Using NDT Methods for Inspection Work Rolls

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Abstract
The rolls used in Rolling Mill included different material and size, such as high alloy forged rolls, multi-casted iron rolls etc. The sizes are from Φ360 mm to Φ1960mm, hardness layer in difference depth by heat-treatment. New rolls and used rolls are inspected by different NDT methods to make sure its in good condition for next rolling turn. In general, longitudinal UT used for internal defects and Rayleigh (Surface) wave UT or MPT/PT used for surface cracks. We also used ECT to measure the surface cracks during grinding roll process. Finally, we will measure the hardness, hardness layers and the residual stress in rolls.

Keywords: Cold Roll Mill (CRM), Ultrasonic Testing (UT), Magnetic Particle Testing (MPT), Penetrant Testing (PT), Eddy Current Testing (ECT)

1. Introduction

Rolls are important consumption items in rolling mill, new purchased rolls are needed to confirm the quality to a certain level before it can be used on the rolling line. Roll of CRM is directly rolling on steel strip, requiring high hardness and high toughness material characteristics. Therefore most of the work rolls are forged steel and common injuries are collisions, fatigue and stress concentrations, which caused surface cracks.

The NDT inspection methods include detection of surface defects and internal defects. Surface defects inspection methods are: Eddy-Current Testing, Ultrasonic testing and Magnetic Particle testing. For internal defects tested by ultrasonic. Identified via Visual inspection of surface defects, it is less controversial. For internal defects of rolls, the buyer and seller both side need the agreements for setting the acceptance criteria.

Rolling force is passing through by the contact of work roll and backup roll, contact pressure will form a stress within rolls, due to long time wearing contact and caused by stress concentrated, work rolls needed regularly detection and track internal interface layer has whether minor or serious of split defects, as can continue with of judgment to avoid breaking roll during rolling process, caused delays in production and material losses. Also, according to the distribution of spalling or peel blemishes for reviewing the wears’ deformation of work roll and backup roll, will provide reference for rolling process.

2. Inspection Preparation

2.1 Roll Surface Inspection

Roll surface should be inspected by manual UT with surface wave technique (double checked by MPT or PT). And roll surface must not have any visible defects, such as cracks, pores, dent and non-metallic inclusions. Fig.1 shows the inspection area.
2.2 **UT Inspection Directions**

Inspection directions are shown in Fig.2 and an example of repeated echoes is shown in Fig.3.

![Fig.2: Inspection direction](image)

3. **New Roll Inspection**

3.1 **Outer Shell Layer Measurement**

By using straight-beam single crystal ultrasonic probe for measuring the interface of layer thickness, increase the gain of the instrument (dB) value until the interface echo clearly and obviously appears, it shall be a working layer thickness.

3.2 **Shell / Core Boundary Inspection**

3.2.1 **UT Method**

By using Φ 20~25mm single crystals, 2MHz, straight beam ultrasonic probe, DGS method used for testing.

3.2.2 **UT Setting**

Using standard gauge block STB-G V3, by 2mm diameter flat bottom hole for setting echo at 50% screen height detection sensitivity.
3.2.3 Detection Location
This test is typically used for centrifugal cast steel rollers. Cast steel rolls generally do not used for this inspection of. Detection location is shown in Figure 4, acceptance criteria are divided into three levels: first level: flaw size equivalent diameter less than 2mm. Level two: defect size equivalent diameters less than 5mm. Level three: defect size equivalent diameter less than 8mm.

![Fig.4: The red marked are the detection area of shell /core boundary](image)

3.3 Forged Roll UT [1][2][4]

3.3.1 UT Inspection Specification
ASTM A-388

3.3.2 Acceptance Criteria
No indication is larger than 20% of reference back reflection. No area showing loss of back reflection larger than 70% of reference back reflection.

3.4 Casting Roll UT [3][5][6]

3.4.1 Roll Shell Layer Quality
There should be no flaw when the equivalent diameter is larger than Φ2mm.

3.4.2 Inner Core
Please refer Table 1 for the acceptance criteria.

3.4.3 Shell / Core Boundary
Please refer Table 1 for the acceptance criteria.

<table>
<thead>
<tr>
<th>Position</th>
<th>Frequency</th>
<th>Transducer</th>
<th>Sensitivity(note1)</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Core (Roll neck include)</td>
<td>Radial</td>
<td>1.0MHz, Φ20-25 mm</td>
<td>STB-G.V15-5.6:60%+12dB</td>
<td>Crack indication echo shouldn’t be detected.</td>
</tr>
<tr>
<td></td>
<td>Axial</td>
<td>0.5MHz, Φ20-25 mm</td>
<td>STB-G.V15-5.6:60%+12dB</td>
<td>The back echo (echo from the opposite surface) should be detected.</td>
</tr>
<tr>
<td>Shell/Core Boundary</td>
<td>Radial</td>
<td>5MHz, Φ20 mm</td>
<td>STB-G.V3-2.0:40%+12dB</td>
<td>Detected repeated echoes from shell/core boundary</td>
</tr>
</tbody>
</table>
Note 1: The standard test blocks (STB-G) are as JIS Z2345 standard shows.

4. Used Roll

We use ECT automatic roll inspection system for simple and quickly check the condition of most used rolls. The inspection system is installed on the roll-grinding machine. Rolls are often scanned on the grinder after they are completely ground. ECT is sensitive to surface defects and can detect pinches and bruises but is distorted by residual magnetic field, deteriorated material, grinding particles, confusing real defect signals, and therefore must continue to be manual-UT supplemented by MPT/PT to determine the flaws. UT is divided in normal UT for finding subsurface defects and surface wave UT, which is very sensitive to surface defects.

4.1 Flaw Detection in Working Layer within 30mm

Using 4MHz double-crystal straight beam φ20-25 mm transducers to detect roll (Working Layer of Roll), testing location as shown in Figure 5.

4.2 Setting Detection Range

During the measurement, increasing the gain of the instrument (dB) until the interface echo clearly and obviously appears, it shall be a working layer thickness, adjust the detection range of 100mm in the ultrasonic detector.

4.3 UT Setting

Using standard gauge block STB-G V3, by 2mm diameter flat bottom hole for setting echo at 80% screen height detection sensitivity. Scan sensitivity of detection sensitivity plus 6dB, Acceptances criteria are divided into three levels: first level: flaw echo height of screen less than 20%. Level two: flaw echo height of screen less than 40%. Level three: flaw echo height of screen less than 80%.

![Diagram](image)

Fig.5: The red marked area are the working layer, the arrow show direction of detection.

5. Conclusion

The majority of rolls are usually not checked for internal defects because of the time consuming in manual UT. Defects are often not visible and can only be found by NDT. Defects on the roll surface, such as cracks, may cause unwanted markings in the product and
may grow and lead to spalling, even to complete roll failure. Not only the roll itself may be damaged beyond repair but it also leads to produce loss and damage to the rest of the mill. Small internal defects do not necessarily create problem but they often grow, with the same harmful results. It is important to discover these defects at an early stage, to track their possible growth and to judge them against approve/reject criteria.

References

1. ASTM A-388 Standard Practice for Ultrasonic Examination of Heavy Steel Forgings.
2. JIS G0587 Method for ultrasonic examination for carbon steel and low alloy steel forgings.
3. GB/T13316 Method for ultrasonic examination for casting steel rolls.
4. GB-T423-RL1 Standard Practice for NDT Examination of Forging Steel Rolls.
5. GB-T423-RL2 Standard Practice for NDT Examination of Casting Steel Rolls.
6. NSC Work Rolls Ultrasonic Inspection Criteria