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Color Strength Modeling of Knitted Fabrics Using Fuzzy Logic Approach

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Abstract

Color strength modeling is an important issue for knitted fabrics in textile dyeing industry because of the high demand for quality products. Subsequently, Dyeing is a complex process which is affected by many factors such as dye concentration,temperature, time, p^H, electrolyte concentration etc.on its final quality. Several mathematical, statistical, empirical and intelligent models have been developed in the earlier research only to prognostic the fabrics qualities. It is noted that some of these models are trained using massive amount of experimental data, which are of course challenging and time consuming to accumulate from the textile industries. In this context, a fuzzy logic expert system (FLES) has been employed in modeling such a complex management of process mechanics. The main objective of this research is to model the color strength of cotton knitted fabric using fuzzy expert system as a function of dye concentration,temperature, and time.

Keywords: *Color strength; dyeing process; dye concentration; FLES.*

1. Introduction

Color strength modeling is one of the most fascinating topics in textile dyeing research for Textile Engineers. Specially, quality characteristic is considered as one of the biggest issue in the many parts of the world.Customers demand in today's Textile market is high quality products with minimum price and short time delivery. Subsequently dyeing is the most complex process for color application in Textile manufacturing and Dyeing process is affected by many inside and outside parameters such as dye concentration,temperature, time, P^H, concentration of electrolytes (salt), bath ratio (material liquor ratio), etc. [1]. But the traditional dyeing process consists on trial and error basis which is time consuming with lower efficiency and inferior quality. Moreover, Automatic control of dyeing process is also developing slowly due to complexity of dyeing process.For this reason, there is a need for more efficient and easier system that could be employed in modeling such a complex management of process mechanics .Hence, Fuzzy intelligent modeling and prediction of color strength have become one of the most viable alternatives toconventional predicting techniques.

In the past, a large number of predictive models have been developed to prognosticate the fabrics quality characteristics like color strength, fastness properties, levelness, pilling resistance, tensile strength etc. [2,3]. These models have been developed in the earlier research only to harvest restricted attainment in terms of prediction accuracy and general applicability [2]. It is noted that there are three distinguished modeling methods for predicting fabric quality characteristic such as mathematical models, statistical regression models and intelligent models. Mathematical models related to this study have been developed by various researchers [4, 5]. In fact, mathematical models are based on the fundamental theories of basicSciences. However, the prediction accuracy of mathematical models is not very encouraging due to the assumptions or simplifications used while building these models. On the other hand, statistical regressions models are developed by various researchers have been used in related research [6, 7]. But, the type of relationship (liner or non-linear) is essential for developing a statistical regression model. In addition, artificial neural network (ANN) models have been applied by several researchers related to this study (8-10).Whatsoever, artificial neural network models are trained using massive amount of noise free experimental data, which are of course challenging and time consuming to accumulate from the Textile Dyeing industries.

In contrast, some lacunas of ANN, Mathematical and statistical regression models can be overcome by fuzzy logic expert system, which can effectively translate the experience of a dyer into a set of expert system rules. In others words, Fuzzy logic are employed to solve problems in which descriptions of activities and observations are imprecise, vague and uncertain. In addition, Fuzzy logic is focused on model of reasoning which are approximate rather than exact. For example, In Textile dyeing industries a dyer often applies the term such as high or low, strong or weak, for assessing the dyed fabrics qualities such as color strength, color fastness, color levelness etc.[2].

There are many publications on fuzzy logic application related to this research has been discussed hereunder.Jahmeerbacus et al. [11] successfully applied fuzzy control method for controlling pH in exhaust dyeing to achieve optimum color yield and levelness of dyeing. Huang et al. [12] developed fuzzy expert model for controlling dye bath concentration, pH and temperature in cotton fabric dyeing with direct dye to achieve expected color shade and even dyed product quality. Nasri and Berlic[13] used Evolutionary Fuzzy model for optimizing polyester dyeing process parameters with disperse dye to achieve desired color yield. Nasri et al. [14] proposed a hybrid modelling system Genetic-Fuzzy approach to model the color yield of polyester fibre in high temperature dyeing as a function of dye concentration, time and temperature.

In the present study, an attempt has been made to model a new fuzzy expert system in MATLAB/Simulink for the color strength of cotton blended knitted fabrics in exhaust dyeing with reactive dye as a function of dye concentration, time and temperature.

2. Materials and Methods

In this experiment, Single Jersey Cotton Lycra blended (95/5) knit bleached fabrics (190 GSM) were used for preparing dyed samples. Sodium carbonate (laboratory grade) was used as alkali origin from china and Glauber salt was used as electrolyte origin from china. Remazol Blue RR was used as dyes from Dystar Germany. Laboratory dyeing machine Ugolin and UV Visible spectrophotometer Data color 650 TM were used for the experiment**.**

All bleached cotton blended knit fabrics samples (Each 5gm) were dyed in a laboratory dyeing machine with alkali concentration 12 g/l, electrolyte concentration 45 g/l, material: liquor ratio 1:8 and according to a set of values for dye concentration (%), dyeing time (min) and dyeing temperature (0^0C) as shown in **Table 1**. However, dye concentration, dyeing time and dyeing temperature are the important factors affecting the color strength in cotton blended knit fabric dyeing. The relative importance of these factors can be seen in models representing the color strength as a function of them. These models may also have application in processing and cost minimization. After dyeing all the samples were washed. At the end, the sampleswere dried and measured reflectance value by the spectrophotometer Data color 650 TM brand in a visible region wavelength at 550 nm. Finally, the color strength (K/S) was calculated by Kubelka- Munk relation [15]as shown in Eq. (1).

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \tag{1}$$

where$K$ is the absorption coefficient, S is the dispersion coefficient and R is the reflectance of dyed fabric.
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Table 1. Dyeing conditions

Process parameter	Value of parameters					
Dye concentration (% o.w.f)	0.5	1	2	2.5	4.5	7
Time (Min)	40	50	60	70		
Temperature (0^0C)	50	60	70			

3.Development of Fuzzy expert system

3.1. Structure of Fuzzy expert system

Fuzzy logic expert system is introduced in this study for the prediction of color strength in cotton blended fabrics dyeing. The general configuration of the fuzzy expert system, which is divided into four main parts as shown in Figure1 are: (1) Fuzzification- which takes the crisp numeric inputs (Dye%, time, and temp) and converts them into information of fuzzy form, (2) Knowledge base- which holds a set of linguistic term, if-then rules that quantify the knowledge like human experts, (3) Decision making logic-which creates the control actions according to the information provided by the fuzzification module by applying knowledge about how best to control the plant, and (4) Defuzzification-which calculates the actual output, i.e. converts fuzzy output into a precise numerical value (crisp value) and then sends them to the physical system (plant).

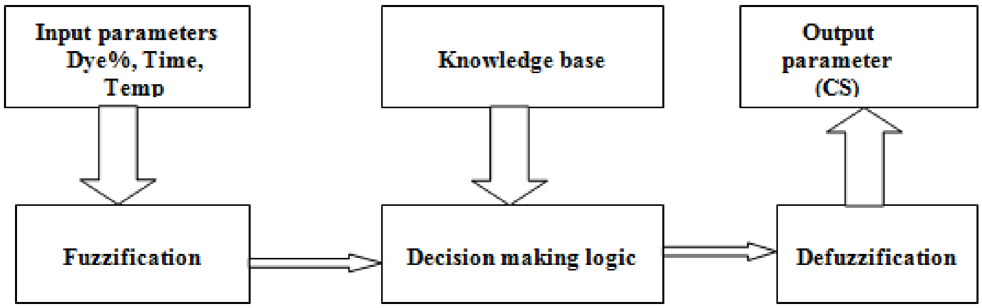

Fig. 1. Basic structure of fuzzy expert system

3.2. Implementation of Fuzzy expert system

In this work, three dyeing process parameters such as dye concentration (DC), dyeing time (DT), and process temperature (PT) have been used as input parameters and color strength (CS) of dyed fabrics has been used as output parameters.For fuzzification of these factors the linguistic variables low (L), medium (M), and high (H) are used for the inputs, and verylow (VL),low (L), medium (M), high (H) and very high (VH) are used for theoutputs. In this study, a Mamdani max-min inference approach and the center of gravity defuzzification method have been used (Fig. 2) because these operators assure a linear interpolation of the output between the rules [16]. The units of the input and output variables are: DC (%), DT (min), PT (0^0C) and CS (dimensionless). For the input and output parameters, a fuzzy associated memory is formed as regulation rules. Total of 27 rules have been formed.

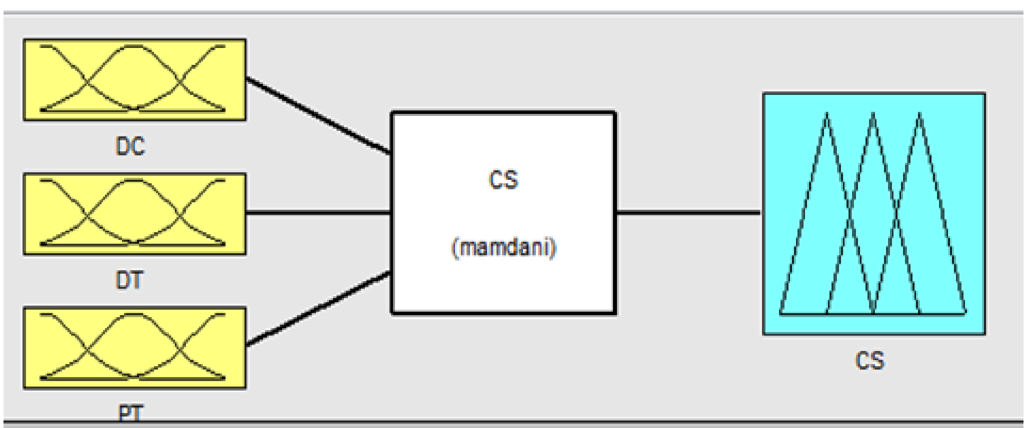

Fig. 2. Basic structure of fuzzy inference system

There is a degree of membership for each linguistic term that applies to that input variable. Fuzzifications of the used factors are made by aid follows functions.

(2)

(3)

$$PT(i_3) = \begin{cases} i_3; & 50 \le i_3 \le 70 \\ 0; & otherwise \end{cases} \quad (4)$$

$$CS(o_1) = \begin{cases} o_1; & 1 \le o_1 \le 22 \\ 0; & otherwise \end{cases} \quad (5)$$

In Eqns. (2)-(5), i_1 is the first input variable (*DC*), i_2 is the second input variable (*DT*),i_3 is thethird input variable (*PT*) and o_1 is the output variable (*CS*). Prototype triangular fuzzy sets for the fuzzy variables, namely,dye concentration (DC), dyeing time (DT), and process temperature (PT) and color strength (CS)are set up using MATLAB FUZZY Toolbox.

To illustrate the fuzzification process, linguistic expressions and membership function of dye concentration (DC) obtained from the developed rules and is presented analytically as follows:

$$\mu_L(DC) = \begin{cases} 1; & x \le 0.5 \\ \dfrac{2-x}{2-0.5} & 0.5 \le x \le 2 \\ 0; & x \ge 2 \end{cases} \quad (6)$$

$$\mu_M(DC) = \begin{cases} \dfrac{x-2}{3.5-2}; & 2 \le x \le 3.5 \\ \dfrac{5-x}{5-3.5}; & 3.5 \le x \le 5 \\ 0; & x \ge 5 \end{cases} \quad (7)$$

$$\mu_H(DC) = \begin{cases} 0; & x \le 5 \\ \dfrac{x-5}{7-5}; & 5 \le x \le 7 \\ 1; & x \ge 7 \end{cases} \quad (8)$$

Similarly,the linguistic expressions and membership functions of other parameters could be calculated. In defuzzificationstage, truth degrees (μ) of the rules are determined for the each rule by aid of the min and then by taking max between working rules. In this stage, the output membership values are multiplied by their corresponding singleton values and then are divided by the sum of membership values to compute CS^{crisp} as follows

$$CS^{crisp} = \frac{\sum_i b_i \mu_{(i)}}{\sum_i \mu_{(i)}} \quad (9)$$

whereb_i is the position of the singleton in the *i*th universe, and $\mu_{(i)}$ is equal to the firing strength of truth values of rule*i*.

4. Result and discussion

Fuzzy logic expert system has been developed based on dye concentration (DC), dyeing time (DT), and process temperature (PT). The final output (CS) of the fuzzy logic system is verified by using MATLAB Fuzzy Toolbox as shown in Figures 3and 4. The output result can be verified by changing the input variables values in the MATLAB® rule viewer as shown in Fig. 3. For example, if DC is 7%, DT is 40 min, and PT is 50^0C, then all twenty seven fuzzy rules are evaluated simultaneously to determine fuzzy output colour strength (CS). However, some of the rules are remain obsolete as ‘fuzzy and’ function has been used in the antecedent part of the fuzzy rules and they do not produce any output fuzzy set. Outputs of active fuzzy rules are then aggregated to get a final output fuzzy set, which is finally defuzzified using centroid method to produce the crisp output

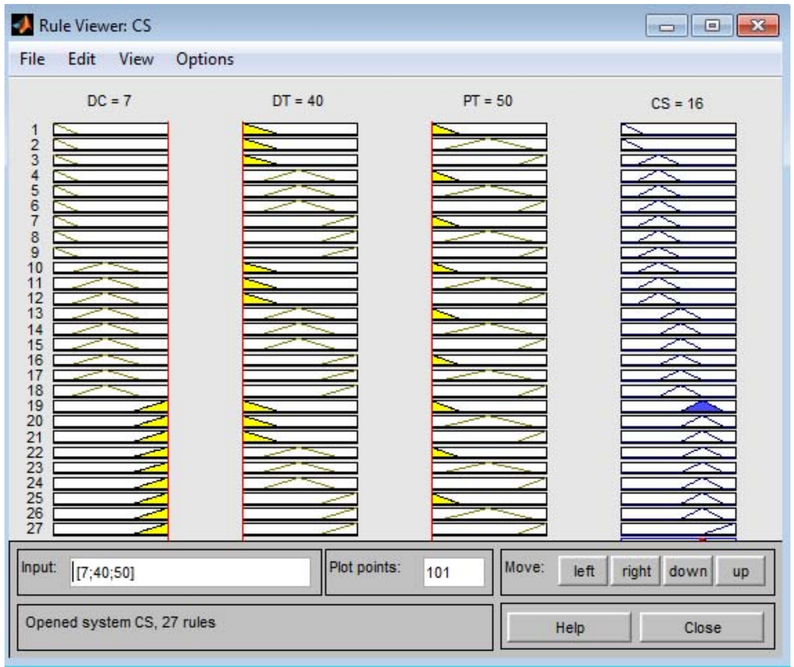

Fig. 3. Graphical representation of the fuzzy logic operation.

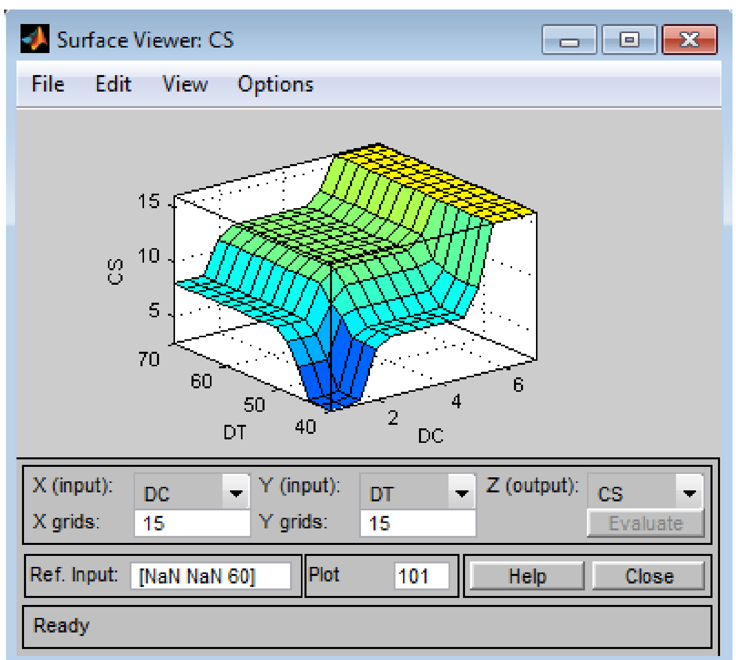

Fig. 4. Control surface of the fuzzy logic system.

(*CS*) of 16 as shown in Figure 3.Using MATLAB the fuzzy control surface is developed as shown in Figure 4. It may serve as visual depiction of how fuzzy logic expert system operates dynamically over time. This is the mesh plot of the example relationship between dye concentration (DC), and dyeing time (DT) on the input side and system outputcolor strength (CS) on the output side. This control surface displays the range of possible defuzzified values for all possible inputs of DC and DT. The plot is used to check the rules and the membership functions and to see if they are appropriate and whether modifications are necessary to improve the output. If necessary, the rule base for the fuzzy sets is modified until the output curves are desired. In fact, the surface plot shown in Fig. 4depicts the impacts of dye concentration and dyeing time parameters on the colour strength. It shows that as the dye concentration and dyeing time increase positively, there is concomitant increase in colour strengthand vice versaas expected. The colour strengthreaches the apex when the dye concentration and dyeing time both reach their respective maximum level. Similarly, another input parameter process temperature can be included with any of the mentioned two input parameters to show their effect on the output colour strength. However, the surface represents in a compact way all the information in the fuzzy logic system. Hence, it can be noted that this representation is limited in that if there are more than three inputs it becomes difficult to visualize the surface. Furthermore, this figure simply represents the range of possible defuzzified values for all possible inputs.Therefore, it is important to keep the dye concentration in optimum level to get the maximum colour strength and hence sufficient time with process temperature to maintain the normal dyeing operation.

5. Conclusion

This paper employs fuzzy logic expert system to model the color strength of cotton blended knitted fabrics. Color strength has been modeled in terms of dye concentration, dyeing time and process temperature. The expert system was developed by translating the perception and experience of a dyer into a set of expert system rules. Development of fuzzy logic expert for color strength measurement of cotton blended knitted fabric can be done by using fuzzy logic toolbox in MATLAB. The developed model can be used in textile dyeing operation to predict the color strength as per requirement.

However, the developed fuzzy expert system is reasonably easy to develop and it could be modified easily if the dyeing process parameter is changed. Furtherresearches are ongoing to incorporate more input variables in the expert system in order to get more reasonably and good accuracy result. In addition, the developed model will be validated by investigating the experimental results which are in process.

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