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ANN Based Study to Evaluate Performance of Rolling Process in Wire & Rod Mill in Steel Plant for Design of Control Systems

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Abstract—*A study preparation of the process of prediction for strand of the rolling mill is done by taking the initial temperature, water flow, water pressure and laying head temperature of rolled product at the time of rolling. This work is done to provide knowledge about the variations in the rolled strengths and elongation and to predict the strength and elongation in final rolled. So that comparison of actual with the predicted output strengths and elongation will provide the accuracy of the adaptive control system, and suggest for adaptive control design to increase productivity and operational improvement in rolling. The adaptive controller is suggested to design based on the output signals of the temperature sensors fitted at the required places of strand. The study is providing that there is possibility of less variation in production quality and the adaptive control will make the production process better in control and semi automatic, which will be able to predict the output properties. The adaptive controller is suggested to design with the help of Artificial Neural Network and parameters selected are important for rolled properties and most effective in rolling mill.*

1. INTRODUCTION

This work is initially started with the aim of study of the production processes of the mill for analysis, but in study it seen that there is a scope of making the process better in controlling at stages of rolling and the work is finally for design of the adaptive strategy with the help of the available equipment in the mill such as pyrometer and analysis purpose is to analysis for variation in process parameters and to suggest the management for adaptive control to control the variation in process parameter.

1.1.1. Brief Description of the Mill

Inspected billets are fed on the charging grate of the furnace by magnetic finger cranes. The billets are fed one by one to the furnace, through roll table and draw-in-roller mechanism. Billets are moved into the furnace by means of pushers at the charging end. Soaked billets are ejected out by means of Ejector Ram from the discharging end.

The reheating furnace of the size 18m x 12m is having 28 burners, which includes 13 in the heating zone and 14 in the soaking zone. Mixed (Coke Oven & Blast Furnace) gas with calorific value of 1800 -2000 k Cal/m^3 is used in the furnace as fuel. Capacity of the furnace is 120T/Hr. Gas and air is preheated to 250°c and 450°c in metallic and ceramic recuperates respectively.

The roughing group consists of nine horizontal stands in which combined drive is provided for stands 2-3 and 4-5; whereas stands 1, 6, 7, 8 and 9 are individually driven. All the drives are controlled by thyristor converter. Flying Shear is provided after stand no. 9 for front-end cutting & cobble cutting.

First intermediate group has 6 horizontal stands, out of which stand No. 12 & 13 are not being used. Stand No. 10 & 11/14 & 15 are used for rolling on all the strands. After strand No. 15, the Mill is divided in four strands, old line (A) and modernized line (B, C&D) [1].

1.1.2. `B', `C' & `D' Strands

The rod exiting from stand no.15 is fed to stand no.16 located at a height of 5.1 meters above ground level through a series of feed guides. Before stand no 16, a Universal Shear is provided for cutting front end and cobbles in C and D strand and drum shear in B strand. Intermediate cooling line is provided after stand no. 15 to ensure that the rod temperature does not exceed 950°C.

After Universal Shear/Drum shear, one Horizontal (# 16) and one Vertical (#17) rolling ring stand are present. One Vertical

Looper is present after Universal Shear and after stand no. 16. One Horizontal Looper is present after stand no. 17 and before NT Block. One eight stand Rod Mill Block (No Twist Block) comprises stands 18-25.

The product from the rod mill block is fed to the Laying Head through the feed guide (primary cooling line). The laying temperature of the rod should not exceed 750°C. After No Twist Block series of Cooling Tubes are provided to produce TMT Coils and Two Pinch Rolls are installed before Laying Head. The rod convolutions formed by the Laying Head fall on the Loop Conveyors/ Roller conveyor that carries the overlapping rings to the reforming tub. The overlapping rings moving over the loop conveyors get cooled by air flow generated by blowers. The rings fall into the Reforming Tub which is consists of an auxiliary mandrel with two catcher arm levels.

The convolutions dropping over the mandrel get collected onto a pallet placed below the reforming tub. The loaded coil pallet then moves to the compacting and strapping installations where the coil is compacted and then strapped at four places. The pallet with the compacted coils are then unloaded at the Tilter and placed on to the Coil Collector with the help of Load Car. Coils from the coil collector are removed by cranes for storage. After stand 15 the rolling in B C and D strand is totally under level -II automation [1].

1.1.2.1. Performance Parameters

Billet dimensions	:105×105× 11600mm^3
Furnace capacity	: 120T/Hr
Actual discharge capacity	: 90 - 93 T/Hr
Billet weight	: 982 Kg
Coil weight	: 940 Kg

1.1.2.2. Rebars

Characterization of steel rebars is as important as that of concrete for a sound RC structure of desired strength. Present paper tries to address the various aspects of characterization of reinforcement and also related issues, which are important for design. Only passive reinforcement bars falls within the scope of the paper. Clear understanding of mechanics of reinforced concrete structures helps in understanding the intricacy involved with the characterization of rebar’s.

Moreover, basic knowledge on manufacturing process of steel helps in appreciating various facets of the characterization. These two aspects are also discussed briefly in the paper along with issues related to characteristics of rebars vies-a-vies performance of RC structure. A comparative study of the national standards of a few countries is presented followed by concluding remarks [3].

2. AFFECTIVE PARAMETERS

2.1. Effect of temperature and other parameters in material properties

Material properties which are varies with the temperature and other parameters are shown in graph form below, these material properties can varies with the parameters according to different parameters which forms the properties of a steel product when steel is passes through the rolling process with heat condition[4].

2.1.1. Chemistry of HCR

C	-	0.16 – 25 %
Mn	-	0.80 – 1.15 %
Cu	-	0.35 % min

2.1.2. Heat Treatment

Quenching & Tempering (Q &T) or Quenching & Self Tempering (QST) THERM(AL) EX(CHANGE) TEMPCORE.

The corrosion effect can be understand with the help of the parameter as rate of corrosion 11.6 mm/year = 456 m/year = 249 g m-2 day-1 this corrosion amount is the one of the main reason of thinking towards the treatment of bars.

3. METHDOLOGY

Pyrometer used for measurement of the temperature is taken as the point of input and the output given by the pyrometer at three decided points, point one at reheating furnace output, second point is after the roughing stands, third point is before finishing stands all point using digital output for is taken as the reading of the temperature. The noted down reading in first point is taken as one input parameter, second and third points are feedback points which may be used as input points in future. The pyrometer is chosen because of the working as tube consists of three or four diaphragms, projecting window and infrared filter one end connected with photovoltaic cell. A radiant energy received by other end. These radiations passing ultimately to the photocell is defined by the area of the first diaphragm. The protective window is made of thin glass and serves to protect the cell and filter from physical damage. The filter is used in the range of 1000°c to 1200°c in order to reduce the infrared radiation passed to the photocell. This helps to preventing the photocell from getting over heated. All infrared systems depends upon the transmission of infrared radiant energy being emitted by a heated body to a detector in the measuring systems through surrounding there is no direct contact with the surface whose temperature is measured[16].

With the help of the pyrometer reading of first stand and before cooling stands, water flow and water pressure is used as input data to the ANN tool (nntool) available with MATLAB is trained and then the testing and simulation is done, the predicted values are taken as a result and comparing with the actual strength values. Comparison of the actual strengths and elongation provide the knowledge about the possibility of the betterment in the production control. According to the point of the pyrometer fit adaptive control will use the output signals of the radiation pyrometer and design to control the water flow and water pressure control valve. The adaptive control will provide better control to production and less variation in the temperature with the use of nntool predicted values and increase automatic control possibility.

4. RESULTS

Prediction of various output parameters (Illustration Based on Methodology)

For prediction of the parameters all the steps of the Fig.4.10 which is illustrated in methodology is followed in the result of which the final result is obtained. The network was trained using historical data with the physical parameters namely Billet temperature after stand no 1, Laying head temperature, Water pressure and Water flow as input and Yield strength, Percentage elongation (N/mm^2), Ultimate tensile strength and used as output respectively.

Various trials were taken out of which 2 trials are depicted in Fig.4.1 and 4.2. The trials were conducted by different combination of number of layers, number of neurons and by varying the transfer function.

Input Parameters

i. Billet temperature after stand no. 1
ii. Laying head temperature
iii. Water pressure
iv. Water flow

Output Parameters

i. Yield strength
ii. Percentage elongation(N/mm^2)
iii. Ultimate tensile strength

Trial net 1

Transfer Function:

Hidden Layer : Tansig,

Number of Neurons: Input layer = 4,

Output layer : Purelin

Hidden layer = 10,

MSE = **0.99996,** Output layer = 3.

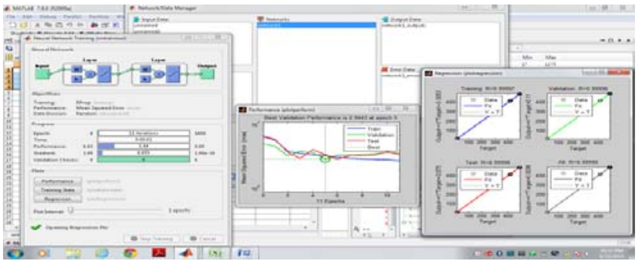

Fig.4. 1 MSE Performance graph and designed network with Data Manager for Trial No 1.

The trial is done to train the network properly or can be say to make the network better and better. Result of each output is observed and plotted for comparison of the predicted and the actual values of the aimed strengths and elongation two of them shown in the Fig.4.2 and Fig.4.3. When the training output is showing that it is similar and now training is giving the same result each time then the testing data fed to the network for the simulation and testing and the output value is compared with the predicted value and the error value is also find out and plotting in the graphical form as shown in the Fig.4.4 to Fig.4.9 and the different required values are analyzed to know about the work and check for feasibility of the work.

This procedure is followed in the every test the. The all work done in ANN tool is possible to understand b following the same steps and the result of work is shown in the form of regression curve which is different for each test which is shown in the Fig.4.1. These all shows the results in combination of curves as shown.

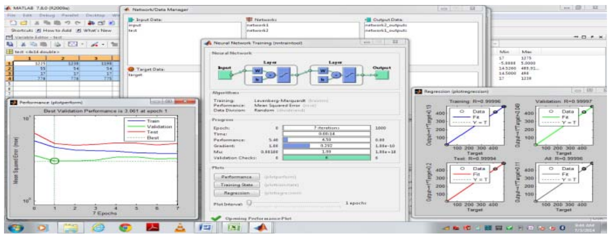

Fig.4. 2 MSE Performance graph and designed network with Data Manager for Trial.

Fig.4. 3MSE Performance graph and designed network with Data Manager for Trial.

The curve shown in the Fig.4.4 shows the input parameters reading data selected to analyze and to know about the variation in the process of working in each of the parameter selected to analyze. These are shows the actual values of the input parameters and the need of control the process with the scope of working in this parameters. The Variation shows that if the control is done better, then the productivity as well as the properties of the rolled products will be increase and the rolling will create the low maintenance low risk in the rolling of steel.

The actual output shown in the Fig.4.6 shows the variation in the products strengths and elongation. These shows that the output is good but it has some variation in the results that can be minimizes with the use of the ANN that uses the predicted values for control. If the variation in the product minimizes then the rejection of the rolled product can be minimizes that will provide the better production rate.

The output prediction is shown in the Fig.4.5. It will provide the values of the output parameters to control the process with the help of the PID controller or direct control used. The difference between the ultimate strength, yield strength and elongation can be measured with the help of the predicted and actual output by comparing them. This will shows that the method of work done is beneficial and can make the work better controlled when arrangement will made. The variation of the final rolled properties will be decrease and the better control on process can be achieved.

The comparison between individual properties of the rolled such as the ultimate strength, yield strength and elongation are shown in the Fig.4.6 to Fig.4.10 which shows the difference between predicted output of the work and the actual output of the properties of the rolled products.

The final result is included with these parameters and its analysis that is showing that if the work is applied to the rolling mill it will provide benefit to the mill. According to that the process is started for feasibility test of the work with one strand of the mill and the future plan is to make the work stable in the strand ‘B’, ‘C’ and ‘D’ for application in the rolling.

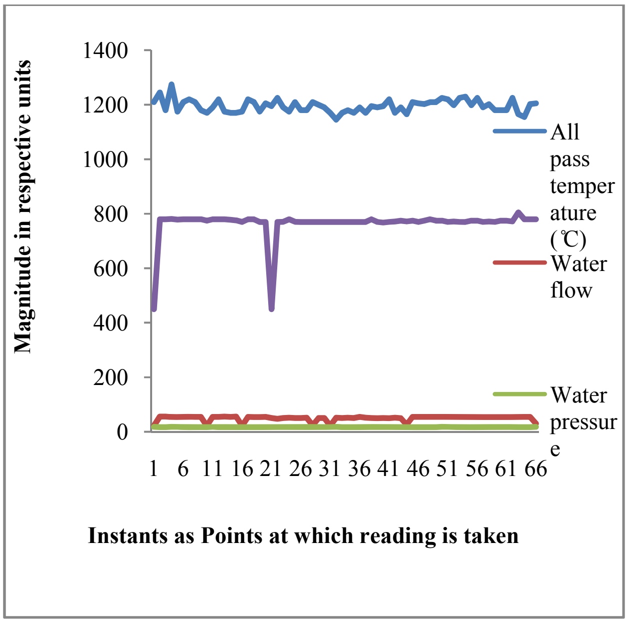

Fig.4. 4 Reading of four input parameters for analysis and training of Neural Networks.

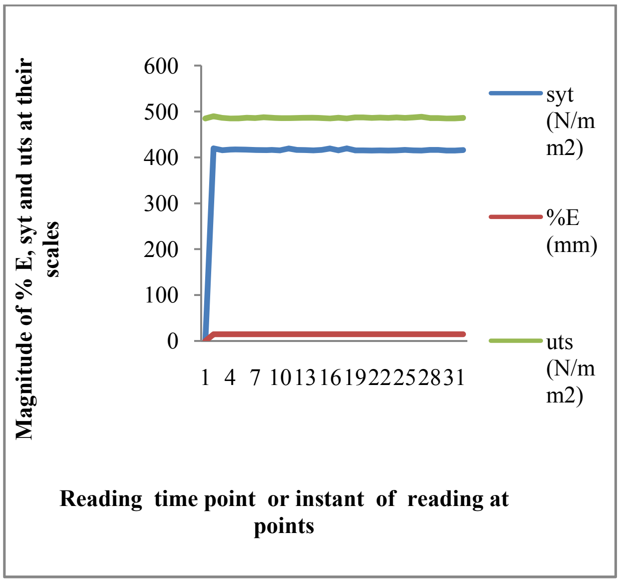

Fig.4. 5 Three output parameters of Neural Networks as predicted values for analysis.

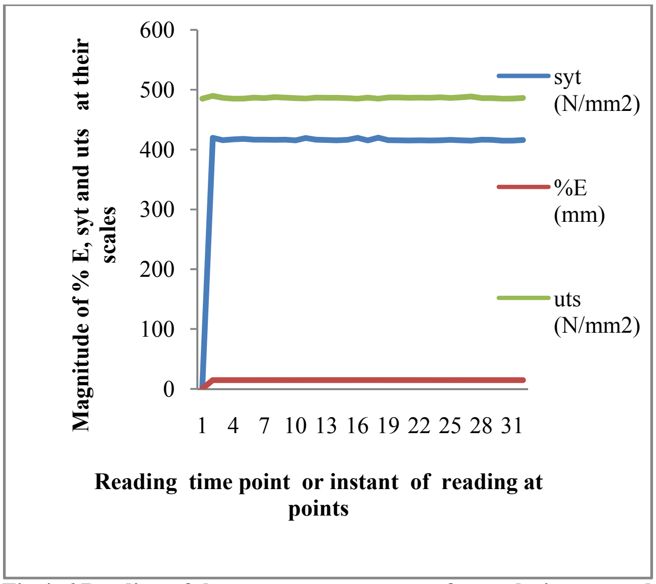

Fig.4. 6 Reading of three output parameters for analysis as actual values for analysis.

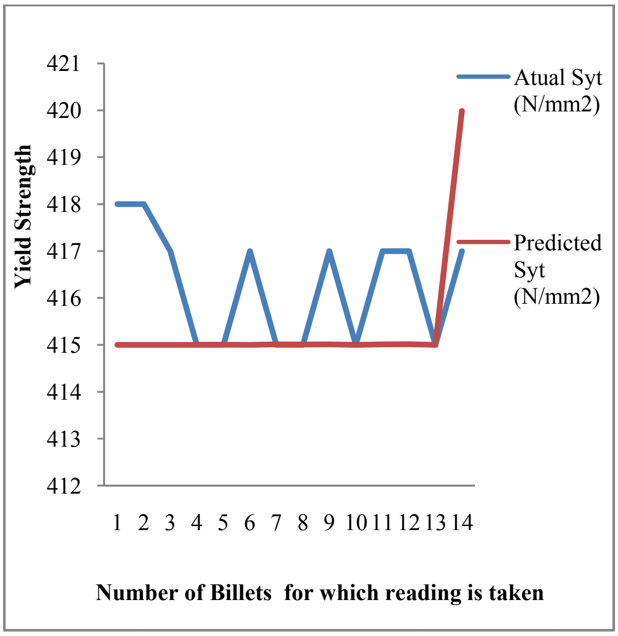

Fig.4. 7 Comparison predicted and actual output of Yield Strength of the rolled TMT.

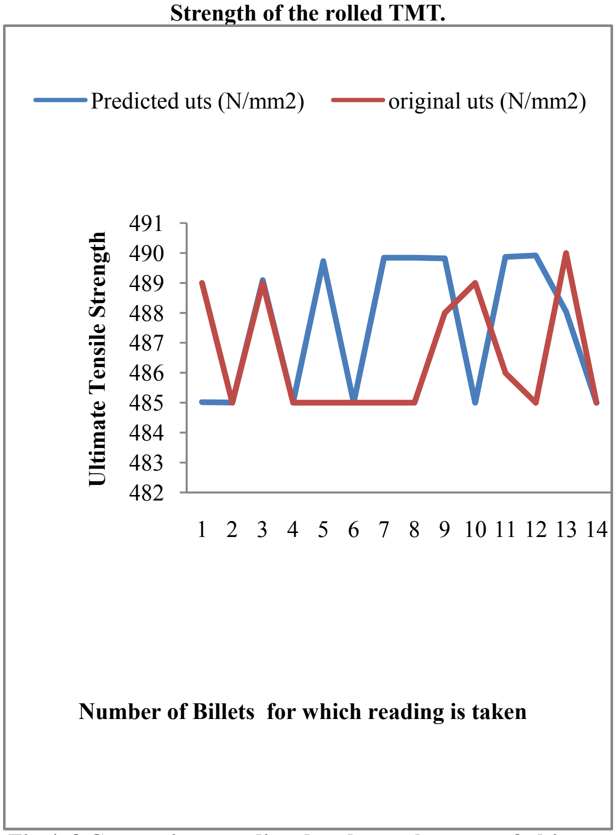

Fig.4. 8 Comparison predicted and actual output of ultimate tensile strength of the rolled TMT.

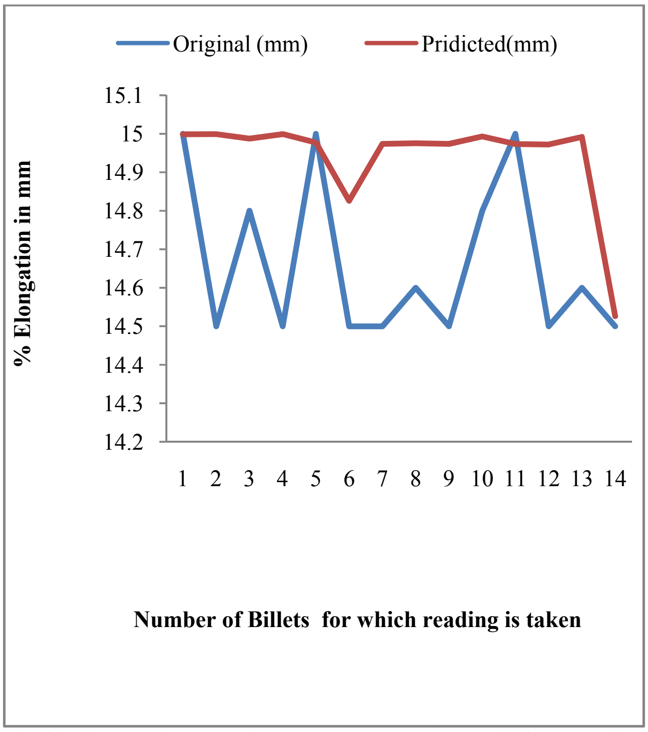

Fig.4.9 Comparison predicted and actual output of % elongation of the rolled TMT

5. CONCLUSION

Mill capacity will be Increase because better control and increase productivity. Rolling of steel grades: Mild Steel, Rimming Steel, Low Carbon, High Carbon, TMT Bars, Tire Bead & Cold Heating Quality, etc will be possible with better controlled rolling.

Rolling of wider range of profiles: 5.5, 6, 7, 8, 10 & 12mm & 8, 10, 12 TMT Bars in the rolling mill is now possible. It was not possible to roll perfectly 12mm TMT Bars before this arrangement without difficulty.

Adaption of the prediction will provide better dimensional tolerances and will be better than before. Improved draw ability of rolled product can be achieved so better shape and packaging of coils will be possible to achieved with this properties in rolled products Rimming steel, SAE 1008, TMT BARS, IS 2062 "A", SA 12, Cold Headed Steel etc. and IS 2879, IS 7887 Grade III, IV, IS 1786, SAE 1015, SEA 1008, SEA 1010. These are specified in the standards for the properties in the Mill.

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