FUZZY INFERENCE SYSTEM MODELING FOR BED ACTIVE CARBON RE-GENERATION PROCESS (CO_2 Gas Factory Case)

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ABSTRACT

Bed active carbon is one of the most important materials that had great impact in determining level of impurities in production of CO_2 gas. In this particular factory case, there is unavailability of standard duration time of heating and cooling and steam flow rate for the re-generation process of bed active carbon. The paper discusses the fuzzy inference system for modeling of re-generation process of bed active carbon to find the optimum setting parameter. The fuzzy inference system was build using real historical daily processing data. After validation process, surface plot analysis was performed to find the optimum setting. The result of re-generation parameter setting is 9-10 hours of heating process, 4.66-5.32 hours of cooling process, and 1500-2500 kg/hr of steam flow rate.

Keywords: fuzzy inference system, bed active carbon, re-generation process.

1. INTRODUCTION

There is a requirement for CO_2 gas production factory to fulfill the Standard of Health Department of Indonesia regarding the quality of their production for food industry. One of the requirements is the maximum impurity of the gas, which the most important substances are water and sulfur.

In CO_2 gas production process, bed active carbon is used as absorber for the impurities (Lenntech, 2005). After being used for several hours in production process, or it is known as running process, it must be re-generated to recover its ability to adsorb the impurities. This process is known as re-generation.

In this case, the particular CO_2 gas factory installs thermal re-generation (Lenntech, 2005). When one bed is regenerated, the other bed remains active for adsorption. The re-generation process parameters that influenced the ability of bed active carbon to adsorb the impurities are duration time of heating and cooling and steam flow rate. The optimal parameters setting for re-generation process will increase the ability of bed active carbon to adsorb the impurities. This paper is based on the work done before by Kurniawati and Febriana (1995).

2. PROBLEM FORMULATION

The paper discuses optimal parameters setting for re-generation process which including duration time for heating and cooling and steam flow rate. The three parameters of re-generation process were used as input for fuzzy inference system model and the density of water (ppm) and sulphur (ppb) impurities in CO_2 gas as the output of model.

3. PROBLEM SOLUTION

The Mamdani method was used to build the fuzzy inference model for the re-generation process (Jang, Sun, and Mizutani; 1995). This model has three inputs and two outputs. The model was build using Matlab 7 and Fuzzy Logic Toolbox software (Jang, 1995). This model is shown in Figure 1.

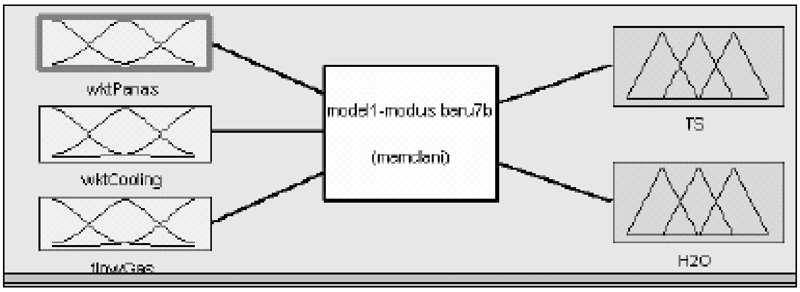

Figure 1. Fuzzy Inference System Model

3.1 Membership Function for Input Variables

Three linguistic variables were defined for duration of heating and cooling process, as listed in Table 1. Figures 2 and 3 shows the membership function for these two input variables.

Table 1. Linguistic Variable for Heating and Cooling

Linguistic Variable	Range of Duration Time of Process (hours)	
	Heating	Cooling
Short/sebentar	0-10	0-5
Medium/sedang	9-12	4-6
Long/lama	11-15	5-10

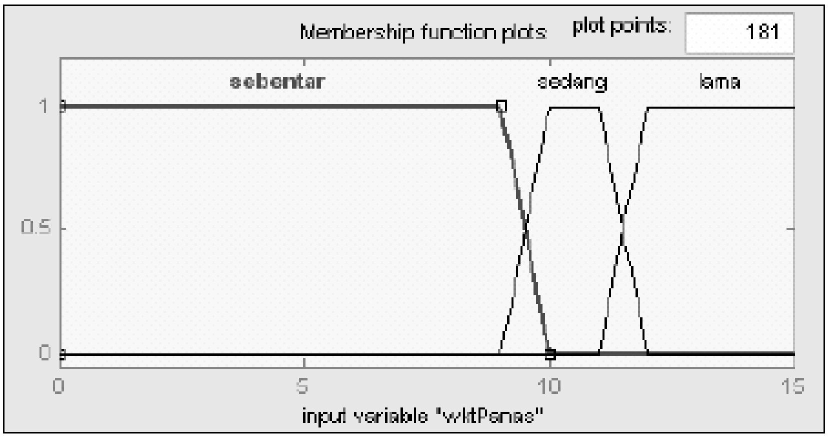

Figure 2. Membership Function for Heating Process

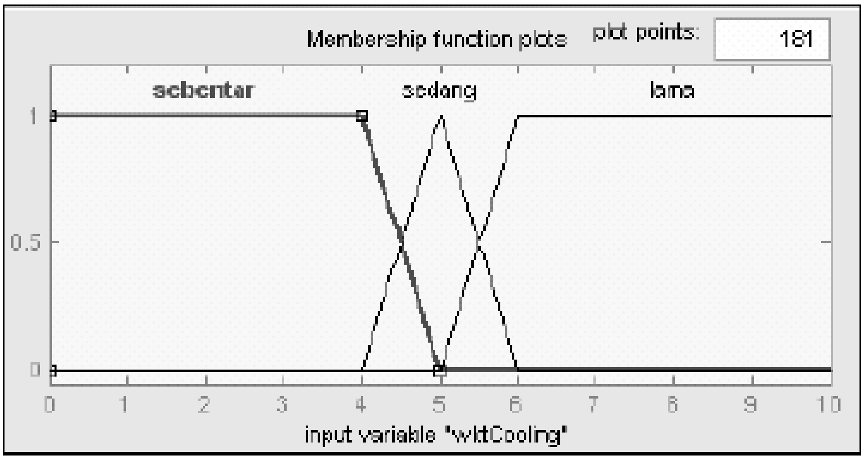

Figure 3. Membership Function for Cooling Process

Two linguistic variables were defined for steam flow rate, as listed in Table 2. Figure 4 shows the membership function for this output.

Table 2. Linguistic Variable for Steam Flow Rate

Linguistic Variable	Range of Rate (kg/hr)
Low/sedikit	900-2500
High/banyak	1500-3300

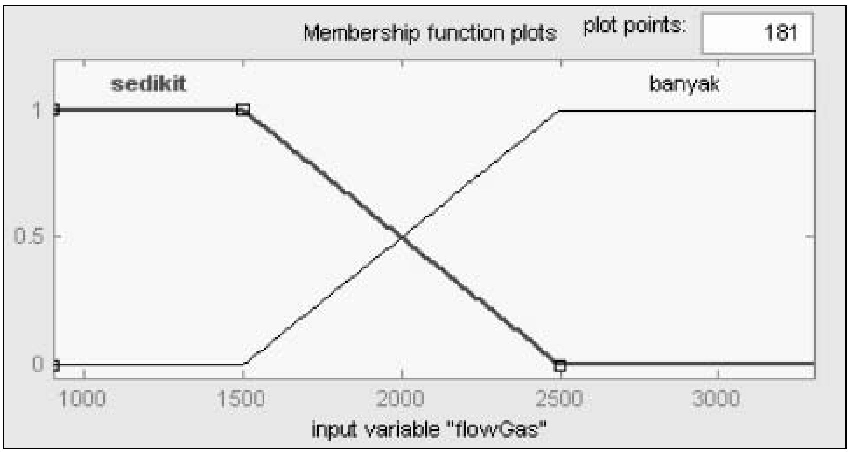

Figure 4. Membership Function for Steam Flow Rate

3.2 Membership Function for Output Variables

Two linguistic variables were defined for density of sulfur (ppb), as listed in Table 3. Figure 5 shows the membership function for this output.

Table 3. Linguistic Variable for Sulfur Density

Linguistic Variable	Range of Density (ppb)
Good/baik	0-15
Bad/tinggi	10-100

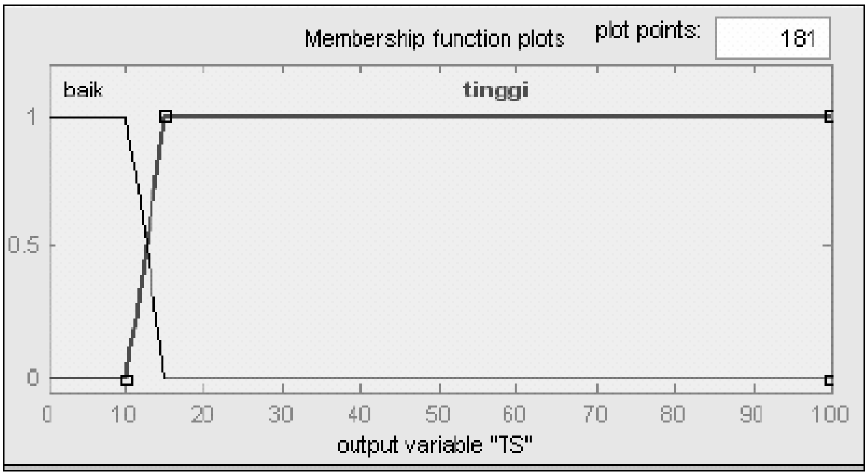

Figure 5. Membership Function for Sulfur Density

Three linguistic variables were defined for the density of water, as listed in Table 4. Figure 6 shows the membership function for this output variable.

Table 4. Linguistic Variable for Water Density

Linguistic Variable	Range of Density (ppm)
Good/baik	0-25
Medium/sedang	15-45
Bad/tinggi	35-100

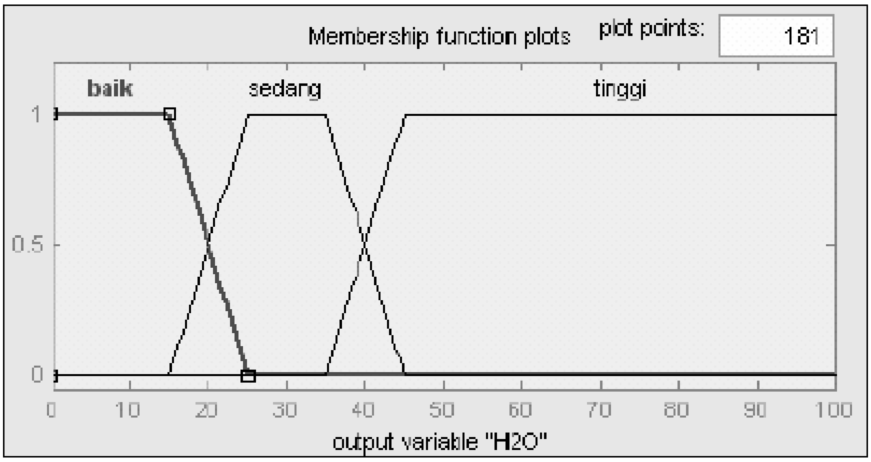

Figure 6. Membership Function for Water Density

3.3 Fuzzy Rule

Interview with factory engineer and historical daily data from on September 2003 were used to define the fuzzy rule for this model. Each value from historical data was classified according to the linguistic variable defined. For output data variable, modulus value was taken. The ‘and’ rule was defined as: *If (input1) and (input2) and (input3) then (output1) and (output2).*

Where *input1* is heating process duration time, *input2* is cooling process duration time, and *input3* is steam flow rate. *Output1* is density of sulfur and *output2* is density of water. Fuzzy rule were defined as listed in Table 5 and the rule viewer can be seen in Figure 7.

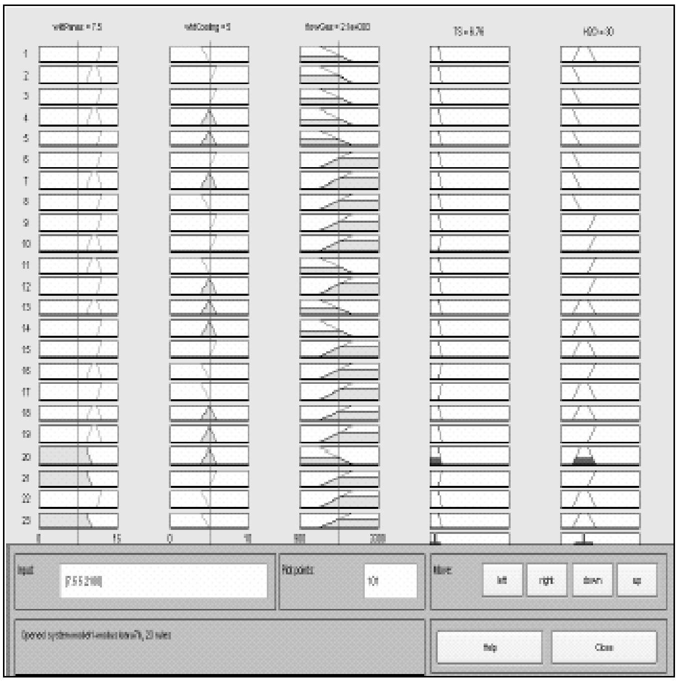

Figure 7. Rule Viewer of the Model

Tabel 5. Fuzzy Rules for the Model

No	*Input1*	*Input2*	*Input3*	*Output1*	*Output2*
1	Long	Short	Low	Good	Medium
2	Medium	Long	Low	Good	Good
3	Long	Long	Low	Good	Good
4	Medium	Medium	Low	Good	Good
5	Long	Medium	Low	Good	Good
6	Long	Long	High	Good	Good
7	Medium	Medium	High	Good	Good
8	Long	Short	High	Good	Good
9	Long	Long	High	Good	Bad
10	Medium	Long	High	Bad	Bad
11	Medium	Short	Low	Good	Bad
12	Long	Medium	High	Good	Bad

Tabel 5. Fuzzy Rules for the Model (lanjutan)

No	*Input1*	*Input2*	*Input3*	*Output1*	*Output2*
13	Medium	Medium	Low	Good	Medium
14	Long	Medium	Low	Good	Medium
15	Long	Long	High	Good	Medium
16	Medium	Short	High	Bad	Bad
17	Long	Short	High	Bad	Medium
18	Medium	Medium	High	Good	Medium
19	Medium	Medium	High	Good	Bad
20	Short	Medium	Low	Good	Medium
21	Short	Long	High	Bad	Bad
22	Long	Short	High	Good	Medium
23	Short	Short	High	Good	Medium

3.4 Defuzzification Method

Centroid method was used as defuzzification method because it is suitable to the process condition. A small change in one of input variable will change the output condition.

3.5 Model Validation

Historical daily data on August 2003 were used as input for model. The output from the model was compared to actual output from historical data using two-sample-t test method (Bhattacharya and Johnson, 1997). Minitab 13 software was used to do the test. Test result shown that the model is significantly valid for representation of the real process, using $\alpha=0.05$.

3.6 Optimal Parameter Setting for Re-generation Process

Using the model as representative of the real condition, the optimal parameter setting was found by analysis of surface viewer of Matlab software. Figure 8 and 9 show some surface plots for several input and output variables.

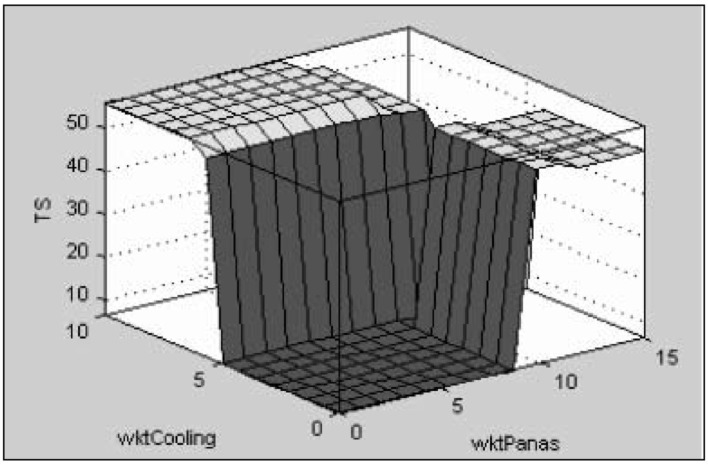

Figure 8. Surface Plot for Heating and Cooling Duration Time related to Density of Sulfur

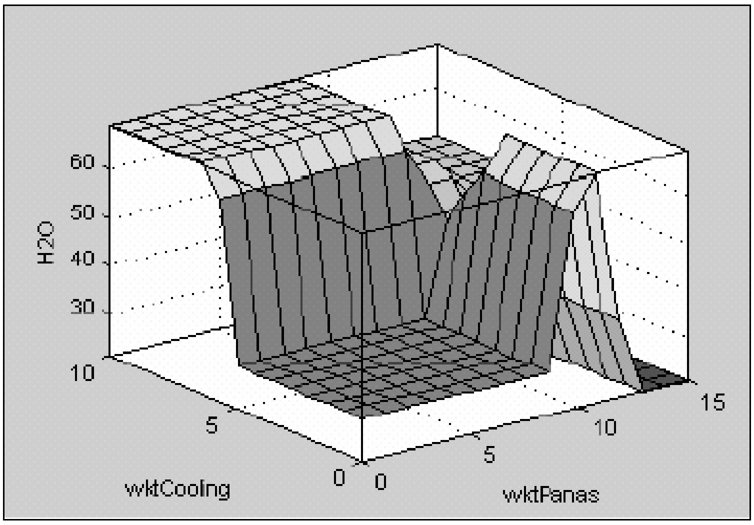

Figure 9. Surface Plot for Heating and Cooling Duration Time related to Density of Water

Using all of surface plots, the intersection area of input variable was defined to produce output values that fulfill the requirement of Health Department standard. Standard of impurity of sulfur is 0-15 ppb and for water is 0-15 ppm. The result is shown in Table 6.

Table 6. Optimal Parameter Setting for Re-generation

Input Variable	Range of Optimum Value
Heating duration time	9-10 hours
Cooling duration time	4.66 - 5.32 hours
Steam flow rate	1500 - 2500 kg/hour

4. CONCLUSION

Fuzzy Inference System has been used for modeling of re-generation process of bed active carbon. The model was a valid representation of the real condition according to the two-sample-t test result using $\alpha=0.05$. Re-generation parameter setting range obtained is 9-10 hours of heating process, 4.66-5.32 hours of cooling process, and 1500-2500 kg/hr of steam flow rate. Future research needed to investigate other re-generation process parameters that affect the adsorption quality of bed active carbon performance.

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