SP4 Advanced Monitoring
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Workpackages and content

**SP 4 – Advanced Monitoring**

- **WP 4.1** Monitoring Strategies and evaluation, Algorithms
  - Mechanical Analysis, Data handling, mathematics, „Customer needs“

- **WP 4.2** Monitoring Technologies & Sensor
  - Measurement technologies, overview and experiences in other industries

- **WP 4.3** Implementation in new structures
  - Civil engineering & monitoring technologies

- **WP 4.4** Migration of innovative technologies to existing structures
  - Infrastructure Knowledge and maintenance problems; measurement tech.

**Demonstrators**
Objectives of the last 36 months …

- Identify components and systems critical for operation/deterioration of the railway infrastructure that should be monitored

- Identify current and future monitoring possibilities. Process for technical and economical assessment

- Identify key operational parameters that govern deterioration of selected key components/systems

- Translation of measured data to deterioration predictions for these Collection strategies
Objectives of the last 36 months ...

- Functional and technical requirements for railway monitoring and inspection
- Identifying and evaluating sensor and energy harvesting technologies
- Identifying and evaluating communications and data integration technologies
- Demonstration of innovative monitoring concepts in the laboratory
Objectives of the last 36 month ...

- Specific monitoring requirements and techniques for the new infrastructure elements incl. build-in technologies and plug&play

- Analysis of the interaction/interference between sensors and infrastructure elements

- Development of procedures for installation, maintenance and replacement of sensors. Recommendations.

- Demonstration of innovative monitoring concepts in new infrastructure
Objectives of the last 36 months ...

- Identify fault and cost drivers. Provide retrofit kits for existing railway infrastructure

- Application without existing power and data infrastructure in a plug and play method

- Integration into existing railway maintenance and operation systems. Standardised Open Interfaces

- Economic evaluation. Recommendations/Guidelines
### Advanced Monitoring - Developments and Demonstrators

- **Analyses based on the available data**

#### Cost per damage

<table>
<thead>
<tr>
<th>Frequency of failure per time slice</th>
<th>Root cause analysis</th>
<th>Early warning</th>
<th>Act</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>Root cause analysis</td>
<td>Early warning</td>
<td>Act</td>
</tr>
<tr>
<td>moderate</td>
<td>Monitoring</td>
<td>Root cause analysis</td>
<td>Early warning</td>
</tr>
<tr>
<td>low</td>
<td>Do nothing</td>
<td>Monitoring</td>
<td>Root cause analysis</td>
</tr>
</tbody>
</table>

- **Frequency of failure per time slice**
- **low**
- **moderate**
- **high**

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**Advanced Monitoring**

- **Developments and Demonstrators**
- **Analyses based on the available data**
The main objective is to reduce the number of technical disruptions and delay minutes as well as reducing the related life cycle costs of the switches. In detail, the defined tasks to achieve the objectives are:

- Establishment of simple key performance indicators related to the availability for controlling substantial production means (performance measurement, analysis and monitoring system).
- Classification of all switches on availability criteria
- Definition of equipment standard for the complete system switch (which switch category gets e.g. a heating system or closure compartment cover) or diagnostic to fulfill performance requirements
- Development of a strategy for the preventive maintenance and implementation concept
- Target-actual comparison regarding the equipment standard sharply outlined on the switch
Important differences

- **Monitoring**
  Measuring of direct or indirect values to identify unusual product behaviour. (Switches $\rightarrow$ measurement of the current)

- **Diagnosis**
  Automatic assessment of measured values. Repeatability ensured by statistic. Clear Knowledge about the behaviour of components or products.

- **Inspection (Self-inspection)**
  Measurement or visual assessment of safety relevant behaviours. The measurement accuracy must be at least 10-times better than the value in the specification. (1.0 mm $\rightarrow$ 0.01 mm)

**TRADITIONAL POINT DIAGNOSTICS**

**DIANA**
Example: Point machine temperature-induced anomalies

**LONG-TERM POINT MACHINE BEHAVIOUR**

**Note:** Proprietary point diagnostic system reports no error
Technologies to be used to develop integrated solutions for next generation railway monitoring and inspection

- Specification, identification and evaluation

Scope

- Sensing, energy harvesting, communications, processing and data integration

Expectations

- Low cost, robust, intelligent, and low power

Near-horizon technologies or technology transfer from other domains

- Not the development of entirely new approaches
Identified Technologies + Technology Evaluation + Context = Technology to be Developed

Advanced Monitoring - Developments and Demonstrators - Technology Identification Framework
Evaluation at multiple levels

High level requirements
- Integration
- Standardisation

Mid level requirements
- Data aggregation, fusion and storage
- Fault detection (defect recognition)
- Diagnosis (evaluation algorithms)
- Prognosis (degradation algorithms)

Low level requirements
- Sensors (data acquisition)
- Energy harvesting (generation/storage)
- Communications

Technologies
Scores in different requirement categories are collated

Average: 5,2 + Average: 6,3 + Average: 7,9 = 19,4
Specific monitoring requirements and techniques

- Identification of weak points in the new slab track system:
  - High lateral forces in the stoppers
  - Possible movements in the gaps between consecutive slabs
  - Loss of tightening force in steel plates
  - Drainage of the blocks channels and the slab

- These possible weak points cause failures in the track components
  - New monitoring system should be designed in order to detect them

Objective: developing a new monitoring system which allow to detect the possible weak points in a remote way
Specific monitoring requirements and techniques

- Requirements for the integrated monitoring system
  - Sensor nodes shall be low-cost
  - Sensor nodes shall be energetically autonomous (battery-free or energy harvesting methods for self-recharging)
  - Sensor nodes shall be embedded in the infrastructure elements (i.e. below some centimetres of concrete)

- Low cost sensors
- No battery (passive RFID)
- Easy remote detection (contactless): hand reader or antenna reader
Specific monitoring requirements and techniques

- **RFID sensors**
  - **Strain** measurement
    - Strain/deformation in the rebar(s) of the concrete slab
  - **Temperature** measurement
    - Changes in concrete behaviour (sensor embedded in the concrete slab)
  - **Humidity** measurement
    - Detection of possible cracks or failures in the slab (embedded in concrete)

Need to perform interference assessment in reinforced concrete (RC) elements
Specific monitoring requirements and techniques

- **Interferences analysis**
  - Different concrete thickness
  - Possible steel interferences
  - PVC coating for RFID sensor
Specific monitoring requirements and techniques

- Results
  - Good range of reading
  - Max. 6 cm for concrete cover
  - PVC coating do not affect to the signals

Next step:
Real scale validation in test box (CEDEX)
• Energy harvesting technologies
  – Identification
  – Evaluation
• Sensors
• Retro-fitting in existing railway
• Future plan
Vibration

- PI Ceramic energy harvesting kit including:
  - 2 DuraAct Patch transducers
  - Electronic Module
Solar

- **Texas Instruments**
  - 400+ transmissions in dark
  - Inputs for external energy harvesters such as thermal, piezoelectric, 2nd solar panel, etc...
  - Ultra low power MCU with 16Mhz performance
  - Integrated temperature sensor
  - Integrated 2.4Ghz wireless transceiver
• Thermoelectric
• Laird Thermal Power Module
  – Self-contained thin-film thermoelectric power generator with regulated output voltage
  – Up to 1.5 mW of usable output power stored in a micro power module
• MicroPelt – Peltier Thermogenerator
  – Packaged thermogenerator
  – Maintenance-free solid state operation;
  – High power density;
  – Low weight and thermal mass
    Output voltage of 60 mV/K
  – Dimensions: 15x10x9 mm.
• Laser/PSD used to measure the vertical displacement of the rail
• Vibration generate by the passing train
Voltage across the capacitor
Total energy = $E = \frac{1}{2} \times C \times V_{cap}^2$
Advanced Monitoring - Developments and Demonstrators
- UoB Wireless Node System Overview

**Sleeper Node**
- Accelerometer
- MCU + Memory
- ISM Wireless Module
- Temperature
- Battery Voltage

**Master Node**
- WiFi / 3G module
- ARM device
- SD Memory Card
- ISM Wireless Module

Low-power
Low-frequency
ISM band
Advanced Monitoring - Developments and Demonstrators
- UoB Sleeper node

• Internal accelerometer
• ‘Sleeps’ until a train is detected
• Samples at 1600 Ss\(^{-1}\)
• Downsampling to 800 Ss\(^{-1}\)
• Stored in memory (16KB)
• Transmitted to master node after train has passed
• Battery powered – designed to last ~5 years
• Small size, to be mounted on sleeper end
- Low frequency ISM band
- 868 MHz FSK
- Very low power
- Each node transmits at specified time slot
- Real-time clocks are periodically synchronised by the master
• Monitoring sleepers at UK high-speed 1 using low power accelerometer and embedded system
  – Eurostars
  – Javelines
  – Freight trains

• Monitoring the noise signature pre/post grinding
  – Use of lower power microphone and embedded system
• 3x accelerometer installed in Kent UK – High speed line

• Around 1400 measurement were taken in 2 weeks
  – Line speed
    220 kph to 300 kph
• Displacement curve for the three accelerometers
• One seems to be slightly different to the other two

Less well supported sleeper
• Lower RMS values in the sound pressure level after grinding
Advanced Monitoring - Developments and Demonstrators
- Rail Grinding – Sound Pressure

Pre-grinding

Post-grinding

Post-grinding wheel/rail interface harmonics
• Transition zone monitoring

New Sado river crossing
• Transition zone site – Rio Sado
A first evaluation of an Optasence-fingerprint of a high-speed line was done and should be analysed by track specialists within the department (DB).
Switch type W874 & W873, km 321,2: EWR 60-1200-1:.., concrete sleeper, movable frog, 
V_max = 250 km/h, typ. 230 km/h

Test site advantages:

- Track geometry by wayside monitoring (tilt-sensors)
- Sleeper voids by accelerometer
- Measurements by regular inspection by measurement train all 3 month
- Weekly monitoring by equipped ICE-2 train
- Acoustic monitoring of the switch (class-1 standard)
...any questions?

Thank you for your attention!

- Mani Entezami, Edd Stewart, Graeme Yeo, - University of Birmingham
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- Gunnar Baumann - DB Netz AG