POLITECNICO DI MILANO

FRIENDCOPTER WP5
Active Twist
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Politecnico di Milano

Outline

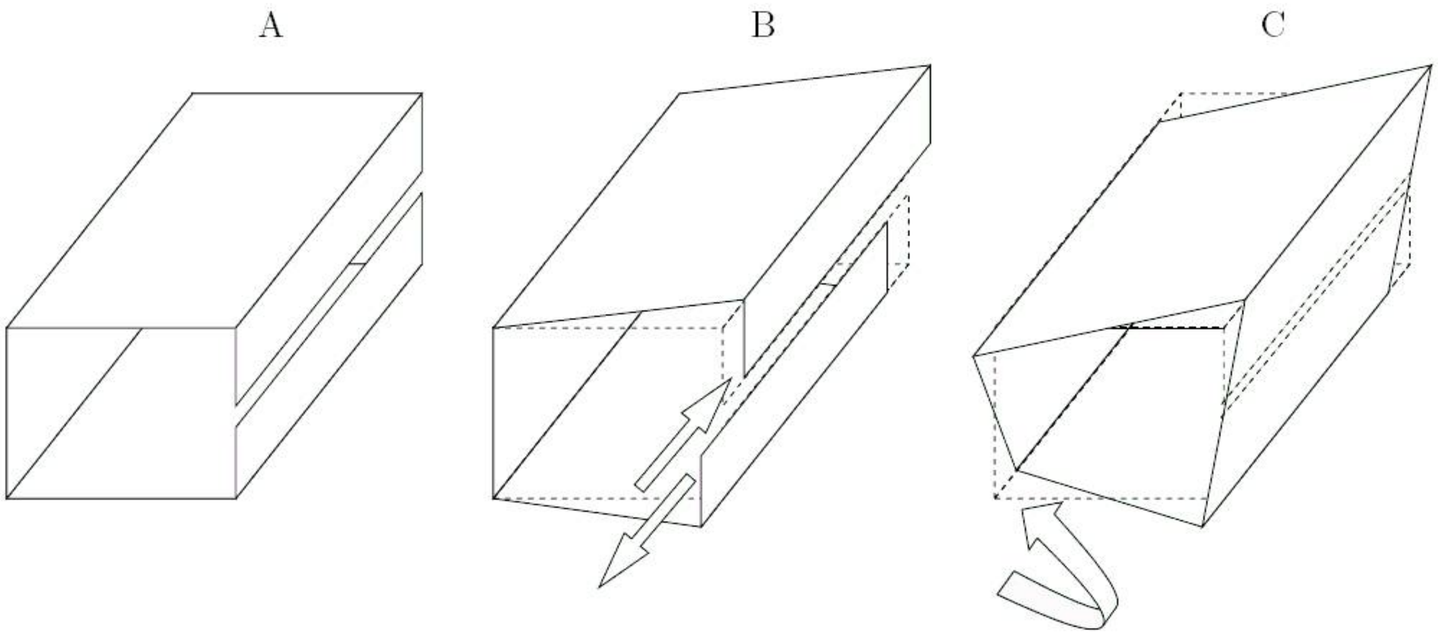
- Blade design and optimization
  - Analytical work

- Design scaling issues
  - Status of activity
  - Open issues
  - Roadmap

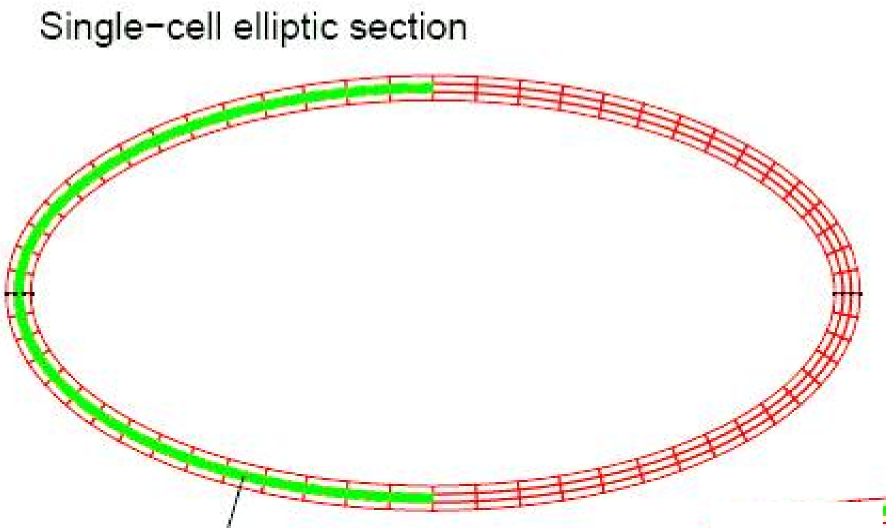
Analytical work

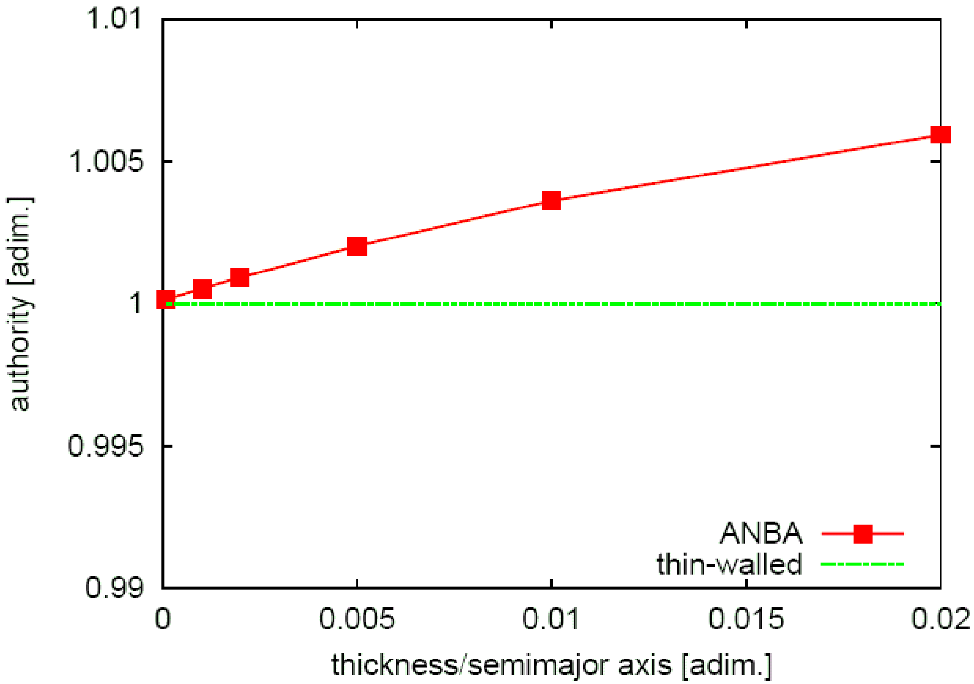
Piezo-induced warping

Compatibility -> torsion



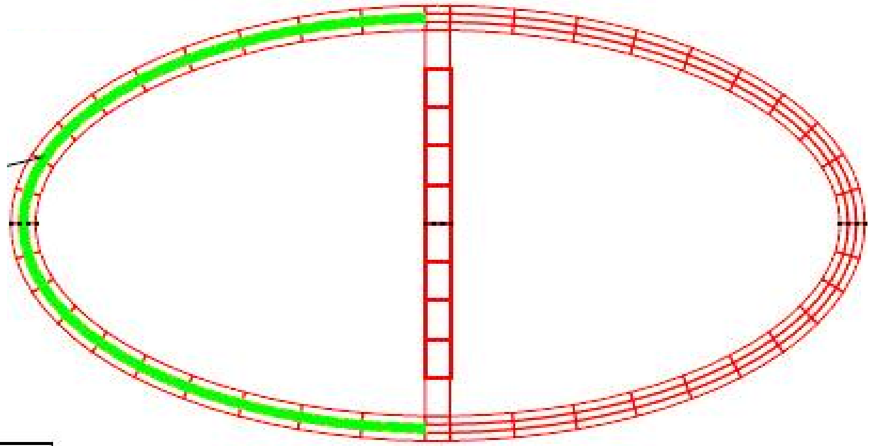
Analytical work

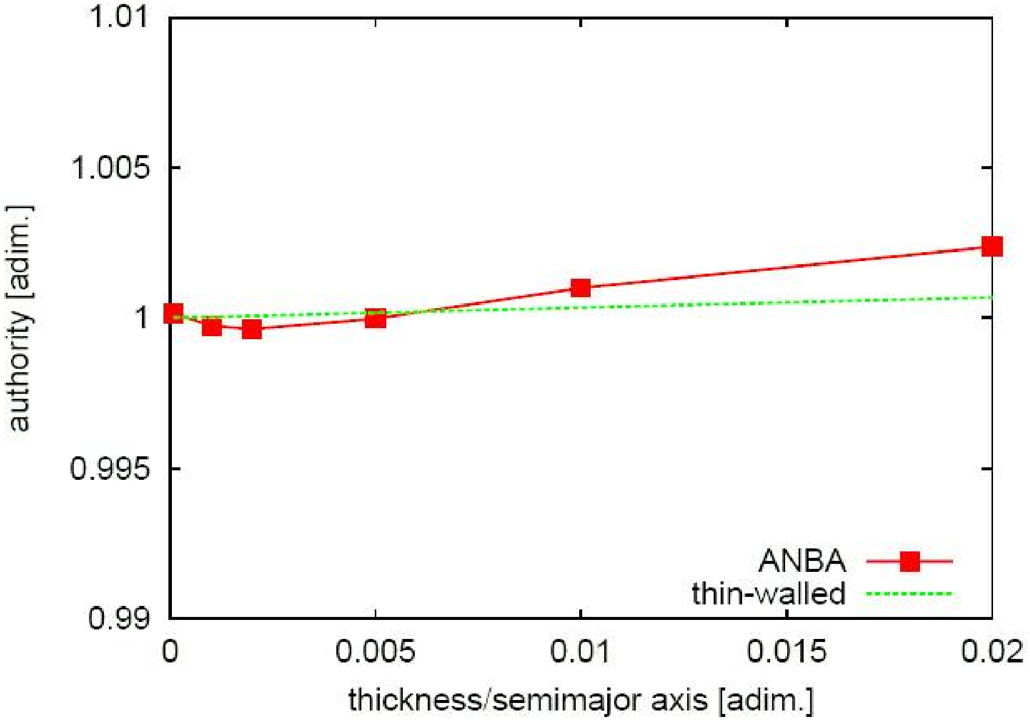




Analytical work

Two−cell elliptic section





Scaling: outline

- AI 5.11 DLR: preliminary mechanical properties on LPS ?
- AI 5.18 POLIMI/RTU: active twist cross section upscale FEM model (design constraint)
  - D-spar ✓
  - change of actuator type Not critical; Pending AI 5.11
  - minimum skin thickness ?✓
  - erosion protection ~
  - material selection ?
- AI 3.8 ATW-optimisation: up-scale optimisation to full scale;
  - EADS puts MATLAB-script on the FPR with ECD detailed cross-sectional data (geometry/ply lay up) of the reference rotor doc ✓
  - **Ongoing**

Design Optimization so Far

- local objective is maximum twist/span per electric field
- constraints (from helicopter manufacturers):
  - outer shape dictated by airfoil
  - “C” shaped spar
  - circular lead additional mass in the front part of the nose
  - chordwise C.G. between 22% and 30%
  - chordwise elastic axis between 20% and 25%
  - upper bound on mass/span
  - lower/upper bounds on blade first torsional frequency
  - upper bound on axial strain
  - lower/upper bounds for beamwise bending stiffness
  - lower bound for torsional stiffness
  - (=> extra: upper bound on distance between S.C. and C.G.)

First upscaling results

- local objective is maximum twist/span per electric field

  NO upper bound on distance between S.C. and C.G.

Chord	Model scale	2.5	2.25	2.25	2.5
Span	Model scale	2.5	2.5	2.5	2.5
Piezo	Model scale	2.5	2.25	2.5	3
$\pm$45 ply	Model scale	2.5	2.25	2.5	2.5
(deg/m)/(V/m)	9.99E-7	4.30E-7	4.77E-7	--	4.59E-7
	9.99E-7	1.08E-6	1.19E-6	--	1.15E-6

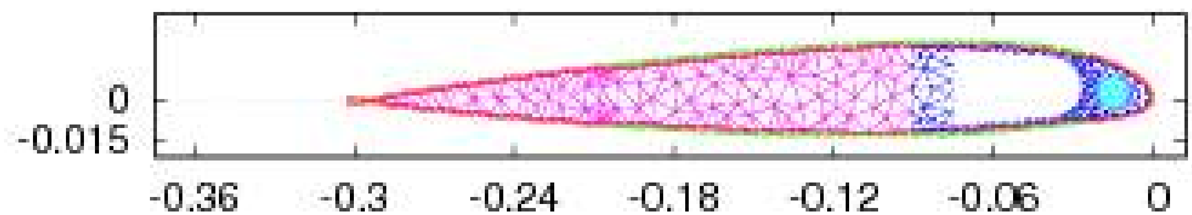
D shape

maximum twist/span per electric field

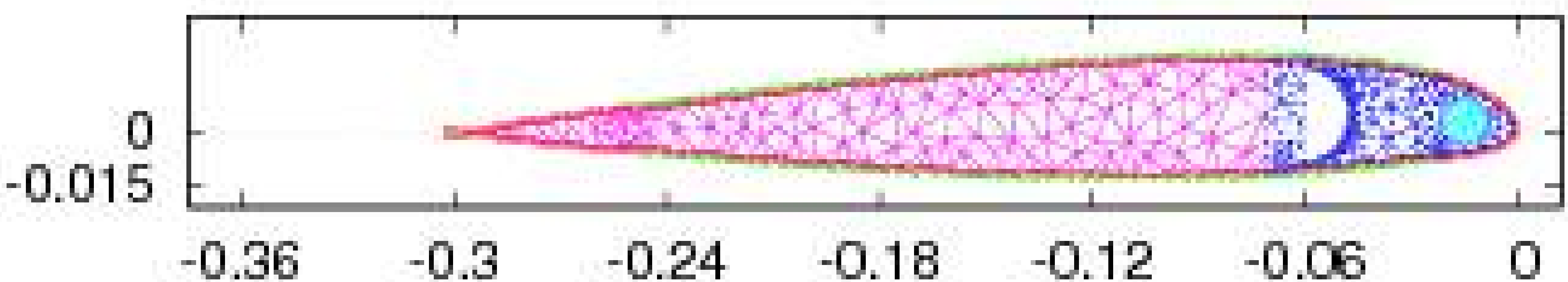
NO upper bound on distance between S.C. and C.G.

			D shape
Chord	Model scale	2.5	2.5
Span	Model scale	2.5	2.5
Piezo	Model scale	3	3
±45 ply	Model scale	2.5	2.5
(deg/m)/(V/m)	9.99E-7	4.59E-7	4.54E-7
	9.99E-7	1.15E-6	1.14E-6

Initial design



Final design (->no D)



CG-SC distance: C shape

- local objective is maximum twist/span per electric field

  upper bound on distance between S.C. and C.G.: 5% chord

	Free	5.00%	Free	5.00%
Chord	Model scale	Model scale	2.5	2.5
Span	Model scale	Model scale	2.5	2.5
Piezo	Model scale	Model scale	3	3
±45 ply	Model scale	Model scale	2.5	2.5
(deg/m)/(V/m)	9.99E-7	5.25E-7	4.59E-7	2.20E-7
	9.99E-7	5.25E-7	1.15E-6	5.50E-7
		52%		48%

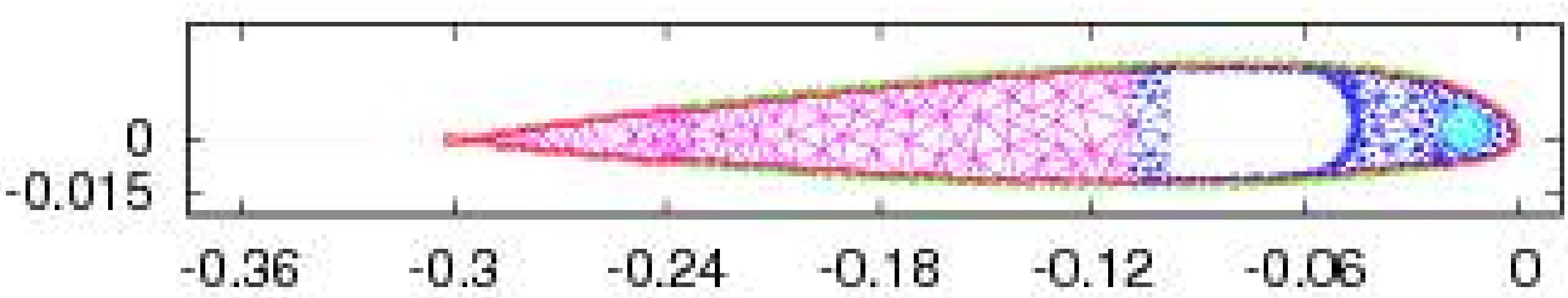
was 30%; better optimization?

CG-SC distance: D shape

- local objective is maximum twist/span per electric field

  upper bound on distance between S.C. and C.G.: 5% chord

Free	5.00%	Free	5.00%
Model scale	Model scale	2.5	2.5
Model scale	Model scale	2.5	2.5
Model scale	Model scale	3	3
Model scale	Model scale	2.5	2.5
9.99E-7	3.30E-7	4.55E-7	4.23E-7
9.99E-7	3.30E-7	1.14E-6	1.06E-6



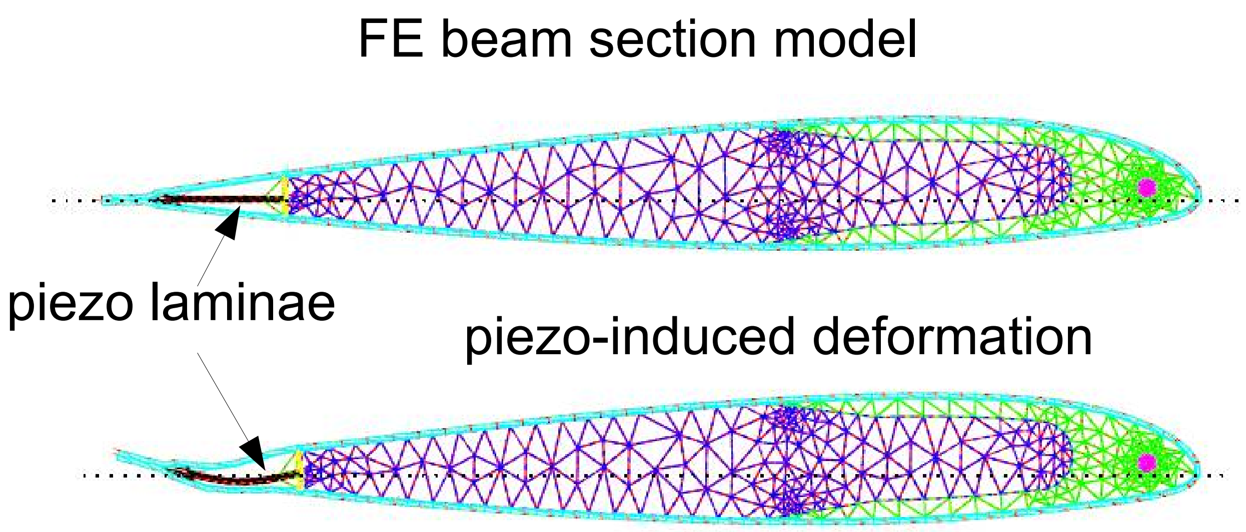
Results/Design Scaling to Full-Scale

- Scaling confirmed
- D shape: useful for aeroelastic constraint ?

- Full-scale blade design issues?
- Lamination sequence?
- Aerostrike?

T.E. blade design and optimization

- Ongoing



Scaling Laws

Scales:

Length:	sf	2.5
Modulus:	1	1
Voltage:	1	1
Elastic torsion stiffness:	sf^4	39.062
Induced twist moment:	sf^3	15.625
Twist authority (deg/m)/(V/m):	1/sf	0.4
Span:	sf	2.5
Twist authority (deg/span)/(V/m):	1	1

The tip twist should (!) be the same, although the twist rate decreases when scaling up to full-scale.

Road Map

- Current assumptions:
  - § MFC can only be produced at the current thickness (0.3 mm; please correct)
  - § Same voltage is used (~300 V; please correct)
- Current approach:
  - § Work with scaling laws applied to the model-scale blade section properties
  - § Introduce scale effects in blade section FEM model (multiple layers of MFC, design similar to original)
  - § Re-run optimization on the full-scale model