The Schedule of Optimal Fuzzy Controller Gain with Multi Model Concept for a Solar Energy Wood Drying Process Kiln

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The paper reports the scheduling Gain of Optimal Fuzzy Control for a solar energy wood drying process kiln. The variable controls of a solar energy wood drying process kiln are temperature and humidity as to use variable of a drying schedule. Because a drying schedule of wood drying process have multi step process, then approximate of state based a concept of multi system with multi gain of control to reset of value set point of temperature and humidity chamber. The Optimal fuzzy controller is simplified to be used for the scheduling of a gain control model of multi system from wood drying process kiln in steady state. From result of simulation by a responses of step obtained a system can be right model, systematic of process, and can be a scheduling of set point drying process, for get at efficient of energy.

Keywords: Optimal Fuzzy Controller, Drying Schedule, Multi System

1. Introduction

A solar energy wood drying process kiln needs a schedule of drying as traffic process. A level from the schedule of drying is a model the system main most necessary, where needs the gain of control. Because wood drying process used the schedule of drying dependent for moisture of content the wood, that condition of kiln is deferent for as level of the schedule of drying.

Variable control the Wood drying of process kiln are temperature and humidity of air in chamber where dependent for moisture of content the wood. Then most need actuator control system for heater, sprayer and damper, whenever the process used doing the optimal from time and energy. The goal of optimal control is the system for achieving effective process for set point target. The Wood drying of process kiln model based of steady state equation, when need for state matrix, input matrix, control matrix, to product gain control based index performance from regulator quadratic optimal.

State matrix and input matrix are computation based on behavior from the condition of system. Whenever control matrix computation based from criteria of performance the regulator quadratic optimal by the product to can have gain of

control. Classification used the schedule of drying based of used of fuzzy logic. We used the membership function of fuzzy logic doing from error variable and change error variable control. Used the rule are result of the schedule of gain control from optimal fuzzy controller, when simulation with MATLAB.

2. Solar Energy Wood Drying Process Kiln

Control variable of a solar energy wood drying process kiln is temperature and humidity as use as variable of a drying schedule. Dimension of wood drying kiln has designed and built several type dry kiln for use lumber of housing structure. The components of wood drying kiln are wall, energy resource with technology of collector or boiler, fan for air circulation, damper and sprayer (Fiqure.1) and the reference of schedule drying is shown in Fiqure.2.

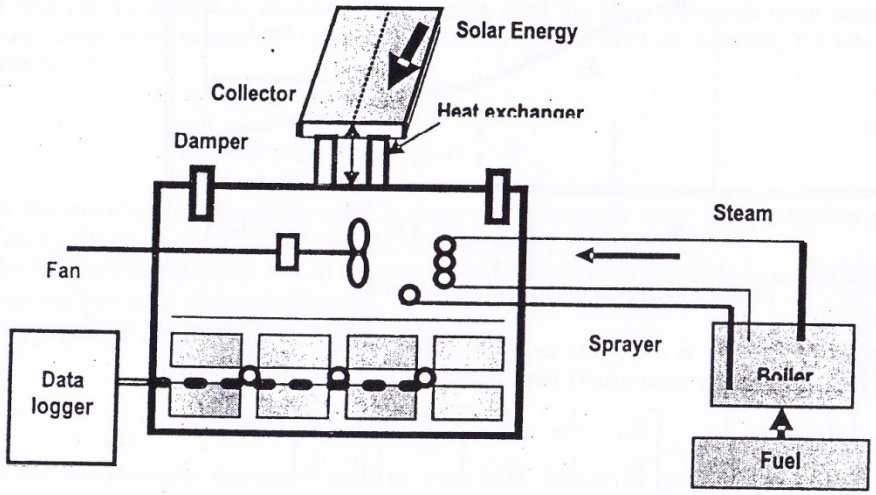


Figure 1. *A solar energy wood drying process kiln*

The Schedule drying is a cycle of drying and has some level of process. A Level process doing at temperature and humidity variable are constant at set point any time. By the way need an actuator control system (heater, sprayer and damper) then doing at effective the time and efficiency of energy.

3. The Steady State Equation of Wood Drying Kiln

Model of steady state equation of drying kiln is shown in Equation 1.

$$\frac{dx(t)}{dt} = Ax(t) + Bu(t) \quad \text{and} \quad y(t) = Cx(t) \qquad (1)$$

with, x(t) : state variable,
A : steady state matrix,
B : control matrix

u(t) : variable control,
C : output matrix

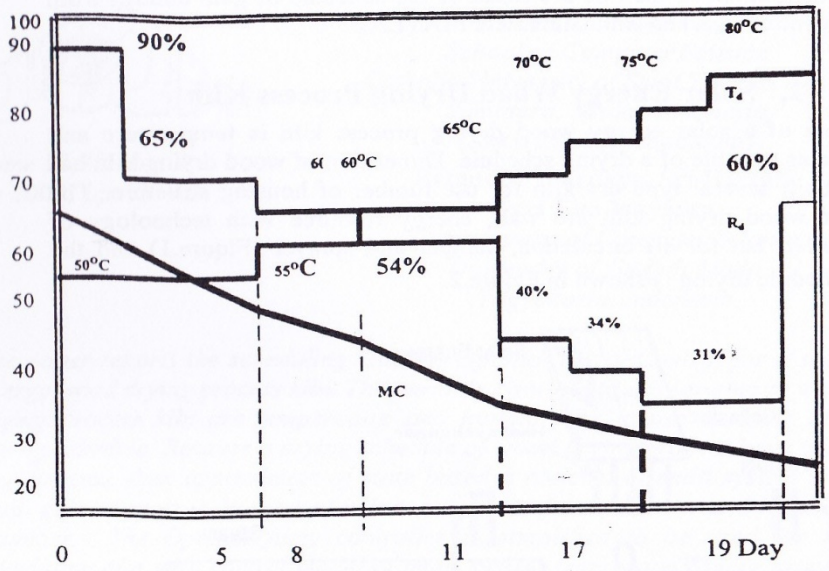


Figure 2 *Reference the scheduling of drying*

Dimension of state variable is 2x1, this $x_1 = T_d$ (temperature of kiln), $x_2 = R_d$ (humidity of kiln), and steady state matrix has dimension is 2 x 2, then is shown:

$$A=\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} B=\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \end{bmatrix} C=\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad (2)$$

with , $a_{11}, a_{12}, a_{21}, a_{22}$, used from computation from behaviors of load

$b_{11}, b_{12}, b_{13}, b_{21}, b_{22}, b_{23}$ used from computation from behaviors of air

Variable x is state variable with dimension 2 x 1, are x_1 = Td and $x_2 = R_d$. Variable u is input matrix with dimension 3 x 1, are $u_1 = Q_h + Q_b$ (energy solar from collector, boiler energy), $u_2 = m_s$ (speed mass of steam from sprayer), and $u_3 = Q_d$ (energy of exhaust from damper. Variable Y is same from state variable.

4. The Gain Optimal Control

Optimal control system is designed to result intemperature and humidity kiln at set point with doing at effective the time and efficiency of energy. Optimal criteria are minimum the function of performance index based state variable and control variable then is shown of Equation 3.

$$J=\int_0^{\infty}(x^T Q.x+u^T R.u)dt \quad (3)$$

With Q and R are weights matrix, is designed at trial and error or with Bryson method for can response of close loop the system as result performance target. Q Matrix is riel symmetry definite positive (or semi definite positive) and matrix R riel symmetry definite positive. With used the control law : $u(t) = -K.x(t)$ and matrix reduction Riccati equation:

$$A^T P + PA - PBR^{-1}B^T P + Q = 0 \quad (4)$$

From Equation 4 to find the gain of control optimal (K_i).

5. The Schedule of Optimal Fuzzy Control Gain

Design control system for regulator quadratic optimal used to the fuzzy logic controller to find the schedule of optimal fuzzy control gain. The solar energy wood drying process kiln has variable control are humidity air in kiln Rd and temperature of kiln Td. To design of membership function used the crisp input and crisp output. Crisp input used to change of variable control temperature or humidity as shown Equation 5.

$$e_T = \text{input} - 65$$
$$\text{and} \quad (5)$$
$$ce_T = \text{error(n)} - \text{error (n-1)}$$

Set the membership functions used to error and change in error of temperature are Z(zero), S(small), M(medium) and H(high), as shown in Table 1.

Definitions of the fuzzy sets in the universe of discourse of variable temperature in memberships map shown in Figure 3.

Crisp input for the humidity shown in Equation 6.

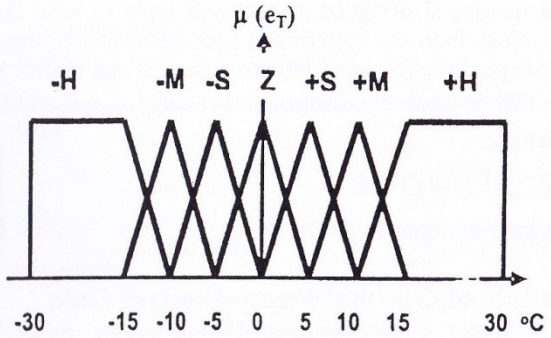
$$e_H = \text{input} - 54$$
$$\text{and} \quad (6)$$
$$ce_H = \text{error (t)} - \text{error (t-1)}$$

Set the membership functions used to error and change in error of humidity are Z(zero), S(small), M(medium) and H(high), as shown in Table 2.

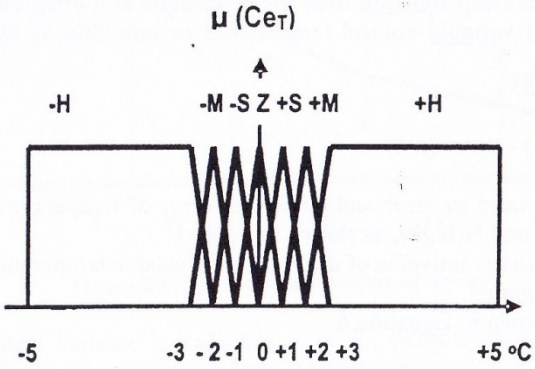
Definitions of the fuzzy sets in the universe of discourse of variable temperature in memberships map shown in Figure 4.

Table 1 *Label of membership function Temperature*

ce \ e	-H	-M	-S	Z	+S	+M	+H
-H	-H	-H	-M	-S	Z	+S	+M
-M	-H	-M	-S	Z	+S	+M	+H
-S	-H	-M	-S	Z	+S	+M	+H
Z	-H	-M	-S	Z	+S	+M	+H
+S	-H	-M	-S	Z	+S	+M	+H
+M	-H	-M	-S	Z	+S	+M	+H
+H	-M	-S	Z	+S	+M	+H	+H



(a) Error temperature



(b) Change error temperature

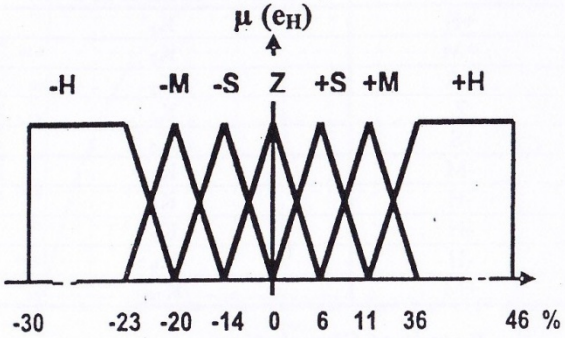
Figure 3 *Rule and Membership function for control of temperature*

Table 2 *Label membership function humidity*

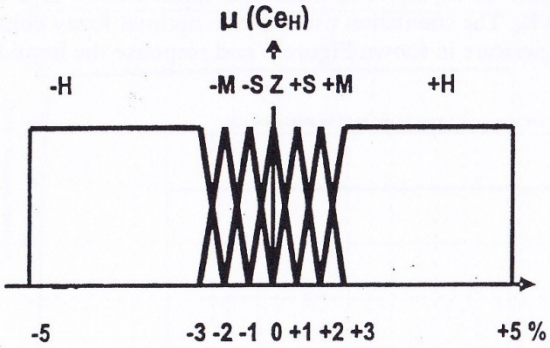
e / ce	-H	-M	-S	Z	+S	+M	+H
-H	-H	-H	-M	Z	Z	+S	+H
-M	-H	-H	-S	Z	+S	+M	+H
-S	-H	-M	-S	Z	+S	+M	+H
Z	-H	-M	-S	Z	+S	+M	+H
+S	-H	-M	-S	Z	+S	+M	+H
+M	-H	-M	-S	Z	+S	+M	+H
+H	-M	-S	-S	Z	+M	+M	+H

Used defuzzification strategy are center of area method. The COA strategy generates the center of gravity of the possibility distribution of a control action. It is widely used in the current implementations of the fuzzy logic development system. Bloc diagram optimal fuzzy controller system as shown in figure 5. and fuzzy relation rule

in Table 3. Because the plant of drying kiln doing in a multi model system then control process used the schedule of gain optimal fuzzy control.



(a) Error Humidity



(b) Change error Humidity

Figure 4 *Rule and Membership function for control of humidity*

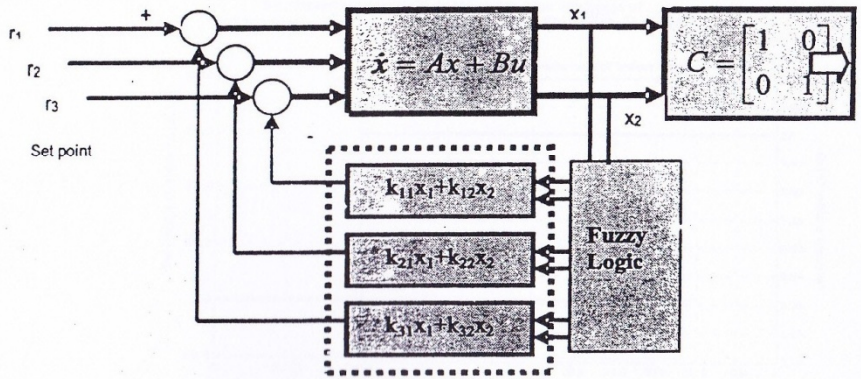


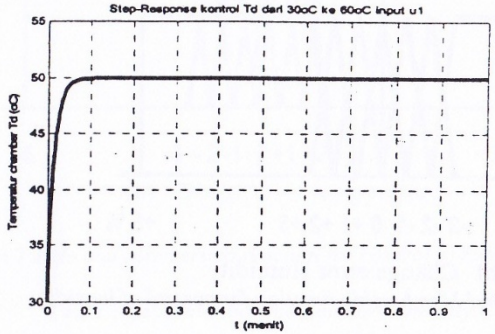
Figure 5 *Optimal fuzzy controller system of Drying Kiln*

Table 3 *Fuzzy relation rule with variable input and variable output of optimal fuzzy controller*

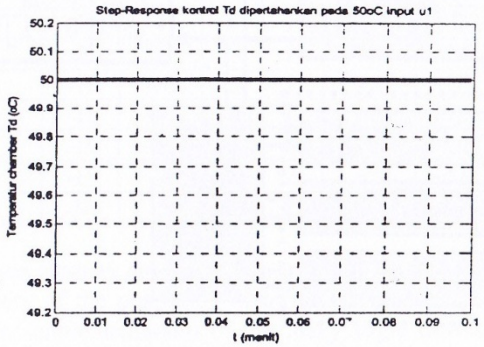
If temperature is ...	And Humidity is ...	Then Gain of control K is ....
-H	+H	K_1
-H	+M	K_2
-M	+S	K_3
-S	Z	K_4
-S	-S	K_5
Z	-M	K_6
+S	-H	K_7
+M	-H	K_8
+H	-H	K_9
+H	+M	K_{10}

6. Result of Simulation

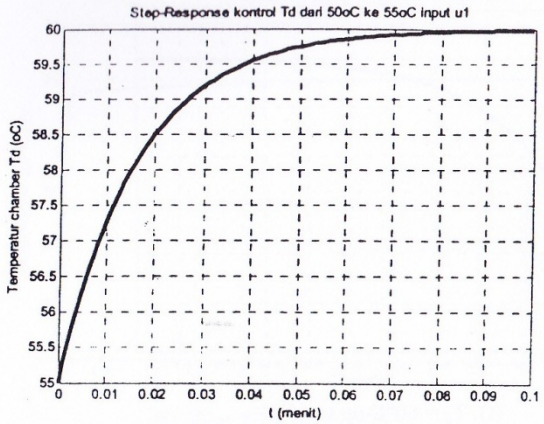
Simulation doing with used state matrix A and input matrix B at temperature and humidity of level the schedule of drying. The state and input matrix is a model system with the gain control K_i. The simulation used to rule optimal fuzzy controller to result the response of temperature in shown Figure 6 and response the humidity in shown Figure 7.



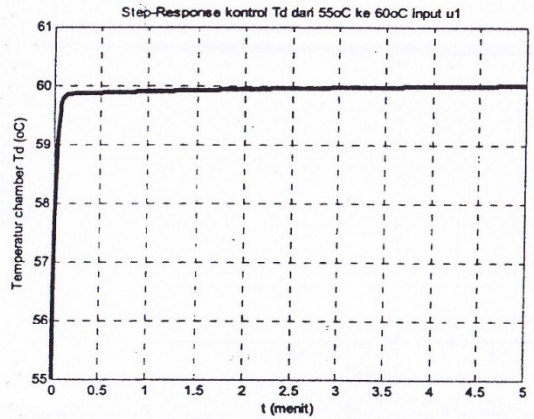
(a) $T_d = 30^0C$ up to 50^0C



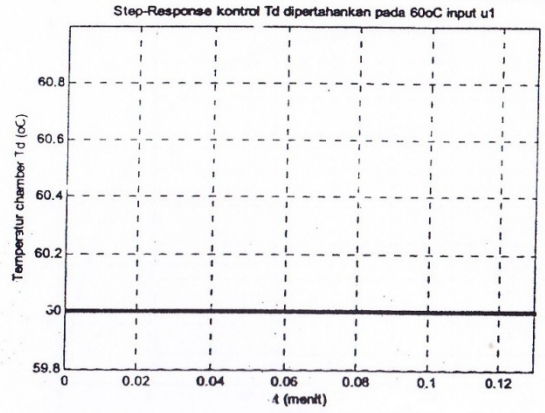
(b). T_d constant at 50^0C



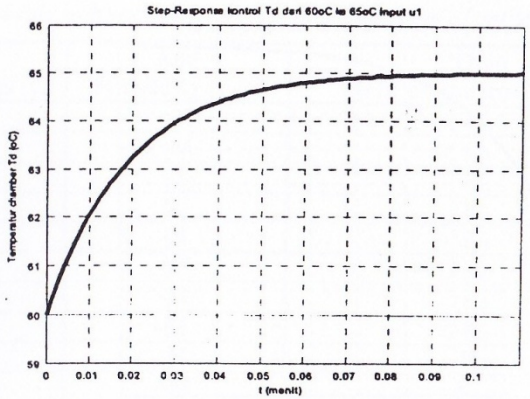
(c). $T_d = 50^0C$ up to 55^0C



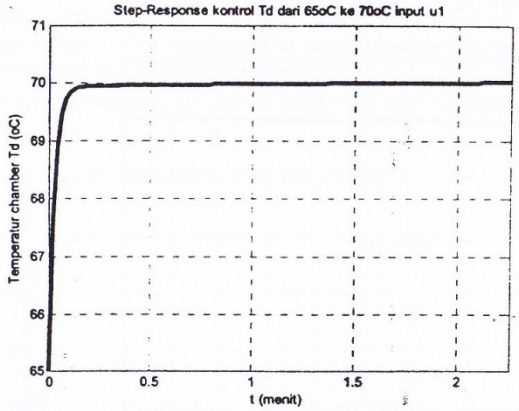
(d). $T_d = 55^0C$ up to 60^0C



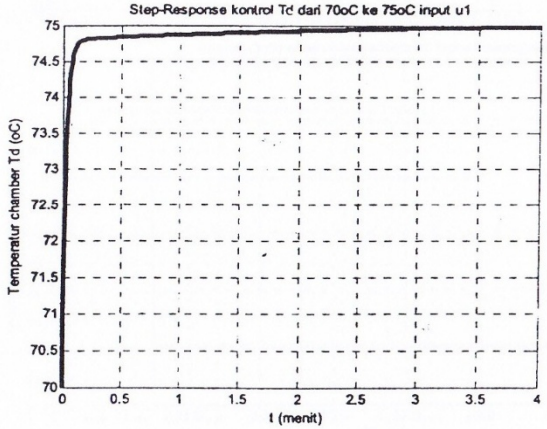
(e). T_d constant at 60^0C



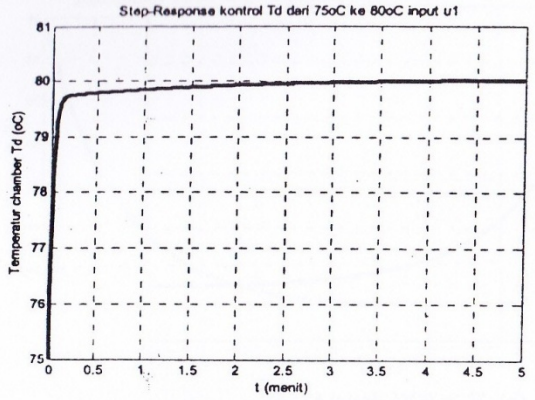
(f). $T_d = 60^0C$ up to 65^0C



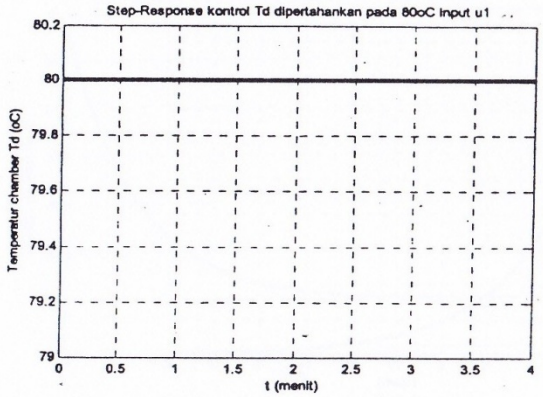
(g). $T_d = 65^0C$ up to 70^0C



(h). $T_d = 70^0C$ up to 75^0C

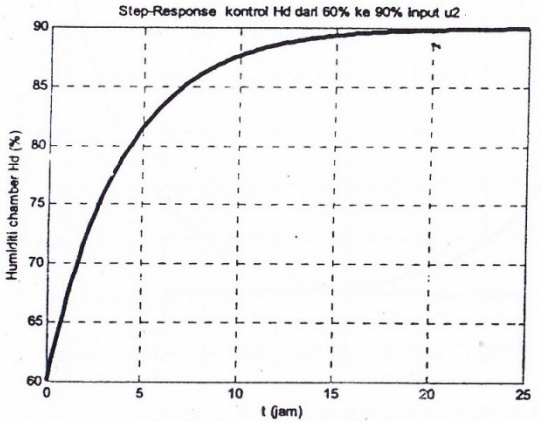


(i). $T_d = 75^0C$ up to 80^0C

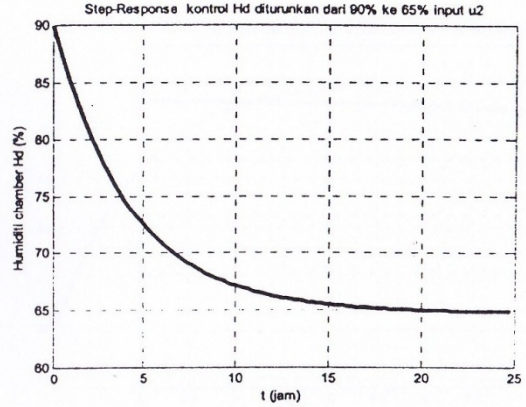


(j). T_d constant at 80^0C

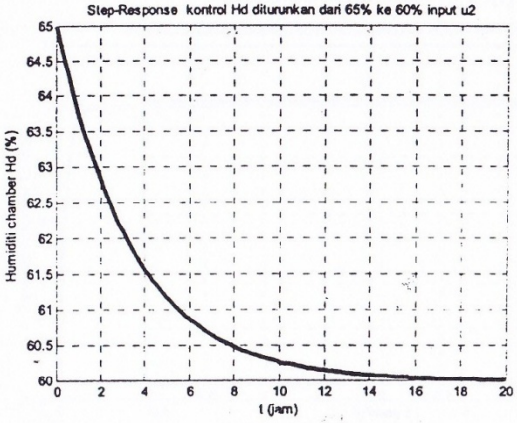
Figure 6 *Result of simulation for temperature chamber*



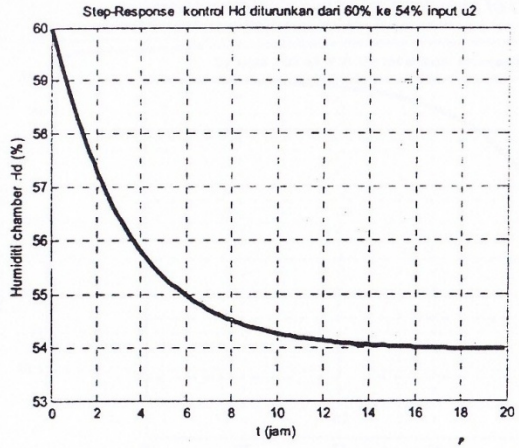
(a). $H_d = 60\%$ up to 90%



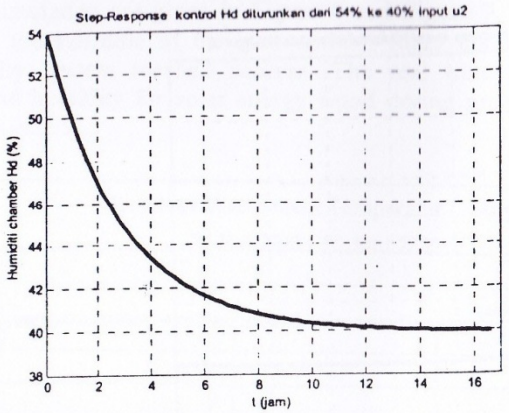
(b). H_d = 90% down to 65%



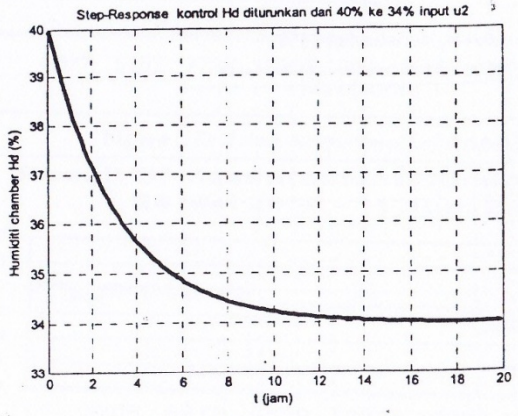
(c). H_d = 65% down to 60%



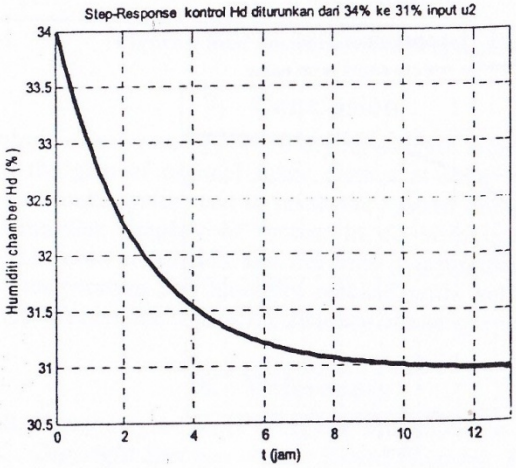
(d). H_d = 60% down to 54%



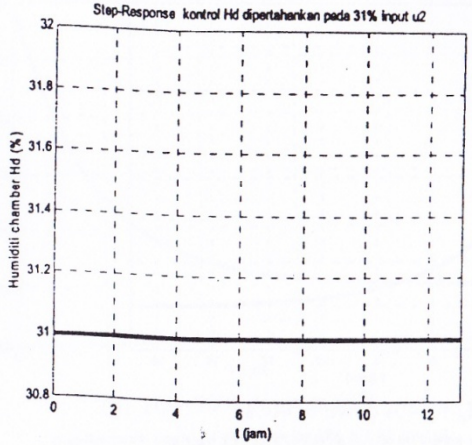
(e). H_d = 54% down to 40%



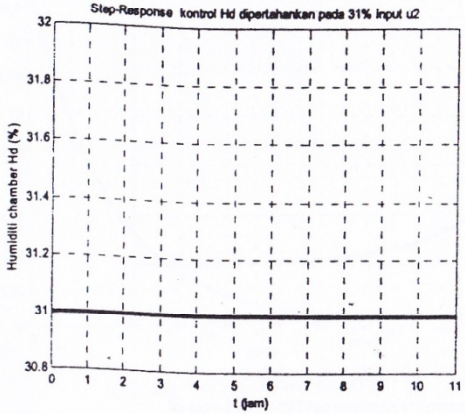
(f). H_d = 40% down to 34%



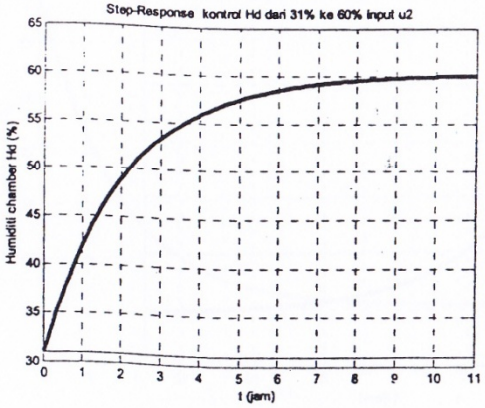
(g). H_d = 34% down to 31%



(h). H_d constant at 31%



(i). H_d constant at 31%



(j). H_d = 31% up to 60

Figure 7 *Result of simulation for humidity chamber* R_d

Results of simulation are given in Figure 6 and Figure 7. They showed that the plant can use the schedule of the gain optimal fuzzy control with multi system model. Stability system reached success. The real time measurements of the temperature and humidity for solar energy wood drying process kiln are shown in Figure 8 and Figure 9.

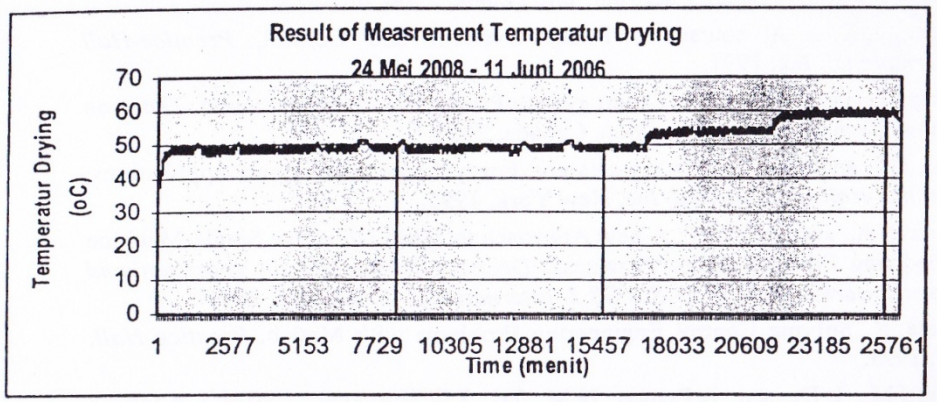


Figure 8 *Real time measurement of temperature*

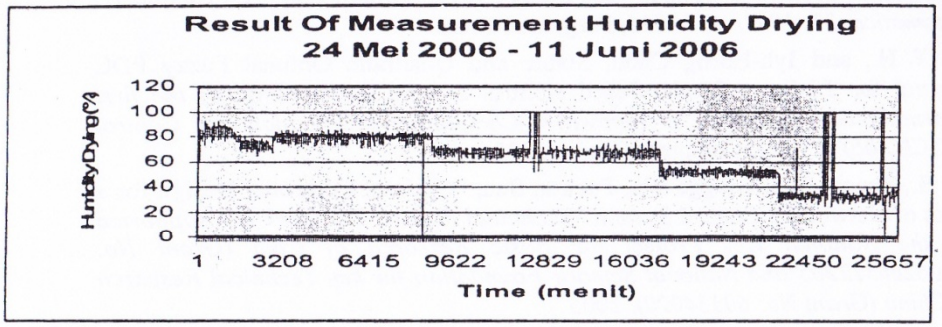


Figure 9 *Real time measurement of humidity*

7. Conclusion

The variable controls of solar energy wood drying process kiln are temperature and humidity. Use of the gain of optimal fuzzy control at solar energy wood drying process kiln at level multi system can to result the system doing is well. Used the Optimal fuzzy controller simplify of system in do with used the steady state equation. From the result simulation and riel time measurement as shown the set point variable of temperature and humidity reached with well. Used the optimal fuzzy control result effective the time and efficiency of energy.

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