Estimating the Life of Galvanized Coatings on Steel Sheet

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Flat, horizontal coupons of galvanized steel sheet exposed to outdoor atmospheres corrode faster on the top surfaces than on the bottom surfaces. The coating fails first on the top side, and the time to first rust is determined by the upper rate. Most corrosion rates reported in the literature are calculated from the total loss on both surfaces. The resulting corrosion rates are an average of top and bottom rates. Use of the average rate to calculate coating life leads to overestimates of 20 to 80%. Thus, estimates of galvanized coating life based on flat coupon corrosion rates should be reduced accordingly.

Zinc coatings are widely used to protect steel from rusting. They can be applied by a variety of methods, such as electroplating, thermal spray, cementation, and most commonly, by the hot-dip process. Hot-dip zinc coatings, commonly referred to as galvanized, have the following attributes:

- Protect coated steel by the barrier mechanism; that is, isolate it from the environment.
- Provide sacrificial protection to steel exposed at pores, scratches, and cut edges by galvanic action.
- Corrode at a much slower rate than steel in outdoor environments.
- Exhibit a corrosion rate that is roughly linear with time.
- Have a life that is roughly proportional to coating thickness.

The relationship between coating life and coating thickness for a variety of environments is commonly displayed in a chart such as Figure 1. This chart is a summary of actual observed times to 5% rust in long-term tests of galvanized steel with various coating thicknesses exposed to a variety of environments. This well-known chart is often used to estimate the life of galvanized coatings in the atmosphere. One drawback to this approach is that the environmental classifications shown in Figure 1 are quite broad and not well-defined. Thus, the chart may not be precise enough for anything more than a preliminary estimate for a particular location.

In an effort to improve the reliability of life predictions for zinc-coated steel, Zhang developed software to estimate the corrosion rate of zinc coatings. This software employs statistical methodology, neural network technology, and a large international collection of corrosion and environmental data. The input data required to calculate the corrosion rate at a given location include temperature, airborne salinity, sulfur dioxide (SO2) concentration, relative humidity, rainfall, and degree of sheltering. Because of the specific nature of the input, the issue of a poorly defined environment is largely overcome, and corrosion rates can be more accurately predicted. The software also calculates the life of the zinc coating from the calculated corrosion rate and the thickness of the coating. Coating lives derived from this software are plotted in Figure 2.

In comparing Figures 1 and 2, it becomes apparent that coating durability predicted by the Zhang software (Figure 2) is significantly greater than that indicated by the data in Figure 1. While some of this disparity may be explained in terms of environmental differences, most
of it can be attributed to the fact that flat galvanized coupons corrode faster on the upward, skyward-facing (top) surface than on the lower, groundward-facing (bottom) surface. The corrosion-rate database used for the Zhang software was obtained by conventional methods in which coupons are weighed, exposed for a given time, then cleaned and reweighed to give a total corrosion loss for top and bottom surfaces. This procedure leads to an averaging of the top and bottom corrosion losses.

Studies have been reported in which the corrosion of skyward and groundward faces of flat galvanized steel panels were measured separately.5-7 The results of those studies are typified by Figure 3, which shows that the corrosion rates are significantly higher on the skyward surface. The washing away of protective corrosion products by rainfall on the skyward surfaces is believed to cause this. It follows that time to rusting is determined by the skyward rates. It also follows that the time to rust is less than what would be predicted from an average of skyward and groundward rates.

As shown in Table 1, the use of average top and bottom corrosion rates leads to a 20 to 80% overestimate of the time to rust. Thus, estimates of coating life from two-side coupon average corrosion rates should be reduced accordingly. Doing so would account for most of the differences between coating life shown in Figure 1 (which is based on time to observed rusting), and that given in Figure 2 (which is estimated from average two-side corrosion rates). Remaining differences may be caused by differences in the definitions of the environment classifications.

It is also noted that Dean reported that corrosion rates of zinc wire helices are roughly 67% higher than those of two-side flat coupons.8 This phenomenon may also be the consequence of reduced corrosion on the sheltered, groundward faces of the flat coupons, whereas the wire helices have no such sheltered areas.
TABLE 1
CALCULATED AND ACTUAL YEARS TO FIRST RUST FOR 25-µm-THICK GALVANIZED COATINGS9-10

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Average Corrosion Rate$\text{ (Average of Top and Bottom Faces)}$ (µm/y)</th>
<th>Calculated Time to Rust (y) (Calculated from Average Rate)</th>
<th>Actual Time to Rust$^\text{10}$ (y)</th>
<th>Ratio, Calculated/Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-m lot</td>
<td>3.8</td>
<td>7</td>
<td>4</td>
<td>1.8</td>
</tr>
<tr>
<td>Kure Beach, NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe marine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250-m lot</td>
<td>1.4</td>
<td>19</td>
<td>16</td>
<td>1.2</td>
</tr>
<tr>
<td>Kure Beach, NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate marine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saylorsburg, PA</td>
<td>1.1</td>
<td>23</td>
<td>14</td>
<td>1.6</td>
</tr>
<tr>
<td>Rural</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bethlehem, PA</td>
<td>1.9</td>
<td>14</td>
<td>10</td>
<td>1.4</td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Corrosion losses on flat coupons of galvanized steel in the industrial environment of Bethlehem, PA.7 The coupons were exposed at 30 degrees to the horizontal. Groundward and skyward losses were measured separately. Both-side losses are the average losses per side as determined with conventional two-sided coupons.

References

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