Application of Phased Array Ultrasonic Testing Technology on Inservice Wheel

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Abstract

In this paper, an Ultrasonic testing method for inservice wheel by use of phased array technology is introduced. To meet the ultrasonic test criterion of inservice CRH wheel, groups of phased array probes and conventional probes are combined used. By study echo wave in wheel rim and wheel disk form different probes, defect analyzing methods in wheel rim and wheel disk are studied. Tests on CRH reference wheels with manmade defects and on CRH wheels online shows that the arrangement of probes and defect analyzing methods can meet the requirement of field application.

Keywords: Phased array, ultrasonic testing, defect analyzing, high speed train, wheel

1. Introduction

Wheel is the most important component of locomotive and vehicle. In China, according to the criterion, ultrasonic inspection must be timely done to wheel flange, wheel rim and wheel disk, to guarantee the safety of CRH wheel in service[1][2]. The depth must be checked is the whole height of wheel rim, and the height of one echo of ultrasonic wave for wheel disk.

As for Chinese locomotive and vehicle wheel concerned, only wheel rim must be checked in service. Traditional inspection way is to place a conventional transverse ultrasonic probe with big angle on wheel tread to inspect the radial defect in wheel rim, and place a conventional longitudinal ultrasonic probe on wheel tread to inspect the circumference defect in wheel rim[3][4][5]. But traditional inspection way can’t meet the requirement of CRH wheel’s inspection.

Considering structure features of different type of CRH wheel, and according to the ultrasonic testing criterion, phased array ultrasonic probes and conventional ultrasonic probes are combing used on wheel tread and inner surface of wheel rim, to inspect fatigue defects along circumference and radial in wheel rim and wheel disk.[6][7]

2. Principle of CRH wheel ultrasonic inspection

By conventional longitudinal ultrasonic probe on wheel tread, circumference defect located in wheel rim and in wheel disk can be inspected. With Pitch Catch inspection mode, circumference defect in wheel disk can be supplement inspected by a pair of transverse phased array ultrasonic probes on wheel tread, especially for defect hided by the bolt hole. With Pitch Echo inspection mode, radial defect in wheel rim and wheel disk can be inspected by a transverse phased array ultrasonic probe on wheel tread. It is shown in Figure 1.
By transverse phased array ultrasonic probe and conventional longitudinal ultrasonic probe on inner surface of wheel rim, defect located in wheel rim, wheel tread, and outer edge of wheel rim can be inspected. By transverse conventional ultrasonic probe with big angle on inner surface of wheel rim, defect located in wheel flange and inner surface of wheel rim can be inspected. It is shown in Figure 2.

3. Data analysis of CRH wheel ultrasonic inspection

Either phased array ultrasonic inspection, or conventional ultrasonic inspection, defects are inspected based on amplitude and distance of echoes. As for CRH wheel, surfaces and sharp changes of geometry can cause fixed echoes, which mix with echoes from defects and disturb defect inspection. Usually, fixed echoes come from surface of wheel tread, bottom of wheel rim, bottom of wheel hub, border of wheel rim and wheel disk, surface of wheel disk bolt holes.

Different type of CRH wheels, which have similar geometric parameter of wheel rim, but different geometric parameter of wheel disk. For example, diameter of different type of new CRH wheel varies from 860mm to 915mm, which mainly causes by different diameter of wheel disk. Wheel disk can be classified as curved or straight disk, with or without bolt holes. For different type of wheel with disk holes, distance from holes to the bottom of wheel hub is different. Even for the same type of wheel, motor wheel and trailer wheel also has different structure.
Table 1. Different structure of CRH wheel disks

<table>
<thead>
<tr>
<th>Wheel Type</th>
<th>CRH1</th>
<th>CRH2</th>
<th>CRH3</th>
<th>CRH5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>Motor</td>
<td>Motor</td>
<td>Motor</td>
<td>Motor</td>
</tr>
<tr>
<td>Trailer</td>
<td>Trailer</td>
<td>Trailer</td>
<td>Trailer</td>
<td>Trailer</td>
</tr>
<tr>
<td>Disk profile</td>
<td>straight</td>
<td>straight</td>
<td>straight</td>
<td>straight</td>
</tr>
<tr>
<td>Bolt holes</td>
<td>with</td>
<td>with</td>
<td>with</td>
<td>without</td>
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</tbody>
</table>

Based on the different feature of wheel rim and wheel disk, different algorithm can be applied for wheel rim and wheel disk data analysis. For wheel rim, ultrasonic data from probes on wheel tread, which beyond the depth of wheel rim needn’t to be analyzed, and defects can be automatically analyzed by set threshold for amplitude and during time, it is shown from strip chart of ultrasonic channels in Figure 5.

For wheel disk, because structures of CRH wheel disks are different, fixed echoes come up in different ultrasonic channel, so data in channels mixed with fixed echoes must be manual analyzed to avoid missing defects, as shown in Figure 6. For other channels, defects can be automatically analyzed with the same algorithm as wheel rim.

Defects automatically defined by algorithm must be manual check, and be evaluated by following rules. If defect is smaller than beam section, equivalent size of defect is calculated by DAC curve; if defect is larger than beam section, extending length of defect is calculated by 6 dB Method.
4. Testing results

CRH reference wheel with artificial defects is used to test composed arrangement of probes and defect analyzing methods. There are 16 artificial defects, which locate in wheel rim and wheel disk, lay along radial direction, circumference direction, and bias direction. Channels with each artificial defect recognized in B-Scan displaying of CRH1 reference trailer wheel and motor wheel is shown in Figure 7 and Figure 8.

Figure 7. B-Scan displaying of CRH1 reference trailer wheel with artificial defects recognized

Figure 8. B-Scan displaying of CRH1 reference motor wheel with artificial defects recognized

Channels with natural defect recognized in B-Scan and A-Scan displaying of real CRH3 wheel is shown in Figure 9.

Figure 9. B-Scan and A-Scan displaying of CRH3 wheel with natural defect
5. Conclusions

Tests on CRH reference wheels with artificial defects and on real CRH wheels online shows that the arrangement of probes can meet the requirement of in service wheel inspection. The defect analyzing methods in wheel rim and wheel disk can partly achieve an automatic defect recognition, which improves efficiency and automation of ultrasonic inspection.

References