17th World Conference on Nondestructive Testing, 25-28 Oct 2008, Shanghai, China

ACOUSTICAL HOLOGRAPHY IMPLEMENTATION FOR DEFECTED RAILS INSPECTION

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Abstract

This paper describes technology of acoustical holography (FT-SAFT processing) implementation for ultrasonic testing of a priory defected rails to improve repairing and exploitation of railway. Mobile system with flaws visualization in all rail volume was developed. System intended for repeated testing of rails which was marked as defected by standard inspection methodology and equipment. System allows flaws detection, size and position calculation. Size and position of flaws is taking into account at the rail lifetime calculation task. Time of next inspection also calculated. Described various types of flaws in various rail parts and inspection procedure used to detect all flaws. Rails flaws acoustical images reconstructed with FT-SAFT algorithm presented. Presented results of flaws sizing which approves possibility of acoustical holography implementation to obtain high resolving power and accurate flaws sizing if any part of rail. Presented results of flaws size measurements by fractography after rails fracturing and similarity of size measured by holography and by fractography. Described procedure of defected rail lifetime calculation which allows to decrease repairing of railway and therefore to decrease trains idle standing.

Keywords: acoustical holography, FT-SAFT, flaws imaging, railway, lifetime calculation

Introduction

Acoustical holography is a two-stage method of inner object image reconstruction [3]. At the first stage the acoustical hologram (acoustical field after its interaction with discontinuities) is recorded on the surface of object, and at the second stage the wave front on the discontinuities reconstruction completed. Ultrasonic field registration is fulfilled with scanning in pulse-echo technique with step about quarter of wavelength. Then with the mathematical coherent data treatment of source A-scans acoustical image reconstruction is proceeding.

Acoustical holography system for rails inspection (Fig. 1) was developed in SPC ECHO+ in 2007 by request of Russian Railways. System is intended for repeated testing of rails on track which marked as defected by standard inspection methodology and equipment. System intended to confirm flaws detection, flaw position and real size measurement and further defected rail lifetime calculation.

Brief system description

Acoustical holography system has main parts: system unit with electronic equipment, scanning device with two axes, storage battery and notebook with installed software. The software is used for A-scan registration and storage, various data processing, flaws images visualization in various rail sections on display (B-, C and D-images) and measurement of flaw position and size.

Main system technical characteristics

Pulse generator: bipolar with varying length
Pulse length adjusting: 0.1…1 ms

Pulse amplitude: 50, 100, 150 V
TVG range (200 ms diapason): at least 30 dB
Minimal scanning step size: 0.01 mm
Probes frequencies : 2.5 and 5.0 MHz
Acoustical channels quantity: 8
Time for inspection of single defected area: about 3 min
Scanning zone along the rail: 250 mm
Operating temperature range: from minus 30° C to plus 40° C
Flaws sizing accuracy: ± 2 mm
Power supply: autonomic storage battery 12 V

Flaws aimed for detection and sizing

Rail head: vertical and horizontal exfoliations, delaminations and metal loss, transversal cracks.

Rail web: cracks including cracks from boltholes.

Rail foot: technological and corrosion-fatigue cracks.

Holographic system peculiarities

- real flaws sizing abilities;
- rails lifetime calculation with use of real flaws size;
- full inspection automation;
- system is a mobile inspection device which could be carried on motor or railway transport;
- all inspection data storage in database.

System implementation description

System is intended for repeated testing of rails on track which marked as defected by standard inspection methodology and equipment. Rail section with flaw is inspected with holography system with parameters suitable for image reconstruction [1]. For inspection used special broadband and broad angle (opening angle 40° at 20 dB cutoff) probes. Scanning device is moving probes along and across the rail. Probes emits and receives ultrasonic pulses in turn as pulse-echo or pitch-and-catch modes. Coordinates binding is adjusted by operator. With use of FT-SAFT processing [2, 3] could be reconstructed acoustical images of flaws with high resolution.

For rail head inspection used two pulse-echo probes with frequency 2.5 MHz, angle of incidence 70º which emits opposite each other and two straight pitch-and-catch probes with frequency 5.0 MHz.

For rail web and foot inspection used two pulse-echo probes with frequency 2.5 MHz, angle of incidence 40º which emits opposite each other and one straight pitch-and-catch probe with frequency 5.0 MHz.

Operator with analysis of images makes a decision about flaws presence, size and location and puts this data in database. The inspection datasheets is generating automatically.

At the Fig. 3 and Fig. 4 presented examples of acoustical images obtained by holography system and photography of fracture at the defected sections. One can see good agreement between real flaws size and positions and its acoustical images.

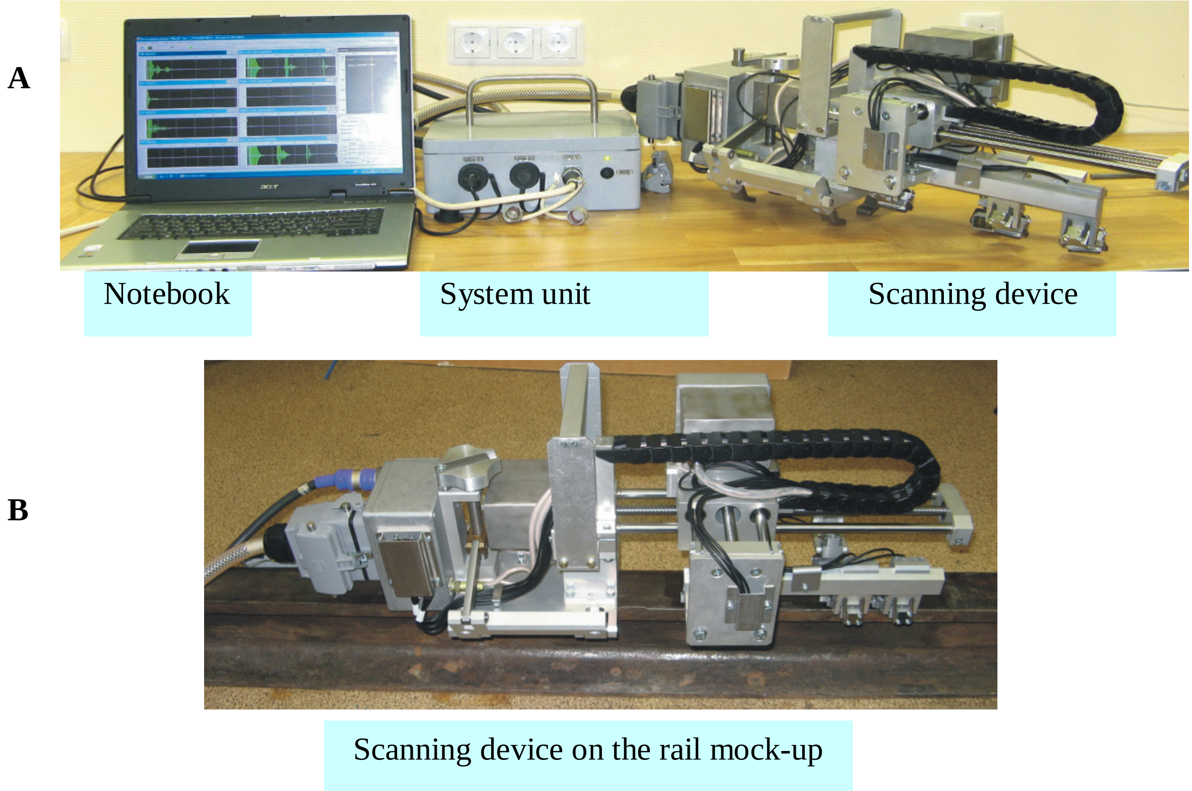

Fig. 1. Acoustical holography system: A. Common view. B. Scanning device on the rail mock-up

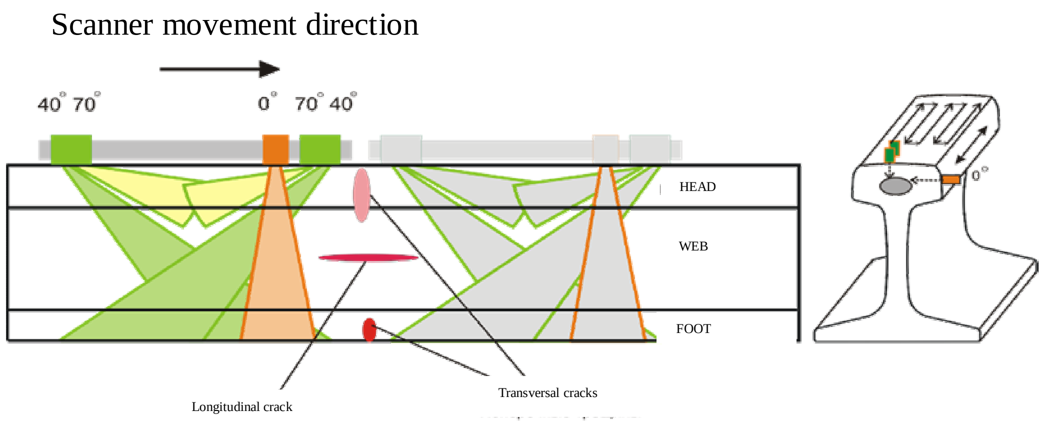

Fig. 2. Inspection techniques scheme

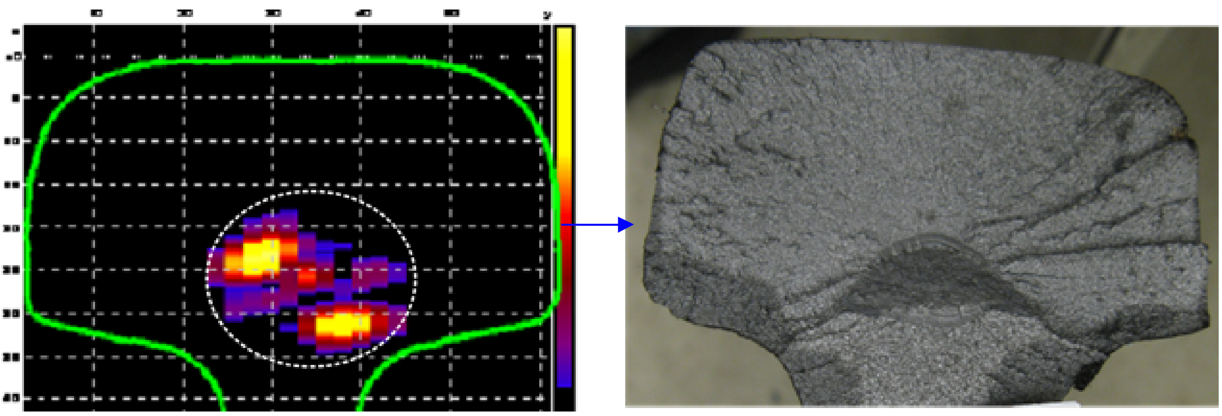

Fig. 3 D-image (across the rail) of rail section with real flaw – transversal crack in the weld (left pane) and photo of fracture at the defected section (right pane)

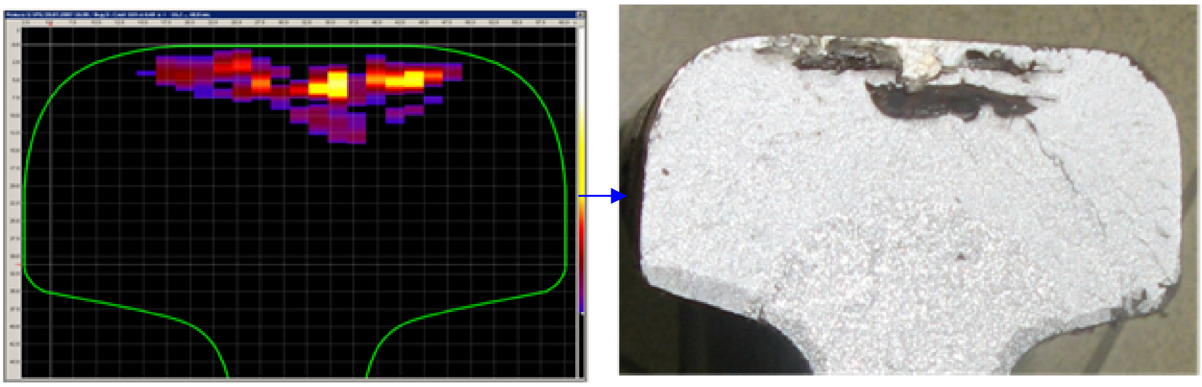

Fig. 4 D-image (across the rail) of rail section with real flaws – horizontal exfoliations and progressive crack (left pane) and photo of fracture at the defected section (right pane)

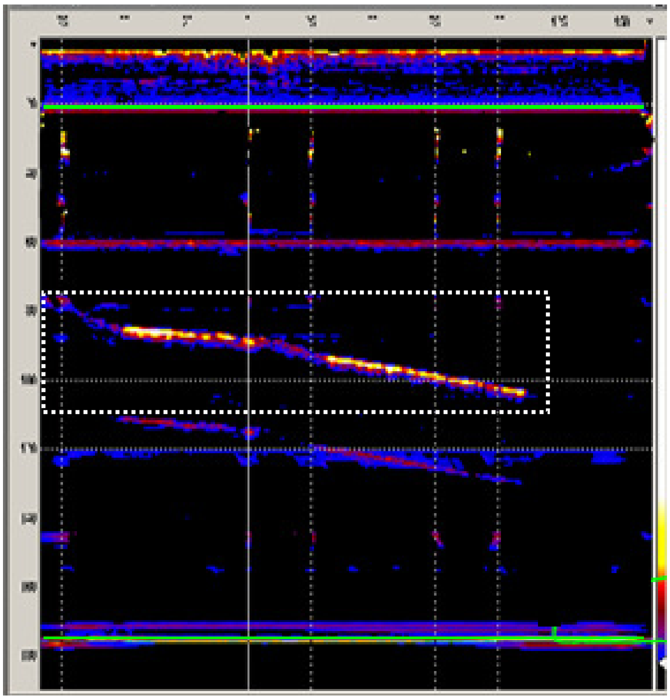

Fig. 5. B-view (along the rail) of rail section with longitudinal horizontal exfoliation in web

Summary and discussion

Acoustical holography system for rails inspection was passed trial on the real rails with intolerable flaws. Comparison between acoustical images and fractographic analysis shown good agreement (flaws size and position measurement accuracy is 5-10%) and possibility of high resolution image reconstruction.

References

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