FUZZY CONTROL FOR FABRICS DRYING ON AN INDUCTION HEATED ROTATING CYLINDER:
Experimental results

Sergio Pérez, Zulay Niño
Departamento de Ingeniería Química, Facultad de Ingeniería, Universidad de Carabobo, Valencia, Venezuela

Normand Thérien, Arthur D. Broadbent
Departement de Génie Chimique, Faculte de Génie, Université de Sherbrooke, Sherbrooke, Québec, Canada

Keywords: Textile contact drying, Fuzzy logic control, Heating by induction

Abstract: The removal of water from materials in textile industry and pulp and paper industries requires a high-energy consumption, increasing significantly the operating costs. Nevertheless, electromagnetic induction heating is an alternative with considerable potential for the thermal treatment of materials. Specifically, heating the surface of a metallic cylinder by electromagnetic induction has opened up a range of applications for continuos heating, pre-drying and drying of fibrous web. Otherwise, these news electrotechnologies with industrial applications have to be used under controlled operational conditions. The past few years witnessed a rapid growth in the use of fuzzy logic controllers for the control of processes, which are complex and ill defined. These control systems are inspired by the approximate reasoning capabilities of the process operator. The purpose of this paper is to improve and apply an digital control structure on the basis of fuzzy logic technique for the textile drying using a rotational cylinder heated by electromagnetic induction, manipulating the power supply to the inductors to control the exit humidity of the web. The proposed fuzzy logic controller was tested experimentally in a dryer pilot-scale plant and the results show the capability of the controller to reach the set point initially fixed at 20 g water/100 g dry fabric. Once reached the set point, continuing the trial, steps changes of the web-cylinder contact surface and the set point were done and the results shows the capacity of the proposed fuzzy logic controller in both perturbations.

1 INTRODUCTION

Energy saving and product quality are among the main concerns in industry today. It is well known that the removal of water from materials in the textile and pulp and paper industries requires a high-energy consumption, significantly increasing the operating costs. Many attemps have been made to minimize energy cost. Nevertheless, the available new technologies, such as infrared (Dhib, 1994; Slitine, 1994), micro-wave and radio-frequency (Cross et al., 1982; Jones, 1992) allow a more efficient use of energy with a better product quality. Among these techniques, the electro-technology processes using infrared, microwave, and radio frequency has proven to be effective in the drying of fabrics. Among electro-technologies, electromagnetic induction is worth mentioning. As described by Tokuden (1995), this process utilizes a metal cylinder heated by electromagnetic induction. The induced energy is transmitted directly to the fabric or fibrous material to be dried, and can be regulated by manipulating the power supply to an electro magnetic inductor (Perez et al., 2001).

The past few years have witnessed a rapid growth in the use of fuzzy logic controllers for the control of processes that are complex and ill defined. These control systems, inspired by the approximate reasoning capability of humans under conditions of uncertainty, consist of linguistic if-then rules. For any reasonably complex chemical process, the number of rules required to ensure adequate control may be extremely large. In this paper, a fuzzy controller based on the strategy proposed by Takagi and Sugeno (Passino et al., 1998) was developed to control the exit humidity of the web for a continuous textile drying process, using the power supply to the electrical inductors as the manipulated variable.

Pérez S., Niño Z., Thérien N. and D. Broadbent A. (2004).
FUZZY CONTROL FOR FABRICS DRYING ON AN INDUCTION HEATED ROTATING CYLINDER: Experimental results.
In *Proceedings of the First International Conference on Informatics in Control, Automation and Robotics*, pages 334-337
DOI: 10.5220/0001140303340337

2 EXPERIMENTAL SETUP

The experimental unit consist of an a small-scale dryer by contact rotating cylinder heated by electromagnetic induction. The external and internal diameters of the cylinder are 457 mm and 448 mm, respectively, and the width 358 mm. Three inductors placed over the entire cylinder width are used to heat the cylinder. The possibles manipulated variables in the experimental unit are: the electrical power supply; the rotational speed of the cylinder; and the position of the movable roller that allows adjustement of the surface area of the web in contact with the heated cylinder.

The surface area of the web in contact with the cylinder is adjusted by means of two rollers one which is movable. The maximun and minimun surface between the movable roller and the fixed roller are 1618 cm^2 y 472 cm^2, respectively.

The temperature inside the cylinder wall are measured by three T-type thermocouples placed at different depths in the wall. A contact thermocouple J-type is placed at the inlet drying section to measure the cylinder temperature at this fixed point.

The data acquisition and control are done by a Hewlett-Packard interface (HP-4848) and a HP VECTRA micro-computer, which allow for on-line measurements of the fabric humidity at the entrance and exit of the dryer using a radio frequency-humidity sensor. An optical pyrometer senses the temperature of the fabric at the exit.

3 FUZZY LOGIC CONTROLLER

The development of a Fuzzy Logic Controller (FLC) involves appropriate definitions of the input and output variables, a number of linguistic terms and their membership functions, the rules base, the inference mechanism, and a defuzzification method.

The proposed controller, has two inputs variables: the error (*e*) and the error velocity (v). The two inputs (*e* and v) are used in the FLC to obtain a value of the output variable, the power supply to the inductors.

For each input variable, the error and the error velocity, were adopted five fuzzy linguistic attributes, so that there were 25 possible fuzzy states, each which implied one defined control action. These rules are of the folowing type: if the error is negative high (NH) and the error velocity is negative low (NL), then the response of the output is high energy increasing (HEI). The Table 1 show these fuzzy states and the decision matrix.

Table 1: Labels defined for the inputs variables

		Error velocity				
		NH	NL	ZERO	PL	PH
Error	NH	LEI	HEI	HEI	HEI	HEI
	NL	HED	STOP	LEI	LEI	HEI
	ZERO	LED	STOP	STOP	STOP	LEI
	PL	HEI	STOP	LED	LED	HED
	PH	LED	HED	HED	HED	HED

The control action implied by each rule was then invoked in proportion to the compatibility of the measured fuzzy state with the antecedent of the relevant fuzzy rule; this later operation was done by determining the membership value of the instantaneous error value and the velocity error. For this particular controller, the so-called Π-function (Yamakawa, 1992) has been used.

$$\mu(x) = \frac{1}{\left(1 + \frac{2(x-b)}{W^{n}}\right)} \quad (1)$$

The Table 2 present the parameters values for the membership functions defined for the inputs and output variables.

In the inference step the elements of the output fuzzy set become activated. In this work this is made according to the folowing process: the elements of the input fuzzy sets having μ function greater than zero are paired one element of the error (*e*) variable set to one element of the error velocity (*v*), making all posibles combinations. Looking at the rules, defined previously, to each pair corresponds an element of output the fuzzy set.

The truth value of this output element will be calculated using the inference method named sum-product. If any one of the output fuzzy set elements is activated more than once, its final μ function value will be the sum of alls the activated μ functions of this element.

Table 2: Parameters for the memberships functions

	Error membership funtion		
Fuzzy State	*b*	*W*	*n*
NH	-3	3	8
NL	-1	1	4
ZERO	0	0.5	2
PL	1	1.5	4
PH	3	2	8
	Error velocity membership funtion		
Fuzzy State	*b*	*W*	*n*
NH	-10	4	8
NL	-4	2	4
ZERO	0	1	2
PL	4	2	4
PH	10	4	8
	Power supply membership funtion		
Fuzzy State	*b*	*W*	*n*
HEI	-3	3	8
LEI	-1	1	4
STOP	0	0.5	2
LED	1	1	4
HED	3	3	8

In the defuzzification stage a numerical final output value is obtained through the center-average defuzzification method.

4 EXPERIMENTAL RESULTS

The objective of this stage is to implement the proposed Fuzzy Logic Controller using the pilot-plant cylinder dryer so as to control the exit web humidity by actuating the power supplied to the inductors.

The trial initially involved manual operating conditions leading to a preliminary decrease in web humidity during drying by using a cylinder rotational speed of 1.7 rev/min., a power supply of 2.42 kW and the maximun degree of web-cylinder surface contact (1618 cm^2). This startup step for the process takes about 26 min. Figure 1 shows the operational variables measured on line during the complete trial: the cylinder temperature and the web humidity at the inlet of the drying section, the temperature of the fabric at the exit of the drying section, and the cylinder rotational speed. Once steady–state conditions were achieved, the process was changed to automatic mode and a set point for the exit web humidity fixed at 20 g water/100 g dry fabric. From this moment on, the process is under the Fuzzy Logic Controller action.

In first stage of the process control, as shown in Figure 2, an important increase of the power supplied to the inductors is observed generating an immediate increase in the cylinder temperature, and consequently a fabric with a low exit humidity. From these conditions of over-drying, a reduction of the power is observed. In this early stage, the web humidity oscillates around the set point of 20 g water/100 g dry fabric and the controller takes approximately 45 min. to control the exit web humidity to the set point.

Once the set point value is attained, a step perturbation was made changing the position of the movable roller, decreasing the contact web-cylinder surface. From this second stage of the trial, there is an immediate increase of the web humidity following a reduction in the area of web-cylinder contact (or reduction of the drying time).

The fuzzy logic controller responds by increasing the power supplied to the inductors but the same previous oscillatory dynamic of the exit web humidity is observed tending towards the set point. In the last stage of the trial, a set point change was made, changing the value from 20 to 10 g water/100 g dry fabric. Figure 6 shows the dynamic reponses, for the controlled and manipulated variables and as in the previous stages, the web humidity tends towards the new set point.

5 CONCLUSIONS

A Fuzzy Logic Controller was used with success to control a complex process, like the drying of a fabric by contact with a rotating cylinder heated by electromagnetic induction. The performance of the controller was tested using a pilot scale dryer and a stable reponse was observed when the process was perturbed with changes in the operational conditions and in the set point for the exit web humidity.

REFERENCES

Dhib, R., 1994. Modelisation, simulation et côntrole numérique d'un procédé de séchage par rayonnement infrarouge, Thèse de doctorat, Université de Sherbrooke, QC.

Jones, P.L. 1992. Electromagnetic wave energy in drying process. In drying 92, A.S. Mujumdar, Ed. Elsevier, Amsterdam, pp. 115-136.

Passino K.M., S. Yurkovich. 1998. Fuzzy Control, Addison-Wesley Longman Inc., Menlo Park, California.

Pérez S., N. Thérien and A.D. Broadbent. 2001. Modelling the continuous drying of a thin sheet of fibres on a cylinder heated by electric induction. Can. J. Chem. Eng. 79, 977-989.

Slitine, M.D., 1994. Identification et commande en temps réel d'un procédé de séchage par radiation infrarouge, thèse de doctorat, Université de Sherbrooke, QC.

Yamakawa, T., 1992. A fuzzy logic controller. J. Biotechnol. 7, 1-32

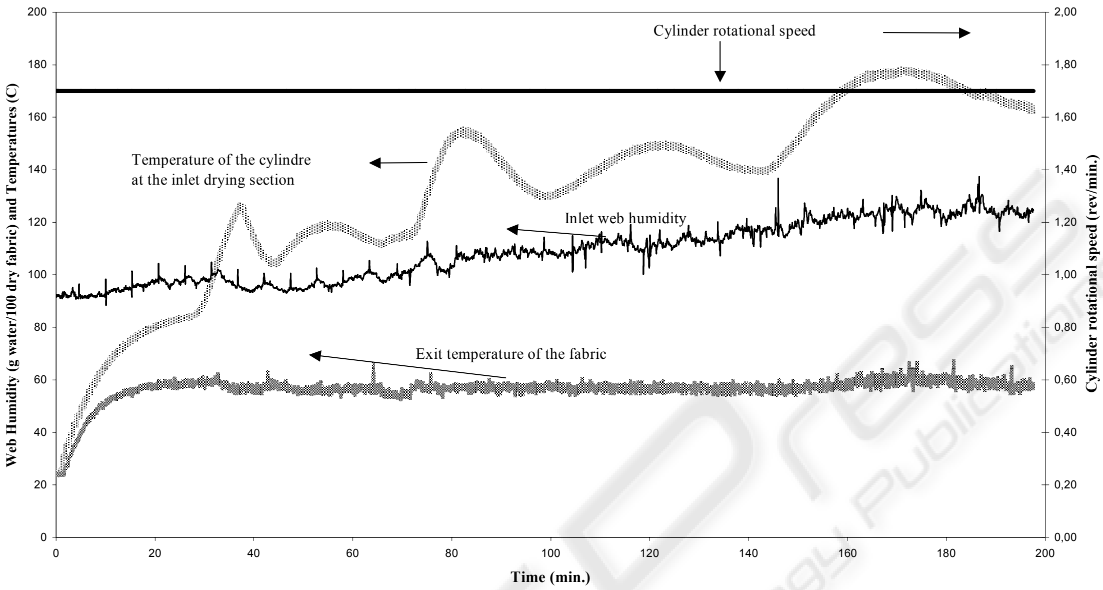

Figure 1: Operational variables during the trial.

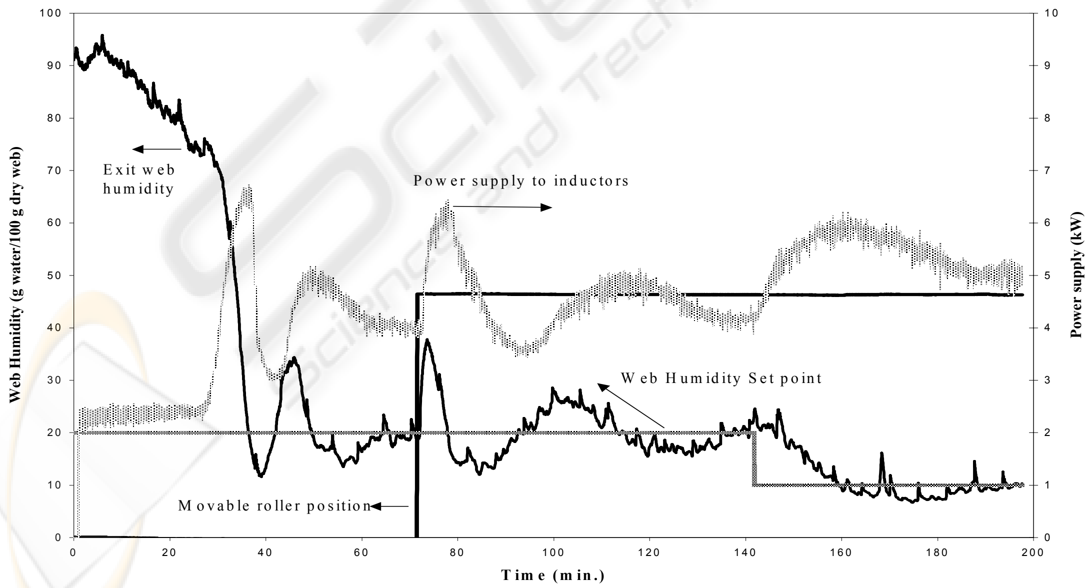

Figure 2: Variables manipulated, controled and perturbations during the trial.