Control of Conditions of Finished Surface of Alloyed Hot-Dip Galvanized Steel Sheets

Elucidation of alloying reaction inside zinc coating

Research method

Beamline used at SPring-8: Engineering Science Research I (BL19B2)

Award for this research: The Japan Institute of Metals Best Paper Award, Material Science (2005)

Achievements

- Clarification of growth behavior of an iron-zinc (Fe-Zn) alloyed layer in an **alloyed hot-dip galvanized steel sheet*** by real-time in situ observation during the alloying process
- Establishment of guidelines for creating a smooth and durable coating surface

R&D facility: Sumitomo Metal Industries, Ltd.

***Alloyed hot-dip galvanized steel sheet:** Hot-dip galvanized steel sheets are obtained by coating zinc (Zn) over a steel sheet surface. These sheets have been used for many years because of their excellent corrosion resistance. However, small swellings are generated under the Zn coating after galvanization, causing the delamination of the coating and the deterioration of weldability. These problems can be solved by changing the Zn coating into an Fe-Zn alloy through heat treatment after hot-dip galvanization. The thus-obtained alloyed hot-dip galvanized steel sheet has been widely used in automobiles in recent years.

Role of SPring-8

Background

The condition of the finished surface of alloyed hot-dip galvanized steel sheets is considerably affected by the initial formation behavior of Fe-Zn intermetallic compounds in the Zn coating. Hence, it was necessary to understand the entire process of the formation of Fe-Zn intermetallic compounds including the initial formation.
Thus far, the observation and measurement had been carried out after temporarily cooling a heat-treated hot-dip galvanized steel sheet to stop the formation of intermetallic compounds in the Zn coating. Therefore, the initial formation behavior of intermetallic compounds had not been clarified.

Results

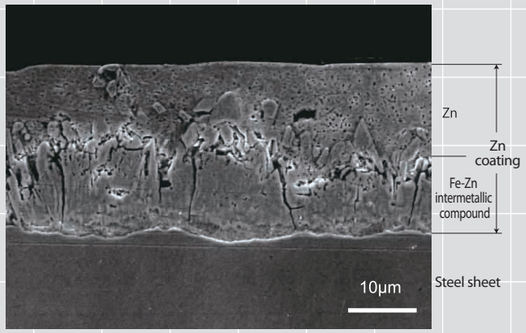
We succeeded in the real-time *in situ* observation of the process by which Fe-Zn intermetallic compounds are grown in the Zn coating of an alloyed hot-dip galvanized steel sheet from the initial stage using the high-brilliance X-ray at SPring-8.
The analysis result of **X-ray diffraction profiles** obtained in real time revealed that the growth rate of Fe-Zn intermetallic compounds depends on the diffusion velocity at which Fe atoms are mixed with Zn atoms, rather than the rate at which Fe atoms react with Zn atoms to form Fe-Zn intermetallic compounds, even at the initial stage of the growth. From this result, we established guidelines for technologies to control the initial stage of the formation of intermetallic compounds, which is important for creating smooth coating surfaces.

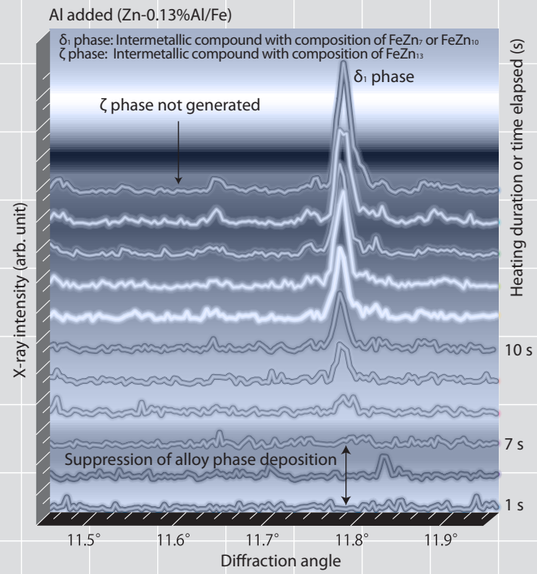
Hot-dip galvanizing line

Zn is attached to a continuously moving steel sheet.

Structure inside coating of alloyed hot-dip galvanized steel sheet (SEM image)

The figure below shows an SEM cross-sectional image of a Zn coating that was cooled in the middle of an alloying reaction. Fe-Zn intermetallic compounds are grown on the interface between the Zn coating and steel sheet.





X-ray diffraction profile associated with heating of hot-dip Zn coating

Formation of the Fe-Zn intermetallic compounds is prevented for 7s after the Zn coating melts; then, Fe-Zn intermetallic compounds are formed. This indicates that a small amount of aluminum (Al) added to Zn forms an Fe-Al intermetallic compound layer on the interface between the Zn coating and steel sheet, preventing the reaction between the two; subsequently, Fe-Zn intermetallic compounds form after this Fe-Al intermetallic compound layer disappears.

Formation behavior of Fe-Zn intermetallic compound

The thickness of the Fe-Zn intermetallic compound layer increases in proportion to the square root of time after the melting of the Zn coating during the formation process. This indicates that the growth rate of the Fe-Zn intermetallic compounds is determined by the diffusion velocity of Fe atoms being mixed with Zn atoms.