

# Development of Chatter Mark Detection Technique Using Vibration Sensor

MORI Takao

## Abstract:

In cold rolling mills and skin pass mills used for producing steel sheets, vibrations caused by resonance phenomena or mechanical wear can sometimes lead to defects with striped pattern on the steel sheets. To address this issue, we focused on the abnormal vibration that occurs when defects are generated. We developed a vibration monitoring system that monitors and analyzes the signals from the vibration sensor installed on the upper part of the rolling mill. By detecting the tendency for chatter marks to occur at an early stage and alerting the operator to the abnormality, appropriate measures can be taken, contributing to the improvement of product quality.

## 1. Introduction

In the skin pass mills of tandem cold mills (TCM), continuous galvanizing lines (CGL) and continuous annealing lines (CAL) used to produce steel sheets with strict surface quality requirements, vibration (chattering) occurs due to the resonance phenomenon or mechanical wear, sometimes resulting in a defect (chatter mark) with a striped pattern accompanying minute thickness fluctuations of few microns in the steel sheet. Focusing on the abnormal vibration when chatter marks occur, a vibration monitoring system that detects chattering in the initial stage was developed to solve this problem<sup>1,2)</sup>. This paper describes the vibration monitoring system, centering on the points to note in system construction.

## 2. Factors Causing Chattering

In general, the occurrence of chattering can be broadly divided into operating condition-induced chattering and bearing deterioration-induced chattering (Table 1). Operation condition-induced chattering is caused by sheet slip when the sheet threading speed

and roll rotational speed during rolling do not match. When the frequency of vibration is the same as the natural frequency of the mill body, vibration generated by slip causes a resonance phenomenon, and the energy of vibration changes the rolling load.

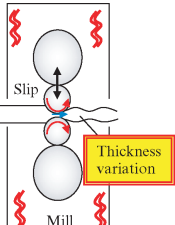
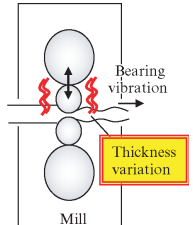
It is known that fluctuations in the rolling load cause variations in the sheet thickness, generating chatter marks. The factors causing slip are mainly as follows:

- ① Tension fluctuations due to manual intervention in the rolling speed.
- ② Characteristics of the rolling oil (type, concentration, temperature).
- ③ Rolling conditions (rolling reduction rate, rolling load).
- ④ Roll wear (reduction of the friction coefficient).

Operating condition-induced chattering is sporadic, and it is known that the frequency component when it occurs is 80 Hz to 300 Hz.

On the other hand, deterioration of the bearings of

Table 1 Chattering occurrence mechanism

Form	Operating conditions-induced	Bearing deterioration-induced
Cause of occurrence	Vibration is generated by the slipping of the strip due to conditions such as rolling oil, rolling conditions, and roll wear, which then causes a resonance phenomenon with the mill body.	Rolls vibrate due to the deterioration and subsequent damage of the bearing components.
Overview mechanism		

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Senior Management Staff, Plant Control Technology Sec.,  
Plant Control Dept., West Japan Works (Fukuyama), JFE Steel



Photo 1 Bearing wear

the rolls that comprise a mill sometimes causes chattering due to roll vibration. **Photo 1** shows examples of bearing damage. Bearing deterioration-induced chattering is continuous, and its frequency varies depending on the location of bearing damage (bearing roller surface, bearing outer raceway, etc.) and rotational speed.

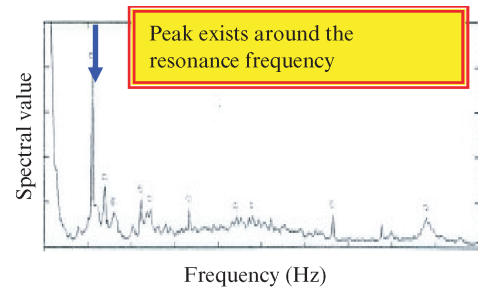
### 3. Chattering Detection Method

To detect chattering, vibration sensors are attached to the top of the mill housing and the work roll bearings. **Table 2** shows the specification of the vibration sensors. Three types of parameters are used to measure vibration, namely, displacement, velocity and acceleration. Displacement is suitable for vibration measurement when the frequency is comparatively low, as in the case of axial runout in rotating machinery. On the other hand, acceleration is suitable for vibration measurement at relatively high frequencies, as in gear damage.

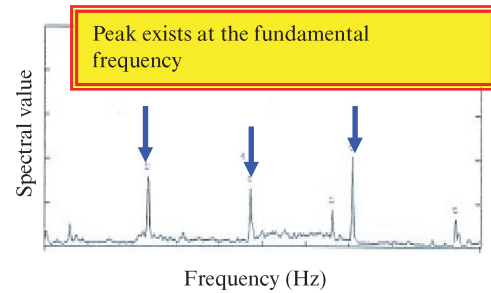
Since the vibration frequency band for the occurrence of chatter marks, which are the object of measurement, is 5 Hz to 1 kHz, velocity was selected as the measurement parameter, as stable measurement is possible in this frequency band.

**Figure 1** shows the results of a vibration frequency analysis when operating condition-induced (slip) chattering and bearing deterioration-induced chattering occurred. In operating condition-induced chattering, a peak exists around the resonance frequency of each mill.

On the other hand, as a characteristic feature of bearing deterioration-induced chattering, peaks occur at a frequency (defined as the fundamental frequency) determined by the line speed and the location of bear-



(a) Operating conditions-induced



(b) Bearing deterioration-induced

Fig. 1 Frequency analysis result

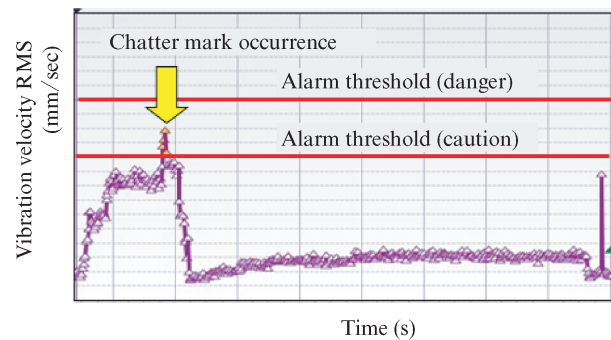


Fig. 2 Chatter mark occurrence situation

ing damage. Accordingly, it is considered possible to identify the cause of chattering occurrence from the results of a frequency analysis of the vibration velocity signals.

Based on the study outlined above, two functions were provided as the chattering detection method: Real-time monitoring by the vibration acceleration, and monitoring by frequency analysis to identify the cause of chattering.

**Figure 2** shows the situation of chatter mark occurrence. In real-time monitoring, an alarm is output when vibration acceleration exceeds a preset threshold, notifying the operator that abnormal vibration has occurred. This allows the operator to suppress operating condition-induced chatter marks by changing the operating conditions, for example, by reducing the line speed, reducing the amount of lubricating oil, or carrying out a roll exchange.

Table 2 Vibration sensor specification

Item	Specification
Voltage sensitivity	$5.0 \pm 10\%$ mV/ ( $m/s^2$ )
Measurement frequency range	5~7 000 Hz
Maximum measurable acceleration	$700 m/s^2$
Supply voltage	15~25 V
Waterproof protection rating	IPX7

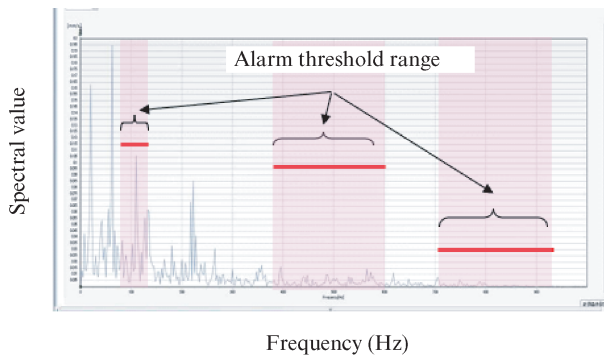


Fig. 3 Threshold monitoring through frequency analysis

**Figure 3** shows a screen for monitoring by frequency analysis. In bearing deterioration-induced abnormal vibration, the generated frequency changes depending on the line speed. Therefore, the system was designed so that the alarm threshold in frequency analysis can be set in arbitrary frequency bands. Performing abnormality judgments with the alarm threshold set in advance in the fundamental frequency band of the bearing makes it possible to identify the cause when bearing deterioration-induced chatter marks occur.

#### 4. System Configuration

**Figure 4** shows the system configuration diagram of the vibration monitoring system. Vibration acceleration during process line operation is monitored by the data processing PC, and the operator is notified by outputting an alarm when vibration acceleration exceeds a predetermined threshold. The measured vibration data are stored in the performance collection server. To prevent the release of coils with a risk of chatter mark occurrence, coils that exceed the alarm thresholds (danger) for both real-time monitoring and monitoring by frequency analysis are held, based on a product pass/fail decision by the host computer.

In addition, a system that enables combined analysis of the past condition of operation and vibration data was also constructed by making it possible to search the vibration data in the performance collection server, by incorporating coil information and process line information (line speed, rolling load, tracking length, tension) in the chattering detection control panel.

A system that allows remote monitoring of the vibration monitoring systems at each process line in real time from the office when monitoring the condition of chatter mark occurrence was also constructed. **Figure 5** shows the system configuration diagram of the remote monitoring system. This system makes it possible to analyze the data accumulated in the respective performance collection servers in real time from the office PC, enabling prompt data analysis work when

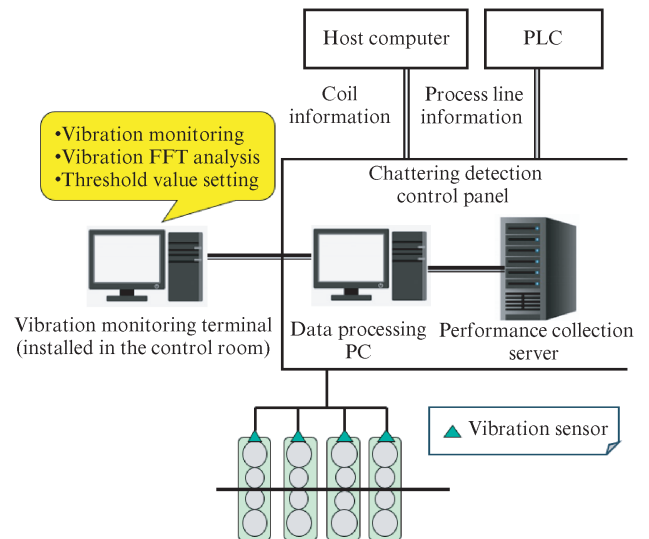


Fig. 4 System configuration diagram of vibration monitoring

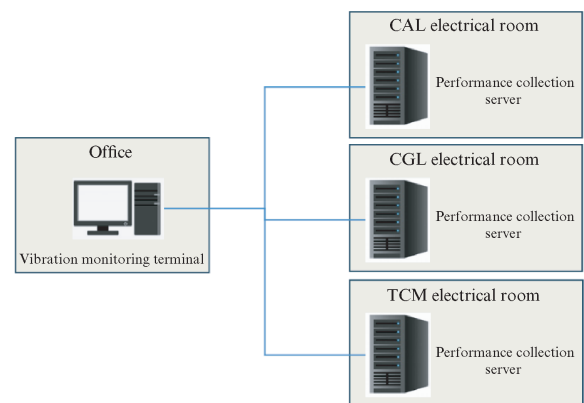


Fig. 5 System configuration diagram of remote monitoring

chatter marks occur.

#### 5. Conclusion

As a countermeasure for the occurrence of chatter marks, vibration monitoring systems were constructed and introduced at the skin pass mills of the cold tandem mill, CGL and CAL. As a result, early detection of chatter mark occurrence is now possible, preventing the release of products with chatter marks to customers.

#### Reference

- 1) Mori, T.; HIroyama, K.; Yamawaki, M.; Hashimukai, T.; Himeji, Y. Detection Technology Development by the Cold-rolling Vibration Sensor. IEEJ Technical Meeting. 2015, MZK15012, p. 17–19.
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This paper is a reprint of the paper listed as reference 1), which was written by the same lead author, with partial revisions of some expressions.