3DCeraTurb:Towards CMC-turbine vane design under engine conditions

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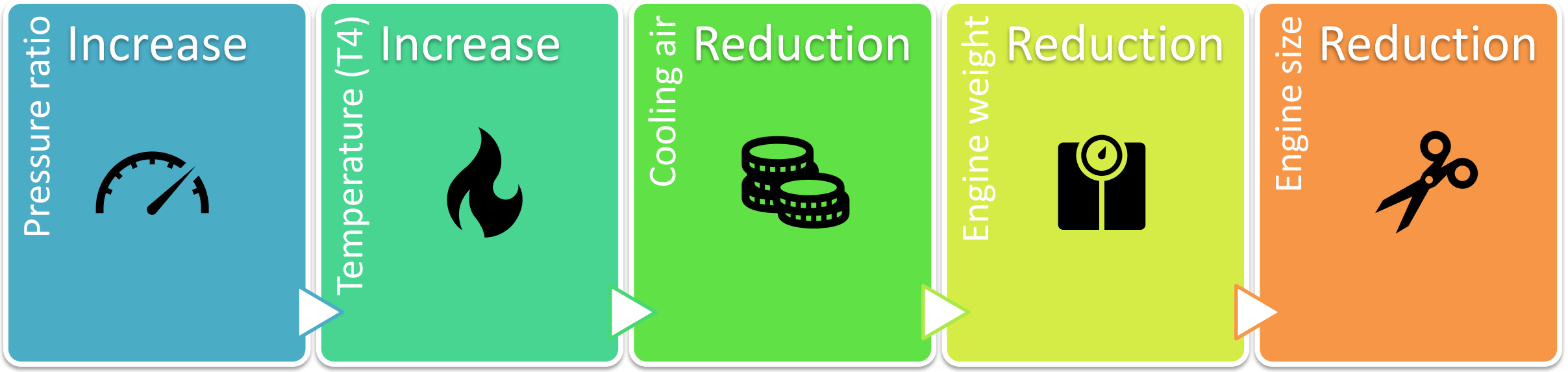
07. December 2021

What is the potential of a CMC-Turbine in an engine?



$\sum$ = superior thrust-to-weight ratio & consequently lower emissions (3)

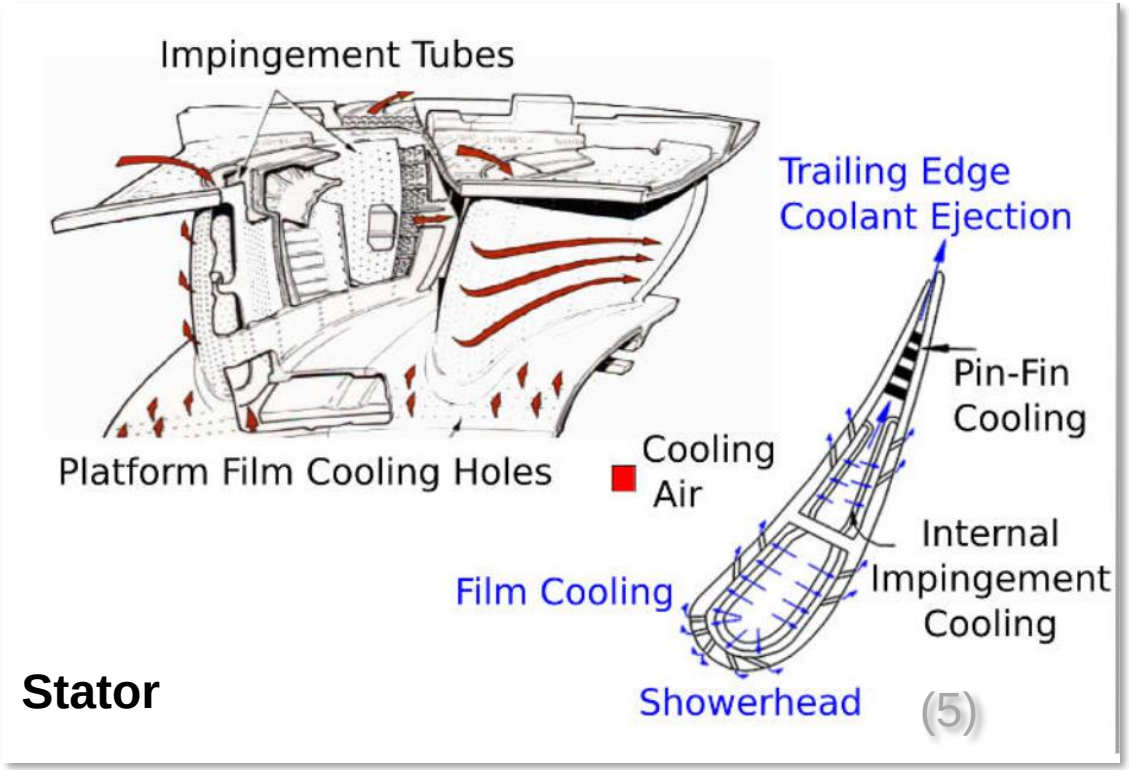
Investigations of a retrofitted combustion-chamber (4) :

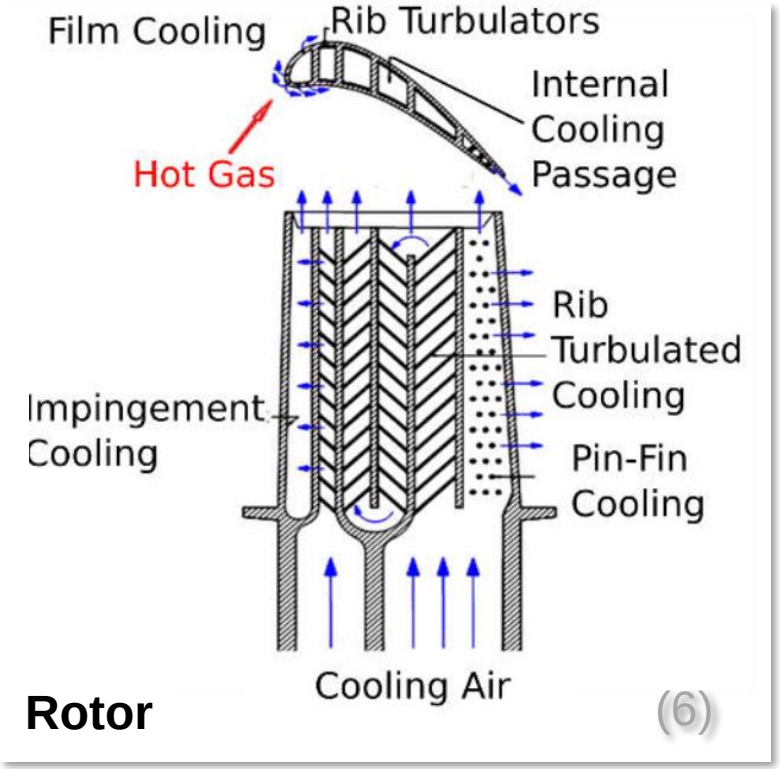
- 30 % reduction of NO_x emissions
- 20 % reduction of CO emissions

(1) (2)

Rethinking from metal to CMC

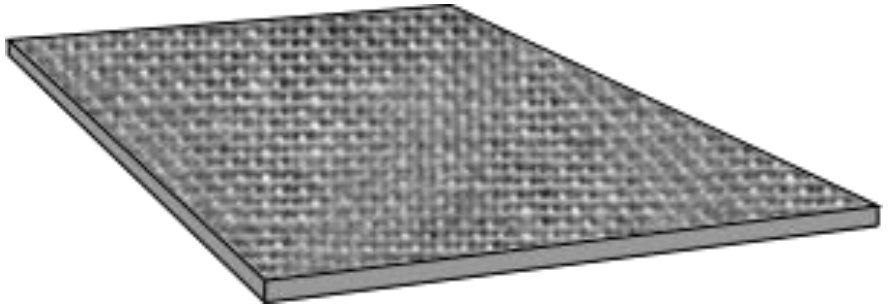
Differences in turbine cooling between stator and rotor

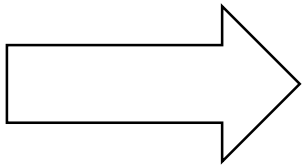


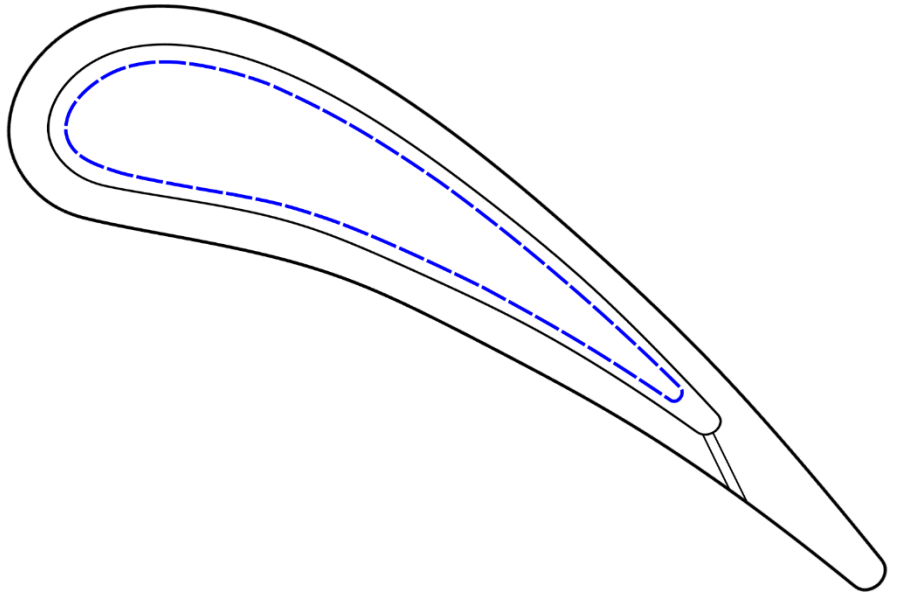


Rethinking from metal to CMC

How to apply for SiC/SiC-CMC in 3DCeraTurb?







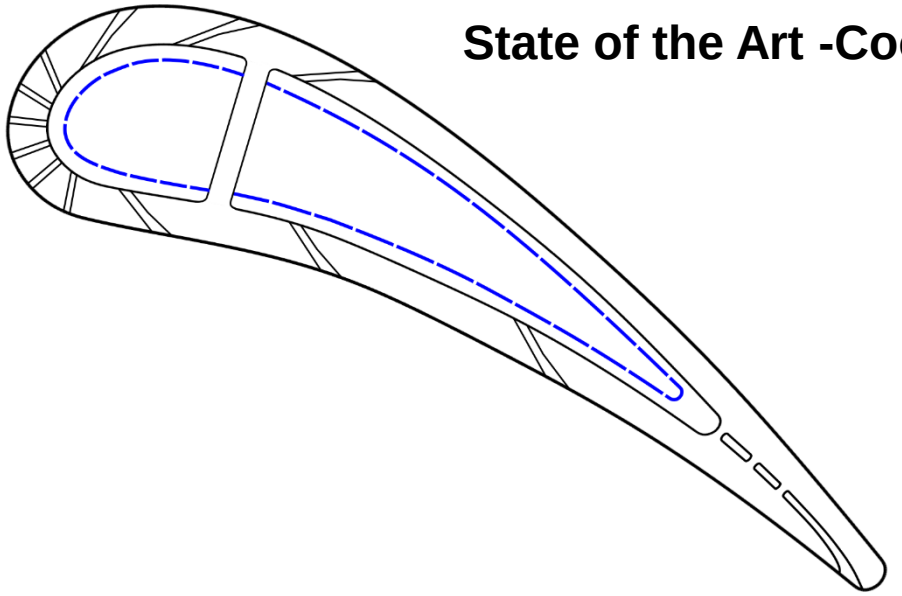
(7)

In 3DCeraTurb: Only Trailing edge cooling!

Rethinking from metal to CMC

How to validate the CMC-design?

State of the Art -Cooling



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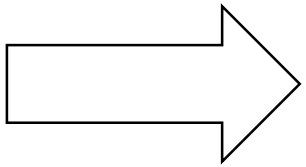
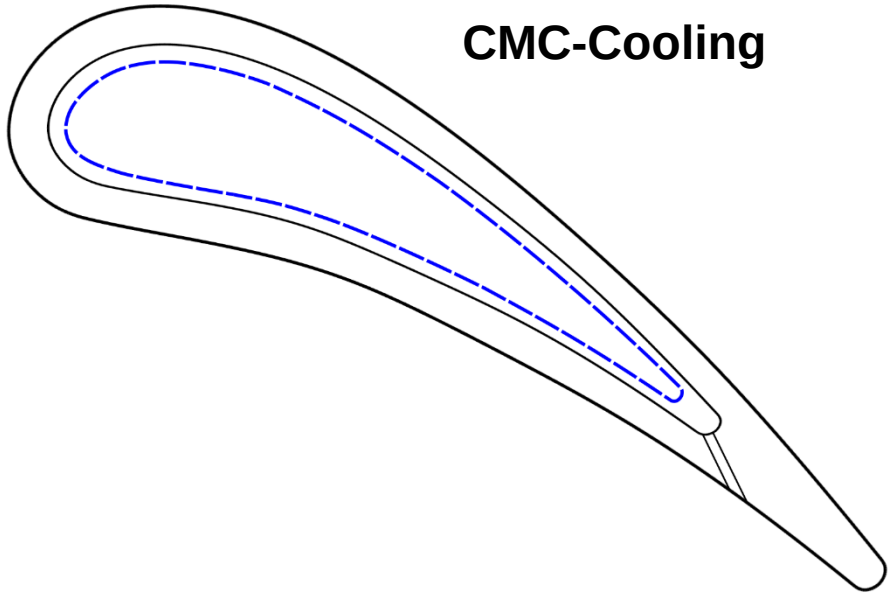


CMC-Cooling

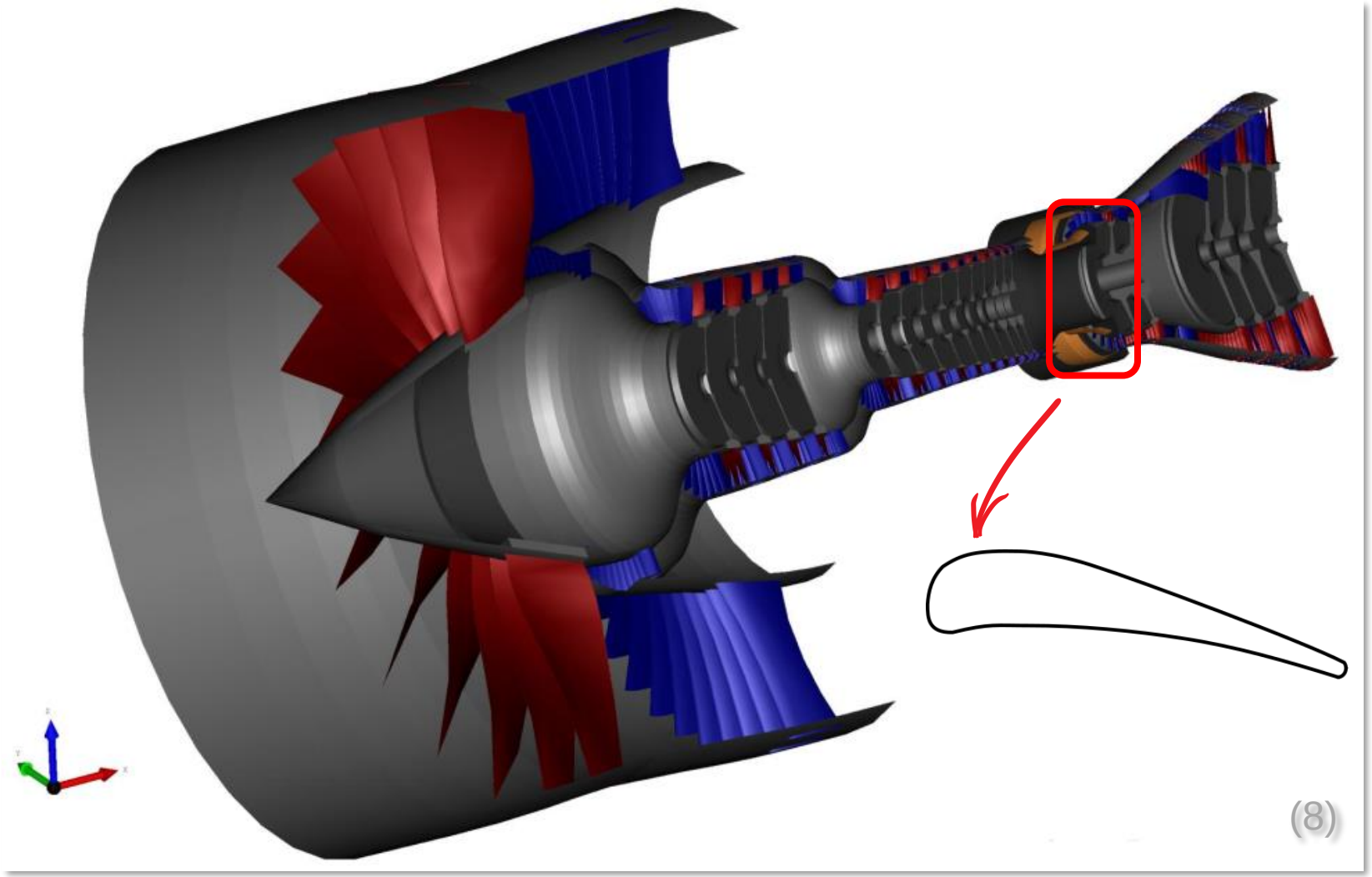


(7)

Where to begin?

UHBR-GTF engine

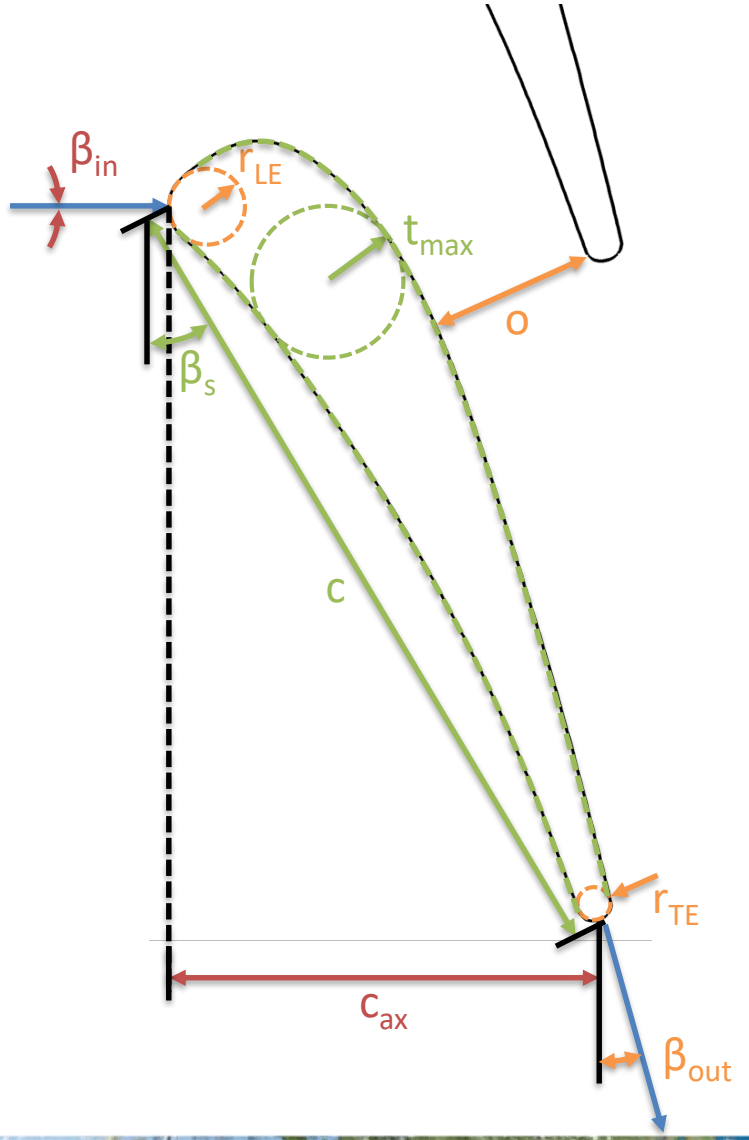
- Designed at DLR on a pre-design-level
- **U**ltra **H**igh **B**ypass **R**atio – **G**eared **T**urbo **F**an (BPR ~16)
- Configuration for a long-range aircraft: For example Airbus 330 / Boeing 767
- Technology level: 2028
- Short takeoff runway (TOFL)
- Respective high thrust demand



Geometric parameters for the CMC-Turbine profile

geometric parameters	
Profileform	
Chordlength c	68.170 mm
Staggerangle β_s	31.024 °
Max. thickness t_{max}	12.238 mm
Trailing edge radius r_{TE}	1.393 mm
Nose radius r_{LE}	3.110 mm
Exit angle β_{out}	16.64 °
Throat o	58.773 mm
Axial chordlength c_{ax}	35.907 mm
Inlet angle β_{in}	90.0 °

free parameter
limited parameter
fixed parameter

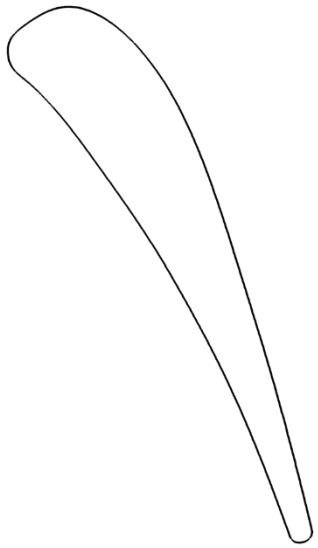


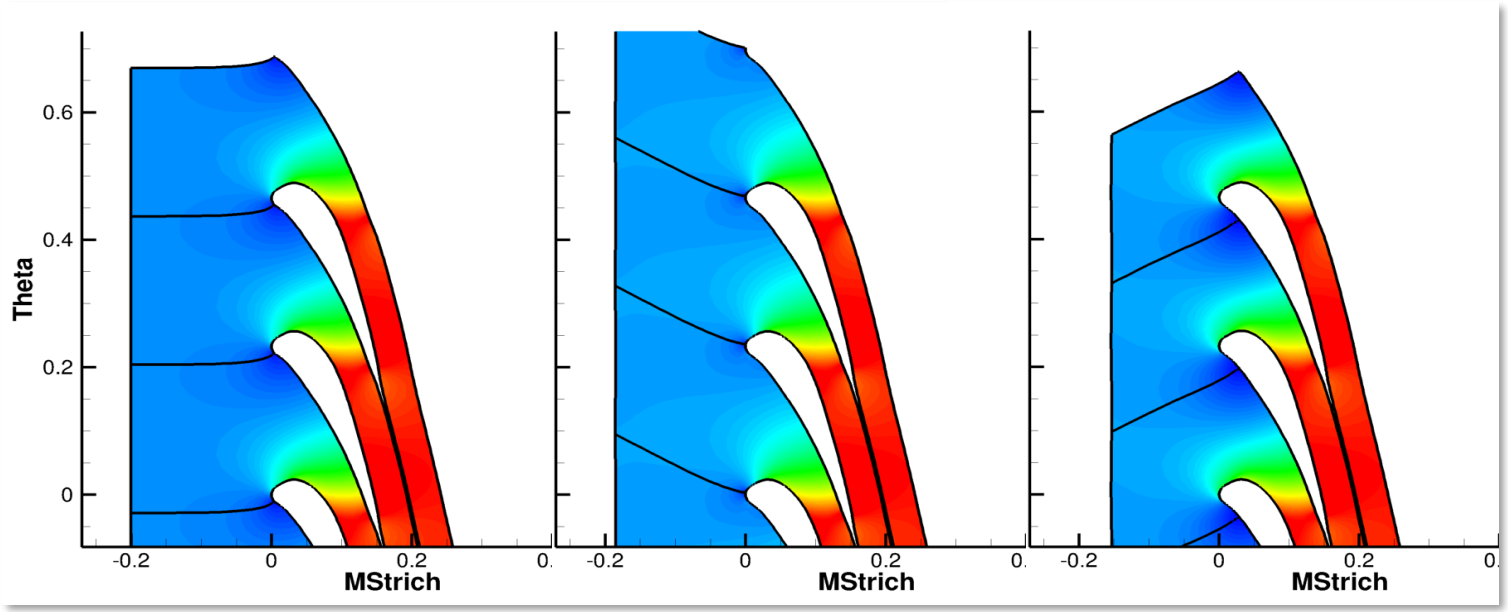
Optimisation
Process chain

BladeGen
Profile generation

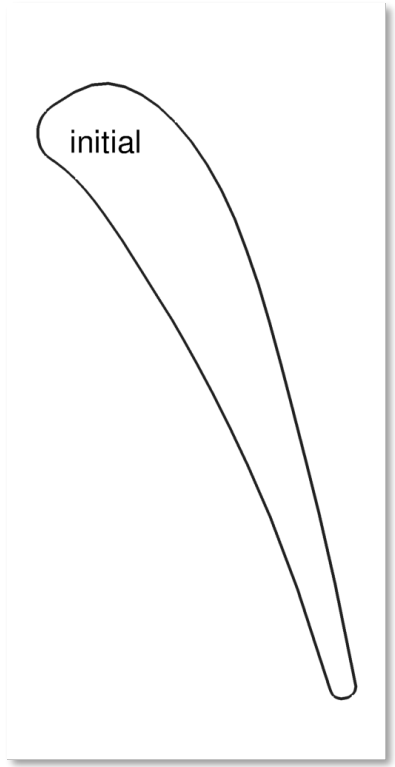
MISES
2D Flowsimulation

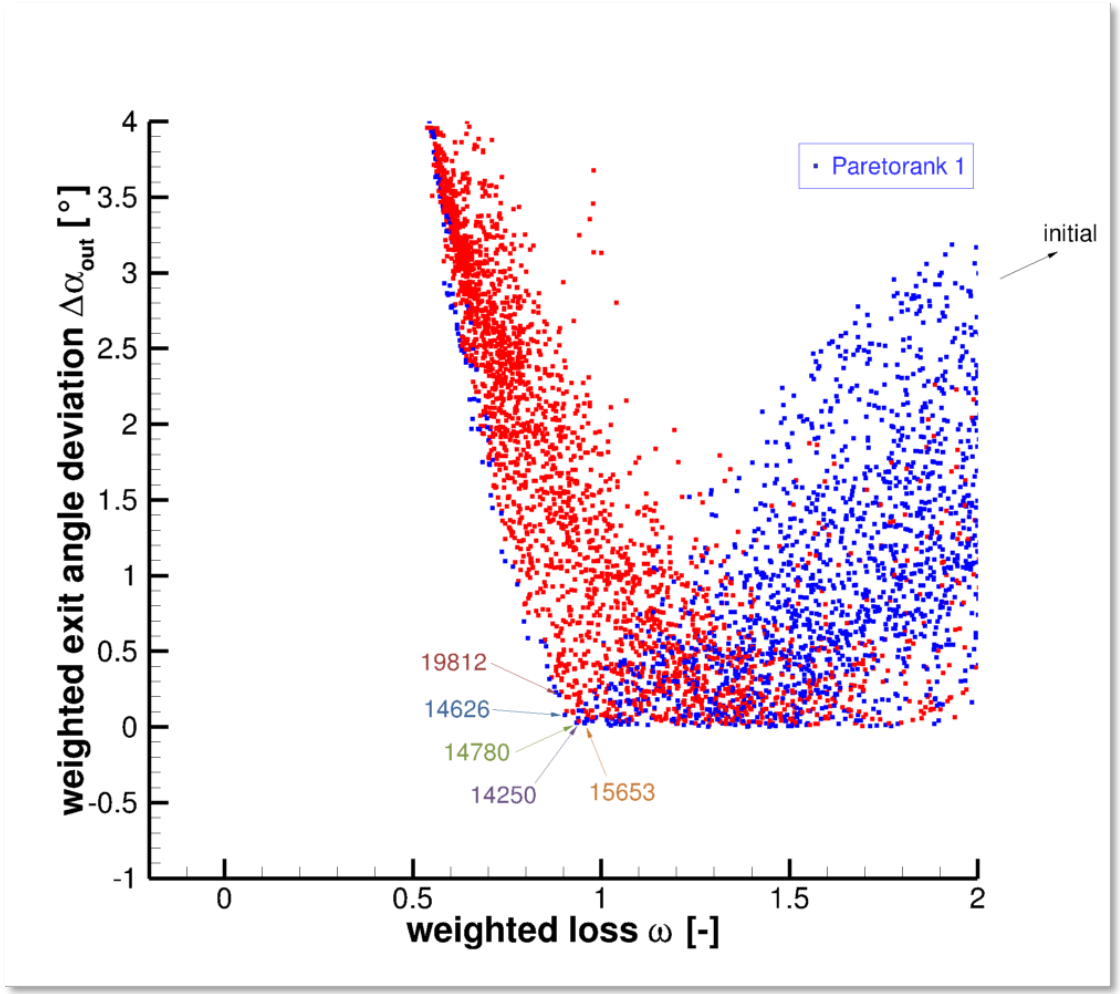
Evaluation
Loss, Mach numbers, angle, …



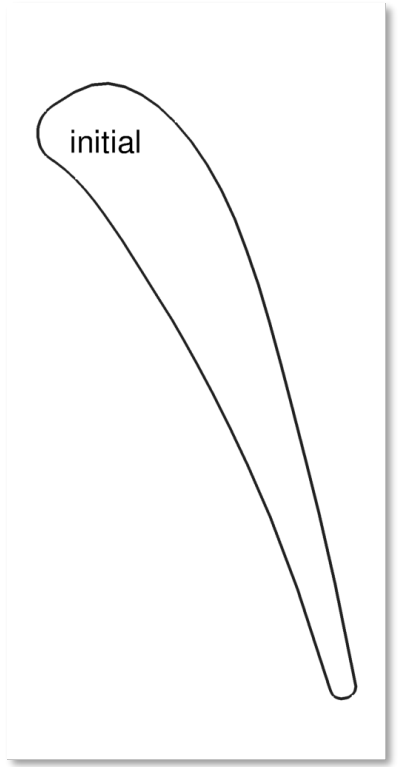


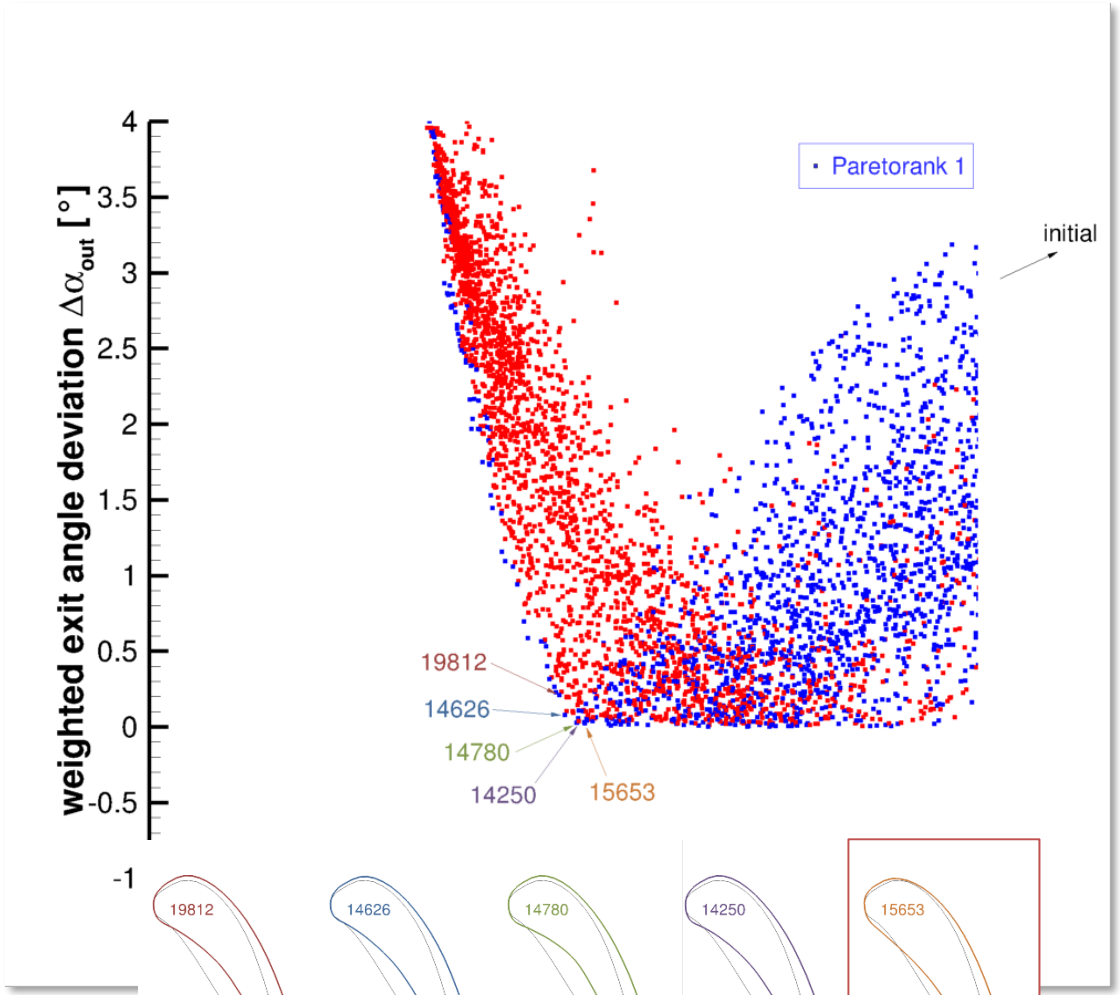
Paretofront
Optimal Member





Paretofront
Optimal Member



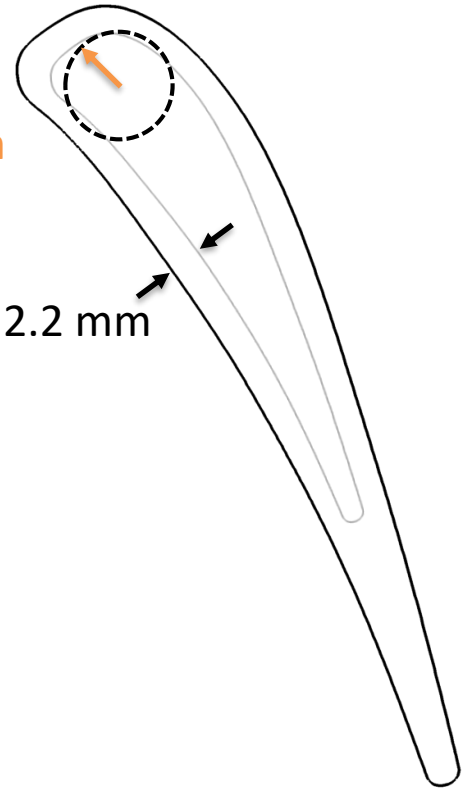


CMC boundary condition: radius of curvature

initial

r_{in} = 4.4 mm

d_{wall} = 2.2 mm



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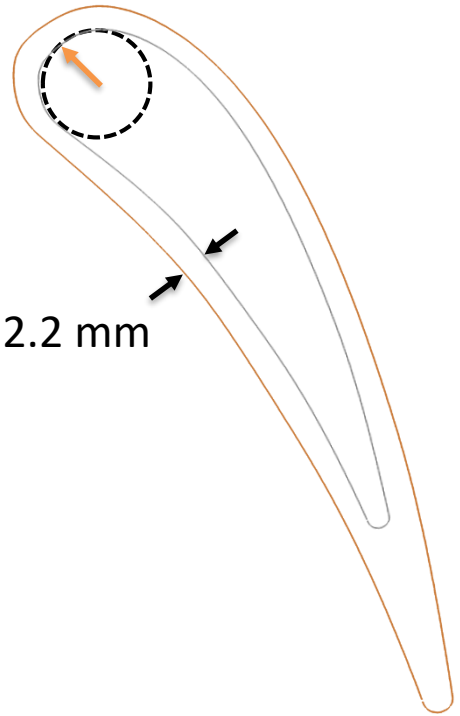
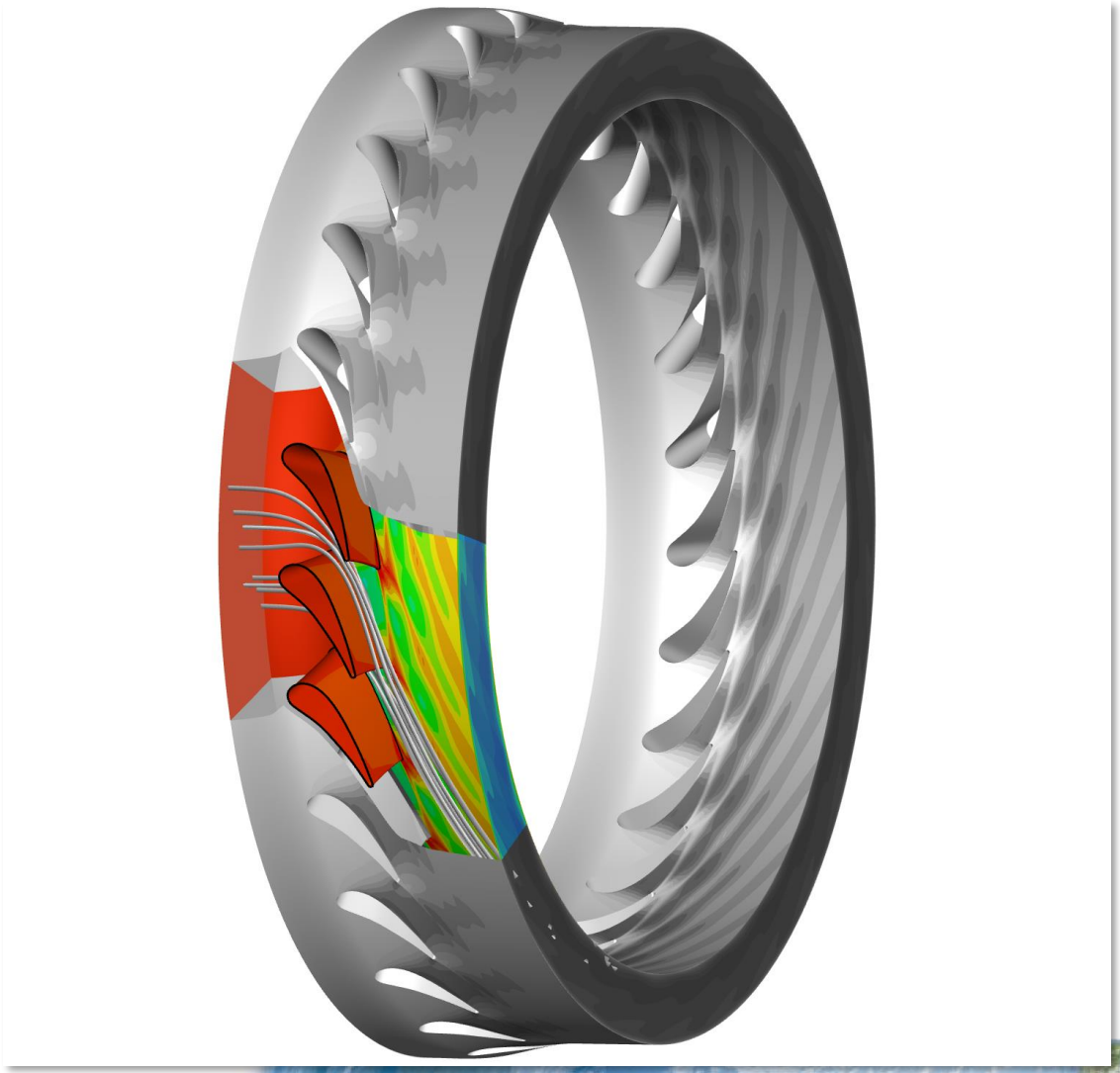
r_{in} = 4.4 mm

d_{wall} = 2.2 mm

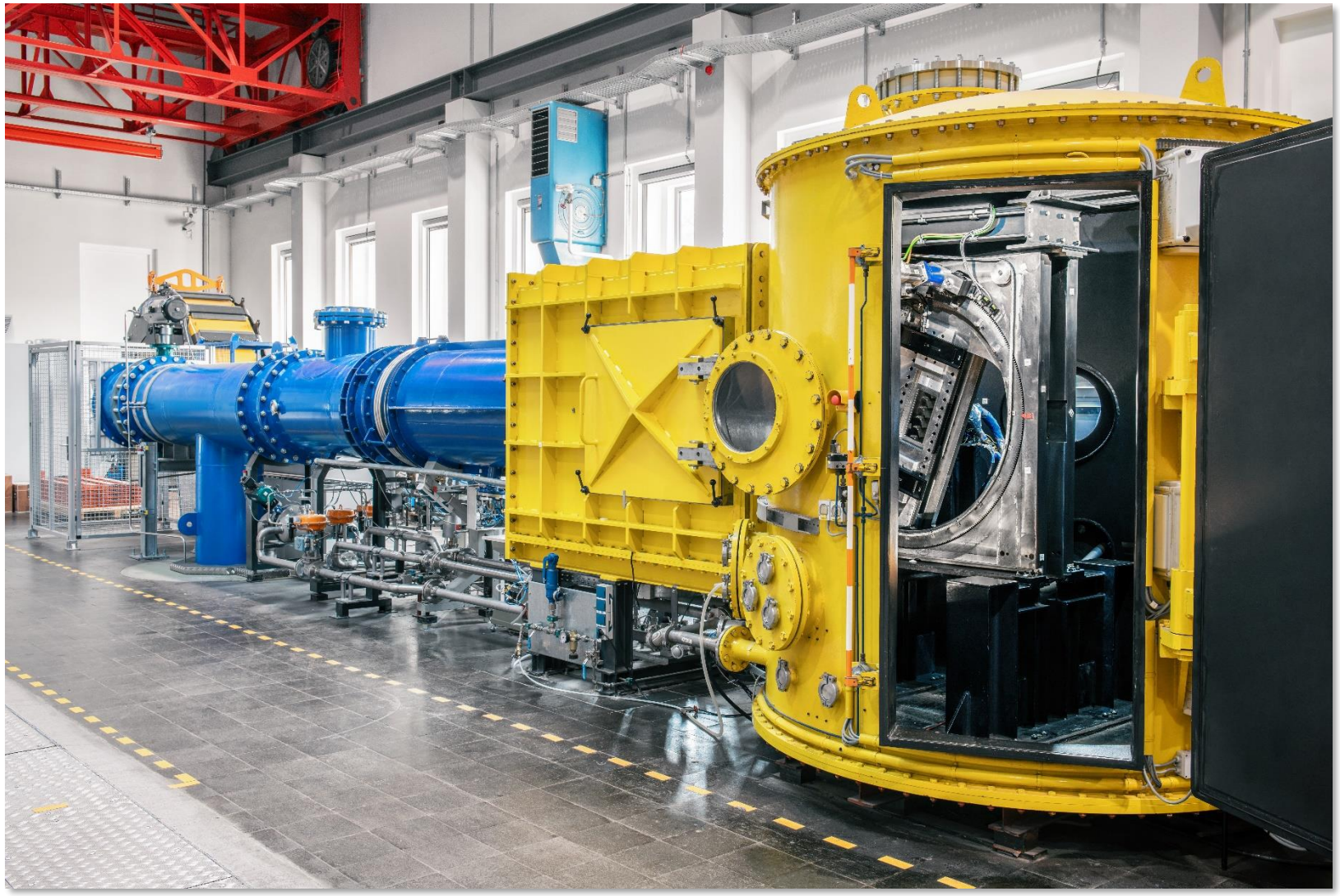


$r_{in} \geq 2 \cdot d_{wall}$

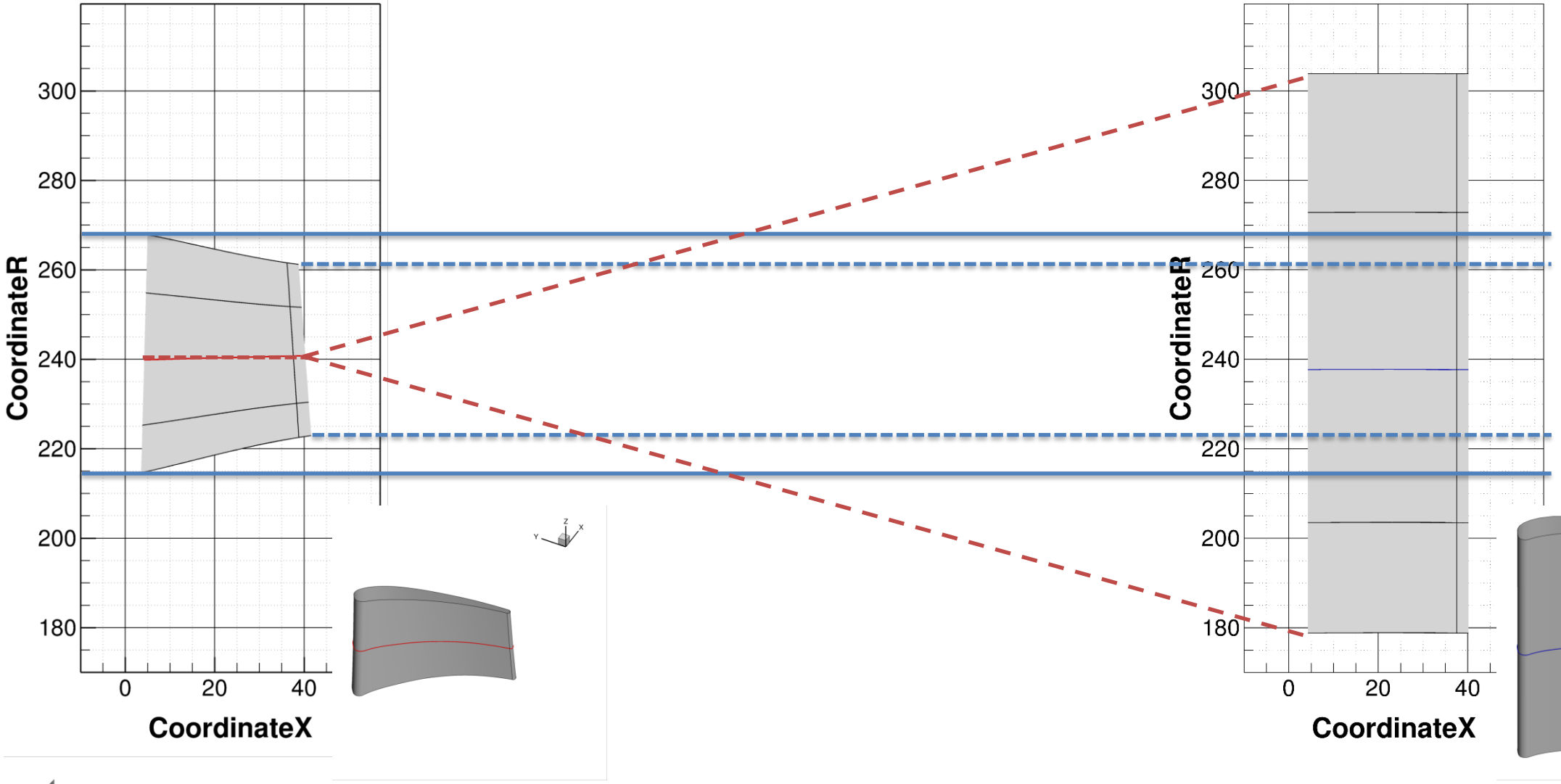
New designed 3DCeraTurb NGV



Wind tunnel for Straight Cascades (EGG)

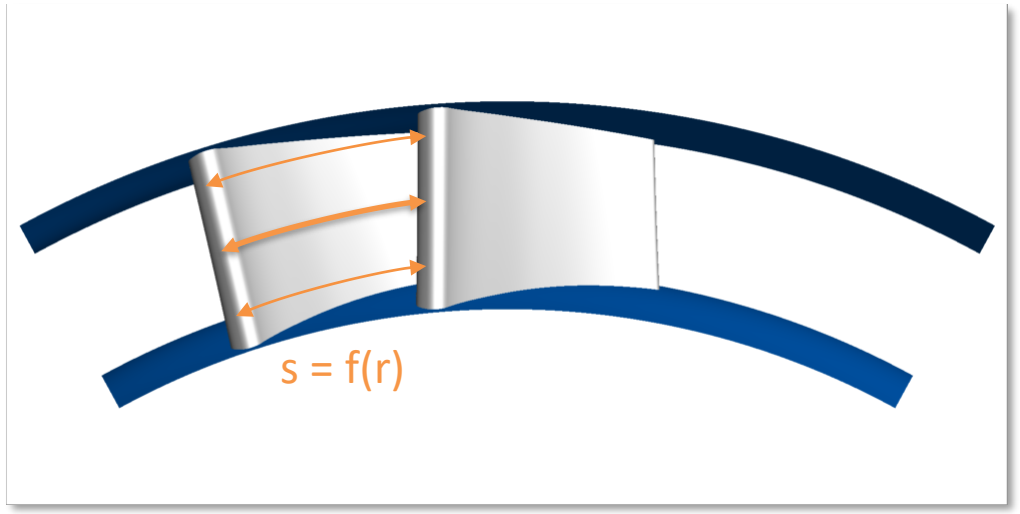


Size ratio: Engine – Wind tunnel

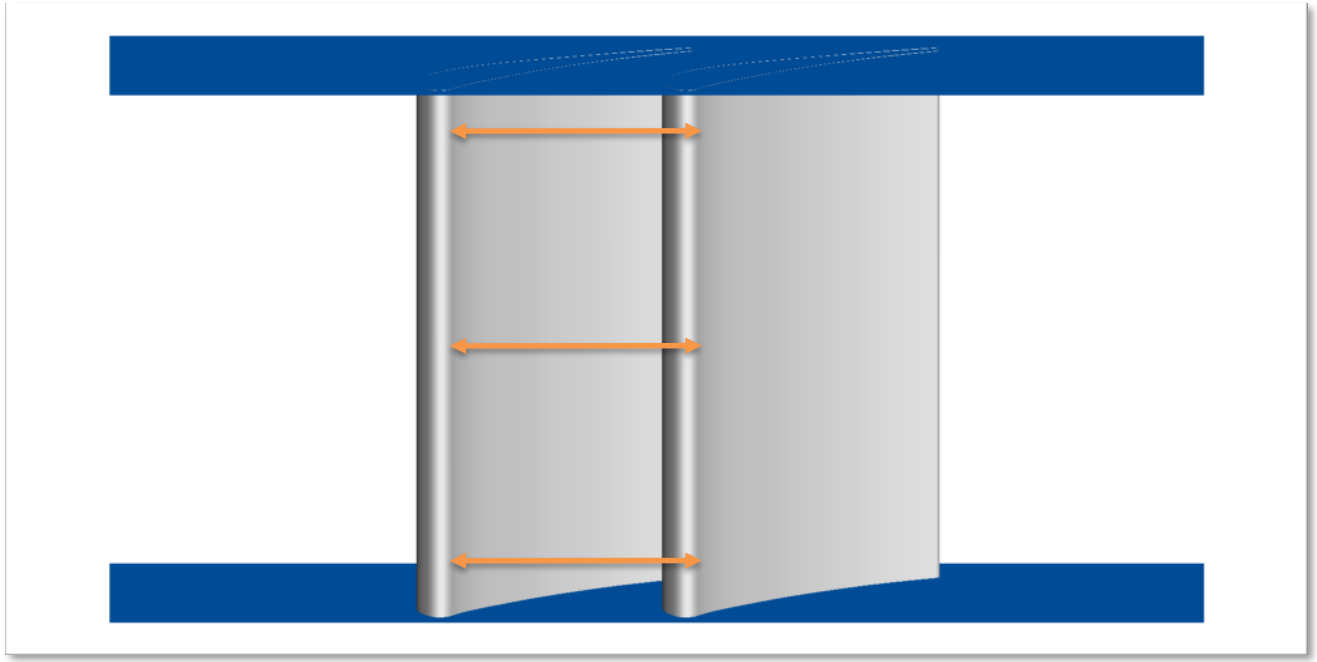


Size ratio

Engine

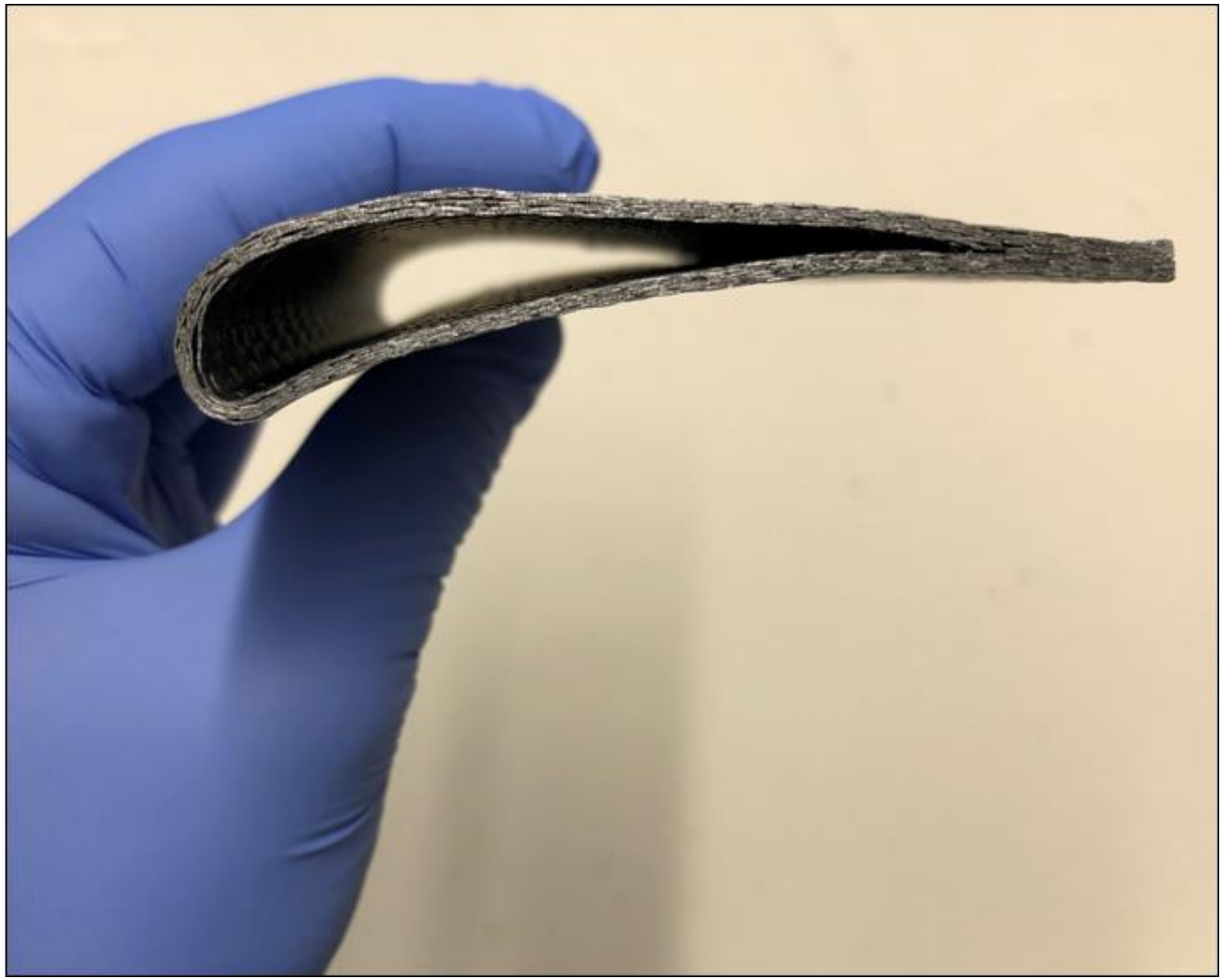


Wind tunnel



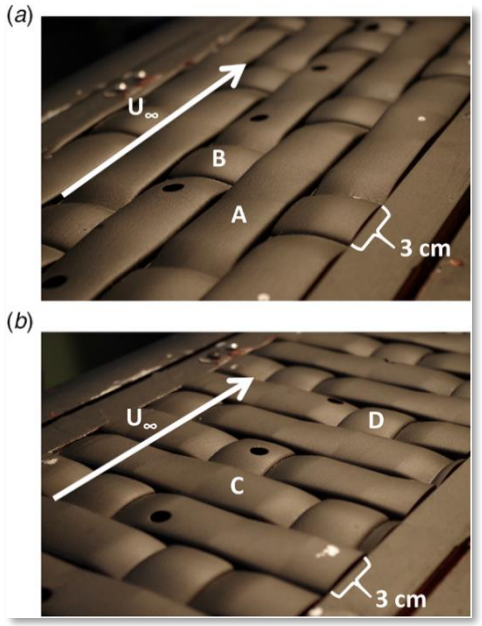
s =const.

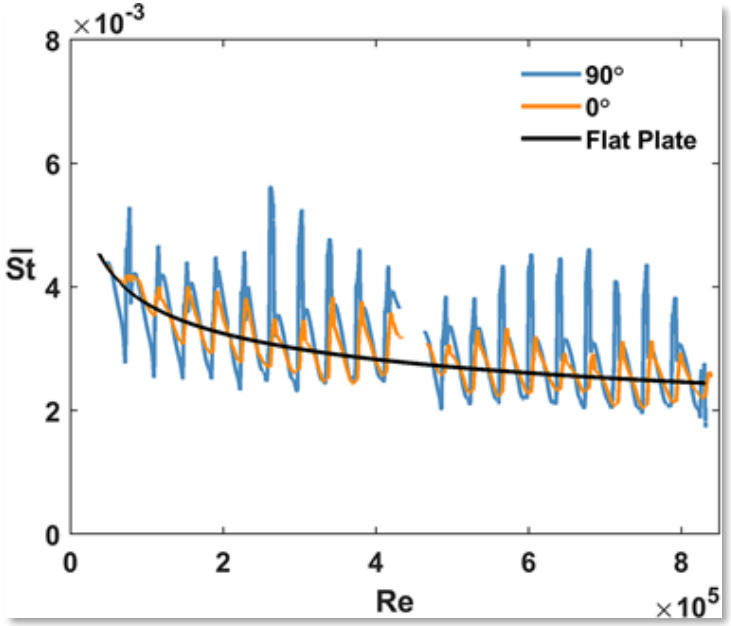
s = pitch

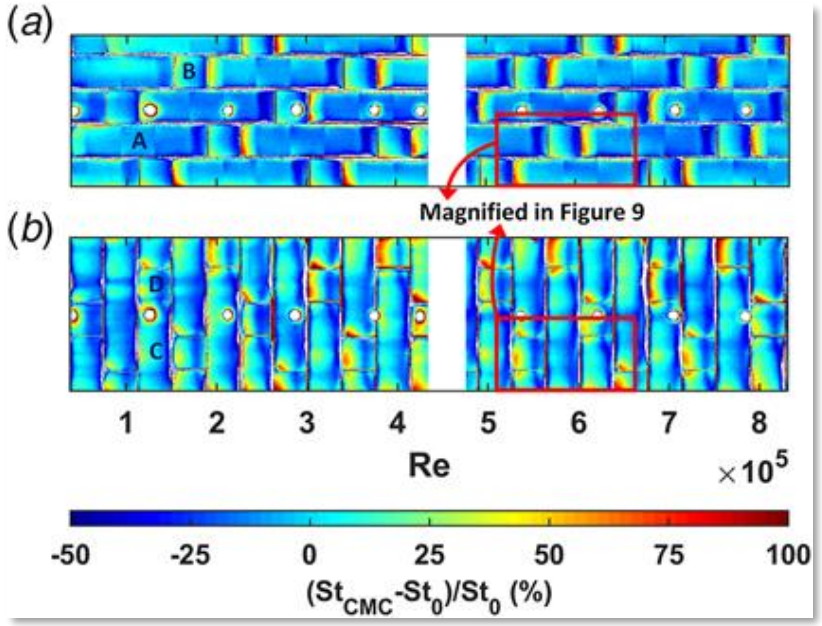


(9)

Wind tunnel tests

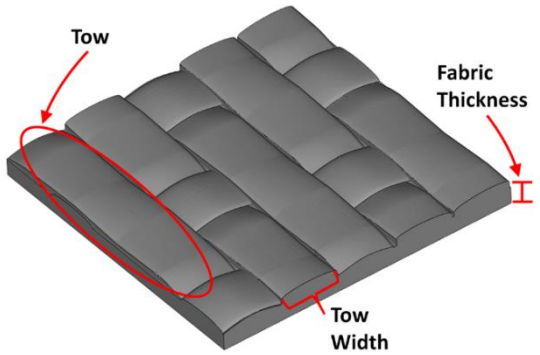






0°

90°

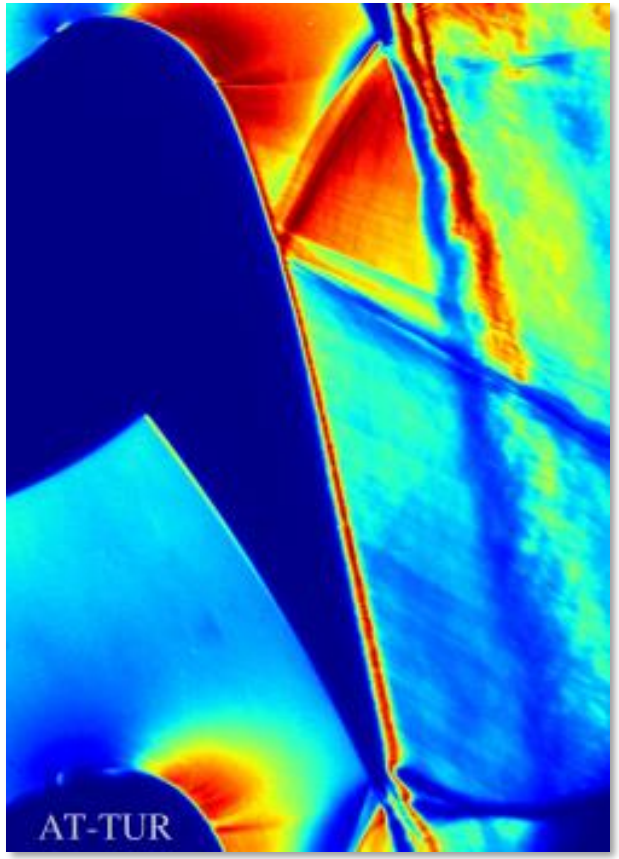


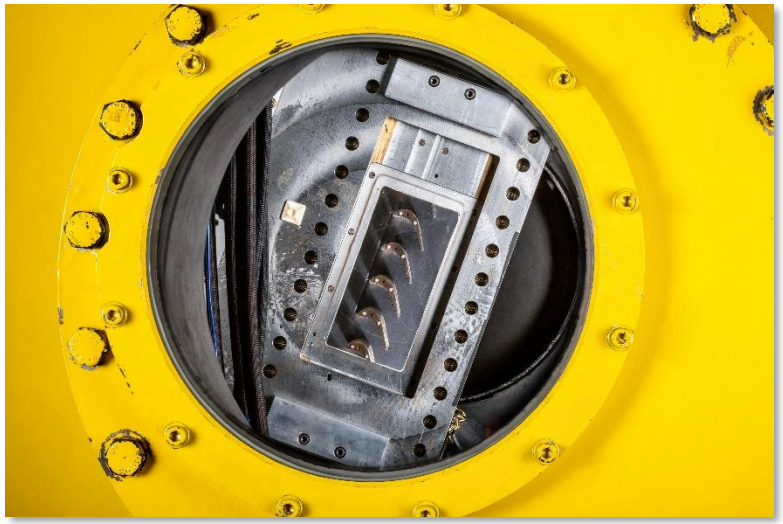
$$St = \frac{h}{\rho c_p u_2}$$

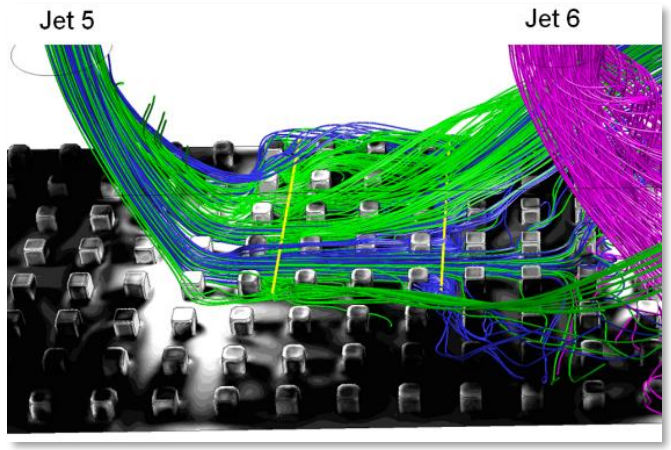
$$Re_x = \frac{\rho_2 u_2 x}{\mu}$$

(10)

Wind tunnel tests







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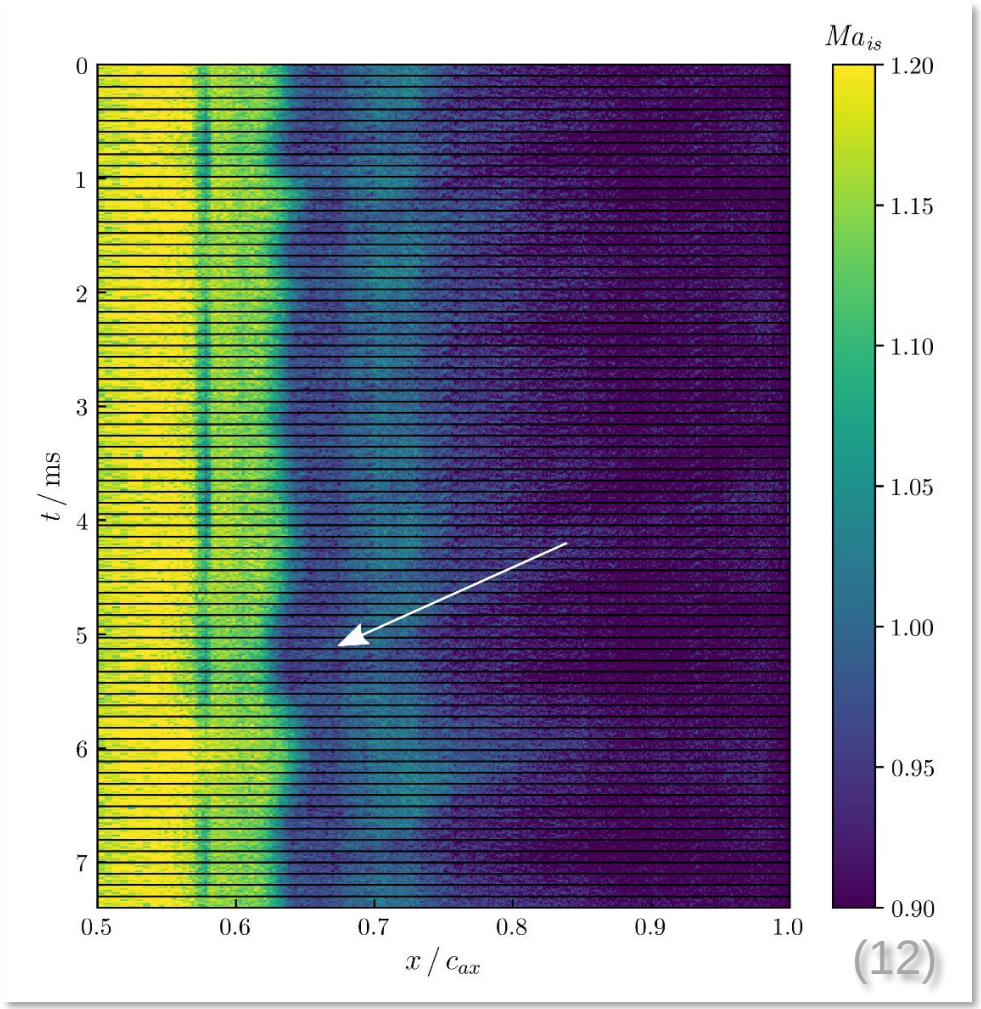
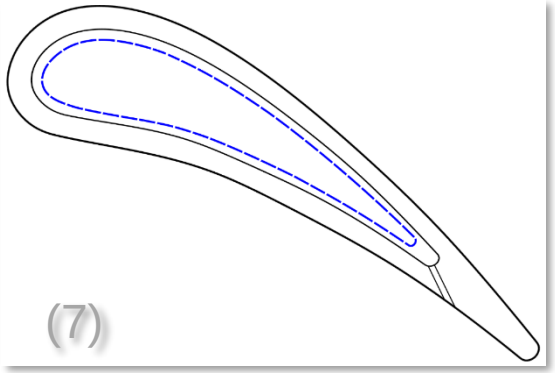
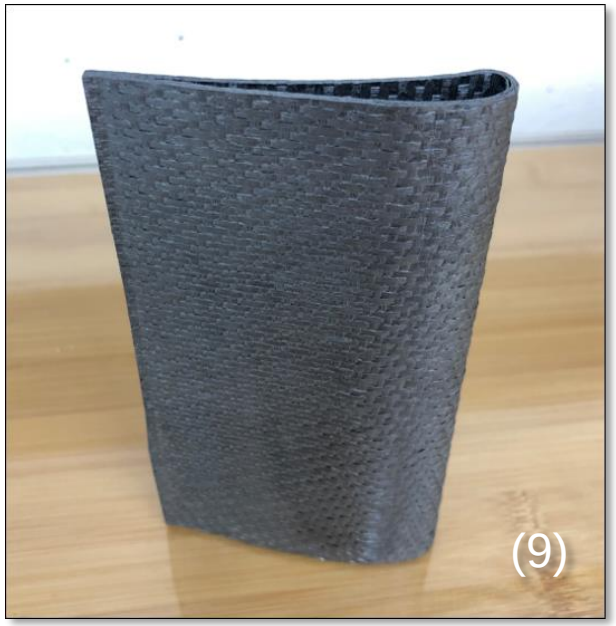


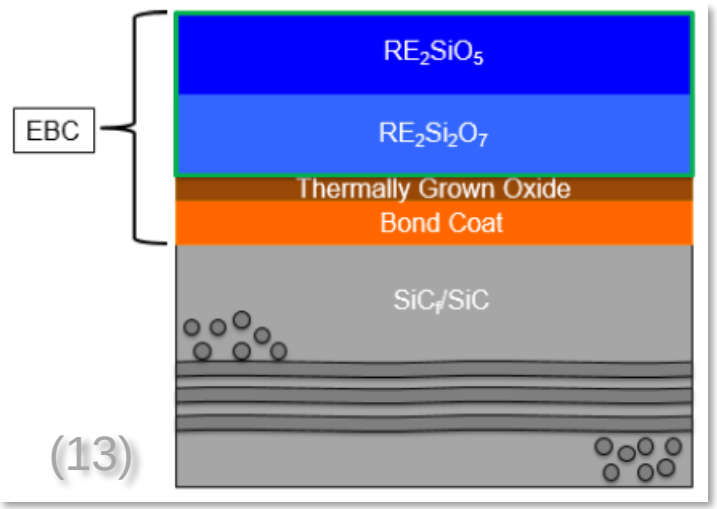
(12)

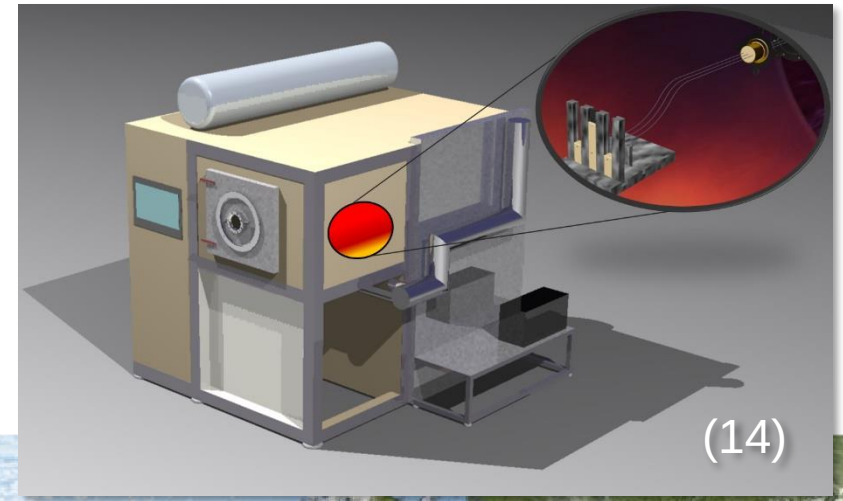
Outlook

Next Steps in 3DCeraTurb

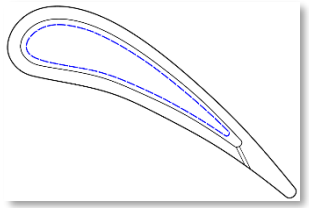


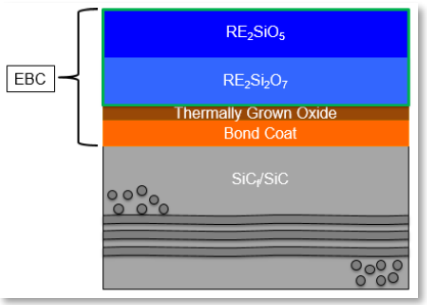


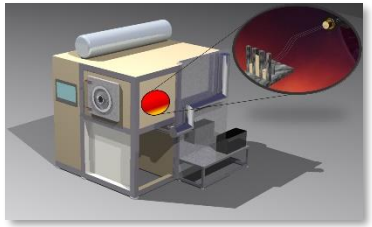


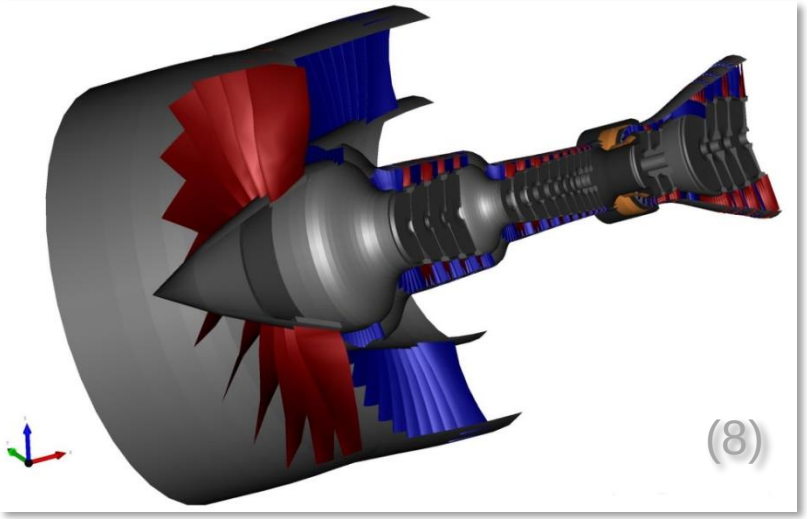


Outlook




EBC
RE_2SiO_5
$RE_2Si_2O_7$
Thermally Grown Oxide
Bond Coat
SiC_f/SiC

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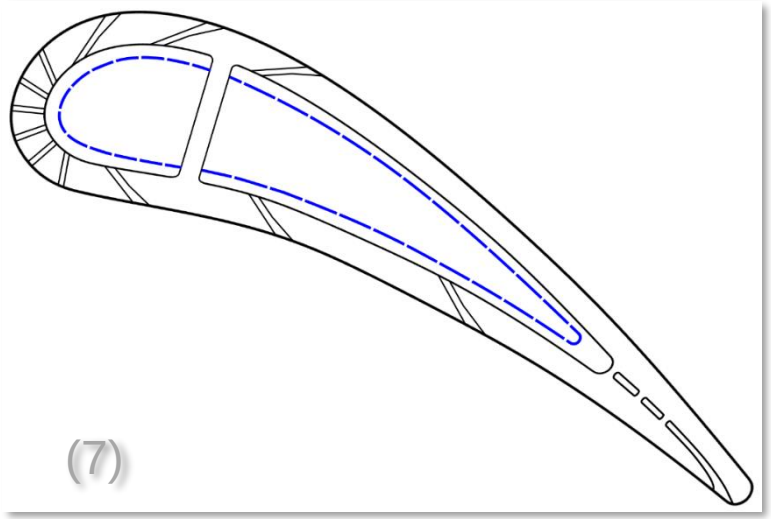
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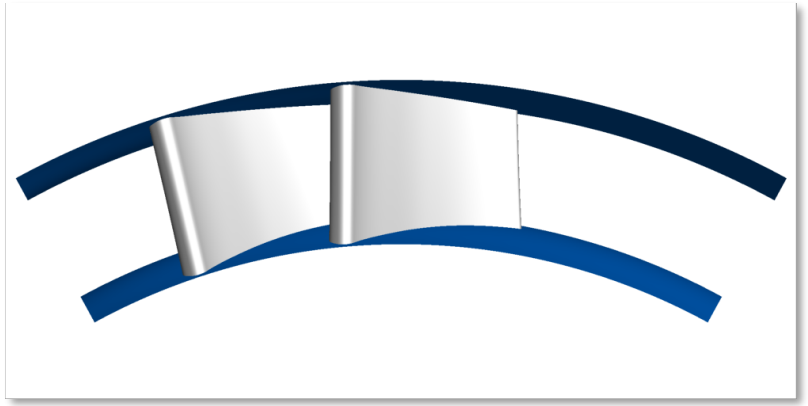

http://s.dlr.de/9OKJx

Thank you!

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Literature and figures:

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(2) Wehrel, P.: *Potenzialanalyse zum Einsatz keramischer Faserverbundwerkstoffe in Flugtriebwerken.* TU Dortmund, Master-Thesis, 2021
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(8) DLR-VirTriP presentation from S. Reitenbach (DLR AT-TWK), 19.06.20
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(10) Wilkins, P. H.; Lynch, S. P.; Thole, K. A.; Quach, S. & Vincent, T.: *Experimental Heat Transfer and Boundary Layer Measurements on a Ceramic Matrix Composite Surface* J. Turbomach, 143, 2021
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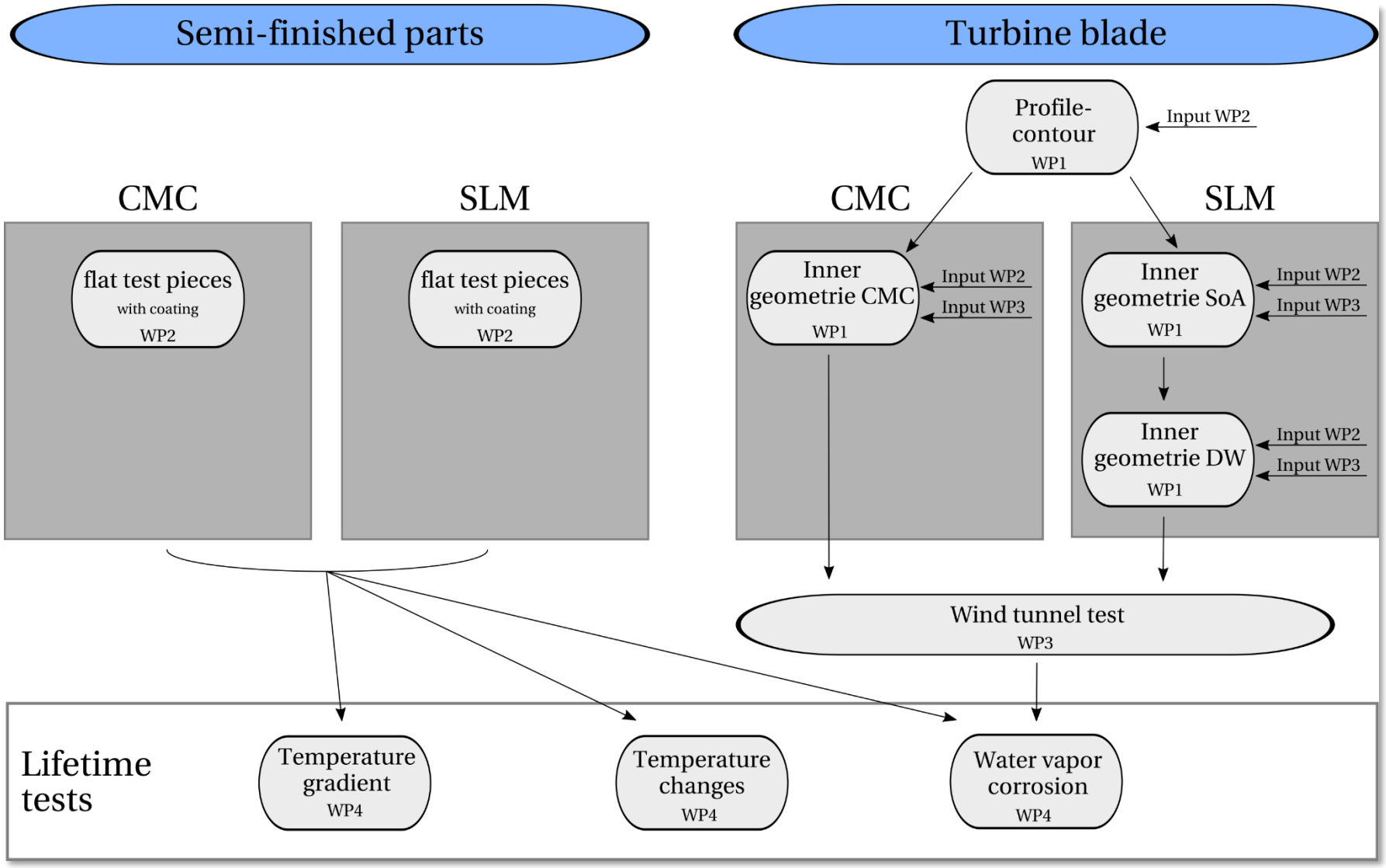
(12) Petersen, A.: *Einfluss pneumatischer Wirbelgeneratoren auf die Effektivität einer gekühlten Hochdruck-Turbine*. TU Braunschweig, Dissertation, 2021
(13) DLR-3DCeraTurb presentation from U. Schulz (DLR WF-HFS), 08.06.21
(14) A. Langfeld-Rosner – DLR SG-TMV, intern transfer


Semi-finished parts
Turbine blade
CMC
SLM
flat test pieces
with coating
WP2
flat test pieces
with coating
WP2
Profile-
contour
WP1
Input WP2
CMC
SLM
Inner
geometrie CMC
WP1
Input WP2
Input WP3
Inner
geometrie SoA
WP1
Input WP2
Input WP3
Inner
geometrie DW
WP1
Input WP2
Input WP3
Wind tunnel test
WP3
Lifetime
tests
Temperature
gradient
WP4
Temperature
changes
WP4
Water vapor
corrosion
WP4