Department of Mechanical Engineering
Indian Institute of Technology New Delhi
II Semester -- 2018 – 2019

MCL 241 Energy systems and Technologies

Problem set 6: Analysis of Renewable Energy Systems

Laboratory Tutorial

List of Experiments:

1. Performance analysis of Solar PV Electricity Generator.
2. Study of Solar Thermal Heater.
3. Performance study of a converted IC engine operating on 100% Biogas.
4. Study of gasification of biomass and working of a downdraft gasifier.
5. Study of Bio-Diesel Reactor.

Experiment 1 : Performance analysis of Solar PV Electricity Generator.

1. Revisiting solar photovoltaic (PV)

The basic element of a PV system is the photovoltaic (PV) cell, also called a solar cell. An example of a PV / solar cell made of mono-crystalline silicon is shown in Fig. 1 below.

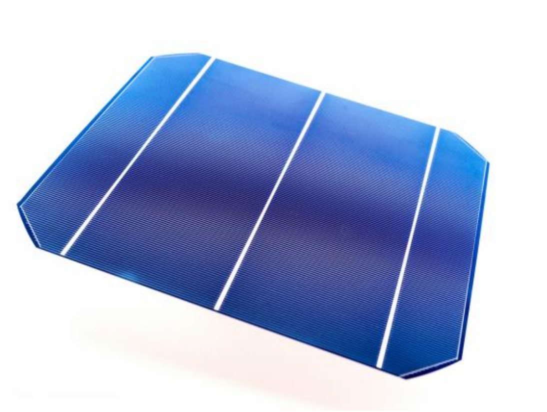


Fig.1: Solar cell

A PV / Solar cell is a semiconductor device that can convert solar energy into DC electricity through the photovoltaic (conversion of solar light energy into electrical energy). When light shines on a PV / solar cell, it may be reflected, absorbed, or passes right through. But only the absorbed light generates electricity. To increase their utility, a number of individual PV cells are interconnected together in a sealed, weatherproof package called a panel (Module). For example, a 12 V panel (Module) will have 36 cells connected in series and a 24 V panel (Module) will have 72 PV cells connected in series. To achieve the desired voltage and current, modules are wired in series and parallel into what is called a PV array. The flexibility of the modular PV system allows designers to create solar power systems that can meet a wide variety of electrical needs. Fig.2 explains the working principle of solar photovoltaic.

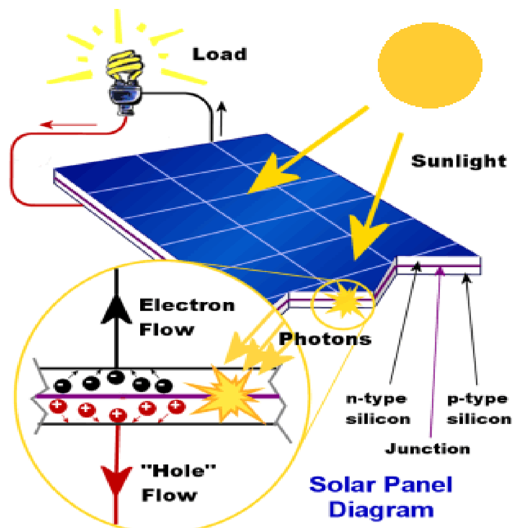


Fig. 3 shows PV cell, panel (Module) and array.

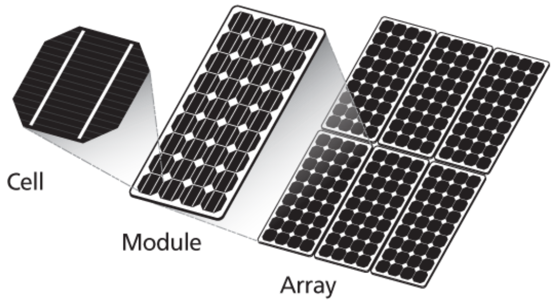


Fig.3: Solar cell, module and array

2. Objective(s):

- To determine the panel angle and azimuth corresponding to maximum open circuit voltage at three time intervals with 20 minutes gap.
- To determine the resistance load that results in maximum power output at predefined panel angle and azimuth by using batteries as loads at each time interval.
- To estimate efficiency of the solar panel at each time interval.

3. Performance Test Circuits and connections:

The basic components of the module and the connections are given in Fig. 4.

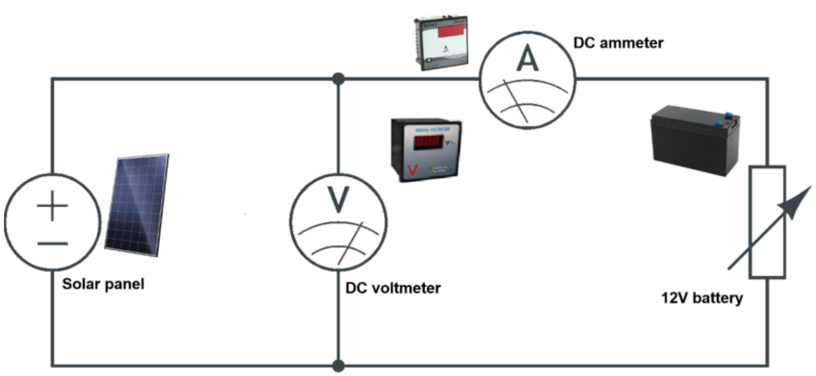


Fig.4: Solar panel, voltmeter, ammeter and battery connections

Solar PV output can be fed to different direct loading applications. However, the common practice is to charge batteries and the discharging of battery is utilized for other power applications.

3. Procedures

a) Open the battery charging circuit and observe the open circuit voltage in the DC voltmeter.

b) Slowly change both the panel angle and azimuth so that maximum open circuit voltage is observed. Note panel angle, azimuth and time.

c) Close the battery charging circuit and note the ammeter and voltmeter readings. Add the DC light (bike head light filament) to the loading circuit and hunt for the resistance corresponding to maximum power using the high and low intensity beam options. (Refer the module test report for voltage current relation at maximum power).

$$R(maximum\ load\ resistance) = \frac{V(load\ voltage)}{I(current)}$$

d) Determine the solar irradiation using irradiation meter and the Cell area of the panel. Compute the total incident solar radiation on the cells.

$$Solar\ irradiation\ recieved\ by\ module\ (P_{in}\ in\ Watt) = Cell\ ar$$

e) Compute the output DC power at maximum load resistance.

$$P_{max} = I^2 X\ R(maximum\ load\ resistance)$$

f) Estimate the efficiency of the solar panel.

$$Panel\ efficiency(\eta) = \frac{DC\ power\ at\ maximum\ load\ resistance\ (P_{ma}}{Solar\ irradiation\ recieved\ by\ module\ (P_{in})}$$

g) Repeat steps (b) to (f) for 03 time intervals with 20 minutes gap. (Note: 20 minutes corresponds to nearly 05 degrees of earth's rotation).

4. Observation tables

Panel angle(^{0})	Azimuth angle(^{0})	OC Voltage(V_{oc})

Table 1: Observation table for determining panel and azimuth angle for maximum open circuit voltage at a given time

Voltage	Current	Resistance	Power

Table 2: Observation table for determining load resistance corresponding to maximum power

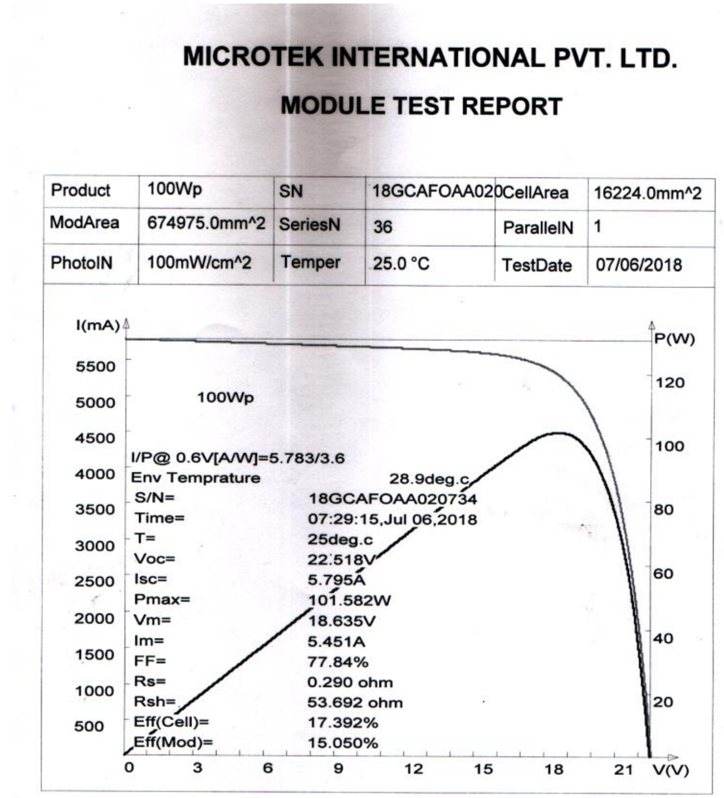
Time	Irradiation(P_{in})	Max power(P_{max})	Panel efficiency(η)

Table 3: Observation table for determining incident radiation, maximum power and panel efficiency

5. Results

a) Plot optimum panel and azimuth angle with time.
b) Plot solar irradiation with time.
c) Plot panel efficiency with time.

APPENDIX: Solar PV module test report



MICROTEK INTERNATIONAL PVT. LTD.

MODULE TEST REPORT

Product	100Wp	SN	18GCAFOAA020	CellArea	16224.0mm^2
ModArea	674975.0mm^2	SeriesN	36	ParallelN	1
PhotoIN	100mW/cm^2	Temper	25.0 °C	TestDate	07/06/2018

Experiment 2: Study of Solar Thermal Heater

Introduction:

Solar water heaters can operate in any climate[1,2,3,4] . The performance of these heaters varies depending on how much solar energy is available at that locality, and more importantly on how cold the water coming into the system is. The colder the incoming water, the more efficiently the solar water heating system operates. A large number of studies have examined the performance of solar water heating system and it is reported that the efficiency of solar thermal conversion is about 70% when compared to solar electrical direct conversion system which has an efficiency of only 17%.

Owing to its ease of operation. and simple maintenance, solar water heating systems play an important role in domestic as well as industrial sector. Solar water heaters can be either active or passive.

The active solar water heating system uses a pump to circulate the heated water through the system. On the other hand, passive solar water heating system move the heated water through the system without pumps. This type of system does not have electric components to break, which makes it more reliable and easier to maintain than active systems.

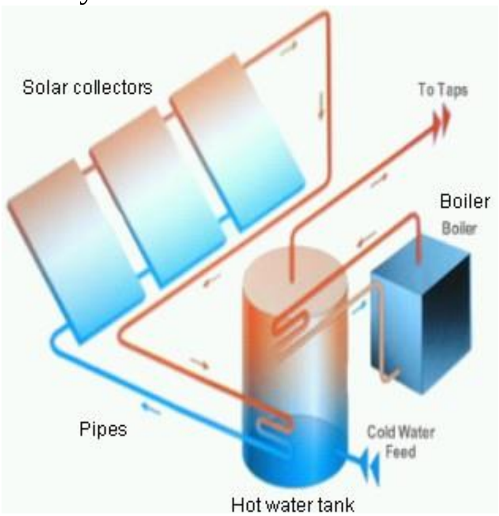


Figure 1 : Solar Thermal Water Heating System

Solar Collector:

The solar collector was designed conceptually to have vertical runs of parallel pipe. The main restriction for the design of the solar collector was the size of the collector. This restriction is due to the fact that it must remain portable and safe.

Along with the solar collector frame, other components such as the piping, absorber, and glass needed to be determined.

Typical solar collector piping is ½"copper, the number of pipes The piping is constructed of ½ nominal copper pipes that run lengthwise through the collector. The absorber is selected based on typical solar collector standards and was constructed of fiberglass. Like the absorber, the glass material is chosen based on industry standards. All of the solar collector components that would be exposed to the sun must be painted black in order to attract more sunlight. The glasscover over the absorber was constructed of low-iron, tempered glass.

Objectives:

1. Collect all the technical details of available Solar Thermal water heating system.
2. Measure, water flow rate, inlet and outlet temperatures of water.
3. Study the effect of water flow rate on overall efficiency of the STWHS.
4. Comment on the differences between standard and present testing methods.

Standard Testing Procedure:

The standard testing procedure is straight forward. It consists of the following steps:
1. Ensure that all piping is connected.
2. Add water to storage tank until the tank-inlet opening is completely submerged.
3. Place the apparatus in the desired testing location, ensuring that sufficient sunlight is available.

5. The solar water heating system was tested several times.
6. Temperature water measurements in the storage tank were recorded every 10 minutes and lasted for 5 hours.
7. Plot efficiency and capacity of heater as a function of water flow rate.

$$\text{Efficiency of A STWH} = \frac{\dot{m}_{water} \times C_{pw} \times \Delta T_{water}}{A_{heater} \times J_{solar}}$$

Experiment 3: Performance study of a converted IC engine operating on 100% Biogas fuel mode

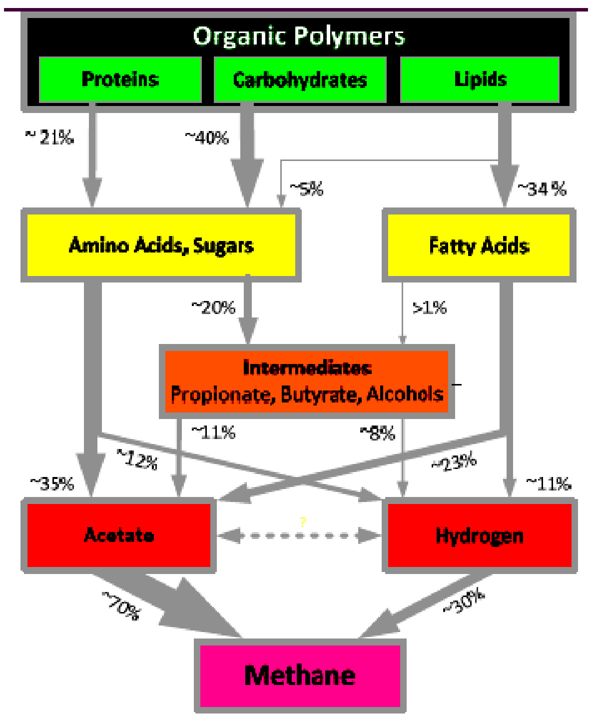
1. Production of Biogas using Biomass Waste

Waste biomass available in IIT campus are collected and converted into biogas using anaerobic digester. Anaerobic Digestion (AD) describes the microbial degradation of organic substances (biomass) under oxygen depleted conditions to gaseous end products CH_4 and CO_2. AD includes 3 metabolical steps:

Hydrolysis
Fermentation = Acidification
Methanogenesis

From a technical point of view it is however considered as an overall Reaction as:

Organics + Water → Methane + CO2 + Water



2. Collection of Waste Biomass:

Weed Seeds Available at/around IIT Delhi

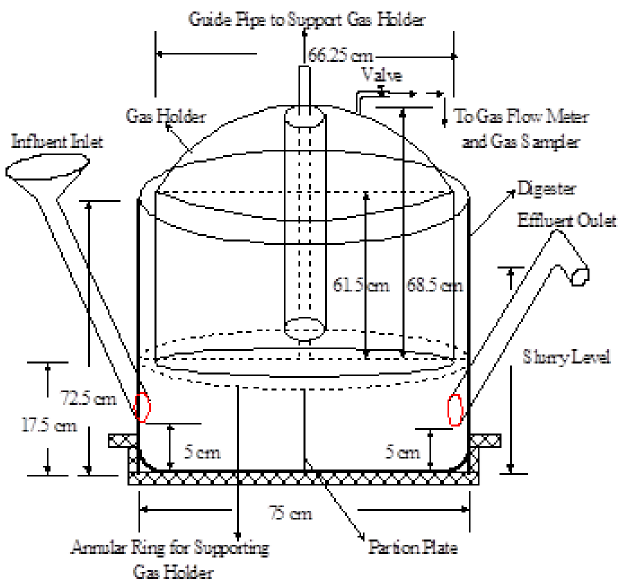
Polyalthia longifolia | *Albizia lebbeck* | *Acacia nilotica* | *Leucaena leucocephala*

Cassia fistula | *Mimusops elengi* | *Terminalia arjuna* | *Prosopis juliflora*

Pongamia pinnata | *Ficus virens* | *Ficus racemosa*

S.No	Local Name	Scientific Name	CV(MJ/kg)
1	Siris Seeds	*Albizia lebbeck*	16.85
2	Siris Pods	*Albizia lebbeck*	16.23
3	Amaltas Seeds	*Cassia fistula*	16.14
4	Amaltas Pods	*Cassia fistula*	15.97
5	Ashoka Seeds	*Polyalthia longifolia*	16.95
6	Babool Seeds	*Acacia nilotica*	17.20
7	Babool(Pods)	*Acacia nilotica*	15.77
8	Moulsari Seeds	*Mimusops elengi*	17.85
9	Moulsari Kernel	*Mimusops elengi*	16.08
10	Vilayati Kikar Seeds	*Prosopis julifora*	16.1
11	Subabool Seeds	*Leucaena leucocephala*	17.45
12	Subabool Pods	*Leucaena leucocephala*	15.73

The Anaerobic Digester:



3. Diesel engine conversion to a 100% biogas engine

A diesel engine is an integral part of rural areas for various agricultural and power generation applications. In this experiment a Kirloskar make (DA-10) diesel engine with a rated power of 7.4 kW at 1500 RPM has been converted into a 100% Biogas Engine in the IC Engine Lab as shown in Fig.1. It is envisaged that rural areas have adequate amount of resources available to produce biogas which can be utilized for meeting local energy demands and replacing conventional diesel fuel. Around 40-50% reduction in the maximum power output of the engine is observed upon conversion as biogas contains only 50–55% combustible constituent, i.e., methane and the rest is largely CO_2. There are several factor contributing to the reduction in the maximum power output such as lesser calorific value of biogas (~20 MJ/kg) in comparison to diesel (~42 MJ/kg), slower combustion characteristics of biogas and displacing of air in the combustion chamber by biogas.

Major modifications required for engine conversion:

- Removal of the fuel injection system including the fuel lines, fuel pump and the fuel injector.
- Installation of a suitable spark plug.
- Modification in intake system of the engine by introducing a suitable air–fuel mixing and control mechanism, i.e., a gas carburettor system.
- Mounting of a specially designed ignition system on the crankshaft.

4. Objective(s):

- Collect the analysis of biogas and feed materials.
- Study the distributed standalone unit for power generation for the lab using biogas.
- Analyse the engine performance on biogas by determining the
  a. Brake Power (BP)
  b. Brake specific fuel consumption (BSFC),
  c. Brake thermal efficiency (BTE) of the engine

5. Schematic diagram of the converted engine

The basic components of the engine and connections are shown in Fig. 2.

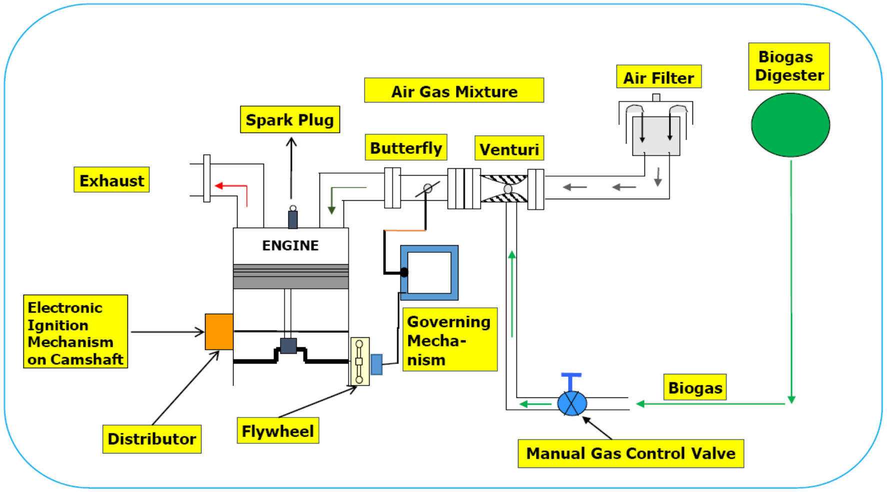
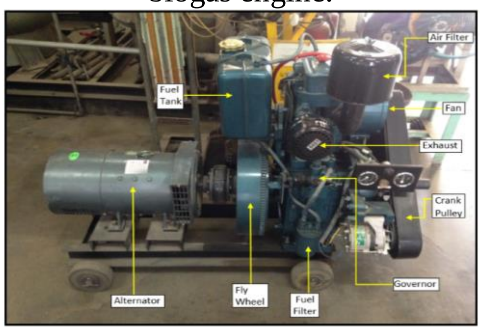


Fig. 3. Schematic diagram for conversion of diesel engine to 100% biogas engine.



(a) Original Engine

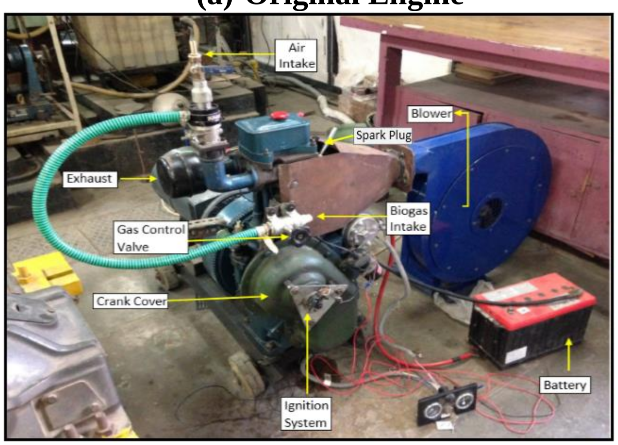


Fig. 3. Pictorial view of engine after conversion

3. Procedure

h) Supply biogas after (measuring its composition) to the engine through manually controlled biogas intake valve.

i) Switch the power supply to the biogas mode from grid electricity supply mode.

j) Switch On the engine and the blower after making sure that all the connections of flow meter, ammeter, electrical supply leads on alternator, battery and the blower are in place.

k) Load has to be varied by switching on more equipment's and heater one at a time with in the lab.

l) For all the different loads note down the time of engine start, volume of gas reflected in the flow meter initially, speed of the engine with a tachometer, the load by recording the current and the voltage using a multimeter.

m) Run the engine on each load for 10 minutes and after that switch off the engine and note down the volume of gas reflected in flowmeter. The difference of initial and final volume will give the volume of gas consumption. Repeat steps b) to f) for each load.

3. Calculations:

a) Brake Power (BP)

$$BP = \frac{V \times I}{1000}$$

Where,

BP	=	Brake power developed by the engine, kW
V	=	Voltage produced, Volts
I	=	Current produced, Ampere

b) Brake Specific Fuel Consumption (BSFC)

$$\dot{m}_f = \frac{\rho \times Vol}{Time}$$

Where,

$\dot{m}_f$ = Mass flow rate of the fuel consumed, kg/h

Vol. = Volume of the fuel consumed, m^3

ρ = Density of the fuel, kg/m^3 (Can be considered as 1.12 kg/m^3 for biogas)

$$BSFC = \frac{\dot{m}_f}{P}$$

Where,

BSFC = Brake specific gas consumption, g/kW–h
P = Brake power developed by the engine, kW

c) Brake Thermal Efficiency (BTE)

$$\eta_{th} = \frac{BP \times 3600}{\dot{m}_f \times CV} \times 100$$

Where,
BP = Brake power developed by the engine, kW;
η_{th} = Brake thermal efficiency, %;
$\dot{m}_f$ = Mass flow rate of the fuel consumed, kg/h;
CV = Calorific value, kJ/kg (Can be considered as 20 MJ/kg for biogas)

d) Torque

$$T = \frac{9549 \times P}{N}$$

Where,
T = Torque, Nm
P = Brake power developed by the engine, kW
N = Engine Speed, RPM

e) Brake Load (%)

$$BL = \frac{T \times 100}{47.11}$$

Where,
T = Torque, Nm
BL = Brake load percentage, %
47.11 = Maximum torque which could be produced by the original diesel engine, Nm

4. Observation tables

Table 1: Observation table for determining Brake Power

Voltage (V)	Current (A)	Brake Power (kW)

Table 2: Observation table for determining BSFC

Time of Run (min)	Volume of biogas consumed (m^3)	Brake Power (kW)	BSFC (g/kWh)

Table 3: Observation table for determining BTE

Brake Power (kW)	BSFC (g/kWh)	Calorific Value of biogas (MJ/kg)	BTE (%)

Table 4: Observation table for determining Torque and Brake load %

Brake Power (kW)	Speed (RPM)	Torque (Nm)	Brake Load (%)

5. Discussion:
Write a paragraph wish to narrate your experiences about this experiment and its utility

6. Results

d) Plot the curve for Brake Power – Brake Load %

e) Plot the curve for Speed – Brake Load %
f) Plot the curve for BSFC – Brake Load %
g) Plot the curve for BTE – Brake Load %

Experiment 4: Study of gasification of biomass and working of a downdraft gasifier

Objectives

- Observe and study of working of a downdraft gasifer; prepare a hand drawn diagram of sub systems of the gasifier;
- Understand the process of biomass gasification in a downdraft gasifier.

Material and equipment

Wood (of sizes 40x20 mm and 20x20 mm mixed together), Downdraft gasifier consisting of water scrubber, coarse and fine filters, measuring systems for pressure and temperature, flaring unit for burning of producer gas, measuring instruments for pressure, temperature and flow rate.

Introduction and principle of gasification

Biomass had been a major energy source prior to discovery of fossil fuels such as coal and petroleum. Presently, use of biomass for energy has been prevailing mainly in rural communities of developing societies. But whenever energy crisis has erupted, focus on use of biomass for energy has returned. Second world war has witnessed a large number of vehicles running on a gas generated from wood. Converting solid woody and non woody biomass into fuel gas known as producer gas has lately been a subject of interest.

Biomass is a natural substance available, which stores solar energy by the process of photosynthesis in the presence of sunlight. It chiefly contains cellulose, hemicellulose and lignin, having an average composition of $C_6H_{10}0_5$, with slight variations depending on the nature of the biomass. Theoretically, the ratio of air-to-fuel required for the complete combustion of biomass, defined as stoichiometric combustion is 6:1 to 6.5:1, with the end products being CO_2 and H_20.

In gasification the combustion is carried at sub-stoichiometric conditions with air-to-fuel ratio being 1.5:1 to 1.8:1. The gas so obtained is called producer gas, which is combustible. This process is made possible in a device called gasifier in a limited supply of air. A gasifier system basically comprises of a reactor, where the gas is generated and is followed by a cooling and cleaning system, which cools and cleans the gas. The clean combustible gas is thus available for power generation application.

The product gas (producer gas) so yielded has a calorific value of 4-5 MJ/kg, with an average composition of CO : 20 ±1%; CH4: 3 ±1%, H2 : 20 ±1%, C02: 12 ±1% and rest, N2. The producer gas can have end use for thermal application or for mechanical/ electrical power generation. The advantages of producer gas are finer power control besides efficient and environment friendly operation. The gas can thus be conveniently used for thermal applications such as dryers, kilns, furnaces, boilers, etc. It can also be used as a fuel for operating an IC engine coupled with an alternator for electrical power generation.

Gasification of biomass is a complex process which involving thermochemical conversion. It takes place in stages without having defined boundaries. It is a combined result of several processes together. These processes take place in the reactor of a gasifier. The main processes are as under:

Partial combustion of biomass for heat generation
Pyrolysis of feedstock
Conversion of devolatised gases in high temperature oxidation zone
Reduction of gases in reduction zone

These processes are taking place simultaneously in the reactor of a gasifier. Various zones get formed inside a gasifier reactor as shown in Figure-1. The associated reactions are also given in the Figure. Air is normally used as the gasifying agent. However, steam and oxygen can also be used as gasifying medium if higher calorific value producer gas is required. The combustion (oxidation) zone may have temperature in the range of 700-1200 deg. C.

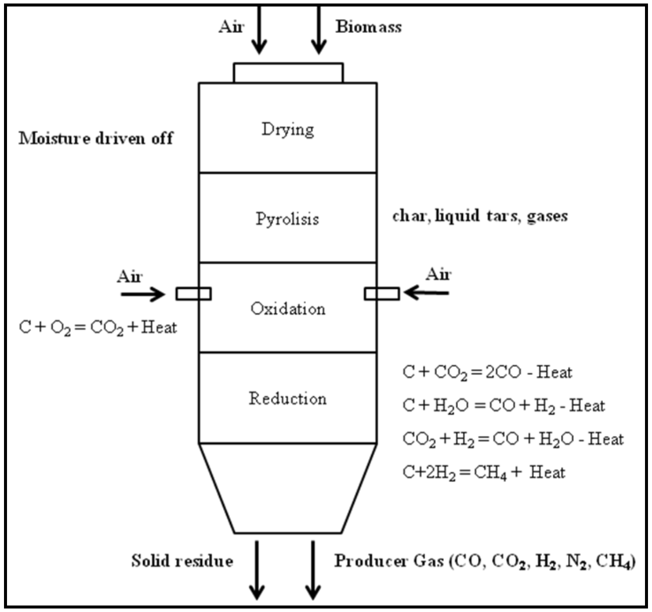


Figure-1: Various zones and sequence of reaction in a downdraft gasifier

The equilibrium composition of the producer gas depends upon the air available for the reactions, per unit weight of biomass. This can be best understood by the term equivalence ratio (ER).

$$ER = \frac{(\text{Weight of oxygen/ weight of dry fuel})_{\text{actual}}}{(\text{Weight of oxygen/ weight of dry fuel})_{\text{stoichiometric}}}$$

For effective gasification the ER is recommended of having values in the range 0.2-0.4. If the value falls below 0.2, then pyrolysis predominates the process and above 0.4, it is combustion which predominates, both ways affecting the quality (calorific value) of the producer gas.

Experimental setup and methodology

The experimental setup comprises of a 20 kW downdraft gasifier system of NETPRO make and layout diagram of the gasifier facility is shown in Figure-2. Gas and feedstock (wood pieces and chips) both move downward as the process advances and feedstock consumed. The air required for gasification is drawn from three air nozzles surrounding the combustion zone and the remaining from the top. Required suction is obtained by use of a blower initially and by an engine later. Wood after drying and pyrolysing in the upper zone of reactor, yield volatile leaving fixed carbon or char by the time it reaches the oxidation zone. In the oxidation zone, the volatiles undergo oxidation with the release of CO_2 and H_2O. These product gases undergo reduction, in the presence of hot bed of charcoal, and yield a combustible gas mixture.

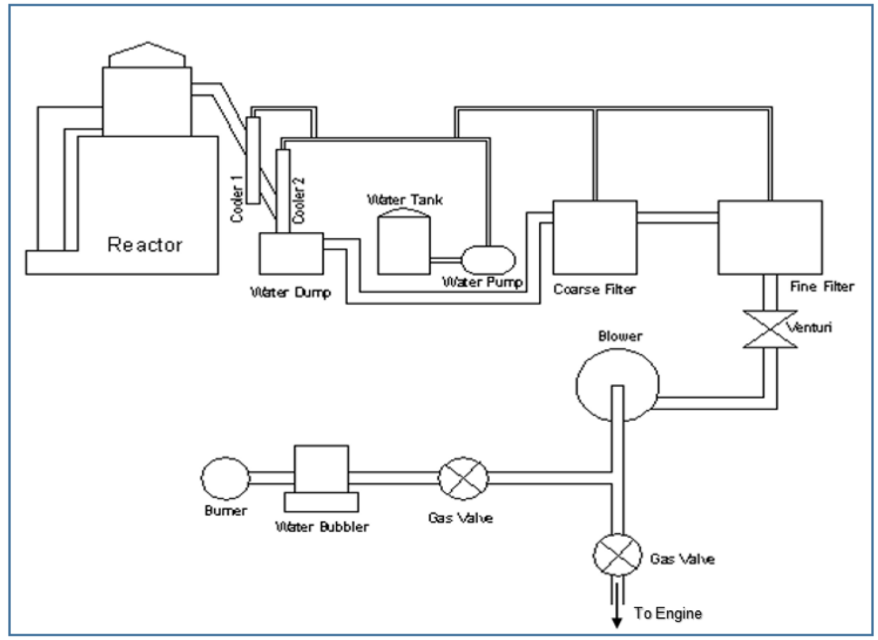


Figure-2: Layout of the 20 kWe downdraft gasifier system (Netpro make)

The hot producer gas exiting at the reactor bottom is passed around the upper region of the reactor, where some sensible heat is transferred into the wood chips thereby assisting drying of wood chips in the reactor. The hot dust laden gas exiting from the top of the reactor is led through a cooling section and cleaned in the coarse and fine sand filters. The gas then flows either to engine or to the burner.

The various sub components of a 20 kW downdraft gasifier are as follows:

Reactor: It is made of two shells, bottom shell being rolled from mild steel and has an inner lining of insulation and high temperature ceramic. The top shell is double walled stainless steel shell having an annular space through which hot gas is passed and allows heat transfer to the biomass chips. The re-circulating duct is the passage linking the bottom reactor with the top shell. The outer wall of the reactor including the re-circulating duct is covered with low density alumina silicate blanket, and cladded with stainless steel sheet to reduce heat loss. The bottom of reactor is dipped in water seal to prevent air entry. A grate mechanism is provided at the bottom of the reactor to hold the charge, with lever attached for grate shaking.

Cooler and filters: Coolers are made up of two sections. The first is a counter current spray whereas the second is a co-current spray. The spray is developed from impinging jet, which mixes with the gas and cools the gas to the ambient temperature and in this process some contaminants are removed from the gas.

Filter section is comprised of two filters, coarse sand filter and fine sand filter. The coarse sand filter is a four-tier filter with total filtering area of approximately 1.8 m^2 to contain 1-2 mm sized sand particles forming a bed of 85-90 mm thickness. The fine filter is also a four-tier filter providing a filtering area of 5.40 m^2 for holding 200-600 μm sized sand particles of 85-90 mm thick.

Plumbing and gas control valves: The cooled and cleaned gas is piped to an engine or a flare using PVC pipe. The producer gas from the gasifier system flows into two steams, one the flare and other to the engine.

Blower: this provides initial suction for starting the gasifier.

Water Bubbler: The gas from the exit of the suction blower is bubbled through a container before enters the flare. This is provided as a safety device to prevent flame flash backs from the flare end in the event of air leaking into the system.

Flaring burner: This enables checking of quality of the combustible gas. The gas is flared in the burner for a few minutes prior to change to the engine. Flame arrester in form of thin GI meshes is provided at the burner entry as a safety device.

Measuring instruments: Venturi meter, U-tube Manometer and thermocouples are integrated with the gasifier system for monitoring and making necessary data collection for control and performance evaluation of the gasifier system. The parameters usually monitored are – pressure across various sections of gasifier, temperature of various zones of the gasifier, flow rate of producer gas, temperature of flare, etc.

Procedure for operation of 20 kW downdraft gasifier is given below.

1. Prepare biomass for gasifier feed.
2. Shake the reactor grate lever lightly a couple of time
3. Open partially the gas valve upstream of the blower and close fully the valve to the engine
4. Switch ON the water pump. Ensure that water is flown into the reactor seal, filter water seals and water bubbler
5. Feed the reactor with biomass feedstock
6. Open air nozzles and switch ON suction blower.
7. Hold a flame in a form of blowtorch or wick near to each air nozzles till the biomass getting burnt.
8. After 5-10 minutes operation, ignite the producer gas in the burner. Flame in the burner shows that producer gas has been generated.
9. Check the pressure drop at all four strategic locations by reading a U-tube water manometer during gasification. Pressure drop at the exit of fine sand filter should not be exceeding 150-200 mm. If pressure drop is high, shake the grate lever to ensure no blocking of gasified biomass at grate section of gasifier.
10. After 15 minutes continuous operation of gasifier on blower mode, open partially the valve to the engine and totally close the valve to the flare, when gasifier is to run the engine.

Observations and calculations:

Parameter	Symbol	Measured value (mm)
Static pressure		
At the exit of reactor.	P_1	……
At the exit of cooling unit.	P_2	……
At the exit of coarse sand filter.	P_3	……
At the exit of fine sand filter.	P_4	……
Sum of P_1 to P_4	P (total)	……
Temperature		
Various zones of the reactor	T1 to T5	……
Temperaure of flare flame	T (flare)	……
Flow rate		
Pressure difference at venturi (mm)	**ΔH**	……
Flow rate of producer gas = 3.3 (sqrt ΔH) in g/sec	**Flow rate**	
Power		
Thermal power of gasifier (instantaneous)	**Power**	

= (gas flow rate) x (CV of producer gas) **Assume CV of produce gas as 3.5 MJ/m^3** **Assume any missing data.**		

Discussion

Give a paragraph discussing the followings with respect to this experiment:

Pyrolysis
Various zones inside a reactor
Producer gas composition
Electric power generation from biomass
Capacity rating of gasifier

References

- Kishore (Ed.), V.V.N., Renewable Energy Engineering and Technology: A Knowledge Compendium, TERI Press, New Delhi, 2008.
- Basu Prabir, Biomass Gasification and Pyrolysis: Practical Design and Theory, Academic Press Elsevier, USA, 2010.
- NETPRO, Users Manual of 20 kWe downdraft Gasifier Manual, Netpro I.I.Sc, Bengaluru.

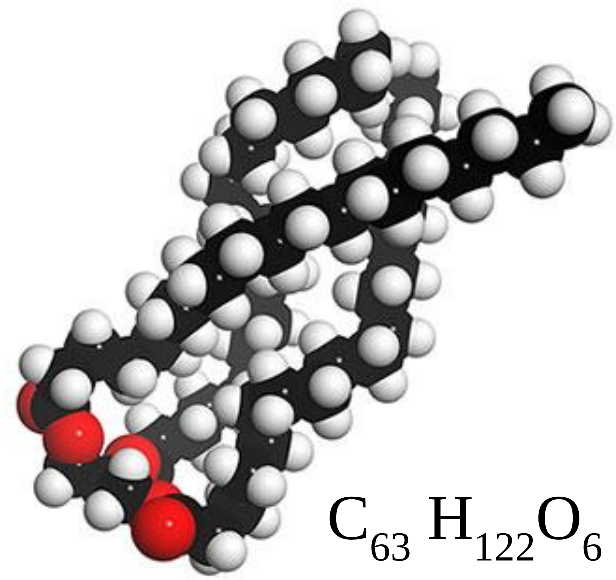
Experiment 5: Study of Bio-Diesel Reactor.

Objective: Study of existing bio-diesel reactor.

Intorduction:

Straight Vegetable Oil Chemistry:

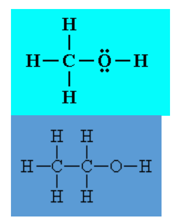
- **The molecular formula is a triglyceride molecule that contains multiple Carbon double bonds.**
- **A molecule with multiple Carbon double bonds tends to be more reactive under heated conditions than a molecule containing fewer or no double bonds.**



$C_{63}H_{122}O_6$

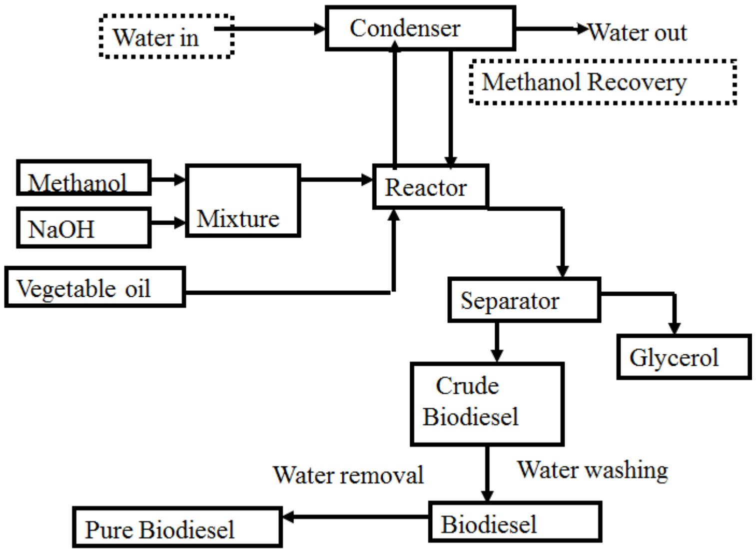
Transesterification process:

CH2-OOC-R1		catalyst	R1-COOR	CH2OH
CH2-OOC-R2	+ 3ROH	↔	R2-COOR	+ CH2OH
CH2-OOC-R3			R3-COOR	CH2OH
Triglyceride	Alcohol		Esters (Bio-diesel)	Glycerol
$C_{63}H_{122}O_6$				



R1, *R2*, *R3*, are long chain alkyl group
R short chain alkyl group
Transesterification of triglycerides with alcohol.
During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkali (NaOH, KOH, or Alkoxides).

Flow Chart : Catalyzed trans-esterification process of vegetable oil



Rural Field Level BIODIESEL REACTOR

Viscosity Testing For Karanja, Biodiesel & Diesel

S No	Name of the oils	Temperature (^{0}c)	Viscosity (cst)	Remarks
1	Karanja oil	40 60 80	20.5 13.2 10.0	With increase of temperature ,viscosity decreases and more bright and lighter
2	Bio-diesel	40 60 80	5.2 4.4 3.8	Darkness decrease in increase of temperature
3	Diesel	40 60 80	4.9 3.8 3.6	More bright in increase of temperature