ISSN 1746-7659, England, UK
Journal of Information and Computing Science
Vol. 8, No. 2, 2013, *pp.*141-152

Modeling Plasma Fabric Surface Treatment Using Fuzzy Logic and Artificial Neural Networks

Radhia Abd Jelil [1], Xianyi Zeng [2], Ludovic Koehl[2] and Anne Perwuelz [2]

[1] Institut Supérieur des Arts et Métiers de Tataouine, 3200 Tataouine, Tunisia
[2] ENSAIT, GEMTEX, F-59000 Roubaix, France

(*Received October 30, 2012, accepted February 28, 2013)*

Abstract. In this paper, Artificial Neural Networks (ANNs) are used to model the effect of atmospheric air-plasma treatment on fabric surfaces with various structures. In order to reduce the complexity of the models and increase the knowledge and comprehension of the underlying process, a fuzzy sensitivity variation criterion is used to select the most relevant parameters which are taken as inputs of the reduced neural models. The model outputs are the water contact angle and the capillarity of woven fabrics, characterizing the change of fabric surfaces. The early stopping and Bayesian regularization techniques are used for improving the network's generalization capability. Two different network configurations are studied. One deals with two networks having each one output layer neuron and another with a single network combining the two outputs. Obtained results showed that the first configuration combined with the Bayesian regularization approach is the most suitable to achieve a good prediction accuracy.

Keywords: neural networks, fuzzy selection criterion, modelling, atmospheric plasma, woven fabric

1. Introduction

In recent years, atmospheric plasma treatment has gained increasing interest for application in the textile industry. This technology is an environmentally friendly alternative to conventional wet-chemical processes, since it does not require the use of water and since there is no waste production. Other advantages of it include: low cost of operation, rapid processing and high efficiency. A plasma is a partially ionized gas composed of highly excited atomic, molecular, ionic and radical species, as well as photons and electrons. These active species can enable a variety of generic surface process including surface activation by bond breaking to create reactive sites, dissociation of surface contaminants (cleaning), material volatilization and removal (etching), and deposition of conformal coatings (polymerization) [1]. In all these processes, only the topmost layer of the material are modified leaving the bulk properties unaffected. The altered surface properties are ideal for dyeing, printing, or adhesive bonding. Although enormous literature is available on plasma surface modification of textile fabrics [2-9], a systematic study on the simultaneous effects of various reaction parameters on the surface properties is still lacking. In practice, the induced plasma effects depend not only on the gas used but on a multiplicity of factors like electrical power, treatment time, substrate nature and so forth [3,4,7,10]. The relationship between these factors and surface wetting properties is very complex and non-linear. It is very difficult to characterize this relationship analytically. Thus, we use neural networks to construct a model. In fact, neural networks have numerous attractive properties for modeling complex systems such as efficient learning from experimental data, universal approximations for any arbitrary complex relation between input and output patterns, resistance to noisy or missing data, and good generalization ability [11-13]. Indeed, neural networks have recently been applied to a variety of plasma-based processes [14-17]. In this way, studies have shown that neural network models exhibit superior accuracy and predictive capabilities over traditional statistical methods and require less experimental training data [18-20].

However, developing neural network models is constrained by many factors such as the complex non-linear relationship between input and output variables, the large dimensionality of the input space, the presence of redundant variables and the lack of available learning data. These factors may cause a deterioration of the generalization ability and an increase of the computational cost. Therefore, selecting the most relevant input variables is critical to enhance model performance and increase interpretability of the results [21,22]. In this way, the selection of process parameters allows manufacturers to adjust only a few number of the most relevant parameters in order meet the requirements. In literature, many features selection techniques have been proposed [23-25]. In our study, as the number of available

+ Corresponding author. Tel.: +216 75 844 930; fax: +216 75 844 930.
E-mail address: abdjelilradhia@yahoo.fr.

experimental data is rather limited, we use the fuzzy sensitivity variation criterion developed by Deng et al. [26,27] to identify the most relevant fabric parameters to achieve the desired modification results by air-plasma treatment. This method has been applied successfully to the design of a non-woven process [27]. By comparison with the classical selection methods, the proposed criterion has shown to be more robust and less sensitive to measured data noises and uncertainties. Furthermore, it can deal with a very few number of learning data. These advantages proved a strong motivation to the present paper for using such method to select the most relevant plasma process parameters in order to reduce data complexity and obtain more interpretable results with a very limited cost. The results obtained from this fuzzy-based method will enable to better understand, control and optimize the plasma process in order to obtain the desired effect.

In this paper, a fuzzy sensitivity criterion is used to select the most relevant input parameters of plasma process to be used to develop neural network models for predicting fabric surface wetting properties. The use of early stopping and Bayesian regularization approaches are considered. Two different network configurations are studied. One deals with two networks each having one output layer neuron and another with a single network that gives two outputs. A comparison between these configurations and training algorithms is performed.

2. Experiments and measurements

2.1. Materials

Six different woven fabrics are used during this study. Two of them are made of viscose fibers, and the others of polyester (PET) fibers. Before air plasma treatment, the woven samples are cleaned and left in a controlled climate (20±2°C, 65±2% relative humidity (RH)) for at least 24 hours prior to all experiments. Table 1 presents the fabric features and their ranges. The numeric values 0 and 1 are used to encode the corresponding woven feature (given in parentheses).

Table1. The range of woven fabric features.

Parameter	Minimum	Maximum
Fiber nature	0 (100% polyester)	1 (100% viscose)
Fabric weight (g/m^2)	160	200
Thickness (mm)	0.31	0.41
Construction	0 (plain)	1 (3/1 twill)
Weft density (picks/cm)	17.2	21
Warp density (ends/cm)	39.2	45
Weft count (dtex)	150	340.29
Fiber count (dtex)	0.9	1.7
Air permeability (l/m^{2}s)	19.62	786.2
Porosity (%)	60.55	69.51
Surface roughness (μm)	41.86	74.4

2.2. Plasma treatments

Plasma treatments are carried out using an atmospheric plasma machine called “Coating star” manufactured by the Ahlbrandt system (Fig.1). The following machine parameters are kept constant: frequency of 30 KHz, electrode length of 0.5m and inter-electrode distance of 1.5mm. The electrical power and treatment speed are varied respectively between 300-1000 Watts and 2-10 m/min. Plasma discharge is generated at atmospheric pressure by two electrodes and a counter-electrode both covered by a dielectric ceramic material. During plasma treatment, woven samples are in contact with the counter-electrode, and passed through the plasma gas present between the electrodes/counter electrode gap.