

Chromate-Free Coated Steel Sheets for Electrical Appliances “ECO FRONTIER JN”[†]

YAMAJI Takafumi^{*1} KUBOTA Takahiro^{*2} KATO Chiaki^{*3}

Abstract:

“ECO FRONTIER JN” is an environment-friendly chromate-free functional coated steel sheet for electrical appliances which was developed by JFE Steel in response to environmental needs. By developing an organic composite coating consisting of a original organic resin with a high barrier effect and inorganic inhibitors with a self-healing effect, JFE realized high corrosion resistance with a thin film for the first time in the world and succeeded in satisfying the mutual contradictory requirements of corrosion resistance and electrical conductivity. Because “JN” has excellent properties, which include corrosion resistance, corrosion resistance after alkaline degreasing, electrical grounding, weldability, anti-fingerprint property, and paint adhesion property, application in the internal parts of OA/AV equipment and electrical appliances is increasing. As related products, JFE Steel has also developed and commercialized various other functional chromate-free steel sheets in the “ECO FRONTIER” series which provide higher levels of corrosion resistance, formability, paint adhesion, lubricity, and other properties.

1. Introduction

Chromate treatment of zinc-coated steel sheets is widely used as a low-cost rust-preventive treatment which suppresses corrosion of zinc. Since the 1980s, the needs for higher corrosion resistance and multifunctionality in materials have increased rapidly. In response, dry-in-place chromate-treated steel sheets with an anti-fingerprint property, paint adhesion property, lubricity, designability, and other features, and organic composite

coated steel sheets with a chromate film and organic resin thin coating (1–2 μm level or thinner) have been developed and are used widely in home electrical appliances and other products¹⁾.

On the other hand, with heightened environmental protection activities, there have also been increasing moves to reduce the use of environmental load substances. In Europe, prohibited substances (Pb, Cr(VI), Cd, Hg, etc.) which are contained in electrical and electronic equipment are regulated under the EU’s directive on restrictions of the use of certain harmful substances, which will become effective in July 2006²⁾. Similarly, in Japan, major makers of electrical appliances and OA equipment have adopted “Green Procurement” policies which require purchasing in consideration of the environment, and are attempting to reduce the use/release of environmental load substances as part of these efforts. These various trends have led to expanded use of chromate-free materials and products^{3,4)}.

JFE Steel began developing chromate-free functional coated steel sheets in anticipation of these environmental needs. This report introduces JFE Steel’s chromate-free coated steel sheets, with particular emphasis on “ECO FRONTIER JN,” which is applied to OA/AV equipment and products with similar requirements.

2. “ECO FRONTIER JN”⁵⁻⁹⁾

2.1 Product Applications

“ECO FRONTIER JN” (hereinafter, “JN”) is a chromate-free anti-fingerprinting steel sheet with multifunctional performance, including corrosion resistance

[†] Originally published in *JFE GIHO* No. 8 (June 2005), p. 77–81



^{*1} Senior Research Deputy General Manager,
Coated Products Res. Dept.,
Steel Res. Lab.,
JFE Steel



^{*2} Senior Researcher Manager,
Coated Products Res. Dept.,
Steel Res. Lab.,
JFE Steel



^{*3} Ph. D.,
Staff General Manager,
Steel Business Planning Dept.,
JFE steel

of 72–120 h to 5% white rust in the salt spray test, an anti-fingerprint property, electrical conductivity (electrical grounding), spot weldability, and paint adhesion. This product is applied in the chassis and bottom plate of OA/AV equipment, inner panels of home electrical appliances, etc.

2.2 Basic Concept of Film Design

In general, increasing the thickness of the coating improves corrosion resistance but reduces electrical conductivity/spot weldability (Fig. 1)¹⁰⁾. To satisfy both requirements, it is necessary to impart high corrosion resistance with a thin film on the order of 1 μm . The key point is a film design which realizes a thin coating film with a high barrier effect and self-healing effect. As shown in Fig. 2¹⁰⁾, in conventional chromate-treated organic composite coated steel sheets, a combination of chromate and an organic resin coating containing silica had been used to impart corrosion resistance. In contrast to this, in chromate-free organic composite coated steel sheets, the basic concept of the film design is to form a special organic composite coating which displays high corrosion resistance with a thin film by taking advantage of the functions of a special organic resin and inorganic inhibitors¹⁰⁾.

Based on the fundamental concept outlined above, the following development was conducted:

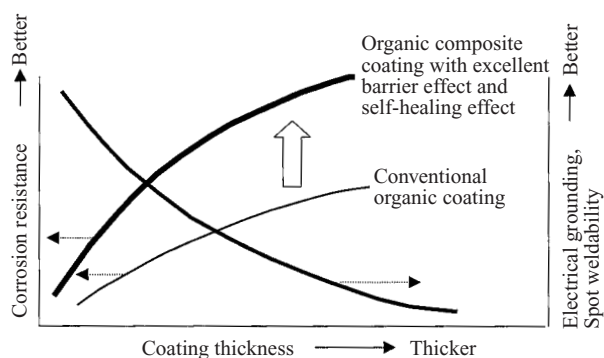


Fig. 1 Basic concept of Cr (VI)-free organic composite coatings¹⁰⁾

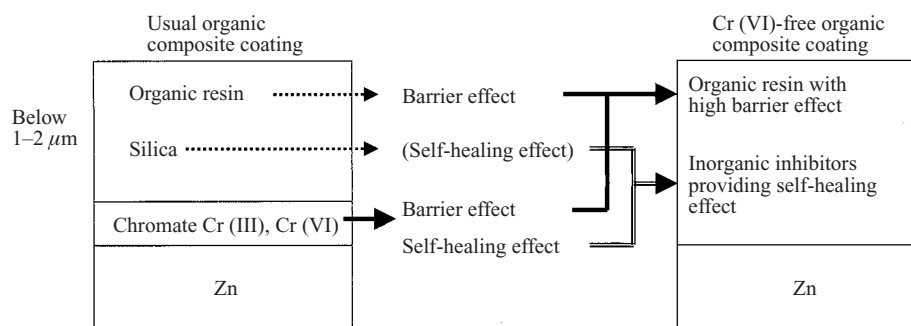


Fig. 2 Basic concept of design Cr (VI)-free organic composite coatings¹⁰⁾

(1) Development of Organic Resin with High Barrier Effect

Focusing on the relationship between the corrosion resistance and oxygen barrier effect of various types of organic resin coating, the corrosion resistance and O_2 permeability coefficients of simple organic resin films were measured. The O_2 permeability coefficient was measured by the oxygen electrode method using film samples 20 μm thick. It was found that corrosion resistance increases in organic resin films with lower O_2 permeability coefficients, in other words, a higher O_2 barrier effect. It was also discovered that a modified epoxy resin has the smallest O_2 permeability coefficient, and thus has the highest corrosion resistance (Fig. 3)¹⁰⁾. Using this resin as a base, JFE Steel developed a proprietary special chelate-modified epoxy resin in which the base resin is modified with a chelating agent.

(2) Development of Inorganic Inhibitors with Self-healing Effect

With the aim of imparting a self-healing effect, various types of inhibitors were added to the above-mentioned special chelate-modified epoxy resin film, and corrosion resistance was measured. As a result, JFE Steel discovered independently that a special silica inhibitor is effective, making it possible to improve corrosion resistance.

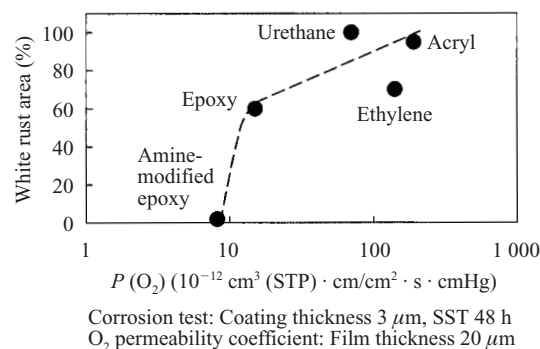


Fig. 3 Relationship between O_2 permeability coefficient and corrosion resistance of organic coatings¹⁰⁾

By developing a chromate-free organic composite coating incorporating a combination of these new technologies, JFE Steel realized high corrosion resistance with a thin film for the first time in the world and succeeded in achieving both corrosion resistance and electrical conductivity at a high level. This product was put into industrial production in 1998, and is currently produced commercially at JFE Steel's West Japan Works.

2.3 Quality Performance

This section will describe the quality properties of “JN.”

(1) Corrosion Resistance, Corrosion Resistance after Alkaline Degreasing

Photo 1 shows the results of an unpainted corrosion test (appearance after salt spray test for 100 h and after alkaline degreasing followed by salt spray test for 72 h). The developed product shows no white rust and has satisfactory corrosion resistance equal to that of chromate-treated coated steel sheets.

As a problem with conventional chromate-free coating technologies, in cases where the user applied alkaline degreasing to remove oil and dirt from the steel sheet surface after press-forming, the coating was degraded by alkaline degreasing, causing a remarkable reduction in corrosion resistance. However, the developed product shows virtually no degradation of corrosion resistance after alkaline degreas-

ing and maintains its excellent properties.

(2) Spot Weldability

“JN” has excellent spot weldability because the thickness of its organic composite coating is thin. The quality performance of “JN” has also received high marks in an evaluation of the spot weldability of chromate-free steel sheets by a major copying machine maker (**Fig. 4**)¹¹⁾.

(3) Electrical Conductivity (Electrical Grounding)

The surface resistance of “JN” showed a low value at the $10^{-4} \Omega$ level, which is similar to that of dry-in-place chromate-treated steel sheets (test with Loresta AP; manufactured by Mitsubishi Chemical Corp.), indicating that “JN” has excellent electrical conduc-

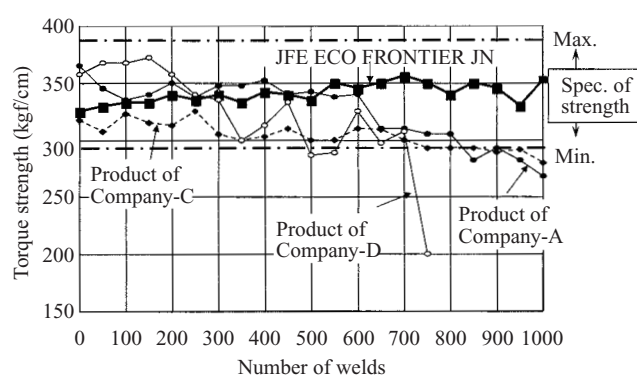










Fig.4 Weldability of various chromate-free coated steel sheets developed by each of major steel companies in Japan¹¹⁾

	Chromate-free	Chromate		
	ECO FRONTIER JN	Chromate + Thin organic coating	Dry-in-place chromate coating	Reacted-in-place chromate coating
SST 100 h				
	No white rust	No white rust	No white rust	Red rust
After alkaline degreasing* ↓ SST 72 h				
	No white rust	No white rust	No white rust	Red rust

* Nippon Parkerizing Corp. CL-N364S

Photo 1 Corrosion resistance of various coated steel sheets

tivity due to its thin film thickness. In recent OA/AV equipment, there has been a tendency to attach importance to electromagnetic wave shielding characteristics. “JN” is also suitable for applications of this type.

In addition to the above, “JN” is a multifunctional chromate-free steel sheet which also offers excellent performance in the anti-fingerprint property and paint adhesion property.

This technology was awarded the Technology Award for 2002 by the Surface Finishing Society of Japan⁷⁾. In the citation, JFE Steel received extremely high evaluations for the originality and progressiveness of the technology, based on the fact that the company “realized high corrosion resistance with a thin film and succeeded in satisfying the mutually contradictory requirements of corrosion resistance and electrical conductivity/spot weldability at a high level by development of an organic composite coating with a high barrier effect,” and for the actual results of industrialization, in that it “succeeded









in industrialization and obtained a high evaluation from the market (OA equipment makers and others).” The results achieved with this product have also received a high evaluation from economic journals¹²⁾.

3. “ECO FRONTIER” Series

In addition to internal parts of OA/AV equipment and home electrical appliances, which are mainly used unpainted, chromate-free steel sheets for electrical appliances are also used after painting, as in the outer panels of refrigerators, washing machines, and showcases, and in applications such as motor covers and oil pans for oil fan heaters, high formability is considered necessary. JFE Steel therefore developed the high barrier effect and self-healing effect of “JN” to a new line of related products called the “ECO FRONTIER” series in order to answer these wide-ranging needs with environment-friendly chromate-free steel sheets.

Table 1 shows the particular strong points and main

Table 1 JFE Steel's ECO FRONTIER series on electrogalvanized steel sheet (Chromate-free type)

Classification	Designation	Corrosion resistance (Time to occur white rust of 5% on surface area)				Characteristics	Applications
		100	200	300			
General use	JP					Paint adhesion	General painted use
	JD					Primary corrosion resistance, Press formability	Electrical apparatus use, Small motor casing use
Anti-fingerprint property	JN					Corrosion resistance, Excellent electrical conductivity and weldability	OA and AV equipment, Electrical appliances
	JF					Corrosion resistance, Anti-abrasion property	OA and AV equipment, Electrical appliances
	JS					Excellent corrosion resistance	Refrigerator, Washing machine
	JT					Excellent paint adhesion, Excellent corrosion resistance	Refrigerator, Washing machine, Showcase
Lubricity	JW					Excellent formability without oil, Corrosion resistance after forming	Cartridge tank of oil stove, Oil drain plate
Black	Z1					Black color without reflection, Absorption and irradiation property of heat	Computer, DVD, HDD, Car audio

applications of JFE Steel’s chromate-free coated steel sheet products based on electrogalvanized steel sheets (EZ). Products which JFE Steel has developed and commercialized in this series are “JD” for temporary corrosion resistance and high press-formability, “JP” for temporary corrosion resistance and general painting substrate use, “JF” for anti-fingerprint and abrasion resistance properties, “JS” for excellent corrosion resistance, “JT” for excellent paint adhesion, “JW” for excellent formability without oil coating and corrosion resistance after press-forming, and “Z1” as a black colored steel sheet. The company has also commercialized a chromate-free coated steel sheet “JC” based on hot-dip galvanized steel sheets (GZ). Thus, JFE Steel has developed a diverse range of chromate-free products with substantially the same quality as conventional chromate-treated steel sheets in order to supply customers with the optimum material for a variety of applications, including OA/AV equipment and home electrical appliances. This chapter will introduce several of these products.

3.1 “ECO FRONTIER JD”

“ECO FRONTIER JD” has corrosion resistance at the temporary corrosion resistance level and excellent press-formability (resistance to coating peeling during forming). In particular, it is suitable for press-formed parts (small motor casings, etc.). This steel sheet has the following features as a result of an original special coating.

- (1) Press-formability: Can be applied in deep drawing applications, and displays extremely little peeling of the coating during press-forming.
- (2) Corrosion resistance after forming: The corrosion resistance of deep drawn parts is superior to that of the conventional general-purpose chromate-treated steel sheet “Excel Zinc C.” The appearance of deep drawn parts after a 16-h salt spray test is shown in **Photo 2**⁹⁾.

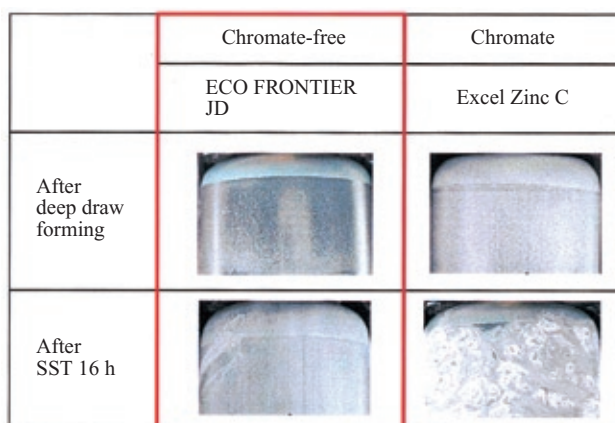


Photo 2 Appearances of ECO FRONTIER JD and usual chromate coated steel sheet after deep draw forming and after SST 16 h⁹⁾

Commercial production of “JD” began in 2003. It is used in small motor casings and products with similar requirements.

3.2 “ECO FRONTIER JT”

“ECO FRONTIER JT” was developed and commercialized in response to the need for high paint adhesion with powder paints. It has the following distinctive features, and is suitable for use in inner and outer panels of showcases and home electric appliances.

- (1) “ECO FRONTIER JT” has extremely high paint adhesion due to the use of a new organic composite coating. Application with powder paints is possible.
- (2) Because “JT” has excellent unpainted corrosion resistance, it can be applied in cases where one side of the product is painted and the other unpainted.

3.3 “ECO FRONTIER JW”

Chromate-treated high lubricity corrosion-resistant steel sheets with high formability without oil coating and corrosion resistance after forming have long been used in order to omit the degreasing processes by the customer. JFE Steel developed and commercialized a chromate-free high lubricity corrosion-resistant steel sheet which responds to this requirement for a high lubrication property.

Using a new, excellent high lubricity organic composite coating technology, “JW” offers the following features:

- (1) Press-formability without oil coating is excellent.
- (2) Corrosion resistance after forming is dramatically superior to that of general-purpose chromate-treated steel sheets, and corrosion resistance is equal to that of conventional chromate-treated lubricated corrosion-resistant steel sheets (**Photo 3**).

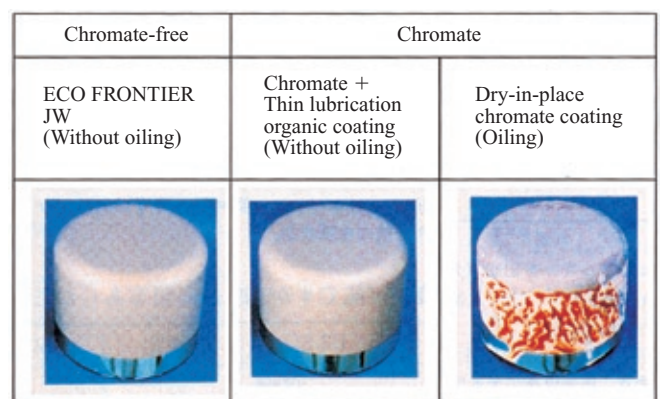


Photo 3 Corrosion resistance after forming of various coated steel sheets (SST 120 h)

4. Conclusion

As an introduction to JFE Steel’s “ECO FRONTIER” series, this report has described the film design and performance of JFE Steel’s chromate-free coated steel sheets, with particular emphasis on “JN.”

Using a new organic resin coating with a high barrier effect and inorganic inhibitors with a self-healing effect, “JN” realized high corrosion resistance with a thin film for the first time in the world, making it possible to satisfy the mutually contradictory requirements of corrosion resistance and electrical conductivity. “JN” is widely used in the internal parts of OA/AV equipment.

JFE Steel has also developed and commercialized a series of unique chromate-free products under the trade-name “ECO FRONTIER.” These include “JD” with primary corrosion resistance and formability, “JT” with excellent paint adhesion, “JW” with excellent press-formability and corrosion resistance after forming, and others.

With increasingly high interest in ecologically-compatible materials, a further expansion and popularization of chromate-free products is anticipated in the future. Because the outstanding properties of the JFE Steel’s “ECO FRONTIER” series have won a high

evaluation from customers, expanded application is expected in the future.

References

- 1) Yamashita, M. Coatings Tech. Jpn. vol. 28, 1993, p. 475.
- 2) European Union. “Directive of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment (Draft),” C5-0487, 2002, p. 7.
- 3) Yoshima, N.; Matsuzaki, A.; Yamashita, M. J. of Surface Finishing Soc. of Jpn. vol. 54, no. 5, 2003, p. 7.
- 4) Yoshimi, N.; Matsuzaki, A.; Yamashita, M. Zairyo-Kankyou. vol. 52, no. 12, 2003, p. 632.
- 5) Yoshimi, N.; Ando, S.; Matsuzaki, A.; Kubota, T.; Horisawa, T.; Okamoto, K. NKK Technical Report. no. 170, 2000, p. 29.
- 6) Yoshimi, N.; Ando, S.; Matsuzaki, A.; Kubota, T.; Yamashita, M. 5th Int. Conf. on Zinc and Zinc Alloy Coated Steel Sheet (GALVATECH’2001). Verlag Stahleisen GmbH. Dusseldorf, 2001, p. 655.
- 7) Yamashita, M.; Kubota, T.; Yoshimi, N.; Ando, S.; Matsuzaki, A.; Horisawa, T.; Okamoto, K. Proc. of 105th Conf. of Surface Finishing Soc. of Jpn. 2003, p. 461.
- 8) Yoshimi, N.; Yoshida, K.; Matsuzaki, A.; Sasaki, K.; Horisawa, T.; Kotani, K. NKK Technical Report. no. 178, 2002, p. 11.
- 9) Yamada, S.; Mitsunari, A.; Taguchi, N.; Kurosawa, M.; Ogawa, T. Hatano, H. JFE Giho. no. 2, 2003, p. 17.
- 10) Yoshimi, N.; Matsuzaki, A.; Ando, S.; Kubota, T.; Yamashita, M. Tetsu-to-Hagané. vol. 89, no. 1, 2002, p. 29.
- 11) Nikkei Mechanical. no. 551, 2000-08, p. 33.
- 12) Nikkei Business. 2002-05-13, p. 56.