CATEGORY: ROLL SURFACE INDICATIONS

TYPE: ORANGE PEEL SURFACE

AFFECTS: WORK ROLL (HOT MILLS and COLD MILLS)

CHARACTERISTICS

Orange peel is characterized as excessive micro-roughening (can also be classified as a measureable differential wear condition) at the barrel surface of a late stand work roll. This may be present throughout the majority of the strip contact area or in localized areas (such as the strip edges, peaks of barrel shape profiles, etc). The roughness is formed by randomly oriented, small alternating peaks and troughs within the surface material.

Due to the mechanism involved, this type of surface condition is most commonly associated with late stand work rolls in hot mill applications (AIC – Alloy Indefinite Chill). If present on the last stand work rolls, the orange peel texture can imprint onto the strip and result in improper strip surface quality. Extreme cases, may result in imprinting of the orange peel texture onto the strip surface from the second to last stand work rolls or even earlier that is unable to be completely rolled out in the last stand.

Orange peel conditions are possible on early stand work rolls in hot mill applications or in any stand of cold mill applications (HiCr Iron and HSS), but the microstructure of these materials are such that any orange peel is typically not deep enough to be considered a problem and any orange peel texture that is imparted onto the strip is typically rolled out by the later stands.
Orange peel surface finish present at the barrel surface of an indefinite chill cast iron work roll after mill service.
Figure 3
Localised area showing a rough orange peel surface at the strip edge zone.

Figure 4
Rough surface resulting from elevated levels of harder enhanced carbides.
GENERAL MECHANISM

Orange peel surface results due to the preferentially accelerated wear of one microstructural component of the roll material relative to another. Carbides are the main wear resistant component of the roll microstructure. The matrix constituent is softer than the carbides and its wear rate in relation to the carbides will determine the surface finish of a roll. The percentage of carbides present in a given grade can vary in size and volume throughout the working layer of a roll typically reducing through depth. If the carbide volume present at depth is insufficient and or the matrix hardness is not optimized then accelerated preferential wear of the matrix relative to the carbides will occur. The wear of the matrix constituents results in the surface pits with the carbide areas forming the peaks.

An accelerated rate of preferential wear can also occur if rolling conditions are not optimized. Unstable rolling conditions, poor roll cooling or non-uniform strip temperature can all accelerate the onset of orange peel surface.

PREVENTION

- The roll maker should ensure an optimized and balanced microstructure for the given application.
- The mill should provide stable rolling conditions and avoid:
  - Excessive temperature variation across the slab e.g. cold edges or overcooling
  - Excessive variations in slab profile across the roll width e.g. dog bone profiles

MECHANISM IN DETAIL

Orange peel surface results due to measureable preferential wear of one microstructural component of the roll material relative to the others. The microstructure of the work roll barrels consists of several different constituents which provide different benefits to the roll material in specific applications.

The microstructure of Alloy Indefinite Chill (AIC) work rolls consists of three or four main constituents:
- Matrix – mixture of bainite and martensite
- Primary Carbide – M₃C
- Graphite
- Secondary Carbide (present only in enhanced carbide grades) – NbC, WC, W₂C, VC and TiC (different roll manufacturers use different carbides or combinations for their enhanced grades).
Example of a standard grade AIC microstructure

The wear resistance of each of the above listed microstructural constituents can be related to their hardness which is generalized in the following table:

<table>
<thead>
<tr>
<th>Microstructural Constituent</th>
<th>Hardness (Brinell - HB)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite</td>
<td>NA</td>
<td>Almost no wear resistance</td>
</tr>
<tr>
<td>Matrix (Bainite)</td>
<td>500 – 900</td>
<td>Hardness depends on heat treatment practice</td>
</tr>
<tr>
<td>Matrix (Martensite)</td>
<td>250 – 650</td>
<td>Hardness depends on heat treatment practice</td>
</tr>
<tr>
<td>M₁C</td>
<td>850 – 1100</td>
<td></td>
</tr>
<tr>
<td>Mo₂C</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>M₁C₃</td>
<td>1200 – 1600</td>
<td></td>
</tr>
<tr>
<td>NbC</td>
<td>2400</td>
<td></td>
</tr>
<tr>
<td>WC, W₂C</td>
<td>2200 – 2600</td>
<td></td>
</tr>
<tr>
<td>VC</td>
<td>2800</td>
<td></td>
</tr>
<tr>
<td>TiC</td>
<td>2900</td>
<td></td>
</tr>
</tbody>
</table>

As can be seen from the table above, the carbides provide the greatest wear resistance for the roll material. The proper balance of hard wear resistant carbides and soft graphite in AIC materials (required for thermal and mechanical damage resistance as well a prevention of sticking of the strip to the roll surface), is required by the roll manufacturer to ensure that the roll provides good, even wear resistance – this balance is know as the carbide-to-graphite ratio. It is also required by the roll manufacturer to achieve a matrix hardness that provides good wear resistance, but also with good resistance to mill damage. As these two matrix properties are inversely related, the typical matrix for AIC materials consists of a mixture of tempered bainite and martensite.
Although Orange Peel (measureable differential wear) is primarily a microstructural issue, the mill conditions will have a significant effect on the uniformity of the wear rate of the barrel. Orange peel can therefore be the result of one or more of the following factors:

- **Low Carbide-to-Graphite Ratio**
  If the carbide-to-graphite ratio is too low (more graphite, less carbide) then a measureable differential wear can occur due as a result of an excessive area percentage of graphite within the microstructure. The preferential wear of the graphite results in surface “pits” compared to the remainder of the roll surface which are large and numerous enough to affect the surface quality of the strip. As the carbide-to-graphite ratio in AIC materials decreases with radial depth (graphite increases, carbide decreases with radial depth), it is possible for a roll to show good even wear behavior at the beginning of its service life but it may begin to exhibit an orange peel pattern toward the end of its service life. Most roll manufacturers have found that enhanced carbide materials provide a more consistent carbide-to-graphite ratio through the entire radial depth which aids in the prevention of orange peel later in the later stages of roll life.

- **Low Hardness Matrix Structure**
  The same mechanism as described above is also possible if the matrix structure is not properly balanced to provide good wear resistance (too soft). In this case the matrix and graphite will begin to preferentially wear at a faster rate than the remaining carbide resulting in a measureable differential wear pattern on the roll surface. The preferential wear of the matrix and graphite results in surface “pits” compared to the remaining carbide which are large and numerous enough to affect the surface quality of the strip. This condition is accelerated by a low carbide-to-graphite ratio as there will be less hard carbide available to support the matrix and graphite. If orange peel occurs as a result of an improper balance of the matrix material, then it will be present through the remainder of the roll cross section as the matrix structure does not significantly change with radial depth.

- **Too Much Enhanced Carbide**
  Orange peel can also occur if too much secondary (enhanced) carbide present in the microstructure. In this case, if the area percentage of enhanced carbide is too high, then measureable differential wear may become apparent as the very hard enhanced carbides begin to “stand proud” as the remainder of the roll surface wears away. When it occurs, this condition is typically only present in the first few millimeters of the rolls diameter. During centrifugal casting, the harder enhanced carbides form first and as they exhibit a higher density than the remaining liquid metal, centrifugal forces can cause a concentration of these carbides in the outer diameter of the casting. The roll manufacturer typically ensures that there is enough stock in the casting to ensure complete removal of this concentrated layer, however residual areas of carbide concentration can sometimes remain.
Mill/Stand Conditions
An accelerated rate of measureable differential wear with any of the cast work roll materials can also occur if rolling conditions are not optimized (including HiCr Iron, HSS and AIC). Unstable rolling conditions, poor or non-uniform roll cooling or non-uniform strip temperature can all accelerate the onset of orange peel surface.