Since 1984

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Semi-ceramic Lunac 2+ (duplex) atomic deposition coating

As a typical hydraulic cylinder and axle coating, Lunac 2+ duplex (L2+D) is among,

- HVOF
- (Nickel-/Duplex-) Chromium
- Lasercladding

mostly compared with lasercladding. Essential in those cases is the typical hardnesss difference (L2+D: HV 1150/2100).

L2+D offers a unique <u>combination</u> of:

- high hardness (harder than quartz sand)
- full substrate bond similar to welding
- (sub-surface) corrosion protection
- moderate ductility
- anti-galling

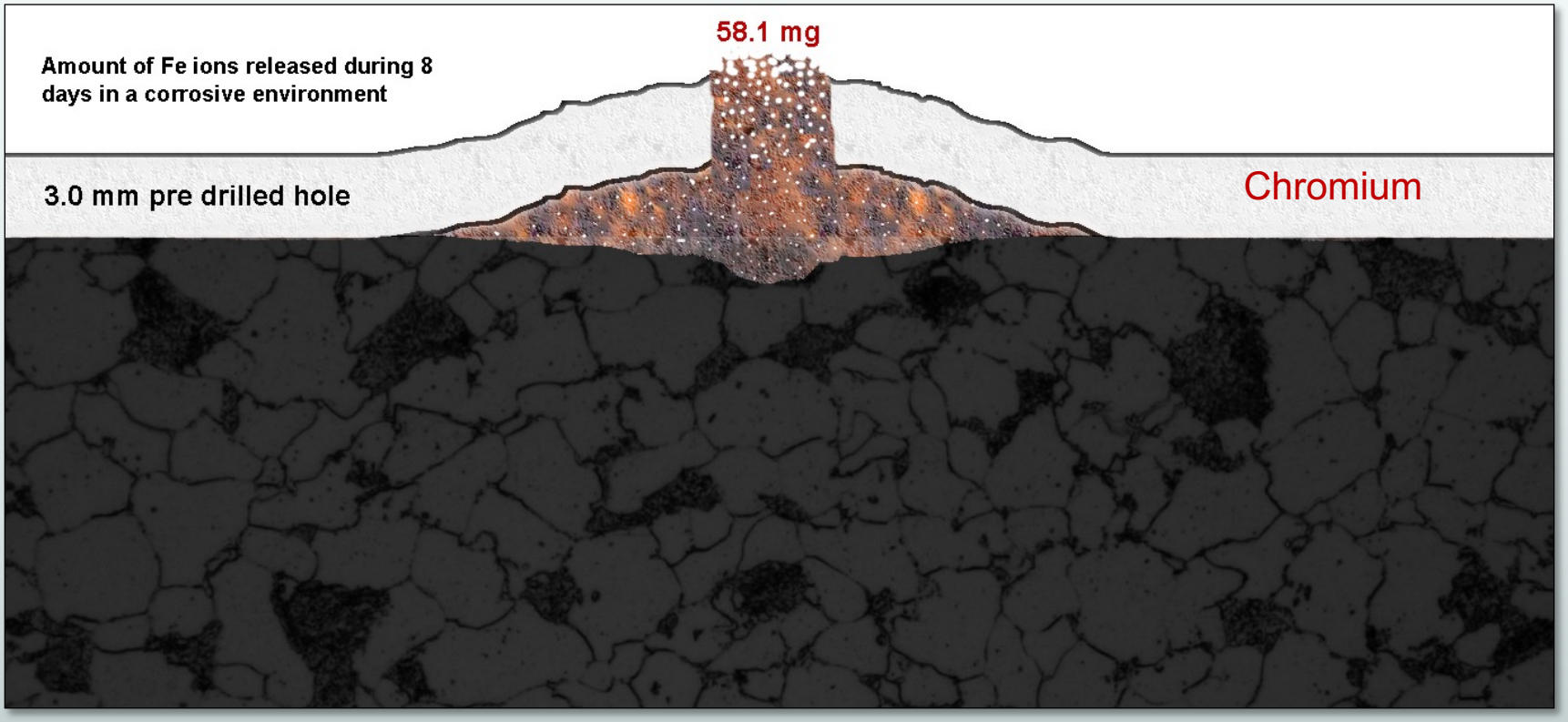
Corrosion protection mechanisms

- **Corrosion protection capability of a (hard) coating is, besides its own corrosion resistance, highly determined by substrate-coating interface stresses, micro-cracks and cathodic or anodic behaviour**

-The substrate-L2+D interface is nearly stress-free

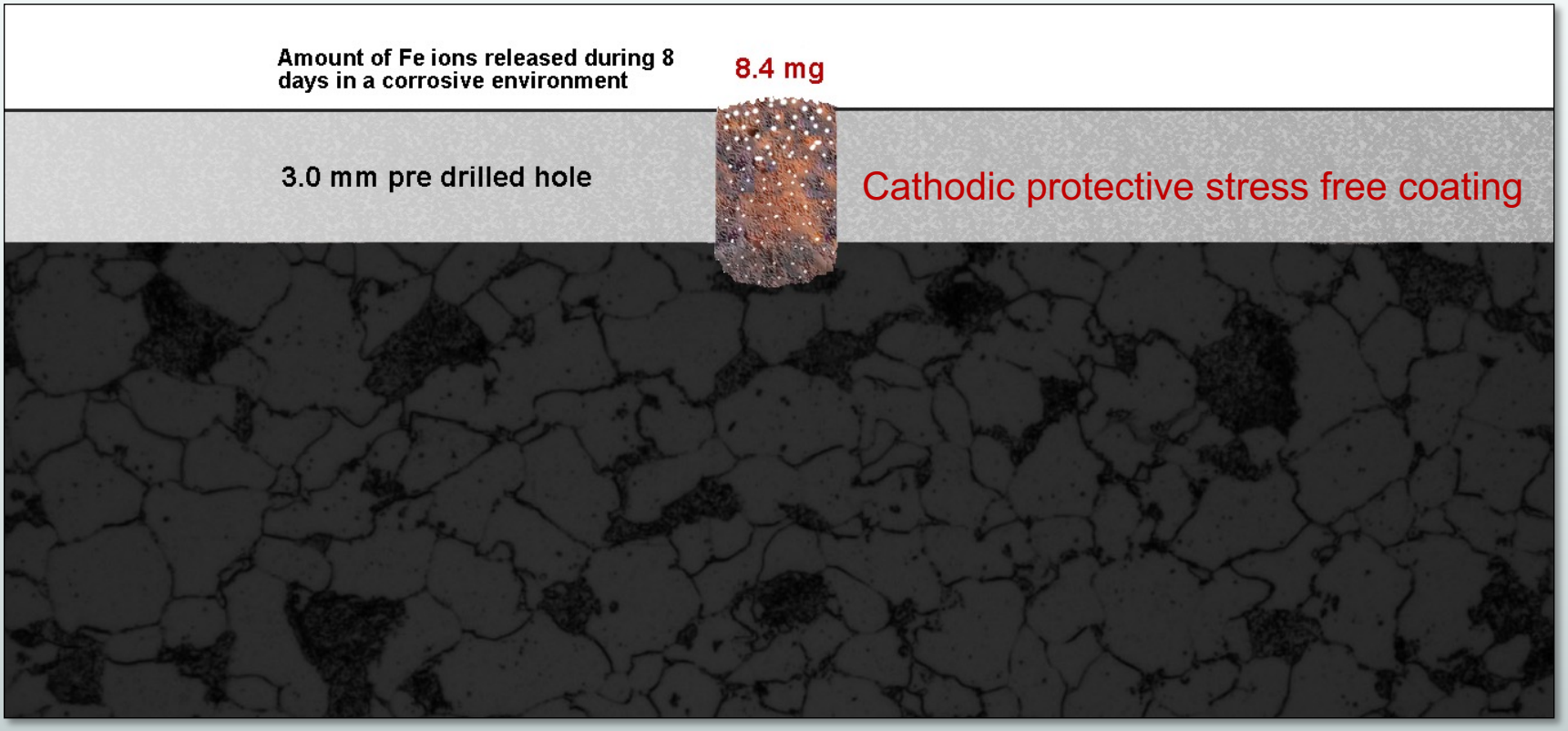
-L2+D behaves like a protective coating, partly similar to Zinc or Aluminium

Major failure mechanism: sub-surface corrosion.



Test condition: hardchromium coated S355J2 steel sample in 4% NaCl water (40°C at PH 3.5). Major sub-surface corrosion progression beneath the coating. Sharp edges are formed and will endanger the seals. Sub-surface corrosion spreading: +/- 30 fold accelerated.

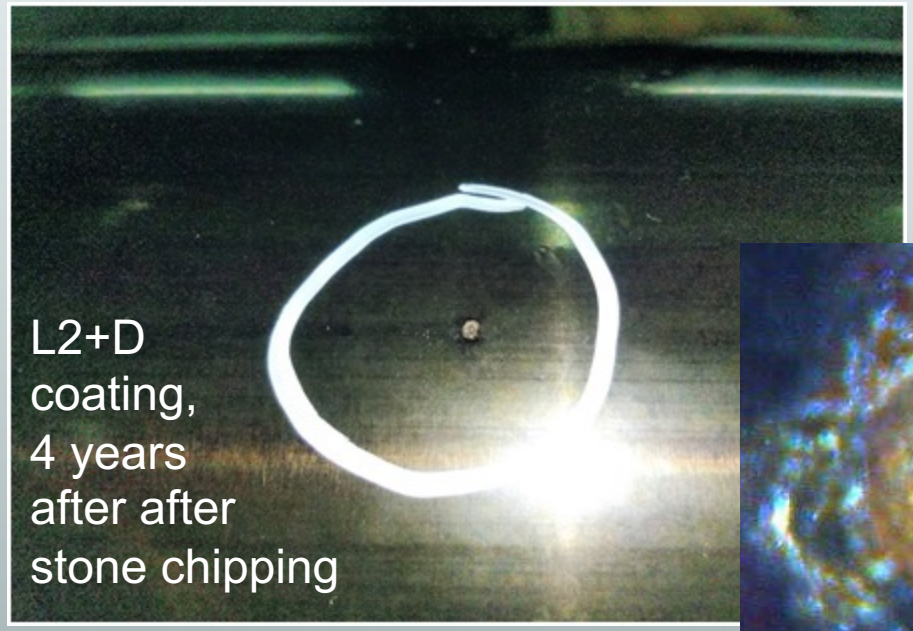
Sub-surface corrosion inhibition by stress free and/or cathodic protective coatings.

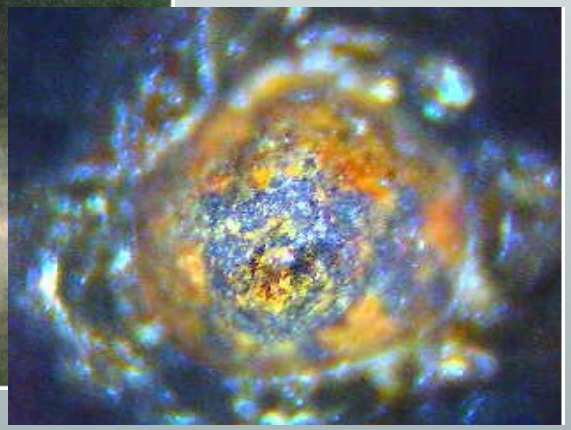


The amount of Fe-ions being released from a drilled hole in L2+D coated S355J2 steel during similar condition. No significant sub-surface corrosion is observed and consequently no raised sharp edges emerge. Main reason L2+D barely returns for overhaul.

Duplex chromium/steel vs. L2+D/steel after 1000 h salt spray testing (original hole: 3.0 mm).

The originally hole in the duplex-chromium plated rod (left) has widened to Ø 12 mm during this test period. The hole in the L2+D coating remained unchanged.





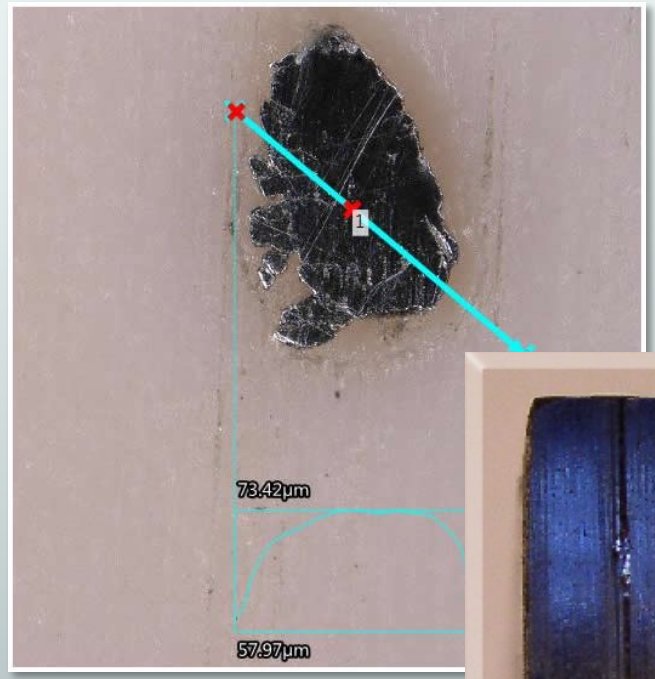
Off shore piston rod cases,
2 and 4 years after damage

Dented surfaces

1000 h NSS corrosion testing

Stainless steel – composites / technical plastic galling after 1.5 hour

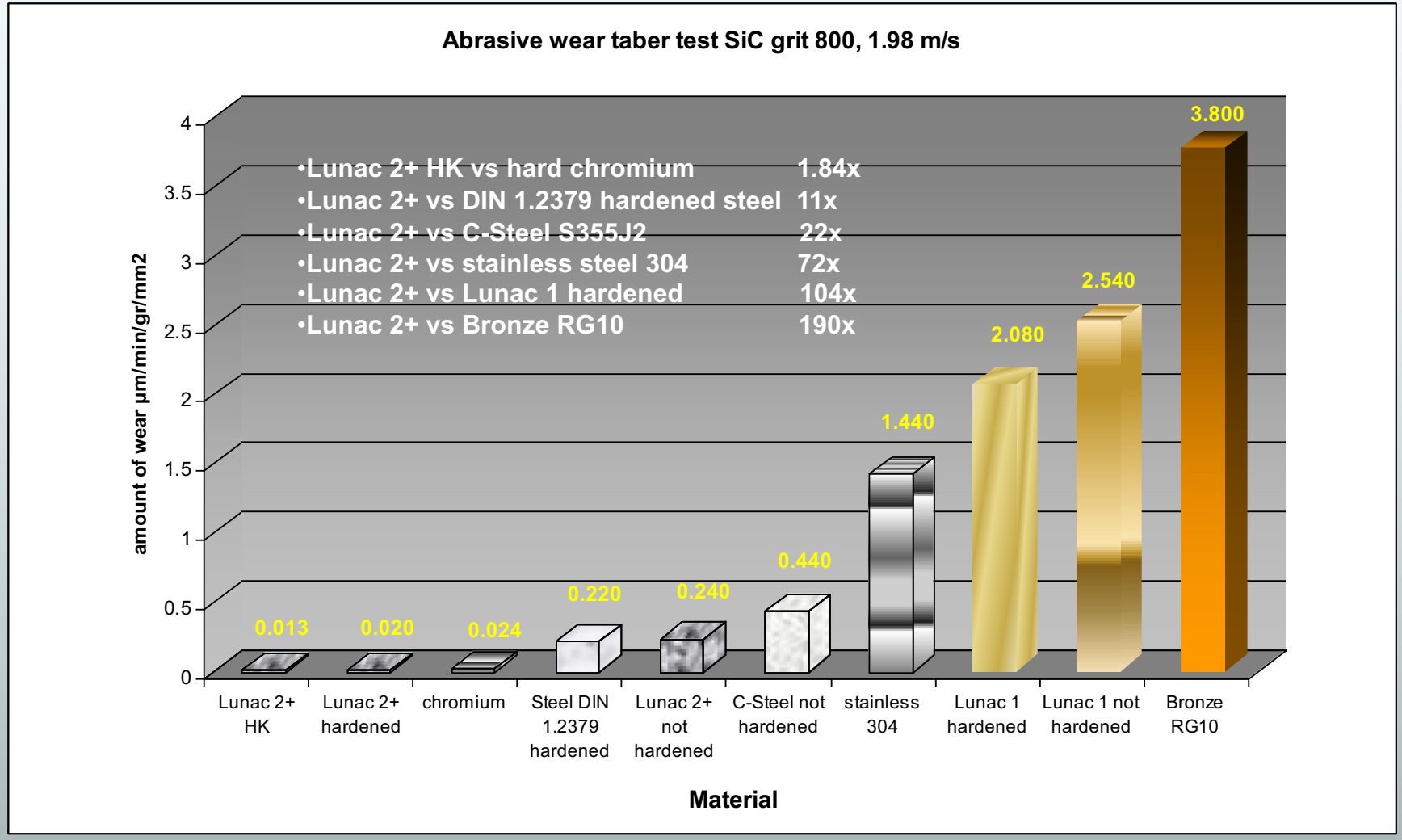
E.g. PEEK, is able to disrupt (e.g. 316) stainless steel surface during sliding. A minimal couterpart hardness is mandatory(> Hb 200) in combination with such plastics and most composites. Lunac 2+ offers the combined high hardness and corrosion resistance.



Effect of anti-galling Lunac 2+ coating applied to duplex stainless steel thread. Rotation possible without lubrication.

Impeller pitch control axle Spanish hydro-electric power plant.

Tabor abrasive wear resistance based on SiC mineral testing

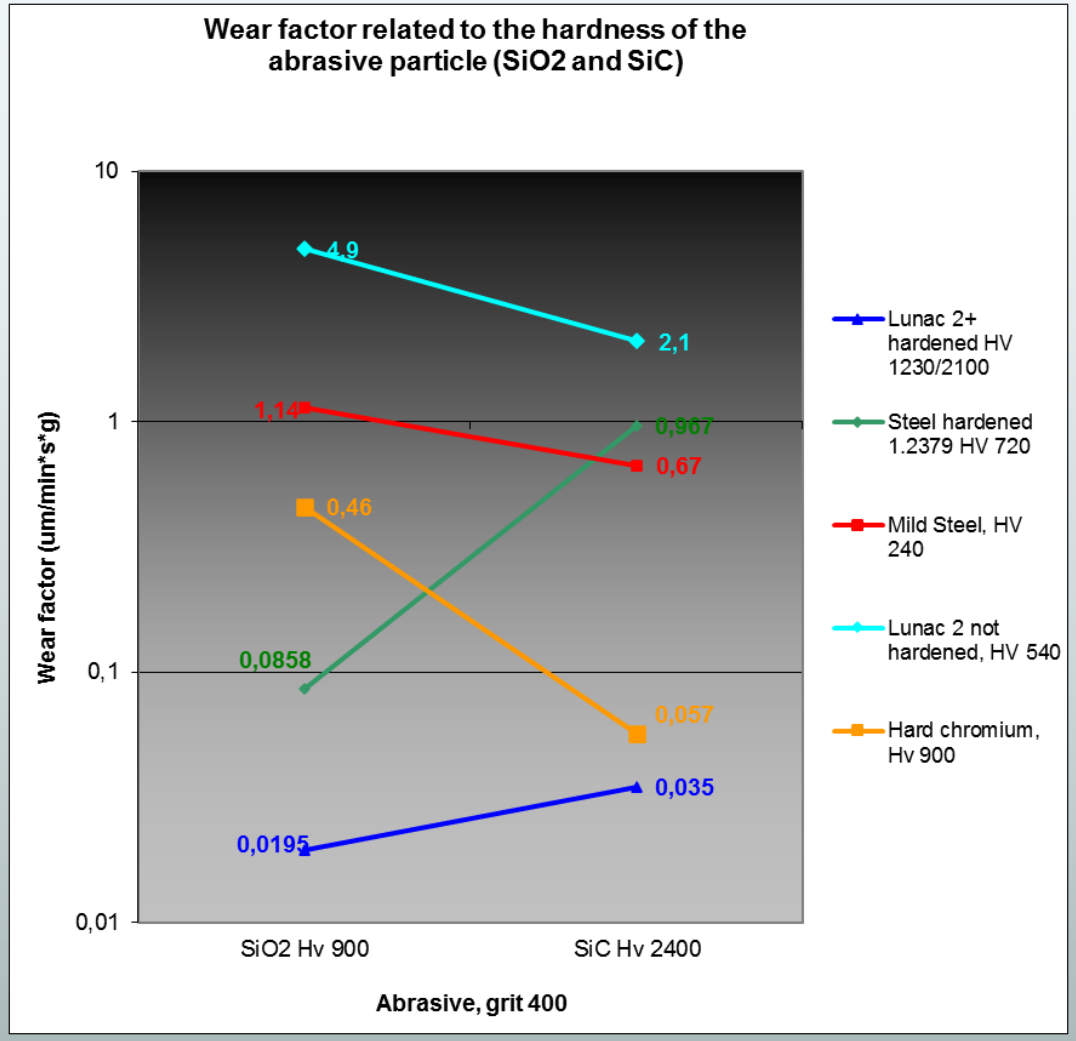


Scratch and abrasive wear resistance in SiO_2 environment.

Note: Lunac 2+ is a
Hv 1150/2100 cermet and principally
harder than quartz sand (SiO_2)

Moreover, a mineral cutting action
can vary on different counterparts

Influence of abrasive particle hardness

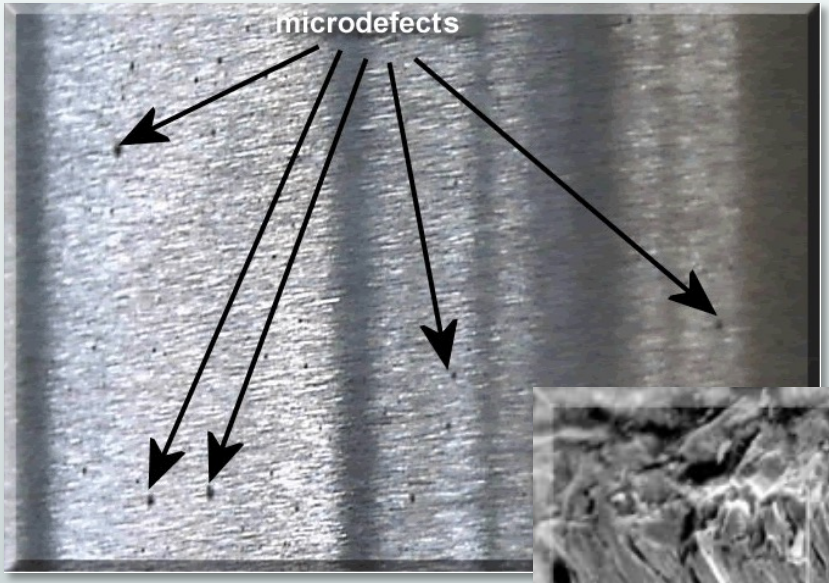


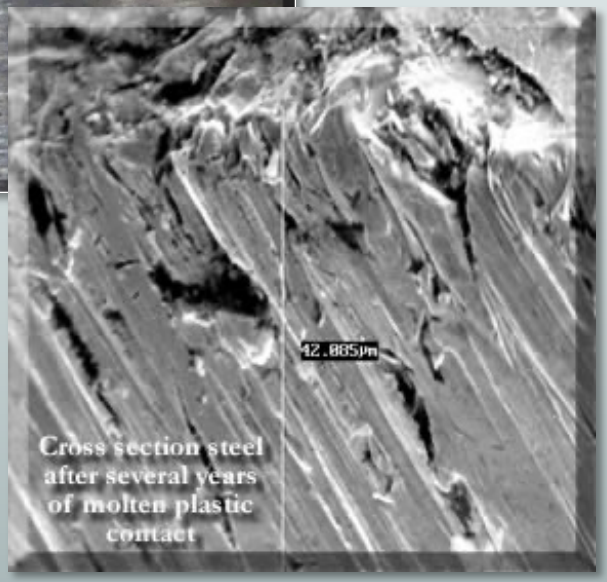
Amount of hardchromium HV 900 wear vs.
Lunac 2+ HV 1150/2100

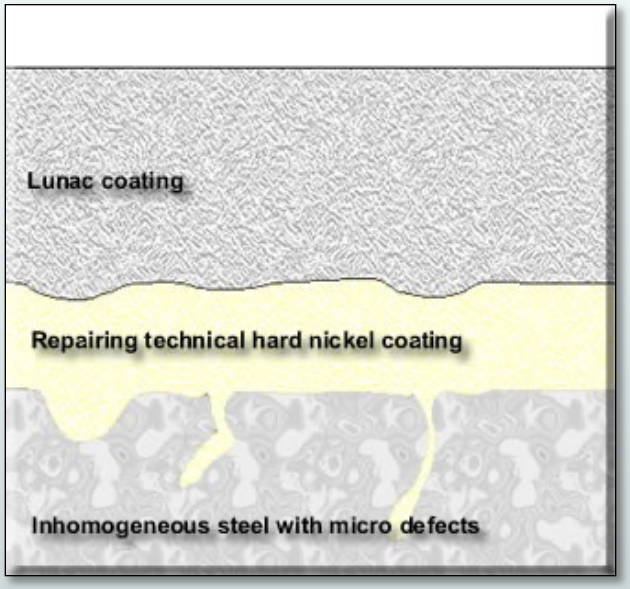
SiC (Carborundum) : 1.6 X
SiO_2 (Quartz) : 24 x

Interestingly the best abrasive wear resistance of Lunac 2+ is recorded in a quartz sand environment

Steel substrate micro defects and repair capability of the L2+D system

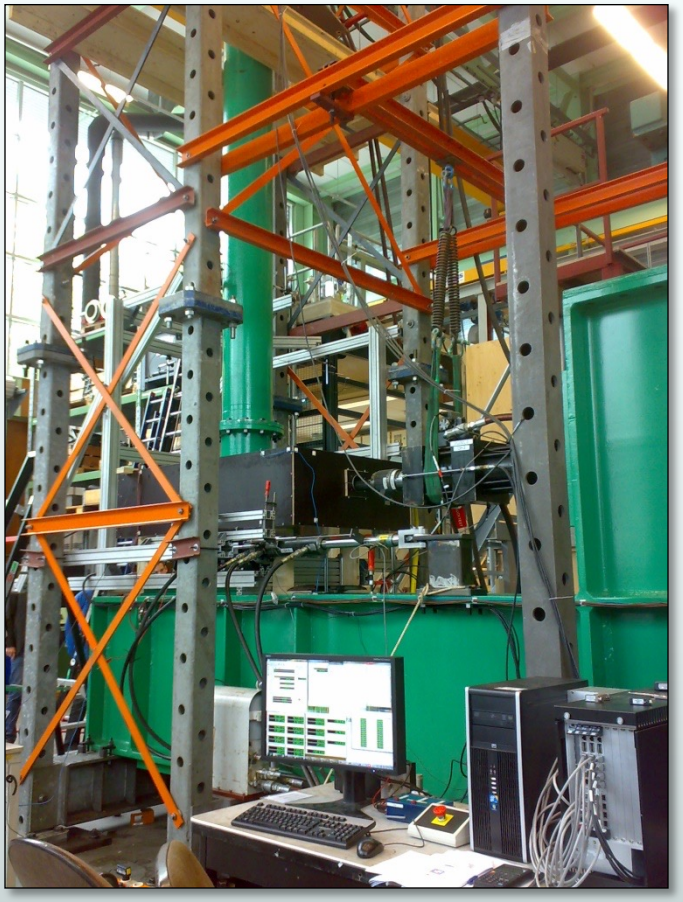






After 20 years development the L2+D / Steel system acquired an optimal chemical and mechanical balance. Consequently, modern L2+D coatings are (RWS) NBD10300 certified (EPQ testing).

(Plating process has to deal with ‘thrower power’)



L2+D applied to lock gate axle for final approval testing at TNO Delft. L2+D / Feroform composite sliding pair. After 8750 full swings at 52 metric ton load in salt water, no detectable wear or corrosion has been recorded.

Veessen-Wapenvelddam 2016. All central 42CrMo4 steel hinges are L2+D coated, because of the long service life demand. According to RWS NBD10300 directive

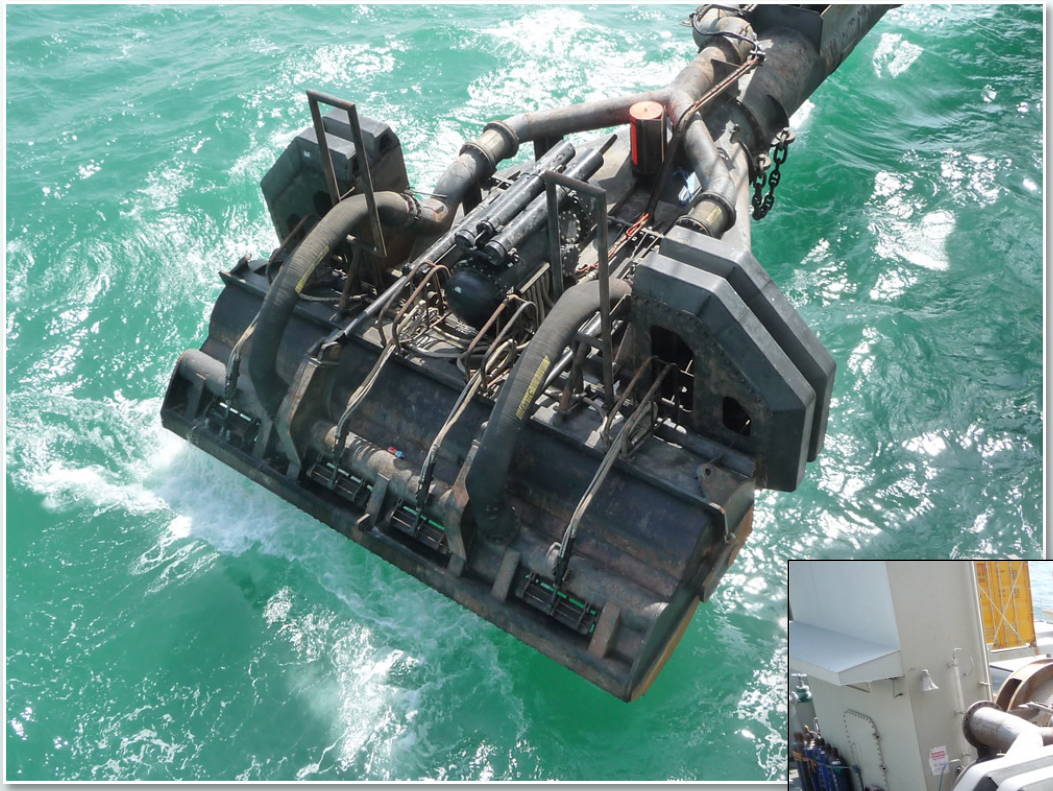
Houtribsluizen (Lelystad) L2+D coated lock gate hinges.

Waddenzee (Kornwerderzand) lock gate axles, coated with Lunac 2+ (2005)

Chromium plated carbon steel cylinder after 27 months (left) in a marine environment clearly displays the detrimental sub-surface corrosion effect.

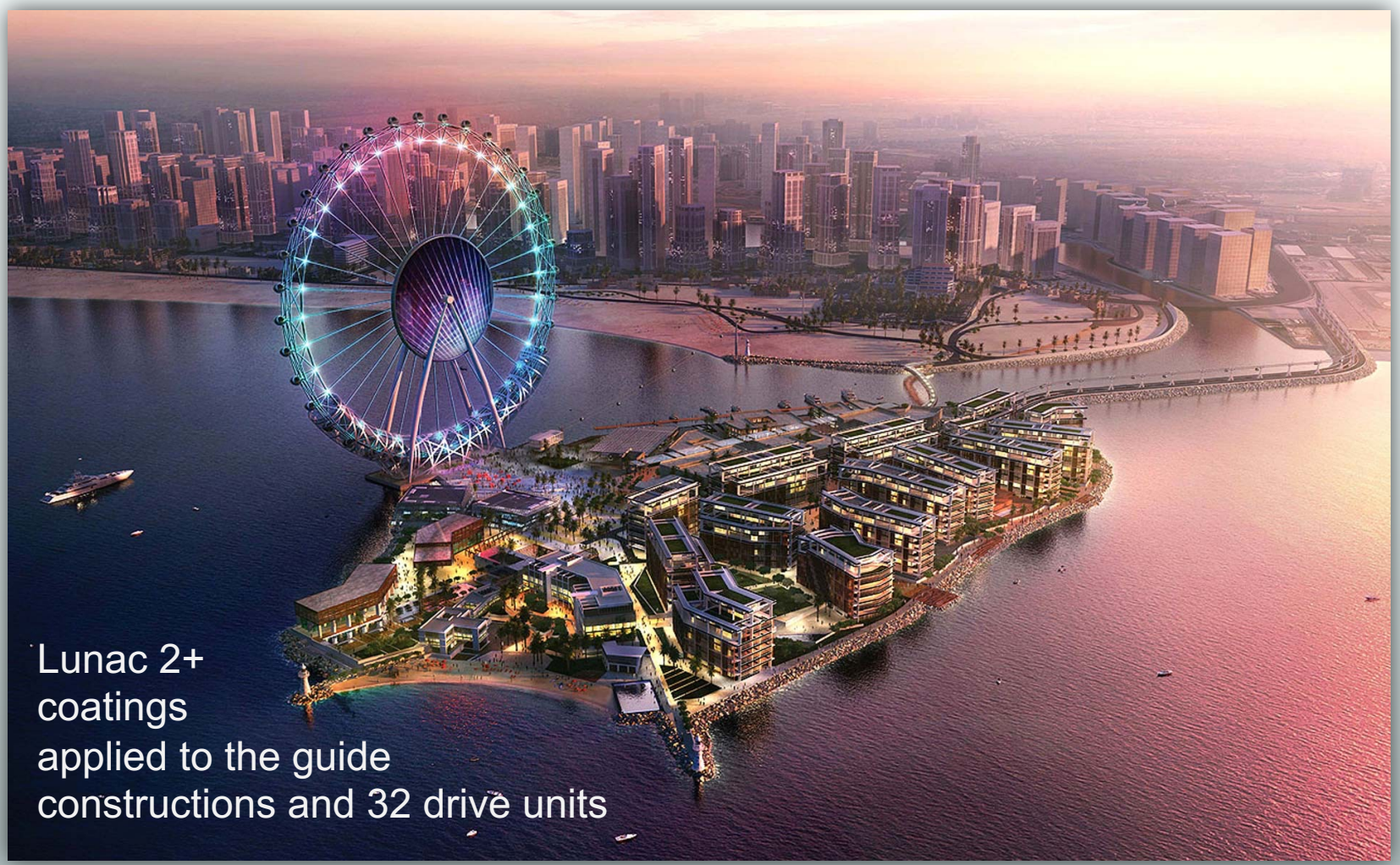
Lower right: L2+D coatings (after 36 months, similar conditions) also offer good protection in the last **never retracted** zone ! Note; these cylinders can also be exposed to corrosive $S0_2$ containing exhaust gasses.

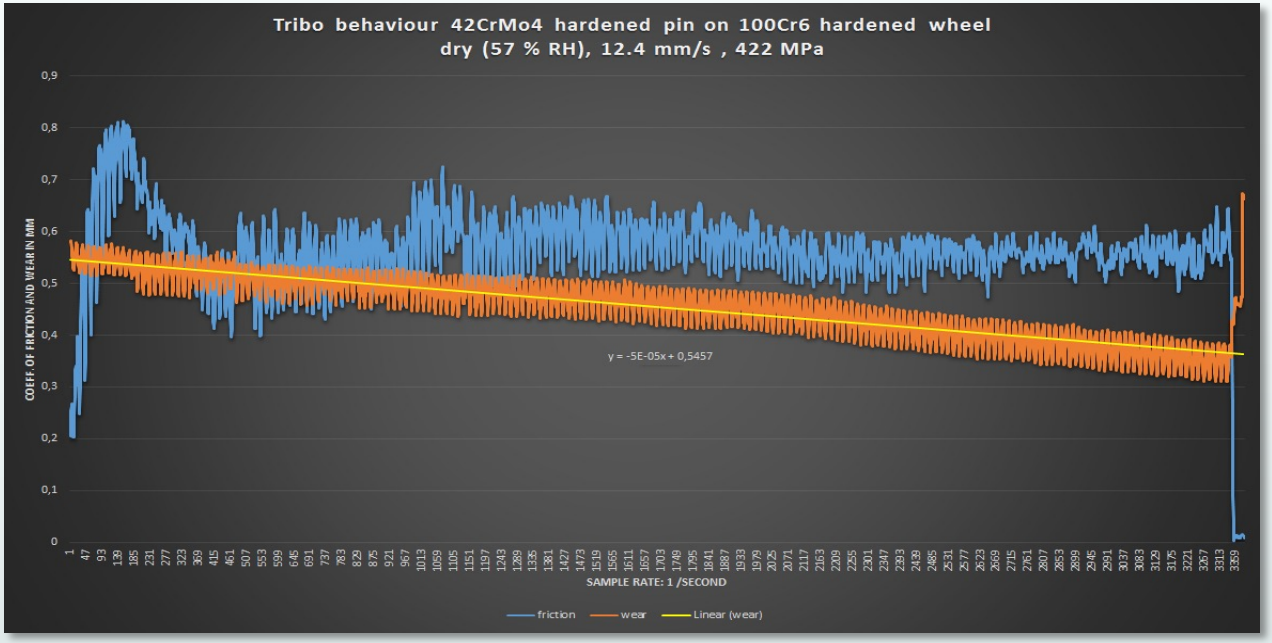
Lower-left: L2+D coated cylinder exposed to intensive sand wear for 2 years. The 0.2 µm patina layer is still present.

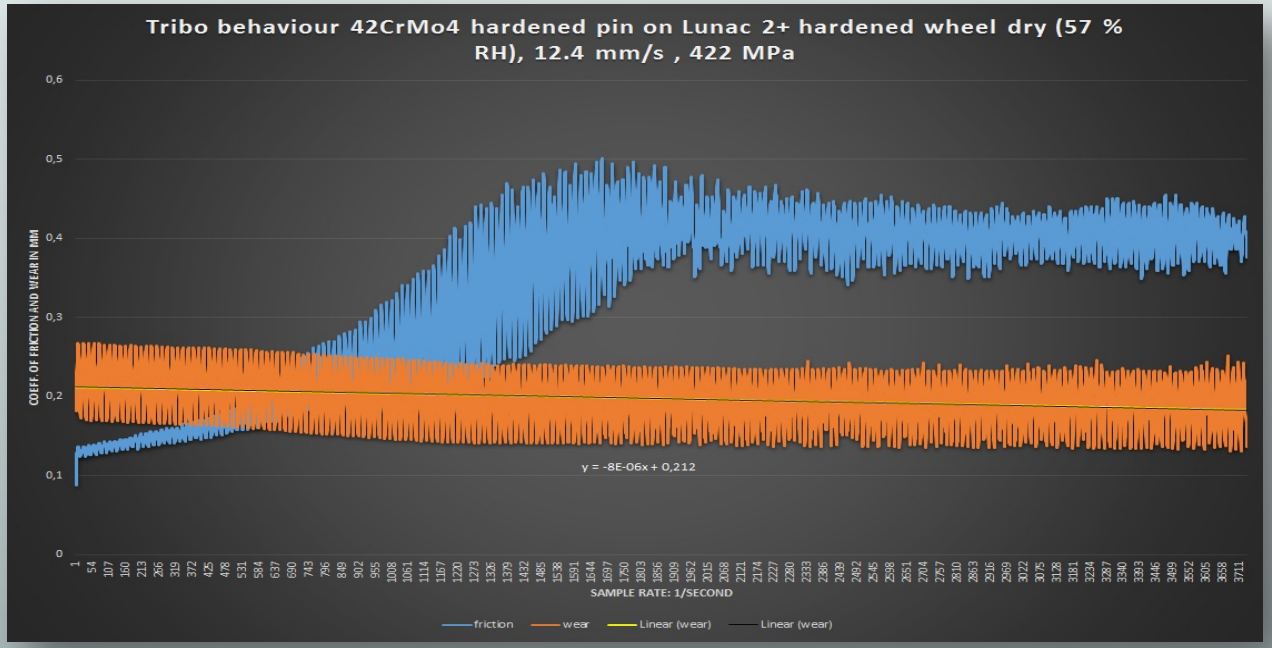


Governing dredging cylinders L2+D coated for reasons of corrosion protection, wear resistance and especially the capability to deal with **stone chipping**. This is caused by the relatively good L2+D **semi-**ceramic ductility and full substrate bond.

Wheel of Dubai







Lunac 2+ stabilisation of C.O.F., the effect of a patina layer and the anti-galling characteristic

CIMOLAI Technology spa
Special Equipment

Disk spring guidance (Ketelbrug). Lunac 2+ coated for reasons of anti-fretting/anti-galling and stable coefficient of friction

Lunac 2+ applied to the new Panama main lock door rail system after 3 years, to prevent the system from corrosion and especially adhesive wear (25 mm side shift during filling locks and earthquakes). Vertical load during lateral movement: up to 975 kN. Wheel-pressure up to 560 MPa.

Experienced limitation

Severe bending (30 mm !) of a L=1500 piston rod can create micro-cracks in the coating and finally expose a massive amount of the steel substrate. L2+D protected the substrate 2 years by its sacrificial cathodic protection behaviour. Still no substrate corrosion, but the coating turned rough.

If such servere bending cannot be prevented, lasercladding is recommended.

La Reunion ocean road positioning and lifting

Lunac 2+ (duplex) has been applied to most heavy lifting cylinders of one of the world's largest offshore over-head gantry cranes and deep water positioning systems for the French consortium, Bouygues Travaux Publics. Lunac 2+ (duplex) was selected due to its >20 years off shore track record to resist the expected harsh conditions.

Reunion ocean road positioning

The Independent Dutch project manager of this project, Koen Reimert, will outline the challenges this project had to cope with.

Operation

- Installation of gravity base (up to 4800T)
- Lifted and lowered using overhead crane
- Touchdown and positioning using Pile Positioning System:

1. Lower base above seabed ~300mm
2. Extend spuds to lock on seabed
3. Positioning of base in XY plane using cylinders

Main challenges:

- Friction, cylinder rod needs to slide through frame
- Sideload, external forces generate sideload up to 10%
- Salt water and tropical temperatures
- Touch down on gravel bed

Lunac 2+ duplex coatings applied to most positioning and lifting cylinders had simultaneously to regulate friction, resist sand wear, withstand possible (stone) impacts and corrosion.

After installation of 48 gravity bases a couple of years later, all cylinder visually looked new!

L2+D final plating result.

Check out the revolving system (goal: perfect circumference coating distribution) and the support systems at the rod ends.

Characteristics Lunac 2+ duplex in detail:

- Exceptional (sub-surface) corrosion protection (EPQ / NBD 10300 approval or > 3500 hours NSS ASTM B117)
- Ultimate hardness (74% HV 1150 (= HRC 72) / 26% HV 2100) and high resistance to abrasive wear/scratching and galling
- Reduced (mostly minus ~25%) and especially stable coefficient of friction in most material combinations
- Resistant to even moderate plastic deformation (up to 0.28% elongation)
- Smooth and crack-free surface Ra 0.11 – 0.3 µm (low seal wear)
- Moisture will slowly trigger the formation of a thin 0.2 µm brown-grey patina layer, which will not impair the functionality.
- Repair capability

WMV capabilities

- Material and tribo research laboratory
- Lifting capacity up to 3 Tons, vertical plating up to 3930 mm
- 3 plating lines
- Hardening ovens
- Pre- and post (diamond) grinding and honing machines

Typical Lunac 2+ (duplex) plating prerequisites

- Steel substrate should be softer than Hrc 50, free of major micro-defects and never be nitrided.
- Shape abberations at part ends affect the local coating thickness.
- The diameter must be reduced by 0.24 mm +/- 0.02 mm with respect to the final tolerated diameter and be smoother than Ra 0.17 µm. If the surface still needs to be finished (only turned ~ Ra 1.5 µm), the under cut should be less: -0.21 +/- 0.015 mm instead of -0.24. Necessary accuracy: +/- 0.015 mm. If that cannot be obtained either, no under cut, honing outsoursing.
- Worn out abrasive belts or rolling should never be applied to acquire the low indicated roughness.
- Steel DIN 1.6582 is most favourable, 42CrMo4 the least. S355J2 is most common

Remarks to the application of Lunac 2+ (duplex)

- Possible galvanic corrosion conditions (by e.g. copper alloys or stainless steel proximity) or crevices in (salt) water should still be monitored (rare).

- Not any guide material is known to be able to scratch Lunac 2+ yet. Hard seals can be applied (Shore-A 95 (PU)). The service life of both guide bands and seals is often increased.

- Lunac 2+ (duplex) on steel can deal with very high (shear) loads (proven: 400 MPa at 5 mm/s and 750 MPa peak at low speed).

- Lunac 2+ (duplex) coatings could also be applied to still uninterrupted rods, which can be cut and machined at the ends afterwards. The coating could be hardened before or after machining. This procedure can reduce costs.

Because of the exceptional low return rate, the new Lunac 2+ duplex coatings can, due to the relative toughness and unique combination of characteristics, be regarded as one of the most robust and competent cylinder and axle coatings nowadays available.

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