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Application of Machine Learning to Tandem Cold Mill Setup

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Abstract:

In response to increased demand for steel sheets that are dif cult to roll (e.g. high-tensile strength steel sheets for automobiles) in recent years, improved accuracy has also been required in tandem cold mill setup systems. Therefore, a newly-developed setup system using machine learning was applied to tandem cold mills at JFE Steel Corporation's West Japan Works. This system includes multiple predictive models, such as draft setting, tension setting, rolling force, rolling torque, and forward slip models, and trains these models using a large volume of actual operational data. Improvement of the accuracy of each predictive model contributes to increased productivity.

1.

As the features of tandem mills, although the strip thickness of the base material and the target thickness in the product specification are given, there is a degree of freedom in the strip thickness at each mill stand, and the rolling force, rolling torque and lubrication condition of each stand affect the steel strip quality, i.e. the thickness, shape and surface appearance at each stand. Due to these features, various setup methods have been proposed for tandem mills, for example, setting the reduction ratio and the inter-stand tension of each stand [1–3].

In the continuous tandem mill, which is now the mainstream technology, flying gauge change is generally used to improve productivity. This is a technique in which the strip is rolled at low speed without a rolling stop when passing a weld point between coils, and the roll gap and roll speed of each stand are changed by feed-forward control when the weld point passes through the stand. Then, after completion of weld point passing, the roll gap and roll speed are controlled by feedback as the operation end of automatic thickness control or automatic tension control. Practical

Specifically, the amount of roll gap change during weld point passing is calculated from the model prediction value of the rolling force and the estimated mill modulus, and the amount of roll speed change is calculated from the setting value of the rolling reduction of each stand and the model prediction value of forward slip.

tributed Control Systems), setup data from the Level-2 computer and production conditions such as the coil logic explained in this section is implemented on the Level-2 computer, and the elapsed time for a predictive calculation is about 1

Table 2 Evaluation of predictive errors of the models (Conventional system = 1)

Steel grade	Model name	Conventional system	Proposed system
A	Rolling force	1	0.41
	Rolling torque	1	0.45
	Forward slip (roll speed)	1	0.82
B	Rolling force	1	0.26
	Rolling torque	1	0.93
	Forward slip (roll speed)	1	0.81

ory, as described in Chapter 2) was defined as "1," and that of the proposed system was evaluated relatively. Second, for the accuracy of forward slip, the predicted error of the ratio of the rolling roll speeds at each stand was evaluated because it is difficult to obtain actual results for forward slip. The evaluation period was approximately 3 months. Each model was evaluated by the prediction errors for two typical steel grades. The prediction errors of the reduction and tension settings cannot be defined because they are setting values, (i.e. suitable reference values). Therefore, the evaluation of these two items is omitted here.

Table 2 shows that the accuracy of each model was improved by the new system. It should be noted that the evaluation greatly depends on the steel grade because the accuracy of the conventional model differs substantially depending on the steel grade.

4.3

3 shows an evaluation of the effects of this system on operation stabilization and productivity improvement.

First, the frequency of occurrence of strip rupture at weld points was reduced by 26.4% by improving the accuracy of rolling force prediction.

Table 3 Evaluation of application of models

Expected effects of application	Main result
Less welded point breaks during flying gauge control	26.4% decrease
Increased productivity	2.4% increase in a typical grade

Second, a 2.4% improvement in productivity was confirmed with a typical steel grade as a result of improvement of the prediction accuracy of rolling torque and forward slip and suitable setting of rolling reduction and tension.

5.

This paper described a new tandem mill setup system using machine learning which is now in operation in the cold rolling mill of JFE Steel Corporation's West Japan Works.

(1) Improvement of the accuracy of various rolling models has contributed to operation stabilization and productivity improvement.

(2) This system also realized maintenance-free operation by an automatic learning process.

1) Kamata, M. Thin sheet continuous rolling. Chijinshokan, 1997, 308 p.

2) Murakami, A.; Nakayama, M.; Okamoto, M.; Sano, K. Path Schedule Optimization of a Tandem Cold Mill. Iron and Steel. 2004, vol. 90, no. 11, p. 953–957.

3) Toyofuku, T.; Takenokoshi, A.; Yamamoto, M.; Tanaka, H. Methods for Determining Draft Schedules in Tandem Mills Using Neural Networks. CAMP-ISIJ. 1991.

4) Matsumoto, H. Theory and Practice of Strip Rolling (Revised), chapter 2. ISIJ, 2000, 350 p.

5) Rumelhart, D. E.; Hinton, G. E.; Williams, R. J. Learning internal representations by error propagation. Parallel Distributed Processing: Exploration in the Microstructure of Cognition. 1986, vol. 1, p. 318–362.