Aerodynamic Investigation of the flow in a Turbine Rear Structure

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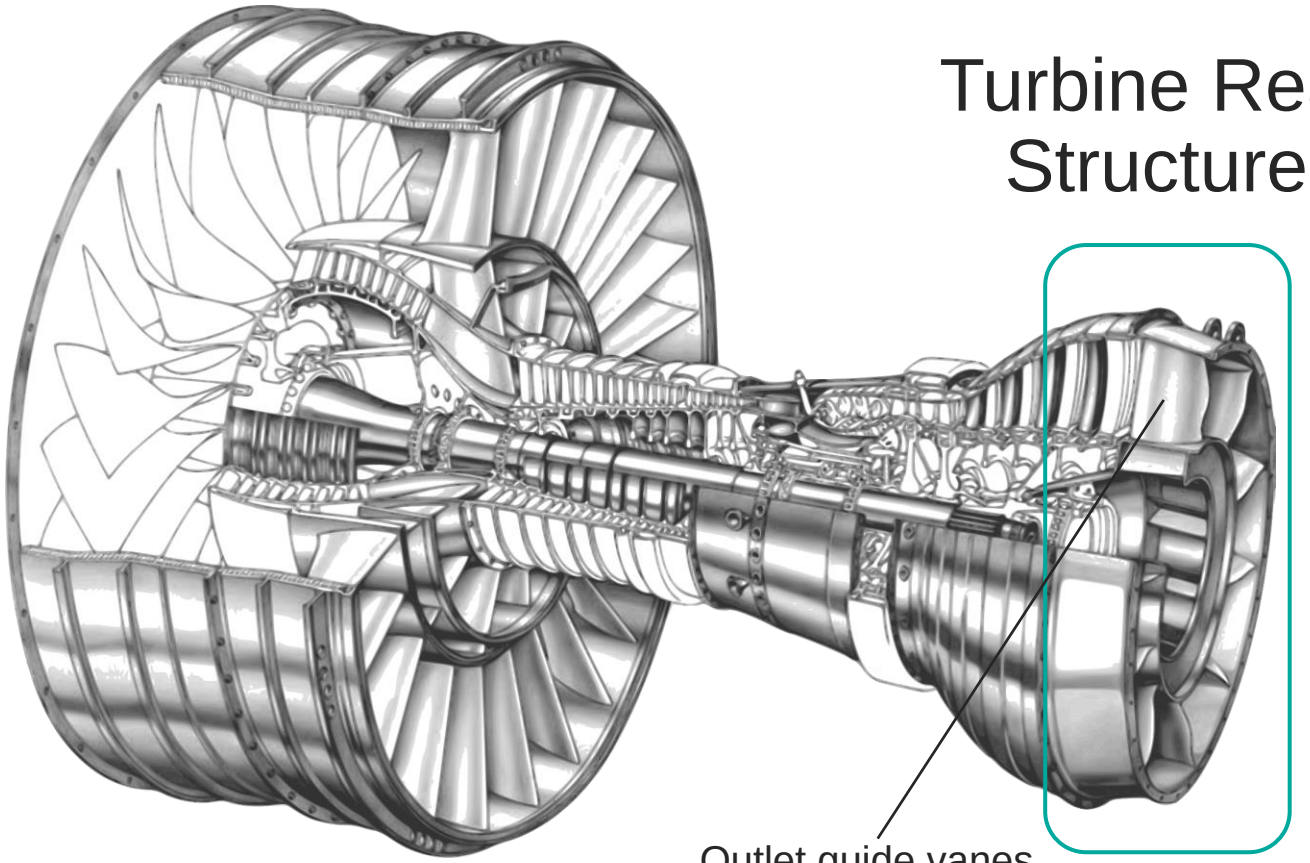
ACARE Goals for 2050:

1) 75% reduction in CO_2 emissions
2) 90% reduction in NOx emissions
3) 65% reduction of the perceived noise

compared to values of the year 2000

Turbofan engine



Turbine Rear Structure

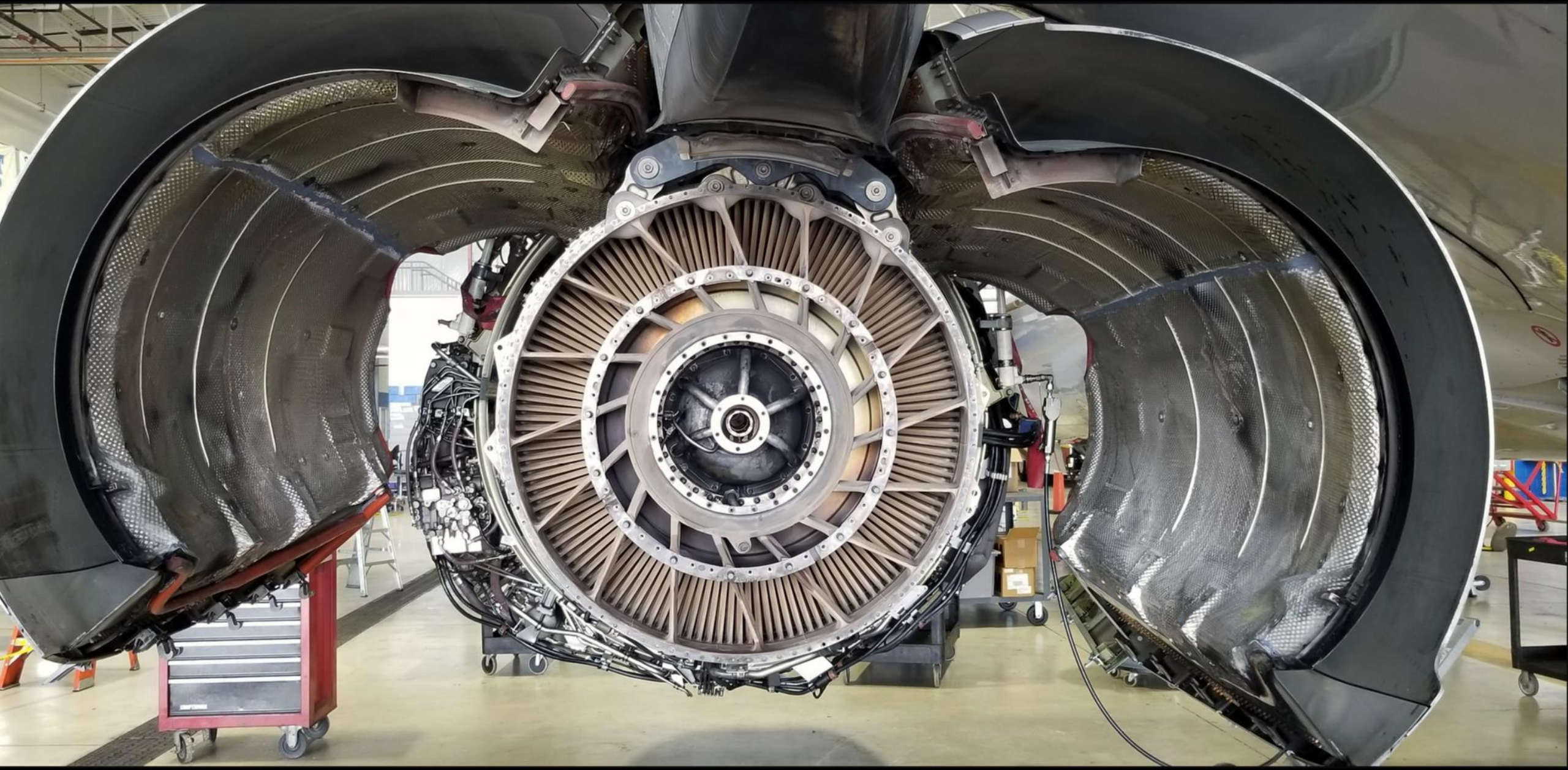
Structural support

To connect the rear engine mounts with the shaft bearings

Aerodynamic purpose

To convert the outlet flow from the low-pressure turbine to the axial flow

To provide paths for the bearing oil tubes



4 ”Performing maintenance on a 737-800 General Electric CFM56” by Reggie Mitchell, 2018, retrieved from https://www.flickr.com/photos/103738927@N06/42673913800
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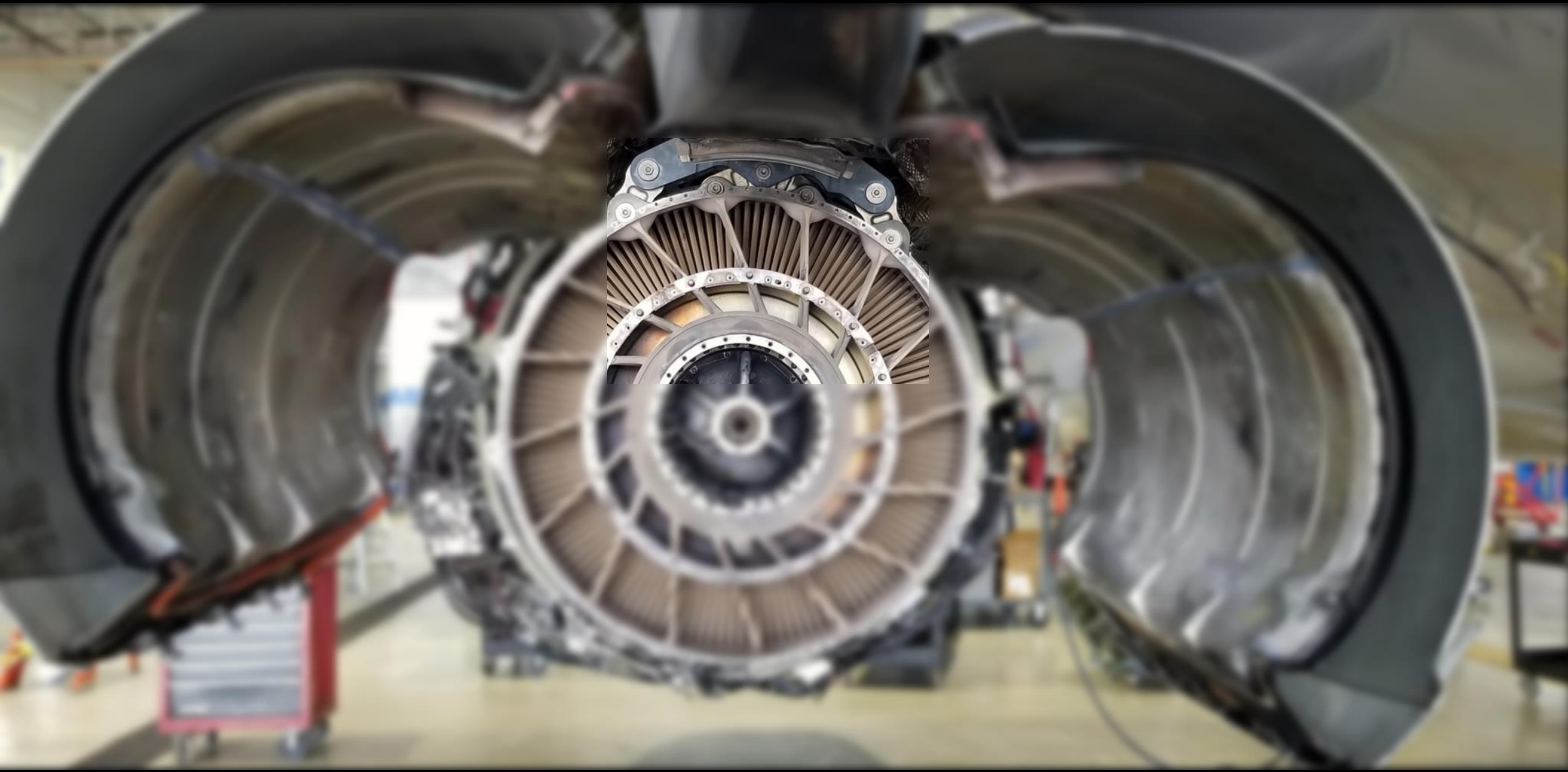

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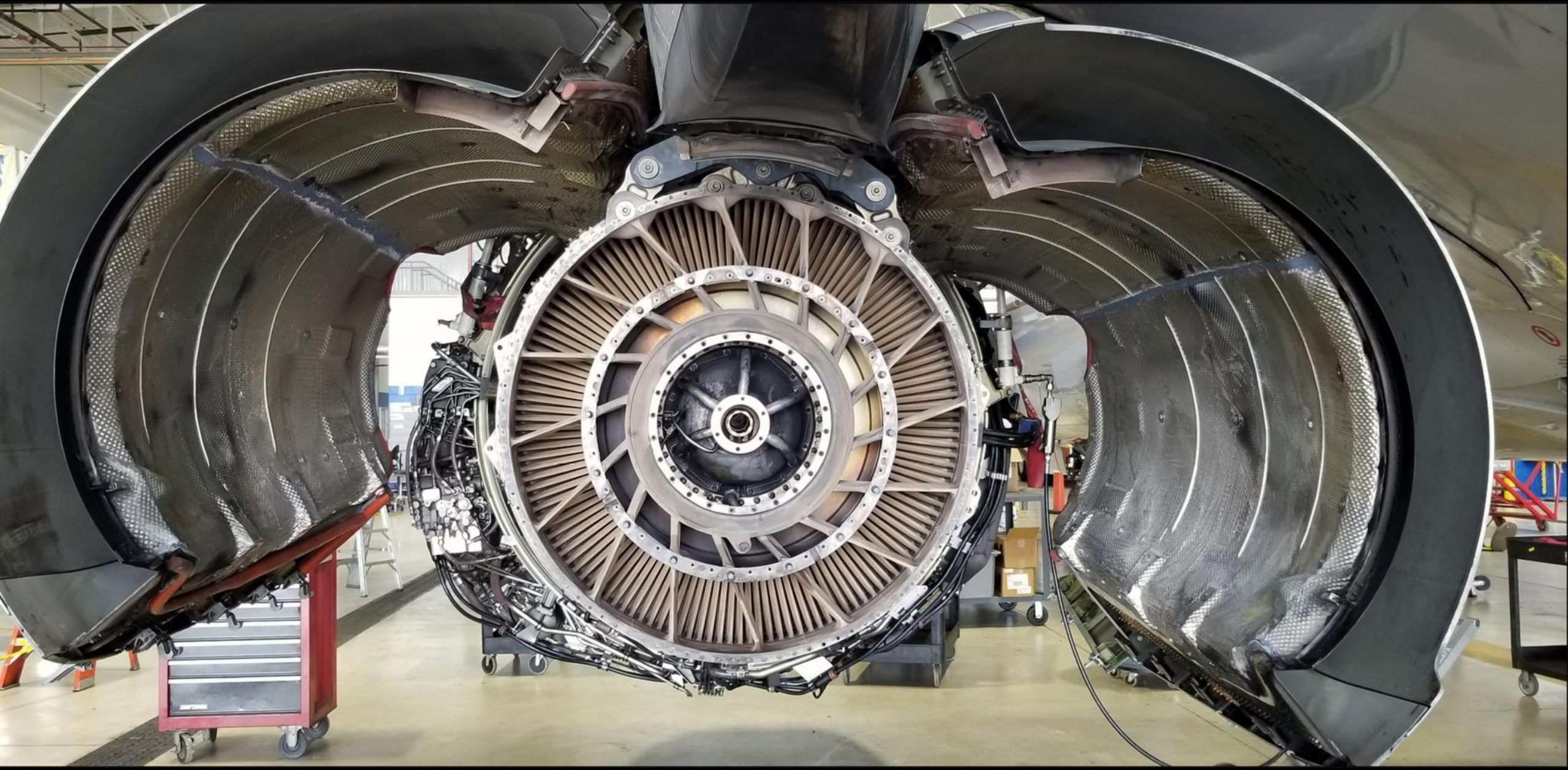

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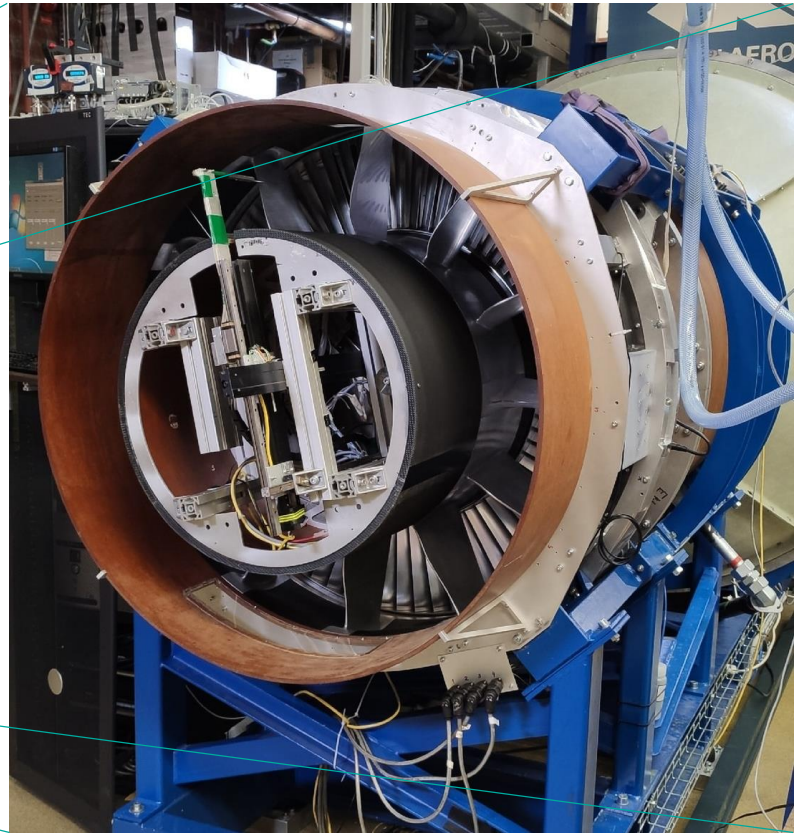
LPT-OGV facility

Low-speed large-scale 1.5 stage LPT-OGV facility



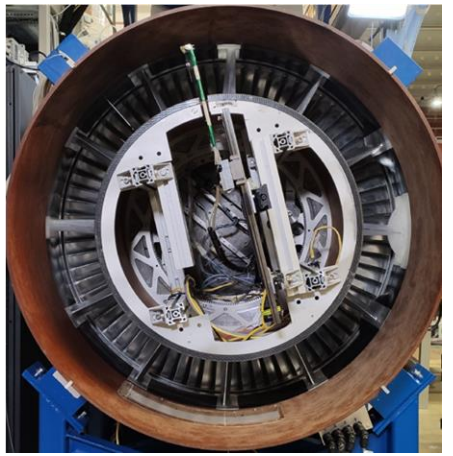
Engine-realistic flow conditions provided by low-pressure turbine

Engine-representative Reynolds number up to 600,000

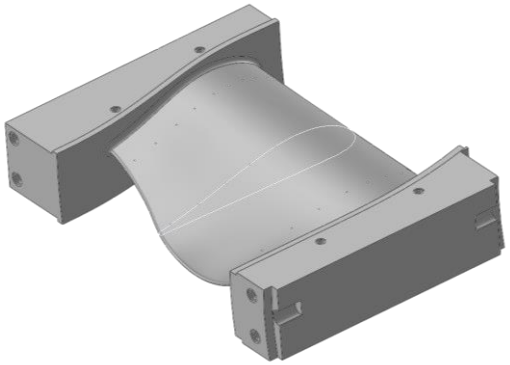
Cost-effective

High repeatability, long time runs

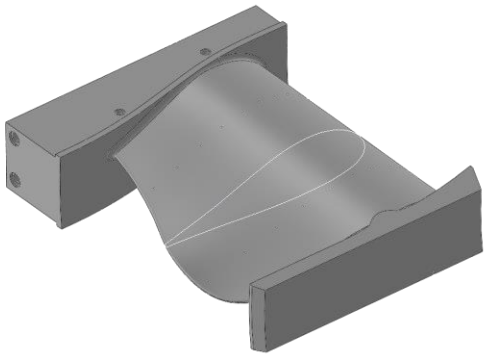
Test objects and operating conditions



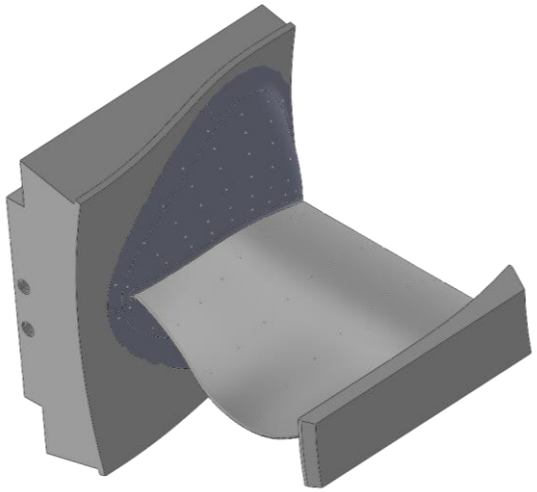
Regular vane



Thick vane



Bump vane



Operating condition	Flow coefficient, φ	Inlet swirl angle, deg	Re
On-design	0.622	-16.5	235000
Off-design (Low loading)	0.588	-11.5	
Off-design (High loading)	0.657	-20.9	
Off-design (High loading)	0.775	-31.6	

Experimental methods

Pressure measurements

Inlet plane
(L-shaped 5-hole probe)

Outlet plane
(straight 7-hole probe)

Wall measurements
(embedded pressure taps)

$$C_{p0} = \frac{P_t - P_{tref}}{P_{tref} - P_{sref}}$$

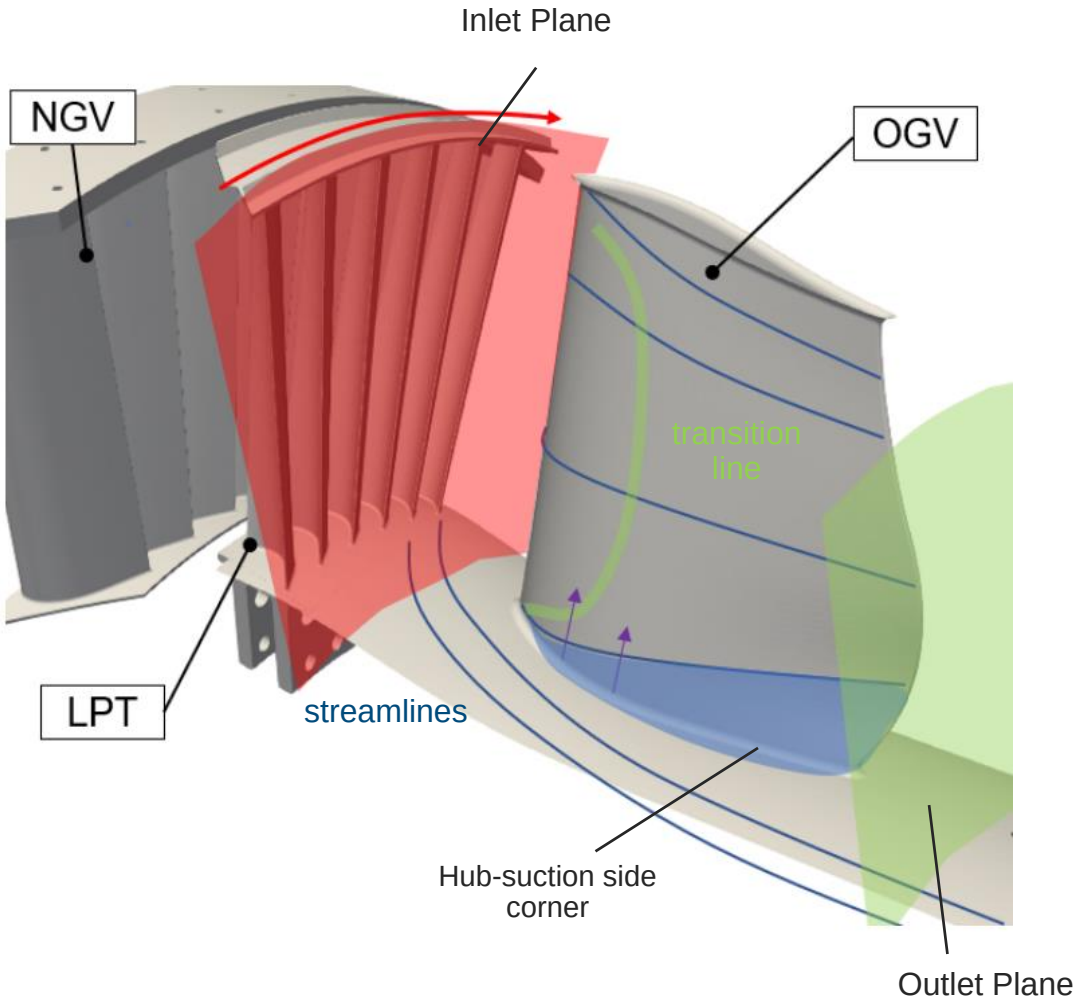
Total pressure coefficient

$$C_p = \frac{P_s - P_{sref}}{P_{tref} - P_{sref}}$$

Static pressure coefficient

Flow visualization

Surface oil-film visualization



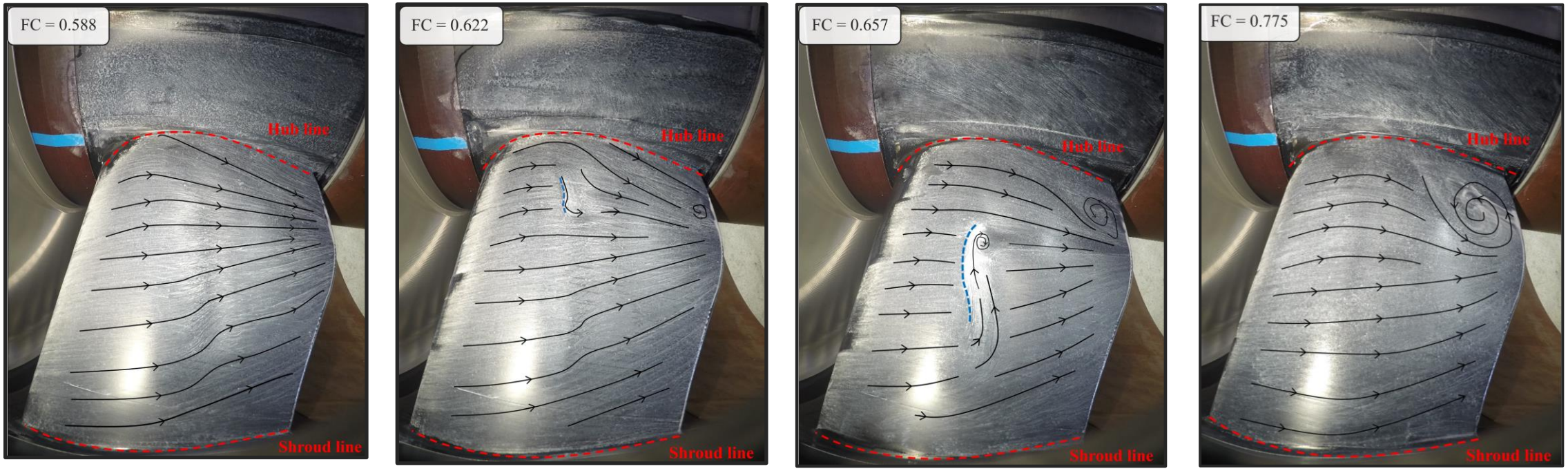
Topology of the TRS

Johnson I. ”Experimental Aerothermal Study on Internal Jet Engine Structures”, Licenciate thesis, 2020

Results

Flow visualization

Oil-film visualizations on a thick OGV (Suction side)



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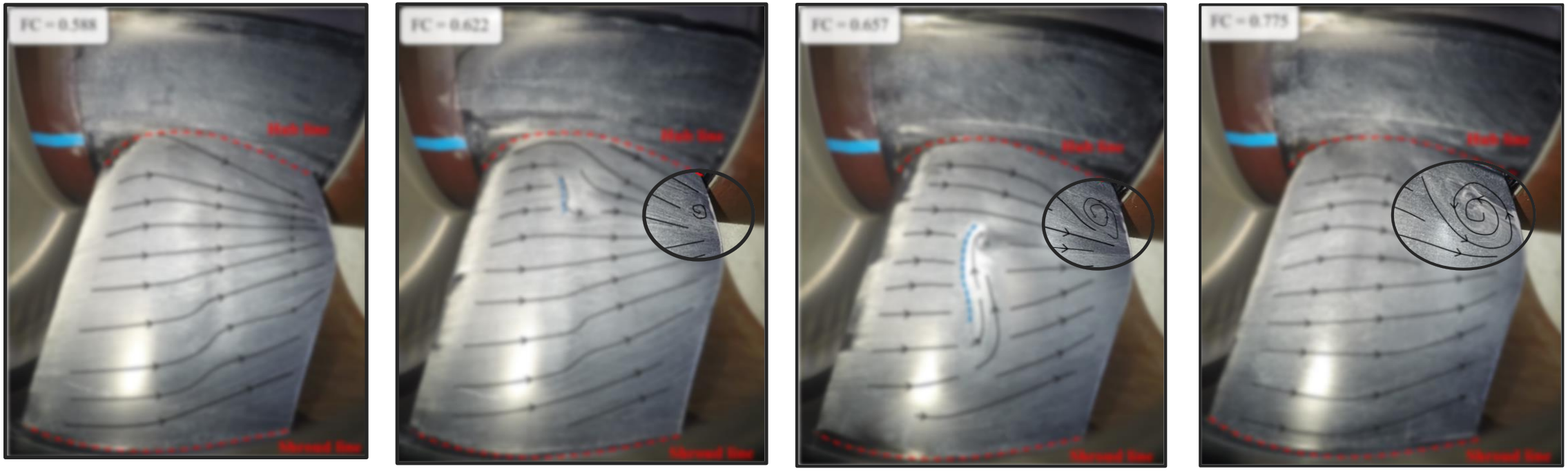
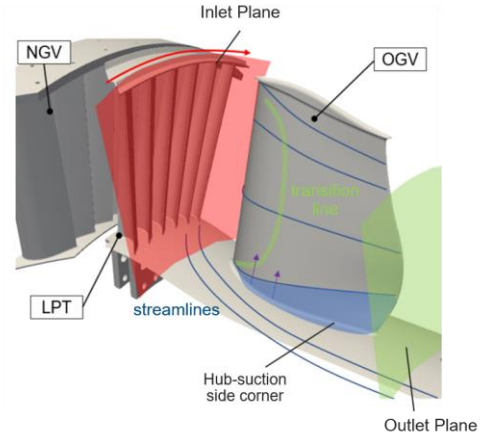


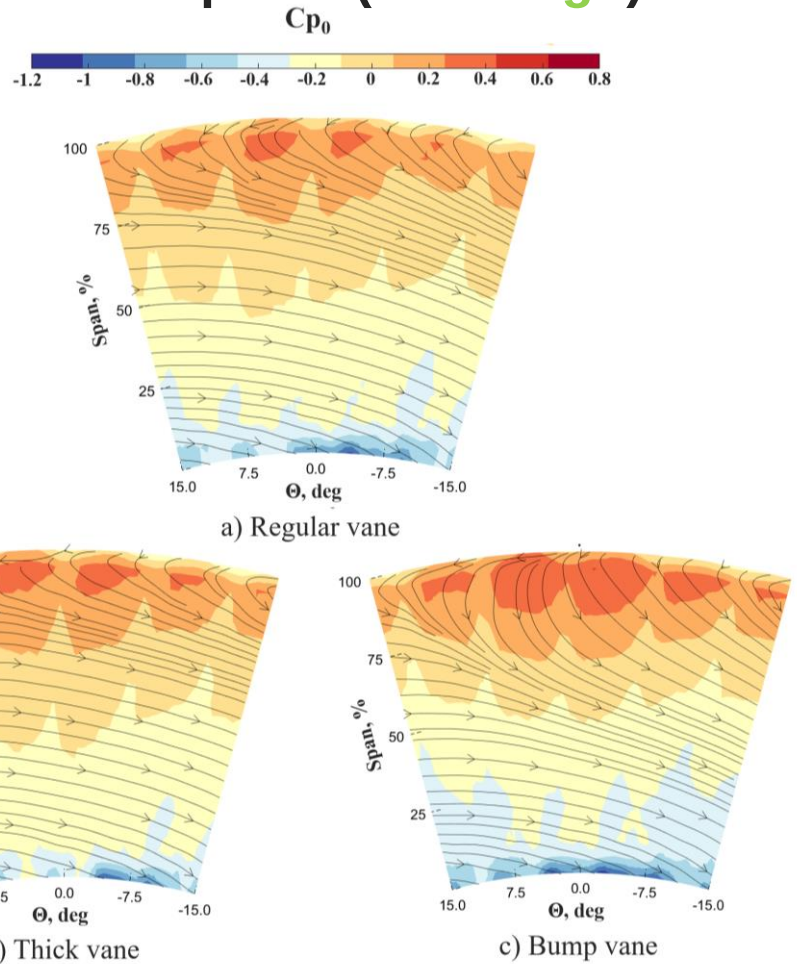
Flow separation in the hub-suction side corner is the **main source of pressure losses**

Results

Inlet plane measurements



Total pressure distribution on Inlet plane (on-design)



a) Regular vane

b) Thick vane

c) Bump vane

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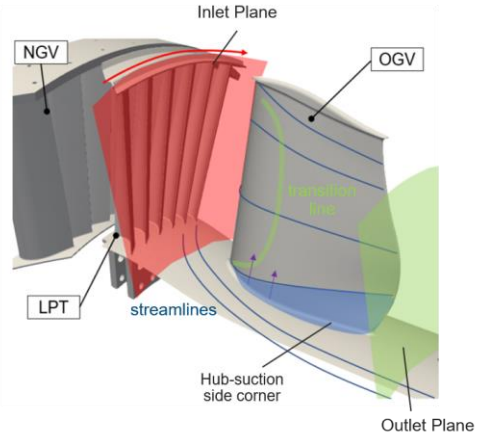

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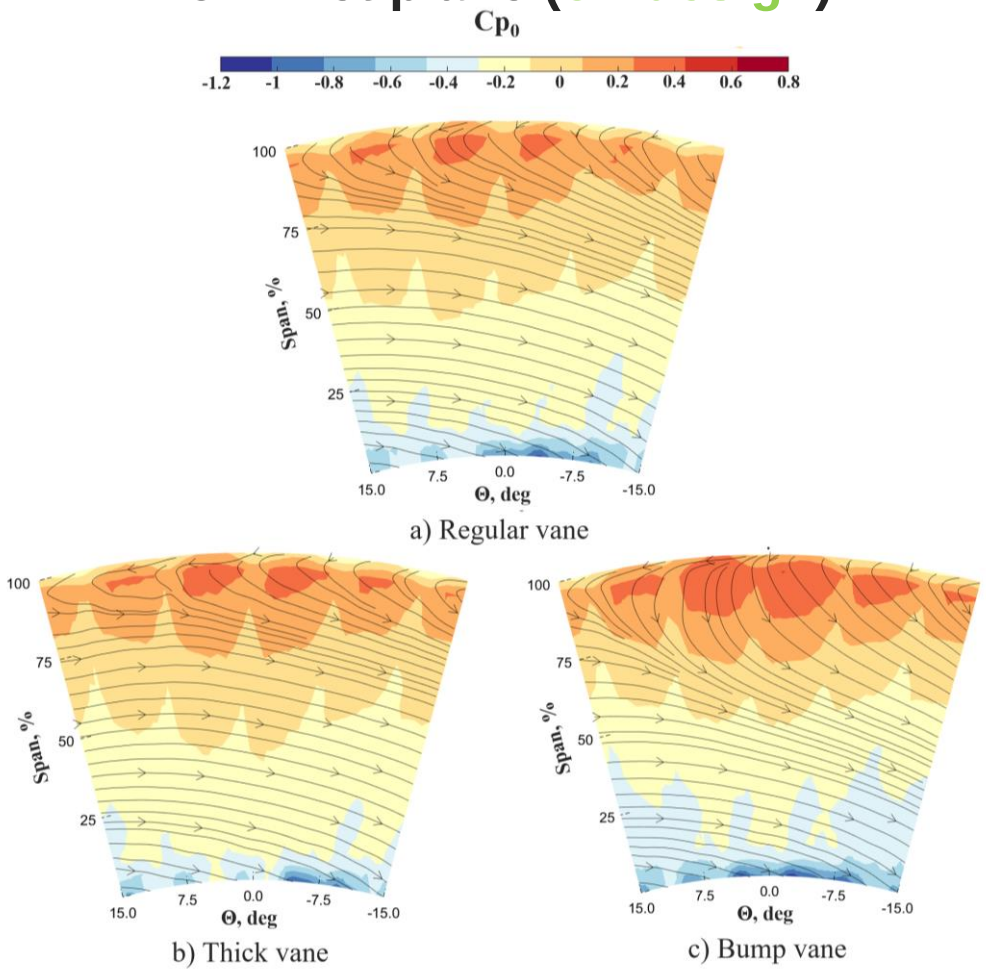

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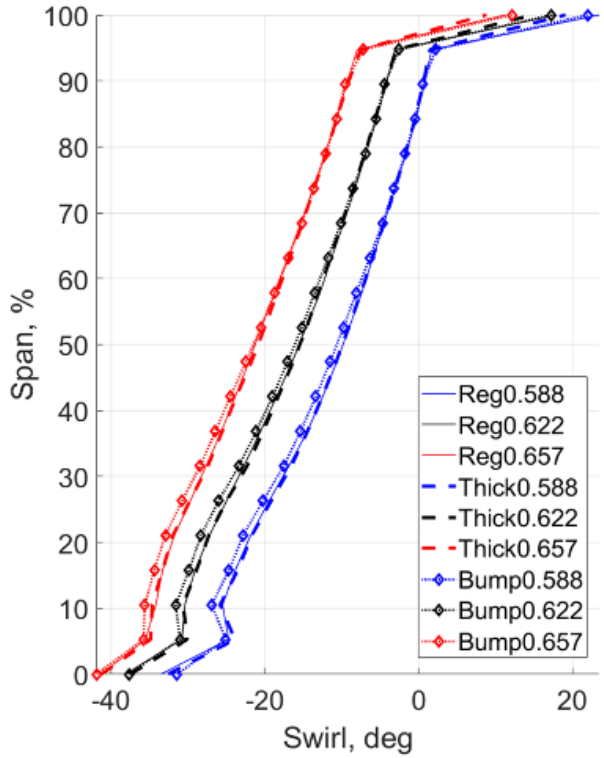
Circumferentially averaged Inlet swirl angle



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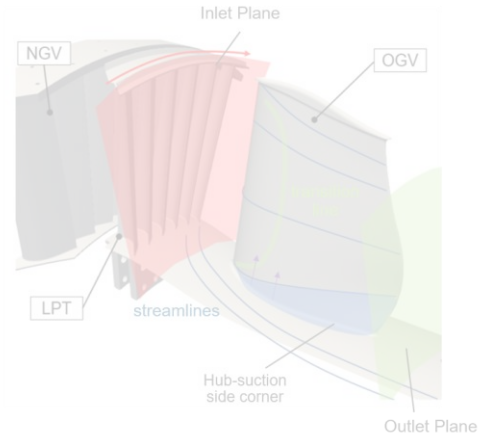
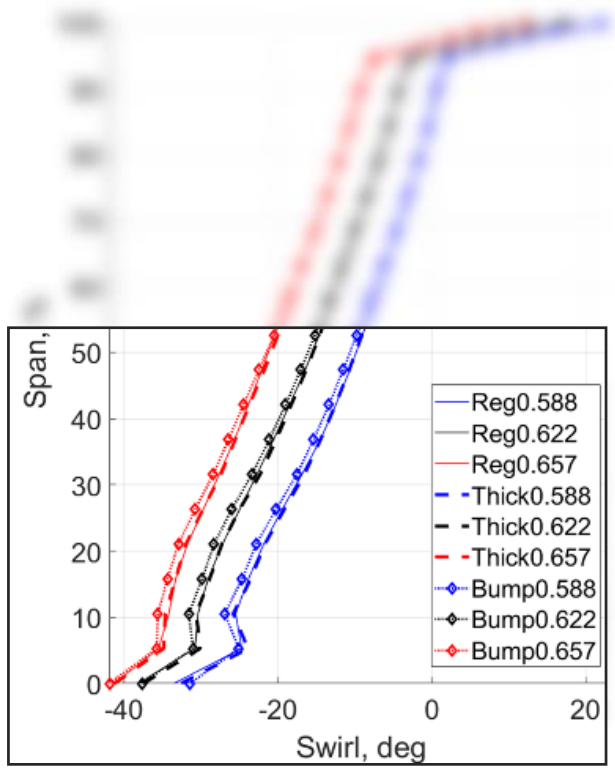


Total pressure coefficient distribution on Inlet plane (on-design)

Circumferentially averaged Inlet swirl angle

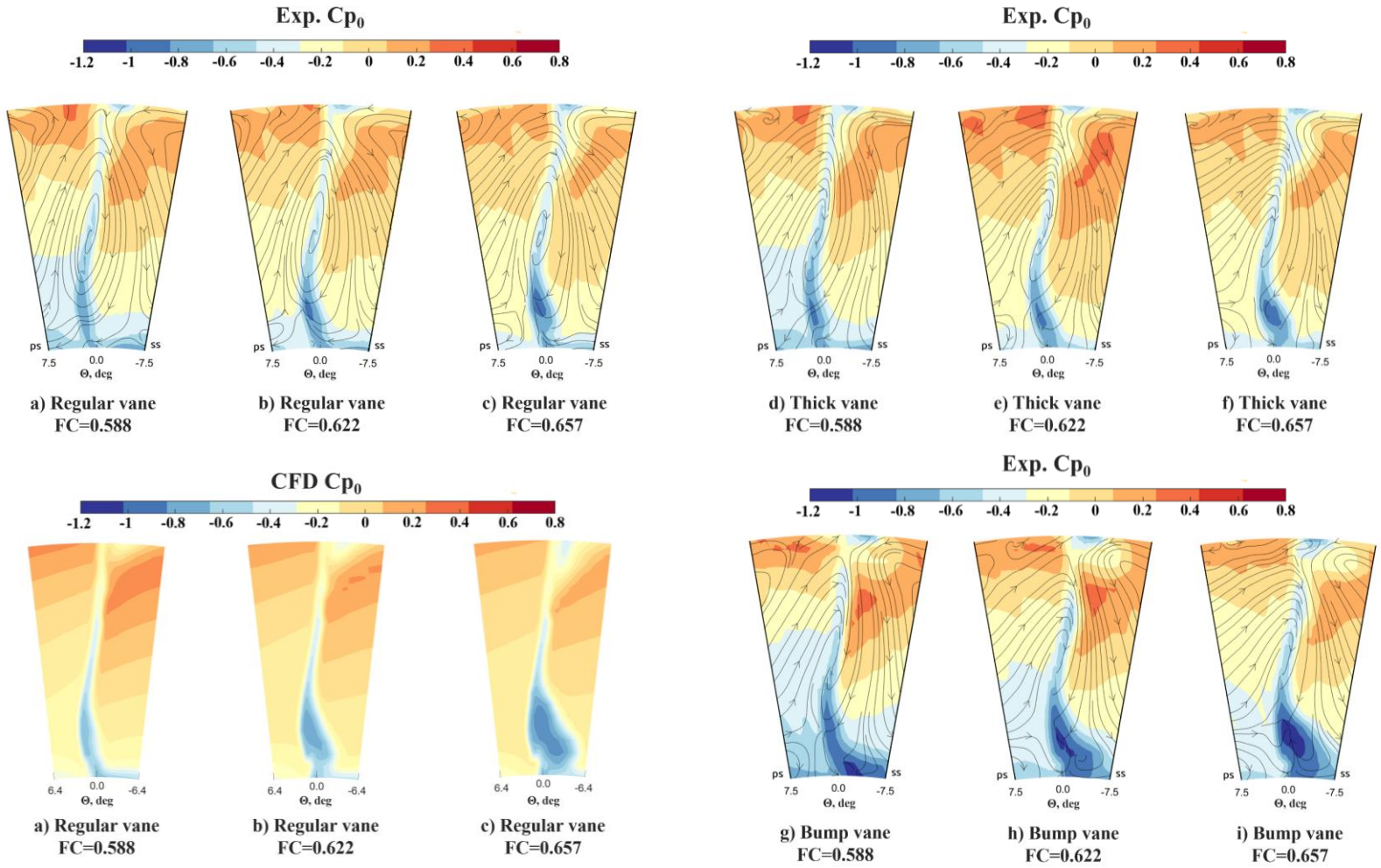


The bump influences inlet conditions in the hub region

Results

Outlet plane measurements

Wake comparison for the regular, thick and bump vanes



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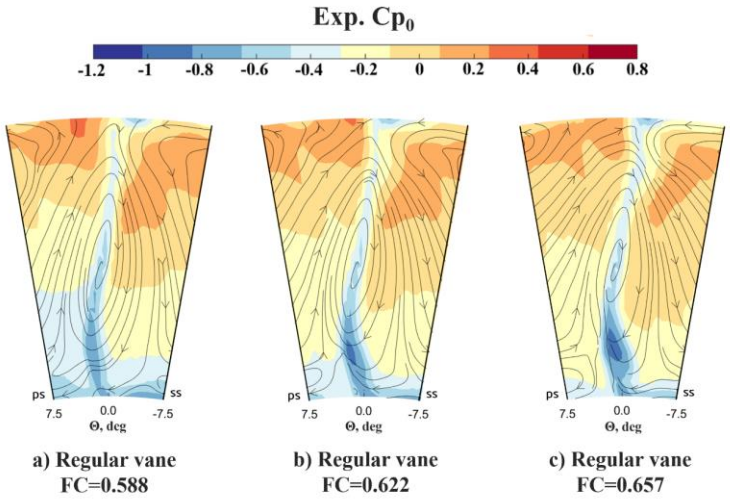
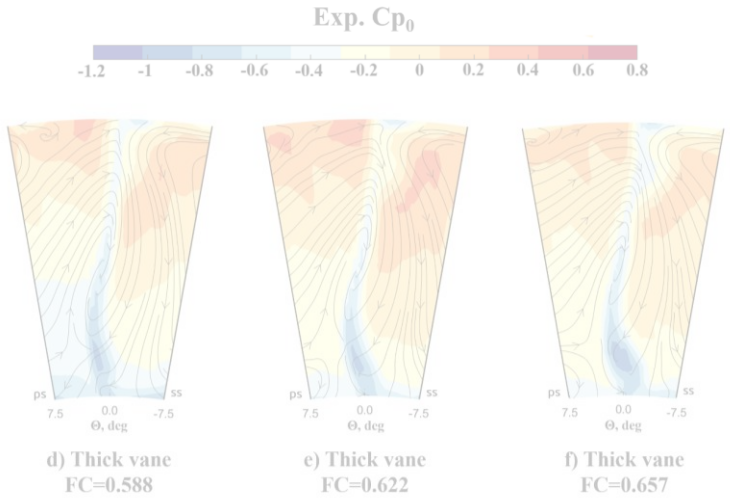
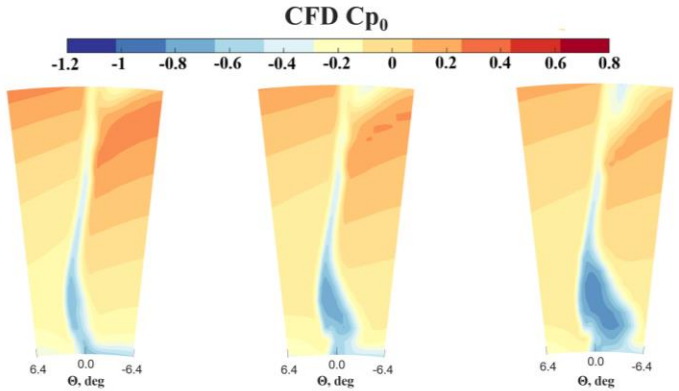


a) Regular vane FC=0.588 b) Regular vane FC=0.622 c) Regular vane FC=0.657



d) Thick vane FC=0.588 e) Thick vane FC=0.622 f) Thick vane FC=0.657



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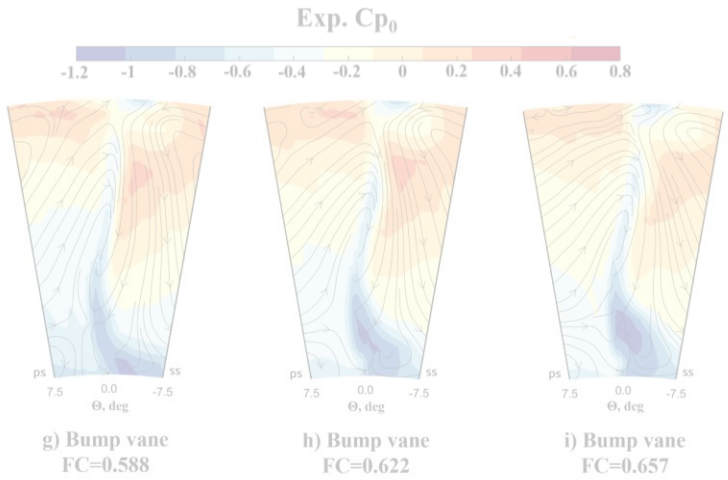


g) Bump vane FC=0.588 h) Bump vane FC=0.622 i) Bump vane FC=0.657

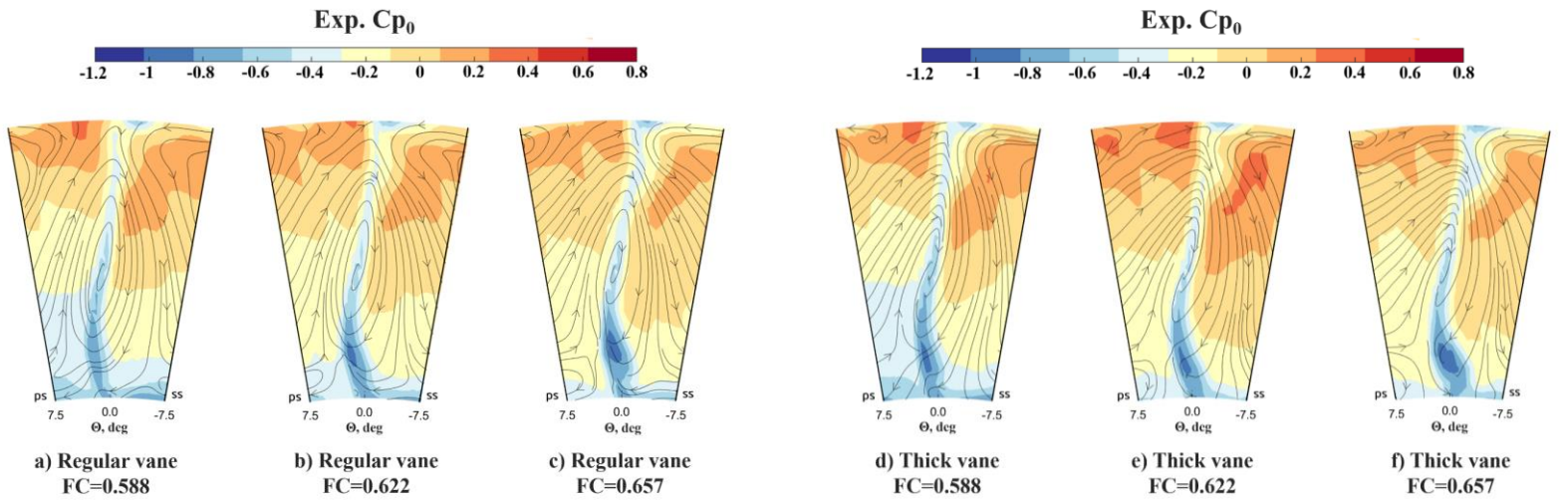
CFD predictions agree well with experimental results.

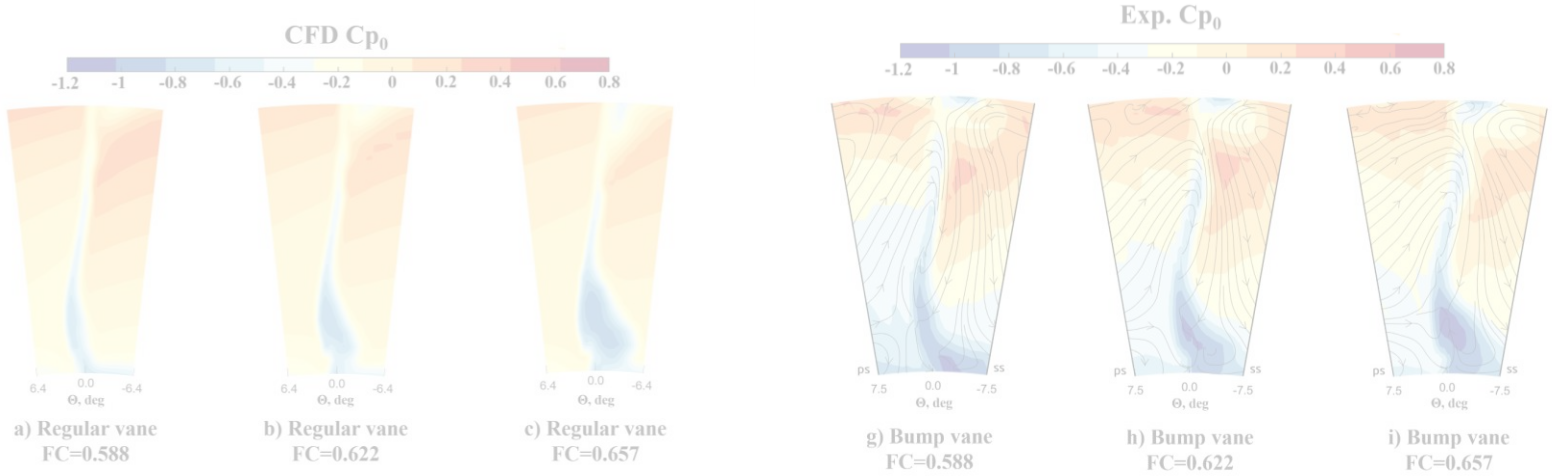
More loaded case:
CFD predicts a bit too large separation around the hub region.

Results

Outlet plane measurements

Wake comparison for the regular, thick and bump vanes





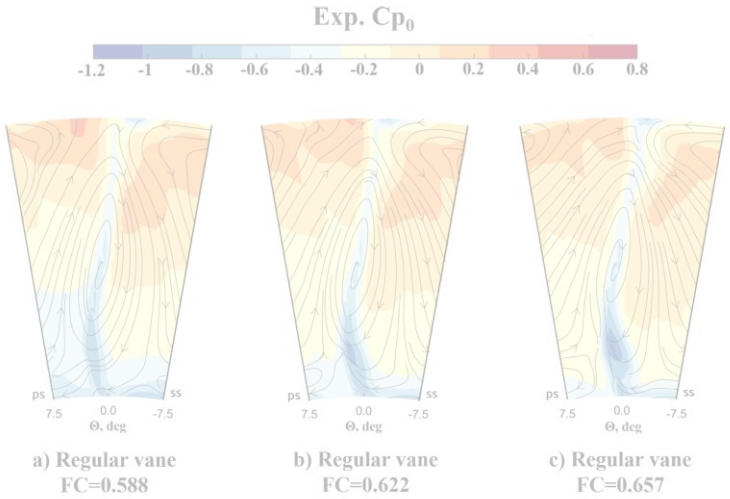
Thick vane:
Slight increase in losses in the near-hub region

The mechanisms for the loss formation are similar for the regular and thick vanes

Results

Outlet plane measurements

Wake comparison for the regular, thick and bump vanes



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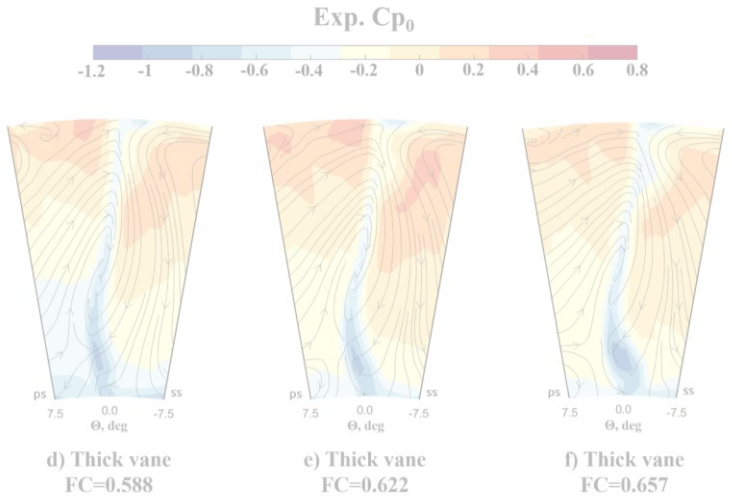

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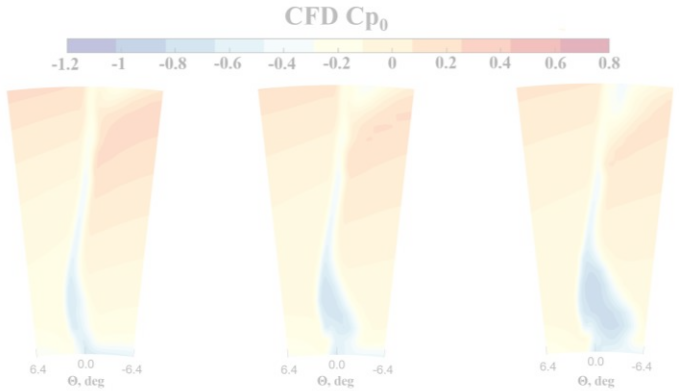

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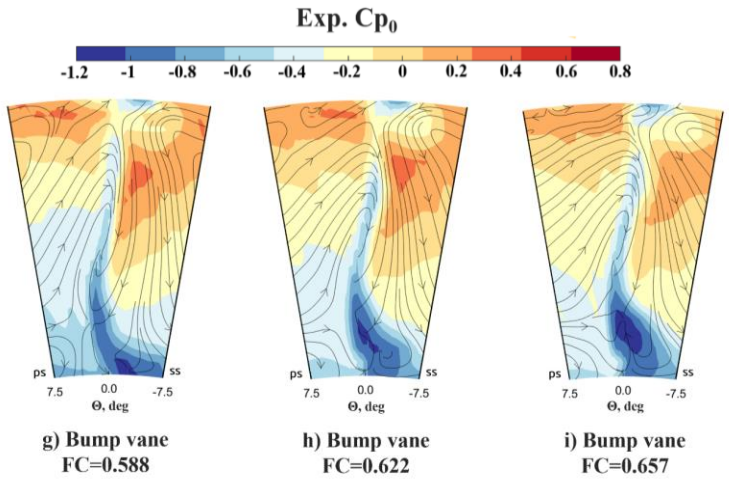

g) Bump vane FC=0.588 | h) Bump vane FC=0.622 | i) Bump vane FC=0.657

Bump vane:

The bump substantially influences pressure losses with additional region close to the hub even for the off-design cases

Ongoing work

Heat transfer measurements

Configuration with polygonal shroud

Influence of the manufacturing non-conformances (welds)

Configuration with leaned vanes

Configuration with different number of vanes