Axle Surface Coatings
IMechE Seminar 2014
Axle Surface Coatings – Alternatives to current UK practices

• UK axle surface coatings
• Limitations of UK axle surface coatings
• Alternative solutions for axle surface coatings
UK Axle Surface Coatings

Coatings are the most conventional method of protecting steel from corrosion

Organic coatings typically used for protection of railway axles

Provide protection either by a barrier action from the layer or from active corrosion inhibition supplied by pigments and additives in the coating

In the UK axle coatings are generally epoxy paint systems with a primer coat and top coat
UK Axle Surface Coatings

Single component oil based epoxy coatings were traditionally used;
- epoxy esters use straight from tin
- cross-linked by reaction with air
- example - BR81 spec

Majority now are a 2 component epoxy system;
- base component + Activator
- cross-linking reaction to form a thermosetting polymer

Epoxy coatings typically have good adhesion on metal substrates, when the conditions are right

Strong mechanical properties and high temperature and chemical resistance

Typical Thicknesses
- thinnest (BR81) 30 - 50μm
- thickest 300μm
UK Axle Surface Coatings

In reality, all polymeric coatings are permeable to corrosive species such as oxygen and water to varying degrees.

Corrosion of the coated substrate is prevented by:
• low water and oxygen permeability of the coating
• corrosion inhibitors in the coating – e.g. zinc primers
• good adhesion of the coating
UK Axle Surface Coatings

Conditions for good adhesion to a metal substrate

• Sa 2.5 very thorough blast cleaning: Near white metal 85% clean
• The surface shall be free from visible oil, dirt and grease.
• Surface profile of 30 – 40 μm
• Coat the surface immediately after cleaning and no handling
• Good wetting of the substrate
Limitations of UK axle coatings

Adhesion of paint to axles is a real challenge for the wheelset assembler

Paint suppliers recommend a surface profile of 30 – 40 microns

However, typical profile values for an axle (Ra 3.2μm):
- New machined axle ≈ 10 μm
- Grit blasted axle ≈ 14 μm
- Less on transition radii
Limitations of axle coatings

Poor adhesion of coating – undercoat corrosion

Poor adhesion at radii and poor overhang protection
Limitations of UK axle coatings

Ballast Strikes

Epoxy coatings are thin, hard and brittle - lend little resistance to high energy ballast impacts

Coating thickness and corrosion inhibitors are limited by in service NDT techniques - UT and ET from axlebody
Limitations of axle coatings

Ballast Strikes

- Small breaks in the protective coating expose a small area of substrate
- Accelerated corrosion of the exposed metal in localised areas

\[
\text{Fe} \rightarrow \text{Fe}^{2+} + 2e^{-}
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Limitations of axle coatings

Ballast Strikes

- If adhesion of the coating is poor, cathodic delamination will occur
- Undercutting leads to larger areas of corrosion
Limitations of axle coatings

Ballast Strikes

- Repair of the paint needs to be performed in situ in the depot.
Effect on industry

Safety – is the failure of axle coatings a safety problem?

- In UK, 17 axle failures identified as due to corrosion between 1983 and 2002
Effect on industry

Current axle coatings are definitely a cost issue

• In-service inspections and repair
• Axle reclamation by manual methods or machining
• Scrap axles (if a motor axle, additional gearbox work required)
Alternative solutions

Prevent undercoat corrosion and reduce corrosion following ballast impact – improve the coating adhesion

Chemical surface pretreatment - Phosphating of metal substrate

• Old technology used in Aerospace and automotive industries
• Applied by hand in the form of a liquid wash
• Cleans surface of oxides
• Forms an thin amorphous iron phosphate layer
• Iron phosphate promotes coating adhesion
• Increases corrosion resistance than just a coating alone
• Currently used in Europe for axles

8x 80x
Alternative solutions

Prevent undercoat corrosion and reduce corrosion following ballast impact – improve the coating adhesion

Increase surface profile

Axle surface profiles are below requirements for good mechanical interlocking

Item of research within the Euraxles project

Surface profile vs Fatigue life
Alternative solutions

Prevent coating failure following ballast impacts

Ballast impacts cause coating failures – corrosion

Also, ballast strikes mechanically damage the axle
- force of the strike is greater at higher speeds
- potential initiation site for fatigue crack

New generation of impact resistant coatings are being developed
• Innovative coating developed to meet EN 13261 class 1 requirements with high impact resistance
• Aerospace Epoxy system based on 3 components:
  - Wash Primer
  - Primer
  - Protective Top-coat (Finish)

The 3 layers have typical thickness of **4-5 mm**:
• Wash Primer, around 10 microns, for improving the adhesion to steel and protect from corrosion
• Primer (high thickness), flexible and reinforced with fibers, for absorbing the impact energy
• Protective Top-coat (Finish, high thickness), reinforced with fibers, for protecting against mechanical damage

The fibres guarantee a high level of consistency and mechanical resistance
Testing Regime

Tests in accordance with European Standards EN 13621, class 1 coating

- Coating adhesion (pull-off test)
- Impact test at -25°C and ambient temperature
- Gritting test
- Salt spray test
- Coating resistance to cyclic mechanical stresses

From the in-service feedback, Lucchini RS concluded that the requirements of EN 13261 may be not totally representative of the real running conditions.

Further tests carried out

- Impact test at -40°C, -30°C and +150°C
- Thermal stress test – Ageing and then Impact test at ambient temperature
- Dynamic test (braking test) in new and aged condition
- Full-scale fatigue test in aged condition
- Flame test
• Excellent adhesion to the railway axle surface

• High protection level against corrosion
  The maximum progress of corrosion, from the edges of the artificial aperture, after 1000 hours is about 0.70 mm: the limit allowed by EN 13261 is 2 mm;

• High protection against ballast impacts
  – suitable for high speed trains up to 450km/h
LURSAK paint remains in place for the life of the axle
- MPI at overhaul is not possible
- ET and UT from the axlebody not possible

For solid axles NDT is performed by UT inspection from the axle end using an innovative semi-automatic device

Device holds multiple probes against the axle end using magnets.
• Probe angle and frequency depends on the axle design
• One probe is used at a time to scan the critical axle areas based on design
Alternative solutions

Prevent coating failure following ballast impacts

Polymeric cover to protect axle against ballast impacts

Cross-linked polyethylene PEX material moulded to create a complete covering around the axle

A system of metallic strips fastens the cover to the railway axle.
Alternative solutions

Axle is painted underneath the cover to protect from corrosion

Thickness of the cover is approx 20mm

Used in Northern Europe to protect axle in extreme temperatures

First application in service since 2003

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- Painting to protect axle from corrosion
- Polymeric cover
Alternative solutions

Advantages

- Approved according to EN 13261
- PEX has high impact strength
- Less frequent in-service inspections
- Expensive paint can be replaced with anti-corrosion products
- Easily removed and replaced to enable in-service axlebody NDT
Other axle reclamation solutions

Mo coating for wheelseat and journal reclamation

- Axial scoring
- Corrosion

Axle seats reclaimed by removing damage/corrosion and rebuilding seat using thermally sprayed layer of Molybdenum

The thermal spraying does not cause critical temperature increases in the axle therefore does not affect the structure or the mechanical properties
Other axle reclamation solutions

1. Remove damage/corrosion by machining
2. Sandblast surface to be coated
3. Heat the axle
4. Thermal spray axle
5. Cool axle
6. Machine/grind to size
Other axle reclamation solutions

Advantages of Mo coating:

- Mo layer of 0.1 – 1.0 mm can be produced
- Increased resistance to mechanical wear and fretting
- Increase of corrosion resistance

Axles with Mo coated wheelseat, bearing journals currently being used by Deutsche Bahn
Other axle reclamation solutions

Axle machining to remove fretting defects

• Journal due to bearing spacers

• Abutment shoulder due to bearing rear seals
Other axle reclamation solutions

- Machined groove

- In use on new design axles as a preventative measure
Requirements for Epoxy axle coatings

- High level of substrate cleanliness
- High impermeability to moisture and oxygen
- Good adhesion to the substrate – mechanical and wet
- Seal both sides of wheel overhang
- **Repair ballast strikes promptly**

OR

- Use an impact and corrosion resistant solution
THANK YOU FOR YOUR ATTENTION