An Attempt to Predict Weathering Indicator (Percentage Transmittance) of Coal using Artificial Neural Network

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Abstract— Weathering is a continuous process; the best way to deal with weathered coal is to identify the extent of weathering. Based on level of weathering its consumption pattern should be changed, this will help in minimizing the effect of weathering on coke quality. Due to weathering, various technological properties of coal get altered such as as ash, free swelling index, fluidity, plastic range and size degradation. There are various methods to monitor coal weathering. Percentage transmittance determined by alkali extraction test is one of the ways to monitor weathered coal. This paper discusses the use of artificial neural network (ANN) to predict the percentage transmittance. ANN model was developed using the experimental data and R Square values for training, testing and validation are 0.99, 0.95 and 0.98 respectively. It means the developed model can successfully predict the deterioration trend of coal weathering. It will help to take suitable action to minimize the effect of coal weathering on coke quality.

Key words: Coal, Coke, Percentage transmittance, ANN

I. Introduction

Coal weathering is a wider term which includes oxidation as major cause for deterioration in coal quality. In present paper, research scope is limited to deterioration of coal quality due to natural weathering mainly due to oxidation. Weathering is a continuous process which starts from seam and continue while transportation and storage. Air (oxygen), Moisture, slackening due to handling of coal are major contributor for weathering.

Due to weathering different technological properties of coal get altered some are ash, volatile matter, free swelling index, and fluidity, plastic range etc.

In the past, many attempts have been made to measure the degree of weathering of a given coal sample. Yongseung Yun et.al (1987) suggested various weathering index. But since coal is heterogeneous material and its properties differ according to rank and seam so it is very difficult to define reliable standard values for the degree of weathering. This was also supported by M. M. Wu et.al [1988]

D.E Lowenhaupt et.al [1980] found that alkali extraction test is a standard test for detecting oxidized metallurgical coal. Lowenhaupt and Gray (1980) used this method to identify weathered coal in coal blends of U.S. Steel. In this test coal was boiled in caustic solution, oxidized coal dissolve and draken the solution. Light transmittance of solution was determined by UV- visible – spectroscopy at 520 nm. They found that if transmittance value is less than 80 % then the coal is not suitable for metallurgical purpose.

This paper discuss about effect of weathering on coal quality. In present work different coals which are used in the Blend of BSP were stored at RCL Lab for a period of 5 months. In every month representative samples were withdrawn and change in its quality were determined. In this work percentage transmittance was measured for every sample. From the generated data ANN was developed to predict the transmittance value. This prediction can be used in forecasting the weathered status of coal received at site. This will help in setting the consumption pattern.

II. Materials and Methods

In this study 5 types of coal Hard-1.Hard-2,Soft, Prime and Medium coking coal, which are used in one of the SAIL plants were collected. Each coal sample was first screened manually using 12 mm screen, and the sample which passed through a 12 mm screen was stored in an open tray and kept at Research and Control Lab of Bhllai Steel Plant for a period of 5 months. To evaluate weathering a representative sample was obtained every 30 days. The average size of coal also determined for each sample. After average size determination these samples were reduced by coning and quartering then ground in a ball mill. Ground samples were screened through 72 and 60 mesh. The sample which passes through 60 mesh was used for pH measurement and (-72 mesh) sample was used for proximate and free swelling index (FSI), petrography, ash chemistry (Basic to Acid ratio.

	Ash (%)	VM(%)	MMR	BAR	CSN	Vitri (%)	Day	Size (mm)	% Transmittance
PCC	28.5	18.7	1.24	0.15	1	38.9	0	4.17	99.85
Hard-1	9	27.2	1.25	0.108	6.5	65	0	2.976	99.85
MCC	33	25.4	0.9	0.16	1	30.3	0	6.1	99.69
Hard-2	8.4	26	1.11	0.312	5	64.4	0	2.809	95.44
Soft	9.2	25	1.02	0.27	3	53.9	0	2.791	99.84

Table 1: Properties of Coal Stored

Parameters	Min	Max
Transmittance (%)	78	99.85
Ash (%)	8.2	33
Vm (%)	18.7	27.2
MMR	0.9	1.25
BAR	0.108	0.312
Vitri (%)	27.4	65
Days	0	153
Size (mm)	2.791	6.1

Table 2: Maximum and minimum values of properties observed

Input data set	Ash, Volatile matter, Mean Max

	Reflectance, Basic Acid Ratio, time (Day), Avg.Size of Coal
Output data	% Transmittance
No of Hidden Layer, no of neurons	1, 10
Training Set	20
Testing set	5
Validation Set	5

Table 3: Details of ANN models

Table (1) show the property of coal stored for study of weathering propensity. Then sample were drawn and testing were conducted every month for all samples. The max and minimum values of each parameter are shown in table (2)

Artificial neural network (ANN) is a powerful tool and has been applied successfully in numerous fields. In the Iron making area some of the work published are Prediction of coke strength after reaction and data analysis (Sulata Maharana et.al [2010]),prediction of operational parameters effect on coal flotation using ANN (E.Jorjani et.al [2008]), use of ANN for prediction of chemical composition of hot metal produced in Blastfurnace (L.A.Dobrzanski et.al. [2014]).

ANN are most often chosen for its ability to generalize results from unseen data, especially for dynamic systems on real time basis. ANN can identify and learn correlated patterns between input data sets and corresponding actual target values. ANNs are networks of highly interconnected neural computing elements that have ability to respond to input stimuli and to learn to adapt to the environment. ANN includes two working phases, the phase of learning and that of recall. During the learning phase, known data sets are used as a training data in the input and output layers. The recall phase is performed by using the weight obtained in the learning phase (Taskin et.al.[2008])

The aim of the present work is the assessment of weathering propensity of coal being used by Indian steel plants. In one of steel plant uses 6 types of coal for coke making viz. Hard-1,Hard-2,Hard-3, Soft, PCC (Prime Coking Coal) & MCC (Medium Coking Coal). As Hard-3 was used in very low percentage so it is not included in this study. By Using data collected from experiment conducted on laboratory, ANN model developed by using MATLAB software . As per literature survey this is the first time that ANN have been used to predict weathering indicator(Percentage transmittance) using different input parameters collected during experiment.

III. DEVELOPMENT OF ANN

ANN's are basically generated with layers of units and are termed as Multilayer ANN's. These multilayer networks are capable of any linear or non-linear computation, and is well suited for approximation functions. It consists of 3 layers namely input layer, hidden layer and an output layer.

Hidden layer may be one or more based on the difficulty of the given problem. The hidden layers are behaved as black box. The input layer passes the signal to the output layer through hidden layer(s). The MLP architect with black box relationship and hidden layer is shown in Fig. 1 and 2, respectively.

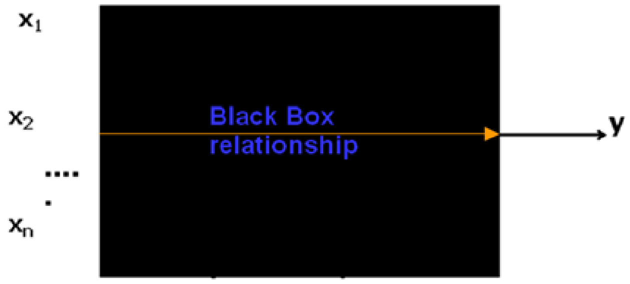

Fig. 1: Multilayer Perception Architecture with Black Box Relationship

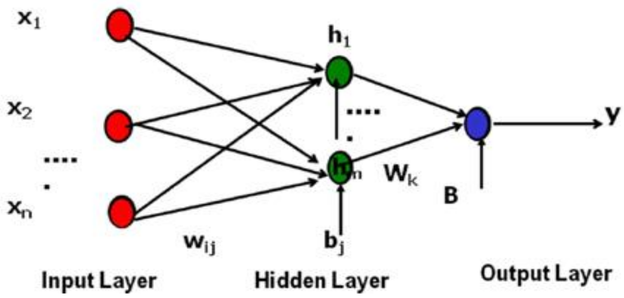

Fig. 2: Multilayer Perception Architecture with Hidden Layers

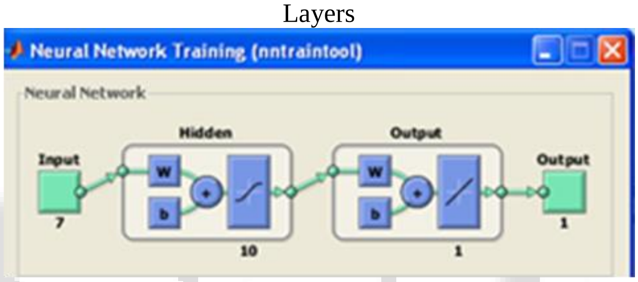

Fig. 3: Architecture of neural network

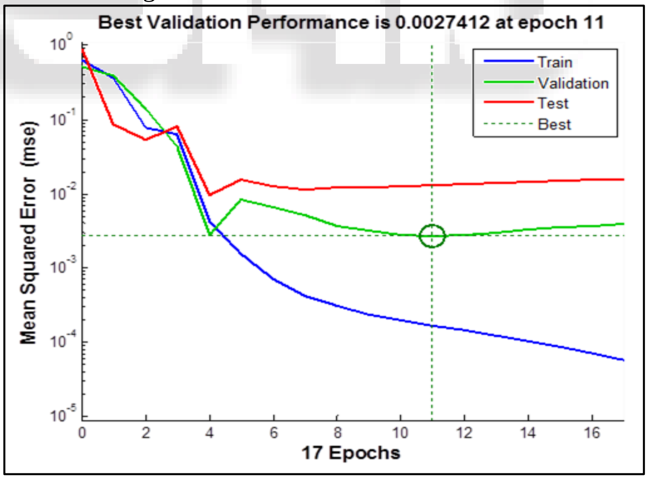

Fig. 4: Mean Squared error

The role of neurons in the input layer is to transmit or distribute the scalar input to the next stage i.e. the hidden layer. The hidden layer adds up the weighted inputs as received from the input nodes, and further adds a bias before passing the result to a non-linear transfer function.

The normalization of all input patterns (set of inputs and outputs) are done by equation 1. The repetition of patterns is defined as epoch. Data mapping was carried out by feed forward network with back propagation algorithm of training. The back propagation network is a multilayer feed forward network with different transfer functions in the artificial neuron and a powerful learning rule.

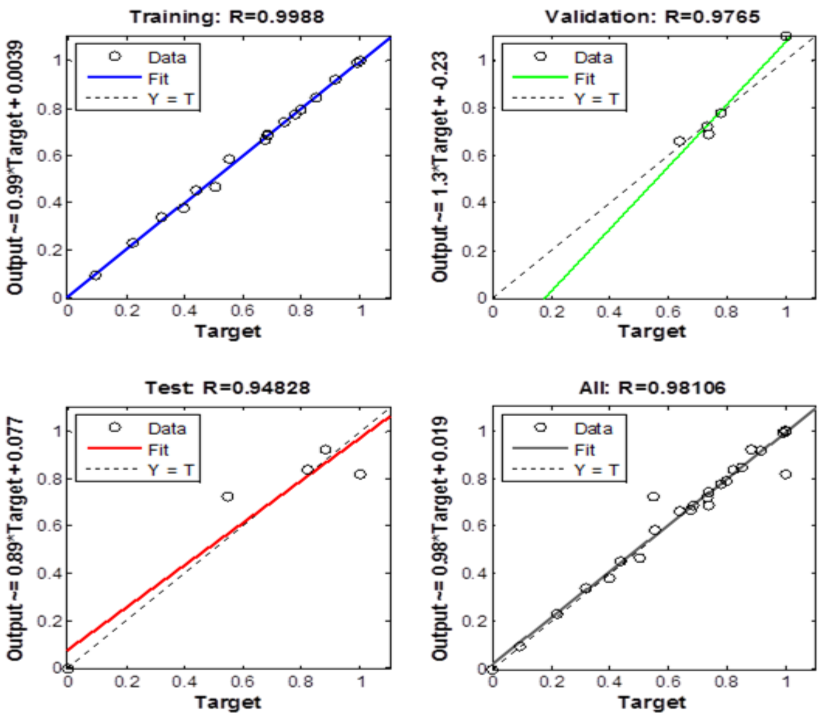

Fig. 5: Regression plot

$V_i^n = (V_i - V_{min}) / (V_{max} - V_{min})$ ----------- (1)

The net values at each hidden neuron (with first pattern inputs and random weights & bias) are calculated by following equation.

$net_j = \sum_{i=1}^{n} W_{ij} x_j + b_j$ ---------------[2]

Where, netj = Net input to node i in hidden or output layer,
Xj = Inputs to node i (or output of previous layer),
Wij = weights representing the strength of the connection between the i^{th} node and j^{th} node, n is the number of nodes
bj =Bias associated with node j

Each neuron consists of a transfer function expressing internal activation level. Generally, the sigmoid function has been used as the activation function for evaluation of hidden neuron values (equation 3). Where, hj is the output of node j, is also an element of the inputs to the nodes in the next layer. In present case it will become output.

$h_j = \frac{1}{(1+e^{-net_j})}$ ---------------[3]

The root mean square error is calculated by equation 5.

$h_j = O$ (4)

$$RMSE = \sqrt{\frac{\sum (O-Y)^2}{n}} \quad (5)$$

IV. Methodology of Modeling

As samples were collected every month so in duration of 5 months total 6 samples were collected for each (5) source. Therefore total 30 nos data set collected. These data were randomly divided in the ratio 70% for training,30% for testing and 30% for validation. Percentage transmittance of coal determined by using ASTM D 5263-15, is a standard method to monitor weathering of coal (D.E Lowenhaupt et.al [1980])so it can be used as Target parameters ,while 7 input parameters are Ash, Volatile matter(Vm), Mean Max reflectance (MMR), Basic Acid Ratio (BAR),CSN, Vitrinite%, Day, Avg size of coal (size).

ANN model designed to predict the percentage transmittance of weathered coal in advance. Figure (3) shows the Architecture of neural network used for prediction of percentage transmittance of coal.

In this study, a two layer feed-forward artificial neural network (FANN) was used to estimate the percentage transmittance of coal, using the experimental data collected. In this network sigmoid hidden neuron and linear output, neuron was used. The network has been trained with Levenberg-Marquardt back propagation algorithm (trainlm). The details of the ANN models are shown in Table 3. The number of neurons in the hidden layers was obtained by the trial and error method so that the error between the desired and estimated outputs was minimum.

In this study, pre-processing step was used, which can make the neural network training more efficient. Pre-processing of the network training set was done by normalizing the inputs and targets by using the above mentioned equation.

The min and max values for each input and target are given in table (2) for pre-processing of data.

A total of 30 sets of data were used in the presentstudy, out of which 20 sets (70%) were used for training the network 5 (30%) sets for testing and 5 (30%) set for validation. The training process was stopped after 11 epochs (Fig. 4). The correlation coefficients (R) for the training set was 0.998, equal to 1

The test set that actually determines how good the model is shows that the models can estimate the outputs quite satisfactorily. The R values for the testing and validation sets were 0.948 and 0.976 for prediction of % transmittance of coal (Fig 5). It was observed that the percentage transmittance of coal can be predicted using the ANN model satisfactorily.

V. Conclusions

- The proposed ANN models can estimate the outputs quite satisfactorily. The correlation coefficients (R) for training, testing and validation sets are 0.998,0.948,0.976 respectively. In the same was mean square error are 1.682X10-4,1.296x10-2,2.741x10-3 respectively.
- This model can be further improved by increasing more inputs, adopting multilayer hidden strategy. As per literature survey earlier no effort was done to make such prediction model
- This type of model can be developed by specific industry; after complete study of weathering propensity of all incoming source to particular industry, this will help in their blend formation and deciding the logistic and usage pattern. This type of model is industry specific, as weathering depend on climatic conditions.
- This ANN model will help in prediction of coal quality deterioration. The test result can further be used as an expert system in coke making industries to optimize the logistic and it usage percentage of coal in coke making.

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