HIPERCOAT

HIGH PERFORMANCE COATINGS TO COMBAT EROSION-DRIVEN DAMAGE IN POWER PLANTS

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KME 805: HIPERCOAT

Swedish Energy Agency

High performance coatings to combat erosion-driven damage in power plants

Energimyndigheten (Swedish Energy Agency), Diarienummer: 46465-1

Project start: 2019-01-01

Project end: 2021-08-31; revised to 2022-02-28

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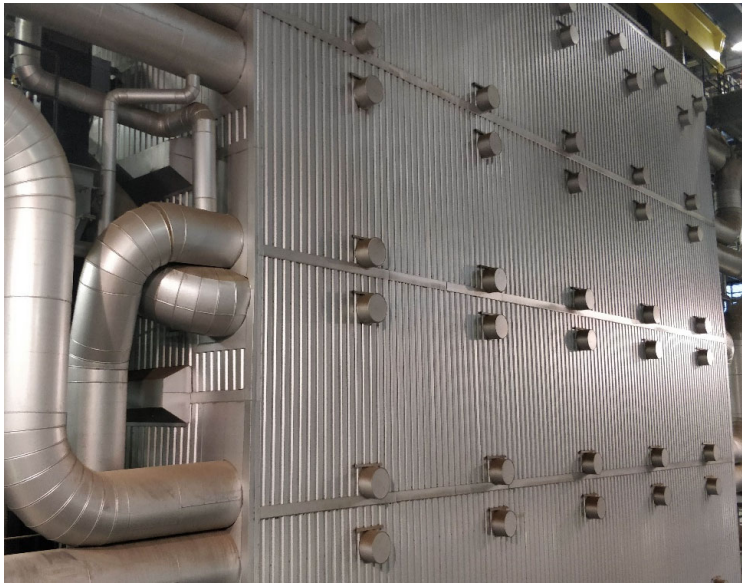
MOTIVATION

- Growing interest in biomass or waste for power generation
- High-temperature **corrosion and erosion are main damage mechanisms** in many components of biomass and waste fired boilers
- **Erosion-driven damage dominant in plants with less corrosive elements** (Cl, K etc.), employing **circulating fluidized beds** (CFBs)



- Refractory lines, corner & roof tubes, regions adjacent to cyclone openings, as well as the superheater and economizer tubes are most erosion prone
- Damage in these parts **needs periodic re-protection of weakened parts or replacement of tubes**, with consequent plant shut-downs.

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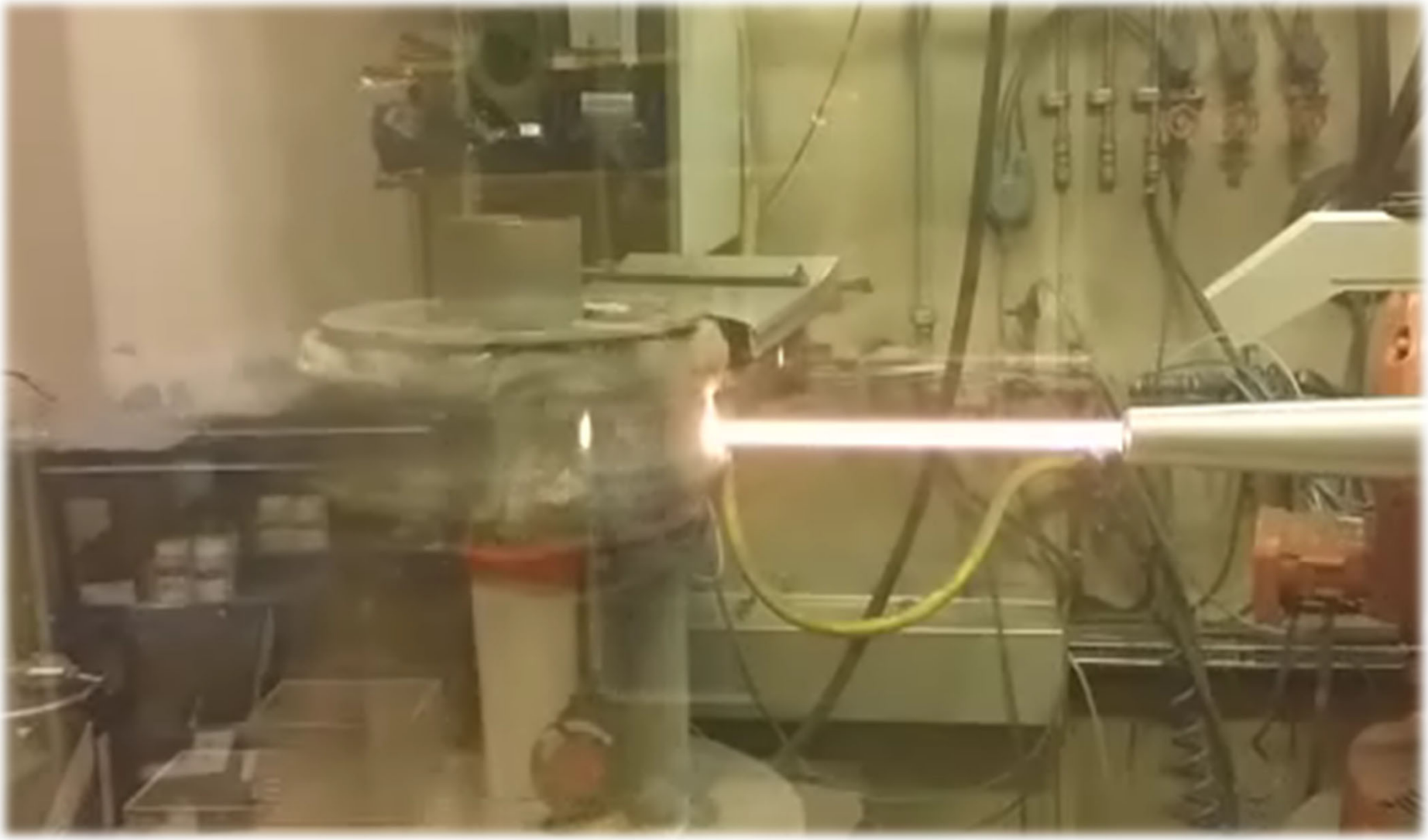
PROJECT GOALS

- Develop high performance coatings to impart **superior protection to power plant components prone to erosion-driven damage**
- Investigate the emergent supersonic **high velocity air-fuel (HVAF) process** to impart improved protection
- Explore coating **chemistries with distributed carbides and/or oxides** in a suitable Ni-based or Fe-based matrix
- After process optimization and coating characterization (lab tests), **evaluate functional performance of most promising coatings <u>in boiler environment</u>**

HVAF at University West



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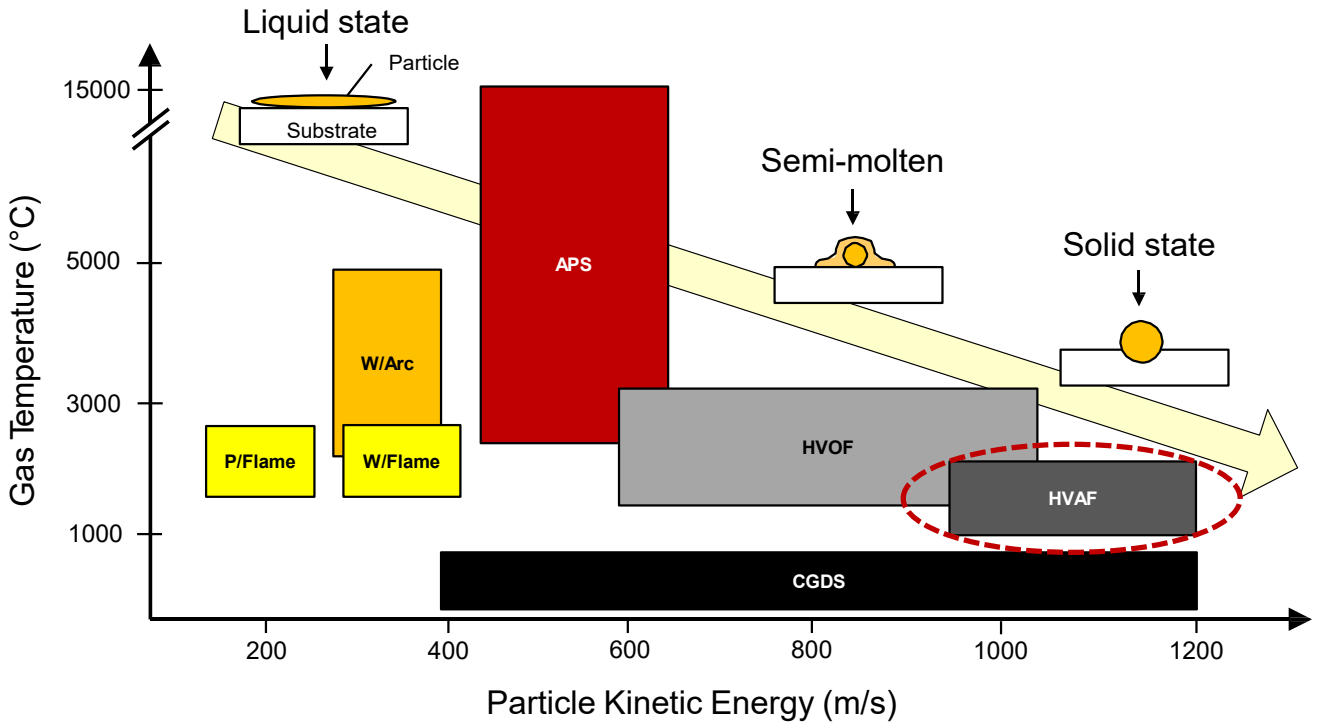
HVAF: RELATIVELY COLDER, HIGHER-VELOCITY PROCESS

Materials

- APS, Arc — Ceramics, Metals
- Flame, HVOF, HVAF, CGDS — Metals, Cermets

Energy source

- APS, Arc — *Electrical*
- Flame, HVOF, HVAF — *Combustion*
- CGDS — *Kinetic*



- APS — Air Plasma Spraying
- Arc — Wire Arc Spraying
- Flame — P/W Flame Spraying
- HVOF — High Velocity Oxy-Fuel
- HVAF — High Velocity Air Fuel
- CGDS — Cold Gas Dynamic Spray

HVAF ~ 1200 m/s

HVOF ~ 400-600 m/s

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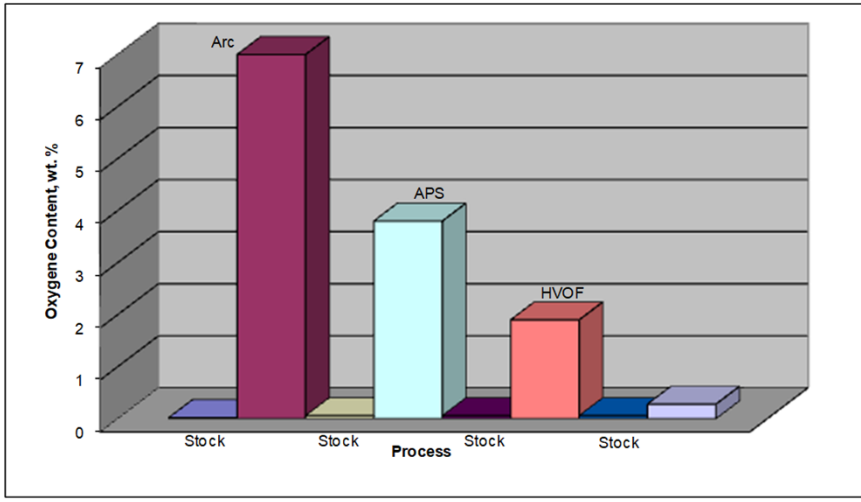
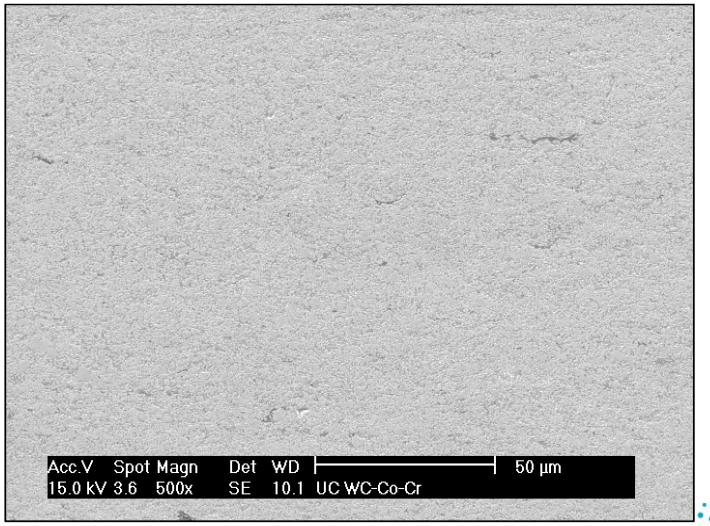
PROMINENT HVAF ADVANTAGES

- Extremely dense coatings
- Excellent bond strength
- Minimal thermal damage to feedstock … oxidation, decarburization etc. significantly suppressed
- Due to very high particle velocity and low temperature, known to yield only compressive stresses in the coatings





** Courtesy of Shinshu University, (Japan)*

Potential to improve upon current best-in-class HVOF coatings

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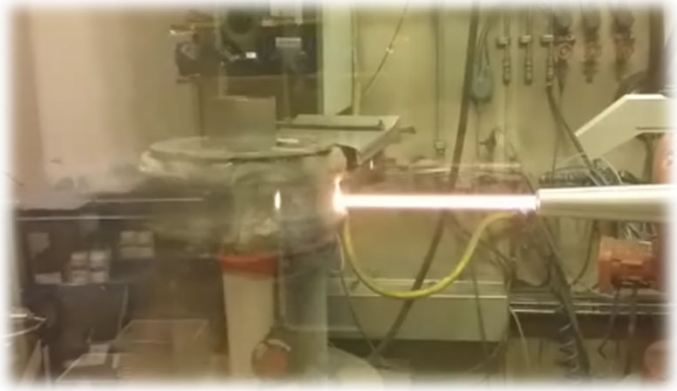
HVAF coatings' development with industrial partners



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ONE STEP AHEAD.

ANDRITZ

AUTOMOTIVE COMPONENTS FLOBY

MHE
MH Engineering AB

TROLLHÄTTAN ENERGI
Hela stans miljöbolag

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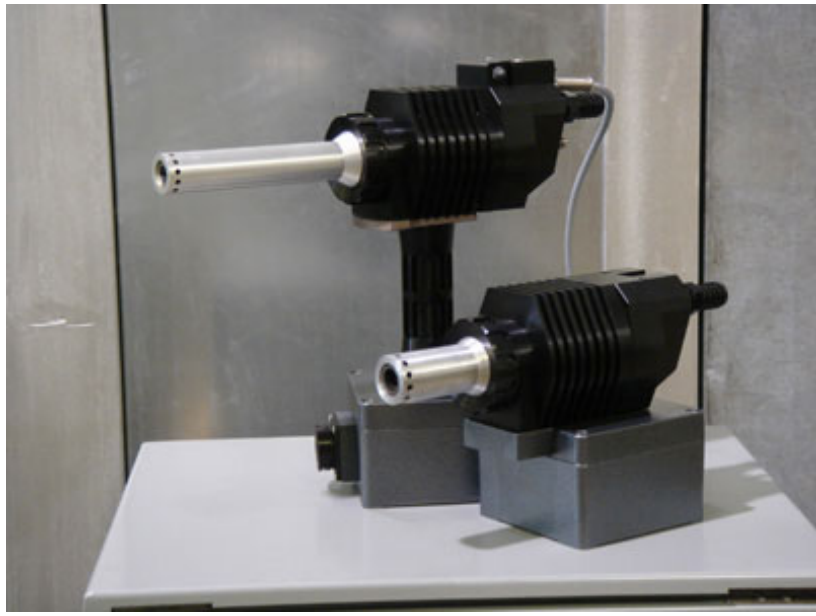
EARLY PROJECT DECISION: USE OF PORTABLE HVAF SPRAY GUN FOR ON-SITE SPRAYING

- A **M2™ Handheld HVAF Spray Gun (M2H)** variant recently available
- Permits **manual spraying**, weighs about 2 kg
- **Built in remote-control option** on the spray gun enables the operator to conveniently access jet and powder controls
- **Incorporates a "dead man" switch** for additional safety



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OVERALL APPROACH

- Identify candidate coating materials
- Spray identified materials with the hand-held M2H at UniqueCoat (USA) and by conventional HVOF at MHE; compare properties and performance (erosion testing in a laboratory rig)
- If M2H coatings found promising, lease M2H for on-site spraying
- Operator training on M2H for MHE engineers by HV
- Spraying at identified boiler plant site: MHE will spray coatings at site for field testing (HV to assist); Mälarenergi will be responsible for facilitating coatings in the plant, their intermittent inspection during shut downs and eventual removal.
- Withdrawn coatings after field exposure to be characterized by Chalmers and HV

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SELECTION OF COATING MATERIALS & PROCESSES

Materials

Powder	Material	Manufacturer	Composition
1	DS300	MHE AB	WC-CrC-NiCo
2	Amperit 593.090	Höganäs AB	Cr3C2-NiCr
3	-	Höganäs AB	Cr3C2-FeNi

Processes

- HVAF-M2H for on site spraying; effect of nozzle geometry, fuel pressure, stand-off distance investigated
- Conventional (not hand-held!) HVOF (MHE) as benchmark for comparison

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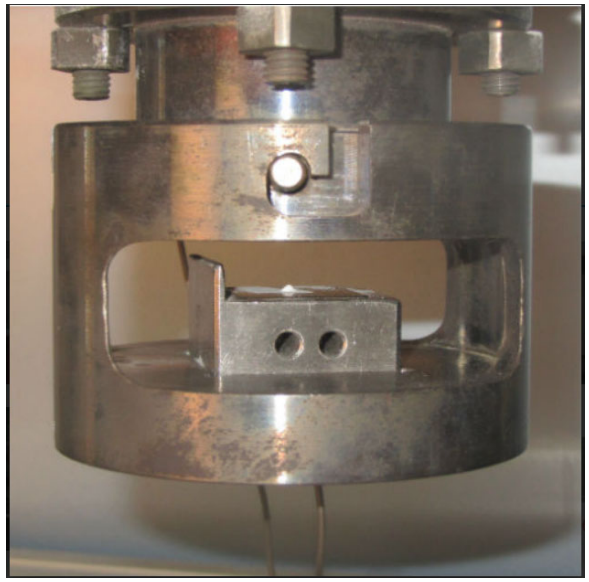
LAB EROSION TESTS

- **Air jet erosion** tests performed using following parameters:
  - 30° angle;
  - 5 g/min erodent flow rate;
  - 30 m/s particle velocity;
  - Erodent: alumina (D_{50}= 50 μm);
  - Erosion time: 10 and 20 minutes;



- Surfaces tested polished to Ra = 0.1 μm
- Samples ultrasonically cleaned with ethanol and weighed before and after each test to evaluate weight loss;
- Ambition was only to compare performance of M2H and conventional HVOF coatings, and **rank** erosion behaviour if remarkably different: <u>does not</u> simulate real conditions in the boiler'.

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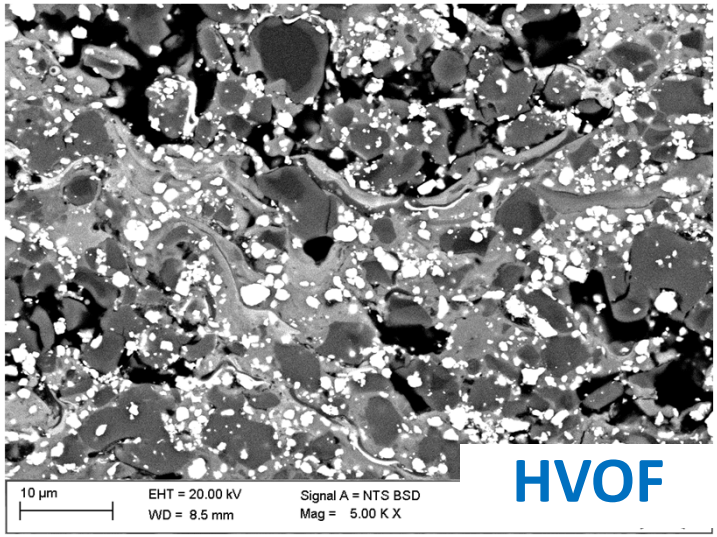
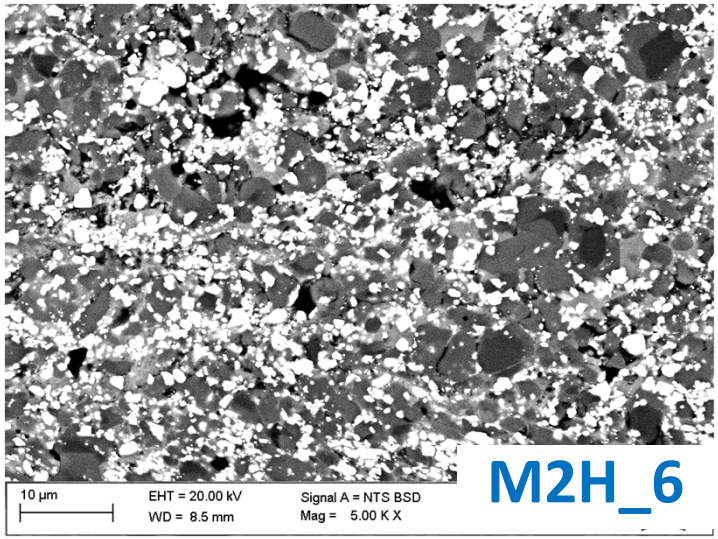
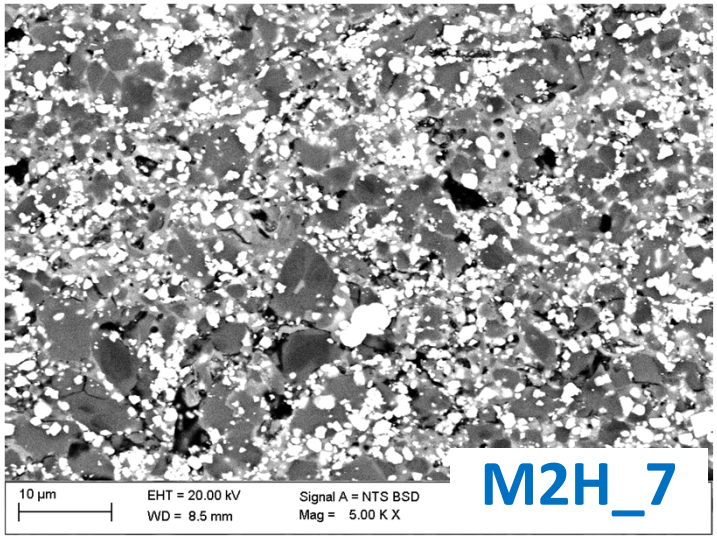
MICROSTRUCTURAL CHARACTERIZATION



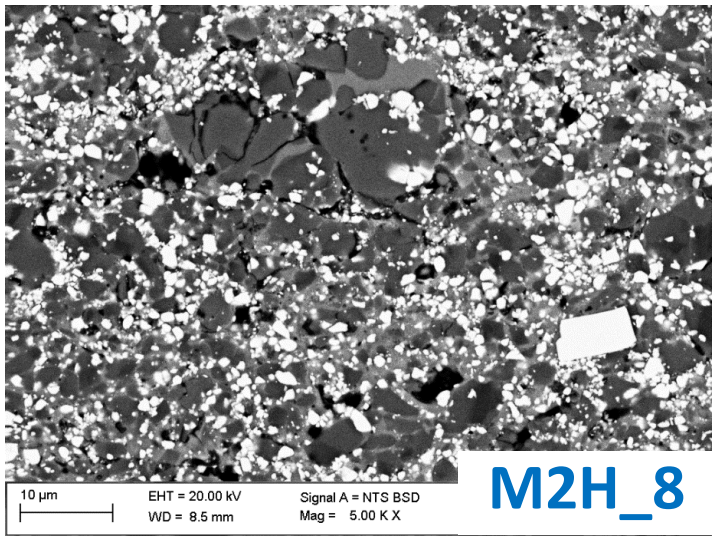
HVOF



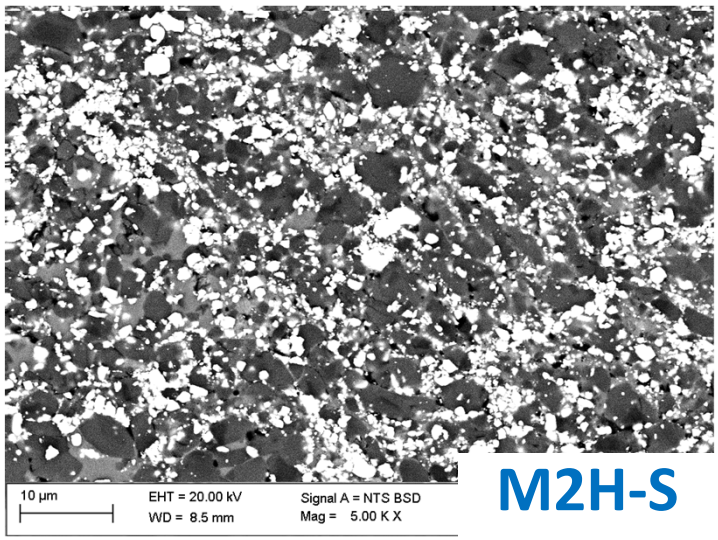
M2H_6



M2H_7



M2H_8



M2H-S

WC- Cr3C2 – NiCo

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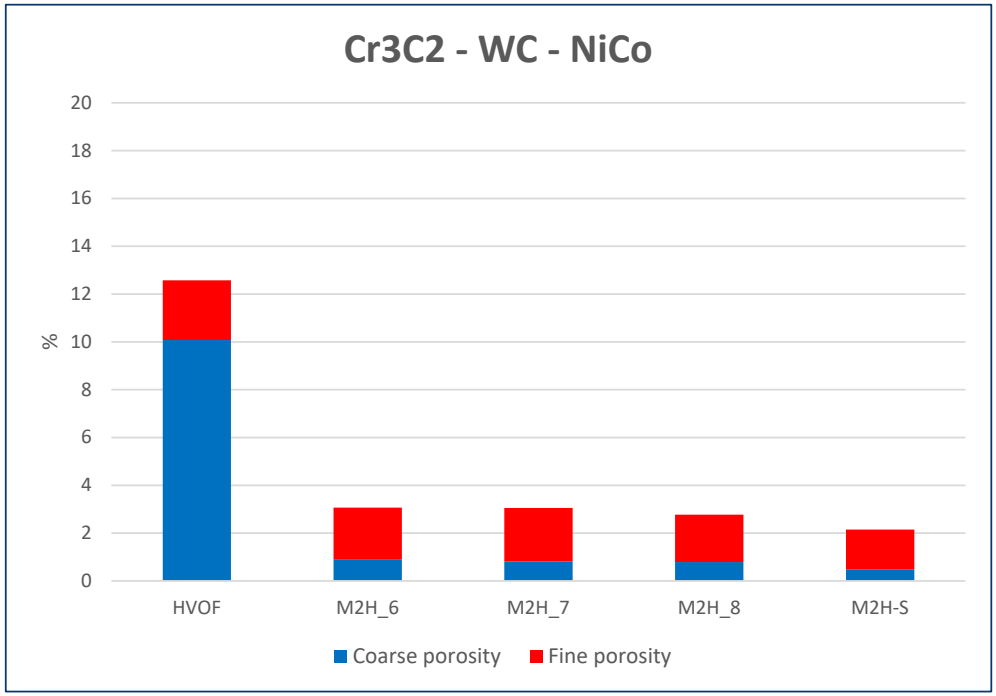
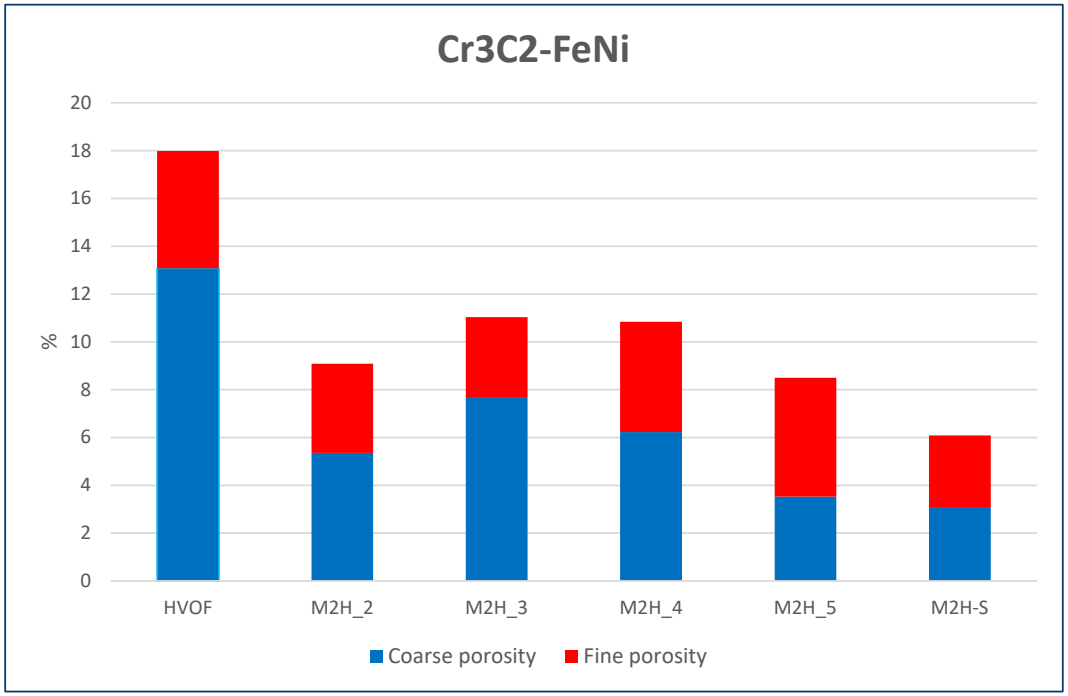
POROSITY CONTENT





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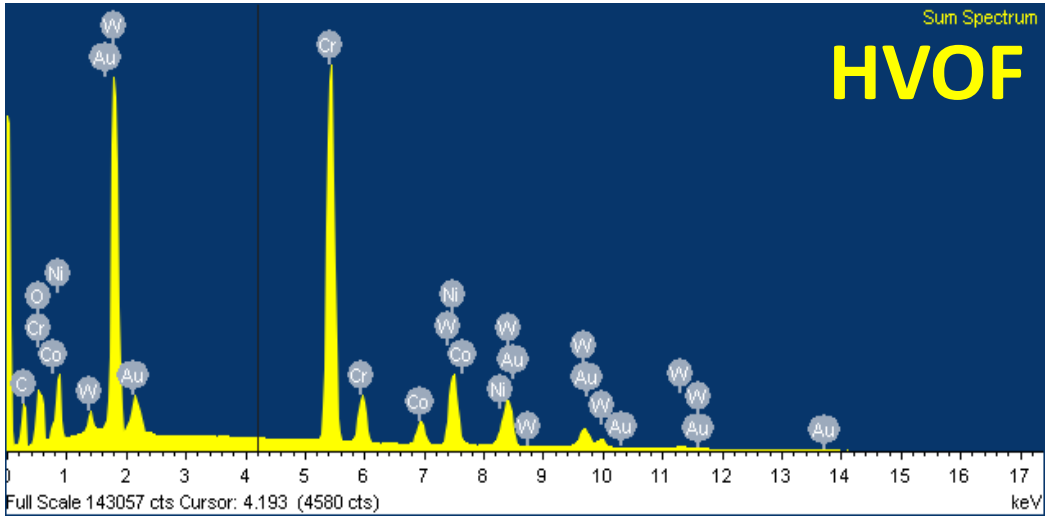
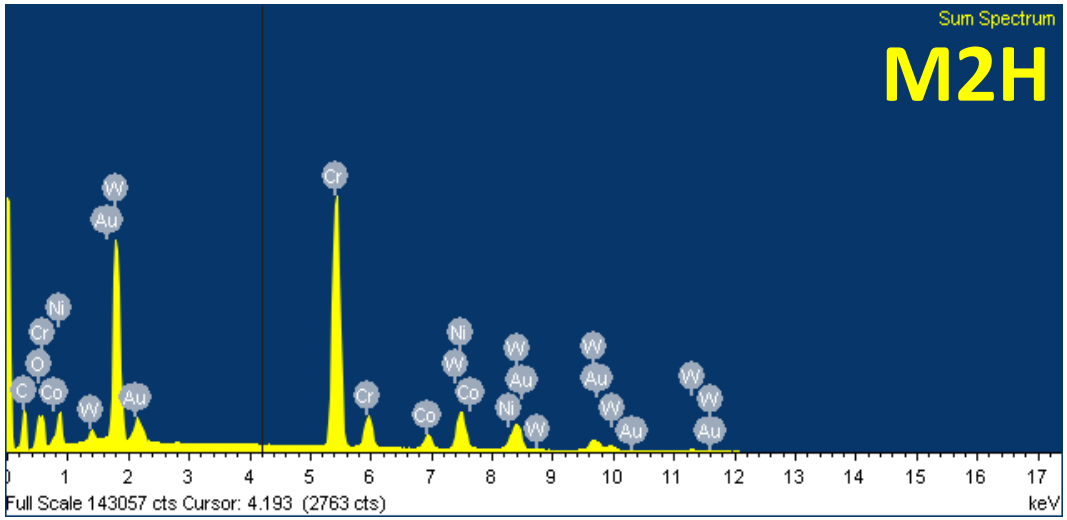
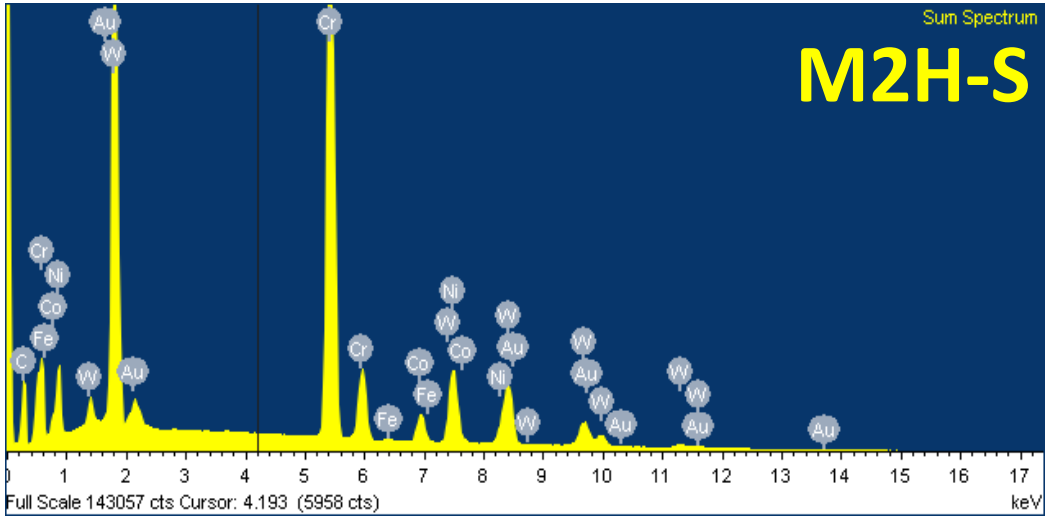
EDS ANALYSIS







WC- Cr3C2 – NiCo

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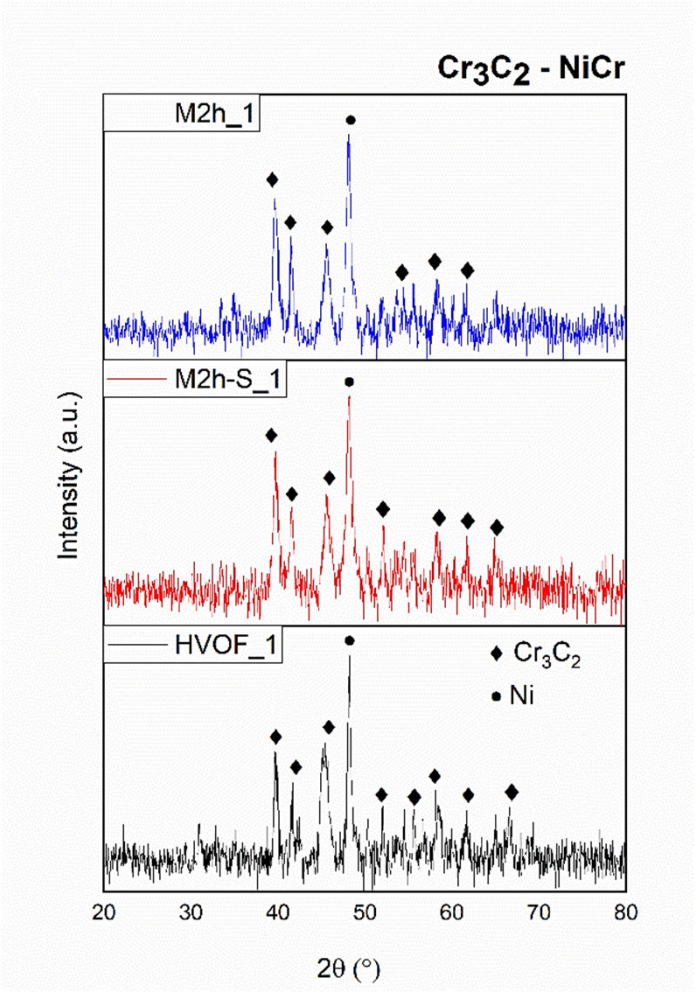
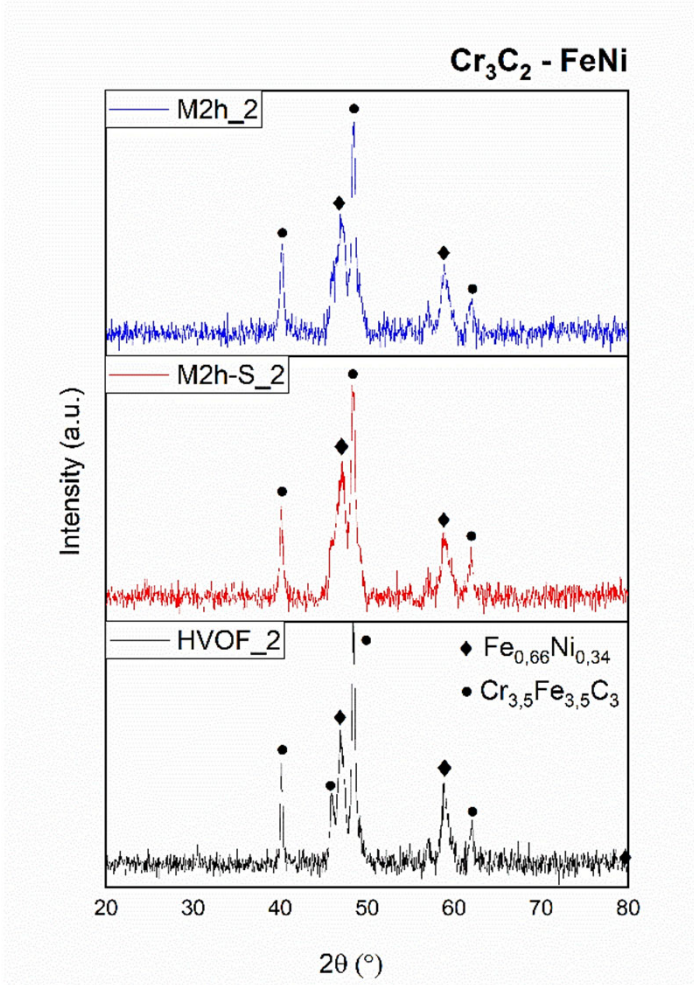
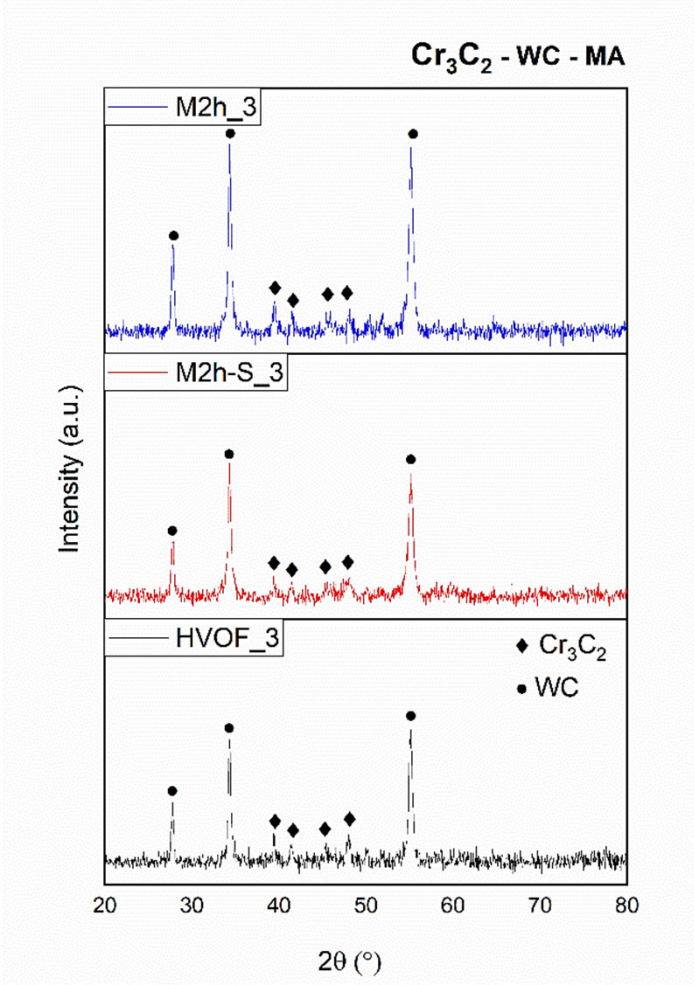
XRD ANALYSIS







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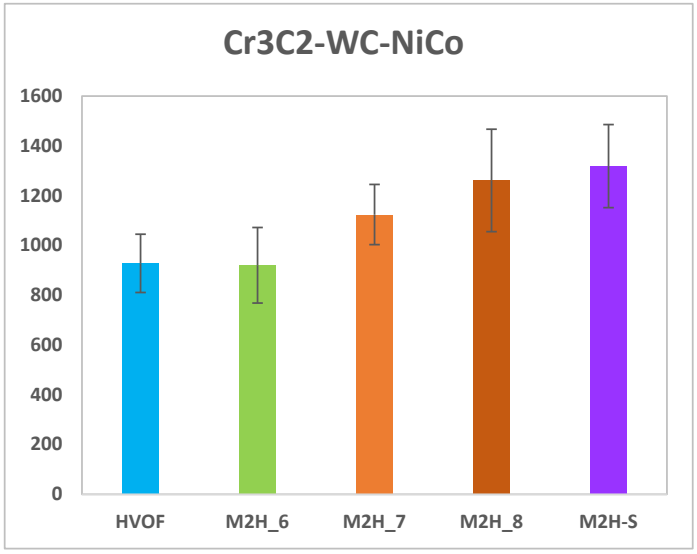
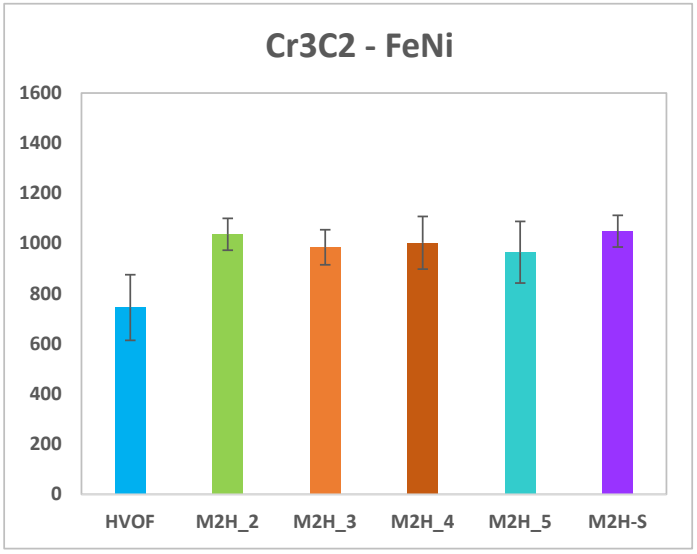
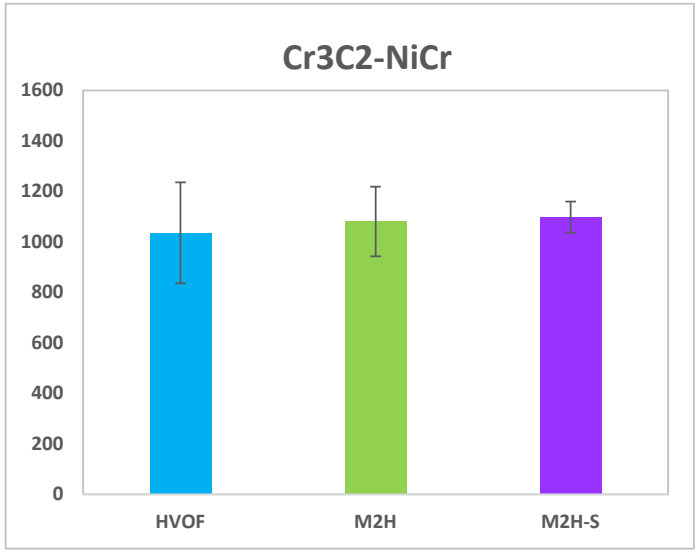
HARDNESS MEASUREMENTS







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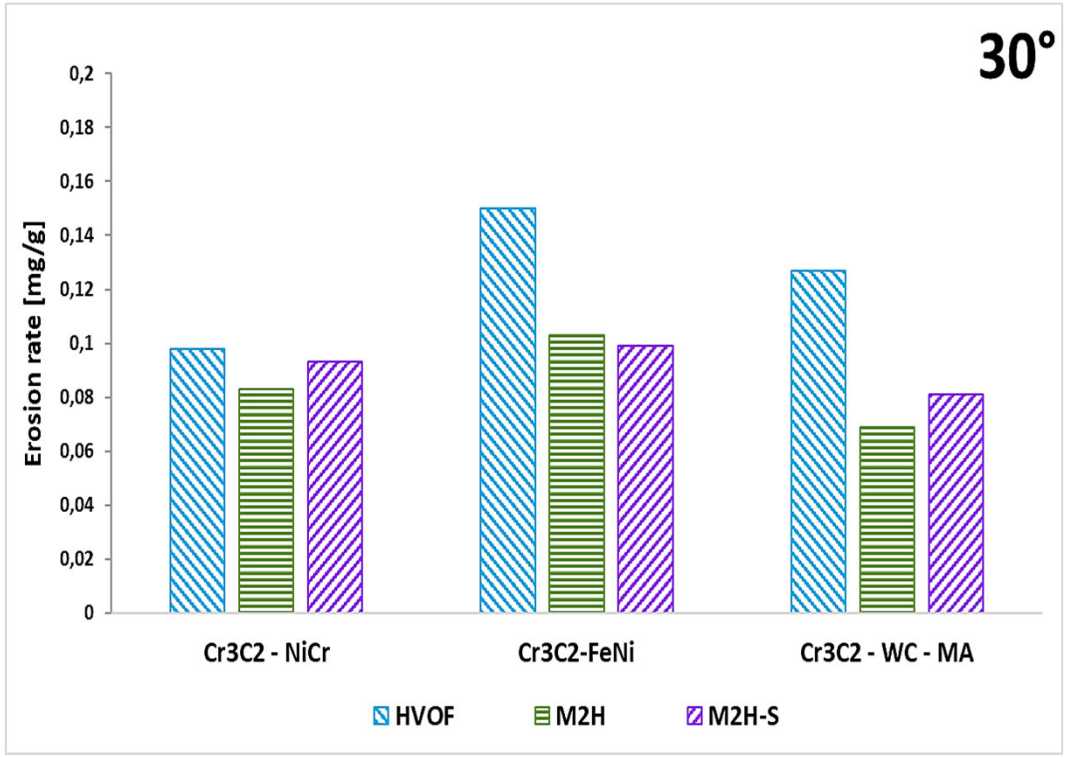
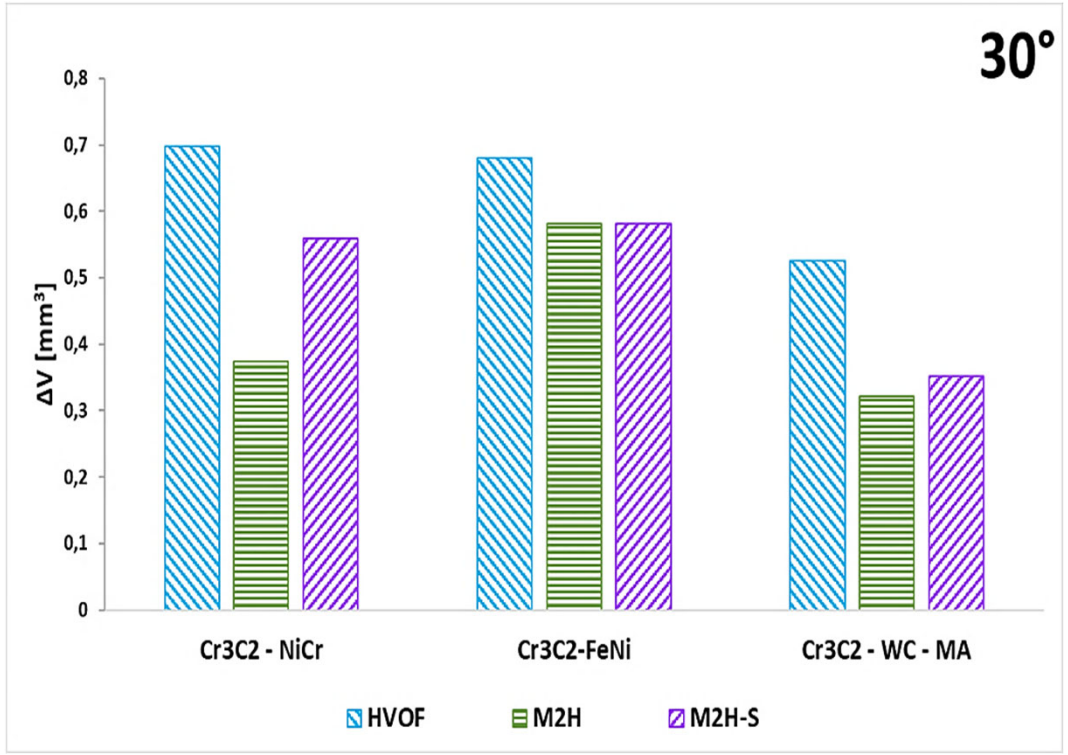
EROSION RATE





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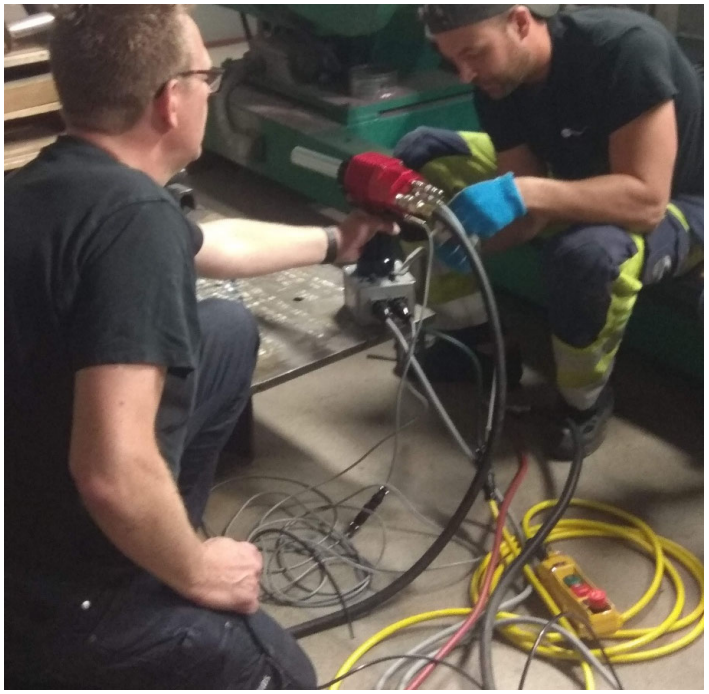
OUTCOME OF LAB TESTS

- M2H coatings are consistently denser than the conventional HVOF coatings
- No in situ oxidation was noted in the HVAF-sprayed coatings, while oxygen was found in the EDS maps of the HVOF-deposited materials.
- The hardness values of the M2H coatings in all cases are either similar to or harder than the HVAF coatings
- The erosion performance of the hand-held HVAF-deposited coatings was overall better, or at least comparable to, the behaviour of the corresponding HVOF coatings

TRANSPORTING M2H SYSTEM, REINSTALLATION…

TRANSPORTING M2H SYSTEM, REINSTALLATION… AND TRAINING



WHAT WAS DECIDED TO BE DONE AT SITE

- Parts coated: 1 tube per material and process will be coated, i.e. there will be 6 coatings in total (3 materials and 2 processes).
- Length: The coating will cover a length of about 1 m; 750 mm full thickness and additionally 250 mm for "zero-out" to ensure that the coating ends smooth and does not have an 'edge'.
- Location: The exact location will be decided after a pre-inspection just prior to coating application.
- Thickness: The thickness of the coating will be 500 µm and needs to be measured.

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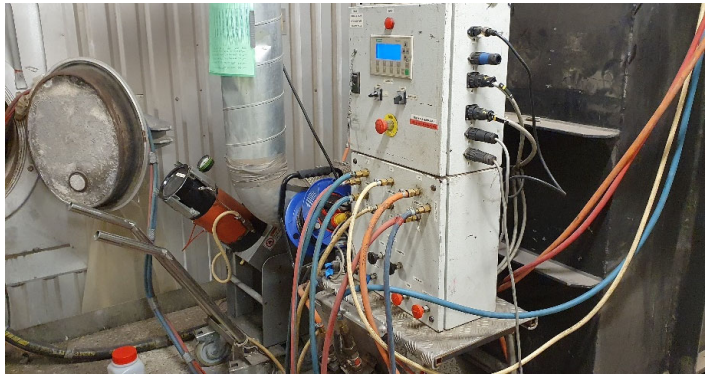


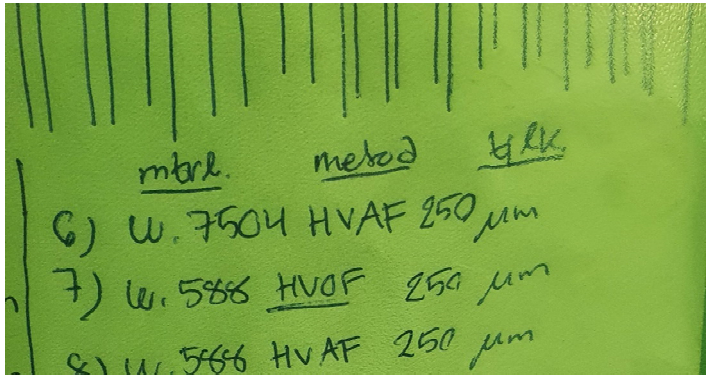

ON SITE COATING AT MÄLARENERGI SITE

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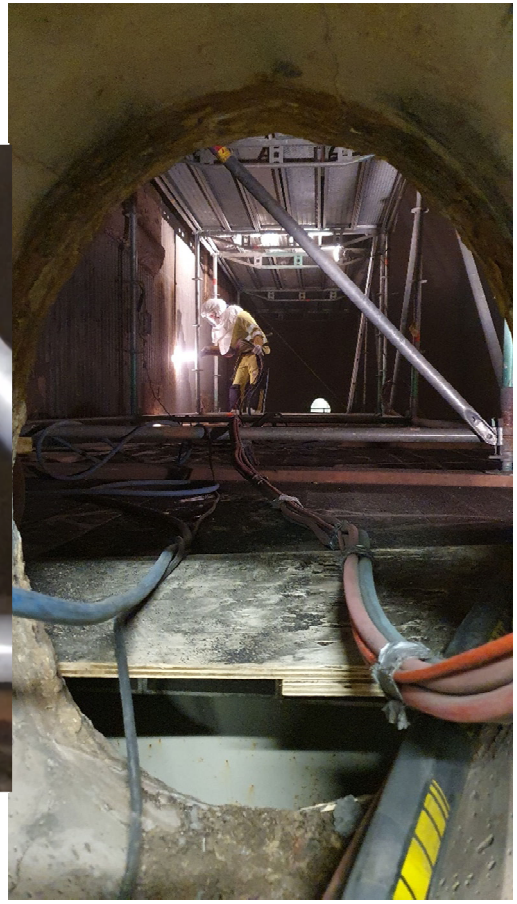
ON SITE COATING AT MÄLARENERGI SITE



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WHAT'S NEXT?

- Intermittent inspection of coatings during shut downs
- Removal of coatings after a year of operation
- Withdrawn coatings after field exposure to be characterized by Chalmers and HV

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Thanks for listening!

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