Ultrasonic and Eddy current Examination of Railway Rolling Stock

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Abstract

The major problems that a rail network has to face during operation of rolling stock are wheel RCFs, cracks in wheels, cracks in wheels tires, cracks in axles, cracks axle box, wheel profile wear and cracks in bogies. 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 money. Talking about "money", scheduling of spare parts orders as well as the early repairing of rail components may be performed before they will turn out to be scrap materials.

Since 2003 the company 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 consultations. For NDT inspections both manual and "automatic" systems are used.

The company ELESYL O.E. together with the railway network developed and implement ultrasonic and eddy current procedures for examination of rolling stock components. The procedures has been developed for detection of RCF type defects along with internal wheel and tyre defects, as well axle defects, providing information of the defected position and depth, without disassembly the components from train.

A brief description of the actual examination procedures and the expected defects will be presented.

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 covers ultrasonic, eddy current, magnetic particle, liquid penetrant and visual inspection in the following rolling stock components:

- Wheels center and tyres,
- Axles,
- Axlebox, etc.

Cracks or other expected discontinuities occurring in service in railway wheels (tyred and solid), axles and axlebox may lead to fracture and thus to operational danger. Where necessary, operational safety is guaranteed by the periodic non-destructive inspection of this components, during which irregularities may not exceed a specified limiting magnitude.

Also any of this component having close relation with operating speed, covering distance, quality of the track, acceleration, profile wear, rail wear, bogie stiffness etc. For this reasons the initial inspection shall be stringer in order to observe all discontinuities or damages. A results database generated in correlation with the rail and track inspection data. This give the necessary information for what discontinuities created in rolling stock components during specific rail and track conditions.

Procedures use data from international standards (EN, ISO) and UIC code. As the EN or ISO standards covers only the acceptance of rolling stock components in manufacturing stage and not covers directly inspections in service, a study of UIC documents and achieved experience after 4 years inspections, in railway networks, focus the inspections requirements.

The available rolling stock standards concerning NDT are:

- ISO 1005-1:1994 Railway rolling stock material - Part 1: Rough-rolled tyres for tractive and trailing stock - Technical delivery conditions
- ISO 1005-3:1982 Railway rolling stock material - Part 3: Axles for tractive and trailing stock - Quality requirements
- ISO 1005-6:1994 Railway rolling stock material - Part 6: Solid wheels for tractive and trailing stock - Technical delivery conditions
- ISO 5948:1994 Railway rolling stock material - Ultrasonic acceptance testing
- ISO 6933:1986 Railway rolling stock material - Magnetic particle acceptance testing

Tyred Wheels inspection

The most common defects in wheel tyres is RCF cracks, flats and internal cracks initiated from manufacturing defects with diameter less than 1 mm. For tyres inspection, ultrasonic, eddy current and magnetic particle testing utilized.

Image 1 shows a tyred wheel cutting profile. Image 2 shows a side view of the rail wheel. Image 3 shows a close look to the wheel tyre and blue lines indicates the critical areas. Image 4 shows the names of different parts of wheel.

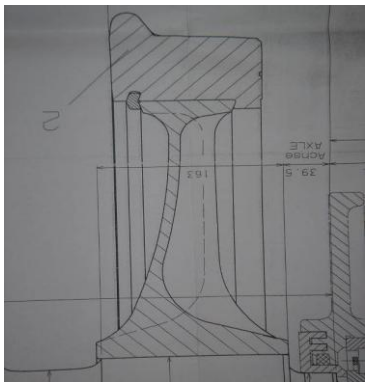


Image 1

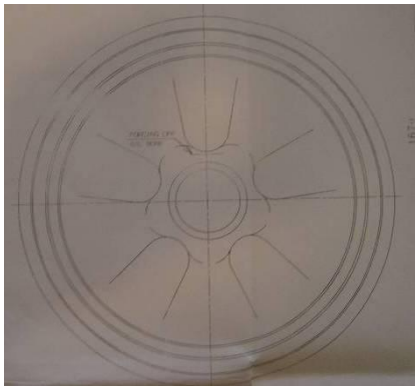


image 2

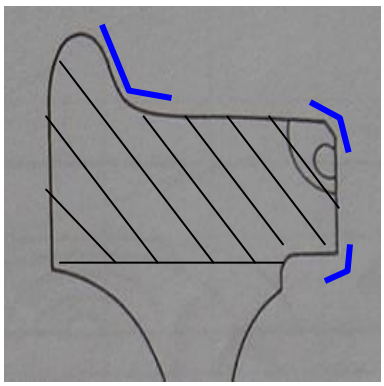


image 3

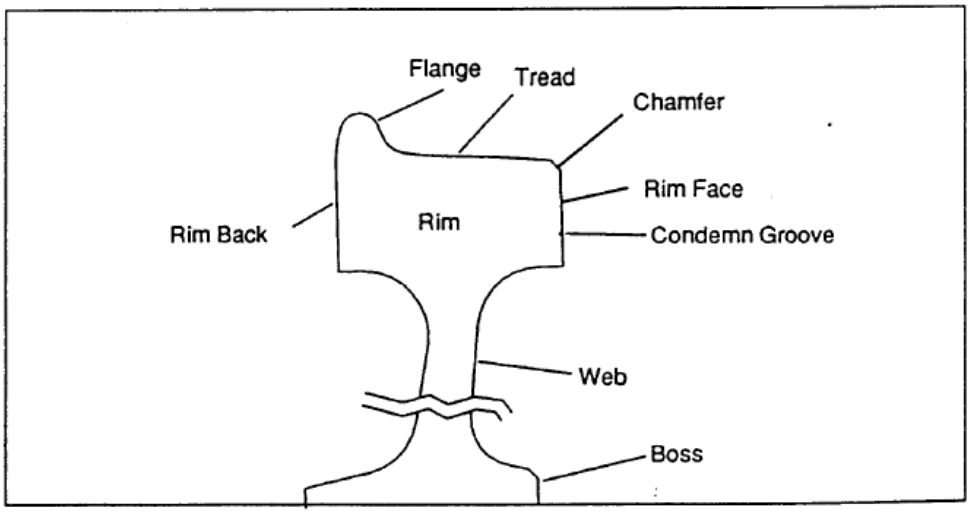


Image 4

Ultrasonic inspection:

General:

- An A-scan conventional ultrasonic apparatus used with:
  - A single normal probe working in 2 MHz frequency examines the volume of the rim for inclusions or large defects.
  - A double normal probe working in 4 MHz frequency examine the volume of the rim looking for small near surface defects also special attention given in condemn groove area.
  - 45, 60 and 70 degree probes working in 2 MHz frequency examine the rim volume, to locate transverse defects in tread, flange, chamfer and identification marks in the rim back. Generally cracks can initiate:
    - On the end face between tread and outside or rim,
    - On the tread,
    - In the flange,
    - At clamping place,
    - Identification marks.

Calibration:

Calibration is made by the use a tyre contains combination of side drilled and flat bottom holes.

For normal probes we use 2 mm diameter flat bottomed holes (image 5 and 6).

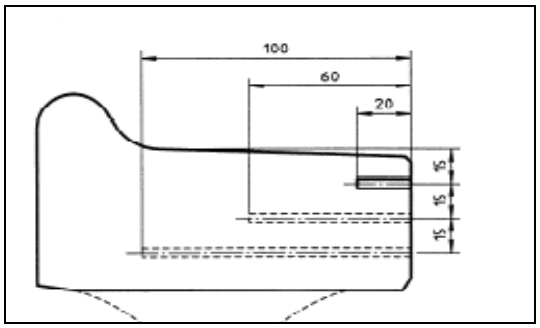


Image 5

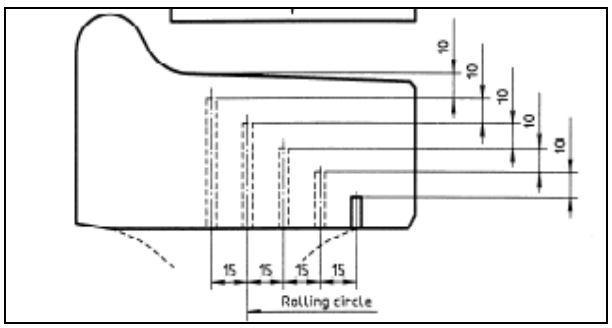


image 6

For angle probes we use 2 mm side drilled holes, at the same depths as above.

Procedure:

Using normal probes we examine the volume of each tyre, and we mark all areas produce signal that can interfere with angle probe examination or evaluated as critical defects.

Following the examination of wheel tyre with normal probe we continuous scanning all accessible tyre area and in any direction (transverse and circumference) with angle probes. Special attention shall be given when examine the outside groove, the identification mark and retaining ring areas. As from this areas can initiate cracks and can propagate in any direction.

Generally rcf's can easily detect by 70 or 60 degree probe in early stage of 0.5 mm.

Eddy current inspection:

General:

- An single channel, dual frequency conventional eddy current apparatus used with:
  - A surface scan probe (send/ receive) of 100 KHz used to examine the areas marked with blue line in image 3.
  - An absolute pencil probe of 500 KHz and, an absolute right angle probe of 500 KHz and used to calculate the depth of defects observed by surface probe,

Calibration:

Calibration is made by the use a block contains EDM notches with depths of 0.2 mm, 0.5 mm, 1.0 mm and 2.0 mm.

Procedure:

Using the surface probe all the rolling area (flange, tread, chamfer,) shall examined. If any area gives signals higher than can obtained from 0.5 mm EDM notch, then a closer examination with the absolute probes took place to calculate the exact depth and location of the defect.

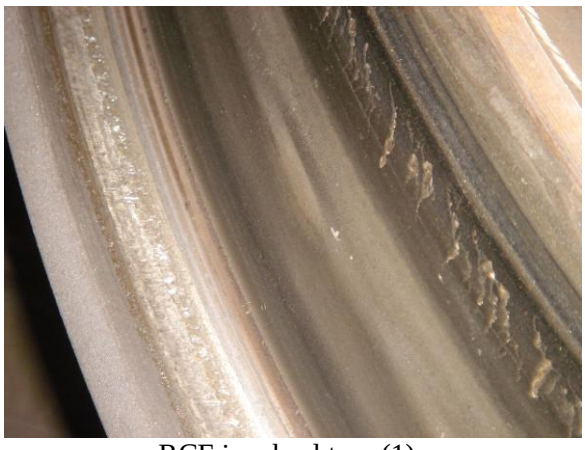
Magnetic particle inspection (common for wheels center, tyres and axles):

General:

Magnetic particle take place only for defect verification after removal of any paint, using magnetic force by a Yoke type apparatus.

Calibration:

For AC type yokes we use 5 kg weights.
For DC type yokes we use 20 kg weights.
The minimum space between poles shall be at least 10 cm greater than the examined area. And any of the poles shall be at least 5 cm away from the examined area.



RCF in wheel tyre (1)

RCF in wheel tyre (2)

Wheels centers inspection

Cracks in wheels centers are very rare and can initiate from holes openings or in the contact surface with axle seat. For wheels web inspection, ultrasonic, eddy current and magnetic particle testing utilized.

Ultrasonic inspection:

General:

- An A-scan conventional ultrasonic apparatus used with:
  - 70 degree probes working in 2 MHz frequency examine the wheel web volume.

Calibration:

Calibration is made by the use a wheel web contains EDM notches with depths of 0.5 mm, 1.0 mm and 2.0 mm.

Procedure:

With the use of 70 degree angle probe we scan all the web area in transverse and circumference direction.

Eddy current inspection:

General:

- An single channel, dual frequency conventional eddy current apparatus used with:
  - An absolute right angle probe of 500 KHz.

Calibration:

Calibration is made by the use a block contains EDM notches with depths of 0.2 mm, 0.5 mm, 1.0 mm and 2.0 mm.

Procedure:

With the right angle probe we scan the entire wheel web surface from inside and outside area.

Vary rare can observed a defect in wheel web

Axle's inspection

Cracks in axles can initiate in any geometry change and from internal inclusions with diameter less than 1 mm. For axle's inspection, ultrasonic, eddy current and magnetic particle testing utilized.

Ultrasonic inspection:

General:

- An A-scan conventional ultrasonic apparatus used with:
  - A double normal probe working in 4 MHz frequency examine the volume of the axle for small near surface defects also special attention given in condemn groove area.

- 45, 60 and 70 degree probes working in 2 MHz frequency examine the axle volume but specific the geometry changes.

Calibration:

Calibration is made by the use an axle contains combination 1.0, 2.0 and 3.0 mm EDM notches in all geometry changes. In a transparent film we design the signal response from every EDM notch from every geometric change.

Procedure:

Using normal probes we examine the volume of each axle, and we mark all areas produce signal that can interfere with angle probe examination.
Following the normal probe examination we continuous scanning the axle with angle probes. The probes placed in all accessible axle area and in any direction (left, right). Any area gives echo larger than the 1.0 mm EDM notch was marked.

Eddy current inspection:

General:

- An single channel, dual frequency conventional eddy current apparatus used with:
  - An absolute right angle probe of 500 KHz.

Calibration:

Calibration is made by the use a block contains EDM notches with depths of 0.2 mm, 0.5 mm, 1.0 mm and 2.0 mm.


Axles for calibration

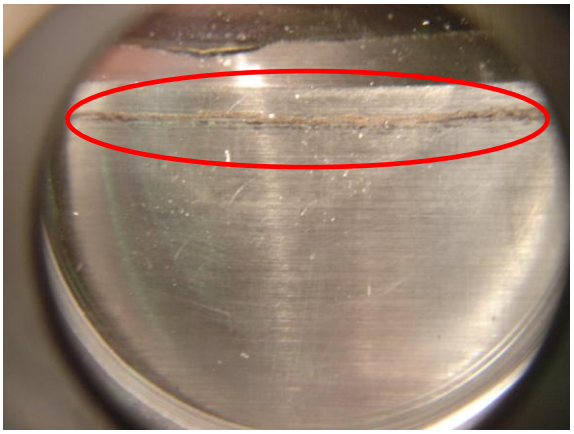

EDM notch for calibration in axle

Procedure:

Using the right angle probe we examine all the accessible axle's geometry changes areas.

Usually cracks can initiate in geometry changes, but during inspection with ultrasonic angle probes we observe internal defects not easily detectable by ultrasonic normal probes. From this areas can also initiated internal cracks. Also corrosion with depth of 0.3 mm observed in specific areas of wheels seats, with rarely indications in disk brake seats. Not any indication observed in "motion" seats.

Axle with discontinuity indication (1)



Corrosion with depth of 0.2 mm (2)

Axlebox inspection

Crack in axleboxes can initiate in geometry changes, from internal inclusions, from forging or grinding marks. For axlebox (aluminum casting) inspection, eddy current testing utilized as main inspection method and liquid penetrant inspection for verification after paint removal.

Eddy current inspection:

General:

- An single channel, dual frequency conventional eddy current apparatus used with:
  - An absolute right angle probe of 500 KHz.

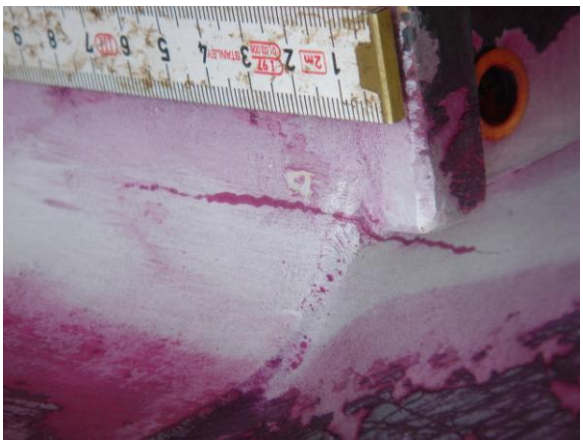
Calibration:

Calibration is made by the use a block contains EDM notches with depths of 0.5 mm, 1.0 mm and 2.0 mm.

Procedure:

Using the right angle probe we examine all the axlebox geometry changes areas. The half part (gauge side area) is not direct visible and a mirror is necessary for the inspection.
All the areas giving signals above than of 0.5 mm EDM notch examined by liquid penetrant, after paint removal.

Axlebox crack verification (1)



Axlebox crack verification (2)

Conclusion

A periodic inspection of railway rolling stock components was necessary in modern railway. An international standard specifies at least a check list or outlines the design and approval requirements for in-service NDT procedures and periodicity for the main components of railway rolling stock (Bogies, Axles, Axleboxes, Wheels - tyred or solid -, Tyres and Primary Suspension Springs) should be issued.

The above described inspection techniques are difficult to implementation as the testing performed on the train and the accessibility is limited (disk brakes, motors, sand equipment etc.). The train shall be moved one or two times to cover 100% the inspection areas.

The NDT inspectors shall be very carefully to testing the 100% of the interesting areas. In addition shall be very carefully to discontinuities characterization (shape, depth and type) as the components disassembly for verification purpose is extreme difficulty, also the paint condition interfere some times with the inspection results.. Even if new technology apparatus and techniques adopted by railway networks, the discontinuity characterization and much more the ability to find the discontinuity (probability of detection) remains a hard job.

A new approach uses phased array ultrasonic and eddy current apparatus with extended software capabilities and adjustments is ready for adopt by railway networks.

Reference

ORE – Question E162 – Type and size of critical defects in wheels and axles.
ELESYL inspection reports 2004-2007.