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Cogeneration Analysis of Krebet Baru II Sugar Factory Milling Capacity

Arif Hidayat[1], Saptyaji Harnowi[2]
Department of Plantation Industry Machinery Engineering Technology, Politeknik LPP Yogyakarta, Indonesia, 55222

arh@polteklpp.ac.id

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Abstract

Sugar producers can extend their sugar companies by expanding into non-sugar products. A sugarcane-based company that focuses on product diversification is electricity generation from bagasse. As the principal energy source, the cogeneration system progressively creates two distinct forms of energy (mechanical energy and thermal energy). Krebet Baru 2's sugar factory has a capacity of 5,200 TCD. Under some conditions, it can generate up to 1.5 MW of additional Power. This research aims to investigate the link between capacity and cogeneration efficiency. As a result, extra electricity may be generated forever. According to the data, capacity did not influence cogeneration efficiency. Excess Power may be acquired by optimizing steam usage, assessing inefficient energy sources, and utilizing high-pressure steam production facilities.

Keywords: Diversification Products, Sugar Mill Capacity, Cogeneration System, Excess Power

Abstrak

Produsen gula dapat mengembangkan perusahaan gula mereka dengan berekspansi ke produk non-gula. Perusahaan berbasis tebu yang berfokus pada diversifikasi produk adalah pembangkit listrik dari ampas tebu. Sebagai sumber energi utama, sistem kogenerasi secara progresif menciptakan dua bentuk energi yang berbeda (energi mekanik dan energi panas). Pabrik gula Krebet Baru 2 memiliki kapasitas 5.200 TCD. Dalam beberapa kondisi, pabrik ini dapat menghasilkan daya tambahan hingga 1,5 MW. Penelitian ini bertujuan untuk menyelidiki hubungan antara kapasitas dan efisiensi kogenerasi. Hasilnya, listrik tambahan dapat dihasilkan selamanya. Menurut data, kapasitas tidak mempengaruhi efisiensi kogenerasi. Kelebihan daya dapat diperoleh dengan mengoptimalkan penggunaan uap, menilai sumber energi yang tidak efisien, dan memanfaatkan fasilitas produksi uap bertekanan tinggi.

***Kata-kata kunci**: Diversifikasi Produk, Kapasitas Pabrik Gula, Sistem Kogenerasi, Kelebihan Daya*

1. Introduction

The sugar industry has been the oldest and most important since colonization. During the 1930s and 1940s, Java Island was a significant sugar producer and exporter, ranking second to Cuba, with a total production of over 3 million tons per year from a sugarcane area of 200 thousand hectares. Diversification of non-sugar items is critical for the survival of Indonesia's sugar industry. Sugarcane is both a meal and a source of energy. Because energy is generated by burning bagasse biomass, the sugar industry is categorized as a self-sufficient energy sector **[1] – [3]**. One is the generation of bagasse-based electricity to realize a sugarcane-based integrated business emphasizing product diversification. Each sugar refinery may generate electricity for the power grid using high-pressure boilers and condensation extraction turbines **[4].**

A cogeneration system is described as generating two distinct forms of energy (often mechanical and thermal) from a single primary energy source **[5]**. The mechanical energy is converted into electrical energy, whereas the heat energy is consumed immediately. Bagasse is used as boiler fuel to generate steam, subsequently used to power alternator turbines in the sugar industry to generate electricity **[6]**. At 50% moisture content, Ampass has a heating value (GCV) of 9600Kj/Kg and an NCV of 7600 Kj/Kg) **[7]**. Ex-turbine steam has sufficient pressure and temperature to be used as a heater in sugar-making. An efficient cogeneration system can increase sugar sector power production from 20 kWh/tc to 70 - 120 kWh/tc. The sugar industry may obtain additional cash by selling excess Power to PLN. Sugarcane might help the government fulfil its 23% renewable energy mix target by 2025.

PT PG Rajawali I has a business unit called PG Krebet Baru II in Krebet Village, Malang Regency, East Java. This sugar mill is equipped with a milling capacity of 5200 TCD. PG Krebet Baru II can create excess Power in certain circumstances, supplied to PG Krebet Baru I to 1.5 MW. Several case studies are available on energy efficiency measures in cogeneration units to increase electricity production capacity **[8]**.

2. Method

This is quantitative research in which data on milling capacity is gathered randomly from the field and examined to make conclusions. The data is acquired by direct observation of the cogeneration system's operations. The data set includes operating data for the mill, boiler, and powerhouse stations. The data was also analyzed to determine the link between milling capacity and cogeneration efficiency. The first is a pulp fuel analysis, which comprises pulp availability and calorific value based on mill station operational data. The second research uses boiler station operational data to conduct a direct method analysis of steam production performance in boilers, including boiler efficiency. Based on powerhouse station operational data, the final investigation looks at the turbine alternator's energy-generating capabilities, including isentropic efficiency and Specific Steam Consumption (SSC). The last investigation is a cogeneration system analysis that covers cogeneration efficiency, Plant Heat Rate, and Plant Fuel Rate.

3. Results and Discussion

3.1 Dreg Fuel

The first phase in the sugar cane production process is sap extraction in the mill, which separates the sap from the pulp. The sap is then turned into sugar. Bagasse, in the meanwhile, is used as boiler fuel. Bagasse has the potential to be a valuable energy source because it is high in PGs and renewable. In just 12 months, one hectare of soil may produce up to 30 tons of bagasse. The amount of bagasse produced by a sugar mill is influenced by the coir composition of the sugarcane variety being processed. The amount of bagasse produced may be calculated using the formula below.

$$\text{Flow Rate Ampas} = \frac{\text{Fiber in Bagasse}}{\text{Bagasse in Cane}} \times \left(\frac{Q}{24}\right) \qquad (1)$$

Where Q is the projected milling capacity over the next 24 hours.

The calorific value of pulp is used to describe its combustibility. The calorific value of dregs from end mill performance is determined by their moisture content (MC) and pol content. The following equation calculates the calorific value of dregs, according to Hugot (1986).

$$\text{Flow Rate Ampas} = \frac{\text{Fiber in Bagasse}}{\text{Bagasse in Cane}} \times \left(\frac{Q}{24}\right) \qquad (2)$$

Where W is the MC of the pulp and P is the pol content of the pulp. The data obtained is used to compute the amount of dregs and the calorific value of dregs. Dreg fuel is presented on **Table 1.**

Table 1. Dreg Fuel

Q (TCD)	Fibre in Bagasse (%)	Bagasse in Cane (%)	MC (%)	Pol (%)	Flow rate Ampas (TPH)	NCV (kJ /kg)
5532	14,05	28,68	49,62	1,35	112,92	7760,2
4812,4	16,14	33,75	50,27	1,74	95,89	7613,4
5239,2	14,74	30,36	49,92	1,59	105,99	7689,9
4903,2	16,14	33,75	50,41	1,77	97,70	7584,0
3414	14,86	30,36	49,89	1,59	69,63	7696,0
5439,7	14,05	28,68	49,61	1,34	111,04	7762,7
4000,2	14,74	30,36	49,93	1,47	80,92	7693,0
5240,8	12,49	25,63	49,73	1,38	106,41	7736,9
5580,7	14,01	29,46	50,16	1,59	110,58	7641,7
5575,2	13,69	28,34	49,91	1,47	112,22	7697,0

3.2 Steam Generation in Boilers

Steam is produced by two types of boilers at PG Krebet Baru II: Yoshimine (working pressure 21 bar, capacity 80 TPH) and Maxitherm (working pressure 46 bar, capacity 70 TPH). Boiler efficiency is employed to assess boiler performance. Direct approaches for calculating boiler efficiency entail comparing the output heat value to the input value. The energy produced by the working fluid (water and steam) is compared to the energy produced by waste fuel. This technique is faster in boiler assessment since it requires parameters and equipment for computation and monitoring. The boiler efficiency is expressed in straightforward methods is presented onbelow.

$$\eta\, boiler = \frac{m\ uap\ (h1 - hfw)}{m\ bb\ \times NCV\ bb} \qquad (3)$$

In which:

η *boiler* = boiler efficiency (%)

m up = mass flow of steam generated (kg/s)

h 1 = enthalpy of vapour (kJ/kg)

h fw = enthalpy feed water boiler (kJ/kg)

m bb = dregs fuel massflow (kg/s)

NCV bb = calorific value of dregs fuel (kJ/kg)

The dregs fuel mass flow is determined by comparing the amount of vapour produced to the evaporation ratio. Yoshimine has an eva ratio of 2, but Maxitherm has an eva ratio of 2.2. The sugar mill boiler fill water temperature is generally 105 degrees Celsius. The performance of steam generation in boilers is presented on **Table 2**.

Table 2. The Performance of Steam Generation in Boilers

Q (TCD)	Yoshimine				Maxitherm			
	m (TPH)	**P (bar g)**	**T (˚C)**	**ɳ (%)**	**m (TPH)**	**P (bar g)**	**T (˚C)**	**ɳ (%)**
5532	72	21,6	333	68,4	57	42,9	407	78,8
4812,4	53	22,2	335	69,8	52,9	40,8	392	80,1
5239,2	72	22,2	332	68,8	56	40,2	399	79,3
4903,2	71	22,1	329	69,6	55,6	41,7	404	80,4
3414	75	22	327	68,5	58,7	46,2	427	80,8
5439,7	68	22,3	329	67,9	55,7	46	417	79,4
4000,2	67	22	327	67,8	56	46	425	80,7
5240,8	75	22	338	68,8	50	44,2	414	79,5
5580,7	76	21,6	334	69,4	61,8	45,6	435	82,0
5575,2	64	22,1	331	68,7	60,3	46,1	423	80,4

3.3 The Energy Generation in Turbine Alternators

Five turbine units generate the Power used by PG Krebet Baru II. Three Brotherhood turbines of 1.5 MW each, one Drasser-Rand turbine of 1.8 MW each, and one Elliot turbine of 7 MW each. The turbine operation is customized to the plant's electrical needs, which range between 5 and 5.5 MW. Yoshimine powers the Brotherhood and Drasser-Rand turbines, while Maxitherm powers the Elliot turbine. In some instances, PG Krebet Baru II can produce excess Power transferred to PG Krebet Baru I up to 1.5 MW from the Elliot turbine. In contrast, in others, there is a deficit of Power (unless Power) so that it adds energy from PLN. Field observations show surplus Power may be acquired while the Elliot turbine is functioning.

The following equation can be used to calculate turbine power.

$$W_T=m\ (h1-h2) \qquad (4)$$

W_T = turbine real power (kW)

m = mass of steam entering the turbine (kg/s)

h_1 = enthalpy of turbine inlet steam (kJ/kg)

h_2 = enthalpy of turbine exit steam (kJ/kg)

Steam turbine performance is measured using isentropic efficiency and Specific Steam Consumption (SSC). The ratio of the enthalpy difference of natural conditions to the enthalpy difference of isentropic theoretical conditions is known as isentropic efficiency.

Steam turbines convert the potential energy of steam into kinetic energy, which is then converted into mechanical energy in the form of turbine shaft rotation, which is then forwarded to the alternator/generator, which converts the mechanical energy (shaft rotation) into electrical energy via electromagnetic induction. The sugar plant steam turbine is a counter pressure / back pressure turbine that uses steam at a pressure of 0.8 - 1.2 kg / cm2 to power the sugar-producing process. The Low-Pressure Steam Header (LPSH) will collect residual turbine steam and distribute it to process units that require spent steam. Steam supplementation is necessary when the used turbine steam is insufficient.

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$$\eta\,isen = \frac{h1 - h2}{h1 - h2s} \times 100\% \qquad (5)$$

In which:

η isen = isentropic efficiency (%)

h_1 = enthalpy of turbine inlet steam (kJ/kg)

h_2 = enthalpy of turbine exit steam (kJ/kg)

h_{2s} = enthalpy of theoretical steam exiting the turbine (kJ/kg)

The isentropic efficiency approach described above may be used to compare the performance of a turbine to its actual efficiency value. In addition to efficiency, turbine performance may be calculated using the following formula, based on the value of the steam turbine's capacity to generate a specific amount of Power.

$$SSC = \frac{3600}{h1 - h2} = kg/kWh \qquad (6)$$

SSC denotes the quantity of steam (kg) needed to generate 1 kWh of electricity. The lower the SSC value, the less costly the usage of steam. Figure 1 (a) shows the isentropic efficiency of the turbine, which varies between 58 and 78%, while Figure 1 (b) shows the SSC of the most cost-effective Elliot turbine, which ranges between 8 and 9 kg/kWh. generation performance on turbine alternator is presented in **Table 3** and relationship between grinding capacity and (a) isentropic efficiency (b) SSC is presented on **Figure 2** and **Figure 3**.

Table 3. Generation Performance on Turbine Alternator

Q (TCD)	5532	4812,4	5239,2	4903,2	3414	5439,7	4000,2	5240,8	5580,7	5575,2
Suplesi Uap (TPH)	16	9,5	18,4	18,4	15,1	12,1	4,3	21,9	9,5	3,6
Excess Power (kW)	1025	0	0	0	1007	825	492	0	1250	1212
Unless Power (kW)	0	946	1027	825	0	249	0	671	0	0

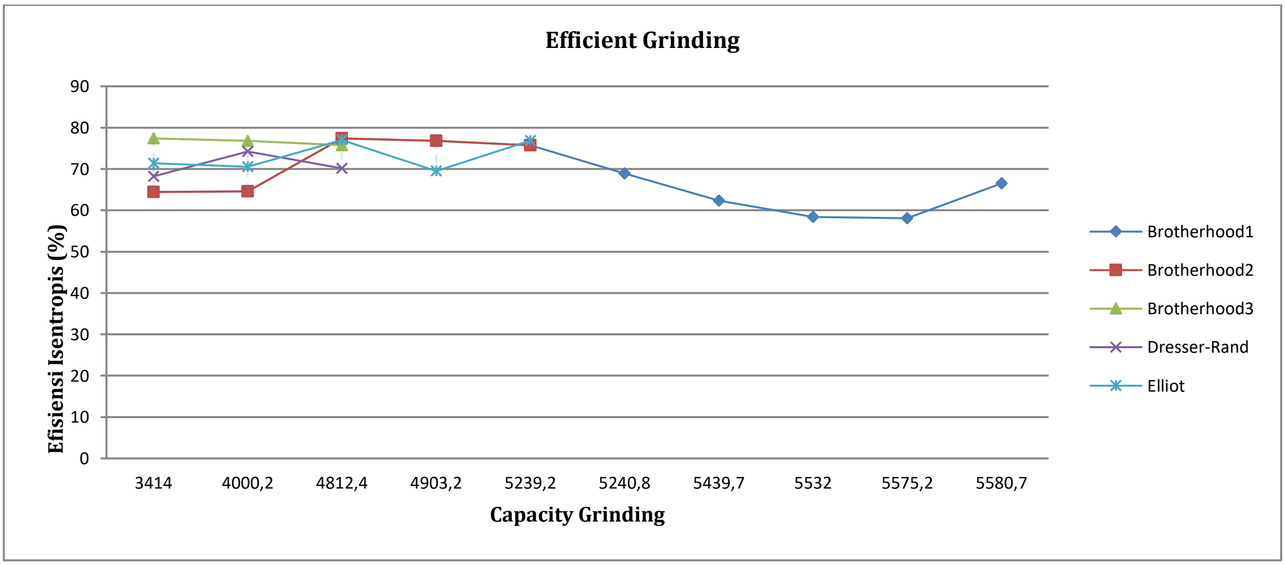

Figure 1. Relationship Between Grinding Capacity and Isentropic Efficiency

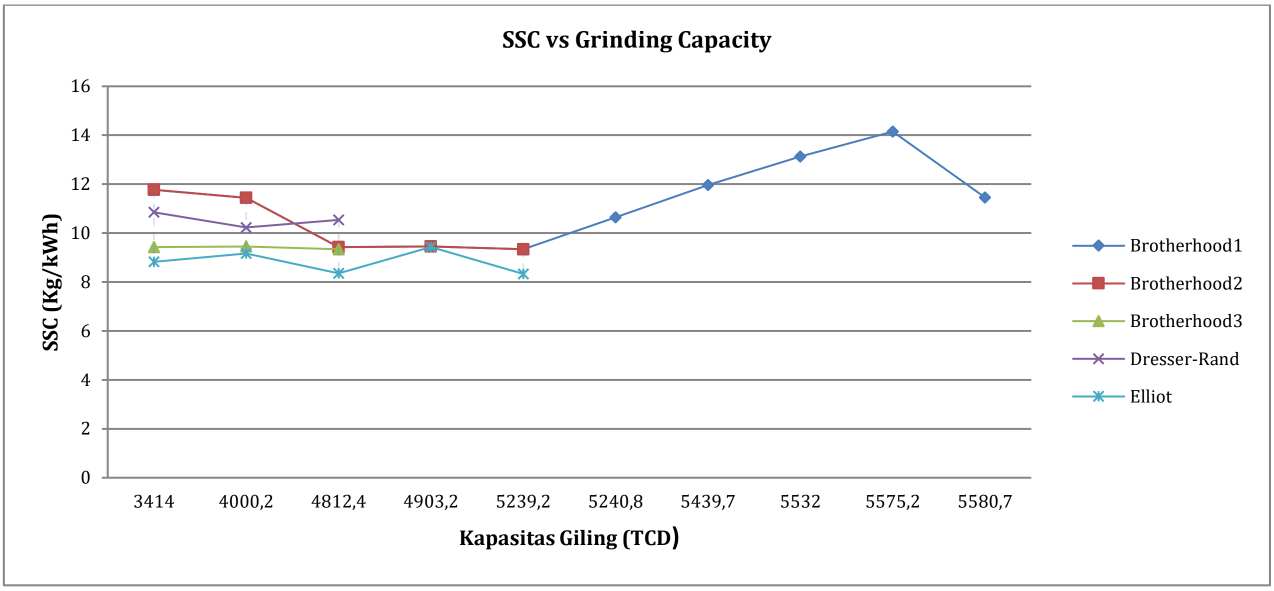

Figure 2. Relationship Between Grinding Capacity and SSC

3.4 Cogeneration System

A cogeneration system in a sugar mill is a sustainable technology that avoids voltage fluctuations by producing electricity. This form of electricity generation is also environmentally friendly because it produces little fly ash and contains no sulfur. They are also less expensive in terms of maintenance than fossil-fuel power plants.

According to the preceding studies, the performance of a cogeneration plant is determined by its cogeneration efficiency. Cogeneration efficiency (cogen) is defined as the ratio of total output energy (electrical and thermal) to fuel input, with a range of 55 to 80%, which is expressed mathematically as:

$$\eta\,\text{cogen} = \frac{W\ electrical + W\ thermal}{W\ fuel} \tag{7}$$

W electrical = Electrical energy generated from TA (kW)

W thermal = Thermal energy of spent steam to the process (kW)

W fuel = Input energy of fuel (kW)

The Plant Heat Rate is the heat energy (kCal) required to generate one kWh of electricity. It may be expressed mathematically as follows.

$$\text{OPHR}= (\text{ms} \times(\text{hs-how}))/(\text{power output (kW)}) \tag{8}$$

Ms = mass of vapour (kg/hr)

hs = vapor enthalpy (kCal/kg)

hfw = enthalpy feed water (kCal/kg)

The overall plant fuel rate is the quantity of fuel (kg) needed to generate one kWh of electricity. It may be expressed mathematically as follows.

$$OPFR = \text{(fuel consumption (kg/hr))/(power output (kW))} \quad (9)$$

The performance of the cogeneration system is presented on **Table 4**.

Table 4. The Performance of The Cogeneration System

Q (TCD)	5532	4812,4	5239,2	4903,2	3414	5439,7	4000,2	5240,8	5580,7	5575,2
PHR (kCal/kWh)	7711,6	7994	9240,7	9044,3	7459	7721,9	6851,5	9201,9	6785,5	7171,7
PFR (kg/kWh)	5,92	6,54	7,71	7,52	5,68	5,87	5,06	7,18	5,05	5,33

Relationship between grinding capacity and cogeneration efficiency is presented on **Figure 3**.

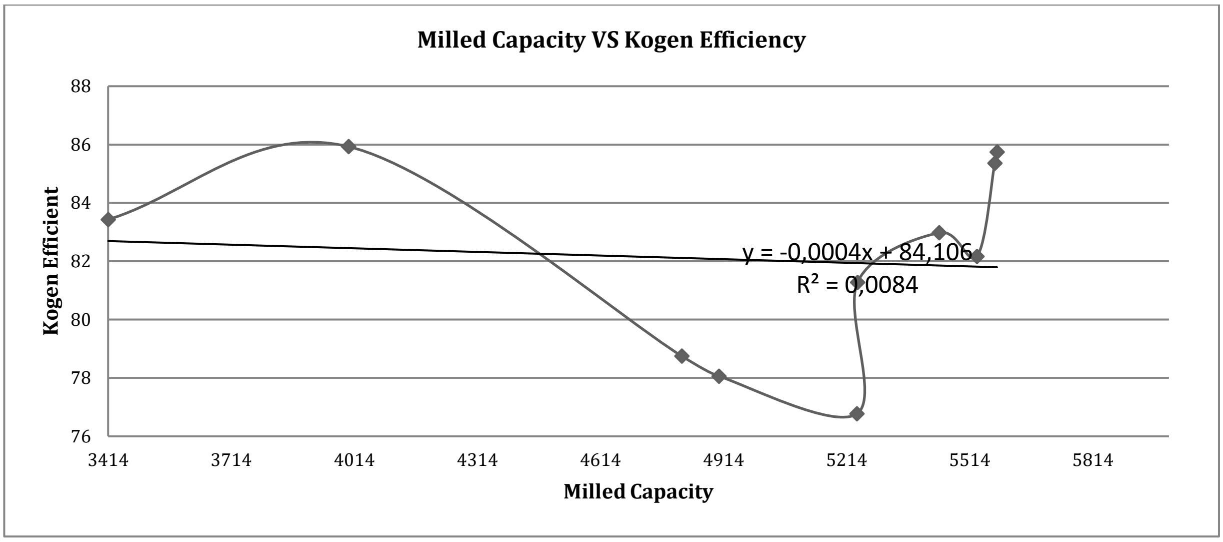

Figure 3. Relationship Between Grinding Capacity and Cogeneration Efficiency

Grinding capacity and cogeneration efficiency have no connection, as shown in Figure 2. A powerful cogeneration system integrates efficient mill operations and optimal energy usage. Using large amounts of steam augmentation to compensate for UBE shortages wastes energy. Energy surplus may be realized in two stages: evaluating energy conditions to determine the source of energy waste and adjusting PG energy strategies to reduce energy waste and attain optimal energy efficiency.

The operation of Maxitherm boilers and Elliot turbines at PG Krebet Baru II might provide more energy. In principle, UBA may be utilized in a cogeneration system and perform better if higher-pressure boilers and turbines (45 kg/cm2) are used. The Maxitherm boiler can generate up to 2.2 kg of steam per kilogram of pulp, but the Elliot turbine only consumes 8-9 kg/kWh of steam.

4. Conclusion

Based on the results, milling capacity does not influence cogeneration efficiency. The first step in obtaining surplus Power is to enhance energy consumption efficiency and identify sources of energy waste. Additionally, high-pressure steam production facilities can cut steam usage, boosting the possibility of generating excess Power. High-pressure steam must also be adapted to the kind of steam turbine.

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