OPTIMIZED OPERATING DRYING CONTROL FOR TEMPERATURE, RELATIVE HUMIDITY AND AIR VELOCITY PARAMETERS BY MEANS OF FUZZY LOGIC APPROACH

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Abstract: The contribution of this paper is to provide a nonlinear MIMO scheme for a drying process, composed by four fuzzy controllers: Fuzzy Dehumidifier Controller (FDC-PD), Fuzzy Humidifier Controller (FHRC-PD), Fuzzy Electrical Resistance controller (FERC-PD) and Fuzzy Blower Controller (FBC-FD) and compare with results obtained previously with PID control scheme. The main aim is to allow the researching of the optimal conditions for codfish drying.

Keywords: drying control, Fuzzy logic, relative humidity, temperature, air velocity

INTRODUCTION

Dryer control is probably one of the less studied areas of process control (Siettos, Kiranoudis and Bafas, 1999). The main reason appointed is the complex dynamic modeling, because their highly non-linear partial differential equations describing heat and mass transfer kinetics involving transport coefficients and thermophysical properties strongly related to the material temperature and moisture content (Zhu, Wang and Qian, 2009). Hence, the model inaccuracy due to several assumptions yield degraded controller’s performance, conducting the expert evaluation as a powerful and alternative tool to develop a high performance control of different process parameters.

The highly nonlinear characteristics of drying processes make classical control theory unable to provide the same performance results as it does in more well behaved systems. Advanced control strategies can be used to design temperature, relative humidity and air velocity nonlinear tracking controllers, in order to overcome its highly non-linear dynamics over the whole drying operating conditions (Liu et al., 2003).

Fuzzy logic has proven its worth as a practical problem-solving tool when the physical constraints are underlined. The fuzzy logic is appropriated for modeling and controlling complex, nonlinear systems because it systematically handles ambiguity (Gou et al., 2005).

The contribution of this paper is to provide a nonlinear MIMO scheme for a drying process, composed by four fuzzy controllers: Fuzzy Dehumidifier Controller (FDC-PD), Fuzzy Humidifier Controller (FHRC-PD), Fuzzy Electrical Resistance controller (FERC-PD) and Fuzzy Blower Controller (FBC-FD) and compare with results obtained previously with PID control scheme. The main aim is to allow the researching of the optimal conditions for codfish drying.

EXPERIMENTAL INSTALLATION

The drying machine has been used for codfish drying, although it can be used to dry any kind of products within its technical specifications. It includes a centrifugal blower, driven by a variable velocity AC motor which defines the air velocity control within the drying chamber. The air is forced through electric heating resistances allowing the air temperature control to be raised. Steam at atmospheric pressure is used for humidification and a dehumidifier is used for cooling and dehumidifying the air. The air velocity is measured by an air velocity transmitter (Omega, model FMA 1000). The air temperature and the relative humidity are acquired through a digital thermo-hygrometer (Omega, model RH411). Figure 1 concerns about the scheme of the dryer where all drying tests were performed.

Fig. 1. Scheme of the drying machine
(1 – centrifugal blower; 2 – humidifier; 3 – electrical resistances of 2 kW; 4 – dehumidifier; 5 – electrical resistances of 1 kW; 6 – air
velocity transmitter; 7 – thermo-hygrometer; 8 – sample; 9 – digital balance).

DRYING PROCESS DYNAMICS

Drying tests were performed for the following operational conditions: air temperature of 15, 18, 20 and 23°C; relative humidity of 40, 45, 50, 55, 60, 65 and 70% and air velocity of 1.5 and 2.5 m/s. Air temperature values should be around 20 °C. Values above 20°C - 22°C will outcome to the deterioration of the codfish. The constraints of the mechanical apparatus have constricted the relative humidity’s values always above 40%. The air velocity’s values stayed in the range used for the fish drying.

CONTROLLERS DESIGN

The overall drying controller was first designed using a PID control scheme (figure 2), but was later upgraded to four fuzzy controllers: FDC-PD, FHRC-PD, FERC-PD and FBC-FD. The control system performance was not designed to be a function of any mathematical model accuracy, avoiding hard questions about lower-order design models required by several control techniques. About the design of the FLCs, the “mamdani” inference mechanism, the “minimum” implication, the “maximum” aggregation and the “COG” defuzzification methods were applied. Manual tuning was used to optimize the FLCs parameters.

Fuzzy Dehumidifier Controller (FDC-PD)

This FDC-PD controller gets a non-linear action of the current and future’s error, through a MISO FLC that defines the proportional and derivative mapping of the relative humidity. Nineteen fuzzy sets and fifty four rules designed the nonlinear behavior between the two inputs and the controller output.

Fig. 4. FDC’s control surface

Fuzzy Blower Controller (FBC-PD)

This MISO-based controller is a nonlinear mapping of the air velocity control action. Nine fuzzy sets and nine rules were parameterized to characterize the behavior with the current and future’s velocity error.

Fig. 5. FBC’s control surface

Fuzzy Electrical Resistance Controller (FERC-PD)

This controller defines the proportional and derivative action of the air temperature. Eleven fuzzy sets and nine rules were designed to map it’s the relation between inputs and the output.

Fig. 6. FERC’s control surface

EXPERIMENTAL RESULTS

From figures 7 to 11 are available the experimental results of both MIMO-based PID and FLC
controllers for temperature and relative humidity parameters.

CONCLUSIONS

This paper proposes high performance non-linear fuzzy controllers for real-time operation of a drying machine. MIMOs-based PID and FLC PD real-time-based controllers were designed, tested and compared for the control of relative humidity and temperature drying parameters. The overall FLC is composed by four fuzzy controllers: Fuzzy Dehumidifier Controller, Fuzzy Humidifier Controller, Fuzzy Electrical Resistances Controller and Fuzzy Blower Controller. Their performance analysis has revealed a better performance of the fuzzy logic controller: absolute mean errors were lower than 2.79% for relative humidity control and 0.349ºC for temperature control, respectively about 3.93 and 3.71 times lower than the experimental results found through PID control. Despite reasonable number of set of rules and fuzzy sets, it was possible to carry out high performance drying controllers, not taken into account the mathematical model of the drying process.

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REFERENCES


