Temperature Behavior of Briquette Using Saw Dust and Cyclone Ash as Basic Raw Material and Checking its Performance and Emission Characteristics Using DFCI Engine

A Dissertation submitted
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for the award of

Master of Engineering
In
Thermal Engineering

By

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Certification

I, Aashish Dua, declare that this thesis entitled "Temperature Behavior of Briquette Using Saw Dust and Cyclone Ash as Basic Raw Material and Checking its Performance and Emission Characteristics Using DFCI Engine" is an authentic record of my work carried out as the requirements for the award of the degree of Master's of Engineering in Thermal Engineering at Thapar University, Patiala under the supervision of Sumeet Sharma, Associate Professor, Mechanical Engineering, Thapar University, Patiala July, 2014 to June 2016.No part of the matter embodied in this report has been submitted to any other university or institute for the award of any degree.

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It is Certify that above statement made by the student is correct to the best of our knowledge and belief.

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Dedicated to my parents and my sister

for their love, endless support &

encouragement

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6th June, 2016 Aashish Dua

ABSTRACT

Power generation using oil is ordinary and pullulating approach also there is dependency on oil and fossil fuel. India is a faster developing country where lots of energy sources are continuously required to fulfill the demand consumption. All the fossil fuels are having high emissions rate due that the there over consumption is quiet dangerous for health. Demand of these fuels is not full filled by country gross production so market of fuel is having surplus opportunity for new type of resources like biomass. Due to scarcity in the production of resources country has to export these fuels will greatly affects the economy of our country. So now a day's country puts great emphasis on green fuel technology so as to beat market scarcity. Biomass gasification had came into existence for the partially the replacement of conventional power generation by the use of biomass based fuels like briquette. In general forestry waste, cattle dung, municipal waste and agriculture leftover are widely used for the production of heat.

Conversion of biomass into the useful fuels like producer gas and further more as a source of electricity is an effective solution for remote areas as well as for commercial and industrial point of view. It will generate employment for the society. Gasification, Esterification and fermentation are some alternative routes which are being used in the remote areas. Gasification is a technique of biomass conversion used since last 180 years. This technology was used to produce combustible gas which was further used in blast furnaces earlier. Several low qualities of coal like peat were used as a feed stroke for gasifier earlier. The biomass is allowed to burn with limited amount of air with a temperature range of 850-1100℃. Maximum moisture content 20% and temperature range of 850-1100℃ is quiet good for generating high calorific value producer gas. Syngas may be ignites directly in gas engines, or can be used directly or can be converted into combustible and non combustible gases like CO_2, CO, H_2, CH_4, N_2. In the complete process major components are as

Biomass +Air→ CO+ CO2+ H_2+ N_2+ CH_4+Char+Tar+C_nH_m+Heat+Ash

In the current study different compression ratios were used to check the performance and emissions characteristic of dual fuel compression ignition engine and also the temperature behavior of briquette with time were checked. In this study sawdust, cyclone ash, tar and tar containing wood chips were used in different ratio to produced briquettes. 14:1 and 18:1 are the two compression ratios on which current study is based. Temperature behavior was studied to find out the pyrocracking temperature.

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NOMENCLATURE

B	
BDC	Bottom dead center
BMEP	Brake mean effective pressure
BThhEff	Brake thermal efficiency
BP	Brake power
BSFC	Brake specific fuel consumption
C	
CFD	Computational fluid dynamics
CFR	Cooperative fuel research
CI	Compression ignition
CO	Carbon monoxide
CO_2	Carbon dioxide
CSFB	Compressive simulator for fluidized bed
D	
DFCI	Dual fuel compression ignition
G	
GCV	Gross calorific value
H	
H_2	Hydrogen
HC	Hydrocarbon
HCV	High calorific value
I	
IC	Internal combustion
IP	Indicated power
IRI	Impact resistance index
K	

KLCR	Knock limited compressive ratio
L	
LHC	Lower heating value
M	
MBT	Minimum advance for best torque
N	
NO_X	Nitrogen oxides
P	
PM	Particulate matter
S	
SBR	Steam to biomass ratio
SEM	Scanning electron microscope
SFC	Specific fuel consumption
SOC	Start of combustion
T	
TPD	Temperature programmed decomposition
V	
VCR	Variable compression ratio
GREEK	
ΔT	Temperature
$\emptyset$	Equivalence ratio
℃	Degree Celsius

CHAPTER -1

Introduction

India is a faster developing country where lots of energy sources are continuously required to fulfill the demand consumption. Due to increasing demand the nonrenewable energy resources like fossil fuels are continuously depleting with high inflation rate. Coal and oil are two major source of energy in our country. As per the continuous increase in the demand the present non renewable resources of energy are depleting in our country. All the fossil fuels are having high emissions rate due that the there over consumption is quiet dangerous for health. On burning fossil fuels ppm level in the exhaust is tremendously high which results in great air pollution. Demand of these fuels is not full filled by country gross production so market of fuel is having surplus opportunity for new type of resources like biomass. Due to scarcity in the production of resources country has to export these fuels will greatly affects the economy of our country. So now a day's country puts great emphasis on green fuel technology so as to beat market scarcity. Many researchers found that small scale remote gasifier plays wide role in green energy projects.

Power generation using oil is ordinary and pullulating approach also there is dependency on oil and fossil fuel. Biomass gasification had came into existence for the partially the replacement of conventional power generation by the use of biomass based fuels like briquette. In general forestry waste, cattle dung, municipal waste and agriculture leftover are widely used for the production of heat. Steam generation, fabrication industry and food processing industries also use biomass for energy. India is producing enormous amount of biomass which comes under various categories like agricultural crop leftover or residue production, so there has to be many odds in favor of gasification process. There we have a great opportunity to replace fossil fuel like coal and petroleum with biomass. In last decades low grade coal (peat) were used as feedstock fuel to produce the producer gas which was more commonly known as town gas and used for cooking and street lighting purpose.

India is having ample resources of green energy like hydel, solar, nuclear, wind etc. Many big projects like solar and hydel are harnessing ample amount of energy. By default conventional fuels are polluting in nature so now Indian markets focusing on less polluting fuels in which green fuels like biomass is an attractive alternative and itself as renewable energy resource. Conversion of biomass into the useful fuels like producer gas and further more as a source of electricity is an effective solution for remote areas as well as for commercial and industrial point of view. It will generate employment for the society. These type of energy generation makes industries self dependent. In India we are having some industry those who are beating there energy demand by using bio energy methods e.g. gasification, boiler based biomass (like briquettes of saw dust and many other biowastes).

Sulphur and ash contend in the biomass are low as compare to other conventional fuels so the use of biomass is not harmful for environment as well as for human being. The carbon conversion process is completely followed in this energy conversion technology (gasification) because CO_2 is delivers to environments and works as fuel for plant and in this way it completes cycle.

Biomass like rice husk, cotton stalk, and woody biomass can be used as source of energy rather great literature is available harnessing technology and advancements in biomass conversion technology, so there were ample scopes to utilize biomass and to study their conversion technology.

Method	Process	Product
Extraction	Transesterification	Biodiesel
Hydrolysis	Fermentation	Bioethanol
Gasification	Thermochemical conversion	Synthesis gas
Pyrolysis	Thermochemical conversion	Bio oil

Table 1.1: Conversion technologies, process and products

By using above conversion technology we can use their products as source of energy for fulfilling own energy requirements.

Gasification, esterification and fermentation are some alternative routes which are being used in the remote areas. Since woody biomass having several forms so it can be utilized by using different technologies like pelleting and briquetting etc. There are five basic elements in any types of woody bio mass 1.Cellulose 2.Hemi cellulose 3.Lignin 4.Organic minerals 5.Inorganic minerals in which lignin is responsible for strength and also for the stability of briquettes and pellets [5]. Moisture Content is also responsible for stability and hardness for briquettes so literature study suggests that high lignin content and low moisture content is more suitable for thermochemical conversion. Bio ethanation is also a good technology for producing bio gas in which methane is major responsible constituents of energy.

Producer gas and bio gas from their respective process could be used in the internal combustion engine as fuel or may be use as heating gas in the fabrication industries for their different application. Biogas has high calorific value but it has very slow conversion speed so commercially we cannot use it and on the other side gasification process is very fast online running technology and by having proper plant setup we can continuously produce synthesis gas and use it in the internal combustion engine so overall gasification is beneficial over biomethanation/biogas [6].

Our agriculture and municipal corporation and somehow our industries continuously rejecting some sort of biomass as there by product so future of this technology is bright. India technologies are not able to use this biomass as per the availability as well as lack of awareness. As per the report published by the ministry of power 60% of biomass is used as fuel for chullahs/open stoves. These types of stoves are harmful for human bodies as well as for environment. They are producing huge quantity of smoke also they are increasing ppm level in the air so creates the breathing problem as well as irritation in the eyes and many other disorders. From past decades government was not giving appreciable funding for this technology as compare to the solar and the wind energy projects. As per the environmental concern now a day's initiative action plans are going to on to implement this technology [7].

A report of ministry of power indicates that 70% of energy is extracting from fossil fuels, 15% from hydel power 13% from other sources and 2% from nuclear power.

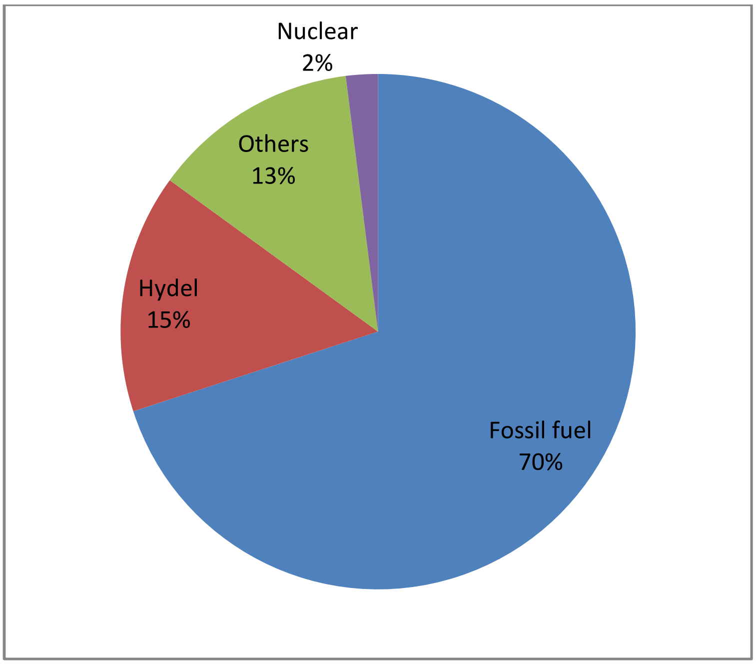


Figure 1.1: Energy extraction trends

CAPTER-2

Gasification Process and its Components

2.1 **Fuel/Biomass**

Biomass is a biochemical organic matter derived from dead or living organisms. Biomass especially woody biomass and its components are as follows

1.) Cellulose

2.) Hemicellulose

3.) Lignin

4.) Inorganic minerals

5.) Organic minerals

Cellulose -:

It is a fibrous carbohydrate linear chain of glucose molecule. A single unit of cellulose molecules contains 5000-10000 units of glucose. It is a very basic structural component of any plant cell wall. Vegetables contents 33% of cellulose, cotton contain 90% of cellulose, wood contains 50% cellulose [8].

During thermochemical conversion at a temperature of 240-380℃, it will converts into volatile material and some part into tar and char. Char can be further used in a line of thermochemical conversion or can be reused in the same process. Cellulose provides strength to the plant cell wall [9].

Hemicellulose-:

It is a heteropolymer of pentose and hexose. It is present in almost all types of plant cells and its total weightage in the plant/Biomass is 20-30%. Hemicellulose is having little bit low strength as compare to cellulose. During thermo chemical conversion at 200-260℃ this will converts into volatile material, tar and char but volatile matter is more as compare to cellulose.

Lignin-:

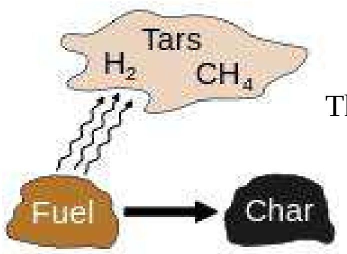
It is an amorphous complex polymer with highly branched three dimensional chain structures. Chemically lignin is phenolic cross linked polymer. Lignin percentage defines the biomass hardness. Lower the lignin percentage results in higher strength and hardness of biomass and vice versa. During the thermochemical conversion at 250-510℃ this will converts into phenols and major part of it converted into char. Lignin is of two types' guaiacyl lignin and guaiacyl springl lignin [10].

Inorganic Mineral-:

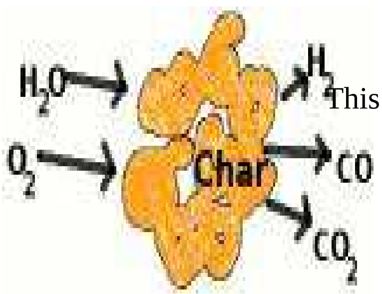
Biomass contains very low amount of organic minerals. Potassium, Sodium, Phosphorous, Calcium, Manganese are some of the inorganic minerals present in the biomass. During thermo chemical conversion they will converts into ash which is very less in amount by mass.

Organic Minerals-:

They are trace elements of woody biomass. These components include sugar, fat, protein and wax.



This reaction shows what happens with fuel (biomass)



This reaction shows what happens with char (by product)

On the basics of availability biomass sources are discuses below:

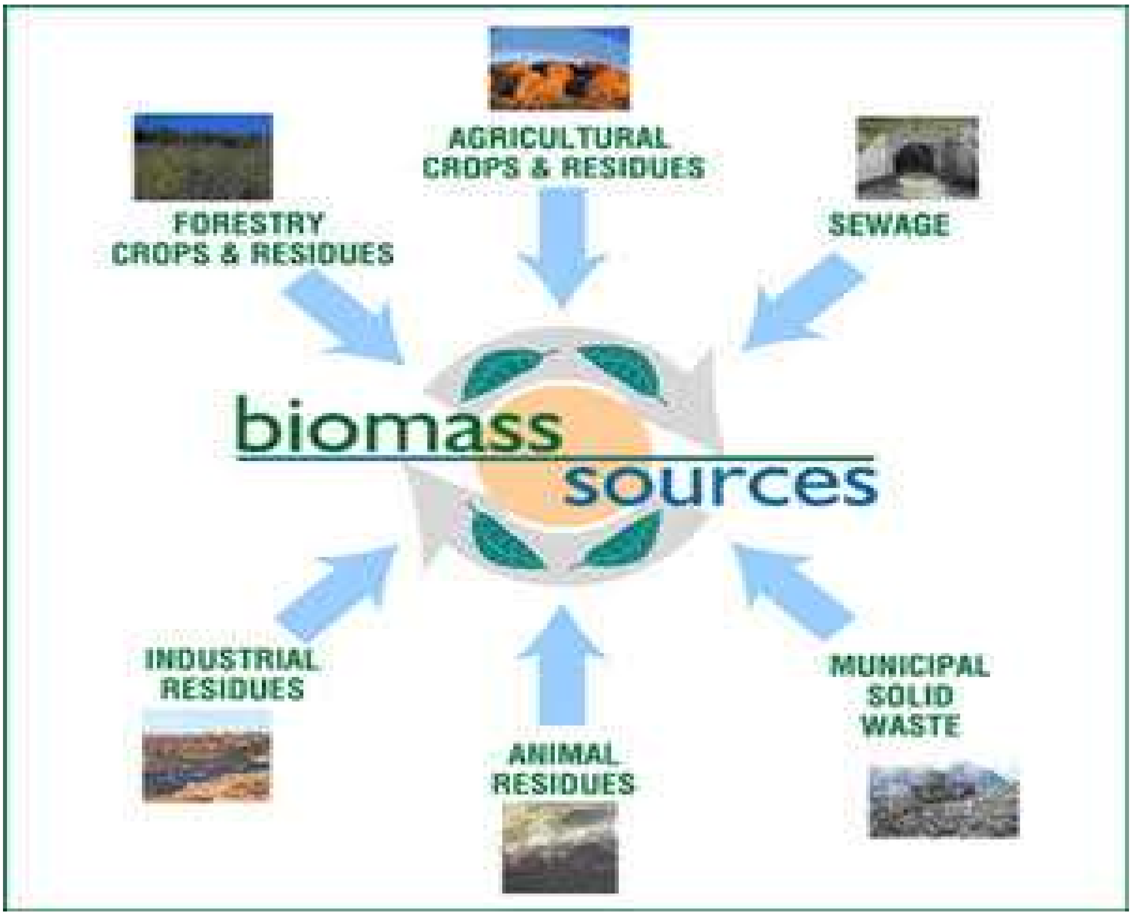


Fig 2.1: Biomass sources from different methods [11]

The above figure gives us the brood idea about the sources of biomass. Sewage and Municipal solid waste like polyethylene material, plastic, pellets of sewage waste can be use directly. Industries like sugar production, plywood have several type of bio waste like bagasse, wood chips which are quiet use full in boiler as well as in the gasifier.

Indian agriculture produces fudge quantities of different varieties of biomass like rice husk, cotton stalk, coconut shell, wheat straw, rice straw etc. All the bio waste can be used by giving some pretreatment like drying, chopping, pyrolysis etc. Different type of biomass's are having different type of conversion efficiency due to which carbon monoxide production is varying continuously which will affects the complete setup continuously and which will cause the system damage. To overcome this type of drawback research has develope different controlling mechanisms.

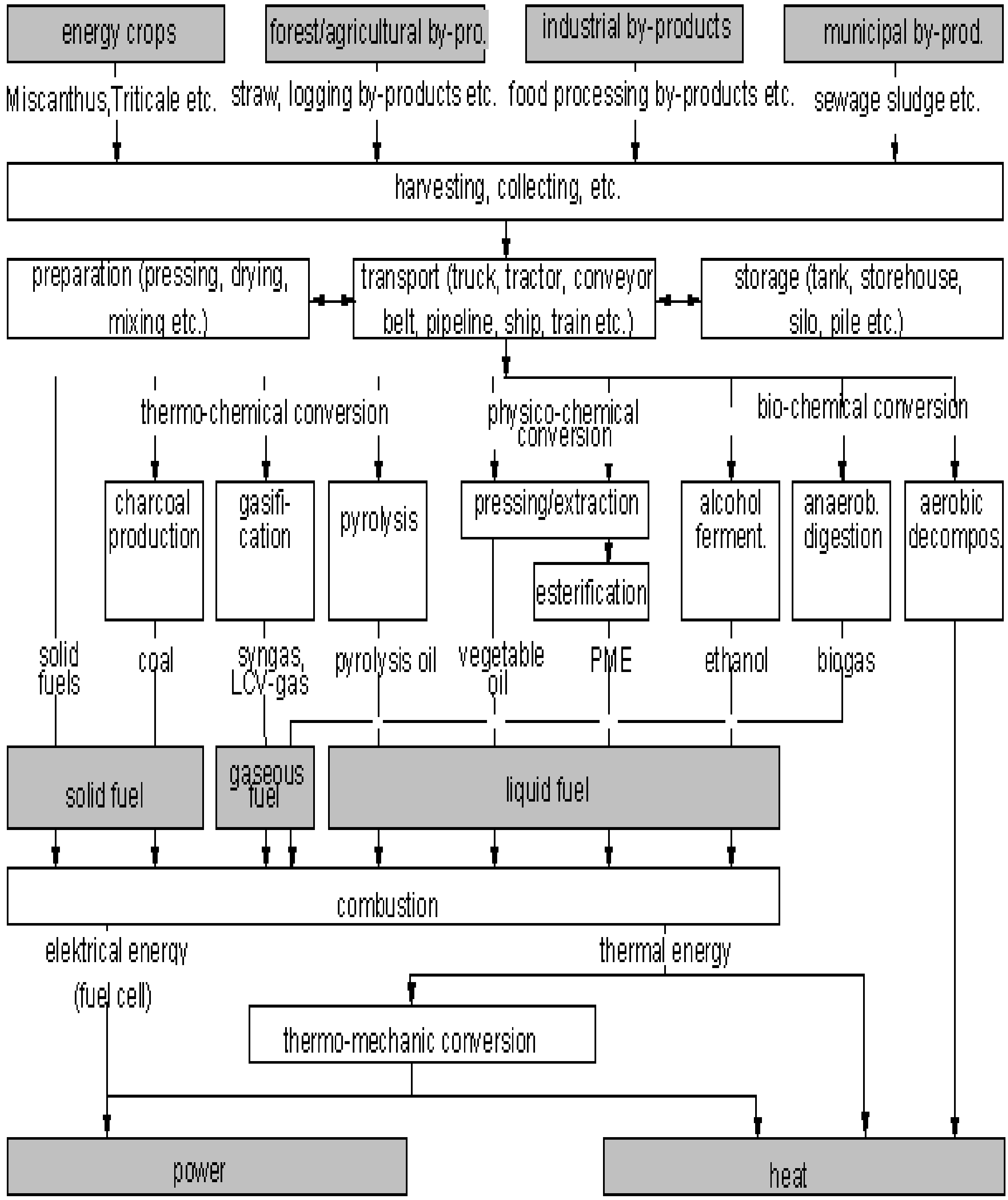


Fig 2.2: Methodology of energy extraction from their energy resource and their products [12]

2.2) **Gasification**

2.2.1) **History-:**

Gasification is a technique of biomass conversion used since last 180 years. This technology was used to produce combustible gas which was further used in blast furnaces earlier. Several low qualities of coal like peat were used as a feed stroke for gasifier. In 1839 the first gasification system had been assembled and it was coupled with internal combustion engine in 1881 so as to produce electricity. During world war 2nd this technology was on its extreme scale due to scarcity of petroleum. After world war 2nd there was a sharp decrease in the prices of fossil fuels so again they become popular and this technology was fading out. Due to energy crisis in 1980 these concepts again become popular [13].

2.2.2) **Methodology-:**

Biomass like agriculture crops forestry crops residence municipal solid waste animal residues and industrial residues etc can never be directly used in the gasification process. These all biomasses have different moisture content and variable size so before using in the gasifier some pretreatments like controlling the moisture content and maintaining its size by chopping it into the unique size have to given. Moisture content and size of biomass use are depending upon the type of gasifier. After preparing the biomass the gasifier hopper is filled with biomass by conveyor or manual feeding system. After feeding, hopper will air tightly closed. After feeding and closing the hopper, ignition starts by using torch once. Once the process starts its will continuously burns inside the reactor and this whole conversion can be termed as thermochemical process. The thermochemical conversion process startup as partial oxidation in the limited supply of air at the end finally producer gas generation starts.

2.2.3) **Working condition-:**

The biomass available in the market or resources of biomass are having moisture up to 50% literature study put emphasis that for good colorific value we will use biomass which is having moisture content up to 20% [14].

So we have to initially dry the biomass may be by sun drying method or using exhaust gas drying system. The biomass is allowed to burn with limited amount of air with a temperature range of 850-1100℃. Maximum moisture content 20% and temperature range of 850-1100℃ is quiet good for generating high calorific value producer gas.

2.2.4) **Process-:**

Gasification is thermochemical partial oxidation in which carbon present in the biomass converts into synthesis/town gas. Biomass is burn in the closed chambers (reactor) with a control supply of air also somewhere control supply of steam. CO is the major source of energy in the producer gas. The syngas produce by gasification process is having more potential efficiency than other direct combustion of the different fuels because it can be combusted at higher temperatures. Syngas may be ignites directly in gas engines, or can be used directly or can be converted into combustible and non combustible gases like CO_2, CO, H_2, CH_4, N_2. Methanol, hydrogen and CO_2 can be reduced by reduction reaction into syngas or by Fischer–tropsch process.

This is achieved when the material react at high temperatures without complete combustion, with a controlled amount of oxygen with or without steam. The resulting gas mixture is called or producer gas and is can work as fuel. Synthesis gas has varying calorific value which continuously varies and blend of diesel and producer gas have to provide constant LHV so lower calorific value results in high the consumption of pilot fuel. Syngas variation affects the efficiency of overall plant. Gasifier bed width is a direct function of consumption. CO gas conversion reaction complete in reduction zone which is above the bed and hence carbon conversion and production of syngas have several types of draw back which can be analyzed by knowing the role of each component in complete plant. Maintenance of each component should be on time other vice plant may get chock and production of producer gas may be effected. Calorific value of syngas can be check by chromatography which works on the principal of retention time.

In addition, the high-temperature process firstly cleaning of the producer gas by removing corrosive ash elements such as Sulphur chloride and Potassium have to done other vice it will creates the problem for engine other vice they will reacts and produced corrosive gases. Gasification of fossil fuels is currently used on large scale in the industries to generate electricity.

The over arrangement/layout of gasifier with cooling and cleaning system is approximately same and its can be shown by the below figure.

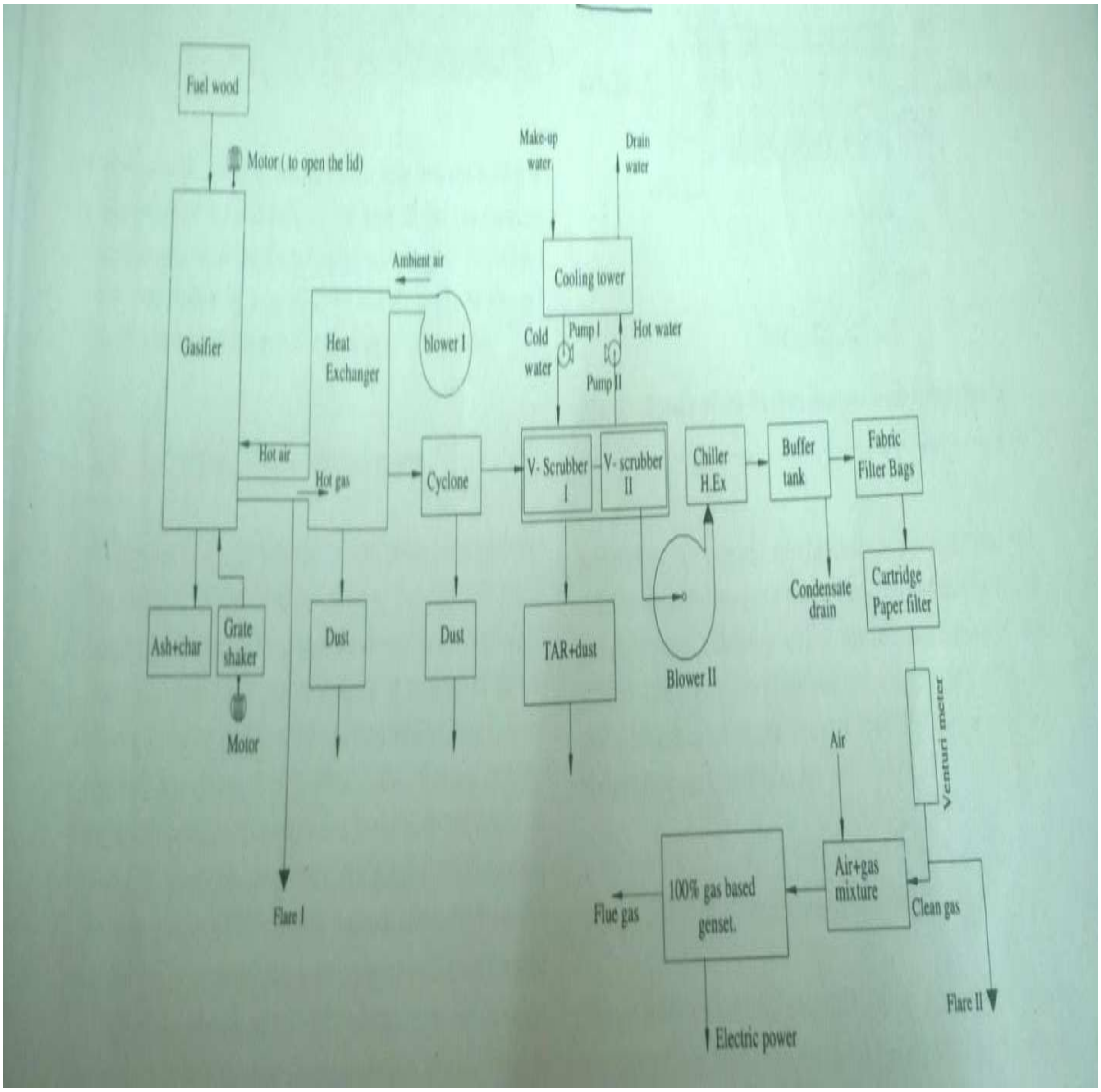


Fig 2.3: A block diagram of gasifier power generating setup

The gasification process is further divided into four sub part.

2.2.4.1) **Drying**

2.2.4.2) **Pyrolysis**

2.2.4.3) **Combustion**

2.2.4.4) **Reduction**

2.2.4.1) **Drying**

The initial state of gasifier is drying where biomass gets dried off. The temperature of this zone is in the range of 100-150℃ . In this zone no chemical changes occur, only latent heat of fusion is release and wood/biomass become dry. Some of the biomasses are having high volatiles matters and that leave in drying zone. Drying area or drying zone is the top most area in the gasifier.

2.2.4.2) **Pyrolysis-:**

This can be termed as thermochemical decomposition of organic material in the absence of air at elevated temperature. Pyro stands for fire and lysis stands for separating. This whole process occurs in particular area and it's called as pyrolysis zone and this zone is located just after drying zone. In this zone biomass converts into char and volatiles. Temperature in this zone is in between 200-250℃.

2.2.4.3) **Combustion-:**

After completing pyrolysis process biomass enters into combustion zone. In this zone a limited amount of air/oxygen is supplied. The average temperature of this zone is in between 850-900℃. The major products after this zone are CO_2, CO, CH_4 and hydrocarbons. It's also known as controlled combustion.

2.2.4.4) **Reduction-:**

This is also known as actual gasification process. All the products of combustion zone are finally converted into finally CO_2, CO, CH_4, N_2 and H_2. Dissociation and recombining occurs in this zone. This zone has various type reactions and these are discussed as below.

Process	Reaction	Enthalpy change(kJ/mol)
Partial oxidation	$C + {}^{1}/{}_{2}O_2 \rightarrow CO$	-120.54
Complete oxidation	$C + O_2 \rightarrow CO_2$	-373.50
Reaction with Hydrogen	$C + 2H_2 \rightarrow CH_4$	-65.86
Bio-methanation	$CO + 3H_2 \rightarrow H_2O + CH_4$	216.14
CO_2 Reduction	$C + CO_2 \rightarrow 2CO$	179.24

Table 2.1: Chemical reaction

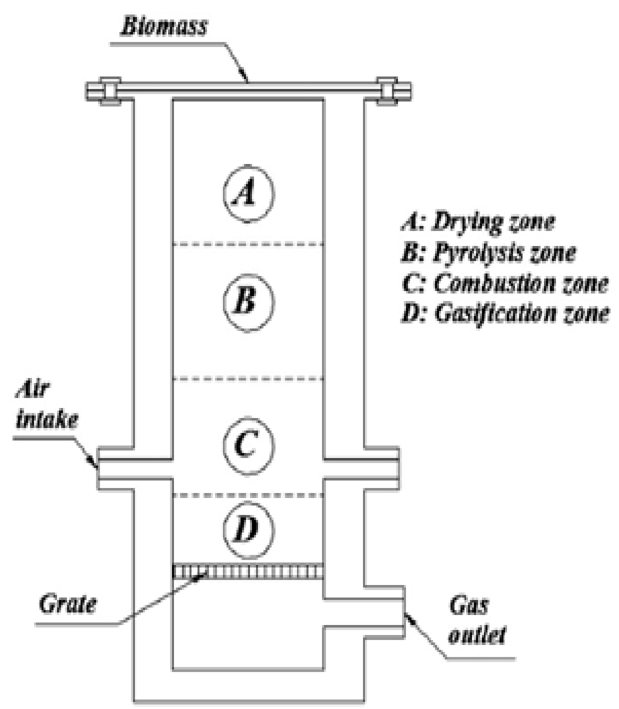
2.2.5) **Types of gasifier**

Gasifier may be classified on the basis of feeding system on the flow of direction.

1. Downdraft gasifier
2. Updraft gasifier
3. Fluidized bed gasifier
4. Entrained flow gasifier
5. Plasma gasifier

Downdraft gasifier-:

It is fixed bed gasifier in which both raw material and gasifying agent moves in downward direction and gas produced also flows in downward direction. In this gasifier 1st zone is drying, 2nd zone is pyrolysis, 3rd zone is combustion, 4th zone is reduction. Air in this gasifier enters in the combustion zone.



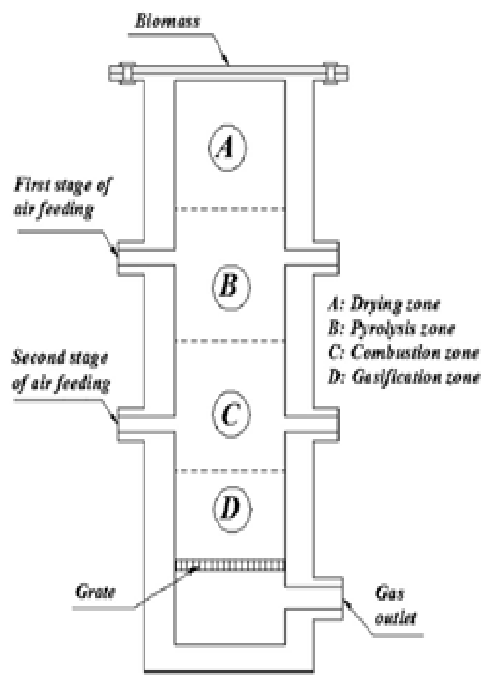


Fig 2.4: Downdraft gasifier with one air inlet   Fig 2.5: Downdraft gasifier with two air inlets

Updraft gasifier-:

This is a fixed bed gasifier in which air flows from bottom to top and fuel/biomass flow top bottom. Producer gas is extract from the upper portion of gasifier. As we know that maximum tar produces in the drying and pyrolysis zone and in this gasifier producer gas extract from the drying zone, which causes the addition in tar level in the producer gas. These types of gasifier are used in the fabrication industries where producer gas has only one application that is flame heating.

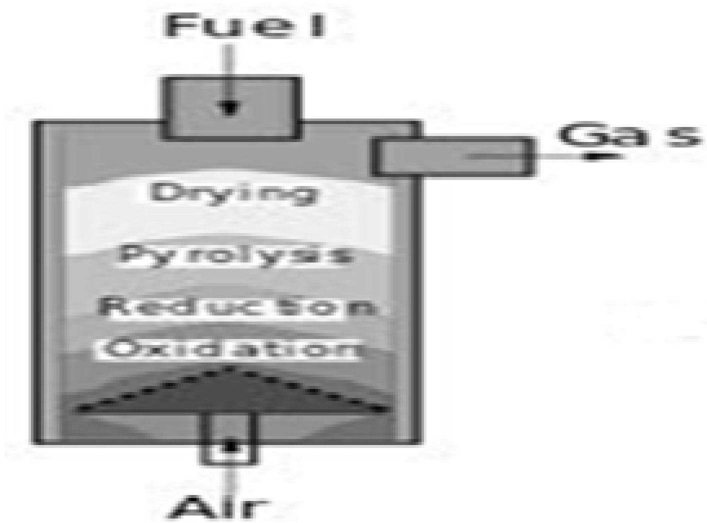


Figure 2.6: Updraft gasifier

Fluidized bed gasifier-:

In this gasifier fuel & air both are supplied from bottom from their respective inlets. Biomass used in this gasifier is pulverized or perfectly crushed so that it can be easily fluidize and can transfer with air. In this gasifier zone are not clearly defined as fluidized bed width is continuously varying in each zone. In this recombination of smaller particles occurs continuously feed due to which all the fuel doesn't participate in the gasification process, which cause the low quality of producer gas and low calorific value. This gasifier has low carbon conversion efficiency.

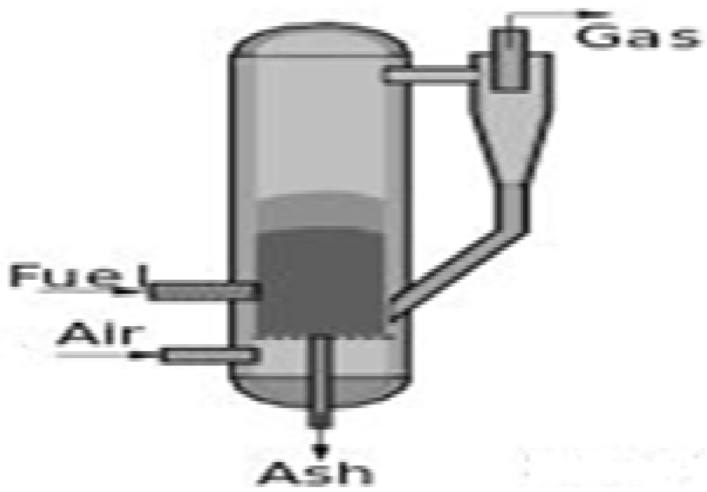


Figure 2.7: Fluidized bed gasifier

Entrained flow gasifier-:

In this gasifier pulverized fuel is entrained with constant supply of oxygen and steam. Temperature and Pressure in this gasifier are high so no air is supplied otherwise it will produce NO_x which is undesirable. The ash formed at high temperature, gets fused and is collected in the form of slag. Tar and methane are not produced in this gasifier due to high temperature and pressure.

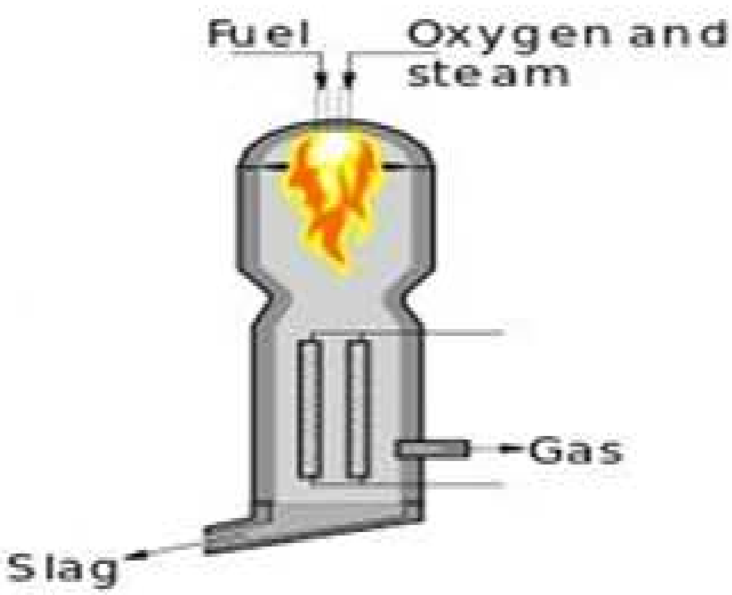


Figure 2.8: Entrained flow gasifier

Plasma gasification-:

This gasification is a combination of downdraft & updraft gasifier. In this gasifier fuel as well as gasifying agents moves in the upward direction. High temperature plasma arc is use to burn the bio waste. It can be used for high moisture bio waste, such as fresh forestry waste, agriculture waste, wet sewage, municipal waste etc.

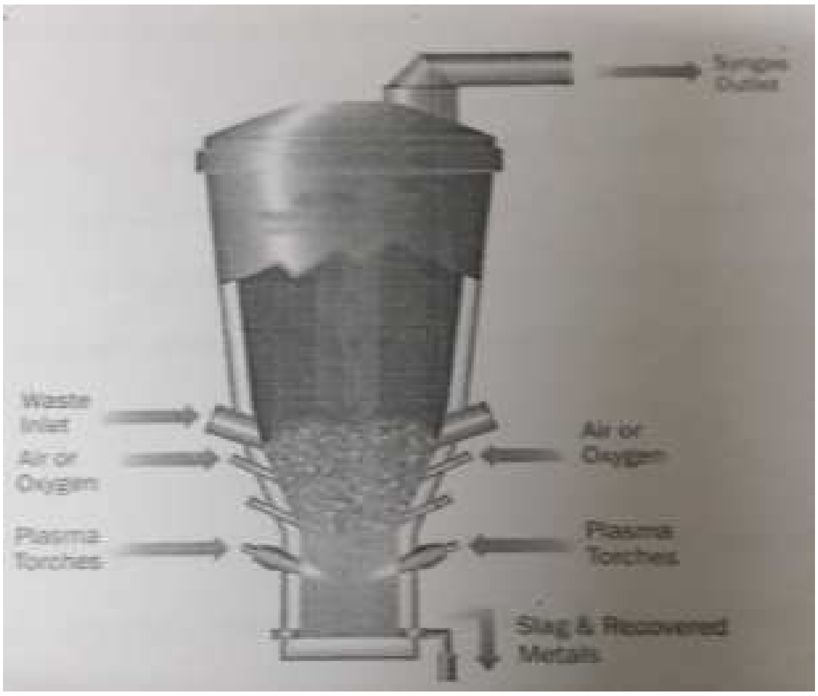


Figure 2.9: Plasma gasifier

2.4) **Gas cleaning & cooling-:**

Gas produce by the gasifier is cannot be directly used in the engine as its temperature is too high due to which density of syngas going inside the engine is too low. Initial gas have dust particulates, if that dust goes inside the gasifier then may cause piston cylinder damage as well as it will chock line of producer gas, so cleaning and cooling both are too much required part of complete process as it can be done by having following parts in the assembly line with required positions.

- Heat exchanger
- Scrubber
- Fabric bag [Primary filter]
- Secondary filter bag
- Cyclone

- Safety filter

2.5) **Products of the process-:**

In the complete process major components are as

Biomass +Air→ CO+ $CO2$+ H_2+ N_2+ CH_4+Char+Tar+C_nH_m+Heat+Ash

2.5.1) **Producer gas-:**

It composes of CO, CO_2, H_2, N_2 and CH_4. CO contributes 20-25% by volume of total gas volume, N_2 contributes 55-65%, CO_2 contributes 5-15%, and CH4 contributes 3-4%. CO is main burning fuel. N_2 behaves like inert gas at 850-1000℃ temperature.

2.5.2) **Tar-:**

Tar is aromatic hydro hydrocarbons such as benzene and thick dark black color, viscous liquid. The aromatic compounds condense and finally thick liquid is produce. It is by product of gasification process.

2.5.3) **Ash-:**

Ash is a residue power by left after combustion of wood. Wood contains very less amount of ash. Major components of ash are $CaCo_3$ and its good source of potash [15]. Wood contains 2-4% ash where as briquettes contain 1-5% ash depends upon the material of briquettes.

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CHAPTER-3

Literature review

This chapter represents the research papers that are studied to formulate the problem. The majority of the research papers are related to emissions, performance characteristics of dual fuel engine and characteristics of briquettes with different parameters.

Sandip Gangil et al. [1] they have studied the energy activation level by checking the lignocelluloses (lignin) level. They have relatively compared ligncellulosic crops, hemicellulosic and celloulics. Thermo-gravimetric of all the above type crops were done under pyrolysis environmental and thermogravimetry was explained. All the raw material like wood and others were replaced with briquettes using piston press. It was examined that pressure of 100MPa increases the temperature of briquettes by 200°C. They have studied with the application of stress (pressure) and temperature, lignin inside the raw material becomes activated and becomes soften. This studied included the research on Soya bin, pigon-pea and local wood (Subabool).

The particle distribution of soya bin was less than .2 mm (15%), .2mm-.4mm (10%), .4mm-.7mm (37%), .7mm-1.4mm (16%), 1.4mm-1.7mm (14%). Density of soya bin briquette was 660 Kg/m^3 and density of loose pore is 255 Kg/m^3. They have studied the decomposition rate with four different rate of increase of temperature. They have finalized that activation energy was more for pigon pea stark briquettes.

The following graph shows the lignin properties.

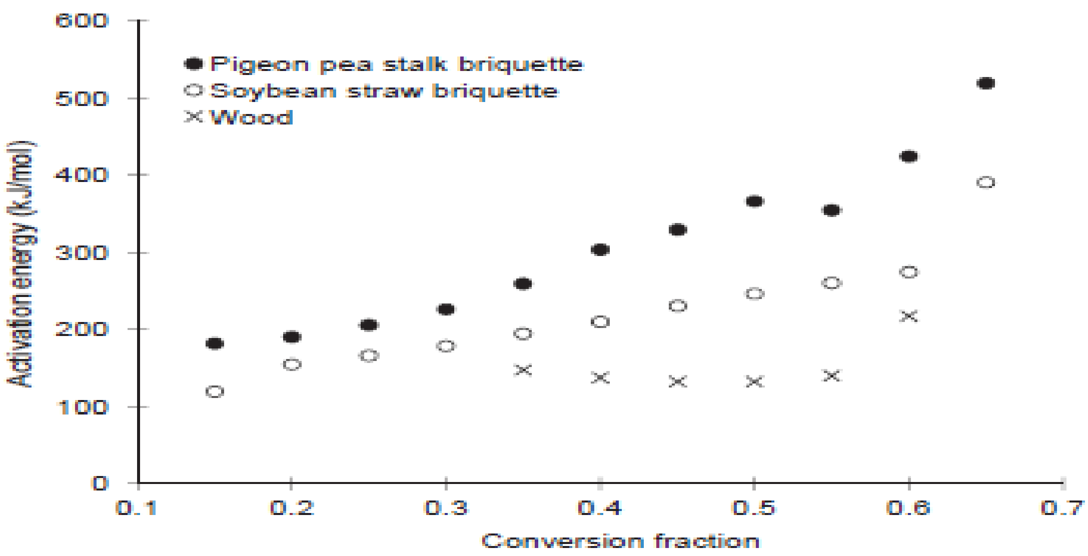


Figure 3.1: Variation of activation energy and conversion fraction

Rukaya I. Muaza et al. [2] they have studied the densification process with different type of variables. They have studied the different sample ratio of rice husk, corn cobs with binder such as starch and water mixture. Briquette density was up to 1.9 times as compared to high biomass bulk density. The compressive strength of briquette was observed 176 MPa at compaction pressure of 31MPa and the material was in the ratio of 3:7 of rice husk to corn cobs respectively. The resultant briquette was durable as well as less water absorber. It was observed that water addition significantly reduces the green and relaxed densities. The experimentation was done to minimize the ash by varying the % of rice husk and corn cobs.

Starch works as binder for densification process. Briquette crumble easily when the pressure ranges in between 30-60MPa and durable when pressure was between 150-250 MPa.1st shear strength of briquette was 1 MPa but after increasing pressure up to 10 MPa its shear strength was increase from 2.88×10^2 to 9.6×10^2 KPa. SEM of both the samples was done.

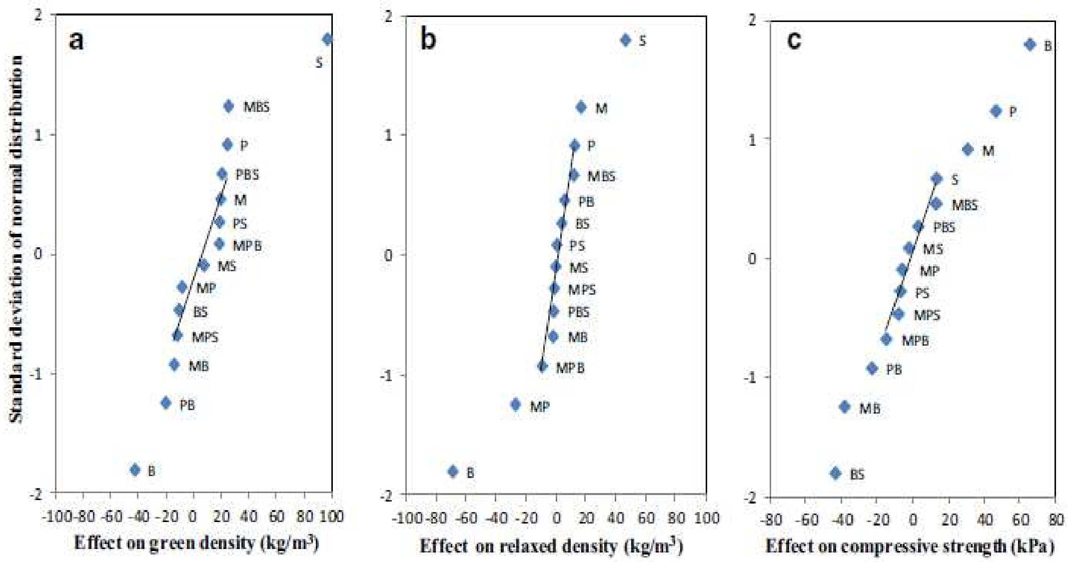


Figure 3.2: Different graph for results

N.Homodong et al. [3] they have studied the performance and emission of small engine operated on producer gas. They have produced gas using biomass and modified the engine by replacing swirl camber to cavity chamber. They have vary the compression ratio in between 9.7:1-17:1 and engine speed in between 1000-2000 rpm and load in between 20-100% ultimately checked different properties like engine torque, thermal efficiency and SFC. Emissions and power outputs were also analyzed. By considering above variable parameters they have finalized that smoke density was lower as compared to diesel only CO emissions were higher and also HC emission was little bit more.

HC and CO were the direct function of volumetric efficiency and it increases with the increase in volumetric efficiency. Fuel consumption increase with the increase in the load on engine by assuming that engine was running on constant air supply. Brake torque increases with the increase in the load as well as rpm of the engine. BSFC decreased with the increase in the load and as well with the increase in the rpm of the engine.

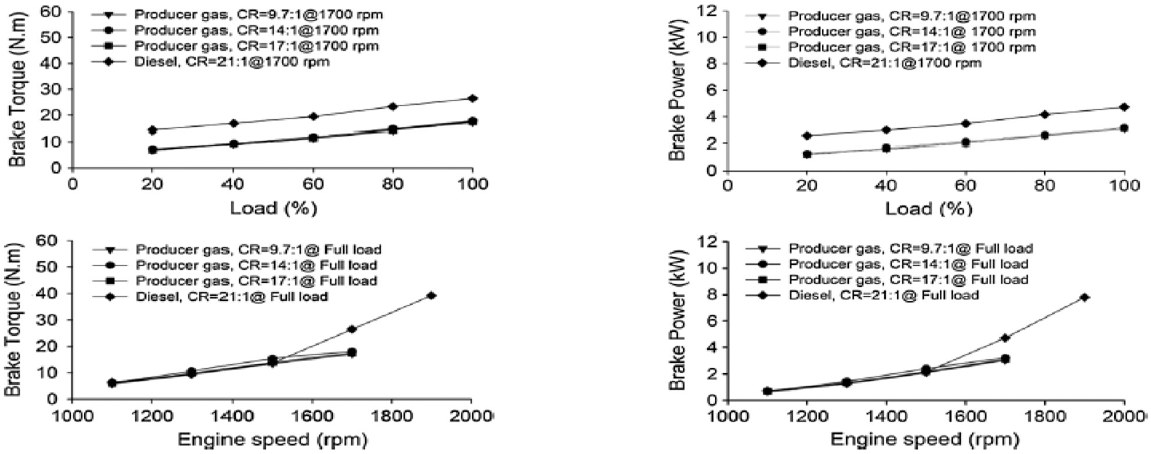


Figure 3.3: Graph of brake torque with engine speed and load

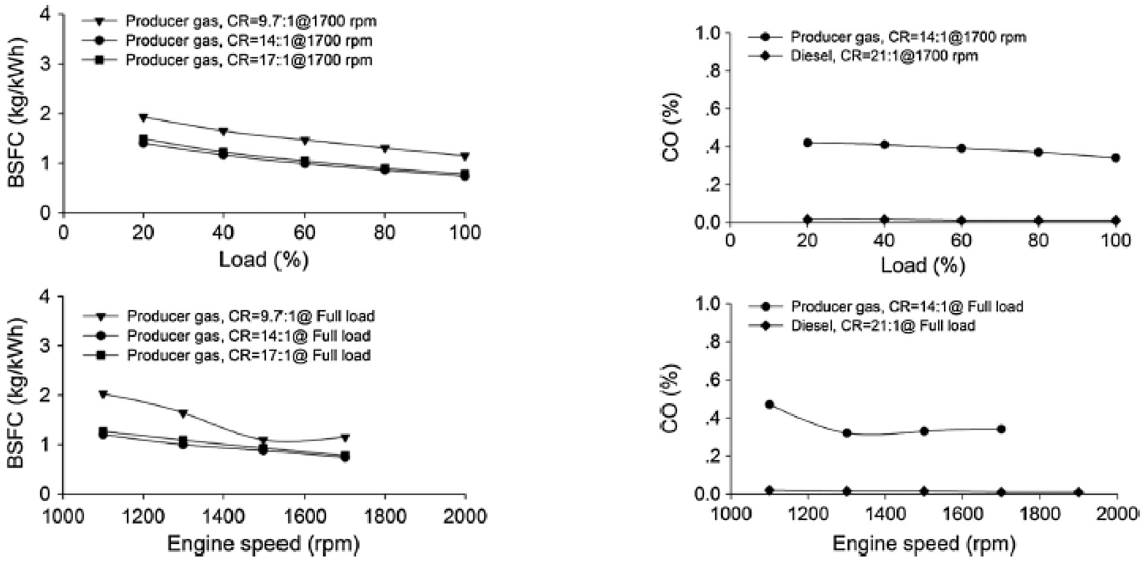


Figure 3.4: Graph of BSFC with engine speed and CO with engine speed

Adrian Irimesvet et al. [4] they have studied the performance and emission of SI engine coupled with generator. They have synchronized engine with new injection technology and then they have checked different parameters like speed, break torque and power. They have observed that after changing the injection system conversion efficiency was improved and CO reduction in exhaust. They have drawn the CO, CO_2, NO_x and HC with electric power with two different variable one with carburetor charging and second is injection charging and their results were discussed as.

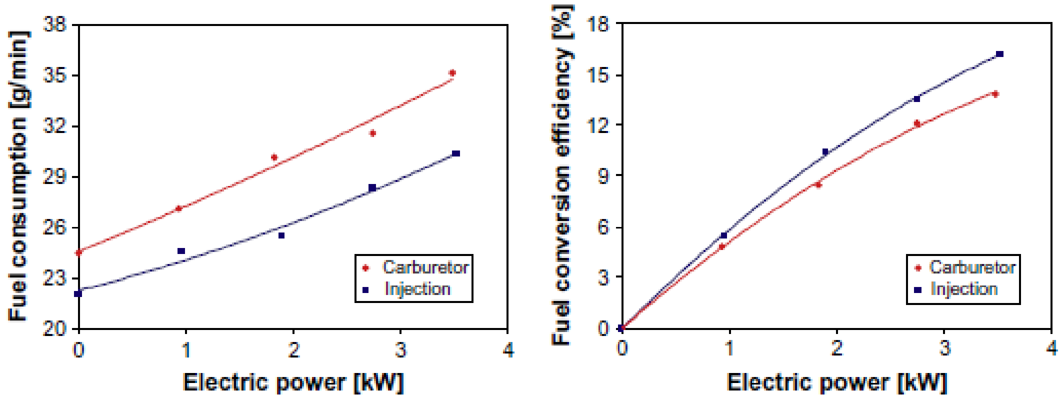


Figure 3.5: Graph of fuel consumption with electric power

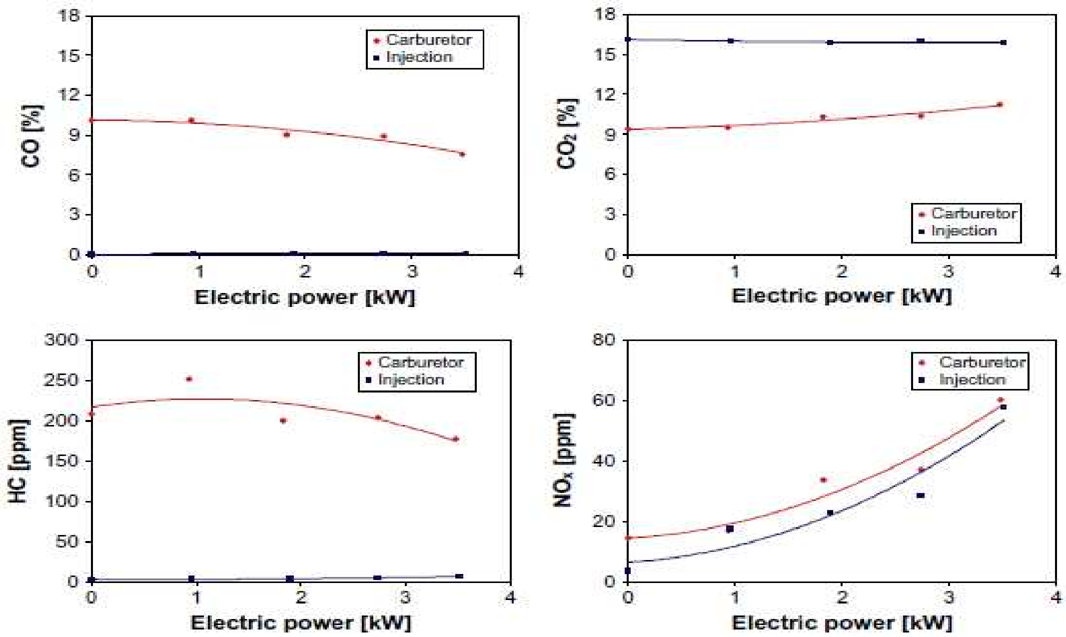


Figure 3.6: Graph of emissions with power

M.J. Blesa et al. [5] they have studied the curing time affects on the mechanical strength of briquettes with special properties i.e. smoke less fuel. They have used olive stone and low rank coal which was already carbonized at 600℃. They have used some binder like humates and molasses. They have studied the molecular changes in material by using Fourier transform infrared spectrometry, also TPD (temperature programmed decomposition) followed by MSC (mass spectrometry). They have finalized that molasses have stable results in strength as compared to other two binders that is H_3PO_4, humates. The size of raw material for briquettes was less than 1 mm. They have finalized that humates binder is giving appreciable results and its % should be in between 5-6%. Molasses giving good results and its percentage should be in between 10-16%. Adequate mechanical resistance was reached by using binders in above percentage. IRTC (impact resistance index) has been finding out and its results have been shown by following graph.

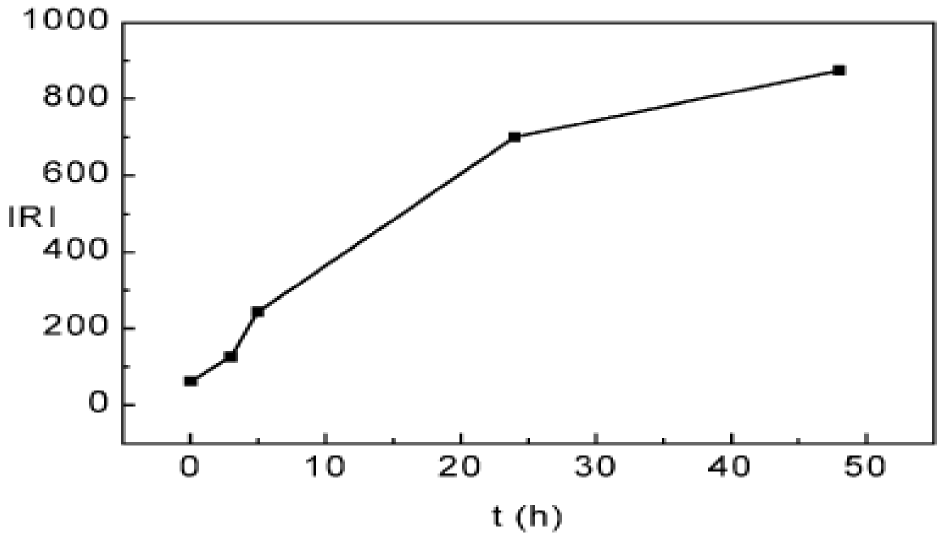
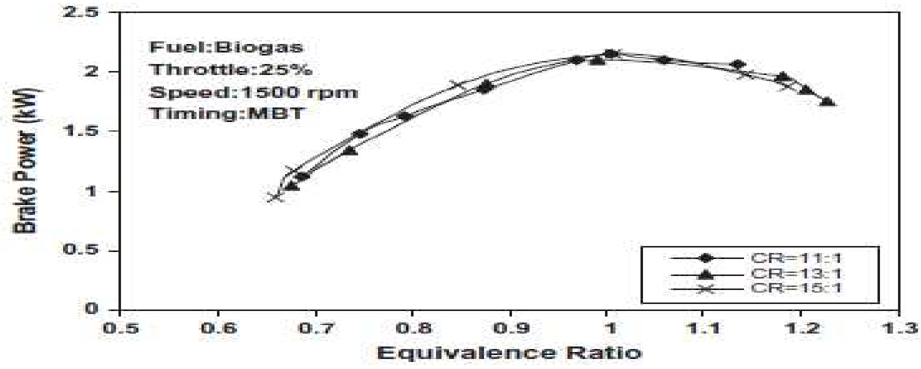
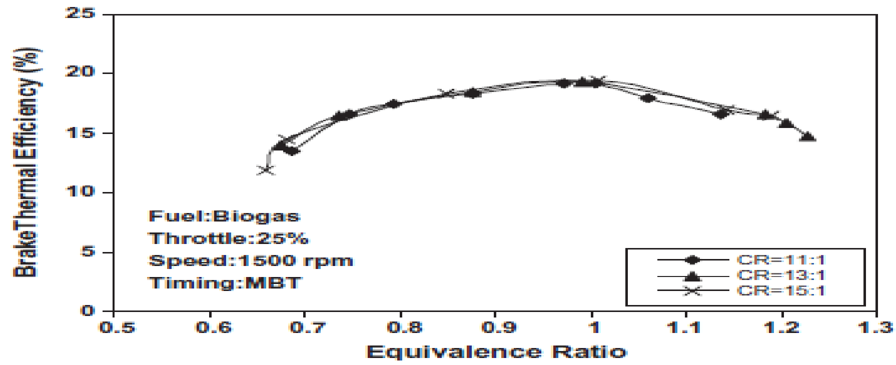


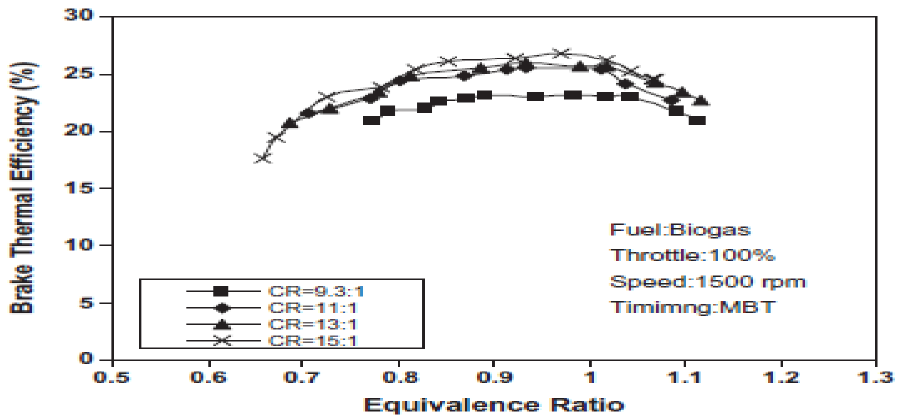
Figure 3.7: Variation of impact resistance index with time

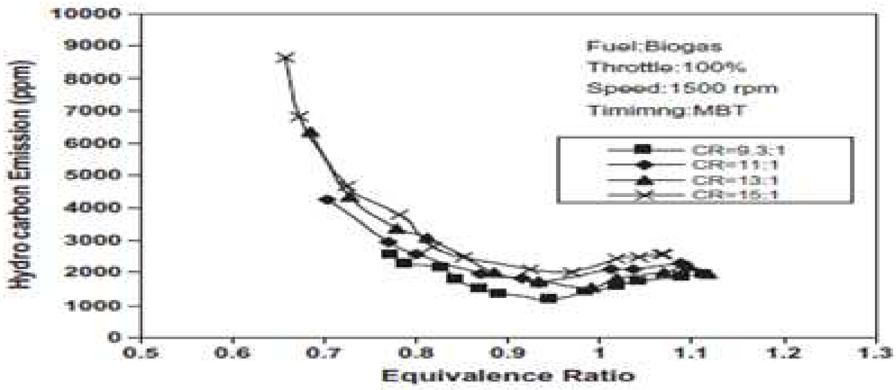
E. Parpathan et al. [6] they have studied the effects of variable compression ratio on performance and combustion using biogas fuel in spark engine. They have set the rpm at 1500 with throttle opening of 100%-25% at different equivalent ratios. They have checked the combustion performance and emission characteristics with different Compression ratio. They have checked BSFC and founded that BSFC was more for higher compression ratio. They have concluded that CO, NO_x, and HC emission increase with increase in the C.R. from 13:1 to the maximum limit also thermal efficiency and power were reduced for leaner mixture. They have observed that with the increase in the CR, MBT retards spark timing.

Some of the results of their study were discussed below.


Fuel:Biogas
Throttle:25%
Speed:1500 rpm
Timing:MBT
CR=11:1
CR=13:1
CR=15:1
Brake Power (kW)
Equivalence Ratio


Fuel:Biogas
Throttle:25%
Speed:1500 rpm
Timing:MBT
CR=11:1
CR=13:1
CR=15:1
Brake Thermal Efficiency (%)
Equivalence Ratio


Fuel:Biogas
Throttle:100%
Speed:1500 rpm
Timimng:MBT
CR=9.3:1
CR=11:1
CR=13:1
CR=15:1
Brake Thermal Efficiency (%)
Equivalence Ratio


Fuel:Biogas
Throttle:100%
Speed:1500 rpm
Timimng:MBT
CR=9.3:1
CR=11:1
CR=13:1
CR=15:1
Hydro carbon Emission (ppm)
Equivalence Ratio

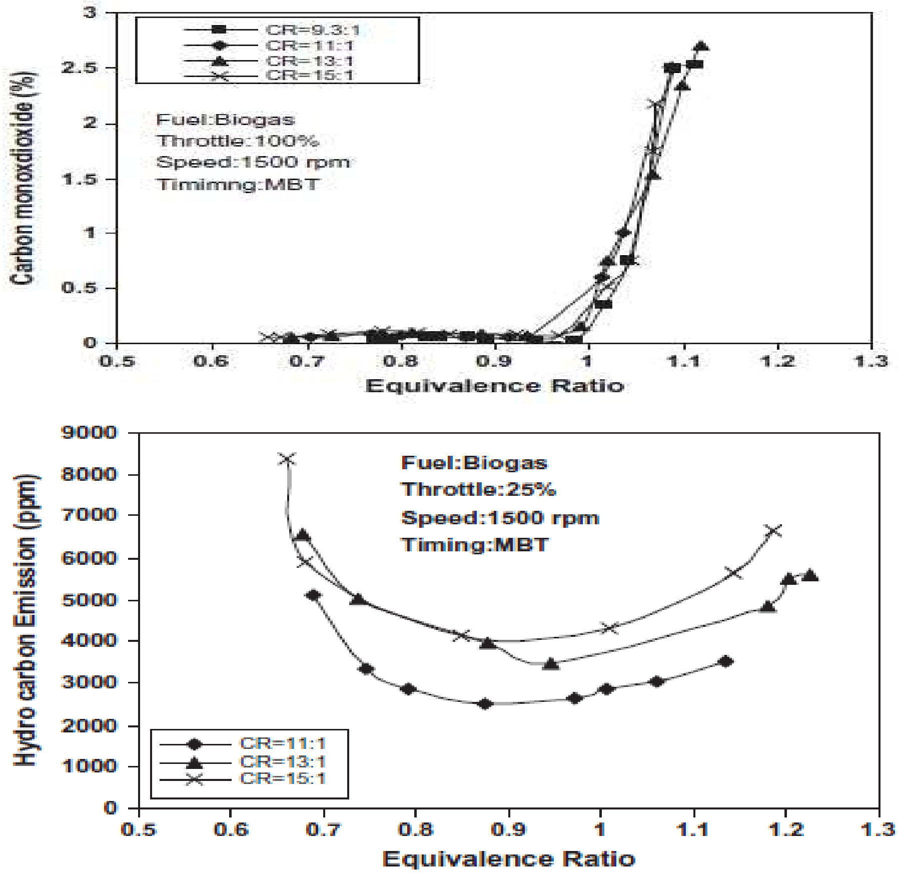


Figure 3.8: Graph of different variable

D. Juan et al.[7] they have studied the down draft gasifier for the production of syngas and its application using IC engine .They have checked the effects of moisture contend, particle size of biomass on the quality o producer gas with different equivalent ratio. They have checked the flame speed, auto ignition, delay period, knocking tendency, typical spark timing.

They have finalized the following results.

1) Equivalent ratio should be in between 0.2 to .4 ,and the particle size should be less than 5cm and Moisture content should be less than 25%

2) They have found that lower heating value is around 4-6 MJ/Nm^3 and process cold efficiency is in between 50-70% for downdraft gasifier.

3) Average temperature of reactor was 1000°C.

4) The lower density of producer gas result in the lower engine power output and also in case of diesel less amount of air for complete combustion of producer gas.

5) They have given the review on the producer gas and their controlling mechanism used.

Some of the results were as.

Presence of pollutants in producer gas and used controlling mechanisms.

Pollutant	Source	Possible problems	Control mechanism and/or mitigation
Particulates	Ash, bed material	Erosion, agglomeration and fouling. Environmental pollution	Filtration, gas cleaning (scrubber)
Alkali metals (sodium, potassium in the ash).	Ash	Corrosion	Cooling, condensation, filtration, adsorption.
Nitrogen compounds (NOx, NH_3, HCN)	Reaction of nitrogen contained i n air and feedstock	Corrosion, environmental pollution	Treatment with substances of basic character, use of pure oxygen in the process
Sulfur and chlorine compounds (HCl, H_2S)	Reaction of sulfur and chlorine contained in the feedstock		Cleaning, capture with $CaCO_3$, $MgCO_3$
Tar (complex hydrocarbon mixtures).	Low temperatures in the process, considerable amount of volatile in the feedstock	Corrosion, agglomerations and fouling. Health hazard	Removal, cracking

Table 3.1: Cause and mitigation of pollutants

Yan Cao et al. [8] they have study the gasification process by using biomass for producing tar free higher gas high heating value. This paper studied the variation in temperature in the reactor of gasifier and also how it was related to reduction of tar. They have given the major two ways to reduce the tar 1st way was catalyst for reduction 2nd way was two stage gasification which was given the prime importance. 2nd way of gasification consists of recirculation of syngas with secondary air injected above the biomass feeding chamber, where as primary air was injected through fluidized bed from bottom. Primary air serves the purpose of heat for partial decomposition and gasification of charcoal feed initially. Secondary air services the purpose of providing the heat for feeding biomass so that volatile compound will released in the oxygen lean environment. They observed that 70°C rises in temperature will result in tar reduction from 28 to 16 g/Nm^3 and fuel gas production and LHV were 3.0 N/m^3, 5000 kJ/m^3 respectively. The air with biomass ratio and assisting fuel gas with biomass ratio were maintained at 2.3 Nm^3/kg and 0.475 Nm^3/kg respectively.

Michael et al. [9] they have studied solar driver gasifier with two zone of heating. They have designed solar driven gasifier so as to provide the heat for pyrolysis and gasification which increased the yield of carbon conversion to syngas. They have designed two zone reactor 1st was upper drop tube zone which provide very high radiative heat flux to dispersed particles which further increased the rate of pyrolysis and 2nd was lower trickle bed zone which would increased the residence time and temperature required for char formation and decomposition of other pyrolysis product was also increased. The raw bagasse particles were heated in the upper zone by infrared radiation from the walls and tickle bed slow down the particles thus increased the residence time in the hot zone. They observed that this concept decomposed carbon monoxide and methane more efficiently. The LHV of syngas produced by this concept was 15.9MJ/kg and maximum energy conversion efficiency was 21%.The team also observed that this concept was limited for short term operation and light particle loading (up to 16g/m^2).

Jin Wook et al. [10] they have studied multiple swirl burners in pilot scale entrained bed gasifier for short residence time. This paper studied was related to increase in pressure and temperature of coal based gasifier so as to check the residence time of the low grade coal with high rank. They adopted ultra dense coal transport method and rapid mixing method with multi nozzles. They observed that with increase in pressure and decrease in temperature the residence time decreased up to .5 second. They have studied the carbon conversion efficiency and cold gas conversion efficiency with the change in temperature. They basically conducted three different experiments with different coal and nitrogen concentration and different duration of running time of gasification process. The results of composition of all that experiments were as discussed below.

1st experiment: $CO+H_2$=62.9%, Co2=14.1%
2nd experiment: $CO+H_2$=70.2%, Co2=14.2%
3rd experiment: $CO+H_2$=71.8%, Co2=9.0%

Ashok kumar et al. [11] they have studied the effect of steam injection location. The objective of this study was to investigate the effects of steam injection location and steam to biomass ration (SBR) on syngas generation from air steam gasification of switch grass with the supply of 2-5 kg/hr in fluidized bed gasifier. Steam injection locations 51mm, 152mm and 254mm above the distributor plate and SBR of 0.1, 0.2 and 0.3 were selected for final study. They have studied the steam gasification in fluidized bed gasifier and there was significant increase in H_2 content in producer gas from 4% to 15% with the increase in temperature from 650°C to 850°C. The overall effects of steam injection and high gasification temperature (above 800°C) were results into H_2 rich producer gas and it was more suitable for further conversation into liquid fuel and chemicals. Result of temperature, SBR with steam injection locations were discussed below.

location (mm)	Temp. (°C)	SBR	Location (mm)	Temp. (°C)	SBR	Location (mm)	Temp (°C)	SBR
51	713	.1	152	549	.1	254	664	.1
	419	.2		437	.2		636	.2
	367	.3		482	.3		587	.3

Table 3.2: Different parameters of locations used in the study

P. Raman et al. [12] they this paper was about the modification in the design of gasifier and its other components. A heat exchanger was designed and installed which recycles the heat of hot gas into reactor which improves the efficiency of gasification production. A new ash removal system was installed that minimize the rate of charcoal removal from reactor and that will increase the carbon conversation efficiency which results in the increase in the CO content in the producer gas. An improved ash removed system was designed to maintain the bed width of gasifier and to minimize the Charcoal removal rate in the gasifier.

Ningbo Gao et al. [13] this paper was studied about to produce hydrogen rich producer gas with a high calorific value in range 8.10 to 13.40 MJ/Nm^3. The hydrogen yield increased from 74.84 to 135 per kg of biomass. The syngas was produced by biomass threw downdraft gasifier. The porous ceramic reforms were combined with the gasifier which produced gas reforming. The increase in the gasifier temperature, equivalence ratio and steam to biomass ratio were results in producing hydrogen rich producer gas. The effect of porous ceramic reforming was the production of water soluble tar. The conversion ratio of total organic carbon contents was increased from 22.61 to 50.23 and hydrogen concentration was also higher. They observed that reforms increased the conversation efficiency and hence results in higher calorific value.

Rocrim Bcah Yono et al. [14] in this paper author was studied the behavior of reduction in tar deposition by using grade iron ore. Pyrolysis tar vapor pyrolysis of low grade coal was introduced to porous ore for tar decomposition and carbon deposition. They have studied that the carbon depositions were more reactive because the nanoscale constant by the results of pyrolysis gas interruption given the more attractive utilization and the process of reduction the low grade iron with coal for smooth decomposition. They also analyzed that at high temperature degree of reduction increased.

Gozde Duman et al. [15] they have studied the gasification of sunflower feed cake and it was carried out using a double bed micro reactor in a two stage process in the presence of ceria oxide and modified Iron oxide catalysts with different ratios. The effects of both catalysts and temperature of catalytic bed on the tar decomposition rate and over all gaseous product yields were investigated. They have studied and given the results as modifications in the iron oxide catalyst were have higher radioactivity than that of individual Fe_2O_3 and CeO_3 for tar decomposition in sunflower feed cake steam gasification. They have concluded that both hydrogen production and the decomposition of lingo cellulose biomass in steam gasification were enhanced by catalysts.

Electo Silva Lora et al. [16] In this paper a design approach for a biomass fluidized bed gasifier using the comprehensive simulator for fluidized bed equipment (CSFB) was proposed. They have studied the performance parameters such as air factor, feeding point position and bed height and determined all the parameters for maximum gasifier efficiency, higher heating value and minimum tar content in the producer gas. Other parameters were also optimized using CSFB software like pressure drop, the bubble diameter and the gas velocities inside the bed reactor.

Krushna Patil et al. [17] they have studied that downdraft gasifier design with tar cracking mechanism. They have designed an internal separate combustion chamber where the turbulence swirling high temperature combustion flows were generated. They have tried several times and finalized that the temperature of 1100°C was best fit for tar cracking. Wood Shavings were used for different trials. Successes of this experiment were such as, volumetric concentrations levels of CO = 22%, hot and cold efficiency were as 72% and 66% respectively.

Thana Pushpak et al. [18] they have studied the two step decomposition and adsorption on tar removal in the producer gas. Active Carbon, wood chip and synthetic porous were selected to evaluate the absorption performance of the tar and they have finalized that active carbon was best fit for tar removal. They have compared the other absorbents like wood chip, wood shavings where as wood chips shown the prominent absorption property under the practical constraints while minimizing the condensable tar without decreasing the efficiency of the system. They have finalized that tar decomposition was maximum at the temperature 800℃. They have also studied improved the efficiency of tar reduction either by using steam or by using air into the reformer as a reforming agent. The success of this study was the maximized tar reduction rates approximated by 88% and 92% by steam and air reforming respectively.

B. Cramino et al. [19] they have studied the numerical simulation of syngas combustion with a multi-spark ignition system in a diesel engine adapted to work on Otto cycle. They completely focused on the construction of 2D dynamic model. They have considered the turbulent flux combustion reaction of syngas inside a combustion chamber. They have given numerical model in which number of grid was fixed to the dimension 5×6. CPU timing per combustion was less than one second. IPSA algorithm was used to simulate the producer gas Combustion of spark engine.
The gaseous phase was modeled as a multi-component mixture comprised of carbon monoxide (CO), hydrogen (H_2), methane(CH_4), nitrogen (N_2), carbon dioxide (CO_2) and oxygen (O_2). They have given numerical model in which the conservation of matter, motion and energy equations were solved and side by side the turbulence intensity and the multiple reactions were also solved. The turbulence was characterized by local values and determined from modeled turbulent kinetic energy and turbulent kinetic energy dissipation rate transport equations. CFD, PHOENICS, with an IPSA algorithm, were used to simulate the producer gas combustion process using dual fuel spark engines. They have studied the various properties of engine like equivalent ration, maximum inlet and outlet pressure, engine speed, brake mean effective pressure, cycle thermal efficiency and gas pressure. They have obtained thermal efficiency 32% at full load condition.

Jaya Shankar Tumuluru et al. [20] this paper have studied that effects of process variable on the density and durability of the pellets made from high moisture corn stock using 8 mm pellet die. They have analyzed that moisture content influenced all the physical properties. They have produced pallets at different die rotation speed (40-60 Hz), preheating temperature of (30-110°C) and feedstock moisture contend (28-38%) also they have developed response surface models and their respective plots. There quality attributes like unit, bulk and tapped density and durability of the pellets measured after drying the partially dry pellets to safe moisture content less than 9% and densities were as 813 kg/m^3, 399kg/m^3 and 445kg/m^3. Durability of pellets were increased by reducing the feedstock moisture content to 30-33% and increased in preheating temperature.

Pholoso malatij et al. [21] they have studied briquettes for gasification in a downdraft gasifier and their production with the help of manual press from a blend of wood, grape skins and children litter. These yielded briquettes were stable enough for transport, but unfortunately they were disintegrated in the combustion zone of the gasifier. The gasification performance was then stimulated and compared to pine wood, which was commonly used fuel for gasification. Finally they have concluded that the briquettes of pine wood with loose pore pine wood with their performance and their stimulation suggested that the briquettes could even perform better than that the direct pine wood in the gasifier.

Shirdhar et al. [22] they have studied the biomass derived producer gas as a fuel in reciprocating engine. They addressed that the use of producer gas in engine at higher compression ratio was more benefices. After their experimentation they have finalized that higher compression ratio turned out to more efficient. Maximum brake power of 17.5 kW was optioned at the higher compression ratio. They have done there experimentation at compression ratio from 11.5:1 to 17.5:1. The overall efficiency was decrease by 32.5%.

J. Natrajan et al. [23] they have studied the laminar flame rate of syngas with different range of atmospheric pressure and preheating temperature. Laminar flame speed was very important fundamental parameter of combustion mixture which contains very basic information of reactivity, diffusivity and exothermicity.
Various parameter like blowers, flashback etc were affected by the flame speed, its combustion characteristics for heating purpose and other operation based on syngas working principal. This paper have studied the lean mixture of syngas however they studied flame speed and finalized that higher pressure was best fit for engine (gas engine) so as to full fill the desired density and calorific value inside the engine. They have used two model GRI Mech 3.0, which included the reaction relevant to combustion of H_2 and CO. They have used two flame speed approaches 1) An indirect technique that measure the luminous flame area of conical flame 2) Direct velocity measure flame speed at

a.) H_2: CO = 95:5, ¢ = 0.61 without knife edge
b.) H_2: CO = 95:5, ¢ = 0.61 with knife edge
c.) H_2: CO = 95:5, ¢ =0.61, CO_2 = 20% without knife edge
d.) H_2: CO = 95:5, ¢ =1 0.61, CO_2 = 20% with knife edge

Finally they have studied and provided data for very lean mixture with 20% dilution and finalized that flame speed was very less intense and hence the knife edge was used to make the tip more visible.

Anil Singh Bital et al. [24] they have studied the engine knock and combustion characteristics of a spark ignition engine operating with different hydrogen (H_2) and carbon monoxide (CO) proportions. They have performed there study on single cylinder cooperative fuel research (CFR) engine so that to investigate the knock and combustion characteristics of three blends of syngas (H_2/CO ratio): 1. 100/0, 2. 75/25, 3. 50/50 by volume. These blends were tested at three compression ratios (CR) of the range 6:1, 8:1, and 10:1, and three equivalence ratios of the range 0.6, 0.7, and 0.8. It was observed that the knock limited compression ratio (KLCR) of a H_2/CO mixture increases with increasing in CO fraction, for a given particular spark timing. For a given equivalence ratio and spark timing, of 50%/50% H_2/CO mixture produced KLCR of 8:1 as compared to 100% H_2 condition, which produced KLCR of 6:1. The burn duration and ignition lag were also increased with increased in CO fraction in the mixture. It was observed that although CO was a slow burning fuel, higher CO fractions in syngas can be beneficial, because of its increase in the resistance to knock, which results that higher potential of producing CO increased the efficiencies of dual fuel spark engine.

Anand M. Shivapuji et al. [25] they have studied SI gas engine fuelled with H_2 and CO rich syngas gas. They have addressed the combustion phasing and ignition timing to combustion descriptors also load and mixture quality on fuelling a multi-cylinder natural gas engine (Otto cycle) with bio waste-derived H_2 and CO rich producer gas. It was found that for producer gas, flammability limits were as 0.42-1.93, the optimal engine operation was at an equivalence ratio of 1.12. A near linear relationship with ignition angle was observed with above parameter. The general trends of the combustion descriptors for producer gas fuelled operation were similar to those of conventional fuels. Influence of H_2 fraction on the terminal and initial combustion phase and hence on the descriptor sensitivity to ignition have been quantified. Gasoline operation agreed strongly with the indicated conditions as compared to syngas. They suggested that above parameters have higher sensitivity with producer gas as compared to gasoline.

Xianglan Zhang et al. [26] they have studied the effect of different treatment conditions on binder biomass preparation for briquette. The tests of treating rice straw with (NaCl) sodium hydroxide, and sulfuric acid were individually done. The possibility of using binding agent based on rice straw as lignite briquette binder was studied. In this study, the lignite from anthracite coal basin was selected as the coal for briquette manufacturing. It was found that the chemical agents and their concentration were the key factors influencing the preparation of a binding agent based on rice straw.

The binding mechanisms of a rice straw-based binder containing (NaOH) sodium hydroxide were quite different from that made. The experiment shown that the rice straw treated with (H_2SO_4) sulfuric acid could not able to be used as briquette binding agent. Additionally, it made clear that comprehensive binders, which were prepared by adding betonies, coal tar and or polypropylene amide into rice straw-based binder, would have water proof property and would benefit the quality of briquettes.

Zhongshu wang et al. [27] they have studied the effects of injection timing of pilot fuel(diesel) on dual fuel engine and also its impacts on performance and emission characteristics of dual fuel engine. They have studied the advancing injection time of diesel and finalized that its impacts have totally different impact as compared to the ordinary diesel injection. They have studied the effects of multistage ignition on cylinder temperature, SOC, ignition delay. They suggested that multistage ignition with auto ignition technology changed the ignition trends in the engine and greatly influence the HC, NO_x and thermal efficiency of the engine. Pre ignition was done in between 27.5° to 45° crank angle before top dead center and it was found that at 42.5° crank angle BTDC thermal efficiency was increased by 35%, NO_x emissions was reduced by 60 ppm and HC emission was reduced by 4%. Some of the results these investigations were as.

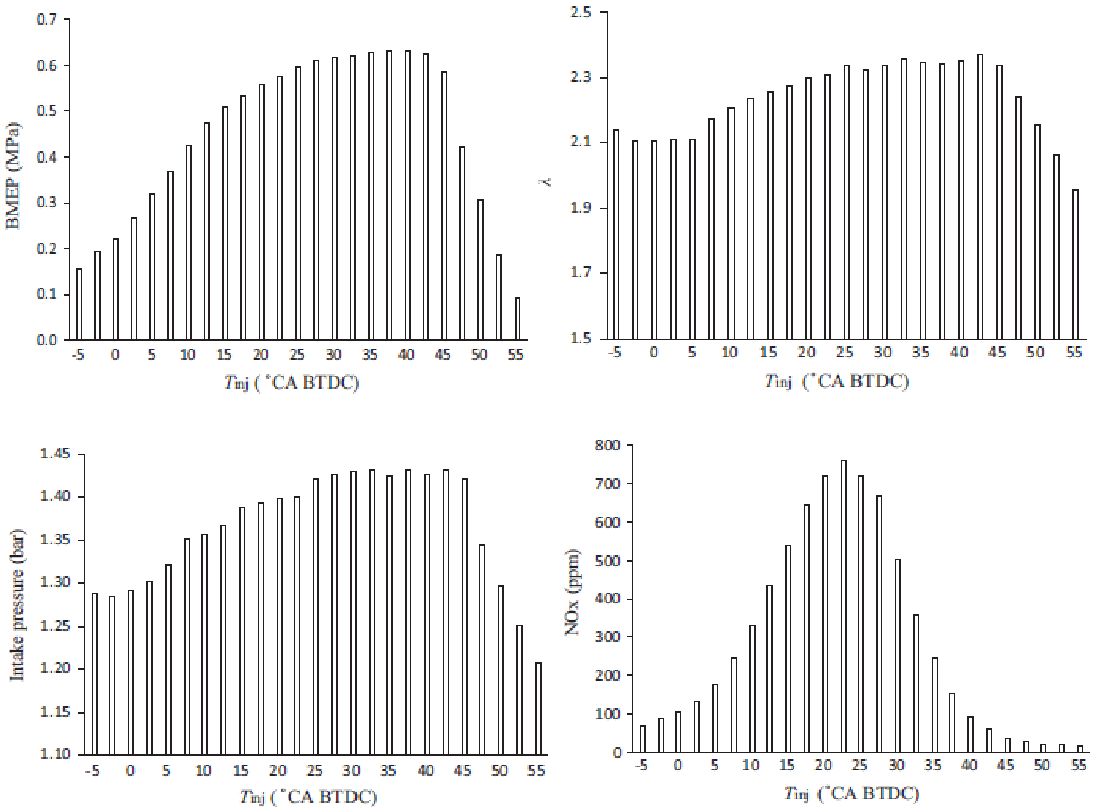


Figure 3.9: Various graph of emissions and performance characteristics of dual fuel engine with respect to the variation in the injection time

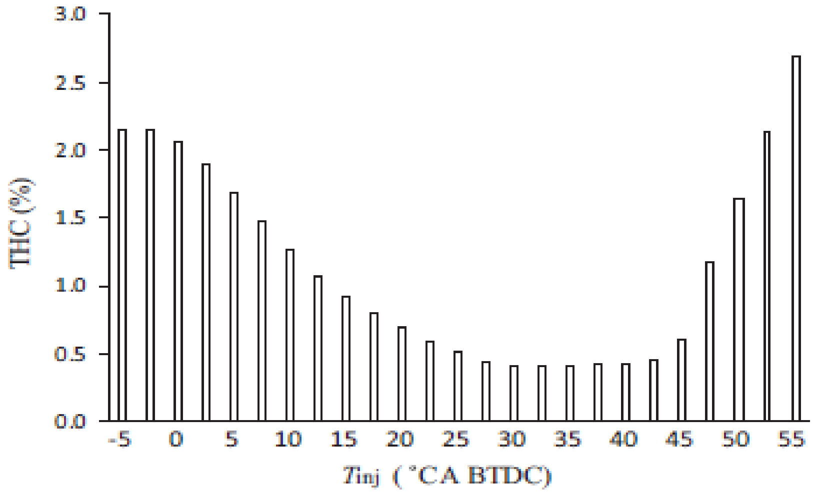


Figure 3.10: HC emissions variation with injection timing

Parmod Kumar et al. [28] they have studied the performance characteristics of dual fuel engine producer gas and diesel blend as fuel. In this studied diesel was used as pilot fuel and synthesis gas primary gaseous fuel. This investigation was carried out at varying load on the engine as well as varying rpm of dual fuel engine. They have studied the specific fuel consumption, brake power, brake thermal efficiency and diesel consumption with producer gas as primary fuel. At full load condition they have noticed the reduction in the diesel consumption i.e. 0.85 kg/hr to 0.3 kg/hr. Brake thermal efficiency was reduced by 45% and diesel consumption was reduced by 64.7%. They have noticed that BSFC was reduced and curve become approximately flat as the load was increasing on the dual fuel engine. The graphical results of this investigation were as.

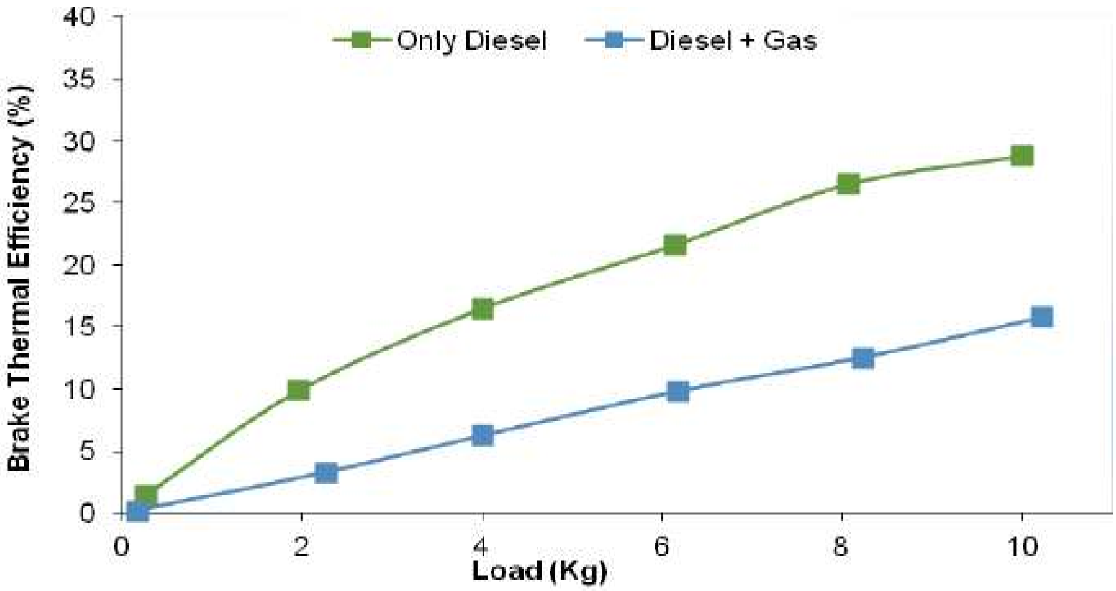


Figure 3.11: Variation brake thermal efficiency with load

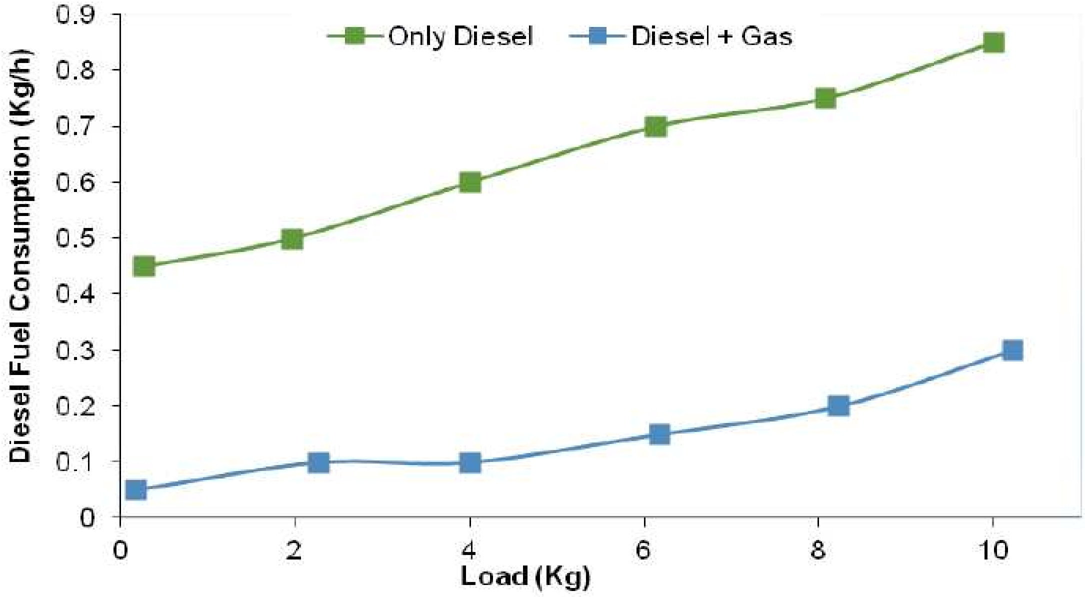


Figure 3.12: Variation of diesel fuel consumption with load

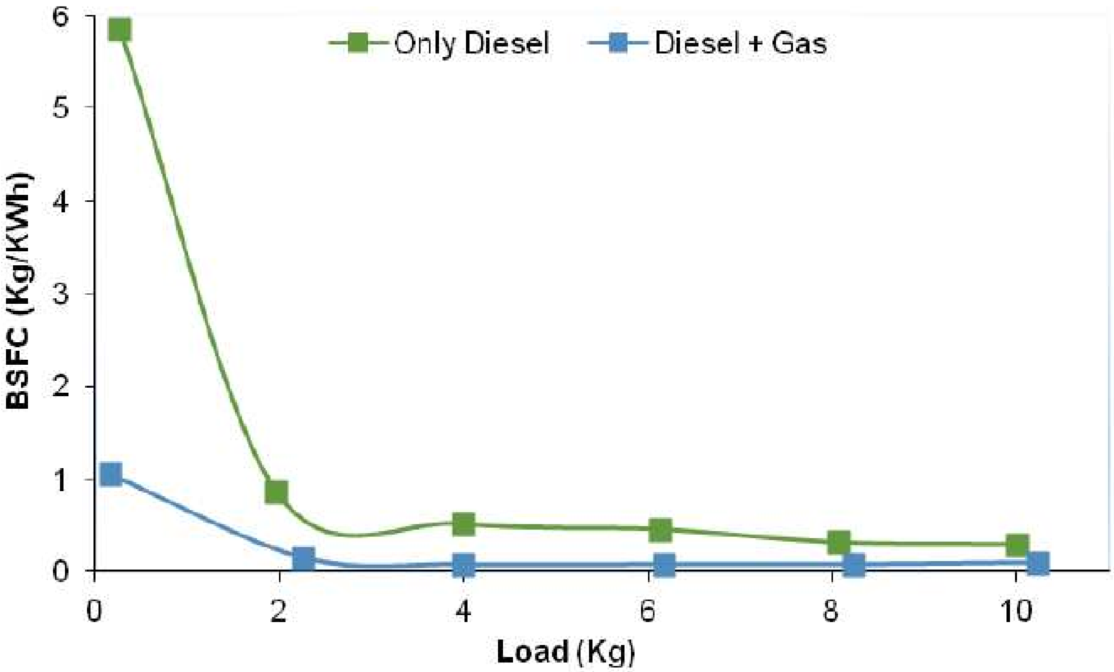


Figure 3.13: Variation of BSFC with load

A.E. Dhole et al. [29] they have studied the effects of blends using hydrogen and producer gas with diesel on performance and emissions characteristics of dual fuel engine. They have founded that blend of hydrogen and diesel in the ratio 20%:80% respectively results in the 8% increase in the brake thermal efficiency where as blend of producer gas and diesel in the ratio 30%:70%

respectively results in the 7% decrease in the brake thermal efficiency. The mixture of producer gas and hydrogen in the ratio 60:40 with diesel in the ratio of 40:60 respectively as a fuel in dual fuel engine, total of 3% decrease in the brake thermal efficiency was observed. There study concludes that the mixture hydrogen, producer gas and diesel have much better results for performance and emissions of dual fuel engine with respect to the blends of producer gas with diesel and hydrogen with diesel. NO_x emissions were reduced by using blends where as hydro carbon emissions were increased by using blends. The graphical results for this investigation were as discussed below.

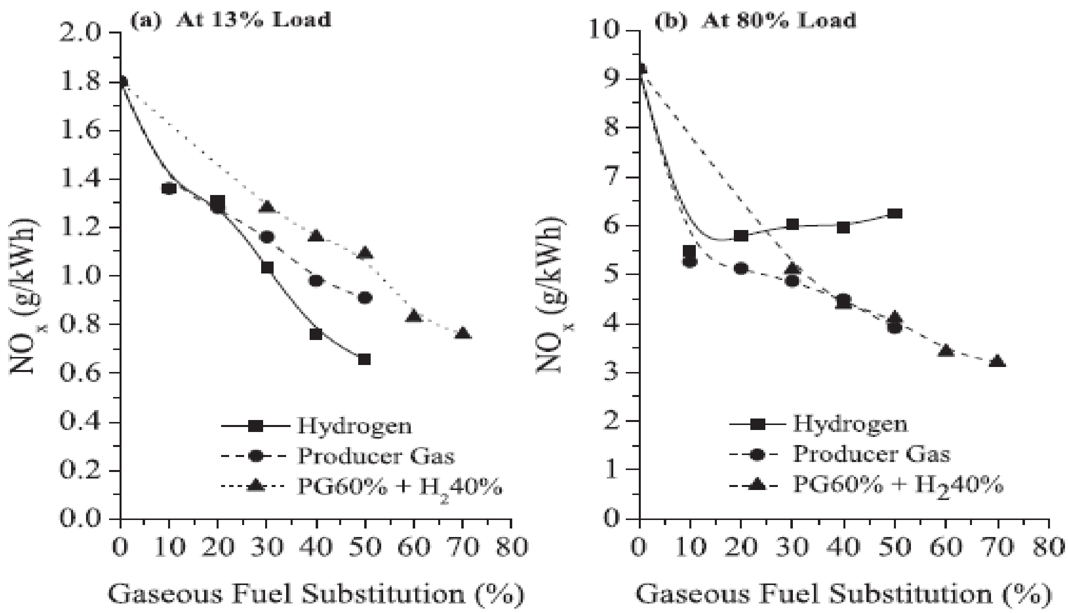


Figure 3.14: Variation of NO_x emissions with gaseous fuel at different loads

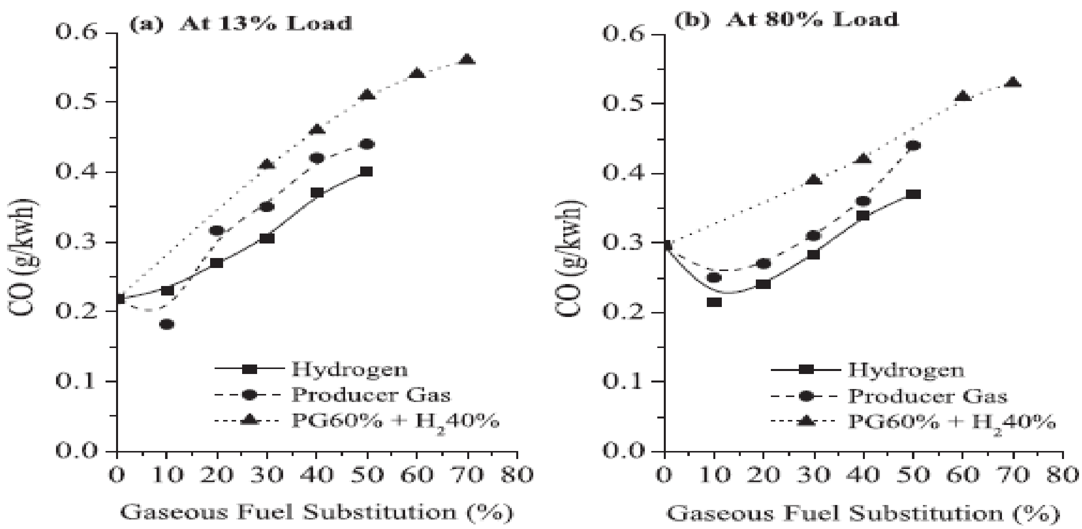


Figure 3.15: Variation of CO emissions with gaseous fuel at different loads

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CHAPTER-4

4.1 Gaps in literature-:

Gasification and its study have lots of variables which need to be further studied like tar free producer gas, retention time of briquettes inside the reactor, bed width maintenance and lots of research work has already been done like engine testing with different parameters (blend composition, emissions etc), producer gas performance, and quantity and quality of producer gas, ease of producer gas. Many researchers have developed new technology for the optimum use of gasification plant setup. We have found gaps in current scenario in this chapter.

1. Briquetting of biomass for the gasifier and its effects and best fit properties for gasifier.
2. Finding out the pyrocracking temperature of different briquettes.
3. Briquetting of highly pore biomass using saw dust and chopped wood chips containing tar (fine filter residue)
4. Tar utilization for the increase in the calorific value of producer (syngas) gas.
5. Performance and engine emission characteristics of dual fuel engine at different compression ratios using producer gas and briquettes.

CHAPTER-5

Methodology and Experimental Investigations-:

Introduction

In the present study, pyrocracking temperature of briquettes was analyzed with two different materials. This study deals with the investigation of temperature behavior of briquette in the gasifier and effects of different parameters on the performance combustion and emissions characteristics on dual fuel engine using producer gas from briquette as a raw material. Raw materials for the briquette were saw dust, fine filter residue and cyclone ash.

5.2 **Materials and methods-:**

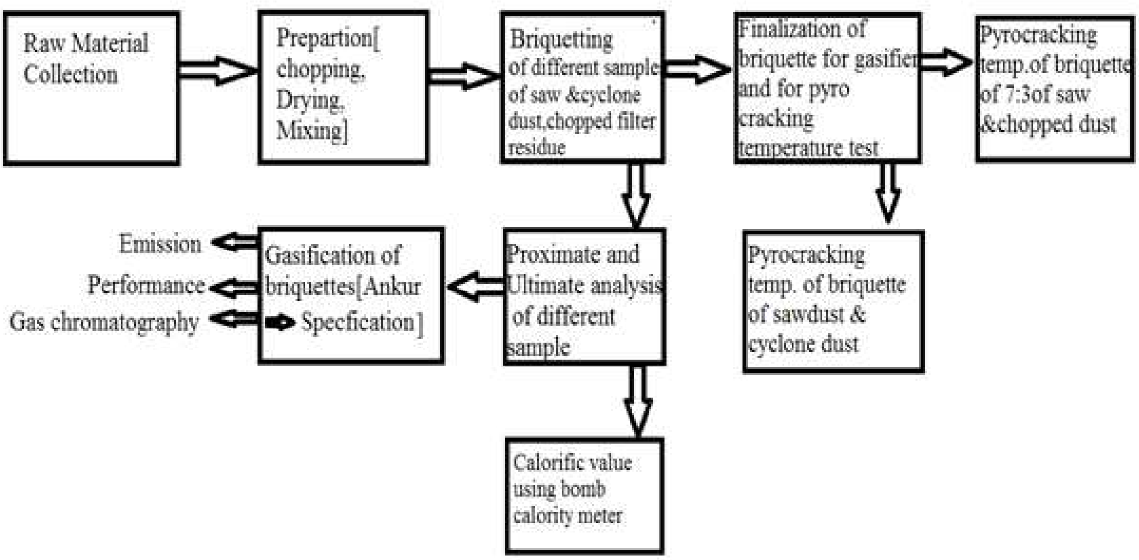


Figure 5.1: Block diagram of process chart

5.3 Fuel collections-:

Fuel used for the production of producer gas was briquette of saw dust and fine filter residue (wood chips containing tar). Initially wooden chips were embedded in the fine filter so as to filtrate the producer gas in the gasifier line. As the time passes its capacity to filtrate diminished and after sometime filters got chocked and further they were used in the production of briquettes. Other material for the briquette was saw dust. Saw dust was collected from cutting shed of wood. Initially moisture content in the saw dust was more than 35%, so it was sundried for three days and its moisture content comes in the range of 12-15%. After collecting fine filter wood chips, it was chopped using shredder machine and its size was reduced and its size was below than 4 mm.

The chopped material was stored in the bags for further use. Temperature behavior of briquettes was done by chosen one more raw material i.e. cyclone dust. Different samples in different ratios of saw dust and cyclone dust were produced and their proximate analysis were done, on the basis briquettes of saw dust and chopped were tested for pyrocracking temperature.

On the basic of proximate analysis of different proportion of 1) Saw dust & cyclone dust 2) Saw dust & chopped fine filter residue. After deciding the composition of the sample pyrocracking temperature test was performed on selected briquettes and its results are shown latter by the certain picture and other look which will gives the resembles view of briquettes inside the reactor below.

Briquette of sawdust and cyclone ash with ratio 8:2

Briquette of sawdust and cyclone ash with ratio 9:1

Briquette of sawdust and cyclone ash with ratio 8:2

Briquette of sawdust and cyclone ash with ratio 9:1

Figure 5.2: Briquettes and their production

Figure 5.3: Material preparation for the gasifier

5.4 Proximate analysis-:

Both the samples were tested in the lab for their proximate analysis. Small crucibles were used for the analysis. 1.5 gm sample of each biomass material was taken into two different crucibles. Initially the samples were placed in oven at a temperature of 100℃ for one hour. They were taken out and were placed in desiccator. The samples were weighted again and the reduction in mass was noted and moisture content in the sample was determined by difference. After finding the moisture content samples were placed in muffle furnace for 6 to 7 minutes at temperature of 900℃ and after completing the time sample were place in the desiccators. After cooling the samples, reduction in mass was noted and reduction in mass was termed as volatile material (VM) in the biomass. Further the samples were heated in the furnace at 600℃ and burnt to ash. After burning they were placed in the desiccator. After cooling in the desiccator, sample was weighted and ash is left behind.

These samples were tested for proximate analysis on oven and muffle furnace (PT350 A/1) and the results of proximate analysis are show in table no. 5.

Fixed carbon (FC) = Total weight – (Moisture content+ VM +Ash).

5.5 Calorific value-:

The calorific values (CV) of both the fuels were calculated using bomb calorimeter. The rise in the temperature of water was noted for the calculation of CV. Following relation is used to find out the CV:

$CV = 2382.32*(\Delta T /x)-(E1+E2)$

ΔT = Rise in the temperature of 2000g of distilled water

x= Mass of fuel used

E1+E2 = weight of nichrome wire and cotton thread

The calculated value of CVs and Proximate analysis of all the samples are as in table no 5.

Table 5.1: Results Proximate Analysis and Calorific Value of Different Sample Used in Complete Study

Sample	Ratio of raw material	Moisture content (%)	Volatile matter (%)	Fixed carbon (%)	Ash content (%)	Calorific Value (kcal/kg)
Sawdust & Cyclone ash	10:0	14.10	70.80	4.18	10.77	4107
Sawdust & Cyclone ash	9:1	11.01	69.73	10.70	8.55	4217
Sawdust & Cyclone ash	8:2	10.42	64.60	11.10	13.85	4556
Sawdust & Cyclone ash	7:3	9.60	58.8	10.60	20.91	4617
Sawdust & Cyclone ash	6:4	10.00	62.00	8.20	19.23	4713
Sawdust & Cyclone ash	5:5	8.77	62.01	8.20	19.24	4800

Sample	Ratio of raw material	Moisture content (%)	Volatile matter (%)	Fixed carbon (%)	Ash content (%)	Calorific Value(K cal/Kg)
Sawdust ,charcoal &tar	5.55:3.70:.75	13.60	56.10	16.72	13.57	5000
Chopped fine filter residue	-	12.21	63.32	11.78	12.69	4719
Saw dust with sundried	-	14.5	70.35	9.75	5.41	4129
Saw dust and chopped tar wood chips	6:4	18.31	62.75	12.78	6.16	4925
Saw dust and chopped tar wood chips	7:3	18	63.75	12.35	5.92	4852
Saw dust and chopped tar wood chips	8:2	13.78	68.75	11.75	5.72	4652
Saw dust and chopped tar wood chips	9:1	13.64	69.92	10.78	5.66	4602

5.6 Ultimate analysis-:

On the basis of proximate analysis, briquette of saw dust and cyclone ash of ratio 8:2 was chosen as best briquette for the gasifier, Ultimate analysis of this briquette was done. This analysis was done in the sophisticated analytical instruments laboratories society (SAI Labs, Patiala) by using

CHONS Analyzer. Test report number of Ultimate analysis was NH/16-17/017 and service no. was NH/16-17/017(01) and finally report of ultimate analysis is as follows.

Table 5.2: Results of Ultimate Analysis using CHONS Analyzer

S.No	Parameter	Test method	Unit	Result (oven dried basis)
1	Carbon	CHONS Analyzer	%	45.86
2	Hydrogen	CHONS Analyzer	%	5.11
3	Nitrogen	CHONS Analyzer	%	0.28
4	Sulphur	CHONS Analyzer	%	Not detected
5	Oxygen	By Difference	%	41.25

5.7 Gasifier system-:

The current study was completed using downdraft gasifier in the university campus for finding out the performance and emission characteristics of dual fuel engine using producer gas of briquette of saw dust and chopped fine filter residue. The specifications of the gasifier were provided in table no. 8 and are according to the catalogue of setup authenticated by the company itself.

Table 5.3: Engine Parameters

Parameter	Specification
Company	Ankur Scientific Energy Technologies Pvt. Ltd.
Gasifier model number	WBG-10
Reactor type	Downdraft with a throat

Numbers of air inlet	2
Allowable moisture content	< 20%
Gas flow rate	$25 Nm^3/hr$(Maximum limit)
Thermal output	30.21 kW
Fuel consumption	8-10 kg/hr
C.V. of producer gas	1434.12-1512.70 $kcal/Nm^3$
Average gas composition	$CO=18\pm3\%$, $CH_4\leq 3.5\%$, $H_2=16\pm2\%$, $CO_2= 6 \pm 2\%$, $N_2=51\%$

5.8 Firing of the gasifier-:

In order to start the gasification process, the raw material was introduced manually into the hopper. Before charging of material into hopper raw material, size was further reduced to less than 20mm as per the throat of gasifier allows this maximum size through it.

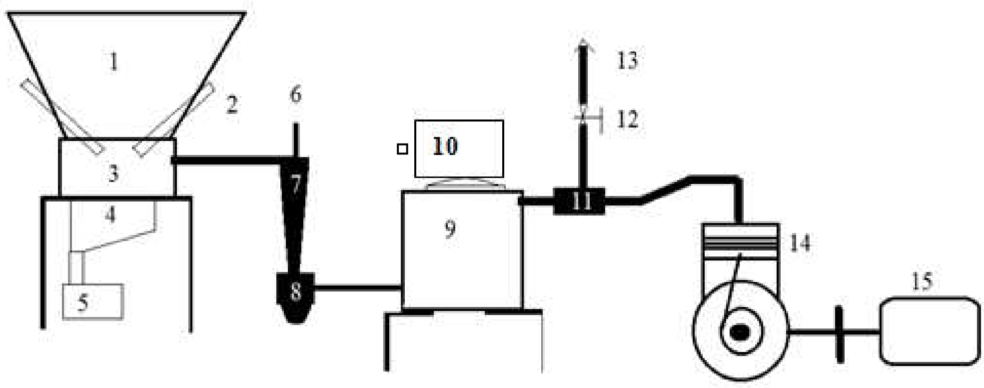


Fig 5.4: Schematic diagram of the experimental setup

1) Hopper 2) Air inlet 3) Reactor 4) Residue collector 5) Ash removal mechanism 6) Water inlet7) Scrubber 8) Drain box 9) Tar box 10) Safety valve 11) Bypass valve 12) Flare control valve 13) Flare burner for testing gas quality 14)DFCI engine test setup 15) Eddy current dynamometer

After loading the gasifier, hopper was sealed so as to supply limited and controlled amount of air in the gasifier. There were two opening on the side walls of the gasifier for air charging in the reactor and these opening were used for initial firing of biomass. Gasifier was fired from the air inlet using diesel torch. Producer gas starts forming after 15-20 minutes of firing.

5.9 Gas cleaning-:

Temperature of producer gas at the outlet of gasifier was ∼460℃ which was quiet high due to which density of producer gas was reduces and it is too dirty and containing tar, so before sending it into dual fuel engine we have to reduces its temperature as well as to clean the gas also. For cooling of gas in the setup have water spray unit which reduces the temperature of gas also condensing the tar through it as well. After this unit gas is passed through secondary filter (fine filter) which contains wood chips. This filter is use to absorbs the moisture content in the gas and soot particles if any. For completing the cleaning of gas we have one unit, i.e. safety filter also termed as ultra filter which provides a clean and less odor gas. After cooling and cleaning the temperature of syngas is about 30-40℃ and gas is ready for experimentation in DFCI engine.

Figure 5.9: Passive filter and cooling unit

Figure 5.10: Hopper and charcoal safety valve

Figure 5.11: Inlet and feeding chamber charging

5.10 Feeding and preparation of briquettes-:

Briquettes of saw dust and fine filter residue were the final material for the gasifier. Material was produced in the R&D lab at Chanderpur Renewable Power Company Private limited, Mulana (Ambala, Haryana) by using reciprocating piston press. Before production of fine filter residue was chopped in the lab by using shredder machine and saw dust was air dried in the lab for 3-4 days. After completing of the treatment, both the materials were mixed in the proportion of 8:2(saw dust: fine filter residue) and finally, briquette press produced briquette and its diameter is 35mm initially. This ratio was selected because it has maximum calorific value and minimum dust content. Both the materials are the waste product in the plant.

Figure 5.13: Briquette press and production of briquettes

5.11 Dual fuel engine setup-:

The optimum cleaned gas after cleaning and cooling was introduced into the dual fuel engine by mixing it with intake air in the intake manifold. The flow rate of producer gas was measured through orifice meter, it gives the reading in the term of pressure drop of H_2O in U tube manometer. Volume flow rate was calibrated through empirical relation (area of pipe×velocity of producer gas)

Velocity of producer gas = density×gravity×pressure head

Below table shows the specification of DFCI engine setup

Table 5.4: Specification of Engine Setup

Parameter	Specification
Engine company	Kirloskar
Engine model	AV-1
Engine type	VCRE (Variable Compression Ratio Dual fuel Compression ignition 4 stroke engine)
Stroke length	110 mm
Bore	87.5 mm
Number of cylinder	1
Stoke volume	553 cc
Maximum power	3.7KW at 1500 rpm
Compression ratio	1:12 & 1:18
Cooling system	Water cooled
Fuel	Diesel alone and blends of diesel and producer gas
Orifice diameter	185 mm

The various emission and performance parameters of DFCI engine were studied by keeping the compression ratio of the engine 14:1 & 18:1. The gas flow rate was controlled by adjusting the flow rate control valve and flow rate was fixed to 5.07Nm^3/hr. In order to ensure the repeatability and the correctness of experiments, keeping all parameter same, three trials of all the tests were conducted. The engine was tested on Dual fuel mode using diesel oil as primary fuel and producer gas secondary fuel. Before stating the engine, water valve was opened to supply cooling water to the water jacket.

250 LPH to 75 LPH water was supplied to the engine for cooing. The engine was fixed for five loads from 1.91kg to 9.93kg. Air flow and gas flow rates were recorded using two orifices of 20 mm and 15.31 mm diameters, respectively. All the graph were represented using these average values of the corresponding parameter

Figure 5.14: Variable compression ratio dual fuel engine test rig

Figure 5.15: Complete setup of engine test rig

Figure 5.16: Complete gasifier unit

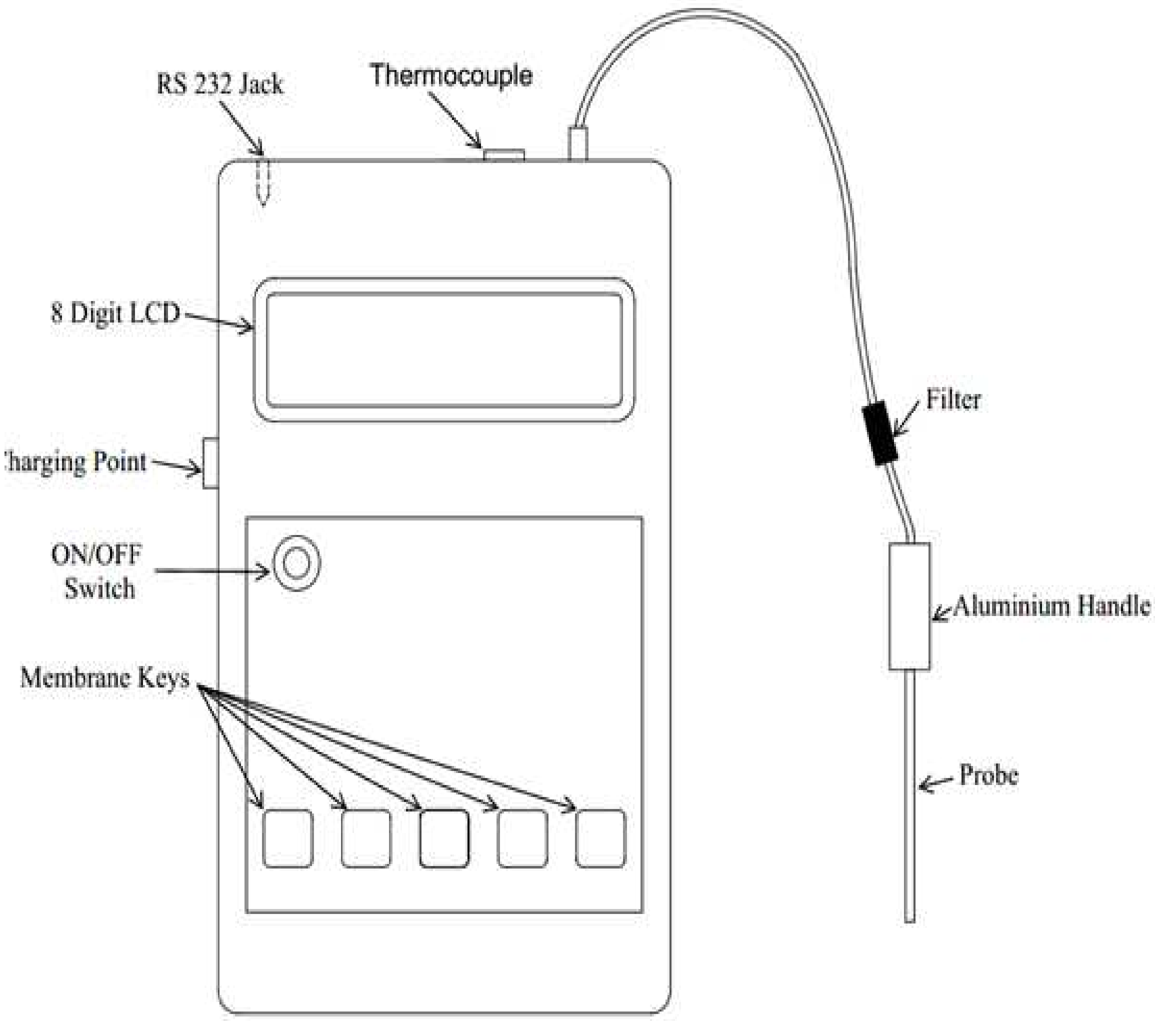


Figure 5.17: Exhaust gas analyser

CHAPTER-6

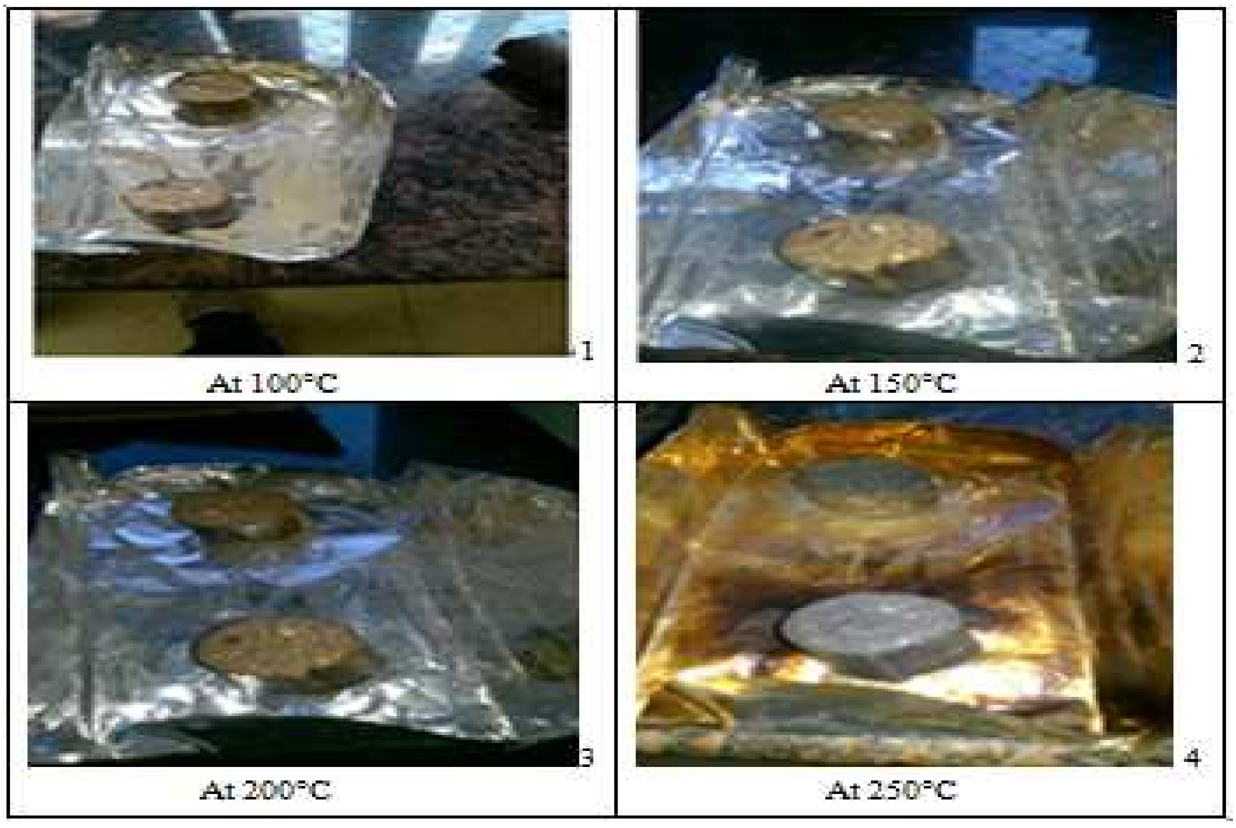
Results and Discussions

6.1 Temperature Behavior of Briquettes-:

Briquettes of sawdust with chopped chips in the ratio 8:2 and sawdust, cyclone dust, tar in the ratio 5.55:3.70:.75 were studied for final checking of pyrocracking temperature. Results of temperature behavior were checked by burning it in the muffle furnace with different temperature for one hour and burst point of briquette and finalized its pyrocracking temperature and the results were listed by taking the picture of briquette after burning it for one hour in the muffle furnace.

Tar is waste by product in the gasifier plant, so it can be used in the manufacturing process because of its high calorific value and finally briquette (sawdust, cyclone dust, tar (5.55:3.70:.75)) was produced and finally consider for the checking its temperature sustainability (temperature behavior) i.e. up which temperature is can maintain bed width of gasifier.

Briquette of saw dust and cyclone (sawdust with cyclone ash (7:3)) ash was also examine because cyclone ash is waste buy product and also have high calorific value.



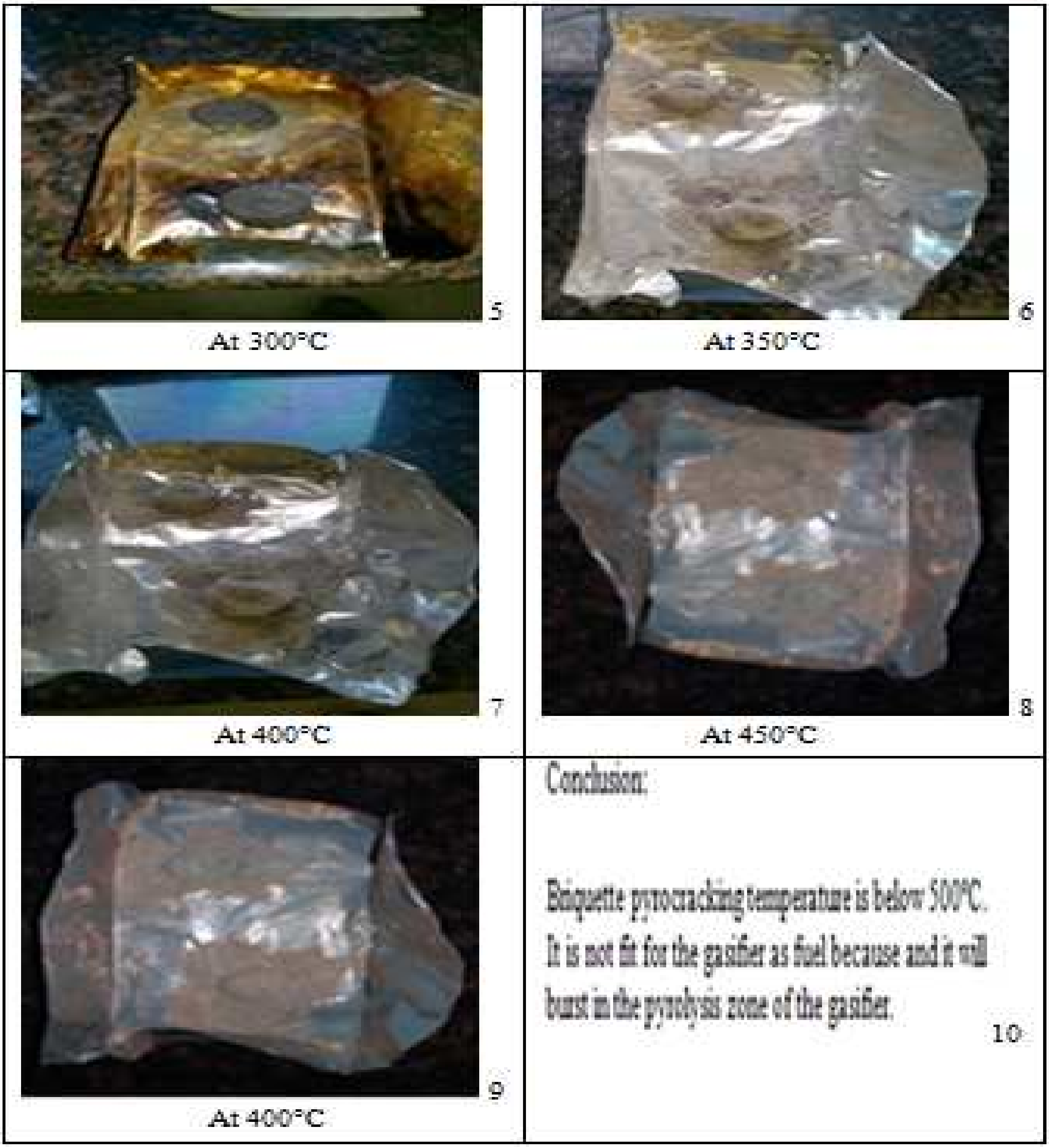


Figure 6.1: Temperature behavior of briquette of sawdust and chopped chips

The above images show the effects of increase in the temperature on the briquette and these effects shown by the degradation of briquette with time at particular temperature and help to decide how much bed width can maintained by briquette in respective temperature range inside the gasifier.

 At 150°C	 At 400°C
 At 200°C	 At 450°C
 At 250°C	 At 500°C
 At 300°C	Conclusion: Briquette pyrocracking temperature is below 400°C. It is not fit for the gasifier as fuel because and it will burst in the pyrolysis zone of the gasifier.

Figure 6.2: Temperature behavior of briquette of sawdust, cyclone dust, tar

The above images also studied to finalize the maximum degradation temperature of briquette and in this case it was 400°C.

6.2 Performance of briquette with diesel engine test rig-:

Different parameters of engine performance with two different compression ratio (14:1, 18:1) with varying load were analyzed by using dual fuel test rig. Results of these investigations are discussed below.

6.2.1 Brake Power with Load-:

The first performance parameter is variation of break power and load. The performance was studied at two compression ratios and both have similar results of increasing order with the increase in the load on engine. The reason behind this as load increased the more power is required to overcome it so it results in increase in the brake power of the engine. Maximum brake power for CR-14 and CR-18 are 2.88kW and 2.81 kW respectively.

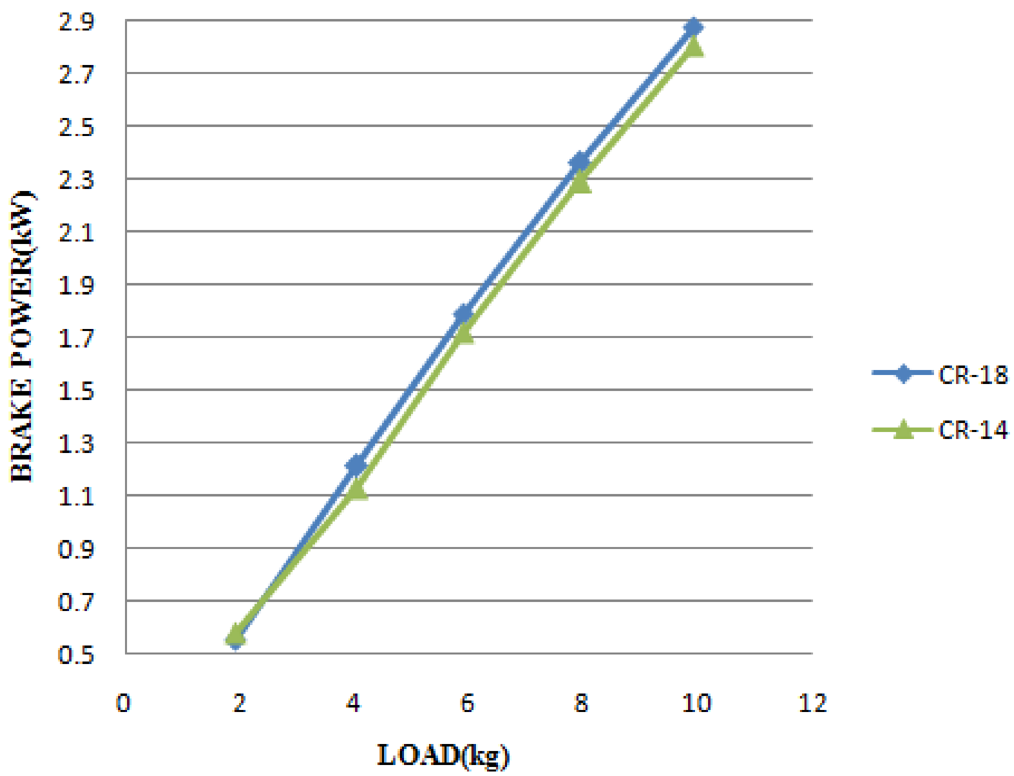


Figure 6.3: Variation of brake power with load

6.2.2 Brake means effective pressure with load-:

Brake mean effective pressure is direct function of brake power and with the increase in the load so brake power is continuously increasing for both the compression ratios. Maximum brake mean effective pressure for CR-18 is 3.42 bar and 3.46 bar for CR-14 at full load condition.

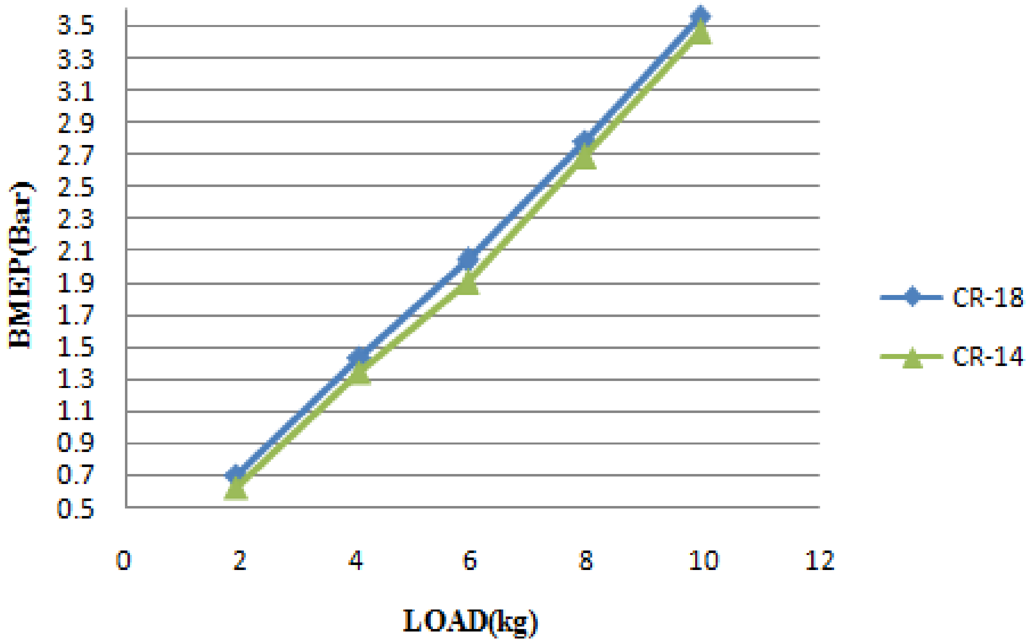


Figure 6.4: Variation of brake mean effective pressure with load

6.2.3 Brake thermal efficiency with Load-:

Brake thermal efficiency is firstly increasing for CR-14 up to half load after that increase in BThEff of CR-18 is more as compared to value for18 up full load. Maximum values BThEff for CR-18 and CR-14 at full load are 34.67% and 30.28% respectively.

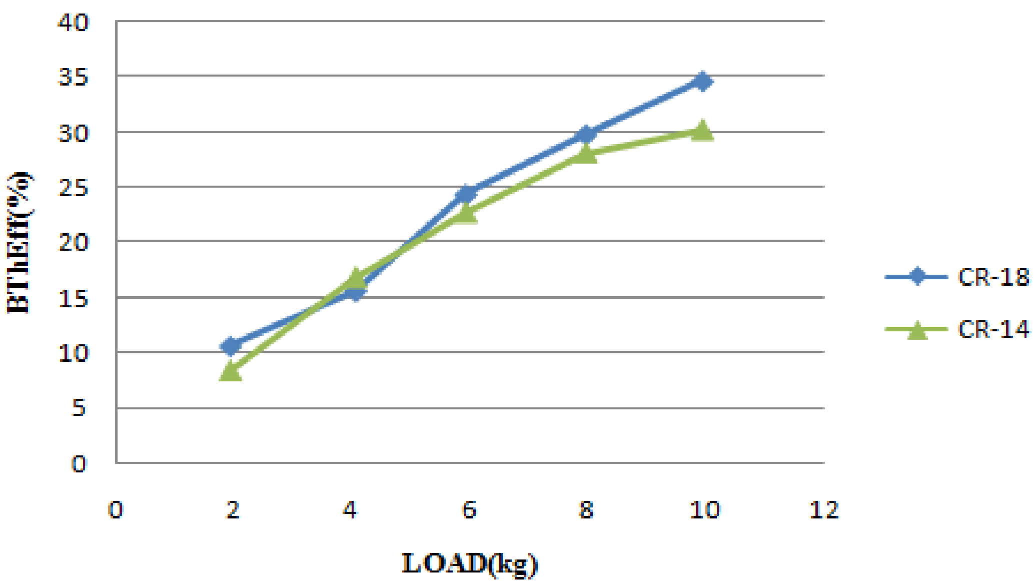


Figure 6.5: Variation of Break thermal efficiency with load

6.2.4 Indicated Power and Load-:

For both the compression ratio indicated power is increasing with the increase in the load. At full load condition CR-14 have more indicated power i.e. 5.14KW and 5.03KW for CR-18. The reason behind this is with the increase in the Compression ratio friction losses increases which results in droop of Indicated power.

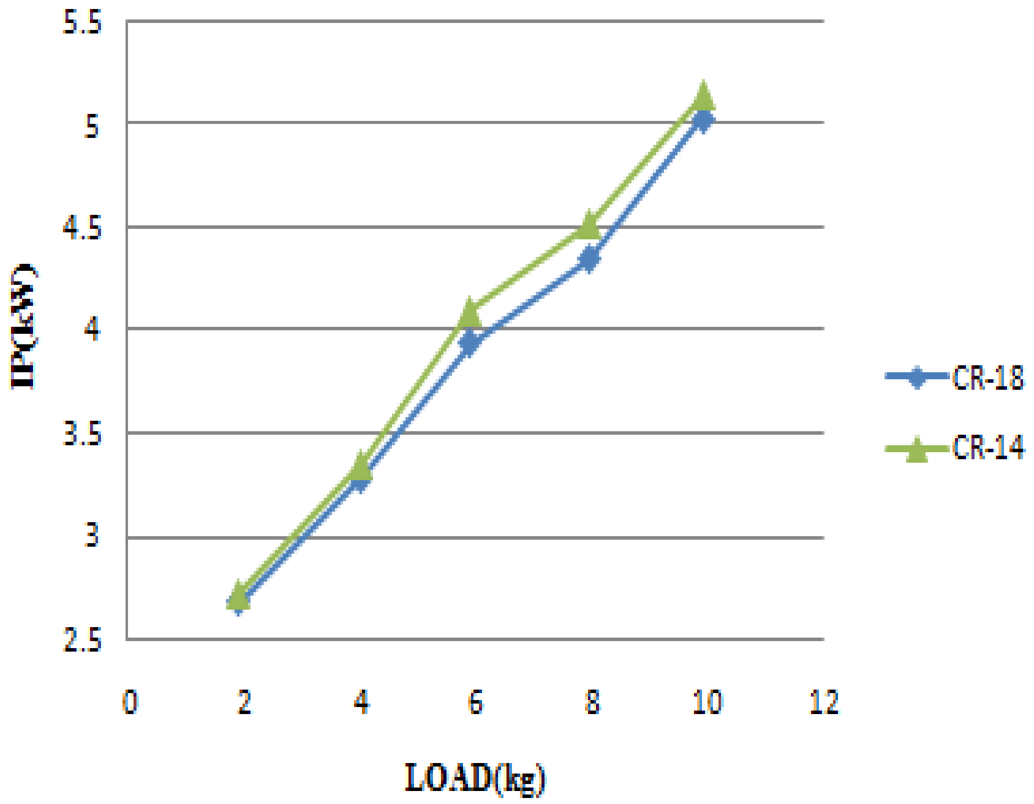


Figure 6.6: Variation of indicated power with load

6.2.5 Indicated mean effective pressure and Load-:

Indicated power is more at full load condition for CR-14 which results in the increase in the indicated mean effective pressure and trend of the increase in the IMEP is same as of BMEP and its maximum value is 6.11 bar for CR-18 and 6.30 bar for CR-14.

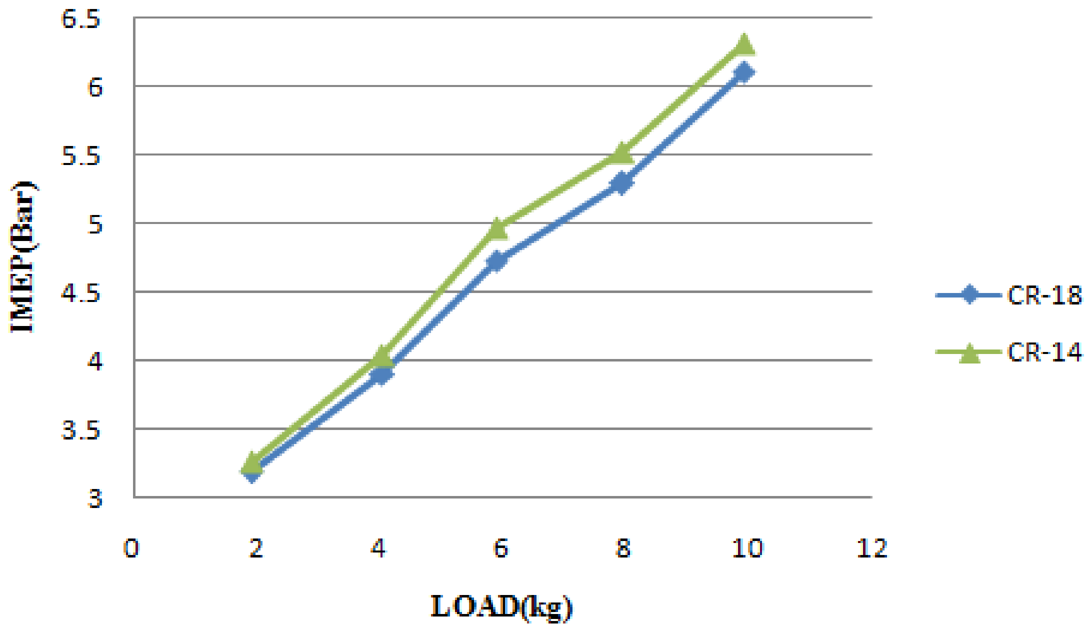


Figure 6.7: Variation of indicated mean effective pressure with load

6.2.6 Fuel with load-:

Fuel for CR-14 and CR-18 is following decreasing increasing trend and its value for CR-14 is more as compared to CR-18. Reason for this is the value of brake power and indicated power are more for CR-14 so fuel to generate the power is also going to increase and higher compression ration results in good combustion so less pilot fuel is require for CR-18.

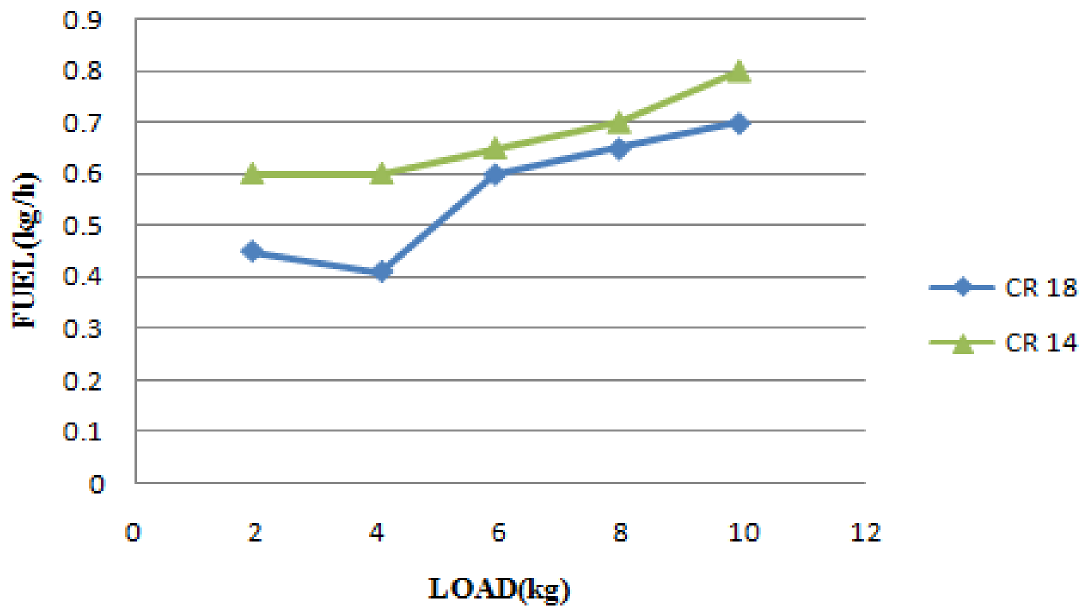


Figure 6.8: Variation of fuel with load

6.2.7 Specific fuel consumption with load-:

This specific fuel consumption is for pilot fuel (diesel) used in the test rig and its value is continuously decreasing which represents that increasing in the volume of producer gas for full and increasing loads are using more producer as compared to the pilot fuel and hence fulfilling the purpose of complete study.

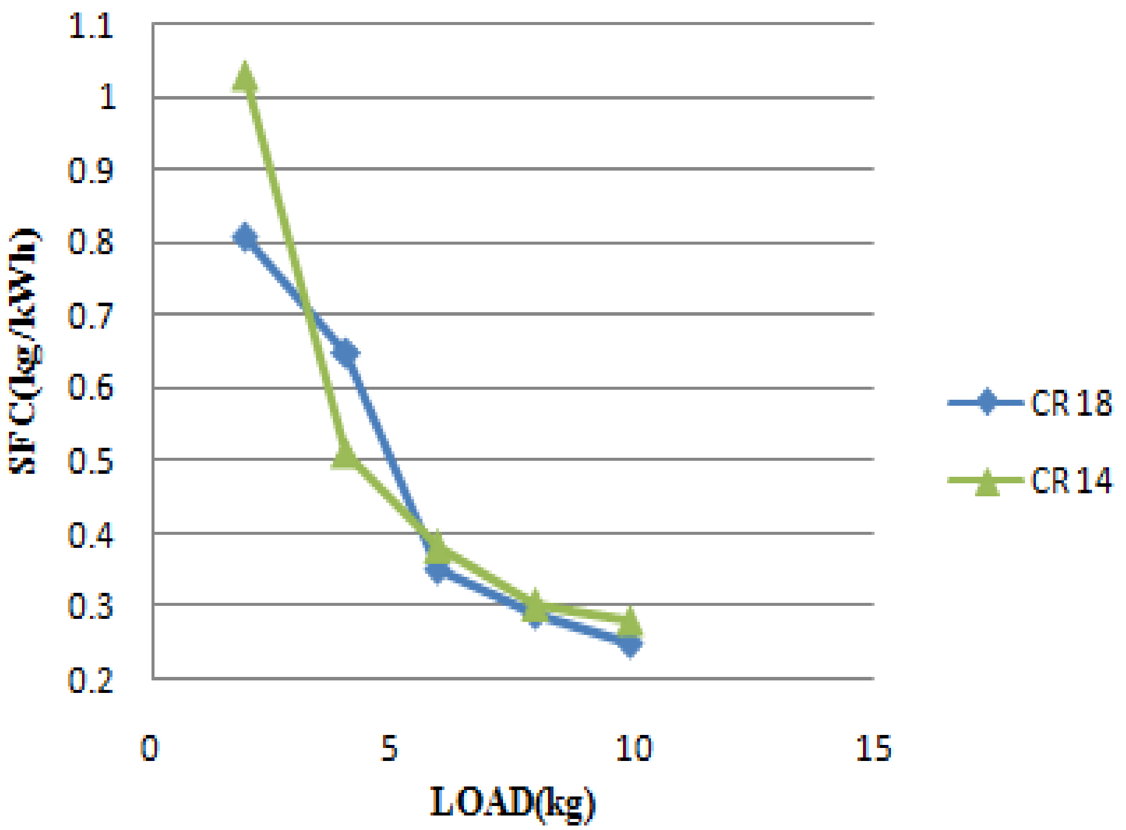


Figure 6.9: Variation of Specific fuel consumption with load

6.2.8 Torque with load-:

Diesel engine always producing more torque as compared to the spark engine as volumetric and thermal efficiency is higher for compression ignition engine and somehow test rig used for conducting this investigate is also showing same increasing trend with the increase in the load.

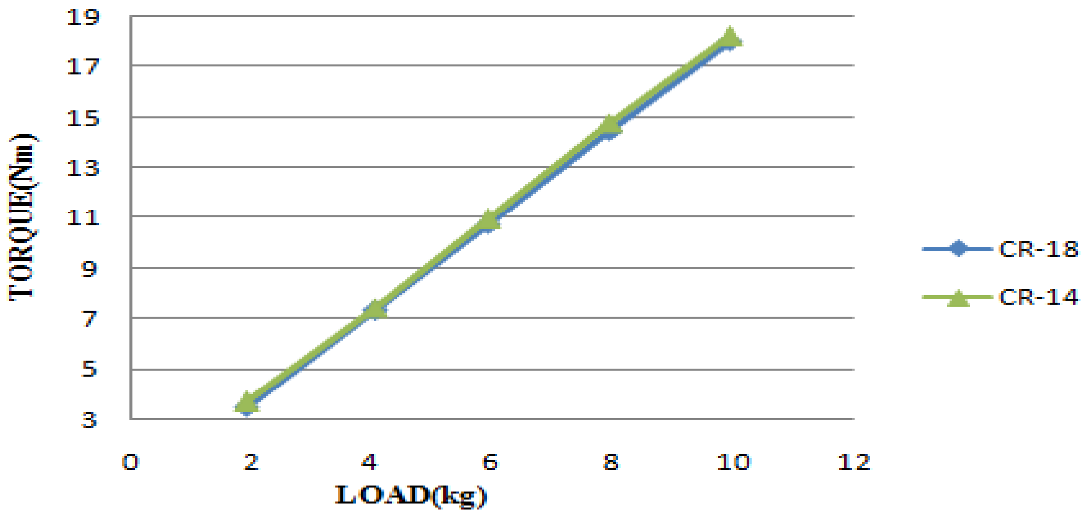


Figure 6.10: Variation of torque with load

6.3 Emission Characteristics of DFCI engine-:

Maxicem portable gas analyser model ACE-800 was used to investigate the emission characteristics of dual fuel compression ignition engine. Results of emissions are discussed below.

6.3.1 Nitrogen oxide emissions (NO_x)-:

It is clearly shown by the Fig. 6.10 that NO_x increases as the load increases on DFCI engine. The reason for this is as the load increases the temperature of combustion chamber increases. Nitrogen has tendency to react with oxygen at higher temperatures so the increase in the temperature of combustion chamber results in the increase of NO_x emissions in the exhaust gas. The maximum value of NO_x emissions for CR-18 and CR-14 are 45 ppm and 42.5 ppm respectively.

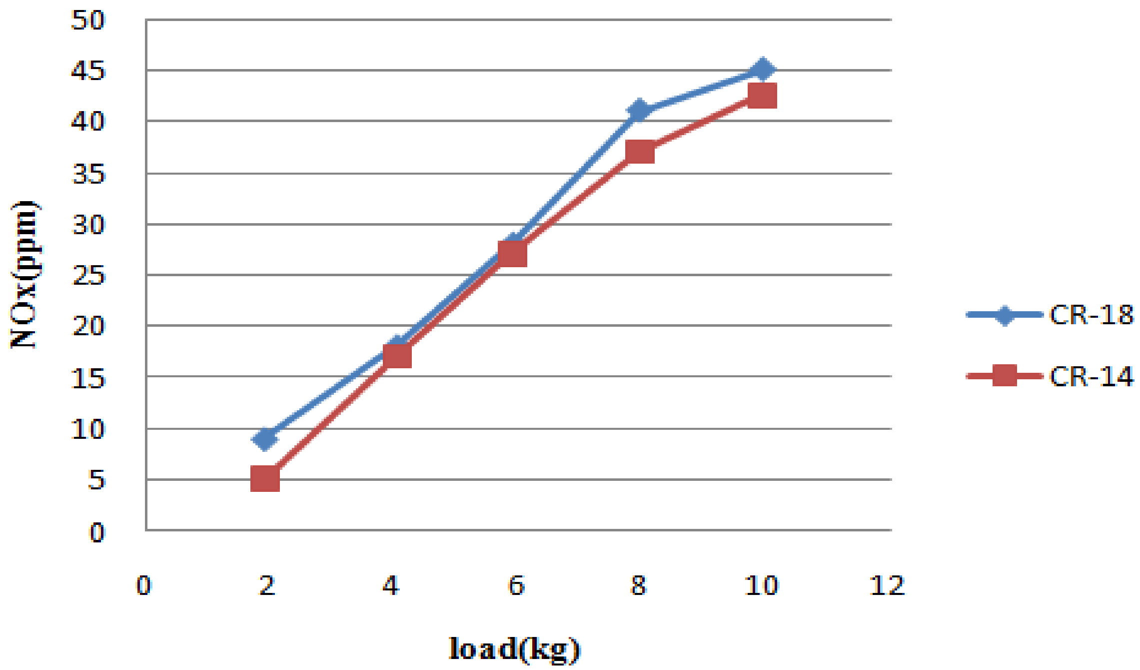


Figure 6.11: Variation of NO_x emission with load

6.3.2 Exhaust gas temperature with load-:

Fig. 6.12 shows that the there is increase in the temperature of exhaust gas as the load increases. Engine in the set up used is constant air supply running at constant rpm. The increase in the load demands more fuel to maintain its rpm so increase in the fuel results in the increase of exhaust gas temperature. The maximum temperature of exhaust gas is 95°C for CR-18 and 85°C for CR-14.

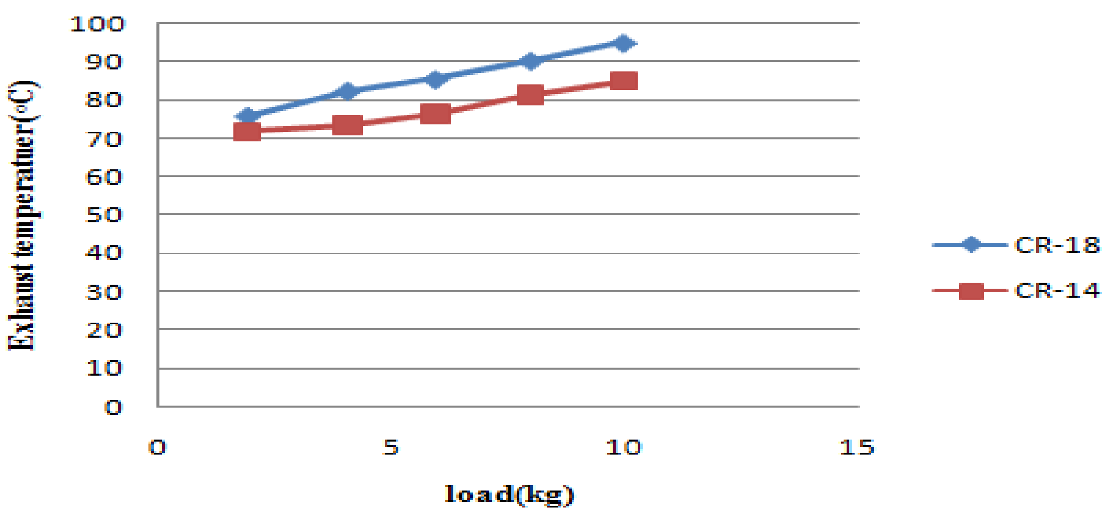


Figure 6.12: Variation of exhaust gas temperature with load

6.3.3 Hydrocarbon (HC) with load-:

Fig. 6.13 shows that hydrocarbon emissions increase with the increase in the load. The volumetric efficiency of the engine increases as the load increases and more heat is carried out by exhaust gas means some part of fuel is going in the exhaust without doing any work, hence HC emissions increase . The maximum value of HC emissions is 159 ppm for CR-18 and 185 ppm for CR-14.

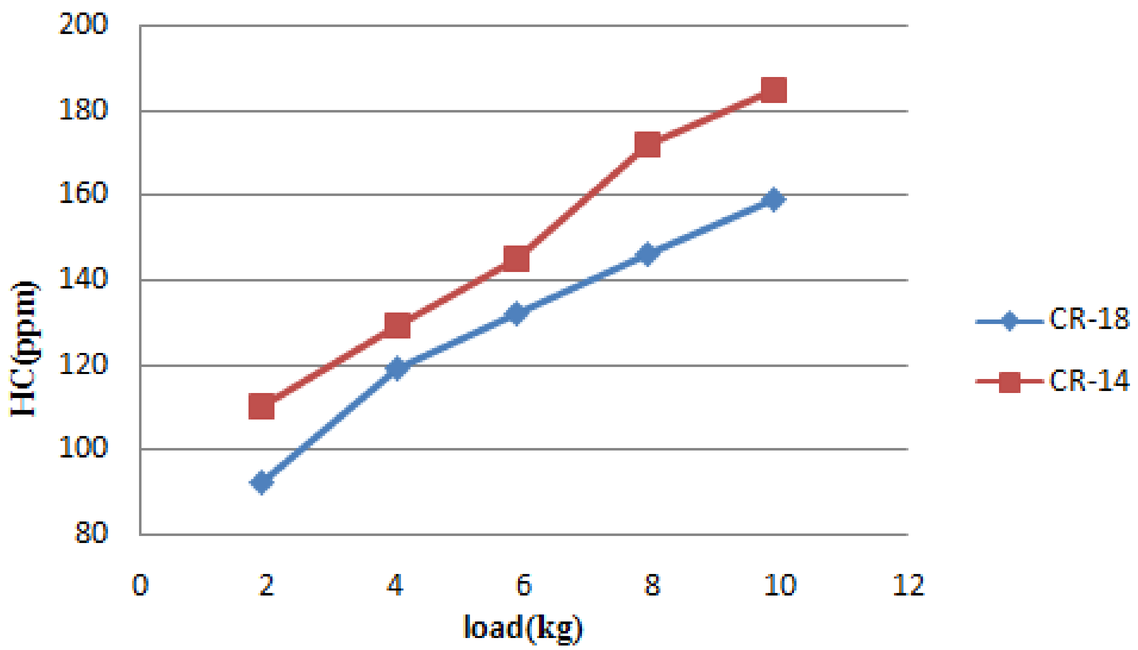


Figure 6.13: Variation of Hydrocarbon (HC) with load

6.3.4 Carbon monoxide (CO) with load-:

Emission of DUCI engine shows more concentration of CO in the exhaust as we increase the load on the engine. Setup engine is working on content rpm and governor of engine will automatically increases the fuel supply and which results in the deficiency of air in the combustion chamber. The deficiency of air results in incomplete combustion and ultimately some part of fuel is wasted, which results in increase in the concentration of CO. The maximum value of CO emissions is 135.2 ppm for CR-18 and 165.75 ppm for CR-14.

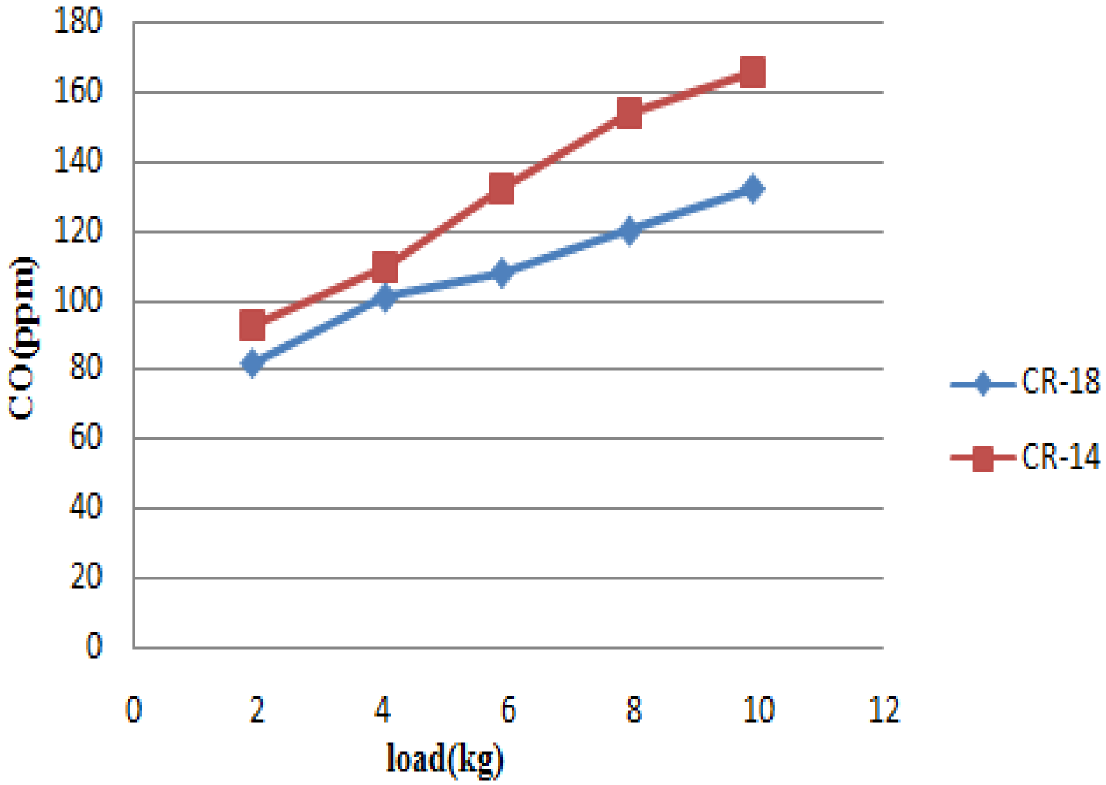


Figure 6.14: Variation of Carbon monoxide (CO) with load

Chapter-7

Conclusion and Scope of Future Research

7.1 Conclusion-:

HC emissions, CO emissions are more for compression ratio 14 as compared to compression ratio 18 which shows that on 14:1 more blend is waste and there is very negligible difference in the NO_x emissions.

The values of brake power, brake mean effective pressure and brake thermal efficiency are more for CR-18:1 then CR-14:1. The values of fuel consumption and specific fuel consumption are less for CR- 18:1 as compare to CR-14:1.

Briquette produce from saw dust and fine filter residue in the ratio of 8:2 respectively shows maximum pyrocracking temperature of 500°C, optimum calorific value is 4556 kcal/kg with second minimum ash content of 13.85% where as briquette produce from saw dust, cyclone ash and tar in the ratio of 5.55: 3.70: .75 respectively shows maximum pyrocracking temperature of 400°C, calorific value is 5000 kcal/kg with second minimum ash content of 13.55%. Briquette of second kind contains very thick compound i.e. tar which produces difficulties in the manufacturing which was practically observed during its manufacturing.

So ultimately briquette of saw dust and fine filter residue in the ratio 8:2 respectively at compression ratio 18:1 is suggest by above investigation for commercial as well as domestic gasifier.

7.2 Scope of Future Research-:

Since literature available on briquettes is not sufficient of give some valuable insight on ultimate results on the use of briquettes as fuel to produce gas generation, so there is further requirement of research work to be done in areas given below.

- Direct use of briquettes from bio waste in the gasifier.
- Remote gasifier working with dual fuel CI engine with high moisture content briquettes.
- Investigation of emissions and performance characteristics of dual fuel (Diesel and producer gas) as well as spark engine using briquettes of other bio waste like bagasse, cotton stalk, rice husks etc.

Appendix

Load (kg)	CR-18	CR-14
1.91	0.55	0.58
4.04	1.21	1.13
5.91	1.79	1.72
7.95	2.36	2.29
9.93	2.88	2.81

Table A1: Results of BP (kW) with different load at CR 18, 14

Load (kg)	CR-18	CR-14
1.91	0.7	0.62
4.04	1.43	1.34
5.91	2.04	1.9
7.95	2.78	2.68
9.93	3.56	3.46

Table A2: Results of BMEP (bar) with different load at CR 18, 14

Load (kg)	CR-18	CR-14
1.91	10.57	8.33
4.04	15.58	16.8
5.91	24.36	22.73
7.95	29.81	28.17
9.93	34.67	30.28

Table A3: Results of BThEff (%) with different load at CR 18, 14

Load (Kg)	CR-18	CR-14
1.91	2.68	2.72
4.04	3.28	3.35
5.91	3.94	4.1
7.95	4.34	4.51
9.93	5.03	5.14

Table A4: Results of BP (kW) with different load at CR 18, 14

Load (kg)	CR-18	CR-14
1.91	3.18	3.26
4.04	3.9	4.04
5.91	4.73	4.97
7.95	5.29	5.52
9.93	6.11	6.32

Table A5: Results of IMEP (bar) with different load at CR 18, 14

Load (Kg)	CR-18	CR-14
1.91	0.45	0.6
4.04	0.41	0.6
5.91	0.6	0.65
7.95	0.65	0.7
9.93	0.7	0.8

Table A6: Results of Fuel (kg/hr) with different load at CR 18, 14

Load (Kg)	CR 18	CR 14
1.91	0.81	1.03
4.04	0.65	0.51
5.91	0.35	0.38
7.95	0.29	0.3
9.93	0.25	0.28

Table A7: Results of SFC (kg/kWh) with different load at CR 18, 14

Load (kg)	CR-18	CR-14
1.91	3.46	3.67
4.04	7.32	7.43
5.91	10.73	10.94
7.95	14.43	14.77
9.93	18.01	18.21

Table A8: Results of SFC (Nm) with different load at CR 18, 14

load(Kg)	CR-18	CR-14
1.91	9	5
4.04	18	17
5.91	28	27
7.95	41	37
9.93	45	42.5

Table B1: Results of NO_x emissions (ppm) with different load at CR 18, 14

load(Kg)	CR-18	CR-14
1.91	9	5
4.04	18	17
5.91	28	27
7.95	41	37
9.93	45	42.5

Table B2: Results of exhaust gas temperature (°C) with different load at CR 18, 14

load(kg)	CR-18	CR-14
1.91	92	110
4.04	119	129
5.91	132	145
7.95	146	172
9.93	159	185

Table B3: Results of HC emissions (ppm) with different load at CR 18, 14

load(Kg)	CR-18	CR-14
1.91	82.23	92.6
4.04	101.06	109.12
5.91	108.12	132.12
7.95	120.14	154.25
9.93	132.21	165.75

Table B4: Results of CO emissions (ppm) with different load at CR 18, 14