Objectives

- Find an alternative treatment to hard chrome plating :
  - same or better corrosion resistance
  - same or better hardness (wear resistance)
  - low roughness (seals protection)
  - environmentally friendly process : Cr^{VI} free
- Solution : oxinitrocarburizing
- Objectives of the reporting period :
  - compatibility between hydraulic oils and impregnation product
  - wetability tests
  - 3D roughness measurements
  - electrochemical measurements for faster corrosion tests

Compatibility hydraulic oils/impregnation

NSS test

- Ref : oxinitrocarburizing treatment (OxNit) — 800 hours

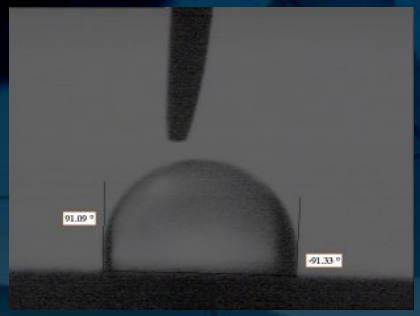
- 5 hydraulic oils tested :

OxNit + Houghton Hydrolubric HL-32	600 hours
OxNit + Fuchs Centraulic HLDP-32	775 hours
OxNit + Houghton Cut-Max TK-14	780 hours
OxNit + Sunnen MB30	1600 hours
OxNit + Houghton Cut-Max HNG-21	1700 hours

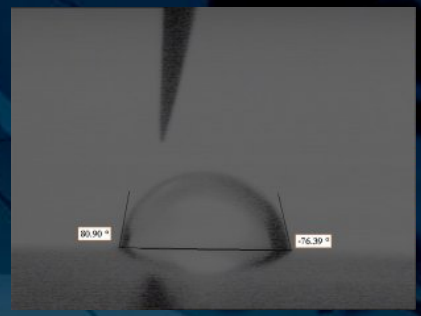
(Prohipp-10-030)

Wetability tests on coatings

- Important for the oil film between seal and rod
- Tested coatings :
  - Standard hard chrome plating
  - Enhanced hard chrome plating
  - Nitrocarburizing
  - Nitrocarburizing + polishing
  - Oxinitrocarburizing
  - Oxinitrocarburizing + polishing
  - Oxinitrocarburizing + impregnation
  - Oxinitrocarburizing + polishing + impregnation
- Results :



Standard hard chrome plating

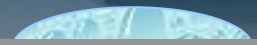


Enhanced hard chrome plating

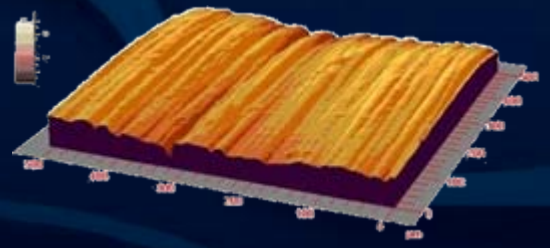
Oxinitrocarburizing + polishing + impregnation

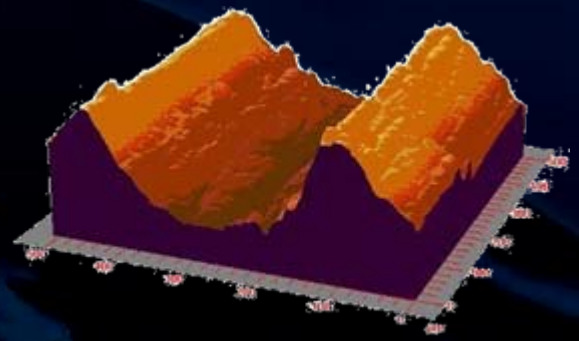
(Prohipp-10-031)


Poor wetability

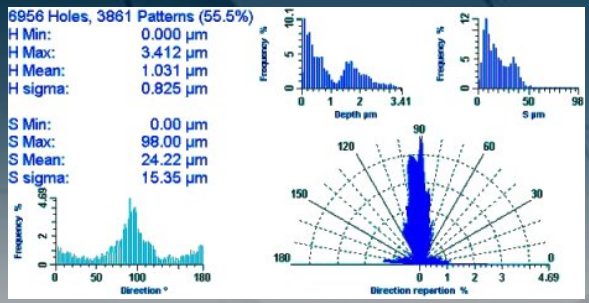

Good wetability

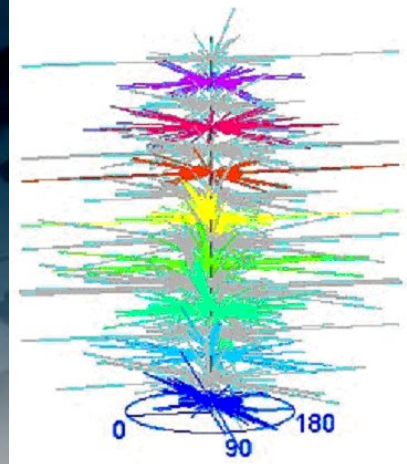
3D roughness measurements on rods

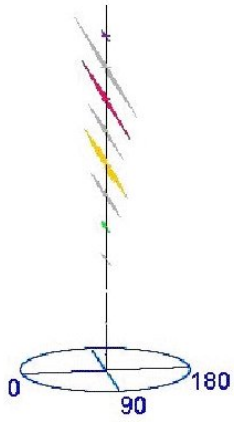




- For better machining parameters
- Rods measured :
  - 5 rods with 5 different grinding parameters (ref G1 to G5)
  - 4 rods with 4 different lubricated machining (lather) parameters (ref L1 to L4)
  - 1 normal CK45 bar (only laminated, not grinded or lathered)
  - 1 standard hard chrome plated bar
  - 1 enhanced hard chrome plated bar
- Results :
  - From a trobological point of view, the grinding parameters associated to rod G2 provide the best results
  - The best surface morphology is achieved with rod L1
  - Hard chrome layers are similar, but the standard hard chrome layer is a little better



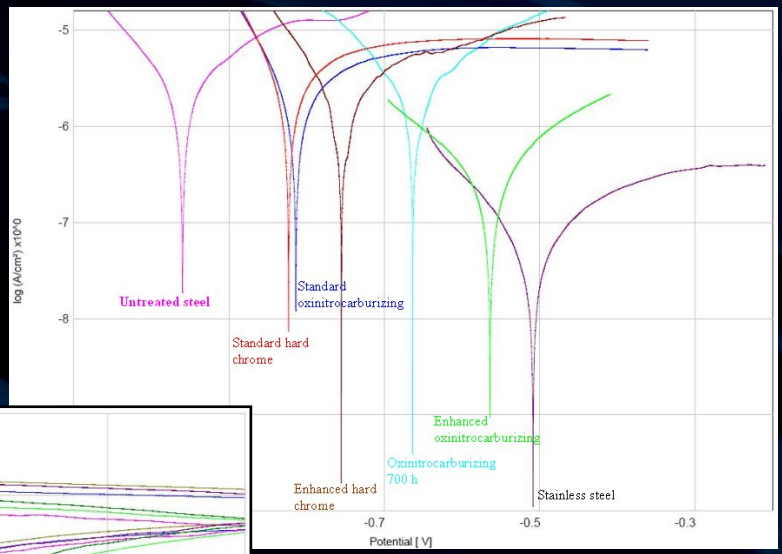


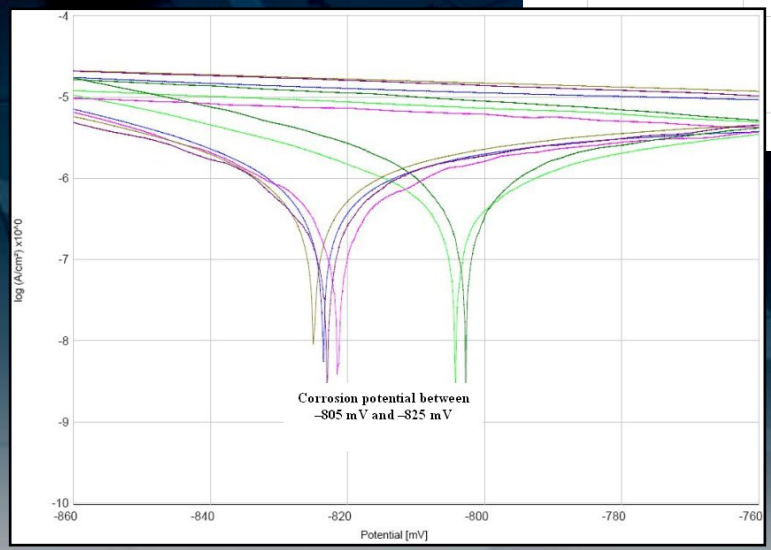


Electrochemical corrosion tests

- Target : to reduce the time needed to check the corrosion resistance of parts (up to 40 days with NSS test !)

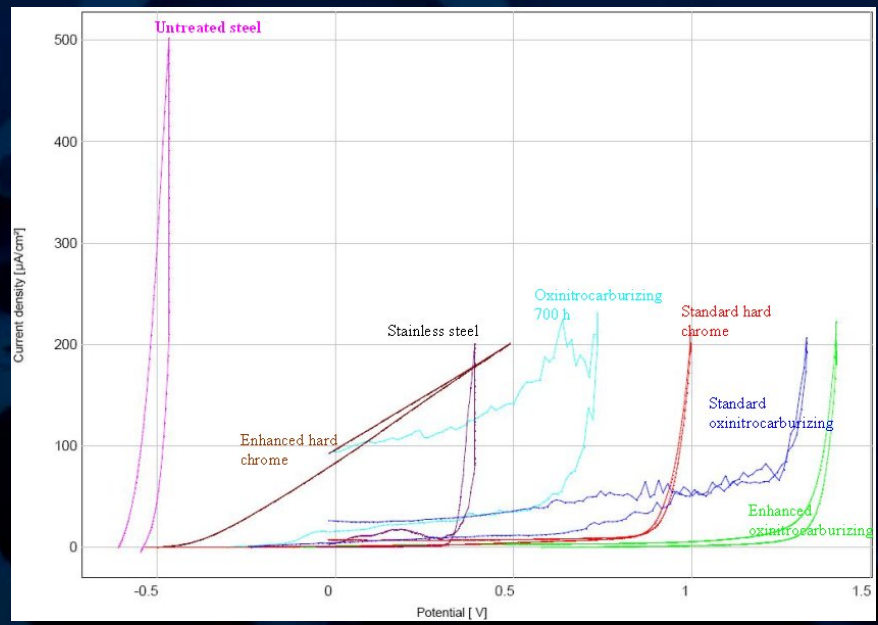
- 3 main ways :
  - Cyclic Voltametry :
    - interesting results
    - not accurate enough



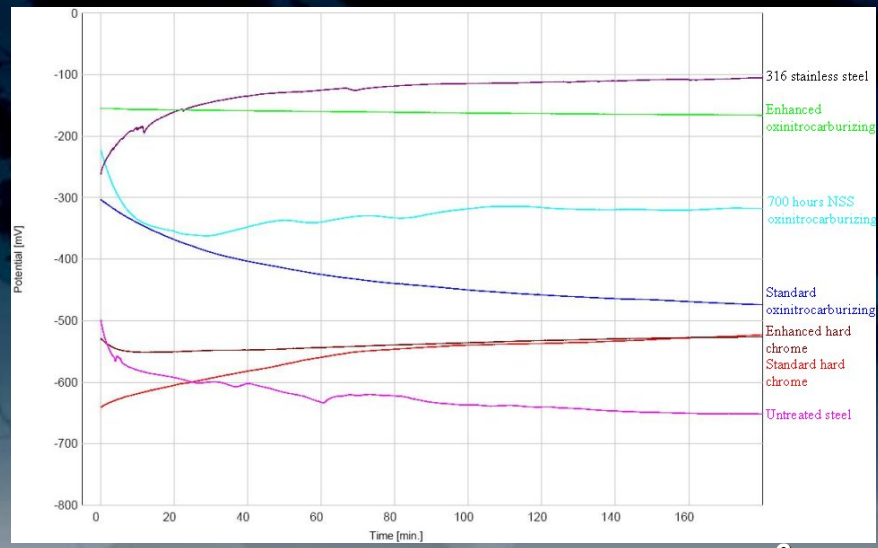


Electrochemical corrosion tests

- Pitting : not good
  - stainless steel less corrosion resistant than hard chrome plating
  - strange result with enhanced hard chrome layers



- Free potential :
  - good results
  - seems to be repeatable
  - best way to test the layers (results in 3 to 6 hours)



(Prohipp-10-033)

Objectives and contractors involved

- Objectives : Find an alternative treatment to hard chrome plating :
  - same or better corrosion resistance
  - same or better hardness (wear resistance)
  - low roughness (seals protection)
  - environmentally friendly process : CrVI free

- Contractors involved :

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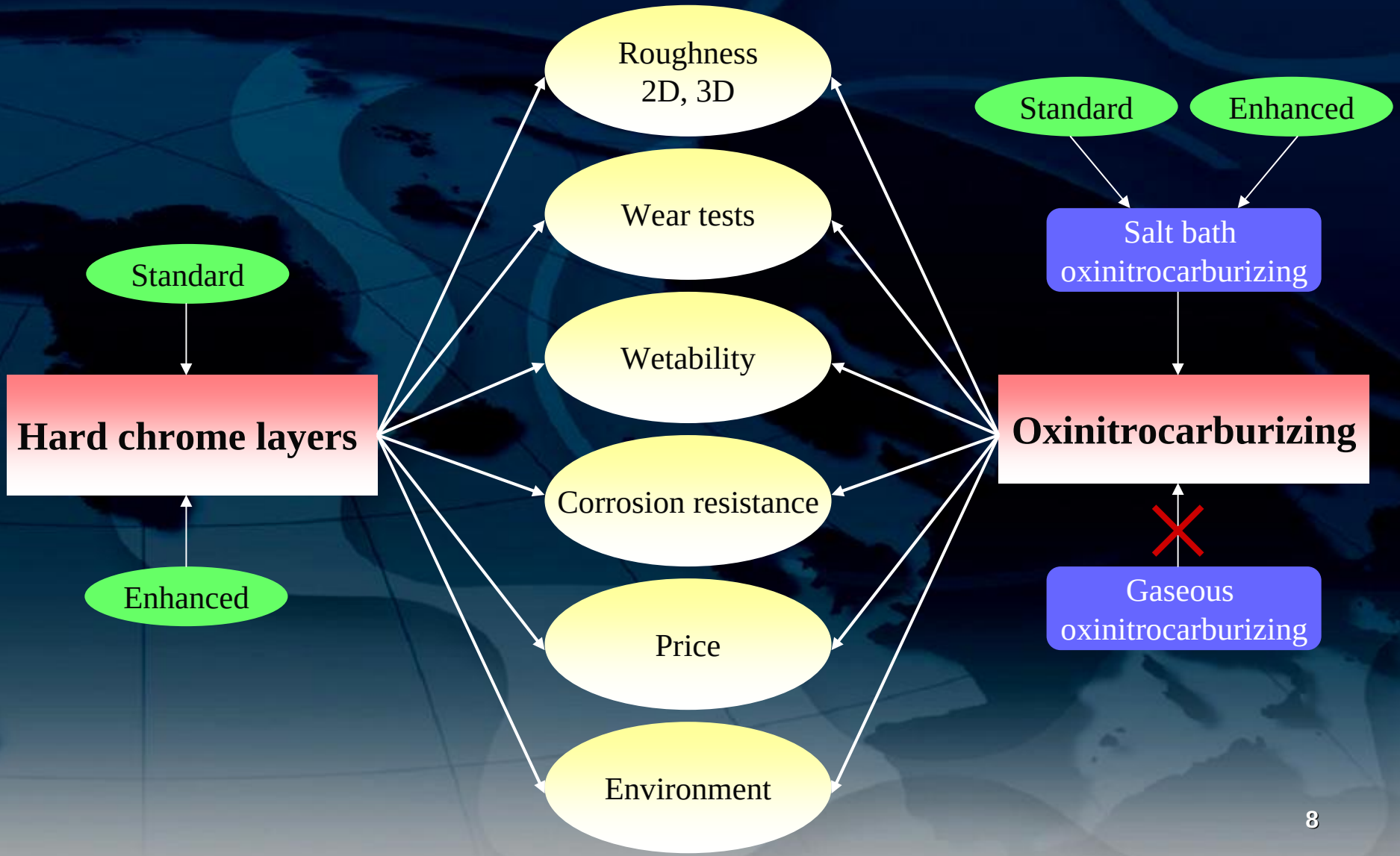
Work performed

Approach : comparisons between oxinitrocarburizing and hard chrome layers



Work performed - Final results

- Roughness :
  - lower with oxinitrocarburizing if final polishing (14 certificates of control, D3.34)
- Wear tests :
  - better with oxinitrocarburizing (D3.26, D3.30, Trelleborg wear tests)
- Wetability tests :
  - better with oxinitrocarburizing (Prohipp-10-031)
- Corrosion tests :
  - standard oxinitrocarburizing better than standard hard chrome plating
  - enhanced hard chrome plating sometime better than standard oxinitrocarburizing

Work performed - Final results

- Corrosion tests (part 2) :
  - enhanced oxinitrocarburizing better than enhanced hard chrome plating
  - inconstant corrosion resistance of enhanced hard chrome plating (Prohipp-10-018, Prohipp-10-021, Prohipp-10-031, Prohipp-10-033, D3.26, D3.30)
- Price :
  - difficult to compare
  - for small series, lower with hard chrome plating (standard or enhanced) than oxinitrocarburizing
  - for large series, depends on who provides the bars/rods (Prohipp-10-022)
- Environment :
  - better with oxinitrocarburizing : non toxic salts, Cr^{VI} free process

Achievements *VS* state of the art

- Demonstration of **oxinitrocarburizing process as a real technical alternative to hard chrome plating** for hydraulic cylinders (corrosion, hardness, roughness, environment), need to work on the price

- **Strong increase of the average corrosion resistance of salt bath oxinitrocarburizing process** (400 to 1200 hours), only for cylindrical parts

- **Faster and reliable new corrosion test** compared to NSS test (3 to 6 hours compared to 5-40 days for NSS)

Exploitable result

Optimised oxinitrocarburized rods for hydraulic cylinders

- Increase of lifetime of rods compared to hard chrome plating (wear resistance, corrosion resistance)
- Patent and trademark (Arcor®) on the process
- Foreseen collaborations :
  - licence agreement
  - manufacturing agreement
  - joint venture