FUZZY RULE SURAM FOR WOOD DRYING

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Abstract. Implemented of fuzzy rule must used a look-up table as defuzzification analysis. Look-up table is the actuator plant to doing the value of fuzzification. Rule suram based of fuzzy logic with variables of weather is temperature ambient and humidity ambient, it implemented for wood drying process. The membership function of variable of state represented in error value and change error with typical map of triangle and map of trapezium. Result of analysis to reach 4 fuzzy rule in 81 conditions to control the output system can be constructed in number of way of weather and conditions of air. It used to minimum of the consumption of electric energy by heater. One cycle of schedule drying is a serial of condition of chamber to process as use as a wood species.

Keywords : Fuzzy rule, look-up table, controller

1. Introduction
The wood drying process used the schedule of drying dependent for moisture of content in the wood, that condition of kiln in temperature and humidity of chamber. The controller used to control the actuators are heater, sprayer and damper, whenever the process used doing the optimal from time and energy and stability in wood schedule of drying. Main source of energy is solar energy from collector and alternative source energy by heater. Number of solar energy based of intensity of solar and alternative energy by heater is consumption of electric (Wang, X.G, et al, 2001)

The maximized use of solar energy in wood drying process is goal of control system. It’s depended by a number solar energy and it’s change and temperature of ambient. Responsibility of the change the solar energy in variable of temperature ambient and humidity ambient is the especial of goal the control system. The process of control is to hope maximized the use of solar energy and the minimized of consumption energy of electric. (Skuratov. N.V., 2003)

Process of wood drying is depended for schedule drying, which used to track of set point for temperature and humidity drying. The conditions of temperature and humidity drying in schedule are different for the each steps of the schedule drying of wood. Variable control the Wood drying of process kiln are temperature and humidity of air in chamber where dependent for moisture of content the wood. It’s need to control of actuator system for heater, sprayer and damper, whenever the process used doing the optimal from time and energy and the actuator doing in the conditions data riel. (Lim P.K. and Natalie R.S,1995)

The Fuzzy rule suram implemented for schedule drying of Albasia Albizia wood and modification of membership function in range [0.5, 1]. (Situmorang,Z, et.all, 2009).

2. Wood Drying Process
Control variable of a solar energy wood drying process kiln is temperature and humidity to adapt 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 Schedule drying is a cycle of drying and have the 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 (Garrahan.P., and Kidlark.J, 2001).

Air drying involves the open piling of freshly processed timber in stacks out of doors or in open sheds so that the wood surfaces are exposed to the surrounding atmosphere. During air drying there is little control over the factors that influence drying and hence the rate of drying is very much controlled by local atmospheric conditions. One guiding principle during air drying of timber is to ensure adequate air circulation through the stack. In practice this is achieved by separating each board within the stack using sticks or stickers.

A drying schedule is a set of directions for the operation of a kiln during the drying period and is usually presented in the form of tables showing the temperatures and humidity to be used at various stages of the process. These schedules vary with species, size and grade of timber being dried; they are also influenced by local production and selling practices, by the degree of care in kiln operation and in kiln characteristics.

3. Solar Energy in a Prototyping of Wood Drying Kiln

Measurement of solar energy by Pyranometer type MS-801 Chino, it has maximum voltage +50 mVDC, which to have a data from Agency of meteorology and geophysics Yogyakarta Indonesia, shown in figure 1. with detail of a prototyping of wood drying.

![Figure 1. Detail of design the prototyping of wood drying kiln](Situmorang, Z, et.al, 2009 and Haque.M.N., 2002)

Most important part of a dehumidifying kiln is a heat pump. Air in the kiln passes through the load of timber and absorbs moisture from the wood. Part of that air circulates through the heat pump where the moisture is condensed and drained out of the chamber. Dried, reheated air comes back to kiln chamber. Energy consumption is minimal, since there is almost no inner/outer air exchange. Air circulation in these kilns is smaller than in conventional kilns while the electrical power of flow fans and heat pump equals approximately the power of flow fans in conventional kilns. *(Virginia Tech, 2007)*

A number of variable solar radiation can be convert to variable temperature ambient and humidity ambient shown in table 1. *(Dion,J.M.et.al, 1991)*
Table 1. Convert solar radiation to variable temp. ambient and humidity for Albacia Ibizia wood

| No | Set Point Td₀(°C) | Set Point Hd₀ (%) | MC (%) | Solar Radiation I₀ (Watt/m²) | Temp. Ambient Ta(°C) | Hum. Ambient Ha (%) |
|----|------------------|-------------------|--------|-----------------------------|----------------------|--------------------|
|    |                  |                   |        |                             | Min     | Rate   | Max   | Min     | Rate   | Max   |
| 1  | 45               | 3                 | 4      | 6                            | 7        | 8      | 9     | 10      | 11     | 12     |
| 2  | 50               | 55                | 10.4-25.5 | 662.0                        | 29.7     | 30.7   | 31.7  | 46      | 54     | 62     |
| 3  | 55               | 50                | 7.8-10.4 | 763.0                        | 30.5     | 31.5   | 32.5  | 40      | 48     | 56     |
| 4  | 60               | 45                | 7.3-7.8 | 617.5                        | 29.4     | 30.4   | 31.4  | 50      | 58     | 66     |
| 5  | 65               | 35                | 6.4-6.7 | 535.0                        | 28.9     | 29.9   | 30.9  | 54      | 62     | 70     |
|    | (F)              |                   |        |                             |          |        |        |          |        |        |

Note:

i. For MC ≥ 25 %, (Td₀ = 45 s/d 55), The Solar Radiation I₀ = 460 ± 20.2(Td₀ = 40) (watt/m²)

ii. For MC ≤ 25 %, (Td₀ = 60 s/d 70), The Solar Radiation I₀ = 700 ± 16.5(Td₀ = 55) (watt/ m²)

iii. Control period for total used the energy from solar, Cp = 0.1 ± 0.0003(I₀ = 400)(C/menit)

F = Faktualat

4. Design Membership Functions

Design of membership function for variables in fuzzy logic implemented to map of typical of triangle and trapezium as of a drying schedule as shown in figure 1 and table 1 It’s needed to implemented control system of wood drying kiln (Klir, G.J, and Yuan.B, 1995 and Laurenzi. W., Popa.V, Comsa.Gh, 2003).

Fuzzification of membership function in range [0.5, 1], and for weather (temperature of ambient Ta and change temperature ambient CTa) for set point temperature drying Td₀ = 45°C and Humidity drying Rd₀ = 60%) describe by figure 2. with variable M: over-cloudy; B: cloudy; CB: bright-cloud; C: clear; SC: clearest and for change of temperature ambient used -H = - High, -M = - Medium, -S = - Small, Z = Zero, S = Small, M = Medium, H = High

Figure 2. Membership function of temperature ambient and change temperature ambient for Td₀ = 45°C and Rd₀ = 60%
Computation process of variable change of temperature ambient are given eq.1. with n \( \neq 0 \) s/d

\[
CTa [(n+1)T] = Ta[(n+1)T] - Ta[nT]
\]

Representative of weather is variable temperature ambient and this change used to maximize and to hoist responsibility of membership Function, with appropriate rule in a table look-up scheme, shown table 2.

| CT | T, Over- | Cloudy | Bright- | Clear | Clearest |
|----|---------|-------|--------|-------|----------|
| -H | Over-   | Cloudy| Cloudy | Bright-| Clear    |
| -M | Over-   | Cloudy| Bright-| Clear  | Clearest |
| -S | Over-   | Cloudy| Bright-| Clear  | Clearest |
| Z  | Over-   | Cloudy| Bright-| Clear  | Clearest |
| +S | Over-   | Cloudy| Bright-| Clear  | Clearest |
| +M | Over-   | Cloudy| Bright-| Clear  | Clearest |
| +H | Cloudy  | Bright-| Clear  | Clearest | Clearest |

Fuzzyfikasi of membership function in range \([0.5, 1]\) of conditions of air (humidity of ambient Ha and change of humidity ambient CHa) for set point temperature drying \((Td_0 = 45^\circ C)\) and humidity drying \((Rd_0 = 60\%)\) describe by figure 3. with variable : P : Hot; AP : Rather-Hot; H : Swarm; S: Fresh; D : Cold, and for change of humidity ambient used -H = - High, -M = -Medium, -S = - Small, Z = Zero, S = Small, M = Medium, H = High.

\[\text{Figure 3. Membership Function of humidity ambient and change humidity for } Td_0 = 45^\circ C \text{ and } Rd_0 = 60\%\]
Computation process of variable change of humidity ambient are given eq.2. with $n \geq 0$

\[ CH_a[(n+1)T] = Ha[(n+1)T] - Ha[nT] \text{ ... (2)} \]

Representative of conditions of air in variable humidity ambient and this change used to maximum of membership function, with appropriate rule in a table look-up scheme, shown table 3. For other step will be to adjust at table 1.

**Table 3. Look-up table for membership Function for humidity of ambient**

| CHa | H_a | Hot | Rather-Hot | Swarm | Fresh | Cold |
|-----|-----|-----|------------|-------|-------|------|
| -H  | Hot | Hot | Rather-Hot | Swarm | Sejuk |
| -M  | Hot | Rather-Hot | Swarm | Fresh | Cold |
| -S  | Hot | Rather-Hot | Swarm | Fresh | Cold |
| Z   | Hot | Rather-Hot | Swarm | Fresh | Cold |
| +S  | Hot | Rather-Hot | Swarm | Fresh | Cold |
| +M  | Hot | Rather-Hot | Swarm | Fresh | Cold |
| +H  | Hot | Swarm | Fresh | Cold | Cold |

5. Implementation Control System

Automatic control unit has built-in programs for drying of all wood types regardless of a starting wood moisture content. It controls drying process automatically, so the operator presence is not needed during drying. Larger energy consumption is only during first day during heating stage when electrical heaters are turned on until working temperature is reached. Later, during drying stage these heaters are rarely turn on.

If a boiler installation exists in the drying complex, it makes sense to mount heat exchangers for hot water or steam (depending on the boiler) in the kiln. In that case, energy from the boiler would be used for heating of the drying chamber. That way kiln becomes combined (automatically uses boiler heat). This option is interesting only for a large capacity kilns and in the cases where electrical power supply is unstable (large voltage or current oscillation or frequent power cut-downs during winter periods). Drying is in that case performed in conventional way, heat pump is turned-off, and electrical energy is used only for flow fans. Combined kiln unites good characteristics of both dehumidifying and conventional kiln. That provides the greatest drying quality with the least energy consumption for the shortest time.

Drying quality in dehumidifying kilns is significantly better than in any conventional kiln, because the drying is equable in whole timber load, so there is no danger of developing degrade in the timber (cracks, checks, warping...). drying is fast enough since the working temperature can reach up 60°C to. These kilns are environment friendly because all wastes that are produced during drying process are harmless for water and environment. Especially good results are achieved with drying of natural (untreated) wood (beech, ash,...).

**Table 4. Input variable**

| No | Variable              | Range    | Describe |
|----|-----------------------|----------|----------|
| 1  | Temperature Drying Td | 0 - 150°C|          |
| 2  | Temperature Ambient Ta| 0 - 150°C| Weather  |
| 3  | Humidity Drying Rd    | 0 - 100% |          |
### Table 5. Output variable and implemented the fuzzy rule suram

| No  | Rule            | Actuator | Conditions                                                                 |
|-----|-----------------|----------|----------------------------------------------------------------------------|
| 1   | SUR-AM-1        | off      | off  | S | To drop of Temperature Drying Td and to hoist of Humidity Drying Rd by very suddenly [Heating-Process] |
| 2   | SUR-AM-2        | H        | off  | off | To hoist of Temperature Drying by very suddenly and to drop of humidity drying Rd. |
| 3   | SUR-AM-3        | H        | D₁   | off | To hoist of Temperature Drying Td and to stay of Humidity Drying Rd. |
| 4   | SUR-AM-4        | H        | D₂   | S   | To hoist of Temperature Drying and to drop of humidity drying Rd. |
| 5   | SUR-AM-5        | H₁       | D₁   | off | To drop of Temperature Drying Td and to stay of Humidity Drying Rd |
| 6   | SUR-AM-6        | H₂       | off  | S   | To drop of Temperature Drying Td and to drop of Humidity Drying Rd |
| 7   | SUR-AM-7        | off      | off  | off | To stay of Temperature Drying Td and to stay of Humidity Drying Rd |
| 8   | SUR-AM-8        | H        | D₁   | off | To stay of Temperature Drying Td and to adjust Humidity Drying Rd with Humidity ambient Ha [Equalizing-Process] |

**Note:**
- D₁ : Damper ON : 5 menit
- H : Heater ON : 15 menit
- D₂ : Damper ON : 2 x 1 menit
- H₁ : Heater ON : 10 menit
- D₃ : Damper ON : 1 x 1 menit
- H₂ : Heater ON : 5 menit
- S : Sprayer ON : 1 x 1 menit
Result of Implementation the fuzzy rule suram for measurement of temperature drying for schedule Albasia Albizia wood drying, with specification: wood dimension: 4 x 6 cm, amount: 22 item. The figure 4 shown, that measurement of temperature drying can be to follow schedule drying.

![Measurement of temperature drying and MC-Wood at 10-14 Juni 2008](image)

**Figure 4.** Measurement of temperature drying and MC-Wood at 10-14 Juni 2016

6. Conclusion

Rule suram based of fuzzy logic with variables of weather is temperature ambient and conditions of air is humidity ambient, and it can implemented for wood drying process. The membership function of variable of state represented in error value and change error with typical of triangle and trapezium. Result from analysis and evaluation, the 8 fuzzy rule to control for output system can be constructed in a number of way of weather and conditions of air. It used to minimum of the consumption of electric energy by heater. The rule suram used to stability and equilibrium of schedule of drying in chamber by control of temperature and humidity. The result of implemented of fuzzy rule suram with the modification of membership function in range [0.5,1] represented approximate to the conditions are near enough and the actuator doing in the conditions data riel

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