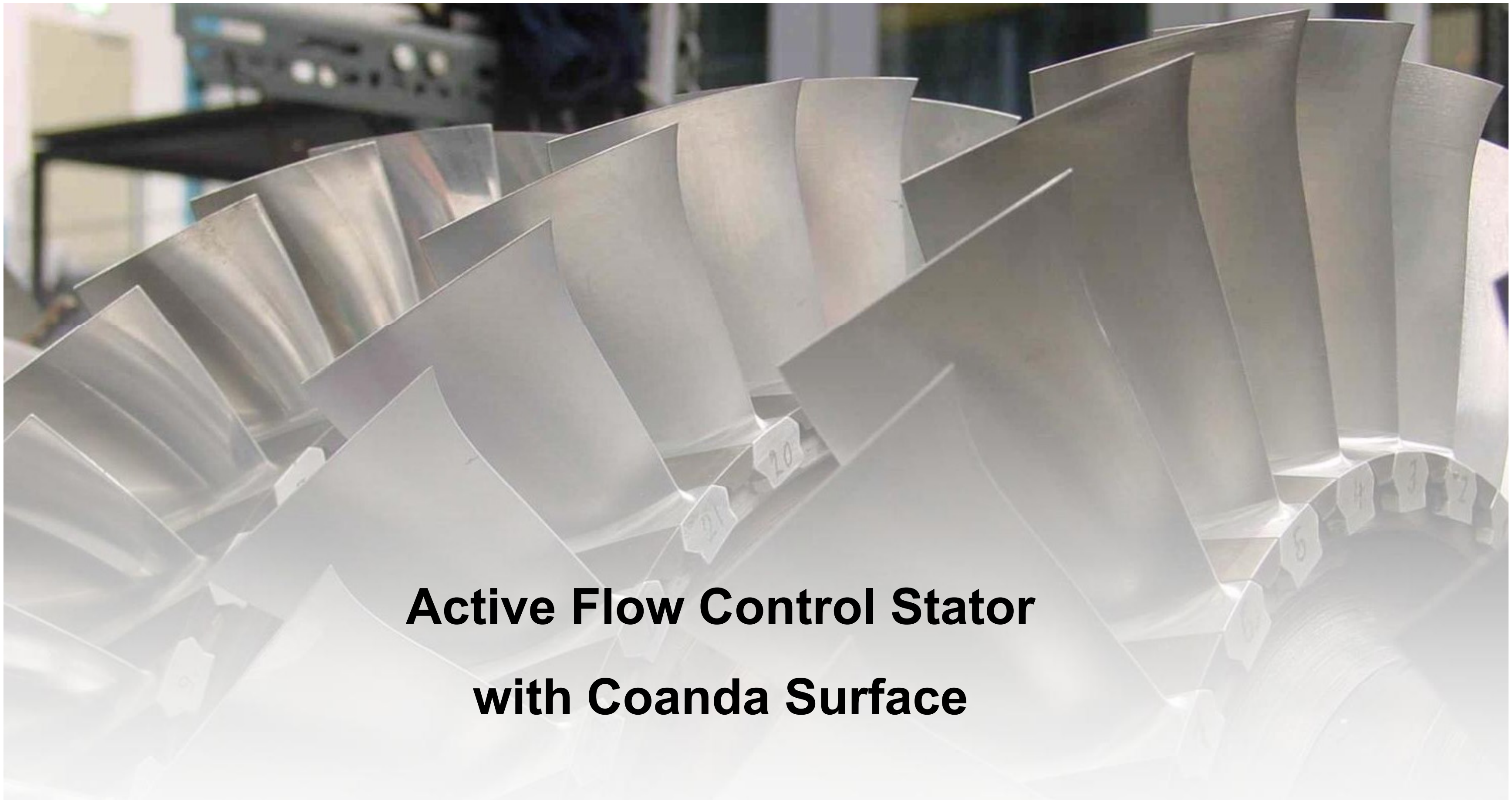

# Active Flow Control Stator with Coanda Surface

## DESIGN OF A LOW SOLIDITY FLOW-CONTROL STATOR WITH COANDA SURFACE IN A HIGH SPEED COMPRESSOR

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Prof. Dr. Seume
Institute of Turbomachinery and Fluid Dynamics

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## Introduction:

- Active Flow Control increases the permissible aerodynamic loading
- Curved surface near the trailing edge ("Coanda surface")
  - increases turning → higher pressure ratio
  - controls boundary layer separation → increased surge margin

## Objective:

Reduce the number of vanes or compressor stages.

## Constraints:

1. In a real compressor, the vane must still function entirely without blowing.
2. Maintain the flow exit angle of the reference stator despite the resulting increase in stator loading.

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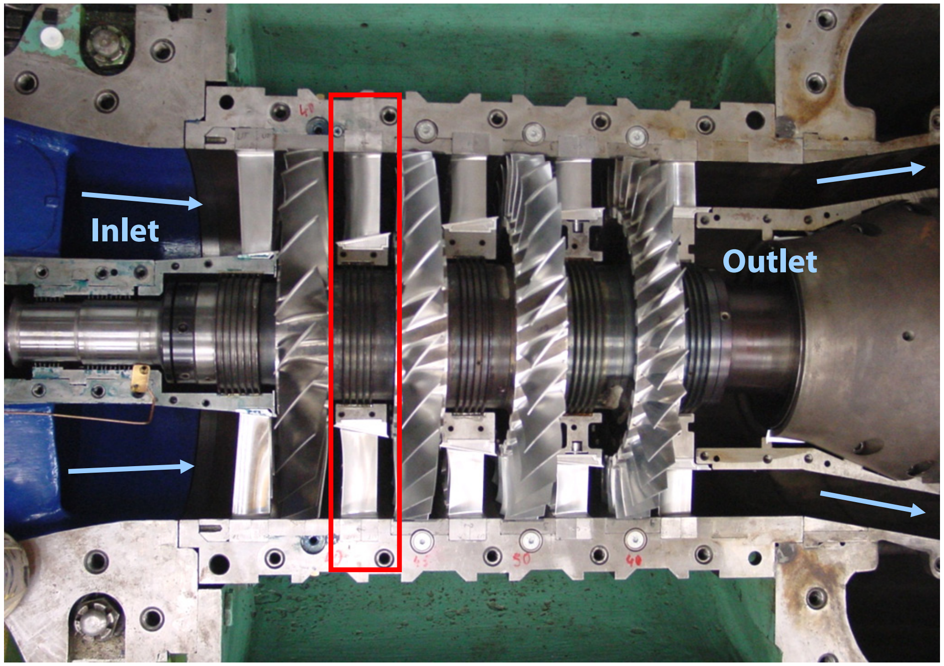
# Compressor test rig at TFD
# Performance Data




| | |
|---|---|
| Design speed | 17100 rpm |
| Mass flow | 7.81 kg/s |
| Total pressure ratio | 2.75 |
| Isentropic efficiency | 90.5% |

| | |
|---|---|
| Power | 950 kW |
| Flow coefficient 1st stage | 0.71 |
| Loading 1st stage | 0.44 |
| Reynolds number (stator 1) | 4 x $10^5$ |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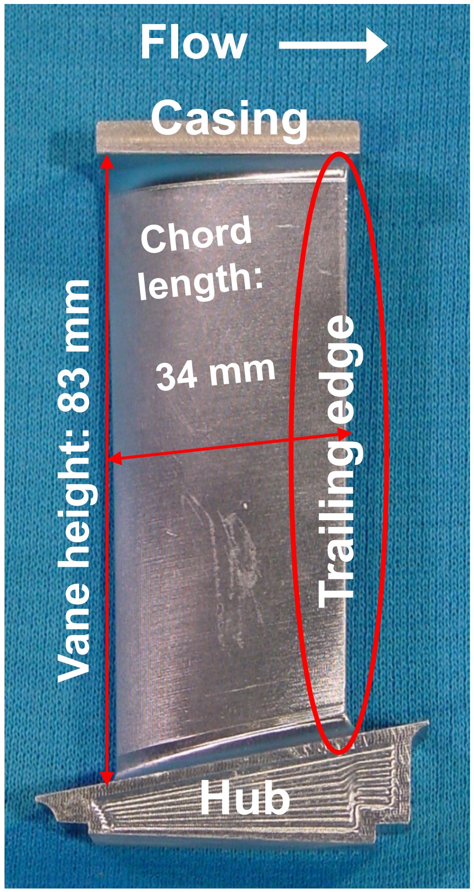
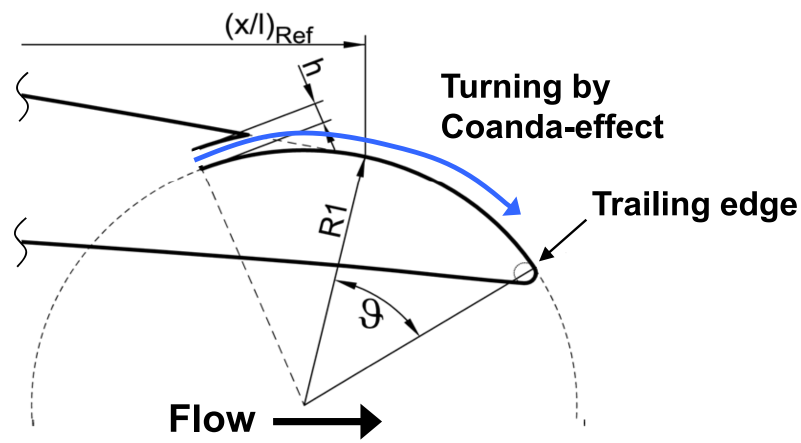
# Concept and Design of the Coanda Stator

## Definition of the Coanda Surface at the Trailing Edge




- Chord length in mid-span, Stator 1: $l = 34$ mm
- Thickness to chord ratio: 8%
- **Slot height** $h = 0.2$ mm
- Slot height/Coanda-radius: $h/R1 = 2\%$
- **Coanda-radius:** $R1 = 10$ mm

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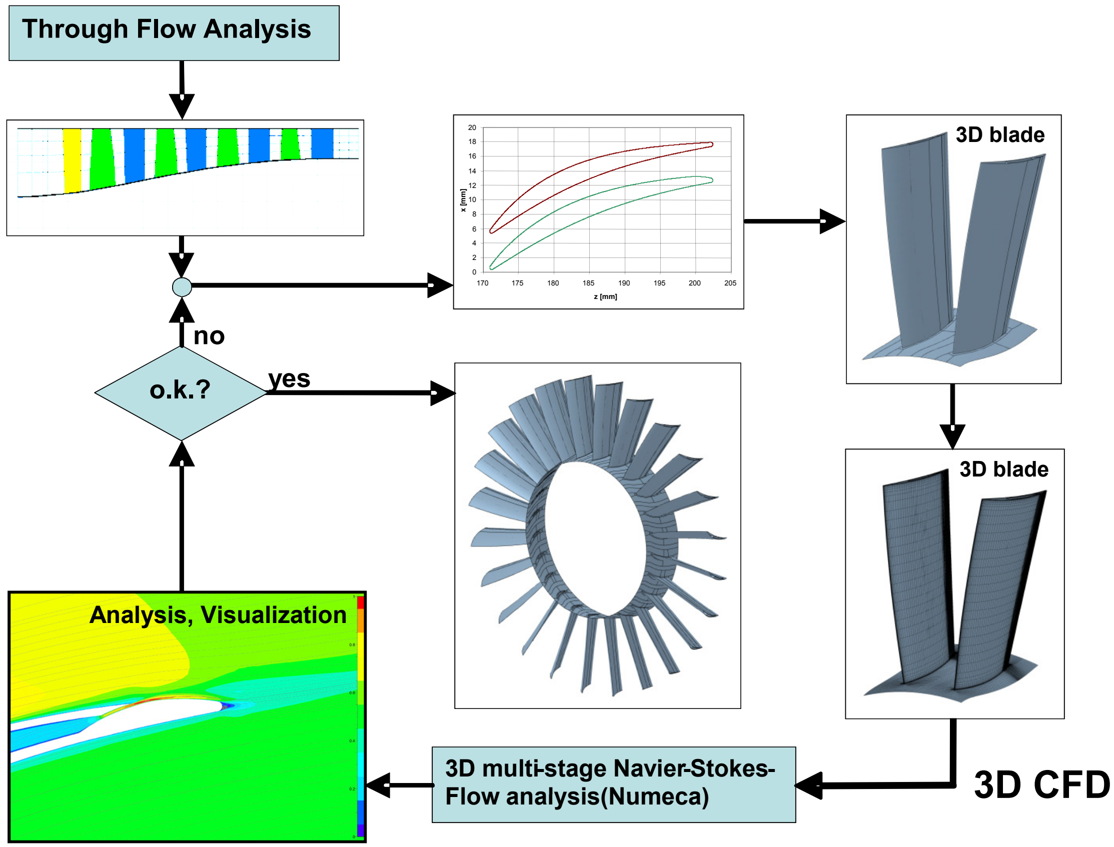
# Concept and Design of the Coanda Stator

## Basic Design Loop



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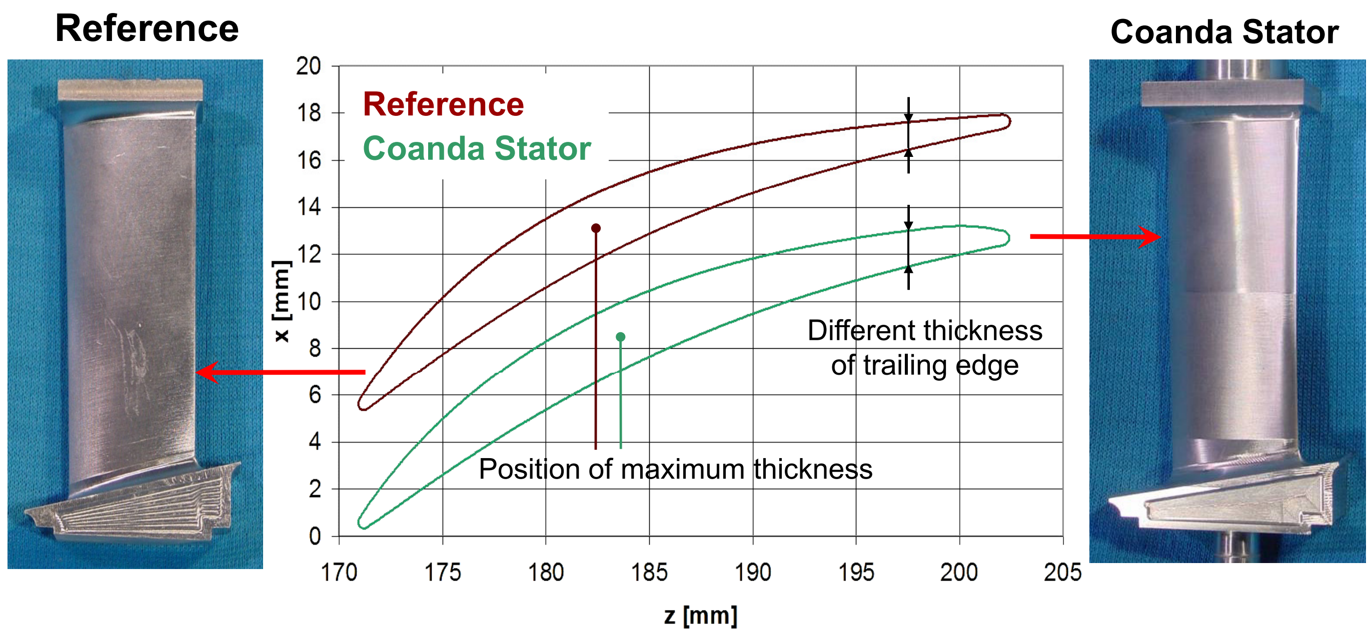
# Concept and Design of the Coanda Stator

## Profile Section in Mid-Span: Reference and Coanda Stator



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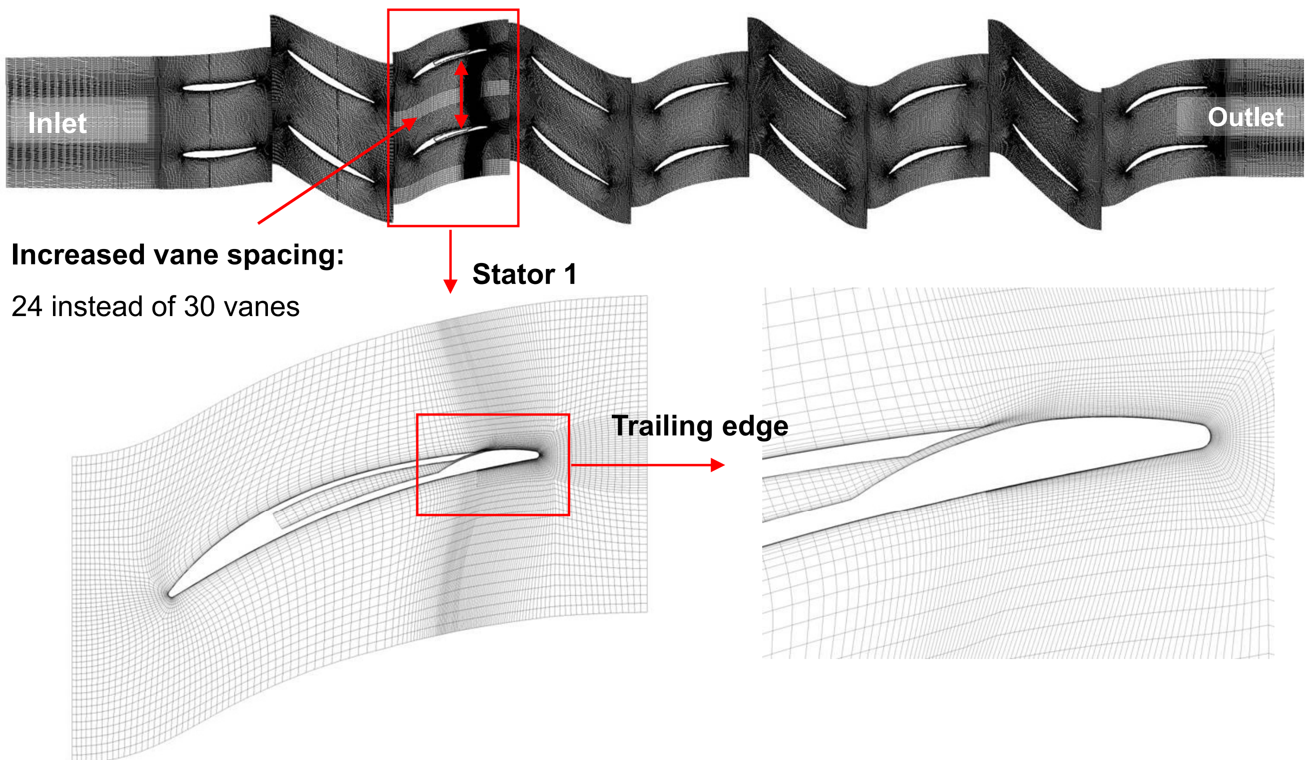
## 3D CFD Simulations

### Mesh for 3D CFD Simulations: Plenum + Slot



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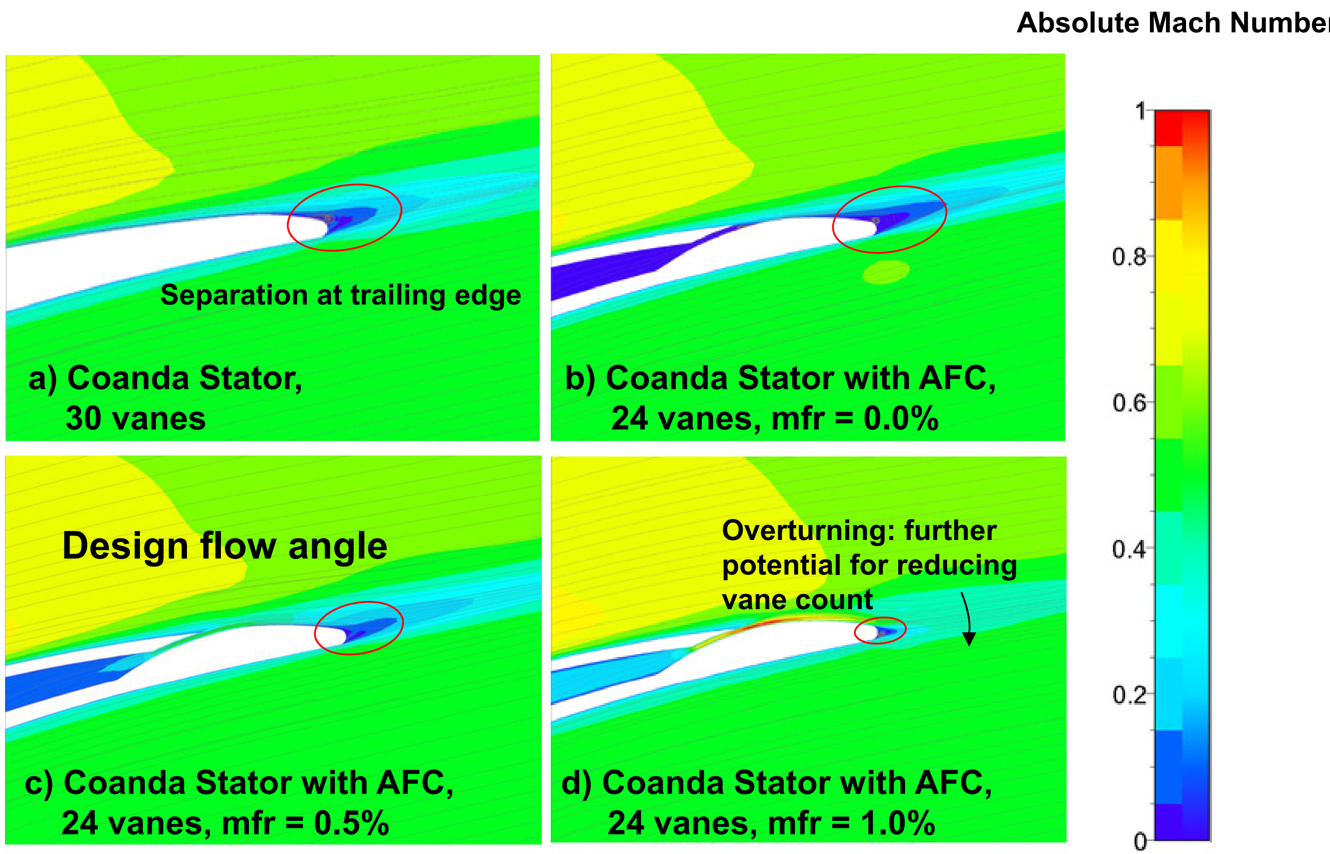
# 3D CFD Simulations

## Mach Number Distribution around Trailing Edge at Mid-Span




Blowing rate: mass flow ratio (mfr) = jet flow / main flow

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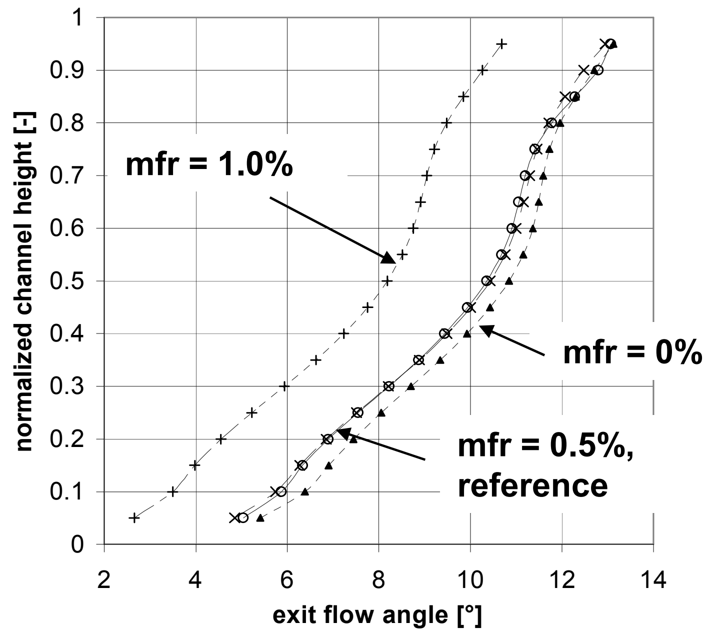
# 3D CFD Simulations

**AFC Stator with Coanda Surface**



## Radial Distribution of the Exit Flow Angle




**→ Reduction of Compressor Stages**

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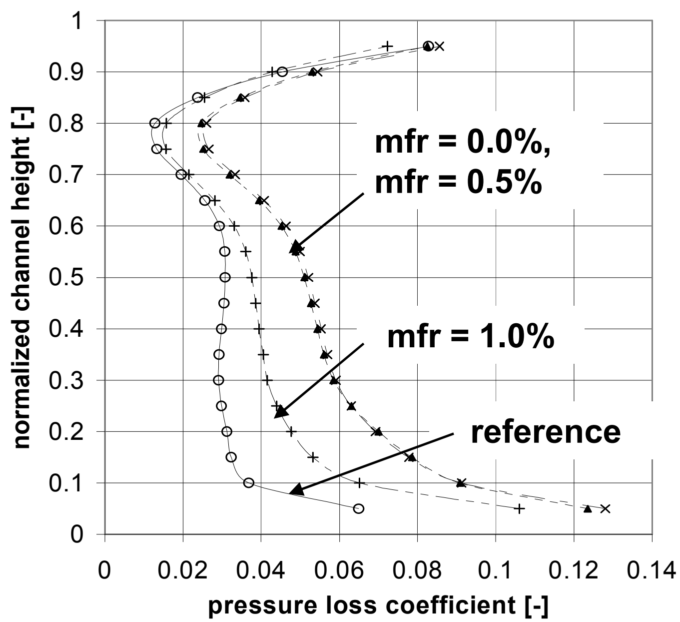
## 3D CFD Simulations

### Radial Distribution of Total Pressure Loss Coefficient




$$\omega = \frac{p_{tot,1} - p_{tot,2}}{p_{tot,1} - p_{stat,1}}$$

**Note:** **momentum of injected flow not accounted for**

**Reduction of Losses → Higher Efficiency**

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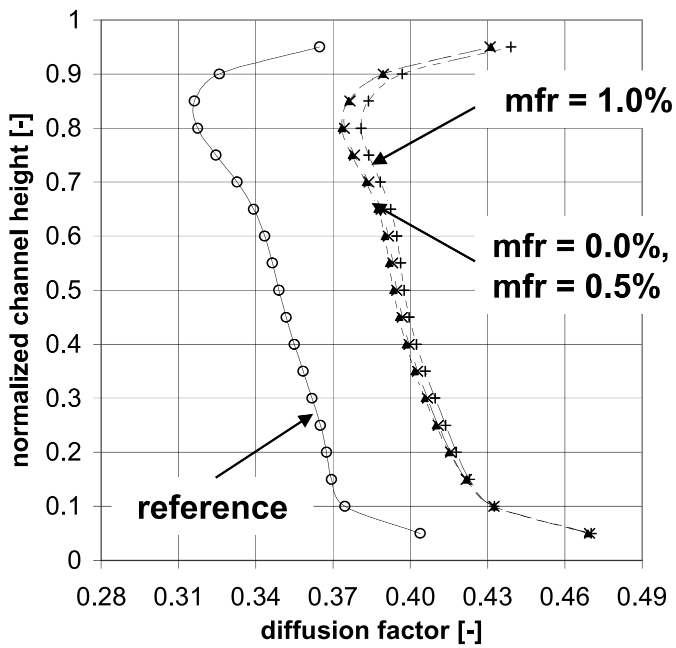
# 3D CFD Simulations

## Radial Distribution of the Diffusion Factor




$$Df = 1 - \frac{w_2}{w_1} + \frac{v_{\theta 2} - v_{\theta 1}}{2\sigma w_1}$$

**Increased Permissible Aerodynamic Loading by 13% at the Design Point**
**→ Better Part Load Performance?**

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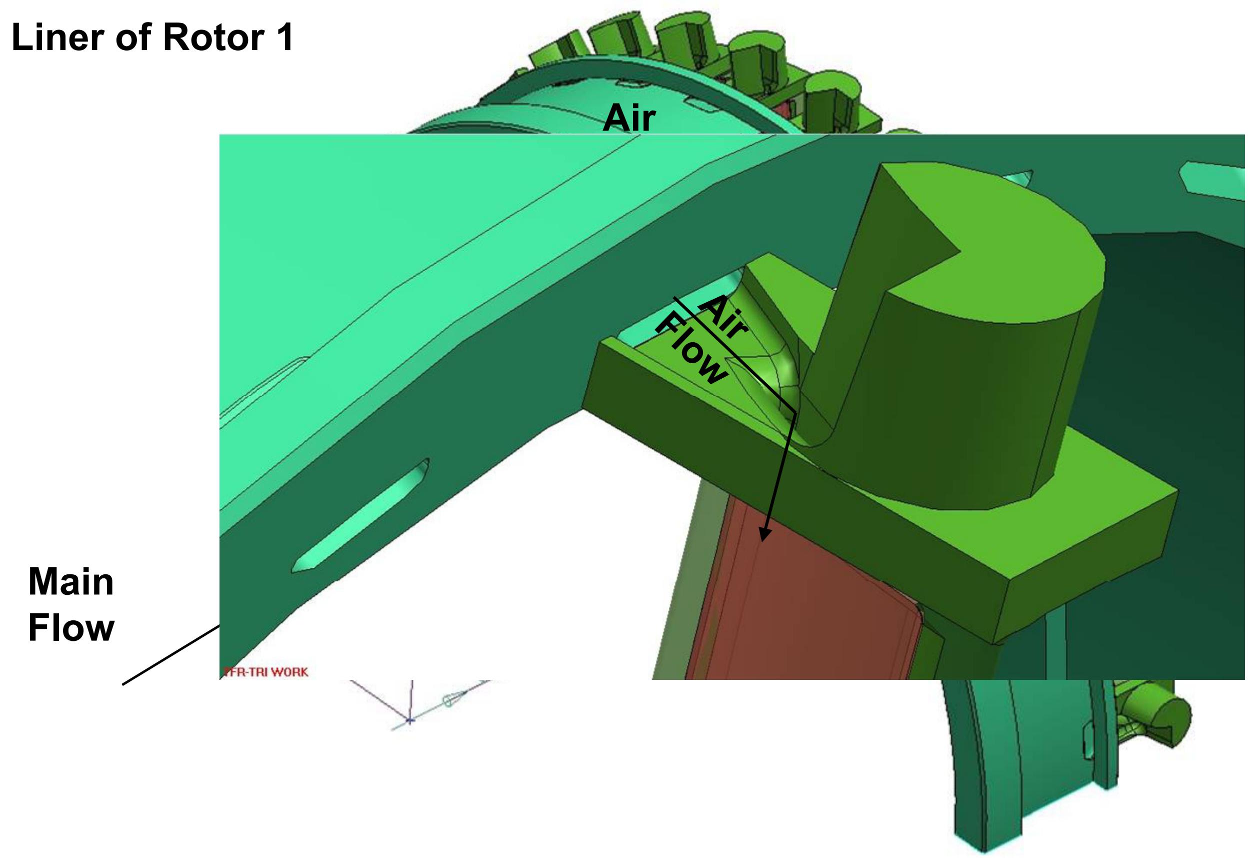
slide 12 / 18

# Design, Manufacture and Integration in Compressor

## Air Supply for Flow Control Stator



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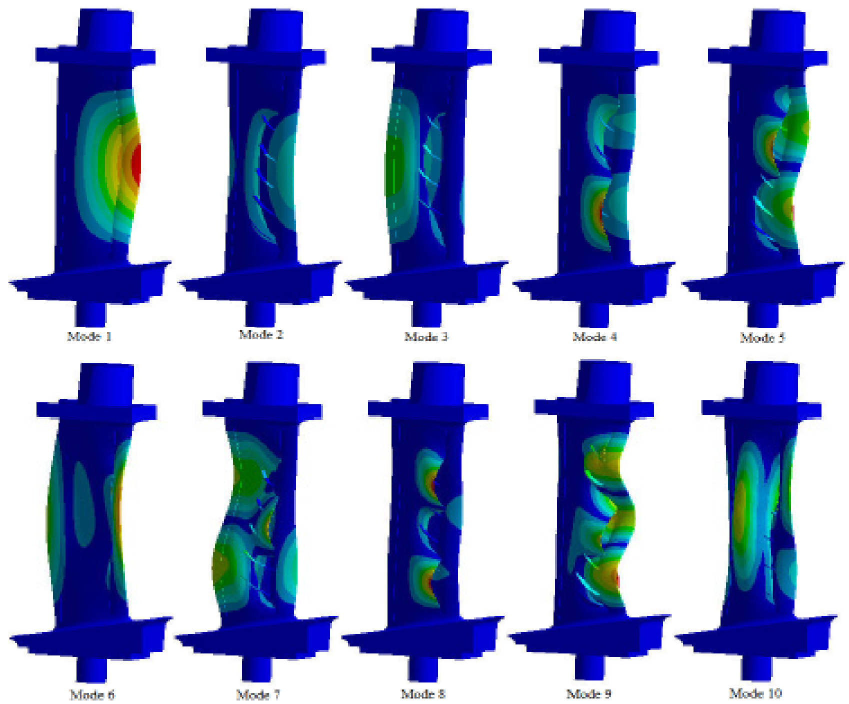
# Design, Manufacture and Integration in Compressor

## FEM-Modal Analysis of Coanda Stator



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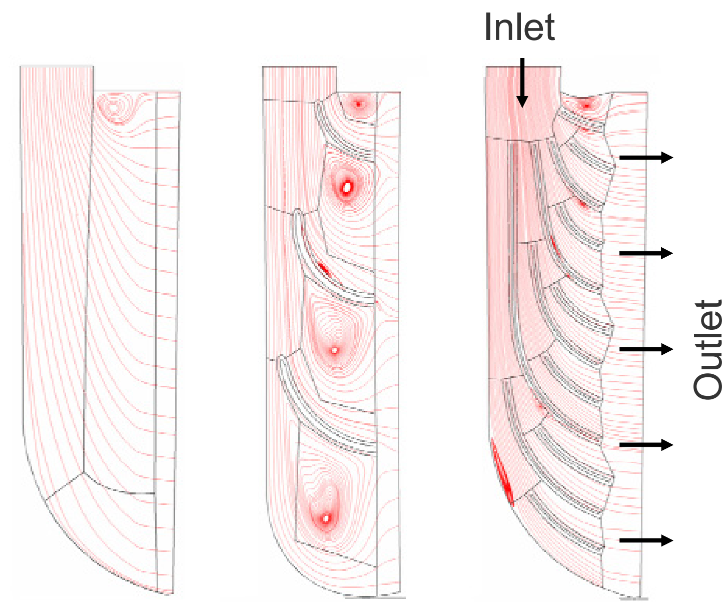
# Design, Manufacture and Integration in Compressor

## Iterative Design of Plenum in Coanda Stator




Aerodynamics: loss-minimized flow in plenum of Coanda stator

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# Design, Manufacture and Integration in Compressor

## Coanda Stator

- Two parts: vane body and cover
- Laser welded: low warpage; durable and leak-proof
- Seamless surface: finish after welding

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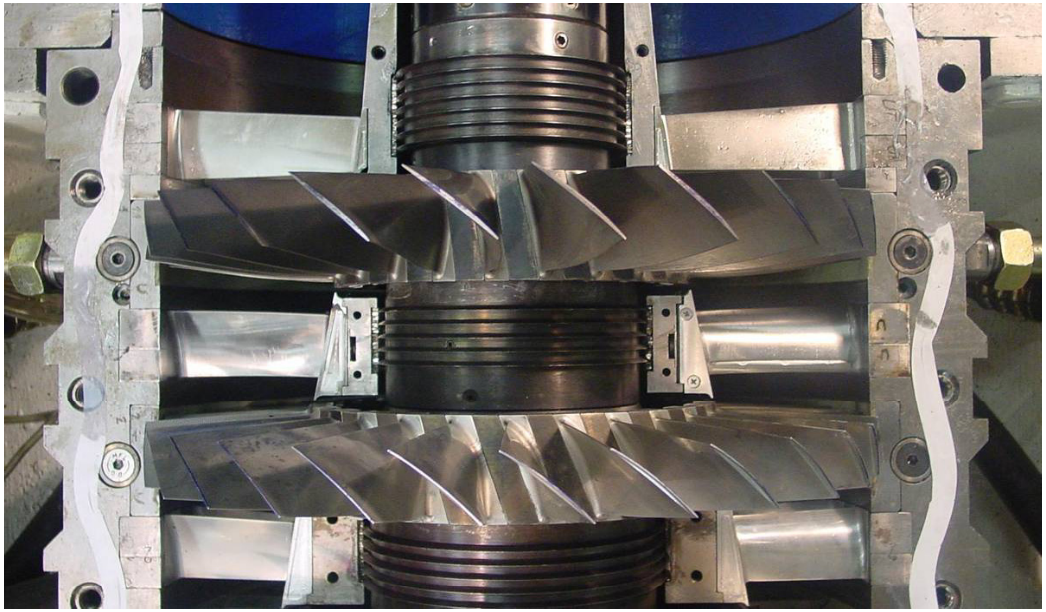
# Design, Manufacture and Integration in Compressor

## Coanda Stator in First Stage of Compressor



No change of geometry except for Coanda Stator

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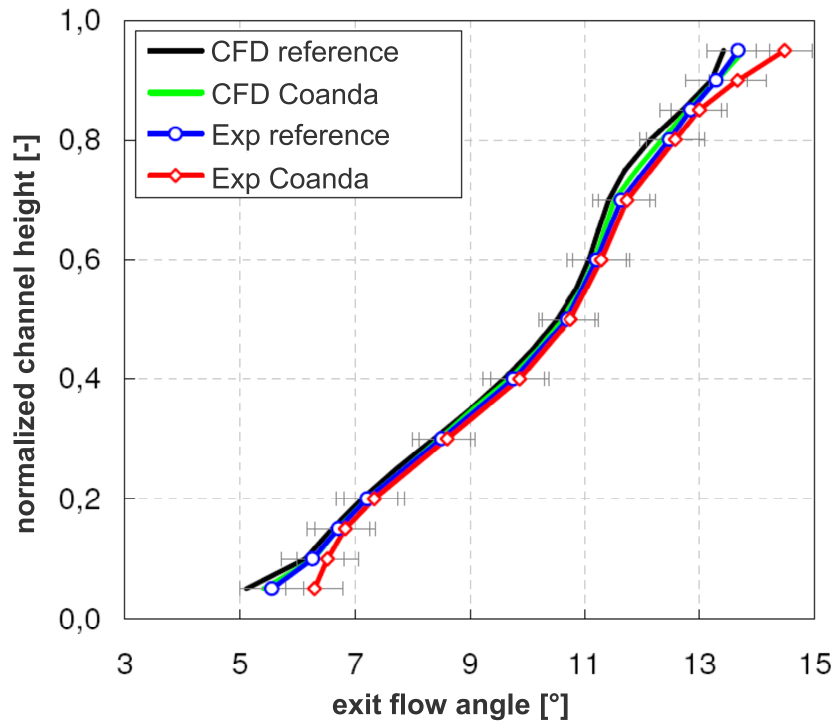
# Experimental Results

## Radial Distribution of the Exit Flow Angle



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# Conclusions

- **Turning of the Coanda-surface augmented by blowing**

  **→ Higher stage pressure ratio**

- **0.5% of Compressor Inlet Mass Flow are sufficient to reduce vane count by 20%**

  **→ Reduced number of stages, reduced weight, lower investment cost possible**

- **Aerodynamic performance confirmed for aerodynamic design point**

  **→ Increased Permissible Aerodynamic Loading by 13%**

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