Overview of Airfoil Design

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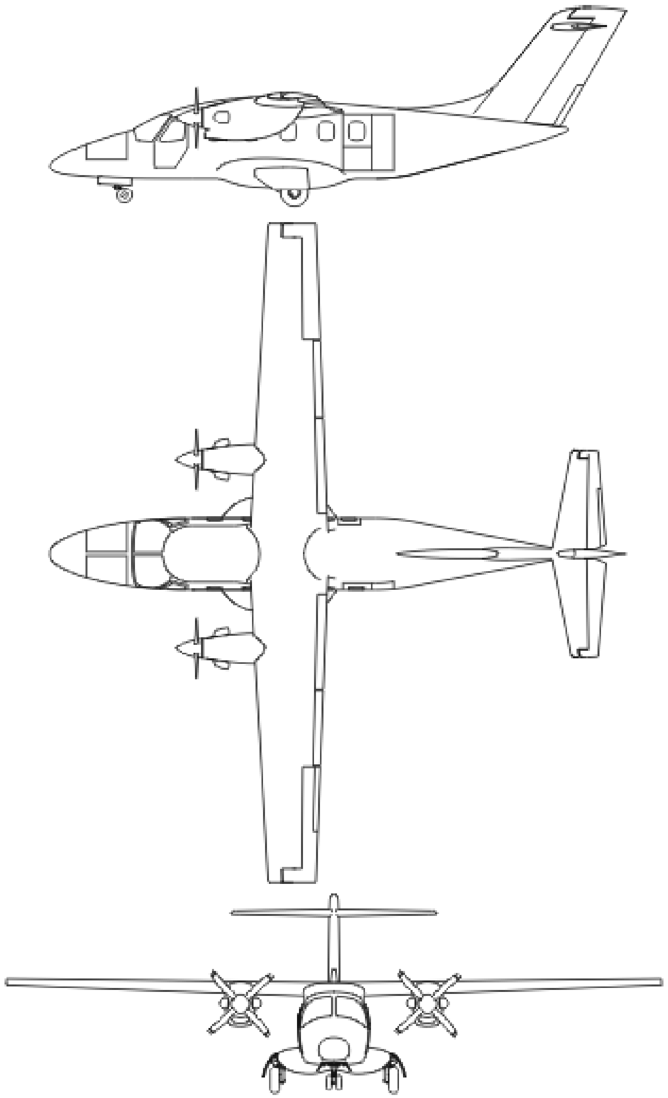
Two Aircraft Concepts

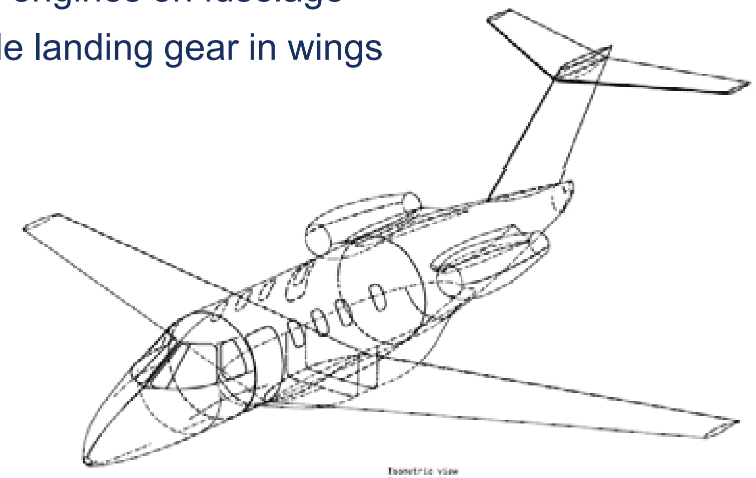


AC1

- low speed (<350 km/h)
- non-pressurized, propeller turboprop
- high wing, engines on wing
- retractable landing gear in fuselage

AC2

- high speed (low transonic)
- pressurized, jet engines
- low wing, engines on fuselage
- retractable landing gear in wings



Two Different Wing Concepts for Each Aircraft

AC1-T

- turbulent wing concept
- with turbulent sections AFT for cruise and HLT for high lift conditions

AC1-L

- laminar wing concept
- with laminar sections AFL for cruise and HLL for high lift conditions

AC2-T

- turbulent wing concept
- with turbulent sections AFT for cruise and HLT for high lift conditions

AC2-L

- laminar wing concept
- with laminar sections AFLT for cruise and HLL for high lift conditions

Partners Involved in Airfoil Design

- 10 partners involved in airfoil design

	AC1-T	AC1-L	AC2-T	AC2-L
EVEKTOR	3 AFT +HLT			
IoA	1 AFT +HLT		1 AFT +HLT	
VUT	1 AFT +HLT		1 AFT +HLT	
VZLU	1 AFT +HLT	1 AFL +HLL		
FOI		2 AFL	2 AFT +HLT	
INCAS		(2 AFL +HLL)		
CENAERO	(3 AFT)			
CIRA				2 AFL
PIAGGIO				HLL for 1 AFL
DLR				2 AFL +HLL

- 3 airfoil designs selected for wind tunnel measurements

AC1-L Airfoil Design Objectives – Root Airfoil Section

Operating Reynolds numbers

- Cruise from 9.10^6 to 13.10^6

Geometrical constraints

- The root airfoil section thickness should be at least 16%.
- The trailing edge relative thickness should be at minimum 0.7%.

Cruise configuration

- The minimum drag coefficient should be achieved at the design lift coefficient and a low value of the drag coefficient should be kept up to $C_{Lmax}/1.44$.
- Design lift coefficient $C_L = 0.4$
- Maximum lift coefficient $C_{Lmax} > 1.8$
- Pitching moment coefficient $C_m > -0.07$
- The drag coefficient in laminar regime should be as low as possible.
- In the case of fully turbulent boundary layer the drag coefficient shouldn't exceed 0.009
- Drag coefficient – turbulent $C_D < 0.009$

Set according the design objectives

Criteria

- C_D (cruise, laminar) → min
- C_D (cruise, turbulent) < 0.009
- C_m (cruise, laminar) > -0.07
- C_{LMAX} (take-off) $\geq$ 1.8
- C_D (C_L = 0.9, laminar) → min
- C_D (C_L = 0.9, turbulent) → min
- Airfoil thickness = 17 %
- T.O. thickness = 0.7 %

Operating conditions

- Operating Reynolds number Re = 1 x 10^7
- Operating Mach number M = 0.37
- Design lift coefficient CL = 0.4

8 optimization criteria

Optimization Method

- The airfoil optimization method was based on the evolution algorithm.
- A multicriteria genetic algorithm was used.
- Ability to scan the design space globally.
- Take into account several optimization criteria, which may be contradictory.
- The result of this optimization process is not any ideal solution, but some compromise surface of convenient solutions.
- Crowding distance method was used to preserve the diversity of individuals.

Airfoil Shape Definition

- A specific GPARSEC method, developed in VZLU, was used for the definition of the airfoil section shapes.
- The method is based on the Parsec functions introduced by H. Sobieczky. The specific form of this method was developed in VZLU for the best performance of parameterization of typical airfoil section.
- An inhouse software, using this method, was used to generate airfoil section coordinates.

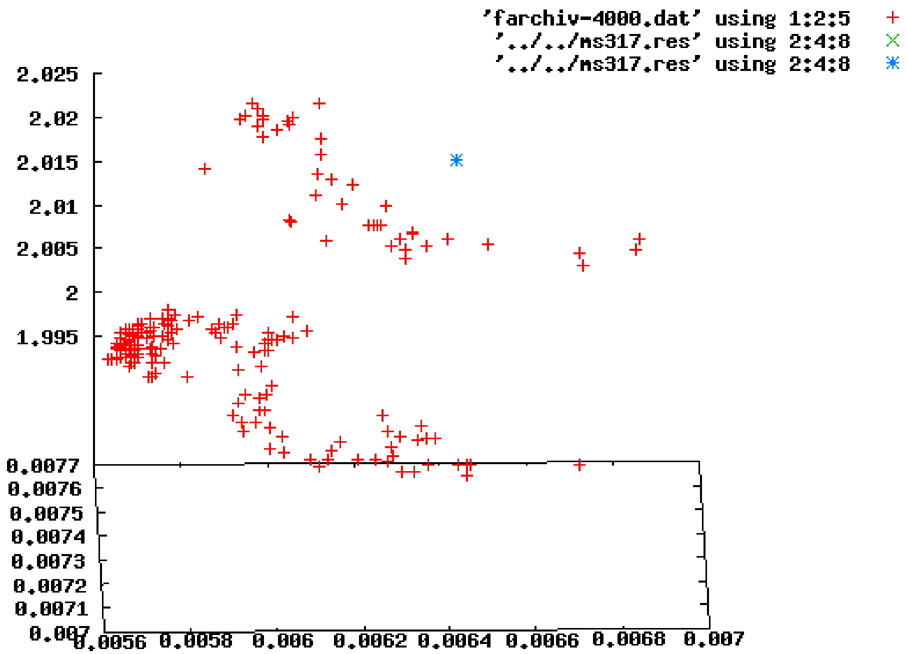
Airfoil Characteristics Computation

- The aerodynamic characteristics of each airfoil were computed with the software X-Foil 6.94.
- It was necessary to use a tool, which can compute the airfoil characteristics in a short time, because of the amount of airfoils necessary to be evaluated when using methods based on evolution algorithms.
- For turbulent flow, the airfoils were computed with prescribing the transition from laminar to turbulent boundary layer at 5% of the airfoil chord on the upper surface and at 15% of the airfoil chord on the lower surface.
- For laminar flow a free transition criterion was used.

Results

- Airfoils were compared with the NASA MS(1)-0317 airfoil

Pareto front – Laminar regime projection



X axis:

≈ $C_{Dmin\ cruise}$

Y axis:

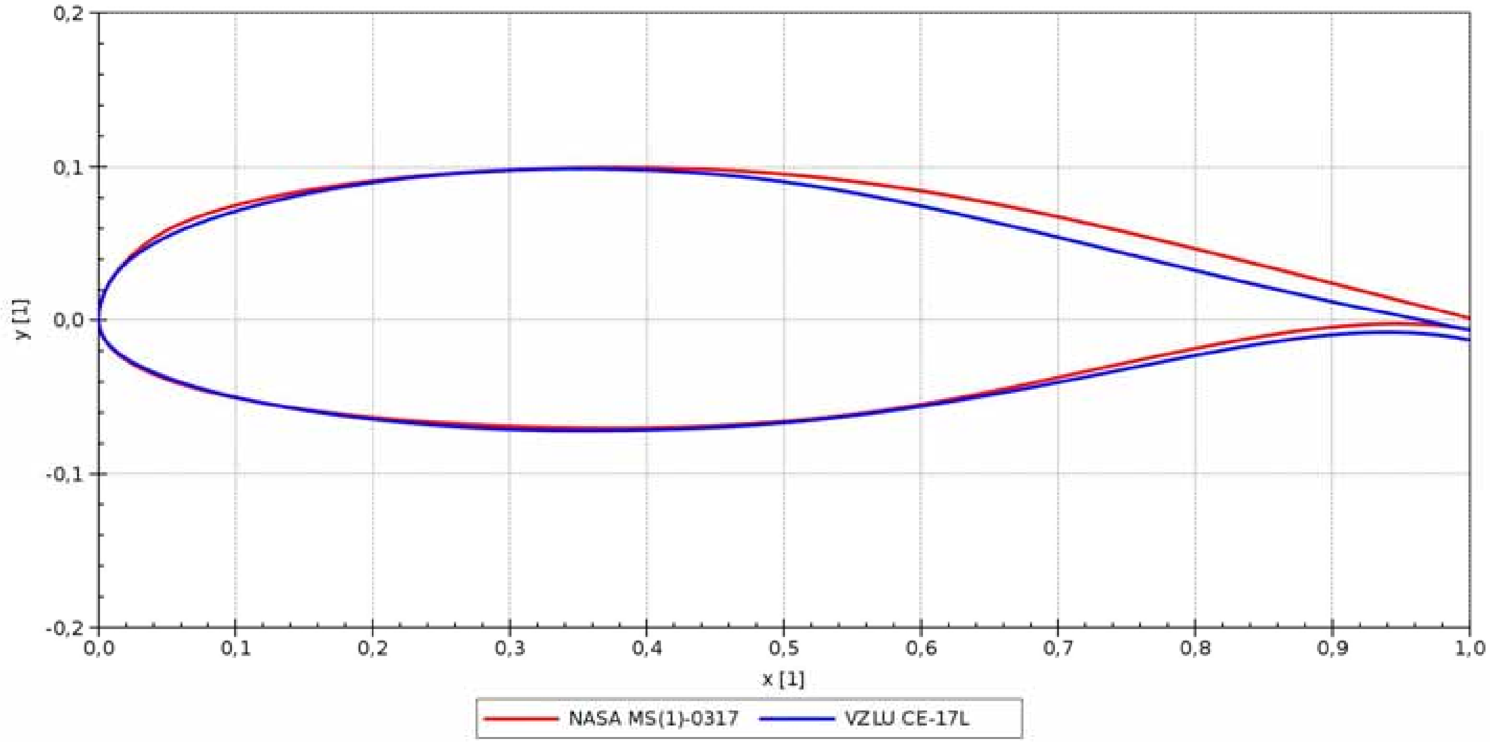
≈ $C_{Dmin\ man}$

Z axis:

≈ C_{Lmax}

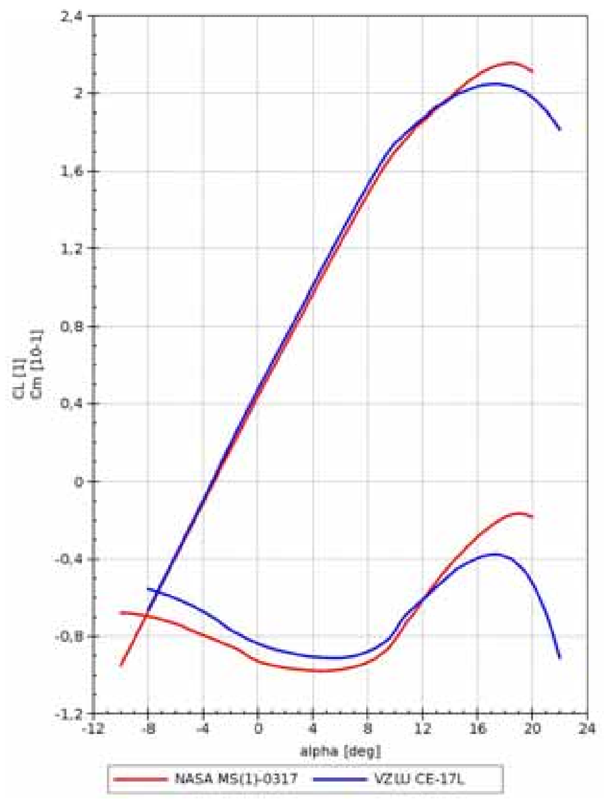
Airfoil

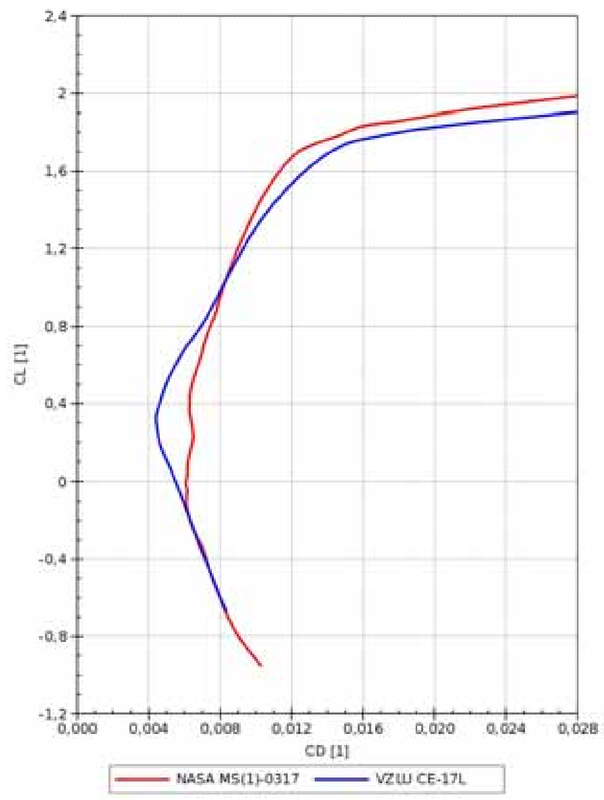
Comparison of the airfoils geometry



Results

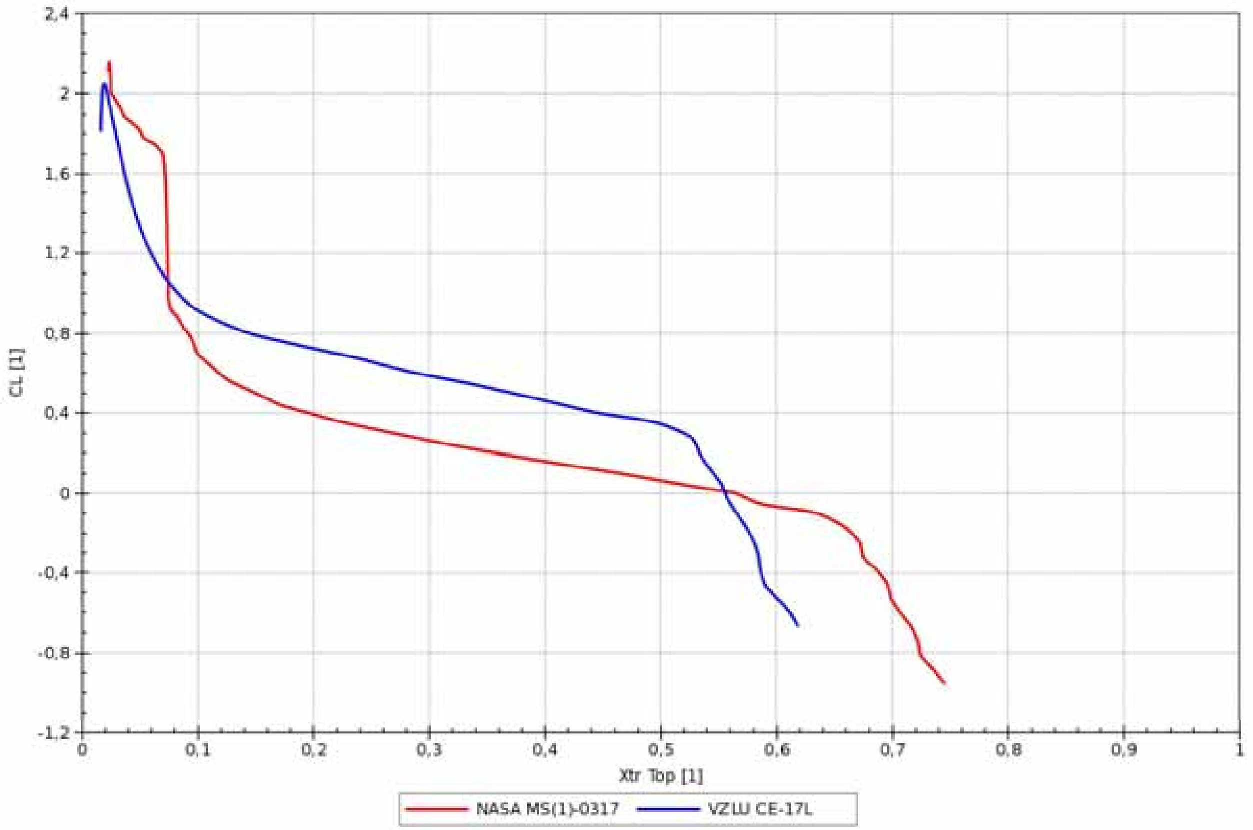
Airfoil's integral characteristics – laminar regime





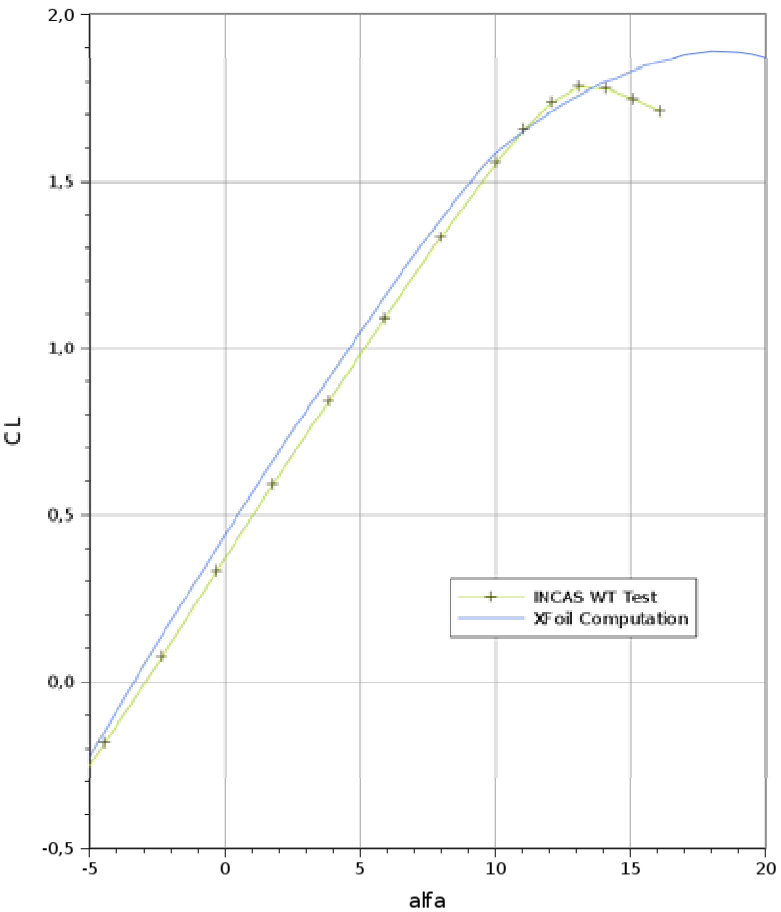
Results

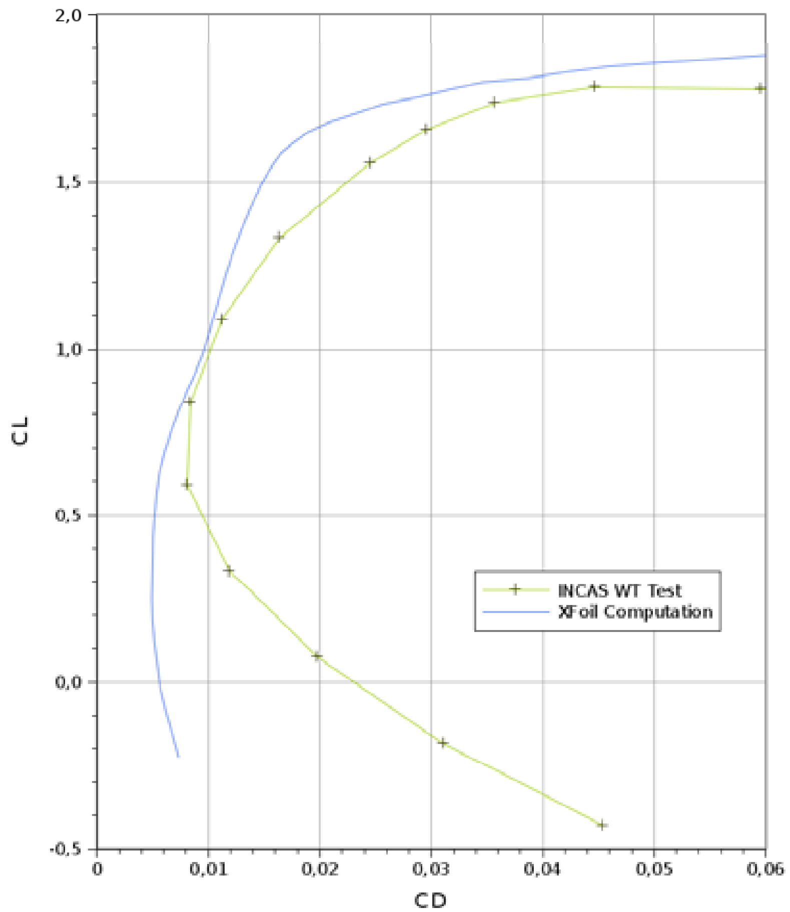
Laminar-turbulent BL transition



Wind Tunnel Tests

Airfoil model built and tests performed in INCAS





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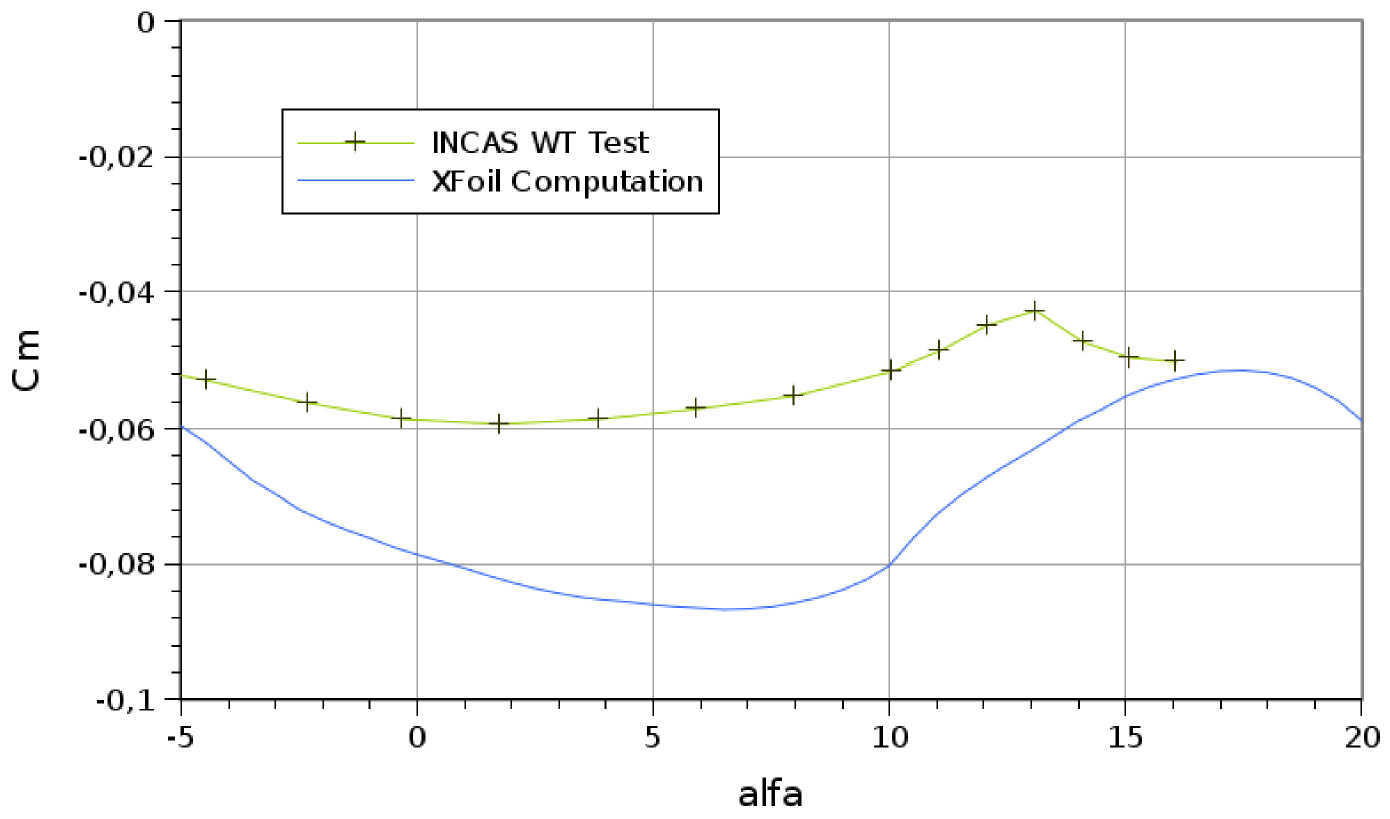

Conclusions

- ✓ Airfoils with better aerodynamic characteristics, than the baseline airfoil, were obtained.
- ✓ Our method can take into account several contradictory criteria.