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DEVELOPMENT OF NEURAL NETWORK AND FRAME WORK TO OPTIMIZE CUT LENGTH IN CONTINUOUS CASTING SHOP USING VARIOUS PARAMETERS

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ABSTRACT

Continuous casting of steel is a process in which liquid steel is continuously solidified into semi-finished or finished product. In continuous casting, one of the major operational irregularities encountered is wrong cutting of slab (long or short) and grade mix of two different steel during casting of slab which leads to productivity loss, capital loss, and safety hazards etc. In the present work, a neural network model is developed to track the tundish filling and casting speed. The model is fully transient and consists of three sub models, which account for mixing in the tundish, mixing in the liquid core of the strand, and solidification. For which two-layer feed forward back-propagation model is developed for predicting the existence of primary intermix region that might lead to a grade mix slab. Firstly, the networks is trained with four input parameter i.e. slab width, casting time, casting speed, tundish weight). Networks training were performed using the Levernberg Marquard training algorithm. The output from these neural networks is logical 1 (if a wrong cut of slab) and a logical 0 (if no wrong cut of slab occur). The neural networks model training, validation, testing is done by MATLAB.

KEYWORDS: Continuous casting, neural network, optimization, MATLAB.

I. INTRODUCTION

Globalization trend situation arising due to upcoming production capacities in flat product with more and more private entrepreneurs investing in the steel field had forced SAIL/BSP (Bokaro Steel Plant) to review its casting/rolling facilities. To be in this competitive market of flat product, BSP under the stage-1 of its modernization program which is under implementation and fast approaching completion have taken up installation of Continuous Casting facilities for casting entire quantity of 2.25 million tone/year of liquid steel produced in Steel Melting Shop-II (SMS-II) with certain upgradation to improve the quality of finished products in the hot strip mill area.

Continuous casting is the manufacturing process in which the cast product is longer than the casting mould. In this process the input material is shapeless liquid metal and the output is the semi-finished solid of required dimension. In a continuous casting of steel, computerization plays an important role in attaining efficiency in process, production quality and time management activities to achieve the plant objectives. The automation system effort to reduce quality slabs at optimum cost maintaining a high level of production while fulfilling the production order and delivery schedule. There are lots of problems presents in continuous casting shop. A list of 73 day to day work related problems were identified section wise in continuous casting shop. After that problems are classified in three categories A, B and C.

Category A: problems which can be solve by technical help and quality circle.
Category B: problem which need involvement of other department.
Category C: problem which need the help of management

The problems were selected through brainstorming by round robin method. Various person of BSP's CCS working at different levels participated in the brainstorming session. One of the hazards problems that come with continuous casting process is the problem of wrong cutting of slab. Hence the wrong cut of slab has a

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profound influence on the caster availability, affecting the productivity and the cost of production. Bloch et al. [1] has proposed neural network control for steel plant to enhance the operating of the process as well as the quality of delivered products. The objective mainly reached by incorporating the skill of the operation neural models, at different level of control. Schlang et al. [2] has proposed a rolling mill process control system to calculate the setup for the mill's actuators based on models of the technological process. Neural networks are applied components of hybrid neuro/analytical process models which was the key to fit the general physical models for the needs of the automation of a specific mill. Singh et al. [3] have proposed the cost optimization of slab by using discrete variables. The optimization techniques in general enable design to find the best design for the structure under consideration. The best design of a structure means the most economic structure without impairing the functional purposes the structure is supposed to serve. Heuristic techniques, namely the Genetic Algorithm was carried out in this research. Genetic algorithms (GA) belong to the family of evolutionary algorithms (EA). Mauder et al. [4] has describes an original algorithm for obtaining such control parameters which ensure the high production rate and the high quality of products as well. This algorithm is based on the keeping surface and core temperatures in the specific ranges corresponding with ductility of steel. The core of the algorithm is our original three-dimensional numerical model of temperature field where heat and mass transfer phenomenon including phase changes is deal with. The optimization algorithm is performed by neural network interface and runs in off-line version. Its results can be used as a preparation tool for the real casting process. Shukla and Goyel [5] has develop a framework that deals with uncertainty and yields robust solution for performance measure. This approach can be installed for other unit operations in steel manufacturing. This in turn will enable development of material with specific properties and reduce the time and cost incurred in the development of new material and the manufacturing. Schlang et al. [6] has deal in the application of artificial neural networks in image preprocessing. In view of this, the main aim of the present work is to optimize the cut length of slab in continuous casting shop. A well-known neural network technology is used to optimize this problem.

II. METHOD

A neural network is an artificial representation of the human brain that tries to simulate its learning process. It is an interconnected group of artificial neurons that uses a mathematical model or computational model for information processing based on connectionist approach for computation. The ANNs are made of interconnecting artificial neurons which may share some properties of biological neural networks as shown in figure 1.

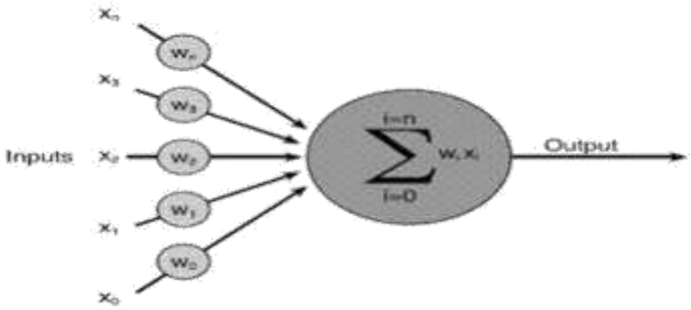

Figure 1 Simple model of artificial neural network

There are two types of Neural network based on learning technique, they can be supervised where output values are known beforehand (back propagation algorithm) and unsupervised where output values are not known (clustering). Neural networks architecture, number of nodes to choose how to set the weights between the nodes, training the network and evaluating the results are covered. Back propagation algorithm, probably the most popular neural network algorithm is demonstrated. First, the connectivity between the neurons is changed so that they are in distinct layers, such that each neuron in one layer is connected to every neuron in the next layer. Further, it is to be define that signals flow only in one direction across the network, and then simplify the neuron and synapse design to behave as analog comparators being driven by the other neurons through simple resistors. Stimulation is applied to the inputs of the first layer, and signals propagate through the middle (hidden) layer(s) to the output layer. Each link between neurons has a unique weighting value as shown in figure 2. Inputs from one or more previous neurons are individually weighted, then summed. The result is non-linearly scaled between 0 and +1, and the output value is passed on to the neurons in the next layer.

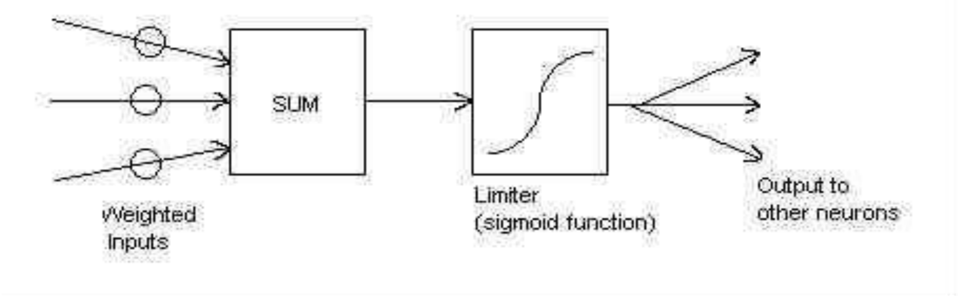

Figure 2 The Structure of a Neuron

Since the real uniqueness or 'intelligence' of the network exists in the values of the weights between neurons, we need a method of adjusting the weights to solve a particular problem. For this type of network, the most common learning algorithm is called Back Propagation (BP). The BP learning process works in small iterative steps: one of the example cases is applied to the network, and the network produces some output based on the current state of its synaptic weights (initially, the output will be random). This output is compared to the known-good output, and a mean-squared error signal is calculated. The error value is then propagated backwards through the network, and small changes are made to the weights in each layer. The weight changes are calculated to reduce the error signal for the case in question. The whole process is repeated for each of the example cases, then back to the first case again, and so on.

In present work one BP neural networks are developed. The neural network is train only with four input parameter i.e. casting speed, casting time, slab width and tundish weight. Four input parameters is consider as an input of neural network. Networks have only one output as shown in figure. Output of neural networks is either 0 for no alarm or 1 for alarm in wrong cut of slab conditions as shown in figure 3.

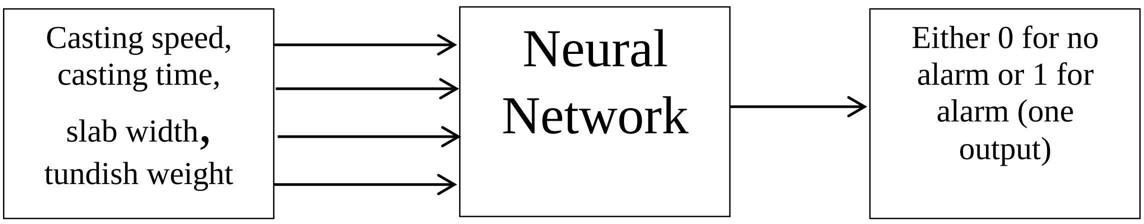

Figure 3 Neural network with four input parameter

To train the neural network, data is collect form continuous casting shop of Bokaro steel plant. There are two types of data is required to train the neural network, data at the time of grade mix of slab and data at the time of no grade mix of slab.

Data at the time of grade mixing of slabs:

- Input data = 4×75 matrix, representing 75 samples of 4 elements
- Target = 1×75 matrix (target is always 1 or alarm)
- Input data = 4×75 matrix, representing 75 samples of 4 elements
- Target = 1×75 matrix (target is always 0 or no alarm)

Total data:

- Input data = 4×150 matrix, representing 150 samples of 4 elements
- Target = 1×150 matrix (target is either 0 or 1)

Input parameters of the neural network

- Slab Width
- Casting speed
- Tundish weight
- Casting time

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Output parameter of the neural network

Either 0 for no alarm or 1 for alarm displays, when grade mix of slab occurs. In above input data there are 4 inputs (casting speed, casting time, width and tundish weight). There are lots of variations within the data, so normalized the total data in the range of 0 to 1 before train the neural network.

The training method used is the Levenberg-Marquardt (trainlm) with the mean square error performance function. The Levenberg-Marquardt method is adopted because it is the fastest training method. The network accepts four inputs (casting speed, casting time, slab width, tundish weight), and a total of 4 neurons make up the input layer. The hidden layer is increased or reduced in the iterative training process. However, after iterating, 20 neurons were used for the hidden layer. The transfer function is the log-sigmoid because of its ability to accept large positive or negative inputs and squash them in between 0 and 1.

Training of Neural Network

The network is train with four numbers of inputs (casting speed, casting time, width, tundish weight) as shown in figure 4.

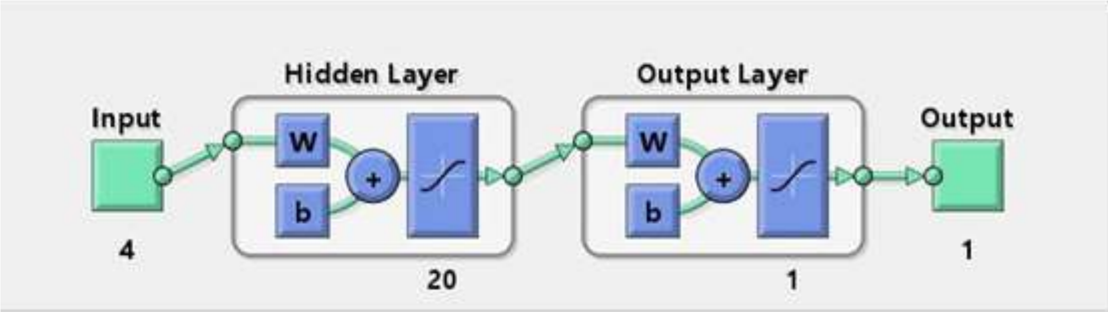

Fig 4 Neural network

Normalized data are used to train the neural network. Neural networks is developed using the neural network pattern recognition tool. The general predictive neural network model with four inputs, twenty hidden neurons and one neuron in the output layer is performed. Neural networks is developed using the neural network pattern recognition tool. There are 150 samples (normalized data) are used to train the neural network. Randomly division of the 150 samples is shown in table 1.

Table 1 Randomly division the 150 samples

Randomly division of 150 samples		
Training	70%	104 samples
Validation	15%	23 samples
Testing	15%	23 samples

III. RESULTS AND DISCUSSION

After completing the training of the neural networks, the performance of the neural network has been checked with the help of performance graph. The output of the performance graph is shown in figure 5. It can be clearly seen from the graph that the best performance of the neural network occurs at epoch 33 and 34 respectively. It can also be seen from the graph that performance provided by the neural network is good i.e. it is predicting the behavior very nicely.

The output graph of the neural network is shown in Figure 6. Output graph shows that output of the neural network is either 0 for no alarm or 1 for grade mix of slab. One small error is present between 0 and 50 and two spikes are generated in it which confirms slight error. Later target graph of the neural network is plotted and shown in figure 7.

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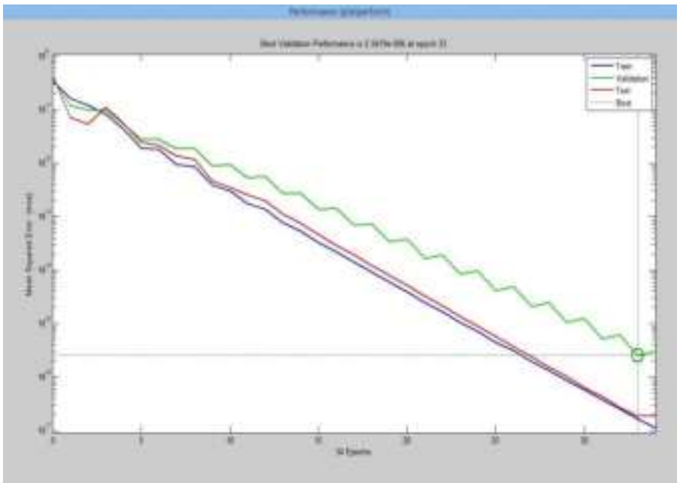

Figure 5 Best performance of the neural network

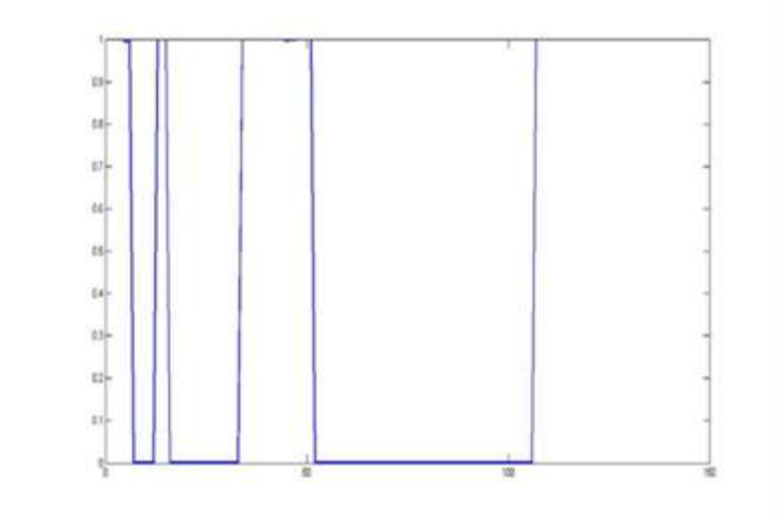

Figure 6 Output graph of the neural network

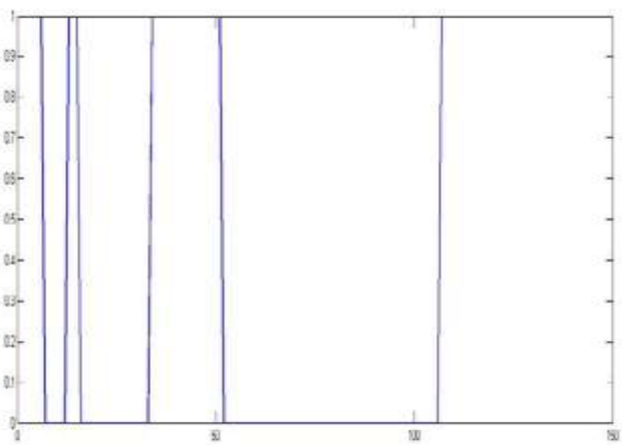

Figure 7 Target graph of the neural network

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The graph represents that testing has been done by neural network is always successfully achieve the given target. In this analysis, twenty three samples are used to test the neural network after completion of the training of neural network.Testing results of the neural network is represented in Table 3. In this table the actual output and calculated output of the neural network is represented. Comparison of both, the actual output and calculated one were performed and was found that there is almost zero error.

Table 3 Testing output of the neural network

Sample no.	Actual output	Calculated output
1	1	1
3	1	0.99908
7	0	0.000332
8	0	0.000343
12	1	0.000453
22	0	0.000455
30	1	0.000509
47	1	0.998913
55	0	0.000346
56	0	0.000411
59	0	0.000551
74	0	0.000429
75	0	0.000449
77	0	0.000332
86	0	0.00087
89	0	0.000219
91	1	0.000297
94	1	0.000483
107	1	1
112	1	1
119	1	1
128	1	1
145	1	1

In order to use the neural network, a simulink model of the predictive neural network is developed using the pattern recognition tool and is shown in Figure 8.

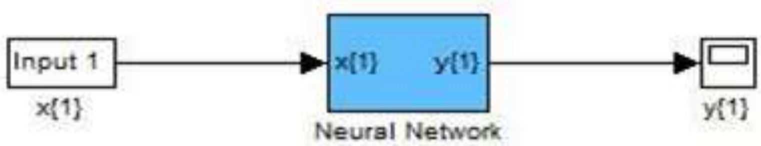

Figure 8 Simulink model of network

The model can provide different inputs and should be able to predict presence of grade mix of slab or no grade mix of slab. The input is the sequence of values that have been measured by slab width, casting speed, casting temperature and tundish weight.

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Figure 9 Model behavior in case of a grade mix of slab (1)

Figure 10 Model behavior in case of no grade mix of slab (0)

In the Simulink model x {1} represent input parameter (width, casting speed, casting temperature and tundish weight) and y {1} represent output (alarm "0" or "1"). Input of neural network can be changed in Simulink model. Now two set of input is applied to the simulink model to test the model. First set of input is {0.251748252, 0.847826087, 0.756097561, 0.930909091} and cross ponding output is 1 as shown in figure 9. When there is a crack on the shell, the output is 1. Second set of input is {0.258741259, 0.847826087, 0.756097561, 0.941818182} and cross ponding output is 0 as shown in figure 10. When there is no wrong cut of slab, the output is 0.

IV. CONCLUSION

In the present work, a contribution to process and quality optimization in continuous casting of steel has been developed. In Bokaro steel plant, there was a problem to optimize the cut length of slab. These are for both type of slab i.e. long and short cutting of slab and also for grade mixing of slab. To minimize the wrong cut of slab, a predictive neural network based model is developed in present work with the set of four input parameters which

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are casting speed, casting time, width and tundish weight. The model is developed such that the output is either 0 or 1 where 0 represents that there is no grade mix slab occur in the process and 1 represents that there is grade mix slab occur in the process. For developing such critical model, the neural network was first has to be trained with the trainlm function using back propagation algorithm.

Also, simulation in matlab/Simulink was performed in present analysis to show how the model predicts the grade mixing of slab. The present work shows that the neural network used in investigation can accurately predict in advance before the grade mixing of slab occur. Further, DPM (digital panel meter) is installed to display casting speed and tundish weight to the OSIB station as it is accurate.

It can be further concluded that, efficient and successful practice may significantly reduce wrong cutting of slab, increase productivity and reduce cost if all wrong cutting of slab are effectively predicted and prevented. The network outputs are very accurate, as it can be seen by the high number of correct responses and the low numbers of incorrect responses. It was reported in present work that the overall accuracy is 100 percent which is very encouraging. In present work 23 samples are used to test the neural network after the training has been completed. The actual output and calculated output of the neural network is than compared and concluded that there is almost zero error which is rather a interesting output.

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