

# Advanced TEM investigation of interfaces in Al-Al<sub>2</sub>O<sub>3</sub> cold sprayed coatings

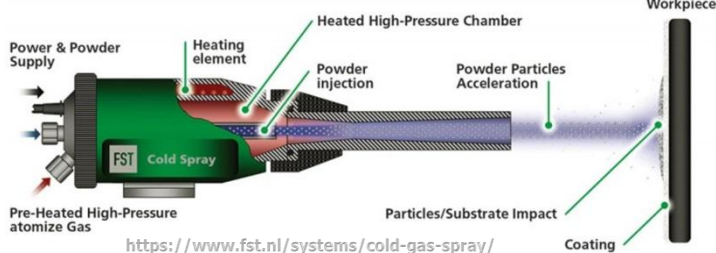
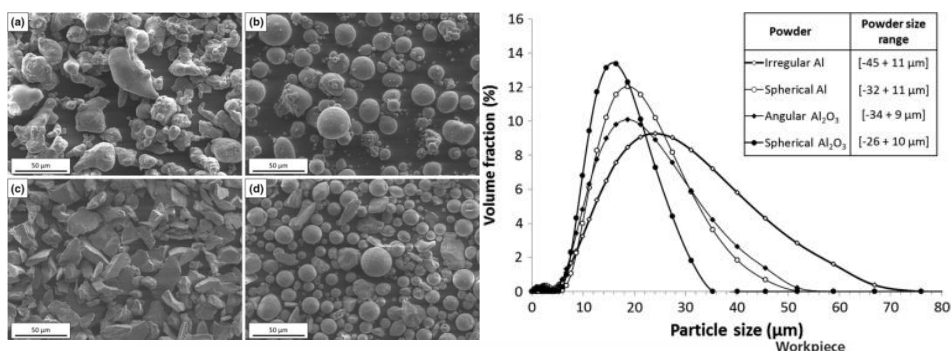
M. Sennour, F. Gaslain, P. E. Leger F. Borit, M. Jeandin

## I. INTRODUCTION

Cold spray coating is recognized as a leading thermal spray process with a high potential to meet industrial demands [1]. In this work, aluminum (Al) powders with spherical and irregular particle shapes were mixed with two alumina (Al<sub>2</sub>O<sub>3</sub>) powders with either a spherical or an angular particle shapes to achieve high-performance cold-sprayed coatings onto steel [2]. Al/Al and Al/Al<sub>2</sub>O<sub>3</sub> interfaces were investigated using TEM to understand coating strengthening effects due to alumina addition at the scale of the particle.

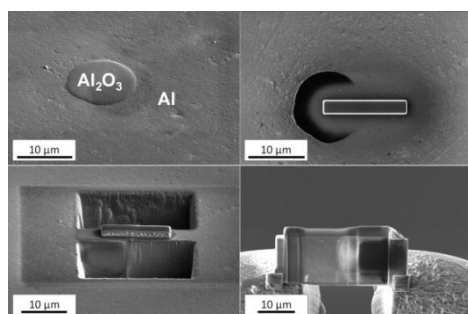
## II. MATERIALS AND METHODS

Al powders and Al-15 wt.% Al<sub>2</sub>O<sub>3</sub> mixtures were cold sprayed using CGT Kinetics 3000M facilities. Nitrogen was used as spraying gas. The process gas pressure was 2.5 MPa with a gas temperature of 400 °C.



## TEM samples

TEM thin foils were extracted using the focused ion beam (FIB) technique on Helios 660 SEM-FIB. TEM observations were carried out on Thermo Fisher Tecnai F20-ST microscope.

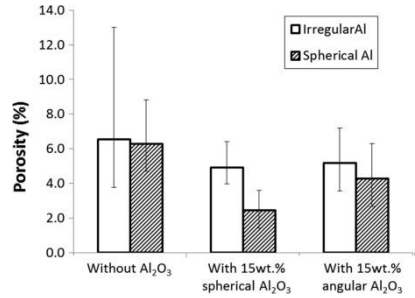
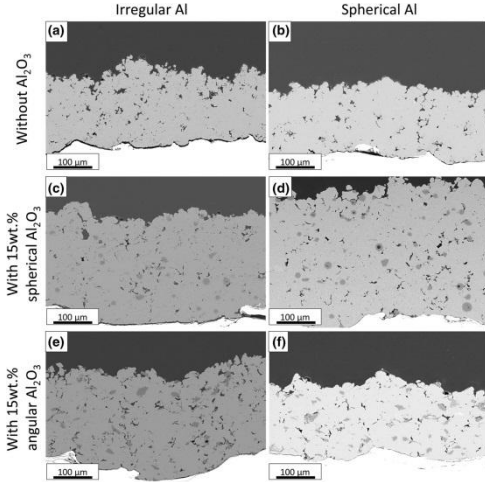


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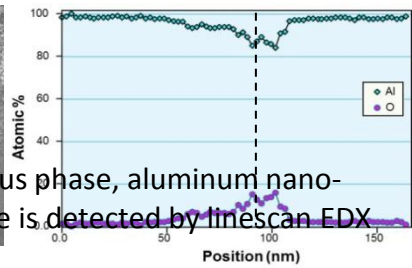
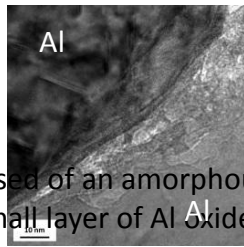
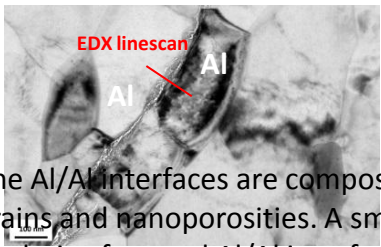
## III. RESULTS

### Microstructure

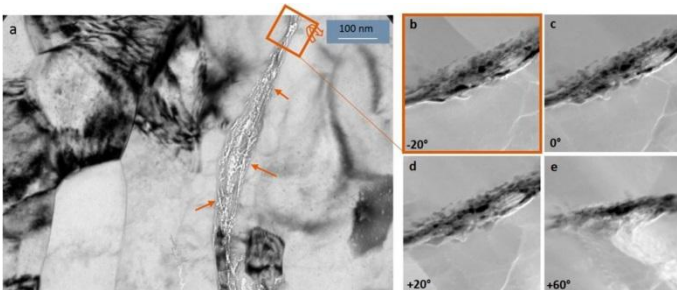


Spherical Al – 15 wt.% spherical Al<sub>2</sub>O<sub>3</sub> mixture presents the best result decreasing the porosity of the coating to about 2%.

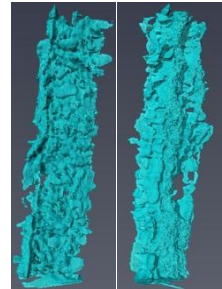
### TEM and nanotomography characterization of the spherical Al-15%wt spherical Al<sub>2</sub>O<sub>3</sub> coating



The Al/Al interfaces are composed of an amorphous phase, aluminum nano-grains and nanoporosities. A small layer of Al oxide is detected by linescan EDX analysis of several Al/Al interfaces.



### 3D reconstruction



TEM nanotomography highlighted that nanoporosities are interconnected forming nanochannels.



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## IV. SUMMARY

- Pure aluminum and composite Al-Al<sub>2</sub>O<sub>3</sub> coatings were successfully cold-sprayed onto grit-blasted steel. The very low oxygen content detected by TEM confirms that cold spray is a really protective process which only oxidized at a very fine scale.
- Alumina addition decreased porosity in aluminum coatings. Spherical alumina addition strengthened the coating at nanoscale.
- From a thorough TEM study, interface improvement was shown to result from alumina addition. Al/Al<sub>2</sub>O<sub>3</sub> interfaces showed no porosity actually, unlike Al/Al interfaces which were somewhat nanoporous.
- TEM nanotomography highlighted that nanopores are interconnected forming nanochannels.
- TEM investigations carried out on corroded Al-Al<sub>2</sub>O<sub>3</sub> coating highlighted that no corrosion products are present at Al/Al<sub>2</sub>O<sub>3</sub> interfaces in contrast to Al/Al interfaces. Using electron diffraction and EDX experiments corrosion products have been identified as being probably a mixture of Al<sub>2</sub>O<sub>3</sub> and Al(OH)<sub>3</sub>.

## REFERENCES

- [1] A. Vardelle et al., J. Therm. Spray Technol., 2016, 25(8), p 1376-1440  
[2] P.E. Leger et al, J. Therm. Spray Technol., 2017, 26(7), p. 1445-1460

## ACKNOWLEDGEMENTS

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