Indian Journal of Science and Technology Vol. 3 No. 6 (June 2010) ISSN: 0974- 6846

A study on biomass in power generation

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Abstract

In the present scenario of energy crisis, emission reduction and carbon trading for clean environment, usage of biomass as alternate energy source for power generation have become ubiquitous. In this work an attempt is made to study the variation in performance of a bio-mass based power plant while using different biomass as fuel. The experiments have been carried out on 6 MW power plant consisting of a boiler with capacity of 28,000 kg/h and a turbine unit with 6000 kW power rating runs on Rankine cycle. The suitability of different biomass sources as fuel for the power plant has been tested. The plant performance is compared while using different bio-mass as fuel. The results show that among tested biomass sources viz., subabul wood with bark, tumma Japan wood, eucalyptus bark, subabul bark, casurina root and coal (grade-E), the tumma Japan wood is giving high overall efficiency.

Keywords: Biomass, power generation, alternate energy, fuel, power plant.

Introduction

In India, about 46% of the total energy consumption is estimated to be met from various biomass resources i.e. agricultural residues, animal dung, forest wastes, fire wood etc. India produces a huge quantity of agricultural residues, which can be converted into energy. Biomass is available in the country in large quantities in the form of agricultural, forestry and agro-industrial residues. More than 500 million tones of crop residues are produced every year, a large portion of which is either wasted or used inefficiently. Conservative estimates indicate that even with the present utilization pattern of these residues and by using the surplus biomass material, more than 16000 MW of grid-quality power can be generated for decentralized applications (TERI Report No. 2000RT45). Furthermore, biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities. It is derived from numerous sources including the byproducts from the wood industry, agricultural crops, raw material from the forest, household wastes etc. Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as fuel. Its advantage is that it can be used to generate electricity with the same equipment that is now being used for burning fossil fuels (Mukunda *et al.,* 1993). Biomass is an important source of energy and the most important fuel world wide after coal, oil and natural gas, bioenergy in the form of biogas, which is derived from biomass. It is expected to become one of the key energy resources for global sustainable development. Nowadays a number of conversion technologies are available for use of various biomass materials for energy purpose. Some of such conversion technologies are biogas plants, biomass briquetting, biomass gasifiers, high efficiency wood burning stoves, bio fuels, bio-power plants and biomass cogeneration. Bio-power can be relevant for dispersed power/energy production, particularly in small and medium capacities. Substantial technology development and demonstration programmes have been undertaken during the last two decades in various countries (Jain, 2000).

Bio-power or biomass power can be obtained by converting the biomass using various technologies viz., direct-fired, co-firing, gasification, anaerobic digestion etc. Most of the bio-power plants in the world use direct-fired systems. Bio energy feed stocks are burnt directly in boiler to produce steam. This steam drives the turbo-generator. In some industries, the steam is also used in manufacturing process or to heat buildings where such systems are called combined heat and power facilities (FAO, 1986). In India, many types of biomass are available and are being used at different locations for the purpose of power generation. In this work, an attempt is made to study the performance of the 6 MW power plant using different biomass.

Materials and methods

Experiments have been carried out at a 6 MW power generation plant. The power plant consists of a boiler with rate capacity of 28,000 kg/h, steam pressure 66 kg/cm^2, feed water temperature around 130°C and steam outlet temperature of 485°C ± 5. The boiler is connected to 6000 kW turbine at a rated speed of 8280 rpm with an alternator with a speed of 1800 rpm. Inlet steam at 64 kg/cm^2 and 485°C enters the turbine with flow of 25600 kg/hr. Other components like economizer, air heater, feed pump, control valves and water treatment plant were arranged as per the requirements.

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Experiments were carried out under different inlet steam pressures. Different parameters *viz*. outlet steam pressure, outlet steam temperature, bleed steam pressure and bleed steam temperature, condenser pressure & temperature, steam flow rate, fuel flow rate, generated power out put and rate of fuel consumption were observed. On the basis of the above parameters, boiler efficiency, generator efficiency, turbine efficiency and cycle efficiency were calculated and subsequently overall efficiency of power plant is calculated. These experiments are repeated for different biomass usage and the variation in the performance of the power plant is observed.

Conclusion

The performance of power generation plant has been studied and the following conclusions are drawn.

- Cycle efficiency of the plant reduces as the inlet steam pressure is decreased.
- By using tumma Japan wood as a fuel, the overall efficiency of the plant increased and is about 17.57%.
- As usual the steam flow rate is the primary parameter which affects the performance of the turbine.

Table 1. Cycle efficiency at 485^{0}C turbine inlet steam temperature

Inlet turbine steam pressure	Bleed steam pressure	Exit steam pressure	Condenser pressure	Cycle efficiency
P_1= 65 bar	P_2=2.5 bar	P_3=0.85 bar	0.1 bar	36.02%
P_1= 60 bar	P_2=2.5 bar	P_3=0.85 bar	0.1 bar	35.00%
P_1= 55 bar	P_2=2.5 bar	P_3=0.85 bar	0.1 bar	35.00%
P_1= 40 bar	P_2=2.5 bar	P_3=0.85 bar	0.1 bar	33.06%

Table 2. Power generated with respect to steam flow rate

Steam flow rate in kg/h	Generated power in MW
11000	1
14800	2
17850	3
21500	4
25020	5
28000	6

Results and discussion

On the basis of observations and relevant calculations the cycle efficiency of the plant at inlet steam temperature of 485°C is changed as shown in Table 1. Steam flow rate is the primary parameter which affects the performance of the turbine (Table 2). Effect of various bio-mass on overall efficiency of the power plant is recorded in Table 3.

References

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Table 3.Overall efficiency with respect to different biomass

Type of fuel	C.V. in Kcal/kg	Fuel consumption/day in tonnes	Consumpti on in kg/hr	Efficiency of the boiler (%)	Overall efficiency of the power plant (%)
Subabul wood with bark	4560	200	8333	55.6	13.8
Tumma Japan wood	3850	185	7708	72.9	17.57
Eucalyptus bark	3800	210	8750	65	16.1
Subabul bark	3850	220	9166	58	14.6
Casuarinas root	3990	205	8542	52	13.06
Coal (Grade E)	3600	155	6458	93.1	23.9