When properly prepared, the refurbished roll functions better than the original roll.

Dennis W. Hetzner*
The Timken Company
Canton, Ohio

Typically, roll repair consists of rebuilding the bodies of the rolls by the submerged arc welding process (SAW). Although new rolls are frequently made from medium-carbon alloy steel or low-carbon steel, the repair process is not limited to this narrow range of materials. By applying proper welding procedures, martensitic stainless steel alloys such as 420 or 423 can be clad onto rolls subjected to moderate wear or moderately elevated temperature applications. In environments that generate higher temperatures or abrasive wear, hot-worked steels such as H11 and a modified hot-worked steel having a high niobium content function quite well. Quite often, the refurbished roll functions better than the original roll. This article describes the submerged arc welding roll repair process and presents the metallurgical reasons for the improved performance.

Submerged arc welding
In the SAW process, the arc and molten metal are shielded by flux that is added in the form of granular powder. As the arc is struck, the tip of the continuously fed metal wire melts and forms a liquid pool. The powder near the arc and molten metal melts to provide excellent shielding of the weld bead. Because the molten metal and the arc are covered by the liquid and powder flux, they are not visible (Fig. 1). The two vertical tubes in the upper part of the photograph are the flux tube and the welding-wire feed head. The granular powder on the upper portion of the roll is the flux. In this photo, the roll is rotating from the top to the bottom; the bright clad in the center of the roll is weld metal that has just been applied. To assure the integrity of the welds, the entire roll repair process is automated and microprocessor-controlled. By carefully controlling the preheating temperatures, interpass temperatures, and post welding tempering cycles, optimum metallurgical properties of the welds can be achieved. The result of the cladding process is a bimetallic roll (Fig. 2).

Cladding alloys
Currently, the clads applied to rolls belong to two major categories.

The first group of alloys is based on the 12% chromium stainless steels. They are Mill Clad 3, similar to 423 stainless steel; and Mill Clad 8, very similar to 420 stainless steel. These martensitic stainless clads have good resistance to wear,
thermal fatigue cracking, and corrosion.

The second group of alloys is based on tool and die steel compositions. Mill Clad 17 is similar in composition to H11 die steel. Mill Clad 17 has excellent resistance to heat checking and thermal fatigue while maintaining high hardness at elevated temperatures. The composition of Mill Clad 4 is similar to a 5% chromium die steel; however, this alloy contains approximately 3.5% niobium and 0.65% carbon (Table 1).

The alloy displays excellent hot hardness and resistance to thermal fatigue, and the numerous small niobium carbides in the microstructure provide excellent wear resistance. Because of the high alloy content of these welds, proper preheat and interpass temperatures are very important. The preheat temperature is generally 325°C (620°F) or higher. Some typical applications for these cladding alloys are contained in Table 2.

- **Mill Clad 3 & 8.** Compositively, these clads are based on the 400 series martensitic stainless steel alloys, Table 1. Because these alloys contain molybdenum, vanadium, and a significant amount of chromium, they demonstrate the secondary hardening phenomena. For example, after welding and cooling to room temperature, tempering at intermediate temperatures causes the hardness of the steel to increase (Fig. 3). This secondary hardening is the result of two factors. First, the transformation of retained austenite to martensite, and second, the precipitation of small complex M2C6 types of carbides. For these alloys, the M portion of the carbides is composed of Cr, Mo, V, and Fe. This tempering response is different from conventional steel, which continuously softens as the tempering temperature is increased.

In the as-welded condition, the microstructure of these clads consists of a fine martensitic cellular dendritic network (Fig. 4). Mill clad 3 contains approximately 6.3% retained austenite, and Mill Clad 8 contains approximately 29.9% retained austenite, as measured by X-ray diffraction. When these types of alloys are etched with electrolytic NaOH, the presence of delta ferrite is clearly observed. After tempering the clad for two hours at 500°C or higher, the austenite within the cells has transformed to tempered martensite.

Because of the relatively rapid solidification experienced in welding, both Mill Clad 3 and Mill Clad 8 can contain several non-equilibrium phases in their microstructures. The chromium, and nickel equivalents can be calculated from the Welding Research Council Schaeffler diagram.

\[
\begin{align*}
C_{\text{req}} &= 5\text{Cr} + 1.5\times\%\text{Si} + \%\text{Mo} + 0.5\times\%\text{Nb} \\
N_{\text{eq}} &= \%\text{Ni} + 30\times\%\text{C} + 0.5\times\%\text{Mn}
\end{align*}
\]

Based on the Schaeffler diagram, and the calculated chromium and nickel equivalents, both alloys should contain martensite, austenite, and delta ferrite in the as-welded condition.

Another important property of these alloys is their resistance to loss of hardness at elevated temperatures. To measure this property, both clads were tested for hot hardness, as shown in Fig. 5.

In both instances, hardness decreased gradually as the temperature rose to approximately 500°C (930°F). Then hardness decreased more rapidly as the temperature was increased.

---

**Table 1 — Nominal compositions of clad metals**

<table>
<thead>
<tr>
<th>Welding alloy</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>V</th>
<th>Nb (Cb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC 3</td>
<td>0.12</td>
<td>1.10</td>
<td>0.40</td>
<td>12.7</td>
<td>1.4</td>
<td>2.8</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>MC 8</td>
<td>0.27</td>
<td>1.30</td>
<td>0.40</td>
<td>13.0</td>
<td>1.75</td>
<td>0.60</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>MC 4</td>
<td>0.65</td>
<td>1.20</td>
<td>1.00</td>
<td>5.3</td>
<td>1.0</td>
<td>—</td>
<td>—</td>
<td>3.50</td>
</tr>
<tr>
<td>MC 17</td>
<td>0.30</td>
<td>1.00</td>
<td>0.60</td>
<td>5.3</td>
<td>3.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Table 2 — Typical applications for various claddings**

<table>
<thead>
<tr>
<th>Clad</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC 3</td>
<td>Caster rolls, hot strip mill table rolls, plate mill furnace table rolls</td>
</tr>
<tr>
<td>MC 4</td>
<td>Hot strip mill looper and side guide rolls, cold mill pickle rolls, long product straighter rolls</td>
</tr>
<tr>
<td>MC 8</td>
<td>Caster rolls, hot strip transfer table rolls, roughing mill stand rolls, vertical edge rolls, finishing rolls, plate mill rolls</td>
</tr>
<tr>
<td>MC 17</td>
<td>Hot strip looper rolls, coiler rolls, pickle line rolls, long product straighter rolls</td>
</tr>
</tbody>
</table>

---

**Fig. 3 — The temper response of Mill Clad 3 and Mill Clad 8.**

**Fig. 4 — Typical microstructures of Mill Clad 3, stain- less steel 423. It is etched with modified potassium metabisulfite, and tempered two hours at 500°C (930°F).**
Mill Clad 17 and 4. Because both of these alloys have a relatively high chromium content and contain Mo and V, they display a secondary hardening phenomena similar to that of the 400 series stainless steel clads, Fig. 6.

In the as-welded condition, Mill Clad 17 has a cellular bainitic microstructure containing numerous small, well-distributed carbides and some retained austenite, Fig. 7. After tempering, the retained austenite content of the clad is nil.

Mill Clad 4 is similar in composition to the 5% chromium hot-work steels. However, the clad contains 0.65% carbon and 3.50% niobium (columbium). In the as-welded condition, the microstructure of Mill Clad 4 is cellular. The matrix of the clads is primarily martensitic; within the solidification cells are numerous NbC particles, Fig. 8. The niobium carbide particles form at temperatures in excess of 1300°C (2370°F) and are very stable.

The hot hardness characteristics of Mill Clad 4 and 17 are excellent, Fig. 9. For temperatures up to 500°C (930°F), hardness decreases only slightly.

New mill rolls.

Generally, new mill rolls are fabricated from forged alloy steels such as 4140 or 4340. Alloy steels have relatively poor hot hardness, Fig. 9. Upon exposure to temperatures exceeding 200°C (400°F), fully hardened 4340 steel begins to lose hardness. After exposure to temperatures of 500°C (930°F), 4340 is relatively soft. New forged alloy steel rolls are hardened and tempered to 28-32 HRC. The primary reasons for having this hardness level is for good fracture resistance and easy machinability of the rolls. If the new rolls were harder, exposure to even moderately high temperatures would soften them.

As discussed in this article, the four clads commonly used for roll repair have excellent hot hardness characteristics. In conjunction with better wear properties or corrosion resistance, this results in repaired rolls that are superior to the original alloy steel rolls. Cladding new rolls is another alternative processing path that could create rolls having enhanced performance when compared with alloy steel rolls.

For more information: Dennis W. Hetzner, The Timken Company, Box 6930, Canton, OH 44706; tel: 330/471-2150; fax: 330/471-2282; e-mail: dennis.hetzner@timken.com; Website: www.Timken.com.