HIPERCOAT

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

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KME 805: HIPERCOAT

High performance coatings to combat <u>erosion-driven</u> damage in power plants

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

Project start: 2019-01-01

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– Höganäs AB	*Owe Mårs*
– MH Engineering AB	*Matti & Kristian Huhtakangas*
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CHALMERS UNIVERSITY WEST Energiforsk Höganäs MHE MH Engineering AB MälarEnergi

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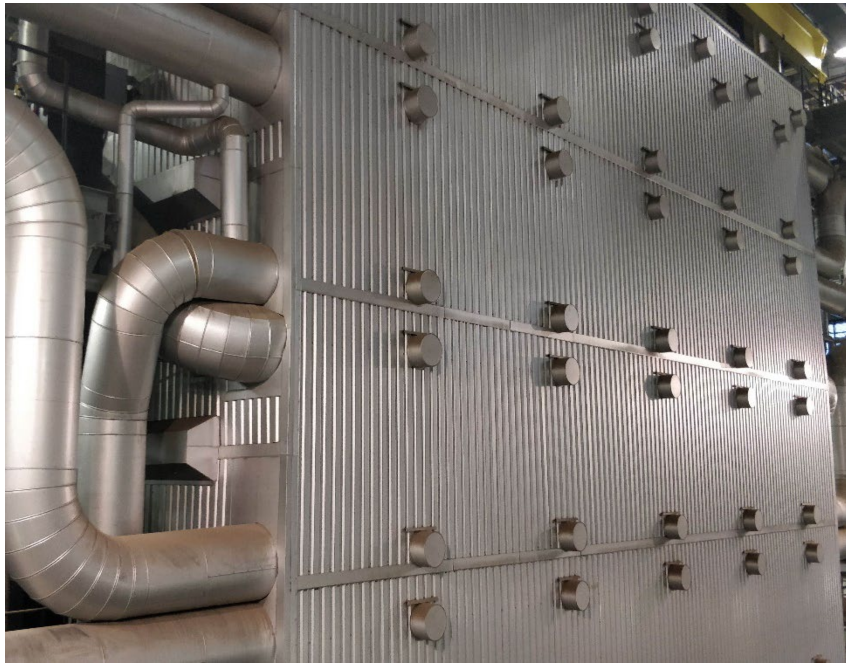
MOTIVATION



- 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** 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>**

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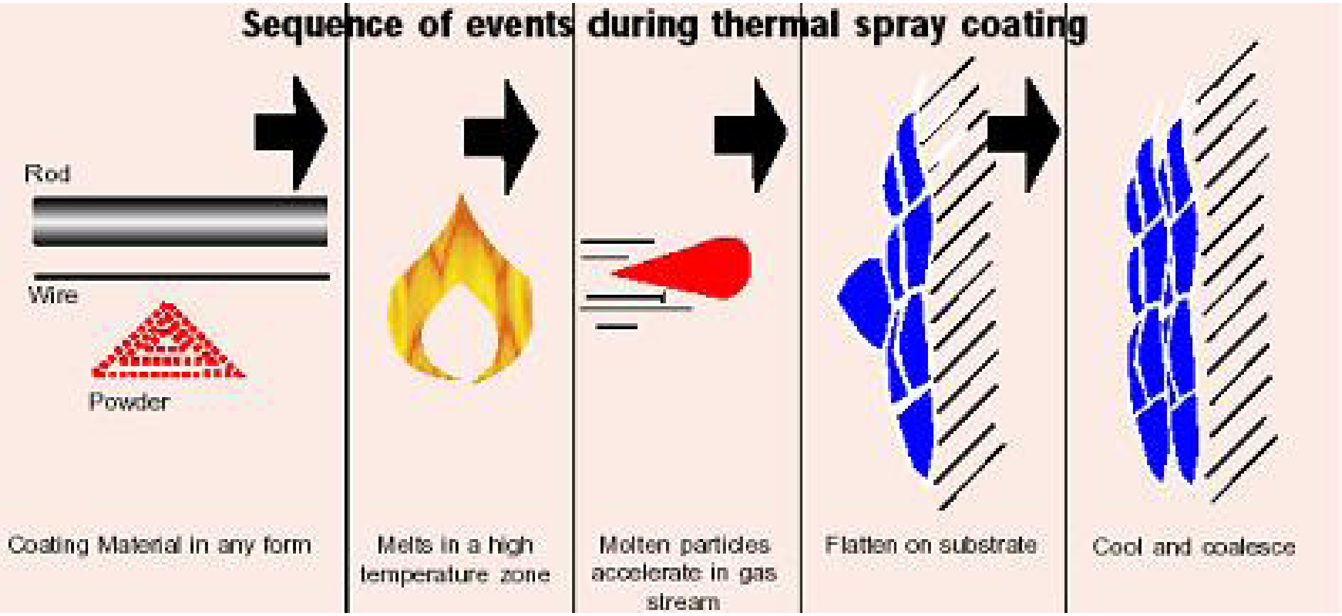
Thermal spraying: As traditionally practiced !!!



- Material to be sprayed introduced into a high temperature, high velocity zone (created by a flame, an arc, a plasma…)
- Heated/molten material is accelerated in a gas stream and propelled onto the surface to be coated
- The partially/fully molten particles flatten upon impacting the substrate and subsequently cool and coalesce to yield the desired coating

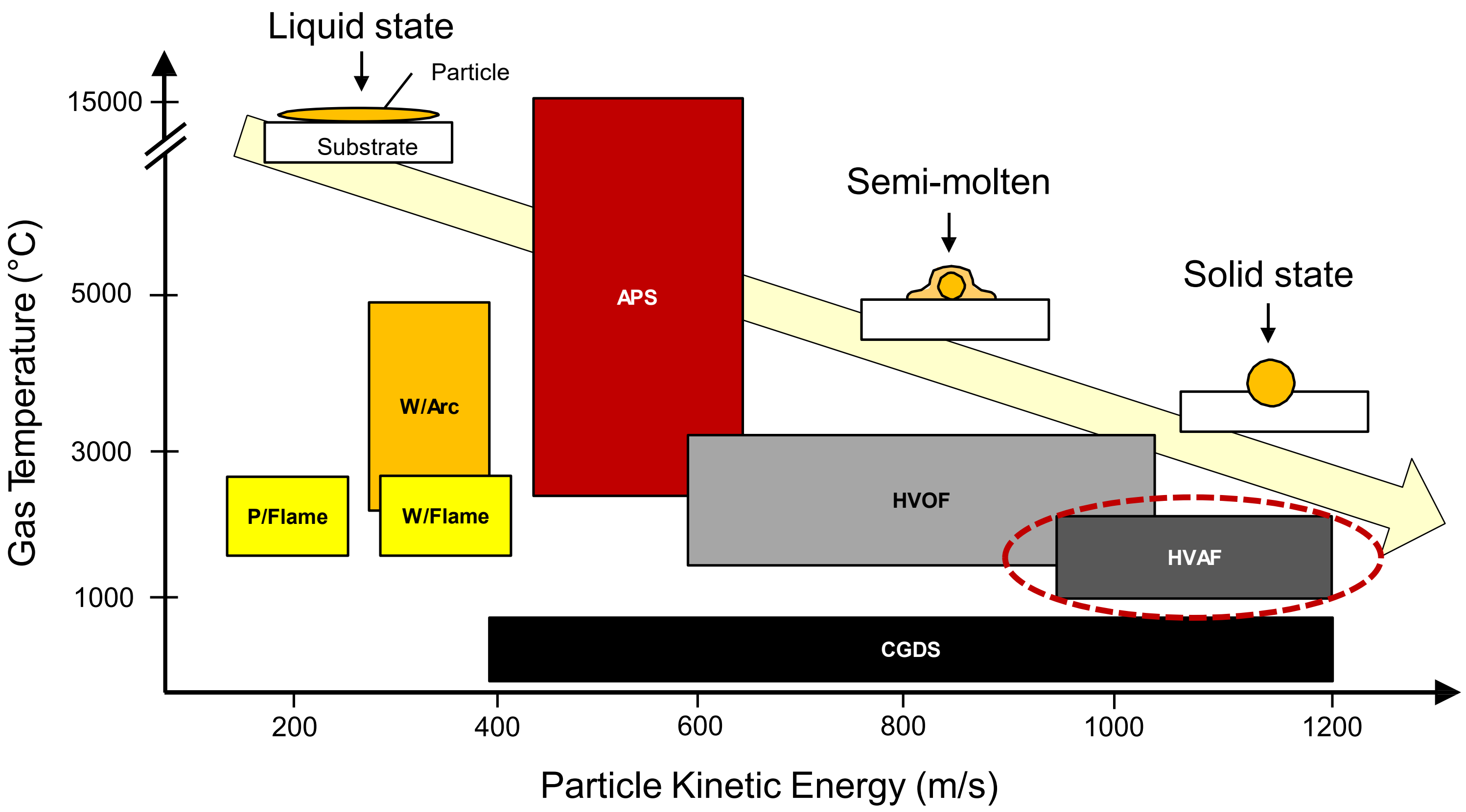
HVAF: RELATIVELY COLDER, HIGHER-VELOCITY PROCESS

Materials

APS	Ceramics
Arc	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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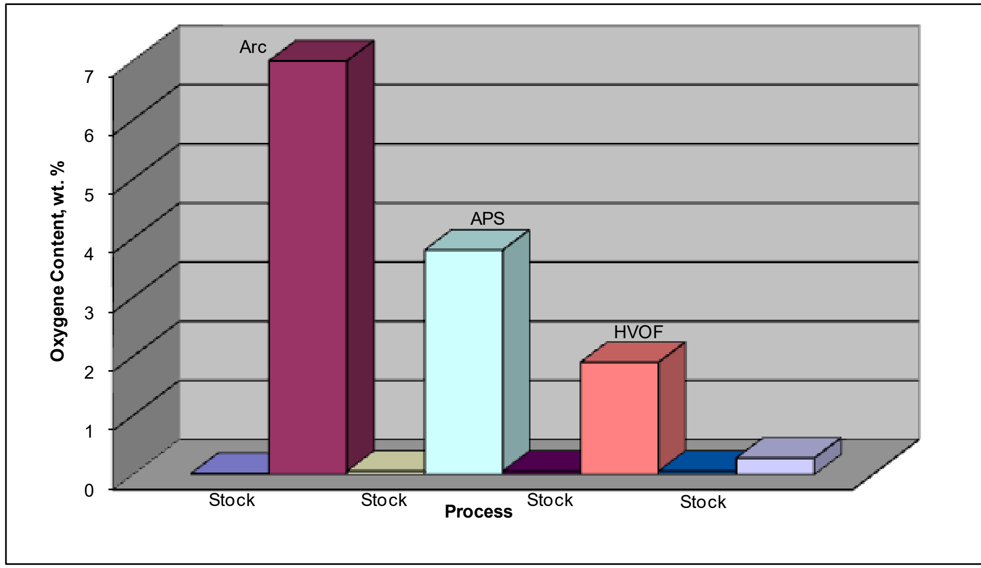
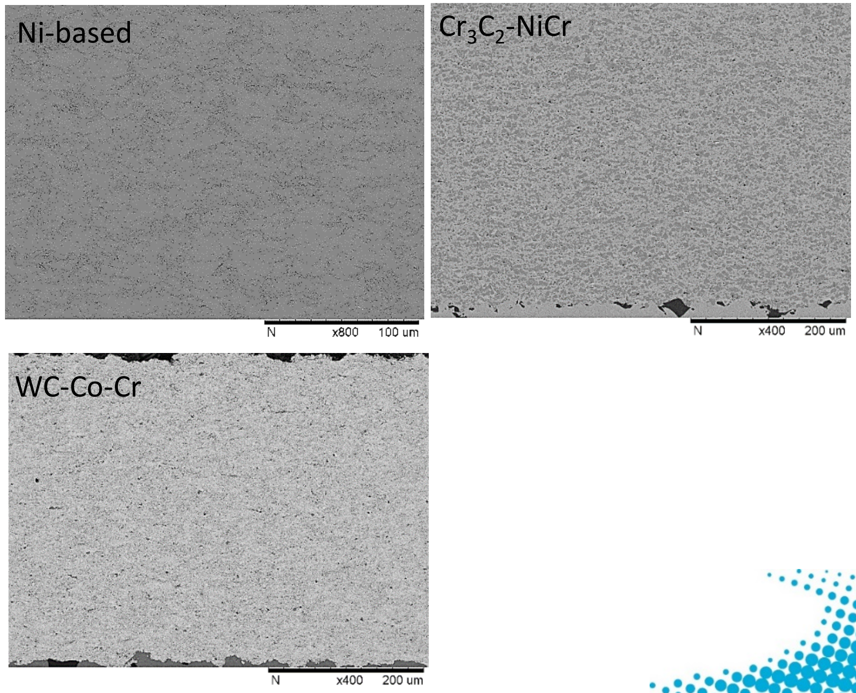
PROMINENT HVAF ADVANTAGES

- 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





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

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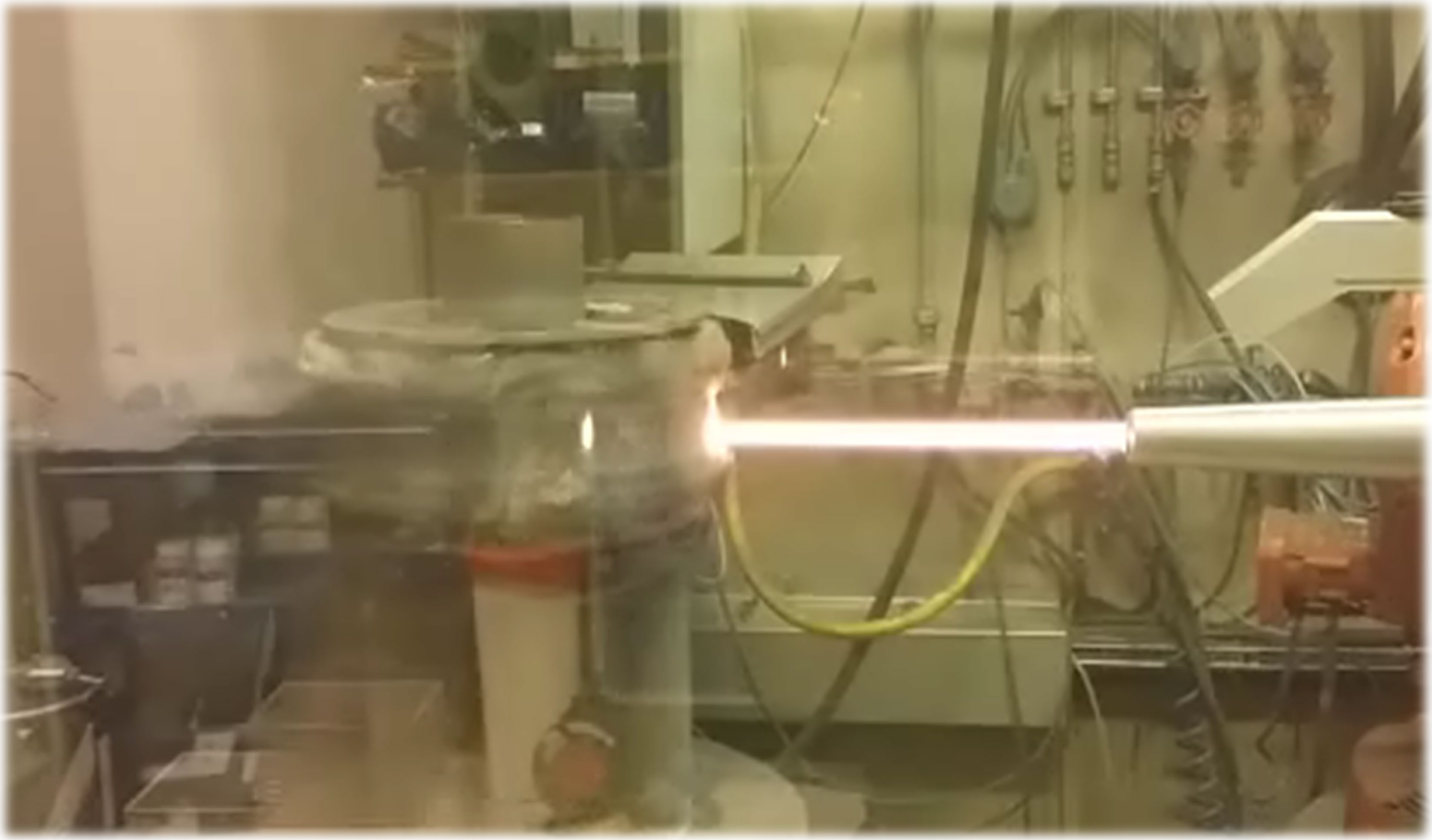
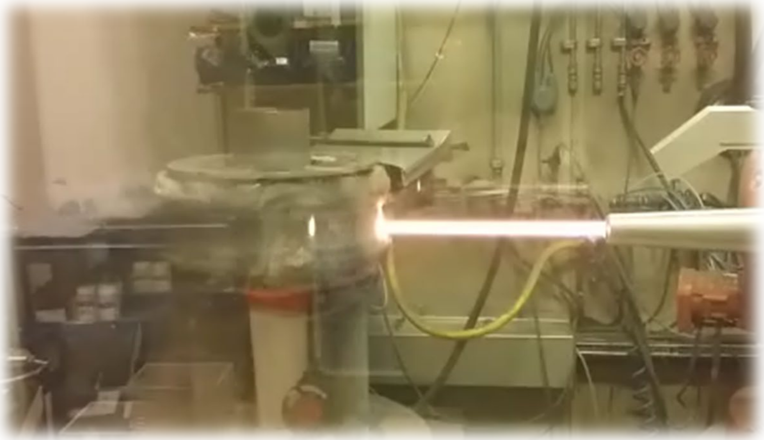
HVAF at University West



HVAF coatings' development with industrial partners



t.s.e
THERMAL SPRAYING ENGINEERING

SIEMENS

SANDVIK

Höganäs

Valmet

MAN Energy Solutions
Future in the making

FEDERAL MOGUL

BILLERUDKORSNÄS

TREIBACHER INDUSTRIE AG

BORÅS ENERGI OCH MILJÖ
Ingår i Borås Stadshus AB

MälarEnergi

voestalpine
ONE STEP AHEAD.

ANDRITZ

AUTOMOTIVE COMPONENTS FLOBY

MH Engineering AB

TROLLHÄTTAN ENERGI
Hela stans miljöbolag

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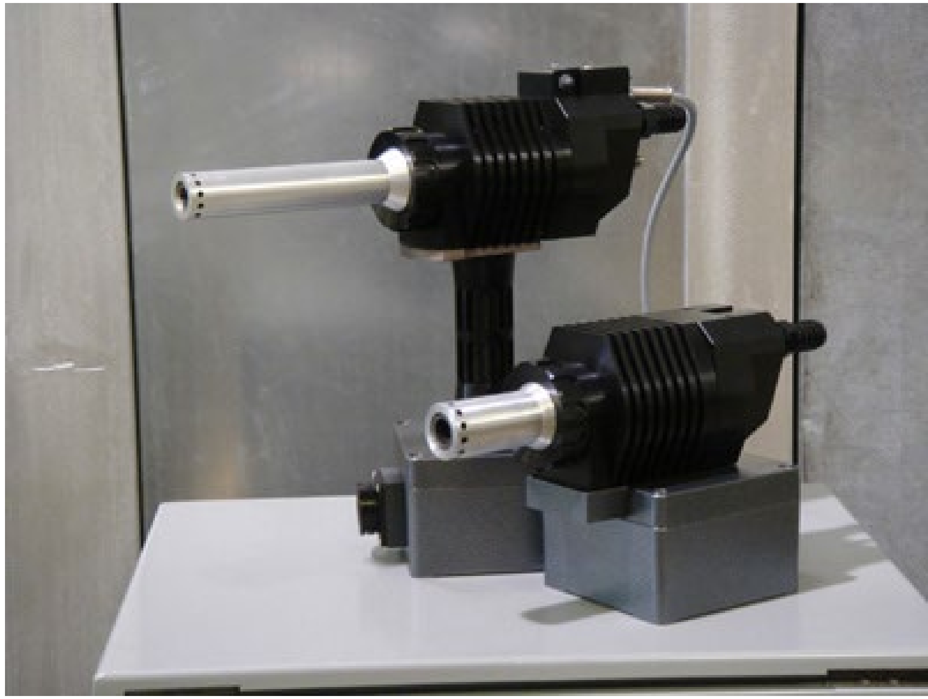
EARLY PROJECT DECISION: USE OF PORTABLE HVAF SPRAY GUN FOR ON-SITE SPRAYING

- 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

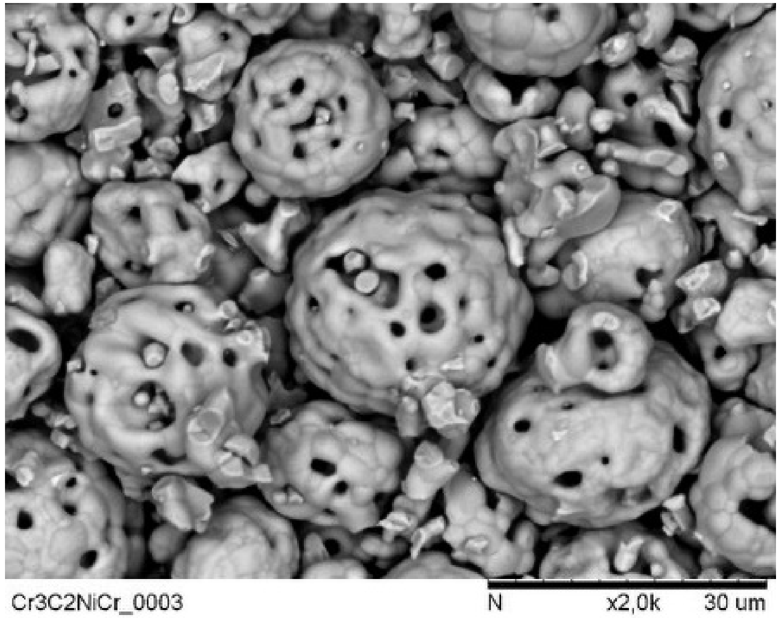
<u>Materials</u>

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

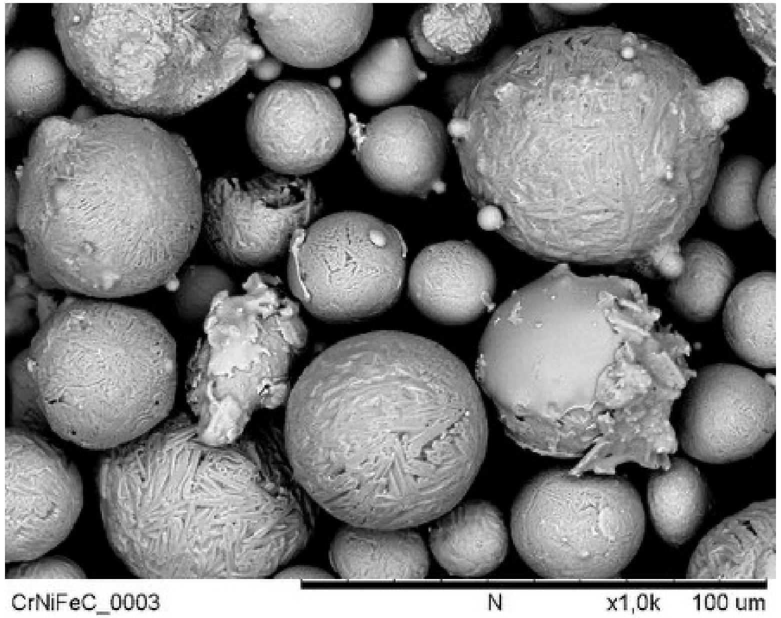
<u>Processes</u>

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

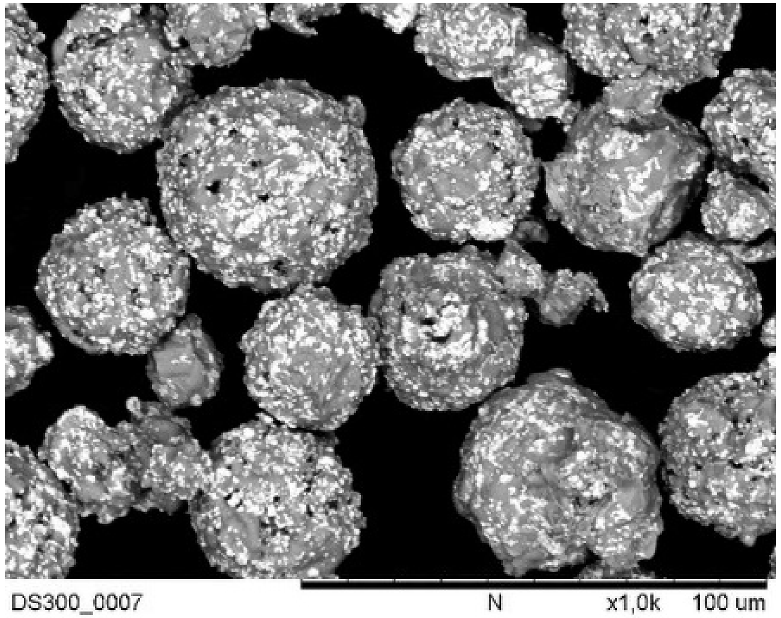
COATING MATERIALS: FEEDSTOCK



Cr3C2 – NiCr



Cr3C2 – FeNi



WC- Cr3C2 – NiCo

SPRAY PARAMETERS

HVAF-M2H coatings deposited using a straight nozzle (M2H_n)

Chemistry	Run	Nozzle	Fuel 1 [psi]	SOD [inches]	Strokes	Avg. Thickness [µm]
Cr_3C_2 – NiCr	#1	4G-15 mm	100	6	9	**275**
Cr_3C_2 – FeNi	#2	4G-15 mm	99	6	5	**200**
	#3	4G-15 mm	99	8	4	**120**
	#4	3S-11 mm	91	6	7	**250**
	#5	3S-11 mm	91	8	7	**180**
Cr_3C_2 – WC - NiCo	#6	3S-11 mm	99	6	8	**290**
	#7	4G-15 mm	99	6	7	**280**
	#8	3S-11 mm	99	8	7	**252**

- **Carbon steel disc-shaped coupons** (Φ 1 inch) were grit blasted (grit size 220 µm) and sprayed
- **Nozzle geometry**, **fuel pressure**, **stand-off distance** and number of **strokes** were selected as **variable** parameters;
- **Air pressure**, **N2 carrier flow rate** and **powder feed** were kept **constant**

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SPRAY PARAMETERS

HVAF-M2H coatings deposited using a supersonic nozzle (M2H-S_n)

Chemistry	Run	Nozzle	Air [psi]	Fuel 1 [psi]	Carrier: N_2 [l/min]	Powder Feed [g/min]	SOD [inches]	Strokes	Avg. Thickness [µm]
Cr_3C_2 – NiCr	#10	4L0-15	100	84	40	100	6	12	**260**
Cr_3C_2 – FeNi	#11	4L0-15	100	99	40	120	6	5	**200**
Cr_3C_2 – WC - NiCo	#12	4L2-15	126	102	40	150	8	10	**270**

- **Carbon steel disc-shaped** coupons (Φ 1 inch) were grit blasted (grit size 150 µm) and sprayed
- Only **one set of parameters** per coating composition was selected

SPRAY PARAMETERS

HVOF-deposited coatings (HVOF)

Chemistry	Fuel and gases	Pressure [bar]	Flow rate [g/s]	Avg. Thickness [µm]
Cr_3C_2 – NiCr	Propane	5,0	1,8 – 2,4	**270 – 290**
	Oxygen	10,0	11,0 – 11,6	
	Nitrogen	6,5	-	
Cr_3C_2 – FeNi	Propane	5,0	1,8 – 2,4	**220 - 270**
	Oxygen	10,0	11,6 – 11,7	
	Nitrogen	6,5	0,5 – 0,7	
Cr_3C_2 - WC - NiCo	Propane	5,0 ± 0,1	2,0 ± 0,3	**270 - 290**
	Oxygen	10,0 ± 0,1	11,0 ± 0,5	
	Nitrogen	6,6 ± 0,1	0,6 ± 0,1	

- **Carbon steel disc-shaped** coupons (Φ 1 inch) were grit blasted (grit size 220 µm) and sprayed
- A **single set of parameters** was selected for each composition, as the HVOF coatings work as a **reference** of the state-of-the-art for erosion-resistant coatings.

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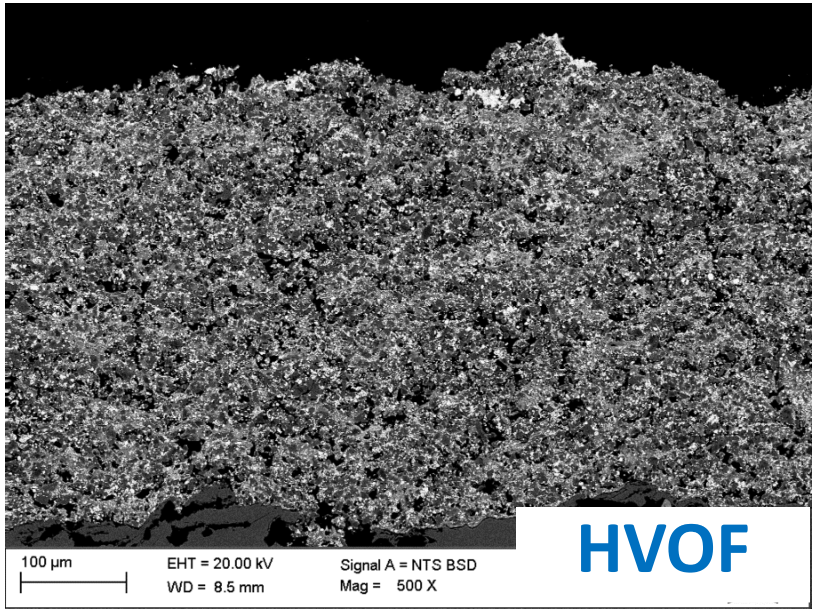
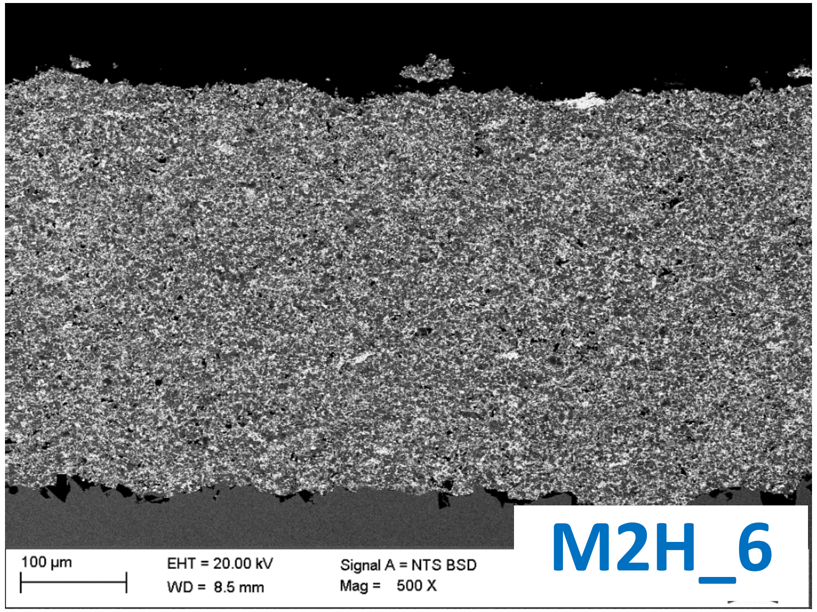
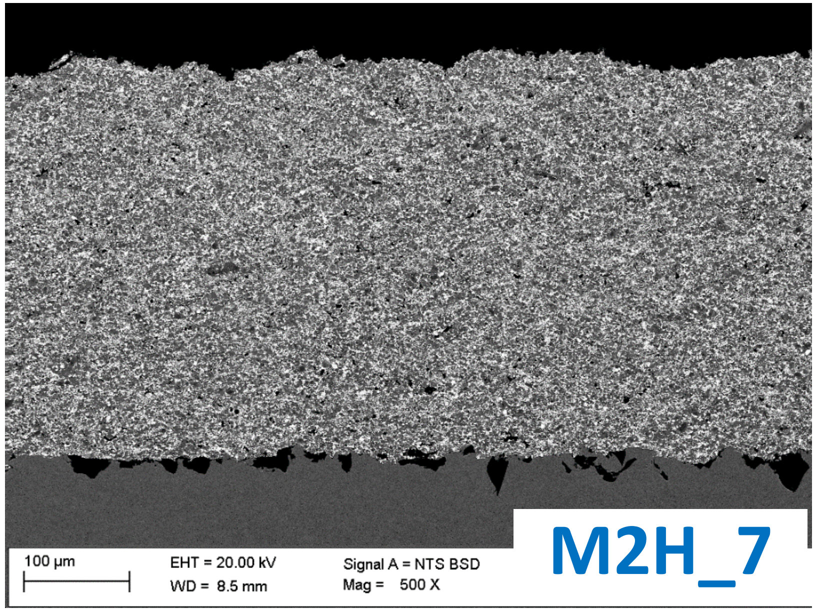
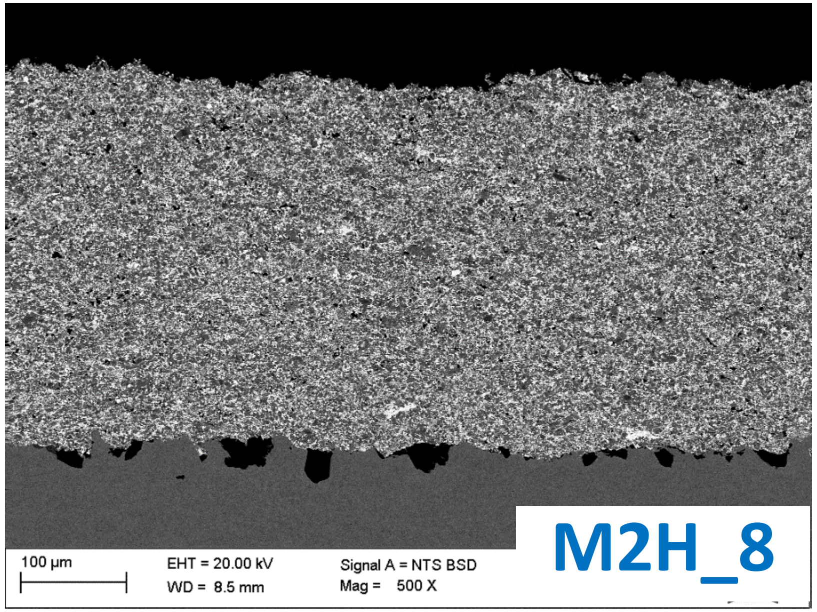
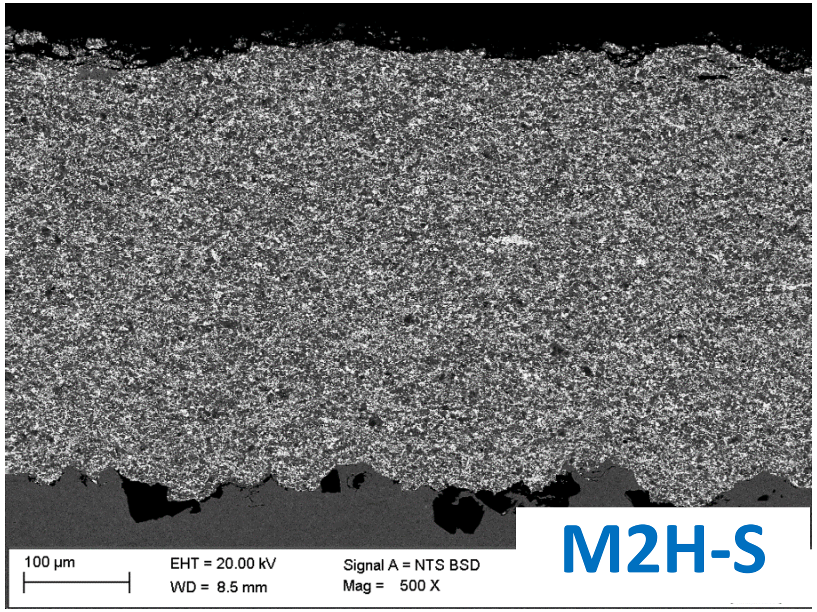
MICROSTRUCTURAL CHARACTERIZATION





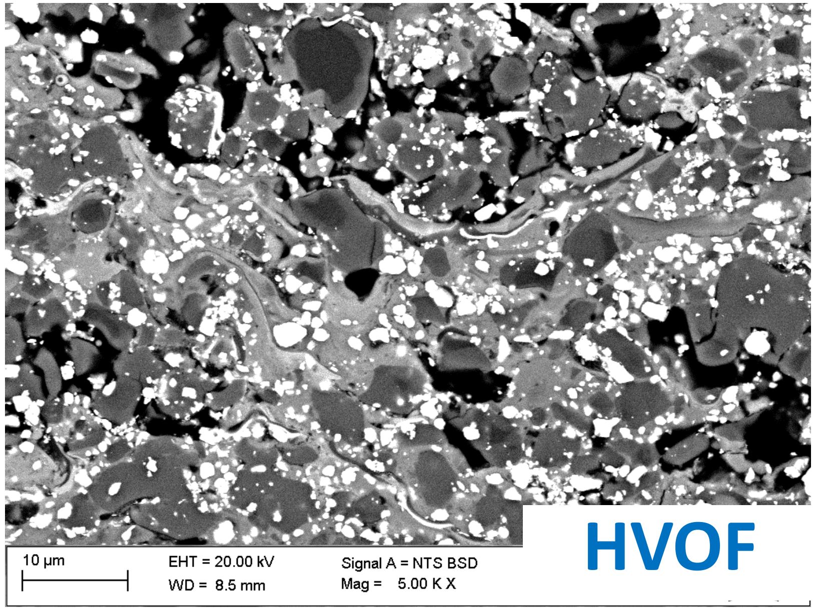


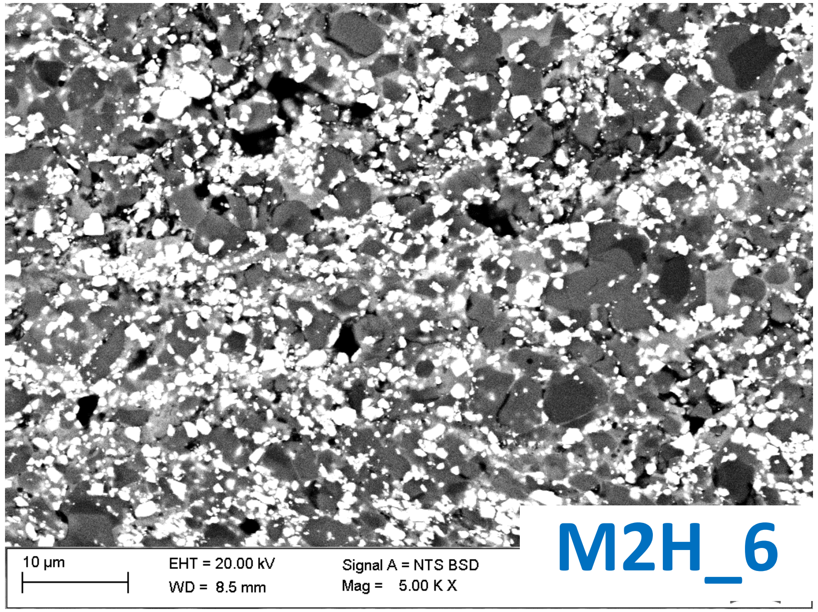


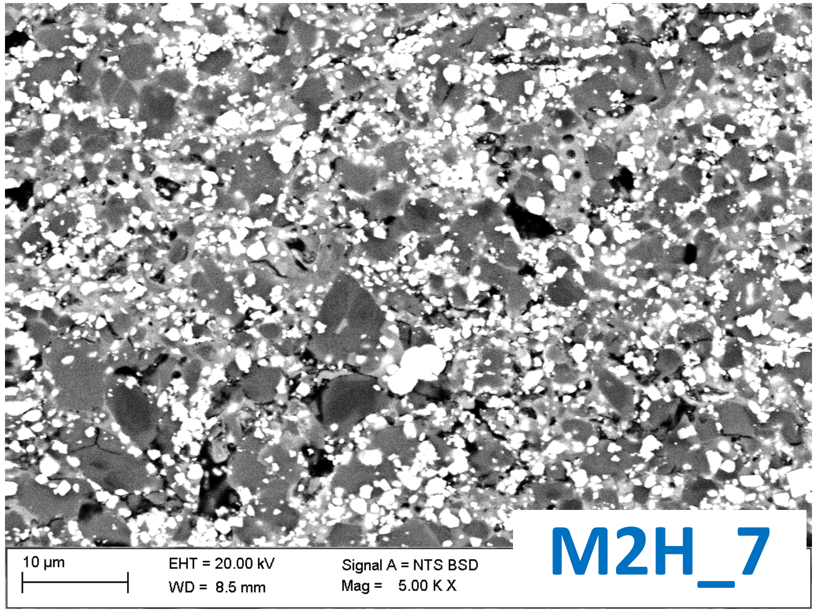


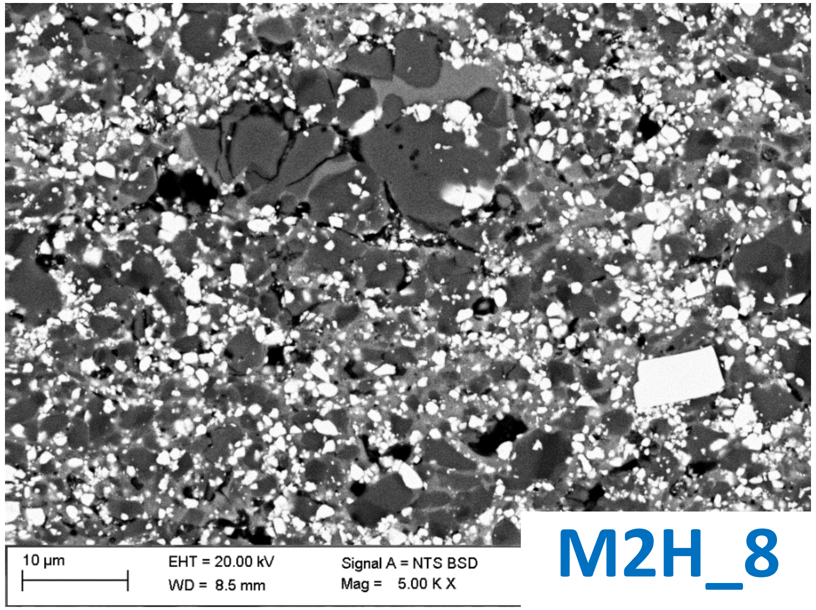
WC- Cr3C2 – NiCo

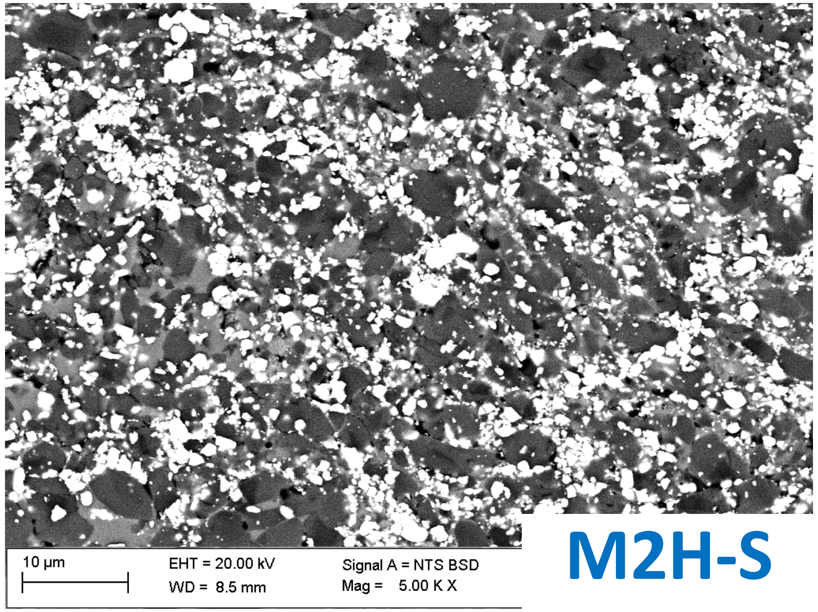
MICROSTRUCTURAL CHARACTERIZATION





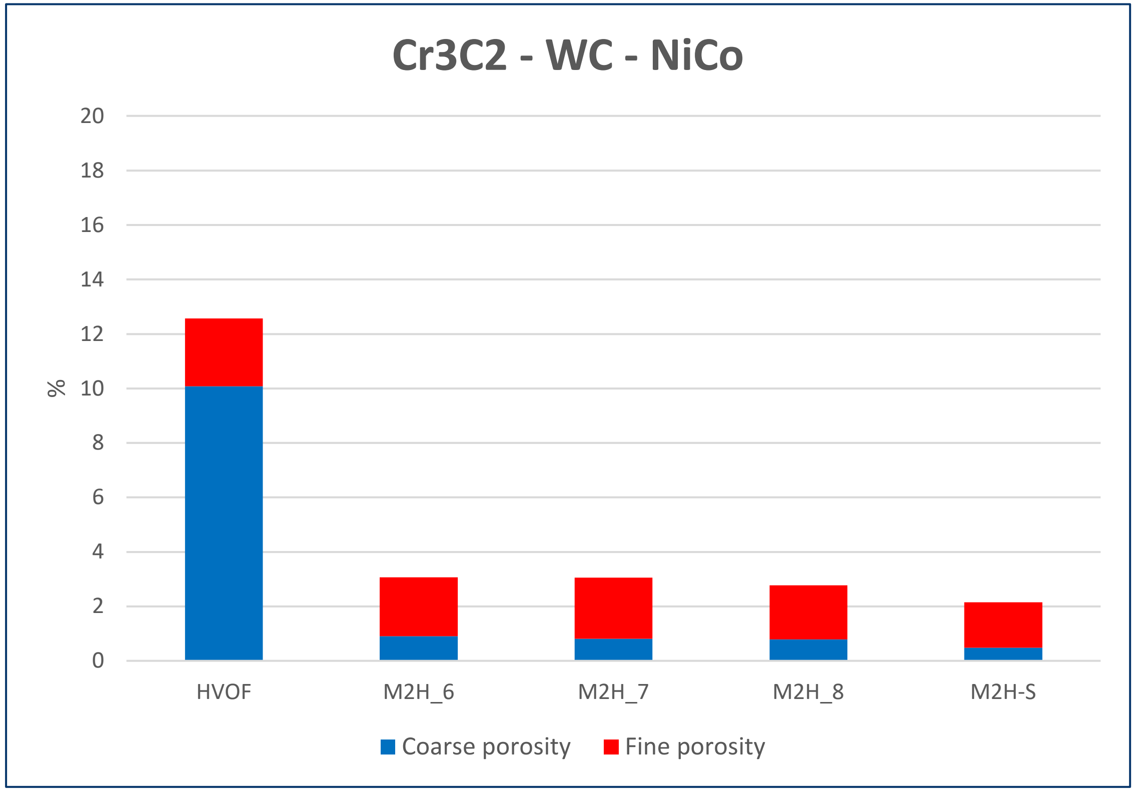


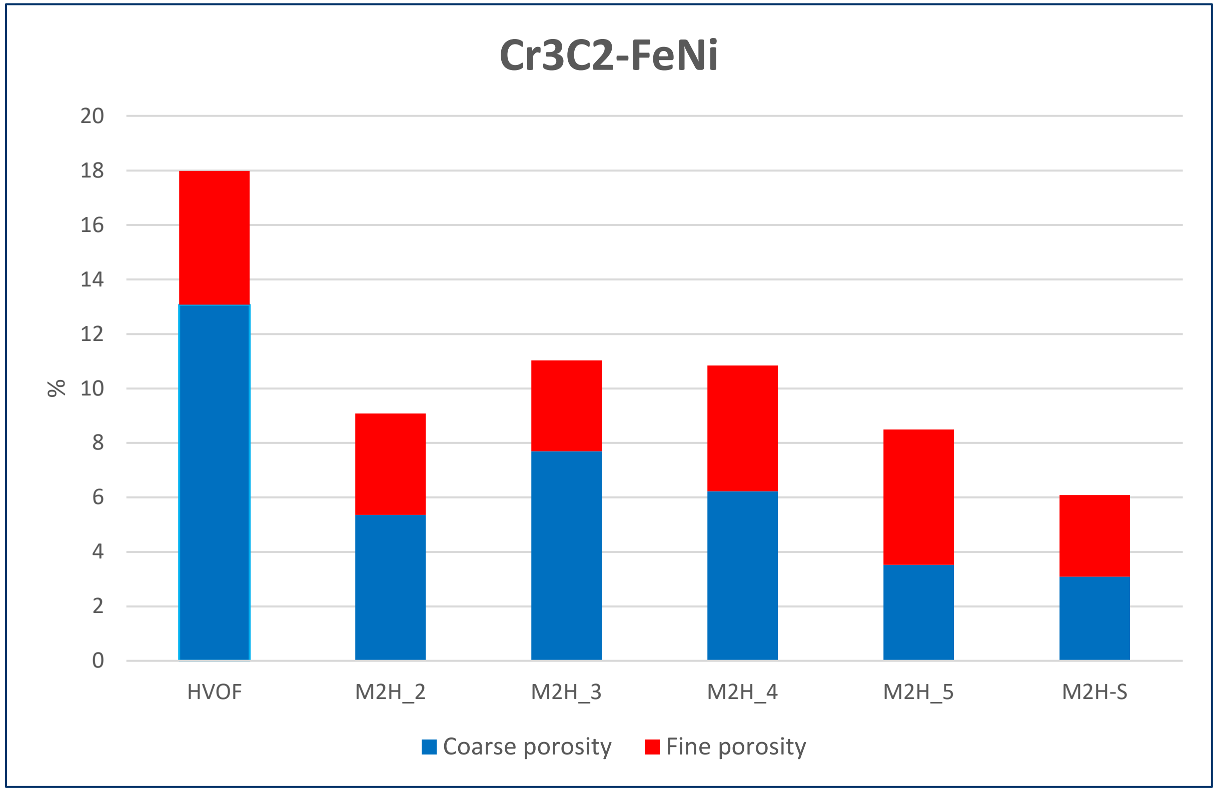




WC- Cr3C2 – NiCo

POROSITY CONTENT





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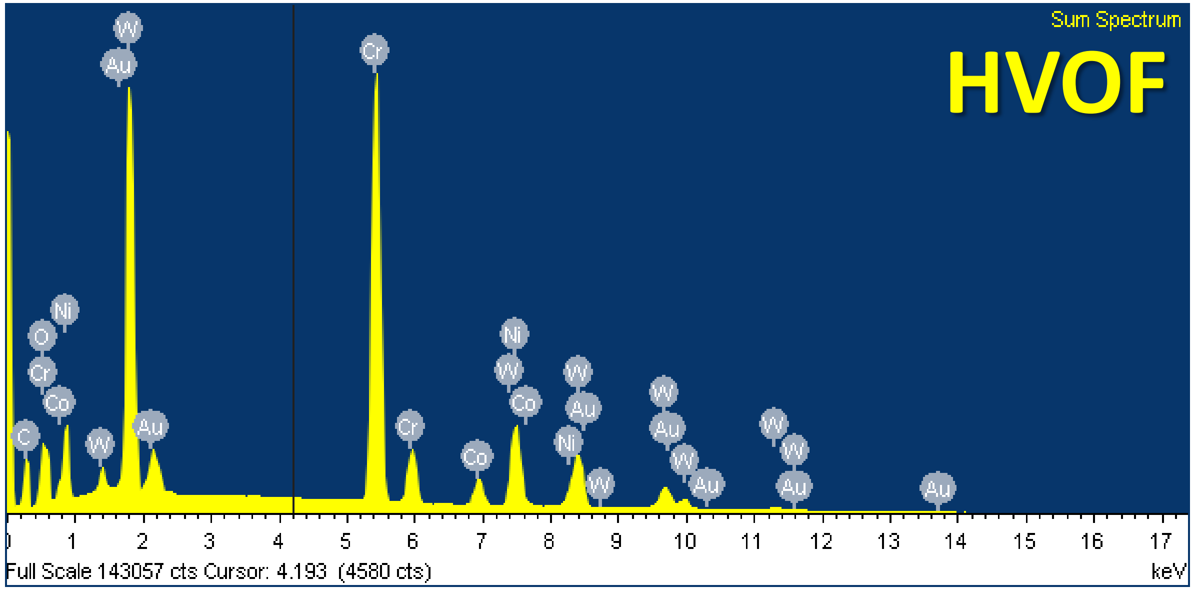
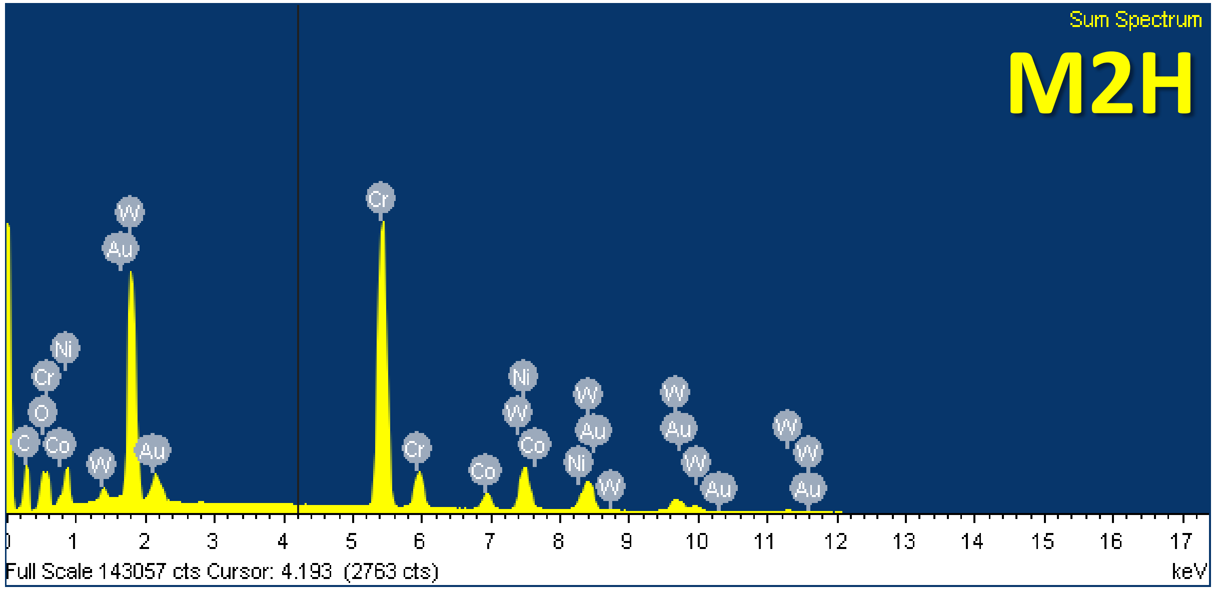
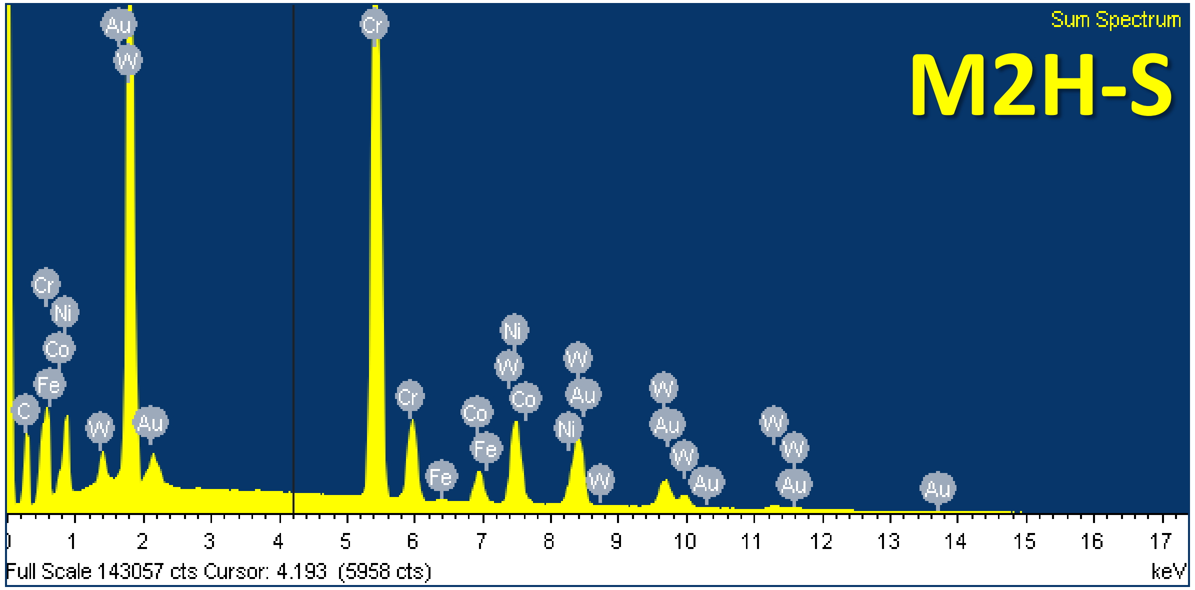
EDS ANALYSIS

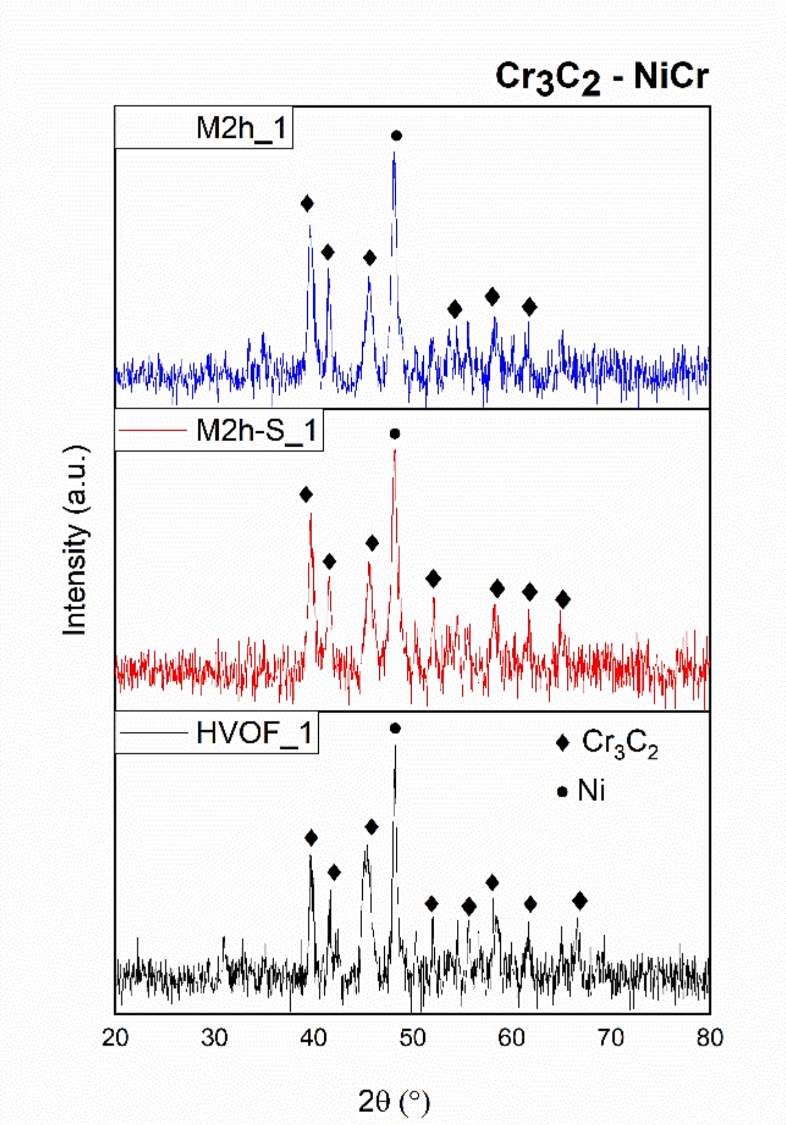


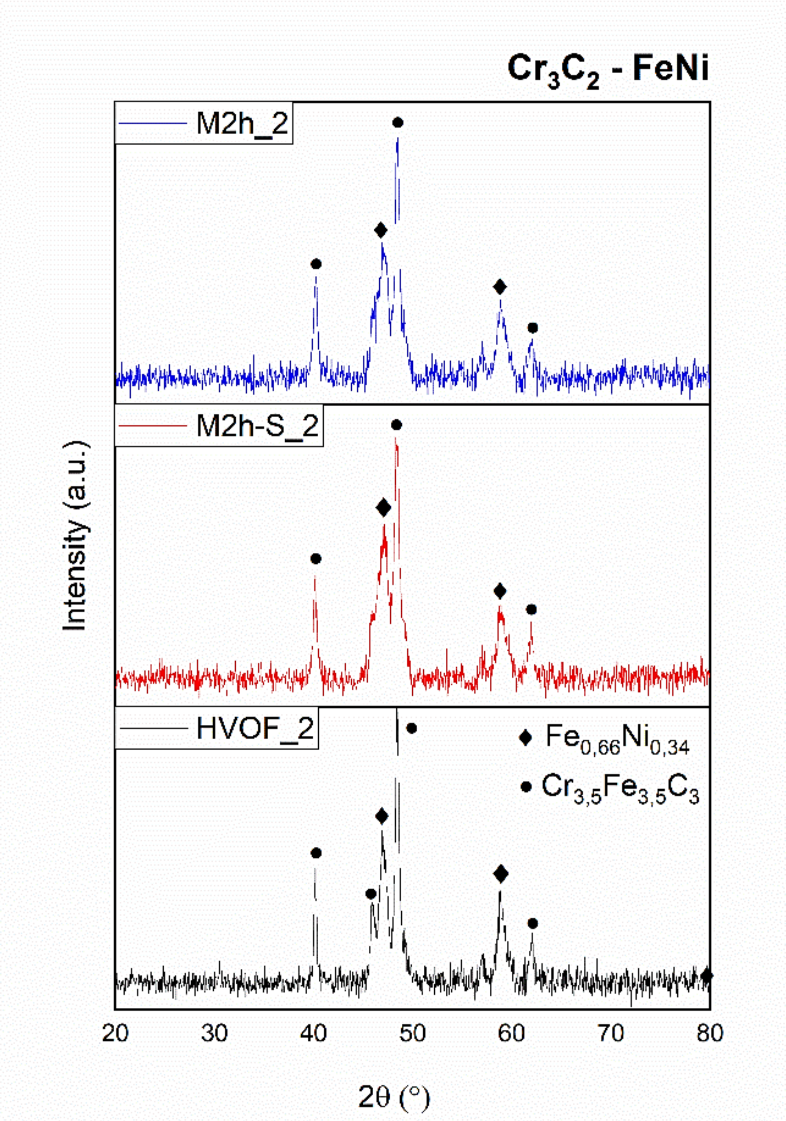


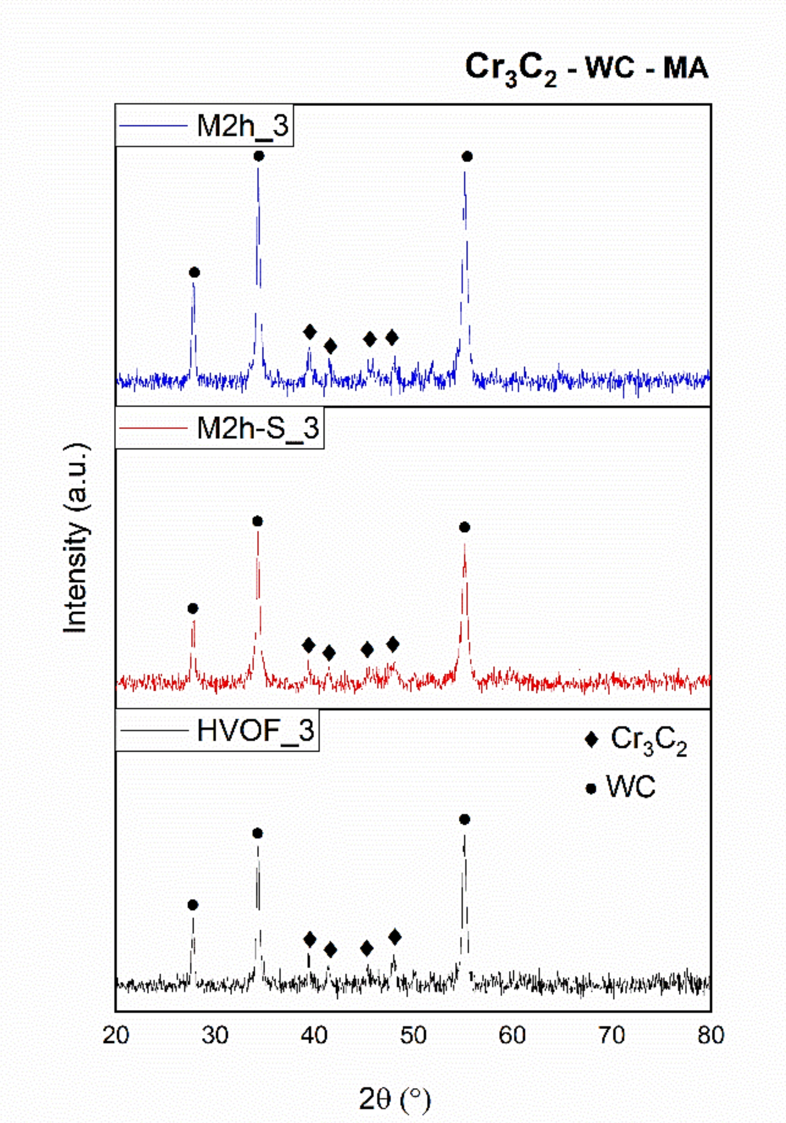


WC- Cr3C2 – NiCo

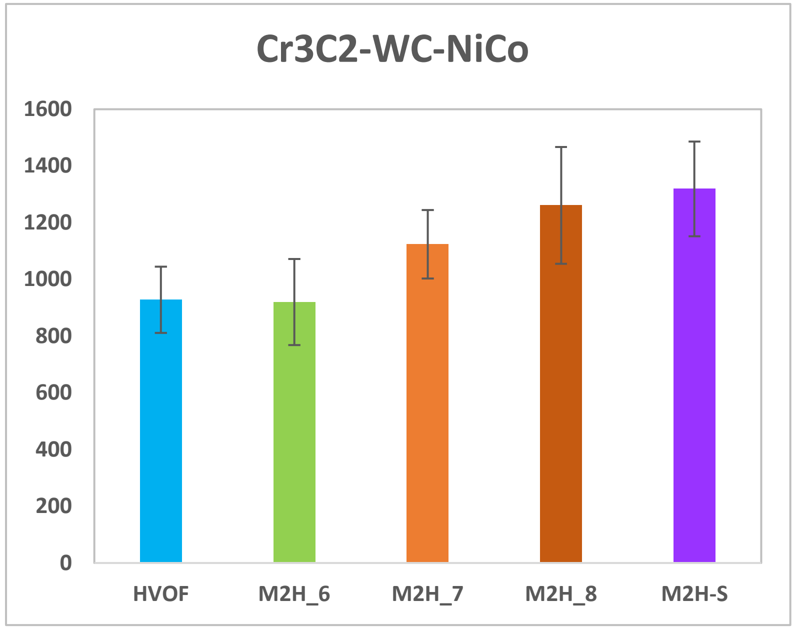
XRD ANALYSIS

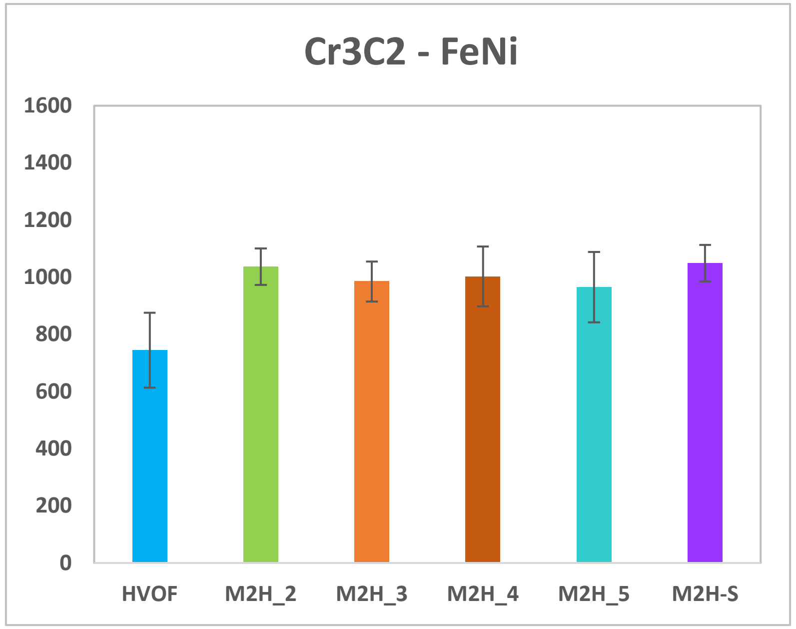


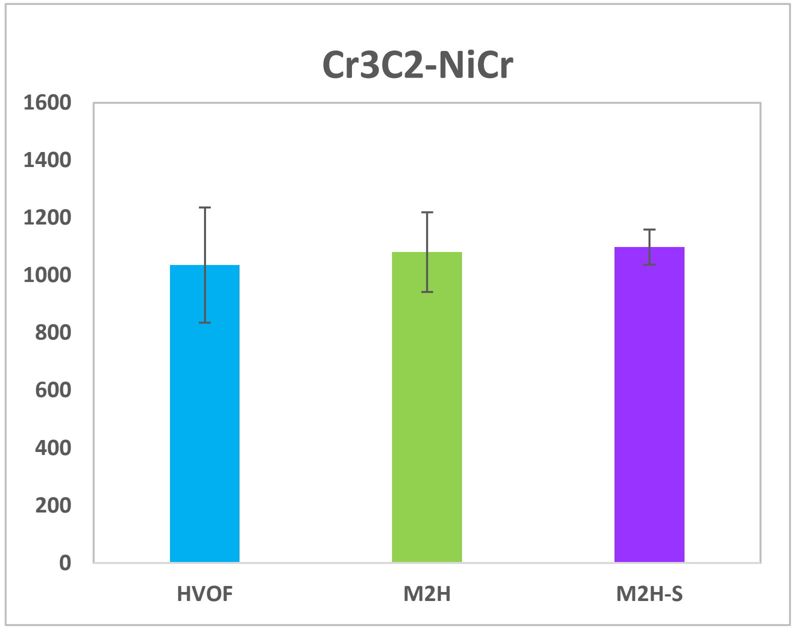




HARDNESS MEASUREMENTS







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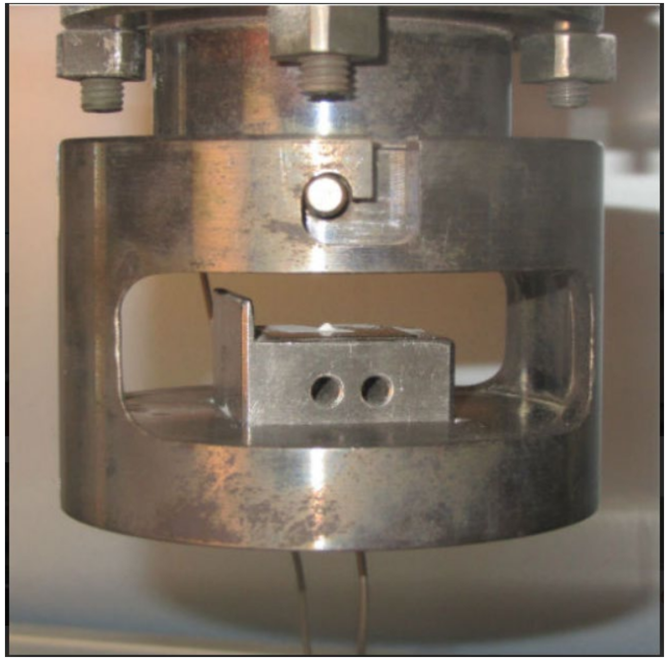
LAB EROSION TESTS

- **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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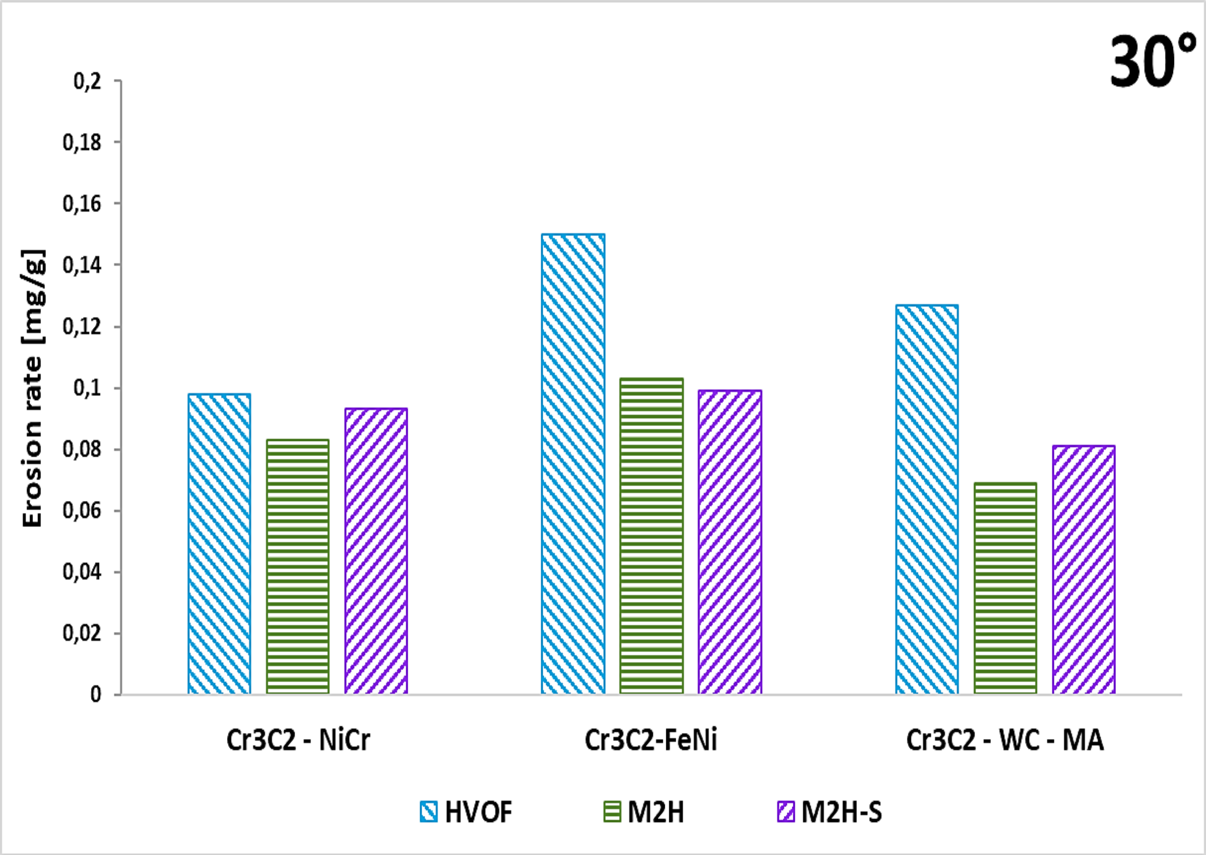
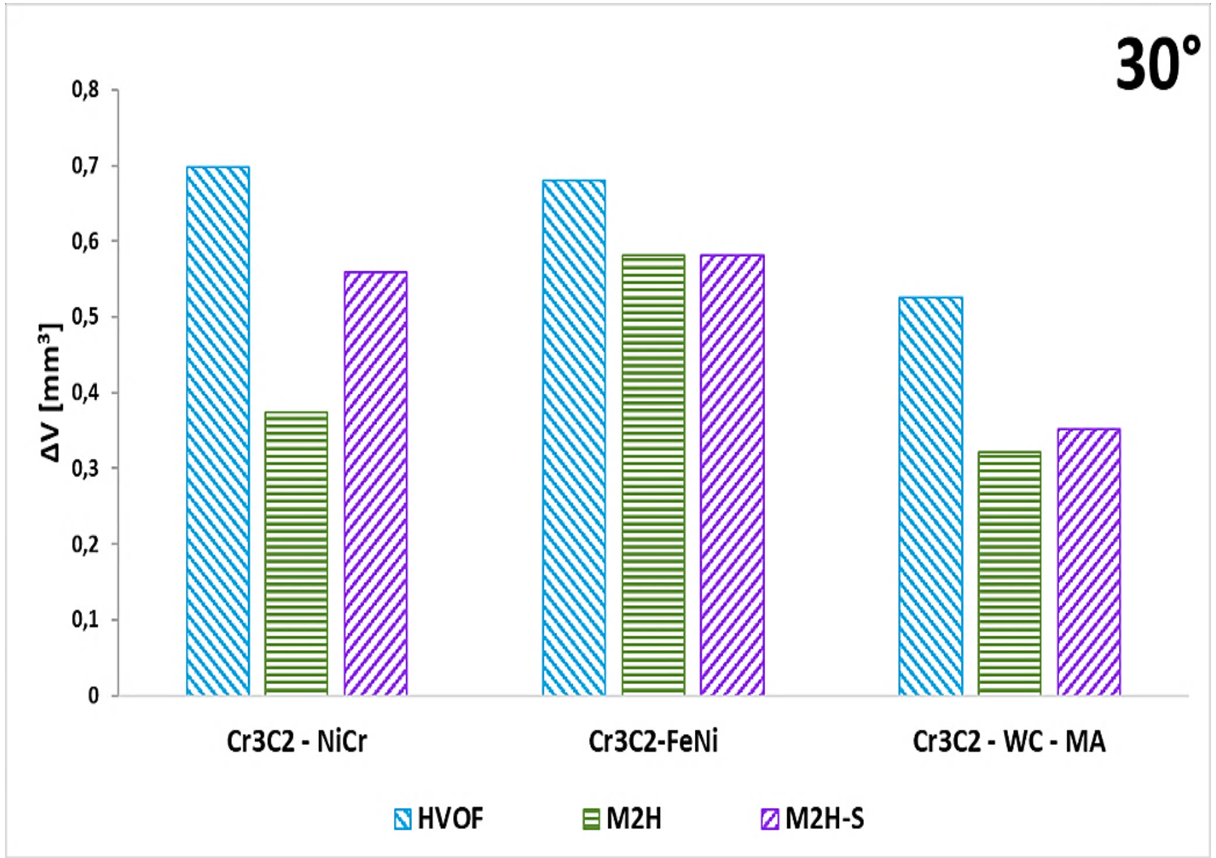
EROSION RATE





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

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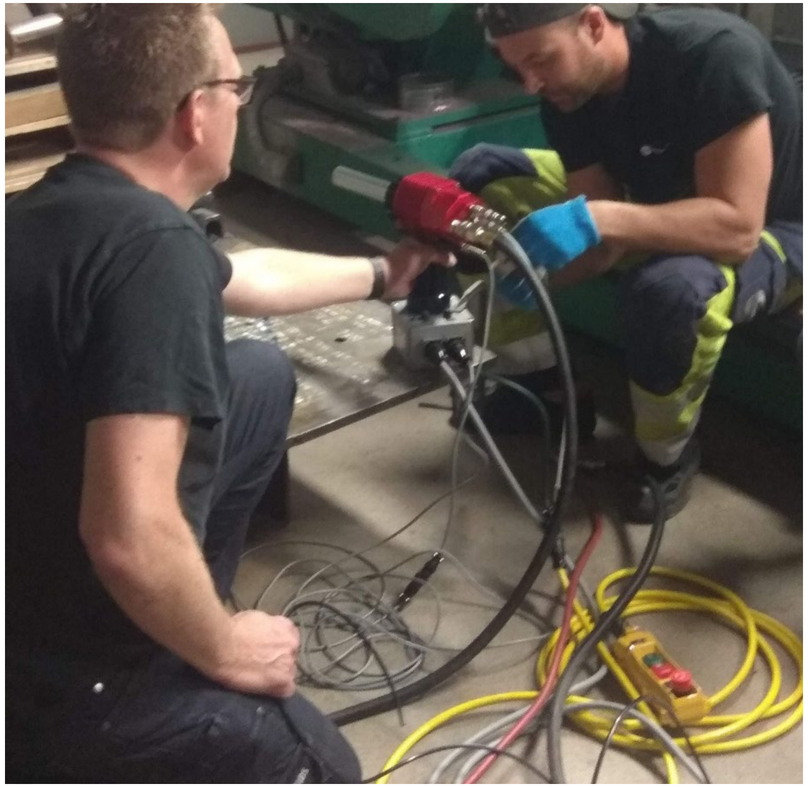
TRANSPORTING M2H SYSTEM, REINSTALLATION…

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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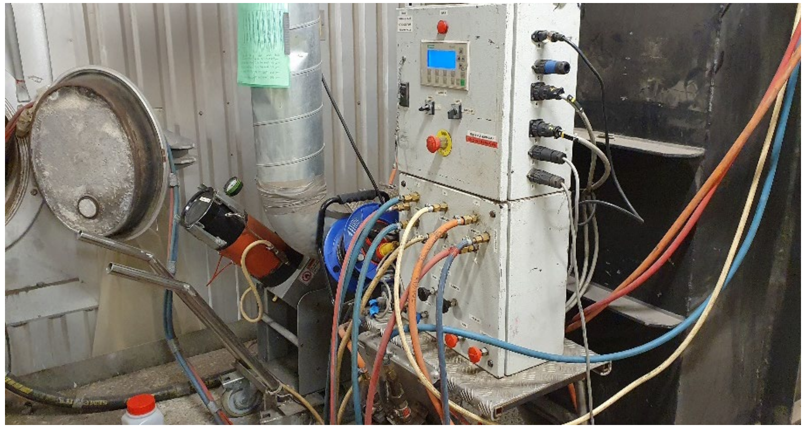

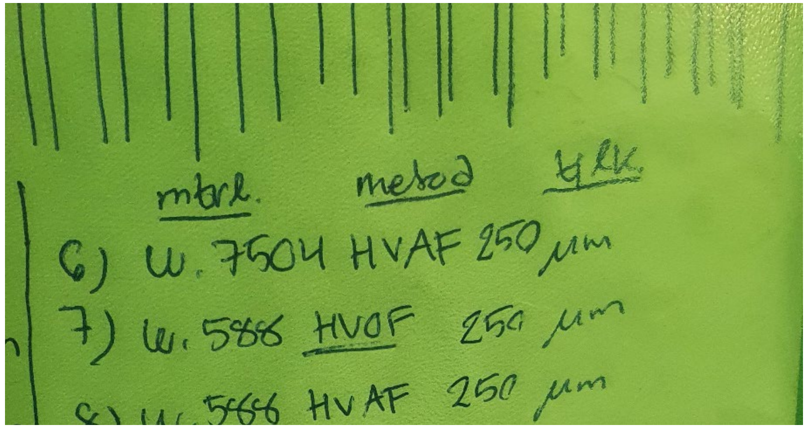

ON SITE COATING AT MÄLARENERGI SITE

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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