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HIPERCOAT

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

Uta Klement

Industrial and Materials Science, Chalmers

KME 805: HIPERCOAT

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

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

Project start: 2019-01-01
Project end: 2021-08-31

CHALMERS UNIVERSITY WEST Energiforsk Höganäs MH Engineering AI MälarEnergi

PARTNER

– Chalmers	Uta Klement, Antonio Mulone
– University West	Shrikant Joshi, Stefan Björklund
– Energiforsk AB	Bertil Wahlund
– Höganäs AB	Owe Mårs
– MH Engineering AB	Matti Huhtakangas + Kristian Huhtakangas
– Mälarenergi AB	Magnus Nyström (Per Tunberg)

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GOAL AND OUR APPROACH

- The project aims at developing high performance coatings capable of imparting **superior protection to power plant components** that are **prone to erosion-driven damage**.
- Distributed carbides and/or oxides, in a suitable Ni-based or Fe-based matrix and deposited by the emergent supersonic **high velocity air-fuel (HVAF) process** will be investigated.
- After process optimization and coating characterization **(lab tests)**, the **functional performance** of the most promising coating will be **evaluated in boiler environment**. This industrial qualification will be complemented by post-exposure characterization.

HIGH VELOCITY AIR-FUEL (HVAF) PROCESS

- HVAF coatings are similar to and are generally comparable to coatings produced by HVOF and Cold Spray. HVAF is a **"warm spray" process** that is cooler than HVOF, but hotter than Cold Spray. HVAF guns utilize axial powder injection into an air-fuel jet with a temperature of about 1900-1950°C.
- The process uses compressed air instead of oxygen and allows for **higher spray rates and deposit efficiency** as well as **lower application costs**. Harder, better performing coatings are possible due to the "warm spray" nature of the process.
- Lower thermal energy and higher kinetic energy of particles are bringing important changes in coating properties making the HVAF coatings have higher adhesion, lower porosity, and lower oxide content than the HVOF coatings.

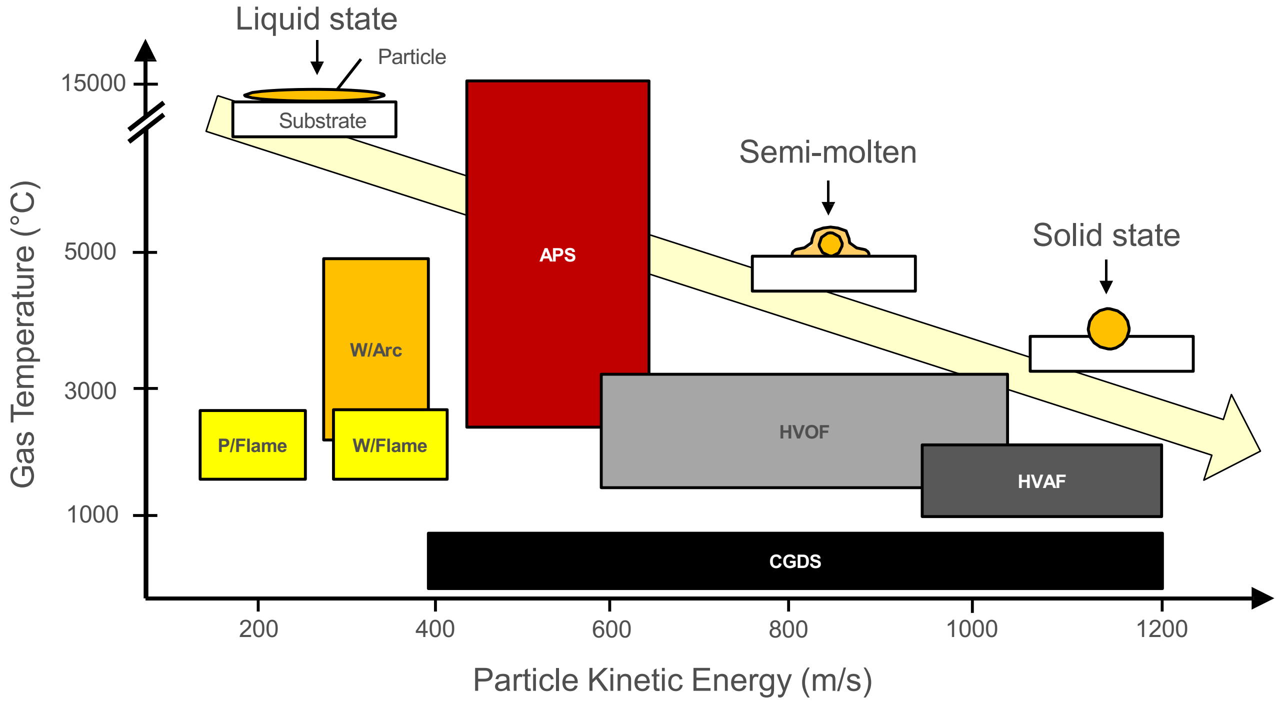
HVAF - Relatively cold, high-velocity process

Materials

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

Energy source

APS	*Electrical*
Arc	*Electrical*
Flame	*Combustion*
HVOF	*Combustion*
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

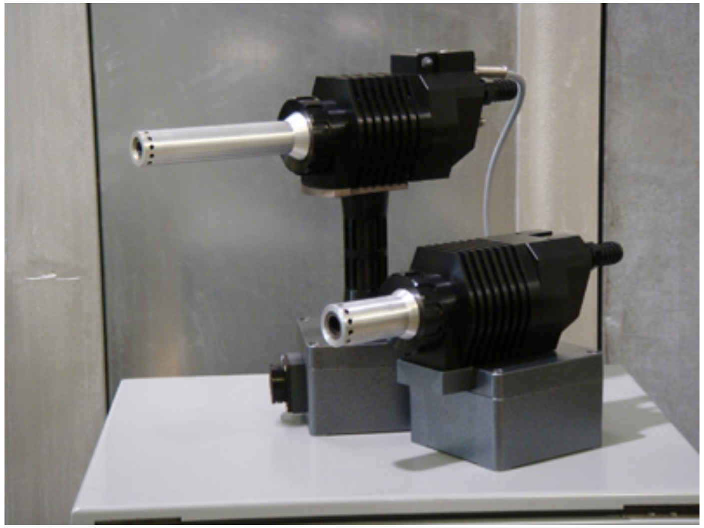
SPRAY GUN FOR ON-SITE SPRAYING

With the **M2™ Handheld HVAF Spray Gun (M2H)**, a HVAF spray gun variant is available for cost-effective deposition of high quality metal, metal alloy and cemented carbide coatings.

Permits **manual spraying** and 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.



OUR APPROACH

- Identify different coating materials
- Spray the identified materials with HVAF at HV with 2 different spray guns (M2 and M3) and compare properties and performance (erosion testing in a laboratory rig)
- Send materials to UniqueCoat (USA) for spraying with M2H (all materials or the best performing one from the lab test)
- Compare M2, M3 and M2H performance
- Lease M2H for on-site spraying
- Operator training for MHE engineers
- Spraying at identified boiler (HV/MHE will spray the samples for field testing, and Mälarenergi will be responsible for introducing the coatings in the plant, their intermittent inspection during shut downs and eventual removal.)

DECISION TAKEN

Materials to be sprayed

- **DS300** – a complex carbide with Ni/Cr binder (Cermet coating), yielding ~1000 HV30
- **Amperit 593** – (Cr_3C_2-NiCr), sintered and crushed
- **FeCr50-C6.5-Ni20**

Boiler to be used

Mälarenergi Boiler P5 will be used; is considered as non-corrosive and low erosive, as long as the fluidizing velocity is not increased. During peak load operations, especially with lower heat value fuels, the fluidizing velocity may increase considerably, and by that the **erosion**. (**Boiler Unit 7** would have been a good choice, but warranty issues with Sumitomo prevented its use in the project).

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palermo@chalmers.se

SCoPe

Superior Corrosion Performance of Coatings through Control of Chemistry, Microstructure and Architecture

Shrikant Joshi (HV) – Financed by Knowledge Foundation (KK)

Project start: 2017-01-01

Project end: 2019-12-31

SCoPe

Superior Corrosion Performance of Coatings through Control of Chemistry, Microstructure and Architecture

Constellation of project partners covering entire value chain

Leading manufacturer of high temperature materials
SANDVIK

—

Leading thermal spray R&D group
UNIVERSITY WEST

—

Applicator of boiler coatings
MH Engineering

—

USER CATEGORY 1
Boiler manufacturer
VALMET

—

USER CATEGORY 2
Boiler users for industrial qualification
BillerudKorsnäs Karlsborg (BK)
BillerudKorsnäs Skärblacka (BS)
Borås Energi och Miljö (BEM)
Trollhättan Energi (TE)

SCoPe

Superior Corrosion Performance of Coatings through Control of Chemistry, Microstructure and Architecture

Aim: To gain fundamental understanding of relationships among

- HVAF spraying process conditions
- Feedstock material
- Coating microstructure
- High temperature corrosion behavior
- Field performance in actual boiler environments

Overall Approach of SCoPe

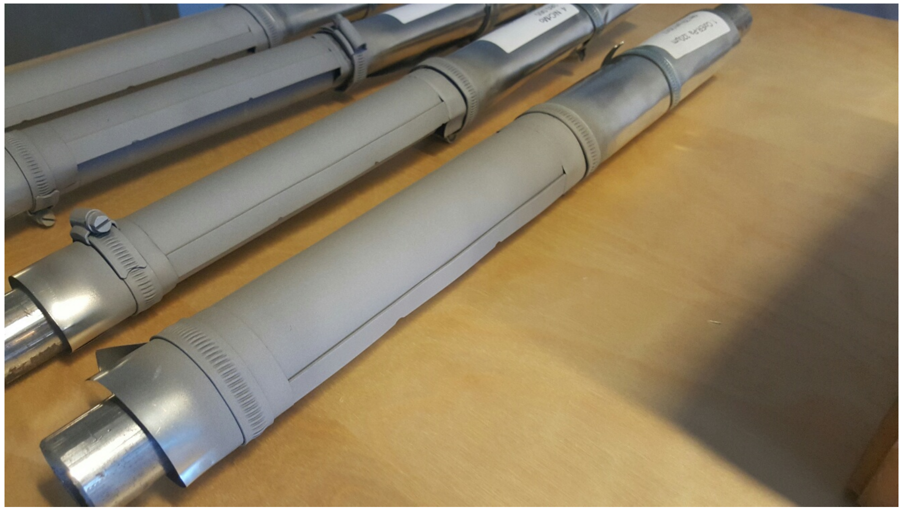
- Focus on relatively unexplored HVAF process
- Different coating materials (Ni5Al, Ni21Cr, Ni21Cr7AlY, NiCrMoNb) with varied scale-forming ability
  - ✓ Alumina
  - ✓ Chromia
  - ✓ Mixed oxide
- Different coating architectures
  - ✓ Composite (NiCrMoNb-SiO2)
- Laboratory assessment through exposures in diverse conditions
- Industrial qualification of coatings in complex environments

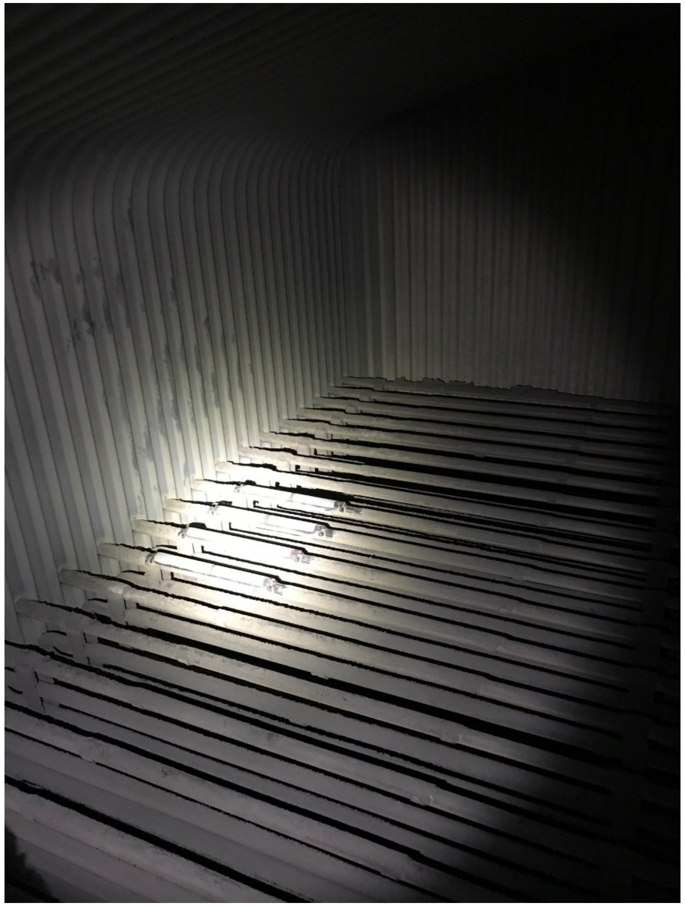
“New” powder chemistry from Sandvik

- Preliminary amounts of a new Sandvik-developed powder for coating trials received at the end of September 2017.
- HVAF trials were carried out with this powder.
- A detailed characterization of the coatings deposited with the Sandvik powder has been carried out and some preliminary corrosion studies have also been conducted.
- Tube pieces also HVAF coated and sent to Sandvik for independent investigation.
- One BillerudKorsnäs Skärblacka nozzle also coated with the Sandvik powder and installed at site.

Summary of coatings installed at various project sites

Project site: Trollhättan Energi; coated tube shields installed on May 18, 2017; withdrawn on May 3, 2018. Will try and install new coated tubes in **May 2019**





Publications

- Esmaeil Sadeghimeresht, Johan Eklund, Julien Phother Simon, Jesper Liske, Nicolaie Markocsan, Shrikant Joshi; *Effect of water vapor on the oxidation behavior of HVAF-sprayed NiCr and NiCrAlY coatings.* **Materials and Corrosion** 2018; *1-10*.
- Esmaeil Sadeghimeresht, Liam Reddy, Tanvir Hussain, Nicolaie Markocsan, Shrikant Joshi; *Influence of KCl and HCl on high temperature corrosion of HVAF-sprayed NiCrAlY and NiCrMo coatings.* **Material and Design** 2018; 148, 17-29.
- Esmaeil Sadeghimeresht, Tanvir Hussain, Nicolaie Markocsan, Shrikant Joshi; *Effect of SiO_2 dispersion on high temperature chlorine-induced corrosion of HVAF-sprayed NiCrMo coating.* **Corrosion** 2018; in press.
- Reza Jafari, Esmaeil Sadeghimeresht, Taghi Shahrabi Farahani, Nicolaie Markocsan, Shrikant Joshi; *KCl-induced high temperature corrosion behavior of HVAF-sprayed Ni-based coatings in ambient air*. **Journal of Thermal Spray Coating** 2017; 27 (500-511).
- Esmaeil Sadeghimeresht, Shrikant Joshi; *Chlorine-induced high-temperature corrosion and erosion-corrosion of HVAF and HVOF-sprayed amorphous Fe-based coatings*. **Surface & Coatings Technology** 2019; in press.
- Johan Eklund; Julien Phother; Esmaeil Sadeghi; Shrikant Joshi; Jesper Liske, High Temperature Corrosion of HVAF–Sprayed Ni-Base Coatings for Boiler Applications, **Oxidation of Metals**, 2019 (in press).

Under review:

- Esmaeil Sadeghi, Nicolaie Markocsan, Shrikant Joshi; *Advances in Corrosion Resistant Thermal Spray Coatings for Renewable Energy Power Plants.* **Advanced Materials**, 2018, with editor.