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PROPOSED IMPLEMENTATION OF COGENERATION REGENERATIVE CYCLE IN SUGAR FACTORY WASTE RECYCLE SYSTEM

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ABSTRACT

Sugar factory is one of the most important manufacturing companies in Indonesia which has high linear impact on the economic field. Ironically, the environmental impact from this production process is high enough. Not only consuming high power of electricity, it also produces a solid and fluid waste. The best way to solve that problem is developing a better management system. It would support the concept of triple bottom line in sustainability which is demanding an effort to incorporate economic, environmental, and social. In the middle of this issue, Gempolkrep as a big sugar factory in Indonesia, plans to become an exporter of electricity power. The focus of this research is calculating technical feasibility of the power generator capability for the exporting electricity project. The calculated work parameters were availability of bagasse, cogeneration efficiency, cycle efficiency, boiler efficiency, and heat rate. The calculation result shows that bagasse availability would be enough for 5 months, 77.6% cogeneration efficiency and 88179.93 kJ/kWh heat rate.

Afterwards, an improvement of waste recycle system by implementing cogeneration regenerative is included in this research. Basically, this method enforces the system to be more efficient in heating process. Every single solid waste which is not combusted well will be recycled in this system. The outcome of proposed improvement planning approximately increase cogeneration efficiency until reach 80% and less than 31185 kJ/kWh heat rate. The same amount bagasse would be enough for more than 6 months operating time.

Keywords: Bagasse availability; Cogeneration; Cogeneration regenerative; Efficiency; Sugar Factory

1. INTRODUCTION

The main purpose of this research is calculating the technical feasibility of the factory to do a project of exporting electricity power. Then, improving the system based on the technical feasibility calculation result. Gempolkrep sugar factory was built in 1849, and still operating as one of the main sugar producers in Indonesia right now. It has a lot of changing in almost two centuries operating time until now. The factory milling capacity is 6000 ton sugarcane per day, with the output almost 480 ton sugar per day.

The factory plans to be an electricity exporter in the near future. At least it is targeted that every year the factory able to export electricity power in 10 months by using solid waste from 5 months production process as a fuel. In the end, the product of sugar factory would be sugar and electricity power.

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2. METHODOLOGY

Power Plant System In Sugar Factory

The main processes of sugar production in the factory are milling process and condensation. Milling process needs sugarcane as a raw material, and the steam is consumed to move the miller. And then, the bulk which is produced by milling process will be condensed in the condensation process with the support of steam. Steam is the main supporting fluids for production process, and it is produced by boiling water in the boiler. The boiling phase needs the fuel which is using solid waste (bagasse) of milling process. Cane components itself are consist of Moisture 50 %, Bagasse 31.5 %, Sugar Crystal 6.6 %, Molasse 4.1 %, Filter Cake 5.1 %, Fibre 14 % (Kummamuru, 2013). Based on the main processes of sugar production, this research focusses on 3 work station. They are Boiler station, Milling Station, and Power House station.

Calculated Variable

Technical feasibility study in this research uses several variable as calculated parameters.

Bagasse availability

Bagasse availability is calculated by using equation 1 (Hugot, 1960), with the waste % sugarcane around 31.5%.

$$Bagasse\ \ Availability = Sugarcane\ mass\ x\ Waste\ \%\ Sugarcane \tag{1}$$

Low Heating Value

The equation of low heating value bagasse (equation 2) is dependent with moisture (w) and pol (s) (Hugot, 1960). In this research, it is founded by the factory research that moisture level 50% and pol 2.1%.

$$LHV = 4250 - (48w) - (7{,}5s) \tag{2}$$

Boiler Efficiency

Here is the equation for calculating the boiler efficiency (Raut, 2014).

$$\eta = \frac{\dot{m}_{steam}\left(h_{steam\ output} - h_{water\ input}\right)}{\dot{m}_{fuel}\ x\ LHV}\ X\ 100 \tag{1}$$

Turbine Power

Turbine power equation is gained from thermodynamics equation (Moran & Shapiro, 2000).

$$W_T = \dot{m}(h_{in} - h_{out}) \tag{2}$$

Pump Power

Calculation of pump power in this research is gained from thermodynamics equation (Moran & Shapiro, 2000).

$$\dot{W}_P = \dot{m}\ (h_{out} - h_{in}) \tag{3}$$

Heat for Boiler

The heat needed for boiler is calculated by equation 6 below (Moran & Shapiro, 2000).

$$\dot{Q}_{in} = \dot{m}(h_{out} - h_{in}) \tag{4}$$

Heat for Production Process

Here is the equation for calculating the heat to produce in the process (Kiameh, 2002).

$$\Delta H_s = \dot{m}(h_{in} - h_{out}) \tag{5}$$

Cogeneration Efficiency

This equation is used to calculate efficiency of cogeneration cycle (Kiameh, 2002).

$$\eta_{co} = \frac{W_T + \Delta H_S}{Q_{in}} \quad (6)$$

Heat Rate

Heat rate of production process could be calculated by the equation 9 below (P. K Nag, 2008).

$$Heat\ rate = \frac{\dot{m}_{fuel} . LHV_{fuel}}{Netto\ Power} \quad (7)$$

Previous Research

Research in the field of sugar factory power system has been done by Moises Alves, Gustavo H.S.F. Ponce, Maria Aparecida Silva, Adriano V. Ensinas, which was published in Energy 91 (2015). It calculated electricity power of a sugar factory which used bagasse and straw as the main fuel.

3. RESULT AND DISCUSSION

Feasibility Study

In a factory that need heat steam to processing their product such a pulp paper factory, sago factory or even sugar factory, using works cycle that is called cogeneration. It means that the factory generate two or more thing in the same time, which is usually electricity or heat (Kiameh, 2002). That's why this research is using cogeneration cycle as a base model.

The first step of this research is collecting all data and reports from the whole production process of sugar in Gempolkrep. Such as boiler station, milling station, and power house station, because they are main processes of the system. Figure 1 below shows existing flow process of sugar factory which is formed by three main boilers, milling machines, power house station, and condenser.

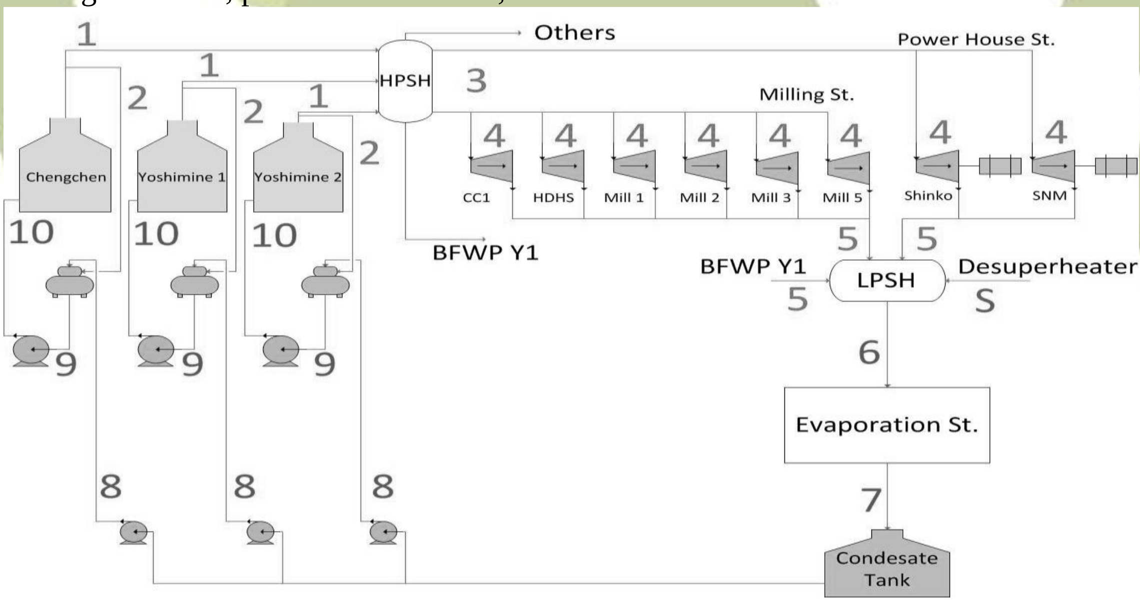

Figure 1 Existing Flow Process (Cogeneration Cycle)

Then, information of flow process shown in the T-s diagram in figure 2.

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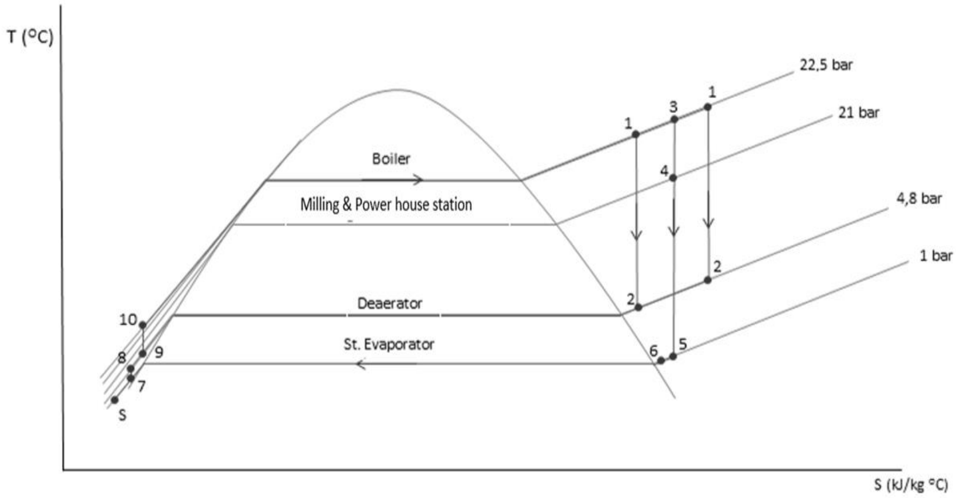

Figure 2 T-s Cycle Diagram of Existing System

Detail of calculated data from the system are shown in table 1 and table 2.

Table 1 Bagasse Availability

Main Data	
Total of Sugarcane in 2015	879100 Ton
Milling Capacity	6000 TCD
Milling Period	146.5 days
Bagasse Available	276916.5 Ton
Bagasse needed per period	Chengchen = 43838.82 Ton Yoshimine 1 = 102870.63 Ton Yoshimine 2 = 102902.31 Ton Total = 249611.76 Ton
Bagasse surplus	27304.74 Ton

By using the given data in research one period and equation 1, total bagasse surplus had gained. It is clear that in a year production period, there would be 27304.74 ton bagasse. Afterwards, all the data of another component in cogeneration cycle are calculated by using equation 2 to equation 9. And the result of calculation is shown in table 2.

Table 2 Cogeneration Efficiency and Heat Rate

Power for Turbines	Turbine Milling : Cane Cutter 1 = 157.9 kW HDHS = 841.21 kW Milling 1 = 220 kW Milling 2 = 213.89 kW Milling 3 = 213.89 kW Milling 4 =213.89 kW Total = 1860.8 kW Turbine Alternator: Shinko = 2113.48 kW SNM = 2068.24 kW Total = 4181.72 kW
Power for Pumps	Pump of Condensat: Chengchen = 2.55 kW Yoshimine 1 = 5.99 kW

	Yoshimine 2 = 5.99 kW Total = 14.54 kW Boiler’s pump: Chengchen = 12.57 kW Yoshimine 1 = 29.50 kW Yoshimine 2 = 29.51 kW Total = 71.58 kW
Production Process Power	73826.106 kW
Power Input for Boilers	Chengchen = 17999.2942 kW Yoshimine 1 = 42688.1849 kW Yoshimine 2 = 42234.6693 kW Total = 102922.148 kW
Cogeneration Efficiency	77.60 %
Heat Rate	85633.35 kJ/kWh

System Improvement: Cogeneration Regenerative Cycle

The improvement of production system in sugar factory by using cogeneration regenerative system in this research focuses on recycling the bagasse as a fuel. While the existing system could not be able to combust the fuel perfectly. There will be several changing in applying cogeneration regenerative system, such as replacement of component.

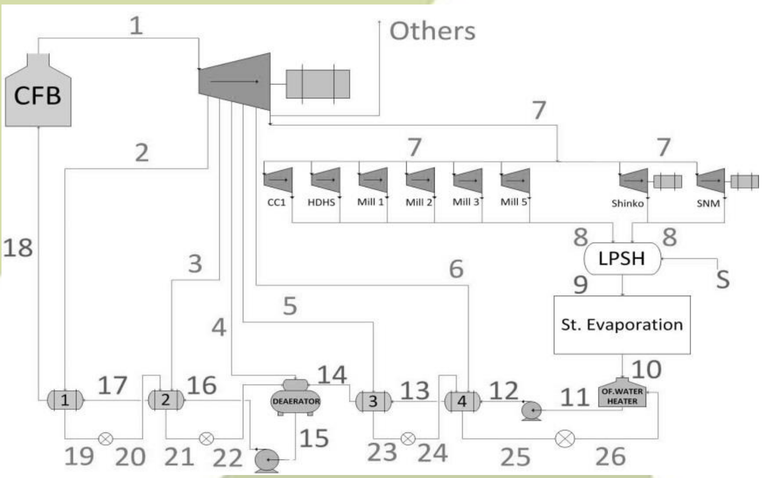

Figure 3 Cogeneration Regenerative Cycle in Gempolkrep Production System (Proposed Improvement)

The improvement process uses one CFB type main boiler as replacement of 3 boilers. This kind of boiler has been chosen because of its capability to combust the fuel better than an existing boilers. It is recycling the waste of fuel which is not combusted well in the process. So that the process efficiency would increase as high as an increasing steam quality which are resulted from the recycling process. Furthermore, an addition of 2 open feed water heater, 4 closed feed water heater and a turbine is important too. Addition of water heater expected to increase the temperature which will enter the boiler and reduce energy needs of condensate. Finally, the additional turbine would increase electricity power output, so that the surplus of power for exporting could be gained.

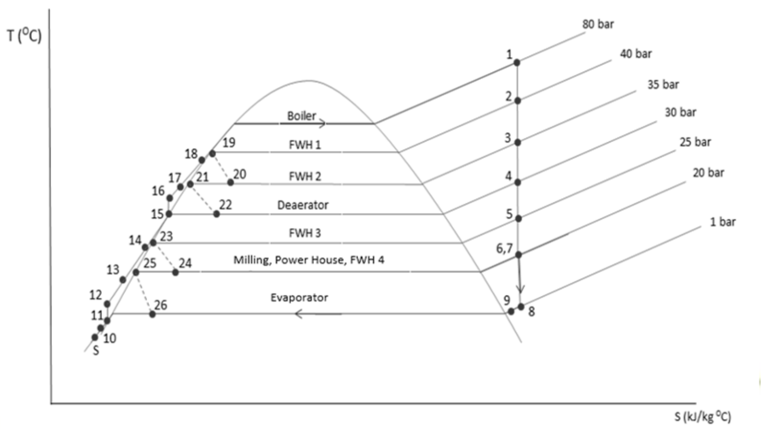

Figure 4 T-s Diagram of Cogeneration Regenerative Cycle

For simulation process. Pressure of boiler becomes independent variable. It is increased from the existing process by several bars, in the same entropy (6.84 kJ/kg). Table 3 contains data of extraction mass process based on the T-s diagram on figure 4. Then, table 4 shows information about the cycle performance according to variation of boiler pressure.

Table 3 Extraction Mass Process

P_{boiler}	**40 bar**	**50 bar**	**60 bar**	**70 bar**	**80 bar**
T (°C)	423.9	459.16	489.2	515.46	538.86
h (kJ/kg)	3268.9	3337.4	3396	3447.5	3493.7
$\dot{m}$ (kg/sec)	53.19	53.19	53.19	53.19	53.19
			Extraction		
FWH 1					
P (bar abs)	40	40	55	65	75
T (°C)	423.9	423.9	474.73	502.74	527.48
h (kJ/kg)	3268.9	3268.9	3367.7	3422.5	3471.2
$\dot{m}$ (kg/sec)	2.22	2.22	2.22	2.22	2.22
FWH 2					
P (bar abs)	35	35	50	60	70
T (°C)	403.59	403.59	459.16	489.2	515.46
h (kJ/kg)	3229.7	3229.7	3337.4	3396	3447.5
$\dot{m}$ (kg/sec)	2.78	2.78	2.78	2.78	2.78
Deaerator					
P (bar abs)	30	30	45	55	65
T (°C)	380.87	380.87	442.31	474.73	502.74
h (kJ/kg)	3185.9	3185.9	3304.6	3367.7	3422.5
$\dot{m}$ (kg/sec)	8.89	8.89	8.89	8.89	8.89
FWH 3					
P (bar abs)	25	25	40	50	60
T (°C)	349.36	349.36	423.9	459.16	489.2
h (kJ/kg)	3136.3	3136.3	3268.9	3337.4	3396
$\dot{m}$ (kg/sec)	1.67	1.67	1.67	1.67	1.67
FWH 4					
P (bar abs)	20	20	35	45	55
T (°C)	324.82	324.82	403.59	442.31	474.73
h (kJ/kg)	3079.7	3079.7	3229.7	3304.6	3367.7
$\dot{m}$ (kg/sec)	0.83	0.83	0.83	0.83	0.83

Table 4 Cycle Performance in Determined Boiler Pressure

P_{boiler}	40 bar	50 bar	60 bar	70 bar	80 bar
$P_{Main\ Turbine}$ (kW)	8205.9	11849.9	13045.9	14762.9	16331.5
$\dot{m}_{bb}$ (kg/sec)	15.84	16.34	16.53	16.77	17.04
$\dot{m}_{bb}$ (Ton/month)	41068.5	42351.3	42834	43471.3	44171
$\eta_{Cogeneration}$	80.69 %	81.50 %	81.65 %	81.95 %	82 %
Heat Rate(kJ/kWh)	31184.2	25860.9	24360.4	22668.9	21108.3
Estimated running Time (Months)	6.74	6.54	6.46	6.37	6.27

The result of cogeneration regenerative implementation in production process of sugar factory is drawn in figure 5 below. It is clear that all of turbines output in determined pressure are resulting more than 73826.106 kW which is production process needed. Furthermore, all of those options would make the operation time longer than in existing condition.

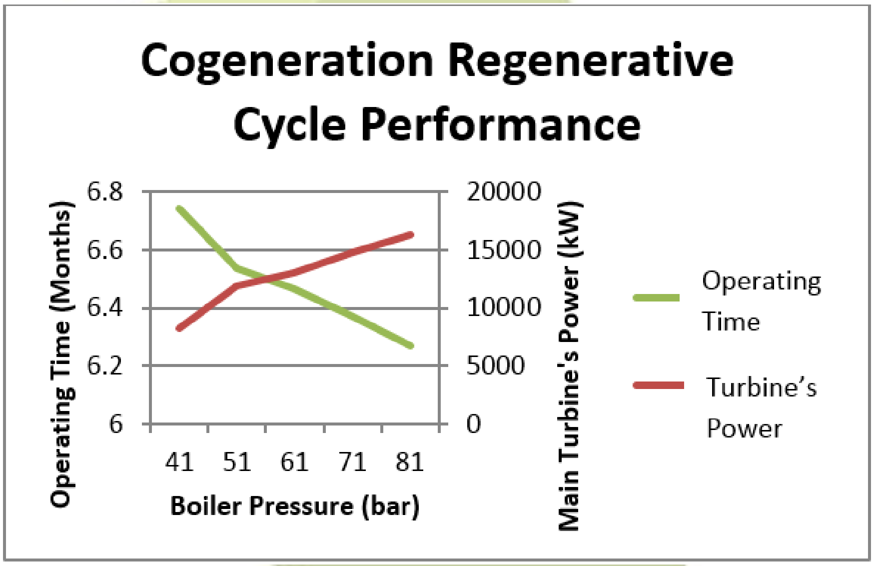

Figure 5 Cogeneration Regenerative Performance

The highest result of power could be gained by determining the pressure at 80 bars. That power result reaches 16,331.5 kW. Power that produced by main turbine will be addresed as exported electricity.

4. CONCLUSION

There are several valuable conclusion gained after finishing this research as a technical feasibility study in exporting energy process of sugar factory. The first conclusion is currently Gempolkrep sugar factory does not capable to export any electricity power because of all gained power is barely enough for production process only. Second, the implementation of cogeneration regenerative in Gempolkrep sugar factory would help to improve the gaining electricity power for the project of electricity export.

5. ACKNOWLEDGMENT

All of data in this research are given by Gempolkrep Sugar Factory in one milling season production process. It would be great if the factory able to implementing the best possible system for improving the production system. The research of feasibility study

in financial and environment aspect is extremely needed. So that, an improvement of waste recycle system would be complete and meeting the standardization of triple bottom line of sustainable development.

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