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Strip Vibration and Shape Control Using Electromagnets at Gas Wipers in CGL

1. Introduction

In comparison with electrogalvanized steel sheets, hot-dip galvanized steel sheets are often used in corrosion-resistant automotive panels, in which high corrosion performance and low cost are required, based on the advantages that hot-dip products with heavy coating weights are easy to produce and the cost of production is also low. Because particular importance is attached to surface quality, and particularly appearance, when these steel sheets are used in exterior body panels of automobiles, steel makers are earnestly working to improve product quality.

This report introduces a strip vibration and shape control technology using electromagnets which was developed by JFE Steel to improve the quality and productivity of hot-dip galvanized steel sheets.

2. Arrangement at Gas Wiping Section in CGL

Figure 1 shows the configuration around the molten zinc pot, which is the key section in coating layer thickness control in a continuous hot-dip galvanizing line (CGL). The steel strip advancing through the molten zinc pot changes direction at the sink roll and then rises vertically from the bath surface with a coating of zinc on the strip surface. Immediately after the strip leaves the bath, the coating layer thickness is controlled by wiping the excess zinc from the strip surface with a jet of air or nitrogen gas from the gas wiping nozzles before the Zn solidifies. A system which automatically sets the gas wiping pressure and the distance between the nozzles and steel strip so as to obtain the target coating weight has also been developed[1].

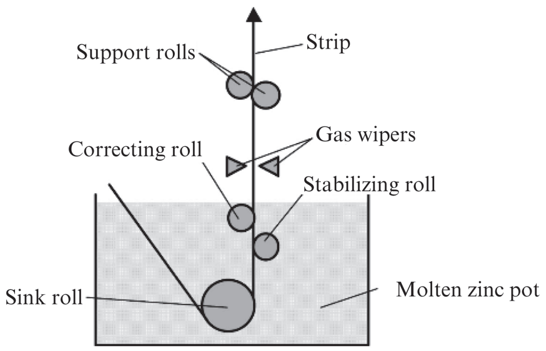

Fig. 1 Schematic of coating and gas wiping section in CGL

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On the other hand, because the coating weight will vary if the distance between the nozzles and the strip fluctuates, strip vibration at the gas wipers will cause an uneven coating thickness in the traveling direction, while cross-bow of the strip will lead to coating thickness unevenness in the width direction. Accordingly, in order to achieve a uniform coating layer thickness and excellent surface appearance, vibration and cross-bow should be eliminated and the behavior of the strip should be stable at the gas wipers.

Although not shown in Fig. 1, in conventional CGLs, after the Zn coating of the steel strip is adjusted to the specified thickness by the gas wipers, the strip travels upward vertically until it reverses direction at a top roll several 10 m above the zinc pot. Although the strip passes through the galvannealing furnace, air-cooling zone, etc. in this process, it basically does not come into contact with any object while traveling over this distance of several 10 m, and vibration occurs easily under this condition. The support rolls installed above the wiping nozzles are designed to prevent this vibration. Because the wiping section is isolated from the vibration source and the span of string vibration is greatly shortened, the support rolls are effective in suppressing low frequency string vibration. However, since the zinc on the steel strip surface is still in a semi-molten state when it comes into contact with the rolls, this contact may impair the surface appearance of the strip in some cases. Moreover, roll-related strip vibration may also occur due to eccentricity of the support rolls and other factors.

3. Control of Strip Vibration and Shape by Electromagnets

3.1 Outline of Device

A noncontact strip threading control device[2] that suppresses strip vibration and cross-bow by a noncontact technique was developed. In this device, the strip vibration and shape are detected by a noncontact dis-

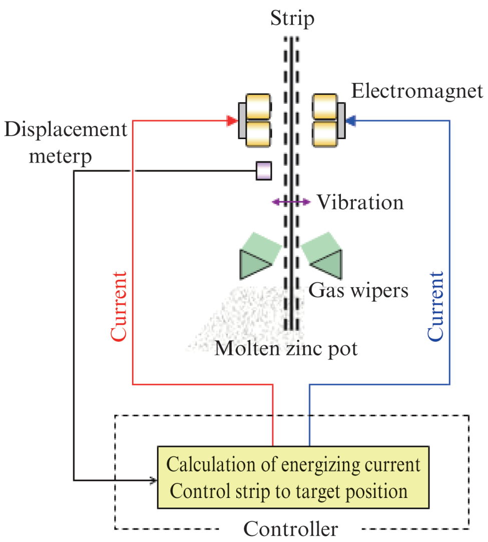

Fig. 2 Basic control system configuration

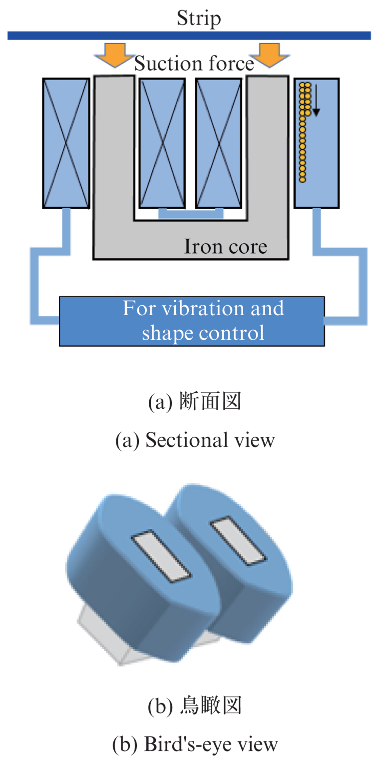

Fig. 3 Schematic of single coil electromagnet

placement meter, and the position of the strip is controlled by the attractive force generated by electromagnets. The basic configuration of the control system is shown in **Fig. 2**. This device comprises a pair of electromagnets installed on the two sides of the strip and a displacement meter. Feedback control is performed by a controller so as to reduce deviation from the target value based on information concerning the strip position from the displacement meter, and the strip is kept flat without fluctuations in its position by controlling the position of the strip opposite the electromagnets, which are arranged in the strip width direction. Because electromagnets can only generate force in the direction that attracts the steel strip, the device is designed so that force can be generated in both directions by using a pair of electromagnets on the front and back sides of the strip. Strip vibration and cross-bow are suppressed by appropriately controlling the attractive force of the electromagnets installed facing the steel strip. As an advantage of this device, since it is a noncontact method, unlike the above-mentioned support rolls, it does not have an adverse influence on the surface quality of the steel strip. A number of studies have been reported since 2005, and practical application is progressing. However, since many CGLs produce steel strips with diverse widths and thicknesses, electromagnet performance that can control strip vibration and shape within the full range of those dimensions is necessary.

3.2 Simultaneous Control Capacity of Strip Vibration and Shape by Dual Coil Electromagnet

Since the conventional single coil electromagnet coil consists of a single circuit, as shown in **Fig. 3**, control had been performed by the sum of vibration control to suppress strip vibration and shape control to suppress strip cross-bow. A high attractive force is required in the electromagnets for strip shape (cross-bow) control, while high response is necessary for vibration control. However, as a characteristic of conventional electromagnets, attractive force can be increased by increasing the coil winding number, but this causes a decrease in magnet response. For this reason, it was difficult to satisfy both high attractive force and high response with conventional-type single coil electromagnets.

In order to solve this problem of conventional-type electromagnets, JFE Steel developed a dual coil electromagnet[3)] consisting of two coil circuits with different winding numbers, as shown in **Fig. 4**. Arranging the coil with the large winding number and the coil with the small winding number as concentric coils makes it possible to perform strip cross-bow shape control and strip vibration control with the respective coils. High attractive force and high response were realized simultaneously by dividing the control functions, which have different performance requirements, and assigning those roles to the respective coils.

A mutual induction prevention circuit connected in series with the shape control circuit was provided to solve the problem of reduced controllability due to the influence of the induced current generated between the coils due to the arrangement of the two coil circuits in a concentric circular shape.

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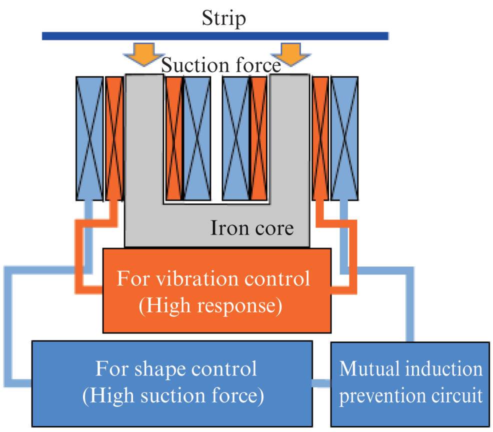
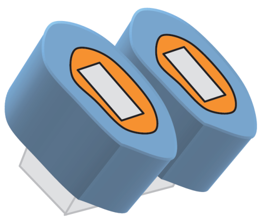


(a) 断面図
(a) Sectional view



(b) 鳥瞰図
(b) bird's-eye view

Fig. 4　Schematic of dual coil electromagnet

conventional technology, by applying a noncontact strip threading control device for coated steel sheets using the developed dual coil electromagnet (**Fig. 5**). Strip vibration was reduced by 40 % in comparison with the conventional single coil electromagnet device, and it is now possible to control both vibration and cross-bow of steel strips by a noncontact technique.

4. Conclusion

By applying the developed device, it has become possible to control both vibration and cross-bow of steel strips in the wiping section of the CGL by a non-contact technique. Stable strip threading was realized

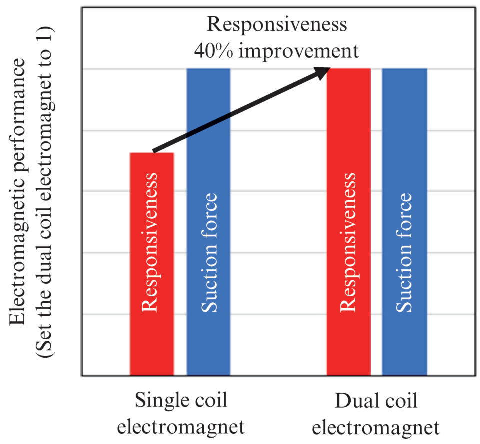


Fig. 5　Compatibility of suction power and responsiveness

in the wiping section of an actual CGL, and variations in the coating weight were reduced and higher line speed was achieved. This is contributing to improved product quality and productivity of hot-dip galvanized steel sheets. By introducing this equipment at hot-dip galvanized steel sheet plants in the JFE Group in Japan and overseas, JFE Steel will respond to the advanced product needs and local procurement demand of automobile manufacturers as they expand operations in countries around the world, and will also contribute to a further expansion of demand for high grade automotive steel sheets.

References

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2) Kabeya, K.; Ishida, K.; Suzuki, H.; Ishigaki, Y.; Ishino, K.; Ishii,T. Tetsu-to-Hagané. 2013, vol. 99, no. 10, p. 610–616.
3) Nishina, Y.; Ishida, K.; Ishigaki, Y.; Nagai, H.; Ozawa Y. Nihon Kikai Gakkaishi. 2014, vol. 117, no. 1146, p. 295.

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