Enhancement of Strength and Corrosion Resistance by Nitrogen Addition in Austenitic Stainless Steel*

I. Introduction

Stainless steel plates or clad steel plates of SUS304L and 316L have been widely used in tanks for chemical carriers. In recent years, these applications necessitate a higher level of strength and corrosion resistance to reduce quantities of material used and to facilitate welding. Nitrogen containing stainless steel plates such as SUS304LN and 316LN have the advantage of high strength as structural materials, but are not always satisfactory in corrosion resistance to the wet process phosphoric acids (WPA), a typical cargo in chemical carriers.

As an important improvements, Nippon Kokan (NKK) has developed a new austenitic stainless steel, NSL317LN, containing a larger amount of N and Mo than SUS316L and 316LN for expanded uses in multi-purpose chemical carriers and vessels in pulp and paper industry.

II. High Nitrogen Austenitic Stainless Steel—NSL317LN—

Strength and corrosion resistance improves remarkably with N addition in austenitic stainless steels. Plates of SUS317L with various N contents were prepared and solution treated at 1 050°C. As shown in Fig. 1, the yield (0.2 % PS) and the tensile (TS) strength raise at an increment of 9.4 and 11 kgf/mm² per 0.1 % N; about 0.15 % N addition brings 30 kgf/mm² of 0.2 % PS. High N contents also reduce the susceptibility to sensitization; SUS317L of 0.15 N is resistant to intergranular corrosion in oxalic acid etch tests (JIS G0571) after long aging at 650°C. Figure 2 shows improvements of pitting corrosion resistance with nitrogen addition up to 0.15 % in the test (JIS G0578) by immersion in FeCl₃ solution at 50°C for 24 h.

III. Production and Performance of NSL317LN Plates

Chemical composition and processing of NSL317LN were optimized for hot workability and product performance. Hot rolling and solution annealing was processed to be the products of 10 to 30-mm thick plates at Fukuyama Works. Chemical compositions, mechanical properties and corrosion test results of the products are compared with those of SUS316L and 317L in Table 1; NSL317LN has 0.2 % PS of 34 kgf/mm² and TS of 63 kgf/mm², both 5 kgf/mm² higher than SUS316L and 317L. The new products show good corrosion resistance in both intergranular and pitting corrosion tests. In particular, the pitting corrosion resistance is excellent because of a larger N and Mo content in NSL317LN. Figure 3 compares corrosion resistance of various alloys immersed in industrial WPAs containing 0.002 or 0.032 % Cl⁻. In the WPA of higher chloride content, Mo free high Cr alloys such as SUS309S and 310S corrode at a higher rate than 1 g/m²·h, while the alloys containing Cr over 18 % and Mo over 2 %, like NSL317LN, Alloy 904, and Alloy 20, have good corrosion resistance with a corrosion rate less than 0.1 g/m²·h.

In summary NSL317LN containing 18 % Cr, 3.5 % Mo and 0.15 % N is characterized by a good combination of high strength and excellent corrosion resistance in WPA and other aggressive environments.

Fig. 1. Effect of nitrogen content on 0.2 % proof strength and ultimate tensile strength.

Fig. 2. Effect of nitrogen content on pitting corrosion rate. (10%FeCl₃, 6H₂O+1/20N HCl, 50°C, 24 h)

Fig. 3. Effect of Cr and Mo contents on corrosion resistance of alloys in industrial WPA at 50°C.

Table 1. Chemical compositions, mechanical properties and corrosion resistance of SUS 316L, 317L, and NSL 317L.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chemical compositions (wt%)</th>
<th>Mechanical properties (kgf/mm²)</th>
<th>Intergranular corrosion JIS G 0572 (g/m²·h)</th>
<th>Critical pitting temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ni Cr Mo N</td>
<td>0.2%PS TS</td>
<td></td>
<td></td>
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<tr>
<td>NSL317LN</td>
<td>13.2 18.5 3.7 0.13</td>
<td>33.7 62.7</td>
<td>0.37</td>
<td>35</td>
</tr>
<tr>
<td>SUS316L</td>
<td>13.5 16.5 2.2 0.06</td>
<td>27.4 56.5</td>
<td>0.57</td>
<td>15</td>
</tr>
<tr>
<td>SUS317L</td>
<td>14.1 18.2 3.1 0.09</td>
<td>28.9 57.2</td>
<td>0.33</td>
<td>25</td>
</tr>
</tbody>
</table>

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