Light Form of Combined Ultrasonic and Eddy Current Examination System For Railway Infrastructure

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Abstract.

The major problems that a rail network has to face during operation are RCFs, cracks in the frog nose, cracks in frog body, and cracks in guard rail base plates, defective welds, crossing blades defects, corrugation and rail profile wear. If these deficiencies are not controlled at early stages that might cause huge economical problems affecting the rail network (unexpected requisition of spare parts, handling of incident and/or accidents). The early and continuous use of NDTs can save both money and human lives. Money wise talking, scheduling of spare parts orders as well as the early repairing of railway components may be performed before they will turn out to be scrap materials. Talking about "human life", by performing NDTs, human lives can be saved since failure of materials can be easily predicted and evaluated under certain procedures and methods applied.

Since 2003 a company called ELESYL O.E. performs extended NDT services within the Greek rail network market. These services are consisting of procedures and specifications' implementation, NDT inspections and Level 3 consultation. For NDT inspections both manual and "automatic" systems are being used.

ELESYL O.E. have developed a rather light form of combined ultrasonic and eddy current examination system. The system has been developed for detection of RCF (head checks) type defects along with internal rail defects, providing information of the defected position and depth. Above mentioned system is adopted and implemented since January 2007.

The actual system and results will be presented.

Acknowledgment

ELESYL compliments Mr. G. Petrolekas of National Instrument Greece - for his time and patience.

Introduction

ELESYL's directors, working in NDT area since 1988. During these 19 years ELESYL is involved in almost all types of construction applying all traditional NDT methods. During the last 4 years ELESYL is specialized in Railway's NDT. During these years we implemented a series of inspection procedures for railway networks. These procedures cover ultrasonic, eddy current, magnetic particle and liquid penetrant inspection in the following infrastructure components:

- Frogs,
- Crossings,
- Blades,
- Welds,
- Rails,
- Guard rail base plates etc.

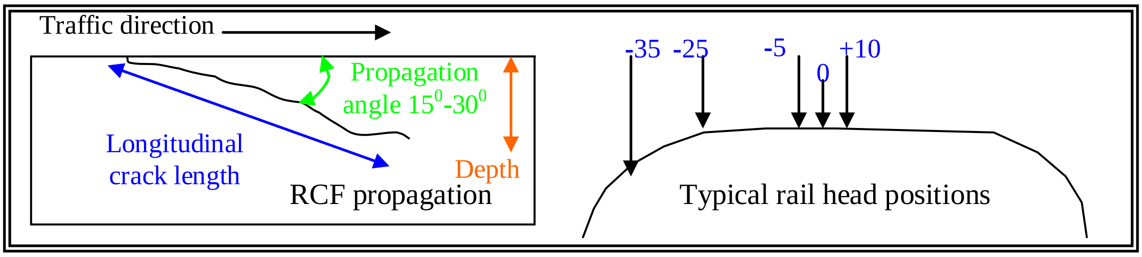
As last accidents investigation indicates that an old known deficiency named "Rolling Contact Fatigue" (RCF) Crack or "Head Check" can create rail fracture and derailment, if the crack size exceeds the 20 mm in length on the running rail surface and/or 2,7 mm in depth from the running surface, the necessity of an inspection system capable to inspect the rails length for RCF cracks with the ability to indicates the critical dimension of length and depth, become a must for the modern railway infrastructure management.

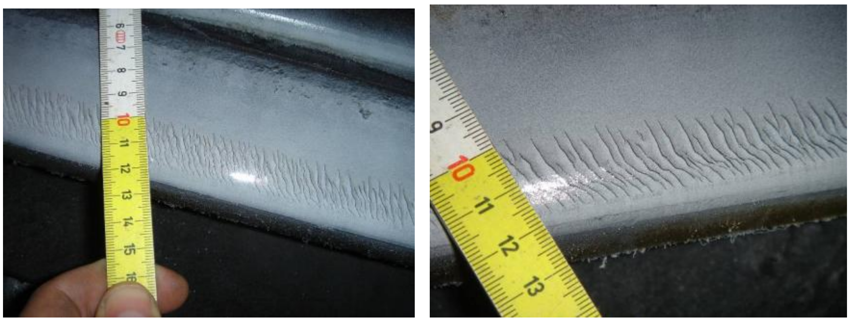
ELESYL is using its experience for this type of defects incorporating also the knowledge of the services' defects in rail and welds design and implement an inspection system using ultrasonic and eddy current technique.

RCF nature and position

RCF is created from rail/wheel interaction. In one way direction track, the cracks propagate following the train direction in an angle of 15 to 30 degrees. The distance from crack to crack can be between 1 to 6 mm.

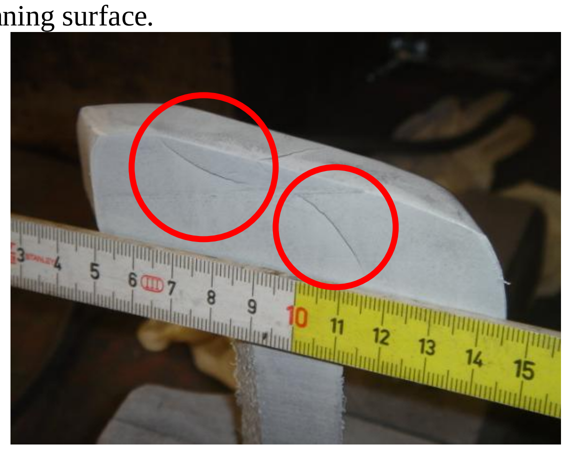
Usually in the curves in high rail, the RCF initiates in the gauge corner between -25 mm and -35 mm position, while in the low rail it appears in -5 mm to +10 mm position.

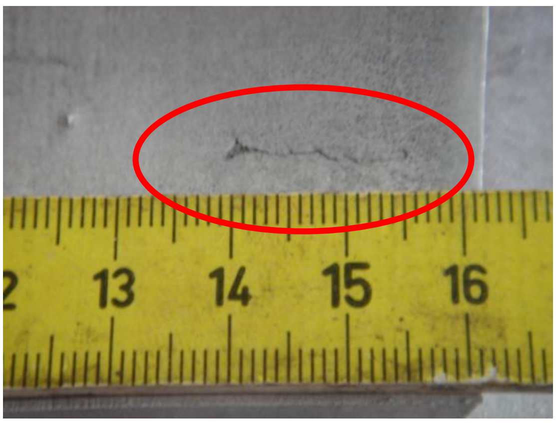



Typical RCF pattern

Weld and rail defects

Defects in rails and welds can be appearing in any direction and depth. Usually, and based in our experience, crack like defects are usually initiated at a depth range between 10 mm and 15 mm from running surface.


Rail defect


Weld defect

<u>The first step</u>

As the railway network management needs to know the extension of RCFs in order to take all necessary actions before they become critical defects, ELESYL is started to design a simplified system combining of both ultrasonic and eddy current methods.

<u>System configuration</u>

The eddy current part of the system is consisted by a common single channel – dual frequency eddy current apparatus with analog signal outputs, and eddy current rail probe (reflection, absolute or send receive). The probe setup may consist of one "GE-rail probe" for examination of the whole rail head to two absolute, or send-receive probes located in different position than that of the rail head for focused inspection.

The ultrasonic part of the system is consisted of a common A-scan ultrasonic apparatus with two analog signal outputs, two 70^0 ultrasonic transducers and one normal 0^0 probe. A small plastic container (16 liters) with a 12VDC submerges pump gives the necessary amount of water used as couplant.

The signals from the analog outputs is then guided in a data logger (NI-USB 6008 with sampling rate 10 KSPS and resolution 12 bit).

An optical encoder (360 pulse/ rotation) with a wheel with 159 mm diameter (500 mm perimeter) shows the "position". The signal from the encoder is guided first in to a digital to analog converter since the USB-6008 does not support encoders. The digital to analog converter display indicates to the user the current moving speed of the system and also produce a signal of 0-10V per rotation; this signal is guided to the USB-6008. The necessary 24 VDC power is required by the encoder and the digital to analog converter comes from two 12 VDC batteries.

The USB-6008 is connected to a USB 2.0 socket of a notebook (Pentium 4®, 1.6 MHz, and Windows XP®) and the data is recorded by NI data logging software.

Any of the four signals (Eddy current:1, Ultrasonic:2, Position:1), can be presented in the data logging graph.

The first test is made by using a steel platform (Image 1) and a separate probe holder (Image 2); while we manufacture an aluminum table having on the one side the probe holder between wheels (Image 3 shows the carrying table loaded in small van).

Image 1

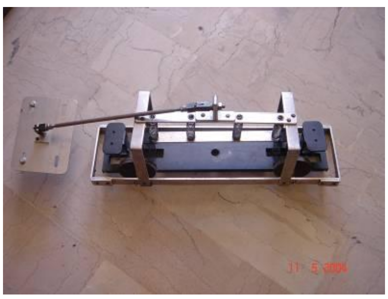


Image 2

Image 3

The available time to setup the system from the test form to a working form configuration is four days.

The working table is carrying out all necessary equipment (image 4) such as notebook computer, ultrasonic device, eddy current device, batteries, water container with pump, encoder, digital to analog converter, USB-6008 signal collector. Image 5 shows the probe holder and the "driving" wheels. The wheels are "U" shaped and can be fitted precisely in any rail profile, as we can adjust its width. The wheels maintain the probe holder in centered position of rail using a spring that allows the movement of the field size half over ungrounded welds.

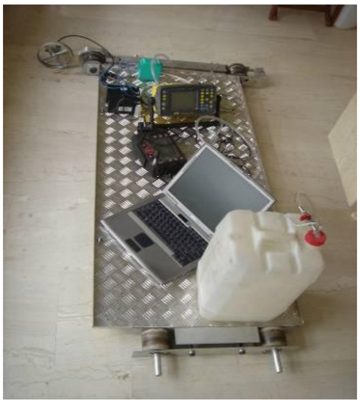


Image 4

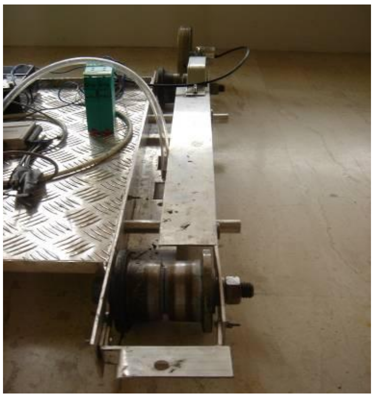


Image 5

Image 6

The total weight of the above configuration is 35 Kg, and can easily be carried and be set up by two persons. Image 6 shows the system ready for transportation. The time required from transportation form to deployment working condition is 8 min.

Calibration

For the eddy current part defected rails are used with known direction, length and depth of the defects. For the ultrasonic part rails with 2 mm side drill holes are used in different depths from the running surface. The encoder wheel has 500 mm calibrated perimeter.

The system is capable to inspect up to 8 km of rail during nights working hours (3 hours shift).

As the inspections give successful results – different welds and rails are removed from the network and the results are confirmed by destructive means; the position accuracy verified to 0.5 meter. Then we go one step further in order to reduce the data examination time in office and to increase the inspection speed.

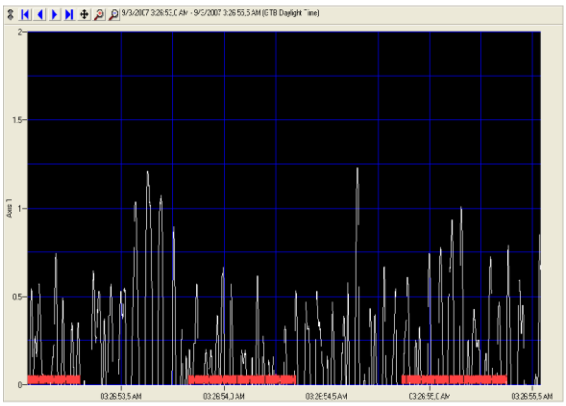


Image 7

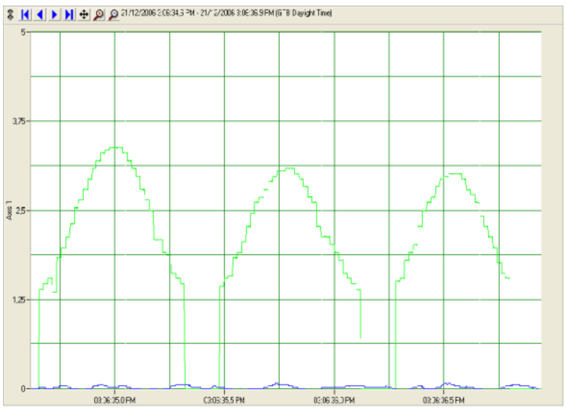


Image 8

Image 7: Signals from eddy current. Y-axis presents cracks depth (0.25 mm to 1.25 mm).
Image 8: Signal from 2 mm hole with ultrasonic. Y-axis presents % full screen high and X-axis gives data for defect height calculation.

Inspection Results

We inspect approx. 30 km of rail, and locate defective areas having RCF and defective welds having cracks in the head. But the main achievement of such an inspection is that we have a complete map of the rail defects as the system can exert comparable results during re-inspections. With this information's the railway network management can program replacements and/ or grinding schedules. Periodic inspections can indicate new RCF initiation and dimensional changes of the known defects.

The second step

By maintaining the first view having also more time for implementation, we can therefore proceed to the second step. The second step implements specialized software using the national instruments "Lab View 8.20" program. The designed software gives to ultrasonic part of the system the ability of B-scan presentation, and the position is now recorded direct in x-axis of the chart with accuracy of 1 mm. Image 9 shows the system components. Image 10 shows the core of the system (eddy current device, ultrasonic device and computer supplied with the NI PCI-6221 card).


Image 9


Image 10

The data logger hardware is upgraded to the NI PCI-6221 having a sampling rate of 250 KSPS, and resolution of 16 bit.

The optical encoder is replaced by another with 2000 pulse/ rotation.

A small tower computer (Pentium 4®, 1.3 MHz with Windows2000®) is used to host the PCI card. The computer works with 12 VDC. The computer can be controlled with a PDA or a small notebook computer via a network connection, or simply by attaching a screen and a cordless desktop. The computer can operate in a harsh environment (humidity, water, dust) since it is waterproof.

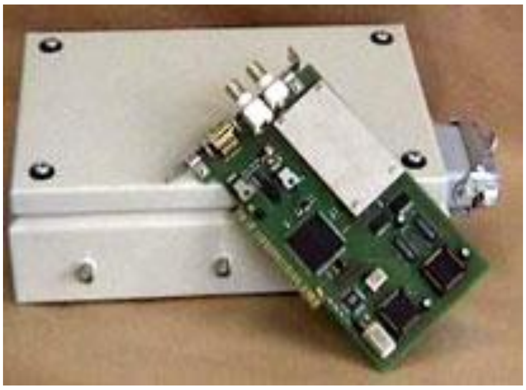
The inspection limit now is 15 Km/h.

The Third step

The third step is still under development foreseen complete change of the system configuration having capability to perform inspection at both rails of a track simultaneously.

The conventional ultrasonic apparatus is replaced by ultrasonic cards (sampling rate up to 100 MSPS, resolution 8 bit) associated by eight channel multiplexers capable to perform inspection in both rails simultaneously. The system works with four 70^0 transducers, two 45^0 transducers and one normal probe per rail.

Ultrasonic PCI board



Multiplexer

The conventional eddy current apparatus will be replaced by a dual channel eddy current cards (sampling rate 40 MSPS, resolution 14 bit). The system will be capable of operating with two or four eddy current probe per rail.

The software is capable for supporting of the above system in real time. In addition C-scan and B-scan may be represented.

The inspection speed shall exceed 20 Km/h.

The Next step

The next step is to expand the system with visual inspection (Video). For the time being we perform experiments by using normal high speed cameras and ultraviolet cameras to decide which camera gives best results for tunnel environment and expected rail defects.
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The required software is designed with the association of NI-Vision software.

Reference

- UIC 712, Rail defects, 4th edition January 2002.
- ELESYL Rail, Welds and Crossing inspection reports (2004-2006).
- ORE Question E162 Non-destructive testing of railway items in service, UTRECHT, April 1988.
- UIC/WEC JRP1, Rail Defect Management, 2nd edition, An International Cross Reference of Rail Defects, June 2003.
- UIC/WEC JRP3, Rail Defect Management, Analytical Modelling of Rail Defects and its Applications to Rail Defect Management, January 2003.