

# Thermal Spraying coatings in the Aircraft MRO business

Dag van de Oppervlakte Technologie

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 Fly Responsibly

Royal Dutch Airlines



## Content:

- Repair Techniques
- Thermal Spray Coatings in the aerospace industry
- The future

# Repair Techniques

# REPAIR TECHNIQUES

Single greatest threat to our global infrastructure !!!!:

## WEAR and CORROSION

- Wear (costs: \$ 200 billion \*)
- Corrosion (costs: \$ 2 trillion \*)
- Including influence of **Temperature**

(\* every year worldwide in early replacement, lost production, poor performance and damage)

Results in a choice of:

- Repairing parts
- Buying new parts



# REPAIR TECHNIQUES

## Different types of wear:

- Adhesion wear
- Abrasion wear
- Erosion wear
- Polishing wear
- Fatigue wear
- Corrosion wear
- Fretting wear
- Frictional corrosion wear
- Electro-Corrosion wear
- Electrical Discharge wear
- Cavitation wear
- etc.



# REPAIR TECHNIQUES

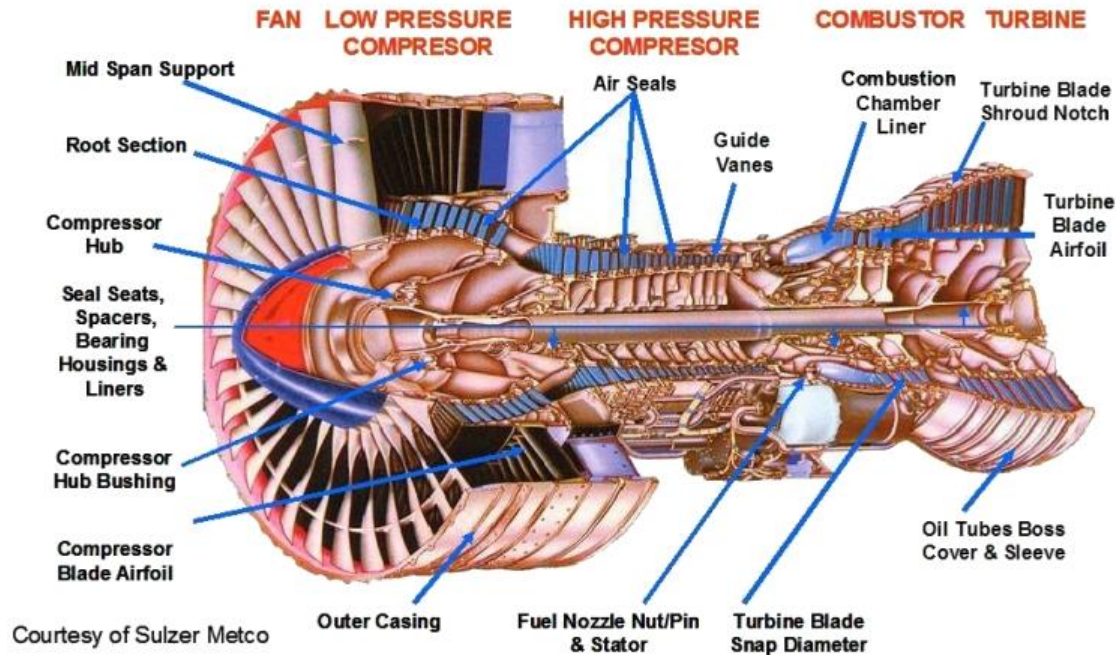
## Most common:

Abrasive wear	50%
Adhesive wear	15%
Erosive wear	8%
Fatigue wear	8%
Corrosive wear	5%
Remainder	14%



# REPAIR TECHNIQUES

Engine parts in need of a (thermal spray) coating:



# REPAIR TECHNIQUES

Rotating parts:            Shafts: fanmidshaft  
                                  Seals: air-oil seals, thermal shield  
                                  Spools: 3-9 spools  
                                  Disks: fandisk, HPT disk, LPT disk  
                                  Blades: HPT, LPT, HPC, LPC  
                                  Spinner Cone

Combustors:                Cowls  
                                  Dome  
                                  Swirlers  
                                  Innerliner / Outerliner

Stator parts:                Supports: Nozzle Support stg. 2  
                                  Sumps: Oil-sump  
                                  Frames: TMF, CRF  
                                  Vaness



# REPAIR TECHNIQUES

By using the “right” repair technique one can not only repair the part, but also improve properties of the base material and therefore also the functionality of a part.

One can think about improving:

- Wear resistance
- High temperature resistance
- Chemical durability
- Non-stickiness effect
- Roughness
- Brazability
- Corrosion resistance
- Hardness
- Electrical conductivity
- (Anti-)Reflection
- Abradability
- etc.

# REPAIR TECHNIQUES

## Choosing a repair technique taking into account:

- Stress / Load factor (torsion- and tension stress / loads)
- Environment (industrial surrounding, offshore, etc.)
- Kind of wear (erosive, abrasive, fretting, adhesive, sliding wear, impact wear, etc.)
- Temperature
- Surface condition
- Geometry (design)
- Kind of material

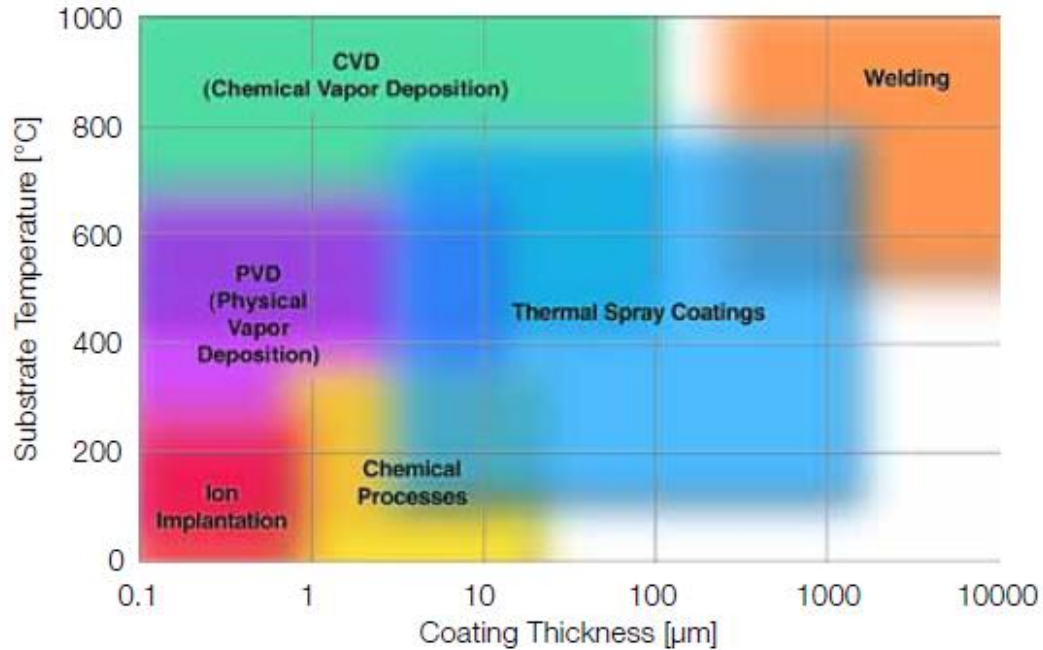
# REPAIR TECHNIQUES

## Different repair techniques:

Techniques with effect <u>in</u> the surface	Ion-implementation	Techniques with effect <u>on</u> the surface	Elektro-chemical: plating (Nickel, Chromium, etc.)
	Thermal-chemical: carbonizing / carbonitriting, nitriting / nitro-carbonizing, borizing, chromating, etc.		Chemical: plating (Nickel)
	Chemical: etching, polishing, elektrochemical (anodizing)		Organic: Paint
	Thermal: tranformation hardening by means of flame, induction, laser		Mechanical: roll cladding, explosion cladding
	Mechanical: shotpeening, laser-shock hardening, rolling, grinding		Clad welding
			<b>Thermal Spraying</b>
			Deposition from gas phase: PVD, CVD
			Liquid metal immersion: (Zinc, Aluminium)

# REPAIR TECHNIQUES

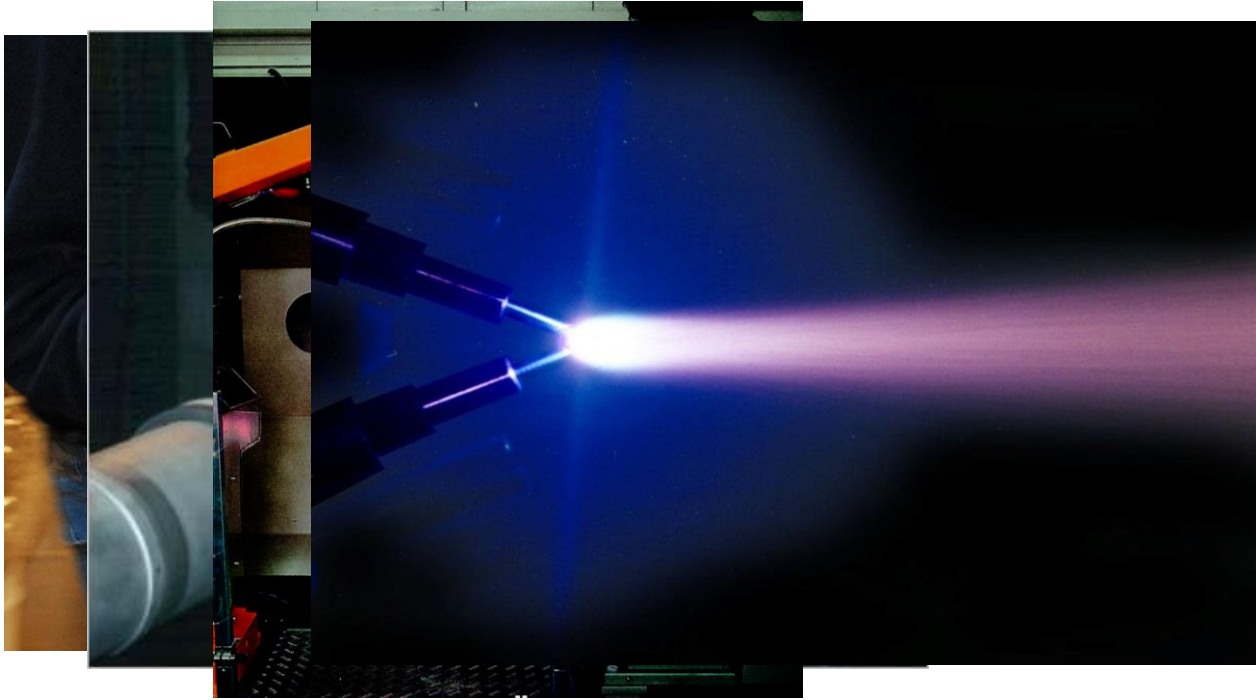
Comparing coating techniques:



# TS Coatings in aerospace industry

# TS Coatings in aerospace industry

Thermal spray processes:



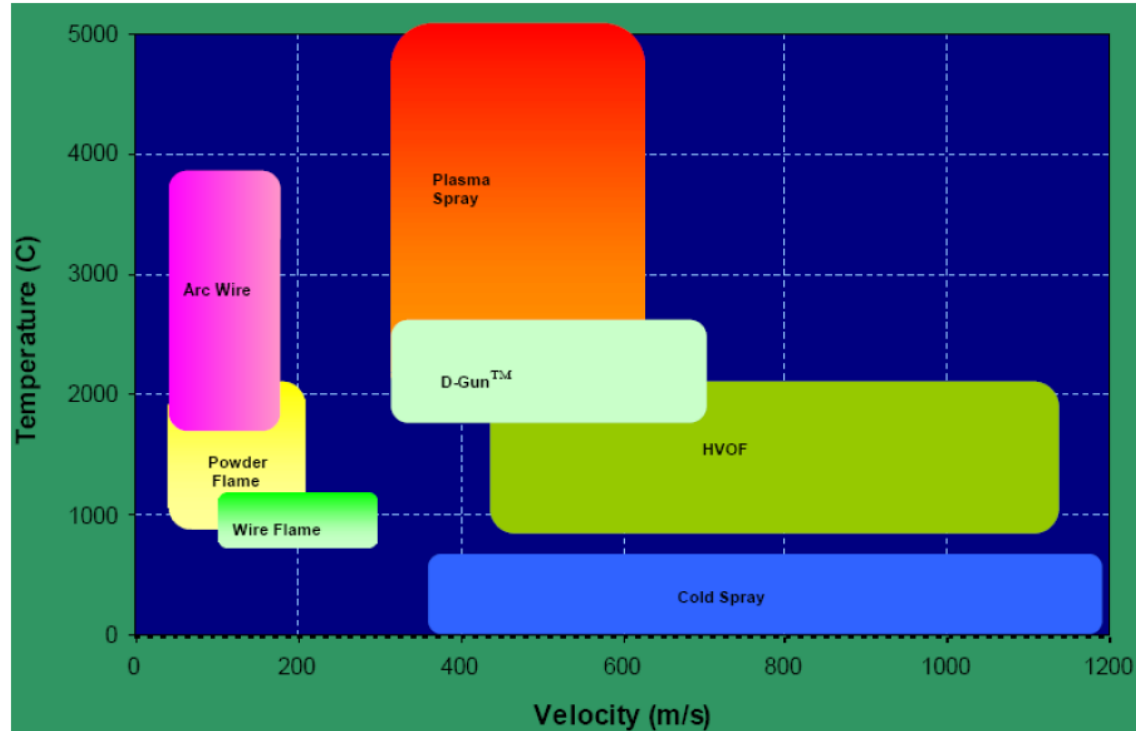
# Thermal spraying

Thermal Spraying is a “simple” process..... 😊



# TS Coatings in aerospace industry

Thermal spray processes:





# TS Coatings in aerospace industry

Engineered aerospace coatings based on materials and thermal spray processes:

## Material groups:

Pure Metals

Alloys

Super Alloys

Non-metals

Carbides

Ceramics

Cermets

Nitrides

Exothermic materials

Plastic Composites

Special blends / Mixtures

## Processes:

Air Plasma Spraying (APS)

Low Pressure Plasma Spraying (LPPS)

Plasma Transfer Arc Spraying (PTAS)

High Enthalpy Plasma Spraying

Powder Flame Spraying

Wire Flame Spraying

Electric Twin Wire Arc Spraying

High Velocity Oxygen Fuel (HVOF)

High Velocity Air Fuel (HVOF)

High Pressure High Velocity Oxygen Fuel (HP-HVOF)

Detonation Spraying

Super Detonation Spraying



# TS Coatings in aerospace industry

Some of the applied materials:

## **Pure metals:**

- Aluminium
- Zinc
- Molybdenum

## **Alloys/Blends:**

- Nickel-alloys:
  - o Inconel
- Cobalt-alloys:
  - o T800
  - o T400
- NiAl
- MCrAlY's
- CuNiIn
- CuZnAg
- CoCrNiW
- Al-bronze

## **Metal/Carbides**

- WC/Co
- CrC/NiCr

## **Oxides**

- Al<sub>2</sub>O<sub>3</sub>
- Al<sub>2</sub>O<sub>3</sub>/TiO<sub>2</sub>
- ZrO<sub>2</sub>/Y<sub>2</sub>O<sub>3</sub>

## **Metal / Non-metal mixtures**

- Ni-graphite
- Al-polyester
- Al-BN

## **Cermets**

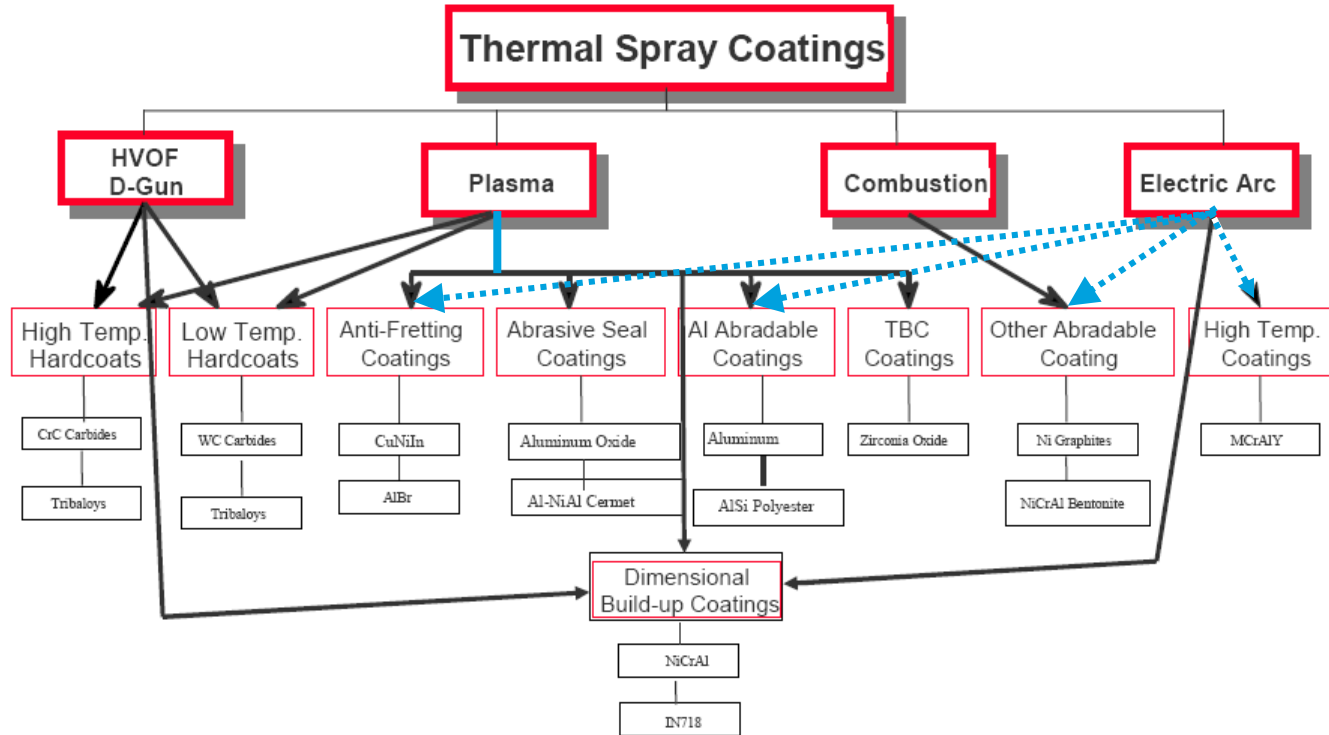
- Al<sub>2</sub>O<sub>3</sub>/NiAl
- ZrO<sub>2</sub>/NiCr

# TS Coatings in aerospace industry

Some examples of functionality and associated coatings:

- Anti-static: Zn, Al
- Anti-fretting: CuNi, CuNiIn, CuAlFe
- Anti Wear and/or Impact (Low Temp.): WC/Co, WC/Co/Cr
- Anti Wear and/or Impact (High Temp.): CrC/NiCr, CrC/NiCo
- Bonding and/or dimensional restauration: NiAl, NiCrAl, Inc718
- Bonding at high temperatures: MCrAlY's
- Electrical Conductivity: Zn, Al
- Machine Element Clearance Control: Al<sub>2</sub>O<sub>3</sub>/TiO<sub>2</sub>
- Sliding wear: Mo
- TBC: ZrO<sub>2</sub>/Y<sub>2</sub>O<sub>3</sub>
- Tribological: T400, T800
- Abradables: Polyester/AlSi, NiC, CuZnAg, AlSi/BN

# TS Coatings in aerospace industry



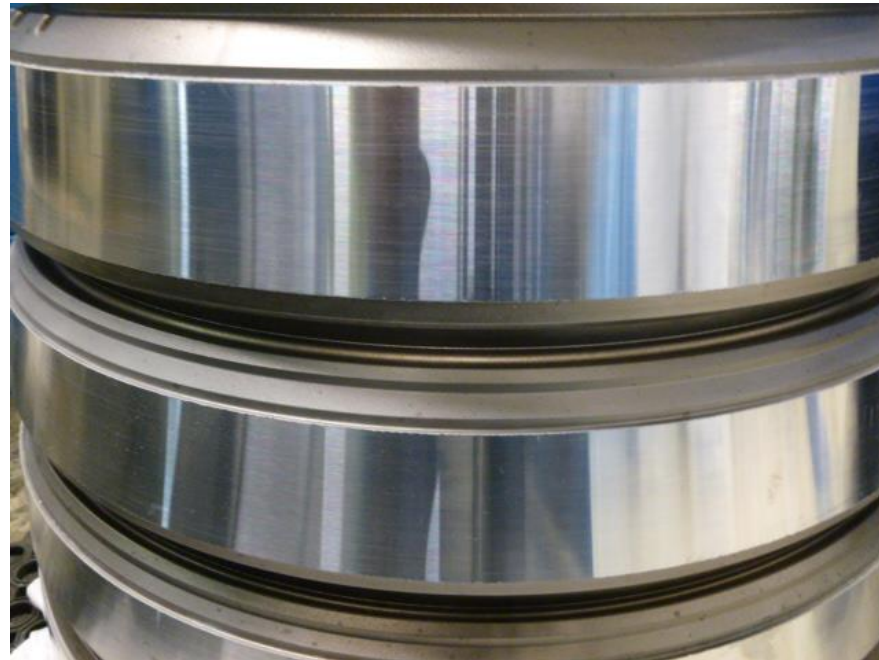
# TS Coatings in aerospace industry

## Cost aspects:

- Investment in thermal spray equipment and automation
- Investment in periferial equipment (shot peening, grit blasting, machining)
- Consumables (spray material, masking, cleaning, filters, etc.)
- Spare parts (for guns, powder feeders, etc.)
- Testing
- Labour
- Energy
- Waste disposal

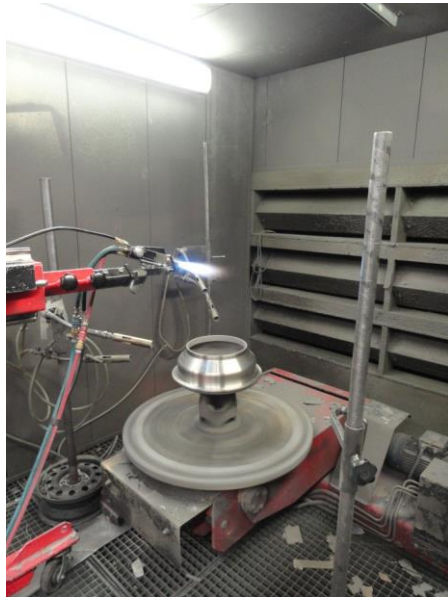
# TS Coatings in aerospace industry

Stage 3 -9 HPC spool with turned Aluminum abrasible coating



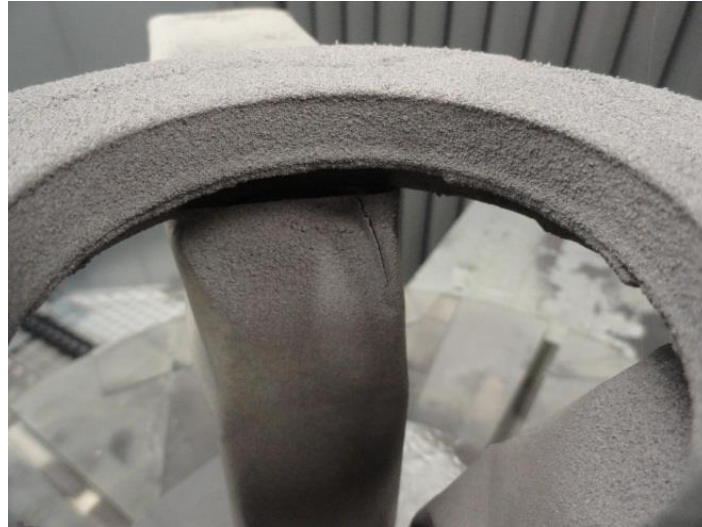
# TS Coatings in aerospace industry

Seals prepared for coating



# TS Coatings in aerospace industry

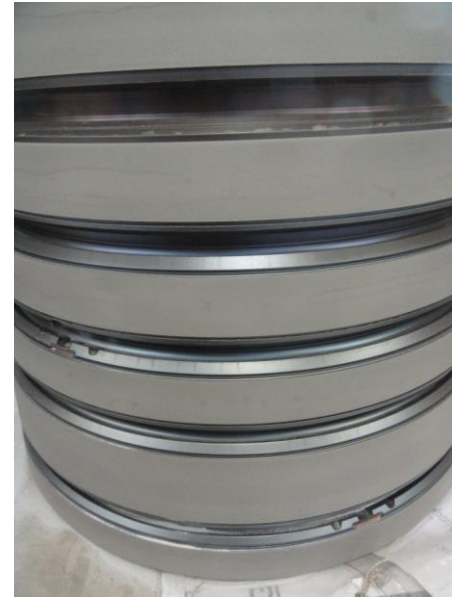
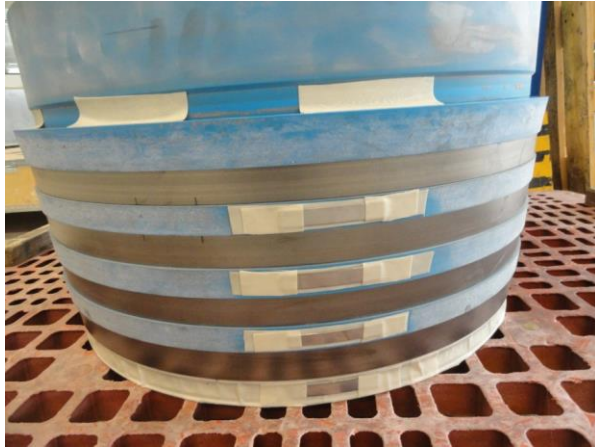
Seals with Nickel-Graphite abradable coating





# TS Coatings in aerospace industry

Spool masked including test samples.



Spool with Al<sub>2</sub>O<sub>3</sub> Machine Element Clearance Control coating.

# TS Coatings in aerospace industry

High Pressure Turbine Forward Seal prepared for Al<sub>2</sub>O<sub>3</sub> coating.



# TS Coatings in aerospace industry

Center Vent Tube for Fan Mid Shaft with ground CuNiIn coating



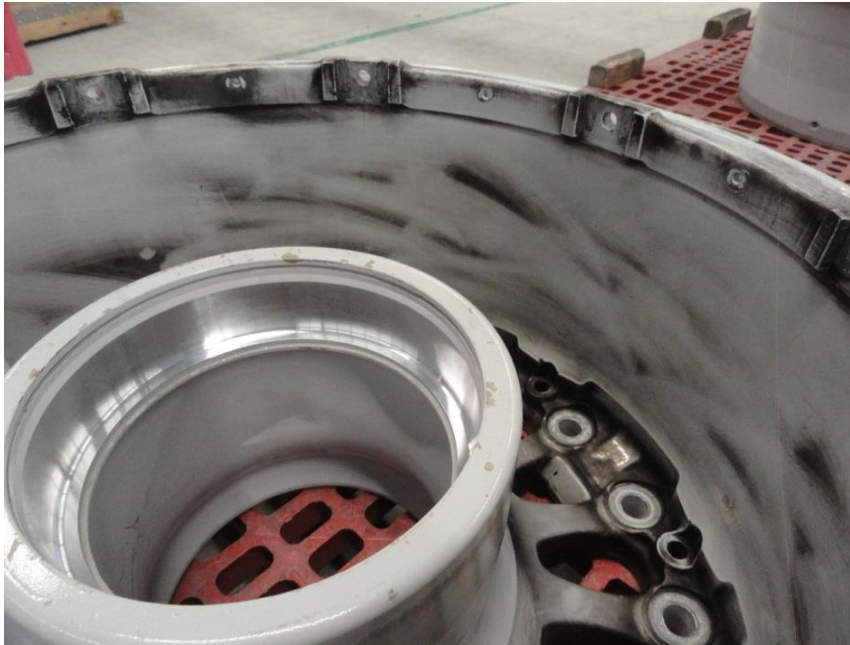
# TS Coatings in aerospace industry

Knife Edges on a Seal with Al<sub>2</sub>O<sub>3</sub> coating



# TS Coatings in aerospace industry

Aircraft Wheel with dimensional restauration.



# TS Coatings in aerospace industry

LPC Fandisk with CuNiIn coating



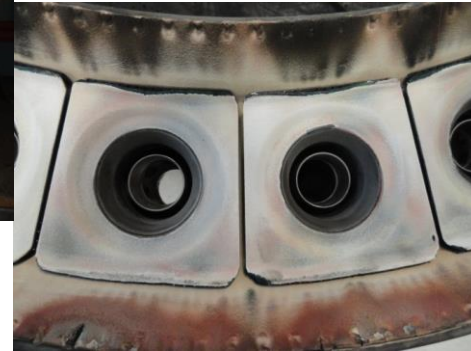
# TS Coatings in aerospace industry

High Pressure Compressor Casing with Al abrasadable coating



# TS Coatings in aerospace industry

Outer liner, inner liner and dome of burner chamber.  
NiCrAlY bondcoat with ZrO<sub>2</sub> topcoat (8% stabilized Y<sub>2</sub>O<sub>3</sub>).

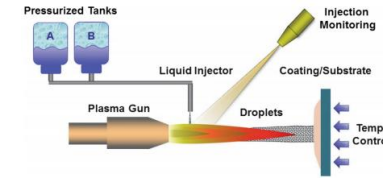
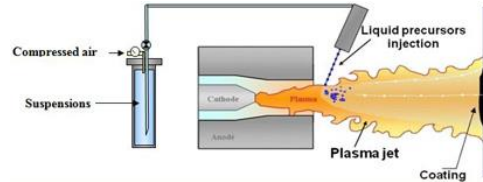
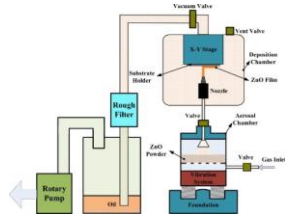
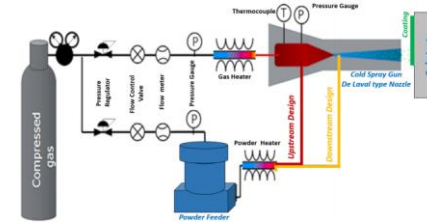




# The Future:

## Innovative spray processes:

- Gas Dynamic Cold Spraying (GDSCS)
- Aerosol Deposition (AD)
- Solution Precursor Plasma Spray (SPPS)
- Suspension Spraying



## New coatings:

- Nanostructured Coatings for Improved Wear Performance
- Smart Wear-Resistant Coatings (high wear resistant & low coefficient of friction tribo-coatings with multiple solid lubricant constituents)
- Smart Corrosion-Resistant Coatings (superhydrophobic coatings with multiple functionalities such as self-cleaning, anti-frosting/-icing, anti-corrosion)
- Improved Abradable coatings for Thermal Spraying

# The Future



# The Future



Thank you