RAILECT Project

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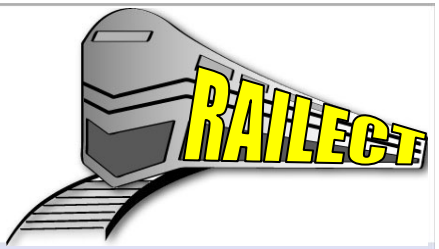
RAILECT Project



- Project title
  - Development of an ultrasonic technique, sensors and systems for the volumetric examination of aluminothermic welds
- Work programme
  - The project funding mechanism is through the EC - FP7 'Capacities' programme
  - Under the call: 'Research to the Benefit SMEs'
- Duration
  - 2 years project (started in September 2008)

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RAILECT consortium

- The consortium consists of 8 partners from 5 member states:
  - 4 SMEs each representing a different EU country SME Partners
    - Optel (Poland)
    - Vermon (France)
    - Spree Engineering Ltd (UK)
    - IKnowHow Informatics (Greece)
  - RTD Partners
    - TWI (TWI Ltd, UK)
    - Kaunas University (Lithuania)
    - NewRail (UK)
  - End user Partner
    - Jarvis (Jarvis Plc, UK)

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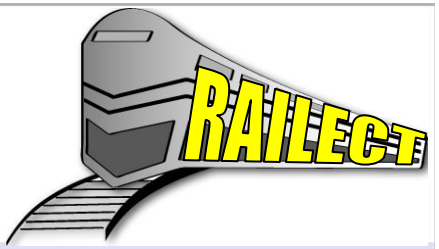
Project background



- Estimated 11 million site aluminothermic welds on the Europe rail network
- Thousands of new welds every day throughout Europe
- Economic and safety drivers – early failures causing operational problems
- No suitable NDT inspection methods for inspection of aluminothermic welds with adequate defect sizing capability for lack of fusion defects (cannot be done with radiography)
- Acceptance criteria for these defects unknown

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Welding Process steps

1- Cutting and Alignment

2- Mould Fastened

3- Preheating

(Courtesy of Jarvis)

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Process steps (cont.)

4- Discharged of molten steel

(Courtesy of Jarvis)

5- Cooling and grinding

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Defect and failure

- Types of volumetric defects
  - Normally associated with gravity feed castings
    - shrinkage (centreline solidification / shrinkage defects particularly in the web/foot zone
    - lack of fusion
    - slag inclusions and porosity
  - The main two types of weld failure are;
    - A vertical fracture associated with shrinkage
    - Split web or S fracture resulting from the cyclic nature of torsional stress in the rail web on bends in the track

LOF in foot defect

Shrinkage defect

Porosity defects

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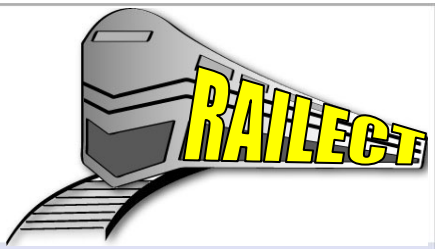
NDT State of Art



- Conventional volumetric methods unsuitable for rapid inspection
- Visual inspection not volumetric
- Radiography limited by health and safety requirement and can only size defect in one dimension
- UT subject to difficult application (complex manual scanning), sophisticated interpretation, no inspection of the weld foot and operator dependant
- Magnetic methods possibility of interference with track circuit rules

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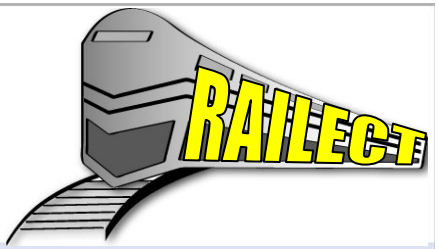
Project objectives



- Collection of information about the performance of aluminothermic welds in the presence of defect
- Development and validation of ultrasonic models describing the detection defect in various locations
- Design of an ultrasonic system containing a combination phased array and conventional multi-probe systems with a combined output
- Development of a prototype system
- Validation of the final prototype by both laboratory and field trials

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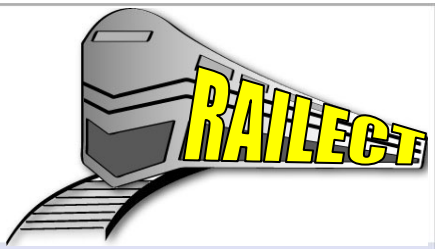
Work Packages



- WP1 - Review, System specification & Sample acquisition
- WP2 - Determine acceptance criteria
- WP3 - Ultrasonic Modelling
- WP4 - Ultrasonic System Design
- WP5 - System Manufacture
- WP6 - Software & System Integration
- WP7 - Laboratory & Field Trials
- WP8 - Exploitation, Dissemination & Training
- WP9 - Project & Coordination Management

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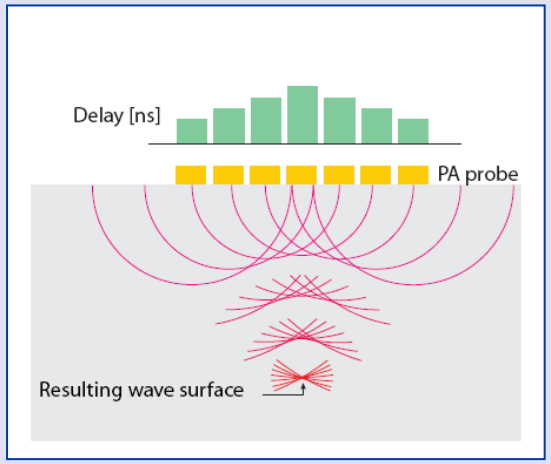
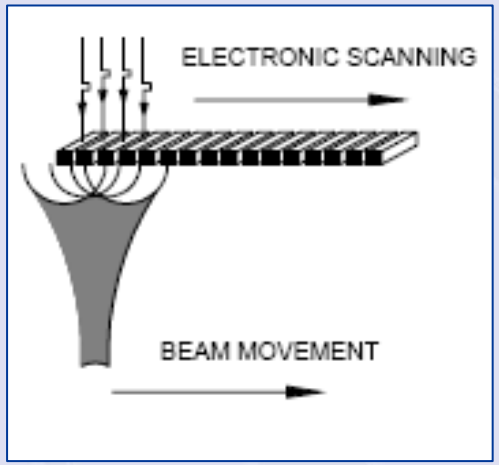
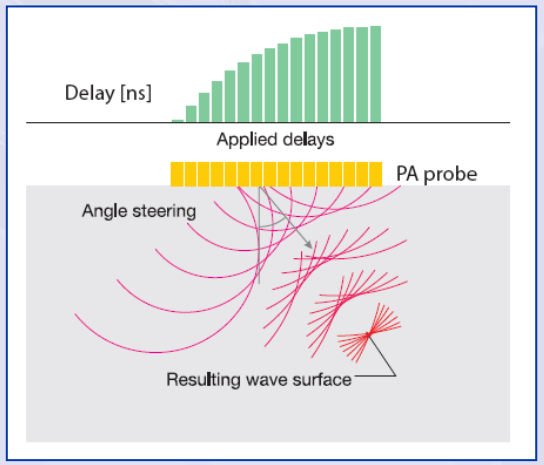
Ultrasonic technique

- Propagation of ultrasonic wave and collection of reflected signal from discontinuity
- Multiple elements enable to steer, focus and scan beams with a single transducer assembly to map components at appropriate angles







Beam focusing principle for normal and angled incidences

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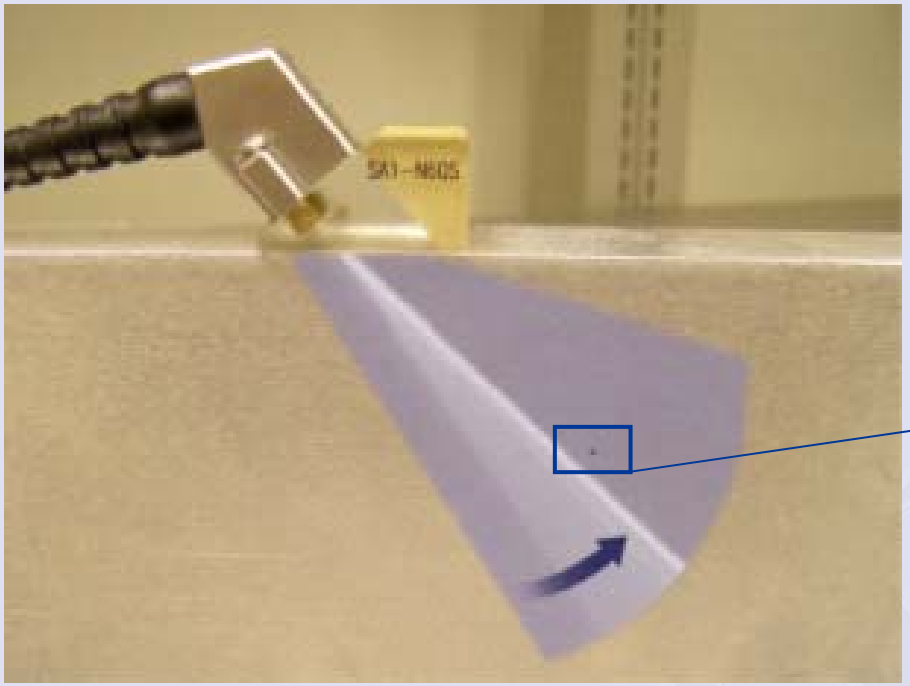
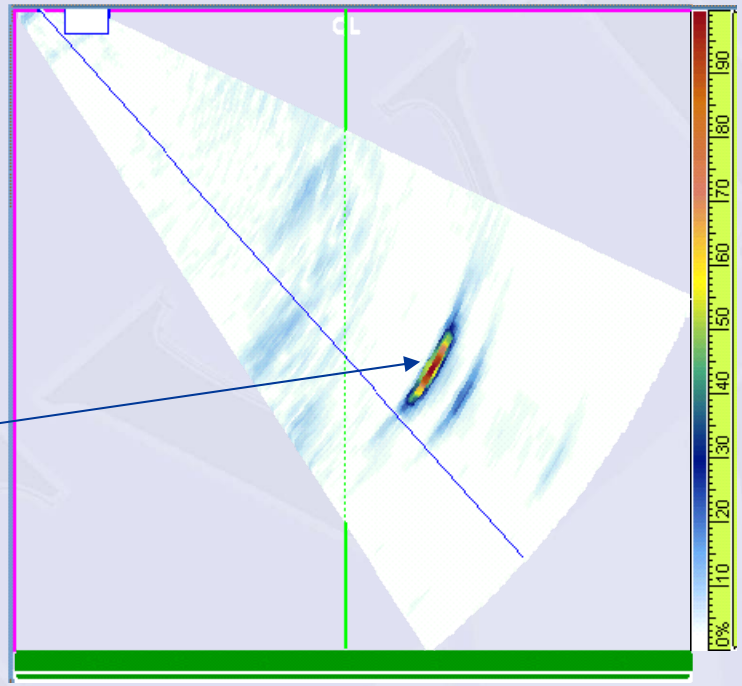
Ultrasonic technique (Cont.)

- Phased array imaging





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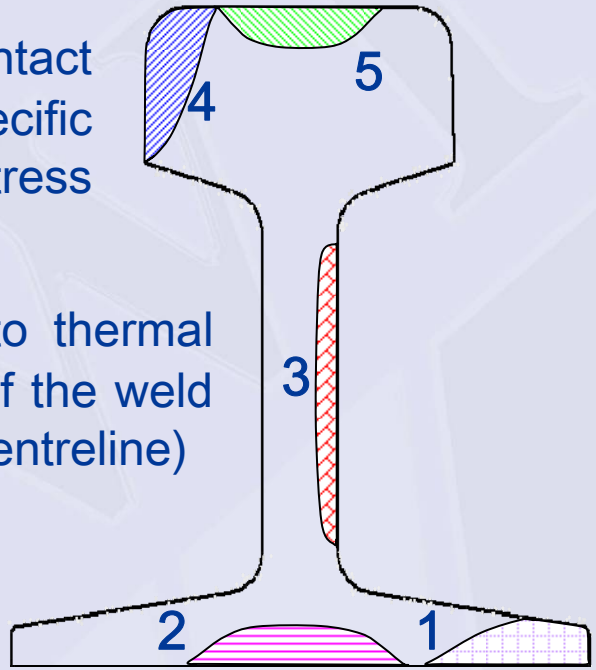
Review of literature

- Rail Defects - Fatigue failures specific to welds
  - **Location 5:** Squat defects and/or rolling contact fatigue. Caused by plastic flow and subsequent crack growth
  - **Location 4:** Gauge corner cracking (rolling contact fatigue). Wear failures. Also subject to weld specific failures in the head are often the result of internal stress concentrations at inclusions or pores.
  - **Location 3:** Shrinkage cavity formation, due to thermal expansion and phase transformations the volume of the weld metal changes during weld formation and cooling (centreline)
  - **Locations 2 and 3:** Centreline defects and micro-shrinkage. Weld defects are often found on the very centreline of the weld
  - **Location 1:** Lack of fusion defect due to welding process



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System specification

- Overview of end user requirements
  - The device is for the inspection of AT rail welds and is to be used after the welding process (few days)
  - The device should be: Portable; Weatherproof and functional in inclement weather; Easy to operate; Give clear indications of defective welds


Gap between rails at the preparation stage


Gap between sleepers and restricted access to the weld foot


Finished cast

  - Normal Gap width: 25mm wide (± 2mm each rail), range: 26 to 80 mm
  - The finished cast width: 35mm (Normal Gap), range: 35 to 90 mm
  - Gap between sleepers: 340mm minimum - welds not always at the centre
  - Consideration must be given to the track housing

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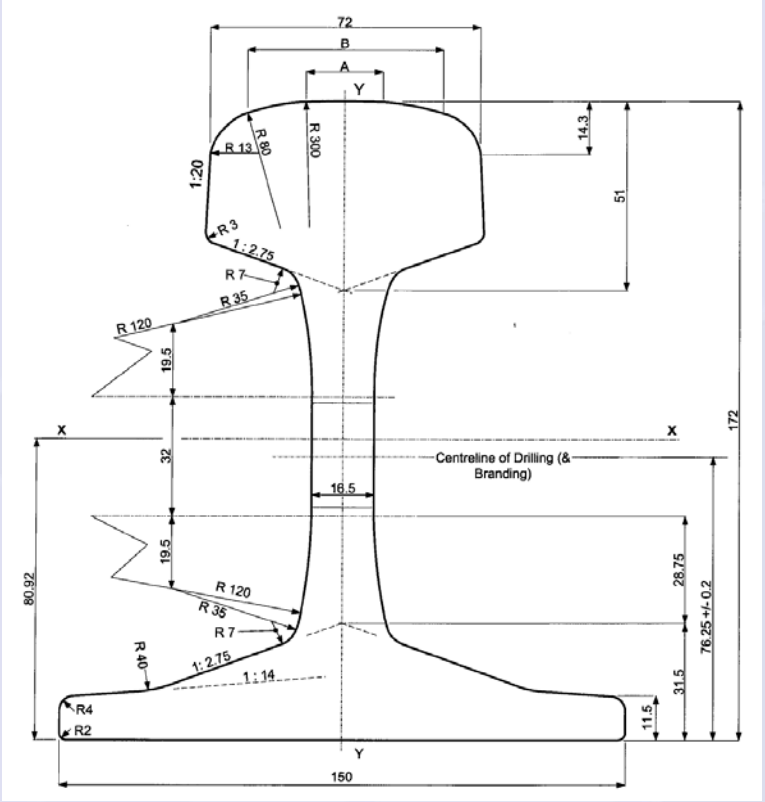
System specification

- Expected performance of the RAILECT device
  - Portability & Weatherproofing
    - Ideal weight: 5Kg (guide weight: up to 20kg)
    - Battery operated (optionally from a vehicle battery)
    - Self contained and operational within ambient temperatures in Europe
  - Operation
    - Being installed on CEN60E1 rail type
    - Being installed within 150mm of weld centre
    - Being installed by a simple clipping mechanism



SEVENTH FRAMEWORK PROGRAMME

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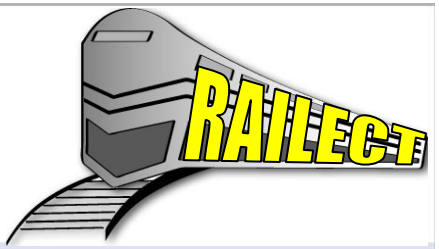
System specification



- Expected performance of the RAILECT device
  - Operation
    - Being installed and operable from the upper section of the rail (i.e. avoiding the need for ballast removal and replacement)
    - Automatically sequence any tests that need to be done
    - Giving an indication of a defective weld in a simple way by comparison of the data with the acceptance criteria through the software to be developed
    - In order to generate ultrasonic waves within the joint, the device will need access to water and / or couplant
  - Technical Performance
    - Should be tolerant to the position of the fusion faces (+/- 5mm)
    - Should detect defects selected within the project

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Design & manufacture of samples

- Test samples

Rail Samples

Batch of good samples
Samples with porosity defect (head)
Samples with LOF defect (foot)
Samples with shrinkage defect (lower body)

Preliminary NDT inspection

All samples to be radiographed to confirm the presence and/or the absence of defect

Fatigue endurance tests

Some samples to be fatigue tested to help establishing the ECA criteria

Development of the PA technique

Some samples to be kept for the development and the validation of the inspection device towards the end of project

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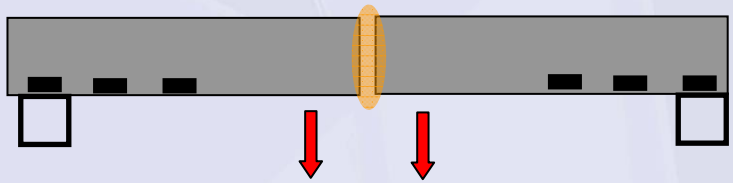
Design & manufacture of samples

- Shrinkage defect
  - Chemical method
    - Making weld metal more susceptible to solidification defects/ hot tears
    - Additions of sulphur/ phosphorus
    - Proven technique for arc welds
  - Manipulation of welded joint
    - Longitudinal stresses >100 tons
    - Vertical manipulation easier
    - After mould break-off
    - 1-2mm deflection
    - 20 ton loads applied



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Design & manufacture of samples

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Ultrasonic modelling

- Objectives
  - To model the output signals from a range of ultrasonic probes and defects
  - To provide the number of probes and types of probes
- Tasks
  - To model the output signals in the rail weld from a range of ultrasonic probes
    - Different types of probes
    - Different frequencies
    - Different angles

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Ultrasonic modelling

- Tasks (cont.)
  - To characterise the ultrasonic beam behaviour in the rail weld
    - In the weld without defects
    - In the weld with different defects (Porosity in the head, Shrinkage defect on the body and Lack of fusion on the foot)
  - Using the modelling results to establish essential variables of the inspection
- Expected problems
  - Non-linearities of the ultrasonic properties in the weld material caused by the grain structure

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Future plans

- Transducer specification for linear / Phased array
  - Acoustical device
    - Number of elements
    - Centre frequency
    - Pitch
    - Elevation
    - Linear / curved, Radius of curvature (if applicable)
    - Focusing distance (if applicable)
    - Acoustical matching (e.g. water)
    - Typical bandwith @-6dB
    - Element to element sensitivity variation (+/-3dB)
    - Probe to probe average sensitivity variation (+/-2dB)
  - Operating conditions
    - Typical temperature in storage (e.g. 0°C to 50°C) and in use (e.g. 10°C to 40°C)
  - Connector / Cable / Housing
    - Connector type
    - Cable length and output (side / top of the housing)
    - Housing external dimensions and shape (in case of space constraints)

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Future plans

- PA equipment
  - Preparation of electronics, that allows to control any kind of phase array head and will deliver description and dll's for the software development (device control, data visualisation)
  - The software will be compatible to the software, delivered with optel ultrasonic cards and boxes but naturally will have functions for control of the phase array (special multiplexer)

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