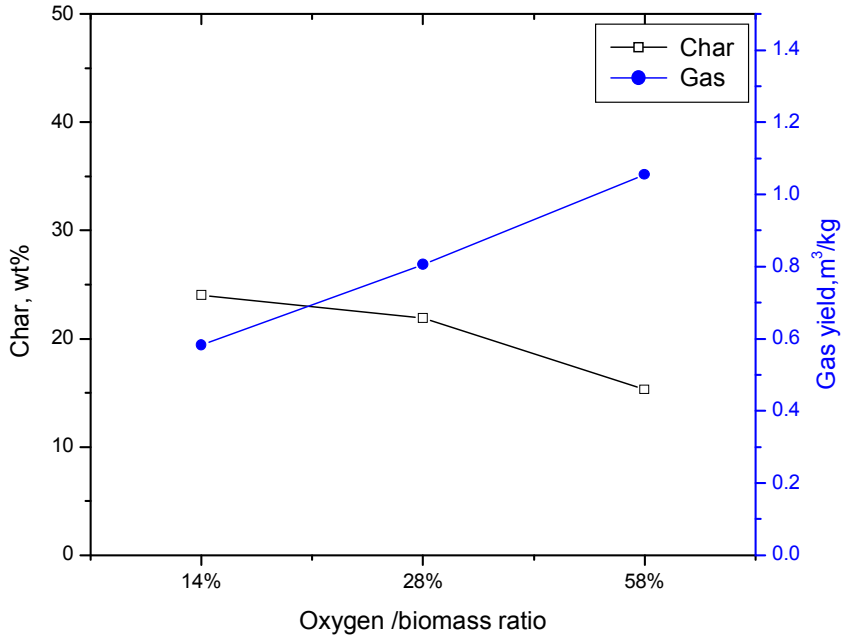


Figure 4. Effect of Oxygen/biomass equivalence ratio on gasification products
Biomass type: Saw dust, Temperature: 700 °C, Time of reaction: 90 min

3.1.2 Effect of temperature on product distribution from gasification process

Gasification temperature of saw dust was carried in the range of 700 -800 °C for 90 min at ER 25%. The product distribution (gas and char) is illustrated in Figure 5.

As long as gasification temperature increases from 700 to 800 °C, gas yield increases from 0. 87 to 1.3 m^3/kg while char remains almost constant as it varies from 21 to 26 wt%, and the tar decrease from 35.6 to 8.3 wt%.

The reaction temperature influences the heating rate, the rate and equilibrium constants and the space time due to changes in the producer gas density which in turn determine the products distribution of the gasification process.

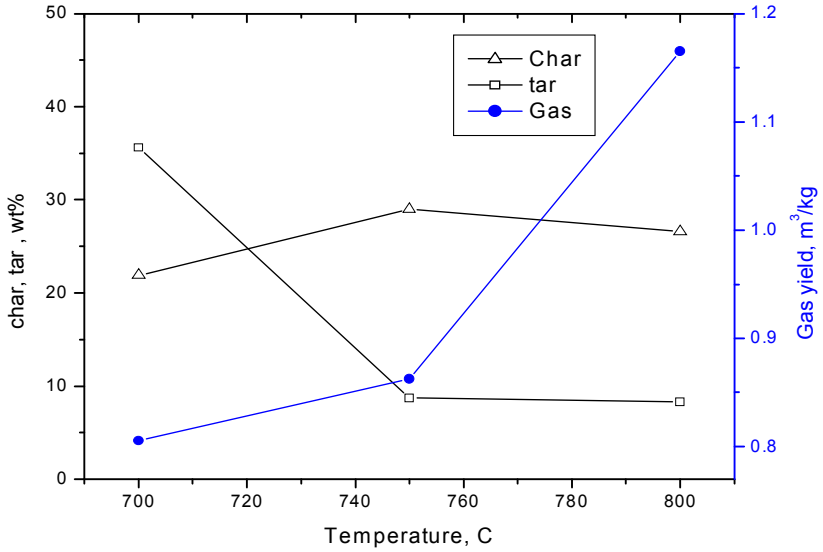


Figure 5. Effect of temperature on gasification products
Biomass type: Saw dust, ER: 0.25, reaction time: 90 min

3.1.3 Effect of reaction time on the performance of gasification process

Figure 6 illustrates the experimental results of gasification of saw dust while varying the reaction time from 15 to 90 min at 700 ºC and relative fuel /oxygen ratio constant. The, results show that the reaction time of 90 min is sufficient for the gasification tests in our system.

Increasing the reaction time, causes an improvement of the produced gas quality and yield. The gas yield rises in the case of saw dust from 0.86to 1.32 (m^3/kg) by increasing the reaction time from 15 to 90 min.

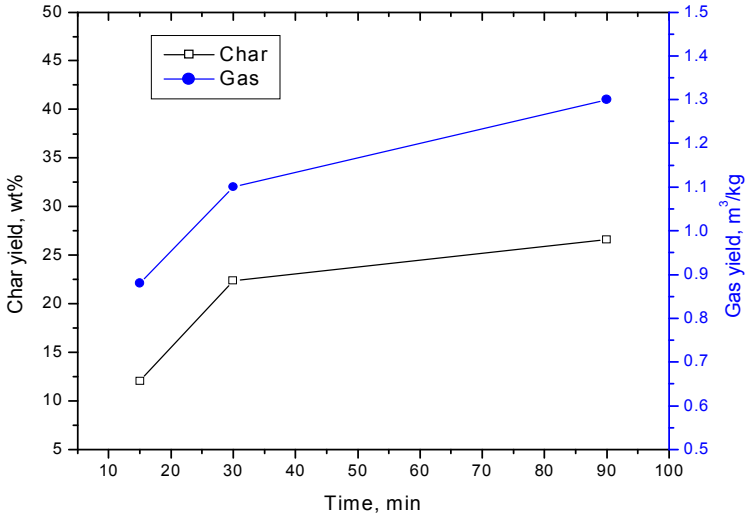


Figure 6. Effect of time of reaction on gasification processes
Biomass: Saw dust, temperature :800 °C, ER:25%

3.1.4 Effect of particle size of biomass on gasification of biomass

Figure 7 illustrates the effect of particle size on gasification of saw dust. All tests were carried at 700 ºC and time of reaction 90 min. The results obtained for the gas yield show a decrease from 0.98 to 0.89 m^3/kg by increasing the particle size from 90 to 1000 µm, while an increase in the char from 19.0 to 25.1 w% was noticed. The smaller the particle size of biomass (saw dust), the more effective are mass and heat transfer, since the particle external surface area/volume is higher and the char formed during the

gasification is expected to be more porous owing to a higher volatile release which is in agreement with the results obtained by Babu and Chaurasia (28), as they concluded that a lower time is required for the completion of gasification of saw dust when the particle size decreases. Therefore, the reactivity of the remaining char increases and thus the gasification reaction take place to a higher extent. On the other hand, mass and heat transfer are improved (lower diffusion resistance coefficients when diminishing the particle size and chemical kinetics could become the rate controlling factor) (29).

When reaction controls the processes, reaction rate grows exponentially with the temperature and with the increase of the external surface area/volume ratio. The uniform temperature reached in the particle allows the reaction to take place throughout the particle, not only the surface areas (since the internal heat transfer conduction resistance and thus the temperature gradient inside the particle is reduced and thus leading to the` high quality producer gas.

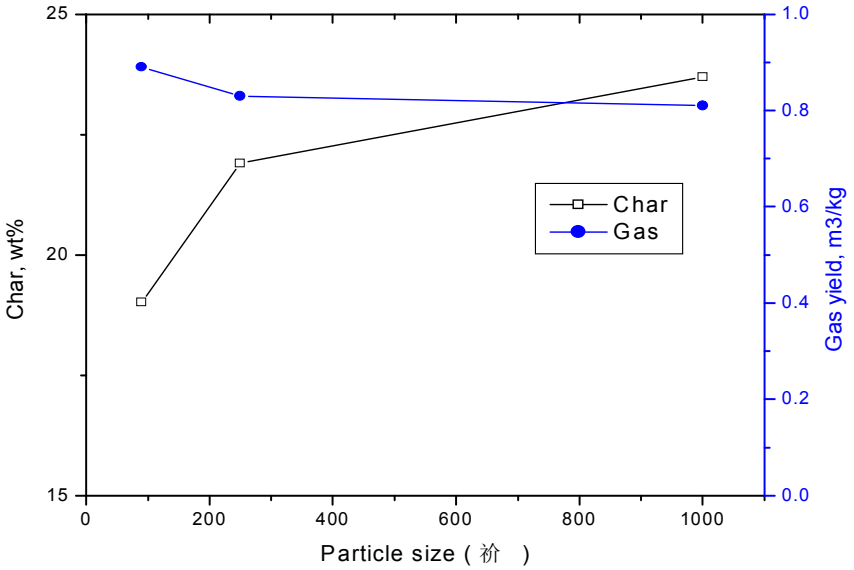


Figure 7. Effect of particle size on gasification processes
Biomass: Saw dust, Temperature: 700 °C, ER:0.25, Time of reaction, 90 min

3.1.5. Effect of particle size of catalyst on gasification processes

For determination of the effect of the catalyst particle size, three experiments were carried at 800 ° C with three different particle sizes between 90-1000µm. The fine particle sizes of the catalyst gave best results compared to other runs under our conditions.

Gasification experiments were conducted using different diameter of catalyst with pre-heating the temperature of gasification at 800 °C. The variation of gasification products and gas characterization with blast furnace slag (BF) size are shown in Figure8**.**

The literaturereview in this part show that with the decrease of BF slag diameter, more light gas H_2, CO, less char and condensate were produced. According to heat transfer theory of dense particle system, in the initial dense phase accumulation flowing state biomass particle are mainly heated by direct contact with hot BF slag. Therefore, heat conduction is the main heat transfer mode. The particle size of BF slag is a key factor influencing heat transfer efficiency. Under the following intensive mixing flowing state, BF slag fills the whole pipe with biomass particle adhesion on its surface. According to the spherical shell heat transfer model, heat conduction and convective heat transfer are the main heat transfer modes, affect by BF slag particle size. With decrease of BF slag size, the surface area of particle size increases, improving the heat conduction efficiency and heating rate of biomass. Higher heating rate can enhance the emission of volatiles of biomass in gasification processes, producing more light gas as well as less char and condensate.

Product distribution (gas, char) at different particle sizes of granulated slag (90-1000 µm size) is shown in Figure 7. It can be concluded from this figure that smallest particle size of granulated slag give high yield of the gas of1.19 m^3/kg. While the char yield was slightly affected.

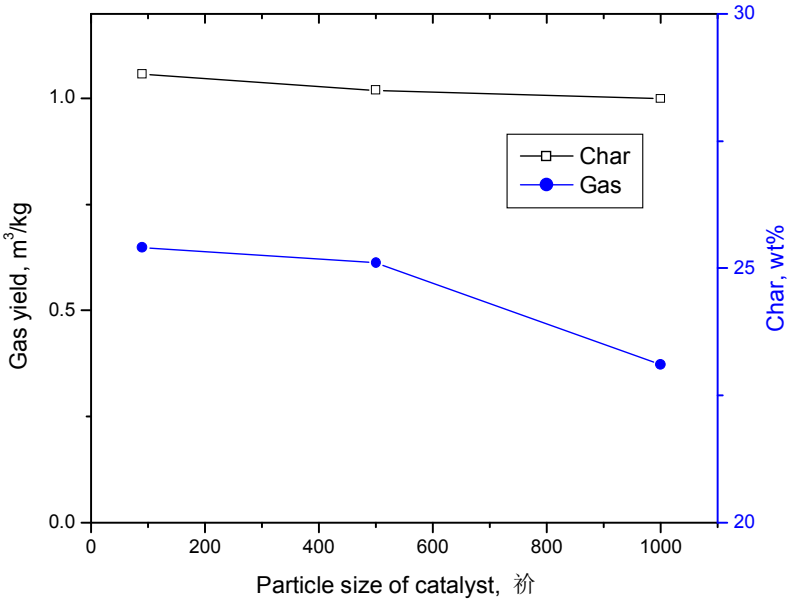


Figure 8. Effect of particle size of catalyst on gasification processes
ER: 0.25, Temp. 800°C, Time of reaction: 90 min

3.1.6 Effect of type of catalysts on the gasification processes

3.1.6.1. Effect of olivine catalysts on the gasification process

Natural olivine (iron and magnesium orthosilicate) has been chosen as catalyst for this gasification process of saw dust because of its hardness required for the use in circulating fluidized bed and its higher catalytic activity than silica in biomass steam gasification.

Product distribution (gas and char) at different loading of the olivine catalyst ranging from 0 to 10 wt% is shown in Figure 9. The results show that the best gas yield from gasification of saw dust was noticed at 5 wt% olivine. Table 3 show the effect of concentration of olivine on gas composition during gasification of saw dust. Table 4 Show elemental analysis of some selected char samples after gasification of saw dust.

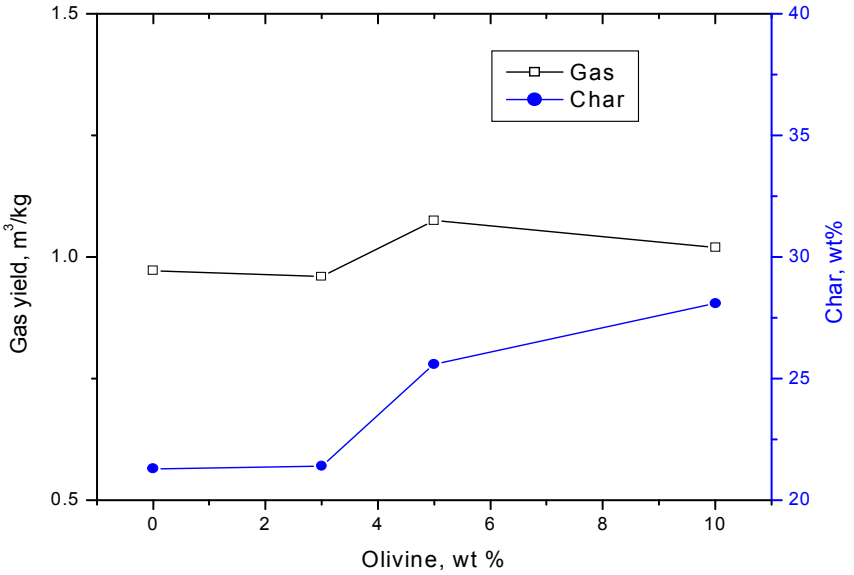


Figure 9. Effect of olivine catalyst on the gasification processes
ER: 0.25, Temp. 800°C, Time of reaction: 90 min

Table (3) Effect of concentration of olivine on gas composition during gasification of saw dust

Catalyst concentration	Gas composition, vol.%					HHV, MJ/Kg
	H_2	CH_4	CO	CO_2	C_2-C_6	
3 % olivine	7.52	10.71	33.34	47.06	1.35	10.68
5% olivine	12.63	15.37	25.31	43.06	1.44	9.89
10% olivine	13.11	9.19	29.54	46.64	1.51	10.32

Table 4 Char analysis after gasification of saw dust

Char	C%	H%	O%	ash	N%	S%	HV MJ/kg
Olivine 3 %	44.9	0.44	34.98	19.6	traces	traces	7.29
Olivine 5%	55.1	0.36	33.54	11.0	traces	traces	10.16

3.1.6.2 Effect of granulated slag on the gasification processes

When blast furnace slag used as heat carrier, there was a remarkable increase in the gas content (29) and a significant decrease in the tar content (3.1% was detected). This means that BF slag demonstrated a better catalytic performance in improving tar cracking, reducing the activation energy on tar conversion and enhancing char gasification reaction

The use of BF slag as heat carrier can increase the contents of hydrogen, CO_2 and decrease the contents of CH_4, CO, C_2H_4 and C_2H_6.It is known that water gas shift reaction, carbon gasification reaction together with steam reforming of hydrocarbons are the main factors responsible for production of H_2 and CO.

This increase of hydrogen contents indicates BF slag can act as a good catalyst in improving above reactions to generate valuable gases. It is because that BF slag contains some metals oxides such as Al_2O_3, CaO and MgO. Metal Oxides can prevent the formation of stable chemicals structures in hydrocarbons, speeds up the degradation of hydrocarbons, weaken the C-C bond and there by decrease the activation energy of gasification reaction (29). Product distribution (gas, char) at different loading of the BF slag catalyst ranging from 0 to 10 wt% is shown in Figure 10.

Catalytic activity of blast furnace slag **(**BFS) for gasification of biomass was studied at temperature 800 °C. As seen from Figure (10) the effect of BF slag on gasification process is extremely poor, which is not in agreement with the above mentioned literatures which can be attributed to the difference in temperatures applied in the two cases.

Table (5) Show the effect of concentration of granulated slag on gas composition for gasification of saw dust.

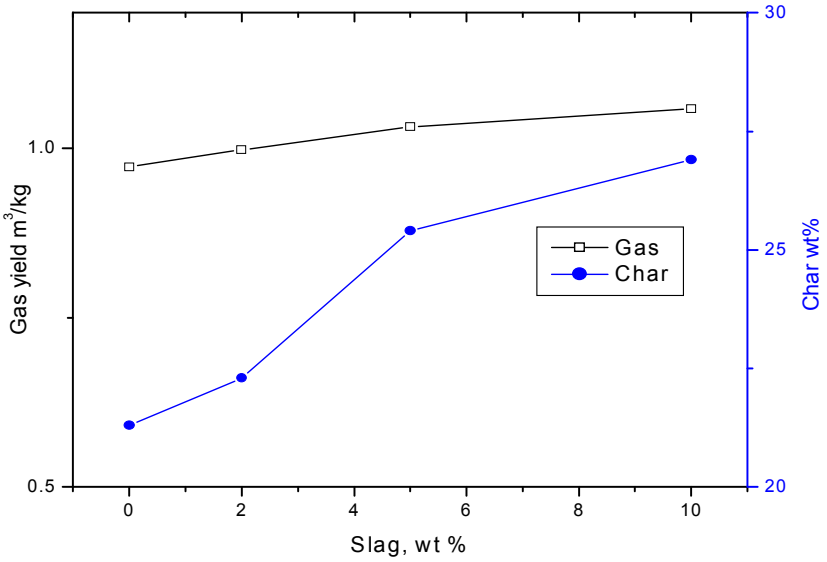


Figure 10. Effect of granulated slag on the gasification processes
ER: 0.25 Temp. 800°C, Time of reaction: 90 min

Table (5) Effect of concentration of granulated slag on gas composition for gasification of saw dust, ER: 0.25, Temp. 800°C, Time of reaction: 90 min

Catalyst concentration	Gas composition, vol.%					HHV, MJ/Kg
	H_2	CH_4	CO	CO_2	C_2-C_6	
2% slag	1.65	0.0	32.6	64.02	1.69	9.60
5 % slag	18.5	11.3	23.60	45.58	0.967	8.48
10 % slag	3.46	0.0	33.60	60.51	2.32	7.83

3.1.6 3. Effect of USY zeolite on the gasification processes

Role of zeolite in biomass conversion;

Zeolite have found wide application as solid acid catalyst or catalyst carriers in the oil refining, petrochemical industries and gasification processes where they have been gradually replacing conventional homogenous and heterogeneous catalysts. In the most of the processes, zeolite and mesoporous materials are involved in the acid catalyzed reactions that proceed through the formation of carbonation like intermediates. Therefore, the chemistry of transformation is closely related to the chemistry of the carbonations in the restricted micro-porous environment. Normally the reactions are performed in a polar gas or liquid phase where the substrate to be converted is a hydrocarbon oil [31].

Ultra stable zeolite (USY) (H-form, SiO_2/Al_2O_3=12, BET surface area 480 m^2/g) obtained from Toso Inc., was used as a catalyst without further treatment.

Product distribution (gas and char) from different loading of USY zeolite is shown in Figure 11.The gas yield increased by increasing the catalyst from 0 to 10 wt% and then decrease. While the char was increased by increasing the concentration of USY zeolite. Table 6 show the effect of concentration of USY zeolite on gas composition, carbon and heat conversion on gasification of saw dust.

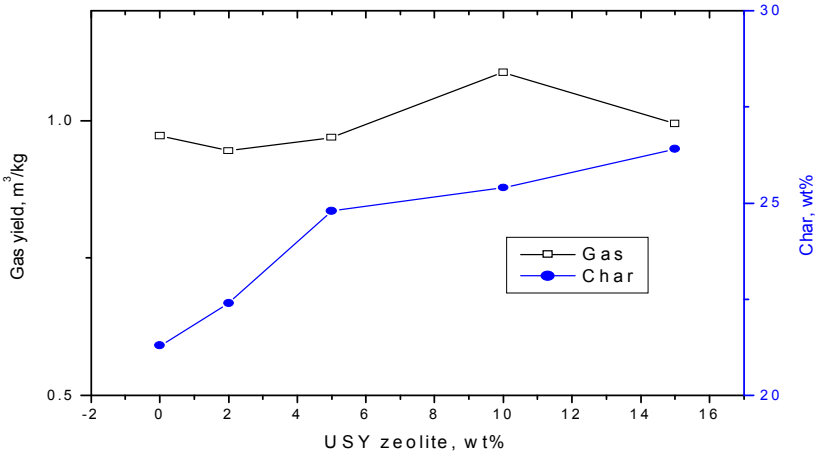


Figure 11. Effect of USY zeolite on the gasification processes
ER: 0.25, Temp. 800°C, Time of reaction: 90 min

Table (6) Effect of concentration of USY zeolite on gas composition from gasification of saw dust. ER: 0.25, Temp. 800°C, time of reaction: 90 min

Catalyst concentration	Gas composition, vol.%					HHV, MJ/Kg
	H_2	CH_4	CO	CO_2	C_2-C_6	
2 wt% USY zeolite	22.39	17.69	24.82	33.98	1.09	9.29
5wt % USYzeolite	26.38	16.88	18.9	36.52	1.29	12.30
10 wt% USYzeolie	11.34	15.46	25.46	46.64	1.49	10.61
15wt% USYzeolie	13.45	12.03	25.03	47.77	1.71	9.16

3.1.6.4. Effect of cement kiln dust on the gasification processes

Product distribution (gas and char) at different loadings of cement kiln dust in the gasification of saw dust in the range from 2 to 10 wt % is shown in Figure 12.The gas yield increases and the char yield also increases, respectively, with additional loading of cement kiln dust from 0 to 5 wt%. However,

cement kiln dust is produced at high temperature (>1000°C) which assumed to ensure being in the oxidized form but when lasts for a long time in an open air it transforms to stable carbonate form. The percentage weight decrease after calcination of cement kiln dust at 850 °C for 2 hrs was 19 wt% which refers to presence of carbonates. Therefore, cement dust catalyst was calcined in this study. Accordingly, It is recommended to use fresh cement kiln dust in gasification to save energy that would be consumed to have CaO instead of $CaCO_3$. The effect of calcined cement kiln dust (CCKD) catalyst on gasification of saw dust is shown in Figure 12.Table (7) illustrates the effect of concentration of cement kiln dust (CCKD) on gas composition, carbon and heat conversion during gasification of saw dust.

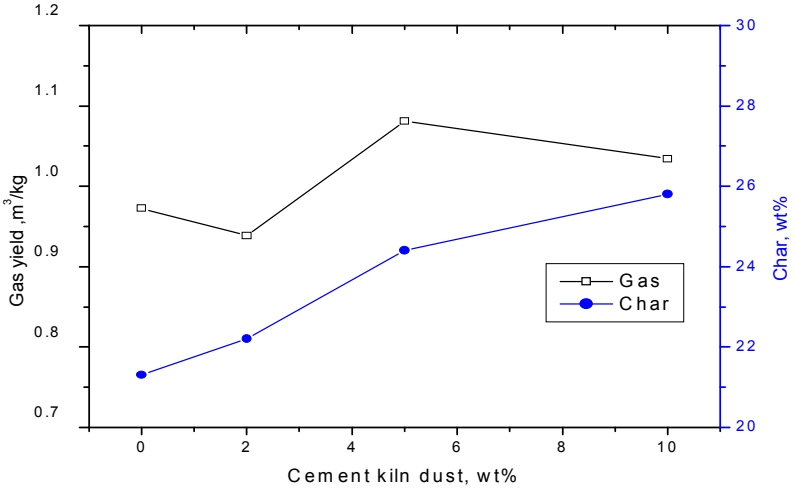


Figure 12. Effect of cement kiln dust on the gasification processes
ER: 0.25, Temp. 800°C, Time of reaction: 90 min

Table (7) Effect of concentration of calcined cement kiln dust (CCKD) on gas composition, carbon and heat conversion on gasification of saw dust

Catalyst concentration	Gas composition, vol.%					HHV, MJ/Kg
	H_2	CH_4	CO	CO_2	C_2-C_6	
2wt% CCKD	10.55	17.57	24.32	52.48	1.38	8.22
5wt% CCKD	20.33	14.59	28.25	32.69	1.13	13.26
10wt% CCKD	6.9	11.23	29.29	47.63	1.49	9.67

CCKD: calcined cement kiln dust

The gasification efficiency using calcined cement kiln dust was about 59.2 % obtained using 5 % CCKD.

3.1.6.5 Effect of red house brick on the gasification processes

Common house clay brick can be effectively used in a CFB gasifier to reduce tar emission and enhance hydrogen production. The alkalies deposited on the bed materials from biomass may potentially behave as catalysts if their agglomerating effect can be managed. (33).

Product distribution (gas and char, tar was neglected) at different loading of red house brick in the range of 0, 10 wt% is shown in Figure (13). From Figure 13, it can be concluded that the gas yield increased slightly by increasing the dose to 2 %, after which it decreased by increasing the dose.Generally it can be concluded that the red house brick is not suitable for improving the gasification process at our experimental conditions of comparatively low reaction temperature (800 °C).

3.1.6.6 Effect of dolomite on the gasification process

Calcined dolomite include higher CaO content with respect to marly clay and a considerable amount of MgO and without SiO_2 in its structure as has been shown in Table (2). Basically, the presence of dolomite causes a decrease in the liquid fraction, increase in secondary decomposition of tars and the specific surface area of solid residue which accounts for big chance of gas contacting solid particle (11, 14).Effective tar destruction was reported using calcined dolomite in temperature range from 800 °C to 900 ° C (15, 16).

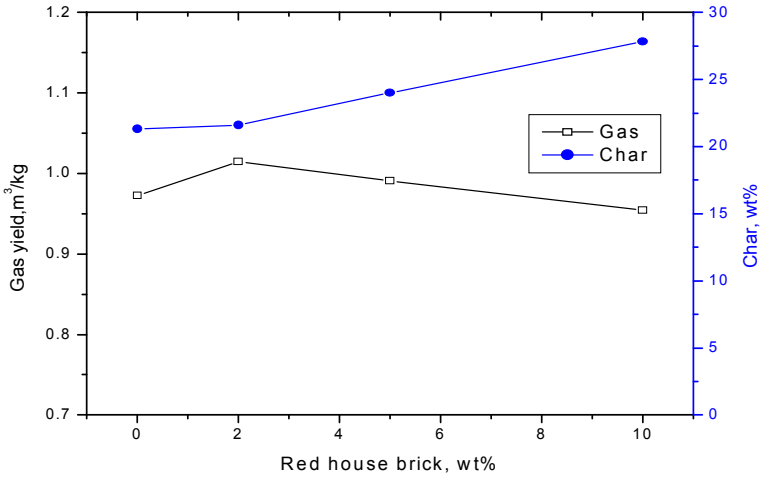


Figure 13. Effect of red house brick on the gasification processes
ER: 0.25, Temp. 800°C, Time of reaction: 90 min

Figure (14) shows the product distribution (gas and char) from gasification of saw dust with different additives of calcined dolomite catalyst (0- 10 wt %) at 800 ºC. Here, gas yield increased with additional loading of dolomite reaching a maximum at 5% dolomite while char yield was increasing till 10 wt%. The effect of dolomite on gas composition and gasification efficiency is shown in Table (8).

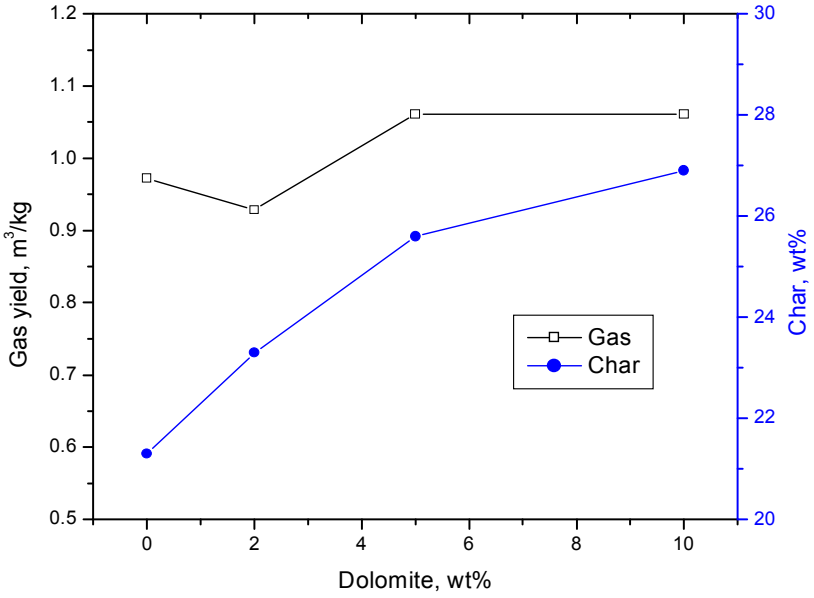


Figure 14. Effect of dolomite catalyst on gasification of saw dust
ER: 0.25, Temp. 800°C, Time of reaction: 90 min

Table (8) Effect of dolomite additions on gas composition and heating value during gasification of saw dust; ER: 0.25, Temp. 800°C, Time of reaction: 90 min

Catalyst concentration	Gas composition, vol.%					HHV, MJ/Kg
	H_2	CH_4	CO	CO_2	C_2-C_6	
Dolomite 5 wt%	32.84	5.17	19.95	40.68	1.33	10.78
Dolomite 10 wt%	22.96	8.25	24.32	42.92	1.51	10.54

3.1. 6.7Effect of CaO on the gasification of saw dust

Steam gasification of biomass with CO_2 sorbent has raised interest of many researchers and has been studied extensively (32-35).Among them is Dalai et al (36).They impregenated CaO with their biomass sample and found that the rate of hydrogen production increased in the temperature programmed gasification. Nevertheless, when CaO was increased, there was no significant increase in the hydrogen production. Mahishi and Goswami (37) found that by using CaO as CO_2 sorbent in the steam gasification of pin bark at 600 C, hydrogen yield and carbon efficiency increased by 48.6% and 83.6% respectively. The gasification of wet biomass using $Ca(OH)_2$ powder as CO_2 sorbent has been investigated (32-37). They succeeded to increase the yield of hydrogen by 51.5% and decrease in the CO_2 content by 28.4%.

Khomah Ismail (38) have studied the effect of particle size CaO as catalyst for gasification of oil palm empty fruit bunch to produce hydrogen. NanoCaO showed high production of hydrogen meanwhile it released significantly low amount of CO_2. The results show that nano-CaO acted as catalystas well as CO_2 sorbent. Calcium oxide was used as catalyst. Nano-sized calcium oxide was prepared in the department of ceramics, National Research Center. Particle size distribution analysis of the finecalcium oxide is shown in Figure 15.

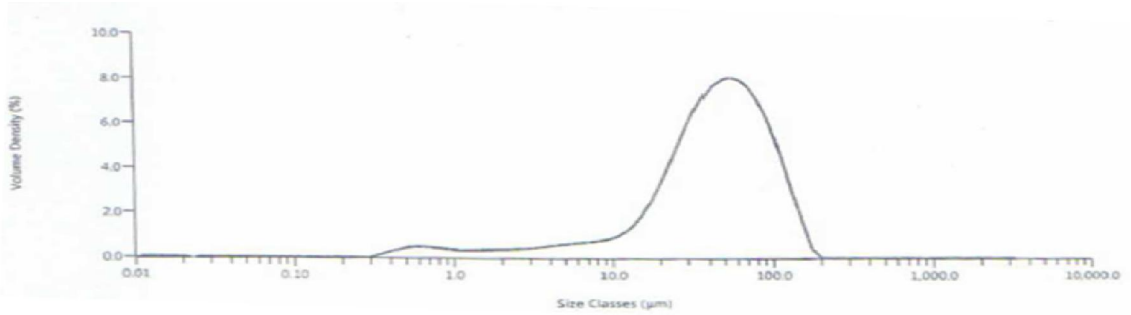


Figure 15. Particle size distribution of CaO

Product distribution (gas, char) at different loading of nano calcium oxide in the range 0 to 7wt%)is shown in Figure 16. From this figure it can be concluded that the gas yield increased from 1.06 to 1.1 m^3/kg with addition of nano-Cao. The char yield was increased slightly also. The tar was difficult to be calculated in these runs due to small amount of the saw dust used. The composition of gases at 5 % nano CaO was, 5% H_2, 30.4 CH_4, 13.02 % CO, 49.87 % CO_2.. In the future work we are going to emphasis the effect of nano catalysts on the performance of the gasification process.

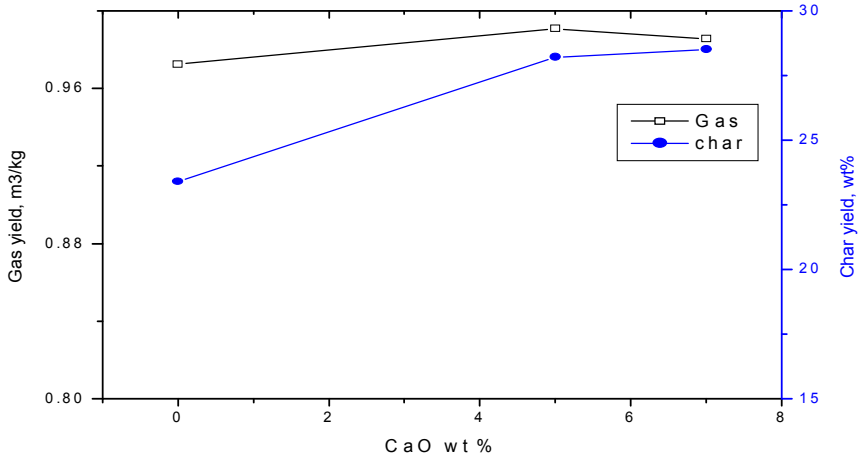


Figure 16.Effect of CaO on gasification of saw dust
ER: 0.25, Temp. 800°C, Time of reaction: 90 min

Conclusions

The experimental studies carried for gasification of saw dust at equivalence ratio of 0.25, temperature, 800^{o}C, reaction time 90 min, and different catalysts type, reveal that,

1. The cement kiln dust is more effective in increasing the gas yield and decreasing both the char and the tar during the gasification process.

2. 5 wt% of cement kiln dust was the best for gasification process.

Acknowledgment

The authors wish to acknowledge the financial support received from National Scientific Research, Science Technology and Development Foundation, Basic and Applied Research Grant STDF. No. ID. 139, Academy of Scientific Research, Egypt.

References

1. Wang Y., K. Yoshika, T. Namioka, Y, Hashimoto “Performance optimization of two staged gasification system for woody biomass” Fuel processing technology, Vol.88, pp., 243-250, 2007.
2. AbeenashV. N, E. Natarajan, “Parameteric analysis of hydrogen rich gas from saw dust gasification”, International Energy Journal, 67-74. 2014.
3. Jaojaruek K., S. Jarungthammachote, M.K.B Gratuito, H. Wongsuwan, S. Homhual ”Experimental study of wood downdraft gasification for an improved producer gas quality through an innovative two stage air and premixed air/gas supply approach. Bio-resource technology, 2011.
4. Ana Paula G. Peers, Betania H Lunellli, Rubens Maciel Fllho, Application of biomass to hydrogen and syngas production” Chemical Engineering Transctions, Vol. 32, 2013.
5. Tomishige K., M. Asadullah, T..Miyazawa, S-Ichi Ito, K. Kunmori” Gasification of different biomass in a dual bed gasifier system combined with novel catalysts with high energy efficiency” Applied Catalysis A. General, v, 267, 2004.
6. Lv P. M., Z. H Xiong, J. Chang, C. Z Wu, Y. Chen and J. X. Zhu T", "An experimental study on biomass air steam gasification in a fluidized bed", Bio-resource Technology 95, 95-101, 2004.
7. Kumabe K., Toshiaki Hanaoka, Shinji Fujimoto, Tomoaki Minowa and Kinya Sakanishi, "Co-gasification of woody biomass and coal with air and steam", Fuel, 56, 684-689, 2007.
8. Demirbas A. "Hydrogen shell to hydrogen rich gaseous products via catalytic gasification process" Energy sources, 26, 25-33, 2004.
9. Demirbas A. "Hydrogen shell to hydrogen rich gaseous products via catalytic gasification process" Energy conversion and management, 43, 897-909, 2002.
10. LvP., Z. Yuan, C. Wu, L. Ma, Y. Chen and N. Tsubaki", Biosyngas production from biomass catalytic gasification", Energy Conversion and Management, 2006.
11. Chen G., H. Spliethoff, L B. Yang and J. Andries, “Hydrogen production from gasification-pyrolysis of biomass”, 111 International Slovak Biomass Forum, 2003.
12. ElifKirtay, "Recencnt advance in production of hydrogen from biomass", Energy conversion and mangament, 52,1778-1789, 2011.
13. Khater E. M. K., N. N. El-Ibiary, I. A. Khatab and M. A. Hamad ”Gasifcation of rice hulls” Biomass and Bioenergy, Vol.3.No.5,pp329-333, 1992.
14. Kumabe K., Toshiaki Hanaoka, Shinji Fujimoto, Tomoaki Minowa and Kinya Sakanishi, "Co-gasification of woody biomass and coal with air and steam", Fuel, 56, 684-689, 2007.
15. Maria Aznar P., Jose Corella, Jesus Delgado and Joaquin Lahoz, "Improved steam gasification of lingo-cellulosic residues in a fluidized bed with commercial steam reforming catalysts” Ind. Eng. Chem. Res. Vol. 32. 1993.
16. Keiichi T., M. Asadullah, T. K. Kunmori, "Syngas production by biomass gasification using $Rh/CeO_2/SiO_2$ catalysts and fluidized bed reactor” Catalysis Today. Vol.89, 2004.
17. Abdul Salam P., S.C.Bhattacharya" A comparative study of char coal gasification in two types of spouted bed reactors" Energy 31, 228-243, 2006.
18. Doucanov D. and G. Angelova “Effect of catalysis and inlet gas on coal gasification” Fuel, Vol. 62, 1983.
19. Philippe M., R. Dubuisson" Performance analysis of a biomass gasifier" Energy conversion and management, 43, 1291-1299, 2002.
20. Warnecke R., "Gasification of biomass: Comparsion of fixed bed and fluidized bed gasifier, Biomass and bio-energy 18, 489-497, 2000.
21. Moghtaderi B. "Effects of controlling parameters on production of hydrogen by catalytic steam gasification of biomass at low temperatures" Fuel, Volume 86, Issue 15, 2422-2430, 2007.

22. Midilli A., M. Dogru, Gr. Howarth, T., Ayhan, "Hydrogen production from hazelnut shell by applying air blown downdraft gasification technique", International Journal of hydrogen energy, 26, 29-37, 2001.
23. Midilli A., M. Dogru M, G. Akay, Gr. Howarth, "Hydrogen production from sewage sludge via affixed bed gasifier product gas", International Journal of hydrogen Energy, 27, 1035-41, 2002.
24. Abu El-Rub Z. EA Bramer, G. Brem "Review of catalysts for tar elimination in biomass gasification process". Ind Eng Chem Res; 43:6911–9, 2004.
25. Channiwala, S.A. and Parikh pp. A unified correlation for estimating HHV of solid, liquid and gaseous fuels 8, 2002, Fuel, vol.81, pp.1051-1063.
26. Scott D.S., J. Piscorz, M.A. Bergougnou, R. Graham and R.P. Overend "The role of temperature in the fast pyrolysis of cellouse and wood", Industrial Engineering Chemical Research, 27:8-15, 1988.
27. Juan J. Hernandez, Guadalupe Aranda Almansa, Antonio Bula ”Gasification of biomass wastes in an entrained flow gasifier: Effect of particle size and the residence time, Fuel Processing Technology, 91, 681-6 92, 2010.
28. Babu, B.V. Chaurasia, A.S.’ modeling for pyrolysis of solid particle: kinetics and heat transfer effects, Energy conversion and Mangment, 44, 2251-2275, 2003.
29. Siyi Luo, Yangmin Zhou, Chuiijie Yi, ”hydrogen rich gas production from biomass catalytic gasification using hot blast furnace slag as heat carrier and catalyst in moving bed reactor, International Journal of hydrogen energy, 37, 15081-15085, 2012.
30. Ross, D., Noda R., Adachi, M., Nishi, K., Tanak, N. Horiro, M., Biomass gasification with clay minerals using a multi bed reactor system In: Cen, K (ED.) circulating fluidized bed technology Viii, International Academic Publishers, pp-468-473, 2005.
31. Carlo Perego, Aldo Bosetti” Biomass to fuels: The role of zeolite and mesoporous materials” Micro-porous and mesoporous materials, 144, 2011.
32. Bishnu Acharya, Animesh Dutta, and Prabir Basu;” An investigation into steam gasification of biomass for hydrogen enriched gas production in presence of CaO”, International Journal of Hydrogen Energy, Volume 35, Issue 4, Pages 1582-89, 2010.
33. Florin NH, Harris AT. ”Enhanced hydrogen production from biomass with in situ carbon dioxide capture using calcium oxide sorbents”. Chemical Engineering Science, 63:287–316, 2008.
34. Qinhui Wang, Nai Rong, Hangtao Fan, Yongie Meng, Mengxiang Fang, Leming Cheng, Kefa Cen, Enhanced hydrogen rich gas production from steam gasification of coal in a pressurized fluidized bed with CaO as a CO2 sorbent”, International Journal of Hydrogen Energy, Pages 1-12, 2014.
35. Lin S.Y., Y. Suzuki, H. Hatano, M. Harada, “Hydrocarbon by integration of Water-Carbon Reaction and Carbon Dioxide. Removal (HyPr-RING) Method”, Energy Fuels 15339, 2001.
36. Dalai AK, Saaoka E. Hikita H, Ferdous D’ Catalytic gasification of saw dust derived from various biomass” ‘ Energy and fuels, 17, 1456-1463, 2003.
37. Mahishi MR, Goswami DY. An experimental study of hydrogen production by gasification of biomass in the presence of sorbent ”International Journal of Hydrogen Energy, Volume 37, Pages 2803-8, 2007.
38. Khomah Ismail, Mohd Ambar Yarmo, Y.H. Taufig Yap, Aishah Ahmad” The effect of particle size of CaO and MgO as catalysts for gasification of oil plam empty fruit bunch to produce hydrogen” International Journal of hydrogen energy, 37, 3693-3644, 2012.

7/25/2015