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ARTIFICIAL NEURAL NETWORK MODELING FOR TENSILE STRENGTH OF PAPER IN PAPER MANUFACTURING PROCESS

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This paper presents artificial neural network modeling for tensile strength of paper. In this paper firstly empirical model for tensile strength has been developed,secondly artificial neural network modeling is done and then empirical model is compared with artificial neural network modeling. Back propagation neural network is used for making artificial neural model for tensile strength of paper. The training of back propagation has been done using Matlab 7.1 software.

1. Introduction

Use of artificial intelligence (AI) has become a tool for optimization and control of various process parameters in chemical process and allied industries including pulp and paper. The AI includes mainly artificial neural network (ANN), Fuzzy Logic (FL), Genetic Algorithm (GA) or their combinations. In majority of cases ANN is found by the designers to be the most convenient one and is currently being applied in almost all process industries for optimizing, process modeling and simulating[2], fault detection and diagnosis and controlling of various processes and operations. Artificial neural network need learning/training which implies that the neuron somehow changes its input/ output behavior in response to the environment. Neurons in the network learn by changing the weights on the inputs. Learning methods in neural networks can be broadly classified into three basic types: supervised, unsupervised, and reinforced. These are further sub classified as: error correction gradient descent, stochastic, least mean square, back propagation and hebbian competitive etc. Application of ANN in modeling and control in paper industry has been in focus in almost all areas except paper machine wet end system.

2. Need for Applying ANN in Paper Making Process

There are many problems found in pulp and paper mills that have characteristics which make this problem difficult to handle from a control standpoint. This is mainly due to the nonlinear nature of most of the subsystems of paper mill. Combination of a neural network system, a rule based system and a conventional computational system can provide a tool to handle these problems with simplicity and effectiveness. Neural networks can also be very useful for "quick and dirty" models. The ANNs are able to accurately represent even complex nonlinear behavior, the nature of which is not known to the user. Paper making process consists of a large number of subsystems (unit operations and processes).

3. Paper Making Process

The paper is produced through a number of unit operations and processes in a paper industry. From instrumentation view point these may be termed as subsystems like raw material preparation, pulping, washing of brown stock, bleaching, stock preparation, approach flow system, wet end operation, drying, calendaring and chemical recovery operation. Surface sizing, Filling and coating are rather additional operations. Attempts can be made to use artificial neural network techniques tensile strength modeling of paper. The tensile strength is measured at the last portion of the paper. In order to get paper of desired quality various measurement and control systems have been attempted for sensing and controlling numerous parameters in the paper mill. But these are not adequate and constant efforts are being made to upgrade the measurement and control of the operations and processes. The following section details about the existing practices of control and instrumentation of the wet end section. The subsystem selected for modeling in this present investigation starts from the machine chest to mainly headbox, and retention for wet end machine. However, the complete paper machine is extended up to the pope reel through presses, driers and calendars as shown in fig 1.

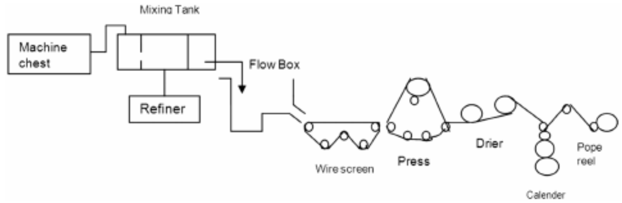

Fig.1: Paper Making Process

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The significant dead times that exist in a papermaking system present process control challenges. In Fig.2 the time associated with the reel is one-half the time required to build a typical reel of paper. Figure shows that a disturbance in any of fiber supply chests might not appear in the produced paper. If the paper quality of interest is not monitored on-line, the reel build time must also be added, along with the off machine sampling and testing times.

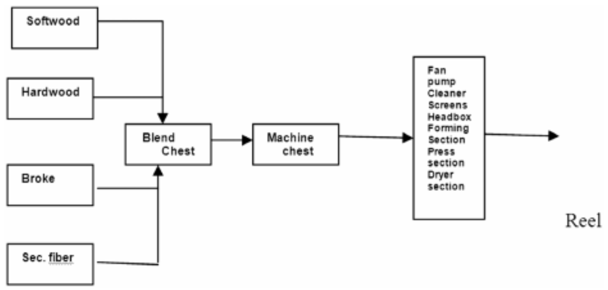

Fig.2: Papermaking System

4. DEVELOPMENT OF A SEMI-EMPIRICAL VERSION OF THE PAGE EQUATION

A new semi-empirical version of the Page Equation has been developed [5]. The model was found to provide good predictions of the machine direction and cross direction tensile strength of paper. The effects of refining, filler level, cationic starch level, and fiber properties are included in the model. A way to integrate the model with a dynamic material and energy balance simulation of a paper machine is described and potential papermaking applications suggested.

The Page Equation for the tensile strength of paper has the following form

(i) $1/T = K1/ Z(CSF) + K2\ W_f /[[(1 - S_f)(1 + 7.44Xcs)]\ l_f(CSF)]$

Where

Z = Zero span tensile strength, reflecting fiber strength.

τ_b = breaking stress of bonds (breaking force over bond area).

W_f = fiber width, l_f = fiber length, RBA = Relative bonded area.

Xcs = the mass of cationic starch added per unit mass of fibers.

S_f = the fraction of the relative bonding area reduced by the addition of filler.

B(CSF) Cowan's B factor.

Z(CSF) Zero span tensile strength.

If(CSF) Average fiber length.

K1 and K2 are constants

MD Tensile

(ii) $1/T = 0.0203/Z + 4.374\ W_f /[[(1 - S_f)(1 + 7.44 Xcs)]BL$

CD Tensile

(iii) $1/T = 0.045/Z + 10.29\ W_f /[[(1 - S_f)\ (1 + 7.44 Xcs)]BL$

Where,

W_f = fiber width in µm

L = mass-weighted average fiber length of hardwood and softwood l_f (CSF) in the furnish, mm

Xcs = the mass of cationic starch per unit mass of fiber = cationic starch add. rate (lb/ton) ÷ 2000

Z, B = mass-weighted average of hardwood and softwood Z(CSF) and B(CSF)in furnish.

Hardwood Z and B

(iv) $B(CSF) = -1E - 05(CSF)^2 + .0027(CSF) + 6.9038$

Softwood Z and B

(v) $Z(CSF) = -3E-05(CSF)^2 + .0147(CSF) + 68.316$

(vi) $B(CSF) = 2E - 06(CSF)^2 + .003(CSF) + 2.8621$
Fiber Lengths

(vii) Hardwood l_f : l_f (CSF) = 0.7

(viii) Softwood l_f: l_f (CSF) = $3.0E - 06(CSF)^2 + 0.0015 (CSF) + 1.629$

Predicted tensile values calculated with Equations (ii) and (iii) were compared to artificial neural network modeling for tensile strength of paper.

5. ARTIFICIAL NEURAL NETWORK MODELING

Bhat[3]suggested that neural network have been shown to be successful in modeling nonlinear dyanamic system. In this present investigation, back propagation neural network is used 2:4:1 network with logsigmoid activation function. The delta rule or gradient decent technique has been used for training .The training parameter like learning rate is the order of 0.7 is used for training the network. In this present investigation, error correction learning has been used for neural network modeling. Learning [4,6] in neural network is known as learning rule, in which weights of the networks are incrementally adjusted so as to improve a predefined performance measure over time. Learning process is an optimization process, it is a search in the multidimensional parameter (weight) space for solution, Which gradually optimizes an objective(cost)function. The technique of back propagation, apply error-correction learning to neural network with one hidden layers. Back propagation requires a perception neural network. Each layer must feed sequentially into the next layer.

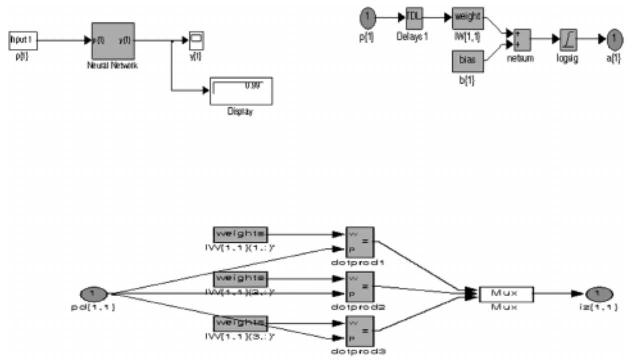

Fig. 3: ANN Model

The ANS becomes a powerful tool that can be used to solve difficult process applications. Figure 3 depicts the designing procedure of Artificial Neural Network modeling. The flow chart[1] for neural network algorithm for tensile strength of paper is depicted in figure 4.

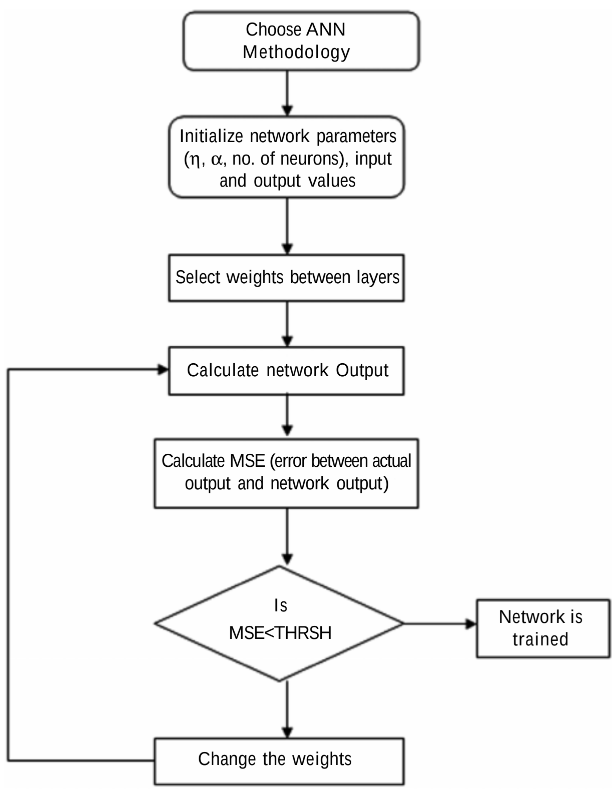

Fig. 4: Flow Chart for Neural Network Algorithm

Artificial Neural Network Training

During training of back propagation neural network, the straight line shows the error goal or performance of network of the order of 0.0001. This performance of network is reducing, and from 1x10^4 epochs it becomes gradual and at Epoch 95454/10000, MSE 9.99997e-005/0.0001, Gradient 5.43691e-005/1e-010 performance goal is met. The training pattern is depicted in fig. 5.

Firstly the model data is obtained through simulation f empirical modeling equations. These data have been used for artificial neural network modeling. For ANN modeling train the BPNN with 2:4:1 network. After training thenetwork or when performance goal is met, found the ANN modeling data. Table 1 shows model data, Neural Network data and the percentage error between both of them. It shows that the maximum error between ANN and model data is 2.845927 and the minimum error is -3.00981, the maximum number of data of neural network model are closely matched with the empirical model data (fig.-6).

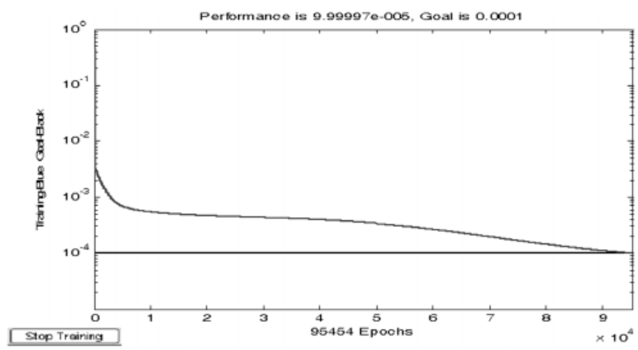

Fig. 5: Training Diagram

Table-1
Comparison of Model Data with Neural Network Data

Model Data (1/T)	Neural Network Data(ANN)	% Error
1.019	0.99	2.845927
1.0176	0.9899	2.722091
1.0156	0.9897	2.550217
1.0002	0.988	1.219756
0.9746	0.9773	-0.27704
0.96585	0.9691	-0.33649
0.93273	0.928	0.507114
0.9722	0.9173	5.646986
0.888	0.9092	-2.38739
0.86123	0.8506	1.234281
0.8264	0.8274	1.07604
0.8246	0.8274	-0.33956
0.8133	0.8274	-1.73368
0.80138	0.8255	-3.00981

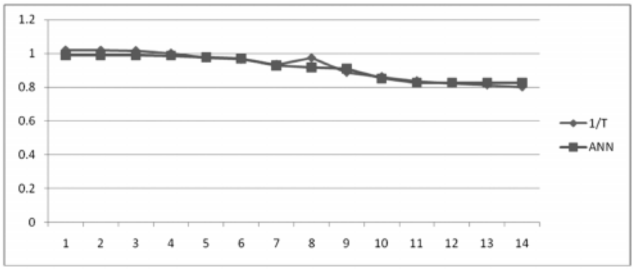

Fig. 6: Graph Between Model Data and Neural Network Data

Result and Discussion

Hence from the above investigation it has been concluded that artificial neural network model gives better performance when it is trained with accuracy. After training the network the maximum number of data of neural network model are closely matched with the empirical model data. Therefore BPNN is the best way to model the tensile strength of paper.

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