LURSAK: The new high performances axle protection

Dimitri Sala
Railway product
Research and Testing
Why protecting railway axles?

1. Wheelsets are the main safety components on the train;
2. It’s important preventing any crack on the axles surface;
3. Impacts from ballast may initiate fatigue cracks on the axle;
4. Protect against corrosion;

It’s important to keep in mind that extreme environmental conditions (e.g. ice, high temperature, etc.) may decrease drastically the performance of protective coating and so the protection of axle.
Referring to the extreme importance of axle integrity, the European Standard EN 13261: “All axles in service shall be protected against corrosion for the areas where there are no fitted components. For some axles, it is necessary to have protection against mechanical aggression (impacts, gritting, etc.).

Four classes of protection are defined:

- class 1: sections of axles subjected to atmospheric corrosion and to mechanical impacts;
- class 2: sections of axles subjected to the action of specific corrosive products;
- class 3: sections of axles subjected to atmospheric corrosion;
- class 4: axles subjected to atmospheric corrosion when the stresses calculated according to EN 13103 and EN 13104 in the sections are less than 60% of the permissible stresses;
- different classes are permitted on the same axle.”
In 2008 Lucchini RS has began to face problems of paint detachments from the axles mounted under some high speed trains running. This happened despite all the axles were protected with a paint which totally fulfilled the EN 13261 requirements (paint certified as class 1).

As example: progression of maximum running speed in service in China:

- 2008: 350 km/h -> Kin. En.: +65% in 3 years -> more critical impact, higher heating due to braking, higher centrifugal force on coating (higher “force of detachment”)
- 2011: 450 km/h

From the in-service feedback, Lucchini RS concluded that the requirements of EN 13261 may be not totally representative of the real running conditions.
Lucchini RS thinks that the boundary conditions that an axle meets during the in-service running are similar to the conditions that the external surface of a plane meets during the take-off and landing:

1. Presence of turbulences which can favor the impact with similar energy to dissipate
   - Normal running speed of train: 350-450 km/h
   - Normal speed during take-off: 250-290 km/h

2. Gradient of temperature extremely high
   - Surface railway axle: in few seconds high heating, up to +90°C, due to the brake disc heating during a braking
   - Surface of plane: in few minutes high cooling, from ground temperature to -40°-50°C

3. Resistance to aggressive atmospheric condition
   - Train: possible presence of water and salt (e.g. the train running near the sea)
   - Plane: possible presence of water and salt (e.g. planes of airplane carrier)
After some attempts to improve the performances of the coating without significantly improving, in 2008 Lucchini RS decided to take advantages of aerospace experience and know-how. -> 2008, September: first contact Lucchini RS - Akzo Nobel Aerospace*

Advantages:

1. **Access to Aerospace technologies** to provide advanced rate of axles protection;

2. **Utilize typical aerospace material and coating systems to grant improved performances** like flexibility, heat resistance, impact resistances and long lasting endurance;

3. Being always **informed on the more advanced best available painting technologies** coming from Aerospace passengers and military market.

* Akzo Nobel Aerospace is the leader company in this field
With the aims to define a new protective coating which totally fulfills the requirements (class 1) of EN 13261 Standard but it is also able to guarantee these performances both in new and aged condition in a wider temperature range (-40°C ÷ +150°C), it has defined LURSAK:

- Aerospace Epoxy system based on 3 components:
  - WashPrimer
  - Primer
  - Protective Top-coat (Finish)

The 3 layers have, usually, a total 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 scratches and creeps.

The fibres guarantee a high level of consistence and structural resistance.
The surface appearance is not smooth, like a classic paint, but rough.
During the period 2009-January 2011, LURSAK has been subjected to an intensive laboratory test program in order to verify its performance in different external conditions:

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**

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**
Coating adhesion (pull-off test)

No detachment of protective coating observed in the most severe condition (up to 25 MPa applied)

Impact test @ -25°C and R.T.
- Projectile Mass M: 0.587 kg
- Height of fall h: 2.08 m,
- Impact energy E: 12 J

No hole found in the protective coating and no alteration of axle surface has been detected.
Gritting test

The gritting test defines the ability of a coating to protect the axle from damage due to repeated sand or grind blasting.

- **Projectiles**: 1 kg of steel nuts dropped on the painted axle surface;
- **Height of fall h**: 5 m

According to EN 13261, **LURSAK can guarantee the maximum level of protection to the axle (Coating loss level 1*) against the repeated sand or grind blasting.**

* Coating loss level 1: level of protection if the percentage of coating came off in flakes is less than 10%
Salt spray test (ISO 9227, Corrosion tests in artificial atmospheres)

- Atmosphere: 5% of NaCl in water

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;

**LURSAK guarantees the protection against corrosion.**

---

**Coating resistance to cyclic mechanical stresses**

Fatigue tests on specimen in A1N steel grade covered with coating determining the ability of the coating to resist cyclic mechanical stresses combined with a corrosive product (demineralized water “drop by drop”) dropping on specimen surface.

Each of the 4 specimen have completed the 5 stress levels required (170 -> 210 MPa) without showing any failure.
Impact test at -40°C and +150°C (EN 13261 required -25°C and R.T.)

- Impact energy E: 12 J, as required by EN 13261.

No hole found, no alteration of axle surface has been detected.

Impact test at R.T. after coating ageing

- Impact energy E: 12 J, as required by EN 13261
- Ageing: 10 days of heating and cooling from +150°C to -30°C.

No hole found, no alteration of axle surface has been detected.
The aim of the dynamic braking tests carried on BU300 test rig is the check of LURSAK behaviour when subjected to the combination of the actions of heating (from the brake disc) and centrifugal force.

The test program

_ Simulation of track section of a Very High Speed train, repeated 40 times (240 brakes, 6 for each section);
_ 6 braking of stops \(a = -0.67 \text{ m/s}^2\), starting from three different speed (150, 220, and 300 km/h)
_ Maximum temperature measured: +93°C

The absence of any detachment, confirms that this type of protective coating is able to tolerate the combination of heating and centrifugal force acting at 300 km/h.
The aim of the fatigue test is the verification of LURSAK resistance when the axle is subjected to very high level of stress: a full-scale test axle painted with LURSAK, in aged condition, has carried out a fatigue test with the application of a completely reversed stress cycle (amplitude of 180 MPa) for 10 millions cycles.

The Visual and Ultrasonic Tests carried out at the end of fatigue test have confirmed that LURSAK is able to resist for 10 millions cycles to the application of an high level of stress without any failure point.
A flame test campaign have been performed on plates and specimen painted with fire proof version of LURSAK. In this test campaign, they are evaluated:

- fire behaviour, smoke emission and dropping behaviour according to DIN 54837;
- smoke toxicity in the test chamber ISO 5658-2 (evaluation according to DIN 5510-2).

The results are satisfying.
## Test campaign results

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Results</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating adhesion</td>
<td>EN 13261 &amp; EN ISO 4624</td>
<td>✔</td>
<td>Resistance $\sigma &gt; 6$ MPa: at this stress value there is the partitioning of glue and no coating detachment</td>
</tr>
<tr>
<td>Impact test @ R.T.</td>
<td>EN 13261</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Impact test @ -25°C</td>
<td>EN 13261</td>
<td>✔</td>
<td>No hole in the coating and no alteration of axle surface detected</td>
</tr>
<tr>
<td>Impact test @ -40°C</td>
<td>EN 13261 @ lower T.</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Impact test @ +150°C</td>
<td>EN 13261 @ higher T.</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Gritting test</td>
<td>EN 13261</td>
<td>✔</td>
<td>No evidence of coating come off in flakes</td>
</tr>
<tr>
<td>Salt spray test</td>
<td>EN 13261 &amp; ISO 9227</td>
<td>✔</td>
<td>Preliminary (after 500 hours) and final results (after 1000 hours) OK</td>
</tr>
<tr>
<td>Coating resistance to cyclic mechanical stresses</td>
<td>EN 13261</td>
<td>✔</td>
<td>No failure of any of 4 specimens</td>
</tr>
<tr>
<td>Thermal test – Ageing</td>
<td>Internal procedure</td>
<td>✔</td>
<td>No defect detected</td>
</tr>
<tr>
<td>Impact test at +25°C after thermal test</td>
<td>EN 13261 after Thermal test</td>
<td>✔</td>
<td>No hole in the coating and no alteration of axle surface detected</td>
</tr>
<tr>
<td>Braking test</td>
<td>Simulation of track section Tianjin – Beijing</td>
<td>✔</td>
<td>No problem of coating detachment</td>
</tr>
<tr>
<td></td>
<td>Braking stop from 150, 220 and 300 km/h</td>
<td>✔</td>
<td>Maximum temperature measured: +88°C</td>
</tr>
<tr>
<td>Fatigue test</td>
<td>Application of 180MPa for 10 millions cycles</td>
<td>✔</td>
<td>No failure point of LURSAK found</td>
</tr>
<tr>
<td>Flame test</td>
<td>DIN 54837, ISO 5658-2 and DIN 5510-2</td>
<td>✔</td>
<td>Product conformed</td>
</tr>
</tbody>
</table>
Thanks for your kind attention