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Analysis of energy utilization and waste in China's processing industry based on a case study

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Abstract

Due to the rapid increase in price of resources, the role of energy management and utilisation has become significant in processing industry. Industries can be more competitive by increasing the energy efficiency and eliminating waste. In this research, an old-style paper plant situated in China has been selected for the case study. The purpose of the study is to test whether the energy usage is reasonable and to exploit the potential of waste as a resource for its production process. To do so, a huge data of the paper plant are obtained, and then based on these figures, a model has been established to find out the potential wastes and thermal energy loss of the process. The simulation results revealed that the mill's energy use is quite reasonable, however, findings found that there are still further possibility for organic waste to be reused.

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Keywords: Energy analysis; waste utilisation; case study; paper plant

1. Introduction

Currently, the rapid increase in energy in can be reflected by if rapid industrialization development, while it is reflected that energy consumption will continuously increase. Many processing industries based on the fossil fuel have to face many significant problems, such as low energy efficiency, shortage of resources, high GHG emissions and environmental damage. To solve these problems and also improve the retrogression of production status in some industries, the Chinese government put forward the policy of energy conservation. At the same time the government requested to reduce the CO2 emission/GDP ratio by 40－45% by the end of 2020 since 2005.[1]

Paper-making industry is a traditional Chinese industry and also an energy-intensive industry. It requires a lot of heat and electricity to run the process. Hence, there will be some energy wastage in the production process due to the aging equipment and unnecessary operations. On the other hand, this kind

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of industry which uses biomass as the raw material, may contain abundant of organic substance in its main stream.

The method of energy saving transformation in this type of processing industry is to analyse the overall process and find out the potential wastes and try to reuse it. This study uses simulation method to describe the whole working processes of the selected case. Finally, the simulation results can be used as a reference of system optimization, by reasonably regulating the energy inputs to achieve the goal of energy saving.

2. Case study

2.1 Brief introduction

A Chinese paper mill is the selected case, which uses sugarcane bagasse as the raw material. The total production of the paper pulp is 150 adt per day. This Paper plant's production process can be summarized in three steps: paper-making process, CHP system and NaOH recovery plant. CHP system, which is driven by burning coal and biogas to provide all the energy and partial electricity for the main paper-making processes as well as NaOH recovery plant; Meanwhile, some wastes coming from paper-making processes can be recovered in the recovery plant. All the data selected by a field study.

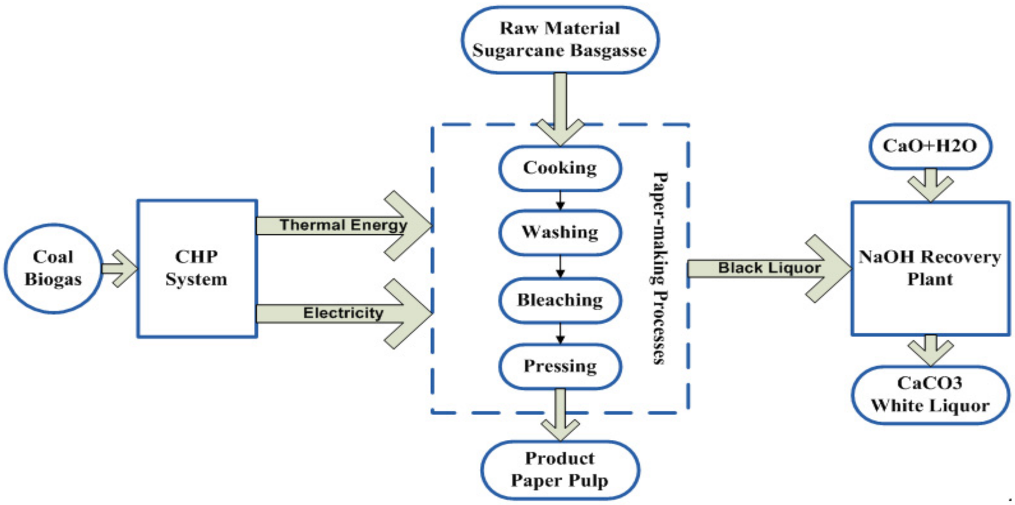

Fig.1. Flow diagram of the paper plant

2.2 Simulation

This study will focus on the simulation of the main paper-making processes by using the ECLIPSE software [2]. ECLIPSE software is a personal-computer-based package containing all of the programming modules necessary to complete rapid and reliable step-by-step technical, environmental and economic evaluations of chemical and allied processes using generic chemical engineering equations and formulae which includes high-accuracy steam-water thermodynamics package for steam cycle analysis.

Paper-making process is the most important part of the mill operation. In this stage the raw material undergoes cooking, washing, bleaching and the final pressing process to get into the final paper pulp production. According to the Pulp and Paper Technology and Equipment and Design Manual Calculation of the Pulping Process's [3] guidance, the models can be established as below:

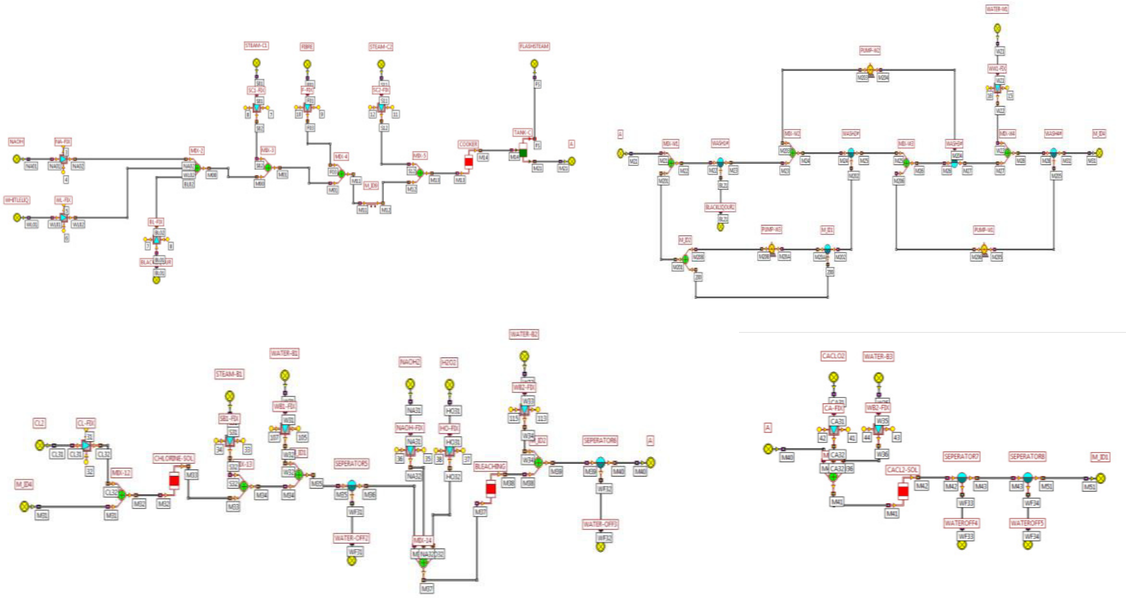

Fig.2.(a)Cooking section;(b)Washing section;(c)Bleaching section;(d)Pressing section

After completion of the model, the collected data can be used to achieve the calculation of mass-balance. In the above four parts, all the liquid material (including NaOH solution, white liquor and a small amount of black liquor) was fed in the cooking section, after a series of processes the final products will come from the pressing part.

The cooker is also a reactor, chemical reaction occurs in an alkaline environment, in which delignification of fibrous substance happened. The remaining solution of the cooking part contains a portion of unnecessary organics (i.e. Lignin) and a large amount of chemical substances. In the washing process, almost all of the unwanted substances will be cleaned. The selected case uses recycled water through four washing machines to clean the main solution. The bleaching section uses chemical method to make the solution white in colour to meet the product requirements. Therefore, the model involved some groups of chemical reactions, wherein the portion of the heat required is provided by steam. The last step of the pulp production is pressing. $CaCO_3$ as a common inorganic material can remove the residual solid impurities.

2.3 Results and discussions

The simulation results provide information about the outputs from the paper-making process. Table.1 demonstrates the errors between simulation results and actual data. Black liquor is the waste from washing section, which contains an abundance of organics, and is also an important fuel for NaOH recovery plant. The error of flow rate is a bit high (9.5%); some possible reasons are as below:

• The actual measurement data is the annual average value, when comparing with the analog data, some fluctuations is reasonable.
• Black liquor is the wash water from the paper-making process, as mentioned above, the quantity of the input water in washing part may be a bit more, which has no influence to the previous process, but may produce some effects to the latter one.

From Table.2, a large number of ingredients are detected in the flow, e.g. water-off from the bleaching section contains many organic and inorganic compounds. At the end of production, the water will be discharged directly into the sewage treatment plant; however, the simulation results show its potential to be a resource.

Table 1. Main outputs simulation data and errors analysis

Compound	Details	Simulation results	Measured data on site(average)	Error (%)
Black Liquor(l)	Be° (15)	6.66	6.6	0.9
	t/d	603.45	551.75	9.5
Flash Steam(g)	Temperature(C°)	102	100	2
Pulp(s)	Fibre(t/shift)	37.35	40	-6.6
	Concentration (%)	30.11	30	0.3

Table 2. Papermaking process output data

Section	Compound	No.	Temperature (C°)	Pressure (Bara)	Flow rate (kg/s)	Ingredients	
COOKING	Flash Steam(g)	FS	102	1	0.7795	Water	100%
WASHING	Black Liquor(l)	BL21	91.9	1	6.985	B-Lignin	0.2%
						Lignin	1.5%
						NaOH	8.9%
						Water	89%
	Fluid(l)	M31	78.9	1	6.846	Bagasse	0.052%
						Cellulose	18.9%
						Lignin	0.004%
						Water	80.5%
BLEACHING	Water-off2(l)	WF31	48.2	1	13.49	Bagasse	0.026%
						CL2	4.63%
						HCLO	0.000007%
						Water	95.1%
	Water-off3(l)	WF32	38.8	1	12.58	H2O2	0.0016%
						NaOH	1%
						O2	0.01%
						Water	99%
	Water-off4(l)	WF33	46.6	1	11.49	CaCO3	0.73%
						CO2	0.43%
						HCLO	0.35%
						Water	98.9%
	Water-off5(g)	WF34	46.6	1	0.0128	O2	100%
PRESSING	Pulp(s)	M55	54.0	1	4.308	Cellulose	18.5%
						Lignin	0.043%
						Water	78.8%

2.4 Opportunities of the wastes

• Waste heat

The temperature of flash steam (see Table 2) from the cooking section is 102 C°. This heat is valuable to be reused. However, considering the discontinuity of cooking, the flash steam cannot be continuously supplied. And its relatively less flow rate (0.7795kg/s) also makes it more difficult to preheat the large amount of water which is needed in the production process.

Consequently, the most appropriate method of reusing this part of energy is to store the heat and then use to heat small amount of water. E.g. heating the domestic water.

• Waste mass

The water-off2 from the bleaching section contains a certain amount (0.026%, see Table 2) of bagasse. This organic compound can be recovered and use to produce biogas. It is worth noting that the solution also contains some acidic substances (CL_2, 4.63%; HCLO, 0.000007%).Therefore, this solution should be neutralized by adding an appropriate amount of alkaline substances before the production of biogas.

All the solution (13.49kg/s) can be reused to produce biogas by an anaerobic digestion plant, and finally the products needed is CH_4. Assume that the temperature of the neutralized solution is 40 C°. The model of biogas production and the simulation result can be found in Fig.3. [4]

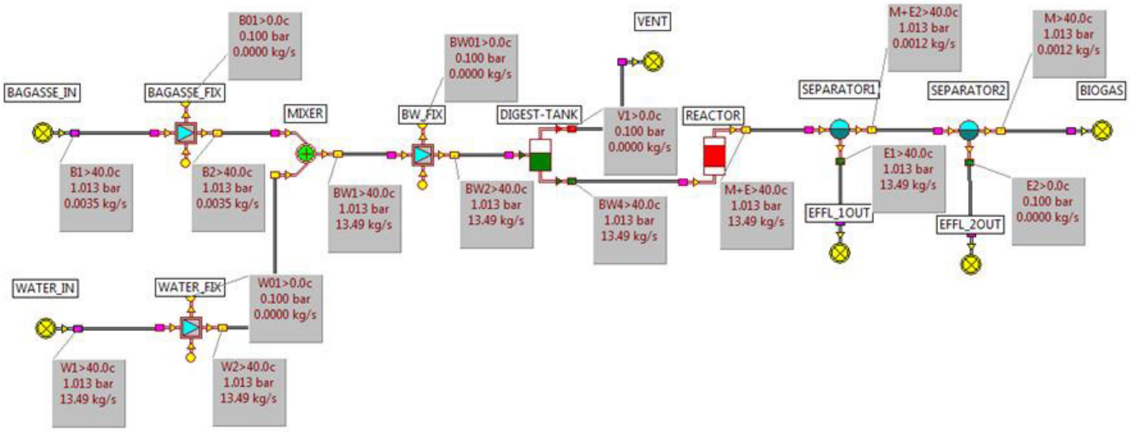

Fig.3 Simulation of the production of biogas by using the wastes

Theoretically, the organic wastes from water-off2 can be reused to produce 0.0012kg biogas per second, which is 52779.9 m^3 biogas per year. If the paper mill can use this biogas as a biofuel for the CHP system, it can replace about 90781.4kg coal every year.

Conclusions

Based on the simulation data, the following conclusions could be obtained:

- The results from the simulation are almost match the actual data from the plant with acceptable error range;
- By simulation analysis, energy and mass flow in each process are identified for the whole production process;
- The potential energy that can be recovered from the waste streams are identified, particularly in waste-water fluid.
- Reusing the potential wastes for the production is feasible. By using the organic compound of water-off2, it can be obtained 52779.9 m^3 biogas per year, which equals to burning approximately 91 tons of coal every year.

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