HARDENABILITY OF STEEL: JOMINY END-QUENCH TEST

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HARDNESS

• Hardness is a function of alloy content, iron phase and metal grain size

• When rapidly cooled (quenched), iron forms into martensite phase with a small grain size.

• Hardness correlates to tensile strength

<table>
<thead>
<tr>
<th>Steel Phase</th>
<th>Hardness (Brinell)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrite</td>
<td>80</td>
</tr>
<tr>
<td>Pearlite</td>
<td>400</td>
</tr>
<tr>
<td>Martensite</td>
<td>700</td>
</tr>
</tbody>
</table>
JOMINY

- Standardized test used to control cooling rates
- Uniform cylindrical sample quenched on one end with water
- Hardness tests performed at distance intervals from quench
QUENCH/COOLING RATE

• Martensite formation depends on cooling rate

• Some metals need to be cooled quicker than others

• Distance from the quench correlates with a cooling rate.

<table>
<thead>
<tr>
<th>Inches</th>
<th>°F/s</th>
<th>ºC/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8”</td>
<td>305</td>
<td>170</td>
</tr>
<tr>
<td>1/4”</td>
<td>125</td>
<td>70</td>
</tr>
<tr>
<td>3/8”</td>
<td>56</td>
<td>31</td>
</tr>
<tr>
<td>1/2”</td>
<td>33</td>
<td>18</td>
</tr>
<tr>
<td>3/4”</td>
<td>16.3</td>
<td>9</td>
</tr>
<tr>
<td>1”</td>
<td>10</td>
<td>5.6</td>
</tr>
<tr>
<td>1 1/4”</td>
<td>7</td>
<td>3.9</td>
</tr>
<tr>
<td>1 1/2”</td>
<td>5.1</td>
<td>2.8</td>
</tr>
<tr>
<td>2”</td>
<td>3.5</td>
<td>2</td>
</tr>
</tbody>
</table>

Cooling rates which correlate to distance from the quench
HARDENABILITY

- Hardness of steel that can be achieved and at what cooling rate
- Curve instead of a single number
- For engineers and in planning process steps to achieve desired properties
PROCEDURE PT 1

1. Heat sample to 1000 degrees C for 30 minutes

2. Remove sample from furnace, place in Jominy fixture for 10 minutes

3. Let cool
PROCEDURE PT 2

4. Cut up top of the sample
5. Grind flat opposite sides of the sample
6. Perform hardness testing
7. Graph the results
RESULTS

- Graph hardness and distance from quench
- How quick does this metal need to be quenched to have a specific hardness?
MICROSCOPY

- 1018 steel samples
- Micrographs in order of distance from quench
- What does the hardenability curve look like?
- There are many varieties of steel
- Engineers often need to control the hardness of a metal
- Use the Jominy test to create a hardenability curve and identify necessary processing conditions (cooling rate)