*Technical Report*

# Development of Chromate-free Treatment QC for Hot Dip Galvanized Steel Sheet

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## Abstract

***Nippon Steel Corporation developed a new chromate-free treatment "QC" for hot dip galvanized steel sheet (HDG). The HDG that is processed with "QC" has the same performance of corrosion resistance, lubricity, electro-conductivity, paint adhesion, and weldability (optimum spot welding current range) as conventional chromate-treated products. This new environmentally-conscious treated HDG can be used as substitute for conventional chromate HDG.***

## 1. Introduction

Various laws and regulations to restrict the use of compounds containing hexavalent Cr, which adversely affects the environment and the human body, have been enacted, and as a result, chemical conversion coating with film not containing compounds of hexavalent Cr (chromate-free treatment) is becoming the standard for the surface treatment of galvanized steel sheets. In the Japanese Industrial Standards (JIS), the references to chromate conversion coating have been deleted from the standard JIS G 3313 for electrogalvanized steel sheets, and the same is expected to take place with the standard JIS G 3302 for hot-dip galvanized steel sheets, which are widely used for building construction.

Under these circumstances, Nippon Steel Corporation has developed various chemical conversion coating films free of chromate for different plated steel sheets, and launched many types of sheet products with such treatment films onto the market.[1–3] This paper describes a new chromate-free chemical conversion film for hot-dip galvanized steel sheets in comparison with the conventional type containing chromate.

## 2. Coating Structure with Chromate-free Film

The developed new chromate-free treatment film, QC, is a special coating film for two types of hot-dip galvanized steel sheets, NS Silver Zinc™ and PAINTITE™ B. **Figure 1** schematically shows the coating structure. The chromate-free layer has a barrier function against corrosion factors and a self-repairing function. With the conventional chromate conversion film, hexavalent Cr compounds exerted both these functions, but the developed film is designed so as to obtain both the two functions by combining different elements other than Cr.

## 3. Test Methods

**Table 1** shows the specifications of the steel sheets used for the tests described below. The test pieces were prepared by applying the chromate free QC film to the substrates of NS Silver Zinc™, hot-dip galvanized steel sheets with a zinc coating weight of 90 g/m$^2$. Other sheets of NS Silver Zinc™ that underwent conventional chromate conversion treatment (Cr coating weight 10 mg/m$^2$, hereinafter referred to as the C treatment) were used as comparative test pieces.

### 3.1 Corrosion resistance

Flat test pieces were subjected to the salt spray test in accor-

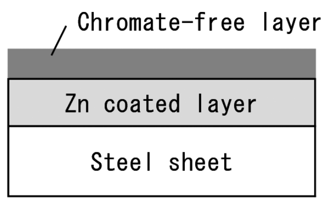


**Fig. 1 Structure of chromate-free hot dip galvanized steel sheet**

**Table 1 Test pieces**

| Substrate | Kind of treatment |
|---|---|
| Hot dip galvanized steel sheet (amount of plated layer: 90 g/m$^2$) | Chromate-free: QC |
| | Chromate: C |

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dance with JIS Z 2371, and white rust resistance was evaluated based on the area ratio of white rust. The edges of the test pieces were sealed.

Other test pieces were subjected to bulging work using an Erichsen cupping testing machine and then the same salt spray test as above, and the white rust resistance was evaluated based on the area ratio of white rust in the formed portion.

### 3.2 Lubricity

The dynamic friction coefficient was measured as an index of press formability. A friction tester (HEIDON-14 made by Shinto Scientific Co., Ltd.) was used for the measurement, and the coefficient was calculated from the stress of sliding a stainless steel ball 10 mm in diameter on the specimen surface at a speed of 150 mm/min under a load of 1.0 N.

In addition to the above, to evaluate the sliding behavior of the test pieces on the blank holding surfaces of press forming dies, the coefficient of dynamic friction was measured by the flat draw bead test as schematically shown in **Fig. 2**: a flat test piece, pressed between flat dies of JIS SKD11, each having a contact area of 30×25 mm, at a load of 0.5 kN, was pulled out, and the coefficient was calculated from the load of pulling it out at a speed of 200 mm/min.

### 3.3 Electrical conductivity

The interlaminar resistance and conduction ratio were measured as the indexes of electrical conductivity. The former was measured at a test voltage of 0.5 V and under a load of 2 $N/mm^2$ in accordance with JIS C 2550. To define the latter, the contact resistance of each specimen was measured 20 times by the four-point probe method using a resistivity meter (Loresta GP made by Nittoseiko Analytech Co., Ltd.), and the ratio of the number of cases in which electrical conduction was confirmed as 20 was regarded as the conduction ratio.

### 3.4 Paint adhesion

Melamine alkyd resin paint (Amilac 1 000 made by Kansai Paint Co., Ltd.) was applied to the surfaces of the test pieces so that the dry film thickness would be 20 $\mu$m, and then baked. The cross cut test of the paint coating was conducted by cutting the paint film in grids of 1 mm intervals, peeling it off with an adhesive tape, and visually observing the state of the paint film.

### 3.5 Spot weldability

Test pieces were spot welded using a single-phase AC spot welder with cone flat type electrodes of 1% Cr-Cu alloy 4.5 mm in tip diameter. The optimum welding current range was defined as between the lowest current at which the nugget diameter was $4\sqrt{t}$ (t being the sheet thickness in mm) or more (lower limit) and the highest current at which expulsion did not occur (upper limit).

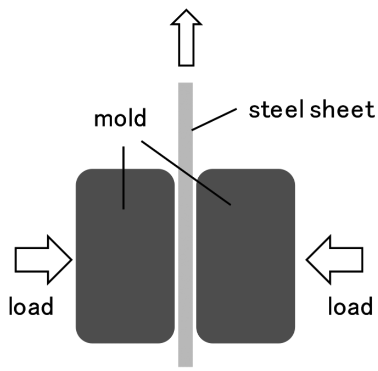



**Fig. 2 Schematic image of flat drawing test**

## 4. Test Results

### 4.1 Corrosion resistance

**Figure 3** shows the white rust ratios in the salt spray test of the flat test pieces, and **Fig. 4** the same of the bulged test pieces. The corrosion resistance of the specimens coated with the QC film was superior to that of the test pieces of the C treatment.

### 4.2 Lubricity

**Figures 5** and **6** show the dynamic friction coefficient measured by the sliding test using the stainless steel ball and that by the flat draw bead test, respectively. The dynamic friction coefficient of the specimens coated with the QC film was the same as that of the test pieces of the C treatment, which confirms the fact that the developed film has the same lubricity as that of the conventional film.

### 4.3 Electrical conductivity

**Figure 7** shows the interlaminar resistance, and **Fig. 8** the conduction ratio measured by using the resistivity meter. The specimens coated with the QC film demonstrated substantially the same interlaminar resistance and conduction ratio as those of the test pieces of the C treatment, which indicates that there was no difference in electrical conductivity between the two types of treatment films.

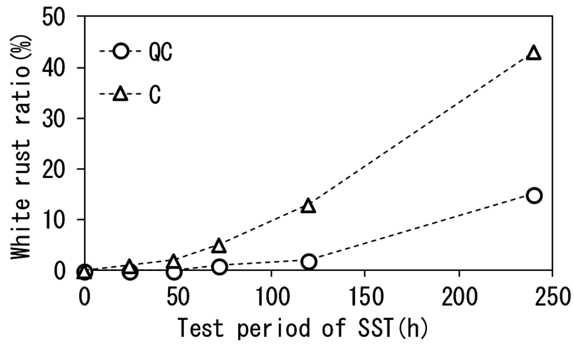



**Fig. 3 Corrosion resistance of flat test specimen in salt spray test (SST)**

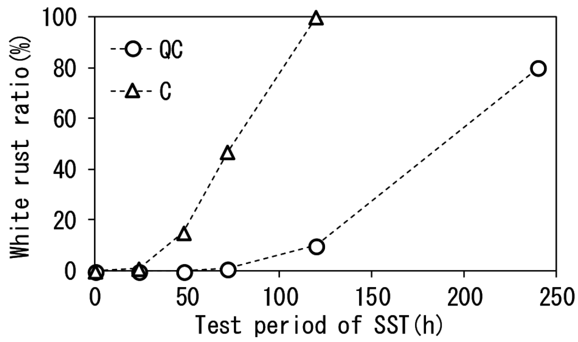



**Fig. 4 Corrosion resistance of bulging test specimen in salt spray test (SST)**

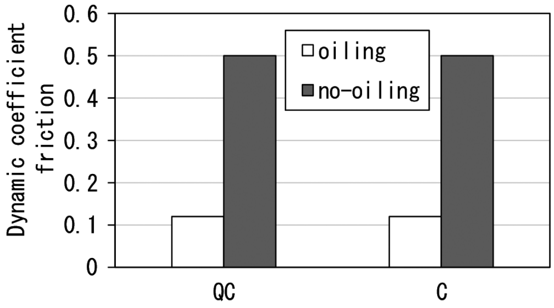



**Fig. 5 Dynamic coefficient friction in stainless steel ball sliding test**

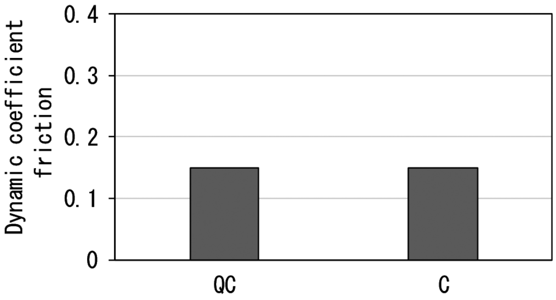



**Fig. 6 Dynamic coefficient friction in flat drawing test**

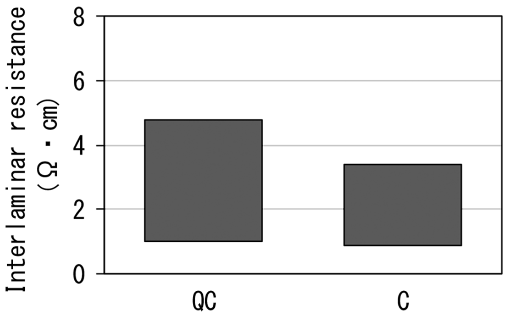



**Fig. 7 Interlaminar resistance**

### 4.4 Paint adhesion

**Table 2** shows the results of the cross cut test. The paint adhesion of the specimens with the QC film was the same as that of the comparative specimens.

### 4.5 Spot weldability

**Figure 9** shows the optimum current range for spot welding. The optimum welding current range of the specimens with the QC film was equal to or higher than that of the comparative specimens.

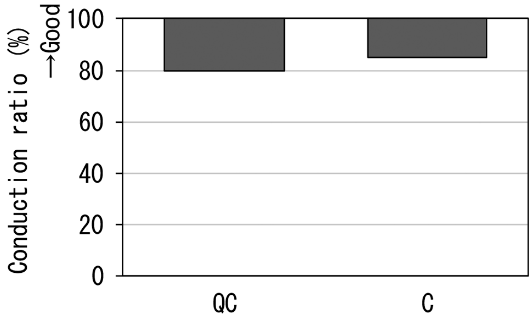



**Fig. 8 Result of conduction ratio by LORESTA**

**Table 2 Results of finishing paint adhesion**

| Kind of treatment | Result |
|---|---|
| QC | Excellent |
| C | Excellent |

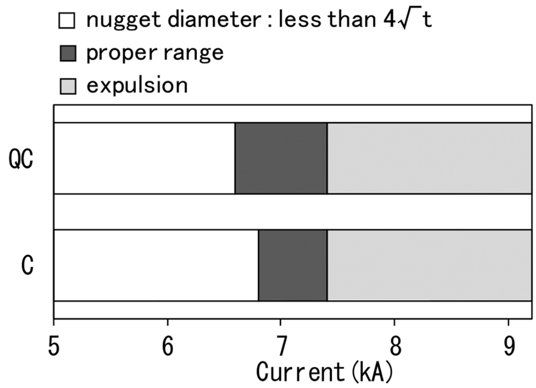


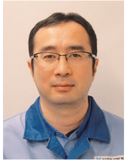

**Fig. 9 Optimum spot welding current range**

## 5. Conclusion

The developed QC coating film exhibits the same corrosion resistance, lubricity, electrical conductivity, paint adhesion and spot weldability as those of the conventional conversion film containing chromate. This therefore confirms that hot-dip galvanized steel sheets coated with the QC film can replace those coated with conventional chromate conversion film.

**References**

1) Morishita, A. et al.: Shinnittetsu Giho. (377), 28 (2002)
2) Kubo, Y. et al.: Shinnittetsu Giho. (391), 48 (2011)
3) Fuda, M. et al.: Shinnittetsu Sumikin Giho. (398), 57 (2014)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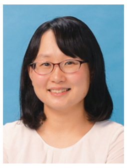
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