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Performance – Evaluation of Lignite in a downdraft Gasifier

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Abstract: India is a developing country which lacks an adequate supply of electricity. For many of the interior regions of India, gasification is a good way to produce electricity with standalone gasifier. In many regions of India as well as in the world, a large reserve of lignite is available. Lignite could be a fuel for gasification system. This paper presents the result of the experimental investigations carried out using lignite to investigate the effect of fuel size variation on gas generation rate and performance parameter in terms of calorific value of producer gas and gasifier efficiency in downdraft gasifier. Based on the realization, while studying the effect of gas generation rate, the choice of particle size is playing an important role for flowability study and performance of gasifier. The present work investigates the effect of lignite size variation on temperature profile at different zones in gasifier. They were in the range of 16-19 mm, 19-22 mm, 22-25 mm particle sizes of lignite. For comparative studies, experiments were also carried out on uneven size wood and lignite. It was observed from three particle sizes of lignite that better calorific value (629 kcal/m³) and efficiency of gasifier (46.092%) were obtained with 22-25 mm particle size of lignite.

Keywords: Gasification, Downdraft, 10kW_e, Lignite

I. Introduction

Energy is very important because everything that people consume, use, eat is energy or has energy embodied in it and also energy is embodied in everything that people use, and in order to have economic growth, people need to have lots of energy and preferably nice and cheap energy. So not only do people need energy, we need large quantities of it [1]. India is a developing country and it demands of energy is continuously increases; electricity consumption per capita is also increases because of increasing living standard of the people in India.

India's energy-mix comprises both non-renewable (coal, lignite, petroleum and natural gas) and renewable energy sources (wind, solar, small hydro, biomass, cogeneration bagasse etc.) [2]. Coal based thermal power plant is a major electricity production source in India as well as all over the world. Information on reserves of non-renewable sources of energy like coal, lignite, petroleum, natural gas and the potential for generation of renewable energy sources is a pre-requisite for assessing the country's potential for meeting its future energy needs [2].

Table I State wise Estimated Reserves of Lignite in India as on 31.03.2011

States/ UTs	Proved	Indicated	Inferred	Total
Gujarat	1.24	0.32	1.16	2.72
Jammu & Kashmir	0.00	0.02	0.01	0.03
Kerala	0.00	0.00	0.01	0.01
Puduchchery	0.00	0.41	0.01	0.42
Rajasthan	1.17	2.15	1.52	4.84
Tamil Nadu	3.74	22.90	6.26	32.90
INDIA	6.15	25.79	8.97	40.90

Source: Office of Coal Controller, Ministry of Coal

The gasification process uses an agent, air, oxygen, hydrogen or steam to convert carbonaceous materials into gaseous product which has usable heating value. The Gasification Systems Program is developing advanced technologies to reduce the cost and increase the efficiency of producing syngas [3]. It can contribute to the demand for heat, electricity and syngas. Carbonaceous fuel like various biomass, wood, coal have been used extensively as a fuel for gasifiers. Producer gas can be burnt as a fuel gas in an internal combustion gas engine or gas turbine for electricity generation in villages. Various types of gasifiers are available like updraft, downdraft, fluidized bed, entrained flow also single throat, double throat etc.

Song Lin et. al. [4] carried out some experiments on 10 kW_e gasifier with rice husk fuel. They have mentioned that in order to generate 10 kW electric power, approximately 28 kg/h of rice husk must be gasified. In the laboratory-scale fixed bed and bench-scale downdraft experiments, it has been concluded that gasification of rice husk was accompanied by a substantial production of syngas at 760-900 K.

Young-II Son et. al. [5] carried out experiments on downdraft gasifier to find characteristics of woody biomass gasification and power generation. They observed that Syngas temperatures from the gasifier were maintained at

a level of 700-1000°C. When the air ratio for gasification was 0.3 to 0.35, the low heating value of syngas was 1100-1200 kcal/Nm³ and the cold gas efficiency was 69-72%.

Jun Yoon *et al.*^[6] carried out experiments on downdraft gasifier with the fuel rice husk and rice husk pellet. Gasification was conducted in a temperature range of 600°C-850°C, fuel feeding rate of 40-60 kg/h and gasification agent, air, feeding rate of 50-75 Nm³/h. As per the results, synthetic gas heating value and cold gas efficiency comes out to be more than 1300 kcal/Nm³ and 70% respectively. The heating value of synthetic gas and the cold gas efficiency from rice husk pellet gasification is comparatively higher than the respective values from rice husk gasification.

Pengmeiet. *al.*^[7] produced hydrogen rich gas from biomass air and oxygen/steam gasification in a downdraft gasifier. They noticed that steam gasification gave excellent result compared to air gasification. Efficiency of steam gasification was higher as per their experiment. The experimental results indicated that compared to biomass air gasification, biomass oxygen/steam gasification has improved hydrogen yield depending on the volume of downdraft gasifier, and also nearly doubled the heating value of fuel gas.

Avdhesh Kr. Sharma^[8] carried out Experimental study on 75 kW_{th} downdraft (biomass) gasifier system to obtain temperature profile, gas composition, calorific value and trends for pressure drop across the porous gasifier bed, cooling cleaning train and across the system as a whole in both firing as well as non-firing mode. Some issues related to re-fabrication of damaged components/parts have been discussed in order to avoid any kind of leakage. In firing mode, the pressure drop across the porous bed, cooling cleaning train, bed temperature profile, gas composition and gas calorific value are found to be sensitive to the gas flow rate. The rise in the bed temperature due to chemical reactions strongly influences the pressure drop through the porous gasifier bed. The experimental data generated in this article may be useful for validation of any simulation codes for gasifiers and the pressure drop characteristics may be useful towards the coupling of a gasifier to the gas engine for motive power generation or decentralized electrification applications.

Zainalet. *al.*^[9] is carried an experimental investigation of a downdraft biomass gasifier using furniture wood and wood chips. The effect of equivalence ratio on the gas composition, calorific value and the gas production rate is presented. The calorific value of the producer gas increases with equivalence ratio initially, attains a peak and then decreases with the increase in equivalence ratio. The gas flow rate per unit weight of the fuel increases linearly with equivalence ratio. It is also observed that complete conversion of carbon to gaseous fuel has not taken place even for the optimum equivalence ratio.

Gokhaleet. *al.*^[10] set up a fixed-bed coal gasification reactor which specifically simulated the devolatilization zone in a gasifier. Samples (100 g) of lignite coal in three size ranges were devolatilized in the temperature range 350-550°C with a steam oxygen mixture, at 1 atm. The effect of these operating variables on tar yield and composition, melting point, viscosity, specific gravity, and molecular weight distribution was determined. A first-order reaction model was fitted to the experimentally observed total loss in weight of the lignite.

Bhattacharya *et al.*^[11] studied the gas composition and temperature profiles for charcoal, gasify bed in the down-draft mode. Parametric studies were made on solid and gas flow rates, char reactivity and particle size, both with dry air and with steam in the system. The results showed the O₂ consumption took place very rapidly, in a distance of about 10-15 cm from the level at which air entered; the CO₂ concentration dropped after increasing to a maximum; the CO and H₂ concentrations continually increased from zero. The model predictions agreed reasonably with experimental results.

II. Experimental

A. Why Lignite Gasification?

1. A lignite recoverable reserve in world is 195 billion tonnes. So, Lignite represents 18% of world coal reserves.
2. Lignite Cheap, easily available and proven reserves in the India are approximately 40 billion tonnes. Occurrence of lignite in India is confined to States of Tamilnadu, Gujarat, Rajasthan, Pondicherry, Jammu & Kashmir and Kerala. In Gujarat, total proven recoverable reserves of Lignite is around 0.785 billion tonnes. So, there is an ample source of Lignite is available in Gujarat. Gujarat being one of the largest producers of the lignite will certainly benefited by this project.
3. Because of its low energy density, brown coal (Lignite) is not traded extensively on the world market compared with higher coal grades.
4. Its high moisture content and susceptibility to spontaneous combustion can cause problems in transportation and storage.
5. Lignite-burning plants also require typical environmental controls for coal-fired power plants to avoid environmental damage from the major air pollutants. These problems could be overcome by gasifying lignite in to producer gas in gasifier.

B. Experimental setup

10 Kw_e laboratory scaled downdraft gasifier is installed at Nirma University, Ahmedabad. Gasifier is coupled with Hindustan motor 22bhp petrol engine. Block Diagram of a gasifier system is shown below.

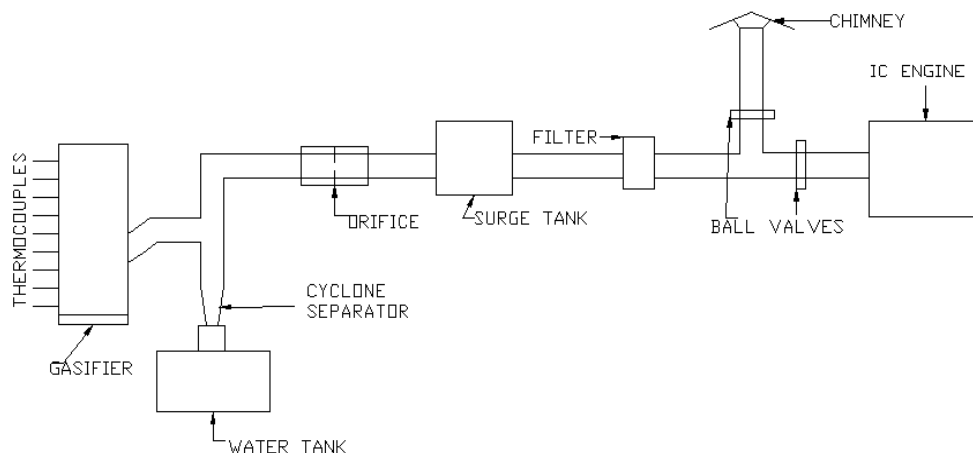


Figure 1 Block Diagram of Gasifier

It is single throat setup and throat diameter is 125mm and throat angle is 45°. For water circulation, 0.56kW motor is used. Saw dust is kept in surge tank and synthetic material is used in filter. For measuring Temperature, K type of thermocouple is used and for measuring the flow rate, U tube manometer and anemometer are used. Gas chromatograph is used to analyse the producer gas sample. Sizing sieves are used to size lignite in appropriate dimensions. Air is used as a reactant agent.

C. Why particle size of Lignite?

Particle size plays important role in the performance of gasifier. Set up is downdraft gasifier. From literature, it is known that low particle size fuel create flow problems and excessive pressure drop. Also due to lignite, in higher particle size create clinker formation. Gasifier is coupled with engine, so downdraft gasifier is better due to tar the free gas which is the major advantage of downdraft gasifier.

Figure 2 Clinkers



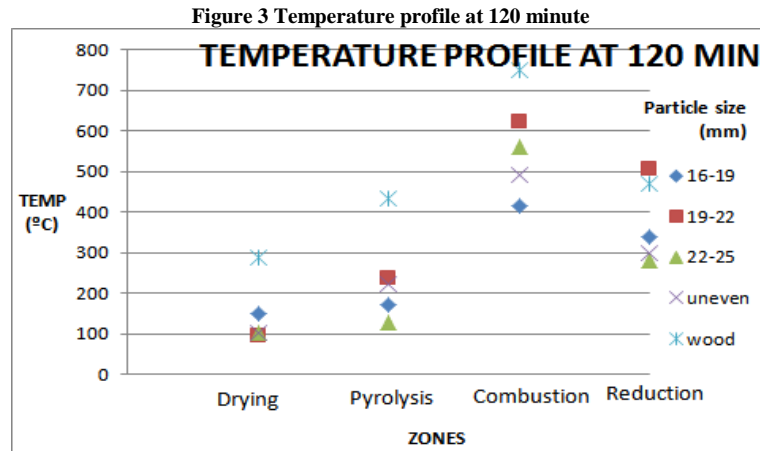
III. Results and Discussions

Experiments are carried out on 10kW_e downdraft gasifier with uneven scaled lignite and wood. Also same experiments are carried out with lignite having sizes 16-19 mm, 19-22 mm and 22-25 mm respectively.

Table II Proximate analysis, sulfur content and GCV for lignite and wood

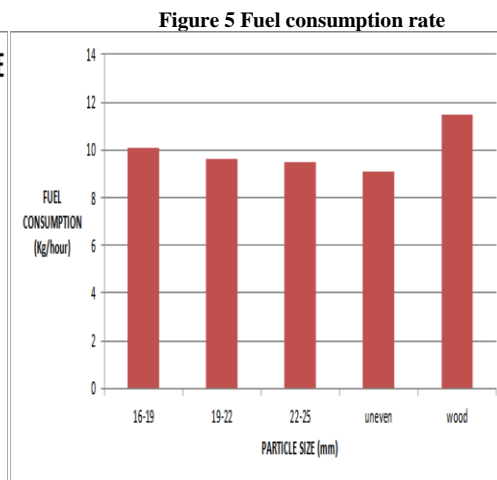
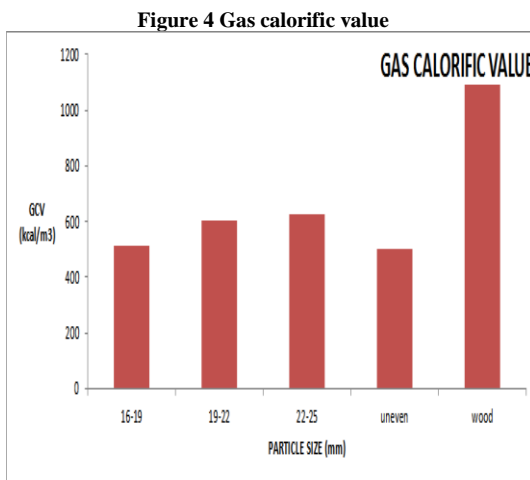
	Moisture (%)	Volatile matter (%)	Ash (%)	Fixed Carbon (%)	Sulfur (%)	GCV (kcal/kg)
LIGNITE	10.198	45.115	12.789	31.898	0.7	3778
WOOD	6.696	82.846	4.551	5.907	N/A	3496

Maximum Temperature of gasification system is obtained in combustion zone. Wood has a good temperature range due to higher volatile matter and lower ash, moisture content. After 60 minutes, the temperature of lignite becomes low; because of clinker formation due to ash fusion. In reduction zone, with uneven lignite fuel, temperature increases gradually because of lower volatile matter available in fuel.



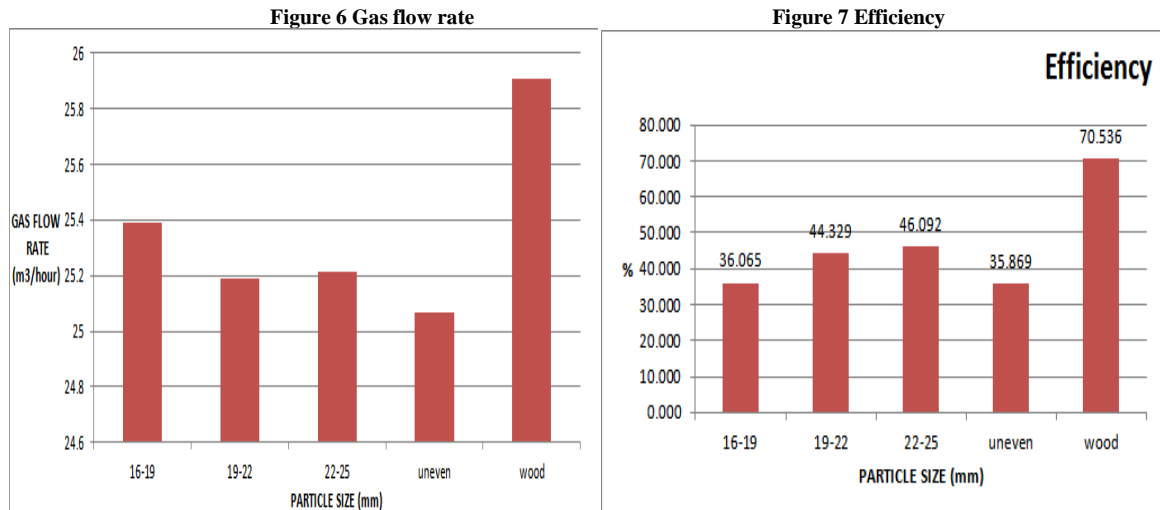
Temperature at 120 minutes for all experiments is measured. Temperatures of different zones with different fuels are shown in figure. Wood gives higher temperature for most of the zones and particle size of 22-25 mm gives lower temperature, this is may be lignite’s higher ash content which creates ash fusion. This is called clinker and it is resistant to heat.

By using wood as a fuel, continuous flame is generated but by using lignite, continuous flame is not generated. As per the gas calorific value, Wood has maximum calorific value. Among three particle sizes, 22-25 mm size gives better result.



Fuel consumption is higher in the case of wood than lignite. From experiments, it is shown that, as particle size increases, fuel consumption decreases.

Previously, it was considered that Gas flow rate is almost constant for all fuel and particle size. It is not much affected. But later on, from experiments, it is shown that system is choked up after few hours for lignite gasification and flow rate decreases due to clinker formations. Cold gas Efficiency of 22-25 mm is higher comparison with other particle sizes. For wood it is 70.536%. Uneven lignite gives lower efficiency.



IV. Results and discussion

1. Fuel consumption of lignite for 10kW downdraft gasifier is typically 8 to 10 kg/hour.
2. Gas generation rate is almost constant in the range 25 to 26 m³/hour in all cases.
3. Efficiency of gasifier is much dependent of particle sizes. Efficiency is better for lignite particle size 22-25 mm among all seven particle sizes.
4. Calorific value of producer gas with lignite particle size 22-25 mm was reported as 629 kcal/m³.
5. Minor Clinkers are found in 22-25 mm particle size of lignite.

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