DESIGNING A UNITFOR CONVERTING WHEAT STRAW INTO BIOFUEL IN SUDAN

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Abstract - Production of bio-fuels by converting wheat straw into syngas (methane, hydrogen, carbon dioxide, carbon monoxide, char, di-hydrogen sulfide, and ammonia) in the fluidized bedreactor (gasifier) is studied in this work. Gasification by steam–oxygen at temperature 870℃, Solid impurities and acid gases were removed in many stages to obtain hydrogen and carbon monoxide. The conversion of hydrogen and carbon monoxide into liquid fuels is taken place in Fischer Tropsch reactor. In the Fischer Tropsch reactor, the gases contact cobalt as a catalyst for the production of long hydrocarbon chains of different petroleum cuts (gas fuel,LPG, naphtha, diesel and heavy oils). The overall carbon monoxide conversion is 66%. The reactors of this unit are well designed a steady state model equations.

Index Terms - Biofuel, syngas, wheat straw, gasifier, Fischer Tropsch.

I. INTRODUCTION

The decrease of non-renewable energy sourcesis expected to occur due to the increase of human consumption from energy. Thus, many countries look for solutions to overcome the problem lack of scarcity expected in fossil fuels andthe harmful environmental impacts from it.Recently,SUDAN has promoted actions for the development ofrenewable energy; the biofuel has had significant participation in its energy and climate change projects. The main motivation for the biofuel policies include, for example, reducing the dependence on fossil fuels, decreasing the greenhouse gases and increasing agriculturalcommodities demand [1, 2]. Different biomass has been used in the production of biofuels involving cropplants, lignocellulosic materials and also organic waste, which include agriculturalresidues, municipal, and industrial

A. Background

A new classification for liquid biofuels includes first-generationand second-generation fuels. There are no strict technical definitions for these terms. First-generation fuel is generallyproduced fromsugars, grains, or seeds that is mean,the one that uses only a specific often-edible biomass, which is at the expense of human food. A relatively simple processing is required to produce a finished fuel from it. Second-generation fuels are generally those made from non-edible lignocellulosic biomass, either non-edible residues of food crop production (e.g.wheat stalks, corn stalks and rice husks) or non-edible wholeplantbiomass (e.g. grasses or trees grown specifically for energy). Bio-fuel is considered one of the most important renewable energy sources.Clean and zero of emissions that lead to avoid the global warming and the environmental pollution more over its cheap costs where it can be obtained at any time. The two main ways of converting the waste into bio fuels and bio-power are bio-chemical conversion and thermo-chemical conversion processes [3]. Biochemical conversions convert the waste into liquid or gaseous fuels by fermentation or anaerobic digestion. Fermentation of the biomass (starch and cellulose) produces primarily ethanol. Anaerobic digestion leads to the production of gaseous fuel primarily containing methane. Thermo-chemical biomass conversion involves processes at much higher temperatures andgenerally higher pressures than those found in biochemical conversion systems. Characteristics distinguishing thermo-chemical from biochemical bio-fuels are the flexibility infeed stocks that can be accommodated with thermo-chemical processing and the diversity of finishedfuels that can be produced.Thermo-chemical production of bio-fuels begins with gasification or pyrolysis. The former isgenerally more capital-intensive and requires larger scale for best economics, but the final product is aclean finished fuel that can be used directly in engines. The discussion here focuses on gasificationbasedprocessing, by which a variety of different bio-fuels can be produced, including Fisher-Tropschliquids (FTL), dimethyl ether (DME), and various alcohols.

B. Wheat

Wheat is the first important and strategic cereal crop for the majority of world's populations. It is the most important fundamental food of about two billion people (36% of the world population). Where it contains highly nutritious for human. Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally. The most important cereal grain crop of the world, which is cultivated over a wide range of climatic conditions. Temperature is the single most important climatic element affecting the growth.

In Sudan it is considered from the winter, crops (usually grow and harvest between mid-October and late April). It grows in many parts of Sudan, notably the Northern State, Gezira State, White Nile State,

New Halfa and Rahad projectwith different productivity rate as it is shown in table (1).

Table 1: Sudan wheat areas and total production [4]

Project	Area cultivated by Feddan	The amount of seed produced, Ton	The amount of waste (stalks and leaves), Ton
Al Gezira	400,000	400,000	10,000,000
New Hlafa	250,000	250,000	625,000
The Northern state	120,000	120,000	300,000
White Nile	100,000	100,000	250,000
Al Rahad	50,000	50,000	125,000
Total	920,000	920,000	11,300,000

The biochemical compositions ofwheat straw andrice straw are characterized by a typical composition of an agricultural-based lignocellulosic residue.They containan average 30 – 45% cellulose, 20 – 25% hemicellulose, 15 – 20 % lignin, as well as a number of minor organic compounds. Rice straw and wheat straw are poor in nitrogen, but relatively high in inorganic compounds, often referred to as ash.Table (2) presents an overview of characteristics of wheat straw and rice straw as they occur in the Phyllis database[5].

Table 2 : Fuel characteristics of wheat straw and rice straw

Component	Wheat Straw	Rice Straw
Water Content, wt%wet	10.4	23.9
Volatiles, wt%	81.2	83.9
Ash, wt% dry	7.1	18
HHV, kj/kg	19555	18824
LHV, kj/kg	18181	17511
C, wt%	49	48.7
H, wt%	5.94	5.92
O, wt%	43.7	44.2
N, wt%	0.77	1.05
S, wt%	0.17	0.14
Cl, wt%	0.544	0.489
Cellulose, wt% dry	37.8	36
Hemi Cellulose, wt% dry	26.5	24
Lignine, wt% dry	17.5	15.6
Lignin Acid Insoluble, wt% dry	-	-
Lignin Acid Soluble, wt% dry	-	-
Lipids, wt% dry	1.5	-
Protein, wt% dry	4.3	0

C. Objectives

This project solve the problem of fuel shortage beside the environmental issues mentioned above. Hence the main objectives of the study are:

1. To conduct material and energy balance calculationsfor designing the reactors.
2. To make simple control system configurationsby determining the degree of freedom.

II. METHODOLOGY

A.Process Description: Low-Temperature scenario Overview[6]:

The low-temperature (LT) is a dry metric ton per day wheat Straw fed gasification bio-refinery that produces naphtha-range and distillate. Feedstock preprocessing is where the Straw is chopped, dried, and grind to 6-mm size and 5% moisture. Dried and grinded Straw enters immediately and conveyed to a lock hopper system for pressurized feeding. Carbon dioxide from the syngas cleaning is used as pressurization gas. After that the dry Straw inter the gasifier, where it is partially oxidized using oxygen coming from air separation unit to produce synthesis gas and steam. Char is removed by cyclone. Synthesis gas cleaning by cold gas cleaning technologies where the syngas is quenched and scrubbed of particulates and ammonia. Acid gas (hydrogen sulfide and carbon dioxide) are absorbed via amine scrubbing. The liquid oxidation catalytic hydrogen sulfide oxidation process is used to separate carbon dioxide from hydrogen sulfide with subsequent recovery of solid sulfur.

Then syngas streamenters to the steam methane reformer (SMR) for reducing methane content and to the water-gas-shift (WGS) for adjusting the ratio of hydrogen and carbon monoxide. It then enters the Fischer-Tropsch (FT) reactor for Conversion of syngas to liquid fuel. The Fischer-Tropsch synthesis reactor operates at 200°C and 25 bar using a cobalt catalyst. The product distribution depends on partial pressures of H_2 and CO and the temperature of the reactor, for cobalt catalyst. The reactor is based on a fixed-bed. To ensure that the hydrocarbon product distribution leans toward the production of diesel fuel. This produces 30 wt% waxes in the FT products, requiring hydro-cracking before addition to the final fuel blend.

Exiting from FT reactor are separated in a gas/liquid after that the liquid is separated. Unconverted syngas is splited into three streams: direct recycle to the FT reactor, recycle to the acid gas removal unit, and to the gas turbine in the power generation area. Gas turbine and steam turbine produce the power that is required throughout the plant, from which the excess power is exported. Electric generators attached to both the gas turbine and the steam turbine produce electricity from the shaft work. Overall CO conversion is 66% due to recycling syngas. The recycle ratio is approximately 2%. FT products from the fuel synthesis area contain significant amounts of high molecular weight. Hydrogen is required to crack these high-molecular-weight paraffins to low-molecular weight hydrocarbons

B. Design Calculations

Steady state material and energy balances calculations were conducted to the above process in order to design its reactors through stoichiometric tables, stoichiometric equations and reaction rates.

Gasifier Reactor Design

The reactions occur in the gasifier are:

1. $C + 0.75\ O_2 \leftrightarrow 0.5\ CO + 0.5\ CO_2$.

2. $C + CO_2 \leftrightarrow 2CO$

3. $C + CO_2 \leftrightarrow 2CO$
4. $C + H_2O \leftrightarrow CO + H_2$
5. $CH_4 + H_2O \leftrightarrow CO + 3H_2$
6. $CO + H_2O \leftrightarrow CO_2 + H_2$
7. $S + H_2 \leftrightarrow H2S$
8. $N + 3H_2 \leftrightarrow 2NH_3$

These reactionsare investigated in a fluidized bed reactor using oxygen and steam, the reactor operating at 1143°k and25bar. In this reactor many reaction occur to produces syngas. The produced gas can be used for various thermal and power applications or, after cleaning and conditioning can be further processed into liquid fuels and chemicals. There advantages of fluidized bed reactor include flexible feeds, uniform temperature distribution across the bed, and large volumetric flow capability. Fluidized-bed a continuous type of well-mixed flow chemical reactor that is used to develop reaction kinetics gasification model. CSTR is the commonly used reactor in chemical industries to design chemical processes. Mixed flow is characterized as a perfectly mixed reactor in which all participating species are assumed to be uniformly distributed throughout the volume of the reactor. The reactor designed based on the kinetics and residence time of various reactions is involved.Table (3) shows the kinetics parameters (reaction rates and rate constants) of the six major gasification reactions.

Table 3: Kinetic parameters of gasification reaction [7]

Chemical equation	Rate equation	Rate Constant
$C + 0.75\,O_2 \leftrightarrow 0.5\,CO + 0.5\,CO_2$	$-r_1 = k_1 C_C + k_2 C_C C_{O2}$	$k_1 = 17.67RTe^{\left(\frac{-13600}{T}\right)}$ $k_2 = 8710e^{\left(\frac{-17967}{T}\right)}$
$C + CO_2 \leftrightarrow 2CO$	$-r_2 = \frac{2k_3 C_{CO2}\, g(x)}{1 + k_4 C_{CO2} + k_5 C_{CO}}$	$k_3 = 4.89 * 10^7 e^{\left(\frac{-268000}{RT}\right)}$ $k_4 = 0.066$ $k_5 = 0.12e^{\left(\frac{+37500}{RT}\right)}$
$C + H_2O \leftrightarrow CO + H_2$	$-r_3 = \frac{2k_6 C_{H2O}\, g(x)}{1 + k_7 C_{H2O} + k_8 C_{H2} + k_9 C_{CO}}$ $g(x) = (1 - X)\frac{\rho_{CHAR}}{M_C}$ ρ_{CHAR}=Char Density M_C= Carbon Molar Weight X = Carbon Conversion	$k_6 = 239e^{\left(\frac{-129000}{RT}\right)}$ $k_7 = 0.0316e^{\left(\frac{-30100}{RT}\right)}$ $k_8 = 0.00536e^{\left(\frac{-59000}{RT}\right)}$ $k_9 = 8.25 * 10^{-5} e^{\left(\frac{-96100}{RT}\right)}$
$CH_4 + H_2O \leftrightarrow CO + 3H_2$	$-r_4 = k_{10}\left(C_{CH4}C_{H2O} - \frac{C_{CO}\,C_{H2}^3}{0.0265\left(\frac{-32900}{T}\right)}\right)$	$k_{10} = 3.1005e^{\left(\frac{-15000}{T}\right)}$
$CO + H_2O \leftrightarrow CO2 + H_2$	$-r_5 = k_{11}\left(C_{CO}C_{H2O} - \frac{C_{CO2}\,C_{H2}}{K_{eq}}\right)f$	$k_{11} = 2.778e^{\left(\frac{-12560}{RT}\right)}$ $K_{eq} = 0.022e^{\left(\frac{34730}{RT}\right)}$ $f = 0.1$
$C + 2H_2 \leftrightarrow CH_4$	$-r_6 = k_{12}C_C^{0.5} - k_{13}C_{CH4}$	$k_{12} = 1.36810^{-3} m_s T * e^{\left(\frac{-8078}{T} - 7.087\right)}$ $k_{13} = 0.151 m_s T^{0.5} * e^{\left(\frac{-13578}{T} - 0.372\right)}$

The extent of reaction (ϑ) for each reaction is calculated and tabulated as in the stoichiometric table 4 to find the net rate of reaction.

Table 4 : Reaction stoichiometry

Material	Material Entering	Material Change
C	F_0C	$-\vartheta_1 - \vartheta_2 - \vartheta_3 - \vartheta_6$
CO	F_0CO	$0.5\vartheta_1 + 2\vartheta_2 + \vartheta_3 + \vartheta_4 - \vartheta_5$
CO2	F_0CO_2	$0.5\vartheta_1 - \vartheta_2 + \vartheta_5$
CH4	F_0CH_4	$\vartheta_6 - \vartheta_4$
H2	F_0H_2	$\vartheta_3 + 3\vartheta_4 + \vartheta_5 - 2\vartheta_6$

Fischer Tropsch Reactor Design

The Fischer-Tropsch synthesis reactor operates at 200°C and 25 bar using a cobalt catalyst. Carbon monoxide conversion in the reactor is set at 66%.

$$CO + 2H_2 \rightarrow -(CH_2) - +H_2O$$

OR:

$$nCO + (2n+1)H_2 \rightarrow C_nH_{(2n+2)} + nH_2$$

Exit stream from FT reactor are separated in a gas and liquid. Unconverted syngas is splited into three streams: direct recycle to the FT reactor, recycle to the acid gas removal unit, and to the gas turbine in the power generation area. Gas turbine and steam turbine produce the power that is required throughout the plant, which the excess power is exported. Electric generators attached to both the gas turbine and the steam turbine produce electricity from the shaft work.Overall CO conversion is 66% due to recycling syngas. The recycle ratio is approximately 2%. FT products from the fuel synthesis area contain significant amounts of high molecular weight. Hydrogen is required to crack these high-molecular-weight paraffin to low-molecular weight hydrocarbons. To ensure that the hydrocarbon product distribution leans toward the production of diesel fuel, the value of alpha should be at least 0.85 and preferably greater than 0.9. Equation for alpha calculation [6] are shown below.

$$\alpha = [0.2332.\frac{y_{co}}{y_{co} + y_{H_2}} + 0.633]\left(1 - 0.0039(T - 533)\right)$$

Fischer Tropsch process conditions are usually chosen to maximize the formation of higher molecular weight hydrocarbons liquid fuels which are higher value product. Depending on the catalyst, temperature, and type the process employed, hydrocarbons ranging from methane to higher molecular paraffin's and olefins can be obtained. The Fischer Tropsch process synthesis reaction in theory is a condensation polymerization reaction of CO. Its products obey a well-defined molecular weight. Figure(1) shows the Fischer Tropsch reactor configuration.

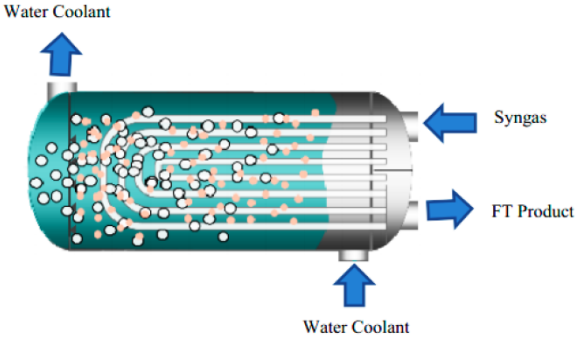


Figure (1): Fischer Tropsch reactor

The cobalt catalytic is used due to longer life, their high FT synthesis activity, high selectivity to long chain hydrocarbons (HCs), better catalyst stability in hydrogen rich environments andlower selectivity to oxygenated compounds. Porosity of catalyst bed = 0.4. The design equation [8]:

$$\frac{V}{F_{A0}} = \int_{x_0}^{x_f} \frac{dx}{-r_{FT}}$$

According to the limiting reactant carbon monoxide, CO, the rate equation is:

$$-r_{CO} = K_{FT} \frac{(1 - x_{CO})(\frac{P_{H_2}}{P_{CO}} - 2x_{CO})}{[\frac{1}{P_{CO}} + a(1 - x_{CO})]^2}$$

Volume of the reactor is found as:

$$\text{Volume of reactor} = \frac{\text{Volume of catalyst}}{1 - \text{Porosity of catalyst bed}}$$

Number of Tubes [N_T]:

$$N_T = \frac{\text{Volume of reactor}}{\text{Volumeinonetube}}$$

$$\text{Innervolumeinonetube} = \text{Areaofonetube} * \text{Lengthofonetube}$$

$$\text{Innercross sectionalareaofonetube} = \frac{\pi {d_i}^2}{4}$$

The surface area available for One Tube can be calculated from$A = \pi d_0 L$

Let 10% additional length is added at both sides of the reactor, hence; the total additional length = 0.2 * Length of tube and the length of shell = Length of tube +Additional length. The bundle diameter of tubes can be calculated as[9]:

$$d_b = d_0(\frac{N_T}{K_t})^{(\frac{1}{n})^2}$$

For Fixed Tube:-

$$\text{shelldimeter} - \text{Bundlediameter} = \text{cleaernce}$$

Pressure Drop[8]:-

$$\frac{\Delta P}{L} = \frac{fCG^2}{\rho D} 10^{-10}$$

$$C = \frac{1.75 * 10^{10}}{144g} \times \frac{1 - \varepsilon}{\varepsilon^3}$$

$$f = 1 + \frac{150}{1.75} \times \left(\frac{DG}{\mu}\right)^{-1} \times 1 - \varepsilon$$

C. Rotary Dryer Design:

The rotary drier is an inclined slightly to the horizontalcylinder, which may be rotated or the shell may be stationary and an agitator inside may revolve slowly. In either case, the wet material is fed in at the upper end and the rotation or agitation advances the material progressively to the lower end where it is discharged.In this dryer the steam in direct contact with straw for dehumidification. Enter the steamer at a temperature of 473K,leave at 393K, and leave the straw with moisture 5%.The heat transferred to produce the drying of wheat straw [10]:-

$Q = (1-\alpha)(Q_1 + Q_2 + Q_3 + Q_4)$

$Q_1 = m_{ds} . Cp_{ds} . (T_{F3} - T_{F2})$

$Q_2 = m_{ds} . X. Cp_w(T_3 - T_2)$

$Q_3 = m_{w,ev} . \lambda$

$Q_4 = m_{w,ev} Cp_V(T_{F2} - T_{sat})$

$Q_5 = m_{w,ev} Cp_V(T_{s,out} - T_{sat})$

To determine the dryer diameter take the ratio L/D (with the rang 4-10) equal to 7, hence;

$$d = \sqrt{\frac{4 * \dot{m}_s}{3600 \pi j u_p}}$$

Then the residence time is calculated as:

$$\tau = \frac{0.23 * 4 * V_d}{SN^{0.9} d^3}$$

Checking the efficiency of the dryer as:

$$\eta = \frac{\text{Actualenergyneeded}}{\text{Requier energy if all the humidity is removed}}$$

$$\eta = \frac{Q_1 + Q_2 + Q_3 + Q_4 + Q_5}{\text{Requireheat}}$$

III. RESULTS AND DISCUSSION

Gasification take place in four stages of carbonaceous material; drying, devolatilization, combustion, and reduction [8]. The grinded straw is introduced into the gasifier unit and heated to 1143°k. Partial combustion occurs with the oxygen after being coming from the air separation unit. Steam added to the gasifier in flow rate is calculated from Stoichiometry. The amount of constituent of the stream leaving the reactor thatare shown in table (6) below, were calculated from the Stoichiometry table (5).These assumptions were taken in designing the reactor:-

1. The reactor is assumed to be a perfectly mixed.
2. Design calculation are based on the seven possible participating reactants (C, H_2O, O_2, CO, H_2, CH_4 and CO_2) and the kinetics of six major gasification reactions; hence concentrations of syngas impurities (NH_3 and H_2S) and lighter hydrocarbons (C_2H_2, C_2H_4 and C_2H_6) are assumed to be negligible.

Table 5: Gasification Stoichiometric calculations results

Reaction 1 (conversion = 40%):			
Species	Feed Mole	Change	Remaining
C	54.252	-21.7	32.552
O_2	16.275	-16.275	0
CO	0	10.85	10.85
CO_2	0	10.85	10.85
Reaction 2 (conversion = 45%):			
C	32.552	-14.648	17.904
H_2	39.498	-29.297	10.201
CH_4	0	14.648	14.648
Reaction 3 (conversion = 55%):			
C	17.904	-9.85	8.054
CO_2	10.85	-9.85	1
CO	0	19.7	19.7
Reaction 4 (conversion = 60%):			
C	8.054	-4.83	3.224
H_2O	4.83	-4.83	0
CO	0	4.83	4.83
H_2	0	4.83	4.83
Reaction 5 (conversion = 80%):			
CH_4	14.648	-11.718	2.93
H_2O	11.718	-11.718	0
CO	0	11.718	11.718
H_2	0	35.154	35.154
Reaction 6 (conversion = 30%):			
CO	47.098	-14.13	32.968
H_2O	14.13	-14.13	0
CO_2	0	14.13	14.13
H_2	0	14.13	14.13
Reaction 7 (conversion = 30%):			
S	0.0772	-0.0232	0.054
H_2	64.315	-0.0232	64.292
H_2S	0	0.0232	0.0232
Reaction 8 (conversion = 30%):			
N	0.654	-0.196	0.458
H_2	69.093	-0.588	63.704
NH_3	0	0.392	0.392

The calculated amounts of components in each stream of the unit are given in table 7 below.Heat of reaction it is a thermodynamic unit of measurement useful for calculating the amount of energy per mole either released or produced in a reaction. The gasification heat of reactions in table (8) are calculated from the components heat of formation and its enthalpies [11, 12]. Design calculations give the gasifier diameter of 5 m and its length equal to 10 m with residence time of about 0.305 seconds.

Table 7: Material Balance

Component	$F_1 = F_2$	$F_3 = F_4$	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{10}=Re	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
C	651.02912	651.02912	-	-	-	-	-	-	-	-	-	-	-	-
O	575.463	575.463	-	-	-	-	-	-		-	-	-	-	-
H	77.01907	77.01907	127.408	127.408	127.408	-	127.408	141.472	142.208	48.352	48.352	-	-	-
S	2.470423	2.470423	1.728	-	-	-	-	-	-	-	-	-	-	-
N	9.155097	9.155097	6.412	6.412	6.412	-	6.412	6.412	6.412	6.412	6.412	-	-	-
H_2O	138.05305	69.218	-	-	-	-	-	-	-	422.352	-	422.352	422.352	-
CO	-	-	923.104	923.104	923.104	-	923.104	988.736	995.456	338.464	338.464	-	-	-
CO_2	-	-	693.286	693.286	693.286	693.286	-	-	-	-	-	-	-	-
NH_3	-	-	6.664	6.664	-	-	-	-	-	-	-	-	-	-
H_2S	-	-	0.789	0.789	0.789	0.789	-	-	-	-	-	-	-	-
CH_4	-	-	46.88	46.88	46.88	-	46.88	9.376	9.376	9.376	9.376	-	-	-
O	-	-	575.463	-	-	-	-	-	-	-	-	-	-	-
Char			615.878	-	-	-	-	-	-	-	-	-	-	-
Loss	-	-	1.004	-	-	-	-	-	-	-	-	-	-	-
Steam	-	-	-	-	-	-	42.192		-	-	-	-	-	-
Oil	-	-	-	-	-	-	-	-	-	328.499	-	328.499	-	328.499
Total	1453.19	1384.354	2421.426	1874.218	1798.884	694.075	1145.996	1145.996	1153.452	1153.455	402.604	750.604	422.352	328.499

$F_5 = F_4 + F_{O2} + F_{re} + F_{steam}$

$F_5 = 1384.354 + 483.986 + 33.286 + 520.8$

$F_5 = 2421.426$ kg

Table 6: Syngas Composition (Mole Basis) Leaving the Gasifier

Species	Mole Out	Mass Out(kg/s)
CO	32.968	923.104
CO_2	15.7565	693.286
NH_3	0.392	6.664
H_2	63.704	127.408
C	3.224	38.688
H_2S	0.0232	0.789
CH_4	2.93	46.88
N	0.458	6.412
S	0.054	1.728
O	17.9832	575.463
Loss		1.004
Total		2421.426

Table 8: Gasification heat of reactions

NO	Chemical equation	$\Delta H_r(298°)$	$\Delta H_r(1143°)$
1	$C + 0.75\ O_2 \leftrightarrow 0.5\ CO + 0.5\ CO_2$	-110.5	44083.276
2	$C + 2H_2 \leftrightarrow CH_4$	-74.8	31459.964
3	$C + CO_2 \leftrightarrow 2CO$	205..3	40044.364
4	$C + H_2O \leftrightarrow CO + H_2$	130.4	-178.252
5	$CH_4 + H_2O \leftrightarrow CO + 3H_2$	172.6	57804.142
6	$CO + H_2O \leftrightarrow CO2 + H_2$	-41.47	-9578.035
7	$S + H_2 \leftrightarrow H_2S$	-20	-80838.578
8	$N_2 + 3H_2 \leftrightarrow 2NH_3$	92.4	-50387.408

The Fischer Tropsch reactor stoichiometric table (9).

Table 9: Fischer Tropschstoichiometric calculations results

Species	Feed Mole	Change (66%)	Remaining
CO	35.552	-23.464	12.088
H_2	71.104	-46.928	2.418
-CH-	0	23.464	23.464
H_2O	0	23.464	23.464

Table (10) shows the calculated composition and amount of the output stream from Fischer Tropsch reactor.

Table 10: Composition of oil

Component	Output stream		
	w%	kg/sec	kg/hr
Gas fuel	2	6.57	23652
LPG	12	39.42	141912
Naphtha	38	124.83	449388
Light oil	28	91.98	331128
Heavy oil	20	65.699	236516.4
Total	100	328.499	1182596.4

Results of the design calculation for Fischer Tropsch reactor are summarized in table 11:

Table 11: Fischer Tropsch Design

Fischer-Tropsch reactor			
Type		Multi-Tubular fixed bed reactor	
Feed	Syngas	Volume of catalyst	2.055m^3
Flow rate	107.7mole/sec	Number of tubes	832
Temperature	473k	Outer diameter of tube	35.3m
Pressure	2.5MP-1	Inner diameter of tube	31.8m
Catalyst	Cobalt	Length of tubes	12m
Volume of reactor	8	Diameter of shell	1.52m
Pressure drop	0.163	Length of shell	14.4m

In energy balance calculations, for multi component stream, heat capacity are calculated by multiplying heat capacity of the component by their composition and flow rate. For the drier, the heat lost by steam is distribution between the straw and its humidity evaporation (latent and sensible). The super heated steam suck all humidity from the straw as water vapour. The amount of steam needed is found 2102.41 kg/sec. The calculations leads to drier diameter of 0.989m and length of 7.0 m with residence time equal to 0.014 seconds. The calculated drier efficiency equal to 67.4%, which is reasonable due to the high severity of the unit.

CONCLUSION

In This study production of bio fuel from wheat straw solve the marketing problems for bio fuel and pollution of environment by producing clean crude oil. This leads to produce clean fuel free from sulfur and other pollutant. This crude can be exported to increase the national income besides raising the life level in northern Sudan community. The design study investigate the production of huge amounts of fuel. The gasifier reactor and Fischer Tropsch reactor and dryer were designed according to material and energy balance.Optimum process control configuration for the unit is chosen.

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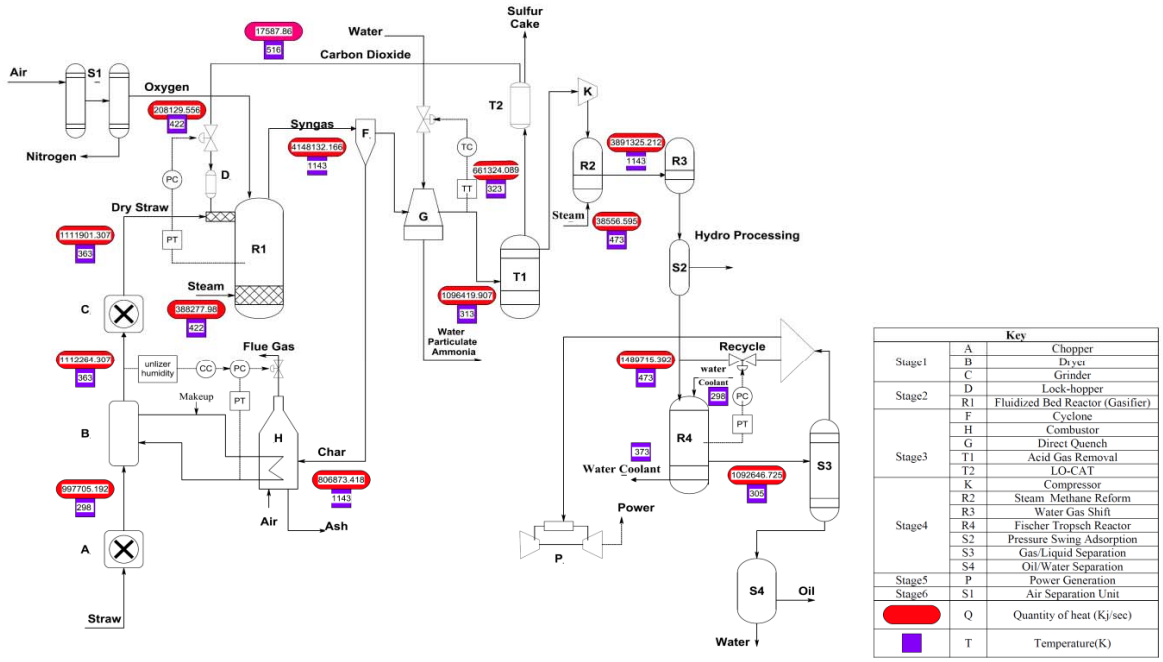


Figure (2): Process Flow Sheet, Overall Energy and Control

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