Simulation of two Stands Cold Rolling Mill Process Using a Combination of Neural Networks and Genetic Algorithms to Avoid the Chatter Phenomenon

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ABSTRACT
Rolling mill Industry is one of the most profitable industries in the world. Chatter phenomenon is one of the key issues in this industry. Chatter or rolling unwanted vibrations not only has an adverse effect on product quality, but also reduces considerably the efficiency with reduced rolling velocities of rolling lines. This paper is an attempt to simulate the phenomenon of Chatter more accurate than the previous performed simulations. In order to increase the production speed, it needs to avoid parameters which effect on the Chatter and varieties with the rolling lines condition. Actual values of these parameters were determined in the archives of the Mobarakeh two stand cold rolling mills and collected on the 210 case study of real chattering. To simulate the experiment, a neural network is trained and weights and bias values of the neural network with genetic optimization algorithm were used to get an optimal neural network which reduces bugs on the test data. So this model is capable to predict speed of Chatter threshold on rolling process of two stand cold rolling mill with the accuracy less than one percent. So it can be used in rolling process with the building intelligent recognition systems to prevent the creator conditions of the chatter frequency range.

KEYWORDS: Cold Rolling Mill, Chatter, Genetic Algorithms, Neural Networks.

1. INTRODUCTION

Thickness reduction in rolling mill process is performed by one or more stands reversing mill or several stands rolling tandem (series) mill. Each stand consists of a frame that rolling steel ball bearings located in and it can withstand the force of rolling process bearings. Back up rollers is used in order to reduce the force, that is applied to work rollers and increase the accuracy and uniformity of thickness of thin strip, so these stands includes back up roller sand and working rollers. Working rollers with the smaller diameter are directly in contact with the strip and back up rollers with the larger diameter are used to prevent deflection and bending working rollers. Figure1 shows a two stand scold rolling mill.

Accelerating this process sometimes can cause vibrations; the vibrations can be divided into three categories: the first is the free vibrations, the second is the vibration cause of excitation forces and the third is the self-exited vibration or Chatter. Natural frequency of the system is equal to the vibration frequency of free sand vibrations. The stimulating effect of this sudden, random, non-periodic arise and will be damped. Forced vibrations are vibrations that come into existence in rolling stands mill like any other dynamic systems.

Many researches have been done so far on this magical phenomenon. But due to the fact that this phenomenon depends on the specifications of the production process and the used oil and many of the parameters in each of the production process, no comprehensive system has been invented to prevent this phenomenon and increase the speed of the rolling. Hu [1,2] developed a linear dynamic rolling process model to simulate the Chatter vibrations. Foruzan [3] also used the Taguchi method to simulate a model for rolling and tried to optimize this model to increase speed by successive changes in the distribution of thickness reduction in stands rolling mill.

A neural network is a powerful data modeling tool that is able to capture and represent complex input/output relationships. The motivation for the development of neural network technology stemmed from the desire to develop an artificial system that could perform "intelligent" tasks similar to those performed by the human brain.

Fig. 1. Two stands cold rolling mill

The true power and advantage of neural networks lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristics.

In the Regularization method, network performance index is modified. Performance index is usually considered to be mean squared error of the network.

$$F = mse = \frac{1}{N}\sum_{i=1}^{N}(e_i)^2 = \frac{1}{N}\sum_{i=1}^{N}(t_i - a_i)^2 \qquad (1\text{-}1)$$

Where the mse is the mean square error, t_i is the favorable outcome and a_i is net output. In this method, the mean squared weight and bias network is added to this value.

$$msereg = \gamma.mse + (1-\gamma)msw \qquad (1\text{-}2)$$

$$msw = \frac{1}{n}\sum_{j=1}^{n}w^{\flat}{}_j \qquad (1\text{-}3)$$

where γ is efficiency ratio and by using this performance index, network can be made with smaller weights and bias and therefore easier and also network replies less to over fitting.

2. METHODS
2.1. Affecting parameters on Chatter
This section aims to identify the factors affecting on Chatter and classifying them in terms of effectiveness and those which can be changed by the operator. The lists of parameters that influence the scientific references cited are as follows [4-11]:

Speed Rolling, Coefficient of friction (lubricant properties), Tension back, forth and between the mill stands, back up roll radius, The natural frequency of the system, the distance between mill stands, Input thickness, Sheet yield stress, Young's modulus of the plate, Sheet width.

Study on the parameters determined that those parameters can be divided in two categories

1-Some parameters, such as yield stress and Young's modulus of the plate is according to costumer order, but in most cases, these items have same value, other parameters such as the distance between the mill stands and the natural frequency of the system is remarkably consistent.

2-The second category includes: rolling speed, coefficient of friction (lubricant properties), tension back, forth and between the mills stands, back up roll radius, Input thickness and sheet width, can be changed and used in this simulation.

These parameters in terms of the manner of collecting are classified in three categories, Tension or mill stands torque, mill tension, thickness feedback of input, output and between the mill stands, the force on strip on two stands, are in process parameters category, second are the damping parameters, including the four back up roll diameter and third are the parameters that simulate friction that are properties of lubricants. Iron number (PPM), chlorine number (PPM), saponification index (mqKOH / gr), oil purity and oil percentage are in this category.

In order to gather the first class parameters, 8 working days between all of 2012 products was selected and the properties of production in these days were extracted, then the Data Logger files (figure 2) was extracted from archive. The information of the process archive in this system with10 (ms) accuracy, therefore with usage of chatter signal that is in data, it collects value of these parameters when chatter really was happened. Then the roll back to collect information about back up roll diameters on selected dates refer to the level 2 data archive system and the other parameters are referred to the Mobarakeh Information System (MIS) system and the oil data that were extracted.
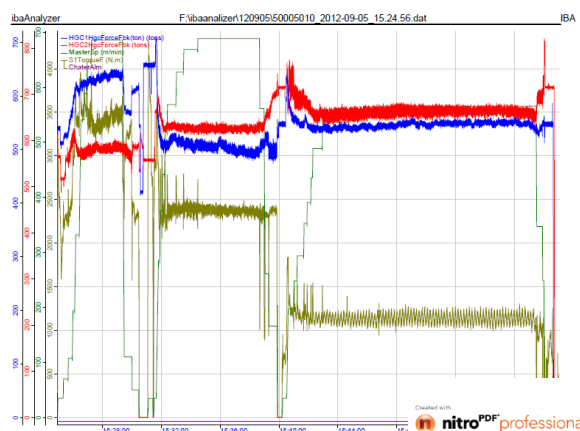

Fig. 2. Data logger display

These data includes 21 characteristics which by using above procedure, 210 experiments of these 21 features

were obtained, and how to use these data will be discussed later.

2.2. Simulation of two stands cold rolling mill process using neural networks

Neural network used for this problem is composed of two layers with the Tansig function. The first layer has two neurons and the second, one neuron. The error back propagation learning rule uses this rule based on the calculation error and update the parameters of the last layer to the first layer with error propagation.

Speed increasing is the major aim of this simulation, so this feature is considered as the target parameter in the neural network and other 20 residual parameters are used as network input Features.

Minimum number of repetitions of the training (epoch) is equal to 2000 and aim of minimum squared error is equal to 0.008. The genetic algorithm is used to optimize network weights and to minimize the error that its optimization function due to the two layer neural network is equal to relation (2-1).

$$y = f^2(w^2(f^1(w^1 p + b^1) + b^2))   \quad (2\text{-}1)$$

Where f^1 and f^2 are the first and second network layer functions and network weights vectors are w^1 and w^2, and b^1 and b^2 are the bias vectors of the first and second layers, and p is the input feature vector.

The parameters of the algorithm is as follows:
Population Size = 5; Elite Count = 2; Cross over Fraction = 0.3000; Migration Fraction = 0.2000; Generations = 5; Stall Gen Limit = 10

3. RESULT

Number of trials to learn the network is 170 vectors and about 40 residual vectors grid were used for testing. The program was repeated 10 times. Every time the MATLAB code was executed with the same tuning and same input data and mean square error related to training and testing data were compared together and were wrote in this table.

Table 1. Results of neural network learning in 10 tests

test No	test 1	test 2	test 3	test 4	test 5	test 6	test 7	test 8	test 9	test 10	mean
MS Etr	0.71%	0.72%	0.88%	0.58%	0.72%	0.72%	0.74%	0.79%	0.79%	0.75%	0.74%
MS Ets	0.76%	0.86%	1.10%	0.69%	0.90%	0.76%	0.63%	0.89%	0.91%	0.45%	0.80%

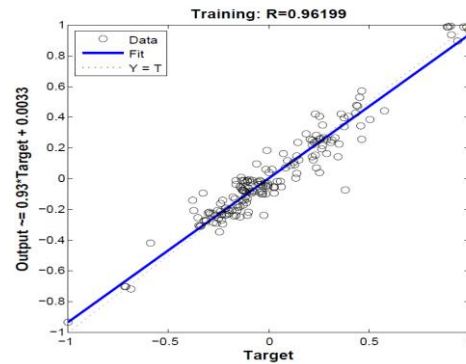Regression and performance diagram during neural network learning is shown in Figures 3 and 4.

Fig. 3. Regression diagram of neural network

The regression diagram approximates a continuous function to an arbitrary accuracy and fits all training data to linear function with the ramp equal to 0.96199
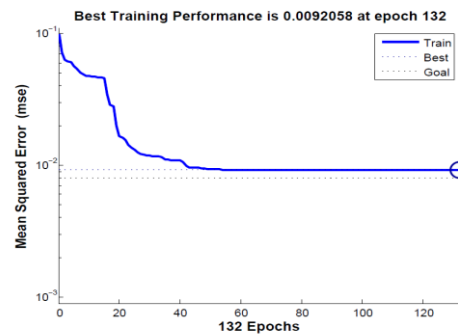

Fig. 4. Performance diagram of neural network

Performance diagram illustrates behavior of a network and commonly the mean squared error of the network outputs verse epochs. This diagram shows that the mean squared error of the best training performance is 0.9 percent occurred at epoch 132.

Using neural network in combination with genetic algorithm achieve a better response and more accuracy in simulation function.

4. DISCUSSIONS

Some of the conditions of cold rolling mill process can be changed and approximately all of these variations such as variation on emulsion properties, variation on stands reductions and BUR diameters, affect on these 21 features and were considered on this simulation function. All simulation that heretofore is accomplished could not consider all of these variations and work in limited condition with big accuracy. This function used in Mobarakeh two stands reversing mill parallel to mount chatter detector system and its result was good in detecting chatter and avoiding reduction of speed caused by mendacious detecting chatter via chatter detector system.

The earlier simulation on this machine is done by Foruzan[3] and his group, their simulation achieved to 6 percent of accuracy that in compare with our simulation, we achieved more accuracy and better simulation.

5. CONCLUSIONS
Using data collection technique provided features with more useful and more accurate in rolling process, and also Neural network learning methods provided a new method that was presented to simulate the two stands rolling mill. Exposure to simulated average error of less than 1% of the experimental data was performed ten times on the train. Due to the fact that the system that is installed on this system chatter detector have error and is commonly used, use of chatter system with neural network parrell with chatter detector at the same time reduces the rolling speed and increased the system error will result.

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