DEVELOPMENT OF THE ECO-FRIENDLY NON-CHROMATE LUBRICATING COATING ON THE GALVANIZED STEEL SHEET

BY

JUNG-HSIUNG SHEN*, HUNG-PING WANG*

SYNOPSIS:

In view of the global trend of environment protection and in order to satisfy customer needs, China Steel Corporation (CSC) is committed to developing eco-friendly non-chromate lubricating coating “UL” (U: Universal; L: Lubrication) which is applied to the galvanized steel sheet for applications such as electrical appliances, sliding rails, vending machines, etc. The UL coated galvanized steel sheet as presented here conforms to the requirements of the WEEE and RoHS directives. The UL coating not only meets the quality requirements of customers but also elevates the lubrication ability. The result shows that the coefficient of friction (COF) of the UL coating sustains at the level of 0.08~0.11 even after a hundred times of sliding test which is superior to other coatings. The UL coating also possesses better as-painted adhesion than the commercial chromate coating. The unique performance of the UL coating produces much product differentiation and makes it a niche product which meet customer’s needs.

Keywords: Hot-dip galvanized steel sheet, Non-chromate, Coefficient of friction

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1. Introduction

There are wide applications of hot-dip galvanized (GI) steel sheet in home appliances, automobile field, and metal-processing industry. The Zn layer provides both the barrier protection and the sacrificial protection. To further protect the zinc-coated steel sheet against corrosion, hexavalent chromium (Cr\textsuperscript{6+}) coating on the Zn layer was employed. However, the use of Cr\textsuperscript{6+} is restricted recently in the law of the WEEE and RoHS directives\textsuperscript{[1]} due to its high toxicity, signifying an urgent necessity to develop non-chromated treatments.

If the GI steel sheet was destined for further processing by forming such as deep-drawing, the lubricants used can contain, in addition to corrosion-inhibiting substances, other ancillary substances, especially matched to the individual forming process, which improve the tribological properties of the sheet during forming process.

In order to achieve international trend and satisfy market needs, China Steel Corporation (CSC) has developed the eco-friendly non-chromate lubricating coating “UL” (U: Universal; L: Lubricating coating).

2. Evaluation of non-chromated UL product

The solution of the UL was composed of film forming agent, chelating agent, and corrosion inhibitor. The film forming agent was made of the organic resin. The chelating agent is useful for increasing the compatibility during film forming. The corrosion inhibitor is combination of the metallic complex and the organic chelating agent showing self-healing capability to restore the corrosion of the coating \textsuperscript{[1]}.

The coating products, UL, commercial non-chromated passivated coating (NC), anti-finger print coating (AFP), and chromated coating (Cr), coated on the galvanized steel sheet was conducted by roll-coating, is a process of applying a protective coating by passing the sheet substrate through a pair of rollers. Industrial steel coil rolling process generally employs a baking process to facilitate the formation of the coating. The baking parameters and the concentration of the various ions in the liquid film on the steel coil were adjusted to produce an acceptable quality level.

The performances of coatings are evaluated as followed:

(1)\textbf{Corrosion resistance}: The white-rust occurrence area is measured less than 5% after 72hrs salt spray testing. (Test method is according to ASTM-B117)

(2)\textbf{Yellow tarnish resistance}: The color difference (ΔE) and the yellow-blue chroma (Δb) are measured after baking at 220 °C for 15 min. Both ΔE and Δb should be less than 3.
(3) **Painting adhesive ability**: The remainder of peeled area was calculated after Erichsen extrusion test and the cross-cut test. All coatings should be remained on the GI sample.

(4) **Conductivity**: The resistivity was measured less than 0.1 Ω by Loresta – EP Low Resistivity Meter.

(5) **Lubricity**: The coefficient of friction (COF) was measured less than 0.15 by Bowden test.

3. **Results and Discussion**

3.1 **Determination of hexavalent chromium (Cr⁶⁺)**

All samples are measured according to the IEC-62321. There is no hexavalent chromium detected in UL samples[^2].

3.2 **Corrosion resistance**

Fig. 1 shows the surface of UL product after a salt spray test for 72 and 144 hours. As a result, there is a bit of corrosion on the UL samples, and the rate of the white-rust occurrence area is still less than 5% (Fig. 1).

![Figure 1. The surface of the UL product after a salt spray test for 72 and 144 hours.](image)

3.3 **Yellow tarnish resistance**

For yellow tarnish resistance, all the samples are baked at 200°C for 15 min. The appearance of heated UL sample displays no change (both ΔE and Δb are less than 3) as shown in Fig. 2. It is suggested the yellow chromatism can be prevented. The yellow tarnish of the UL sample is equivalent to the NC, AFP and the Chromated samples. The result of yellow tarnish is presented in Table 1.
Figure 2. The picture of the UL product on the GI steel sheet after baking at 220°C for 15 min.

Table 1. Various coatings on the GI steel sheet are baked at 220°C for 15min.

<table>
<thead>
<tr>
<th>Evaluation of yellow tarnish resistance</th>
<th>Results(ΔE/Δb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL sample</td>
<td>(0.80/0.39)</td>
</tr>
<tr>
<td>NC sample</td>
<td>(0.73/0.69)</td>
</tr>
<tr>
<td>AFP sample</td>
<td>(1.37/1.19)</td>
</tr>
<tr>
<td>Chromated sample</td>
<td>(1.71/1.36)</td>
</tr>
</tbody>
</table>

### 3.4 Painting adhesive ability

The painting ability was evaluated by Erichsen extrusion test according to ASTM D3359 method and the cross-cut test. Both the UL and Chromated samples are painted by the acrylic resin and the alkyd resin. The Chromated sample was peeled off after impact but well adhesion for the UL sample as shown in Fig. 3.

Figure 3. The picture of (a) the UL and (b) the Chromated coated on the GI steel sheet after Erichsen extrusion plus cross-cut test.

### 3.5 Conductivity

Conductivity of each sample was measured by Loresta – EP Low Resistivity Meter. Measurement was performed at five positions of the sample. The resistivity of at least three positions should be less than 0.1 Ω which was defined as a rate of conductivity.
development. The present UL sample was conductive as well as NC, AFP and Chromated samples listed in Table 2.

Table 2. Resultant conductivity of UL, NC, and Cr samples

<table>
<thead>
<tr>
<th>Evaluation of conductivity</th>
<th>UL sample</th>
<th>NC sample</th>
<th>AFP sample</th>
<th>Chromated sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conformity</td>
<td>Conformity</td>
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Conformity

<table>
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<th>The resistivity is less than 0.1 Ω</th>
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3.6 **Lubricity**

For evaluating the lubricity, the sliding testing was applied in the present work. Fig. 4 shows the coefficient of friction (COF) of the UL, NC, and AFP samples versus the sliding times. The UL sample expressed excellent lubricity since the COF was kept to 0.08~0.11 after 100 times of sliding. In comparison, the COF of the AFP sample and the NC sample increased to 0.2 and 0.4 after 40 times of sliding, respectively.

![Figure 4. The COF of the UL, NC, and AFP samples versus sliding times.](image)

3.7 **Comprehensive comparison of the UL coating**

Hot-dip galvanized steel sheet surfaces coated with the UL, NC, AFP and Chromate have been characterized and evaluated in terms of corrosion resistance, yellow tarnish resistance, painting adhesive ability, conductivity, and lubricity shown in Table 3. The present work revealed as followed:

(1) The painting adhesive ability of UL sample is better than Chromated sample.

(2) The lubricity of UL sample is superior to both NC and AFP samples.

Table 3. Evaluation results of various kinds of coating samples.
For conforming to international environmental regulations, CSC has successfully developed the eco-friendly non-chromate lubricating coating product. The present UL product development relates to a hot-dip galvanized steel sheet having a coating formed thereon which exhibits a superior coating performance as well as the NC. Since the overseas sale of hot-dip galvanized steel sheet continues to expand, markets demands of such products are growing. The profit products can lead in the niche product effectively and look forward to design the right one in keeping with customer requests in the future.

4. Summary

(1) CSC has successfully developed the eco-friendly non-chromate lubricating coating (UL) for hot-dip galvanized steel sheet having a uniform surface appearance, good at corrosion resistance, yellow tarnish resistance, paint adhesive ability, conductivity, and lubricity.

(2) The painting adhesive ability of the UL is better than the chromated coating. Moreover, the excellent lubricity of UL product was developed in the present work. It not only can reduce the costs of outsourcing coating agent but also establish the core technology of domestic non-chromate lubricating coating.

(3) The superior lubricity of the UL, the COF is less than 0.1 after 100 times of sliding test, is nowadays beneficial to home appliances such as sliders, deep drawing motor shells, and the supported plate of the vending machine.

(4) The UL product's launch has performed in cooperation with downstream customers and look forward to design more niche products in keeping with customer requests in the future.

5. References
