On Line Measuring and Control Equipment for Alloy Degree in Continuous Galvanizing Process*

Sachihiro Iida** Masahiro Kawahara*** Hisashi Tsuchida****

1 Introduction

Zn-Fe galvanized steel has excellent properties, including spot weldability, paint adhesion, and corrosion resistance. On the other hand, the coating layer has poor formability, and it is an important quality problem to prevent the flaking off of the coating layer on bending or press forming, a phenomenon called powdering. It is well known that the powdering property is closely related to alloying degree (average Fe content in the coating layer). Therefore, at commercial galvanizing lines, it is of great importance to measure the alloying degree and control it within the allowable range. In addition, recent years have seen stricter customer quality requirements, under which every quality characteristic must be assured over the entire strip length and width, obliging steelmakers to develop methods of continuously measuring and controlling the alloying degree in-process.

An alloy degree control system was developed at Kawasaki Steel using an alloy sensor which measures the alloying degree continuously. This paper describes the alloy sensor and the results of adoption of the alloying degree control system at Mizushima Works.

2 Continuous Hot Dip Galvanizing Line

The general layout of the facilities is shown in **Fig. 1**. After the hot dipping zinc pot, the coating weight is controlled by a gas wiping system. The strip is then heated by the heating section of the galvannealing furnace, promoting an interdiffusion reaction between the Zn in the coating layer and Fe in the base metal. The alloy sensor and coating gauge are generally installed together after galvannealing treatment for practical use.

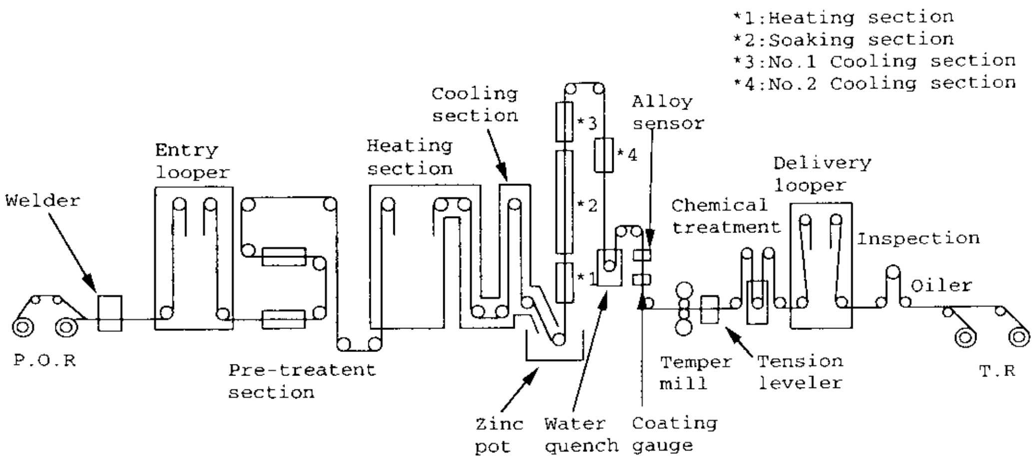

Fig. 1 Hot dip continuous galvanizing line

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** Staff Manager, Cold Rolling Technology Sec., Rolling Technology Dept., Steel Plant Div., Engineering & Construction Div. Gr.

*** Staff Deputy Manager, Cold Rolling Plant Control Sec., Plant Control Technology Dept., Mizushima Works

**** Staff Assistant Manager, Plant Control Technology Sec., Plant Control Technology Dept., Mizushima Works

3 Alloy Sensor

The coating layer of galvannealed steel contains various types of Fe-Zn intermetallic compounds, their structure depending on the Fe-Zn ratio of the layer. The Fe-Zn ratio in turn varies with the galvannealing treatment temperature, base steel chemical composition, coating weight, and other coating or galvannealing conditions. Each phase has characteristic physical properties, one of which, the lattice constant, can be used to distinguish the type of phases and measure the amount of each phase by X-ray diffraction analysis. On the other hand, it is well known that in measuring the coating weight of Zn coated steel, the intensity of the Zn fluorescent X-ray depends on the coating weight. Therefore, both the alloying degree and coating weight can be measured using this method.

In actual alloying degree measurement, it is necessary to measure the intensity of diffraction of the background ($I_{BG\Gamma}$) in order to estimate the value exactly. The alloying degree (Fe content) of the coating layer can be calculated by correlating the alloying degree and the intensity ratio of Γ to the background, as shown in **Fig. 2**.

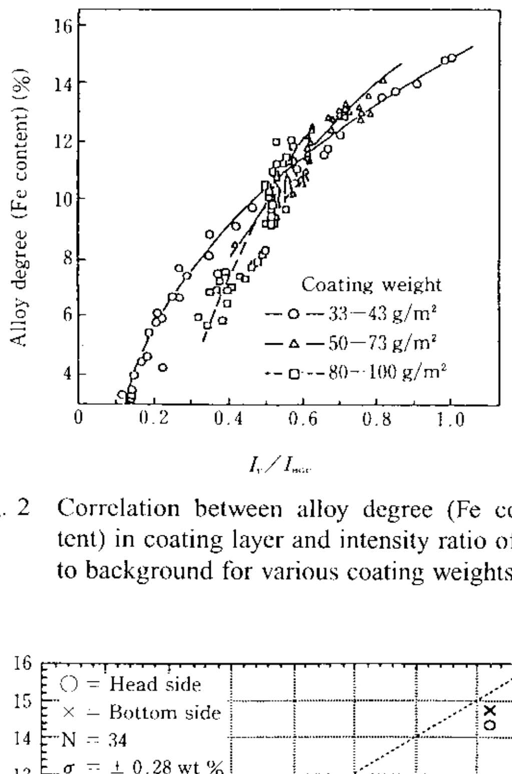

Fig. 2 Correlation between alloy degree (Fe content) in coating layer and intensity ratio of Γ to background for various coating weights

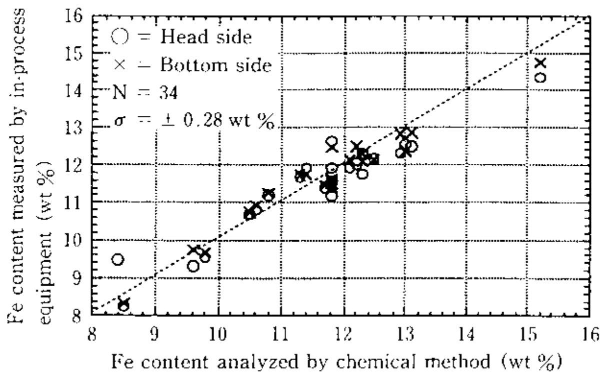

Fig. 3 Comparison of the in-process measured data with chemically analyzed data in Fe content

Alloying degree data measured by the alloy sensor are sent to the process computer for use in alloy quality assurance and control. A comparison of the in-process measured data with the chemical analysis data for the Fe content is shown in **Fig. 3**. The measurement accuracy is σ = 0.3 wt% in the alloying degree, which is adequate for alloy quality control.

In total, 16 alloy sensors (8 at Kawasaki Steel, the other 8 at other companies) are used practically for alloying degree control.

4 Automatic Control System for Alloying Degree

The configuration of the alloying degree control system is shown in **Fig. 4**. This system consists of a galvannealing furnace presetting function, based on the alloying model, and a feedfoward control system to improve the response in transition periods such as welding point passing and strip thickness changes. The alloying model also has a system to maintain accuracy during process transitions to some extent using a learning function which automatically performs adaptive corrections of the model parameters based on operational data of the galvannealing furnace and measurement results of the alloy sensor. The features of this system are as follows.

(1) Based on precise physical model.
(2) Realizes on-line processing by high speed computing of a very large alloying model calculation.
(3) In transition periods, utilizes a feedfoward strip temperature control system to improve response; this system changes the strip temperature setting value according to the calculation results of the influence coefficient between the alloying degree and strip temperature.

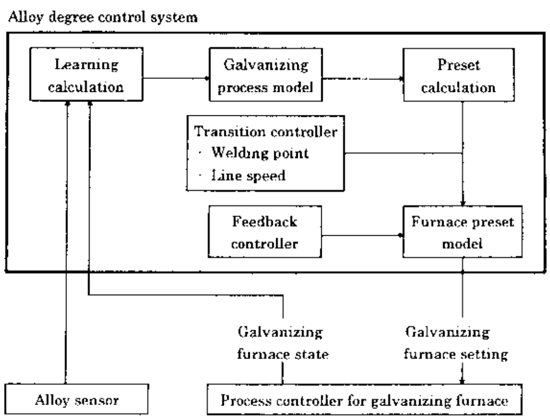

Fig. 4 Construction of alloy degree control system

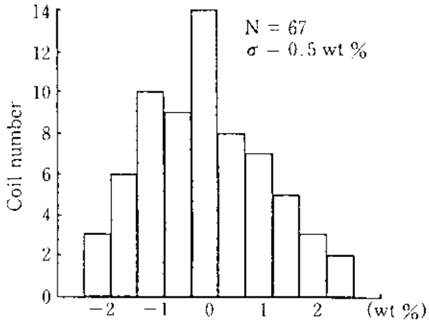

Fig. 5 Difference between aimed value and actual value

Figure 5 shows the results of adopting this control system to production of ultra-low carbon steel at Mizushima Works. The deviation of alloying degree has been improved to $\sigma = 0.5$ wt%, which is about half the value in conventional operation.

5 Conclusion

An alloying degree control system was developed utilizing an in-process alloy sensor at a continuous galvanizing line. As a result of on-line measurement, control accuracy was improved significantly. In the future, the authors will expand the range of applicable steel grades by adjusting the parameters.

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For Further Information, Please Contact to:

Engineering & Construction Div. Gr.
Fax: (81) 3-3597-4208 Phone: (81) 3-3597-4248