

1. Introduction

In virtually all press forming of metal materials, press oil is used to control the friction between the tool and the work and to prevent damage of the metal surface. However, if press forming of galvanized steel sheets with conversion coatings is performed continuously and at high speed, lubricity decreases due to the increased temperature of the press die and press oil, resulting in galling of the die and galvanized steel sheet. In this case, products are extremely susceptible to deterioration of surface appearance after press forming.

In the ironing process during continuous high-speed press forming, at least some of the galvanized coating and conversion coating on the steel sheet unavoidably form peelings as a result of rubbing between the galvanized steel sheet and the die, and as a result, black stains (surface blackened and dimmed after press forming) form on the pressed surface. These black stains are difficult to remove even by washing, and deteriorate surface appearance after press forming. On the other hand, if peelings accumulate in the press oil, they may re-adhere to later press formed materials, and degreasing and washing in the final process become necessary. Therefore, from the viewpoint of productivity, surface appearance which does not require degreasing and washing after the press forming process has been demanded¹⁾.

In response to this need, JFE Steel developed a chrome-free galvanized steel sheet with excellent appearance after press forming, “Eco Frontier™ JE” (hereinafter, JE), and has begun production and sales.

2. Concept of Coating Design of “Eco Frontier™”

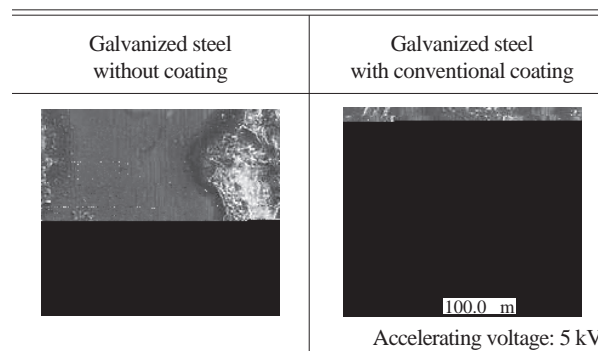


Photo 1 Scanning electron microscope (SEM) images of the surfaces at the drawn area

tinuous high-speed pressing, and is easily damaged. Therefore, a conventional conversion-coated steel sheet which is used as a general-purpose material for electrical machinery and a steel sheet without a conversion coating were evaluated. As shown in **Photo 1**, black stains cannot be observed on the steel sheet without a coating, and the surface shape of the ironed part is smooth. In contrast to this, with the conventional sheet, approximately 50% of the coating remains in the black-stained part, and the part which was subjected to ironing displays a very fine irregular shape (roughness). Based on this, the fact that coating that was damaged during press forming developed an irregular shape, and a large amount of this coating remained in the ironed part, is considered to be the cause of black stain. Since coating damage is unavoidable in continuous high-speed press forming, the following countermeasures are considered to be effective for improving black stains.

- (1) Reduction of the amount of coating remaining in ironed parts of the steel sheet
 - Reduction (optimization) of adhesion with zinc, Formation of a thin film
- (2) Reduction of re-adhesion of peelings
 - Use of a low adhesiveness component

2.2 Study of Effect of Conversion Coating Composition on Appearance after Press Forming

Considering the fact that a correlation exists between the amount of remaining coating in ironed parts of steel sheets and the reactivity of the conversion treatment solution with the zinc coating, the surface appearance after press forming of conversion coatings applied using treatment solutions with different reactivity was investigated. As a result of this investigation, virtually no black stains occurred when using a low-reactivity inorganic coating, but in contrast, occurrence of black stains became remarkable when a reaction accelerant was added to impart reactivity. Thus, it was found that a low-reactivity coating is effective for improving black stains. On the other hand, because peelings generated during press forming tend not to re-adhere to coatings which do not have adhesiveness, the appearance of the coating after heating and drying ($110^{\circ}\text{C} \times 90 \text{ min}$) conversion treatment solutions with different contents of reaction accelerants was evaluated, as shown in **Photo 2**. With the conventional steel sheet, the coating displays a flm-like form after heating and drying, and has high adhesiveness. However, when reactivity was changed by adding a reaction accelerant, it was found that the solution with a smaller amount of reaction accelerant displayed a powdery form and had lower adhesiveness.

To also reduce the absolute amount of coating peel-off, a search was conducted for a composition that would satisfy various properties, premised on the use of a thin coating flm. As a result, it was possible to maintain an excellent appearance after press forming and impart the various required properties by forming a polymer flm containing very small amounts of a reac-

