



# Remanufacturing of Pumps – Optimising Performance and Increasing Lifetime

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Director

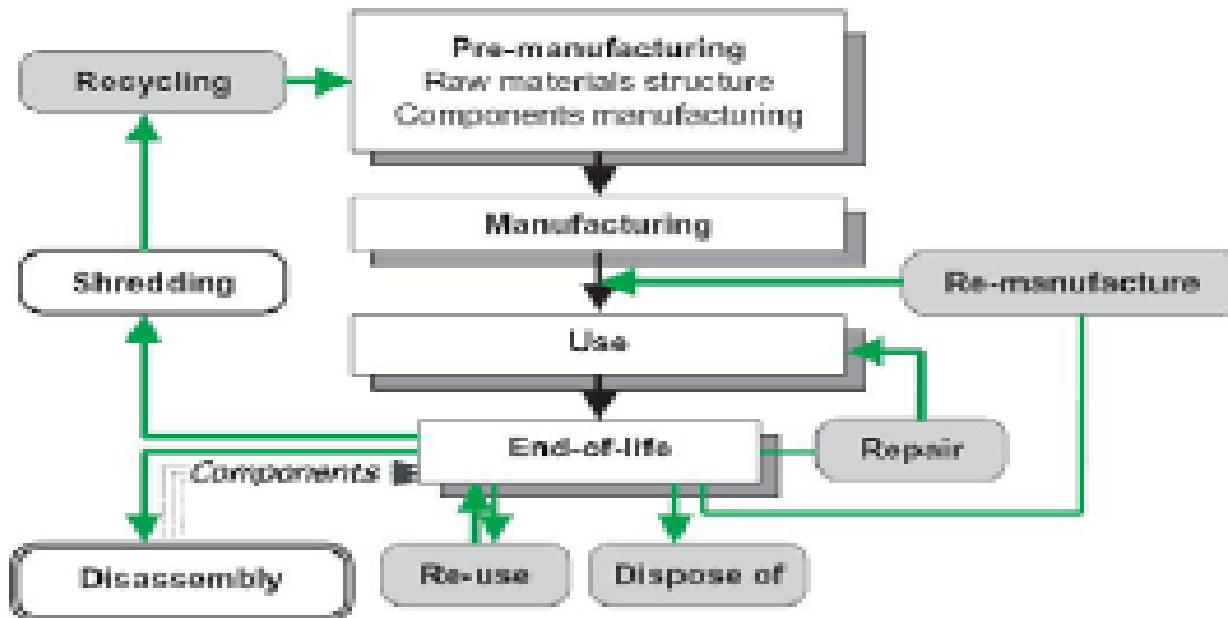
*Institute of Engineering Thermofluids, Surfaces and  
Interfaces*

- Remanufacturing – general aspects
- Pump damage in service and the potential for remanufacturing
- Challenges in remanufacturing in pumps
- Opportunities



# Product Life Cycle

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- PUMPS
- SURFACE ENGINEERING

**FOCUS ON WHERE  
THEY HAVE BEEN IN  
SERVICE**



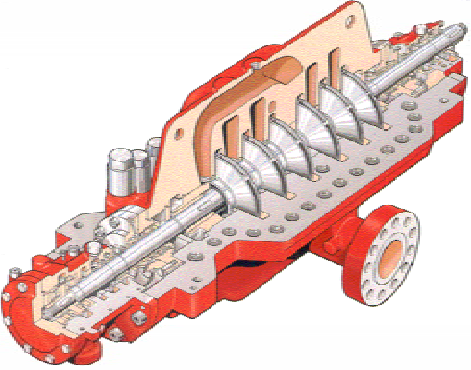
# Definition and focus of this talk

**Remanufacturing** – is the process of disassembling, cleaning, inspecting, repairing, replacing and reassembling the components of a part or product in order to return it to “as-new” condition. The part or product is then returned to service in a system.

**Upward remanufacturing** – the process of disassembling, cleaning, inspecting, repairing, replacing and reassembling the components of a part or product in order to return it to “as-new” condition and *incorporate it into a new, or “next generation” system. This might require that new features be built into the product during remanufacture.*

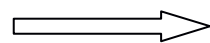


Particularly important in surface engineering as new systems evolve



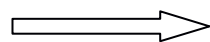
## What do we expect from centrifugal pumps?

- Cost-effectiveness
- Reliability
- Low maintenance time
- **Predictability**



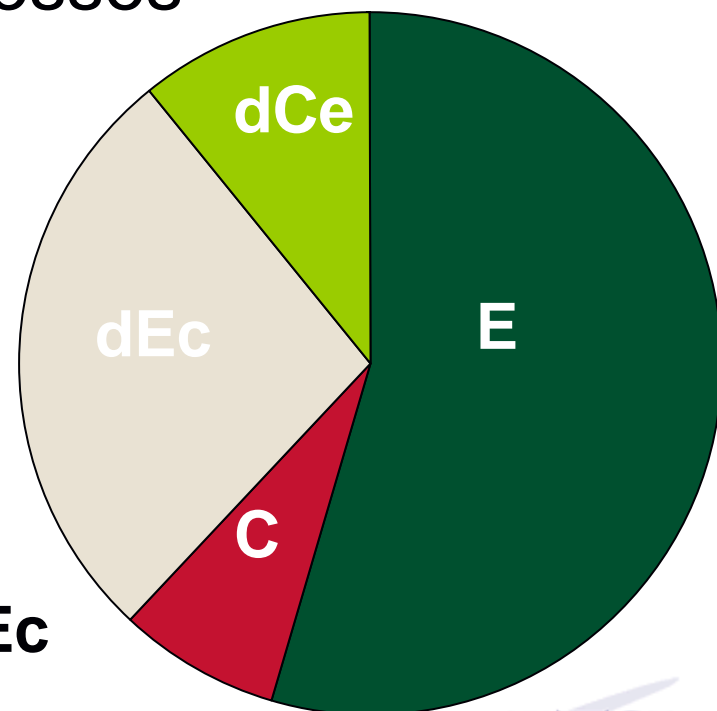
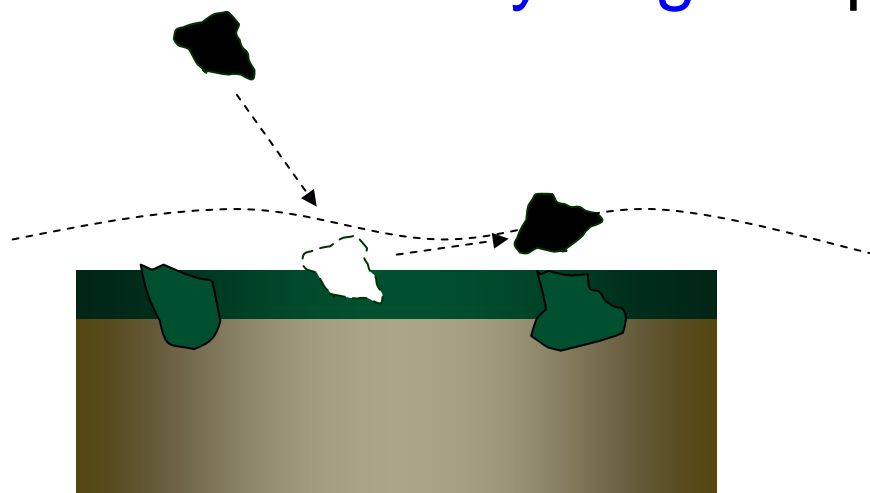
Corrosive

Environments



Corrosive-erosive (silt presence)  
**WEAR**

Complex degradation mechanism which involves **electrochemical** processes, **mechanical** processes and **interactive/synergistic** processes



$$\text{Material loss} = E + C + dCe + dEc$$

$$\text{Or Material Loss} = E + C + S$$

# Damage by Erosion-Corrosion



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US/Canadian  
oilsands industry

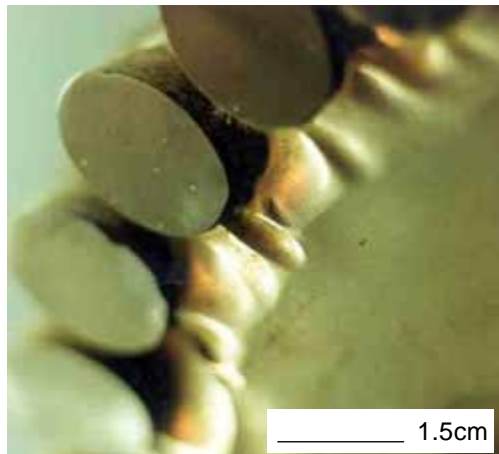
Maintenance and  
new component  
bills are massive  
(\$Ms/month on  
one mine)

Damage can be  
extremely severe –  
set limits for  
remanufacture

# Subsea drill bits



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- £25-£75K/drill bit
- Lifetime can be in the 10s of hours
- Overhaul is currently very popular (reconditioning)

# Challenges for Pump Manufacturers - Injection Pumps in Alaska



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1980s - Duplex SS with  
Co-base weld overlays



Quality of injection fluid  
deteriorated - overhaul frequency  
increased



1989 - Super Duplex with sintered WC  
wear rings and HVOF WC-NiCrSiB for  
impeller eye wear ring



Standard Duplex Stainless  
Steel Impeller after 7 months  
services "1989- Service  
Conditions"



# Typical Wear Damage



← Super Duplex Stainless Steel Impeller and Eye Wear Ring. Wear ring coated with HVOF-applied WC (50%). After 9½ months service "1989 conditions"

Super Duplex Stainless Steel Impeller and Eye Wear Ring. Wear ring coated with HVOF-applied WC (90%) with 10%Ni. After 2 years service "2001 conditions" →





The challenge in the **remanufacturing** process is to manufacture a pump from a **used** or surplus piece of equipment that will meet or exceed the mechanical, hydraulic and service life requirements of the end user.

# Remanufacturing of pumps

## - Specific Issues



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- Understand the failure and service life – assess if the new life is different
- Could lessons be learnt from this initial service period?
- Logistics of the remanufacturing process – disassembly etc (paper by Maddox, World Pumps, February 2001)
- Options for optimising the new product
- Costs and benefit analysis
- Considerations for design for remanufacture – to pass on to next generation new products

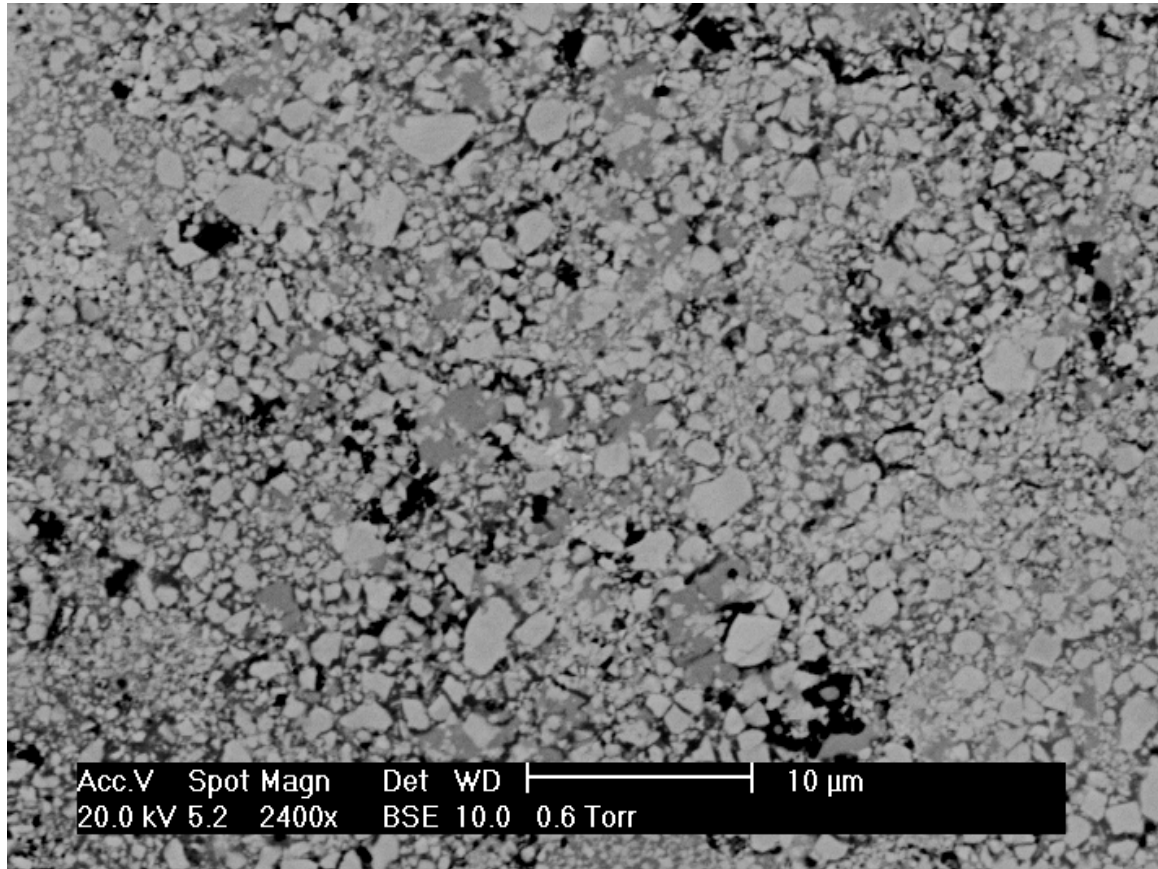
# Understanding Failures

# Coating Microstructure (HVOF WC-Co-Cr)



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Element	Mean value (%wt)
C	5.76
O	0.65
Cr	4.03
Co	10.3
W	79.25

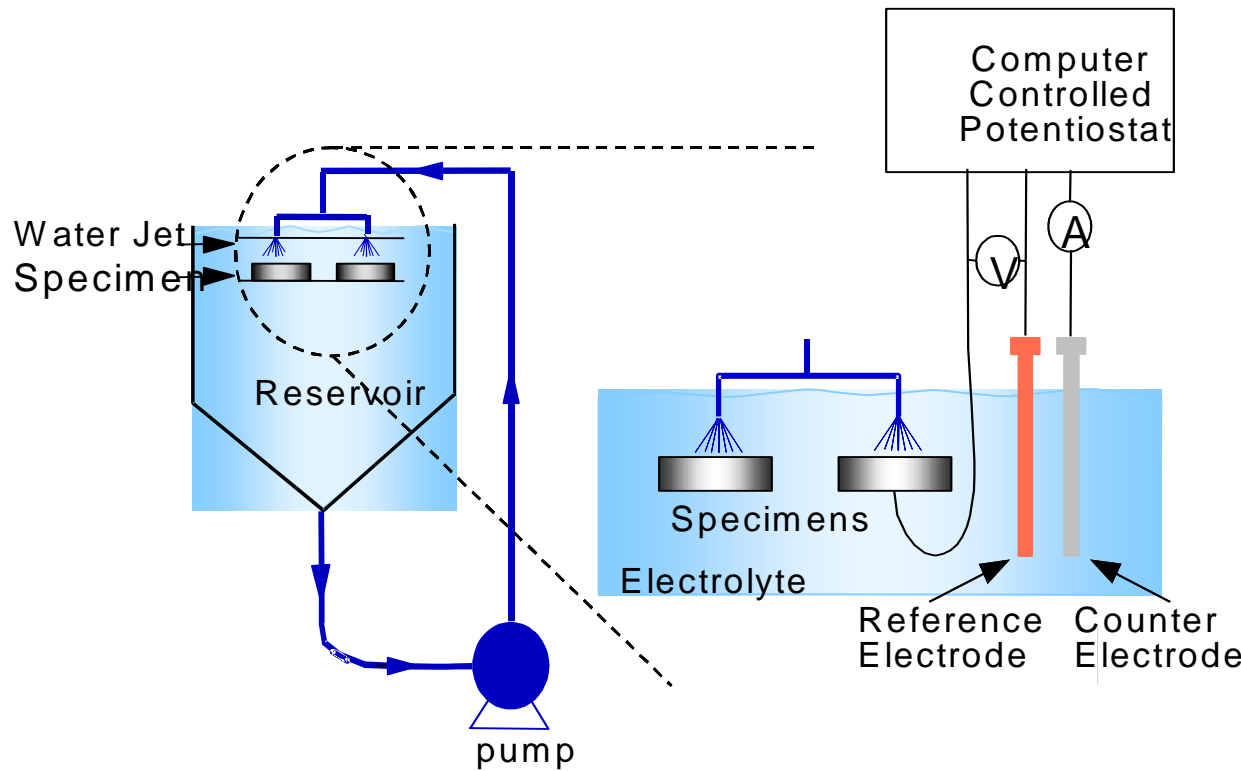


- Uniform particle size
- Uniform distribution of hard phase

# Laboratory Simulation of Erosion-Corrosion



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## Test Conditions:

90° angle of impingement

8 hours

3.5% NaCl

20°C and 50°C

17 m/s jet velocity

200, 500 and 1000 mg/l solids

# Degradation Mechanisms



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**TVL= Total Volume Loss**

$$C=C'+\Delta C_e$$

**Corrosion in static conditions (C')**  
**Enhancement due to erosion ( $\Delta C_e$ )**

**The increase of erosion  
due to corrosion ( $\Delta E_c$ )**

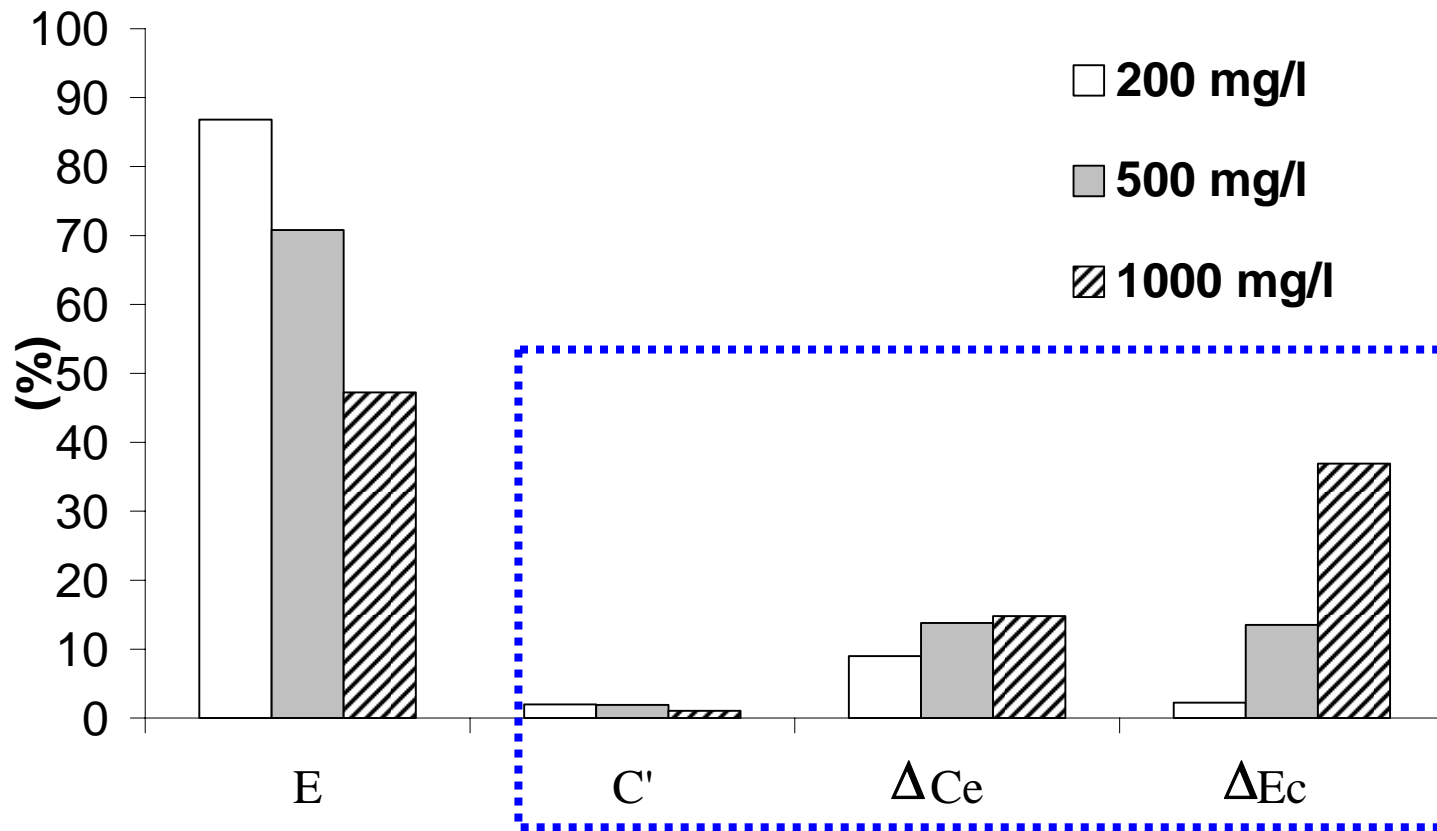
**TVL= Corrosion (C) + Pure erosion (E) + Synergy ( $\Delta E_c$ )**

$$\mathbf{TVL = C' + \Delta C_e + E + \Delta E_c}$$



# Mapping at 20°C

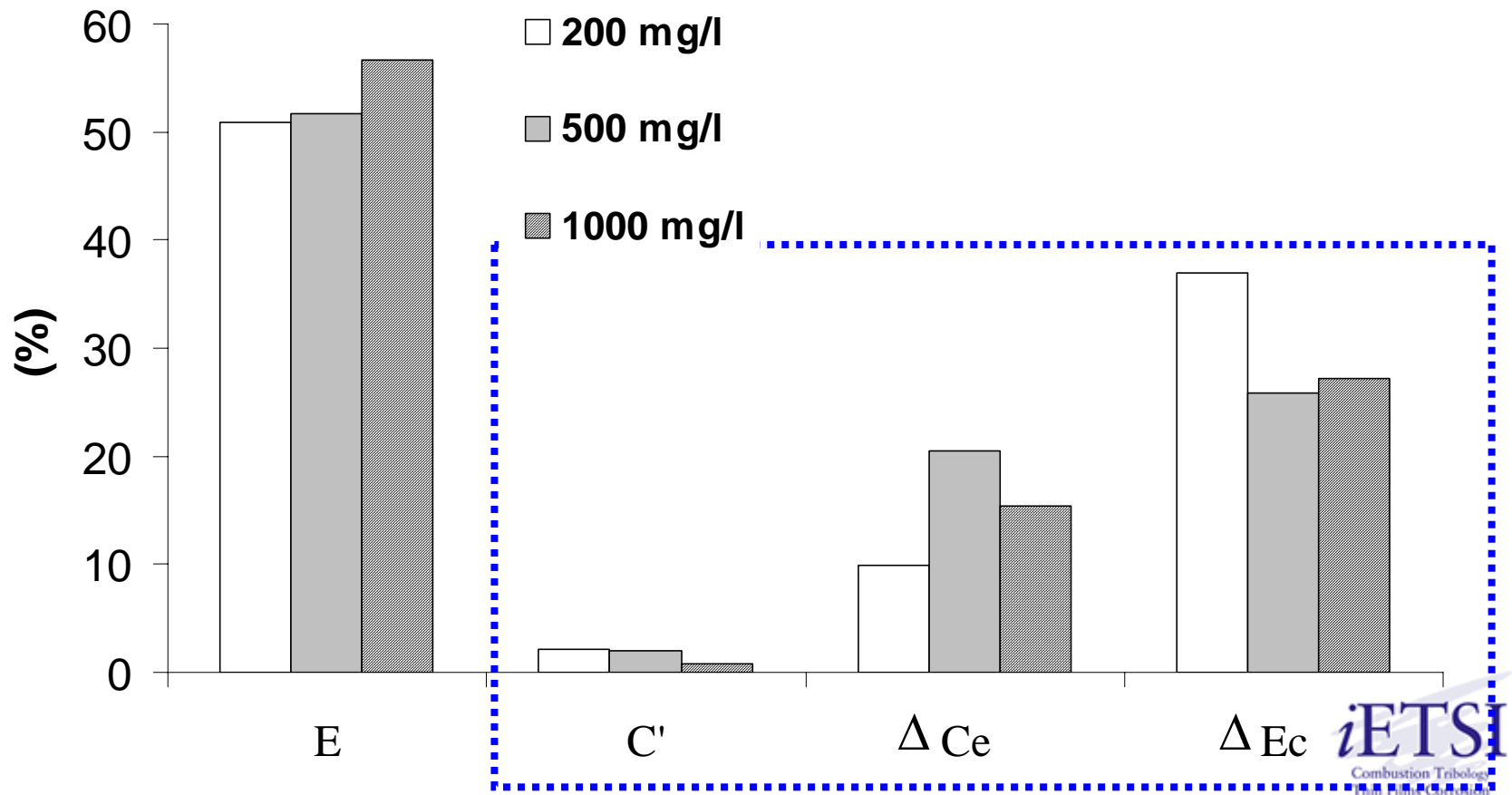
## Corrosion and synergy effect on material degradation





# Mapping at 50°C

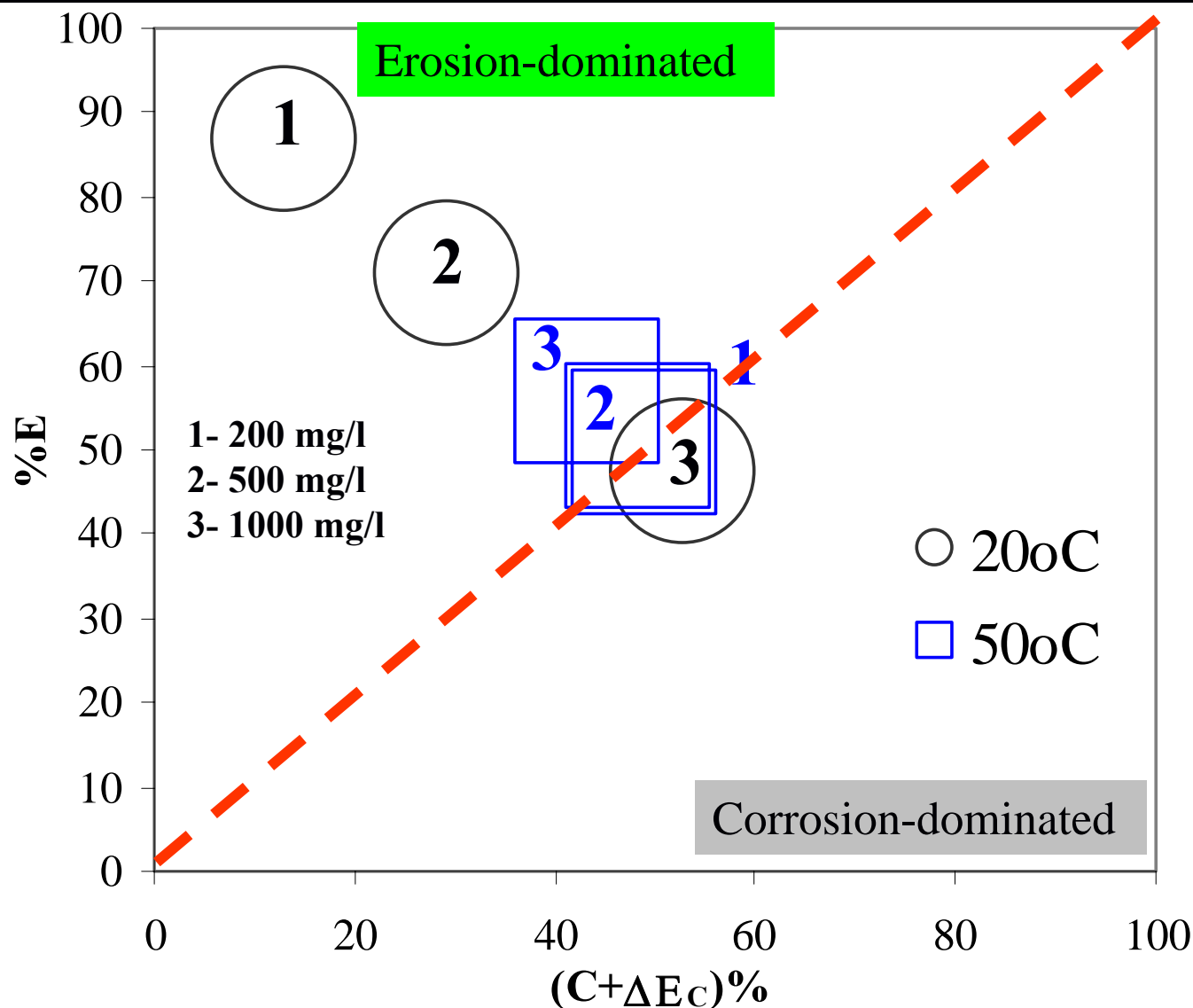
Temperature increases corrosion and synergy components



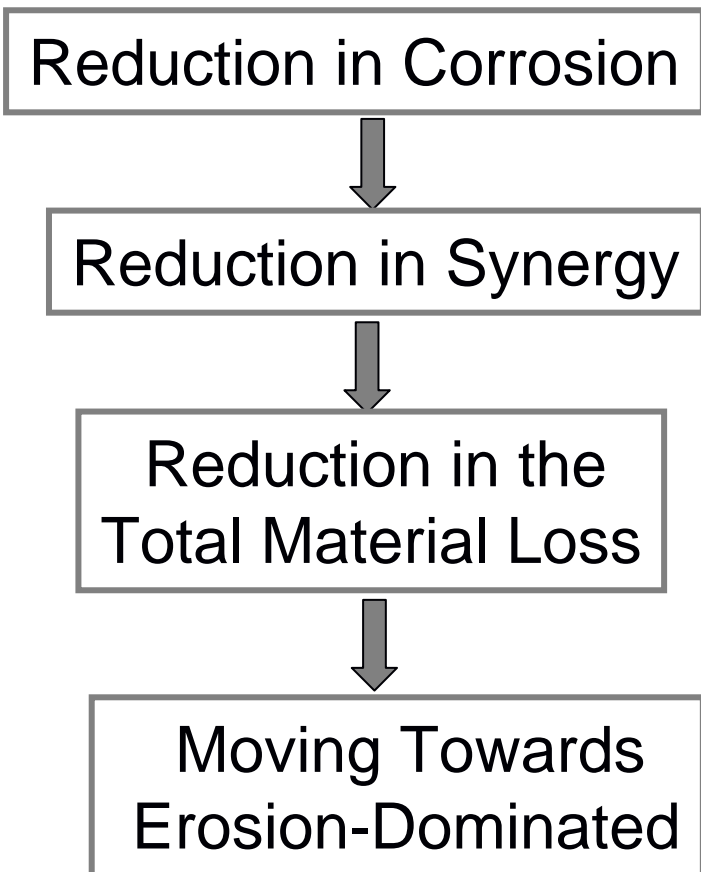
# Erosion or corrosion dominated?



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## Can HVOF Coatings be Improved?



## Possible points for improvements

Increase binder resistance

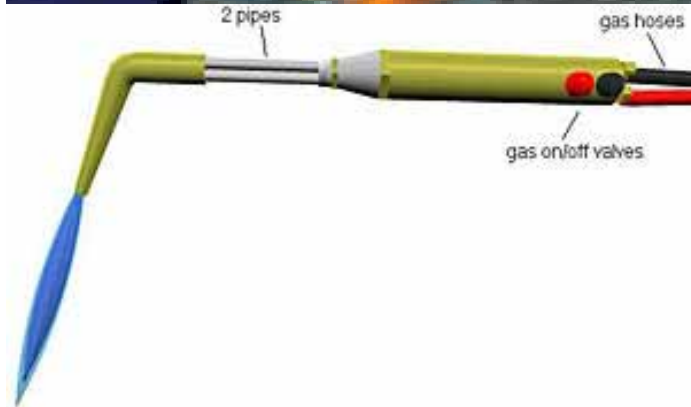
Combination hard-phase/binder  
(alternative hard-phases)

Reduce oxidation and dissolution of hard phase  
(Tungsten species)= V.Souza (2002)  
B. Bozzini (2004)

# Surface Engineering Options



# Plasma Transferred Arc



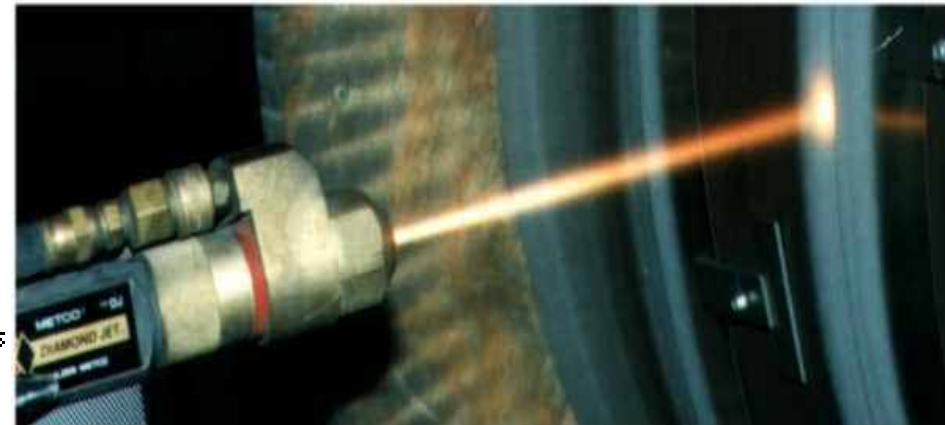
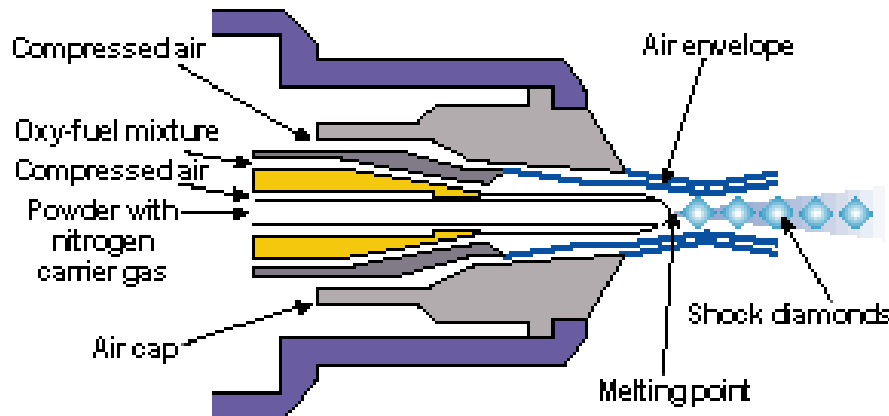
- *high deposition rate up to 10 kg/h*
- *high quality of deposited metal*
- *minimum penetration into base metal (< 5%)*
- *minimum losses of filler material*
- *deposits between 0,5 - 5,0 thickness and 3,0 - 50,0 mm width can be produced rapidly in a single pass*
- *Fe-, Ni-, Co-, Cu- base alloys as well as composite materials can be clad*



# HVOF Thermal Spray Process

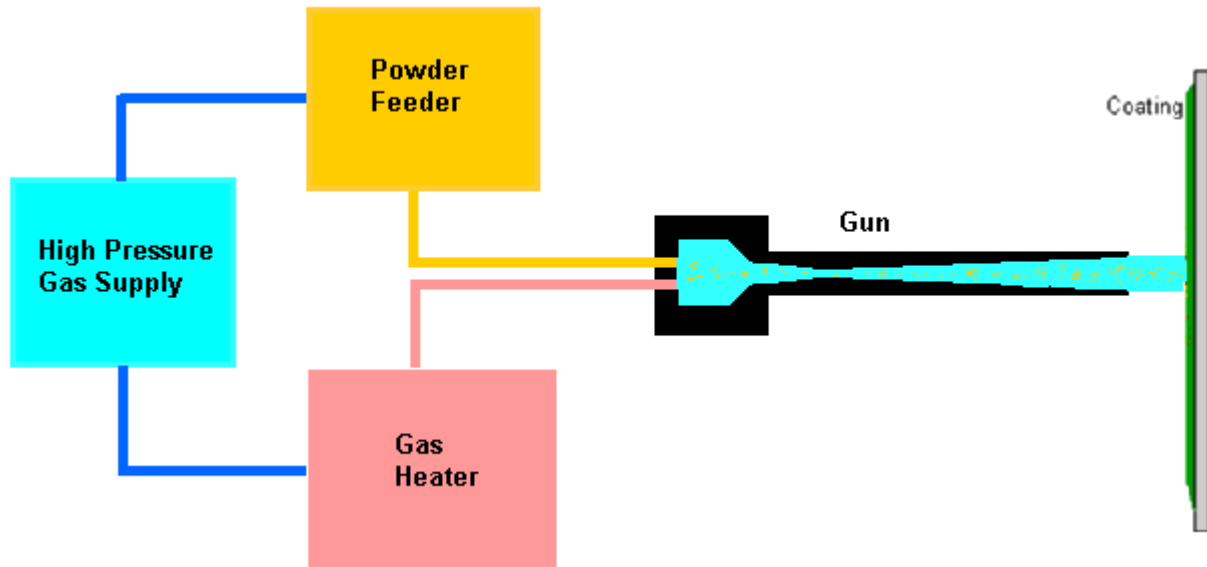


- Lower flame temperature (less likely to alter the properties of WC particles)
- Low porosity (<1%)





# Cold Spray Technology



- Russian Academy of Sciences were the first to demonstrate the cold spray process in the mid-1980s
- Next progressive step in the development of high kinetic energy coating processes (very high velocities (500 - 1500 m/s))

# Cold Spray Technology



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Conventional 'thermal spray' processes require sprayed materials to be preheated so they reach the substrate in a semi-molten state – splats are integral part of process

Cold-sprayed materials typically remain at or near room temperature until impact forming a metallurgical bond

Researchers believe this high-velocity impact disrupts thin oxide films on the particle and substrate surfaces, pressing their atomic structures into intimate contact with one another under momentarily high interfacial pressures.

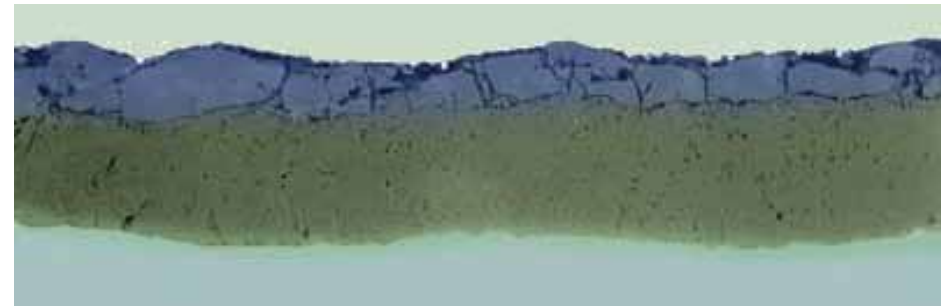
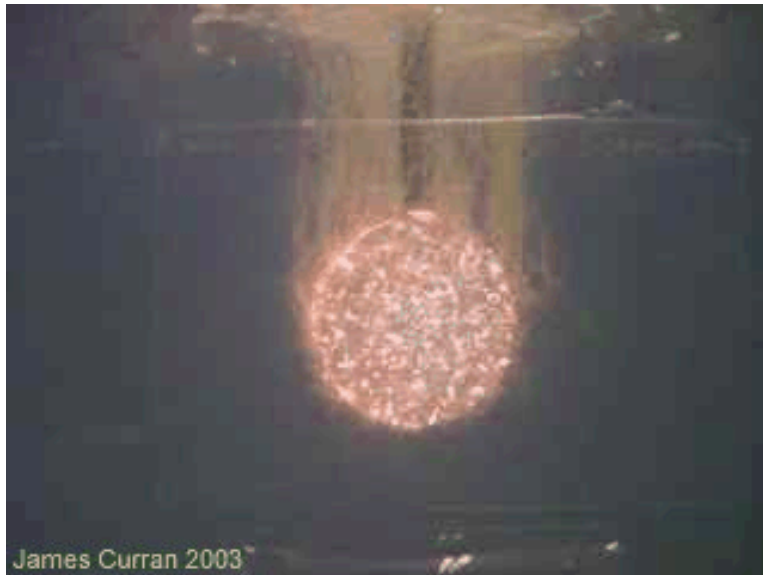
Cold-sprayed materials exhibit remarkably high densities and thermal and electrical conductivities once fabricated.

# Plasma Electrolytic Oxidation (PEO)



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- micro-arc oxidation (MAO) or spark discharge anodizing



alumina coatings consist of a relatively dense polycrystalline layer of alpha-alumina, with a softer, more porous layer of gamma-alumina formed on top

# **Cost Benefit Analysis**

Two major benefits from using remanufactured **pumps** are the utilization of existing pump resources no longer required in the original services and reduced lead-time.

**Costs** – capital, recurrent, environmental (??)

- level of damage beyond which remanufacturing is not feasible (economic or other reason)

# **Design for Remanufacture**



- For pumps – are current designs adequate?
  - ease of removal of current surfacing
  - are current surface engineering options optimised (or over-specified)? Could surface life be designed to fit maintenance schedule?
- Can we design the failure mode or the degradation to be more appropriate for remanufacturing via surface engineering?

# Concluding Remarks



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- Remanufacturing in pumps has enormous potential for recovery of properties to “as-new” but also to enhance properties of original product
- Surface engineering is evolving rapidly and this will widen the envelope of applications for which remanufacturing is feasible
- Considering the remanufacturing process at the design stage can mean that surfaces are designed to be remanufactured