Properties of NKK Galvalume Steel Sheet "Super Genius Coat"

Masaaki Yamashita*, Keiji Yoshida**, Takafumi Yamaji***,
Akira Matsuzaki***, Etsuo Hamada**** and Hiroyuki Shinka*****

* General Manager, Dr, Coated Products Lab. Materials & Processing Research Center
** Team Manager, Coated Products Lab. Materials & Processing Research Center
*** Senior Research Engineer, Coated Products Lab. Materials & Processing Research Center
**** Senior Research Engineer, Materials Characterization Research Dept., Applied Technology Research Center
***** Manager, Products Development Section, NKK Steel Sheet & Strip Corporation

A new passivation treatment method of 55%Al-Zn coated steel sheets (galvalume steel sheets) was developed that applies an organic-inorganic hybrid coating named "Super Genius Coat". Newly developed inhibitors introduced into this passivation treatment significantly enhanced corrosion resistance at formed areas, which has been a challenge for passivation treatments of 55%Al-Zn coated steel sheets. In addition, high formability was achieved by applying new organic resin.

1. Introduction

55%Al-Zn coated steel sheets (galvalume steel sheets) are rapidly replacing conventional galvanized steel sheets particularly in the construction material field. The movement is driven by the need of long-term durability of construction materials under recent trends of increased acidic rainfall induced by air pollution, increased use of deicing salt to prevent road surface freezing in heavy snowfall regions such as Hokkaido and the Tohoku district of Japan, and increased development in coastal areas. In addition, maintenance-free materials are in greater demand. 55%Al-Zn coated steel sheets have excellent corrosion resistance of two to five times that of galvanized steel sheets. Accordingly, the demand for 55%Al-Zn coated steel sheets is expected to increase at an accelerated pace.

In addition to corrosion resistance, excellent formability (the ability to suppress galling on the metallic coating during forming) and high quality appearance (homogeneous appearance without surface irregularities) are basic prerequisites for materials used for construction. Therefore, in order to meet ever-increasing demands, it has become important to develop alloy coated steel sheets that have excellent properties in every aspect of corrosion resistance, formability, and appearance.

NKK carried out the investigation to develop a high performance chemical coating for application on the surface of 55%Al-Zn coated steel sheets, and successfully commercialized a highly corrosion resistant chemical coating named "Genius Coat"[1] (hereinafter referred to as "G Coat"). G Coat is a three-component organic-inorganic hybrid coating that was developed based on the conventional organic chemical coating. G Coat gained high regard of the market as an environmentally compatible, surface-treated steel sheet for construction that provides higher level of corrosion resistance and formability than those of conventional materials, while maintaining high quality appearance. To meet the market demand for even higher quality construction materials, NKK next developed "Super Genius Coat" (hereinafter referred to as "SG Coat") that offers further improved corrosion resistance and formability. SG Coat was developed based on the coating structure of G Coat that had already demonstrated superior characteristics. It exhibits superior corrosion resistance even at formed areas due to a novel corrosion-resistance technology newly developed by NKK. SG Coat also utilizes an improved organic resin component to enhance formability.

This paper describes the basic concept applied in designing SG Coat and its basic characteristics in corrosion resistance and formability.

2. Design concept of SG Coat

The basic concept applied in designing SG Coat to realize enhanced corrosion resistance and formability is as follows.

(1) Corrosion resistance

The effect of the chemical coating on corrosion resistance is significantly influenced by the corrosion resistance of the passivation coating that covers the metallic coating, and by the durability of the corrosion resistance under corrosive environments. With the goal of improving the corrosion resistance durability of the chemical coating by making it an insoluble corrosion-resistant coating possessing a high chromium fixing rate, we designed a new coating based on the technology[1] applied to G Coat. With G Coat, the surface of the metallic coating is covered by a passivation coating that is composed of an insoluble product generated by the reaction between the metallic coating and components in the chemical surface treatment solution (phosphate and chromate). A 55%Al-Zn coated steel sheet has a hard metallic coating that is susceptible to cracking during forming. Therefore, it is important to develop a technology that prevents corrosion from propagating from cracks in the metallic coating. In this regard, we developed a new chemical coating based on the idea of adding a new corrosion inhibitor that has excellent self-healing characteristics. The objective was to form a corrosion-resistant protective layer over cracks generated during sheet forming and to prevent corrosion propagation from these cracks even under corrosive environments. While it was known that Cr^{6+} could perform this function, its addition was avoided in view of environmental compatibility. Therefore, we investigated a non-chromium corrosion inhibitor that enhances corrosion resistance when added to the chemical coating.

(2) Formability

Since an inorganic coating is not flexible enough, it tends to separate during roll forming and induce galling[2]. Our development was therefore based on the technology[1] of forming a three-component organic-inorganic hybrid coating with a soft upper layer rich in organic resin. Further, in our coating design, we employed an organic resin with high adherence to the metallic coating. A highly adherent chemical coating was expected to enhance the prevention of galling of the metallic coating induced when the chemical coating was damaged or separated during sheet forming.

The concept of the coating design that provides excellent corrosion resistance and formability while having environmental compatibility is illustrated in **Fig.1** and **Fig.2**. On the surface of a 55%Al-Zn coated steel sheet, a new chemical coating was formed that consists mainly of the new corrosion inhibitor, phosphate, insoluble chromic compounds, and a special organic resin. The new coating was expected to have excellent flexibility and adhesiveness, and provide excellent self-healing at formed areas in addition to passivation function (**Fig.1**). Furthermore, the coating design aimed at realizing an organic-inorganic hybrid structure promoting effective functioning of the chemical coating (**Fig.2**). An insoluble passivation layer that is rich in chromic compounds and provides excellent corrosion resistance is in contact with the metallic coating. The upper coating layer consists mainly of an organic resin providing superior formability. The organic-resin-rich layer contains a new corrosion inhibitor that provides excellent self-healing function at formed areas of the sheet.

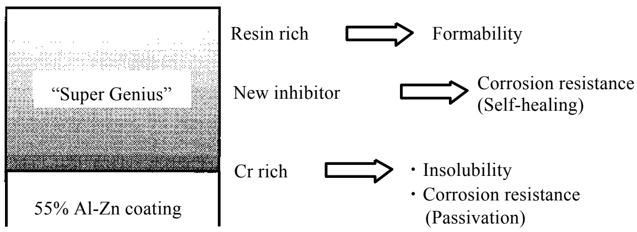


Fig.2 Cross-sectional structural design of "Super Genius Coat"

3. Test method

Specimens were prepared with three types of chemical coatings on 55%Al-Zn coated steel sheets (AZ150,

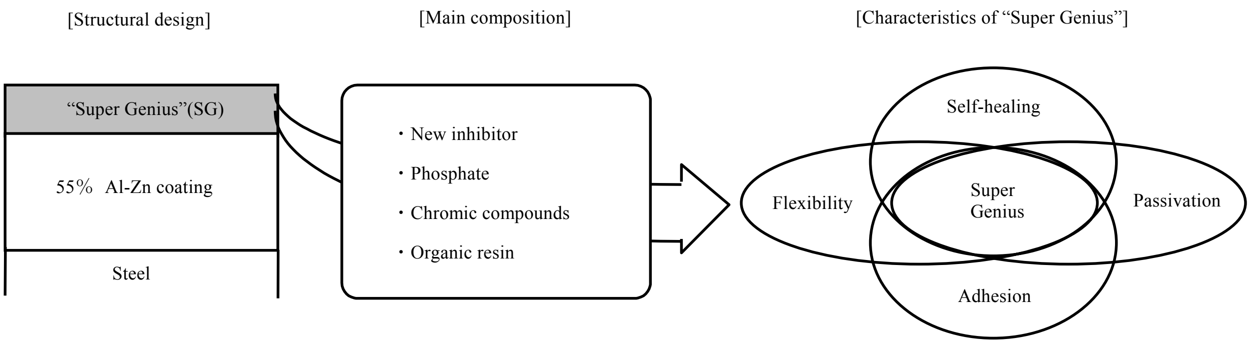


Fig.1 Structural design of "Super Genius Coat"

0.5 mm in thickness) as shown in **Table 1**. The first is SG Coat (SG), the organic-inorganic hybrid coating containing the new corrosion inhibitor. The second is G Coat (G), the organic-inorganic hybrid coating. The third is the conventional organic chromate coating mainly consisting of soluble chromate. The characteristics of these specimens were evaluated under the conditions given below.

Table 1 Type of chromate coatings

Samples	Composition
“Super Genius” (SG)	Resin/New inhibitor/Phosphate/Insoluble chromate
“Genius” (G)	Resin/Phosphate/Insoluble chromate
Organic chromate	Resin/Soluble chromate

(1) Corrosion resistance at flat areas

Salt spray testing (SST, JIS Z2371) was applied to the specimens with their rear face and cut edges sealed. The extent of white rust and black rust generation at flat areas was visually evaluated.

(2) Corrosion resistance at formed areas

SST was applied to the specimens after 5T bending. The extent of white rust and black rust generation at formed areas was visually evaluated.

(3) Formability

In order to simulate damage caused on the steel sheet surface by the friction between the roll and the sheet surface during roll forming, a flat sheet draw bead test was applied using a bead as shown in **Fig.3**. Anti-galling properties were evaluated by varying the normal force applied between the bead and the surface of steel sheet and determining the limiting normal force that does not induce significant galling on the coating surface.

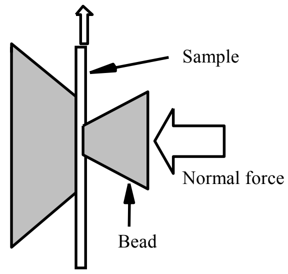


Fig.3 Formability test apparatus

(4) Resistance against chromium elusion

Specimens were immersed in boiling water for 30 minutes, and chromium content in the coating was measured by fluorescent X-ray spectrometry before and after immersion. Resistance against chromium elusion was determined by the amount of chromium that remained in the coating after immersion (chromium fixing rate).

4. Result and consideration

4.1 Corrosion resistance

Photo 1 shows flat areas of the specimens after SST. White rust, which is a corrosion product of Zn, appeared after 500 hours on the specimens with the conventional organic chromate coating. After 2000 hours, black rust, which is a corrosion product mainly consisting of Al, appeared over almost all the surface area, suggesting that

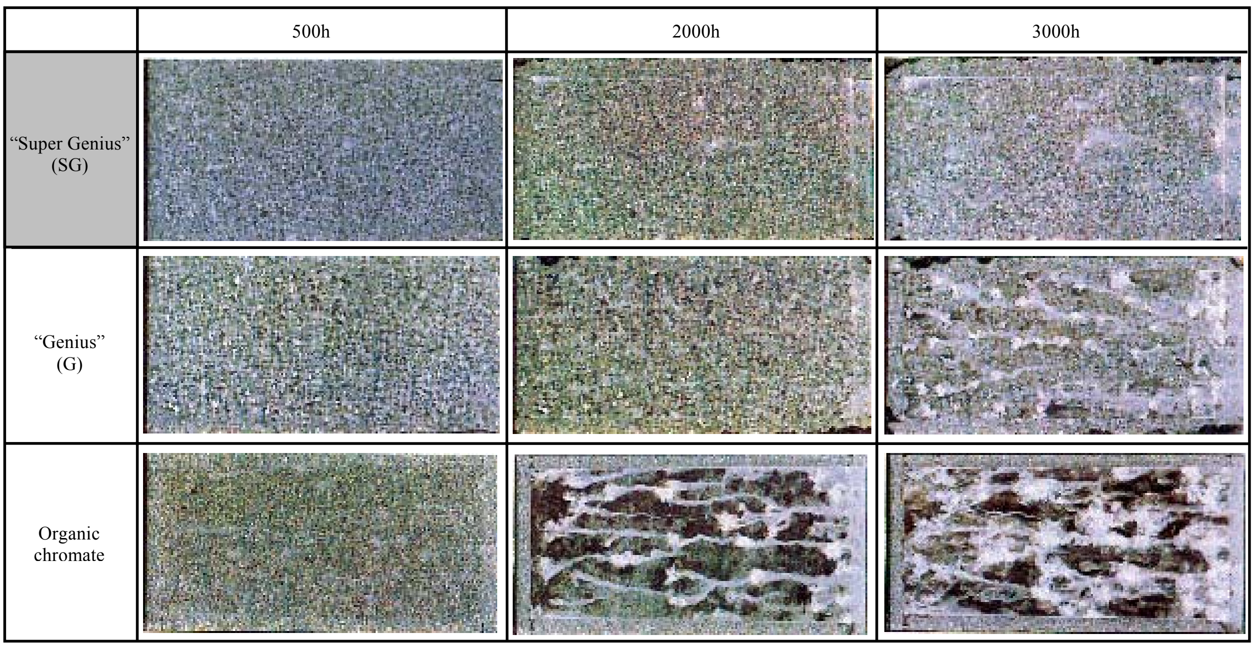


Photo 1 Appearance after salt spray tests

the corrosion of the metallic coating was significantly advanced. In contrast, specimens with the organic-inorganic hybrid G Coat and SG Coat showed almost no white rust after 500 hours and only a small amount of white rust after 2000 hours. Thus, it was verified that corrosion resistance was significantly improved by these two types of coatings. Further, SG Coat, containing the new corrosion inhibitor, suppressed black rust generation for 3000 hours, and exhibited the best flat-area corrosion resistance.

Photo 2 shows areas of the specimens subjected to 5T bending after 240 hours of SST. The specimen with conventional organic chromate coating showed black rust over the entire bent area, while the specimen with G Coat, which showed superior flat-area corrosion resistance, exhibited partially generated black rust at the formed area. In contrast, SG Coat, containing the new corrosion inhibitor, suppressed the corrosion to such a level that only small amounts of white rust were generated. Thus, it was shown that SG Coat drastically improved formed-area corrosion resistance.

A chromate coating suppresses the corrosion through two means. One is the barrier protection offered by the passivated layer formed on the metallic coating, and the other is the self-healing function where partially dissolved chromic compounds regenerate a corrosion-resistant layer at a position where the coating was damaged. Therefore, the dissolution behavior of chromic compounds under corrosive environments has a significant influence on the corrosion resistance. In other words, to make chromic compounds insoluble extends the period over which rust generation is suppressed[1),2)]. **Fig.4** shows the evaluation results for the insolubility of three types of chromate coatings. The figure indicates that both SG Coat and G Coat, which outperformed the conventional organic chromate coating in the corrosion resistance tests, have higher insolubility. This is presumably the reason why they have superior corrosion resistance. SG Coat provides higher corrosion resistance than G Coat at formed areas, where the metallic coating tends to crack and damage the chemical coating. This is presumably because the new corrosion inhibitor added to SG Coat significantly enhanced the self-healing function and as a result, drastically improved the corrosion resistance.

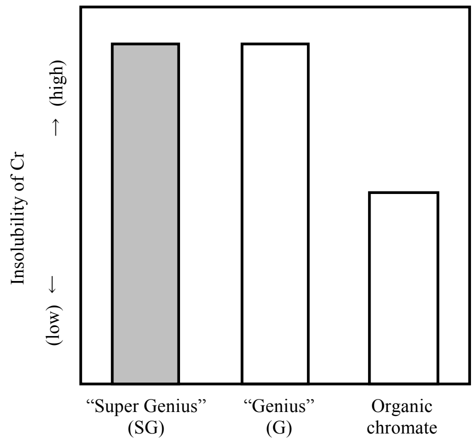


Fig.4 Insolubility of various chromate coatings on 55%Al-Zn coated steel sheets

Photo 3 compares the result of cyclic corrosion testing (CCT : SST → wet → dry → dry) applied to the bent areas of three types of highly corrosion-resistant coated steel sheets used as building materials. The 5%Al-Zn coated steel sheet has a highly formable metallic coating layer. The three-component 5%Al-Zn-Mg coated steel sheet has a metallic coating layer in which Mg is added to improve the corrosion resistance of a 5%Al-Zn coated steel sheet. Both of these steel sheets developed red rust at bent areas. In contrast, the 55%Al-Zn coated steel sheet to which SG Coat was applied developed only small amounts of white rust, and no red rust. Thus, SG Coat provides the best corrosion resistance among the three types of highly corrosion-resistant coated steel sheets used as building materials.

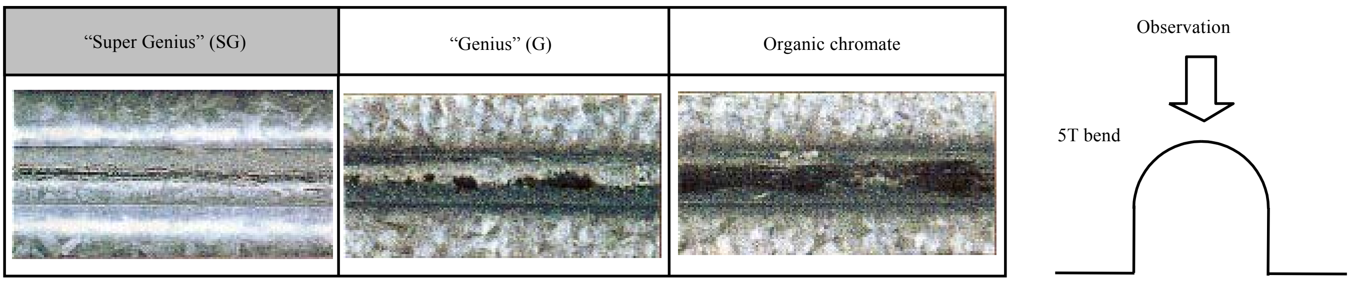
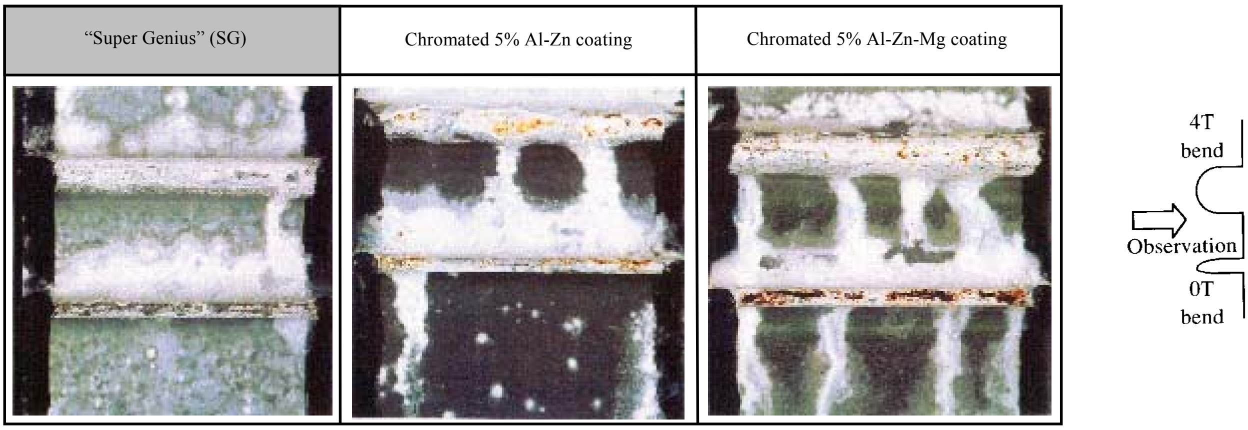


Photo 2 Appearance of formed areas after salt spray tests of 240h



1 cycle ; SST (30℃, 0.5h) → Wet (30℃, 1.5h) → Dries (50℃, 2h) → Dries (30℃, 2h)

Photo 3 Appearance of formed areas after cyclic corrosion tests of 180 cycles

4.2 Formability

Fig.5 shows the result of formability evaluations by the draw bead test measured in terms of the limiting normal force that does not induce galling. **Photo 4** shows examples of appearance after the draw bead tests. These results verify that the organic-inorganic hybrid SG Coat and G Coat resist galling up to much larger loads compared to the conventional organic chromate coating. In particular, SG Coat demonstrated the best anti-galling performance. Although the addition of organic resin to the coating generally improves the formability[2),3)], these results suggest that the degree of improvement significantly differs among the coating types.

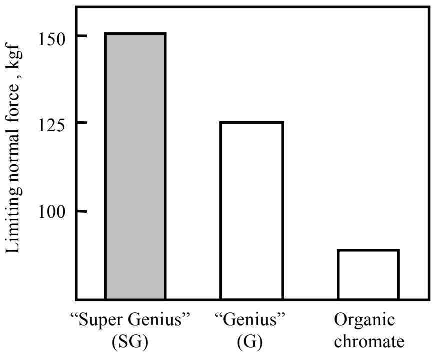


Fig.5 Formability of various chromate-coated 55%Al-Zn steel sheets evaluated by draw bead tests

Fig.6 shows the weight loss (ΔW) caused by the draw bead tests. This value is considered to represent the amount of coating separated from the steels during the tests. SG Coat and G Coat do not show much difference in the amount of separated coating when the applied load was in a range that does not induce galling. However, SG Coat suppressed the coating separation more effectively than G Coat under the higher loads.

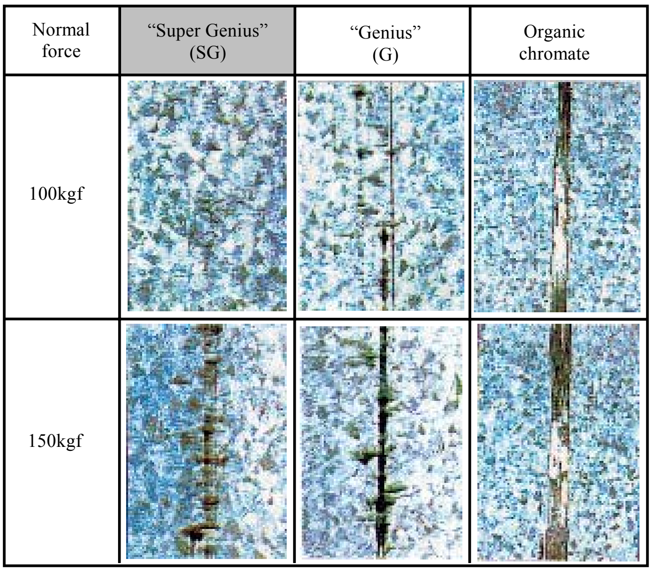


Photo 4 Appearance after draw bead tests

As a result, SG Coat is estimated to have superior formability under severe forming conditions where high normal force is applied.

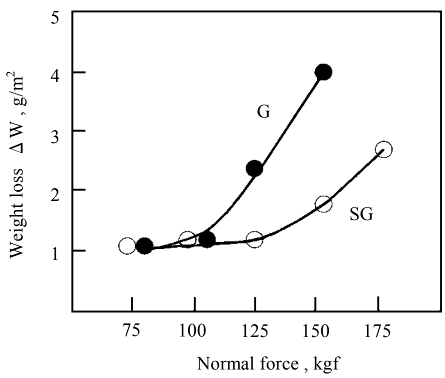


Fig.6 Result of draw bead tests of organic-inorganic hybrid coated steel sheets without lubricant

5. Conclusion

Responding to increasing demands for highly corrosion-resistant materials mainly from the building materials field, we developed and commercialized a unique 55%Al-Zn coated steel sheet that is coated by the highly corrosion-resistant chemical coating named "Super Genius Coat". It is characterized by excellent corrosion resistance, formability, and environmental compatibility. The newly-developed product is expected to be adopted in a variety of fields. Typical applications are building exterior materials such as roofs and exterior walls of plants, warehouses, and silos. It is also expected to be used in fields where hot-dip galvanized products are traditionally used, such as cable racks and outdoor electricity distribution panel boxes. The product is drawing attention as a low-cost, highly-corrosion-resistant material.

References

1) Yamashita, M. et al. "Highly corrosion-resistant 55%Al-Zn coated steel sheet : NKK galvalume steel sheet (Genius Coat)". NKK Giho. No.167, pp.20–23, (1999).
2) Yamaji, T. et al. "Influence of types of chemical coating on characteristics of coatings of 55%Al-Zn coated steel sheets". ZAIRYO TO PROCESS. Vol.12, p.364, (1999).
3) Yamaji, T. et al. "Influence of types of chemical coating on the characteristics of coatings of 55%Al-Zn coated steel sheets: Part 2". ZAIRYO TO PROCESS. Vol.13, p.1322, (2000).

<Please refer to>
Takafumi Yamaji
Coated Products Lab. Materials & Processing Research Center
Tel. 044 (322) 1453
E-mail address : Takafumi_Yamaji@ntsgw.tokyo.nkk.co.jp
Hiroyuki Shinka
Products Development Section, NKK Steel Sheet & Strip Corporation
Tel. 044 (322) 1024