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# Cold spray repair of cavitation damages on hydropower components: impact of the deposition process and cavitation resistance benchmarking

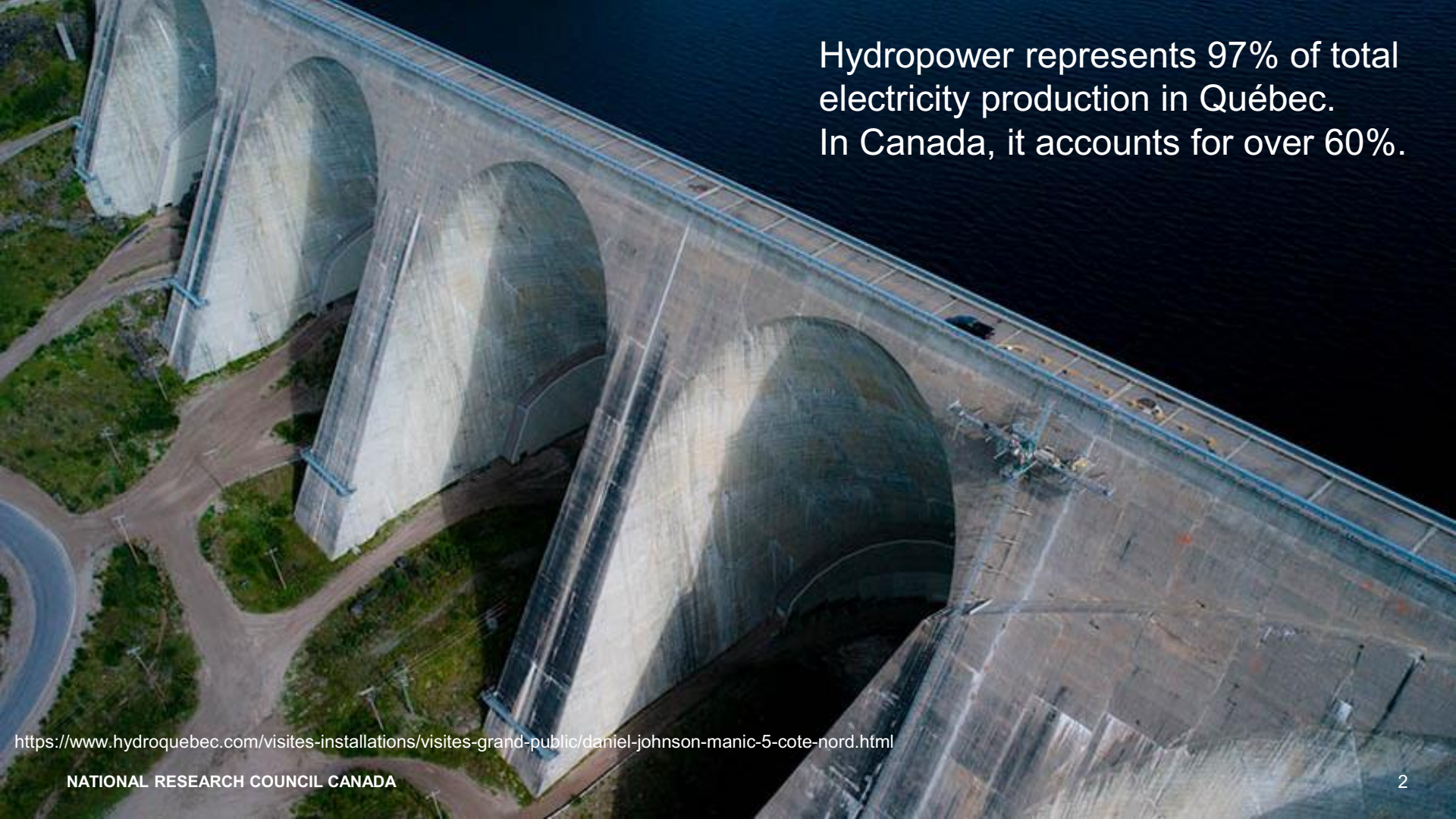
**ITSC 2023**

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Fernanda Caio<sup>2</sup>, Alexandre Nascimento<sup>2</sup>, Luc Pouliot<sup>2</sup>

Stéphane Godin<sup>3</sup>, Geneviève Gauthier<sup>3</sup>, Laurent Tôn-Thât<sup>3</sup>, Robert Schulz<sup>3</sup>

*1: National Research Council Canada; 2: Polycontrols Technologies; 3: Hydro-Québec*



Hydropower represents 97% of total electricity production in Québec.  
In Canada, it accounts for over 60%.

<https://www.hydroquebec.com/visites-installations/visites-grand-public/daniel-johnson-manic-5-cote-nord.html>

# Cavitation on turbines: challenges, solutions and opportunities



## **Materials:**

Carbon steel (A27)  
Martensitic  
stainless steel  
(CA6NM)

## **Damages:**

Corrosion  
Wear  
Cavitation

## **Current repair solution:**

Welding (TIG or  
MIG)

## **Limitations:**

Time & cost  
Tensile stresses  
Heat affected zone  
and warpage

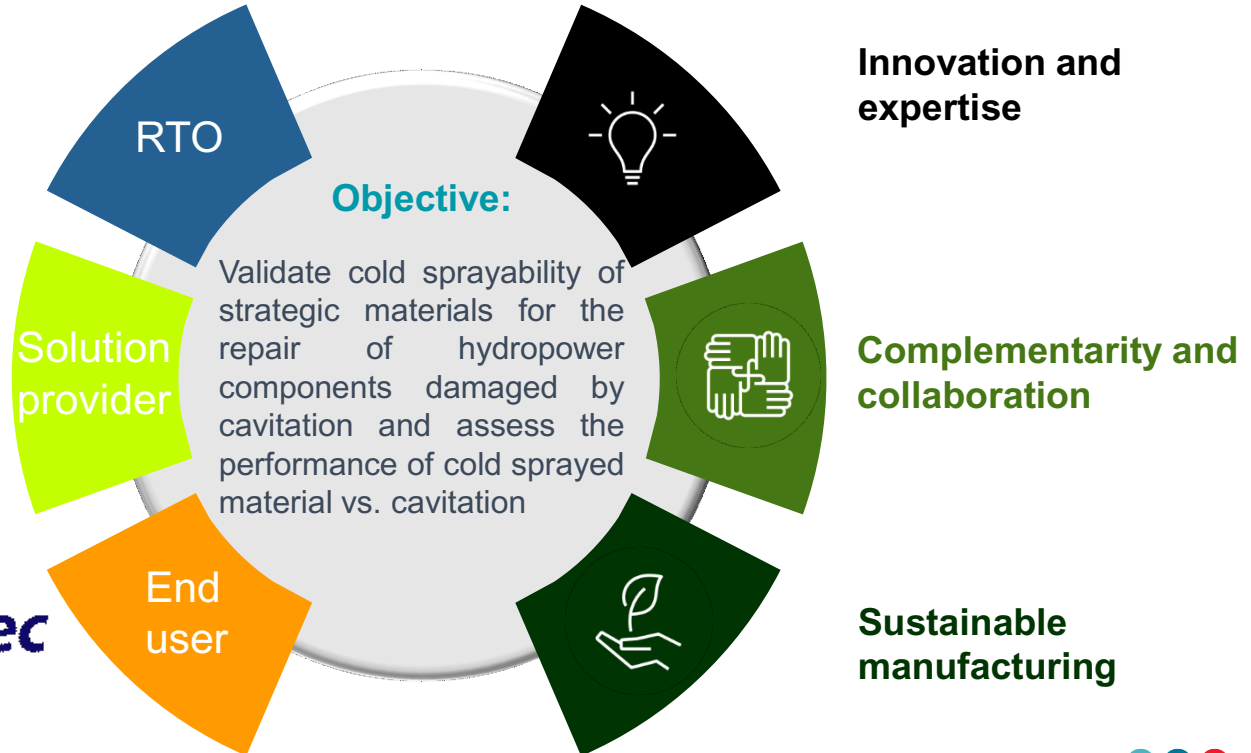
## **Opportunity for cold spray:**

Fast  
Solid state  
No HAZ, no  
deformation

# Collaborative project on the benchmarking of cold spray for cavitation damage repair



**POLYCONTROLS**



# Selection of materials for repair of cavitation damages

## What is a good material for repair of cavitation damages?

### Compatibility with base material

- Most of turbines are made of A27 or CA6NM

### Damage Resistance

- Corrosion and cavitation



### *Legacy process:* welding

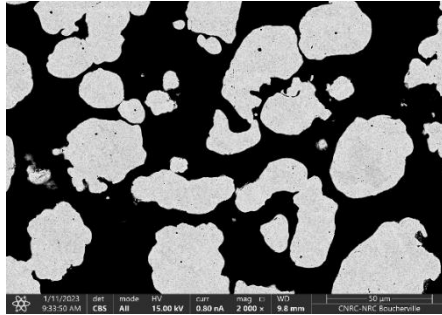
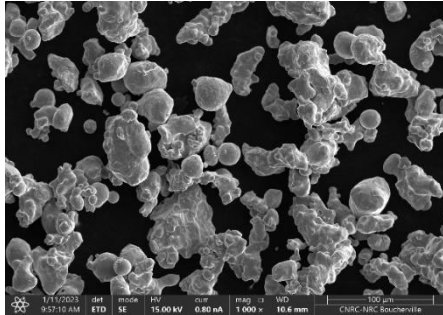
- 309L stainless steel
- Cavitec

### *Cold spray*

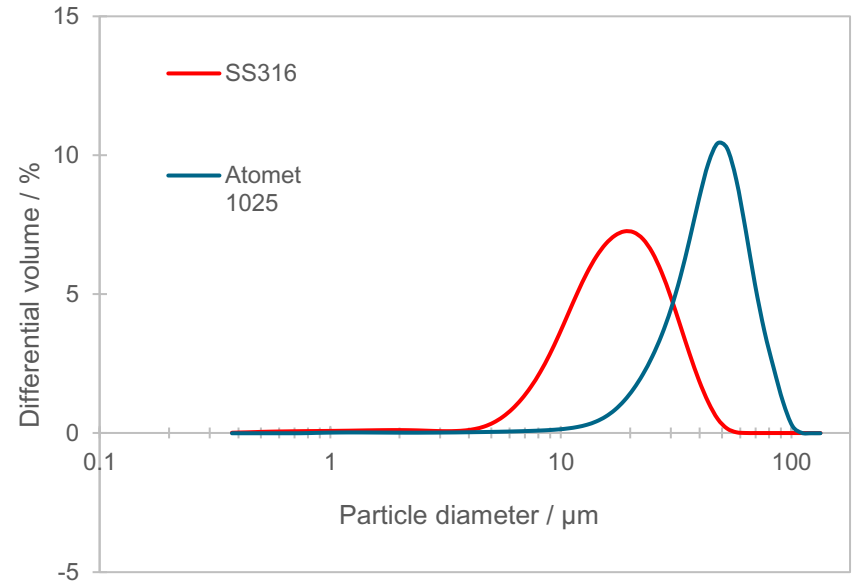
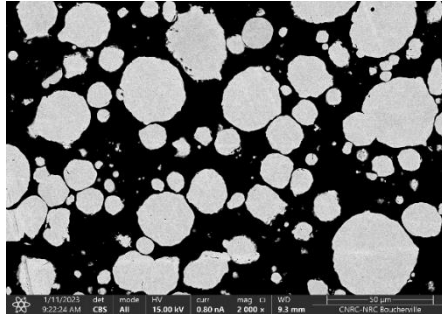
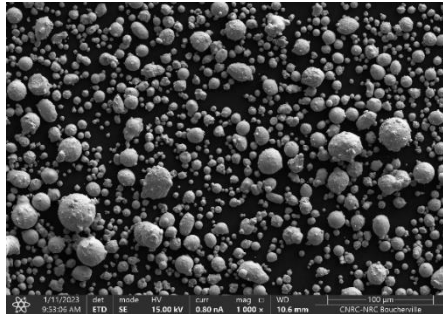
- Atomet 1025 carbon steel
- 316 stainless steel
- Cavitec

# Atomet 1025 and 316 SS powders

## Atomet 1025 carbon steel

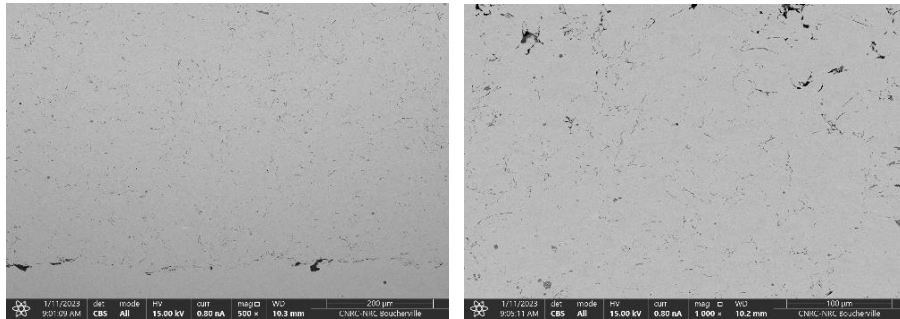


## 316 stainless steel



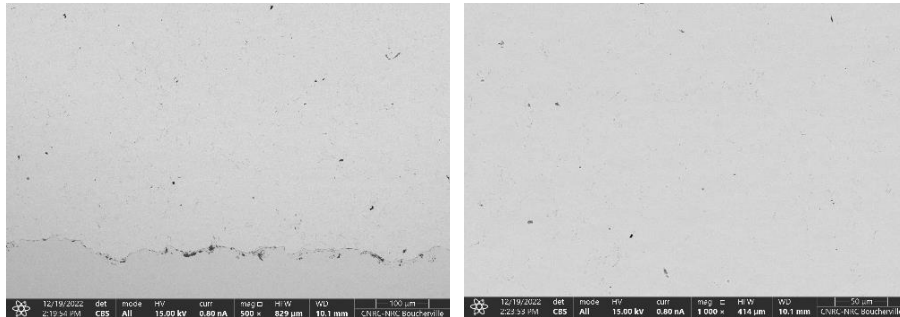
# Atomet 1025 and 316 SS coatings

## Atomet 1025 carbon steel



Dense, adherent, thick (>1mm) deposits produced with Plasma Giken PCS100, using N<sub>2</sub> as propeling gas.

## 316 stainless steel

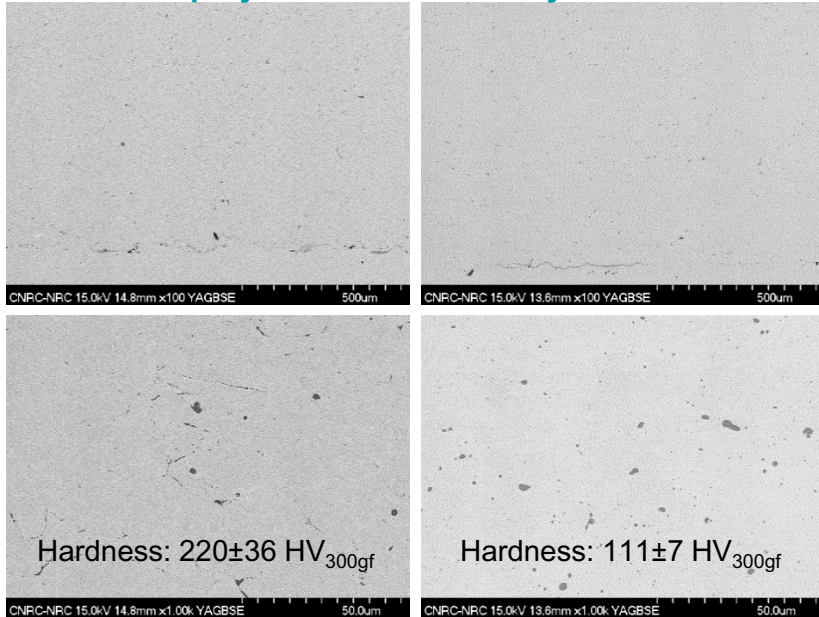


Powder	Hardness powder (HV <sub>10gf</sub> )	Particle velocity (m/s)	Hardness coating (HV <sub>300gf</sub> )
316SS	200 ± 18	710	336 ± 31
1025	116 ± 19	740	220 ± 36

# Atomet 1025 and 316 SS heat treatment

Atomet 1025  
As-sprayed

Atomet 1025  
Fully heat treated



Material	UTS (MPa)	YS (MPa)	Strain at break (%)
Bulk 1025	440	370	15
CS 1025 HT	390	295	20
316 sheet	685	377	89
CS 316 HT	620	384	40

For more information on mechanical properties of cold sprayed 316 SS, check the presentation of Phuong Vo on Wednesday afternoon, 5:30.

# Ultrasonic cavitation test – Methodology

ASTM G32 – 16 (2021)<sup>ε1</sup>

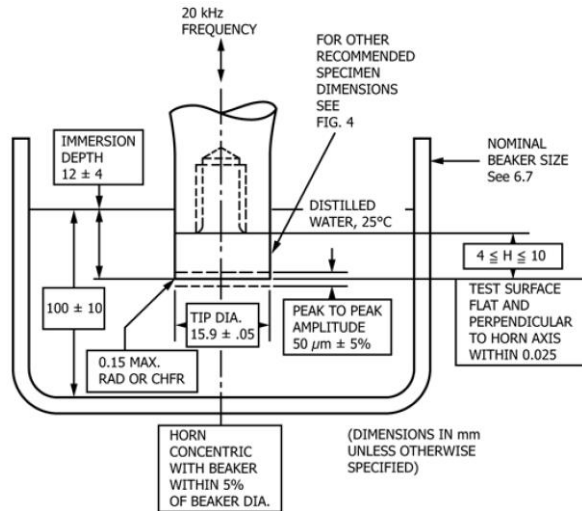


FIG. 1 Important Parameters of the Vibratory Cavitation Test

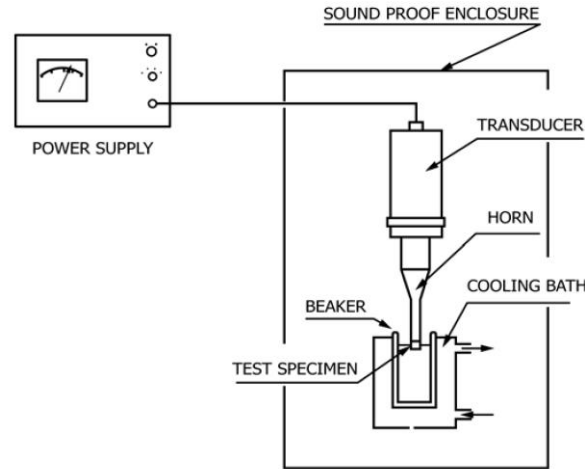
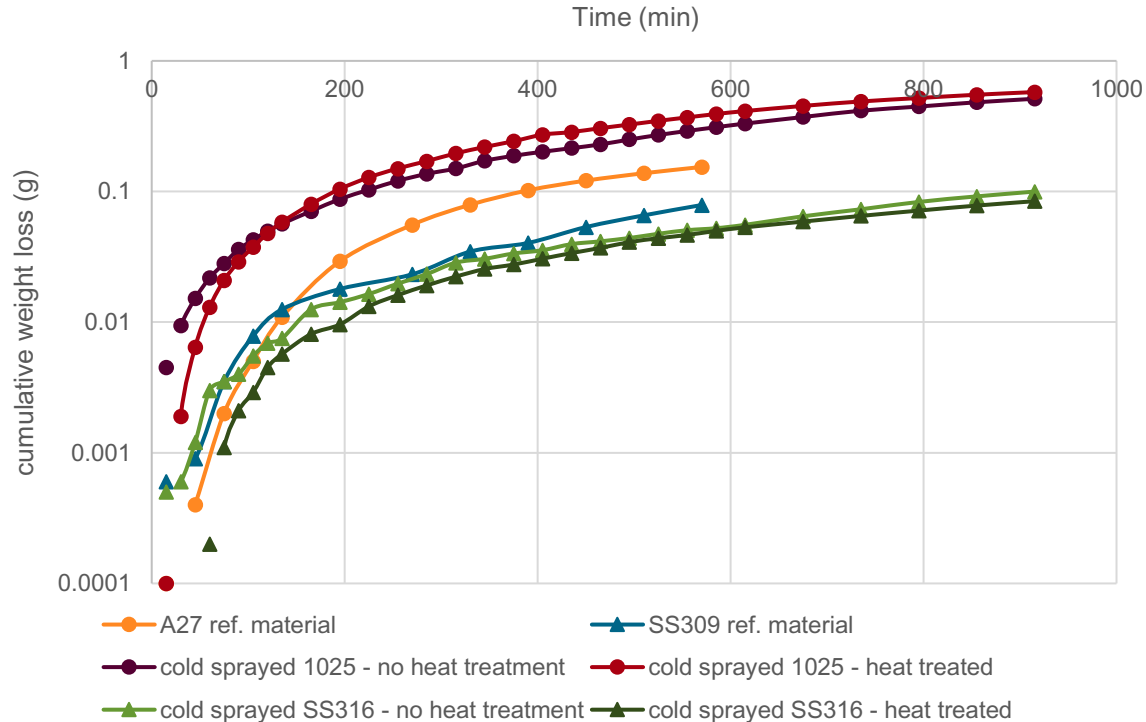


FIG. 2 Schematic of Vibratory Cavitation Erosion Apparatus

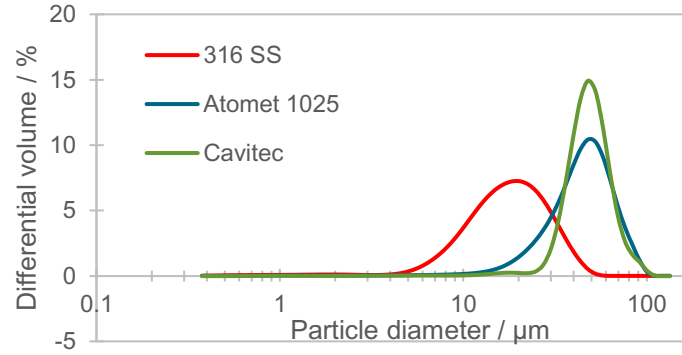
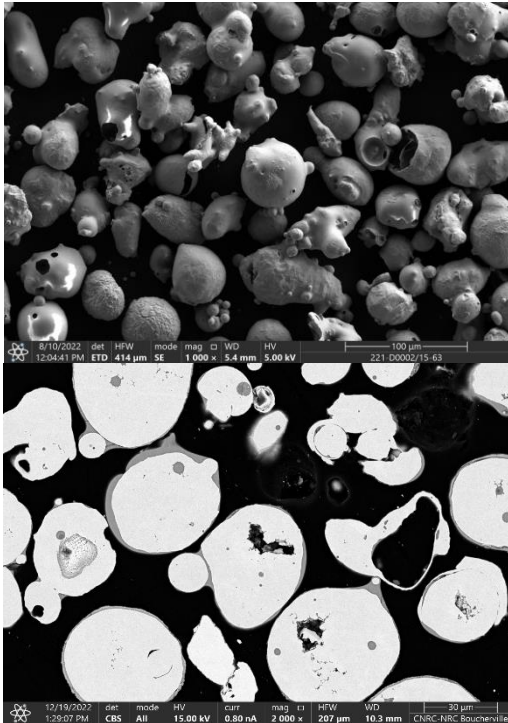
Frequency	20kHz
Peak-to-peak amplitude	50µm
Tip-sample distance	500µm
Water temperature	21°C

# Ultrasonic cavitation test – Results for 1025 and 316 SS



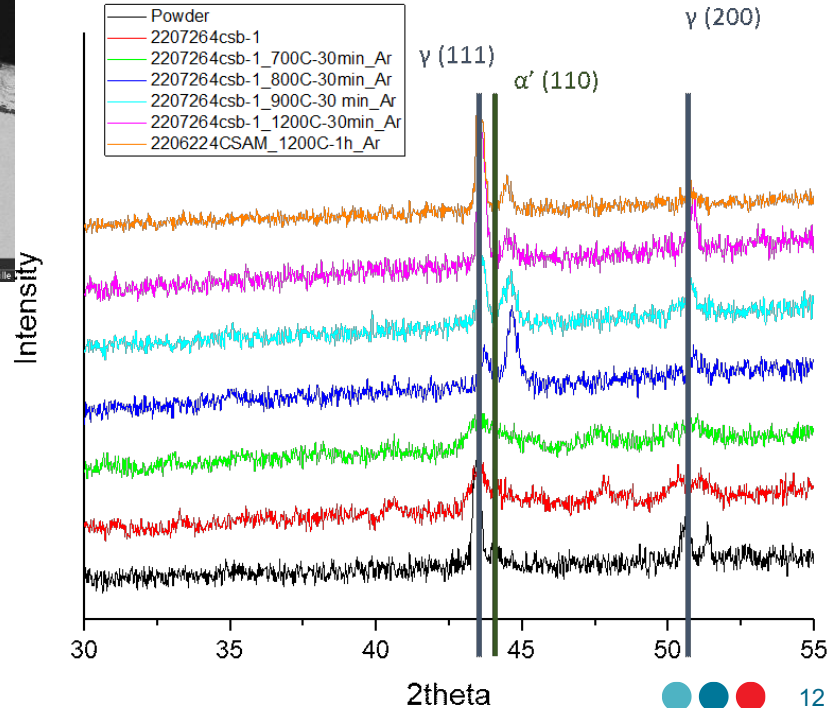
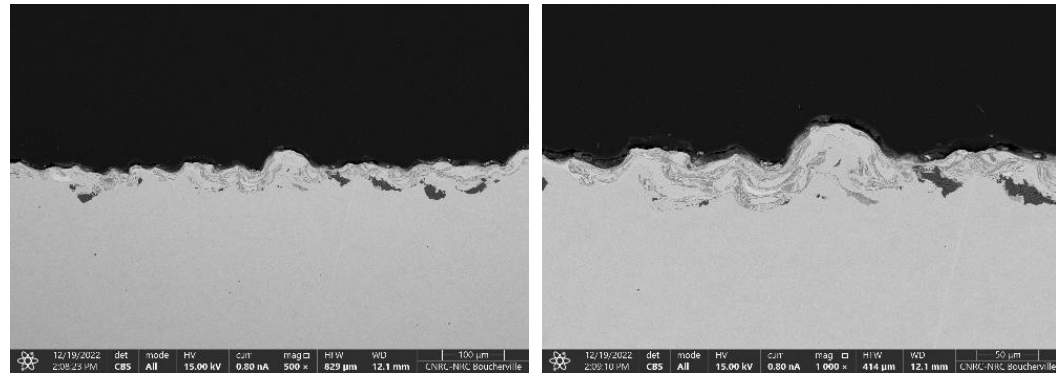
Material	Nominal incubation time (min)	Maximum rate of erosion (mg/min)
A27	108	0.35
Cold sprayed 1025	30	0.54
Cold sprayed 1025 heat treated	52	0.74
309SS, welded	101	0.15
Cold sprayed 316SS	54	0.10
Cold sprayed 316SS heat treated	95	0.10

# Tailored cavitation-resistant alloys might be a real challenge for cold spray



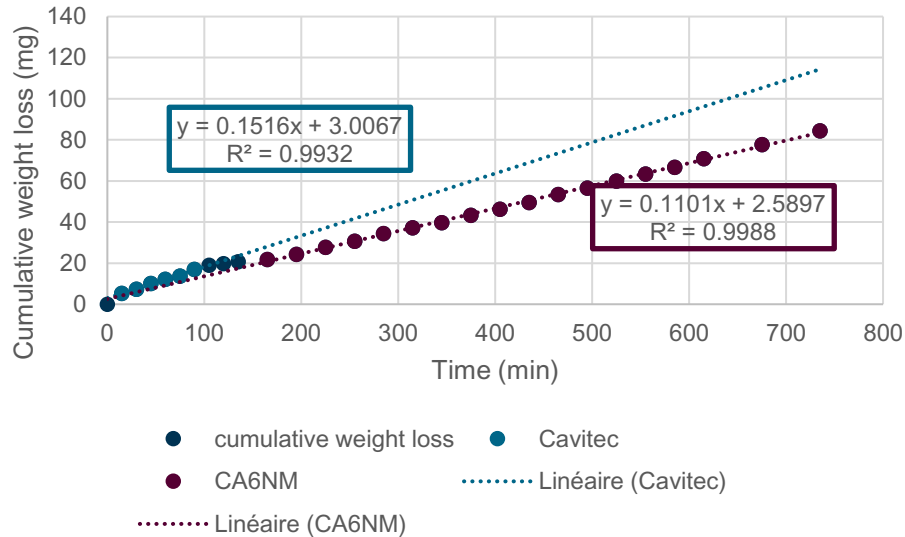
Powder	Hardness powder (HV <sub>10gf</sub> )	Particle velocity (m/s)	Hardness coating (HV <sub>300gf</sub> )
316SS	200 ± 18	710	336 ± 31
1025	116 ± 19	740	220 ± 36
Cavitec	379 ± 24	660	486 ± 96

# Phase transition during cold spray?



Powder	Hardness powder (HV <sub>10gf</sub> )	Particle velocity (m/s)	Hardness coating (HV <sub>300gf</sub> )
316SS	200 ± 18	710	336 ± 31
1025	116 ± 19	740	220 ± 36
Cavitec	379 ± 24	660	486 ± 96

# Cavitation test results



Material	Nominal incubation time (min)	Maximum rate of erosion (mg/min)
Cold sprayed 1025	30	0.54
Cold sprayed 1025 heat treated	52	0.74
Cold sprayed 316SS	54	0.10
Cold sprayed 316SS heat treated	95	0.10
Cold sprayed Cavitec	3	0.15
Typical Cavitec weld	~ 1200	< 0.015

# Conclusions and next steps

## Conclusions

- Cold spray can be used to produce **1025 and 316SS coatings with reasonable resistance to cavitation**.
- **Heat treatment does not necessarily impact overall cavitation resistance** on these 2 materials.
- **Cavitec**, a TRIP-steel, is **very challenging to cold spray**; can be related to phase transformation upon impact.

## Continuation of this phase

- **Further cavitation tests** (high pressure tests)
- **Analyses of samples** to understand cavitation mechanisms (with vs. without heat treatment, 1025 vs. 316, bulk vs. cold spray)

## Next phase

- **Cold spray of 309 SS** to compare with 316 SS
- **Cold spray of Cavitec**: effect of PSD and laser assistance
- **Optimization** of coating procedure to maximize performance in cavitation

# THANK YOU

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