

Development of New 55%Al-Zn Alloy Coated Steel Sheets with Excellent Corrosion Resistance and Formability, “SUPER GENIUS” and “GALFLEX-COLOR”

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Higher durability is increasingly required for construction materials in order to conserve resources and reduce maintenance work. Since 55%Al-Zn alloy coated steel sheets exhibit excellent corrosion resistance, their use in construction for roofing and siding is expanding. NKK has developed and marketed a high-quality, thin organic composite coated 55%Al-Zn alloy coated steel sheet, “SUPER GENIUS”, and a prepainted steel sheet, “GALFLEX-COLOR” for these applications. This paper outlines the development processes and main properties of these two new products.

1. Introduction

Coated steel sheets such as hot-dip galvanized steel sheets and prepainted steel sheets are widely used in the construction industry as exterior, interior, and structural materials. Prepainted steel sheets are produced by forming polymer films 10 to 30 μ m thick on the surfaces of galvanized steel sheets in order to provide specific colors and designs. They are mainly used in applications such as roofing, siding, and shutters on various buildings. On the other hand, organic composite coated steel sheets are produced by forming thin organic composite films 1 to 2 μ m thick on the surfaces of galvanized steel sheets. They are used in applications that do not require such aesthetic designs as prepainted steel sheets; for example roofing, siding, and structural materials of nonresidential, industrial and commercial buildings. Basic properties required of organic composite coated steel sheets are formability (the property that suppresses the peeling and scoring of metal coatings during roll forming) and corrosion resistance. In addition to these properties, prepainted steel sheets have to have an excellent surface appearance, free from cracks and other damage. This has to be maintained even after forming.

In the construction industry, higher durability and

longer life of construction materials are being increasingly required in order to promote resource conservation and reduce maintenance work. With regard to coated steel sheets, there is a limit in the increase of corrosion resistance of conventional Zn coated steel sheets. As a result, the more corrosion resistant Zn-Al alloy coated steel sheets are being used increasingly. In particular, since 55%Al-Zn alloy coated steel sheets exhibit excellent corrosion resistance, their use as a construction material for roofing and siding is rapidly expanding.

However, 55%Al-Zn alloy coated steel sheets have a shortcoming in that their metal coating layers are rigid and can easily crack when bent in comparison with Zn coated steel sheets, as shown in **Fig.1**.

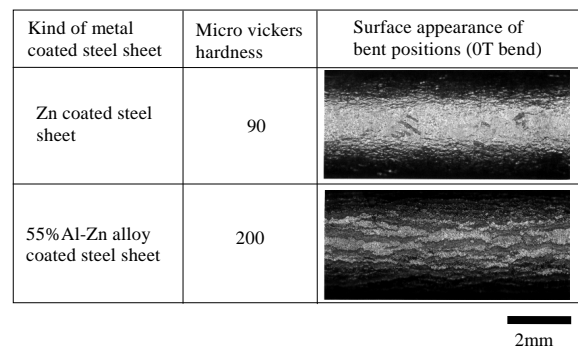


Fig.1 Cracks formed on bent steel sheets

Based on 55%Al-Zn alloy coated steel sheets, NKK has developed and marketed new coated products that have, at the same time, excellent corrosion resistance and formability²⁾⁻⁴⁾. One is an organic composite coated steel sheet, "SUPER GENIUS". This was developed by applying a unique thin organic composite coating film over a 55%Al-Zn alloy coated steel sheet substrate. The other is a prepainted steel sheet, "GALFLEX-COLOR" in which both the metal coating and paint film were designed to be highly functional. These new products for the construction industry will contribute to global environmental conservation by prolonging the life of construction materials. This paper outlines these two products developed from 55%Al-Zn alloy coated steel sheets.

2. "SUPER GENIUS" – a new organic composite coated steel sheet for the construction industry

2.1 Coating design

In the past, mainly prepainted steel sheets were used in roofing, siding, and other exterior applications. Recently, organic composite coated steel sheets with thinner organic coatings over highly corrosion resistant metal coated steel sheets are increasingly being used¹⁾.

Organic composite coated steel sheets that have thin organic coating films of 1 to 2 μ m over 55%Al-Zn alloy coated steel sheets are highly corrosion resistant while having a beautiful appearance of spangled texture. Due to

excellent cost performance, they have been increasingly used since the 1990's in applications concentrating on the roofing and siding of nonresidential buildings. Although basic properties required of these steel sheets are formability and corrosion resistance, environmental compatibility is also one that is increasingly valued in recent years. By improving conventional organic composite coating films, NKK developed a unique gradient coating design and applied it to 55%Al-Zn alloy coated steel sheets. The resultant product was marketed under the name, "GENIUS". Conventional organic coating films are mainly composed of resin and chromate. In contrast, the organic coating film of "GENIUS" has a coating design that has a gradient structure. An insoluble passivation layer is formed at the bottom by the reaction between the metal in the underlying metal coating layer and the corrosion inhibitors (chromate, phosphate) contained in the organic coating film. The product's top layer is resin-rich. Owing to this gradient structure, corrosion resistance and formability are both enhanced at the same time. **Fig.2** shows the scanning auger microscopy at the top and bottom of GENIUS's thin organic coating layer. These charts confirm that a gradient structure is formed, where the top layer is resin-rich while there is an insoluble passivation layer (mainly composed of Cr^{3+}) at the bottom interface with the metal coating layer. Enhanced corrosion resistance and formability of "GENIUS" have earned it a high reputation in the market.

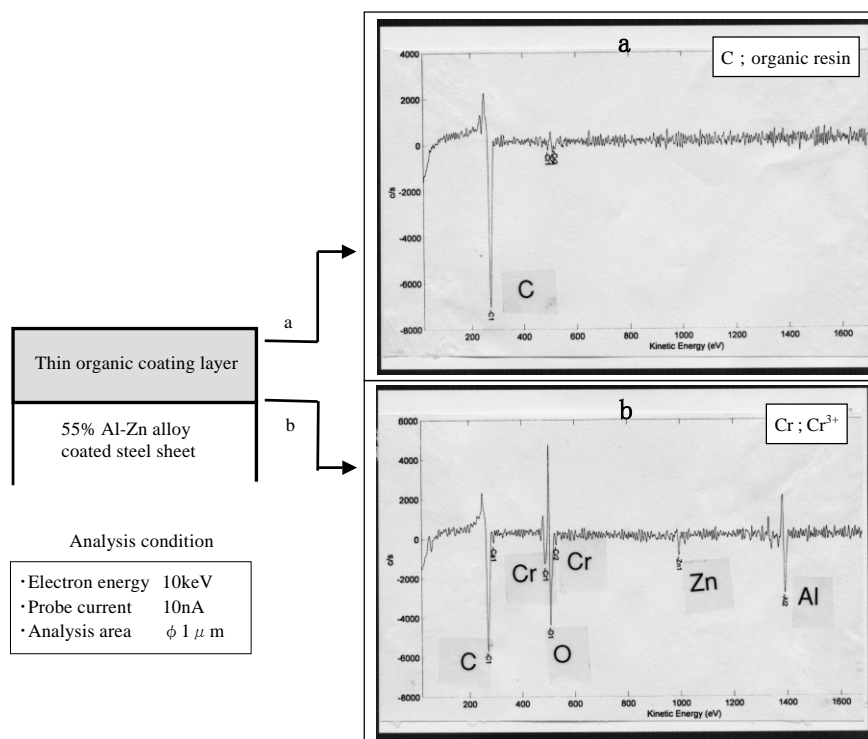


Fig.2 Scanning auger microscopy at the top and bottom of the organic coating layer of "GENIUS"

Furthermore, a new chromium-free corrosion inhibitor was developed and introduced into the organic coating film with the gradient structure developed for "GENIUS". This technology overcame the remaining shortcoming of 55%Al-Zn alloy coated steel sheets, that is, poor corrosion resistance in bent positions. A new organic resin was also developed to improve formability. Based on these improvements, a new product, "SUPER GENIUS" was developed (Fig.3). Excellent flexibility and adhesion were obtained as well as excellent passivation and self-healing effects in bent positions. These properties were gained by applying the new organic coating film (SG coat), which is mainly composed of the newly developed corrosion inhibitor, phosphate, insoluble chromic compounds, and special organic resin (Fig.4).

2.2 Features of "SUPER GENIUS"

Corrosion resistance properties in bent positions of the SG coat and a conventional organic composite coating film were evaluated. The results are shown in Fig.5. Owing to the excellent self-healing effect of the new corrosion inhibitor adopted in "SUPER GENIUS", cracks generated by bending in the metal coating layer are eventually covered by a corrosion inhibiting film in a corrosive environment and further progress of the corrosion is suppressed. Corrosion resistance enhanced by using a chromium-free corrosion inhibitor contributes to the environmental compatibility of the new product. A typical forming method applied to construction materials is roll forming. In order to simulate the sliding motion between the steel sheet and roll in

Kind of coatings	Composition	Corrosion area, % (degree of rust at 5T bent position)		
		(superior)	50	(inferior)
SG coat	<ul style="list-style-type: none"> ● New inhibitor ● Phosphoric acid ● Cr³⁺ ● Organic resin 	0	50	100
Organic composite	<ul style="list-style-type: none"> ● Cr⁶⁺ ● Organic resin 	0	50	100

Salt spray test (JIS Z2371) for 240 hr

Fig.5 Corrosion resistance in bent positions

the roll forming process, a bead was pressed against the steel sheet. Maximum normal force that did not cause peeling and scoring was compared on steel sheet specimens with SG coat and a conventional organic composite coating. The results are shown in Fig.6. Superior formability of "SUPER GENIUS" was verified. Fig.7 is an example of "SUPER GENIUS" that was formed into a special roofing structure. "SUPER GENIUS" can be formed into severely bent shapes that are difficult to achieve using conventional materials because of prominent peeling and scoring they cause.

Kind of coatings	Composition	Limiting normal force, Kgf		
		(inferior)	75	(superior)
SG coat	<ul style="list-style-type: none"> ● New inhibitor ● Phosphoric acid ● Cr³⁺ ● Organic resin 	0	75	150
Organic composite	<ul style="list-style-type: none"> ● Cr⁶⁺ ● Organic resin 	0	75	150

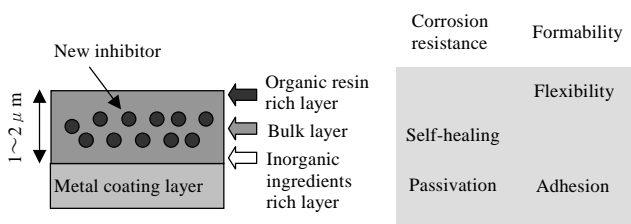


Fig.4 Schematic cross-section of SG Coat

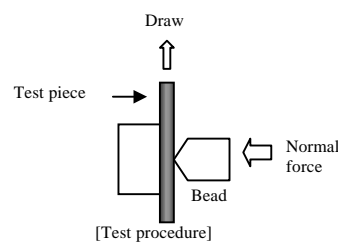


Fig.6 Formability laboratory simulation test

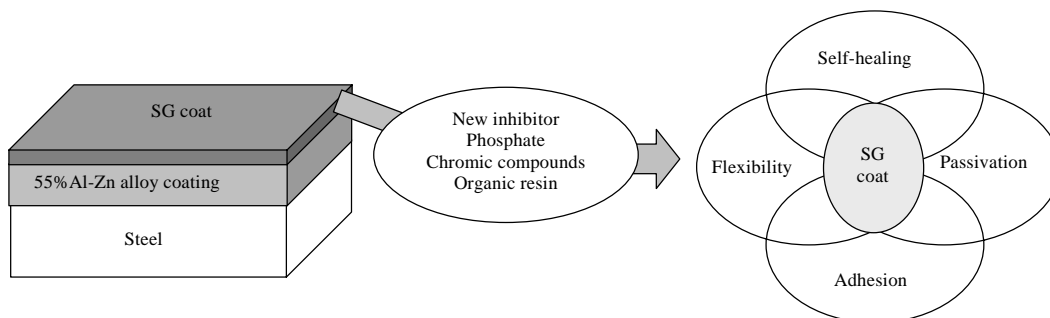


Fig.3 Design of "SUPER GENIUS"

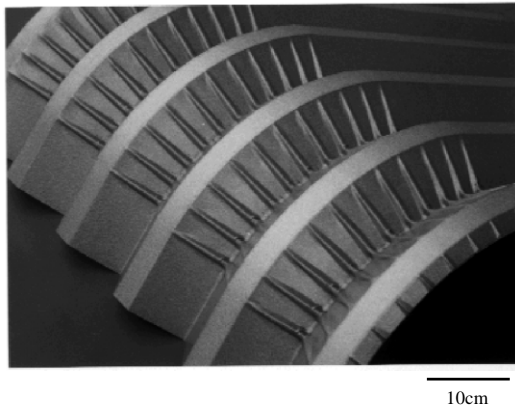


Fig.7 "SUPER GENIUS" after severe forming

3. "GALFLEX-COLOR" - a new prepainted steel sheet for construction applications

3.1 Coating design

The type of steel sheet that is most commonly used as the substrate for a prepainted steel sheet is hot-dip galvanized steel sheet¹⁾. However in recent years, it is losing its share of the market to a more corrosion resistant Zn-Al alloy coated steel sheet. In particular, prepainted steel sheets that use 55%Al-Zn alloy coated steel sheets as substrates are rapidly expanding their application in the roofing and siding area. However, when a 55%Al-Zn alloy coated steel sheet is used as a substrate for a prepainted steel sheet, cracks can be caused easily in the metal coating layer by bending. These cracks spread to the overlying paint film, not only degrading the surface appearance but also promoting the progress of corrosion to adjacent areas. This drawback makes it difficult to use this type of prepainted steel sheet in positions that demand severe forming. NKK planned to develop a prepainted 55%Al-Zn alloy coated steel sheet that has excellent formability, aiming at expanding the construction market for coated steel sheets. By giving high formability to both the metal coating and paint film through the company's unique methods, NKK has successfully developed a world-first, highly formable prepainted 55%Al-Zn alloy coated steel sheet. This is now on the market as "GALFLEX-COLOR".

The development concept of "GALFLEX-COLOR" is shown in Fig.8. A formability superior to that of a conventional prepainted 55%Al-Zn alloy coated steel sheet was given to both the metal coating layer and paint film. Thus, excellent formability was added to the 55%Al-Zn alloy-coated steel sheet that was already inherently highly corrosion resistant.

3.2 Features of "GALFLEX-COLOR"

The hardness of metal coating layers of various metal

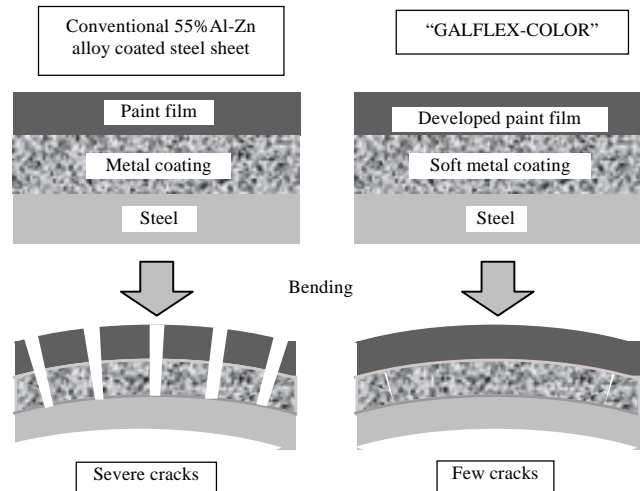


Fig.8 Development concept of "GALFLEX-COLOR"

coated steel sheets is compared in Fig.9. The metal coating layer of "GALFLEX-COLOR" was softened by controlling its structure to a level comparable to hot-dip galvanized steel sheet and Zn-5%Al alloy coated steel sheet.

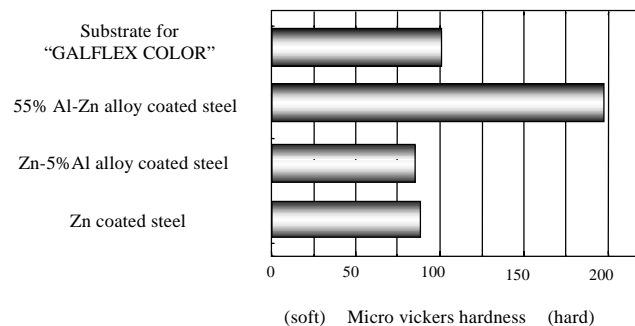


Fig.9 Comparison of metal coating hardness

Paint film needs to be sufficiently flexible in order to have good formability. In addition, paint film needs to adhere firmly to the substrate metal layer in order to prevent surface damage being caused by scratching during and after construction (Fig.10). However, hitherto it has been difficult to achieve both excellent flexibility and adhesion at the same time. Focusing on the resin component of paint film, NKK developed a composite resin that is composed of highly adhesive resin and highly flexible polymer. NKK became the first in the industry to successfully improve paint film flexibility while securing adhesion to the substrate, an essential property for prepainted steel sheet used in construction.

Fig.11 compares the appearance of "GALFLEX-COLOR" in a bent position with those of other prepainted steel sheets. Susceptibility of "GALFLEX-COLOR" to cracking in bent positions is markedly improved when compared

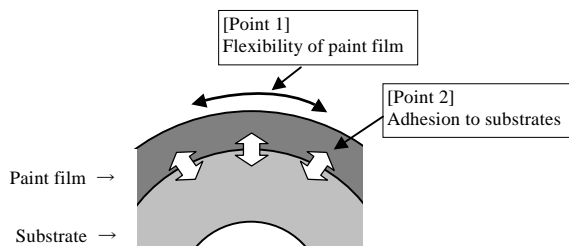


Fig.10 Properties needed of paint film in order to improve formability

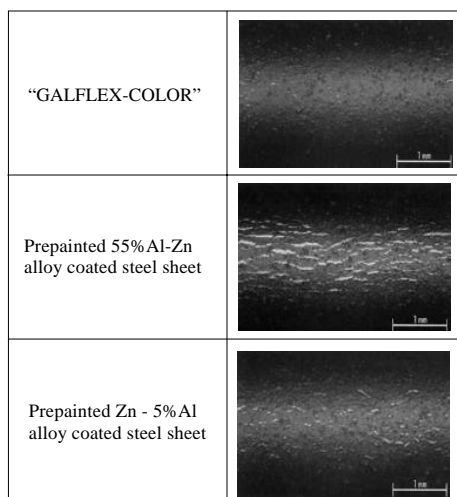


Fig.11 Close-up views of 3T bent positions

with a conventional prepainted 55%Al-Zn alloy coated steel sheet. 3T bending did not cause any cracks. This performance is more than equal to a prepainted Zn-5%Al alloy coated steel sheet - a construction product that has the best formability among conventional prepainted steel sheets. A cyclic corrosion test that simulated the actual use environment was performed to evaluate the corrosion resistance of 3T bent positions of various prepainted steel sheets. The results are shown in **Fig.12**. "GALFLEX-COLOR" generated only a very small amount of rust and blister at the bend, and its excellent corrosion resistance in bent positions was verified. GALFLEX-COLOR can be applied when forming such a hard-to-form member that is not possible to form from conventional prepainted 55%Al-Zn alloy coated steel sheets.

4. Conclusions

In response to the increasing need for highly durable construction materials, NKK has developed a unique coating design, and applied it to 55%Al-Zn alloy coated steel sheets that are inherently highly corrosion resistant. New products resulted, a high-quality, organic composite coated 55%Al-Zn alloy coated steel sheet "SUPER GENIUS" and

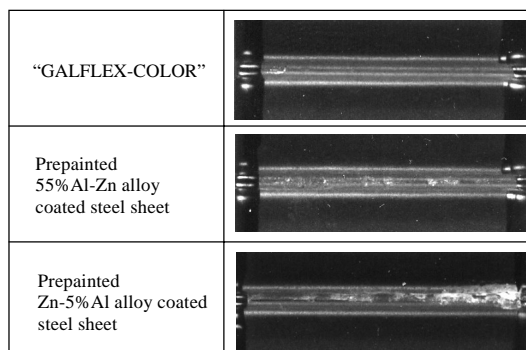


Fig.12 Appearance of 3T bent positions after cyclic corrosion test

a prepainted steel sheet "GALFLEX-COLOR". Both are highly corrosion resistant and at the same time highly formable. Commercial production of "SUPER GENIUS" was started in October 2000, "GALFLEX-COLOR" in April 2001. Both products have gained high reputations among customers as they satisfy the customers' requirements for longer life and design versatility in construction materials. Currently, the market demand for construction materials is sluggish. However, NKK will continue to develop new steel sheet products that are superior in quality and environmental compatibility, and contribute to the expansion of the construction market for steel sheet products.

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