- NEW AXLE COATINGS AND AXLE PREPARATION –

RESULTS FROM EURAXLES

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POLITECNICO DI MILANO

GHH-BONATRANS GROUP

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Introduction

- **EURAXLES**

- **Duration:** 3.5 years , November 2010 – April 2014

- **EU-Project** under the Seventh Framework Programme FP7 (FP7- 265706)
- In total **23 European partner**

- **Objective:**
  - Minimizing the Risk of Fatigue Failure of Railway Axles,
  - Increasing the reliability of the European interoperable railway traffic operation

Changes *at one position of the whole system design, production, operation, inspection and maintenance could jeopardise the system stability.*

- **EURAXLES**: **Global approach** for design, production and maintenance, The project was organized into 5 technical work packages completing themselves, and into 3 fundamental scopes.

Introduction

1. a **new fatigue design approach**, coupled with a consistent numerical calculation methodology which predicts the probability of failure of an axle,

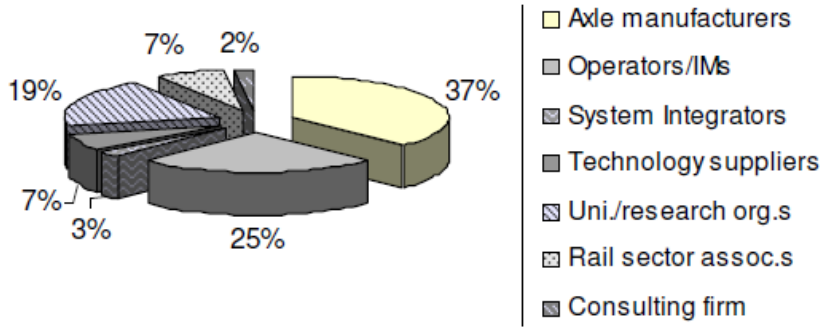
2. an **improved design of the axles for roughness including the development of innovative painting and coating solutions** with regard to environmental requirements,

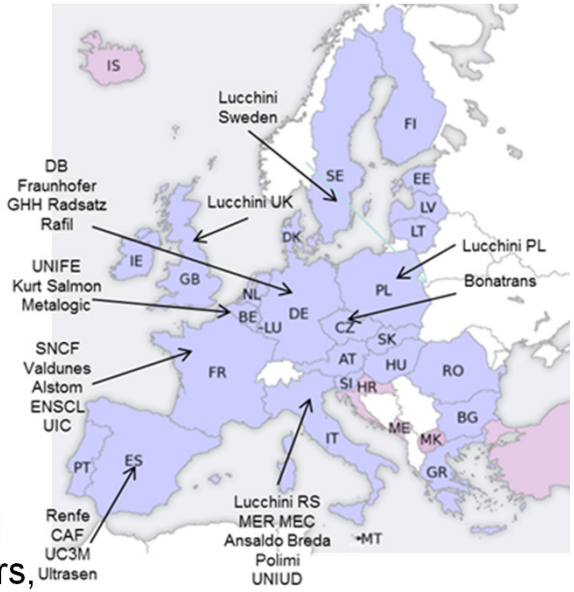
3. **simplified improved/new non-destructive testing techniques** that will allow accurate inspection under the train without any disassembly and train stopping for several days.

RAMS and LCC analyses undertaken will allow a cost benefit comparison of the proposed solutions for an optimised market uptake.

WP 4 - Tools, technologies and surface protection systems minimizing the negative influence of corrosion or surface damages on the free axle surface -

Introduction, Consortium





Project led by UNIFE, uniting 23 partners across Europe including 6 axle manufacturers, 4 railway operators/IMs, 2 system integrators, 3 technology suppliers, 5 universities, 2 rail sector associations and 1 consulting company.

Advisory Groups:

Paint suppliers:

- **Arcane Industries**
- **AXSON France**
- **Mäder Aqualack**
- **Mankiewicz**
- **Novatic**
- **Weckerle**
- **Weilburger Coatings**

End users:

- **Nedtrein**

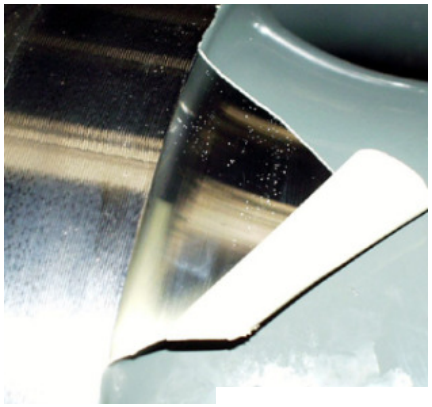
- **Project-start: 01.11.2010 End: 30.04.2014, Duration: 42 months**

Current situation/ motivation for WP4

WP 4- Tools, technologies and surface protection systems minimizing the negative influence of corrosion or surface damages on the free axle surface -

- Decrease of VOC pollution due to legislation has led to change of painting systems in use.
- Many adhesion problems occurred on the very smooth surface of railway axles, especially in the transition area.

Operators, wheelset manufacturers and paint suppliers need to work jointly on a feasible solution.



Objectives of WP4

- Develop new reliable methods for **improvement of the adhesion behaviour** of **water based painting systems** applied on axles with various surface roughness conditions; new requirements for the paint process technology.
- Investigate **innovative painting and coating systems**, introducing more environmentally friendly technologies and reducing VOC pollution versus traditional methods.
- Define the **requirements for new alternative design method** recommendations without a necessary painting system and for innovative treatment solutions
- Investigate **alternative quality test methods** for the painting/coating and protection systems to meet a quality standard under consideration of the realistic operating conditions.
- Implement the results into the **rules for new production and maintenance** of wheel-sets and act as a guideline for more cost/time efficient wheel-set production, maintenance and repair.
- Improve and revise the **European standards for wheel-sets** by deriving recommendations concerning **design and product requirements**.

Main work items

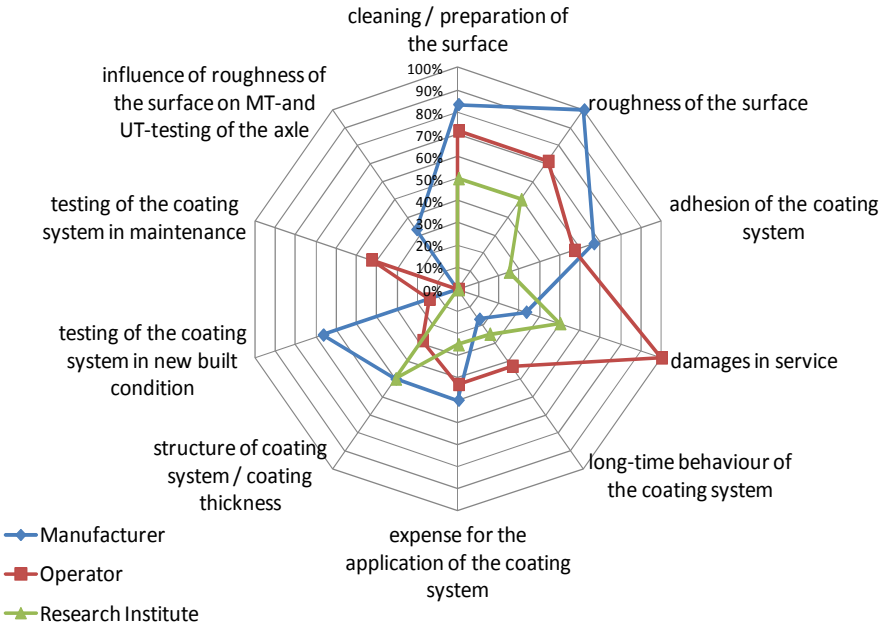
- **State of the art:** database for painting and coating systems, process technologies, quality test methods and service conditions, build up by a survey among European axle producers, operators and paint supplier. Review of European standards and national requirements.
- **Test series** to analyse the correlation between **surface preparation and adhesion** of the painting systems.
- Investigation of the corrosion on **unpainted axles from service**.
- **Alternative coating systems** from other industries.
- **Innovative coating systems**: APECVD and PECVD coating, plasma nitriding, Ni-SiC nano-coating.
- Analysis of the **painting test methods in standard EN 13261** regarding their significance and applicability. Investigation of alternative testing methods.

Survey results

Survey among operators, manufacturers, paint suppliers and research institutes to determine state of the art:

- A wide range of different types of paintings and coatings are used nowadays in the railway industry.
- In recent years a trend is apparent to reduce the consumption of paints containing VOC's.

- But only limited application of VOC-free, water based paintings.
- There is not sufficient knowledge of the connection between paintings, the operating conditions and the environment.
- The reliability of paint and coating systems need to be increased to prolong the lifetime of the corrosion protection
- SNCB use axles without painting or coating systems, and the axles do not have special problems to corrosion fatigue.



Reasons for problems with paint systems

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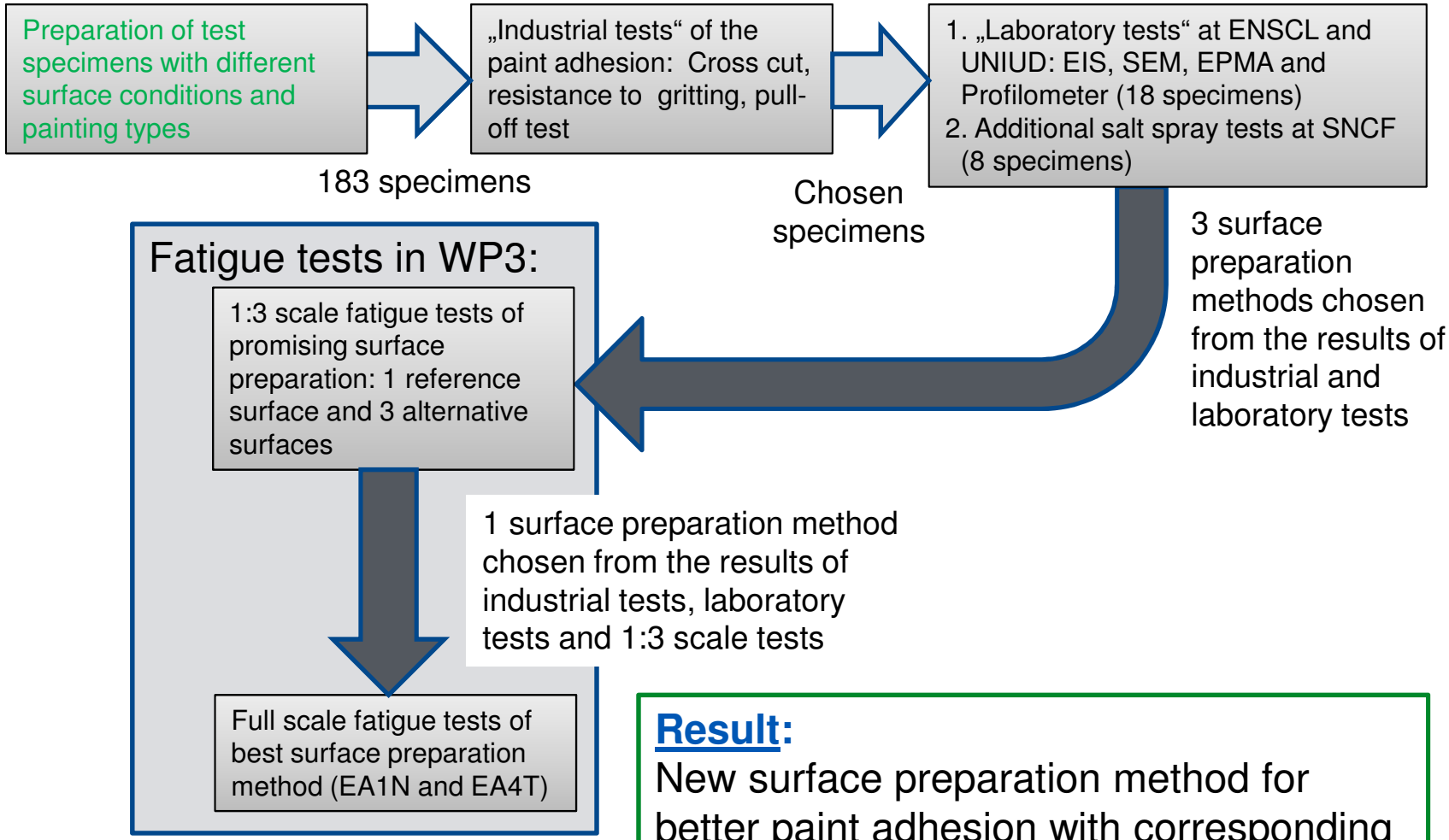
Determine a new surface preparation method

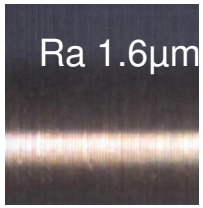


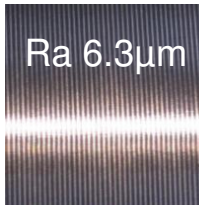
Result:
New surface preparation method for better paint adhesion with corresponding fatigue limit

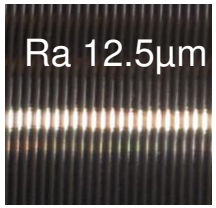
Preparation of test specimens (183)

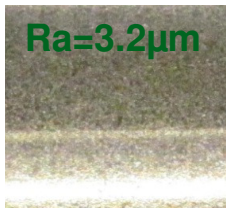
Roughness after turning Ra	Roughness after grit blasting Ra	Chemical adhesion promoter	Paint System
0.8 µm 1.6 µm 3.2 µm 6.3 µm 12.5 µm	No blasting 3.2 µm 6.3 µm 12.5 µm	No promoter Phosphating agent Silane agent	6 different Monolayer Systems 6 different Duolayer Systems

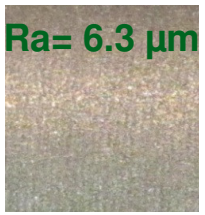
Examples of different surfaces after turning and blasting



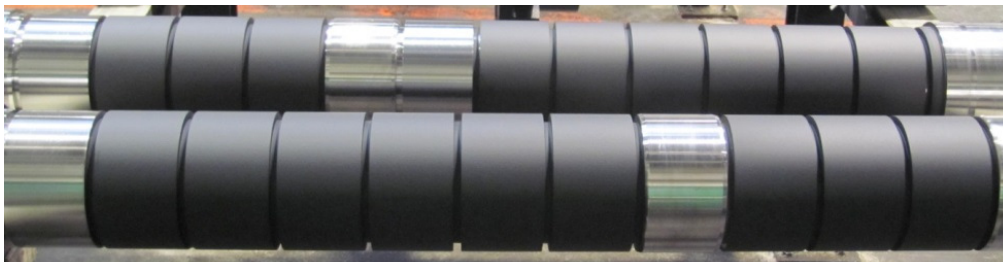




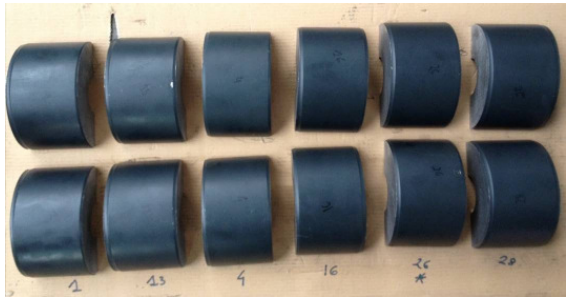




Example: two axles with different surfaces preparations on each section



Finished samples



Results of test series

- The obtained results were **mainly depending on the paint system**
- **No clear correlation** between surface preparation and adhesion in industrial tests
- The tests did not generally prove the increase of adhesion for rougher surfaces (higher Ra value)
- Tests with artificial ageing (like the EIS tests at UNIUD and the additional salt spray tests) showed an **improvement of paint adhesion on blasted surface**
- The **surface preparation method** (blasting or turning) **is more important** than the obtained roughness
- Surface conditions were defined and reproduced on test specimens (scale 1:3 and 1:1) in order to obtain the **fatigue validation** (done in WP3)

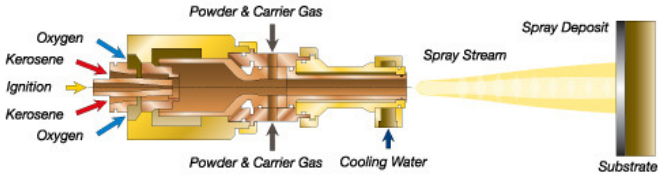
Recommendation from WP4

- **Recommendation for surface preparation for improved paint adhesion:**
  - Grit blasting with high carbon steel, angular (alternative: ceramic shot).
  - Maximum roughness Ra=6.3µm

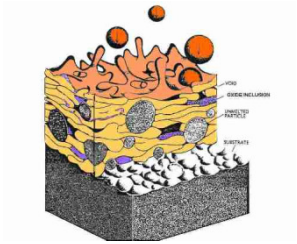
- **Reasons:**
  - Test series showed that main improvement for paint adhesion after ageing depends on surface preparation method
  - Grit blasting showed best results, as also experience from service shows
  - In maintenance blasting is current practise, in new production it is currently not intended in the standards

Alternative coatings from other industries

- From literature search and survey among institutes and coating companies Zi-Al coating by thermal spraying was found as promising solution regarding corrosion protection and cost effectiveness.



scheme of HVOF thermal sprayed coating,



thermal flame sprayed coating,

Innovative coatings

- ENSCL investigated Plasma Nitriding and (A)PECVD:
  - Dry processes (no solvent is used)
  - Good adhesion of the coatings
  - Environmentally friendly
- UNIUD investigated Ni/SiC nano coatings:
  - Already tested on axles
  - No solvent necessary
  - Environmentally friendly

Recommendations from WP4

- **Recommendation for alternative and innovative coatings:**
  - Further investigations are recommended for
    - Zi-Al coating by thermal spraying
    - Cold plasma nitriding
    - Ni/SiC nano coating

- **Reasons:**
  - Expectation of good corrosion protection
  - Further investigations need to concern maintenance operations and general service experience

Investigations on unpainted axles

- Unpainted corroded axles from SNCB
  - Passenger coach axles
  - Age: 10 to 12 years in service
  - Milage: between 877.000 km and 1.540.000 km
  - Last overhaul: between 280.000 km and 1.000.000 km
  - 9 axles were tested

  The experience of SNCB is very good, no failures due to corrosion were reported

- Unpainted axles were gathered for fatigue testing in WP3

Recommendations from WP4

- Unpainted axles:
  - Artificial corrosion was not possible: Tests could only be performed with axles from service
  - Reduction of fatigue limit to 60% seems to be very conservative For results and evaluation of the; fatigue tests-> see WP3, first estimation about 80 – 85%

Quality test methods acc. EN 13261

- **General recommendations for quality test methods from manufacturers and operators:**
  - Tests should reflect the **real conditions**
  - Tests must be **repeatable**
  - Test methods should be defined **clearly and consistently**
  - Tests should be as **simple** as possible

- **Possible improvements:**
  - Tests from **automotive industry** can **reduce costs**, as they are commonly available
  - Definition of **scope of application**: For homologation of painting system, for each batch (production control), and maintenance of axles

Quality test methods acc. EN 13261

Painting systems are divided into **4 classes**:

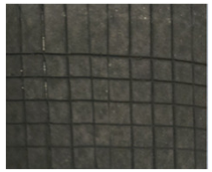
- **Class 1:** axles that are subject to atmospheric corrosion and to mechanical impacts;
- **Class 2:** axles that are subject to the action of specific corrosive products;
- **Class 3:** axles that are subject to atmospheric corrosion;
- **Class 4:** axles that are subject to atmospheric corrosion when the stresses calculated according to EN 13103 and EN 13104 are less than 60 % of limit stresses.

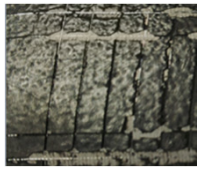
The European standard for axles **EN 13261** defines **7 test methods** for testing of paint systems:

		Class 1	Class 2	Class 3	Class 4
1	Coating thickness	X	X	X	-
2	Coating adhesion	X	X	X	-
3	Resistance to impacts	X	-	-	-
4	Resistance to gritting	X	X	X	-
5	Resistance to salt spray	X	X	X	-
6	Resistance to specific corrosive products	-	X	-	-
7	Coating resistance to cyclic mechanical stresses	X	X	X	-

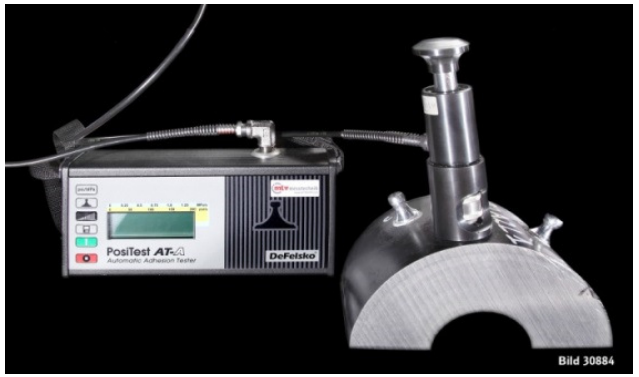
Quality test methods acc. EN 13261

- **1. Coating thickness**:
  - Only editorial remarks

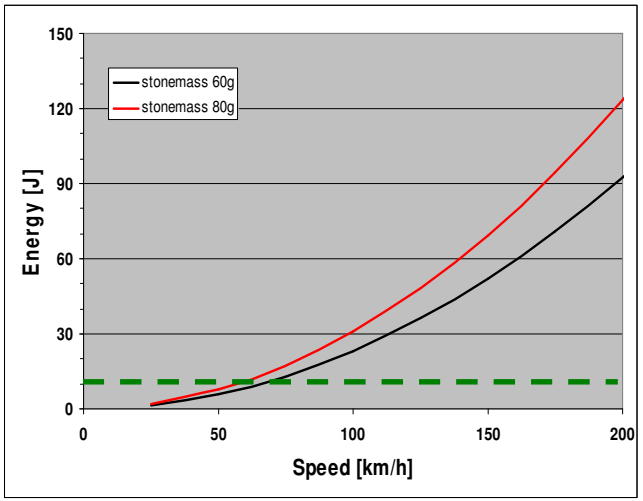




- **2. Adhesion testing**:
  - The adhesion is a characteristic of all adhesive forces applied between the coating and the axle surface
  - Alternative test method “Pull-off test” was investigated and already used in test series (acc. EN ISO 4624)
  - Proposal to use it also for thickness greater than 250µm additionally and greater than 1000µm
  - Cohesion break greater than 90%, minimum break force of 4 MPa recommended

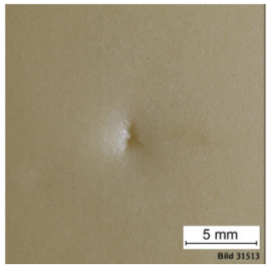


- **3. Resistance to impact** (for class 1):
  - Simulation of ballast impact
  - Currently 11,3 J impact energy in standard
  - 50J and 90J tested in the project
    (90J is the energy of stone with 60g at speed of 200km/h)

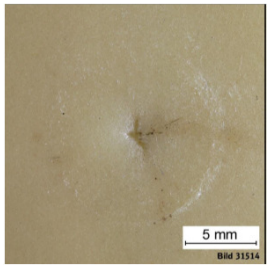


Quality test methods acc. EN 13261

- **3. Testing of new method for resistance to impact:**
  - Results of samples with existing class 1 coating: conditions: temperature -25°C / vertical impact / thickness 6-8 mm / energy 50J (left) 90 J (right)

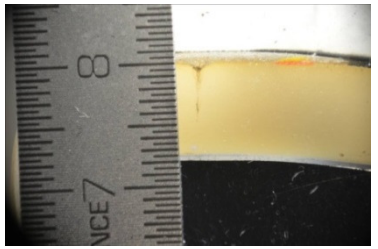


50 J

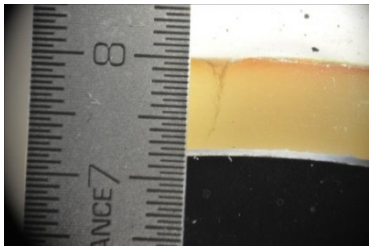


90 J

Impact from service

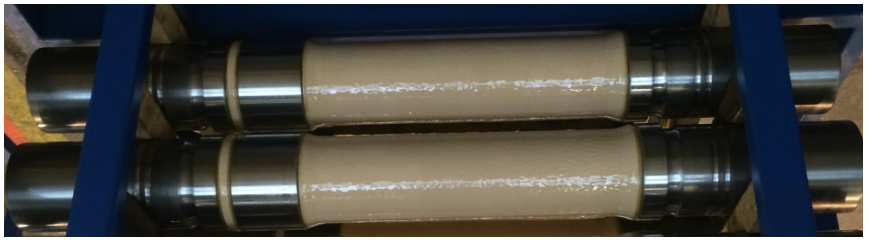


50 J

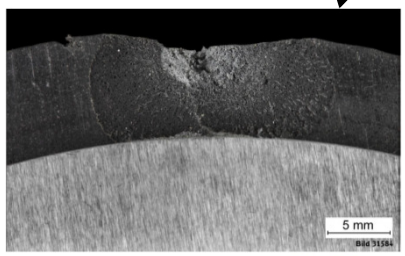


90 J

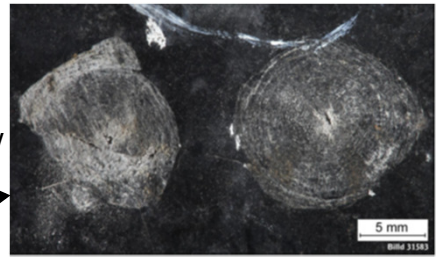
- Results of sample with another existing class 1 coating (cross-section after impact): conditions: temperature -25°C / vertical impact / thickness 5,5-8 mm energy 90J



Coated axles ICX, GHH Radsatz



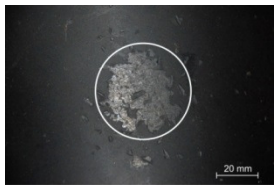
- Results of another class 1 coating conditions: temperature -25°C / vertical impact / thickness 6-8 mm / energy 90J (left) 50 J (right)



Quality test methods acc. EN 13261

- **4. Resistance to gritting**
  - Possible alternative: DIN EN ISO 20567-1 B - determination of stone chip resistance (common test method in automotive industry)
  - Currently experience with alternative test is missing

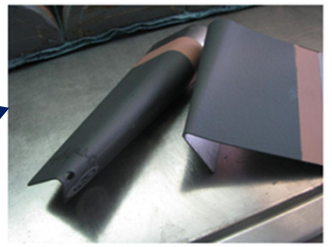
Examples of specimens after gritting test acc. EN 13262 (fall test with nuts)



- **5. Resistance to salt spray**
  - Test duration needs to be defined (480h, 750h or 1000h, depending from coating class). 480h recommended class 1,3. class 2 longer
  - Alternatively proposed test method: cyclic corrosion test (VDA) and humidity test (DIN EN ISO 11997-1 cycle B), consisting of 6 cycles:
  - 1 Day: Salt spray test (DIN EN ISO 9227)
  - 4 days: humidity test (DIN EN ISO 6270-2)
  - 2 days: recondition 18 – 28°C, 40 –60 % rel. humidity

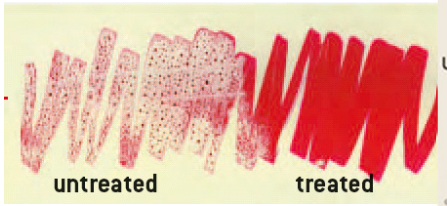
Quality test methods acc. EN 13261

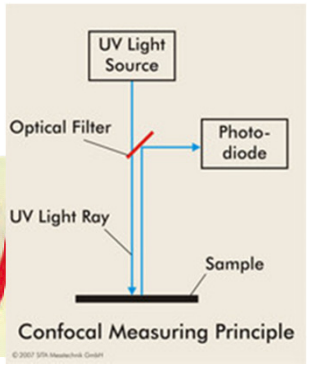
- **6. Resistance to specific corrosive products**
  - Only editorial remarks
- **7. Resistance to cyclic mechanical stresses**
  - Actual test is very time and cost consuming (cyclic bending)
  - Alternative methods only test the flexibility of the coating without cyclic bending:
    - Bend test (cylindrical mandrel bending)
      DIN EN ISO 1519 (mandrel diameter 40 mm) or
    - Bend test (conical mandrel bending) (EN ISO 6860)



    - Ericson test EN 1520

- Further topics:
  - **Test method for cleanliness test:**
    - Test methods: With testing ink, or fluorescence measurement





    - No property of the final axle, so not recommended for EN 13261

Recommendations from WP4

Quality test methods for painting systems in EN 13261

- Clarification in the standard for each test method, at which stage the test method shall be applied:

	Homologation of a coating system	Homologation of a manufacturer	Quality control in the production / maintenance process
Coating thickness	X	X	X
Coating adhesion	X	X	X
Resistance to impacts	X		
Resistance to gritting	X		
Resistance to corrosion	X		
Resistance to specific corrosive products	X		
Coating resistance to cyclic mechanical stresses	X		

Recommendations from WP4

- **Test methods for painting systems/ proposals for EN 13261:**
  - The tests of three class 1 protections were successful, no breakdown, only cracks in the coating, the energy of 90 J is recommended
  - A proposal for changes in EN 13261 clause 3.9 and related annexes was worked out and was given to European CEN standardisation group WG 11
  - Some alternative test methods could not be included, as experience is missing. These test methods are described in deliverable D4.7 and could still have an impact on the standard in a later revision
- **Test methods not related to EN 13261:**
  - Recommendation for testing of cleanliness an for fire protection
    - Requirements of EN 45545-2 and TSI also affect paint systems
    - Different test methods are required in EN 45545-2 and TSI CR WAG
    - No necessity to add in EN 13261, as already described in other documents

Standards related to fire protection of wheel sets

	Standard	Content	Comment
1	TSI WAG, 12.4.2013	Tests acc. ISO 5658-2 (2006-09-15) + Amendment 1 2011-11-01), flammability and lateral spread of flame, limit value CFE ≥ 18/KW/m² for thicknesses > 300µm	TSI WAG revision start 2014
2	TSI HS, 26.3.2008	At the moment only advice to draft EN 45545-2, that means it is not mandatory to apply this EN. Expected: in future reference to EN 45 545-2	National standard e.g. DIN 5510-2 2009-05 until 31.03.2016 (transition period) valid and applicable. TSI HS and TSI Loc&Pas merger started.
3	TSI Loc & Pas, 26.5.2011	At the moment only advice to draft EN 45545-2, that means it is not mandatory to apply this EN. Expected: in future reference to EN 45 545-2	National standard e.g. DIN 5510-2 2009-05 until 31.03.2016 (transition period) valid and applicable. TSI HS and TSI Loc&Pas merging in progress.
4	DIN 5510-2 2009-05	Procedure acc. DIN 54837, requirements acc. DIN 5510-2;	Intended recall the standard until 31.03.2016. (Substitution then by EN 45545-2)
5	EN 45545-2 2013-03 (DIN EN 45545-2 2013-08)	Wheel set = part no..: EX 10, requirement R9, reference T03.02, T10.02, T11,02: ISO 5660-1, heat release, ISO 5659-2, smoke density ISO 5659-2, smoke toxicity	Revision started, CEN/TC256/WG1 – Fire protection requirements comparable with other running gear components, such as air suspension, flexible metal-/-rubber-components
6.	EN 13 261 2009 + A1: 2010	Product requirements axles, inclusive verification for coatings => No requirements on fire protection.	At the moment under revision, CEN/TC256/SC2/WG11 – wheel sets
7.	EN 13 260 2009 + A1: 2010 and 13 262 2005 + A2: 2011	Product requirements wheel sets and wheels => No requirements on fire protection. .	At the moment under revision, CEN/TC256/SC2/WG11 – wheel sets

Status fire protection

Status standards:

- 1. **EN 45545-2** 2013-08 is **in force**.
  Requirements must be fulfilled for all painting / coating systems **independent from their thickness**.
- 2. When the **TSI HS, Loc&Pas und SRT** were published the EN 45545-2 was not published but only drafted.
  The TSI reference on this draft. But it is **not consequently necessary to apply the EN 45545-2** (see also RFU-RST-072).
  The TSI Loc&Pas and SRT reference to the TSI HS RST, where **is referenced to national standards**.
  In Germany we also can apply the DIN 5510-2.
- 3. **But after a transition period until 31.03.2016 the DIN EN 45545-2 replace national standards, in Germany the DIN 5510-2.**
- 4. The **TSI WAG** defines otherwise. For paintings / **coatings thicker than 0,3 mm tests according ISO 5658-2** 2006 (flammability and lateral spread of flame) has to be performed.

Status tests:

- **Class 1 coatings** (against impact) were already tested **sufficient acc. DIN 5510-2**.
- **Questionable** is **if** these systems can **fulfil also the EN 45545-2!**
- For **all other painting or coatings** systems it is **not known** if the fulfil the requirements acc. EN 45545-2 and ISO 5658-2.

Need for action:

- Known are fire resistant coatings but they were not developed to protect also against corrosion and impact.
- **Two different objectives!**
- A question is if the Class1 coating could be improved fort the requirements acc. EN 45545-2.

- **It is recommended to have only one standard for fire protection (EN 45545-2) were the other reference**

Possibilities to influence the standardisation:

- The EN 45545-2 in under revision. So we have the possibility to propose amendments via CEN WG11 to the fire protection WG.
- The TSI WAG is under revision. So we have the possibility to propose amendments via UNIFE / ERWA to the ERA.
- The TSI HS and TSI Loc&Pas will be merged at the moment.
  So we have also the possibility to propose amendments via UNIFE / ERWA to the ERA.

First proposal:

- **In a first step to perform some test with the main painting systems to get an impression about (1 test/ system) the fulfilment of the EN 45545-2 and ISO 5658-2.**

Main results, Conclusion

- **Summary of results and recommendations:**
  - State of the art was determined: Experience from service, painting process, analysis of quality test methods in standard and service conditions
  - Improved surface preparation method: Grit blasting shows improved adhesion behaviour, also for water-based (VOC reduced) painting systems.
  - Alternative and innovative coatings: Three environmental friendly coatings are recommended for further investigations. Especially service behaviour, maintenance aspects and inspection methods should be examined.
  - Proposals for revision of EN 13261, clause 3.9 for quality test methods of painting systems was prepared in WP4 and were be given to working group CEN/WG 11
  - Further recommendations were worked out for cleanliness check and for fire protection

Thank you for your kind attention

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Reports of the work-packages (Deliverables) are published on the internet side: www.euraxles.eu.

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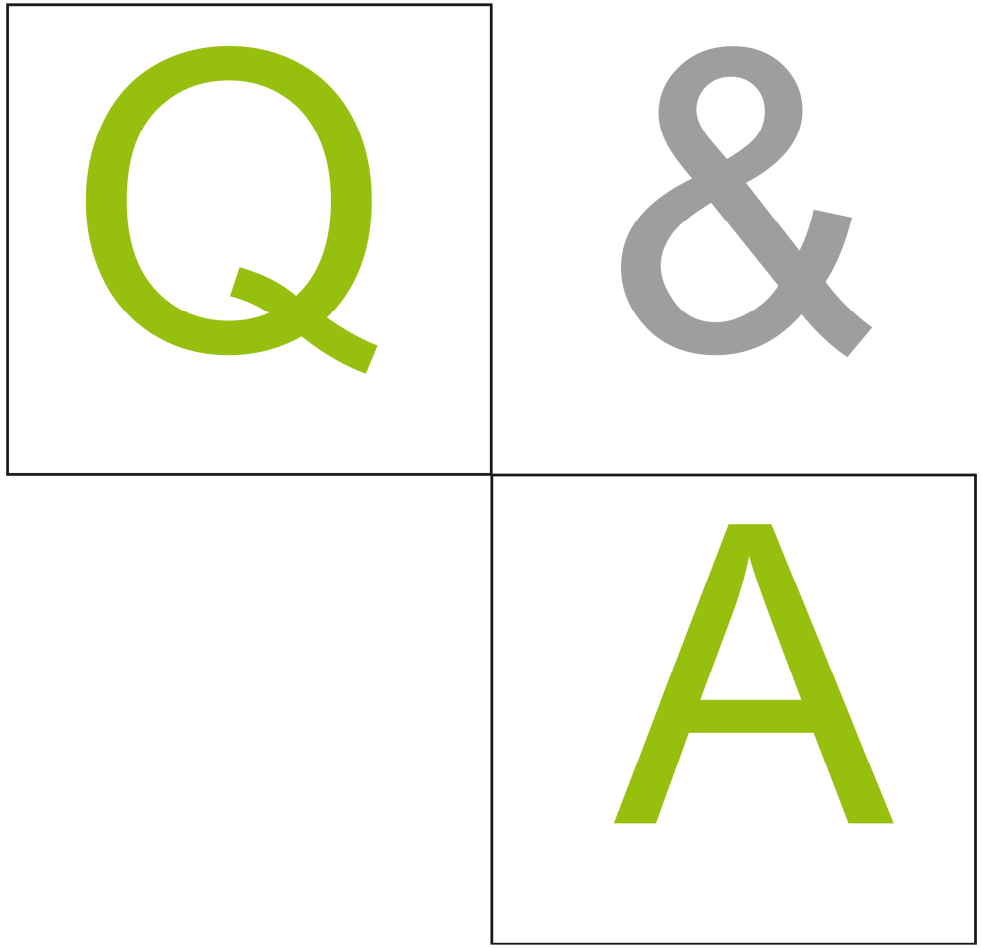

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