CLEAN SKY
SAGE

Optimal High Speed Turbine Blade Aero-Mechanical Design (SAGE-02-012)

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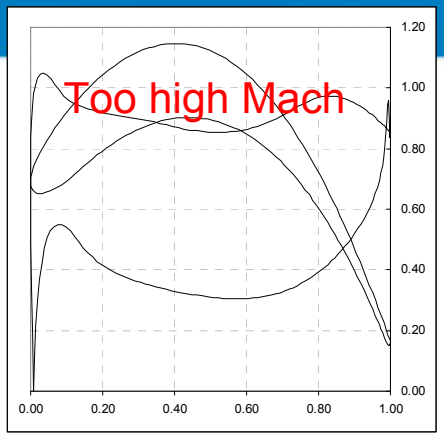
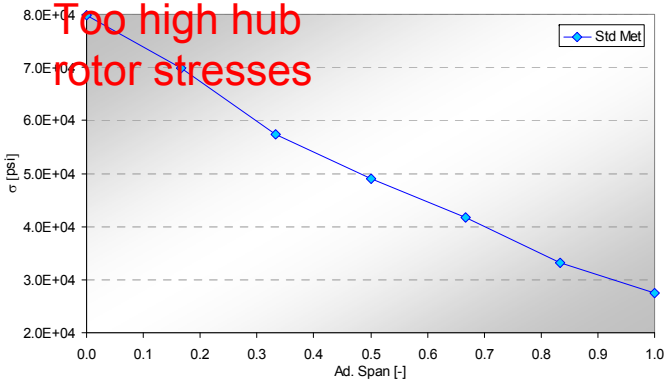
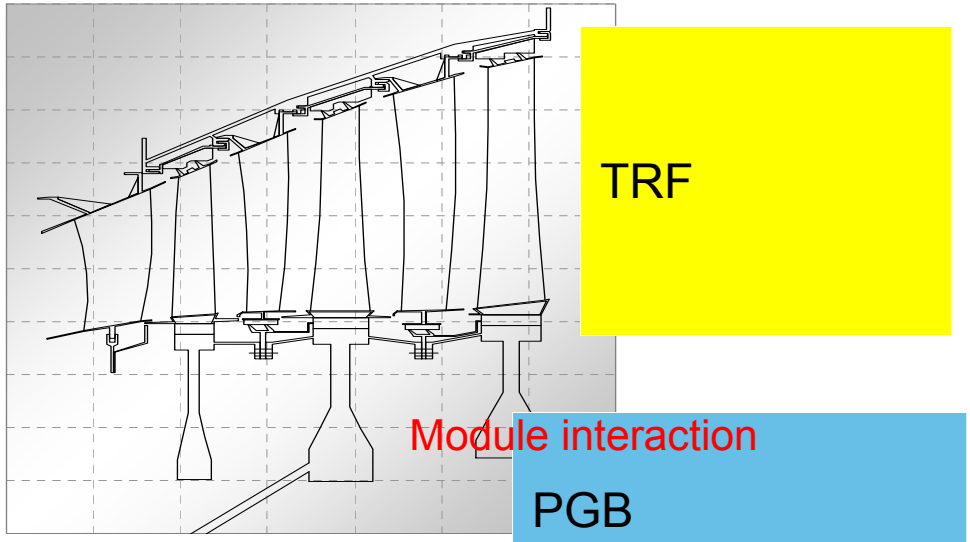
HIGH SPEED TURBINE

Main features:

- **High exit and profile Mach number to be controlled**;
- **High hub rotor centrifugal stresses to be reduced**;
- **Big disks size (Interaction with PGB)** & LPT-TRF interface to be considered;
- High diffusion coupled with low Reynolds numbers to be accounted for;
- Specific components to be suitably designed;
- **Specific blade aero-mechanical optimization needed**.







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CFP OBJECTIVES

Main Research Goals:

- To reduce high hub rotor centrifugal stresses:
  - → Define a specific blade airfoil area tapering suitable for high speed turbines;
  - → Optimize spanwise chord distribution from aero-mechanical point of view.

- To avoid PWT-PGB interaction problem:
  - → Minimize airfoil weight to reduce disk size respecting minimal airfoil thickness.

- To aerodynamically optimize airfoil for high speed configurations:
  - → Define specific design to deal with high Mach numbers;
  - → Define specific airfoil design to deal with mechanical requests.

- To study reported problems and identify specific solutions;

- To perform trade off studies to identify best configuration for the multi-objective problem:
  - → Reduced turbine height;
  - → Increased hub/tip area ratio;
  - → Increased axial chord tapering.

- To perform experimental validation tests for baseline and proposed solution.

TASK DESCRIPTION

Optimal High Lift Turbine Blade Aero-Mechanical Design	1st year				2nd year			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
MANAGEMENT								
Detailed time-schedule agreed with Avio	D1							
AIRFOIL OPTIMIZATION FOR ROTOR HIGH SPEED BLADES								
Numerical study of Avio proposed baseline profile and experimental baseline test preparation			D2					
Aero-mechanical trade off studies to improve proposed solution								
Experimental final design preparation				D4				
EXPERIMENTAL TESTS DESIGN AND HARDWARE PROCUREMENT								
Cycle scaling for test, hardware design, test matrix preparation								
Measurement plan								
Test rig preparation								
EXPERIMENTAL TESTS EXECUTION								
Experimental investigation on baseline profile				D3				
Experimental investigation on improved profiles					D5			
EXPERIMENTAL-NUMERICAL COMPARISON AND FINAL DESIGN VALIDATION								
Exp-Num comparison for final design validation					D6			
Innovative blade model								

Task duration

Numerical, theoretical or planning activity

Experimental investigation

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Deliverables, Topic Value

Overall Research duration: 18 months

Topic Value: 850.000 €

Deliverable	Title	Description	Due date
D1	Detailed Project Plan	Schedule with milestones, technical specification of experimental system	T0+1M
D2	Profile optimization study report and baseline experimental profiles definition (for aerodynamic validation)	Description of aero-mechanical optimization concept study and preparation of baseline (only aerodynamic) profile for test	T0+6M
D3	Test on Baseline profile	Experimental results on baseline profile	T0+12M
D4	Aero-mechanical profiles optimization and experimental solution definition	Description of numerical results on the aero-mechanical optimized profiles and test preparation for optimized configuration	T0+12M
D5	Test on aero-mechanical optimized profiles	Experimental results on aero-mechanical optimized profiles	T0+16M
D6	Numerical-Experimental comparison and final project report	Description of numerical experimental comparison and final consideration on optimized aero-mechanical high speed profile	T0+18M

Annex

HIGH SPEED TURBINE

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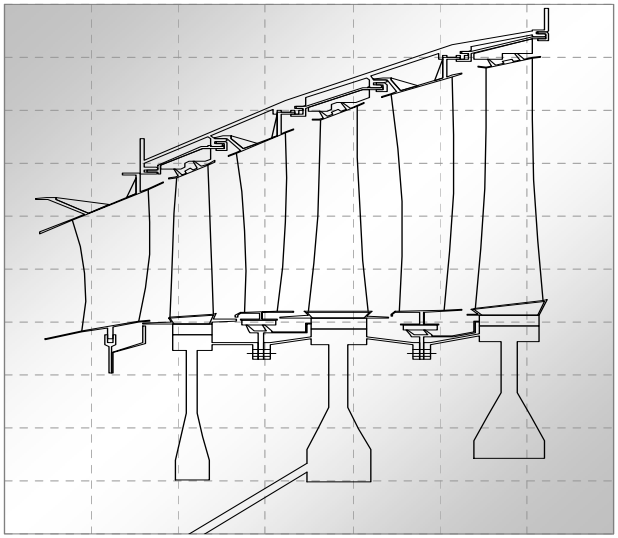
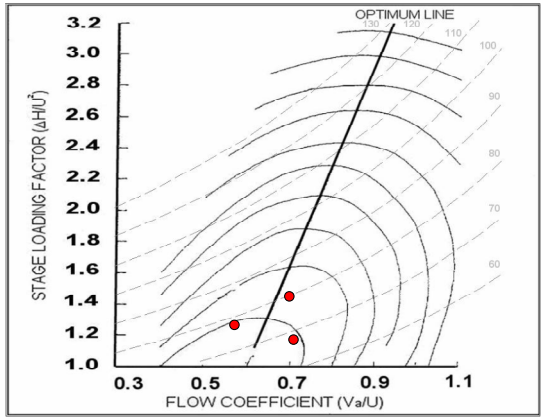
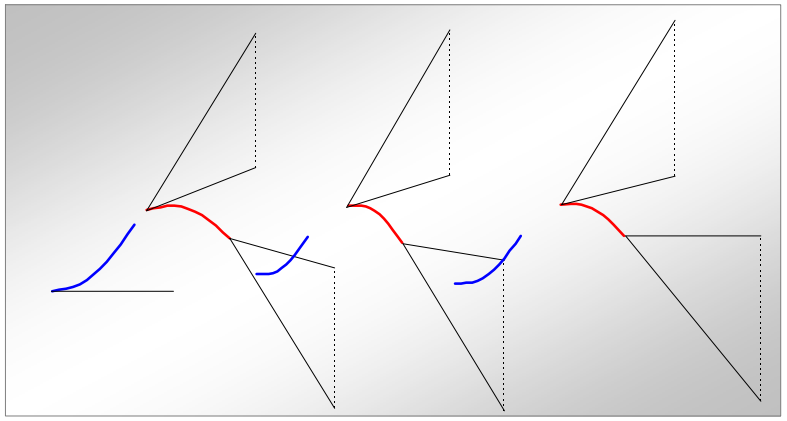
HIGH SPEED TURBINE

Features

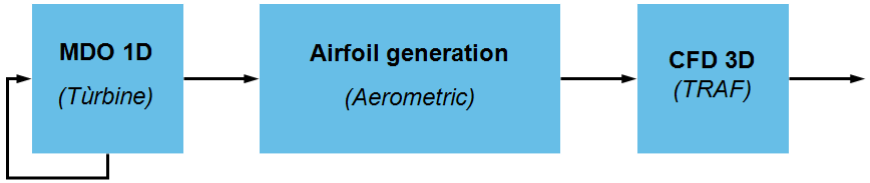
- High exit Mach number to be controlled;
- High hub rotor stresses to be reduced;
- High diffusion coupled with low Reynolds numbers to be accounted for;
- Specific components to be suitably designed;
- Specific blade aero-mechanical optimization needed.





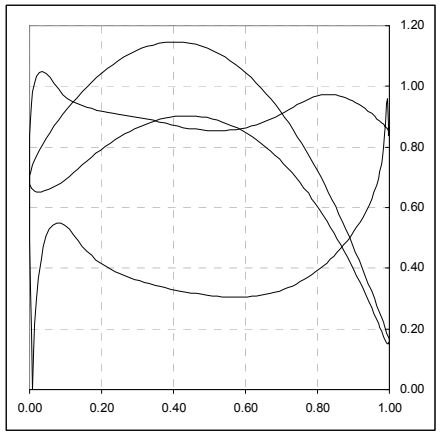


STANDARD DESIGN PROCESS

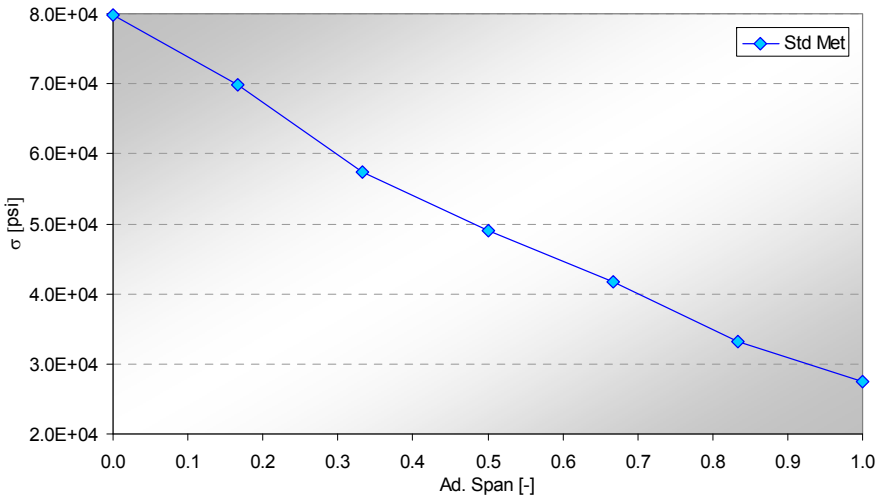


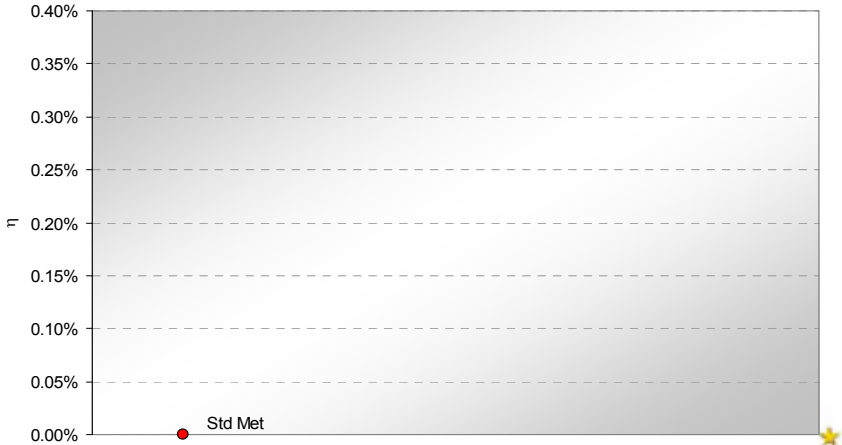
1D Objectives:

- Efficiency
- Airfoils
- Weight
- Acoustic



Blade #3 - Hub





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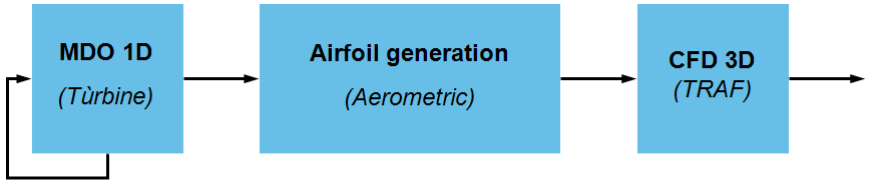
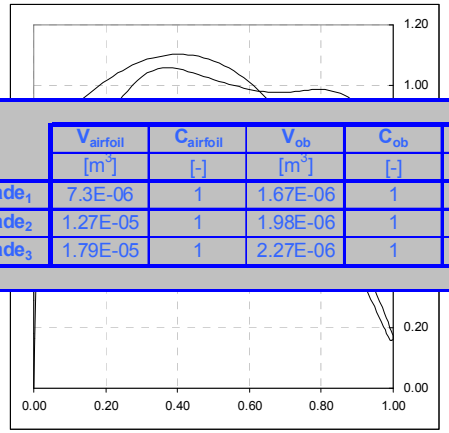
NEW 1D OPT. OBJECTIVES



1D Objectives:

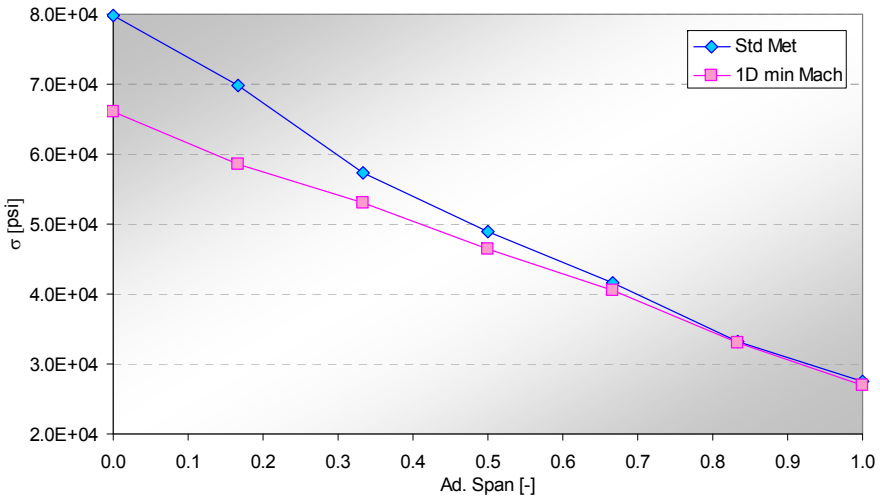
- Efficiency
- Airfoils
- Mach out
- σ_{rot} (hub)

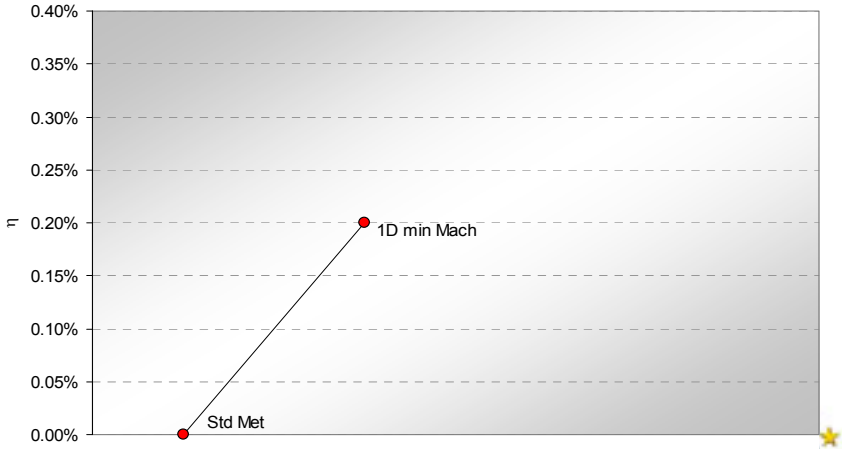


Blade #3 - Hub

P/A

	$V_{airfoil}$ [m^3]	$C_{airfoil}$ [-]	V_{ob} [m^3]	C_{ob} [-]	CG_{tot} [m]	P/A [psi]
$Blade_1$	7.3E-06	1	1.67E-06	1	0.383032	42534.35
$Blade_2$	1.27E-05	1	1.98E-06	1	0.412334	36100.77
$Blade_3$	1.79E-05	1	2.27E-06	1	0.438961	46965.41





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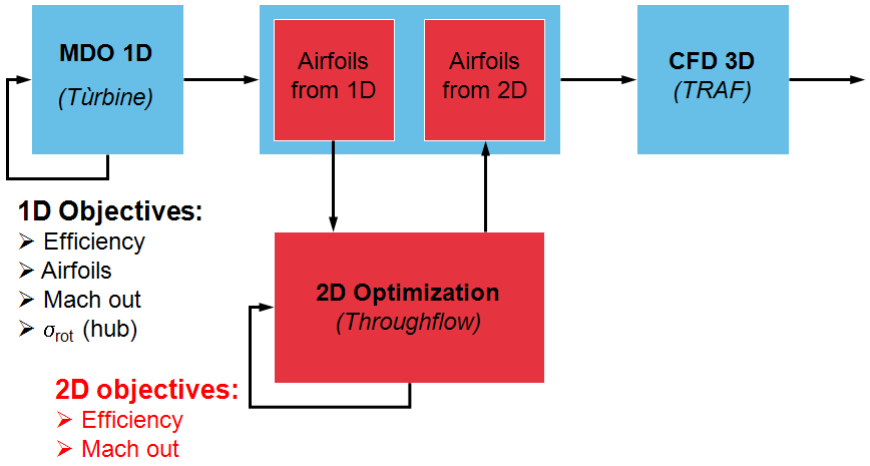
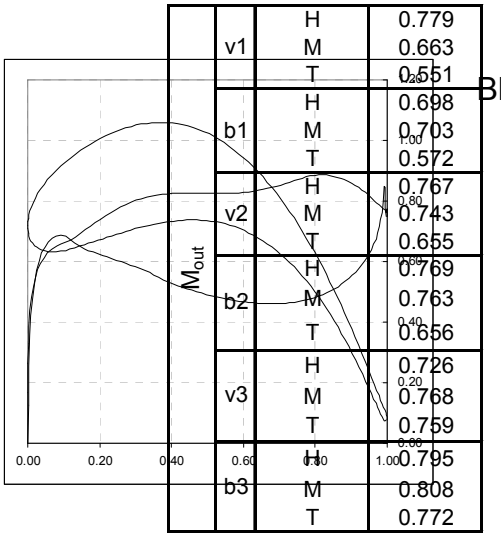
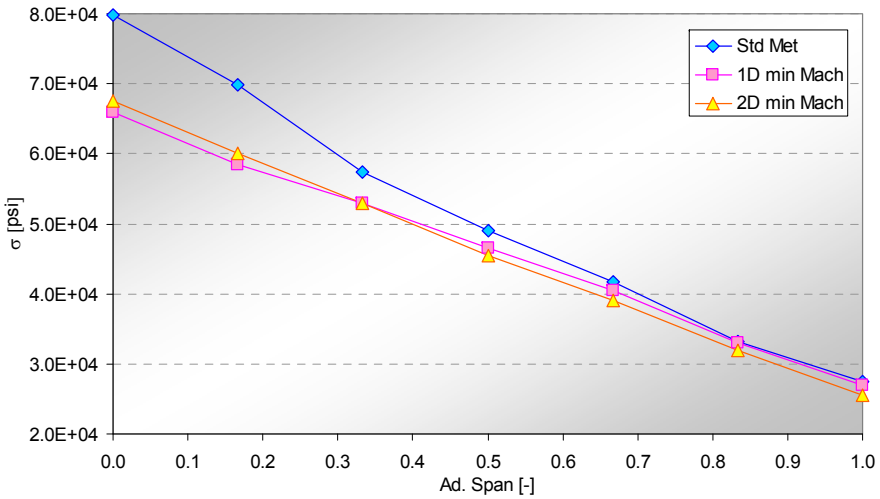
NEW 2D OPT. OBJECTIVES

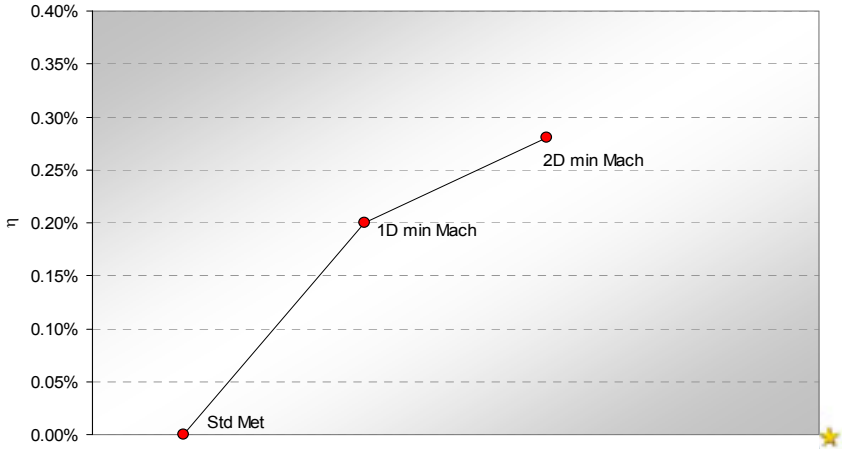




v1	H	0.779
	M	0.663
	T	0.551
b1	H	0.698
	M	0.703
	T	0.572
v2	H	0.767
	M	0.743
	T	0.655
b2	H	0.769
	M	0.763
	T	0.656
v3	H	0.726
	M	0.768
	T	0.759
b3	H	0.795
	M	0.808
	T	0.772

Blade #3 - Hub





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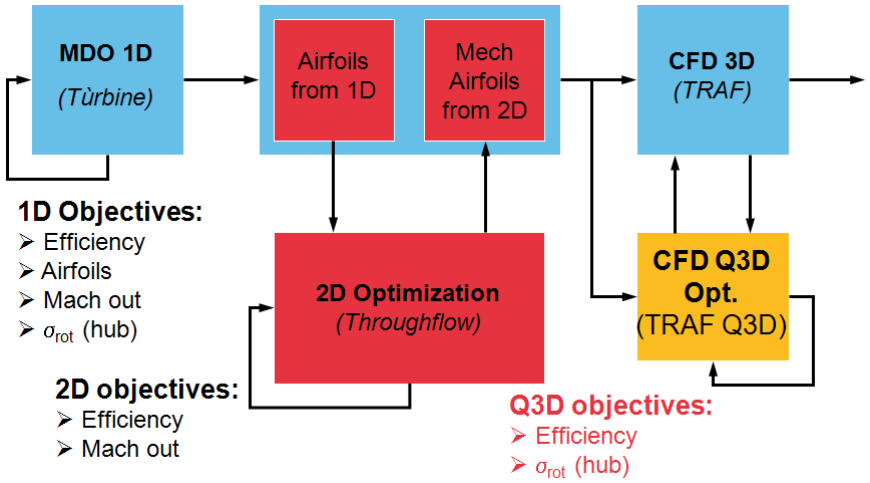
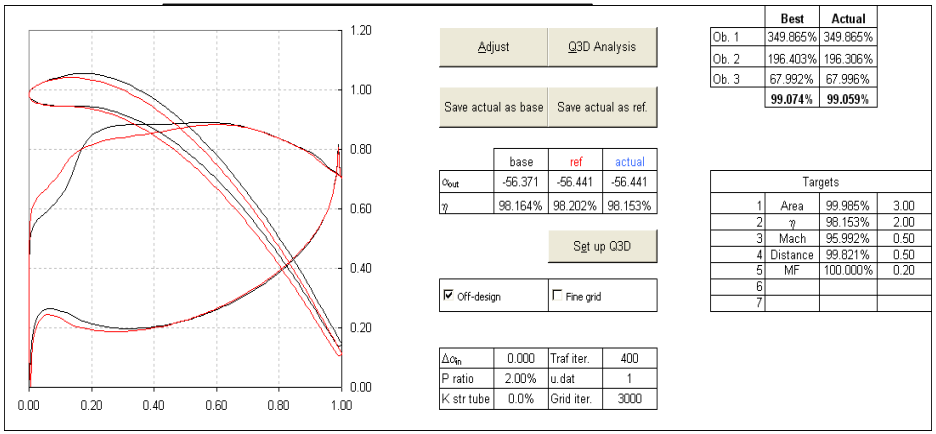
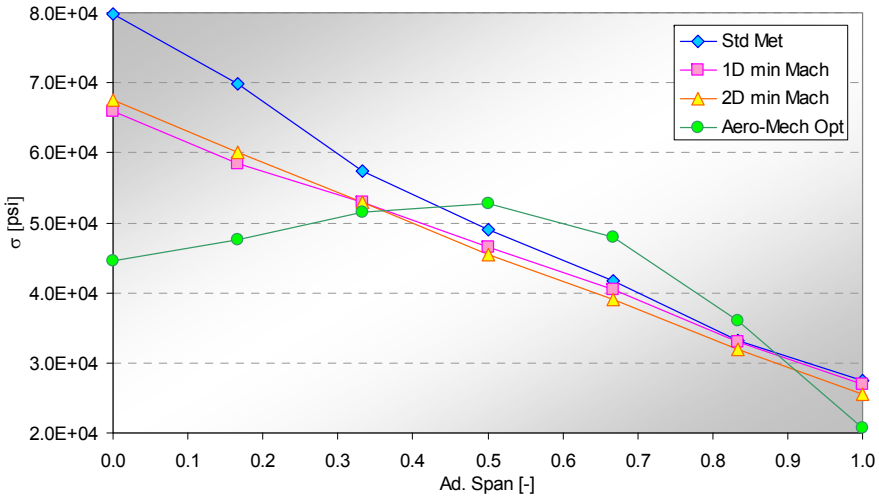
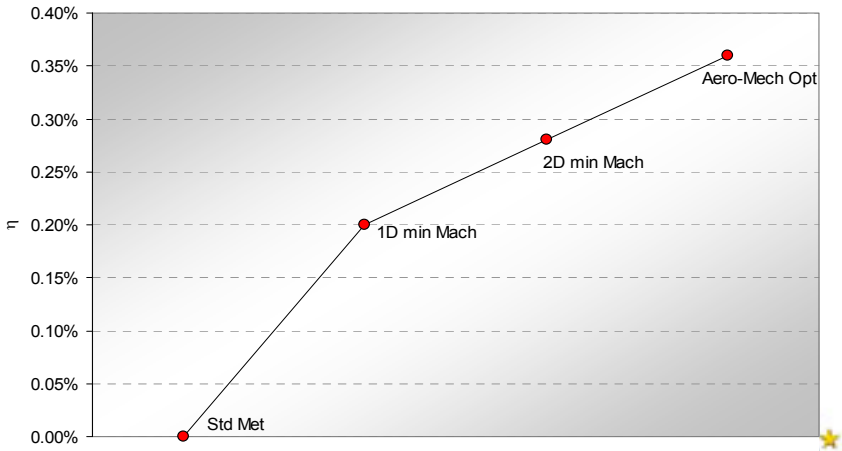
Q3D OPT. OBJECTIVES









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