Set-Up model for the silicon steel cold rolling mill

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Abstract: In this paper, we propose set-up model of silicon steel cold rolling mill. Until now, the working of Silicon Steel is operated using the look-up table value of roll force which a field operator finds by making good use of his experience. Therefore, the standardization of data and an improvement of the quality on product are very difficult. So we establish neural model using field data of various kinds of coil at each pass.

Keywords: set-up model; silicon steel cold rolling mill; neural network; Roll force

1. INTRODUCTION

Silicon steel cold rolling mill is the process which thicker strips produced by hot rolling is further rolled thinner strips for making steel for use in the electric and electronics industries such as motors or transformer. Since silicon steel has a special quality, Silicon steel cold rolling is different from cold tandem mill. Silicon steel cold rolling mill is composed of one stand and has a reversible rolling which passes strip three or five times. Generally tandem cold rolling mill has set-up model, so roll force and several reference values are calculated by mathematical model before starting rolling operation. But silicon steel do not has any set-up model because of its characteristic operation. When silicon steel cold rolling mill rolls strip, the value of tension, roll force must be set up differently at each pass. Since the set-up values have an effect on the quality of product, a suitable value must be found. In the silicon steel rolling process, proper design and control requires the determination of deformation mechanics involved in process. Without the knowledge of influences of the variables such as friction conditions, material properties on the process mechanics, it will not be possible to design and control the equipment, or to predict and prevent the occurrence of failure.

Silicon steel cold rolling process is a typical complicated nonlinear process with many-input many-output and serious delay. As a result, it is very difficult to obtain perfect set-up model in this process. In this paper, we develop set-up model for silicon steel cold rolling mill focusing roll force. This set-up model is consisted of mathematical model and neural network model. Basic parameters such as strip thickness are directly used at mathematical model and unknown parameter such as friction coefficient is obtained by neural network model. For this neural network model, we collect more than 400 actual coil data gathered from silicon steel cold rolling mill at POHANG POSCO.

2. PROCESS DESCRIPTION

2.1 Lay-out of silicon steel cold rolling mill

A silicon steel mill is shown in Fig1. It is reversing mill using 1 mill stand and rolls steel coil to desired thickness over a number of passes depending on reduction required. Pass number is 3 or 5 pass and thickness is reduced at each pass. For example, 2.0mm -> 1.2mm -> 0.8mm -> 0.5mm -> 0.2mm like this pattern. Material thickness is 2.0 – 2.5 mm and final product thickness is 0.64 – 0.20 mm. It consists of 3 reels (pay off reel, tension reel 1, tension reel 2) and 1 mill stand (top mill, bottom mill). Pay off reel is used only at first pass milling and driven by tension control. Tension reel 1,2 are used at 2-5 passes milling and driven by tension control. Mill stand is consists of top mill and bottom mill and each mill is driven by speed control.

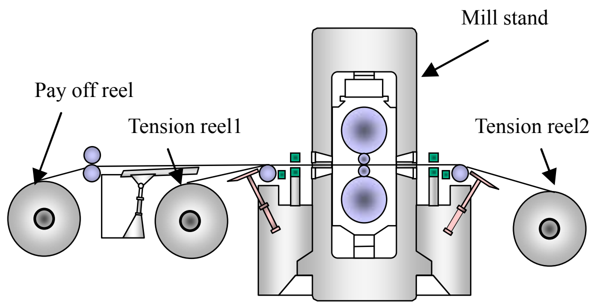

Fig1.Lay out of silicon steel cold rolling mill

2.2 Existing control system in silicon steel cold rolling mill

Control lay out of silicon steel cold rolling mill is shown in Fig.2. Silicon steel cold rolling mill use the set-up value such as thickness reduction ratio, tension, roll force and rolling speed using look-up table made by operator's experience.

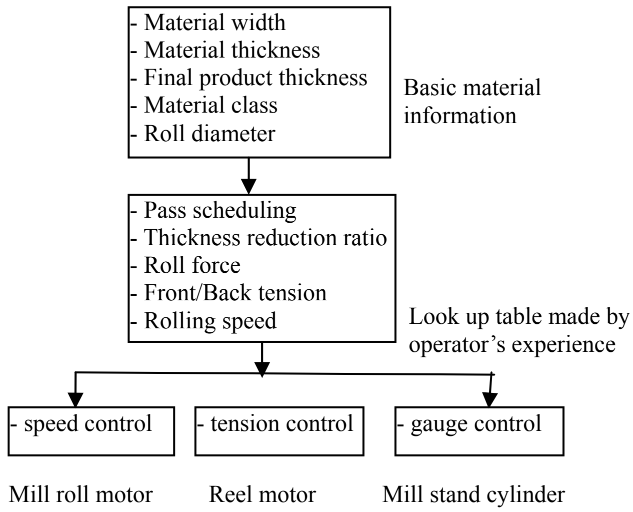

Fig.2 Existing control lay out

3. SET-UP MODEL DESIGN

3.1 Set up model architecture

We design set-up model instead of existing look-up table made by operator's experience. Basic set up values are calculated from mathematical model, but the mathematical model does not take all the factors into account. So, neural network model is employed to fill up mathematical model.

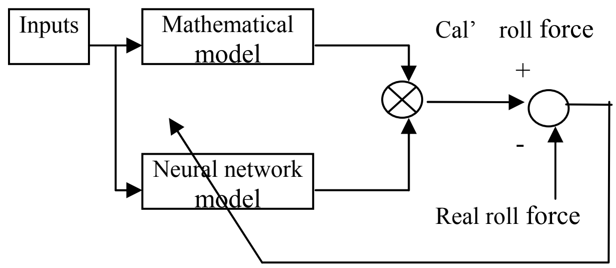

Fig.3 Set-up model architecture

Fig.3 shows set up model architecture. In precalculation, the roll force is determined from mathematical model and neural network model before a strip enters the mill, and then adaptive neural model determine new roll force from actual running data after mill runs. And this compensated roll force value is used from next operation.

3.2 Mathematical model

Among a number of theoretical equations for computing rolling force, Hill's equation may be most useful as an online model. It is an approximation of Bland & Ford's equation, which has been theoretically deduced, and is simple in form despite its theoretical nature.

$$P = b \cdot kp \cdot \kappa \cdot Dp \cdot \sqrt{R' \cdot (H-h)} + Pe$$

$$Dp = 1.08 + 1.79 \cdot r \cdot \sqrt{1-r} \cdot \mu \cdot \sqrt{\frac{R'}{h}} - 1.02 \cdot r$$

$$\kappa = \left(1 - \frac{tb}{kp}\right) \cdot \left(1.05 + 0.1 \cdot \frac{1 - \frac{tf}{kp}}{1 - \frac{tb}{kp}} - 0.15 \cdot \frac{1 - \frac{tb}{kp}}{1 - \frac{tf}{kp}}\right)$$

P : Rolling force [kg]
b : Width of material [mm]
kp : Deformation resistance[kg/mm2]
μ : Friction coefficient
Dp: Friction effect
κ : Tension effect
R' : Deformed work roll radius [mm]
H : Mill entry side thickness [mm]
Pe : Roll force of elastic effect
h : Mill delivery side thickness [mm]
r : Work roll radius [mm]
k p: Mean yield stress
t b : Back unit tension
t f : Front unit tension

Since the accuracy of a model which predicts rolling force is mainly governed by the factors, constrained yield stress kp and the coefficient of friction μ, it is better in most cases to determine μ by data logging procedures. Coefficient of friction varies slightly with roll speed.

3.3 Neural network model

Neural network can reflect nonlinear relationship between system inputs and system output. And neural networks have a built-in capability to adapt their synaptic weights to changes in the surrounding environment. In particular, a neural network trained to operate in a specific environment can be easily retrained to deal with minor changes in the operating environmental conditions. Moreover, when it is operating in a nonstationary environment, a neural network can be designed to change its synaptic weights in real time. The nature architecture of neural network for pattern classification, signal processing, and control applications, coupled with the adaptive capability of the network, make it a useful tool in adaptive pattern classification, adaptive signal processing, and adaptive control. As a general rule, it may be said that the more adaptive we make a system, all the time ensuring that the system remains stable, the more robust its performance will likely be when the system is required to operate in nonstationary environment.

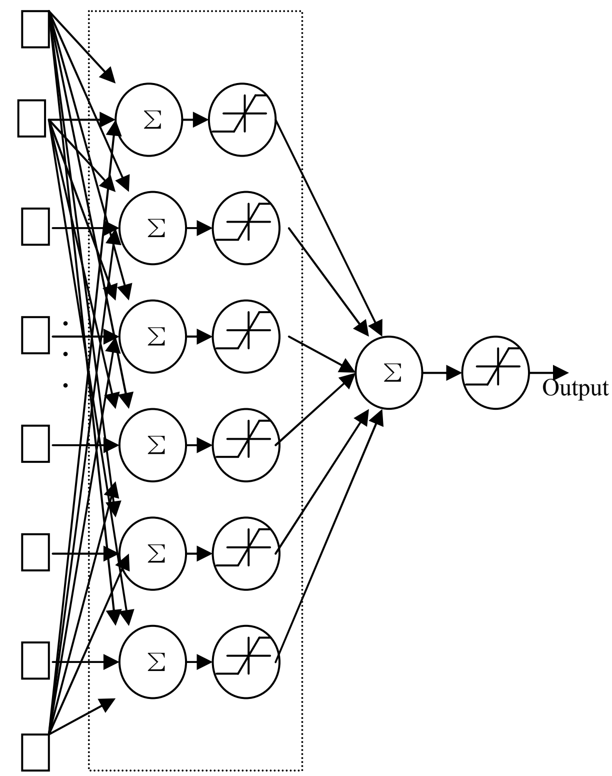

Fig.4 Diagram of neural network

Fig.4 shows diagram of neural network and table 1 shows inputs and hidden layers of our neural network model.

Item	Description
Inputs	8 inputs are used . Entry speed . Exit speed . Back up roll speed . Front tension . Back tension . Entry strip thickness . Exit strip thickness . Back up roll torque
Hidden layer	20 hidden layers are used

Table 1. Architecture of neural network

3.4 Simulation result

We collect about 400 coils for this simulation and divided 2 types of coil, one is non-grain oriented silicon steel (PML), the other is grain oriented silicon steel (PEL). These two types of coil have different silicon percentage and each type has different rolling method. So, we simulated each type of coils. Fig.5 and Fig.6 are simulation result of non-grain oriented silicon steel and Fig.7 and Fig.8 are simulation result of grain oriented silicon steel. Each simulation use 80% training data and 20% test data

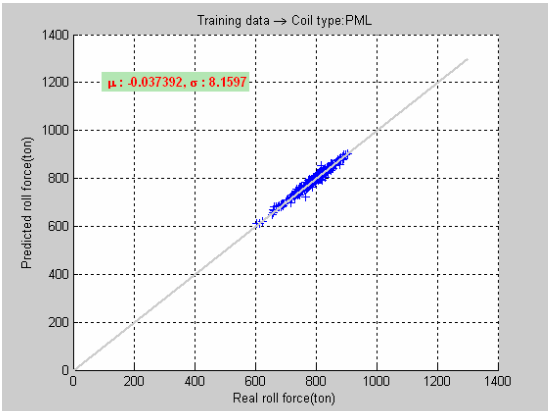

Fig.5 Training data of PML

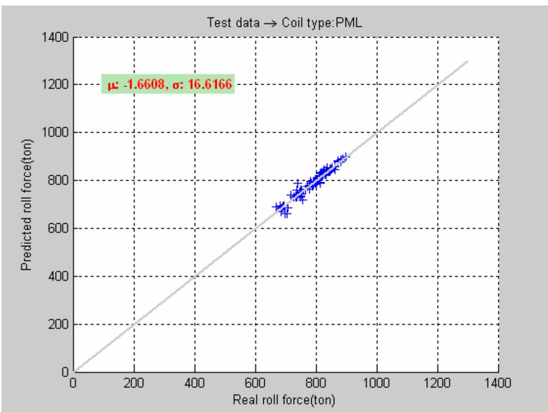

Fig.5 Test data of PML

In simulation result of PML, the mean square error of training data is 8.1597 ton and test data is 16.6166 ton.

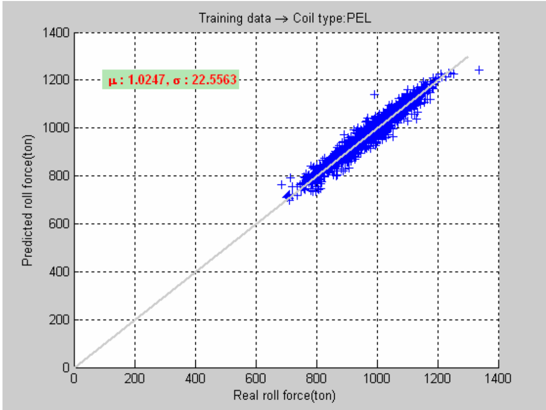

Fig.5 Training data of PEL

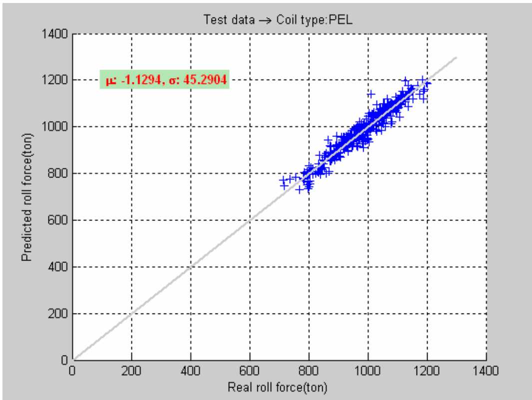

Fig.5 Test data of PEL

In simulation result of PEL, the mean square error of training data is 22.5563 ton and test data is 45.2904 ton.
From above simulation shows training data has better accuracy.

4. CONCLUSION

In this paper, we proposed roll force set-up model for silicon steel using mathematical model and neural network model. We predict that this set-up model is able to substitute existing look-up table, so it can improve product quality.

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