Mill Setting Calculation System for Aluminum Rolling Mill

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IHI has constructed many aluminum rolling mills in the world besides Japan. Recent IHI rolling mills have incorporated a setting calculation system that has been supplied in corporation with electronic system supplier. This system has an automatic mill setting function with mathematical models obtained from rolling theories as well as actual setting values stored in the database. This has enabled the stable operation of rolling mill line, ensuring rolling accuracy of aluminum strip. IHI and IHI Metaltech will continue to develop and improve rolling technologies.

1. Introduction

IHI has constructed many aluminum rolling mills not only in Japan but also in other countries around the world, for both hot and cold rolling. No other manufacturers in the world can consistently manufacture and supply aluminum hot rolling mill facilities to foil rolling mills.

This paper outlines the setting calculation systems we have provided to recent rolling mills. **Table 1** shows our supply records of mill setting calculation systems for aluminum rolling mills.

2. Setting calculation

Before starting operation, rolling mills require settings, including ① roll gap settings, ② entry and delivery tension settings, ③ speed settings, ④ default settings of a flatness controller, and ⑤ settings of coolant spray timing and pressure for roll cooling and rolling lubrication.

Setting calculation is done to model the data that can be theoretically calculated into mathematical models, from among the rolling mill setting data, and to calculate them numerically.

The setting calculation system transfers these calculation results together with the setting conditions of auxiliary equipment to be determined based on the actual records of rolling operation, into the mechanical system, as the default data.

The accuracy of each rolling operation is evaluated using the adaptive learning function included in this system. Based on these results, the setting data for next rolling operation is modified to improve the setting accuracy. A setting calculation system with an adaptive learning function achieves stable operation and improves the thickness distribution accuracy of product coils. In the industry, machine operation command sequence programs are conventionally called “Level-1” and setting calculation systems are called “Level-2” to clarify the sharing of functions.

When it is necessary to maximize the accuracy at the end of a rolled coil, the prediction accuracy must be

Table 1 Supply records of mill setting calculation system for aluminum rolling mills

Type	Configuration of rolling mill	Delivery (year)	Remarks
Hot rolling mill	2 350 mm*1 1 stand (rougher) + 4 stands (finisher) rolling line	2006	New installation
Cold rolling mill	1 850 mm cold rolling mill	2005	New installation
	1 900 mm cold rolling mill	2005	New installation
Foil rolling mill	1 800 mm foil rolling mill	2005	New installation
	1 800 mm finishing foil rolling mill	2005	New installation
	1 830 mm foil rolling mill	2004	New installation
	2 083 mm foil rolling mill	2001	Modification
	2 032 mm foil rolling mill	2001	Modification
	1 930 mm foil rolling mill	1999	New installation
	1 930 mm finishing foil rolling mill	1999	New installation

(Note) *1 : Work roll barrel length

improved and a setting calculation system called "Level 2" plays an important role in calculating the rolling load, calculating the strip crown (index of thickness distribution in the strip width direction), and predicting the coil winding temperature. On the contrary, a machine operation command sequence program called "Level-1" fulfills its functions in the feedback control immediately after rolling is started.

Without this setting calculation technique, settings at the beginning of rolling depend on the institution and the experience of the rolling operators. For example, a company that has just entered the rolling industry and is building a new rolling mill will continue to stumble around in the dark and waste management resources until it accumulates rolling skills and experience. This setting calculation technique is also beneficial for a rolling company that has many past achievements. When that company renews its equipment, it can reflect its accumulated achievements and the setting calculation technique it has used off-line so far, in the newly introduced setting calculation system, and thereby can restart operations quickly.

This has been proven in cases where a setting calculation system is newly introduced at the same time as aluminum rolling mills are modified.

Steel and aluminum rolling companies in Japan attach importance to this technical field as a technique that forms the foundation of rolling operation technology, and they have been making efforts to improve their own operation technology through repeated development and improvement.

The setting calculation technique is indispensable not only for rolling mill users in foreign countries that will enter the aluminum rolling field, but also for future rolling mill facilities.

Figure 1 shows examples of the setting calculation interface screen ("HMI" stands for "Human-Machine Interface") for an aluminum foil rolling mill. **Figure 2** shows a schematic chart of a rolling mill setting calculation system. This system consists of the following.

(1) Set up calculation in the setting calculation system

(2) Programs for feedback control of rolling mill

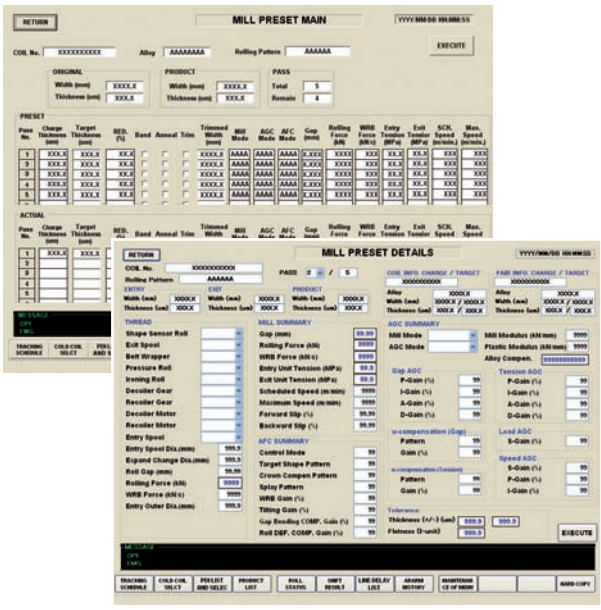
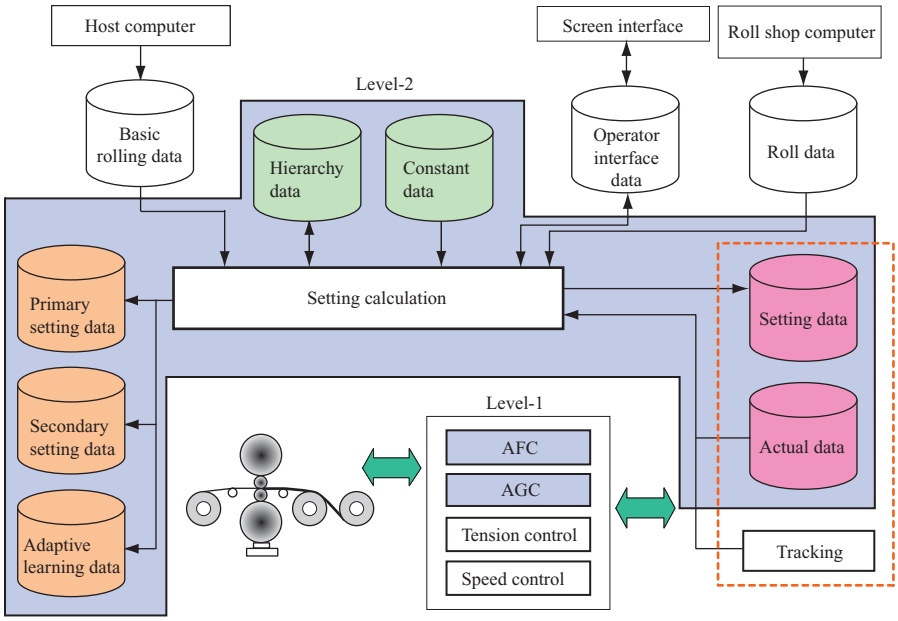


Fig. 1 Interface samples for aluminum foil mill setting calculation system



(Note) AFC : Automatic Flatness Control
AGC : Automatic Gauge Control

Fig. 2 Schematic chart of rolling mill setting system

- Automatic flatness control (AFC) program
- Automatic gauge control (AGC) program
- Tension control program
- Speed control program

(3) Tracking program for controlling the entry and delivery coils

(4) Relation to the database shared by programs

After receiving the primary data information (PDI) as basic rolling data from the host computer and information of rolls from the roll shop computer (RSC), set up calculation is performed using constant data and hierarchy data.

These results are accumulated as set up data for a rolling mill and transmitted to the rolling mill. The actual data is collected after rolling each coil. Adaptive learning data is accumulated by the adaptive learning calculation program in the setting calculation program and is reflected in the rolling set values for the subsequent rolling operations.

3. History of development of setting calculation system

Our company mainly supplied the hardware-machinery and equipment-to customers, such as steel and other rolling companies. Conventional customers generally manufactured their own setting calculation systems or commissioned electronic system suppliers to create basic systems and then improved and refined the delivered systems.

In 1995, we received an inquiry about aluminum foil rolling mills from a company. The prerequisite condition for the bid was to supply a setting calculation system at the same time. Details of aluminum rolling operations were rarely made public, unlike steel rolling, and so theoretical setting calculation systems were a new type of need of those companies that had just entered the industry. We had delivered a setting calculation system for aluminum cold rolling mills before, but had no experience in delivering it for aluminum foil rolling mills. In those days, electronic system suppliers could not create such systems to meet a foil rolling customer need in a short time.

We already had a theoretical off-line setting calculation technique. To seize an opportunity to enter this field, we tackled this matter by building a setting calculation system in a short time based on the roll deformation analysis program for aluminum foil rolling mills, in which the author and other people had been conducting development by making use of our accumulated technologies. In cooperation with an electronic system supplier, our company delivered two aluminum foil rolling mills, one for roughing rolling and the other for finishing rolling, together with a setting calculation system. Thus we achieved a good result in building an aluminum foil rolling mill equipped with a setting calculation system.

4. Features of aluminum rolling setting calculation

The important matters to be considered for each type of rolling mill are summarized below.

(1) For both cold and hot rolling, the hardness of materials varies significantly, from pure aluminum to alloys as hard as steel. Some coil manufacturers roll special alloys. It is necessary to accurately predict the rolling load in each case when making setting calculations.

We configure a program to determine general rolling characteristics by reducing the numbers of assumptions for calculating the rolling characteristics, such as the rolling load and the rolling torque, which vary widely depending on the material and rolling conditions of aluminum. We employ Orowan's theory[1] for hot rolling, Bland & Ford's equation[2] for cold rolling, and Stone's equation[3] for foil rolling as the basis of calculation.

(2) The contact arc of hot aluminum rolling is under mixed lubrication conditions between the rolled sheet and the mill roll. In this state, both slipping friction and sticking friction are present in a roll gap. Therefore, it is necessary to make calculations based on the appropriate theory that allows for this phenomenon when predicting the rolling load.

For both hot and cold rolling, the surface quality of rolled coils generally greatly affects the surface quality of the final products, and it is important to properly control the coolant (the liquid for both rolling lubrication and roll cooling) and control the coating on the roll surfaces by brush rolls. The setting calculation system contains the brush roll push timing, pressure and number of rotations as the setting items.

(3) In aluminum foil rolling, the work rolls come into contact with each other (kiss rolling) in regions outside the strip width. This makes it difficult to distinguish the real rolling load applied to aluminum foils from the value measured by the load measuring device, and affects learning for roll gap calculation using the value measured by the load measuring device as the actual value. For this reason, it is necessary to make a roll elastic deformation model that also considers the roll contact deformation in the kiss rolling regions.

At the same time, stable roll gap calculation is required in the foil rolling region. The conventional roll gap calculation used an iterative calculation process to determine a roll gap that satisfies the boundary conditions between the roll and the material, considering the influence of the tension distribution on the pressure distribution in the width direction (the tension feedback effect) between the roll elastic deformation model and the material plastic deformation model. However, it was not

practical because the calculation was hard to converge with a thickness of 1 mm or less.

We integrated the roll elastic deformation model, the plastic deformation model and the tension feedback model into one matrix calculation. This allowed us to develop a practical model that can be used for setting calculation systems for actual rolling mills, without placing a burden on calculators for iterative calculation processes. This has led to the commercialization of the world's first setting calculation system for aluminum foil rolling machines.

(4) Materials for aluminum foils require a low rolling load and cause a small amount of elastic deformation of mill rolls, but it takes as long as four hours to finish rolling one coil of foil. Therefore, it is necessary to establish a technique to predict the thermal expansion curve of rolls caused by heat generated during processing from the initial cutting curve, and keep the thickness distribution within a specified range.

By using the setting calculation system off-line, it becomes possible to determine an initial cutting curve that allows for rolling disturbance in advance, in order to effectively use the control function for the strip flatness control at the time of planning the rolling production.

5. Application example

Figure 3 shows an aluminum foil rolling mill equipped with a setting calculation system.

6. Conclusion

IHI Metaltech Co., Ltd. was established in June 2005 to take over the rolling mill business of IHI. The setting calculation technique for aluminum rolling mills, as introduced in this paper, is being handed down as a technique essential for future rolling mills. We will make further efforts to develop our rolling technologies.

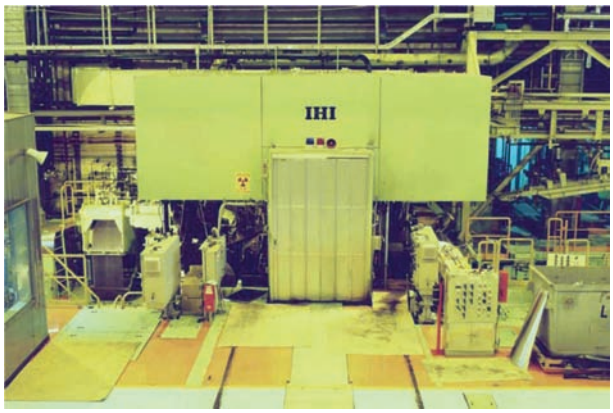


Fig. 3 Foil mills for CSAC (TAIWAN)

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