POLYTECHNIQUE MONTRÉAL
UNIVERSITÉ D'INGÉNIERIE

Mechanical Properties of newly developed abradable materials for additive manufacturing

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Laboratory of multiscale mechanics
Laboratoire de mécanique multi-échelles

Laboratoire d'analyse vibratoire et acoustique

centre de recherche en … et composites

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Chaires de recherche du Canada

SAFRAN

BACKGROUND

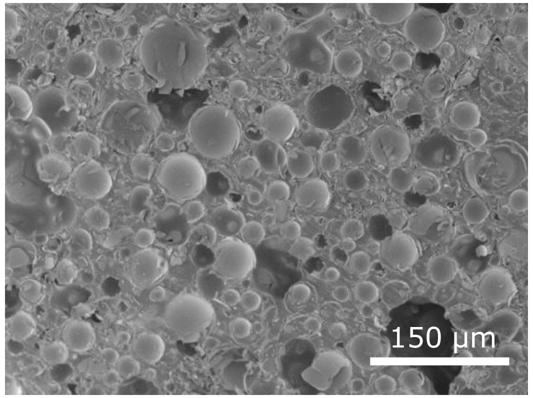
ICAO environmental objectives for 2050

1- Reduce CO_2 emissions by 75%

2- Reduce noise level by 65%

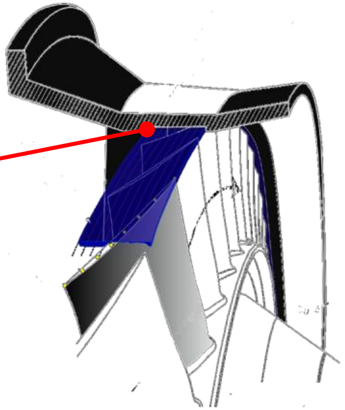
1. Venturebeat.com, 2017

INTRODUCTION

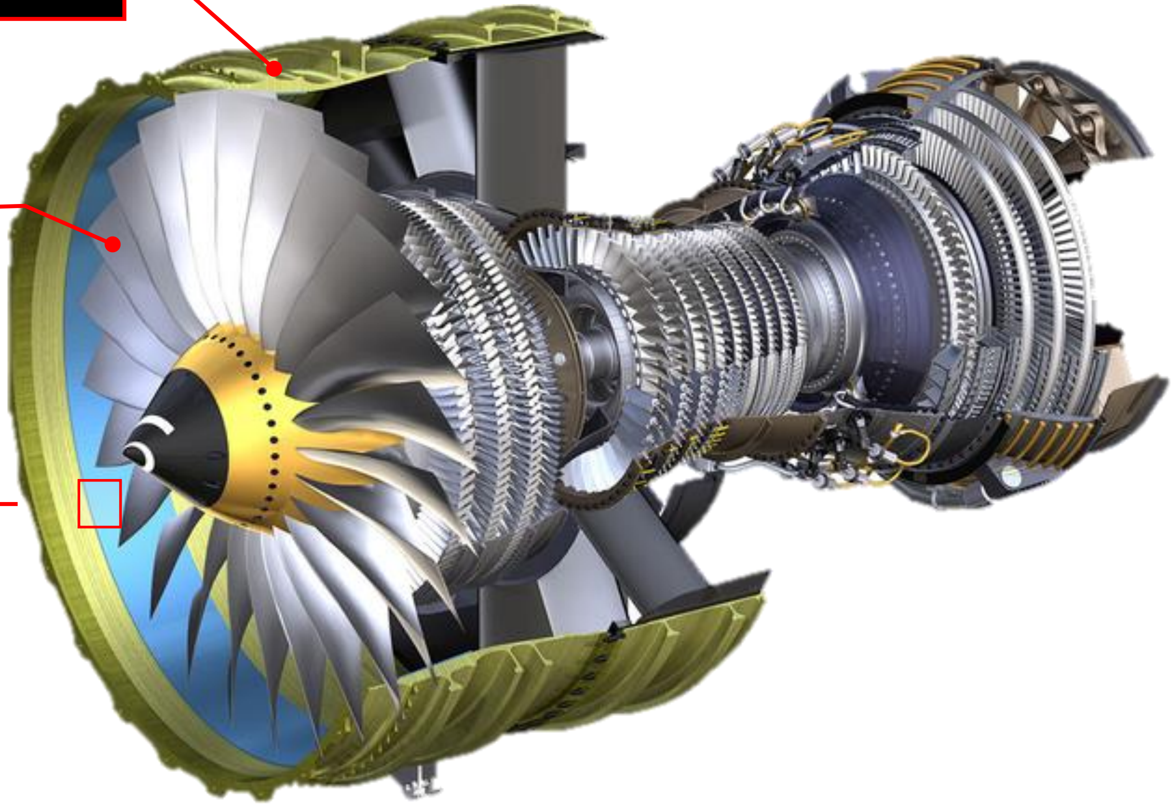


Thermoset composite

Manual application [4]



Abradable coating [3]



Leap-1A turbofan [2]

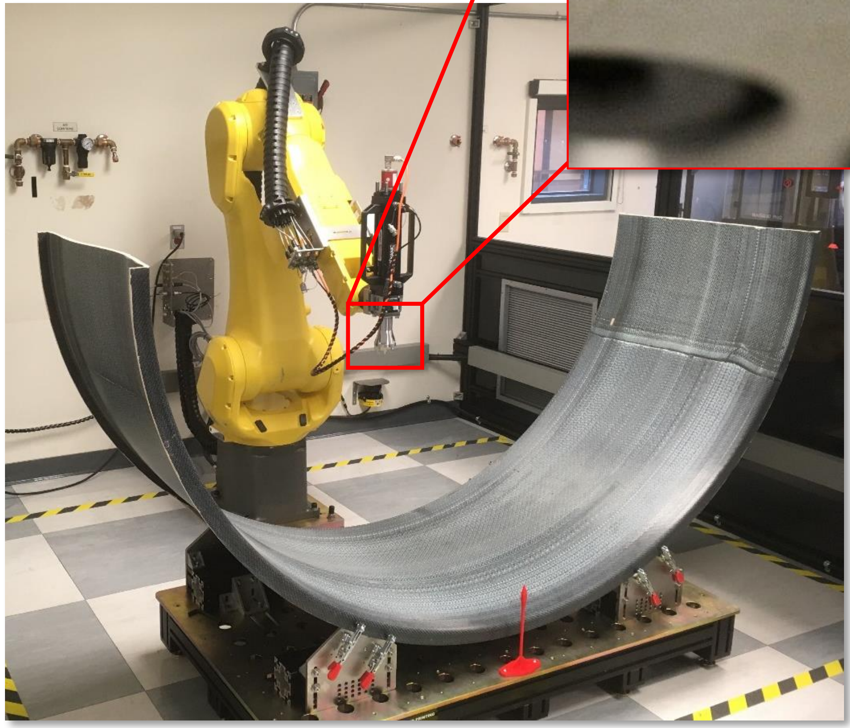
Abradable composite materials

- Reduce clearance
- Limit aerodynamic loses
- Blade tip sealing
- Preferential coating wear
- Decrease fuel consumption

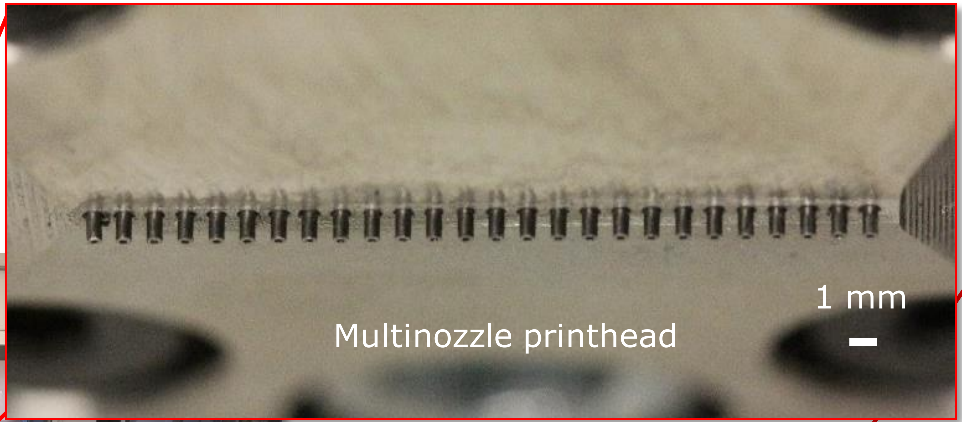
2. safran-group.com, 2016
3. Legrand et al., 2012
4. http://www.afiklmem.com

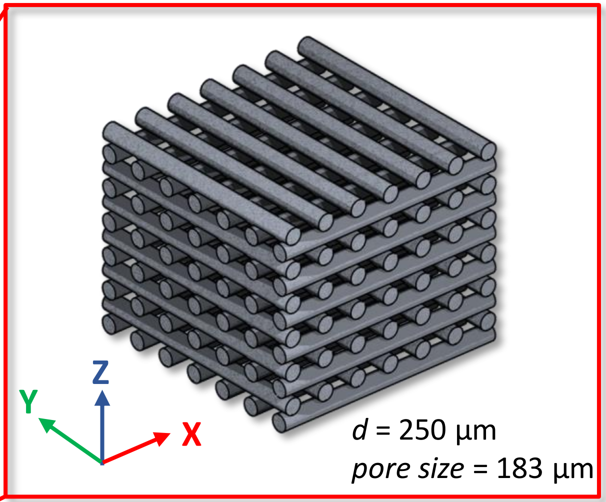
ADDITIVE MANUFACTURING OF ABRADABLE MICROSCAFFOLD

Jean-François Chauvette, PhD



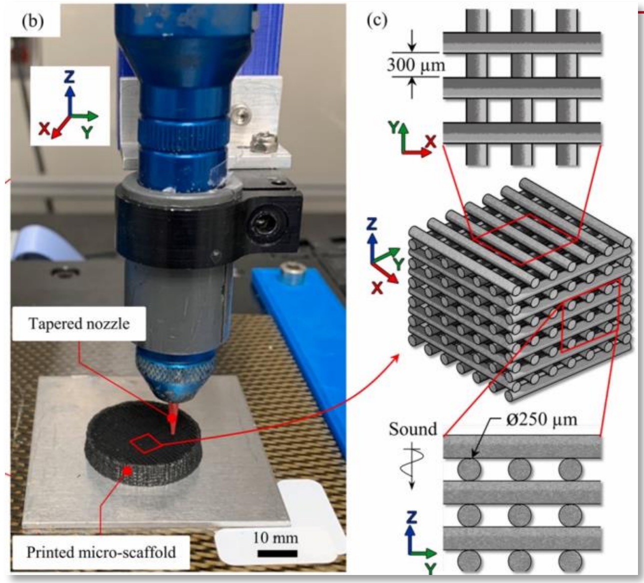
6-axis robot with a half engine fan case





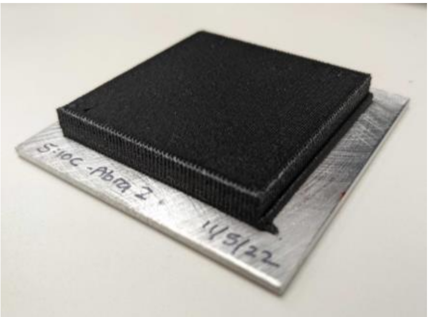
Non-planar DIW of abradable microscaffold network using multinozzle printhead on a FFF of a curved HTRP sandwich panel

ABRADABLE MATERIAL FORMULATIONS



DIW of abradable microscaffold [5]

ABRADABLE FORMULATIONS



<u>Materials</u>

i) Epoxy resin

ii) Glass microspheres (GM)

iii) Fumed silica (FS)

Iee Lee Hia, Postdoc

David Brzeski, Msc

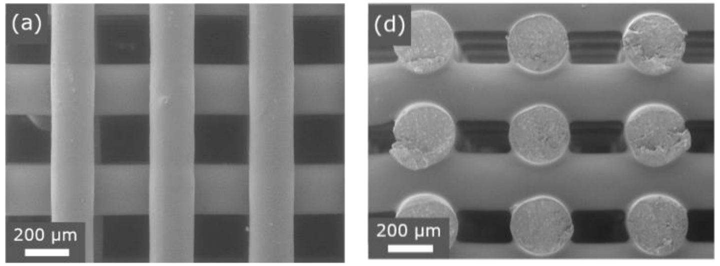
Fail microscaffold - DIW of commercial abradable product

DIW MICROSCAFFOLD

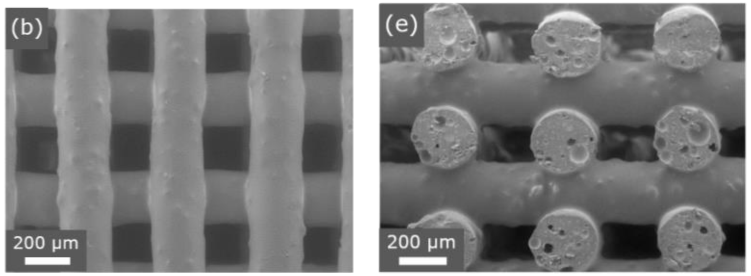
0GM.12FS

5GM.10FS

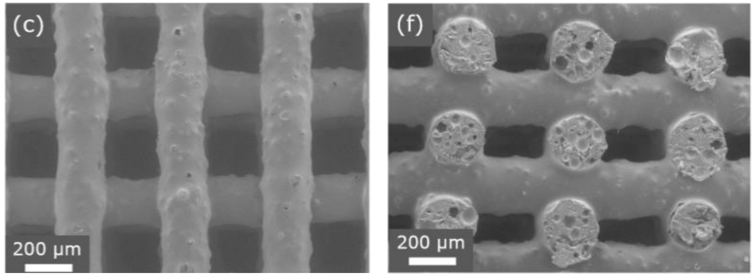
10GM.8FS



$\rho = 1.279$ g/cm3



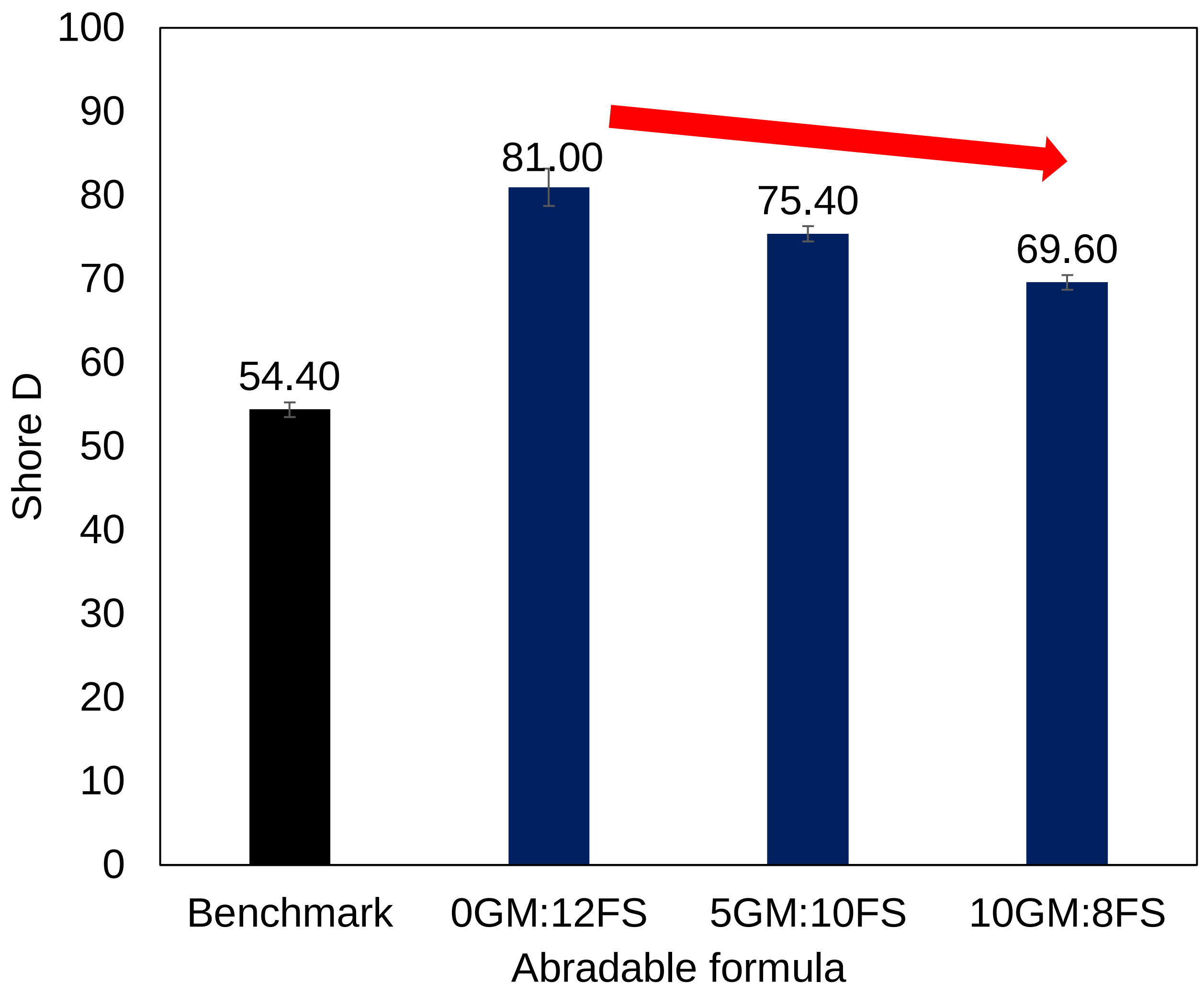
$\rho = 0.598$ g/cm3

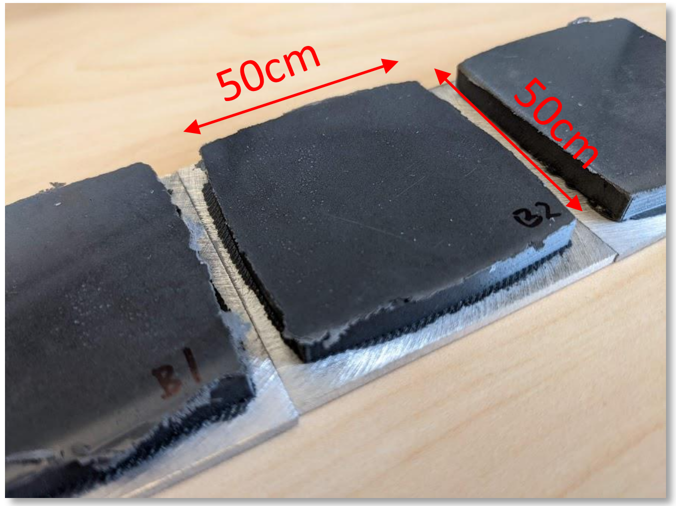


$\rho = 0.792$ g/cm3

[5] D Brzeski, IL Hia, JF Chauvette, etc., Additive Manufacturing, 47, 2021, 102245.

MECHANICAL TEST I: SHORE D



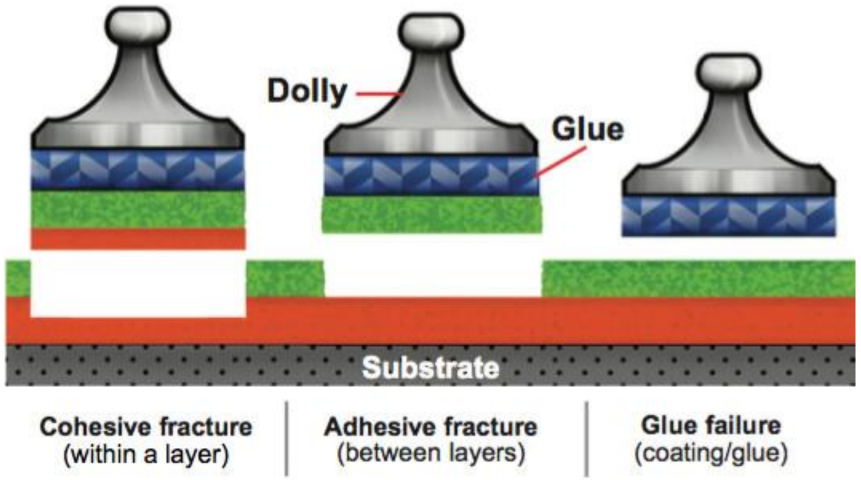


Molded 0GM12FS abradable coating

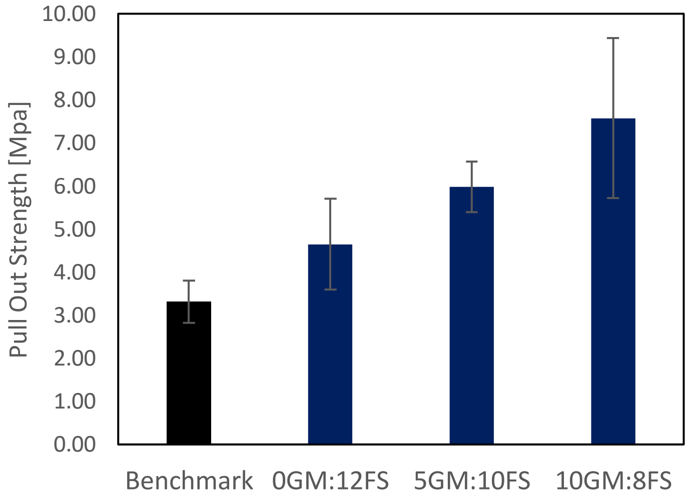
Shore D durometer

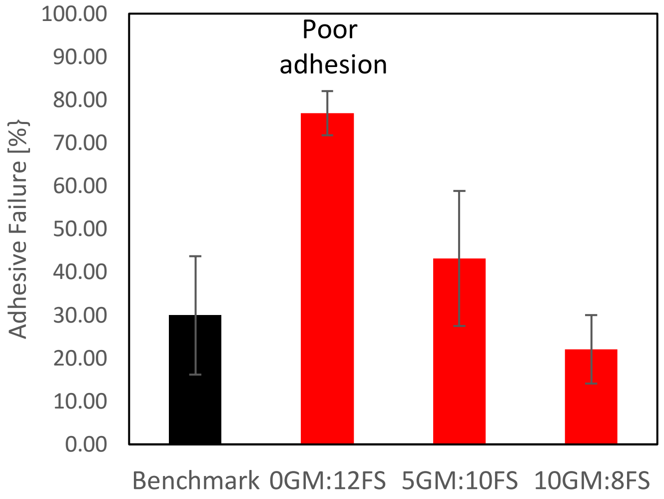
- Increasing of GM loading decreases in Shore D hardness
- Higher GM loading leads to higher porosity, thus reducing hardness

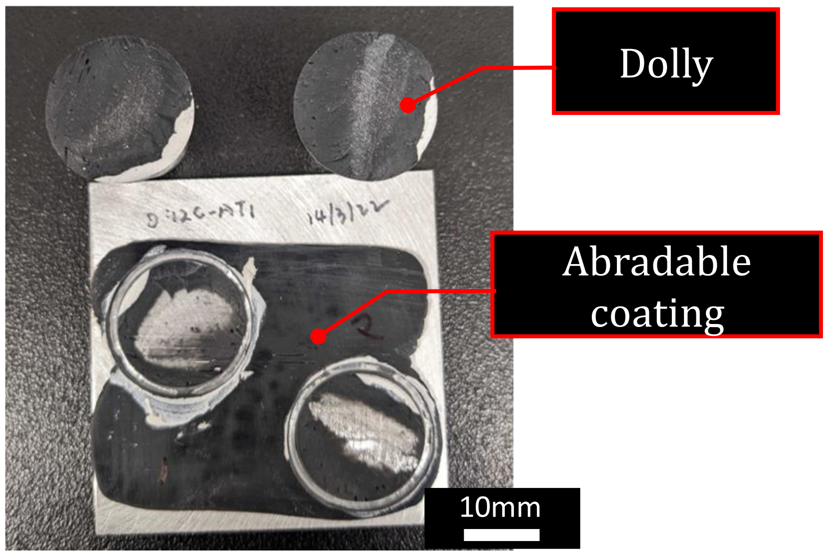
MECHANICAL TEST II: ADHESION TEST



Pull off adhesion test [6]



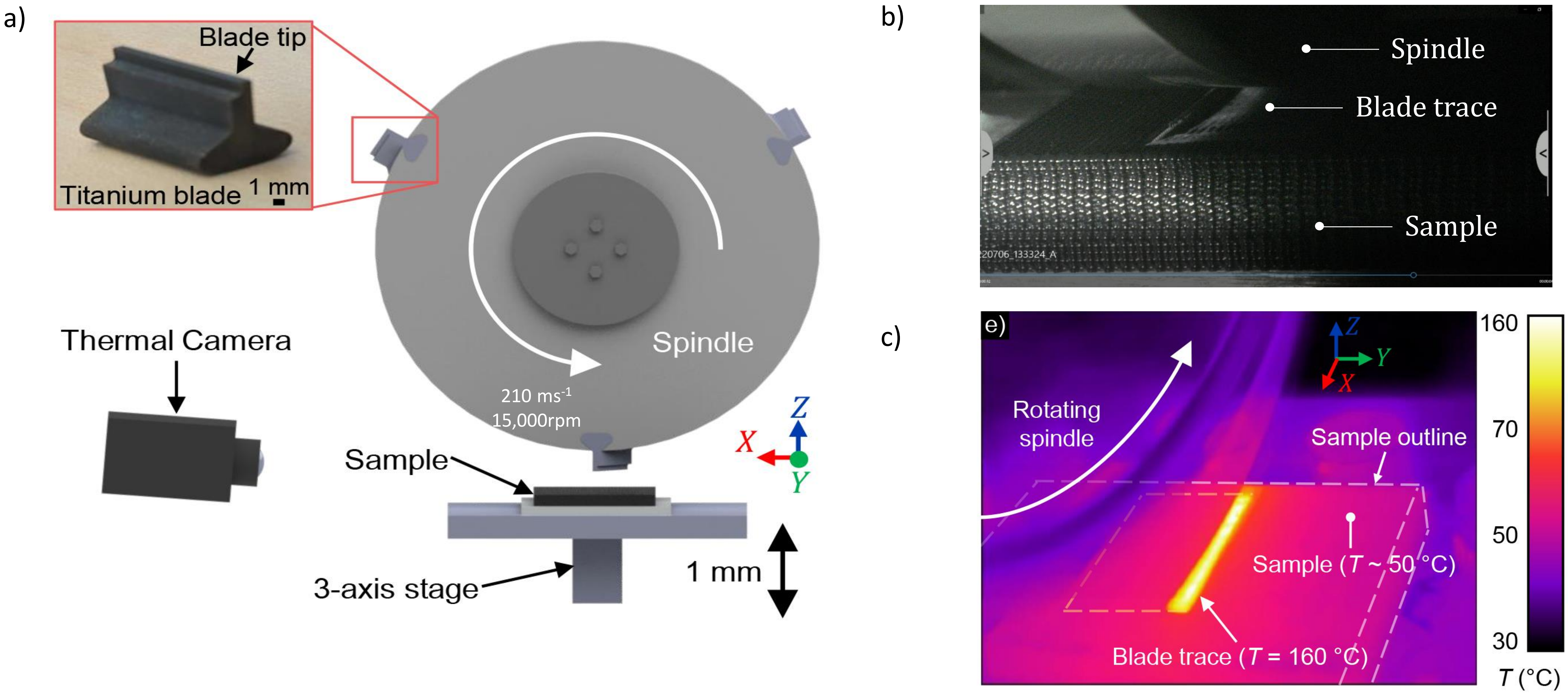




Pull off adhesion test on abradable coating

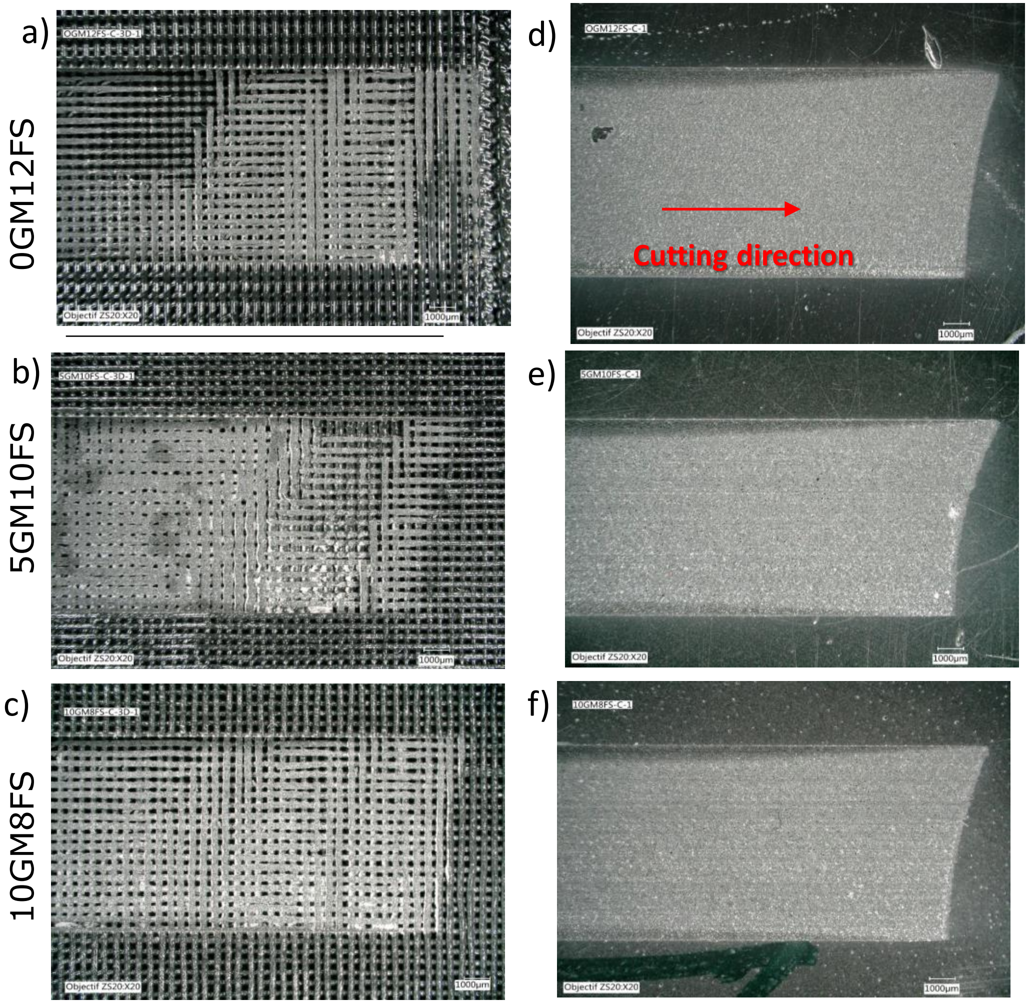
- The pull out strength increases with GM loading
- Without GM, the adhesion of the abradable coating is poor on the aluminium substrate
- Benchmark with highest GM loading (~23wt%) has poor adhesion on the substrate

[6] https://www.defelsko.com/resources/test-methods-for-coating-adhesionhttps://www.defelsko.com/resources/test-methods-for-coating-adhesion



(a) Schematic of abradability test rig with three titanium blades attach on rotating disk. Images taken from the (b) camera and (c) thermal camera during the abradability test.

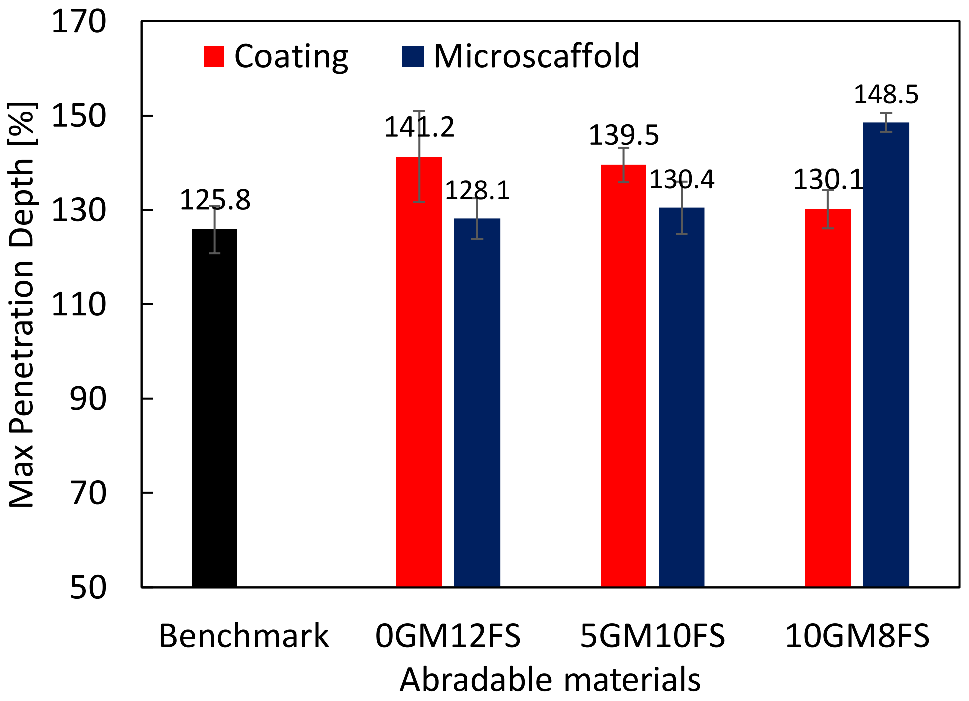
MECHANICAL TEST III: ABRADABILITY TEST

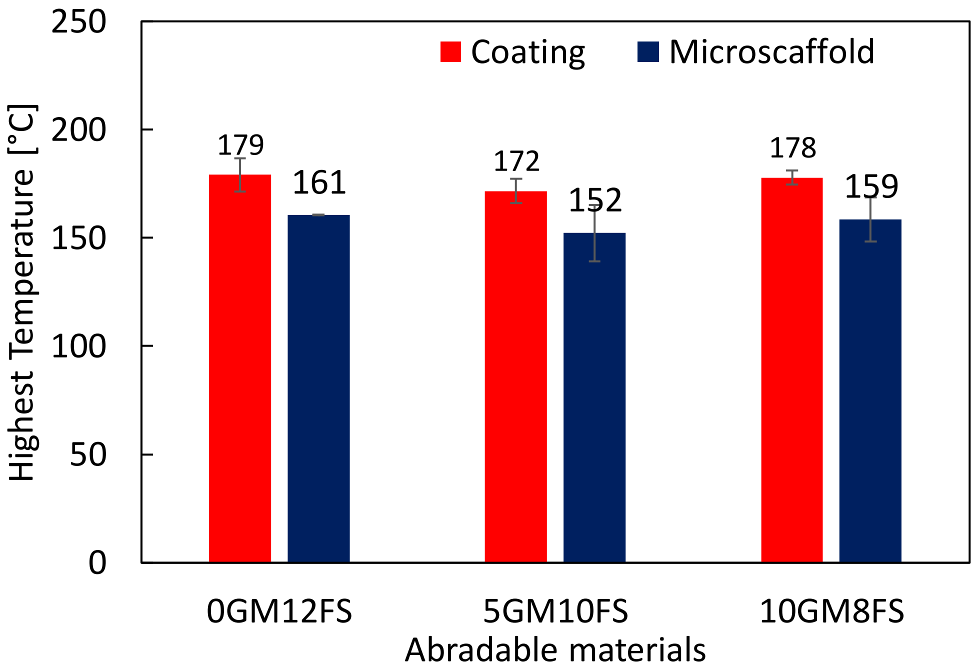


- Overall, the abradability of 3 new abradable materials are comparable with Benchmark
- There is no material adhesion on the TA6V blades, smooth cutting tracks observed thus the abradables are being removed easily
- Dust formation and pores clogging might affect acoustic properties

Top view of (a-c) 3D printed abradables micro-scaffolds and (d-f) coatings showing the tracks after being abraded by TA6V blades. Dust traces generated are found in the pores of microscaffolds.

MECHANICAL TEST III: ABRADABILITY TEST





- The higher penetration depth of abradable coating compared to microscaffold could be due to the higher temperature recorded which also soften the materials, thus more materials being abraded
- The highest penetration depth found in 10GM8FS microscaffold could be due to the high porosity and fragility of abradable materials, thus the internal structures could be easily compacted during the blade scratching rather than being removed
- Overall, the DIW microscaffold made of 0GM12FS and 5GM10FS were having great abradability which is very similar to the Benchmark

SUMMARY

- New DIW abradable materials have been developed and they are successfully printed into microscaffold network
- Their mechanical properties (i.e. Shore D, adhesion and abradability tests) were evaluated as compared to the commercial abradable product
- Impact of fume silica on the hardness is insignificant compared to glass microspheres. Increasing of glass microsphere increase the Shore D hardness of abradable materials
- Higher GM loadings lead to higher pull out strength and also the adhesion on the aluminium substrate
- Two abradable materials (0GM12FS and 5GM10FS) showed better abradability as compared to 10GM8FS material

Thank You Team Objective 4!