Design Study of a Two-Parted Variable Inlet Guide Vane with an Optimized Axial Gap

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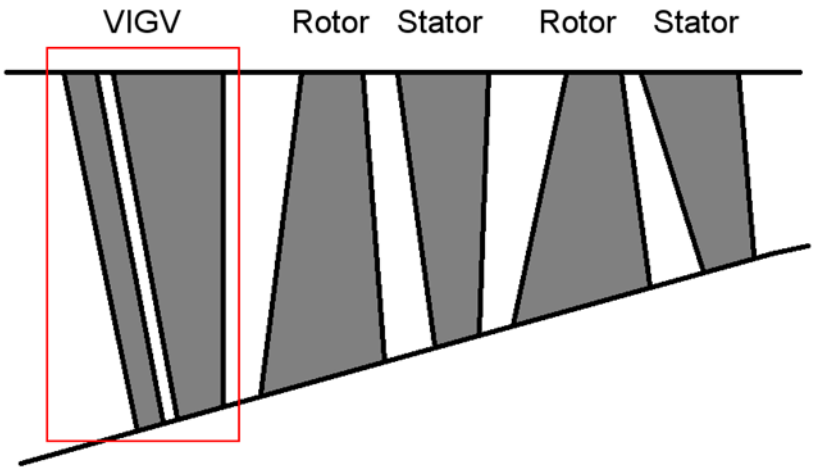
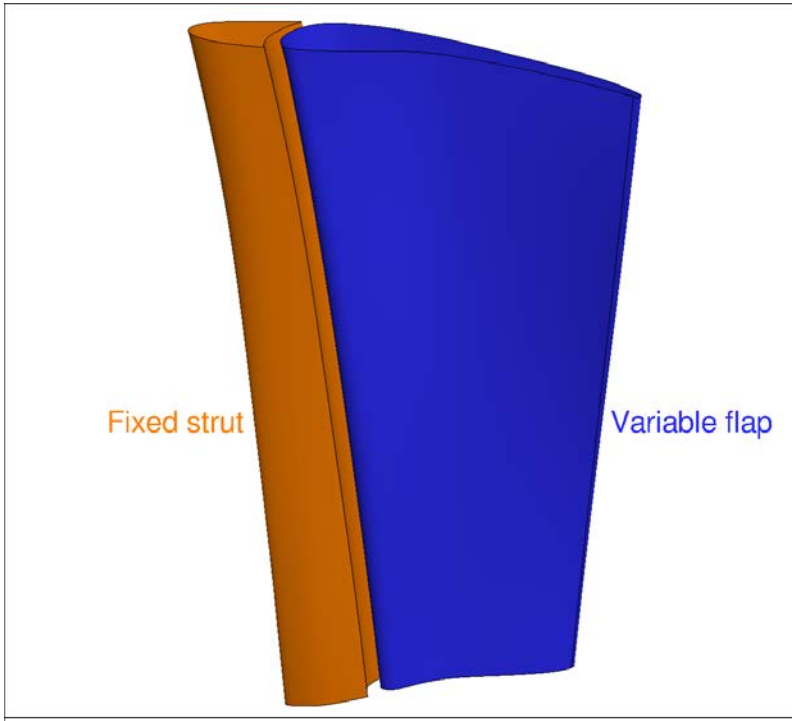
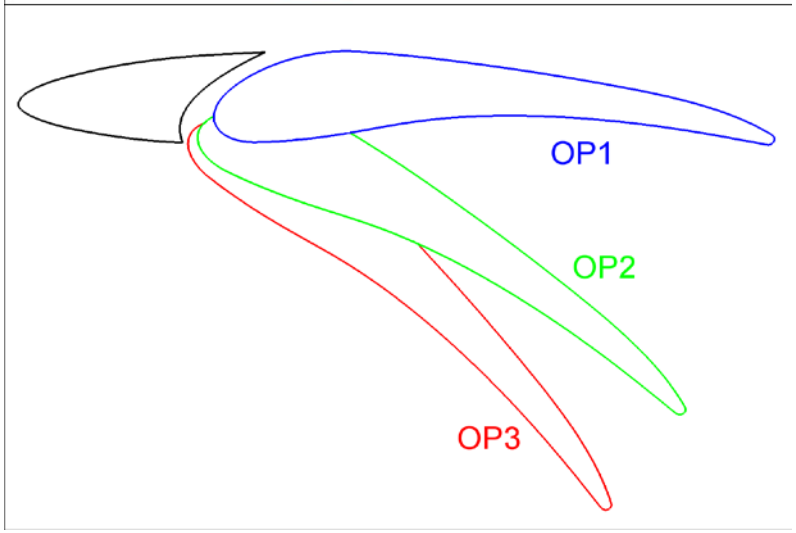
1. Introduction

Objectives: reduce the total pressure losses and maintain the deflection



- VIGV is located at the beginning of the compressor channel
- VIGV is composed of two parts: the fixed strut and the variable flap
- VIGV is studied on 3 operating points





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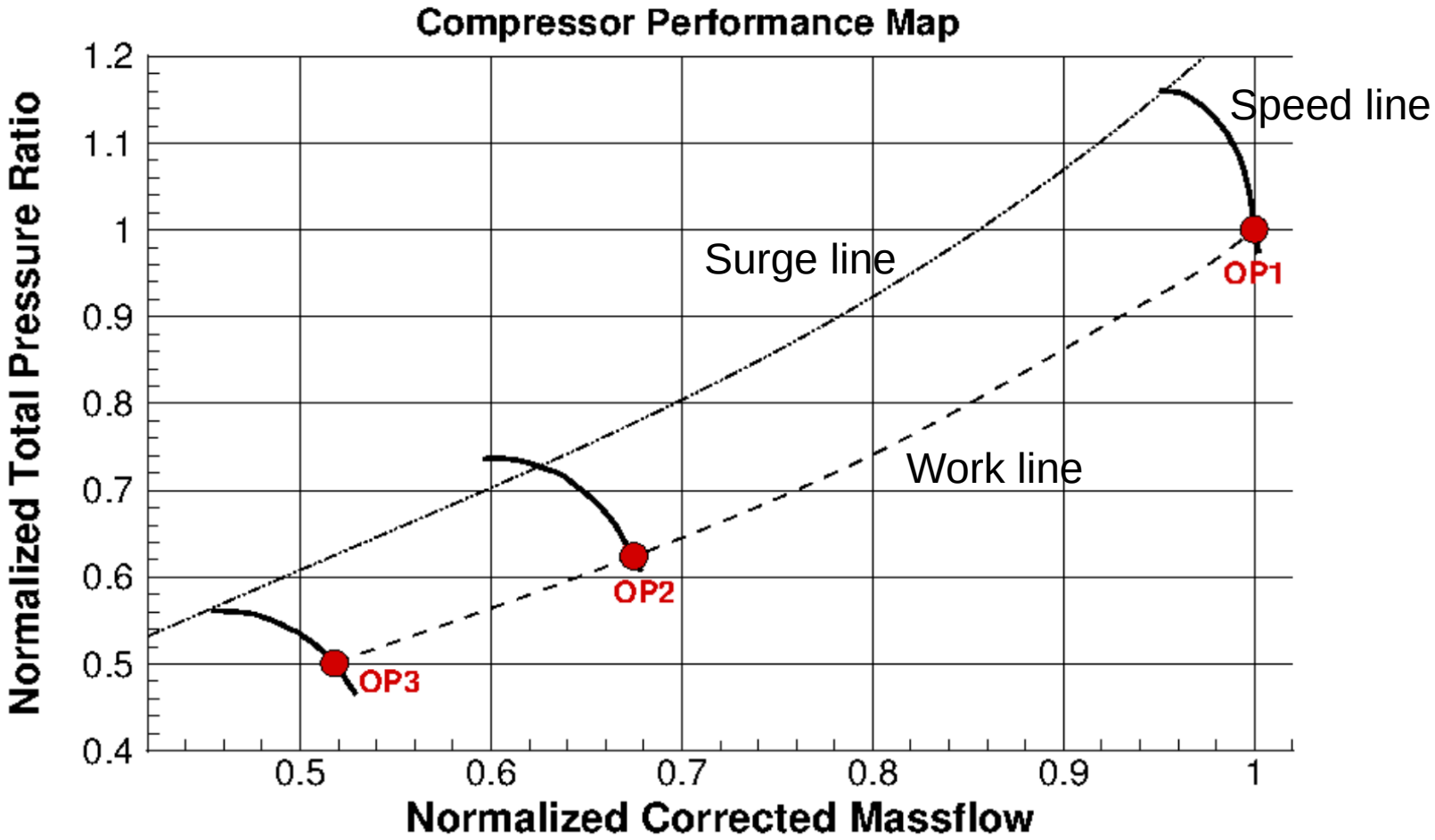
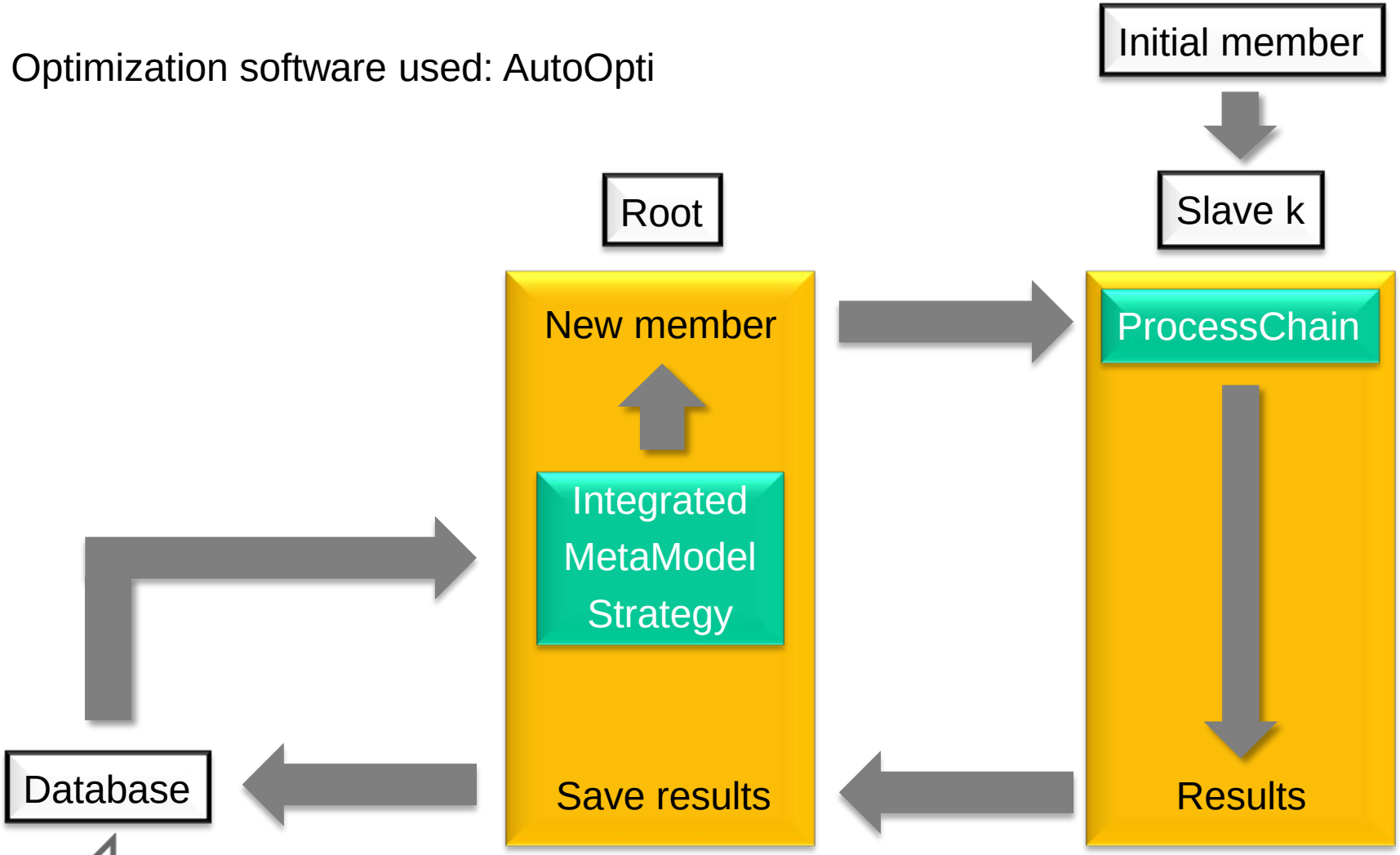


2. Optimization description

Optimization model I Processchain I Reference Member

Optimization software used: AutoOpti



2. Optimization description

Optimization model I **Processchain** I Reference Member

1	• BladeGenerator	Design the shape of blade geometry
2	• SplitBlade	Define the shape of the axial gap
3	• GTA	Create the calculation volume
4	• Centaur	Construct the mesh
5	• GMC	Set the boundary conditions
6	• TRACE	Conduct the calculations

2. Optimization description

Optimization model I **Processchain** I Reference Member

1. BladeGenerator
2. SplitBlade
3. GTA
4. Centaur
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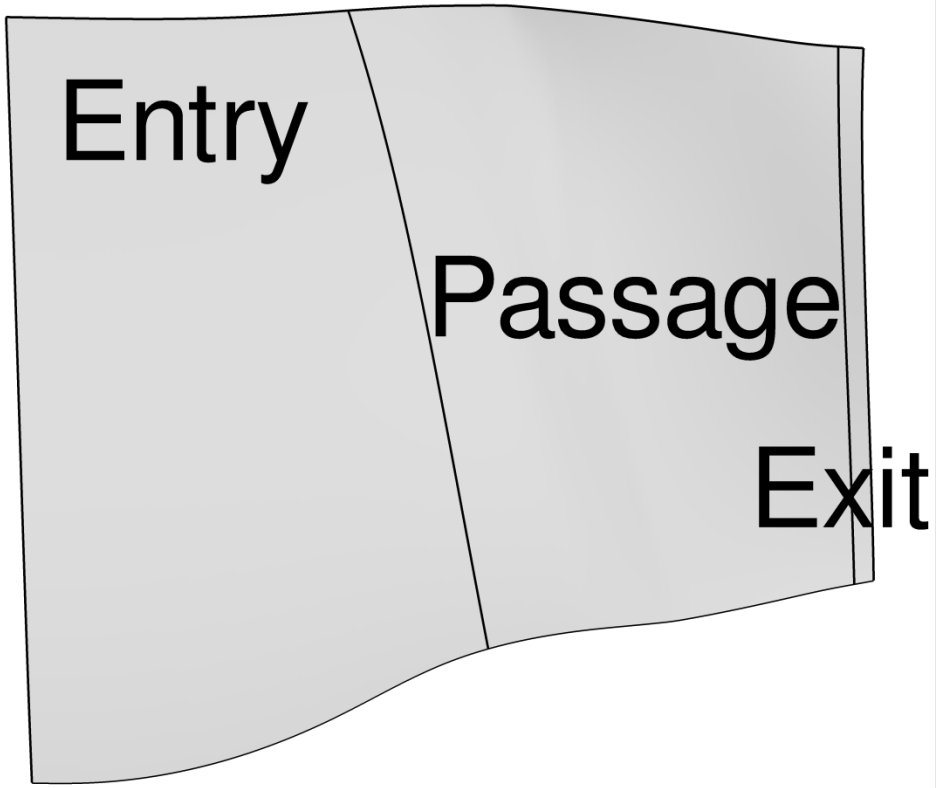

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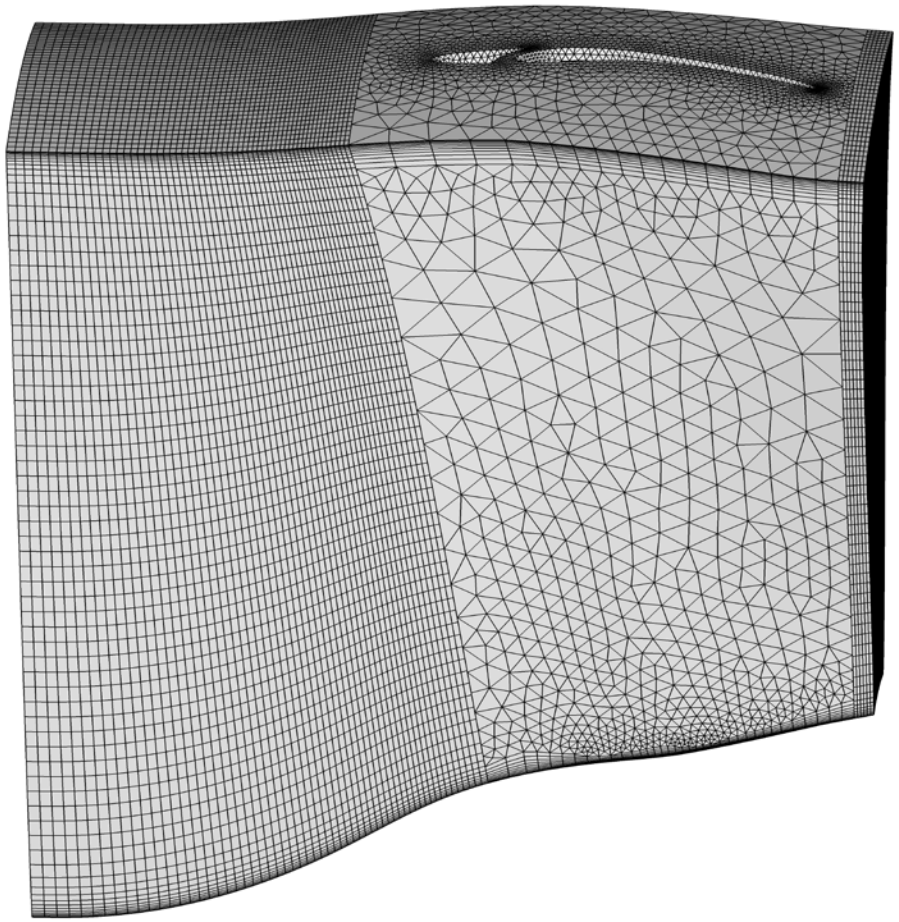

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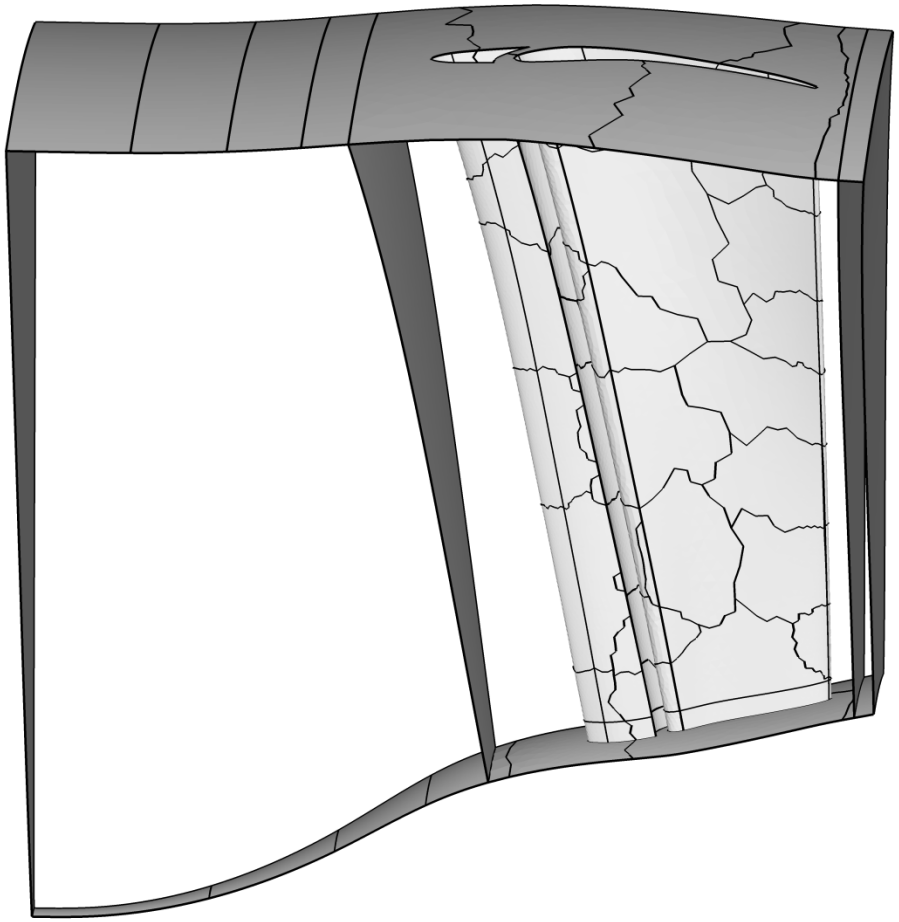

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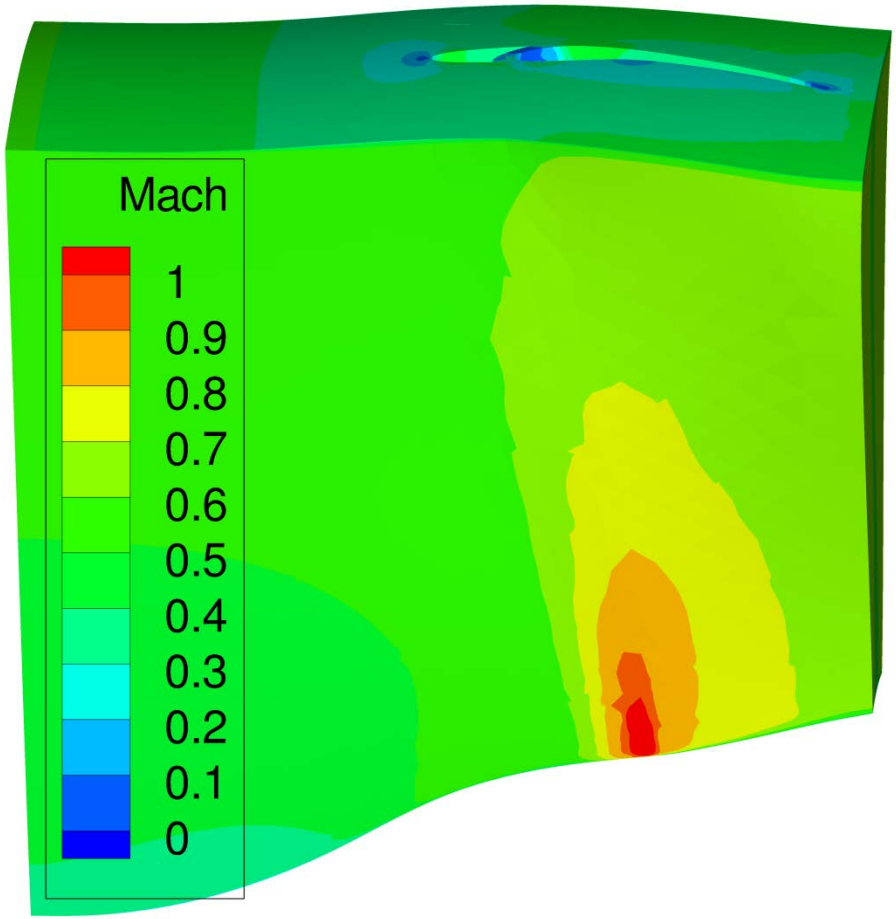

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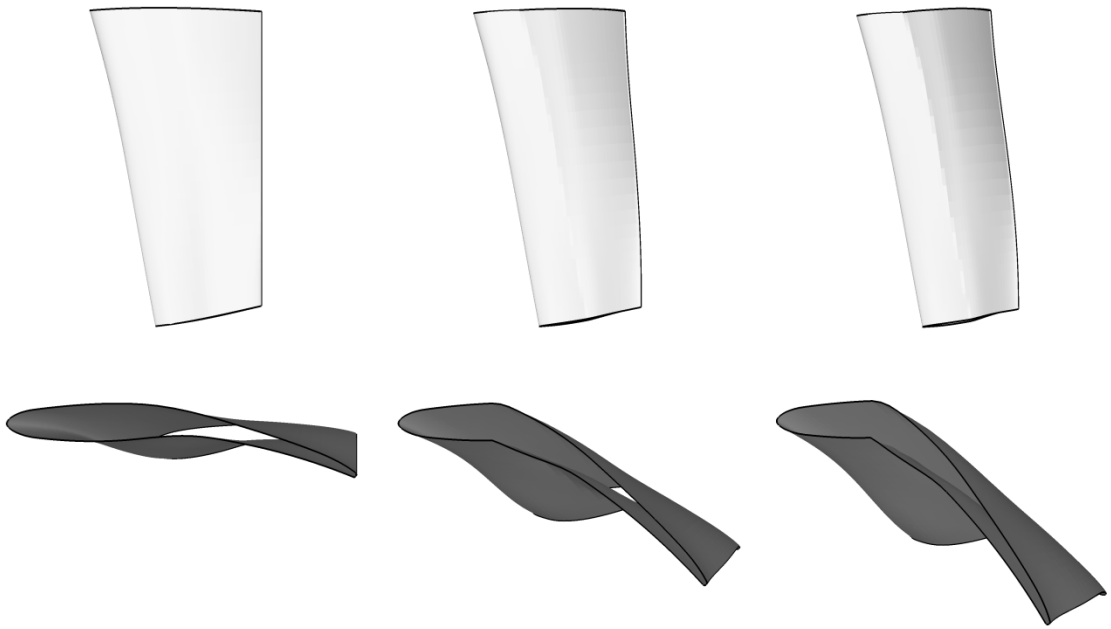


OP1 OP2 OP3

	ω OP1	ω OP2	ω OP3
Ref. Member	0.1192	0.0968	0.0548

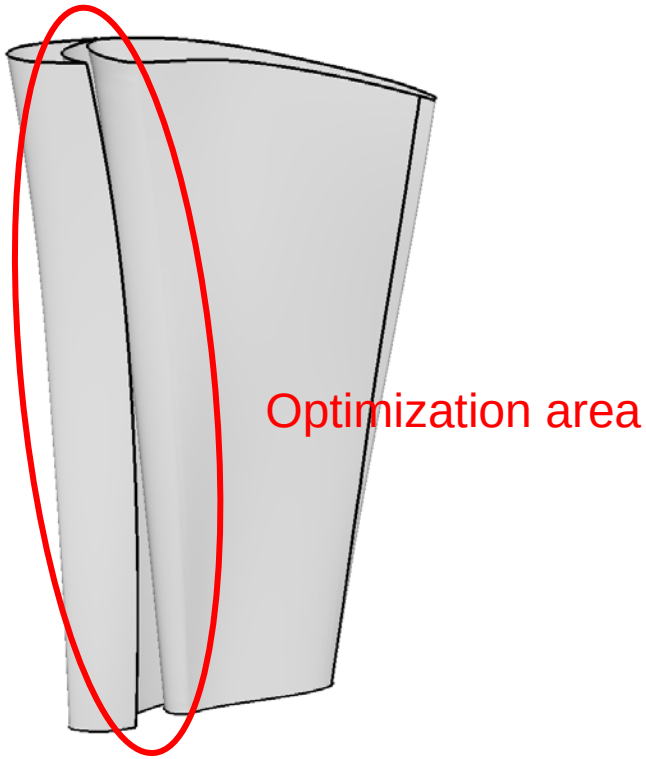
* from „*Design studies of a variable inlet guide vane in a 2.5-stage low pressure compressor*, Gouezou, DLR report 2016“

3. Optimization 1: Axial gap only

Description | Free parameters | Results

Objective: Reduce the total pressure loss coefficients

Reference blade



Processchain

1. SplitBlade
2. GTA
3. Centaur
4. GMC
5. TRACE

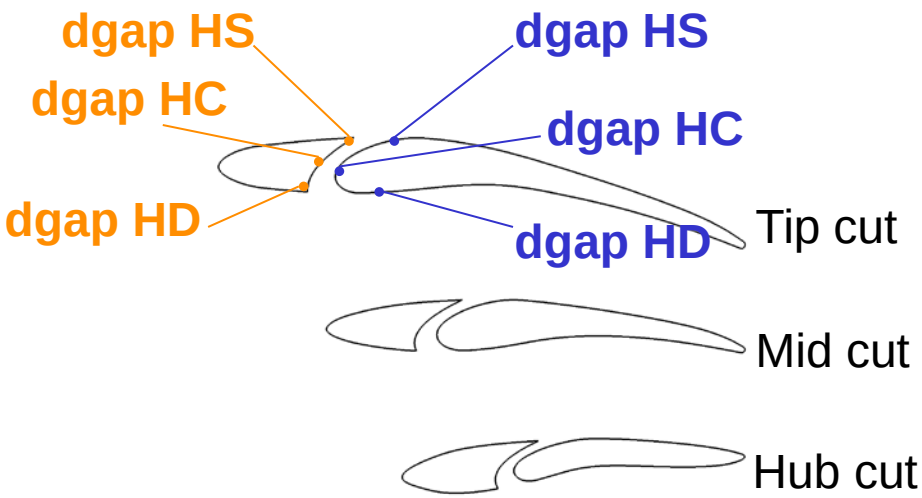
3. Optimization 1: Axial gap only

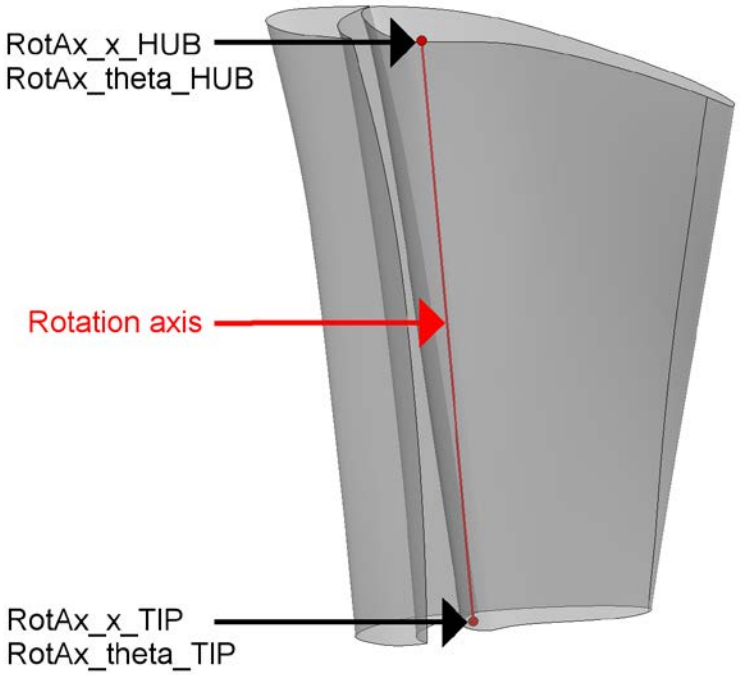
Description | **Free parameters** | Results

SplitBlade

- The gap is constructed with 3 cuts (hub, middle and tip)
- There are 6 free parameters per cut
- There are 4 free parameters for the rotation axis

→ 22 free parameters





Rotation angle OP2: 28.3°

Rotation angle OP3: 40°

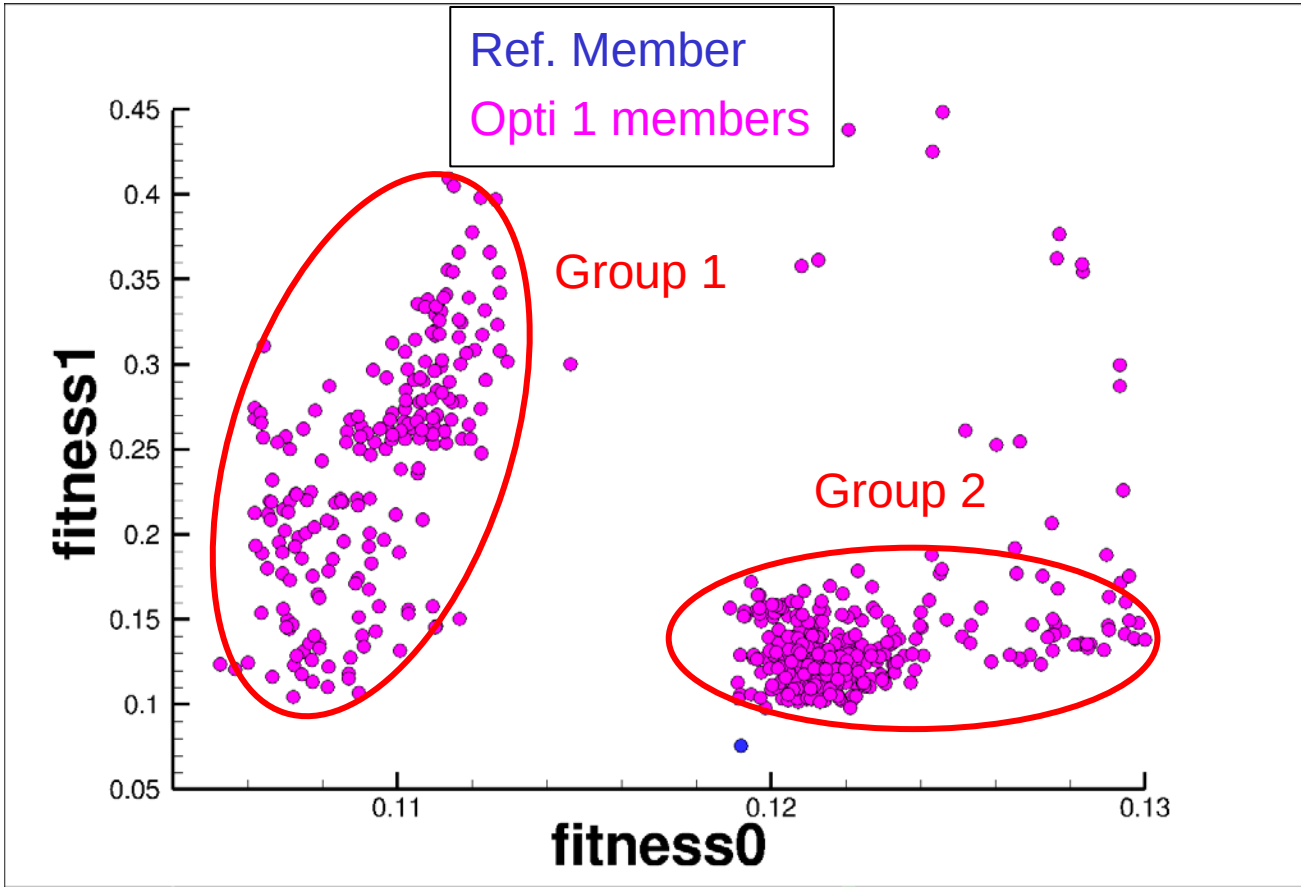
3. Optimization 1: Axial gap only

Database

Objectives

- fitness0 = ω_{OP1}
- fitness1 = $\frac{\omega_{OP2}+\omega_{OP3}}{2}$

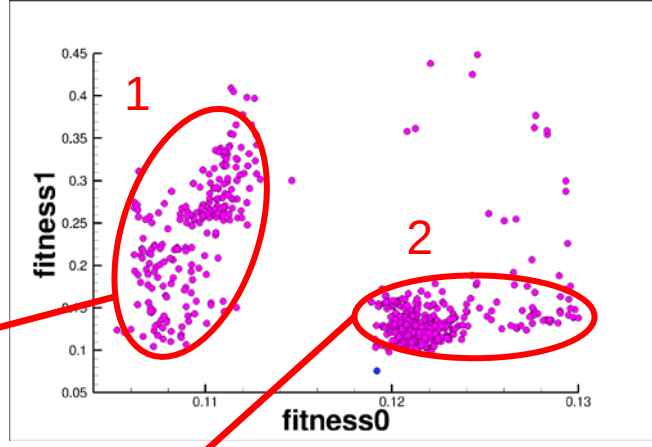
ω = total pressure loss coefficient



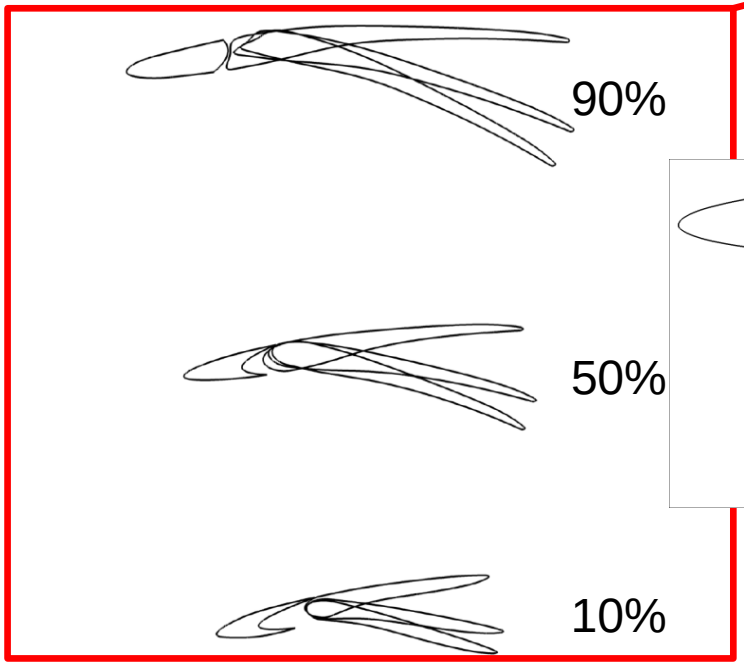
- Two groups of optimized members appear
- Reference member dominates opti-members in fitness1
- Group 1 members show better fitness0

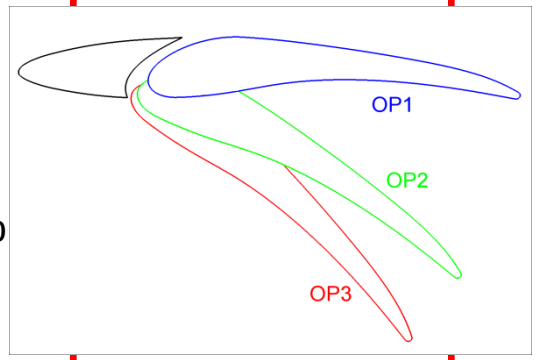
3. Optimization 1: Axial gap only

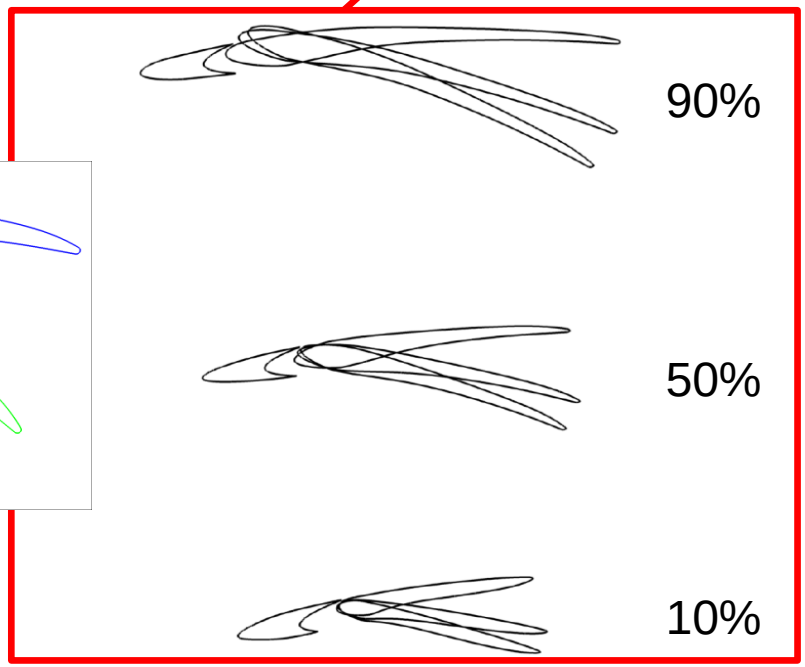
Description | Free parameters | **Results**



Groups of geometries





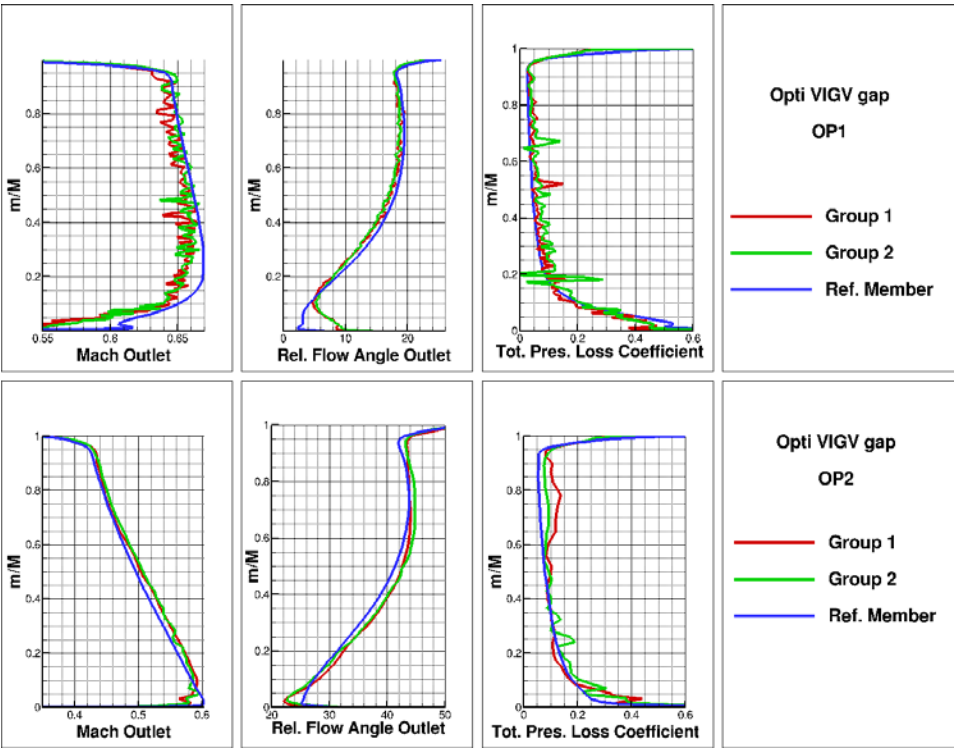


Group 1 selected member

Group 2 selected member

3. Optimization 1: Axial gap only

Description | Free parameters | Results



- Irregular curves due to the unstructured mesh
- Radial parameters globally the same
- Difference for the flow angle at hub

4. Optimization 2: Whole VIGV

Description | Free parameters | Results

Processchain

1. BladeGenerator
2. SplitBlade
3. GTA
4. Centaur
5. GMC
6. TRACE

Fitness functions and restrictions

<u>The objectives are the same:</u>

$$\text{fitness0} = \omega_{OP1}$$

$$\text{fitness1} = \frac{\omega_{OP2}+\omega_{OP3}}{2}$$

<u>7 constraints are added:</u>

- outflow angle (OP1) at 5 radial positions
- outflow angle (OP2) at midspan
- outflow angle (OP3) at midspan

4. Optimization 2: Whole VIGV

Description | **Free parameters** | Results

The initialization is based on group 2 of optimization 1

Envelope parameters
(BladeGenerator)

- Angles and radii : 18 parameters
- Control Points Suction side : 24
- Control Points Pressure side : 24

66 free parameters

Gap parameters
(Changes for SplitBlade)

- Same RotAx_theta for the two rotation points
- The RotAx_x_TIP is calculated in function of RotAx_x_HUB
- Rotation angles OP2/OP3

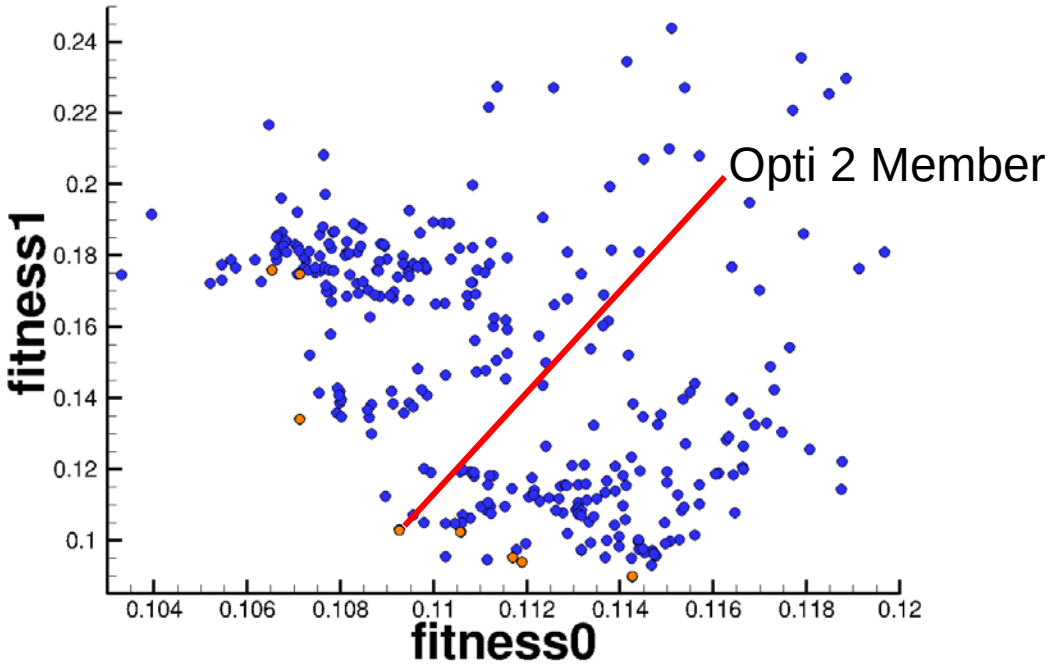
22 free parameters

88 free parameters

4. Optimization 2: Whole VIGV

Description | Free parameters | Results

Database

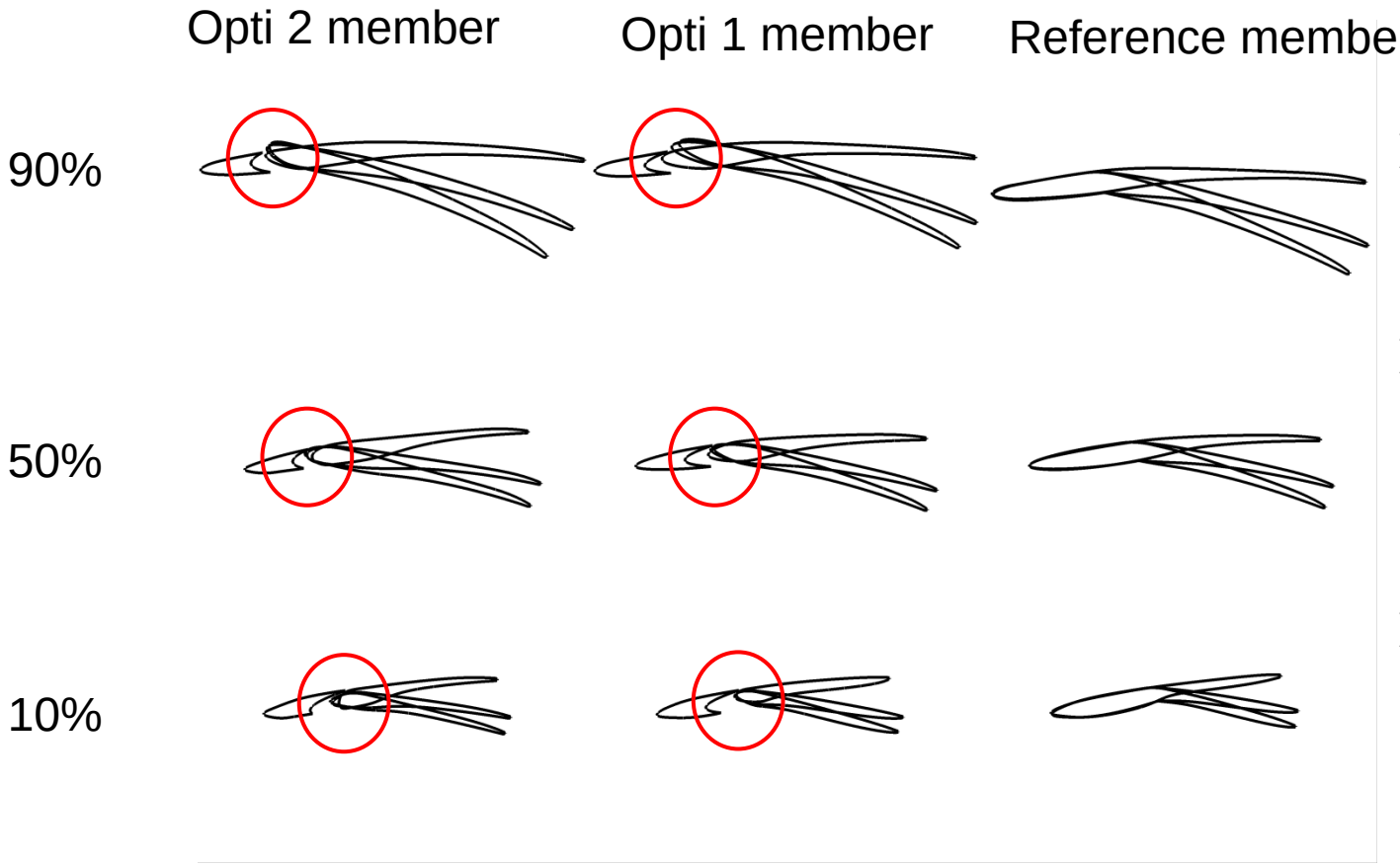


Opti 2 Database
Paretofront

Opti 2	ωOP1	ωOP2	ωOP3
Opti 2 Member	0.1093	0.1108	0.0952
Opti 1 Member	0.1198	0.1188	0.0774
Ref. Member	0.1192	0.0968	0.0548

4. Optimization 2: Whole VIGV

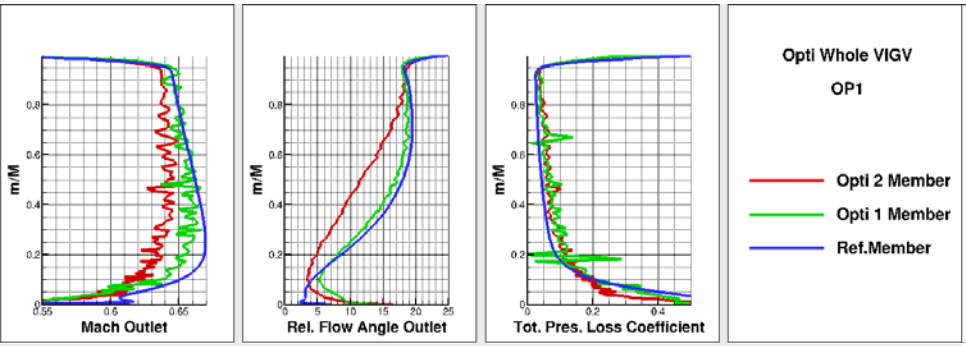
Description | Free parameters | **Results**

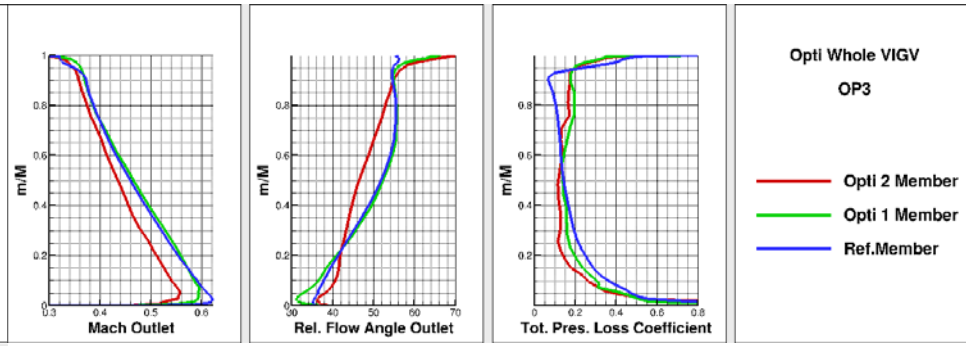


- At 90%, step made by opti 1 member is smaller
- At 50%, the fixed strut of opti 1 member is more symetric
- At 10%, the fixed strut of opti 1 member has a pear form

4. Optimization 2: Whole VIGV

Description | Free parameters | **Results**





- Lower Mach numbers for Opti 2 member
- Difference of flow angle because of the constraints
- Same behavior of total pressure losses for OP1 and OP2

5. Conclusion

- A tool to create an axial gap between strut and flap has successfully been integrated in the design process
- 2 VIGV optimizations have been conducted:
  - Optimization 1 has resulted in two groups with big geometric differences
  - The second optimization has given better results than the first optimization only in terms of total pressure losses in OP2 and OP3
  - The geometric differences between optimization 1 and optimization 2 are small, even though the free parameters were increased significantly
- Optimized geometries with axial gap show lower losses in OP1 and higher losses in OP2 and OP3 compared to the reference blade

Outlook

- Optimization with an initial geometry from the first group of optimization 1
- Study about the secondary axial gap flow
- CFD calculations with the 2.5 stage compressor

Thank you for your attention!

Questions?

DLR