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INVESTIGATION OF SPLITTERED TANDEM STATORS FOR HIGHLY-LOADED LOW-ASPECT-RATIO TRANSONIC FAN STAGE FOR A SMALL-SCALE TURBOFAN

SERCAN ACARER

MECHANICAL ENGINEERING DEPARTMENT

İZMİR KATİP ÇELEBİ UNİVERSITY

İZMİR/TÜRKİYE

Papers regarding to the concept

Micro-Turbojet to Turbofan Conversion Via Continuously Variable Transmission: Thermodynamic Performance Study

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In this study, the viability, performance, and characteristics of a turbojet-to-turbofan conversion through the use of a continuously variable transmission (CVT) are investigated. By an in-house thermodynamic simulation code, the performance of the simple cycle turbojet, a direct shaft joined turbofan, and a CVT coupled turbofan with variable bypass is contrasted. The baseline turbojet and turbofan findings are validated against a commercial software. The comparison indicates high quantitative agreement. Analyzing the results of the turbofan engine equipped with a variable bypass and CVT, it is observed that both the thrust and the efficiency are increased. The augmented thrust is observed to be an artifact of enhanced component matching and wider operational range introduced by variable bypass capability. On the other hand, the introduction of CVT contributes to the reduction in fuel consumption. Therefore, the current research suggests that adaptation of a micro-turbojet into a variable cycle micro-turbofan will greatly improve the performance and efficiency of existing engines, in addition to providing a pathway toward extended use in various applications. [DOI: 10.1115/1.4034262]

Keywords: variable cycle engine, continuously variable transmission, turbojet–turbofan conversion, thermodynamic cycle modeling

Mission Analysis and Operational Optimization of Adaptive Cycle Microturbofan Engine in Surveillance and Firefighting Scenarios

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The current work focuses on mission-based evaluation of a novel engine architecture arising from the conversion of a microturbojet to a microturbofan via introduction of a variable speed fan and bypass nozzle. The solution significantly improves maximum thrust by 260%, reduces fuel consumption by as much as 60% through maintaining the core independently running at its optimum, and enables a wider operational range, all the meanwhile preserving a simple single spool configuration. Particularly, the introduction of a variable-speed fan enables real-time optimization for both high-speed cruise and low-speed loitering. In order to characterize the performance of the adaptive cycle engine with increased number of controls (engine speed, gear ratio, bypass opening), a component map-based thermodynamic study is used to contrast it against other similar propulsion systems with incrementally reduced input variables. In the following, a shortest path-based optimization is conducted over the locally minimum fuel consumption operating points, based on a set of gradient driven connectivity constraints for changes in gear ratio and bypass nozzle area. The resultant state transition graphs provide global optimum for fuel consumption at a thrust range in a given altitude and Mach flight envelope. Then, the engine model is coupled to a flight mechanics solver supplied with a conceptual design for a representative multipurpose unmanned aerial vehicle (UAV). Finally, the associated mission benefits are demonstrated in surveillance and firefighting scenarios. [DOI: 10.1115/1.4040734]

The paper regarding to FAN/LPC design

Institution of MECHANICAL ENGINEERS
Journal of AEROSPACE ENGINEERING

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SAGE

Unified low-pressure compressor concept for engines of future high-speed micro-unmanned aerial vehicles

Menal İlhan, M Tayyip Gürbüz and Sercan Acarer

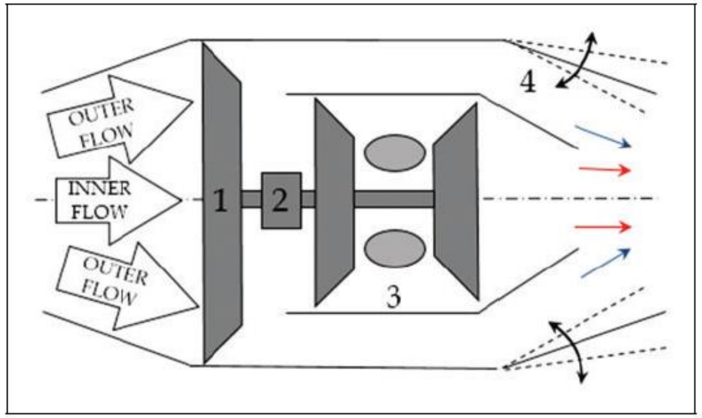


Figure 1. Schematic representation of the concept: (1) LPC (fan), (2) CVT, (3) gas generator without additional turbine, and (4) variable bypass nozzle.[10]

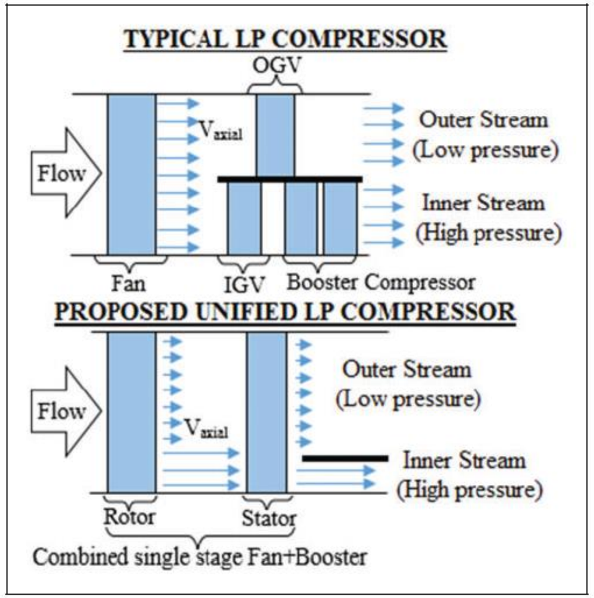
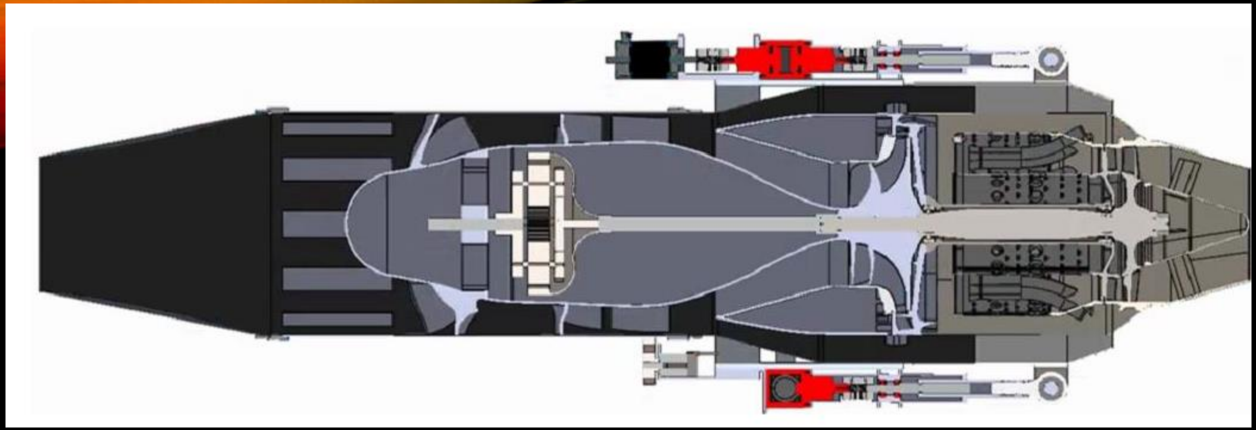
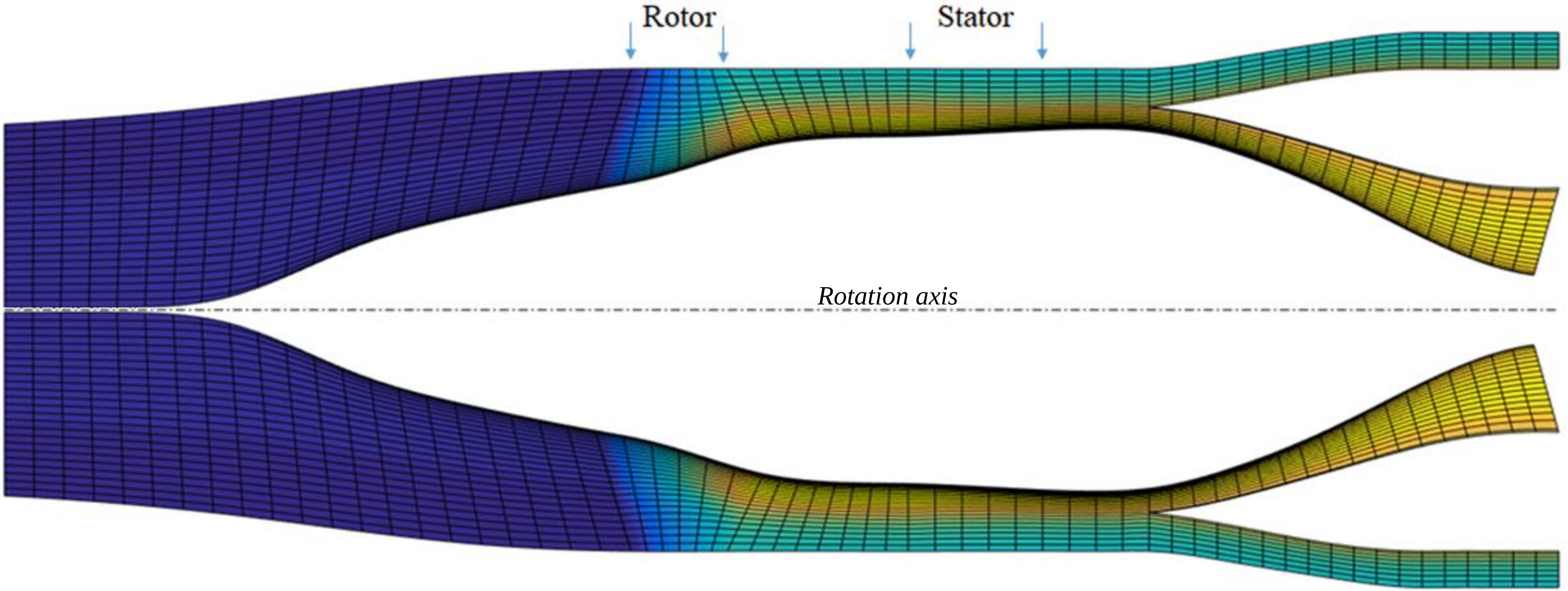


Figure 2. Schematic comparison of the proposed and conventional LP compressors for similar bypass ratio.

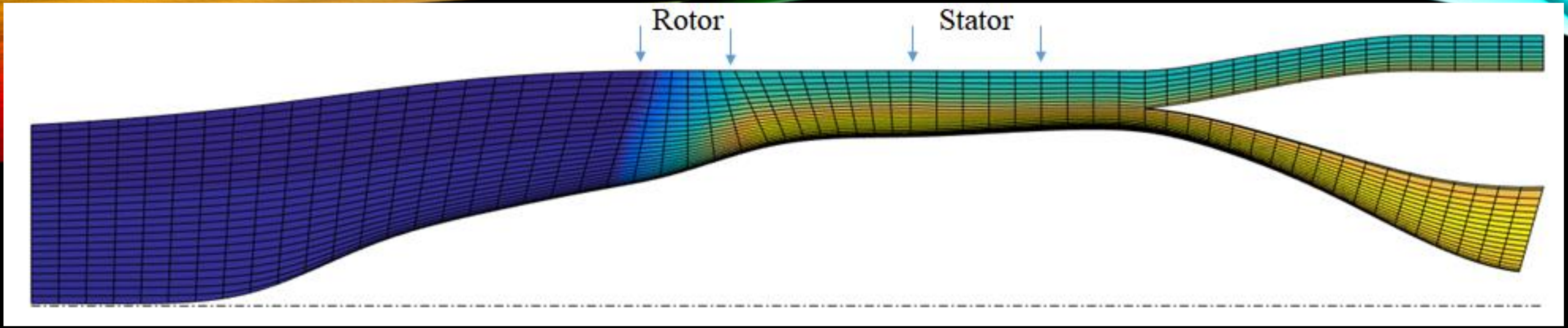
THE ENGINE CAD MODEL

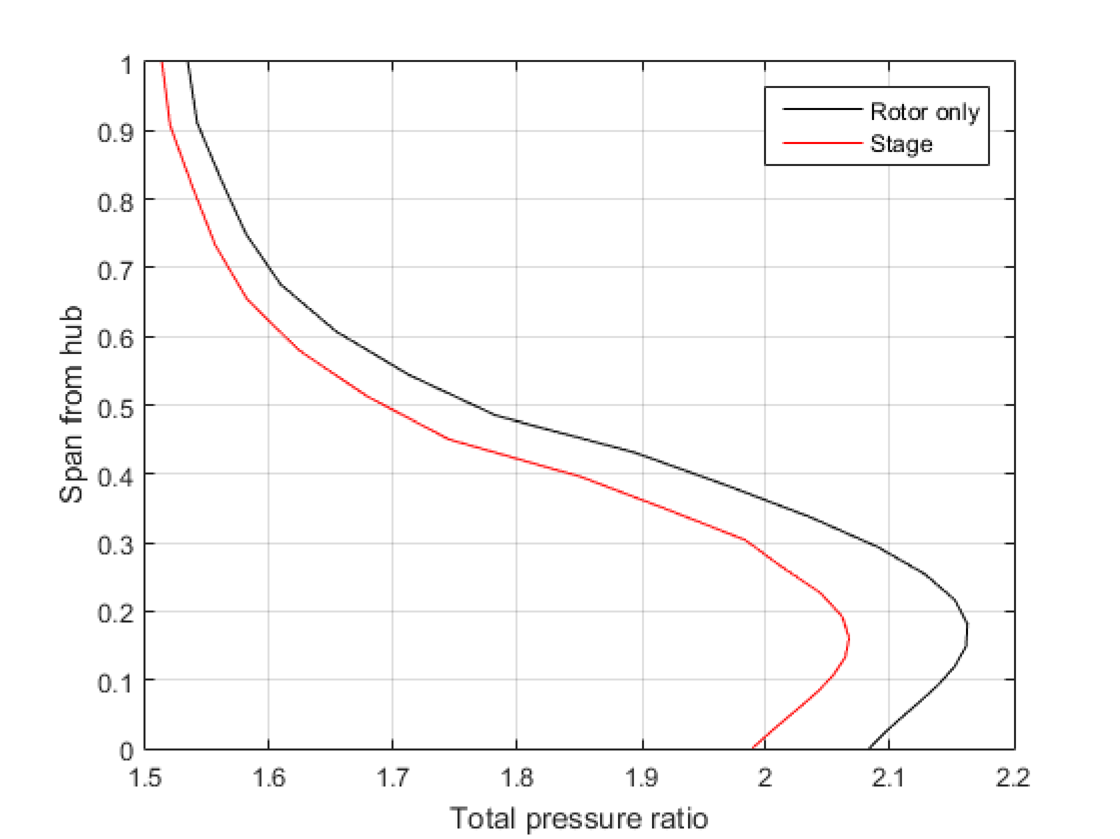


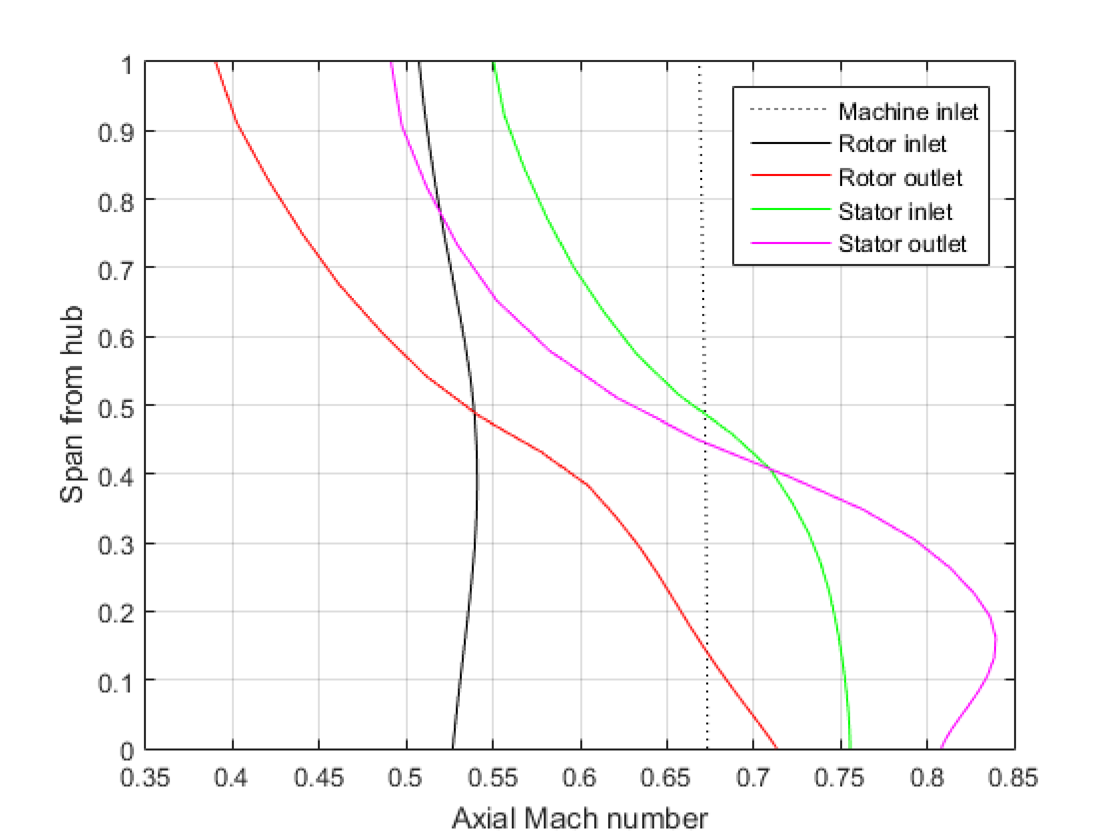
IN-HOUSE DEVELOPED THROUGHFLOW MODEL

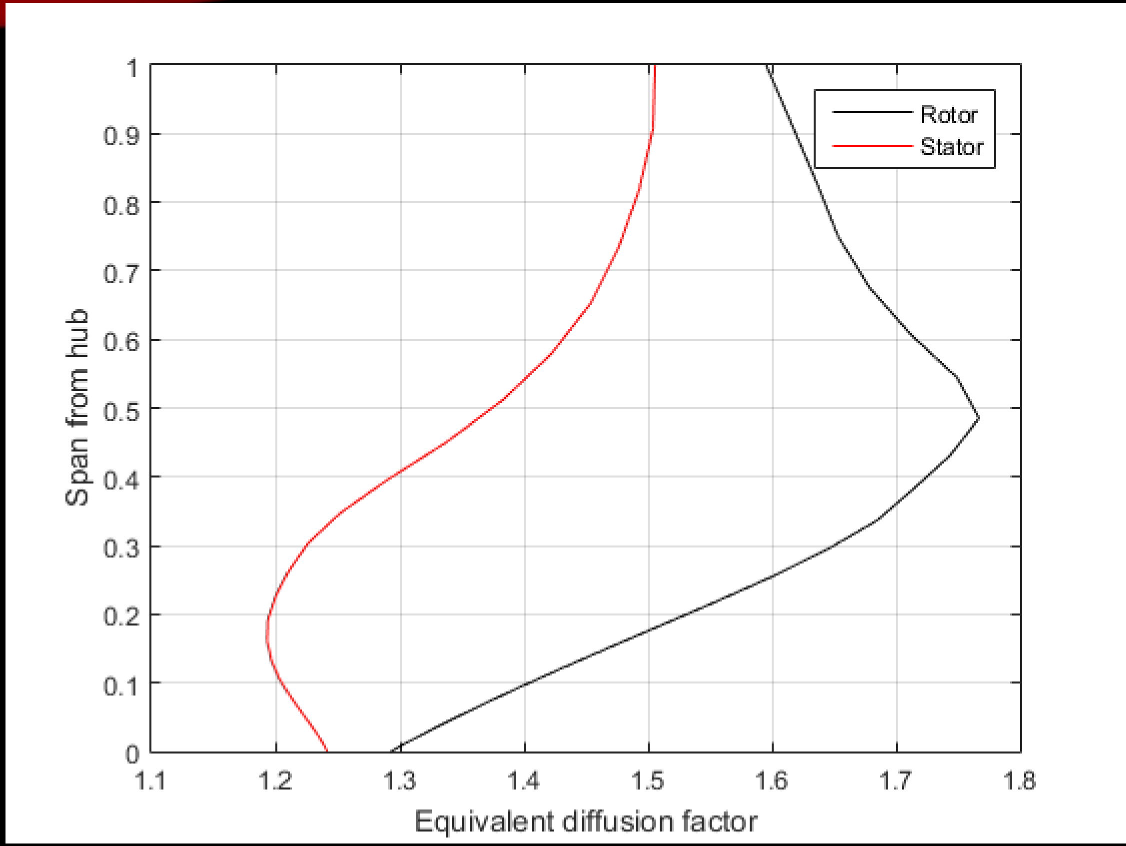


Colour for axial velocity or pressure

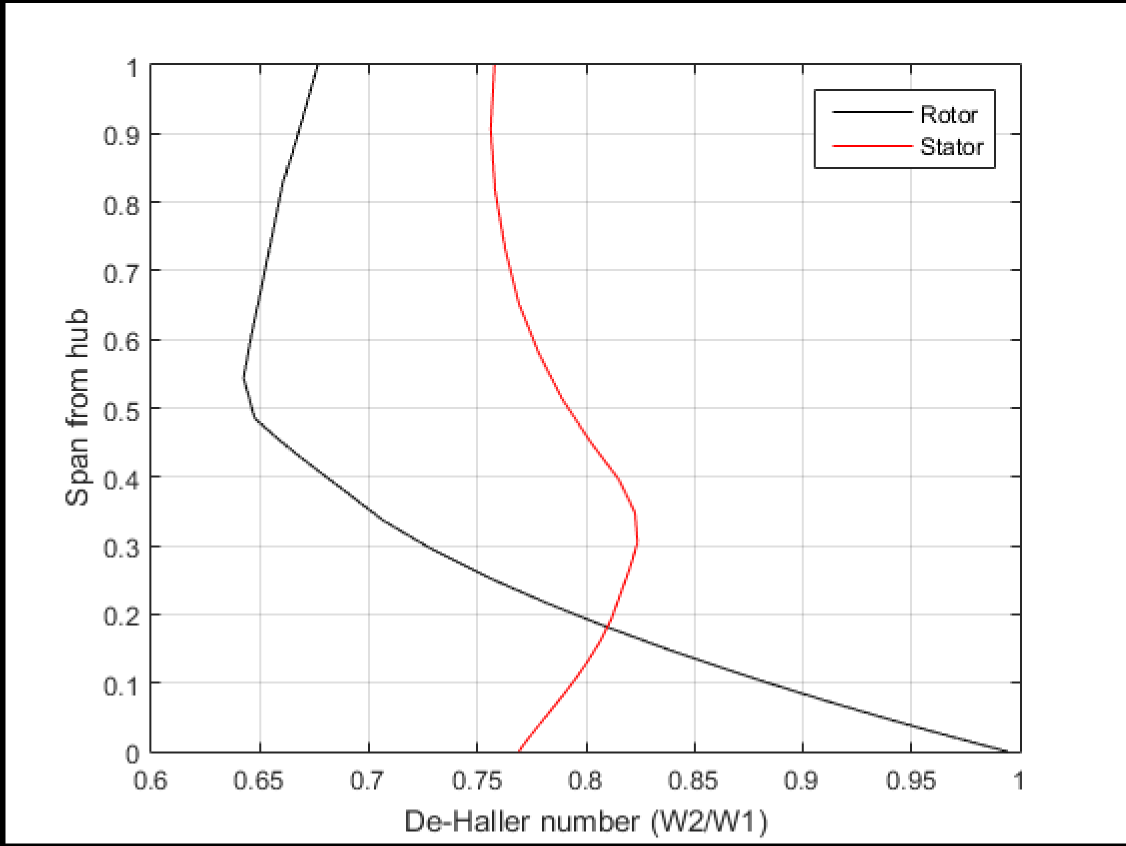

Rotor
Stator


Rotor only
Stage
Span from hub
Total pressure ratio
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2

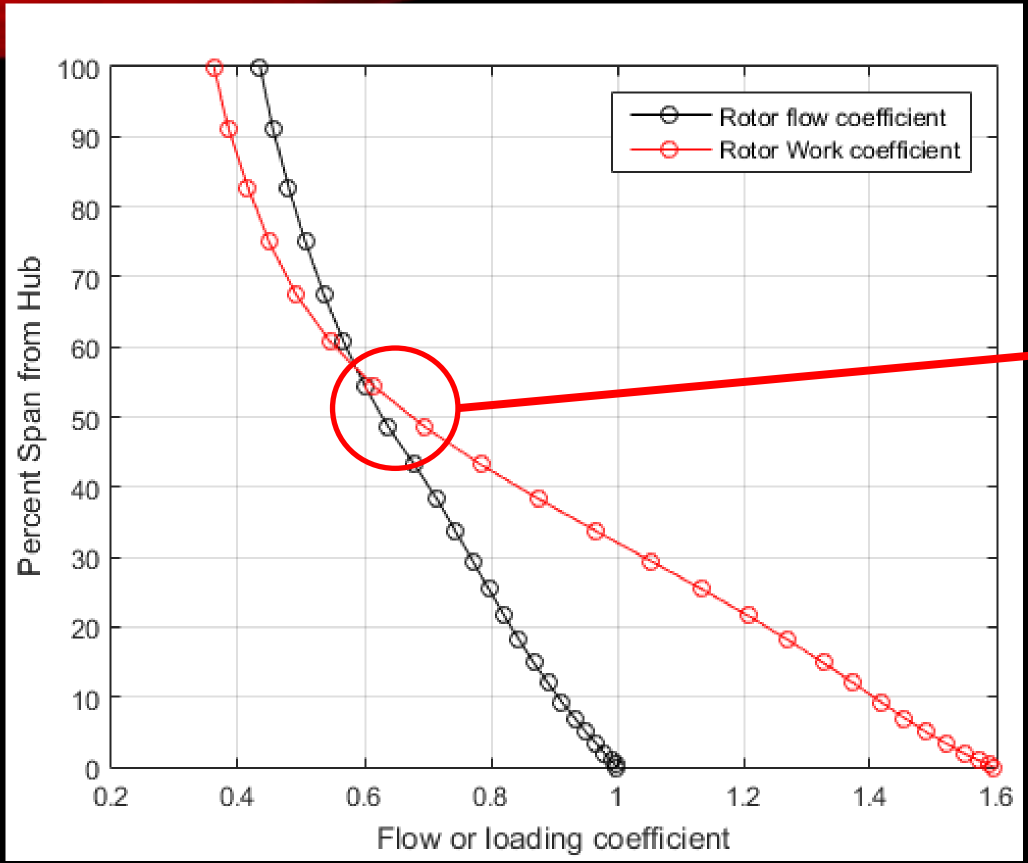

Machine inlet
Rotor inlet
Rotor outlet
Stator inlet
Stator outlet
Span from hub
Axial Mach number
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85


Rotor
Stator
Span from hub
Equivalent diffusion factor
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8

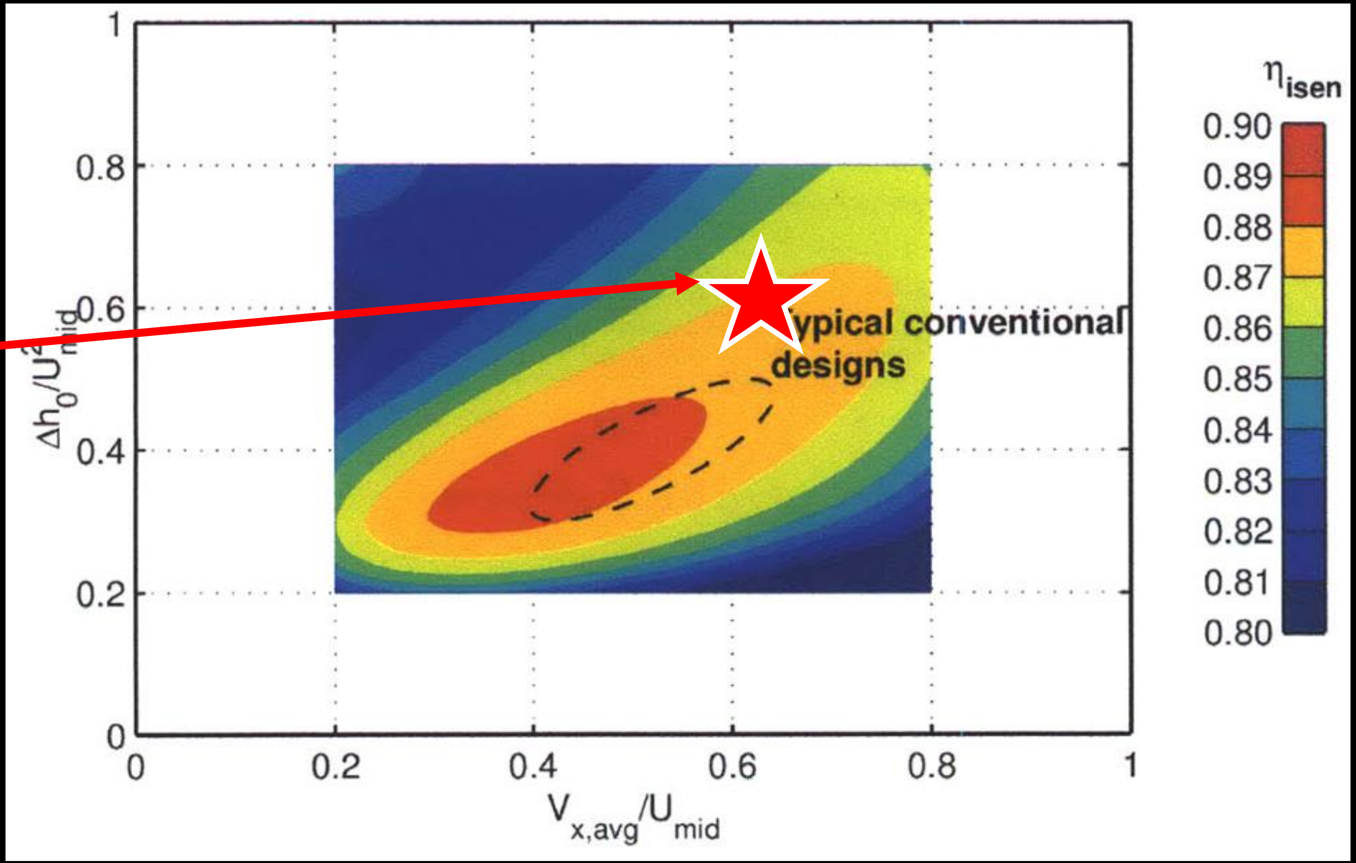
W_{max}/W_2


Rotor
Stator
Span from hub
De-Haller number (W2/W1)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1

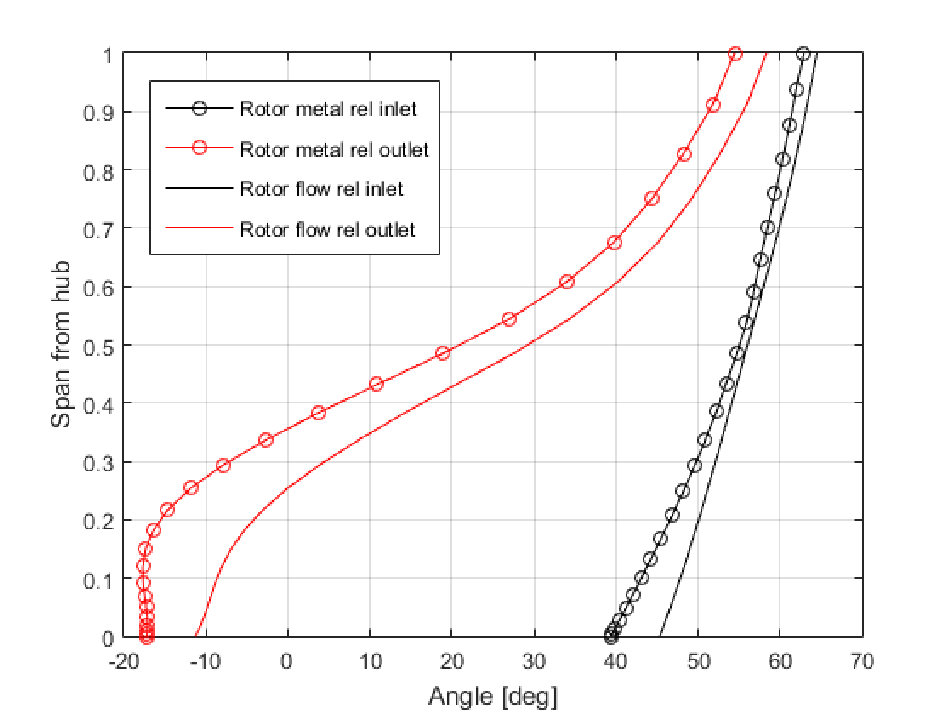
W_2/W_1

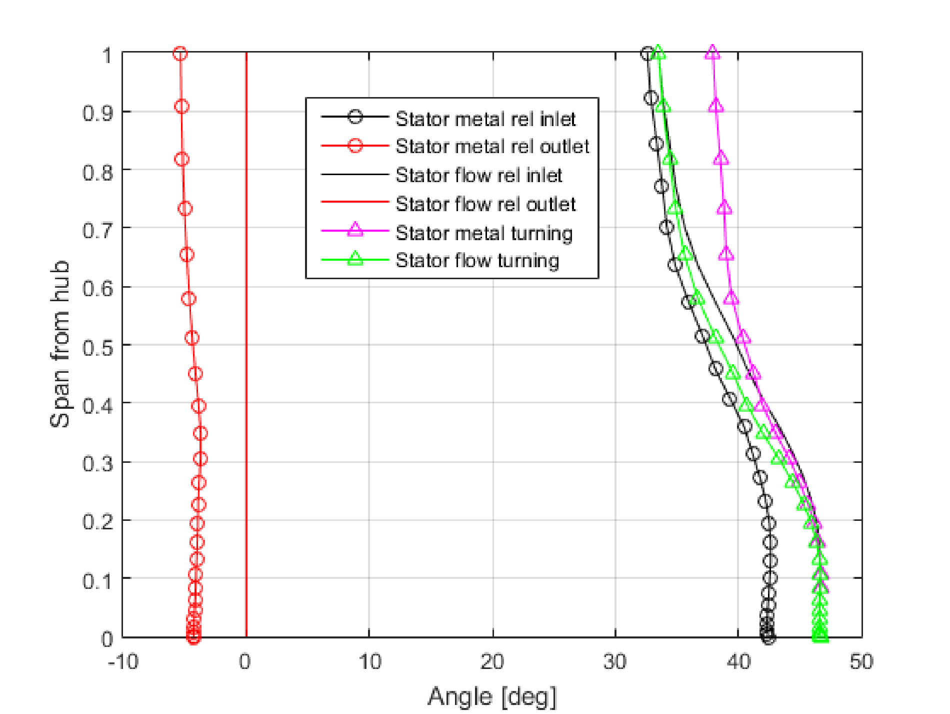


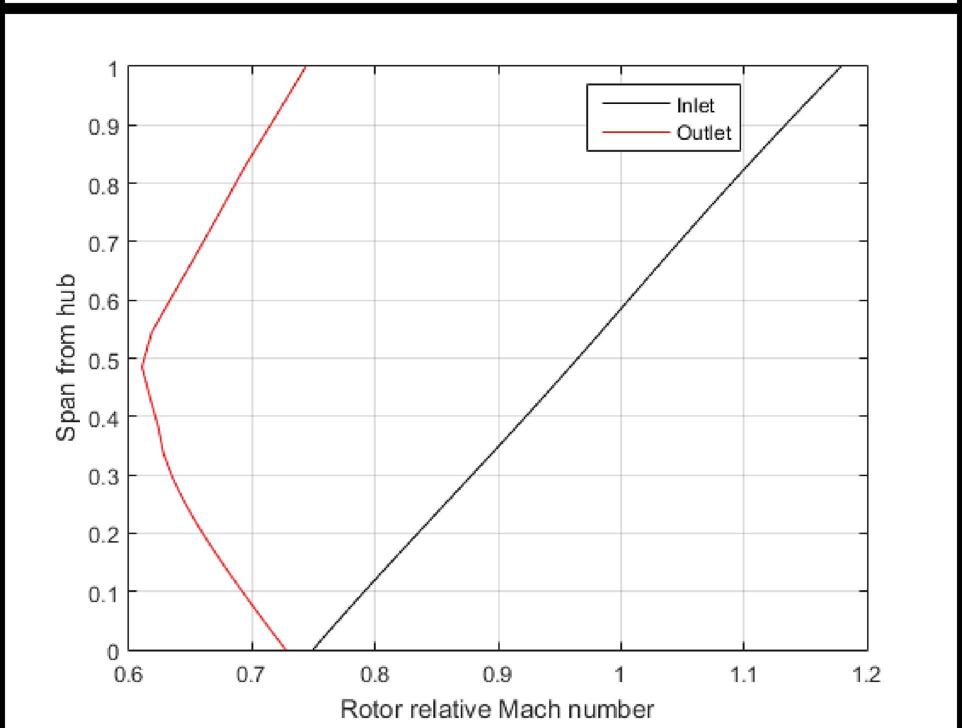
Rotor flow coefficient
Rotor Work coefficient
Percent Span from Hub
Flow or loading coefficient
100
90
80
70
60
50
40
30
20
10
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

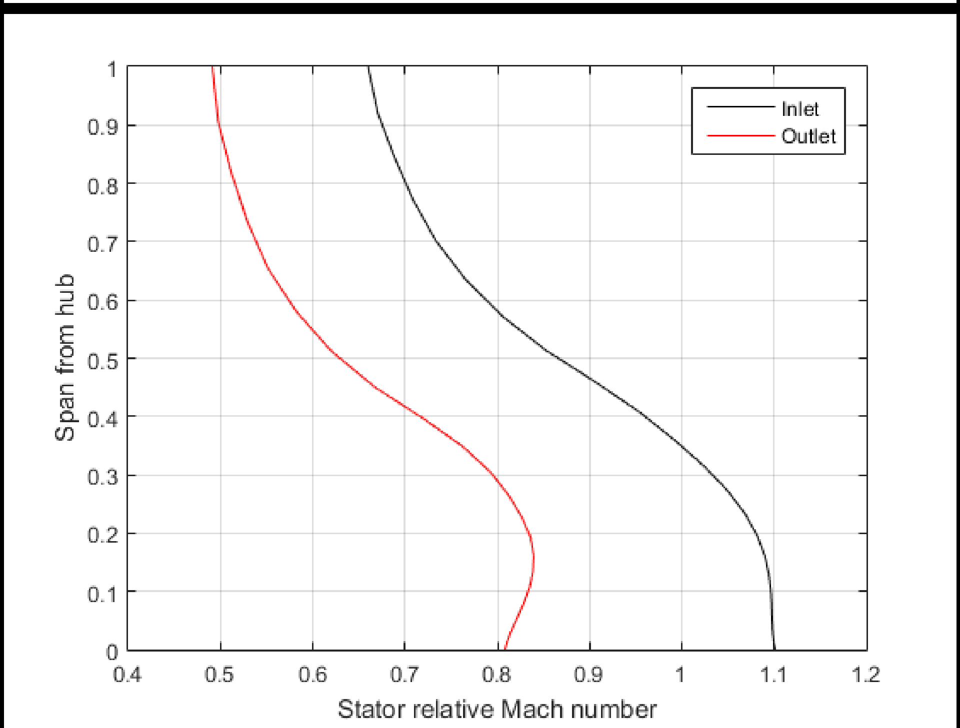


η_{isen}
0.90
0.89
0.88
0.87
0.86
0.85
0.84
0.83
0.82
0.81
0.80
Typical conventional designs
$\Delta h_0/U^2_{mid}$
$V_{x,avg}/U_{mid}$
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1


Rotor metal rel inlet
Rotor metal rel outlet
Rotor flow rel inlet
Rotor flow rel outlet
Span from hub
Angle [deg]


Stator metal rel inlet
Stator metal rel outlet
Stator flow rel inlet
Stator flow rel outlet
Stator metal turning
Stator flow turning
Span from hub
Angle [deg]


Inlet
Outlet
Span from hub
Rotor relative Mach number


Inlet
Outlet
Span from hub
Stator relative Mach number

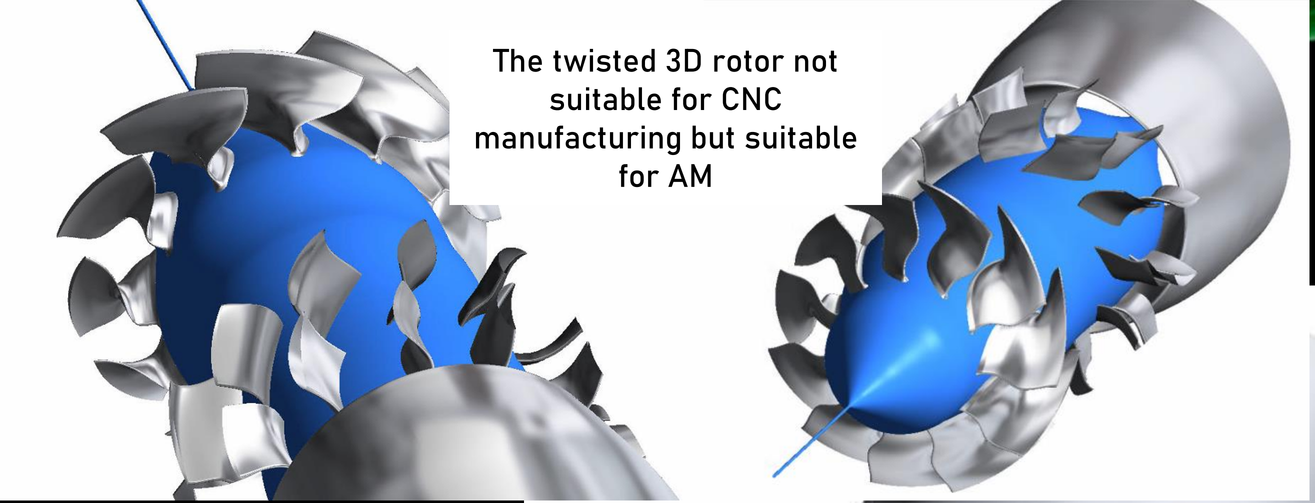
WHAT WE COULD ACHIEVE AT THE END?

- Core pressure ratio 1.65 for both cases instead of 1.9-2
- Bypass pressure ratio 1.54 for both cases, as intended

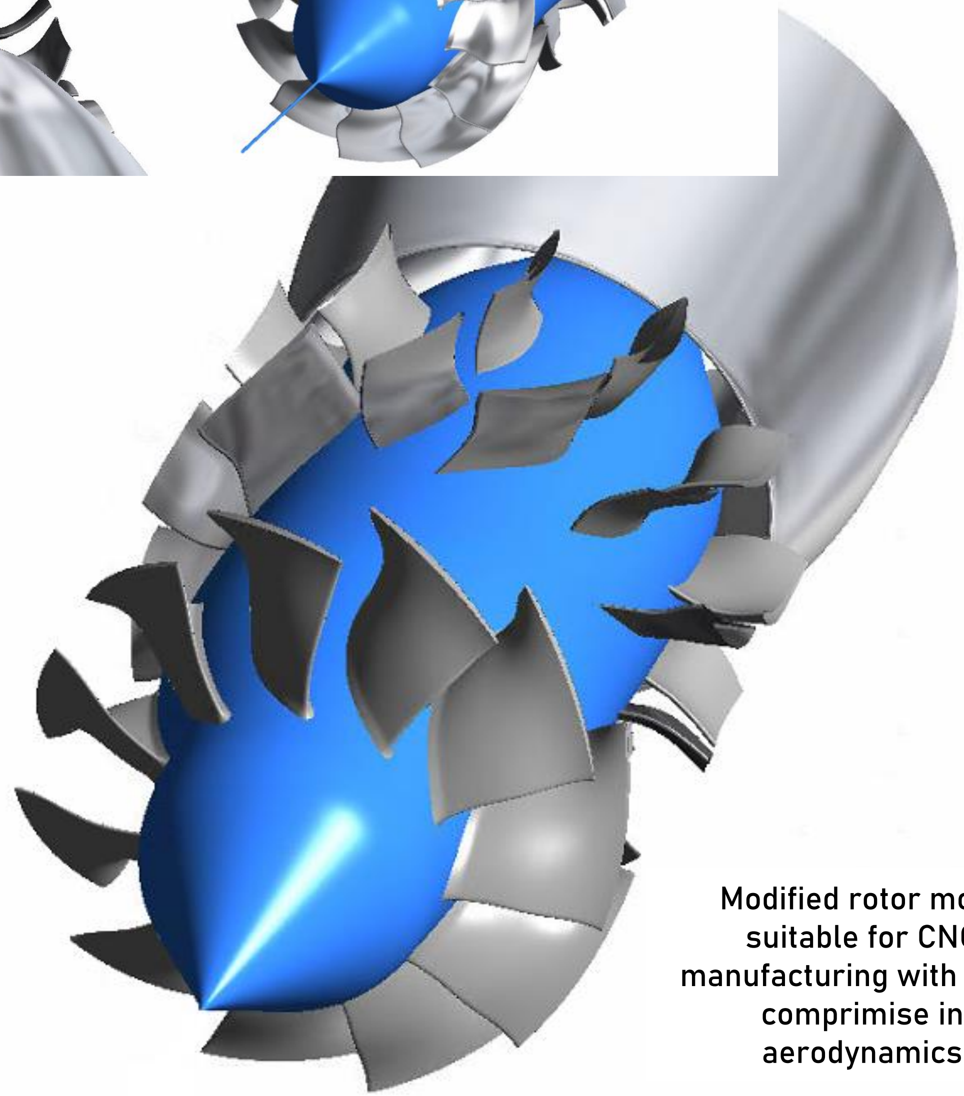
For the hub portion of the stator;

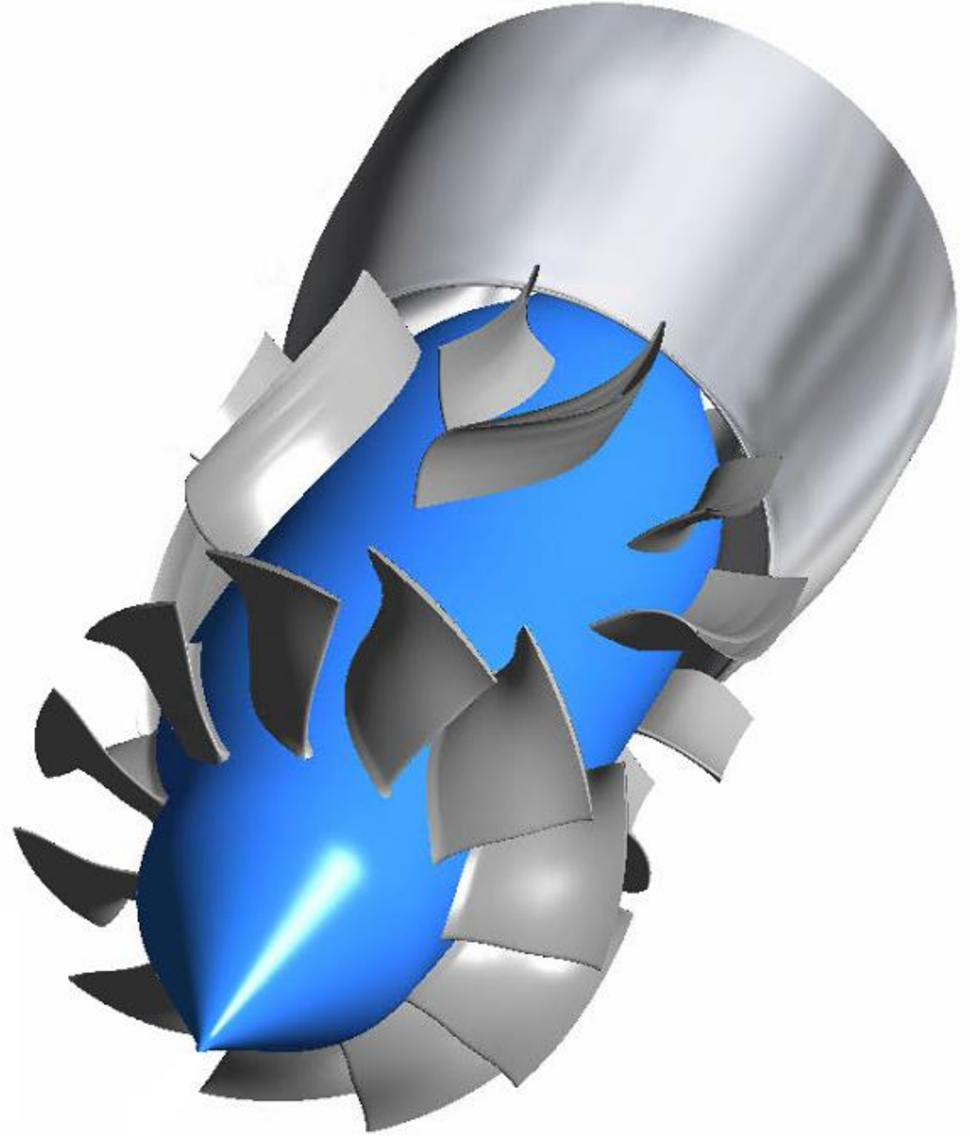
- ➢ The required wide-chord (low-aspect-ratio) design,
- ➢ transonic speeds at the inlet,
- ➢ high stator exit velocity to reduce loading and
- ➢ manufacturing constraints

causes excessive pressure losses and the design intent cannot be matched.

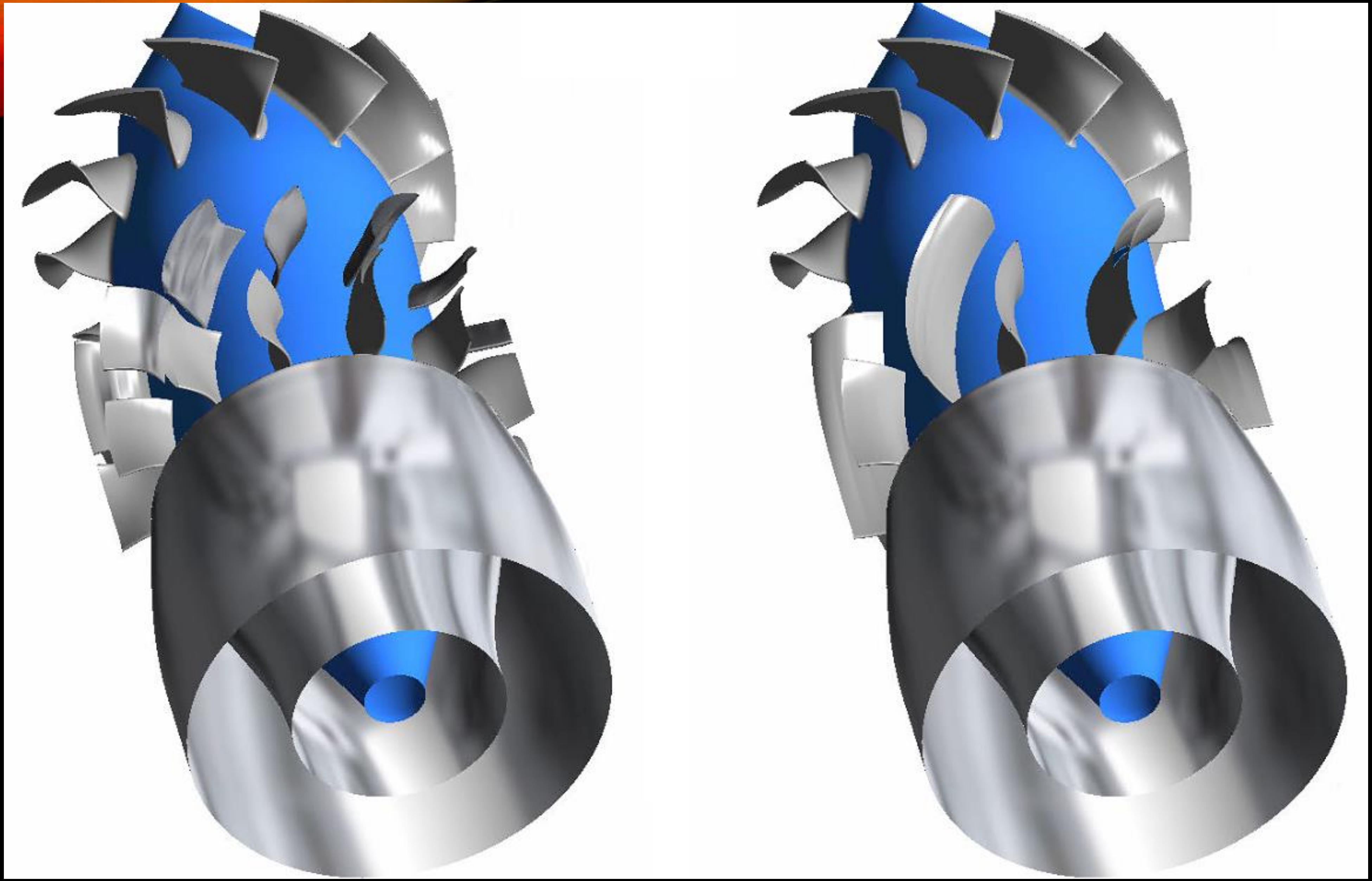


The twisted 3D rotor not suitable for CNC manufacturing but suitable for AM



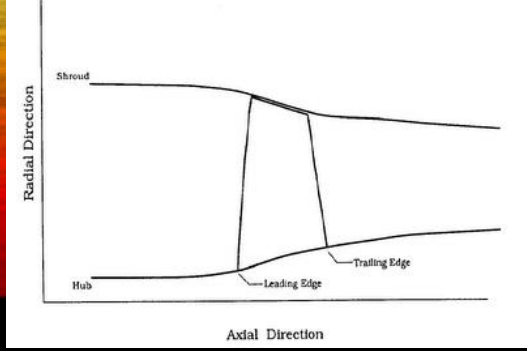


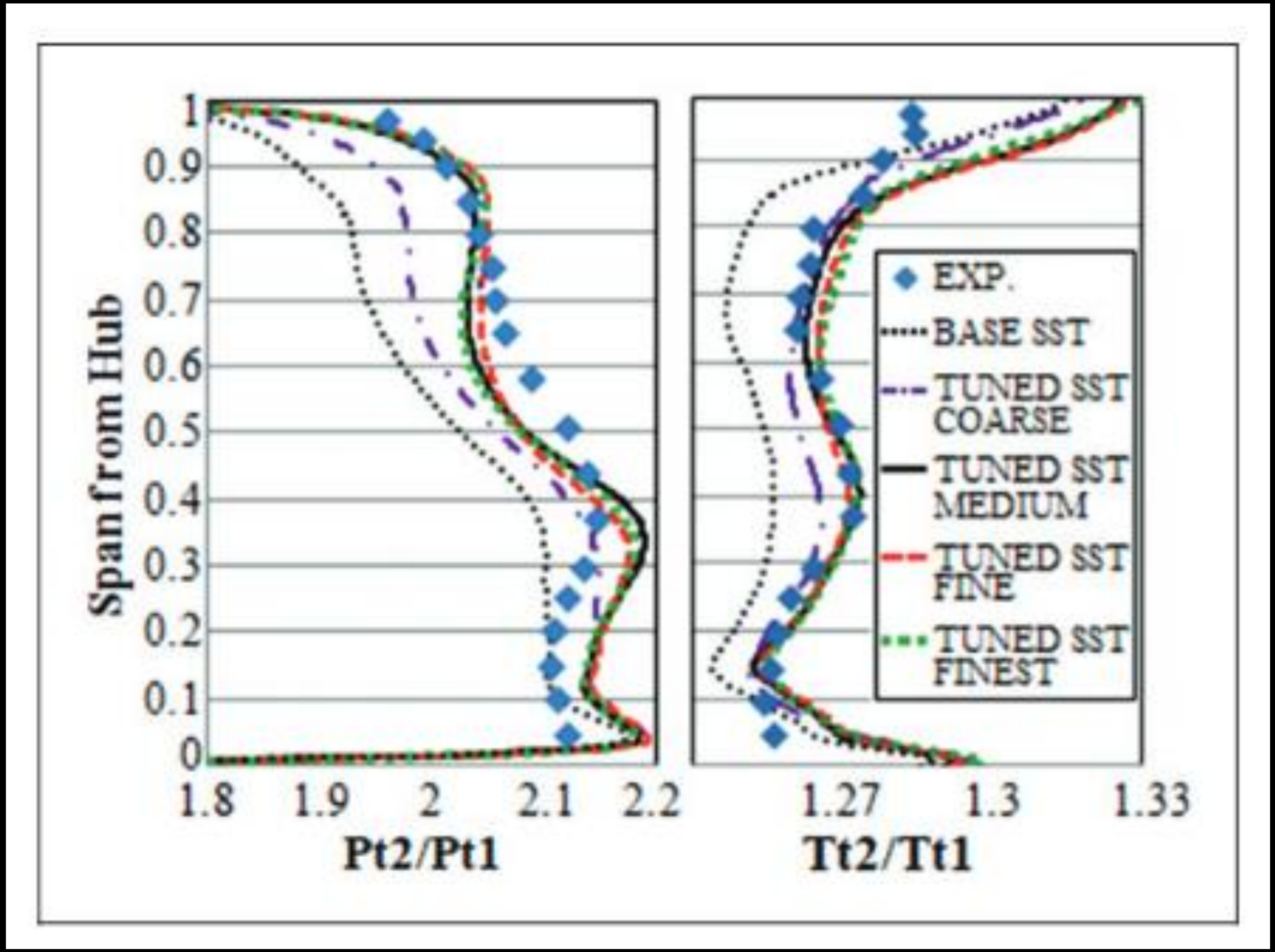
Modified rotor more suitable for CNC manufacturing with some comprimise in aerodynamics

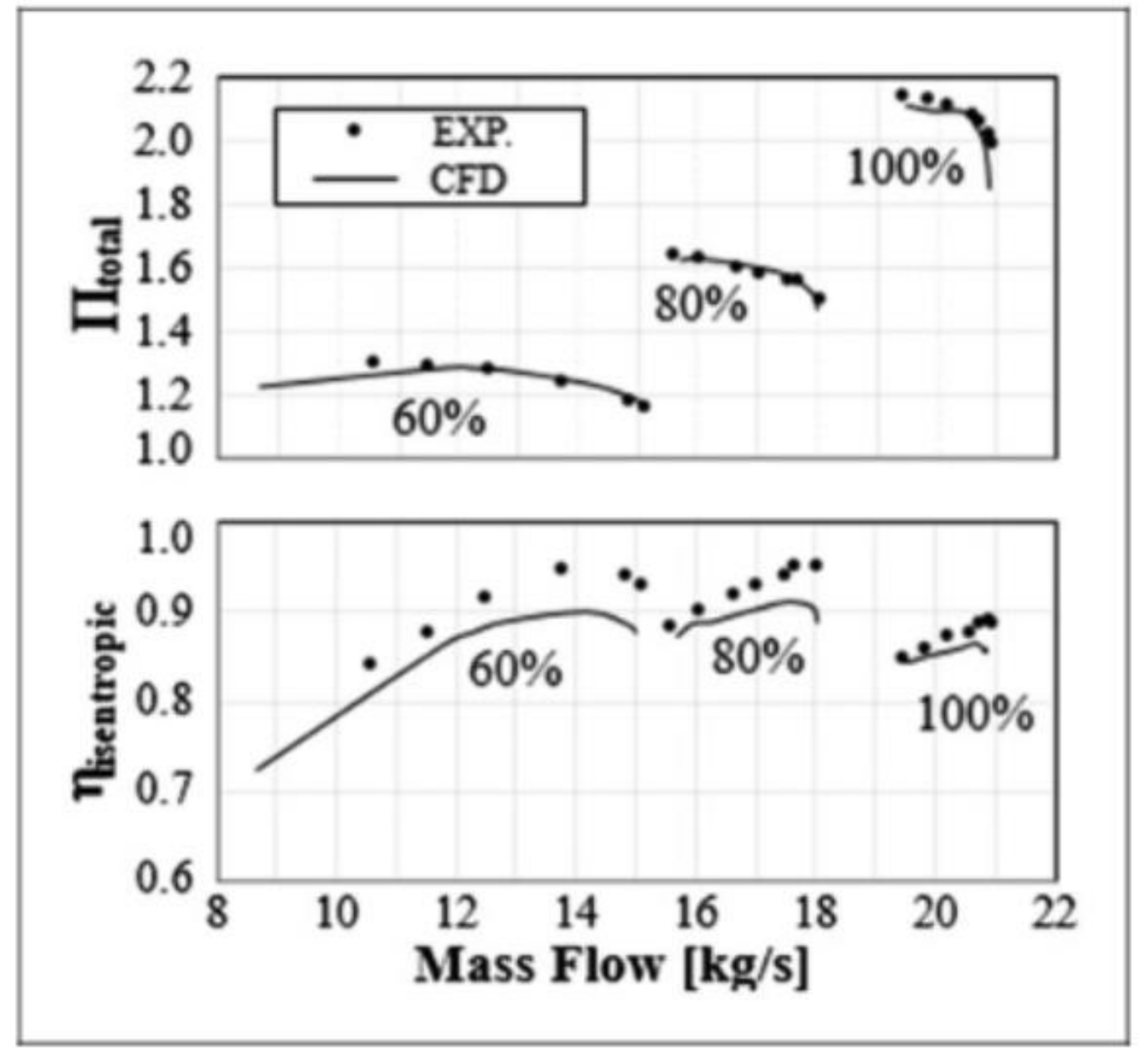


The manufactured fan and tandem stators with durable aluminum alloy 7075 instead of titanium.
In process of testing.

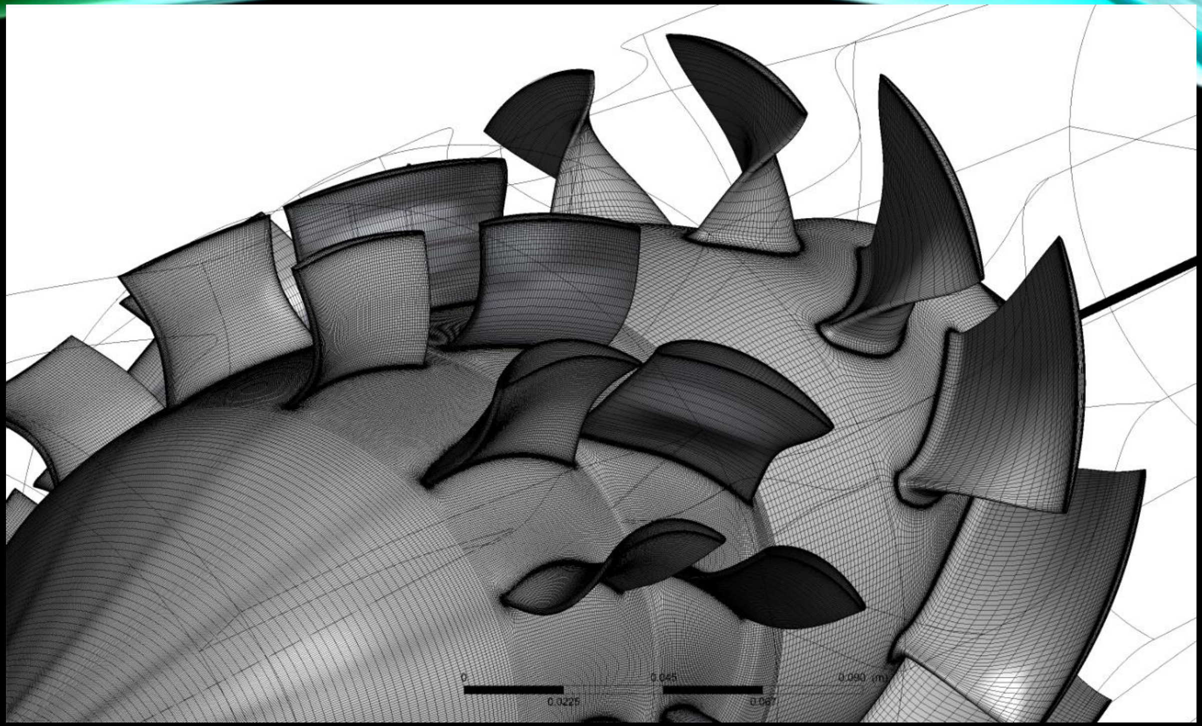
CFD VALIDATION ON ROTOR 37 WITH 2.1 PR

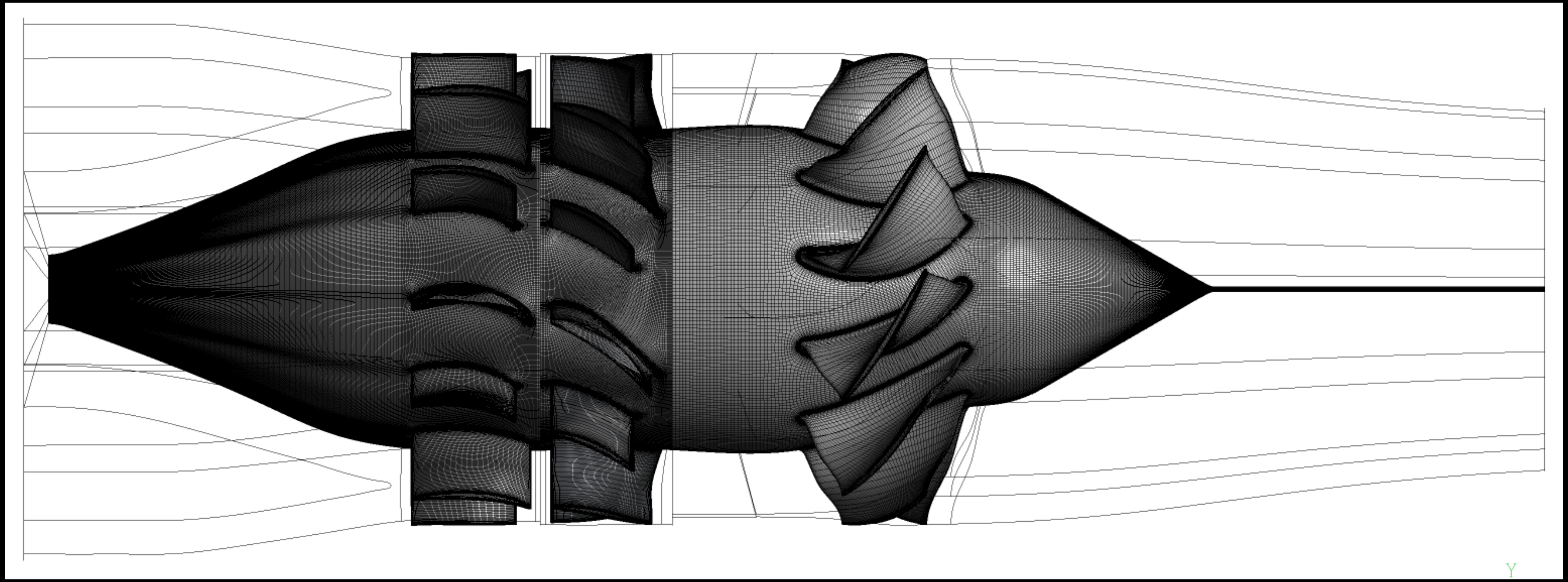




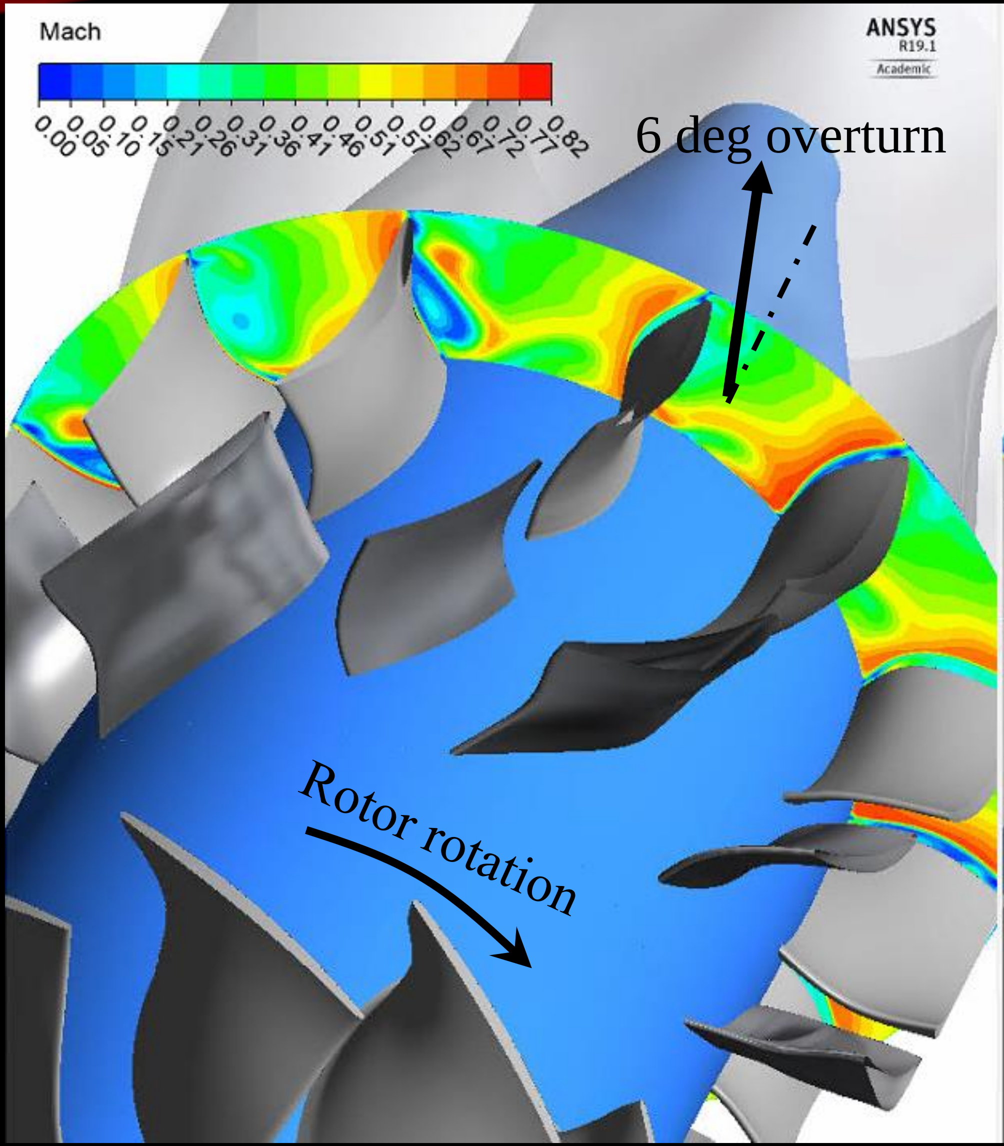


GENERATED MESH

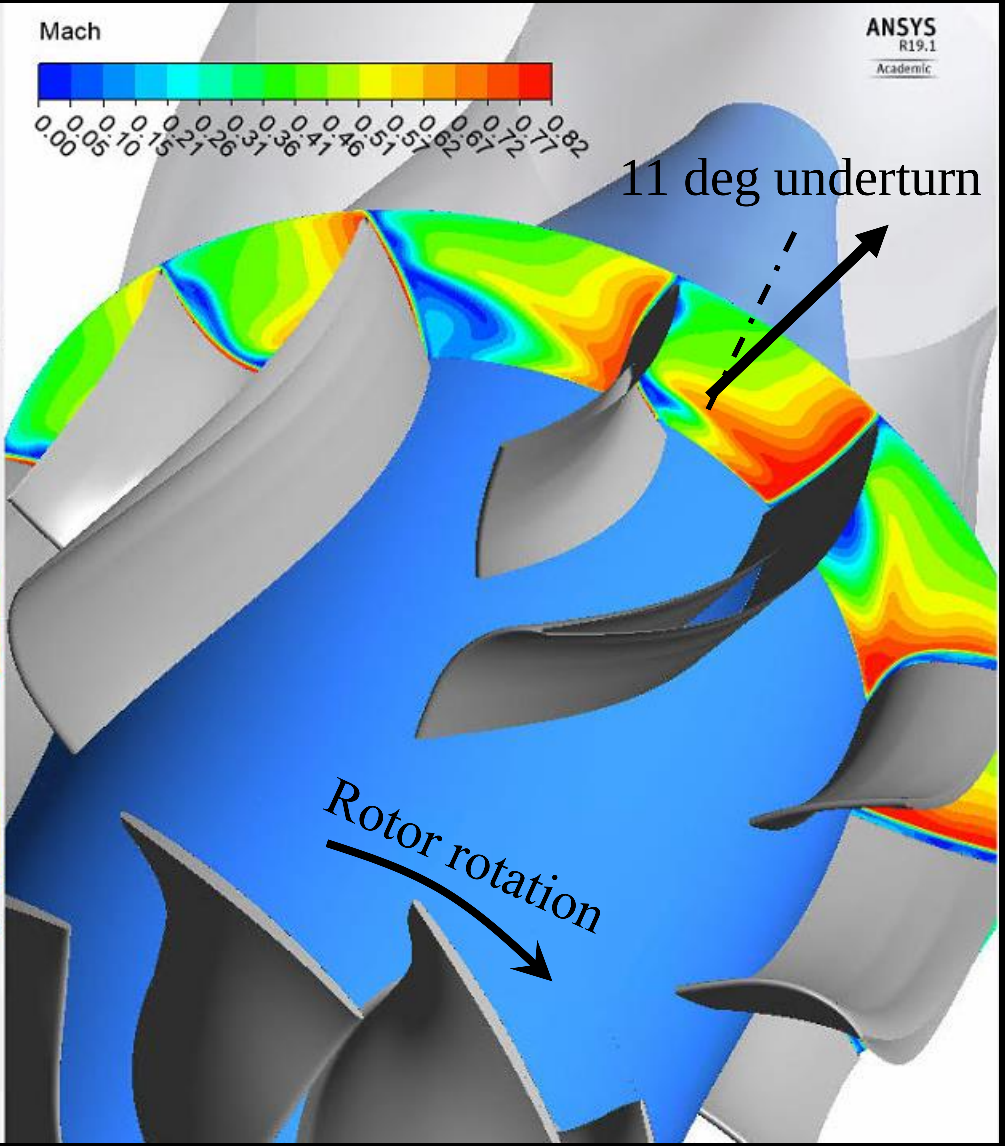


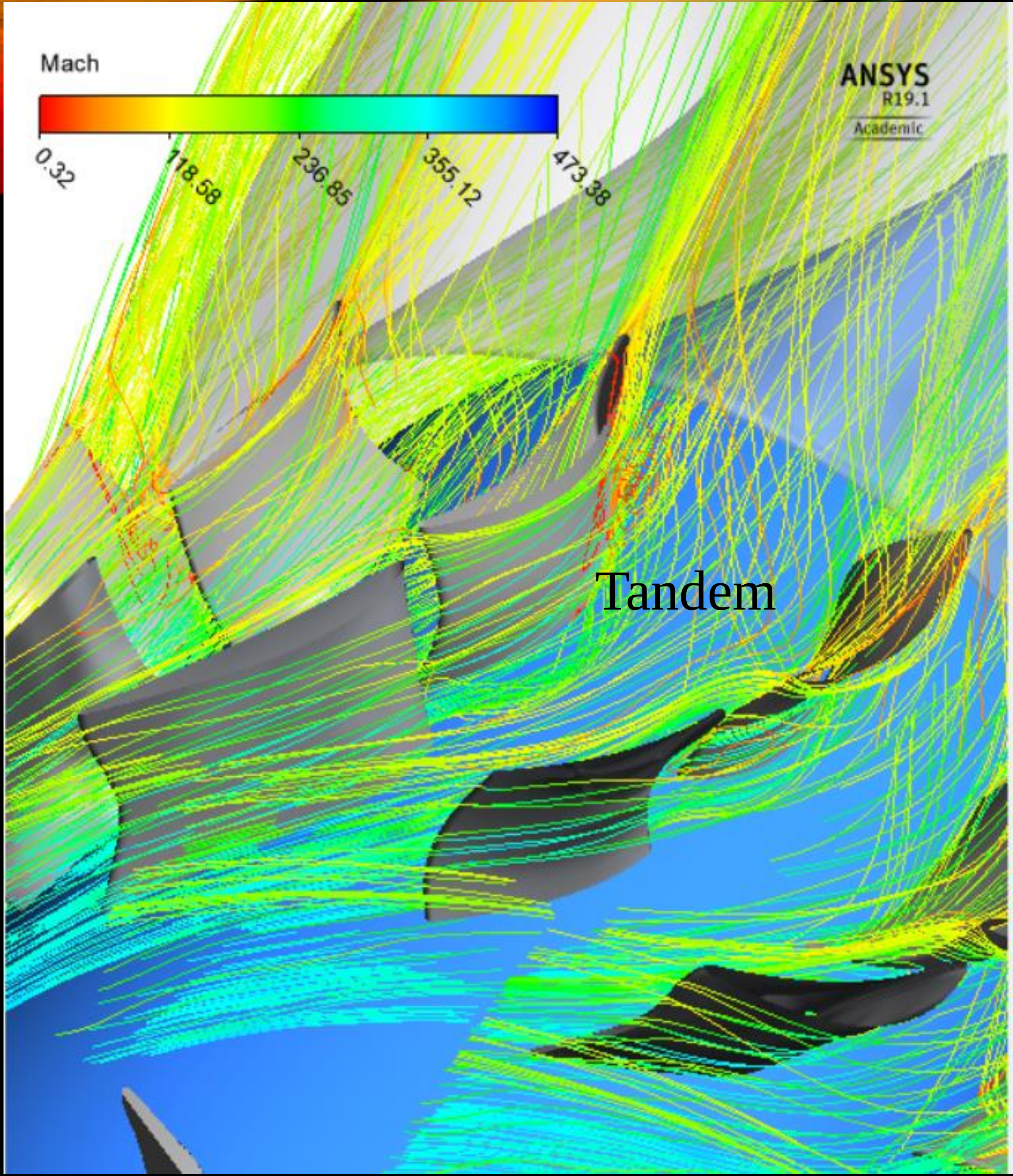


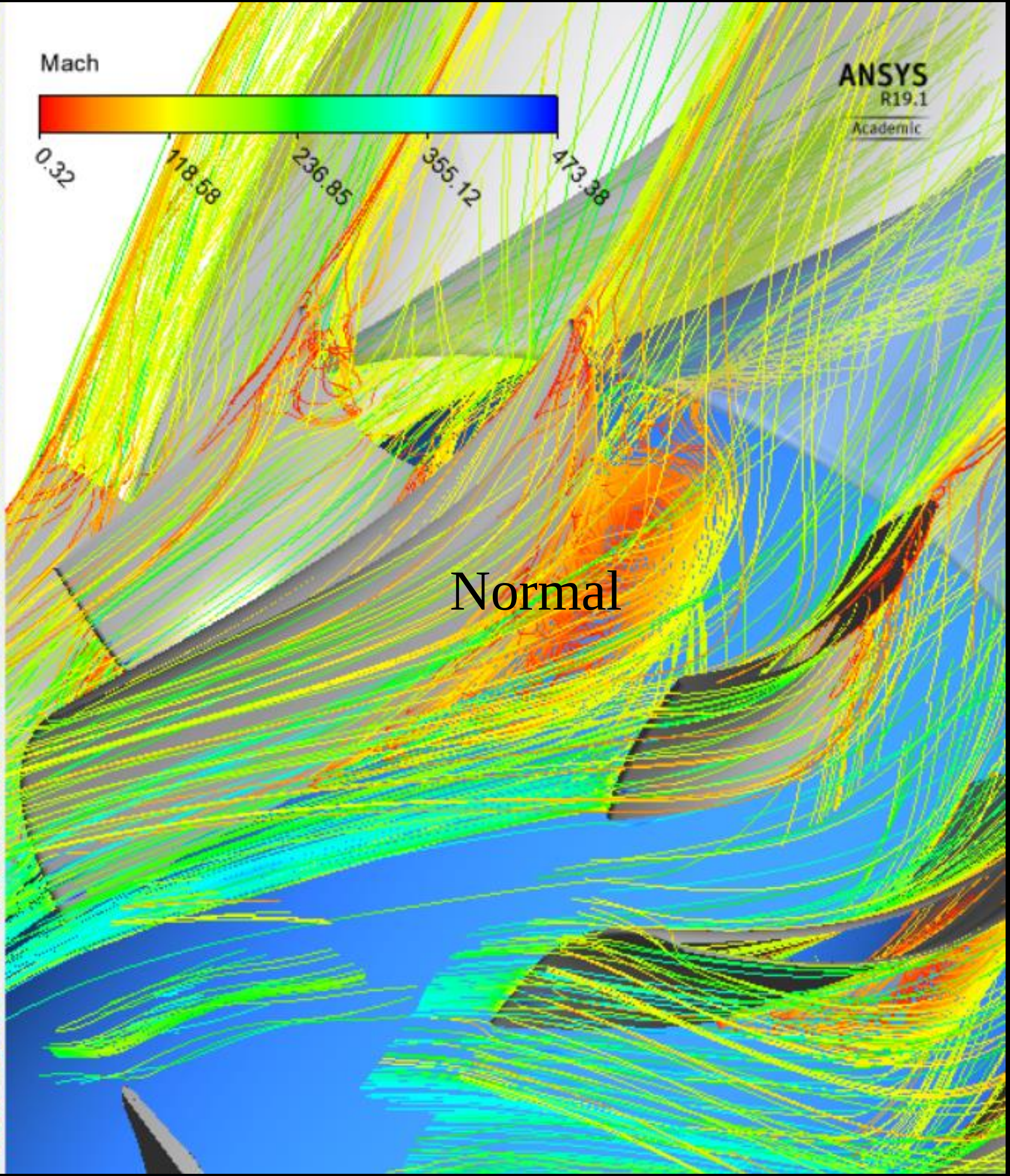
Tandem (with Splitter)



Normal (wide chord with splitter)

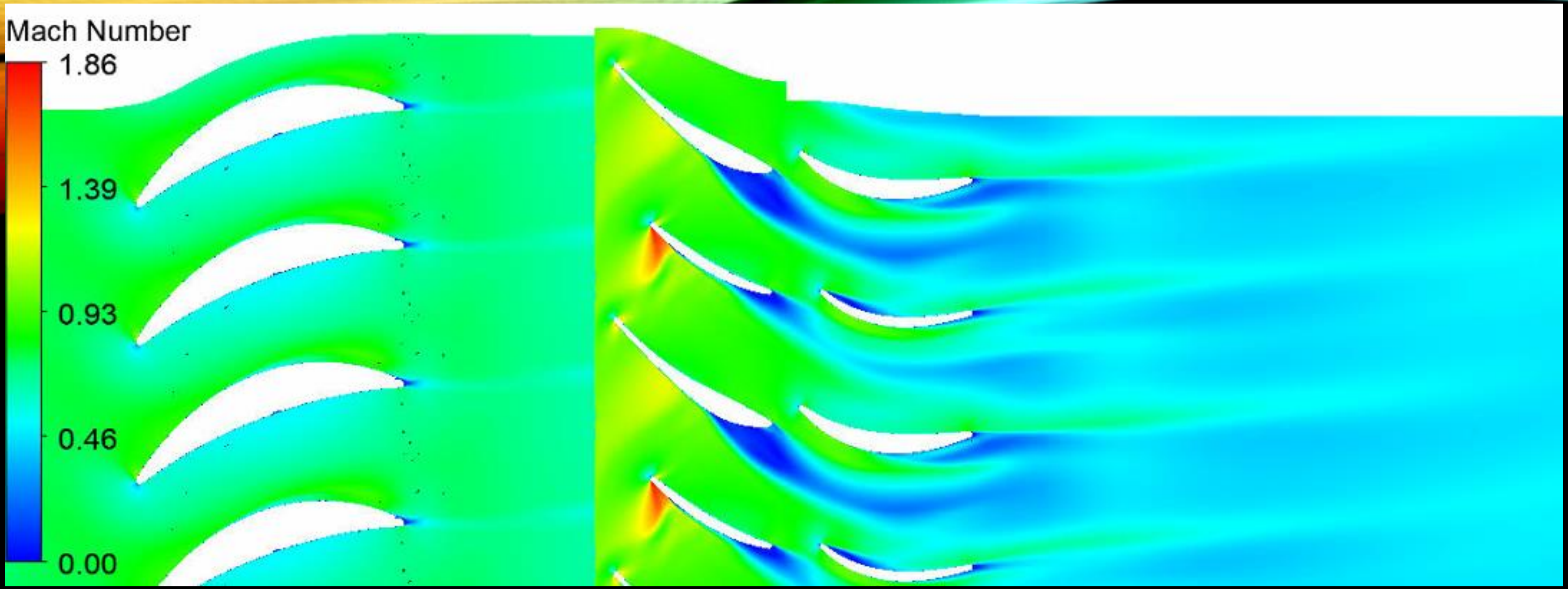



Mach
0.32
118.58
236.85
355.12
473.38
ANSYS
R19.1
Academic
Tandem

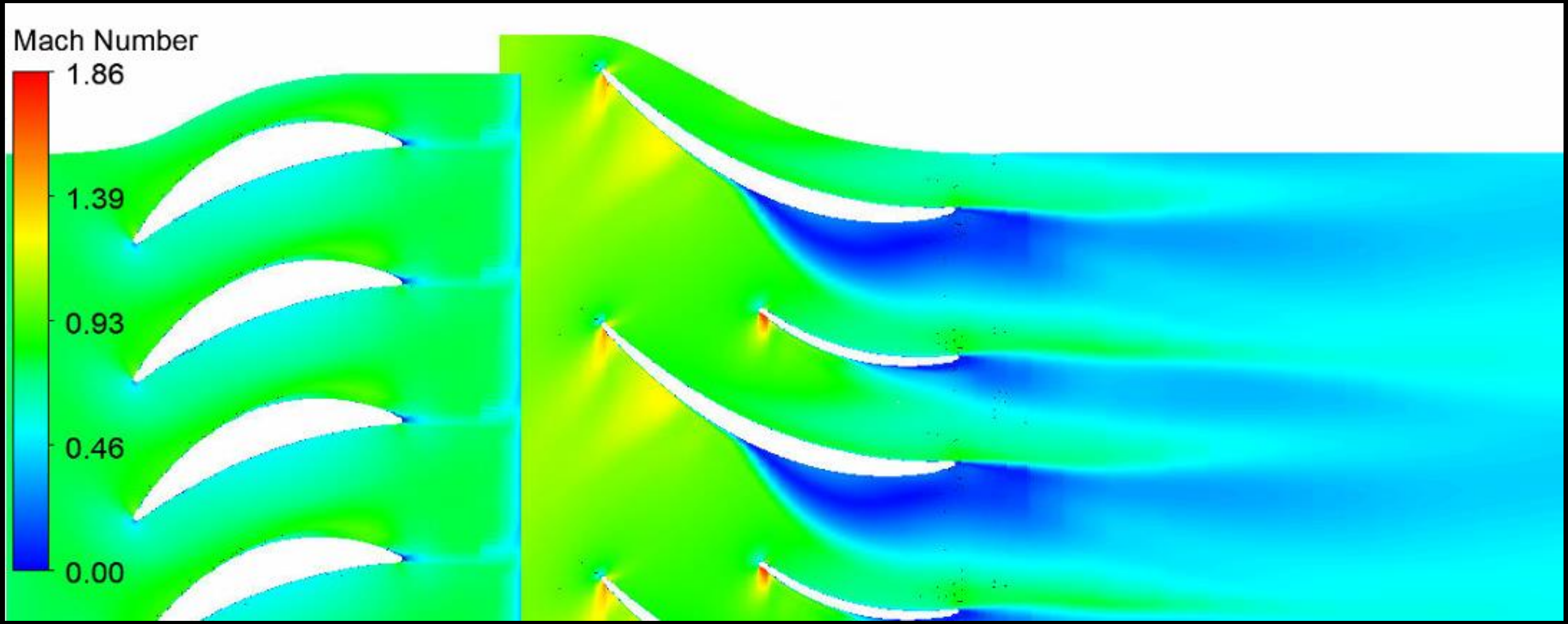

Mach
0.32
118.58
236.85
355.12
473.38
ANSYS
R19.1
Academic
Normal

10% span

Tandem

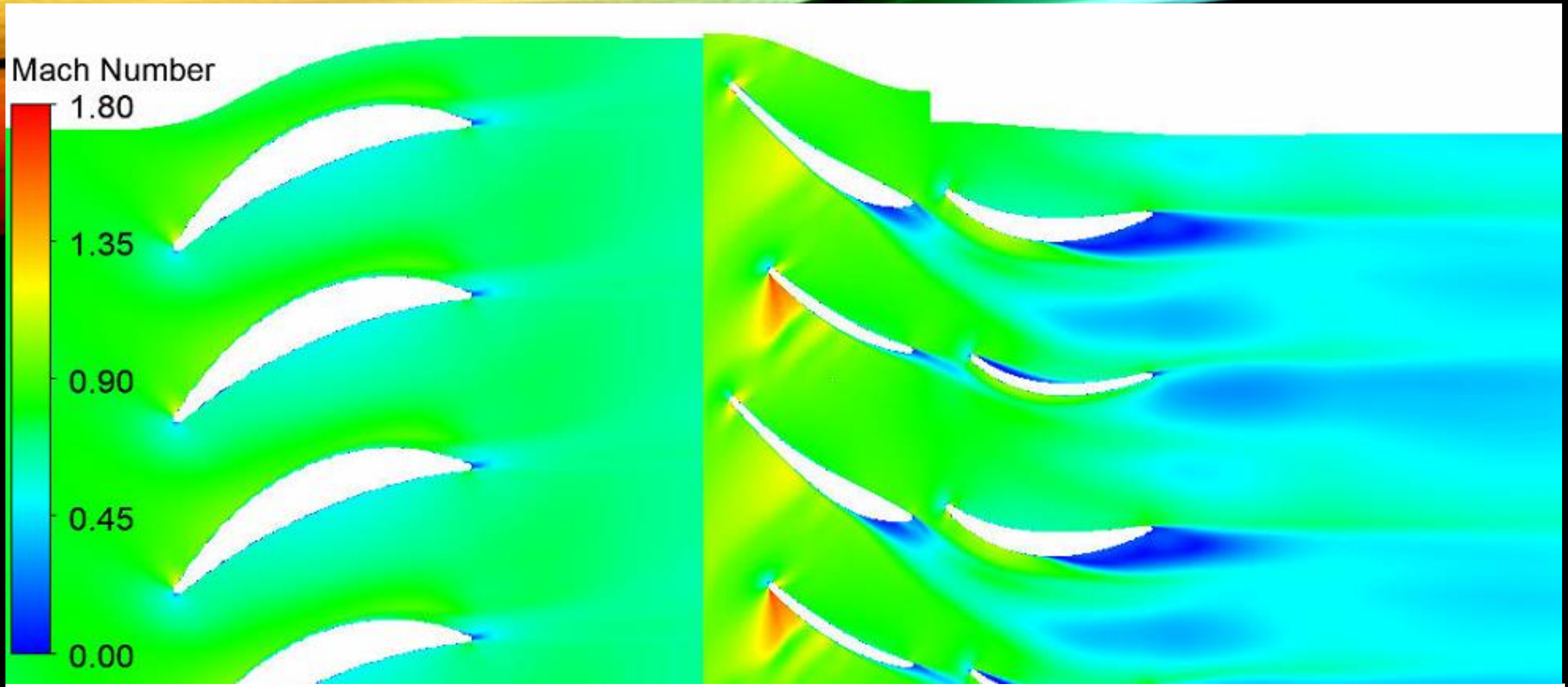


Normal

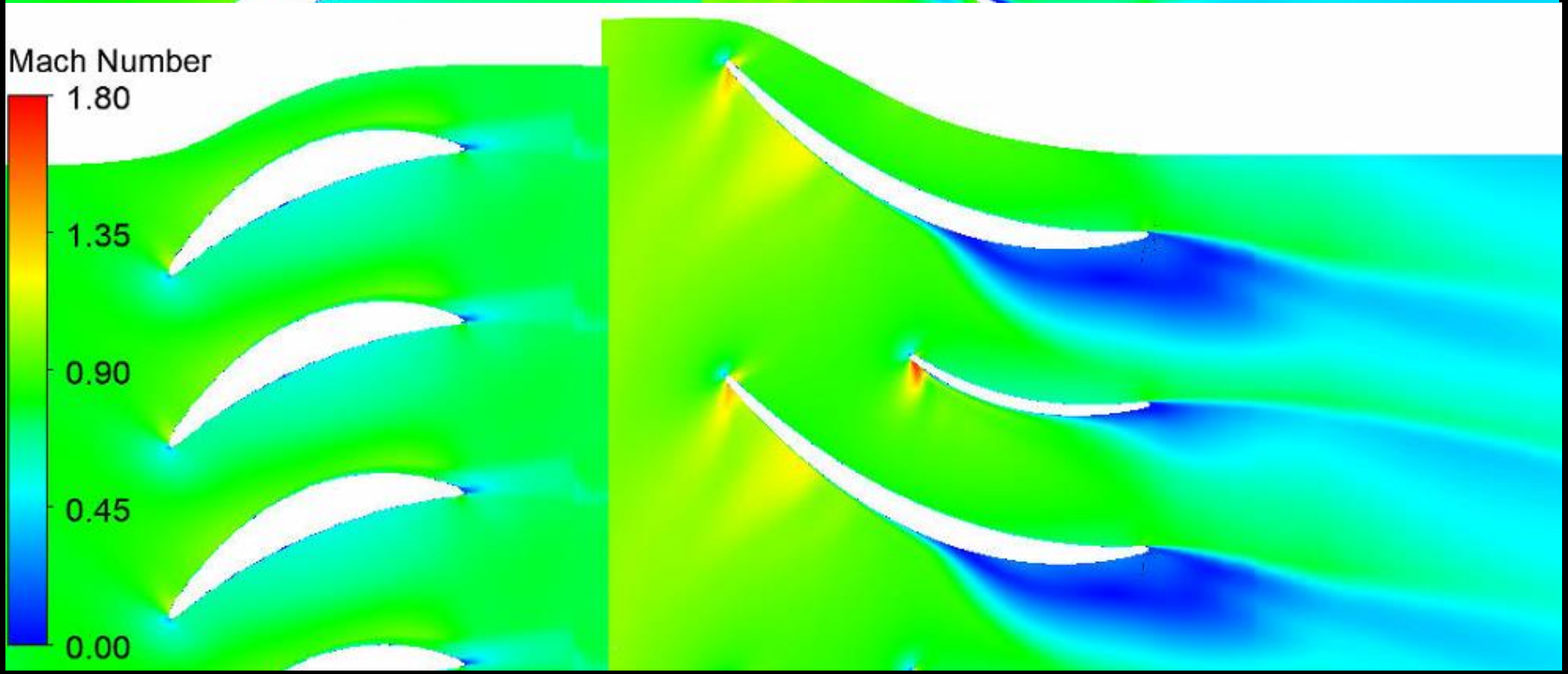


20% span

Tandem

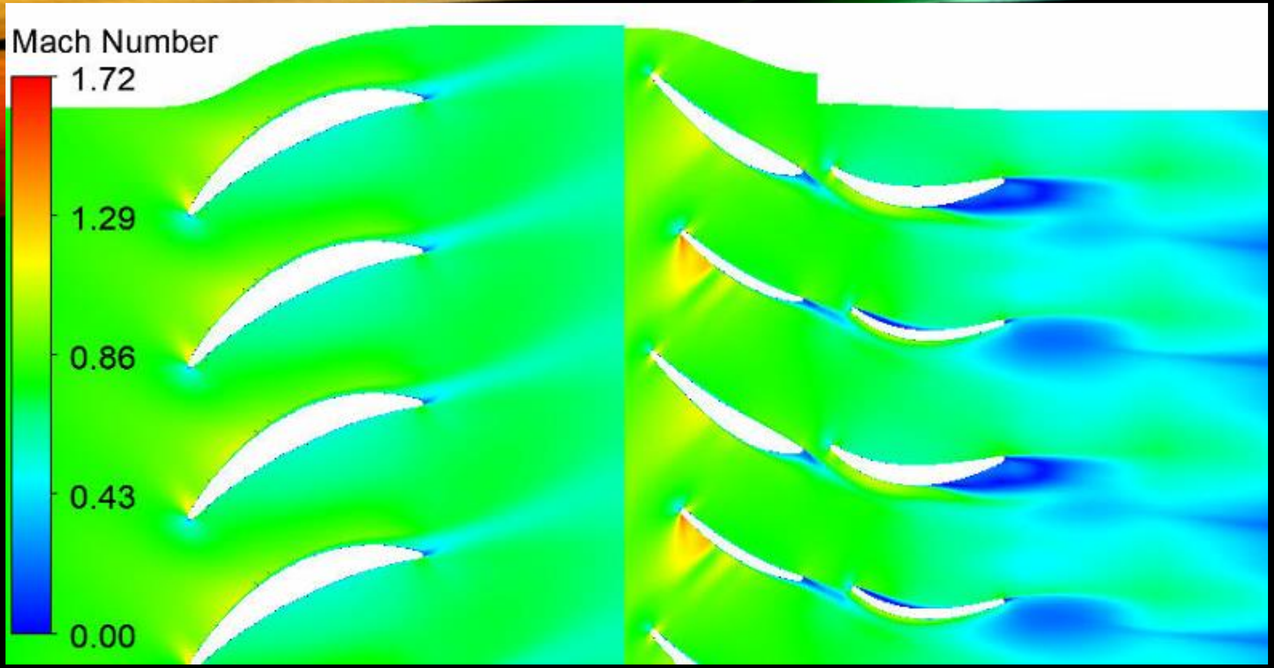


Normal

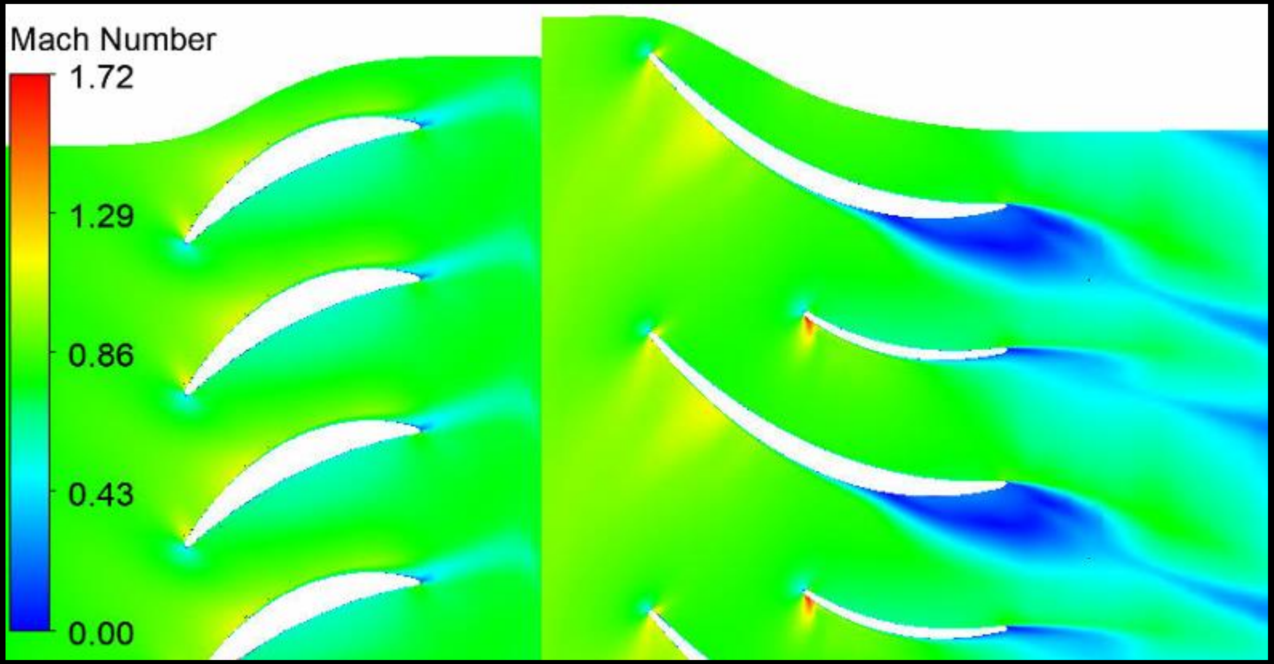


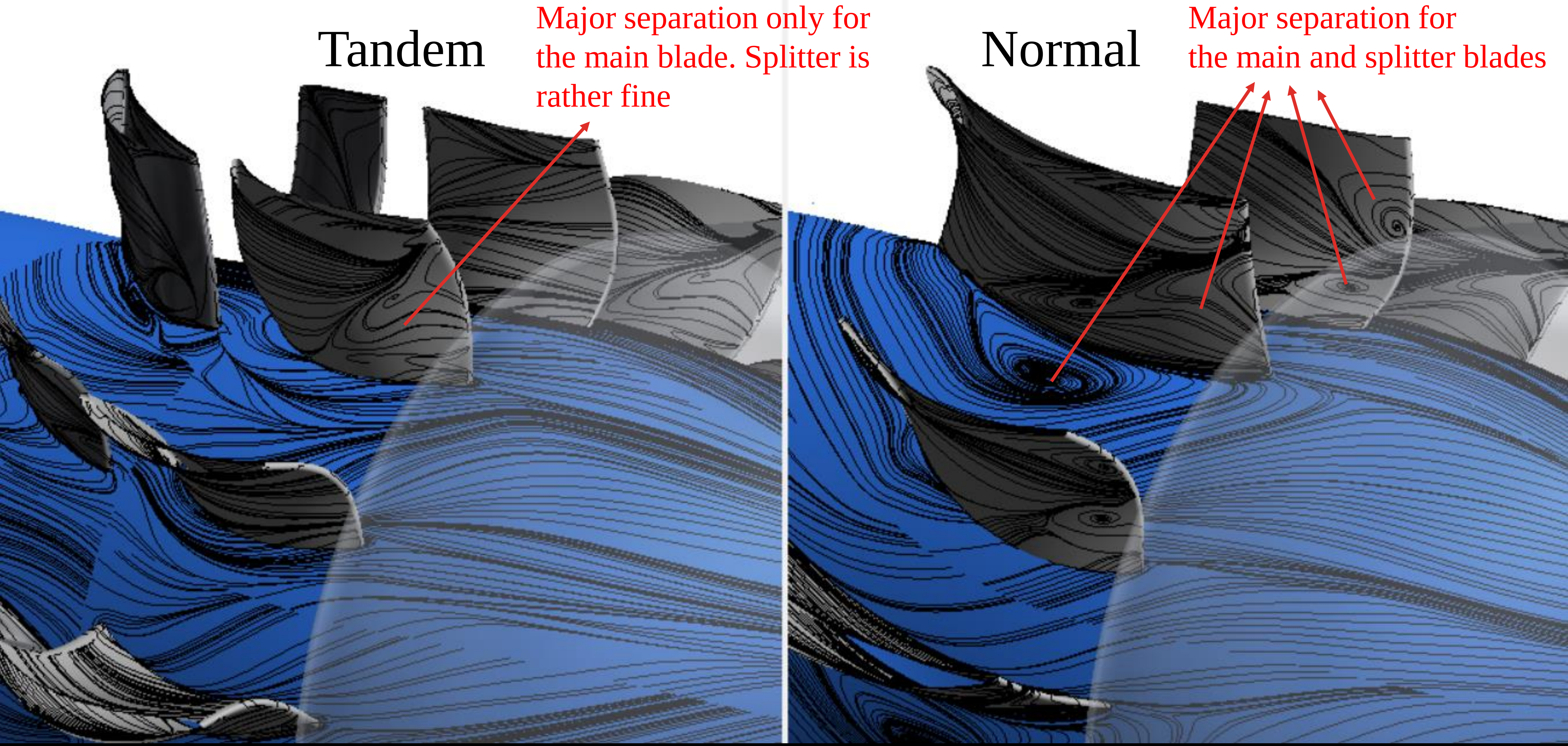
30% span

Tandem



Normal





Tandem
Major separation only for the main blade. Splitter is rather fine
Normal
Major separation for the main and splitter blades

THANK YOU FOR LISTENING

Any questions?