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Chromate-free Coated Steel Sheet with Excellent Appearance after Press Forming "Eco Frontier™ JE" †

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 demanded[1].

In response to this need, JFE Steel developed a chromate-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™ JE"

2.1 Concept of Improvement of Appearance after Press Forming

Black stains on the surface of galvanized steel sheets after press forming are considered to occur because the coating film on the galvanized sheet loses the ability to follow deformation during the forming process in continuous 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

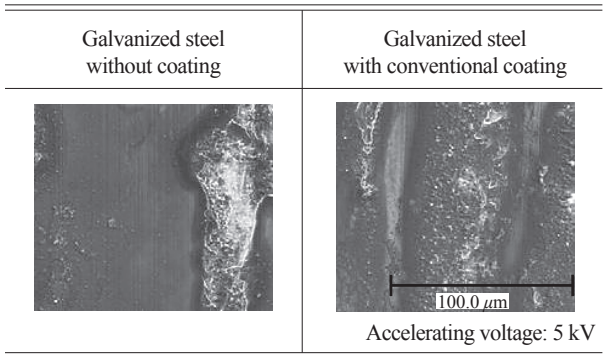

Photo 1 Scanning electron microscope (SEM) images of the surfaces at the drawn area

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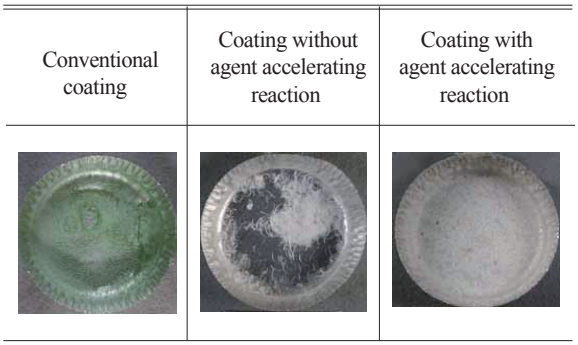

Photo 2 Appearance after drying by heating treatment solutions

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 an low-reactivity inorganic coating, but in contrast, occurrence of black stains became remarkable when an 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°C × 90 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 film-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 film. As a result, it was possible to maintain an excellent appearance after press forming and impart the various required properties by forming a polymer film containing very small amounts of a reaction accelerant and silica[2], which also makes it possible to realize a corrosion-resistant function in the developed JE, to a coating based mainly on an inorganic composition.

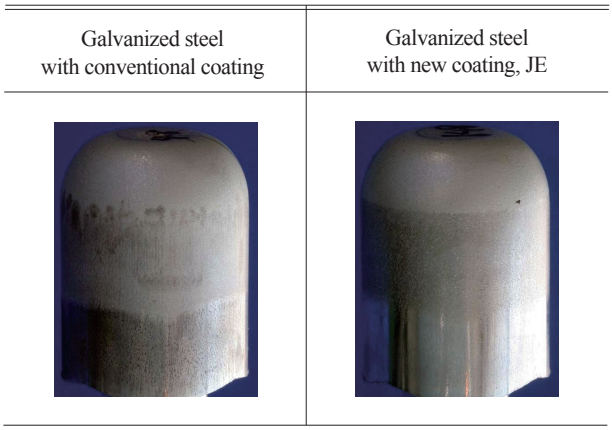

Photo 3 Surface appearances after press forming

3. Quality Properties

3.1 Surface Appearance after Press Forming

Photo 3 shows the surface appearance of samples after 2-step drawing. With the conventional steel sheet, black stain and re-adherence of peelings can be observed. However, with the developed JE, no black stain or re-adherence of peelings can be observed on the sheet surface, and the sheet has a surface with a glossy appearance, as the sheet surface is smooth.

3.2 Stability of Surface Appearance over Time (Blackening Resistance, Water Spotting Resistance)

When a coating contains a large amount of reaction accelerating components and is used under a humid environment, these components are dissolved and the phenomenon called blackening occurs easily (blackening is the phenomenon in which a galvanized steel sheet appears black due to formation of a very thin oxide film in the surface layer) [3]. In some cases, dissolution of the reaction accelerating components during degreasing and washing, etc. also causes remaining spots on the sheet surface. Because only a very small amount of reaction accelerant is used in the JE coating, excellent surface appearance after press forming can be maintained, and the problems of blackening and spotting can be avoided.

3.3 Corrosion Resistance

Figure 1 shows the relation between the conversion coating thickness and corrosion resistance as evaluated in the salt spray test (SST). In comparison with conventional material with the same coating weight, the corrosion resistance of JE is greatly improved by forming a composite inorganic polymer coating containing silica, and securing a certain degree of adhesiveness by reaction with the Zn galvanized coating using the reaction accelerant composition. It is possible to secure the same

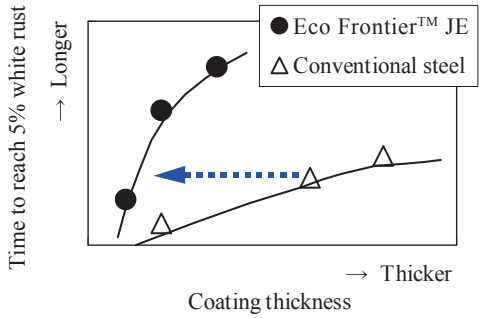

Fig. 1 Relation between coating thickness and corrosion resistance

level of corrosion resistance as that of the conventional material with JE with a thinner coating thickness, and surface appearance after press forming is also improved.

3.4 Electrical Conductivity

Electrical resistance was measured by the 4-probe method using a surface resistivity meter. As the coating thickness can be reduced as much as 60–70% in comparison with conventional conversion-coated steel sheets, JE displays a low resistance value of 0.1 mΩ or less, and possesses excellent electrical conductivity.

4. Conclusion

JFE Steel's "Eco Frontier™ JE" steel sheet provides high corrosion resistance on the order of primary corrosion resistance and excellent surface appearance after press forming (excellent formability). JE is particularly suitable for products formed by deep drawing and similar severe forming processes, and has already been applied to small-scale motor cases, etc., which are expected to enjoy increasing demand in the future.

References

1) Kataoka, Seiji. Light Metals. 2005, vol. 55, no. 1, p. 39.
2) Kubota, Takahiro; Yamashita, Masaaki. Tetsu-to-Hagané. 1995, vol. 81, no. 1, p. 633.
3) Okuma, Toshiyuki et al. CAMP- ISIJ. 1990, vol. 3, no. 5, p. 1562.