การประชุมวิชาการเครือข่ายวิศวกรรมเครื่องกลแห่งประเทศไทยครั้งที่ 14
2-3 พฤศจิกายน 2543 โรงแรม โนโวเทล เชียงใหม่

BIOMASS-FIRED BOILERS IN SOUTHERN THAILAND: THE CHARACTERISTICS AND OPPORTUNITIES

Phutthipong Saensabai, Suteera Prasertsan and Gumpon Prateepchaikul
Department of Mechanical Engineering, Faculty of Engineering, Prince of Songkla University,
Hat Yai, Songkla 90110, Thailand

ABSTRACT

Biomass is a high potential renewable energy source which can be found locally and replantable. The important biomass in the South of Thailand are rubber wood and oil palm residues. This paper presents the survey results of biomass usage in ten factories of three industries namely; fishmeal, wood-based furniture manufacturing and palm oil milling. Characteristic of fuel oil-fired boiler in seafood processing and beverage bottling factories were studied for comparison. Rubber wood fuel appears in the forms of wood off-cuts, lumber and saw dust while that of the palm oil are fiber and shell. The energy costs from the biomass were 20.16, 24.49, 29.41 and 45.10 Baht/GJ for oil palm fiber, saw dust, rubber wood off-cuts, and wood lumber, respectively, which is substantially low compared to that of 113.15 Baht/GJ of fuel oil. The efficiencies of the biomass-fired boilers were about 36.5-45.0 % for oil palm fiber, 36.1-65.7 % for rubber wood waste and 78.5-80.4 % for saw dust. The fuel oil-fired boiler had an efficiency of 82.7-86.0%. However, the steam generation cost were 101-125, 101-184, 69-71 and 297-309 Bahts per ton of steam for oil palm fiber, rubber wood waste, saw dust and fuel oil, respectively. Economically, there is an opportunity for biomass to substitute the fuel oil.

1. INTRODUCTION

In 1995, Thailand consumed 10,137.9x10^6 liters of fuel oil [1]. Since domestic production is minor, almost all of the fuel oil is imported. The recent devaluation of the Baht severely affected the energy cost of all sectors.

Biomass residues from rubber and palm oil plantation are important energy sources of local industries in Southern Thailand. The rubber plantation and oil palm plantation cover areas of 10x10^6 and 1x10^6 rais, respectively (1 rai = 0.16 ha). Since the rotation period of the rubber trees is 25-30 years, about 300,000 rais of rubber plantation have to be cleared every year for replantation. This activity generates huge amount of wood off-cuts and lumber at the saw mills and rubber wood furniture factories. The wood off-cuts are available for boiler feed for many local industries such as rubber wood drying, brick making and fish meal. Palm oil fruit bunches are delivered to the palm oil mills for milling. The solid wastes generated from the milling process are the empty fruit bunches (EFB) (25-27%), pressed pericarp fiber (PPF) (10-13%) and shell (16-20%) [2-3]. The PPF and only some shell are the boiler feed for the mills. In the past, it is not surprising that some modern industries such as seafood processing and soft drink bottling prefer fuel oil to biomass as their boiler feed. However, the devaluation of the Baht has changed the attitude of the factories'owners to look for a cheaper alternative; the biomass-fired boiler.

Concurrently, in 1997 the Department of Energy Development and Promotion (DEDP) embarked a field survey study of the production and utilization of biomass as fuel. One of the main objectives is to estimate the availability of biomass if cogeneration or small power producer projects are to be implemented. Prince of Songkla University, by the Department of Mechanical Engineering, has surveyed and collected data of 1500 factories in the South of Thailand. The work included extensive study of energy usage and energy conservation opportunity of ten factories in five industries namely; fishmeal, wood -based furniture, palm oil milling, seafood processing and beverage bottling. All these industries consumed steam for their processes, hence boilers are commonly installed in these factories. Energy auditing of boilers was of interest. This paper reports a survey study of the characteristic of the biomass-fired boilers in comparison to the fuel oil-fired boilers in the above-mentioned industries. It is a preliminary study that will hopefully lead to an extensive study on the improvement of using biomass in these industries.

2. MATERIAL AND METHOD

Method of collecting data in biomass-fired boiler varied from factory to factory because these factories were not properly equipped with instrumentation. The measured data were fuel consumption, temperature and humidity of ambient, temperature and composition of flue gas, pH and conductivity of feed water, and steam production rate and quality (P,T).

Fuel consumption was the most important data, but, in some cases, was quite difficult to measure accurately. Not only because of the non-steady feeding nature of the bulk biomass (e.g., in case of firewood), but also the feeding rate and method depend on the boiler operators. Moreover, energy quality of the fuel depends on moisture content. Firewood consumption was obtained by weighing scale. Fine biomass like saw dust and palm fiber consumptions were determined from the conveyor feeding rates. Temperatures were measured by a digital thermometer. The flue gas composition was analyzed by Bachrach Fyrite Gas Analiser. Data were analyzed by Combustion Analysis and Efficiency Calculation Version 1.20, a software developed by SSC, USA.

3. RESULTS AND DISCUSSION

The survey results are tabulated in Table 1. It was obvious that in term of energy cost, the biomass waste generating industries enjoy the use of biomass waste as their energy source because it help mitigating the dispose off problem. Therefore, there is no procuring cost involved. In fact, for the waste generating industries, the use of biomass waste has a positive value in term of economics. Fishmeal and rubber smoking factories bough biomass fuel from rubber wood and palm oil factories. The fuel cost is negligible in comparison of the transportation cost. The survey found that the cost of lumber, wood off-cuts, saw dust and palm fiber were 45.10, 29.41, 24.49 and 20.16 Baht/GJ, respectively. Saw dust and palm fiber are cheaper because they are freely available, but the firewood (lumber and wood off-cuts) is a salable waste, e.g., to particle board and MDF board manufacturers and as firewood to local industries.

Efficiencies of the biomass-fired and fuel oil-fire boilers are given in Table 2. It is apparent that because of the controllable burner, the fuel oil boilers are higher in efficiency than that of the biomass-fired boilers. Saw dust was fed by screw conveyors and the efficiency was in the range of 80%, which is relatively high in comparison to the palm fiber boiler. The saw dust was rather dry (10% moisture content, dry basis). The palm fiber, especially at the palm oil mills, was rather wet since it was fresh from the screw presses. In addition,

Table 1. Biomass utilization in industries.

Factories	Fuel	Fuel consumption (ton/yr)	Fuel price (Baht/kg)
Palm oil mill 1	palm oil fiber	23,000	free
Palm oil mill 2	palm oil fiber	19,829	free
Furniture manufacturing 1	Wood off-cuts	283	free
	Wood off-cuts	1,425	0.40
Furniture manufacturing 2	Wood off-cuts	30	Free
Furniture manufacturing 3	wood off-cuts	6,077	Free
Rubber smoking factory	Lumbers	5,452	0.61
Fishmeal factory 1	saw dust	4,954	0.33
Fishmeal factory 2	palm oil fiber	2,113	0.25
Seafood processing	fuel oil	4,015,944 (l/yr)	4.5 (Bath/l)
Beverage bottling factory	fuel oil	503,700 (l/yr)	4.5 (Bath/l)

the palm fiber was conveyed pneumatically. It is inevitable that the pneumatic conveyors of a wet (and heavy) fiber supplied excess air of several hundred percent to the boiler. These are the main causes of the very poor efficiency. Efficiencies of the firewood-fired boilers are in the range of 36-65%. It was interpreted that the noncontinuous feeding was responsible for the poor efficiency. It also depends on the operating manner of the furnace operator.

The comparison of different fuels (different cost) is properly indicated by the steam generation cost. The comparison is made for saturated steam at 100 °C (h_{fg} =2256.94 kJ/kg). The steam cost (SC) is given by,

$$SC = 2256.94\text{x}10^{-3}\,\frac{EC}{\eta} \qquad (1)$$

where, η = boiler efficiency

EC= energy cost (Baht/GJ heat)

Steam costs in Table 2 revealed that saw dust produced the cheapest steam at 70 Baht/ton. The corresponding figures for the palm fiber and firewood are 101-125 and 111-114 Baht/ton. As expected, the fuel oil was the most expensive fuel for steam production. Steam produced by fuel oil was over four times of that of the saw dust. The recent economic crisis in the country has worsen the competitiveness ability of the fuel oil. The fuel oil price was doubled while there was no adverse change on the biomass fuels. In fact, the rubber wood processing industries, as the export industry, gained advantage from the devaluation of the Baht. The more the rubber wood furniture is produced (to meet the increasing order), the more the woody waste is generated. Wood off-cut was sold at 0.18 Baht/kg in March 1998, over 10 % reduction from the same month in 1997.

Apart from the cost advantage, the use of biomass waste has 2-fold benefit for the biomass waste generating industries; i. e., waste reduction (reduce the dispose off cost) and self sufficient in energy (reduce production cost). The sale of biomass waste to other industries provides additional income. Or if the amount of waste is sufficient to feed a power plant, electricity can be sold to the grid. Electricity produced from the renewable biomass is friendly to environment as no net CO_2 emission and negligible amount of SOx is released to the atmosphere [4-5].

Table 2. Boiler efficiency.

Factories	Fuel type	Boiler combustion efficiency (%)	SC (B/t)
Palm oil milling 1	palm oil fiber	36.5	124.7
Palm oil milling 2	palm oil fiber	39.4	115.3
Furniture manufacturing 1	wood off-cuts	65.6	101.1
Furniture manufacturing 2	wood off-cuts	36.1	184.0
Furniture manufacturing 3	wood off-cuts boiler 1	51.6	128.7
	wood off-cuts boiler 2	59.6	111.3
Fishmeal factory 1	saw dust boiler 1	80.4	68.7
	saw dust boiler 2	78.4	70.5
Fishmeal factory 2	palm oil fiber	45.0	101.0
Seafood processing	fuel oil boiler 1	86.0	297.1
	fuel oil boiler 2	84.8	301.0
	fuel oil boiler 3	82.7	308.6
	fuel oil boiler 4	83.1	307.3
Beverage bottling factory	fuel oil	85.6	298.2

Opportunity of the biomass-fired boiler is apparent from an example case in a seafood factory in Hat Yai, South of Thailand. Because of the increase of the fuel oil price, the factory has looked for alternative source of energy. One of the fuel oil-fired boiler was replaced by a wood-fired boiler. The annual energy cost saving (ECS) can be calculated from.

$$ECS = \left[\left(\frac{QP}{(HV)\eta}\right)_{FO} - \left(\frac{QP}{(HV)\eta}\right)_{W}\right]h \qquad (2)$$

where, Q = heat required by the steam (kJ/h)

P = fuel price (B/kg or B/l)

HV = heating value of fuel (kJ/kg)

h = operating hour (h/y)

FO and W stand for fuel oil and wood, respectively

Heat required by the boiler was determined from the steam generation capacity (7 t/h) (at 175 °C and 8 bars) as 18,464,460 kJ/h. Fuel prices were 0.21 Baht/kg and 5.30 Baht/l for the firewood and fuel oil, respectively. The corresponding heating values are 13.6 MJ/kg (calculated from LHV of 17.9 MJ/kg and 24% moisture content) and 39.77 MJ/l (DEDP, 1995). The heating value of the firewood was analyzed by the Department of Science Service. The operating hour was estimated as 5,600 h/y. The installation of the biomass-fired boiler costed the factory about 4 million Bahts. It was calculated that the annual saving on energy cost was over 13 million Bahts, which is a very attractive figure.

The annual energy saving depends on the relative specific energy cost (RC) of the two fuels as given in Equation 3 and depicted in Figure 1. Boiler efficiencies of the oil and biomass boilers for Figure 1 are 80% and 65%, respectively.

$$RC = \left(\frac{P}{HV.\eta}\right)_{FO}\left(\frac{HV.\eta}{P}\right)_{W} \qquad (3)$$

$$= 0.241\ P_{FO}/P_{W}$$

Equations (2) and (3) were simulated for firewood price of 0.15-0.31 Baht/kg and fuel oil price of 4.5-6.9 Baht/liter. It is obvious that the energy cost saving increases as the relative specific energy cost increases. The minimum energy cost saving of about 9.8 million Bahts per year occurred at the minimum fuel oil price but maximum biomass price.

4. CONCLUSION

The economic crisis in Thailand offered an opportunity for the biomass waste to play an important role in the industrial sector in the South of Thailand. The overlooked energy source becomes a rescue agent for the local industries. Even with lower boiler efficiency, the biomass fuel substitution is feasible economically.

5. REFERENCES

[1] DEDP, *Oil and Thailand 1995*, Department of Energy Development and Promotion, Ministry of Science, Technology and Environment, Bangkok, 1995

[2] Kirkaldy J. L. R. and Sutanto, J. B., Posible Utilization of By-products from Palm Oil Industry, *Planter*, Vol. 52, pp. 118-126, 1976.

[3] Okiy, D.A., Chemical and Biological Characterization of the By-products of NIFOR Palm Oil Mill, International Oil Palm/Palm Oil Conferences Progress & Prospect: Conference II: Technology, 29 June – 1 July 1987, Kuala Lumpur, pp.1-16.

[4] Halim Shamsuddin and Ilmi Abdullah, Clean and Efficient Combustion of Palm Oil Solid Waste in Fluidized Bed Combustion, *Proceeding of International Symposium on Advances in Alternative & Renewable Energy*, 22-24 July 1997, Malaysia, pp. 447-455.

[5] Mohd. Rozainee Taib, Foo Chek Gee, Chan Site Chun and Ramli Mat, Characteristic of Particulate Emission from Palm Oil Mill Steam Boiler Plants Using Palm Shell and Fiber as Fuel, *Proceeding of EUROPEAN-ASEAN Conference on Combustion of Solids and Treatment of Products*, 16-17 February 1995, Hua Hin, Thailand, pp. 387-396.

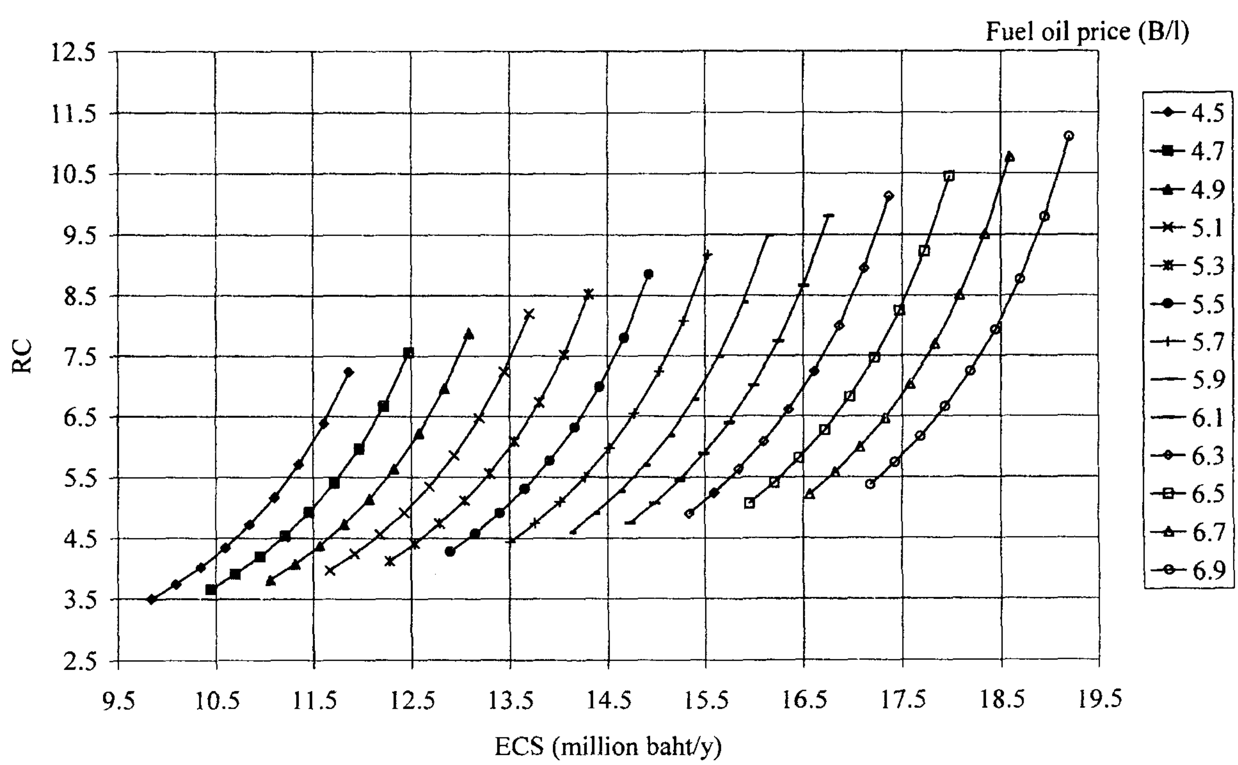

Fig. 1 : Energy cost saving of biomass-fired boiler