COMPOSITE CHILL CAST IRON ROLLING MILL ROLLS HAVING INCREASED RESISTANCE TO THE SPALLING

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ABSTRACT OF THE DISCLOSURE

A composite chill cast iron roll in which the chill area has a composition of about 3.20% to about 3.40% carbon, about 0.55% to about 0.65% manganese, about 1.45% to about 1.65% silicon, about 4.00% to about 4.40% nickel, about 0.90% to about 1.10% chromium, about 0.50% to about 0.70% molybdenum and about 0.03% to about 0.08% magnesium, about 0.07% phosphorus, about 0.02% sulfur, the remainder iron and incidental impurities and the core is a low alloy cast iron composition of about 3.40% to about 3.50% carbon, about 0.50% to about 0.60% manganese, about 1.25% to about 1.35% silicon, about 0.30% to about 0.50% chromium, about 0.75% to about 1.25% nickel, about 0.15% phosphorus, about 0.10% sulfur, the remainder iron and incidental impurities.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The composite chill cast iron working rolls of the invention contain about 3.20% to about 3.40% carbon, about 0.55% to about 0.65% manganese, about 1.45% to about 1.65% silicon, about 4.00% to about 4.40% nickel, about 0.90% to about 1.10% chromium, about 0.50% to about 0.70% molybdenum, about 0.03% to about 0.08% magnesium, not more than 0.17% phosphorus and not more than 0.02% sulfur and the remainder iron and incidental impurities. Rolls having a composition within the above specified ranges have good resistance to wear, high surface hardness, improved resistance to bruising, increased resistance to spalling and sufficient strength to resist deflection stresses and will not mark the material being rolled. By a composite chill cast iron roll I mean a roll having a chill portion and a core, said chill portion having a composition as hereofore described and said core being a low alloy cast iron composition as hereofore described. Such a composition may contain about 3.40% to about 3.50% carbon, about 0.50% to about 0.60% manganese, about 1.25% to about 1.35% silicon, about 0.30% to about 0.50% chromium, about 0.75% to about 1.25% nickel, about 0.15% phosphorus, not more than 0.10% sulfur, the remainder iron and incidental impurities.

The composition of the rolls must be balanced to obtain the optimum mechanical properties. The carbon content in the surface of the rolls must be sufficient to impart the hardness necessary for the surface to resist deformation when rolling cold sheet products. However, the carbon content must be low enough to provide sufficient depth of the chill in the roll. Therefore, I use a carbon content of between about 3.20% to about 3.40%, but I prefer a carbon content of between about 3.25% and 3.35%. The manganese must be sufficient to prevent softening of the iron in heavy sections, that is, about 0.55% to about 0.65%. Nickel in the iron suppresses pearlite formation and favors formation of martensite and also aids in refining carbides. The nickel should be from about 4.00% to about 4.40%, but I prefer to limit the upper range of the nickel to about 4.20%. Chromium is added to the chill cast iron to prevent the formation of nodular graphite. For this purpose I prefer to control the magnesium content within a range of about 0.145% to about 1.65%, however, I prefer to use a range of 1.50% to about 1.60%. Molybdenum is added to the chill cast iron to promote the formation of nodular graphite. For this purpose I prefer to control the magnesium content within a range of about 0.03% to about 0.08% and prefer a magnesium content of 0.05% to 0.07%. There may be a distinct line of demarcation between the chill and core areas in composite rolls, because of the sudden transition from nodular to flake graphite. In the past, this has been of great concern since this line is a metallurgical notch and may become a focal point for spalling. It has been found to be of no consequence in the rolls of the invention since the transition of graphite from nodular to flake has been found to be gradual through this area because of the comparatively low sulfur content of the chill area and core of the rolls.
The above mentioned microstructure may be obtained by subjecting the rolls to a stress-relief treatment. Two such treatments are listed below:

**A**

Cast molten iron and cool to ambient temperature, Reheat to 850° F.—hold 4 hrs., Cool at 50° F./hr. to 100° F., Reheat to 500° F.—hold 4 hrs., Cool 50° F./hr. to ambient temperature.

**B**

Cast molten iron and cool to about —100° F., Stress relieve at 500° F., Hold 1 hour/inch of thickness, Cool to ambient temperature.

Rolls treated by the above methods were found to have a surface hardness of Rockwell C 57.0 to 59.0, an ultimate bend strength of about 86,000 to 90,000 psi., a total deflection on bend test of about 0.044 to 0.047 inch and a bend to fracture strength of about 1.10 ft. lbs. to about 1.15 ft. lbs. and about 11.3% retained austenite in the microstructure. The bend test used to determine the ultimate bend strength, total deflection and toughness (bend to fracture strength) is described in International Nickel Company, Inc., Technical Paper 541-CP dated Nov. 3, 1967, by F. K. Kies and R. D. Schelleng.

Rolls having a standard white cast iron composition and treated as above had a surface hardness of Rockwell C 54.0 to 56.5, an ultimate bend strength of 77,000 to 78,000 psi., a total deflection on bend test of 0.037 to 0.040 inch and a bend to fracture strength of 92 to 1.03 ft. lbs. and 18% retained austenite in the microstructure of massive continuous carbide network, martensite, nodular graphite and eutectic austenite. It must be understood that where percent retained austenite is noted such percent is by volume.

**EXAMPLE 1**

In a specific example of the invention, a composite chill cast iron work roll 21” x 45” was made in the conventional method. The chill area and core were found to have the following chemical compositions:

<table>
<thead>
<tr>
<th>Percent</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>Si</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chill</td>
<td>3.29</td>
<td>0.88</td>
<td>0.03</td>
<td>0.07</td>
<td>1.54</td>
<td>6.10</td>
<td>0.60</td>
<td>0.61</td>
</tr>
<tr>
<td>Core</td>
<td>3.44</td>
<td>0.88</td>
<td>0.09</td>
<td>0.06</td>
<td>1.58</td>
<td>6.04</td>
<td>0.64</td>
<td>0.64</td>
</tr>
</tbody>
</table>

The casting was cooled in the mold to about 300° F., shaken from the mold and cooled to ambient temperature. The roll was placed in a furnace and heated to 850° F. held for 4 hours, cooled at 50° F./hour to 100° F., re-heated to 500° F., held for 4 hours and cooled to ambient temperature. Test specimens from the casting had a surface hardness of Rockwell C 58, an ultimate bend strength of 88,410 psi., a total deflection on bend test of 0.042 inch and a bend to fracture strength of 1.15 ft. lbs. Microscopic examination of the test specimens showed the roll to have finely-divided well dispersed nodules of primary graphite, fine primary and eutectic martensite, fine austenite-martensite grains, a secondary precipitation of fine carbides in areas of former austenitic grains, a discontinuous carbide network and 11.3% retained austenite.

The roll was mated with a standard white cast iron roll in the No. 5 stand of a 5 stand, 4 high, 48” cold mill rolling tandem. The pair of rolls rotated 2.522 tons of tandem. The standard roll was bruisied four times and had to be redressed to prevent marking the sheet. The roll of the invention was also redressed so as to mate with the standard roll although it had not shown evidence of bruising nor did it mark the sheet.

**EXAMPLE 2**

In another specific example of the invention, 2 composite as-cast chill cast iron work rolls 21” x 78” were processed in a conventional manner. The chill and core were found to have the following chemical compositions:

<table>
<thead>
<tr>
<th>Percent</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>Si</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chill</td>
<td>3.80</td>
<td>0.76</td>
<td>0.06</td>
<td>0.01</td>
<td>1.60</td>
<td>6.15</td>
<td>1.01</td>
<td>0.64</td>
</tr>
<tr>
<td>Core</td>
<td>3.43</td>
<td>0.74</td>
<td>0.09</td>
<td>0.01</td>
<td>1.56</td>
<td>6.02</td>
<td>0.92</td>
<td>0.51</td>
</tr>
</tbody>
</table>

The rolls were processed in the manner described in Example 1 above and were found to have a similar microstructure as the roll in Example 1. The rolls were ground to a finish of 20 microinches and shot-blasted to a finish of 75 microinches. The rolls were placed in a 78 inch 4 high temper mill and were used to process sheet for use in forming exterior automotive body parts. The rolls processed 8 coils of sheet before redressing was required.

Rolls of the invention may be used as work rolls in the final stands of a tandem mill to cold roll blackplate and in a temper mill to cold roll sheet from which exterior automotive body parts are formed. Rolls of the invention when used in this application have processed as many as 9 coils of sheet before requiring redressing due to wear of the blast pattern, while standard forged rolls process about 3 to 4 coils before requiring dressing. The rolls of the invention may be redressed by removing less metal than rolls heretofore used in these applications and therefore have a longer life expectancy than prior art rolls.

In this specification and claims wherever percentages are referred to such percentages are by weight unless otherwise noted.

1. I claim:

1. A composite work roll for cold rolling sheet stock, said roll having a low alloy cast iron core consisting of:

   Carbon: about 3.40% to about 3.50%
   Manganese: about 0.50% to about 0.60%
   Phosphorus: not more than about 0.15%
   Sulfur: not more than about 0.10%
   Silicon: about 1.25% to about 1.35%
   Nickel: about 0.75% to about 1.25%
   Chromium: about 0.30% to about 0.50%

2. The remainder iron and incidental impurities and a chill surface area consisting essentially of:

   Carbon: about 3.20% to about 3.40%
   Manganese: about 0.55% to about 0.65%
   Phosphorus: not more than about 0.07%
   Sulfur: not more than about 0.02%
   Silicon: about 1.45% to about 1.65%
   Nickel: about 4.00% to about 4.40%
   Chromium: about 0.90% to about 1.10%
   Molybdenum: about 0.30% to about 0.70%
   Magnesium: about 0.03% to about 0.08%

   the remainder iron and incidental impurities, the microstructure in said chill area comprising finely divided, well-dispersed nodules of graphite, finer than normal primary and eutectic carbides and martensite-austenite grains not more than 15% retained austenite, a secondary precipitation of carbides in areas of former austenitic grains, and a discontinuous carbide network and characterized by having an ultimate bend strength of about 86,000 psi. to about 90,000 psi.

2. The composite work roll of claim 1 having a grit-blasted surface of a roughness of between 55 microinches to about 70 microinches.

3. A composite work roll for cold rolling sheet stock, said roll having a low alloy cast iron core consisting of:

   Carbon: about 3.40% to about 3.50%
   Manganese: about 0.50% to about 0.60%
   Phosphorus: not more than about 0.15%
   Sulfur: not more than about 0.10%
   Silicon: about 1.25% to about 1.35%
   Nickel: about 0.75% to about 1.25%
   Chromium: about 0.30% to about 0.50%
remainder iron and incidental impurities and a chill surface area consisting essentially of:

- Carbon: about 3.25% to about 3.35%
- Manganese: about 0.55% to about 0.65%
- Phosphorus: not more than 0.07%
- Sulfur: not more than 0.02%
- Silicon: about 1.50% to about 1.60%
- Nickel: about 4.00% to about 4.20%
- Chromium: about 0.95% to about 1.05%
- Molybdenum: about 0.55% to about 0.65%
- Magnesium: about 0.04% to about 0.08%

the remainder iron and incidental impurities, the microstructure in said chill area comprising finely divided, well-dispersed nodules of graphite, finer than normal primary and eutectic martensite and martensite-austenite grains, not more than 15% retained austenite, a secondary precipitation of carbides in areas of former austenitic grains, and a discontinuous carbide network and characterized by having an ultimate bend strength of about 86,000 p.s.i. to about 90,000 p.s.i.

4. The composite work roll of claim 3 having a grit-blasted surface of a roughness of between 55 microinches to about 70 microinches.

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