Clean Sky

RIBES

Aeroelastic Experimental measurements on the RIBES wing

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Sezione Ingegneria Aerospaziale

DAF

Design of Aircraft and Flight technologies
RESEARCH GROUP
www.daf.unina.it

DAF *(Design of Aircraft and Flight Technologies)*

research group

- Focused on Aircraft Design
- Applied aerodynamics and aerodynamic design of transport aircraft
- Wind-Tunnel tests
- Flight Mechanics and performance
- Flight Dynamics, flight tests and flight simulation

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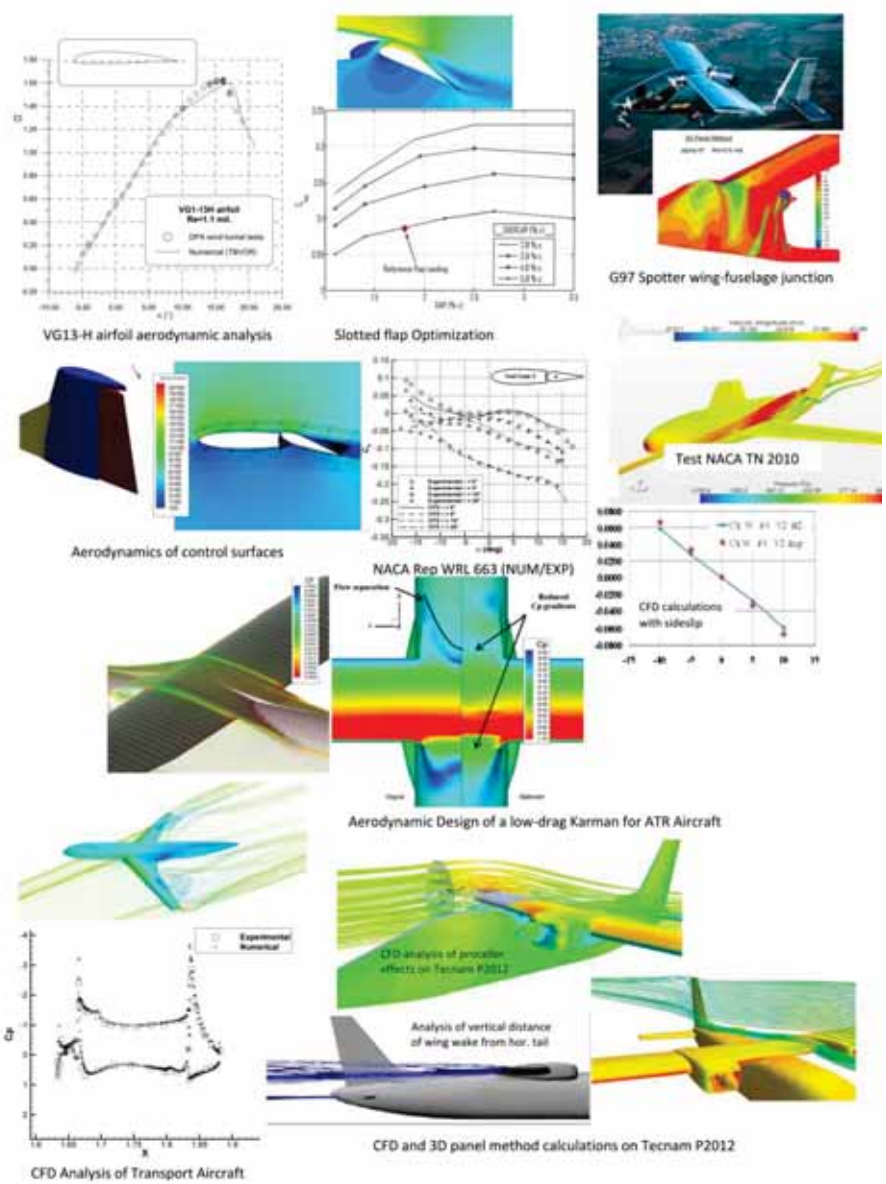
Applied Aerodynamics, CFD, Aerodynamic design
Aircraft Design and Flight Mechanics
Flight Tests and Simulation
Wind Tunnel Tests
UPPER SURFACE
flow direction

Aircraft applied aerodynamics and aerodynamic design

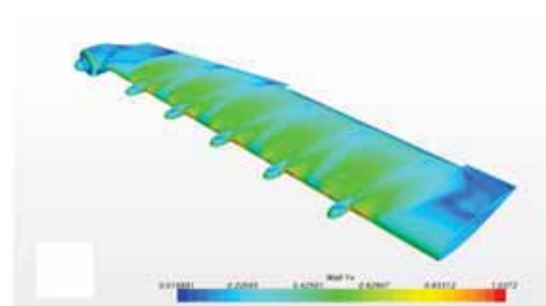


<u>USE and development of different tools:</u>

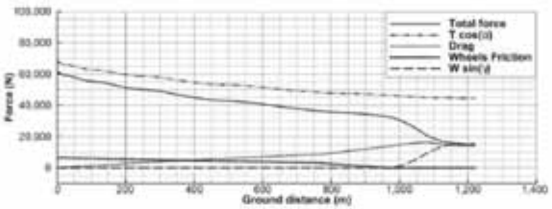
- CFD Navier-Stokes analysis
- Panel method
- Vortex lattice
- L1,5 procedures

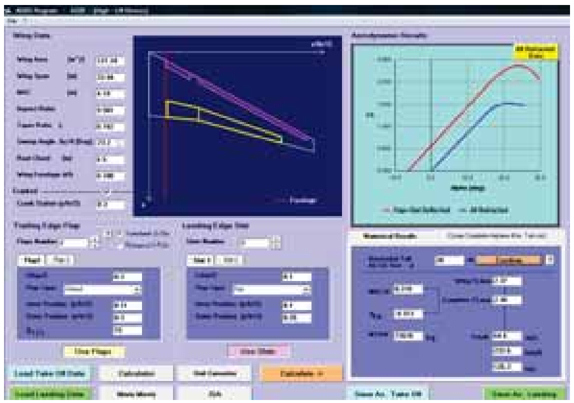
<u>Component design and optimization</u>

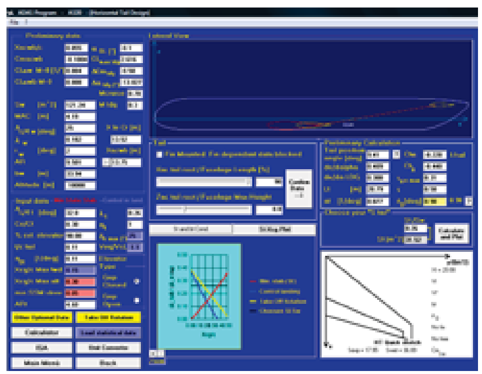
- 2-D airfoil optimization
- Wing optimization
- Winglet
- Fairing and karman
- Control surfaces
- Distributed propulsion



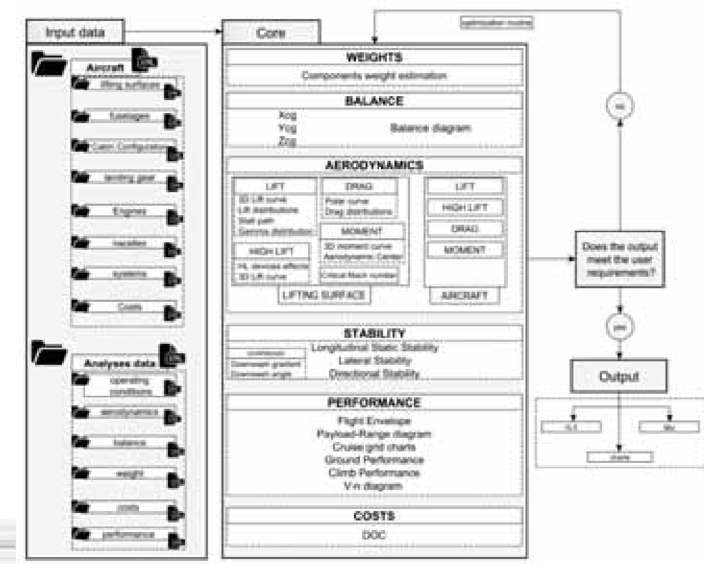
Aircraft Design and Flight Mechanics

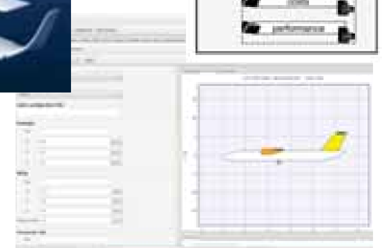




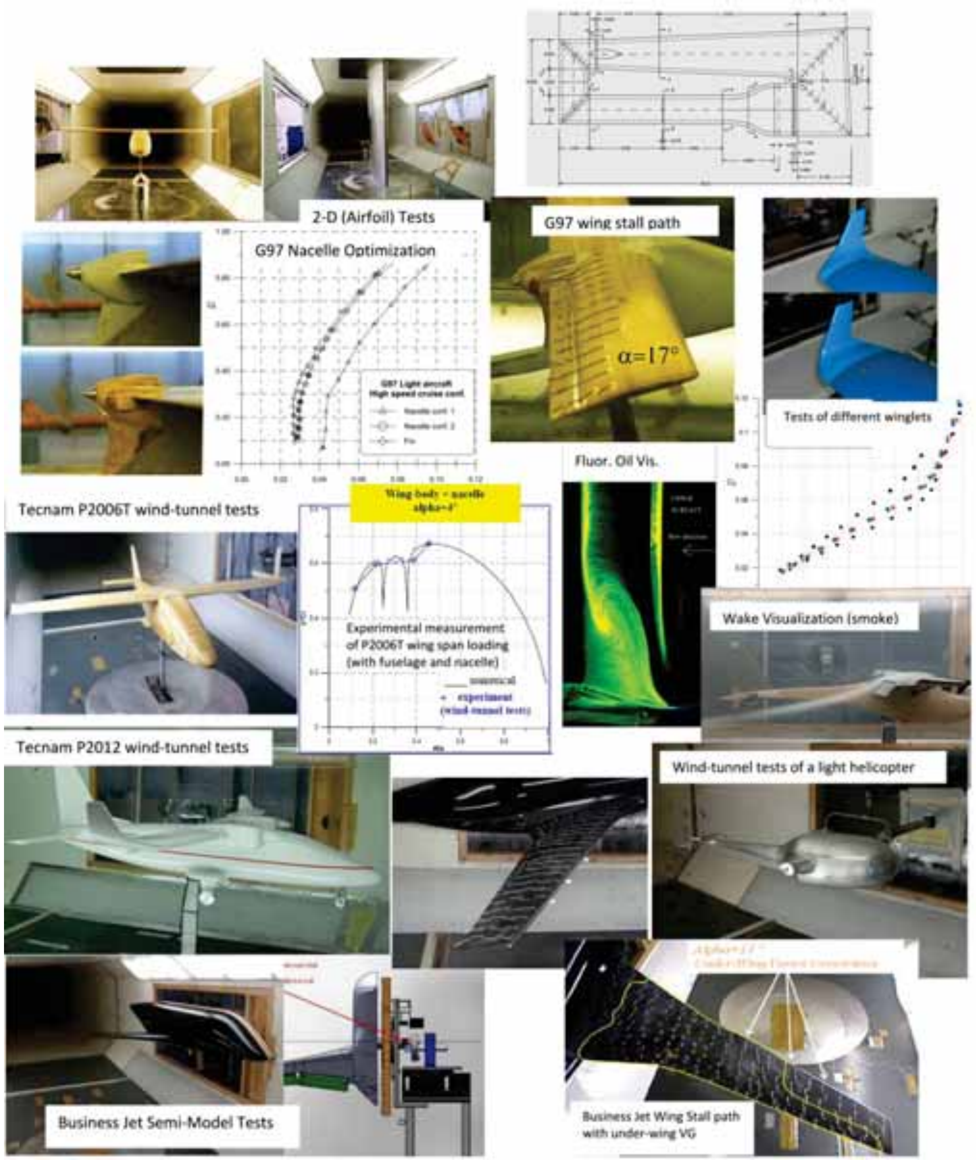


- Aircraft Design
- Aircraft Design framework Development
- Flight Mechanics
- Aircraft Performance
- Aircraft cost and operations
- Aircraft MDO





Wind-Tunnel tests



- Design of wind-tunnel models
- Test article instrumentation
- Wind tunnel instrumentation

(i.e. visualization)

- Numerical-Experimental comparison

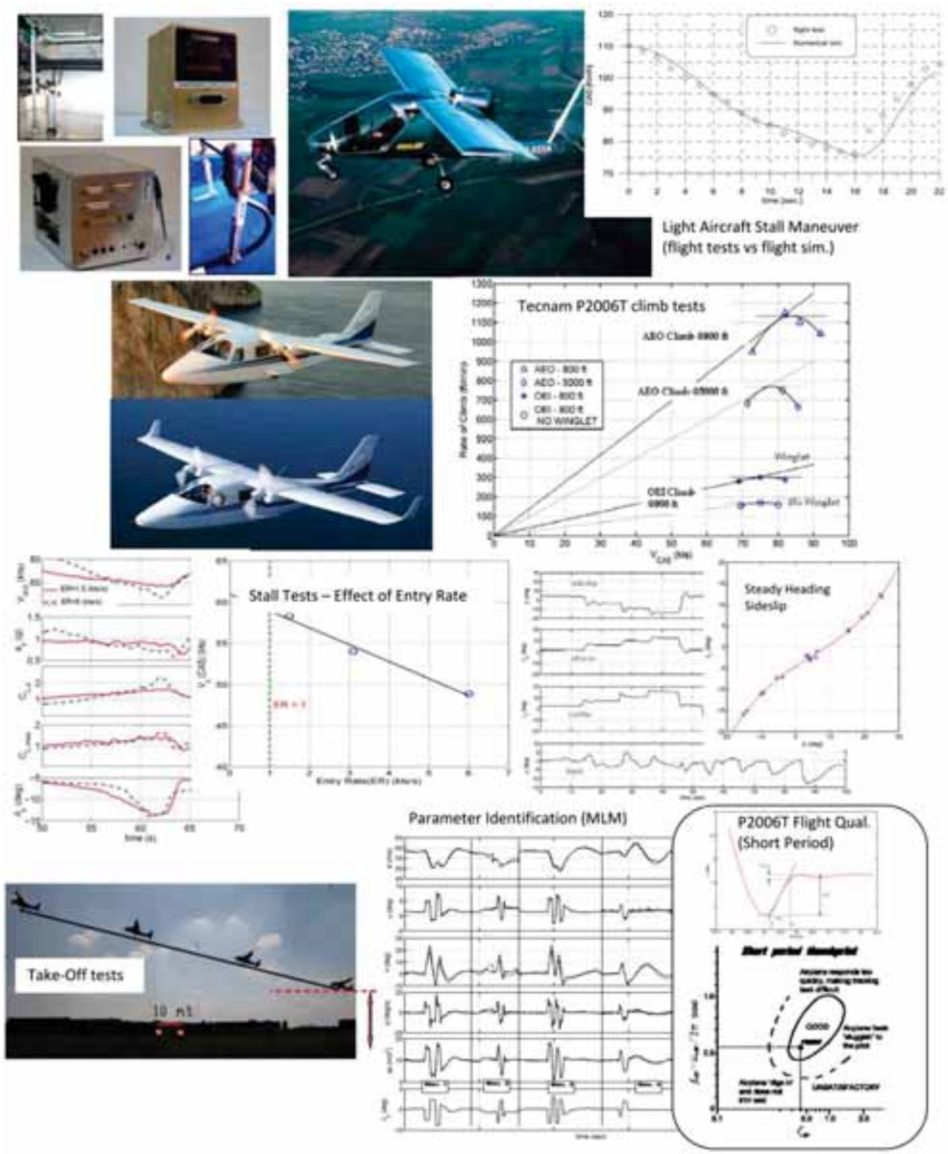
TESTS

- 3-D scaled model
- Semi-model
- 2-D airfoil tests
- Helicopter (no rotor)

⇒ About 20 airfoils tested (10 designed at UNINA for light aircraft and wind-turbine applications)

⇒ Since 1996 30 aircraft models tested

Flight Tests and flight simulation



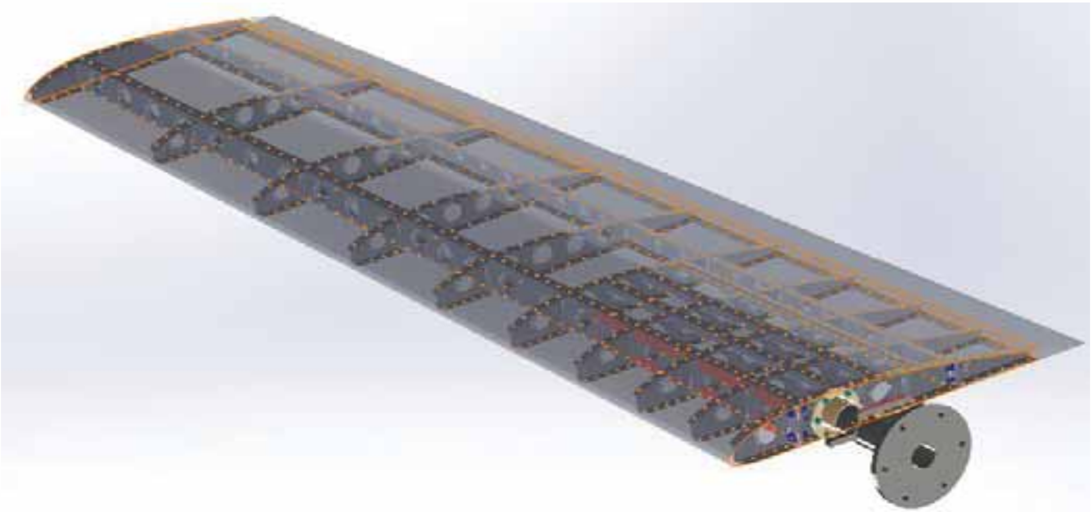
- Flight tests certification
- Performance Estimation and tests
- System identification
- Flight qualities
- Set-up of the flight simulation model

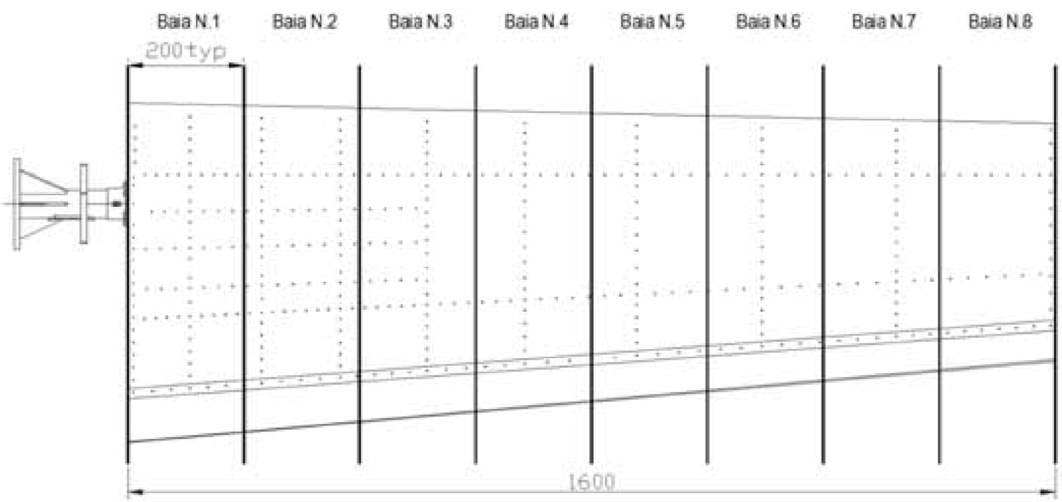
APPLICATIONS:

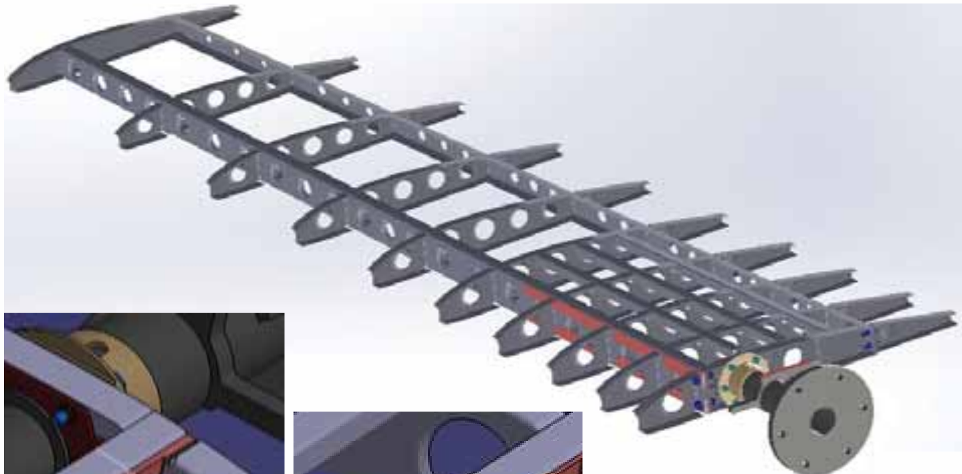
- Flight tests of P92 and P96 (Tecnam)
- Flight tests and VLA certification of G97 Spotter (2000-2004)
- Flight tests and VLA certification of P2000 RG (Tecnam)
- Flight tests and certification of P2006T
- Support for Oma-Sud Sky Car
- Flight tests of P2008

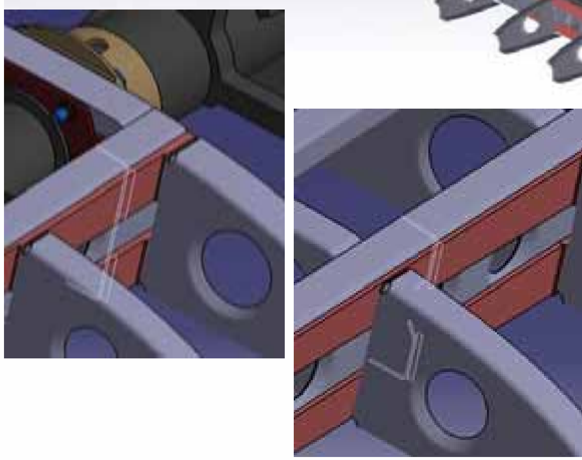
Design of the wing model for RIBES wind-tunnel tests

Wing span b	1.60 m
Root chord c_{root}	0.6 m
Taper ratio TR	0.7
Aft spar position % of chord	20 %
Rear spar position % of chord	65 %
Airfoil	GOE 398
Material	AL2024T3 alluminum alloy

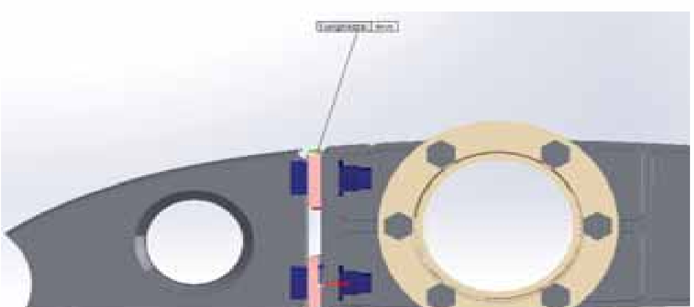


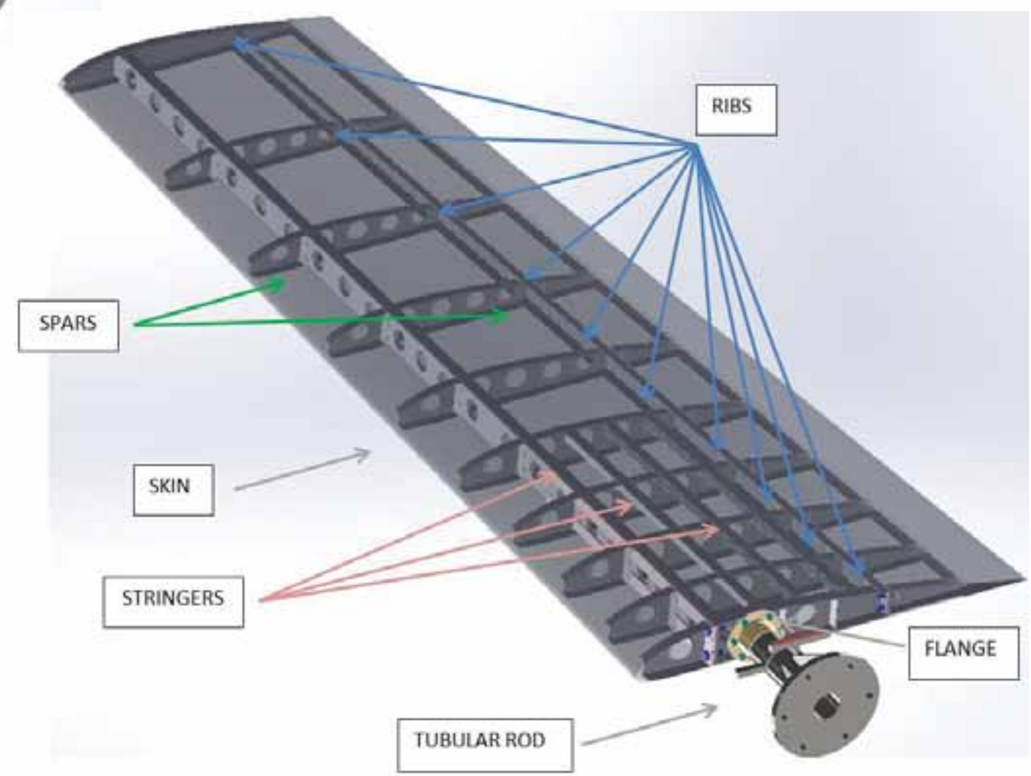


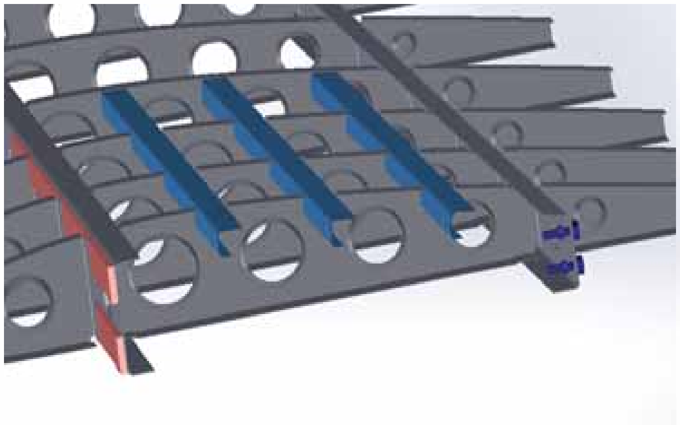


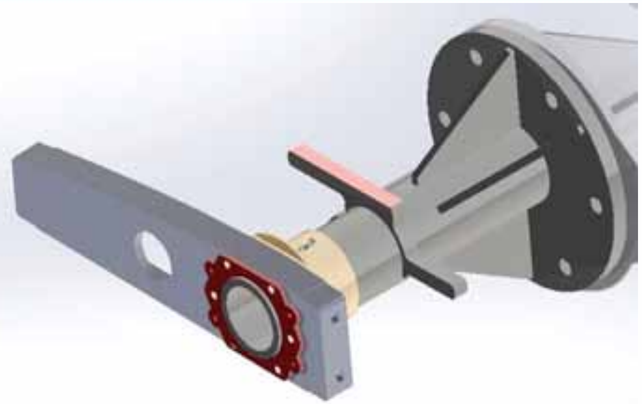


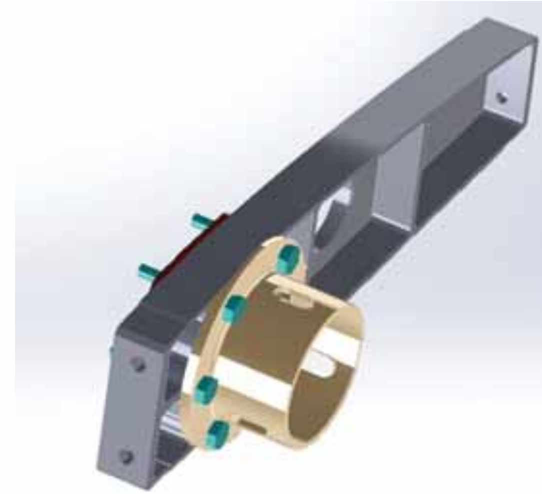
thickening of T2024T3 aluminum alloy on the front spar



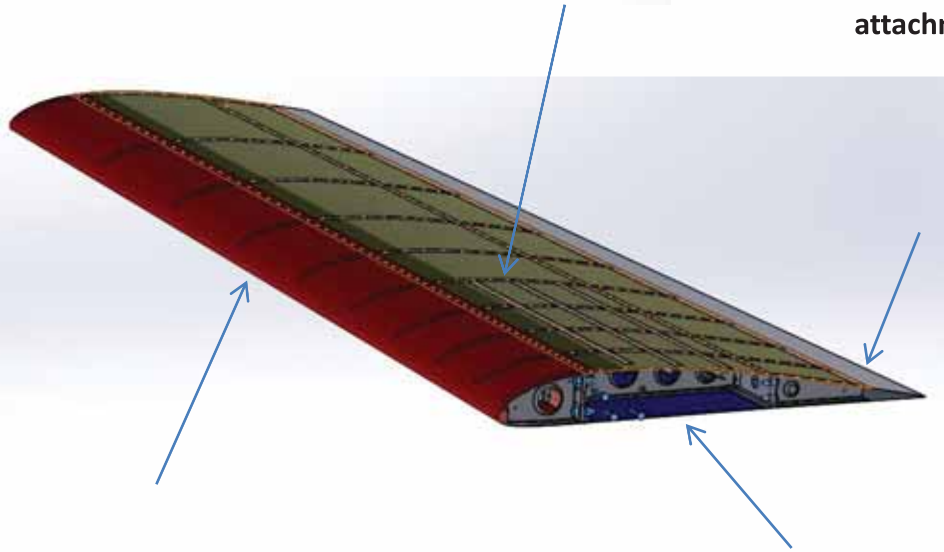




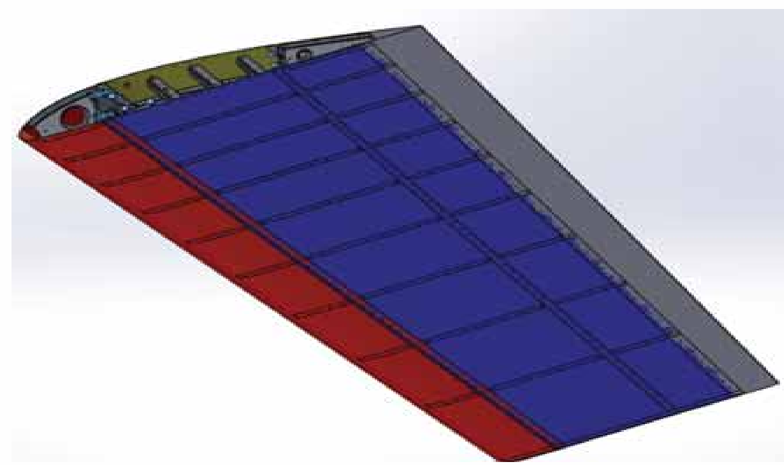


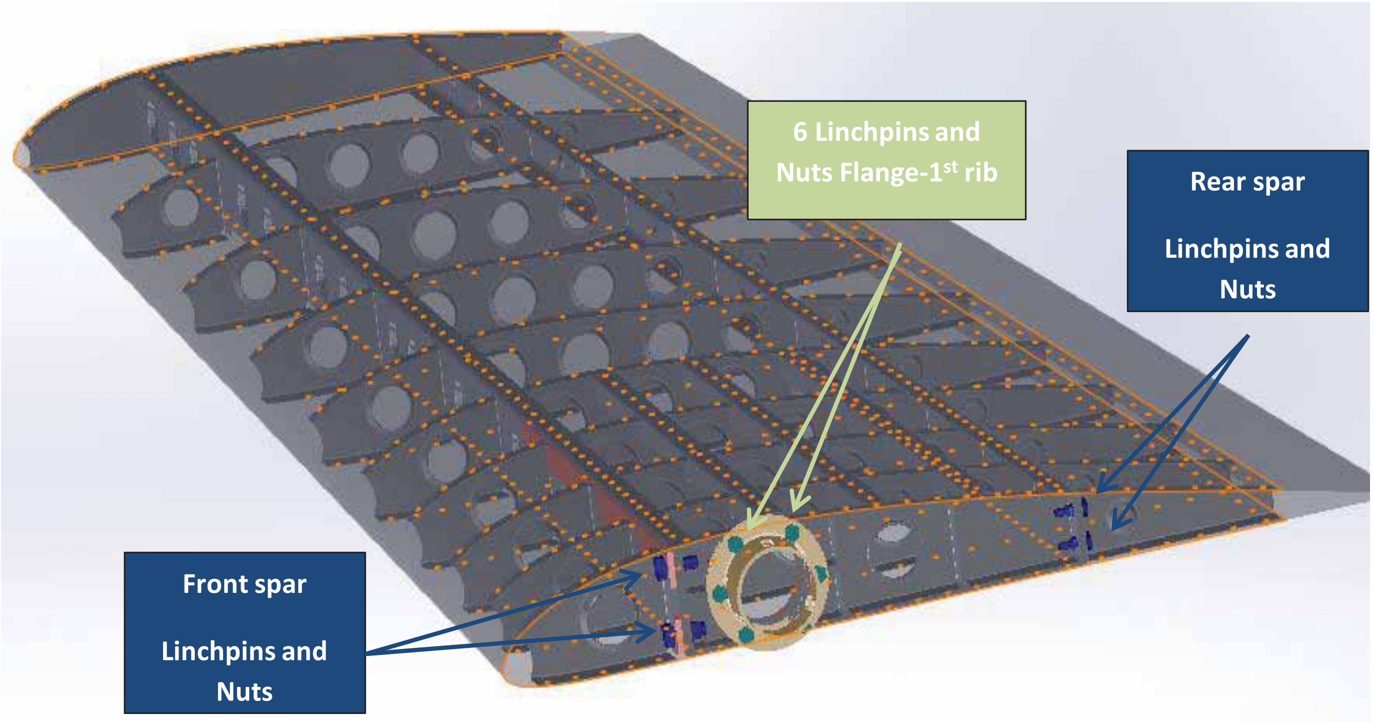


First machined rib and tubular rod attachment for model a. of a. reg.



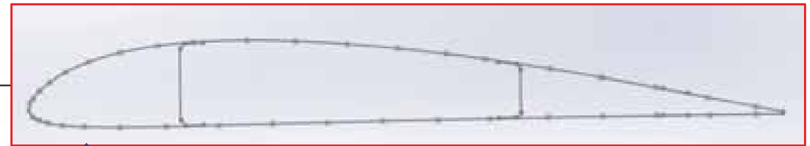
4 Aluminum alloy panels

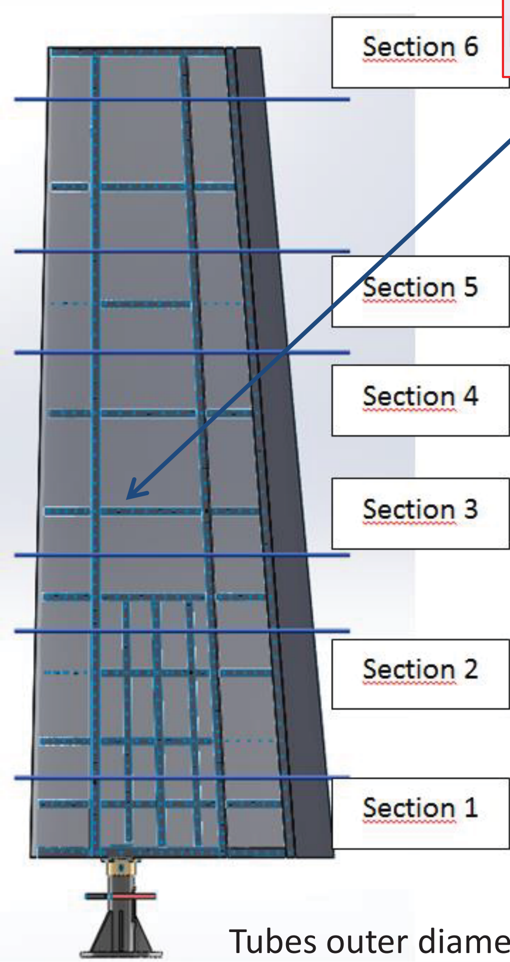


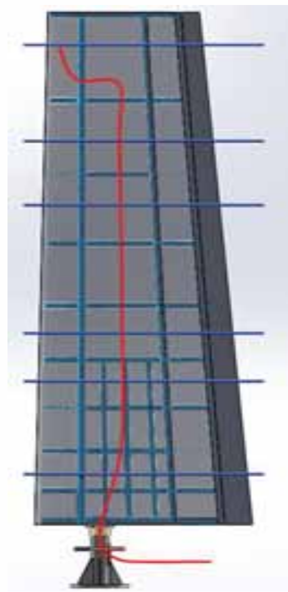


- n. 800 (eight hundred) rivets cherry max (see Section 4.4 and 4.5)
- n.6 (six) linchpins of 4.8 mm AN type
- n.6 (six) nuts of 4.8 mm MS210442 or equivalent type
- n.2 (two) linchpins of 7.92 mm e n.2 (two) nuts to join front spar to the 1st ribs.
- n.2 (two) linchpins of 4.8 mm e n.2 (two) nuts to join rear spar to the 1st ribs.

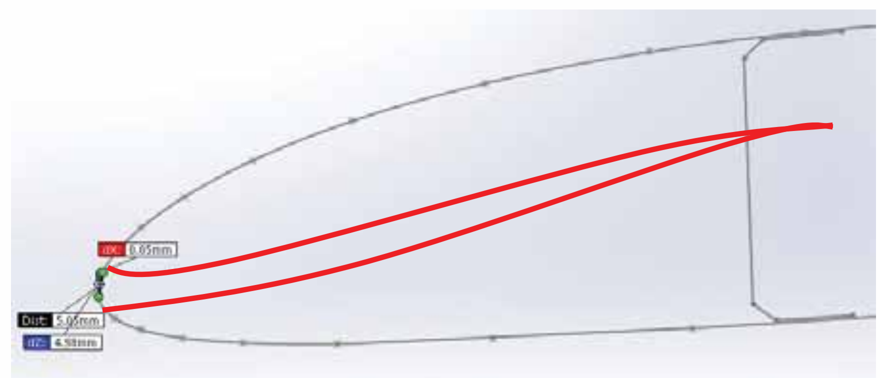
Pressure taps







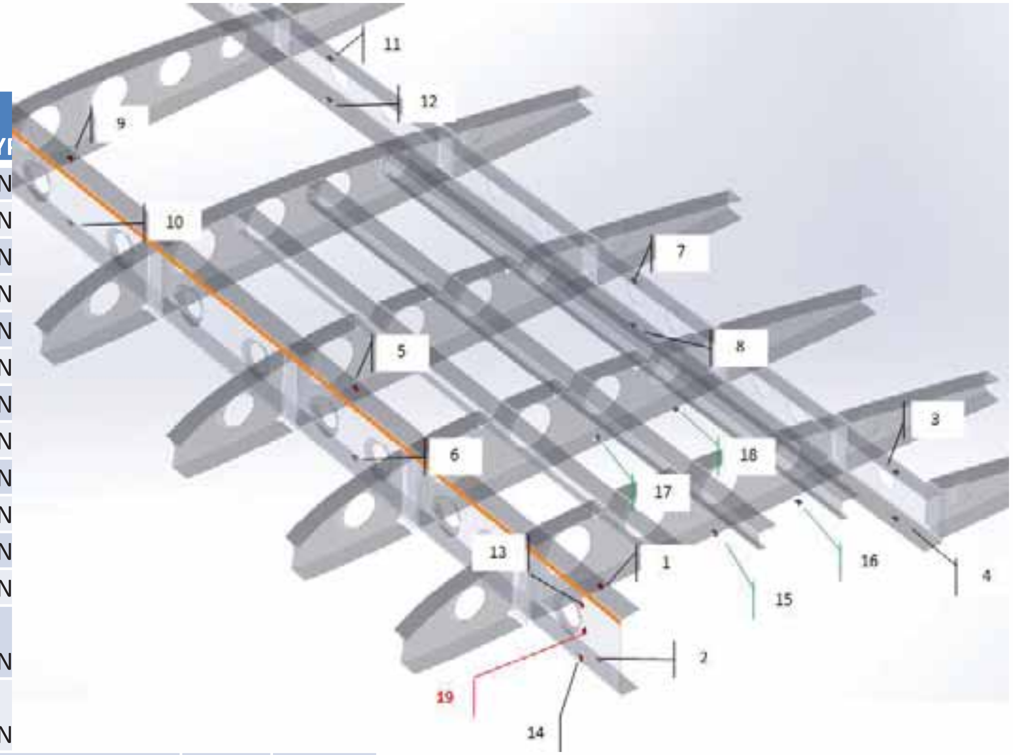
NAME ID	SECT	y(mm)	η	Chord(m)	N. Pressure taps
A	1	160	0.100	0.582	4
B	2	450	0.281	0.549	4
C	3	600	0.375	0.533	38
D	4	990	0.619	0.488	4
E	5	1200	0.750	0.465	26
F	6	1600	0.938	0.431	4
				Total	80



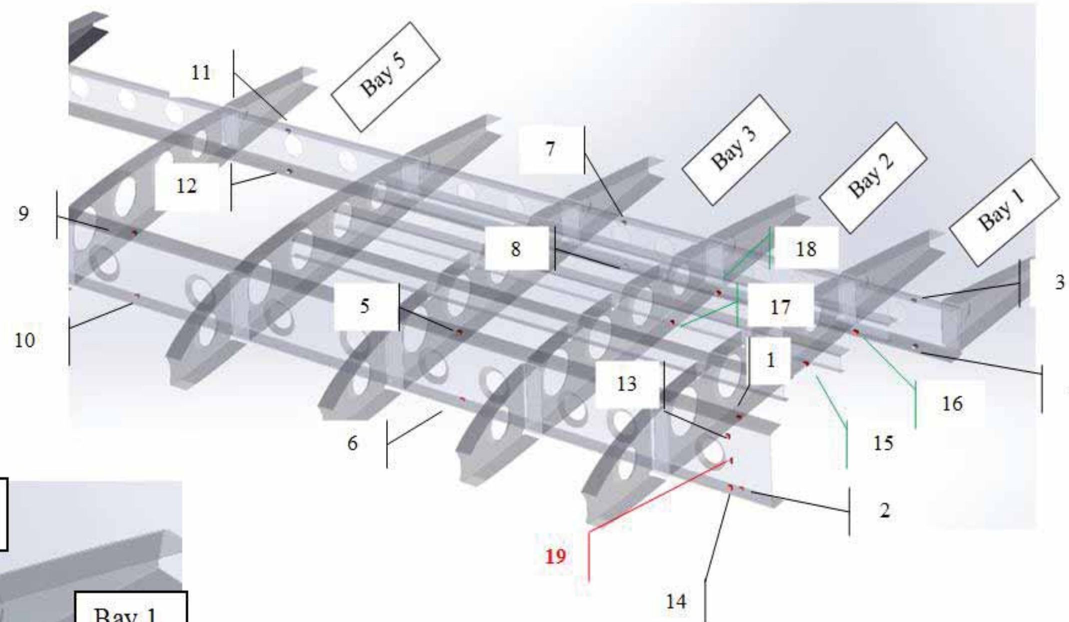
Tubes outer diameter is 2 mm
Tubes inner diameter is 1 mm
Tubes do not coincide with rivets and ribs
Tubes go through ribs and spars holes

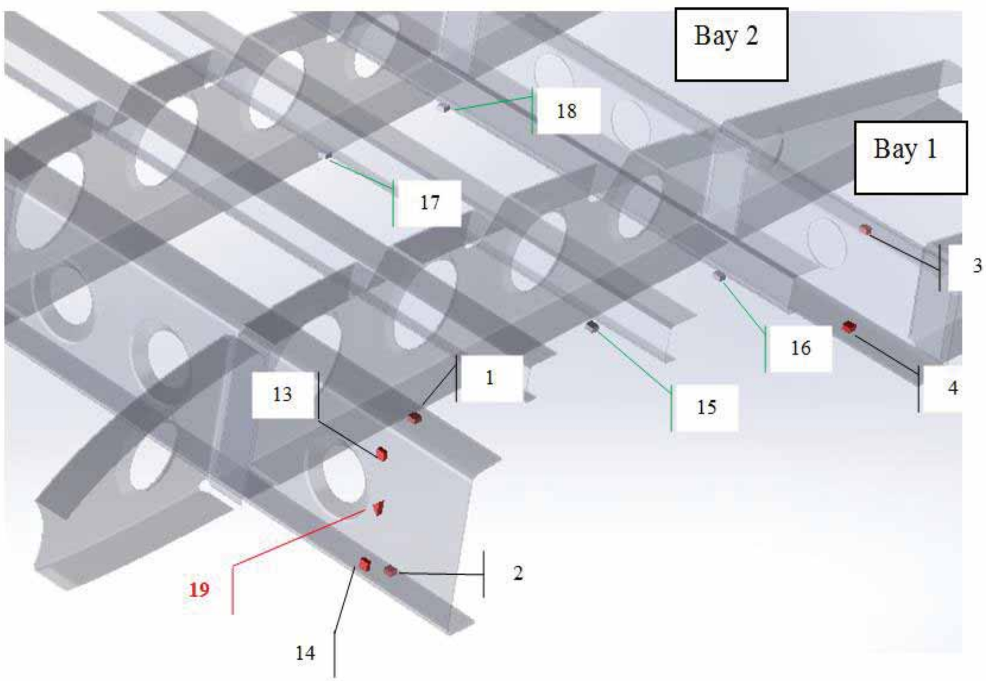
Strain gauges

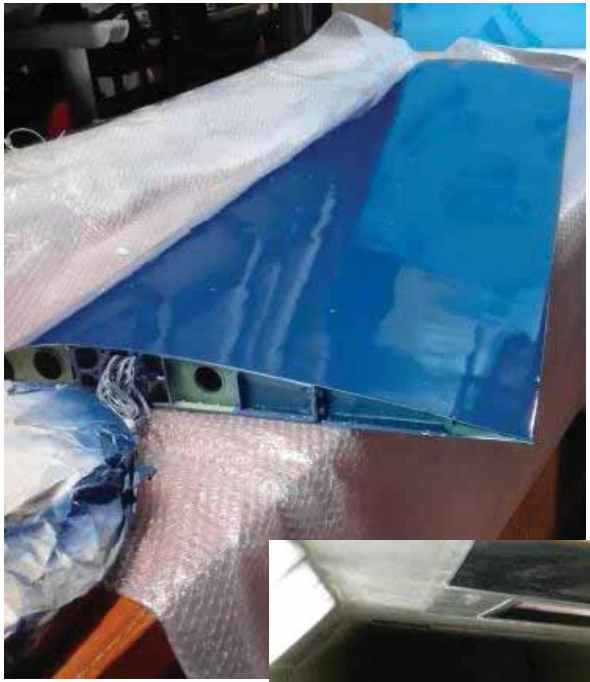
ID	Bay	POSITION	INSTALLATION	TYP		
1	1	between rib1-rib2	front spar	UN		
2	1	between rib1-rib2	front spar	UN		
3	1	between rib1-rib2	rear spar	UN		
4	1	between rib1-rib2	rear spar	UN		
5	3	between rib3-rib4	front spar	UN		
6	3	between rib3-rib4	front spar	UN		
7	3	between rib3-rib4	rear spar	UN		
8	3	between rib3-rib4	rear spar	UN		
9	5	between rib5-rib6	front spar	UN		
10	5	between rib5-rib6	front spar	UN		
11	5	between rib5-rib6	rear spar	UN		
12	5	between rib5-rib6	rear spar	UN		
13	1	between rib1-rib2	front spar thickening	UN		
14	1	between rib1-rib2	front spar thickening	UN		
15	1	1stbay, between 1st and 2nd stringer	Skin	UNIDIRECTIONAL	39.5	0.025
16	1	1stbay, between 2nd and 3rd stringer	Skin	UNIDIRECTIONAL	39.5	0.025
17	2	2ndbay, between 1st and 2nd stringer	Skin	UNIDIRECTIONAL	170	0.106
18	2	2ndbay, between 2nd and 3rd stringer	Skin	UNIDIRECTIONAL	170	0.106
19	1	between rib1-rib2	front spar	ROSETTE-3SIGNAL	39.5	0.025



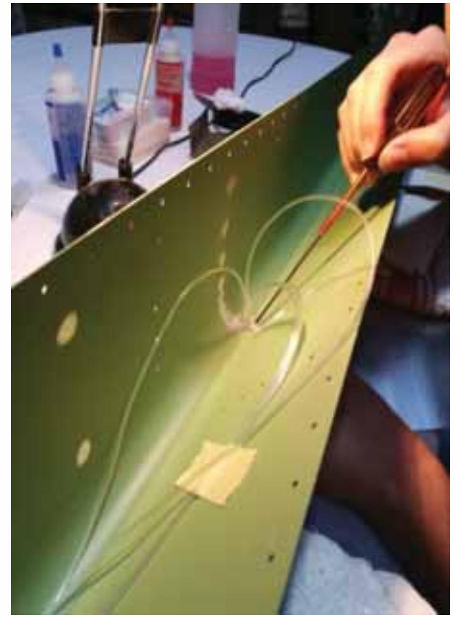
Strain gauges

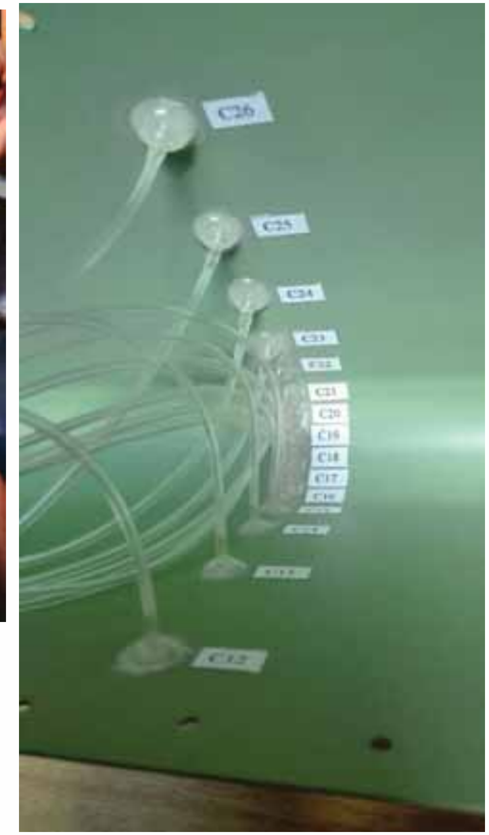


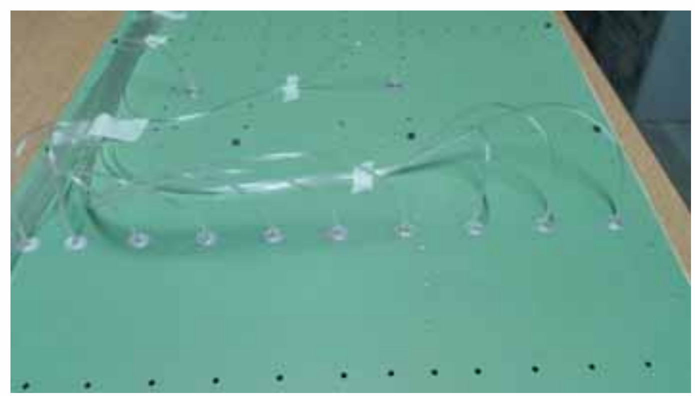


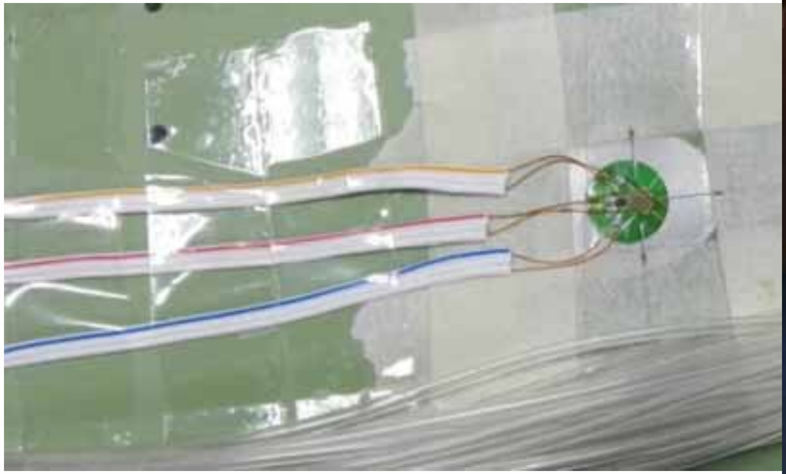


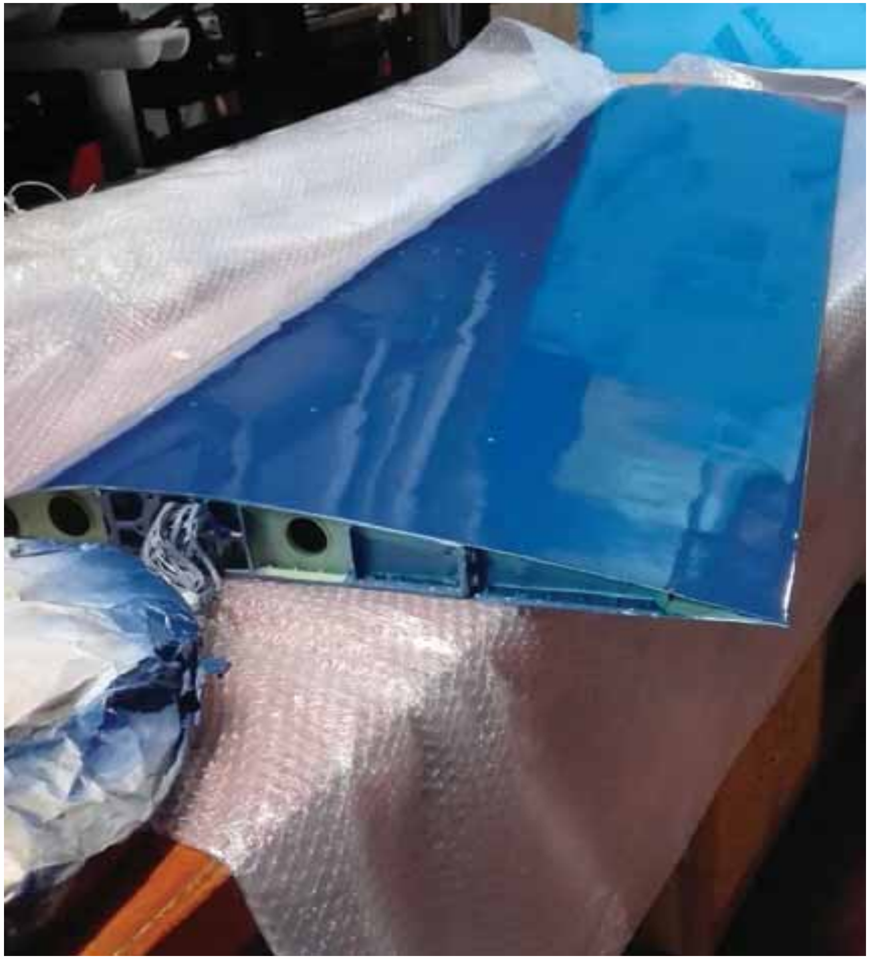

SECTION 6
F TAPS
SECTION 5
E TAPS
SECTION 4
D TAPS
SECTION 3
C TAPS
SECTION 2
B TAPS
SECTION 1
A TAPS



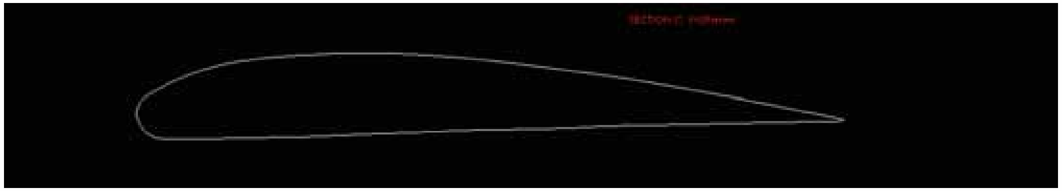

C26
C25
C24

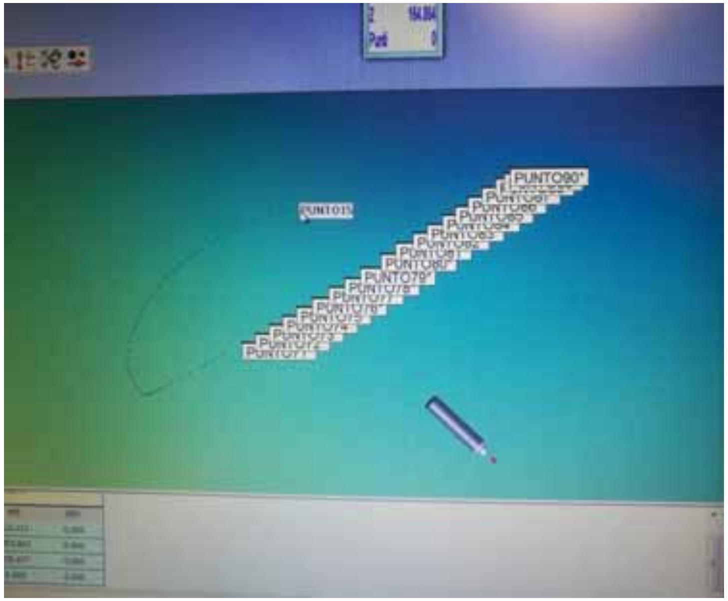


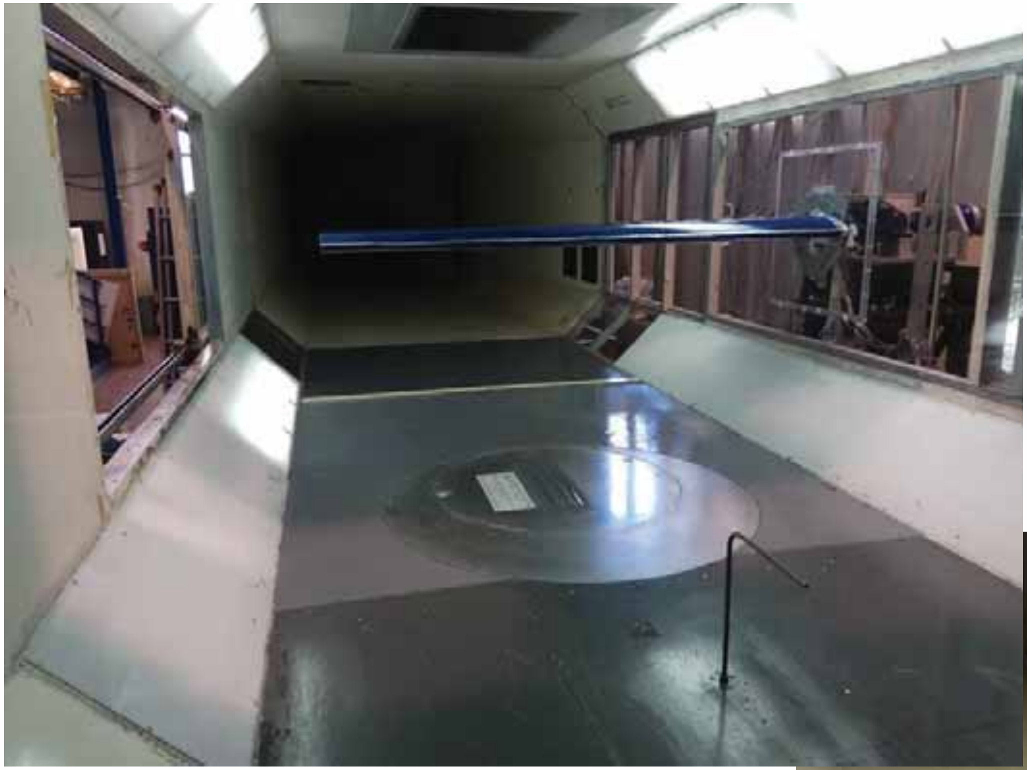




The model geometry has been also reconstructed through a **HEXAGON metrology electronic harm**



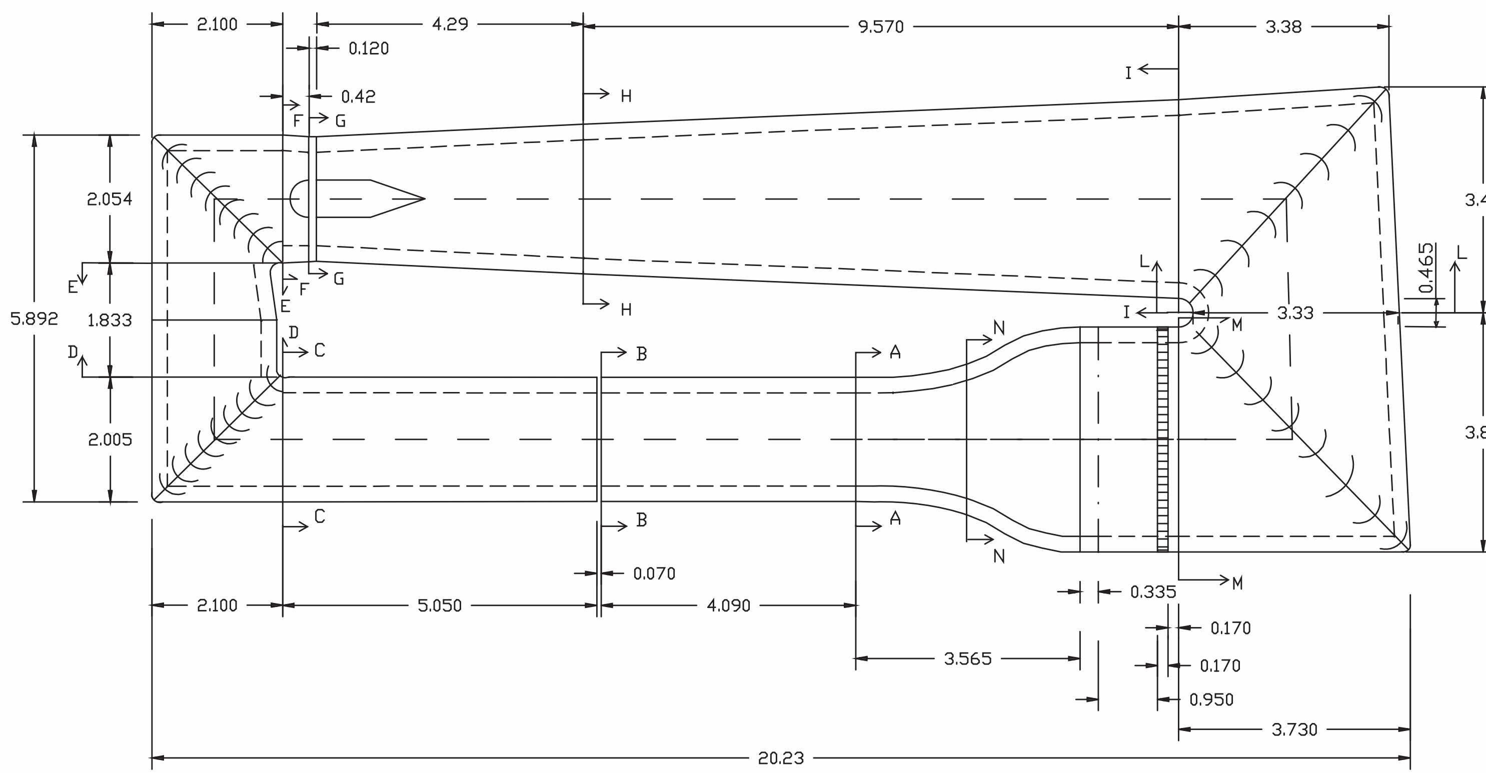


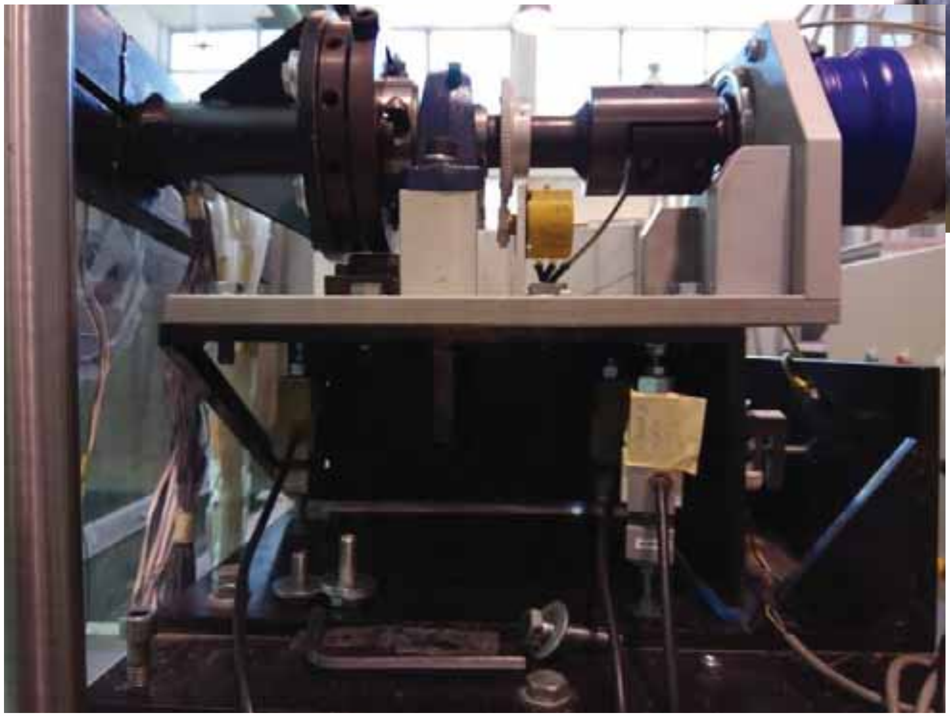


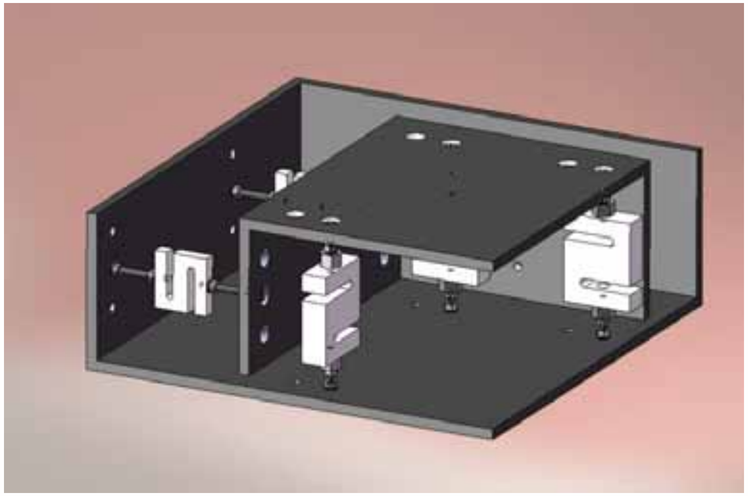
UNINA Low-speed wind-tunnel facility

Type: *closed circuit-closed test section*
Test section dimensions : 2.0 m x 1.4 m
Maximum speed : about 160 Km/h (45 m/s)
Turbulence level : 0.1%
Temperature range : 10-50 °C

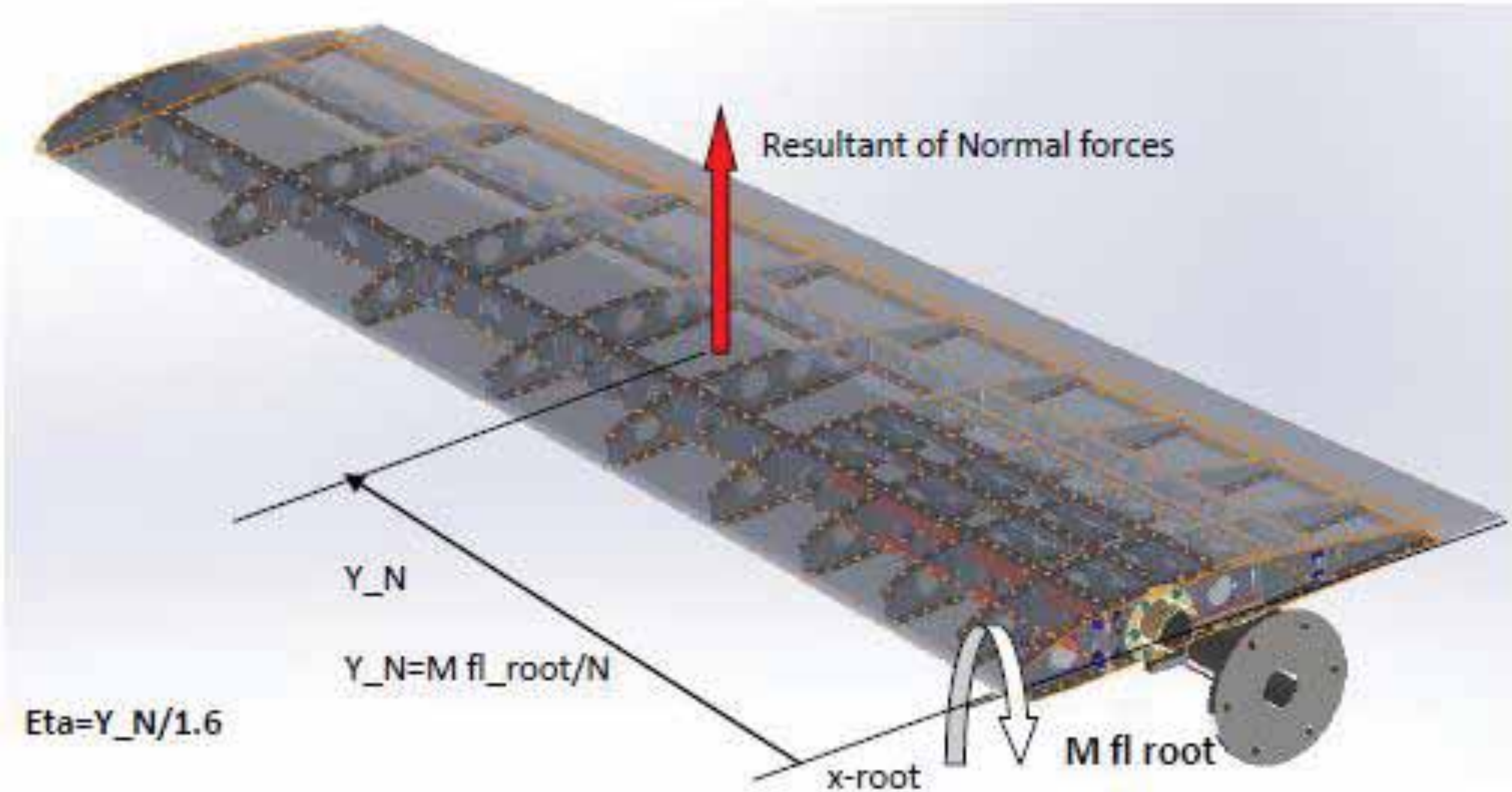
Speed range : 5-45 m/s
Reynolds number : 1 - 2 mil. For airfoil 2-D tests.
Usually about 0.9 – 1.0 mil. For 3D model tests (chord of about 0.25 m)
Dynamic Pressure : 15 – 1200 Pa
Stagnation pressure : Dyn press + ambient pressure
(about 103500 Pa + q = 104700 Pa)



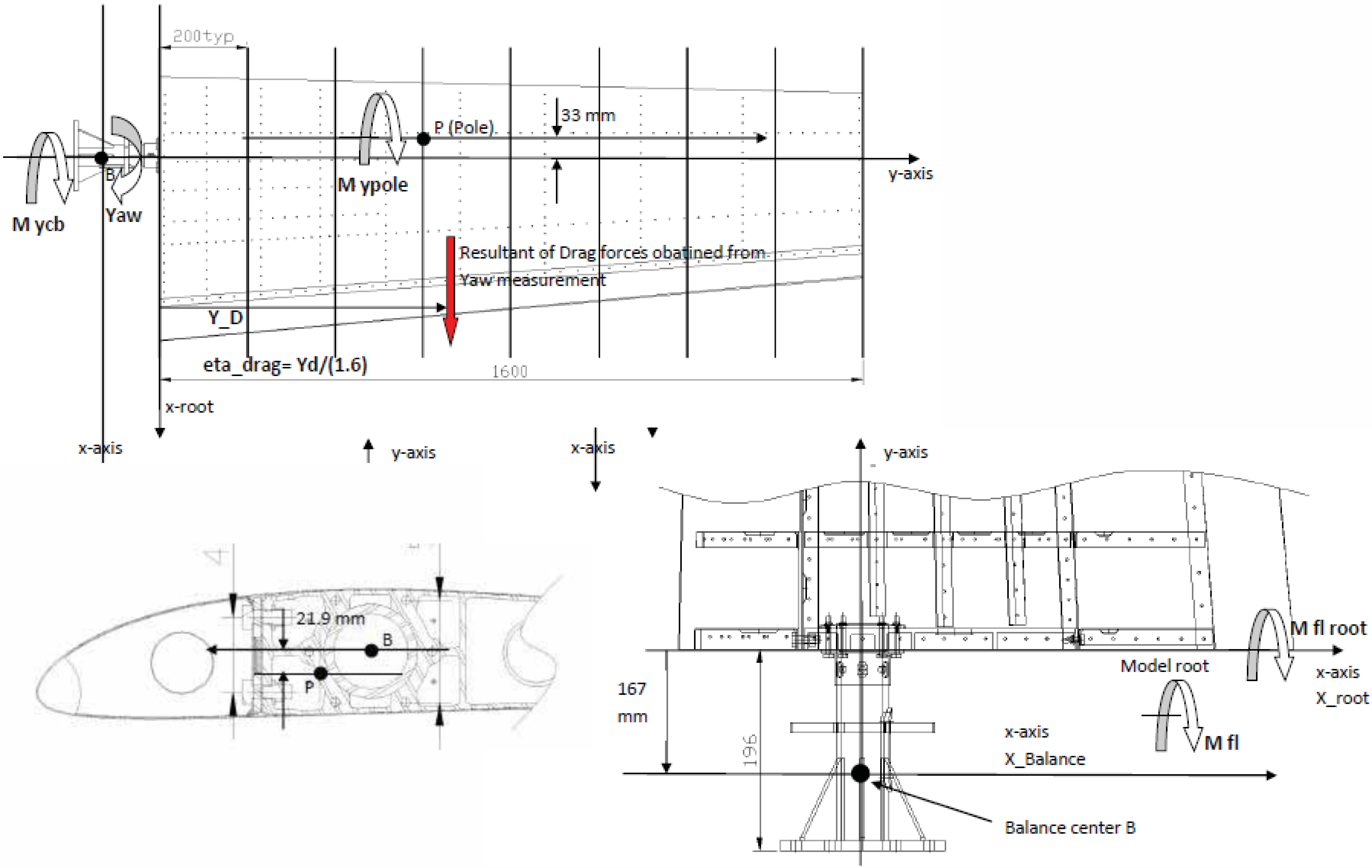


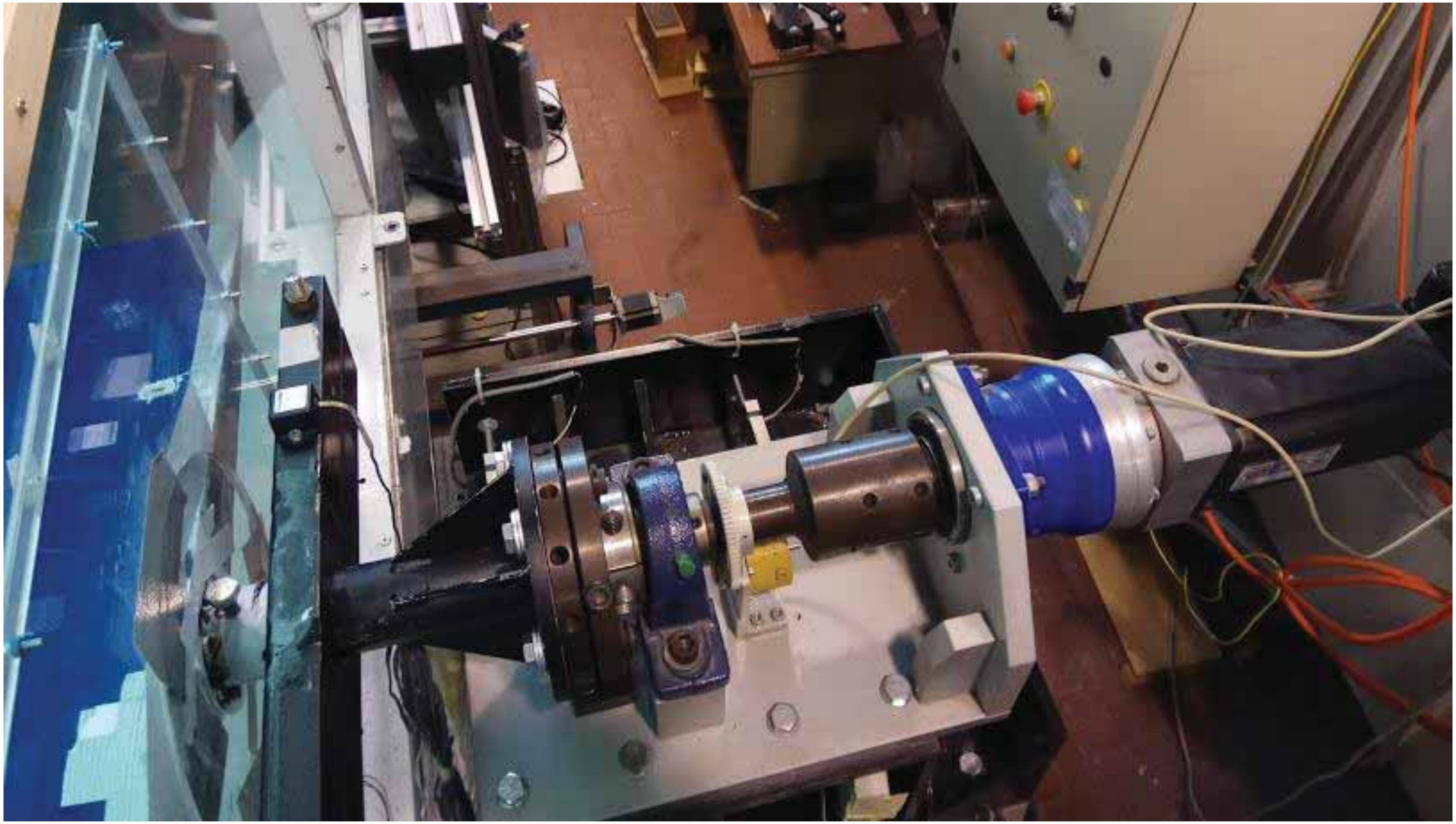


Component	Range		Accuracy
	Min	Max	
Normal force (Lift) L	-80 Kg	100 Kg	0.030 Kg
Horizontal force (Drag) D	-12 Kg	12 Kg	0.005 Kg
Pitching moment My	-15 Kg*m	15 Kg*m	0.010 Kg*m
Bending moment Mfl	-40 Kg*m	60 Kg*m	0.030 Kg*m
Yawing moment Myaw	-8 Kg*m	8 Kg*m	0.006 Kg*m



S=0.815 m^2 model reference area (planform area)
c : model reference chord (mean aerodynamic chord, **c =0.5153 m**


200typ
33 mm
P (Pole)
y-axis
M ypole
M ycb
B
Yaw
Resultant of Drag forces obatined from
Yaw measurement
Y_D
eta_drag= Yd/(1.6)
1600
x-root
x-axis
y-axis
x-axis
y-axis
21.9 mm
B
P
M fl root
Model root
x-axis
X_root
167
mm
196
x-axis
X_Balance
M fl
Balance center B



Wind-Tunnel corrections

Upwash and streamline curvature

$$\Delta\alpha = (1+\tau_{2w})\cdot\delta\cdot\left(\frac{S}{A_{wt}}\right)\cdot CL \qquad \alpha_{cor} = \alpha_g + \Delta\alpha$$

$$\tau_{2w} = 0.18 \qquad \delta = 0.61$$

The correction is proportional to the developed lift and lift coefficient.
The correction to be applied is positive, it means that with a certain geometrical angle of attack, the effective corrected angle of attack will be slightly higher.
At an angle of attack of about 6° and a lift coefficient of about 0.80 (CL=0.80), the correction is about 1°, it means that the effective angle of attack is 7°.

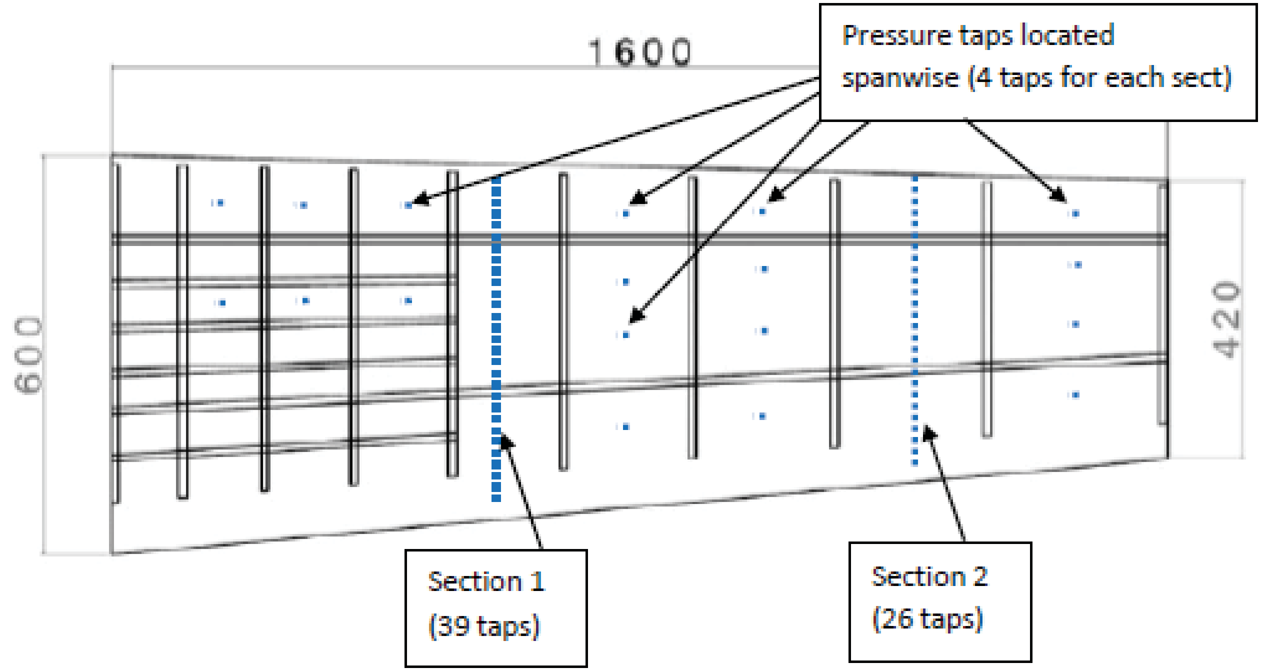
Solid and wake blockage

Due to the model solid blockage, and due to the wake blockage the dynamic pressure around the model will be increased by a factor that in this case is around 1.013.
That means :
$q_{cor}/q=1.013$ or $q/q_{cor}=0.987$

$CL_{cor}=CL*(q/ q_{cor})$
$CD_{cor}=CD*(q/ q_{cor})$
$CM_{cor}=CM*(q/ q_{cor})$

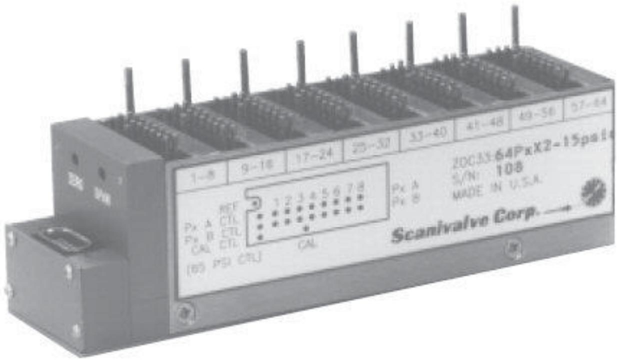
$$\Delta CD = \Delta\alpha\cdot CL - \Delta CD_{wake\_blockage} \qquad CD_{cor} = CD\cdot\left(\frac{q}{q_{cor}}\right) + \Delta\alpha\cdot CL - \Delta CD_{wake\_blockage}$$

Pressure measurements



SCANIVALVE 128 channel electronic pressure measurement system

- Accuracy (about 3 Pa)
- Very Fast
- Unsteady measurements



TEST MATRIX PLANNED and COVERED

Name	flow speed	Reynolds	Measurements and Conditions
Oil	30 m/s	1.06 mill.	Flow vis with fluorescent oil at several a of att
			CLEAN Conditions
TEST L30	30 m/s	1.06 mill.	Full polar (up to stall) free transition L, D, M, Cp
TEST L35	35 m/s	1.25 mill.	(Up to 10°) polar free trans. L, D, M, Cp
TEST L40	40 m/s	1.43 mill.	Limited (up to 8°) polar free trans. L, D, M, Cp
			TURBULENT Conditions(b.l. tripped at l.e)
TEST 7/8/13	35 m/s	1.06	Tests at 35 m/s and repeatability check (L,D,M)
TEST T30	30 m/s	1.06 mill.	Full polar fixed trans 1-2% L, D, M, Cp, strain
TEST T35	35 m/s	1.25 mill.	Full polar fixed trans 1-2% L, D, M, Cp, strain
TEST T40	40 m/s	1.43 mill.	Limited polar fixed trans 1-2% L, D, M, Cp, strain
TEST F28	Var speed	Var	a=4°& 6° fixed trans 1-2% L, D, M, Cp, strain

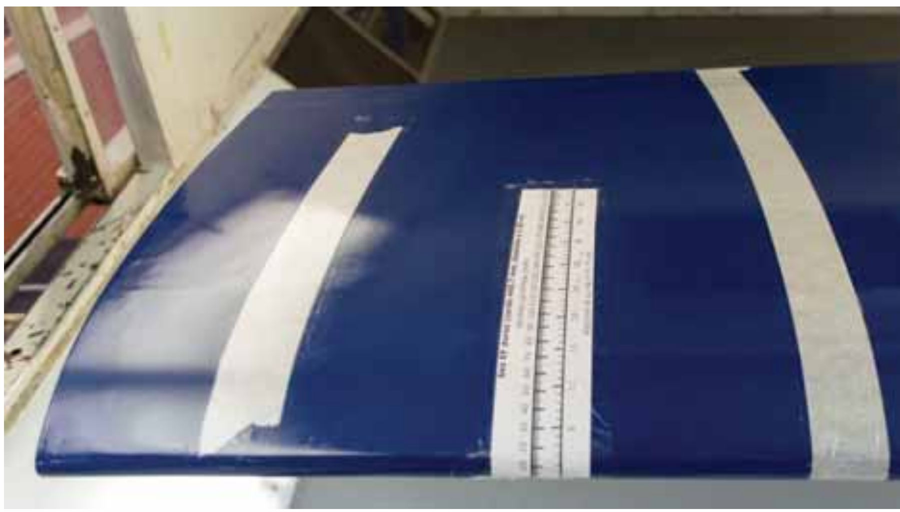
Model deformation measurement through LASER

TEST Da6	40 m/s	1.43 mill.	a=6°, L=60.3Kgf fixed trans 1-2% L, D, M, strain, Model deformation

TEST RESULTS, FLUORESCENT OIL VISUALIZATION

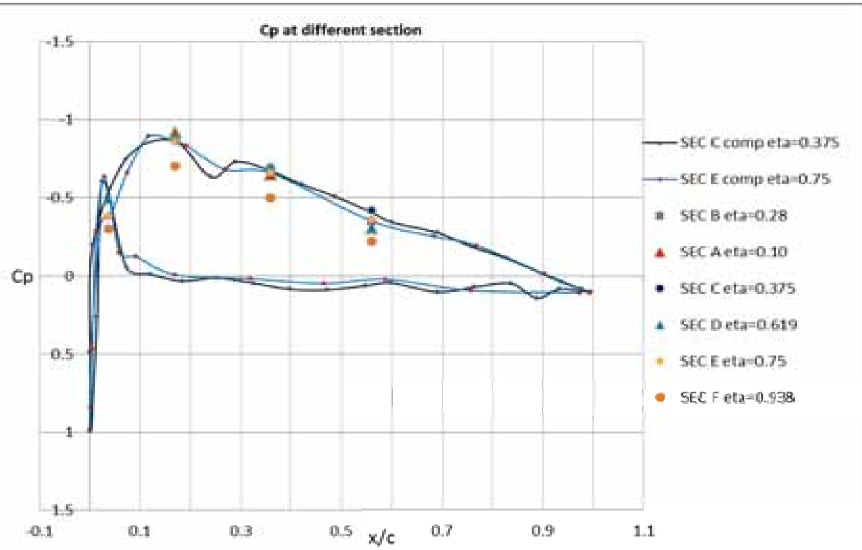
The clean model installed in the wind-tunnel has been covered with some fluorescent oil in several section along the span.

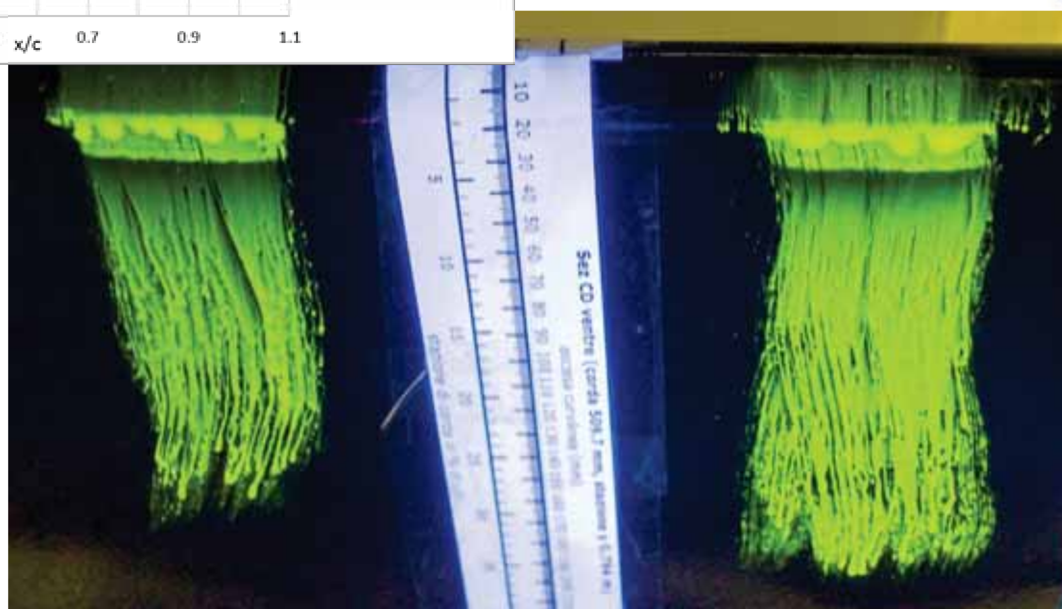
Some paper strip has been placed close to station C (y=600 mm) and station E (y=1200 mm) to highlight with pictures the accurate measurement of the position of the laminar separation bubble, both in terms of curvilinear abscissa (in [mm]) and in terms of fraction of local chord.

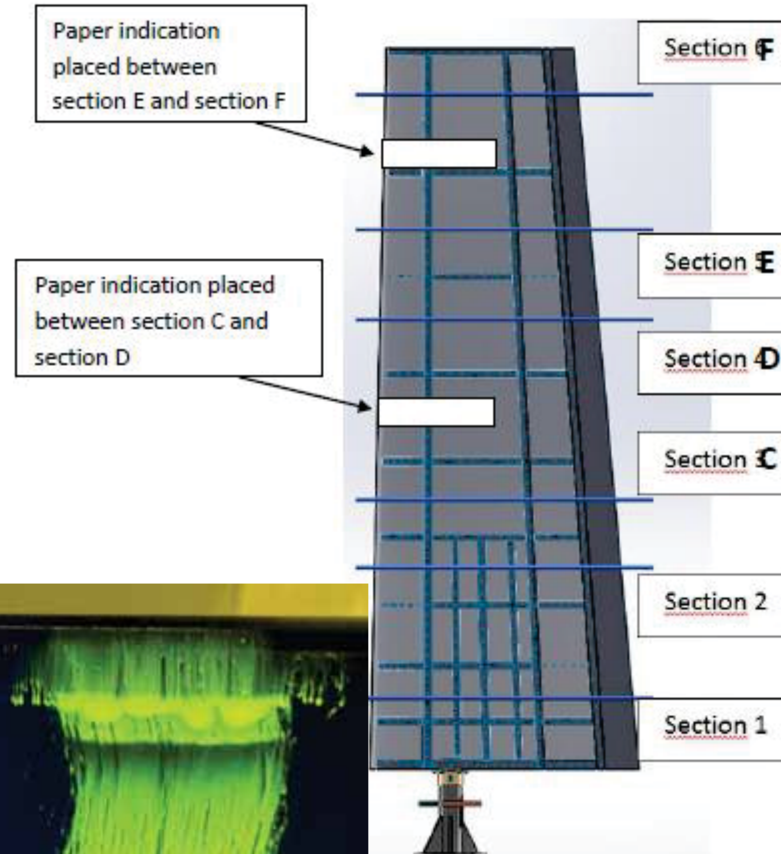


TEST RESULTS, FLUORESCENT OIL VISUALIZATION

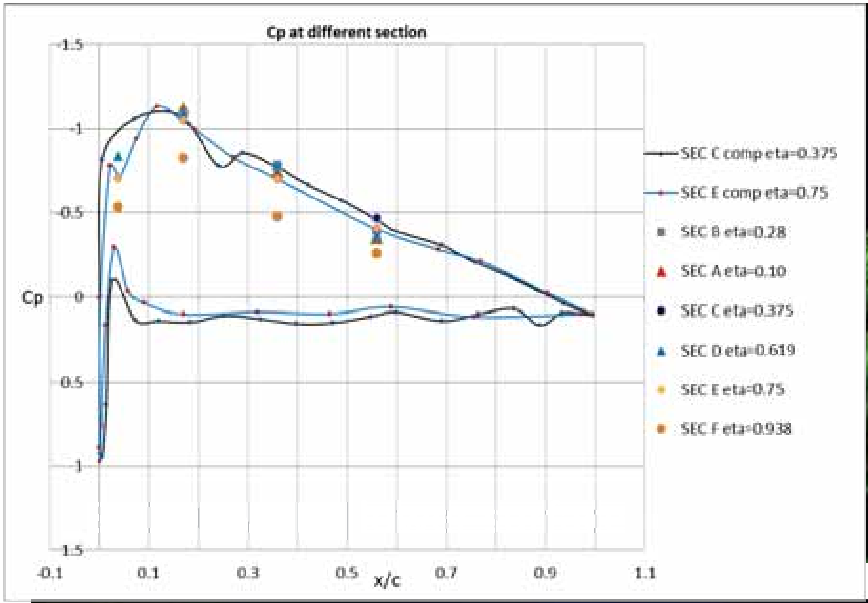
Alpha (geometrical) = 2°, V=30 m/s

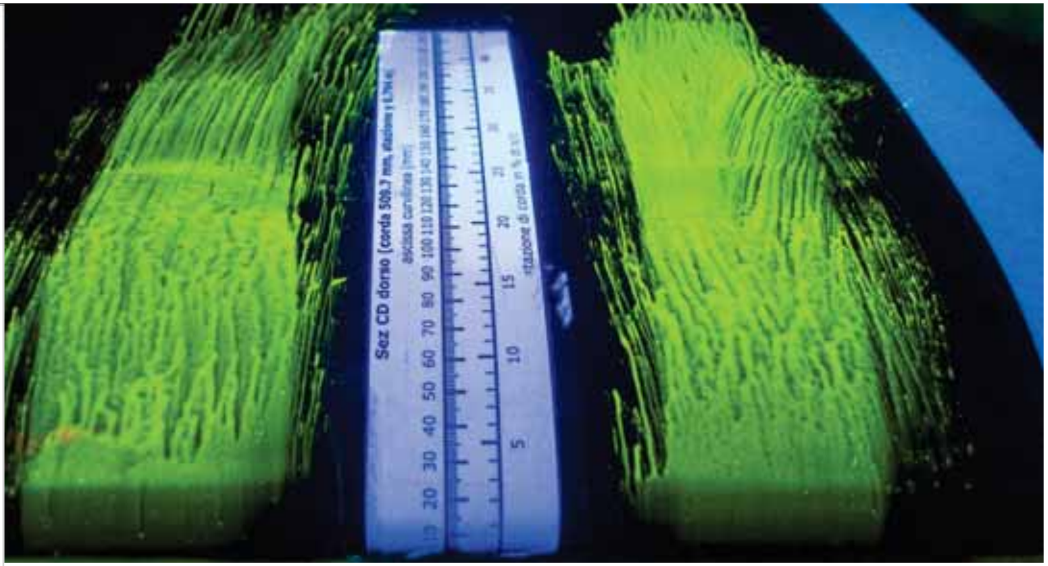




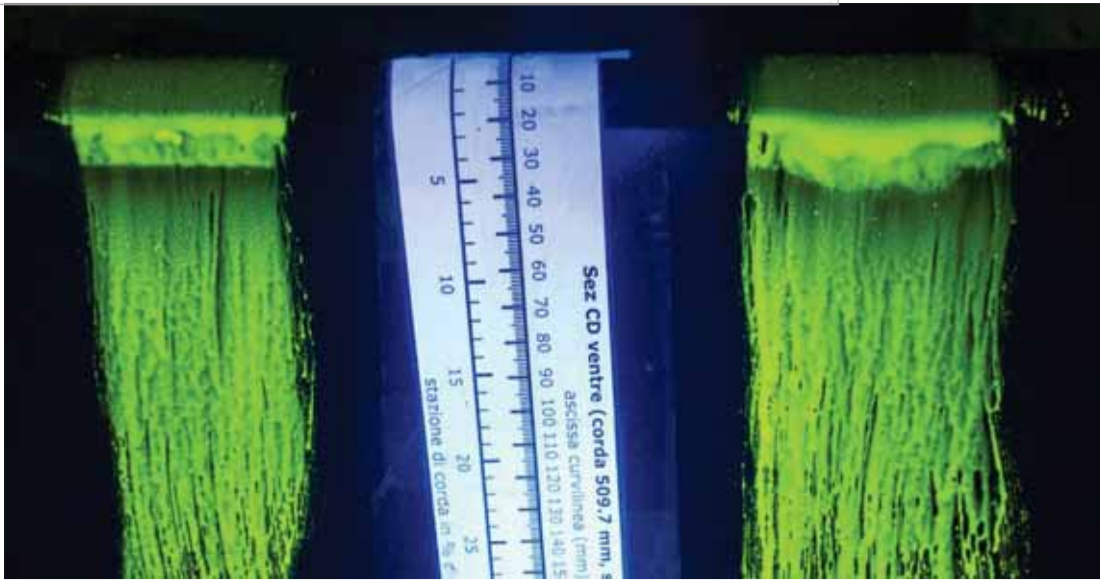


Alpha (geometrical) = 4°, V=30 m/s

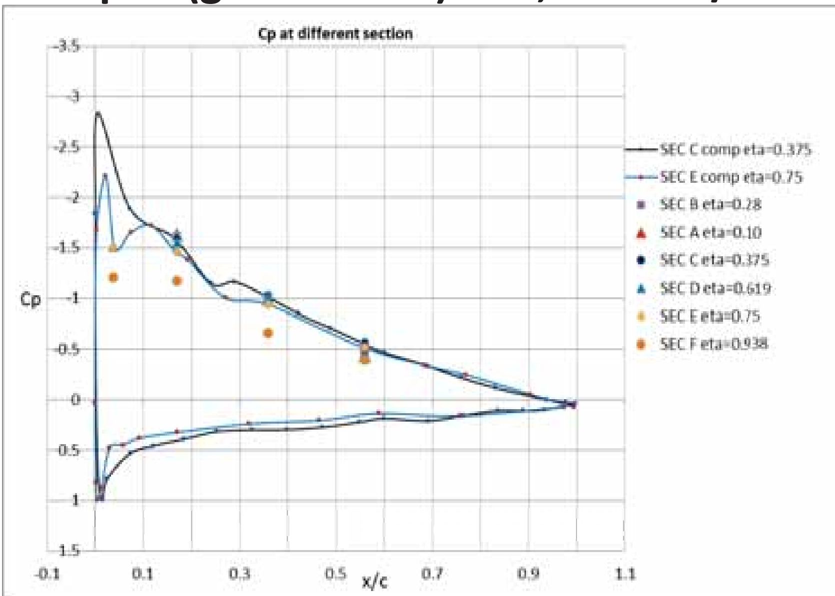


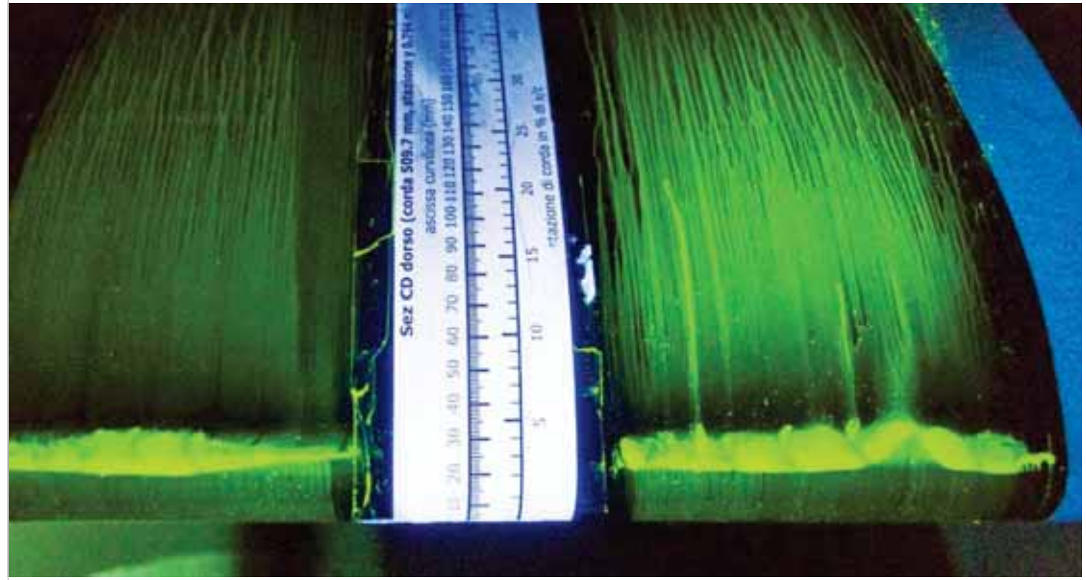


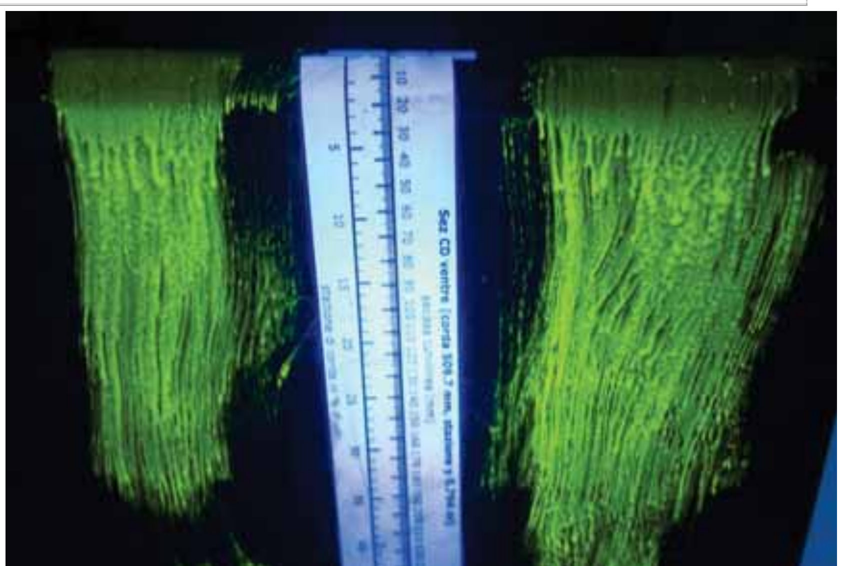
SECTION CD , upper surface



Alpha (geometrical) = 8°, V=30 m/s

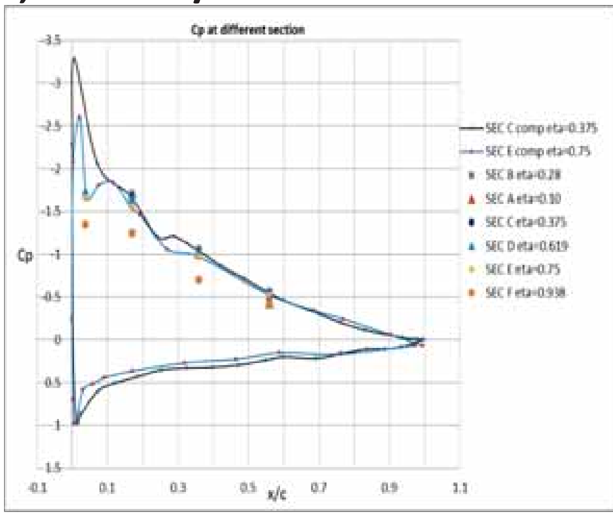


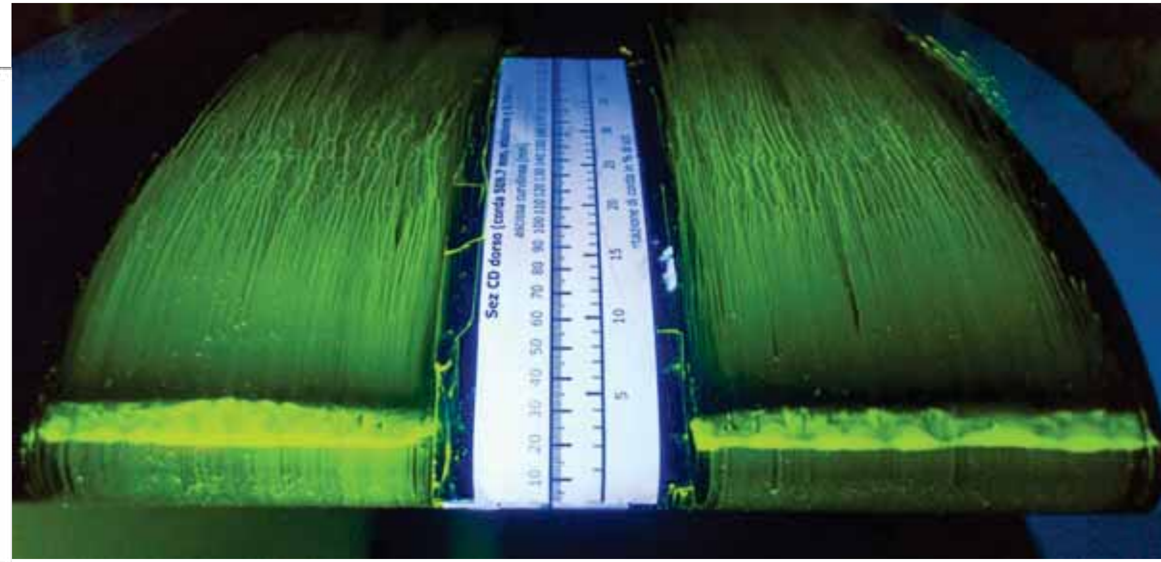




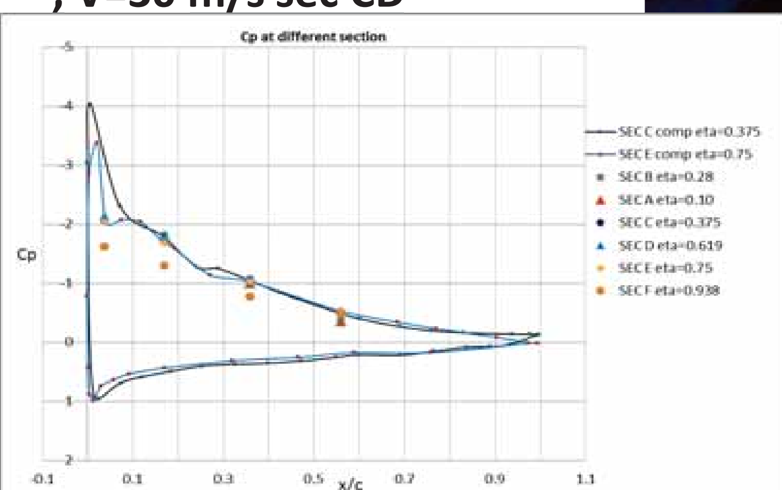
SECTION CD , upper surface

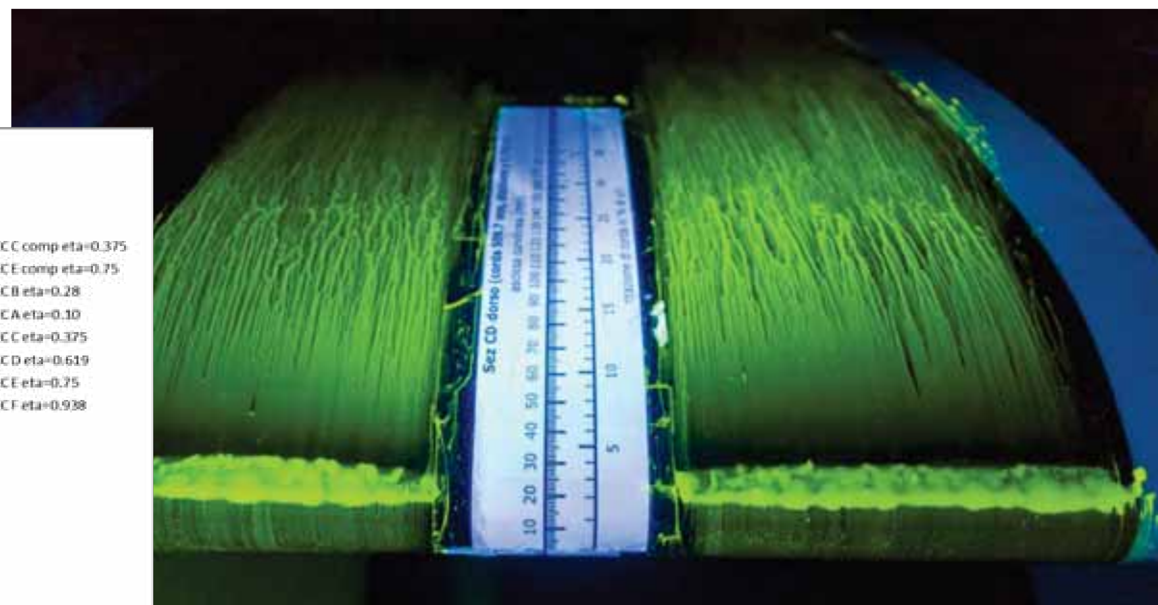
Alpha (geometrical) = 10° , V=30 m/s sec CD



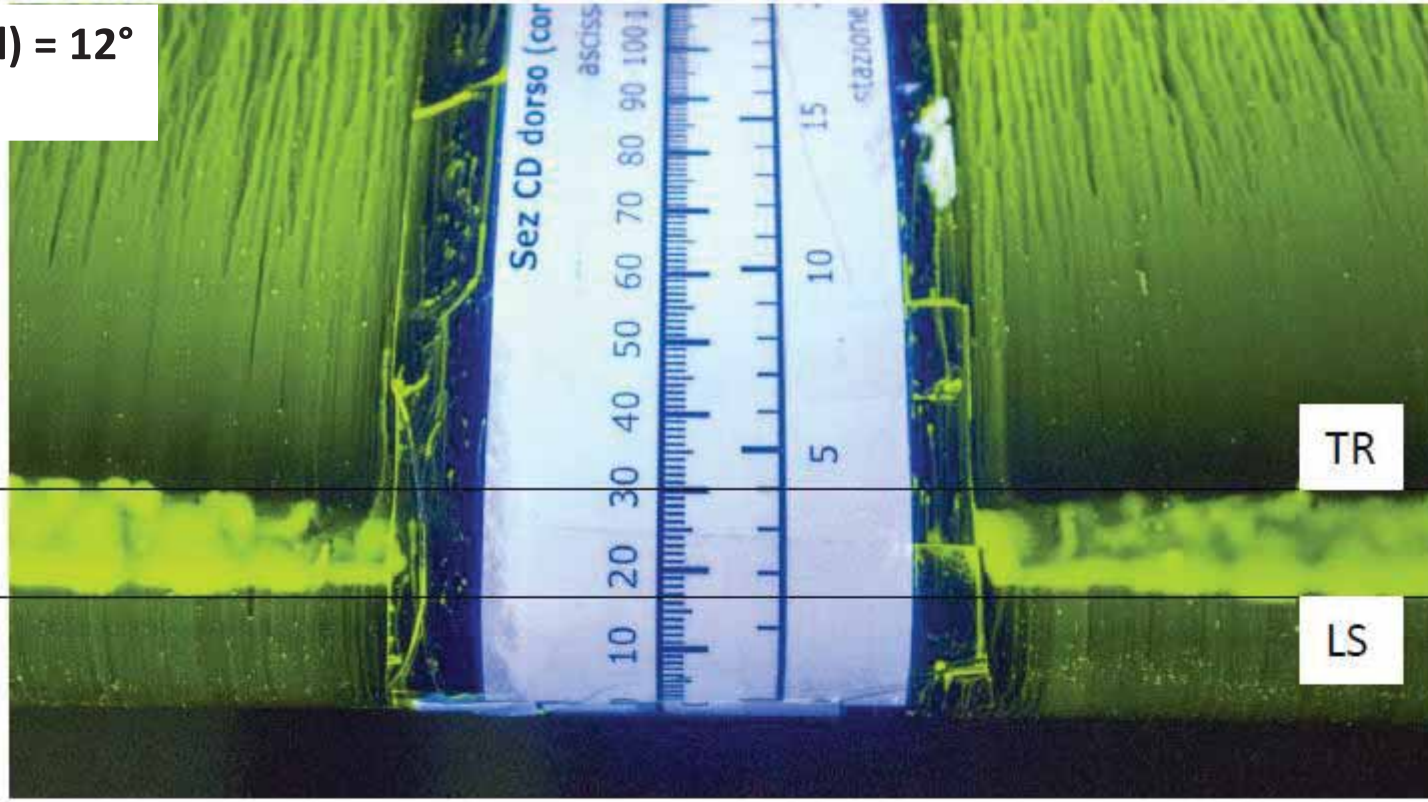


Alpha (geometrical) = 12° , V=30 m/s sec CD

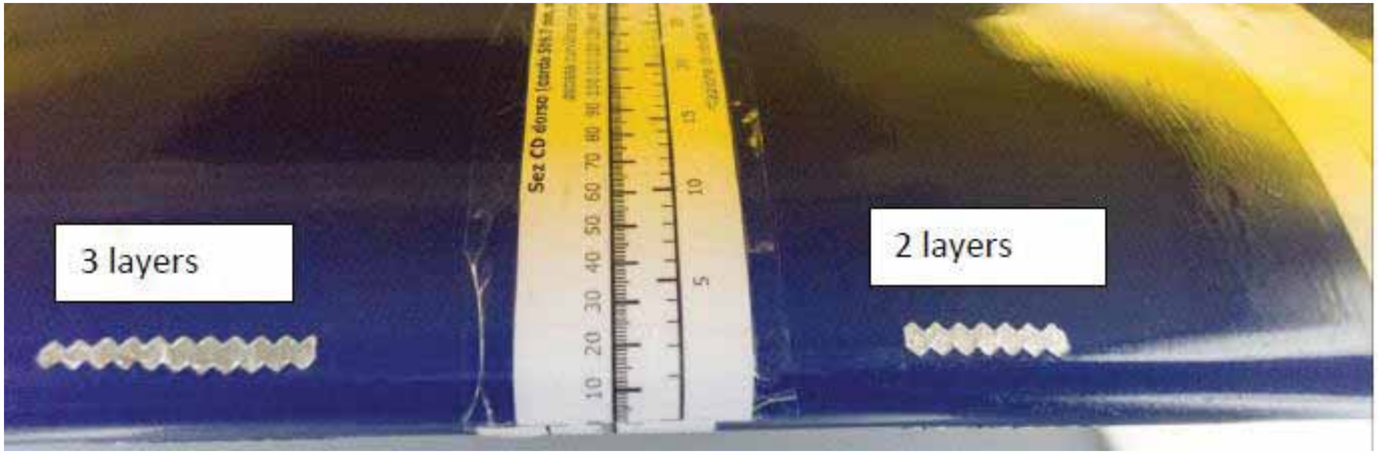




Alpha (geometrical) = 12° , V=30 m/s sec CD

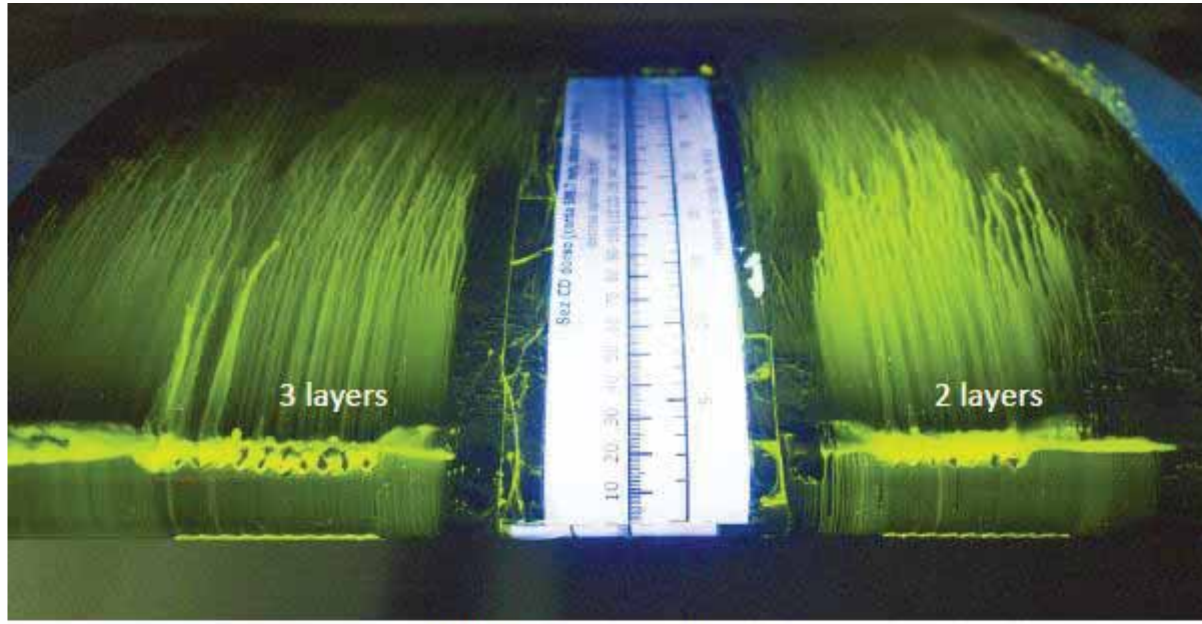


	s [mm]	x/c (local fraction of chord)
LS (Laminar separation) :	17 mm	0.016 (1.6%)
TR (Turbulent reattachment)	30 mm	0.040 (4%)

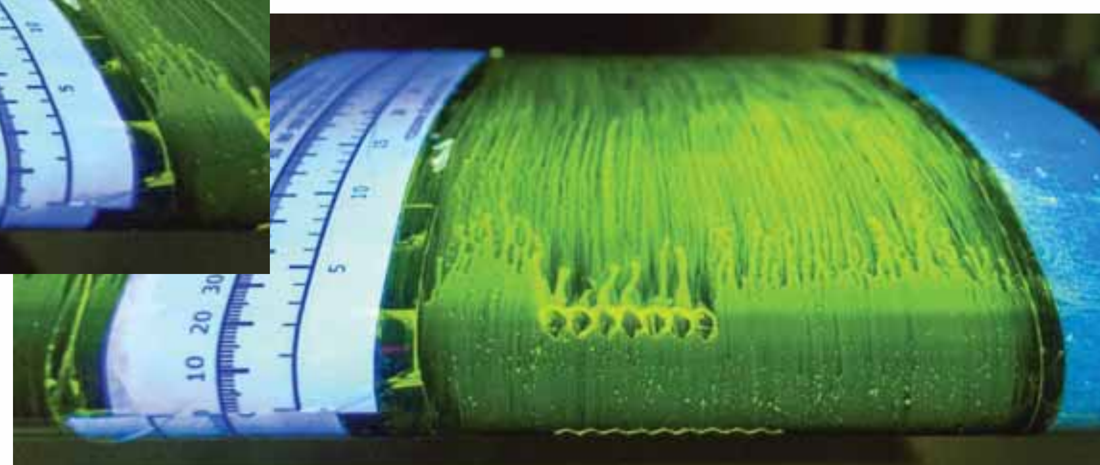


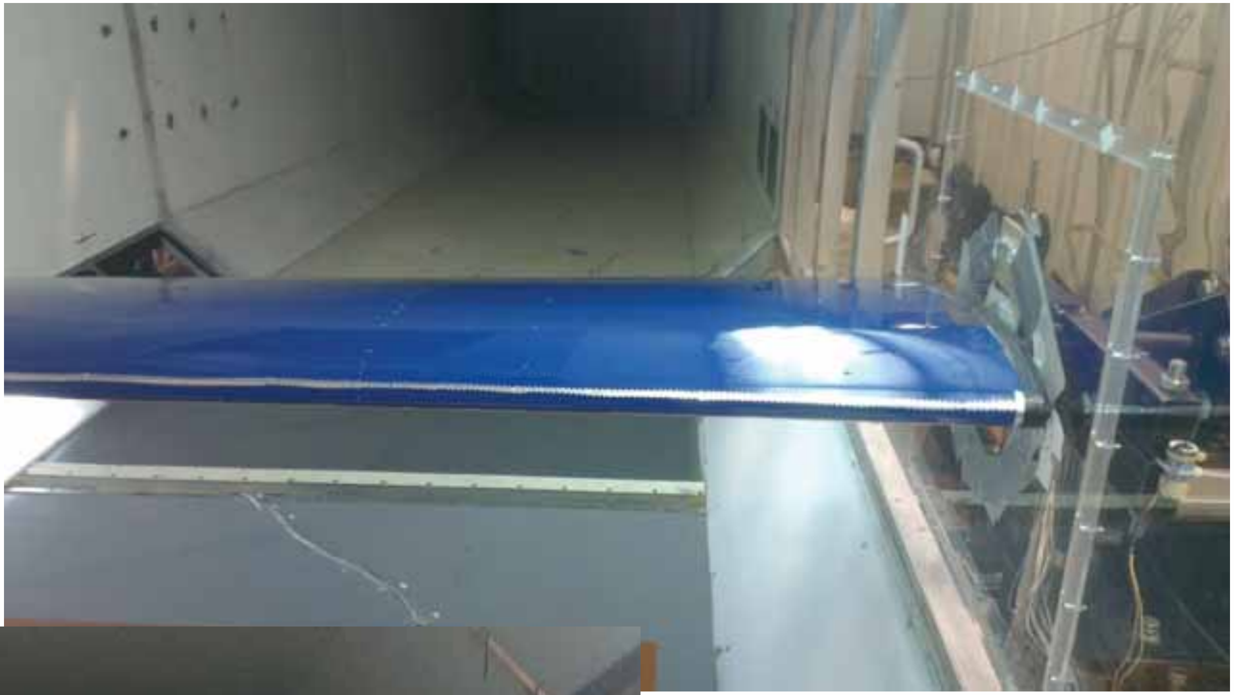
2 layers, about 0.4 mm
3 layers, about 0.6 mm

3 Layers is better

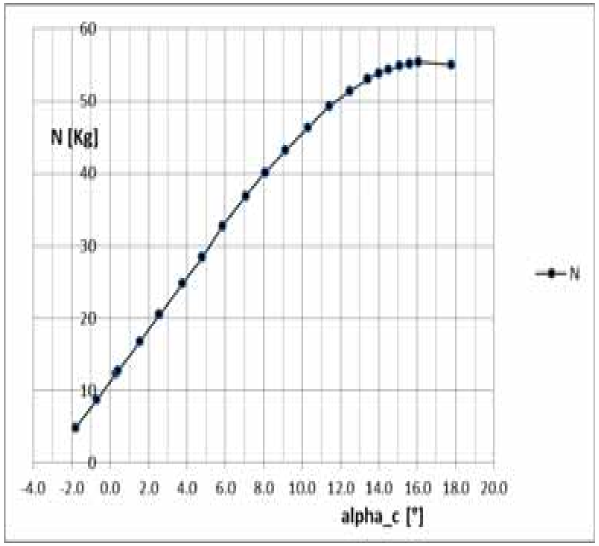


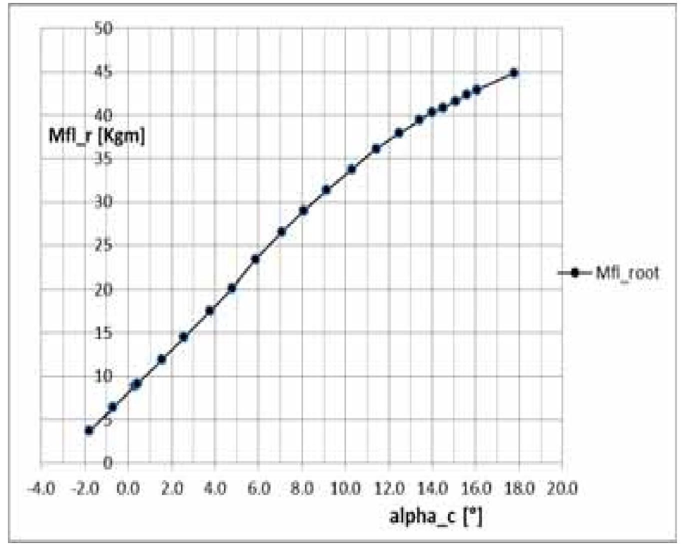
Alpha=12°, section CD

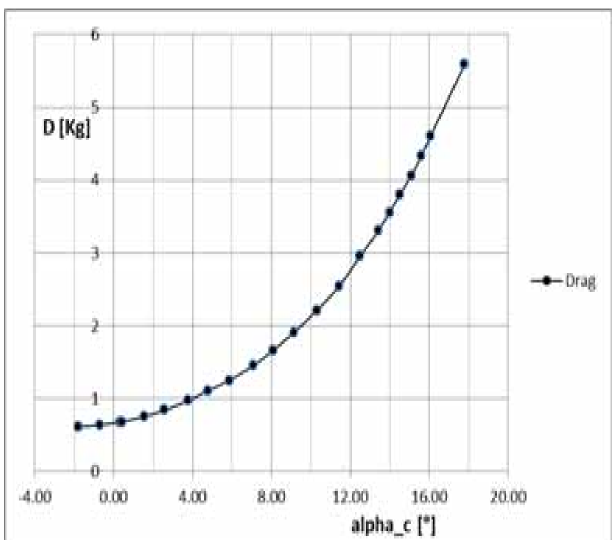


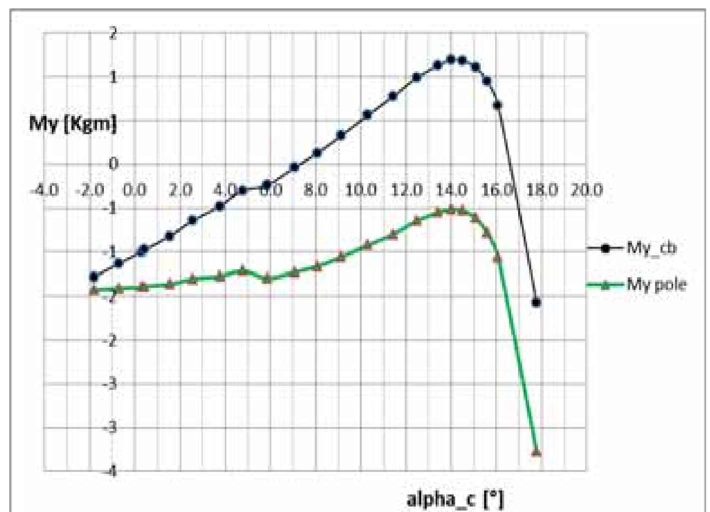


TEST L30,   V=30 m/s   Clean Model , Forces and Moments

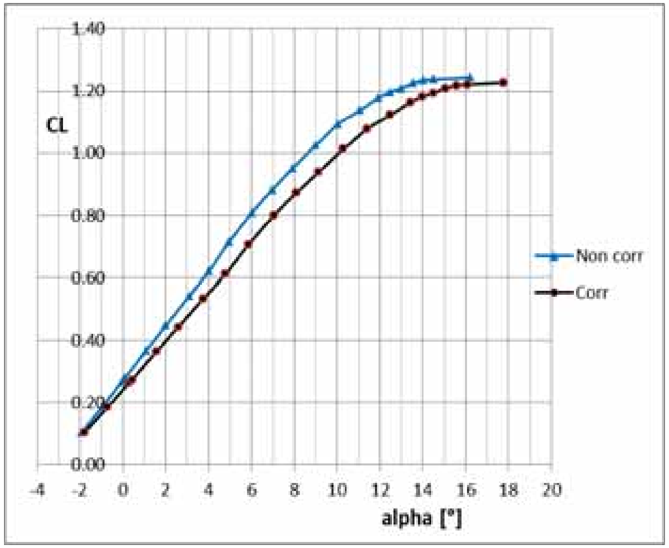


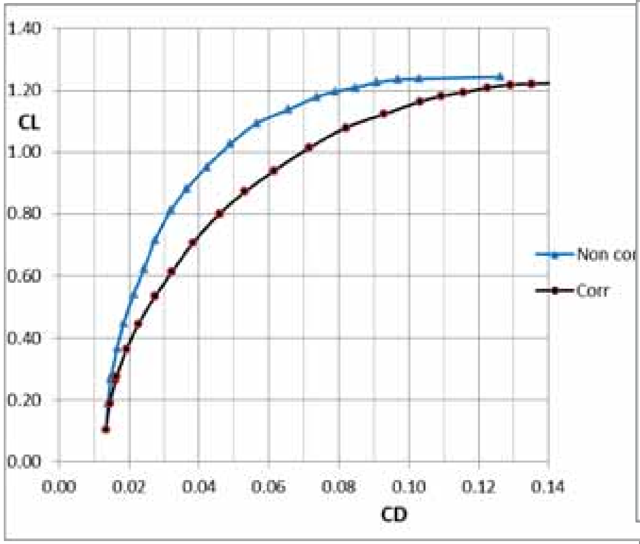


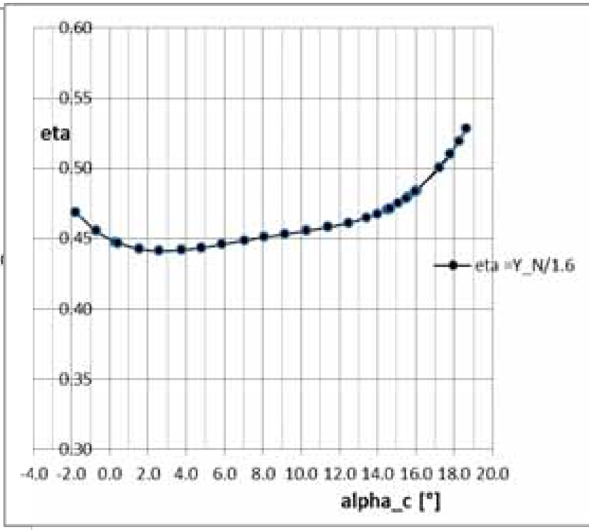


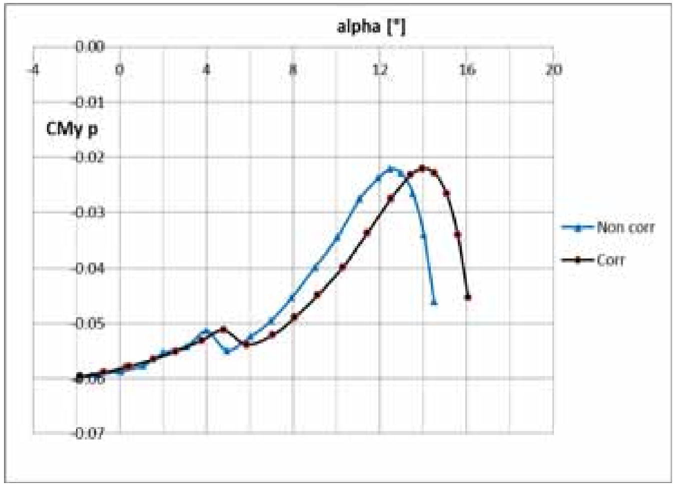


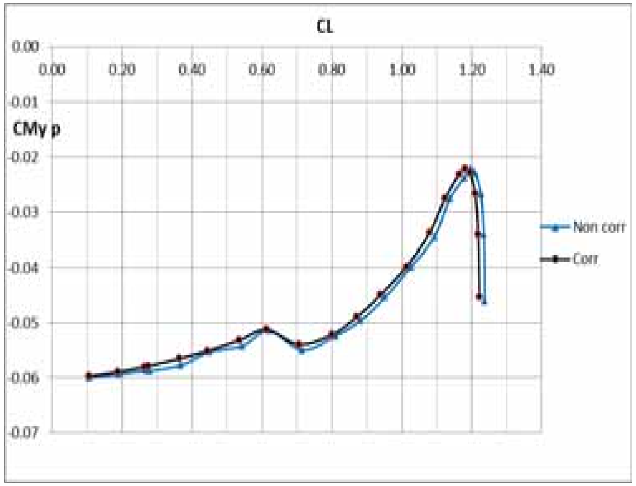
TEST L30, V=30 m/s Clean Model , corrected and non-corrected coefficients

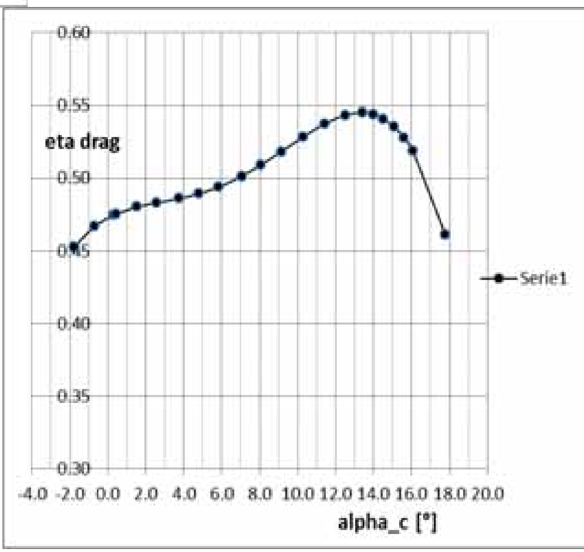




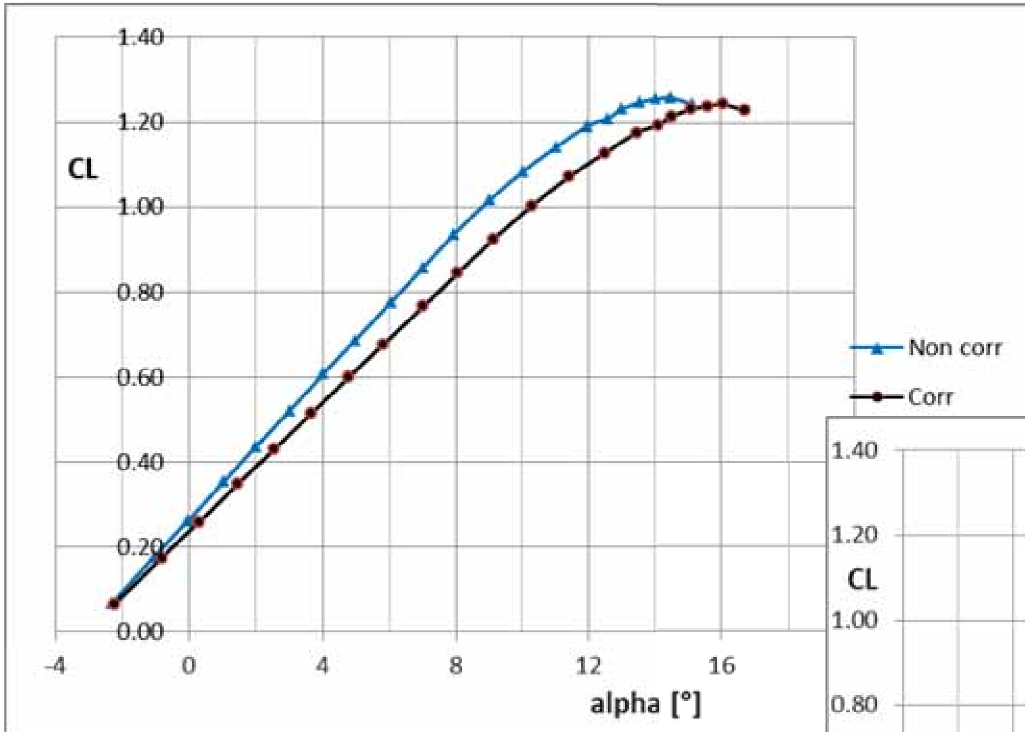


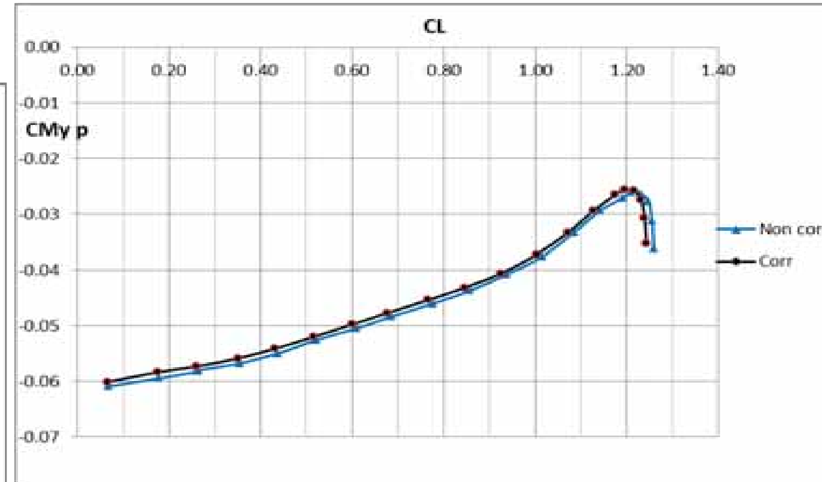


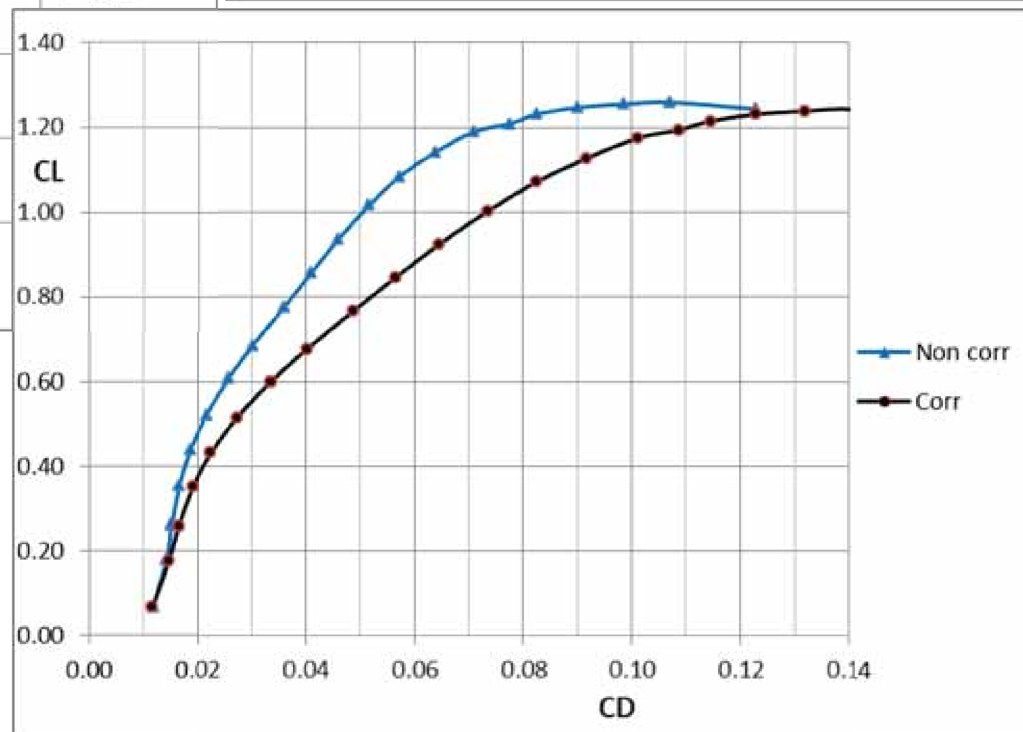




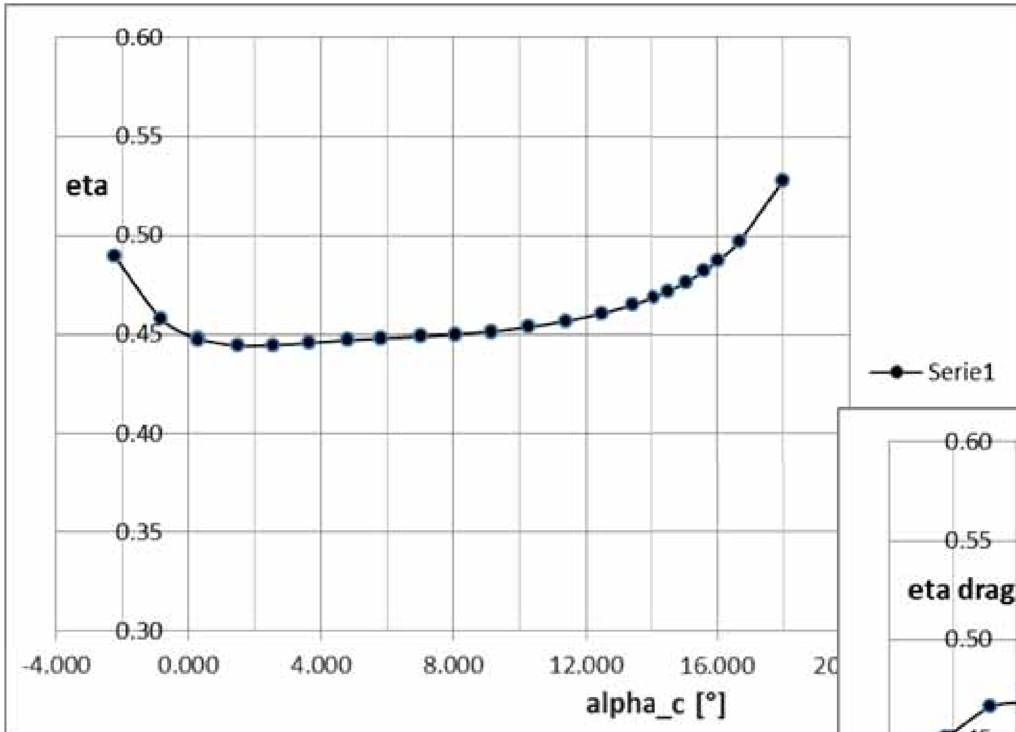
TEST T30, V=30 m/s Turbulent b.l.

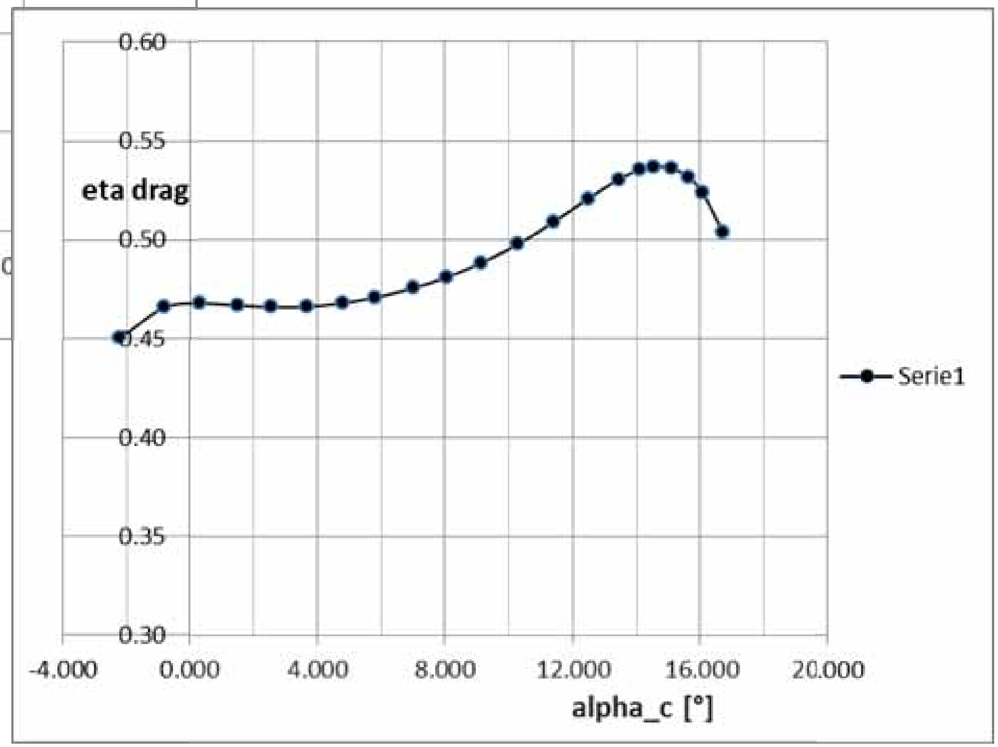






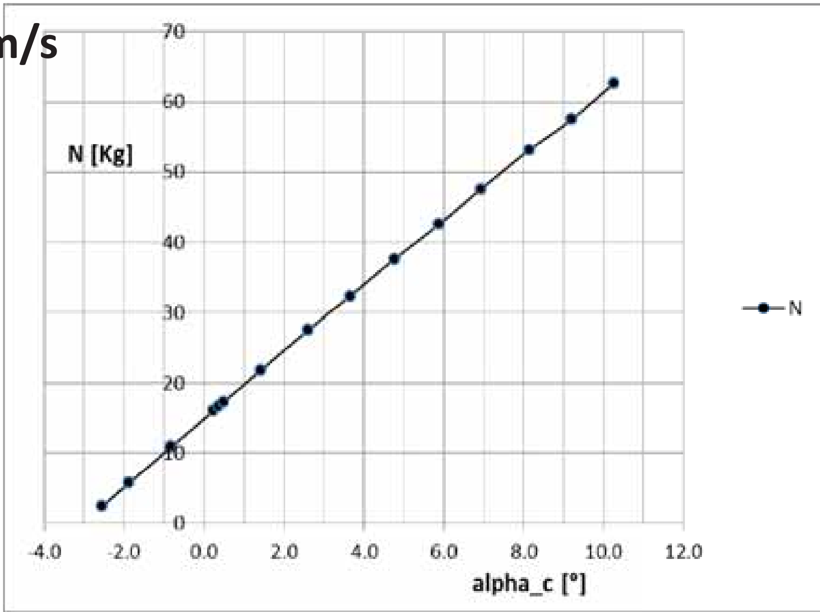
TEST T30, V=30 m/s Turbulent b.l.

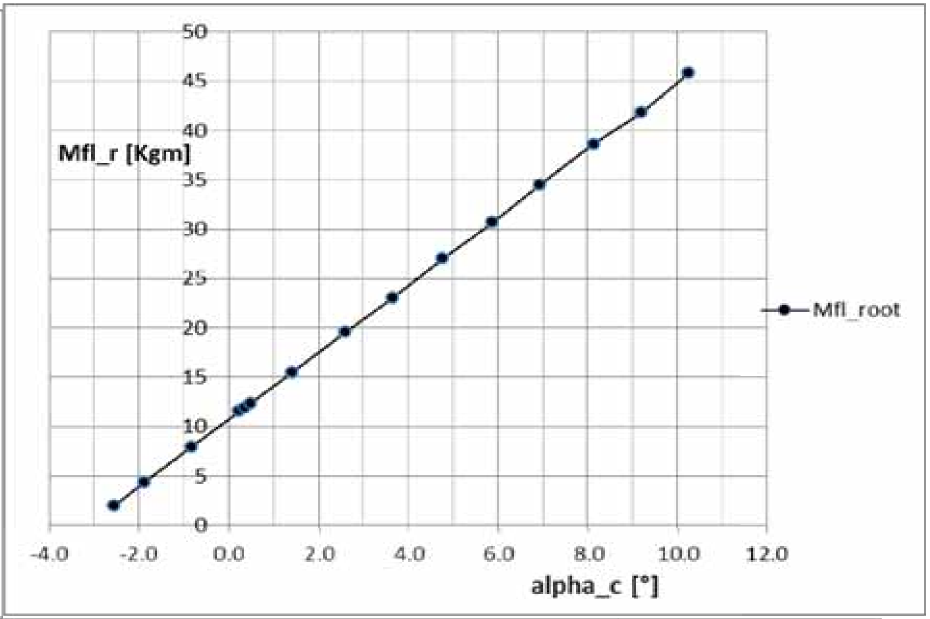




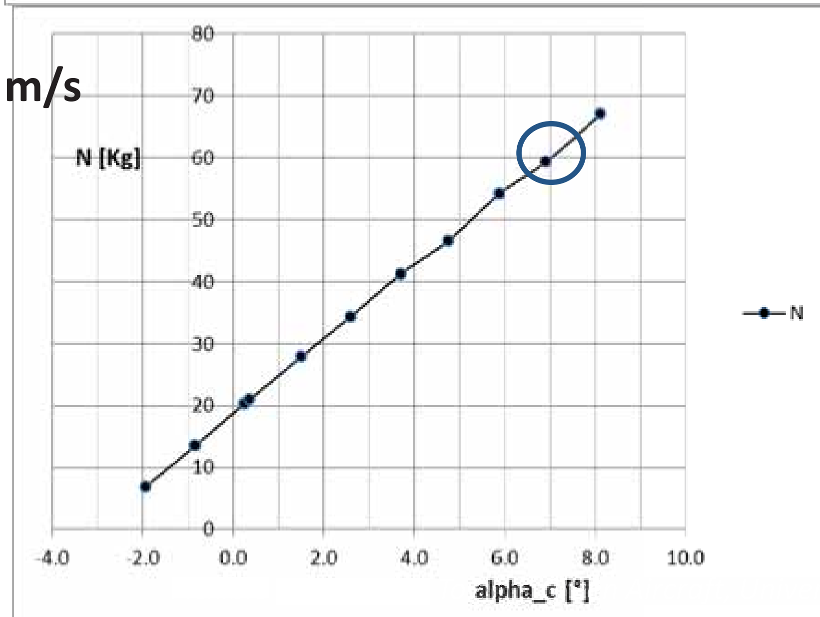
TEST T35 and T40 Turbulent b.l. LOADS CONDITIONS

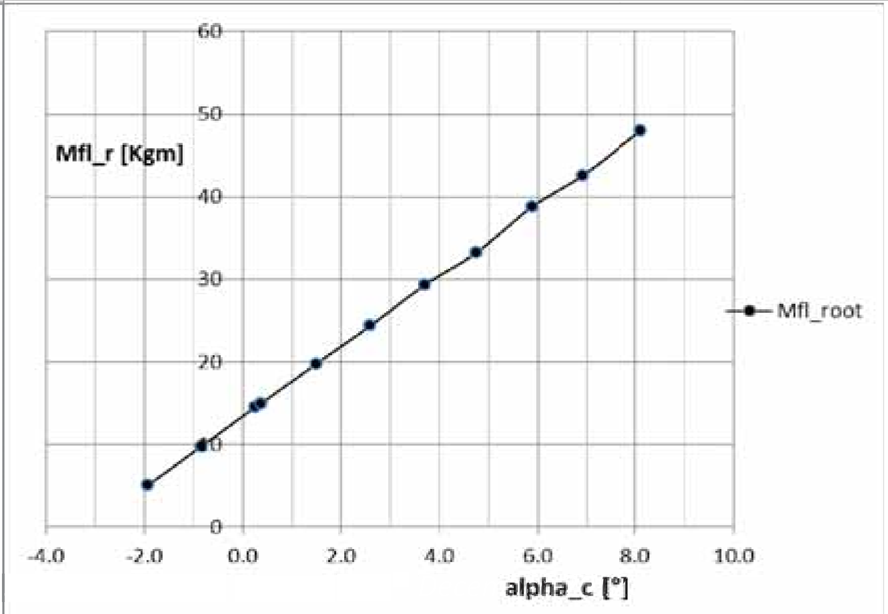
V=35 m/s



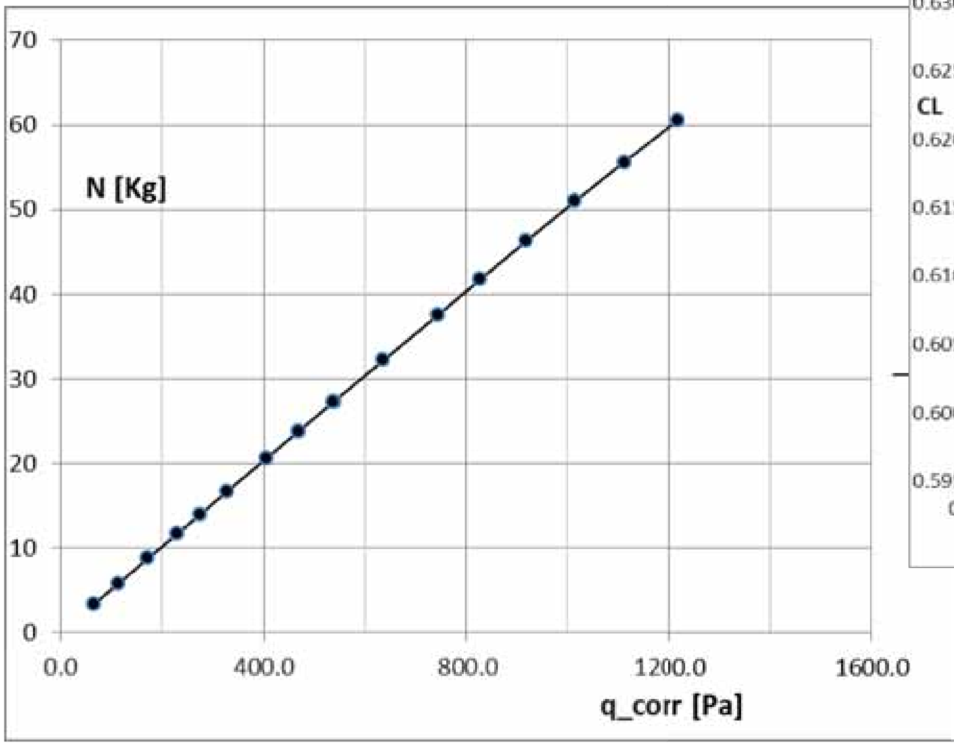


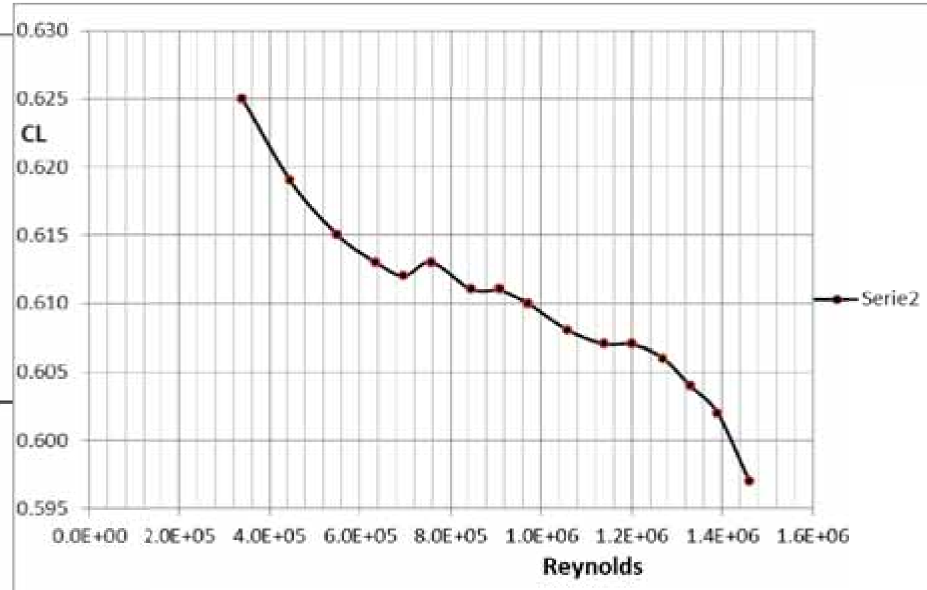
V=40 m/s



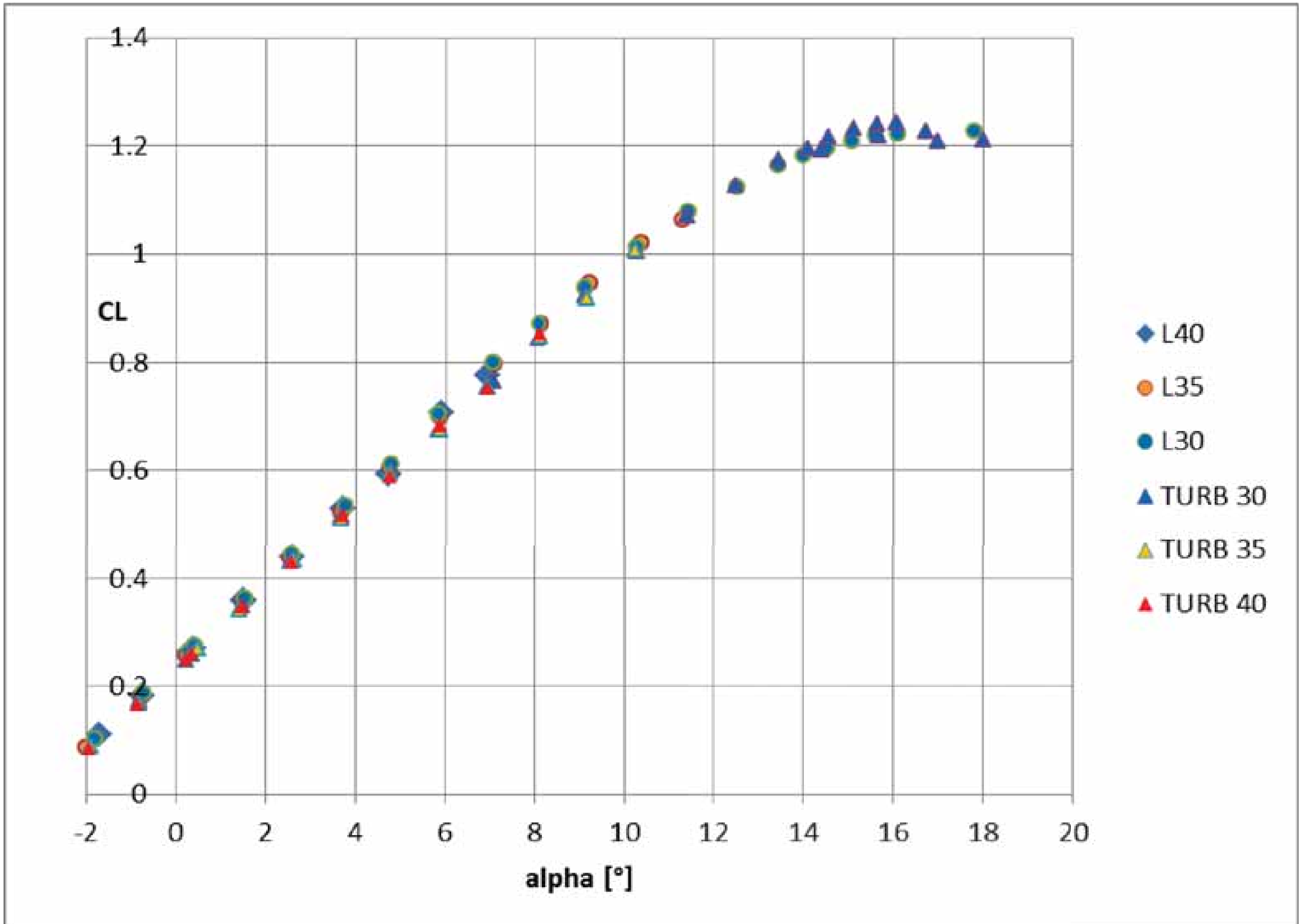


TEST F28, V=variable, alpha=4°, Turbulent b.l.

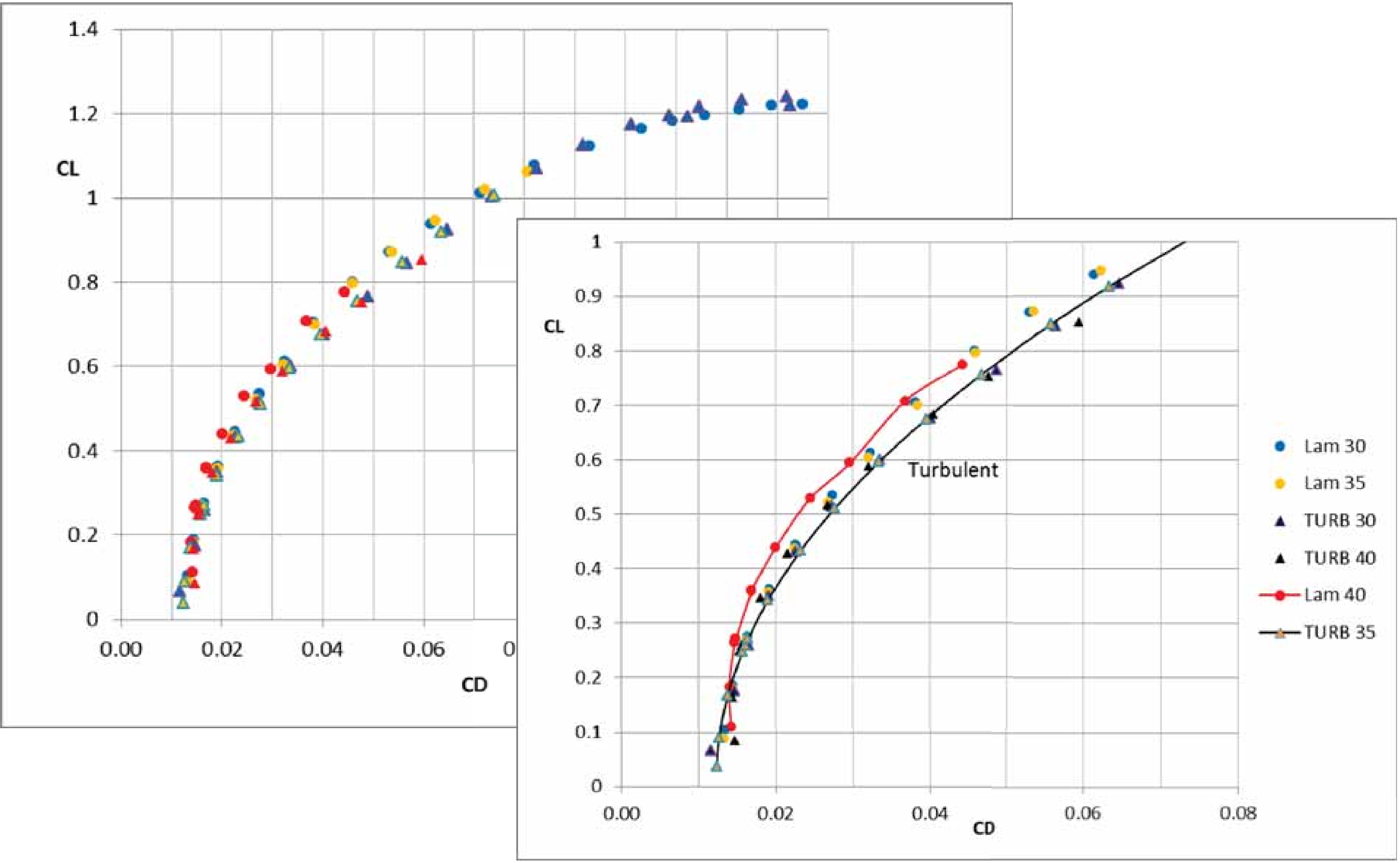




Comparison of Aerodynamic coefficients. Effect of turbulent b.l. and wind speed (Reynolds)

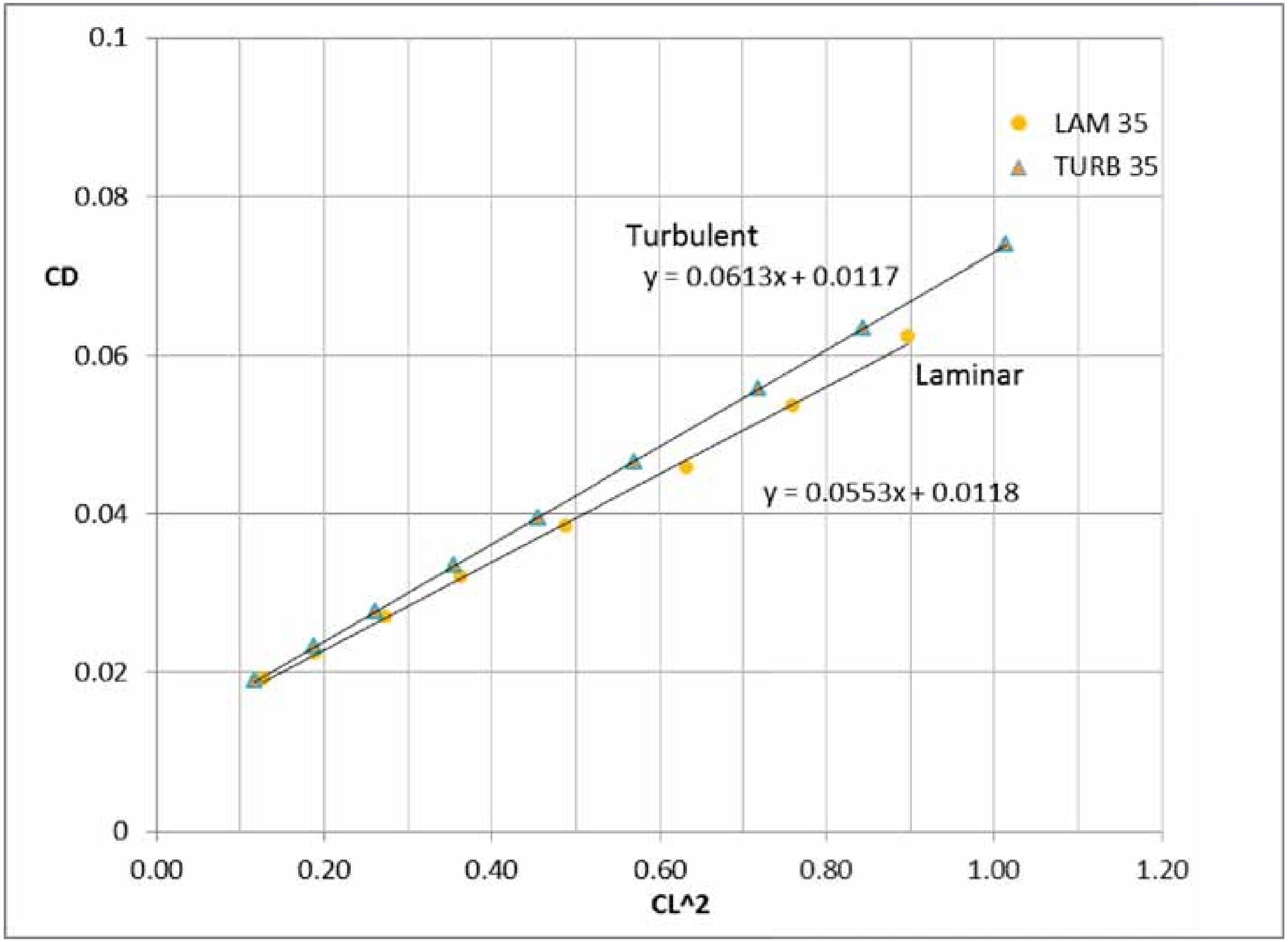


Comparison of Aerodynamic coefficients. Effect of turbulent b.l. and wind speed (Reynolds)

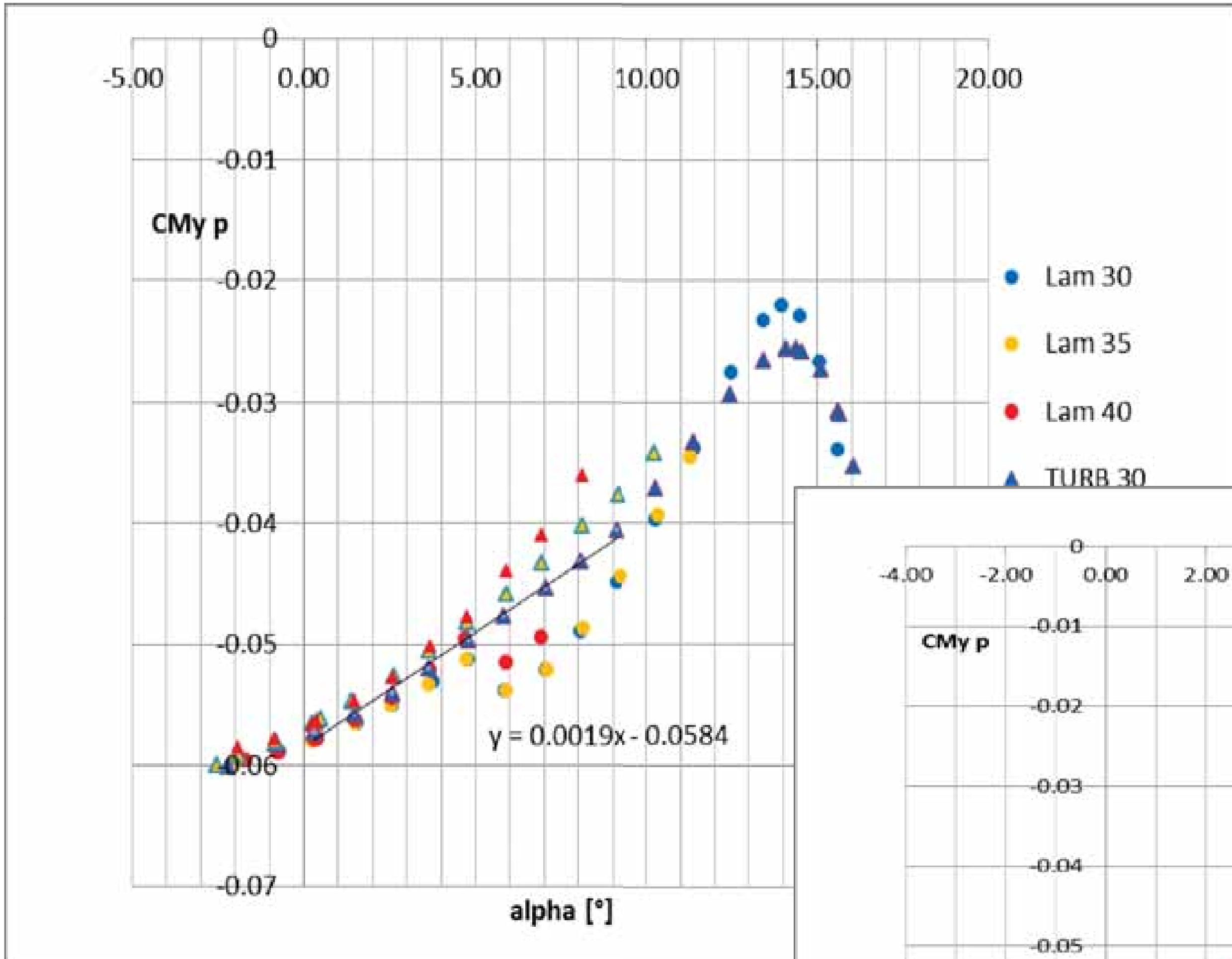


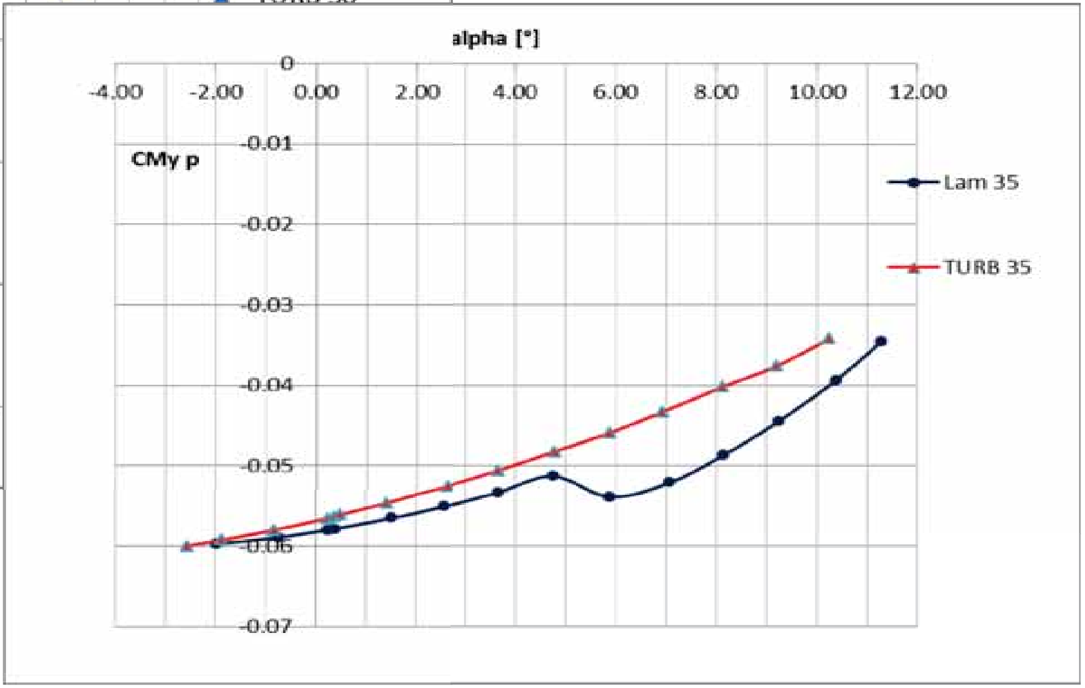
Comparison of Aerodynamic coefficients. Effect of turbulent b.l. and wind speed (Reynolds)

Wing drag polar

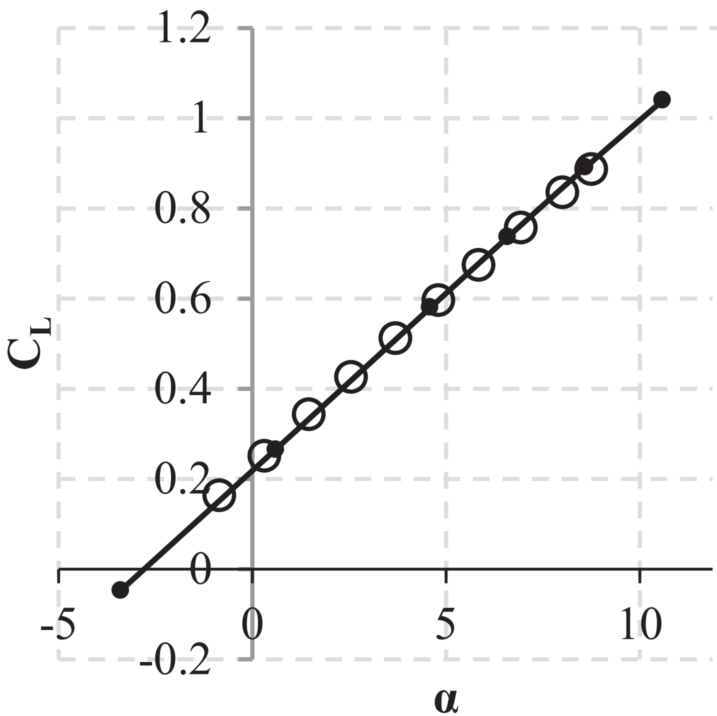


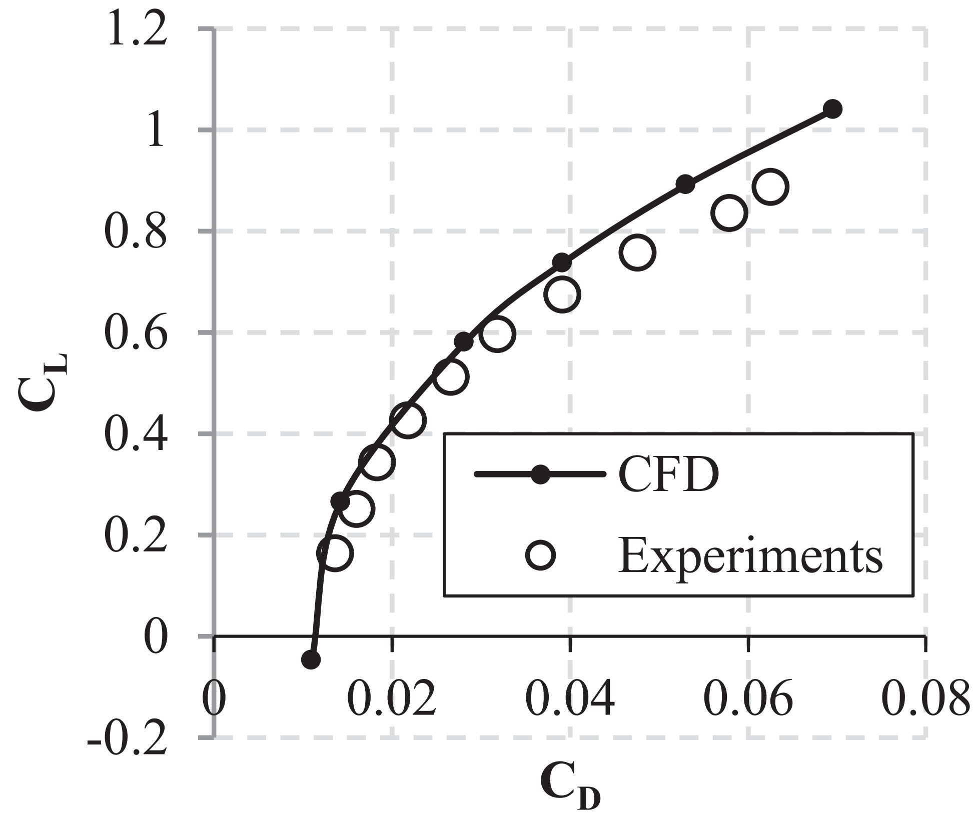
Comparison of Aerodynamic coefficients. Effect of turbulent b.l. and wind speed (Reynolds)





FORCE MEAUREMENT – Comparison with CFD prediction





TEST RESULTS. Pressure measurements

CLEAN Conditions

TEST L30 30 m/s 1.06 mill. Full polar (up to stall) free transition L, D, M, Cp
TEST L35 35 m/s 1.25 mill. (Alpha=0-10°) polar free trans. L, D, M, Cp
TEST L40 40 m/s 1.43 mill. Limited (up to 8°) polar free trans. L, D, M, Cp

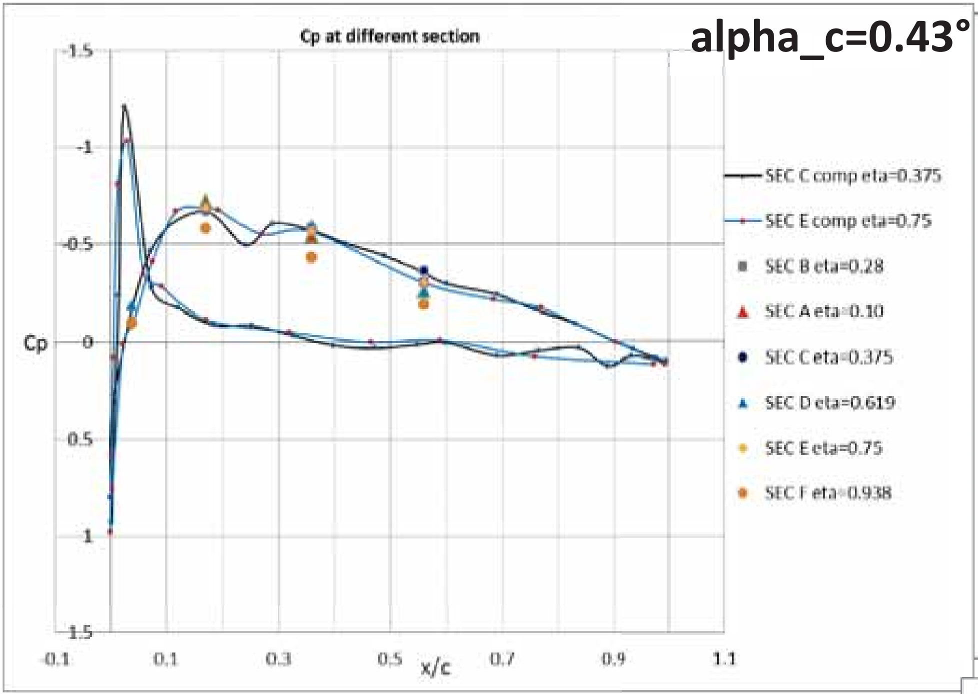
TURBULENT Conditions(b.l. tripped at l.e)

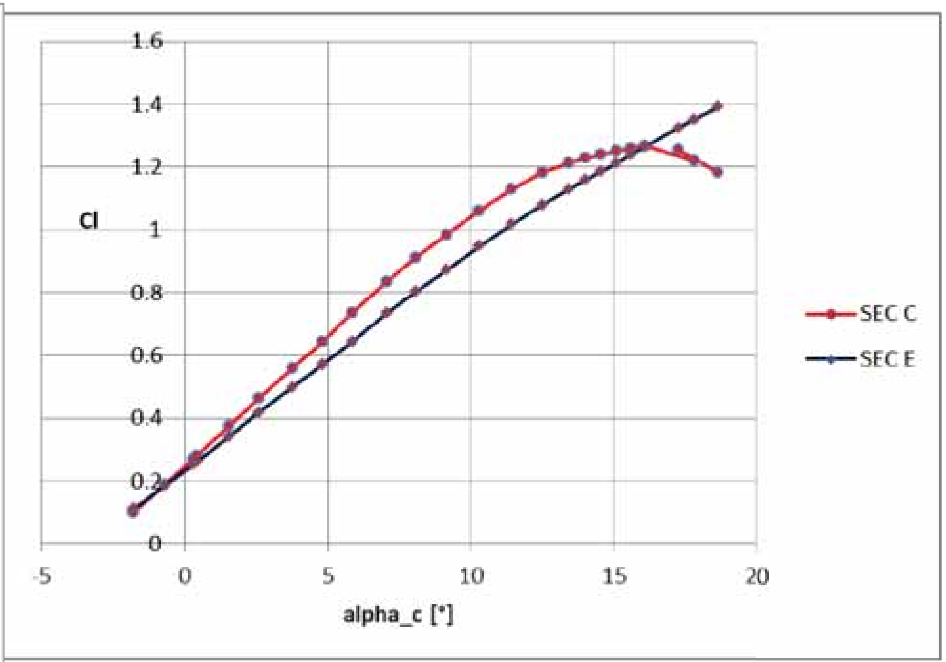
TEST T30 30 m/s 1.06 mill. Full polar fixed trans 1-2% L, D, M, Cp, strain
TEST T35 35 m/s 1.25 mill. Full polar fixed trans 1-2% L, D, M, Cp, strain
TEST T40 40 m/s 1.43 mill. Limited polar fixed trans 1-2% L, D, M, Cp, strain

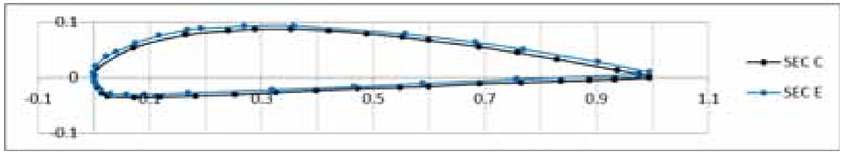
TEST RESULTS. Pressure measurements

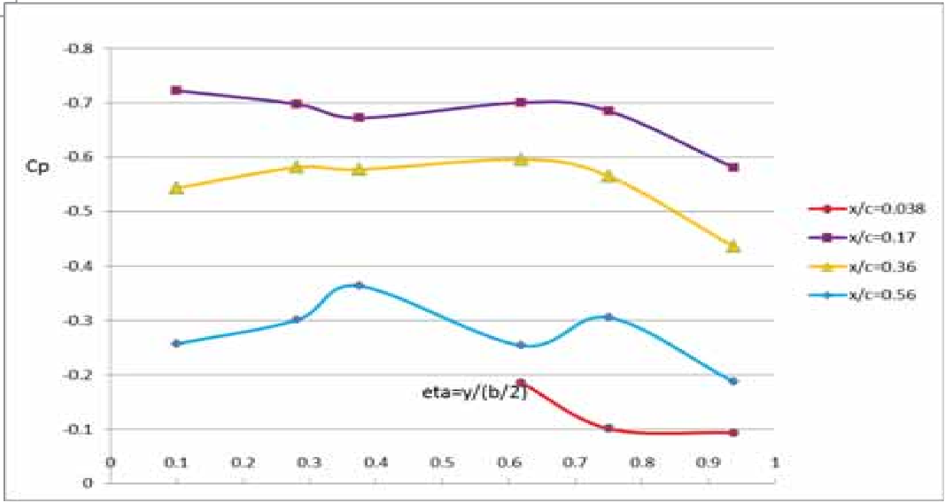
TEST L30, V=30 m/s Clean Model

alpha_c=0.43°



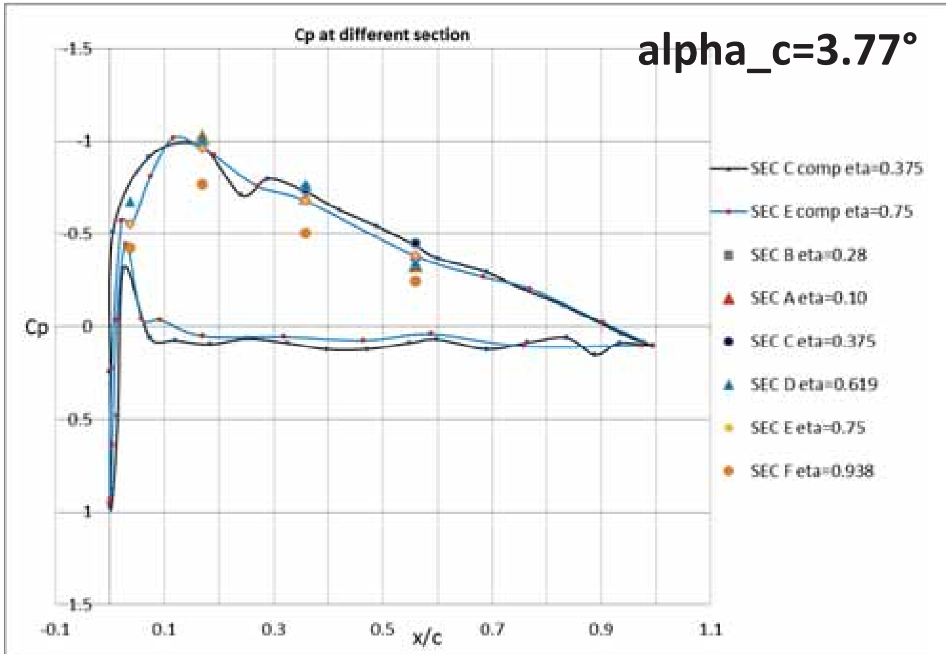


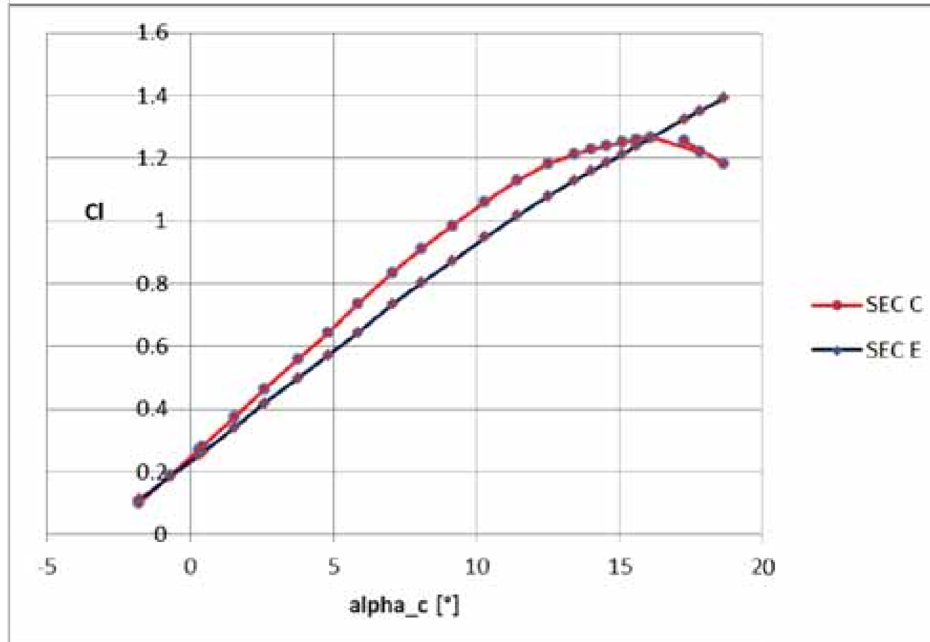


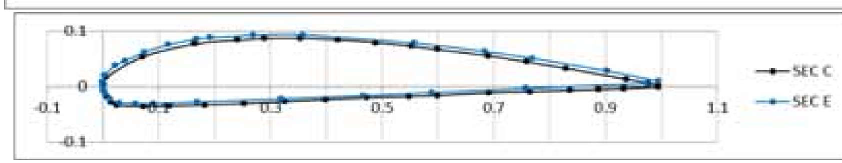


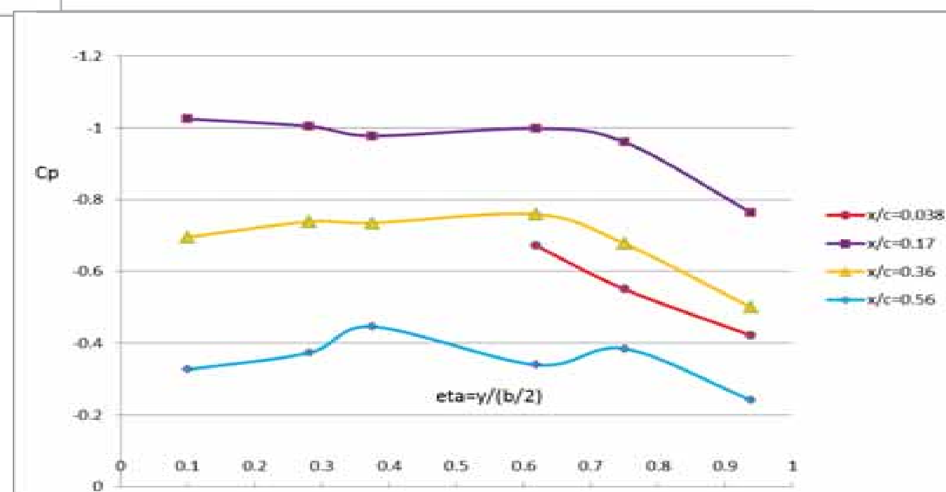
TEST RESULTS. Pressure measurements

TEST L30, V=30 m/s Clean Model





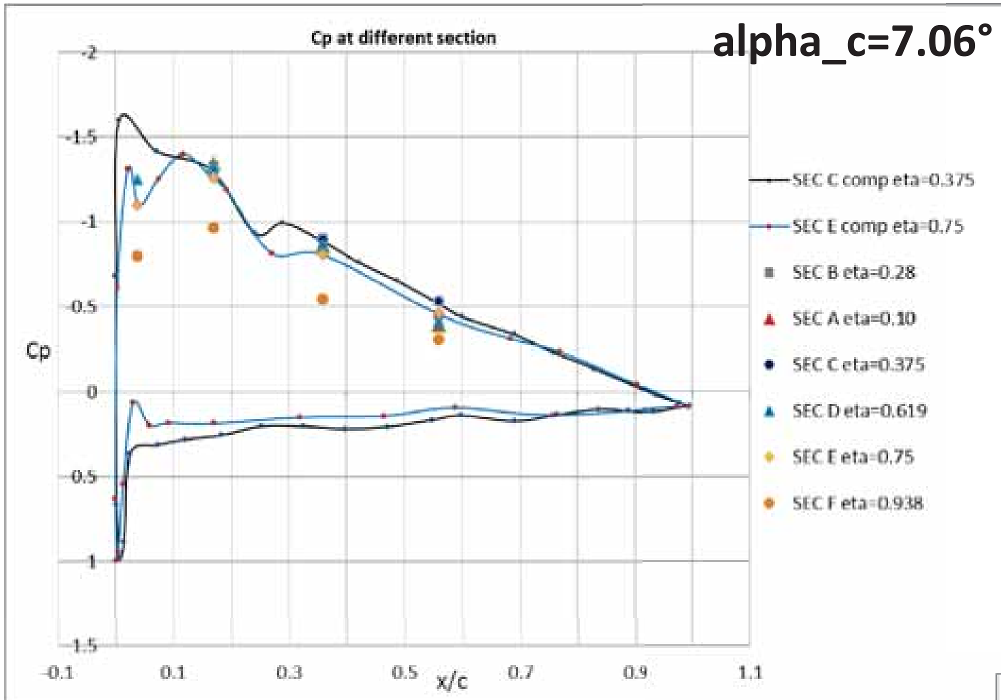


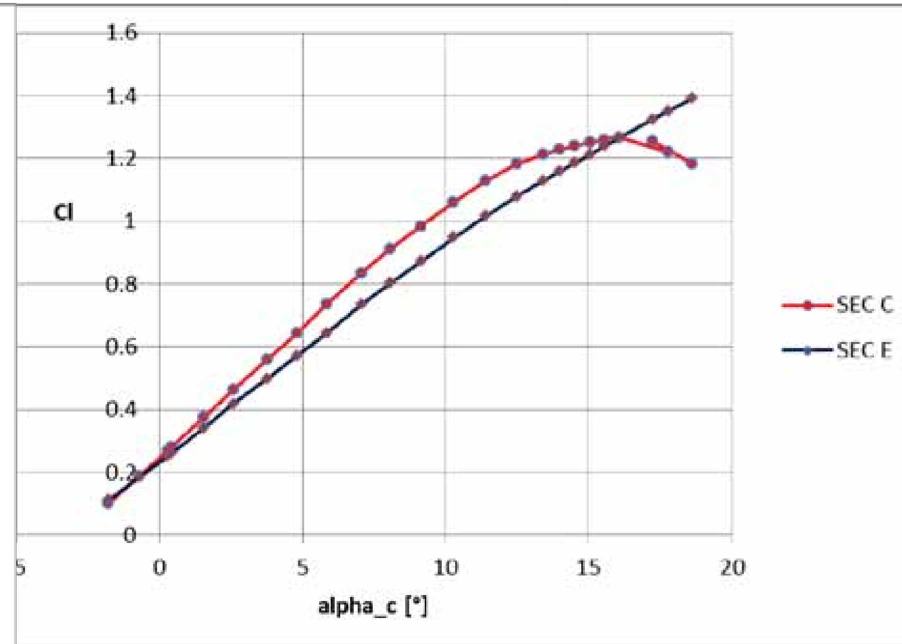


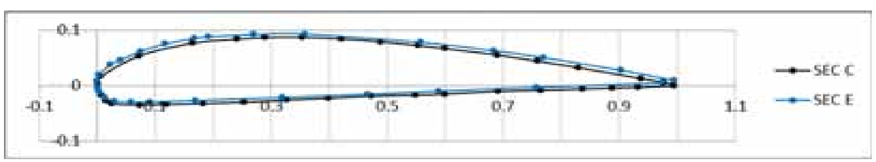
TEST RESULTS. Pressure measurements

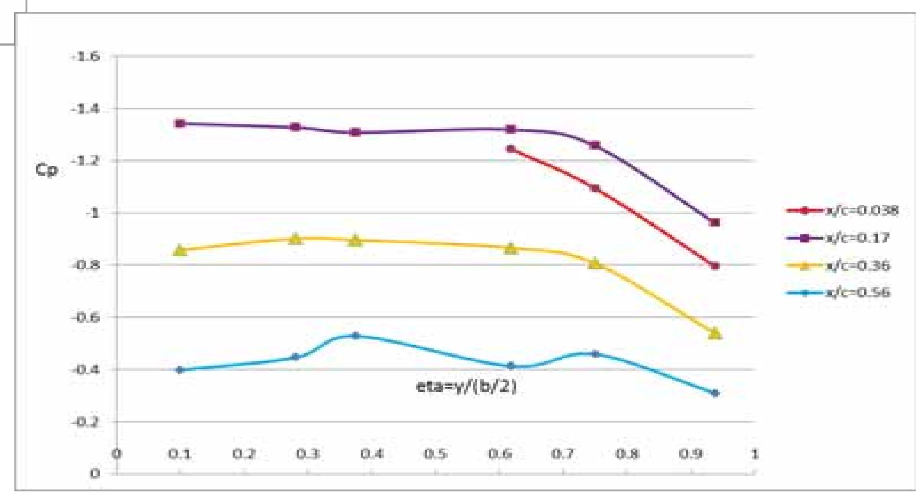
TEST L30, V=30 m/s Clean Model

alpha_c=7.06°



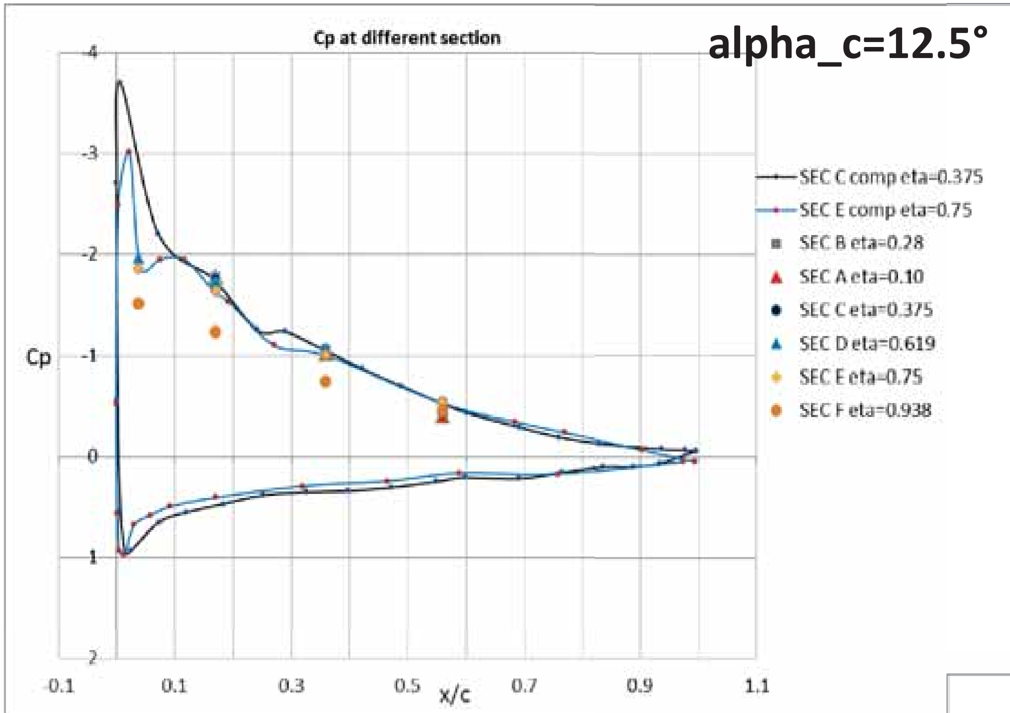


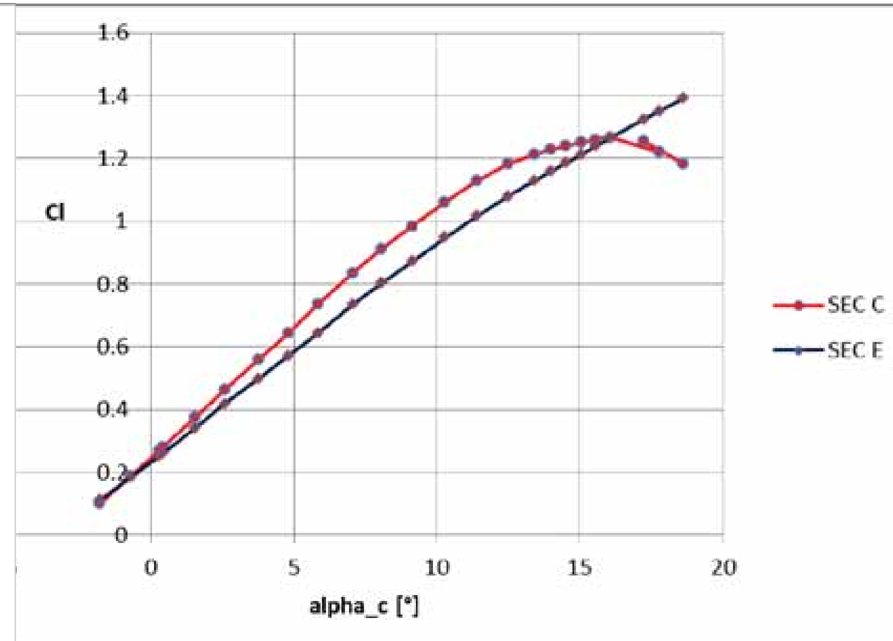


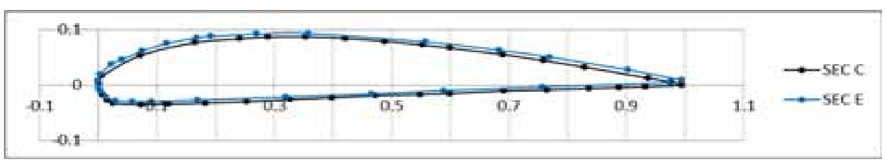


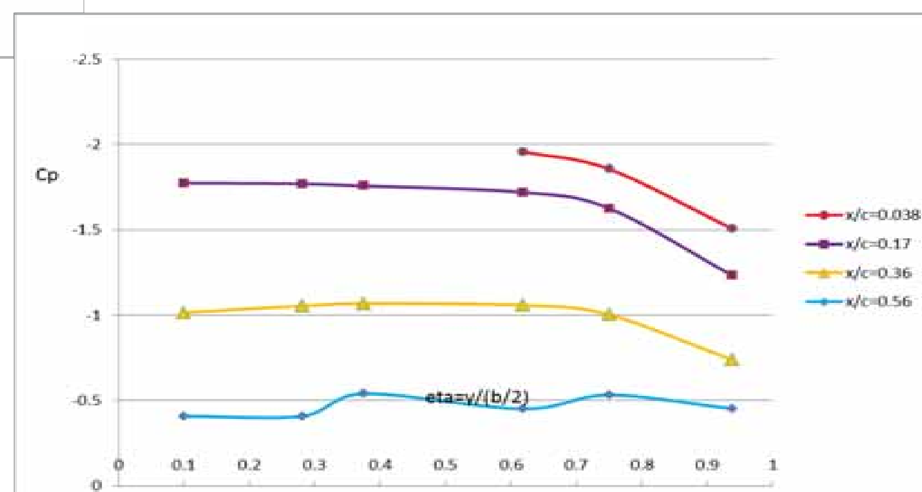
TEST RESULTS. Pressure measurements

TEST L30, V=30 m/s Clean Model



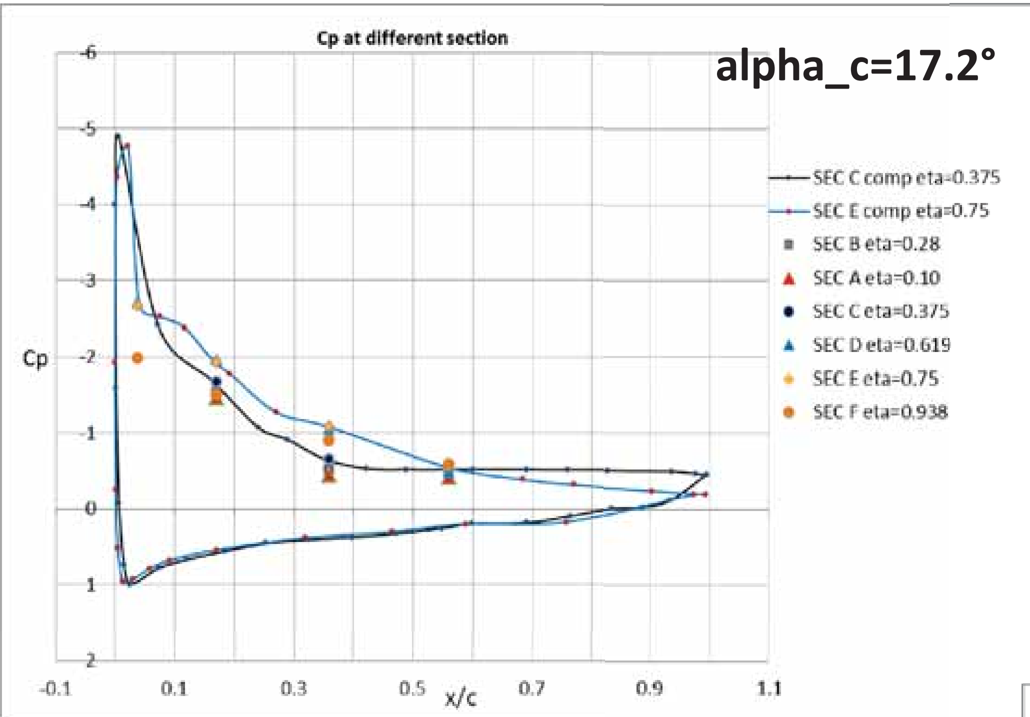


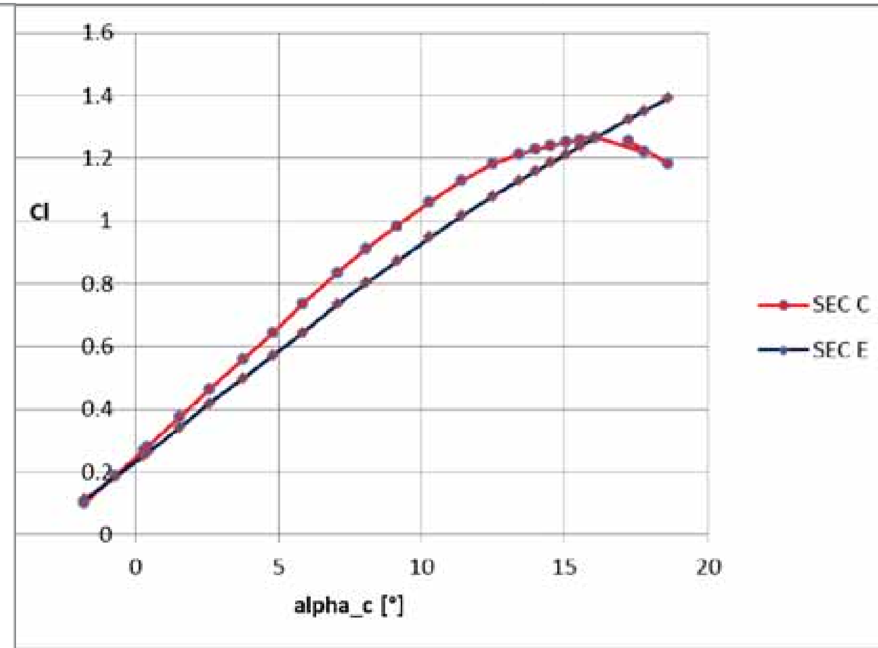


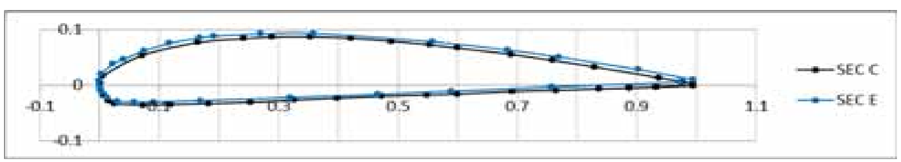


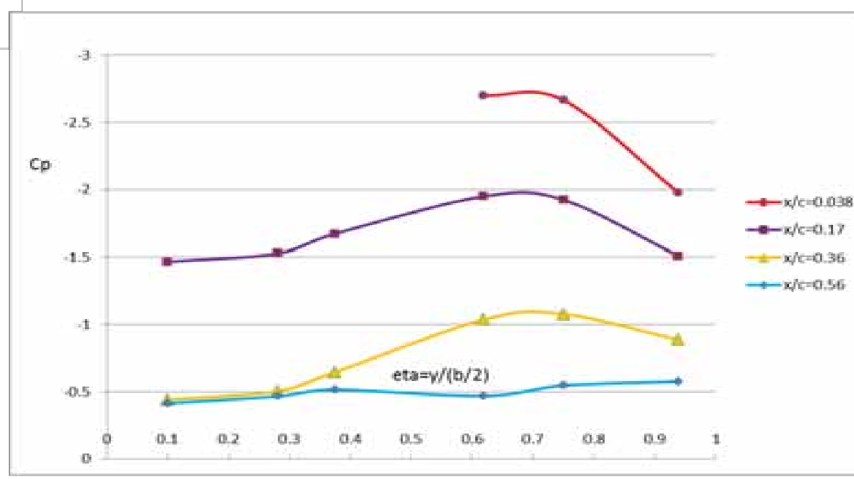
TEST RESULTS. Pressure measurements

TEST L30, V=30 m/s Clean Model



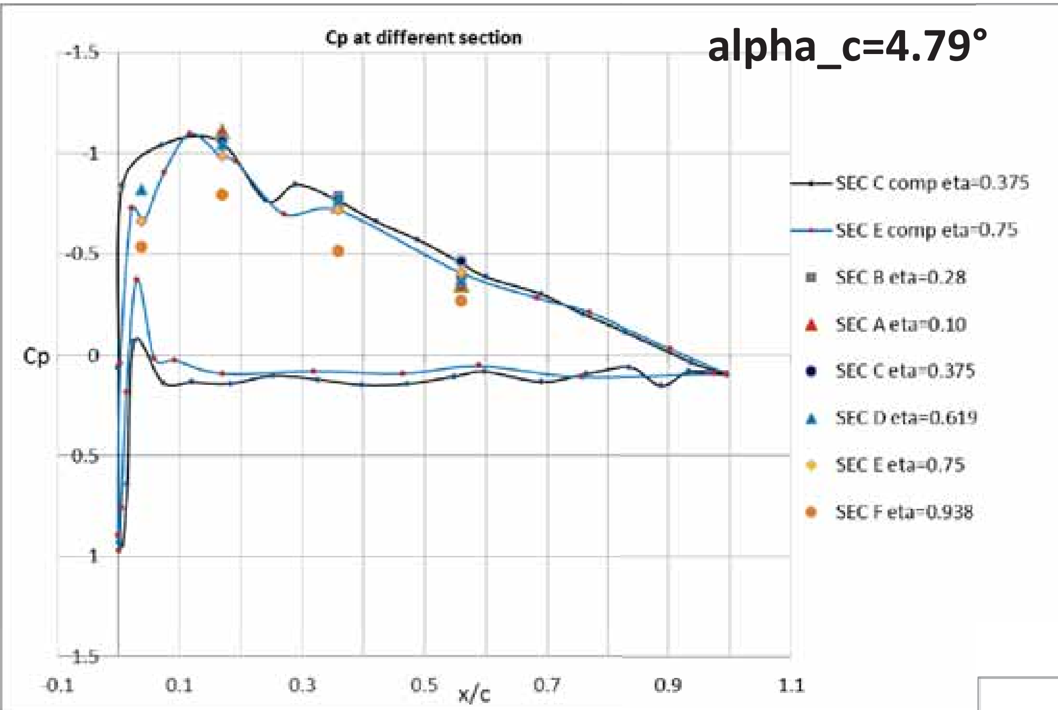


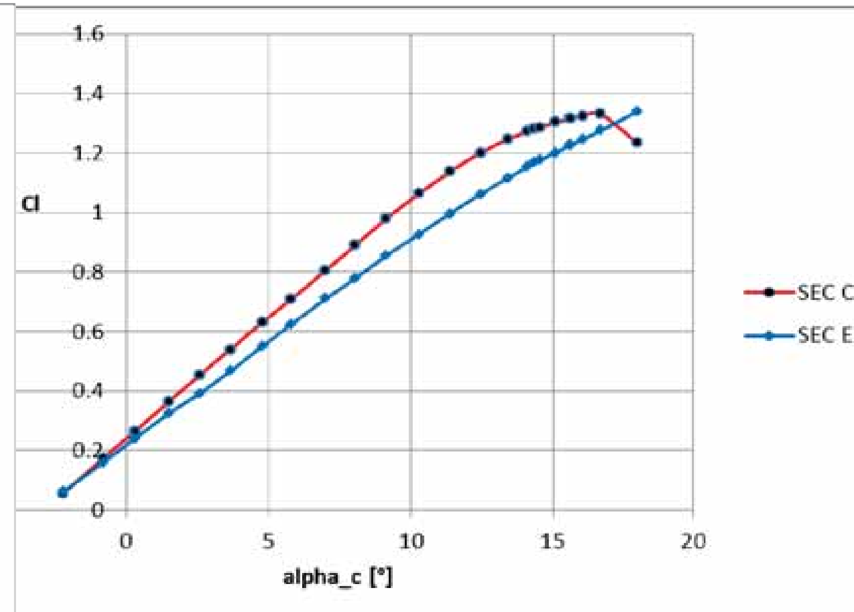


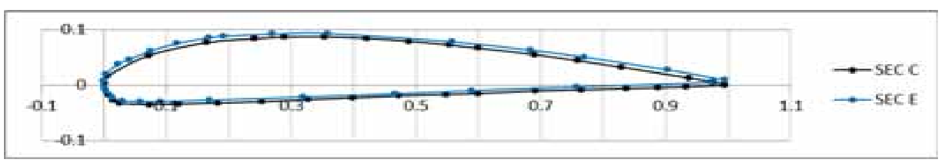


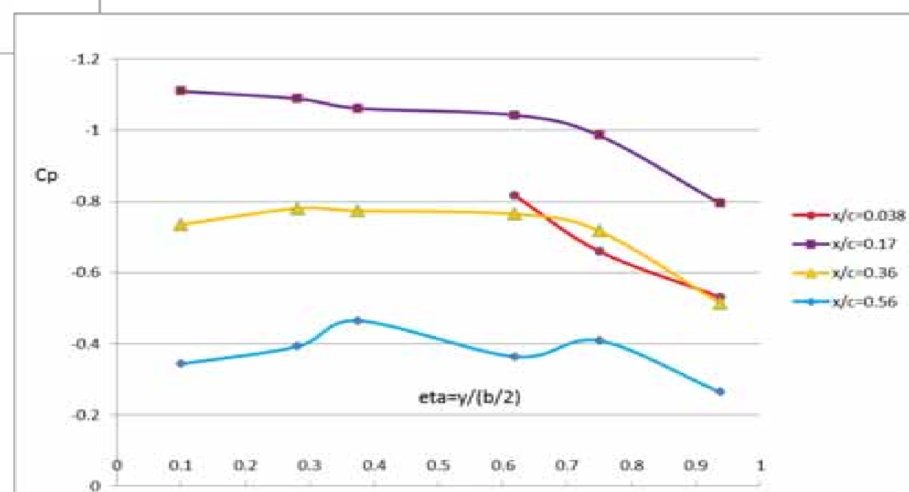
TEST RESULTS. Pressure measurements

TEST T30, V=30 m/s Turbulent



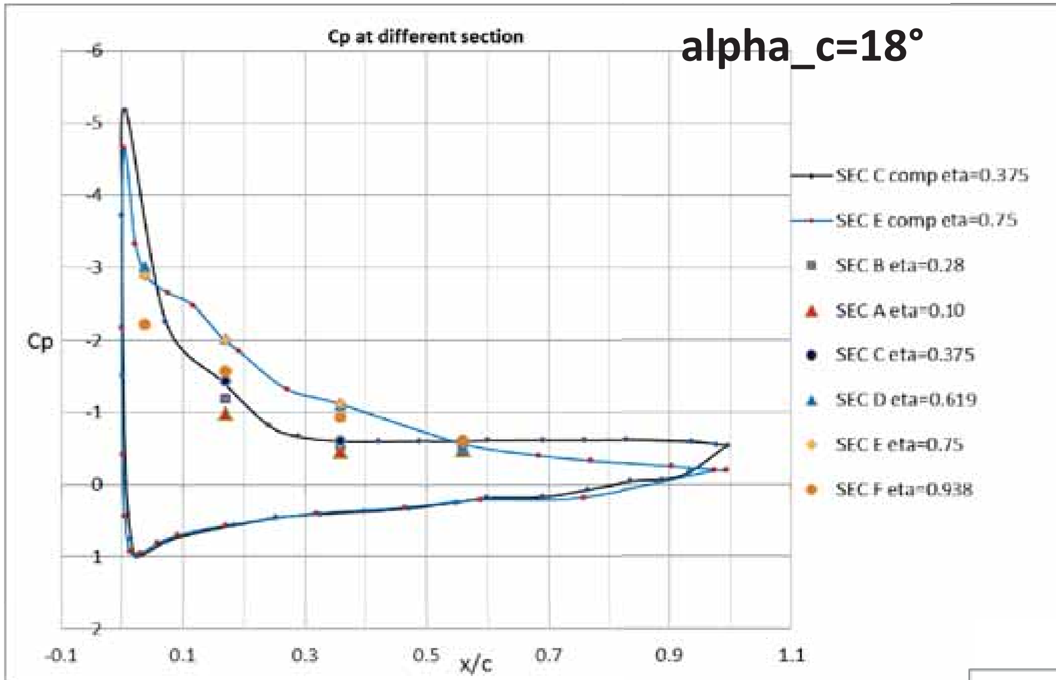


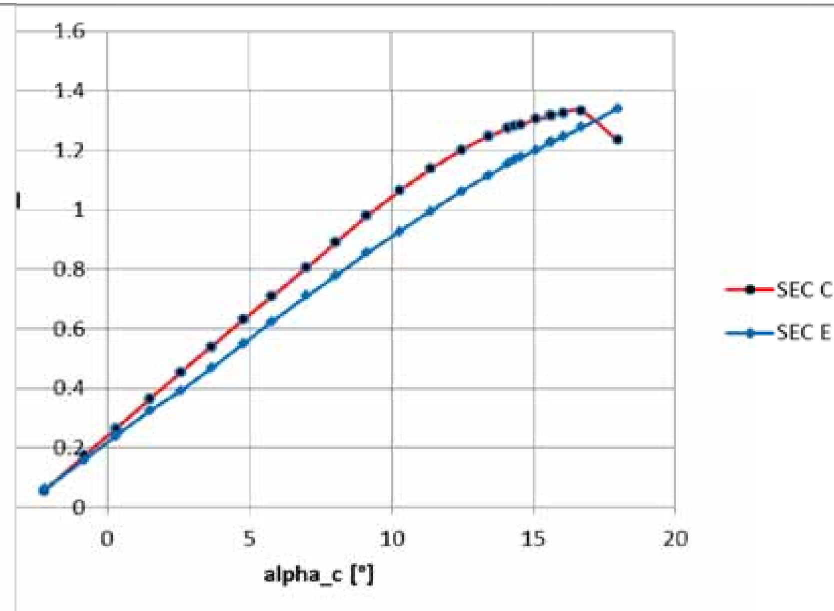


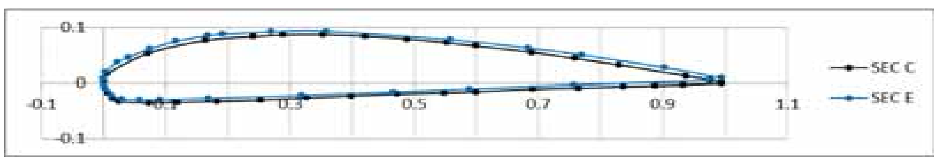


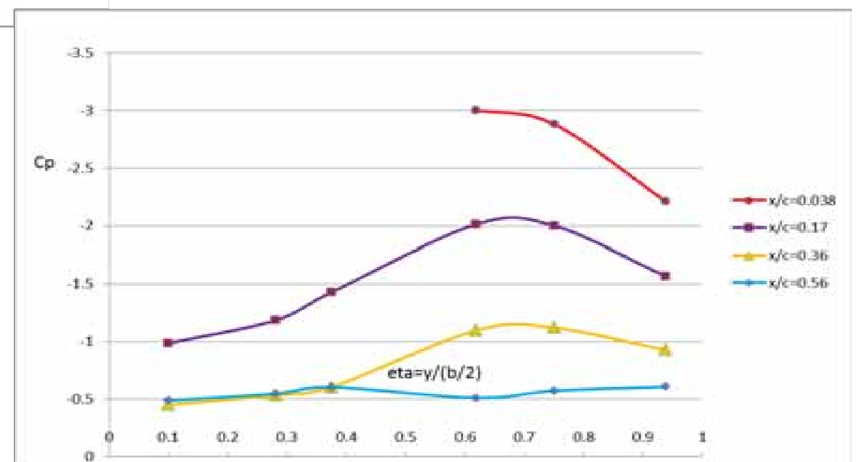
TEST RESULTS. Pressure measurements

TEST T30, V=30 m/s Turbulent



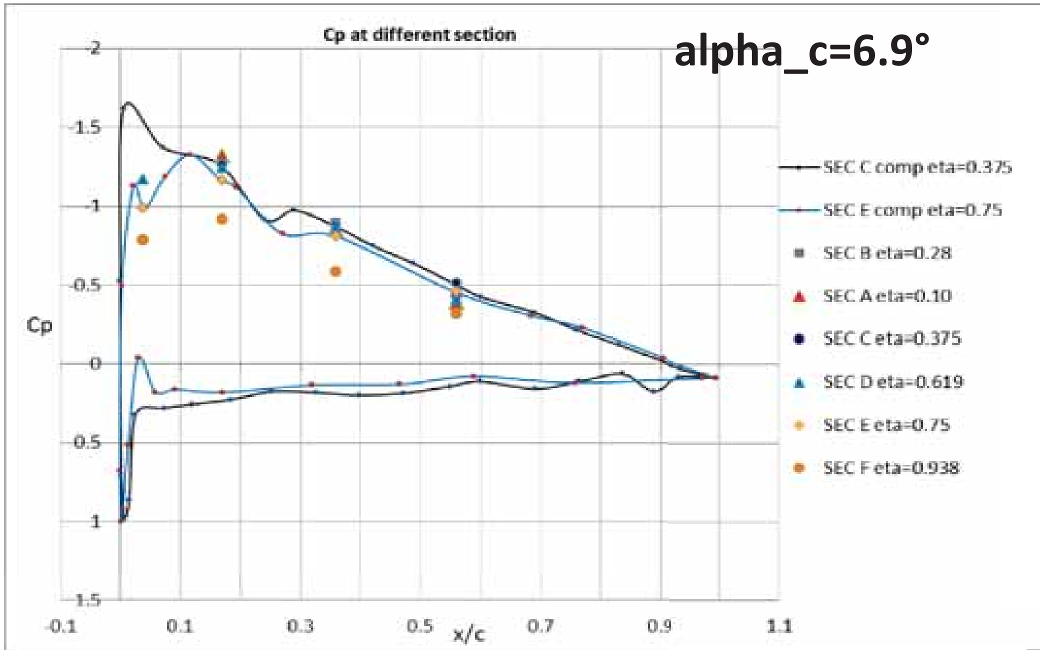


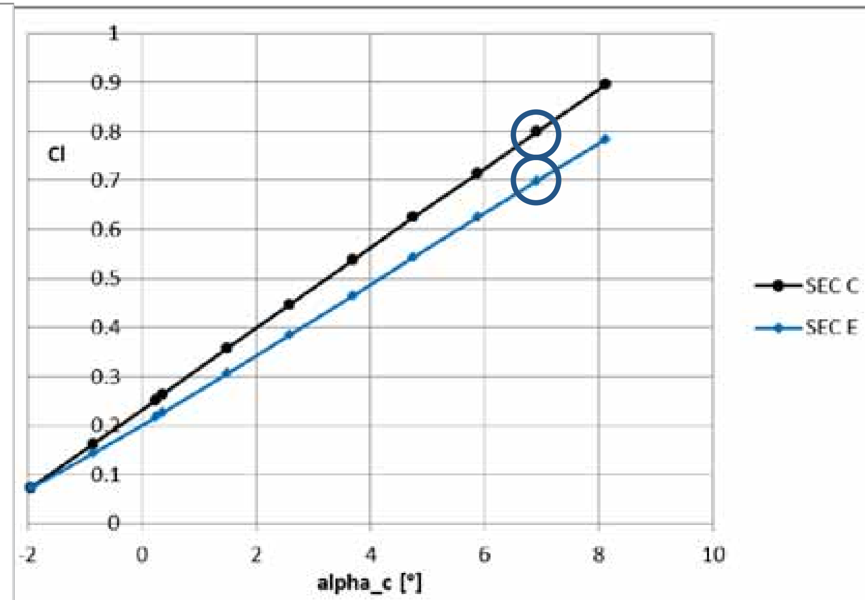


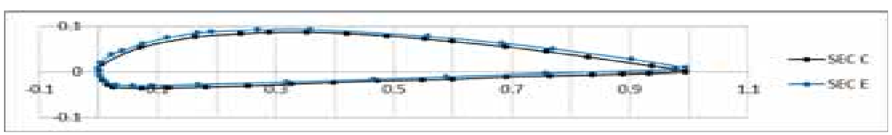


TEST RESULTS. Pressure measurements

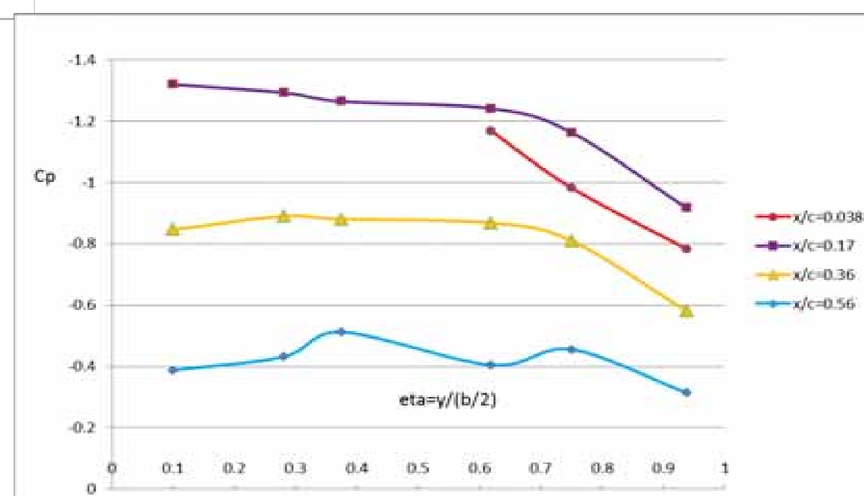
TEST T40, V=40 m/s Turbulent



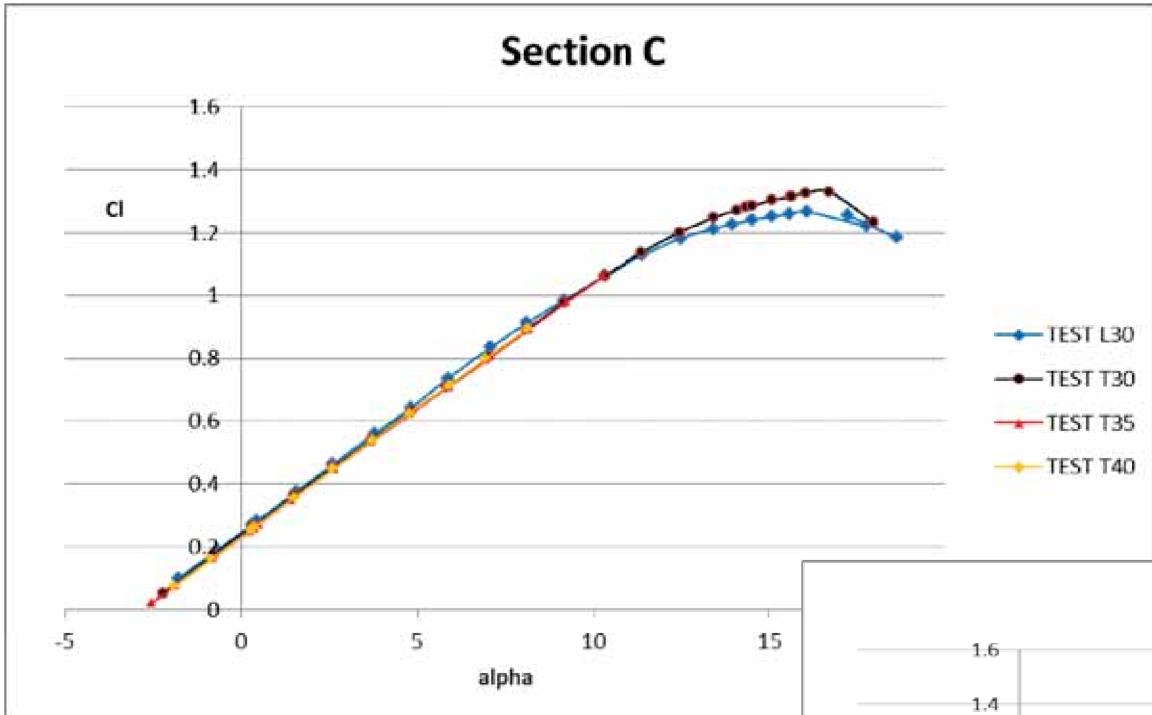


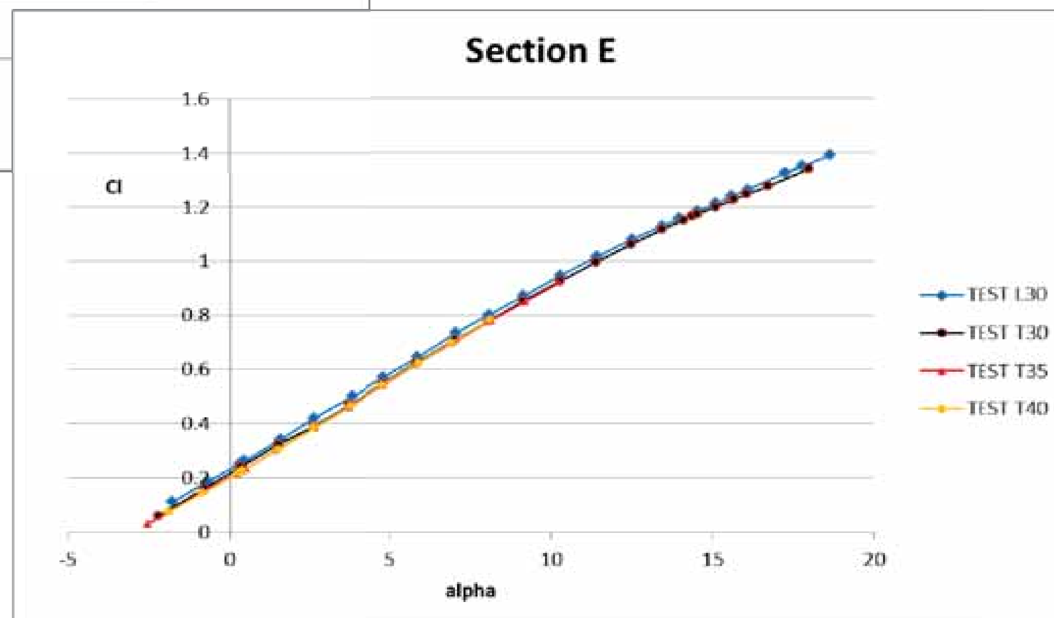


Load condition chosen for stress and deformation monitoring

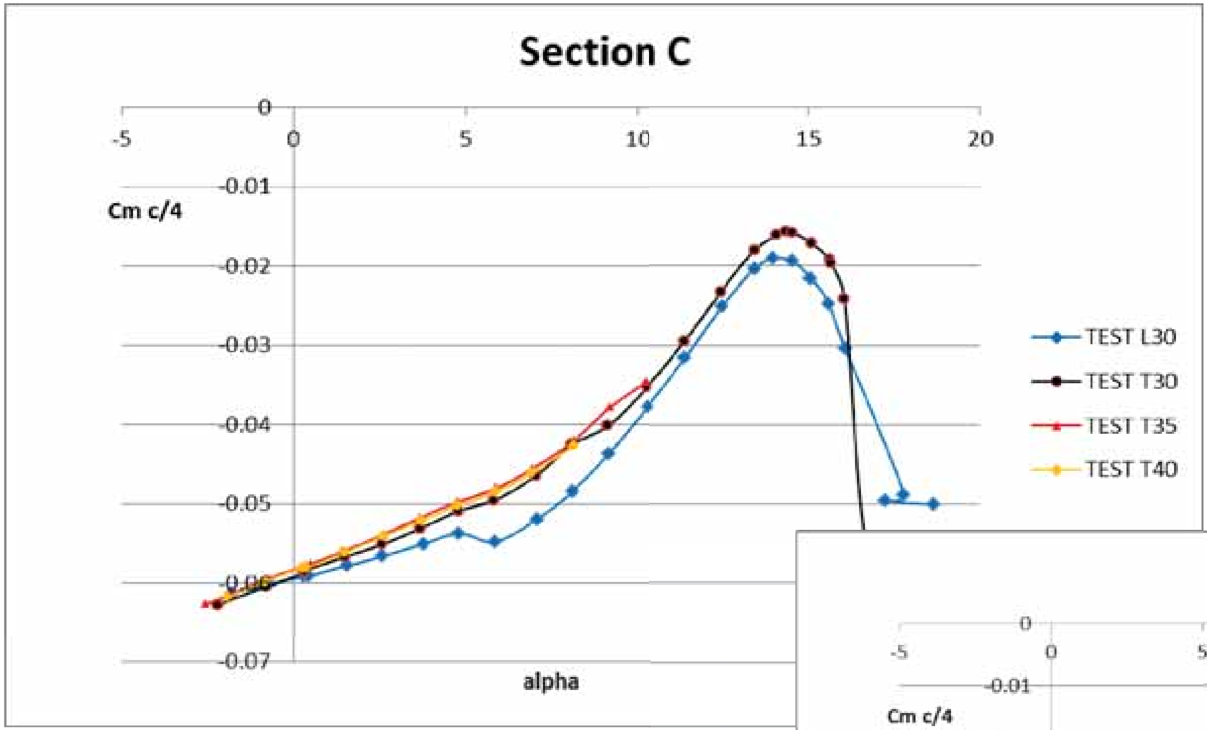


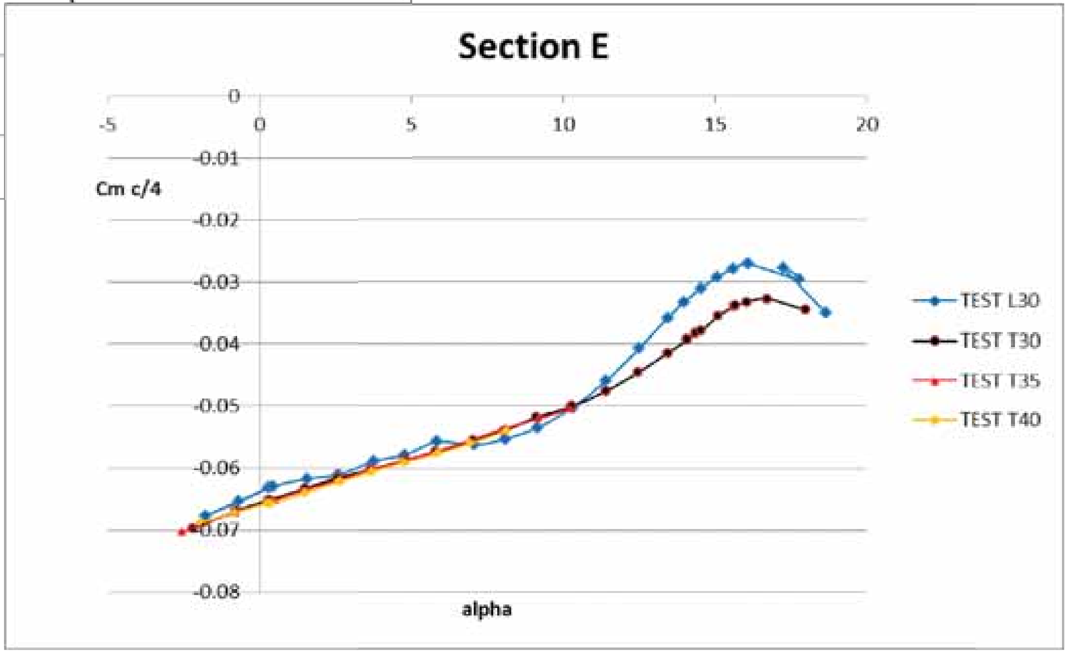
TEST RESULTS. Pressure measurements COMPARISON



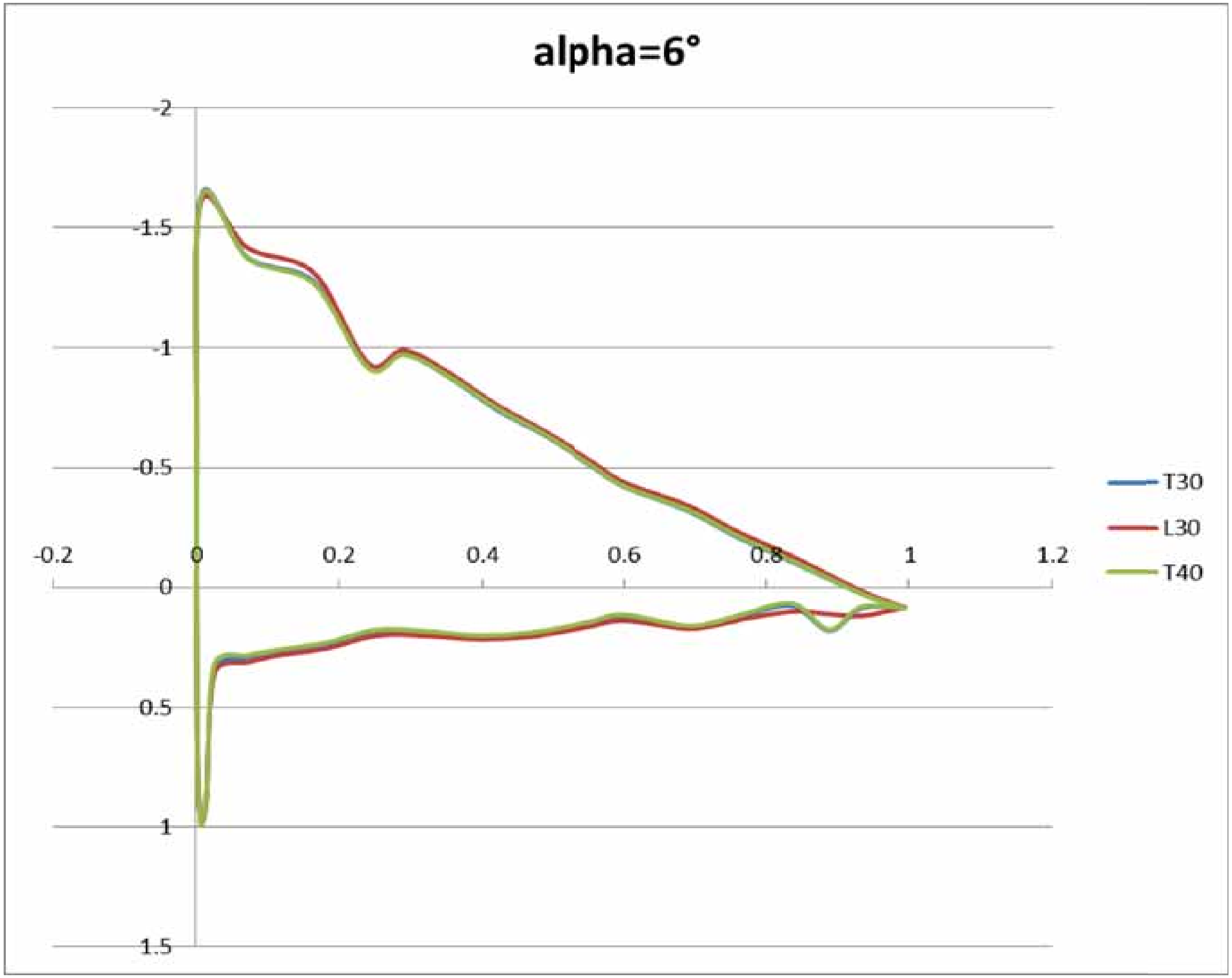


TEST RESULTS. Pressure measurements COMPARISON

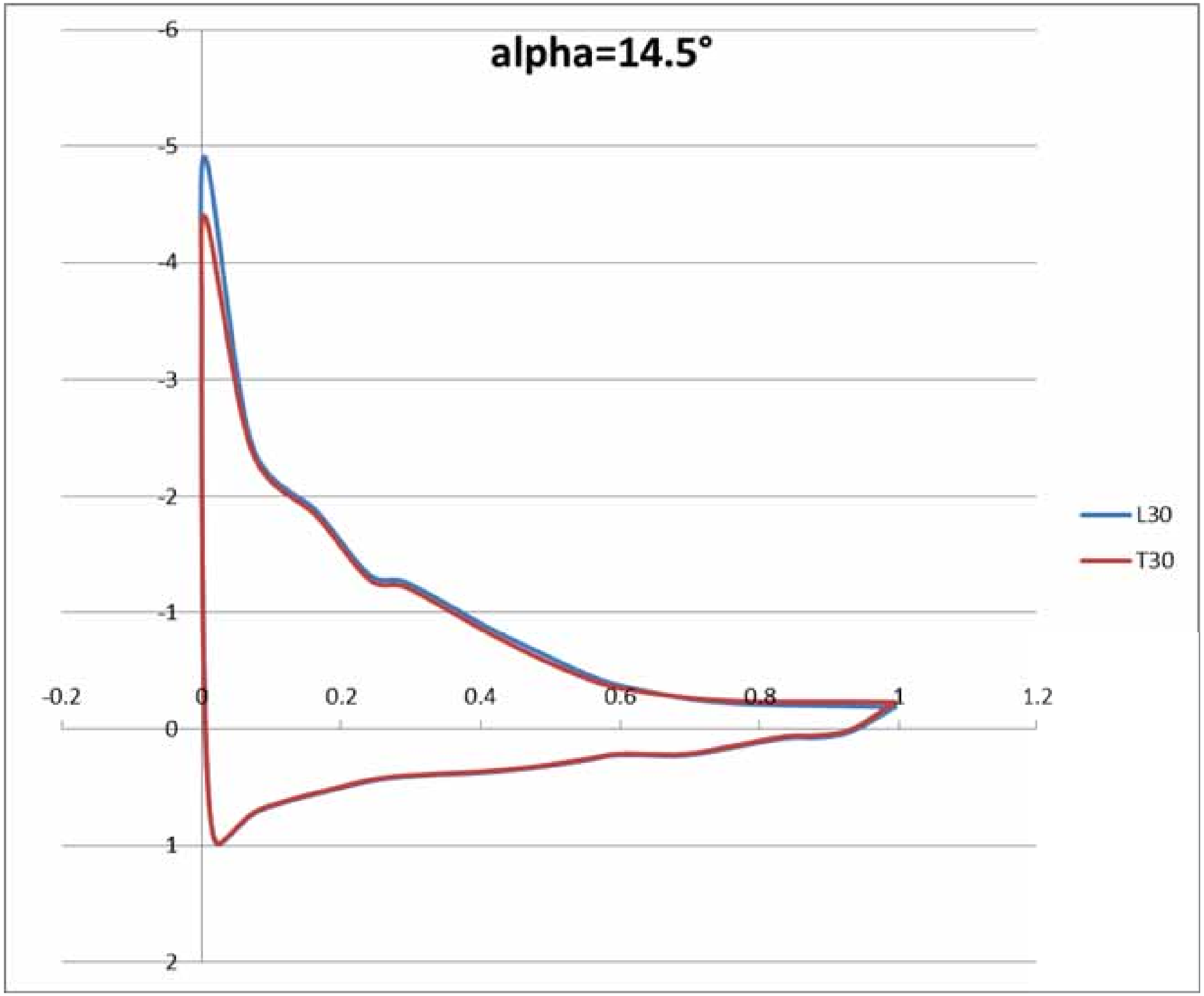




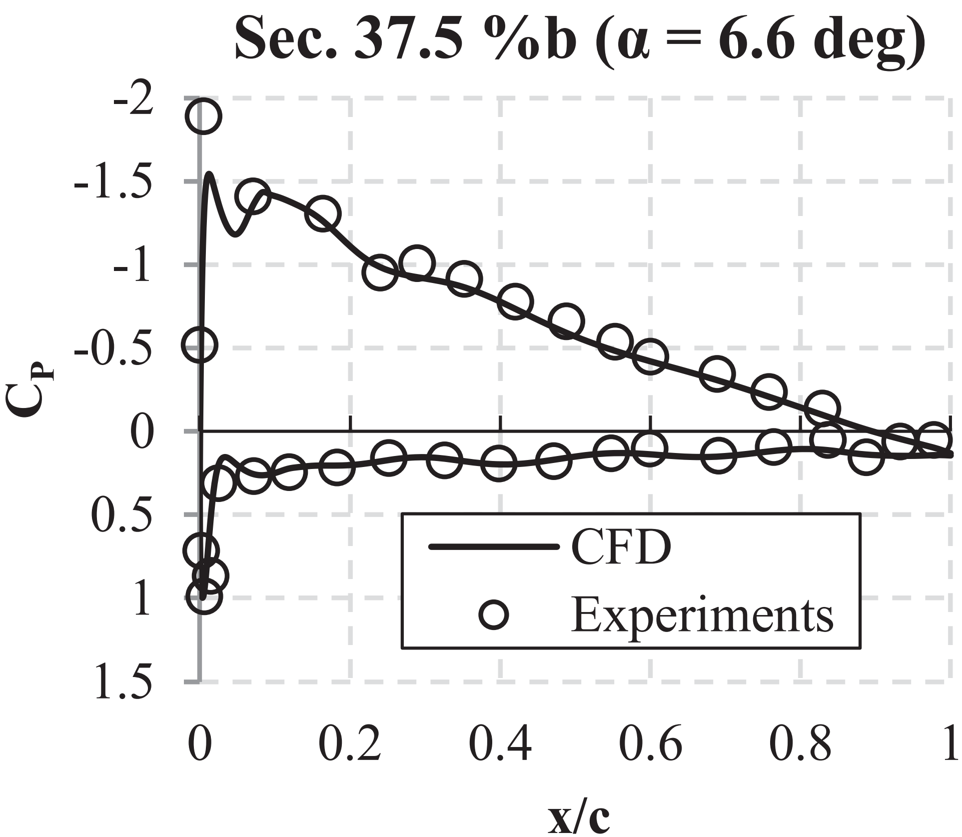
TEST RESULTS. Pressure measurements COMPARISON section C

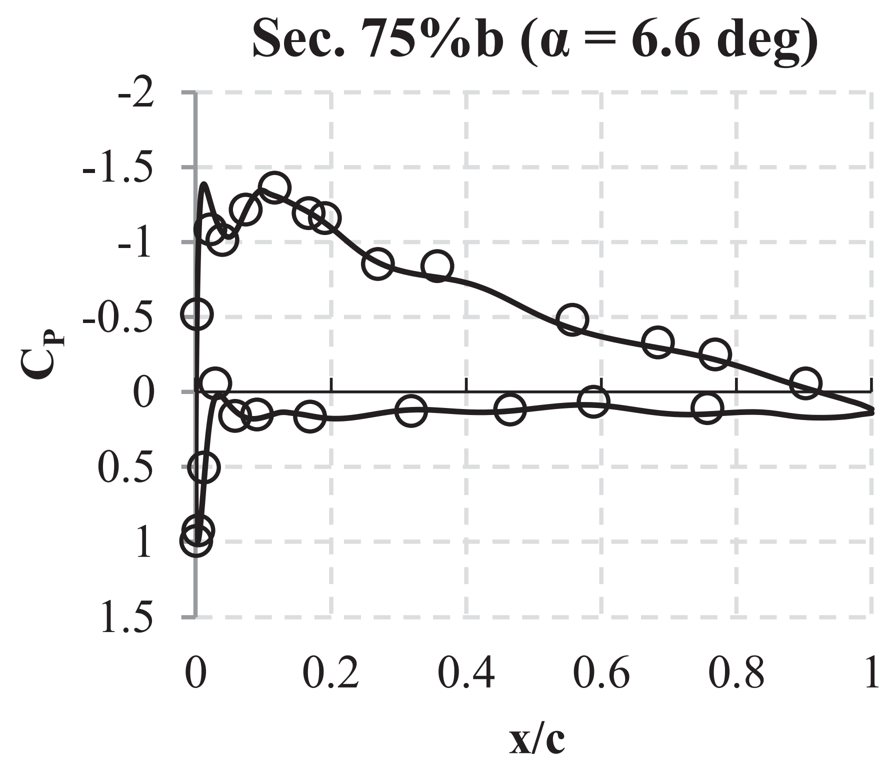


TEST RESULTS. Pressure measurements COMPARISON section C

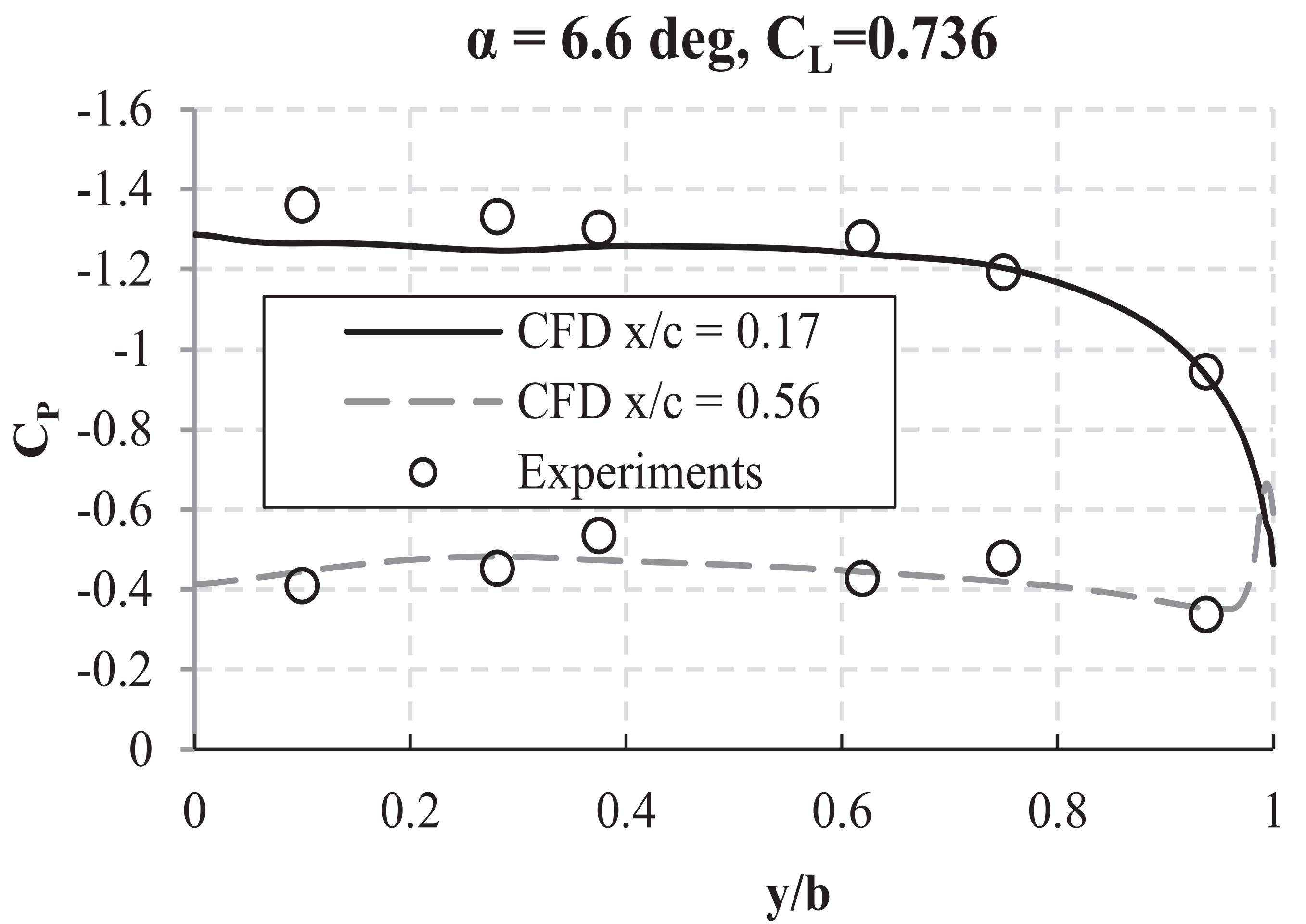


TEST RESULTS. Pressure measurements

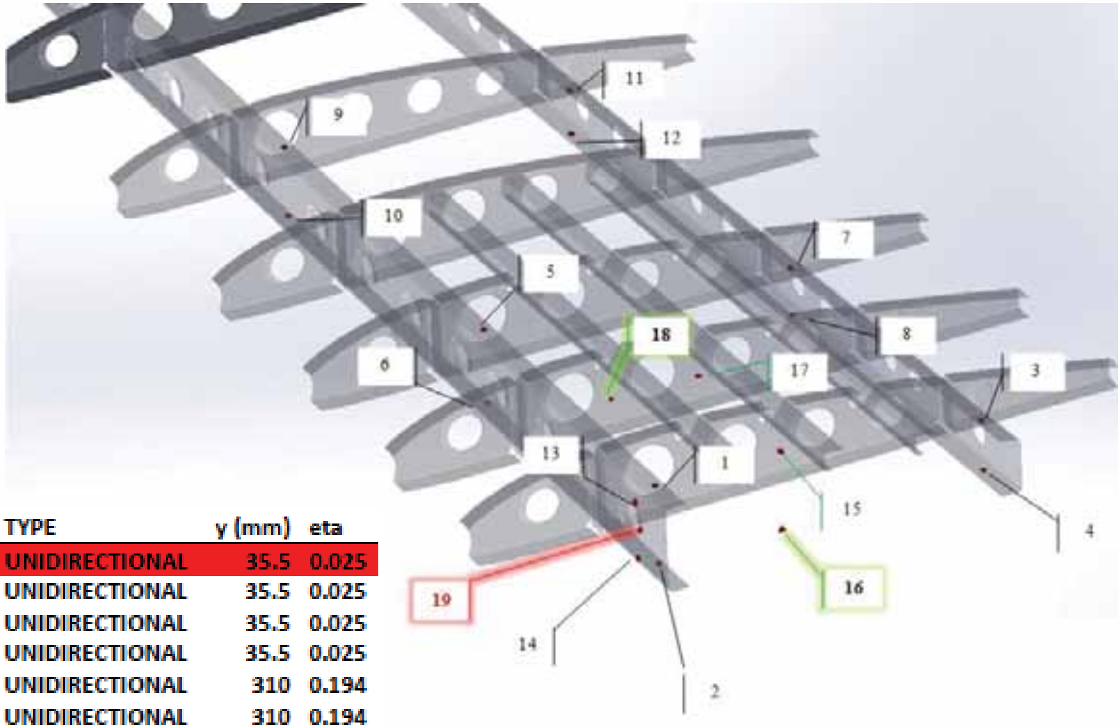




TEST RESULTS. Pressure measurements

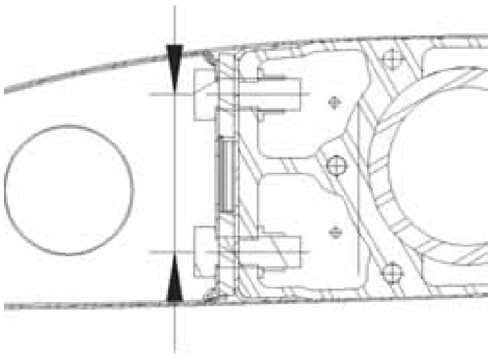


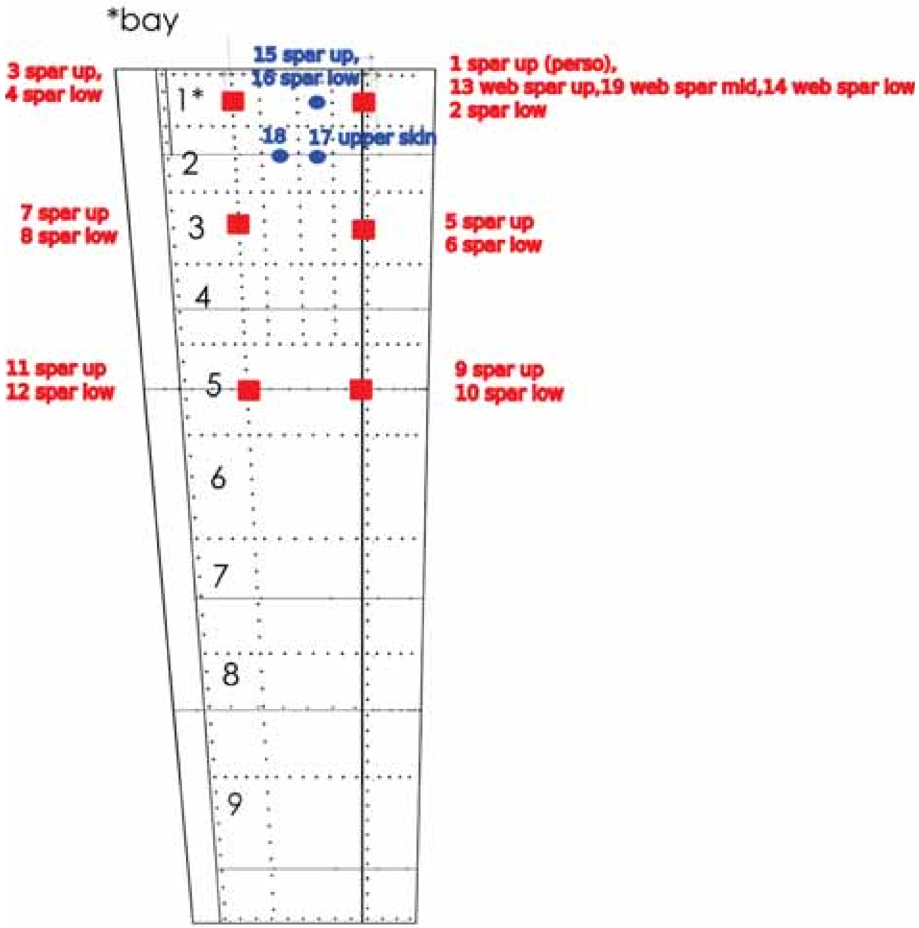
TEST RESULTS. Strain and stress measurement



ID	Bay	POSITION	INSTALLATION	TYPE	y (mm)	eta
1	1	between rib1-rib2	front spar	UNIDIRECTIONAL	35.5	0.025
2	1	between rib1-rib2	front spar	UNIDIRECTIONAL	35.5	0.025
3	1	between rib1-rib2	rear spar	UNIDIRECTIONAL	35.5	0.025
4	1	between rib1-rib2	rear spar	UNIDIRECTIONAL	35.5	0.025
5	3	between rib3-rib4	front spar	UNIDIRECTIONAL	310	0.194
6	3	between rib3-rib4	front spar	UNIDIRECTIONAL	310	0.194
7	3	between rib3-rib4	rear spar	UNIDIRECTIONAL	297	0.194
8	3	between rib3-rib4	rear spar	UNIDIRECTIONAL	297	0.194
9	5	between rib5-rib6	front spar	UNIDIRECTIONAL	600	0.391
10	5	between rib5-rib6	front spar	UNIDIRECTIONAL	600	0.391
11	5	between rib5-rib6	rear spar	UNIDIRECTIONAL	598	0.391
12	5	between rib5-rib6	rear spar	UNIDIRECTIONAL	598	0.391
13	1	between rib1-rib2	front spar thickening	UNIDIRECTIONAL	35.5	0.025
14	1	between rib1-rib2	front spar thickening	UNIDIRECTIONAL	35.5	0.025
15	1	1stbay, between 1st and 2nd stringer	Upper Skin	UNIDIRECTIONAL	35.5	0.025
16	1	1stbay, correspondence to UD N.15	Lower Skin	ROSETTE-3SIGNAL	35.5	0.025
17	2	2ndbay, between 1st and 2nd stringer	Upper Skin	UNIDIRECTIONAL	169	0.106
18	2	2ndbay, between 2nd and 3rd stringer	Upper Skin	ROSETTE-3SIGNAL	169	0.106
19	1	between rib1-rib2	front spar	ROSETTE-3SIGNAL	35.5	0.025

TEST RESULTS. Strain and stress measurement



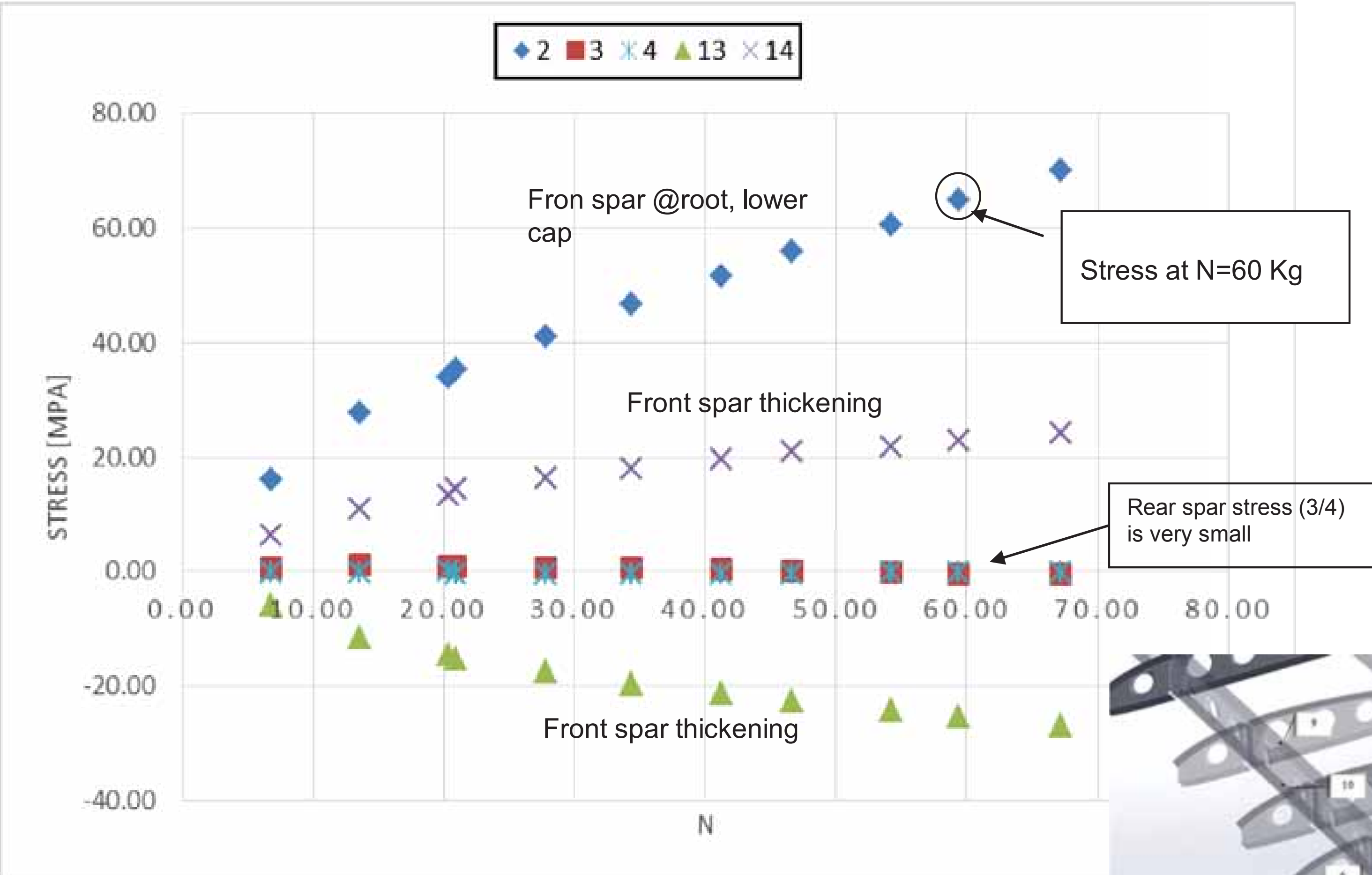


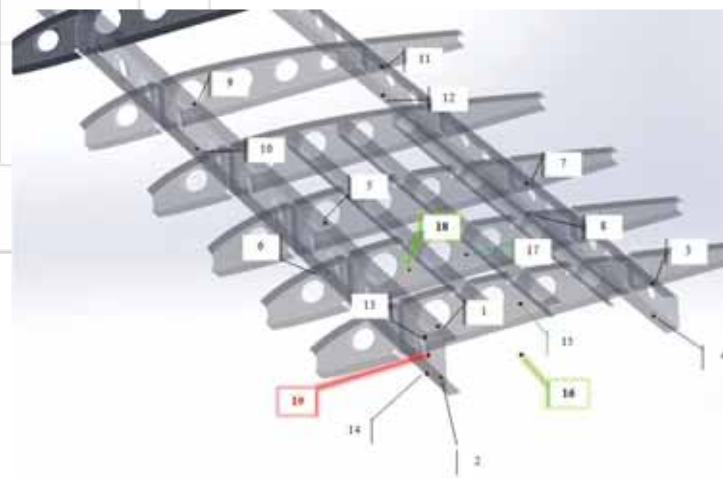
TEST RESULTS. Strain and stress measurement

Strain and stress measurement
TEST T40, V=40 m/s , Fully turbulent

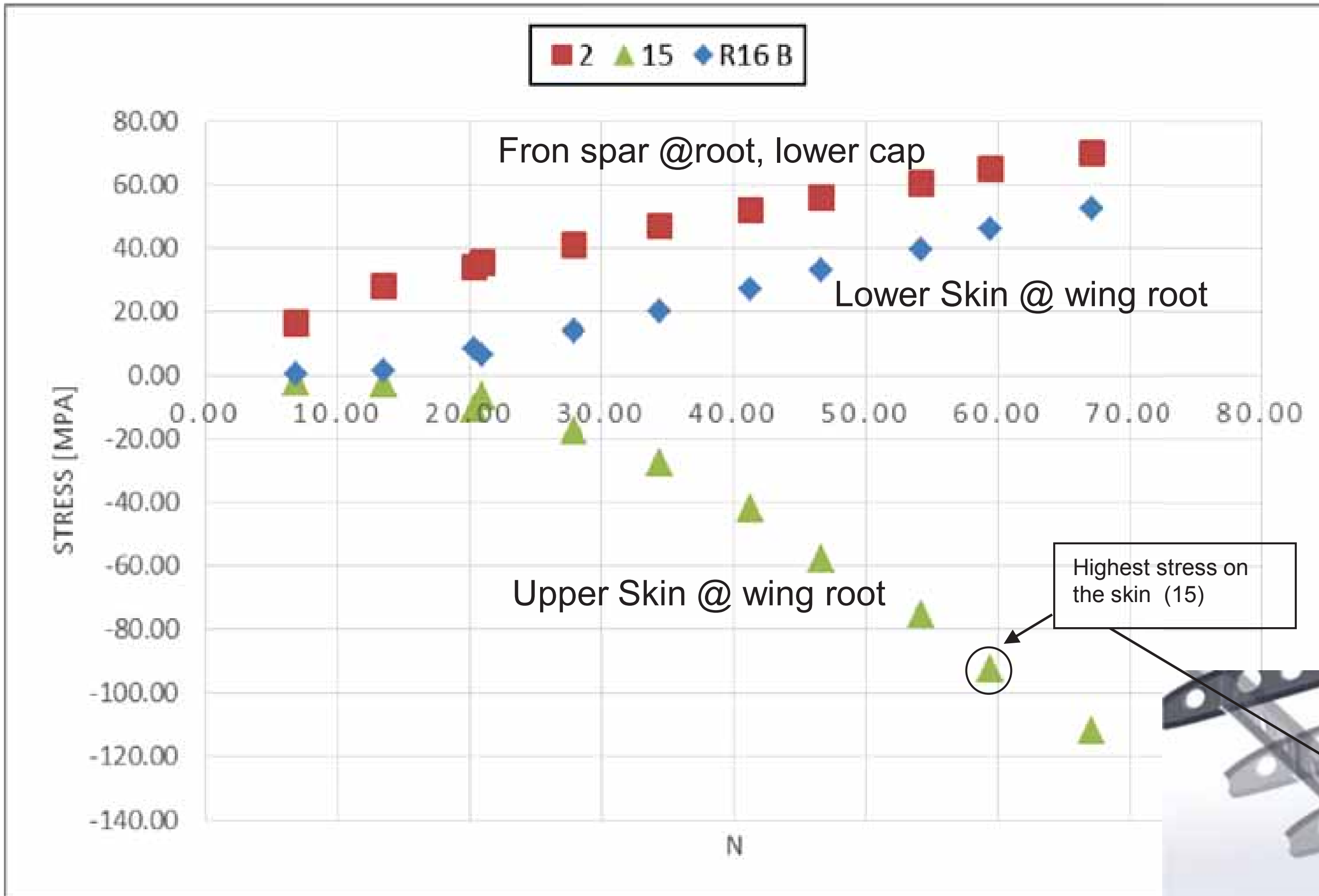
	Measured Forces and Moments							
Alfa_cor	N	Mfl	Yaw	Yaw_root	D	Mycb= My-My_tara	Mypolo	Mfl root
[°]	[kg]	[kgm]	[kgm]	[kg*m]	[Kg]	[kg*m]	[kg*m]	Kg m
-1.940	6.839	6.181	1.115	0.915	1.195	-2.279	-2.479	5.039
-0.850	13.536	12.042	1.039	0.849	1.137	-2.018	-2.441	9.782
0.250	20.370	17.941	1.049	0.857	1.151	-1.746	-2.395	14.540
0.360	20.989	18.470	1.043	0.852	1.143	-1.690	-2.360	14.964
1.490	27.873	24.419	1.145	0.938	1.241	-1.362	-2.257	19.765
2.590	34.378	30.105	1.321	1.085	1.413	-1.085	-2.192	24.364
3.700	41.261	36.209	1.577	1.298	1.670	-0.736	-2.066	29.318
4.750	46.616	41.015	1.819	1.496	1.929	-0.453	-1.954	33.230
5.880	54.178	47.827	2.192	1.794	2.384	-0.069	-1.810	38.779
6.920	59.420	52.519	2.436	1.975	2.761	0.244	-1.663	42.596
8.120	67.153	59.259	2.686	2.117	3.404	0.685	-1.463	48.044

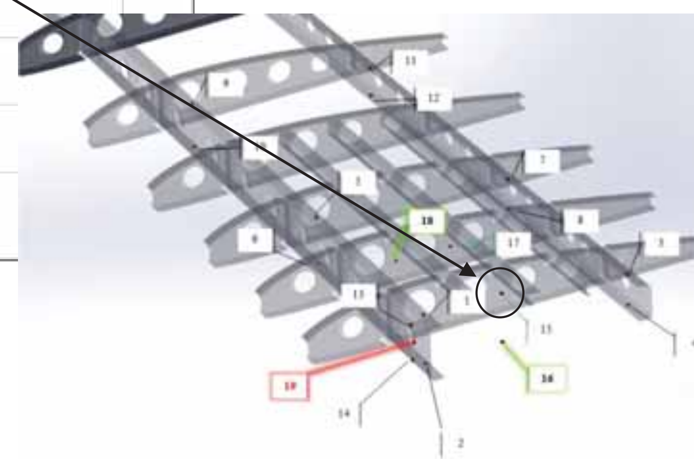
TEST RESULTS. Strain and stress measurement V=40 m/s – Stress for different alpha (loads)



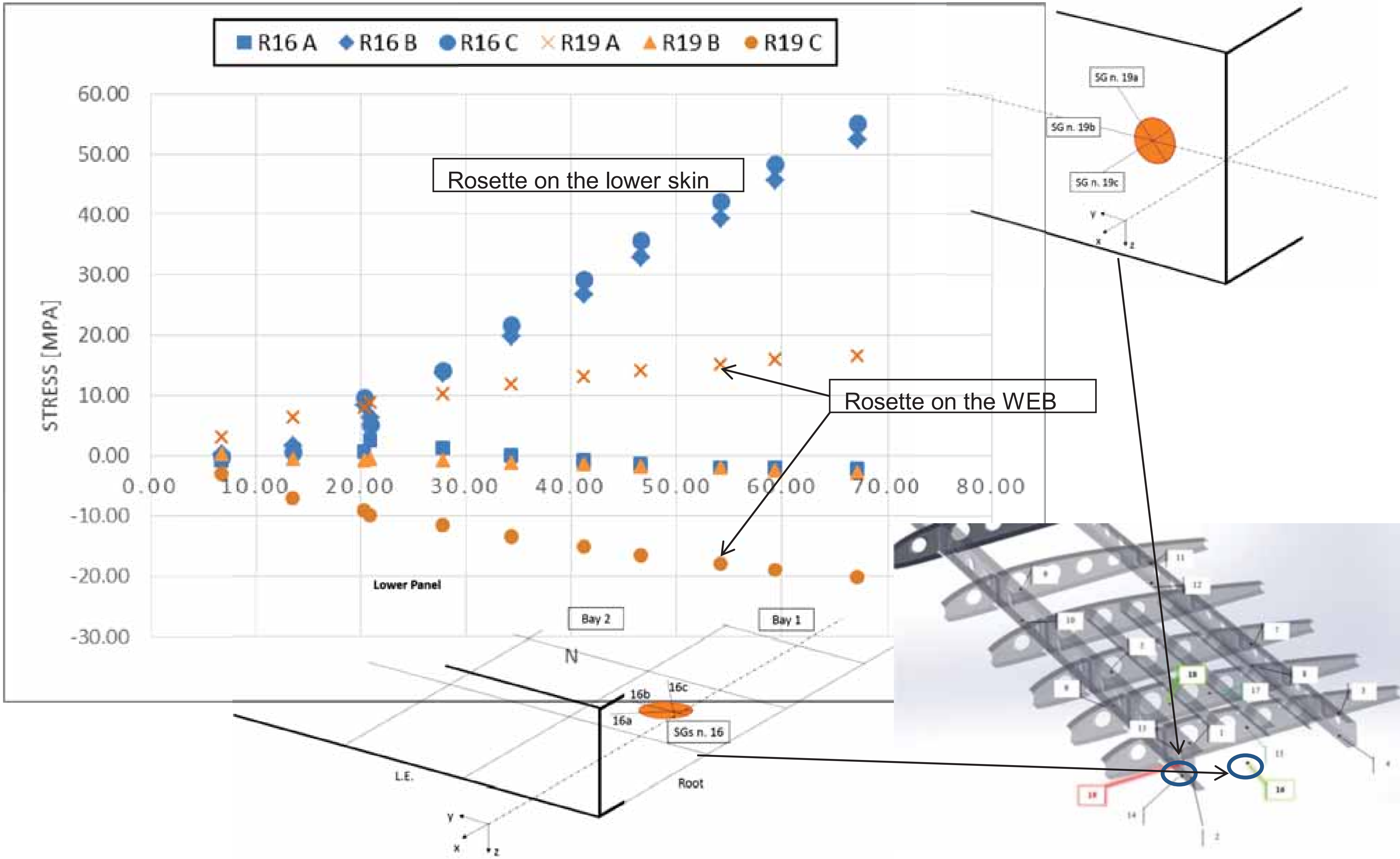


TEST RESULTS. Strain and stress measurement V=40 m/s – Stress for different alpha (loads)

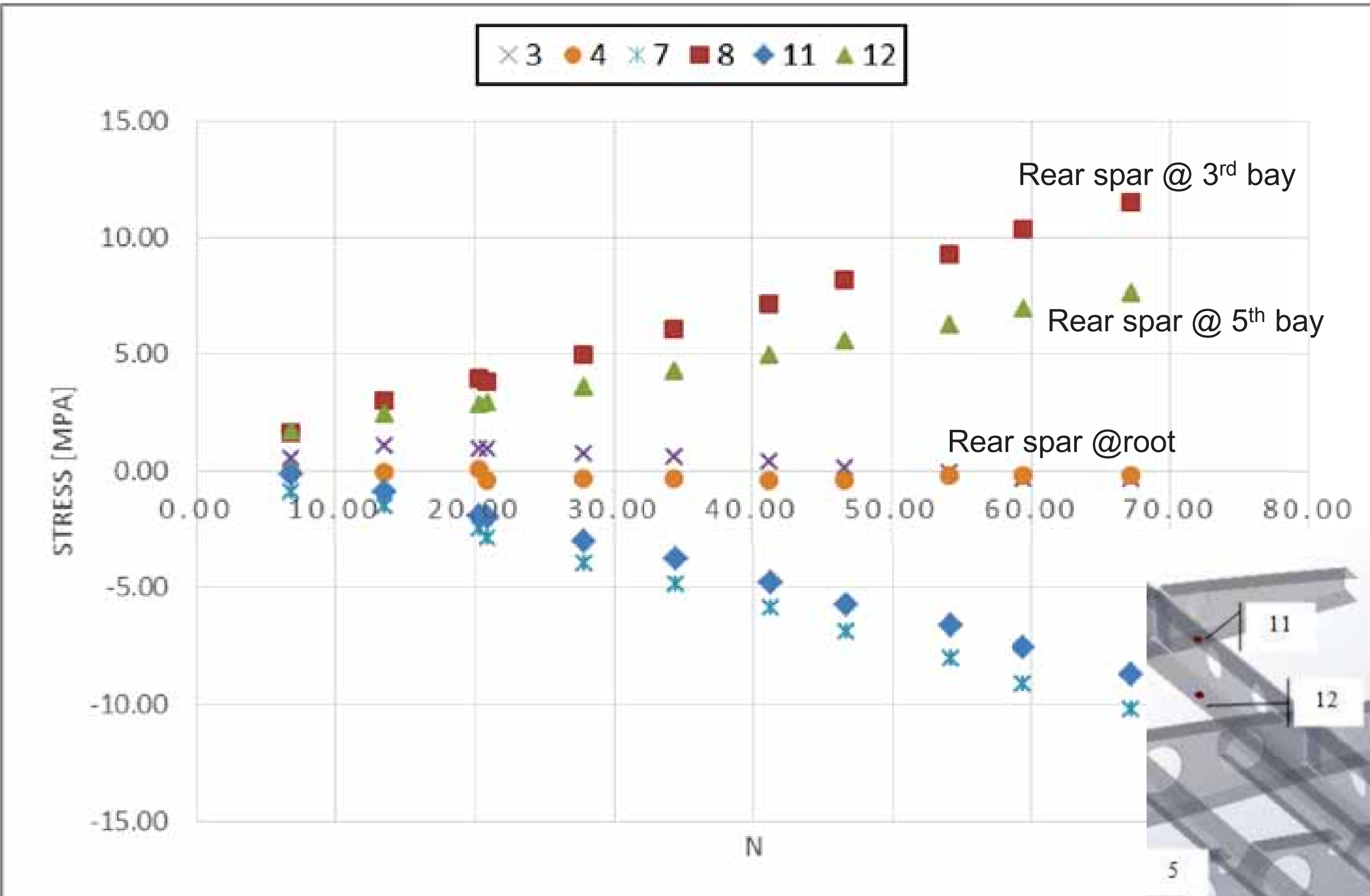


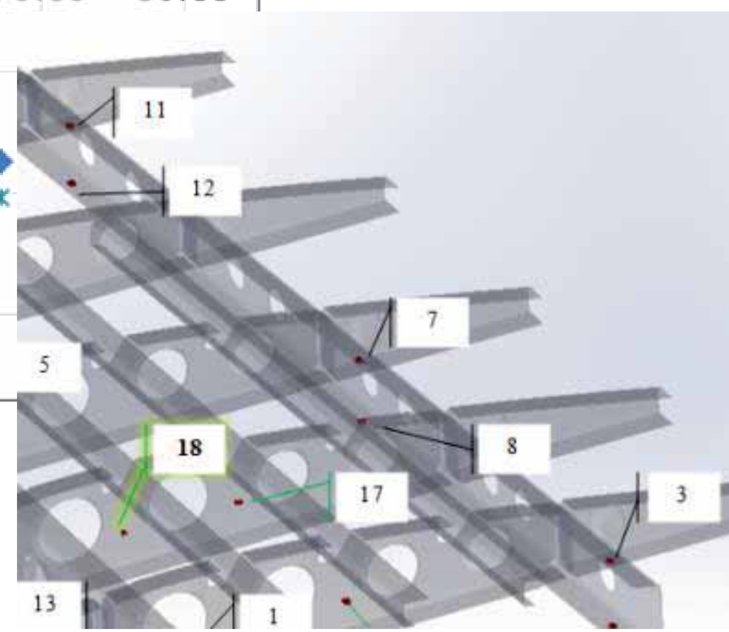


TEST RESULTS. Strain and stress measurement V=40 m/s – Stress for different alpha (loads)

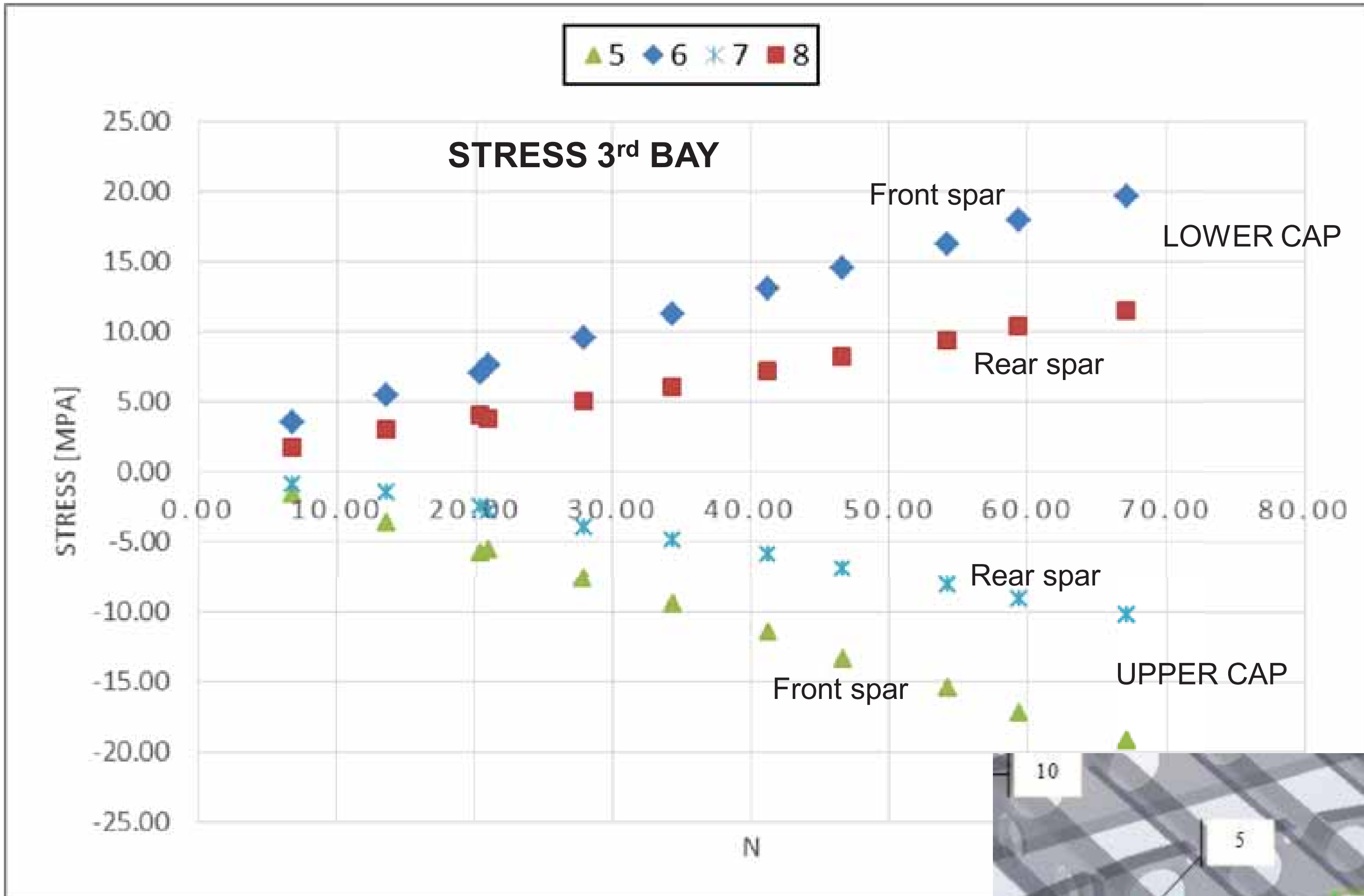


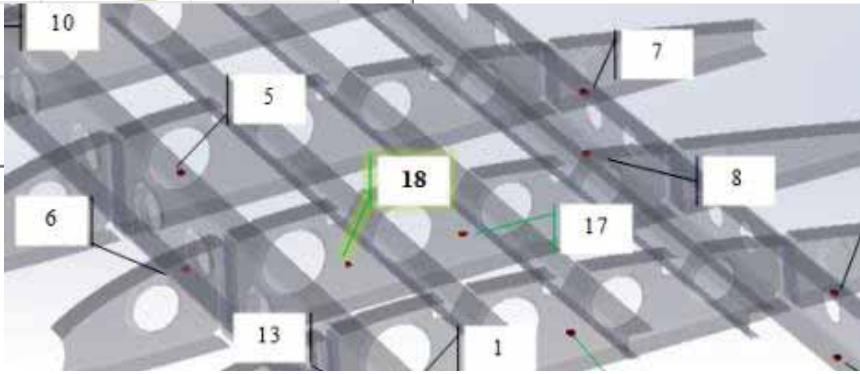
TEST RESULTS. Strain and stress measurement V=40 m/s – Stress for different alpha (loads)



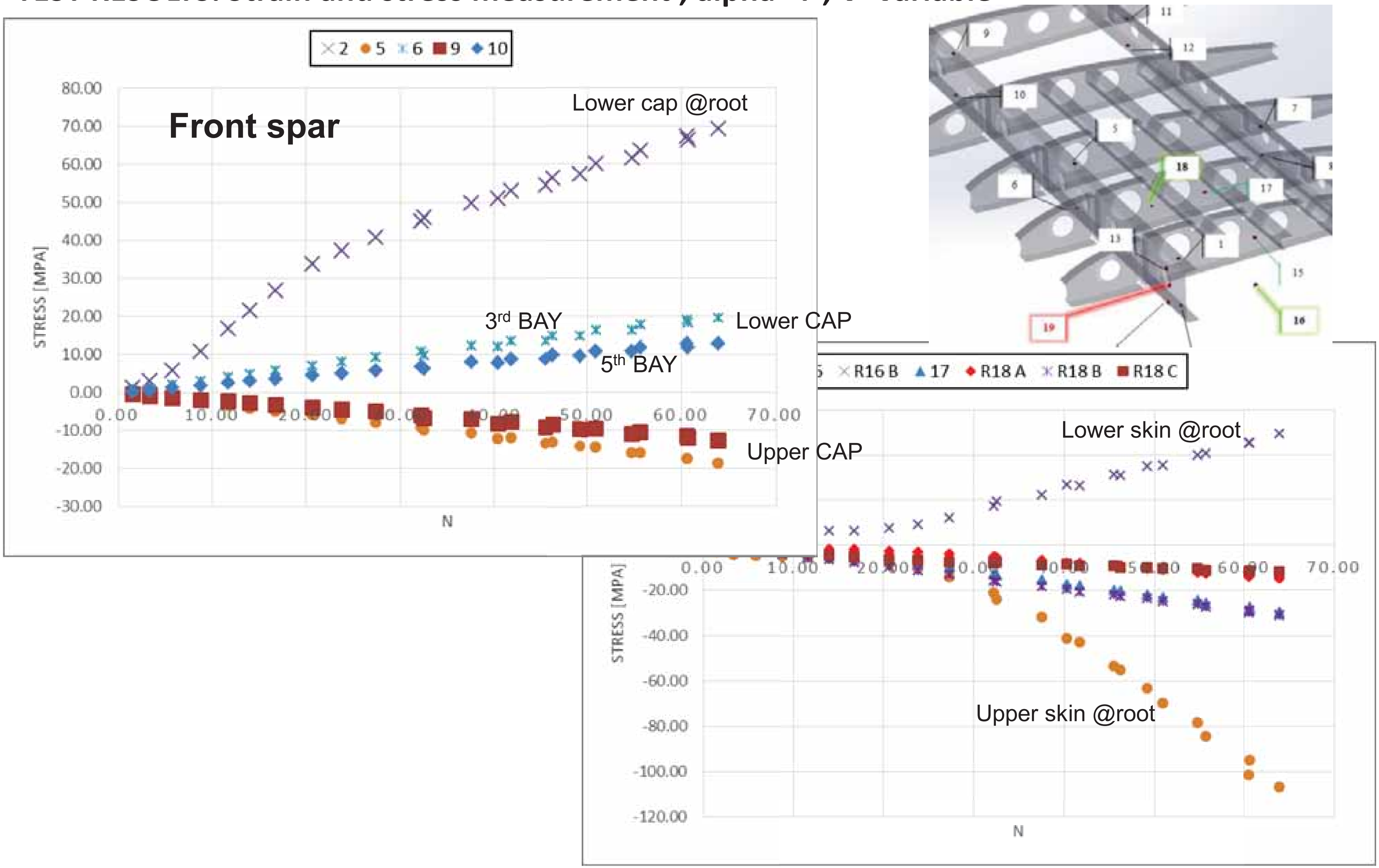


TEST RESULTS. Strain and stress measurement V=40 m/s – Stress for different alpha (loads)

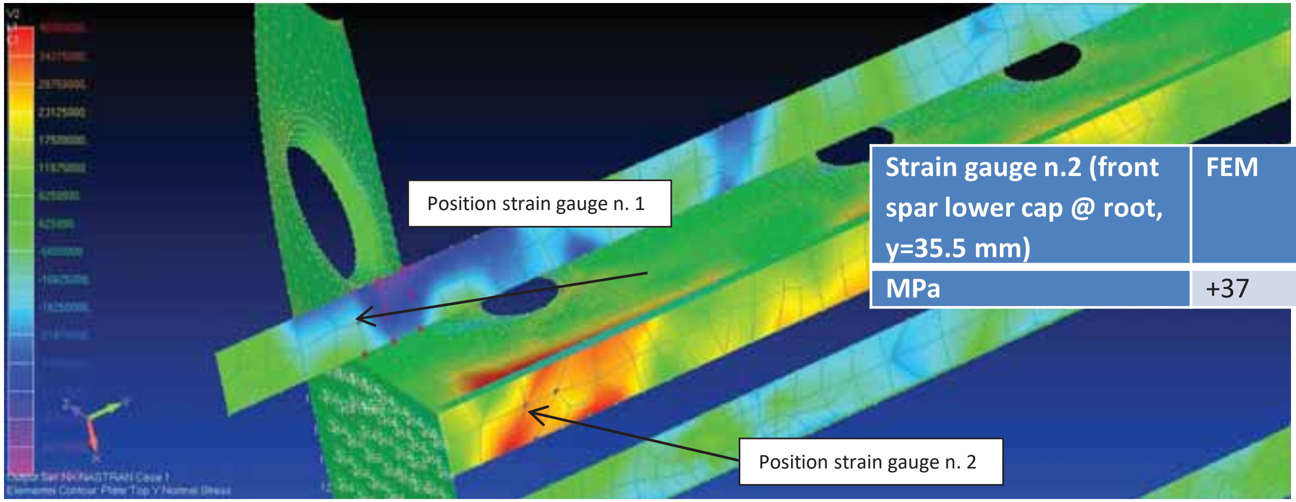




TEST RESULTS. Strain and stress measurement , alpha=4°, V=variable

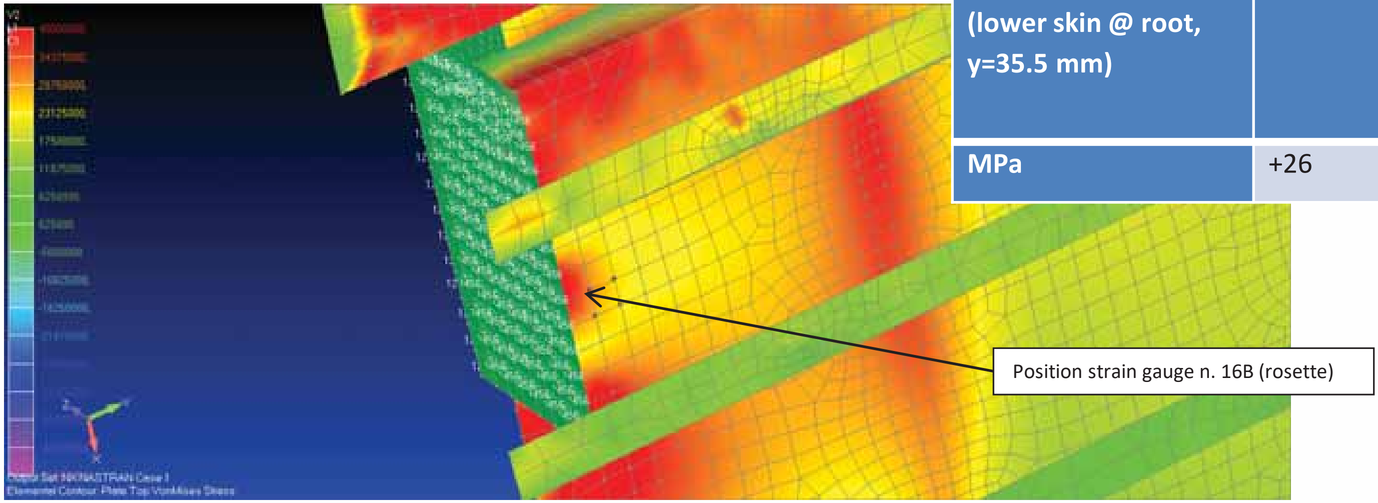


TEST RESULTS. Strain and stress measurement , design condition V=40 m/s N=60 Kg

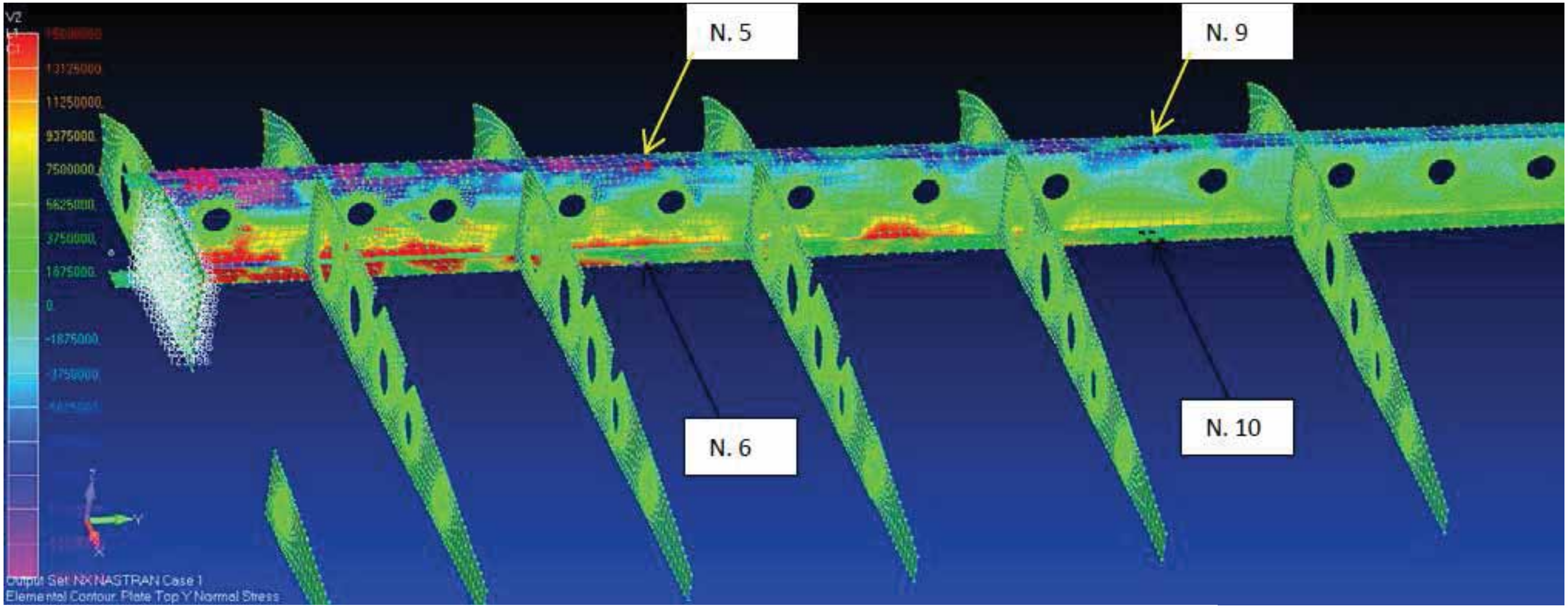


Strain gauge n.2 (front spar lower cap @ root, y=35.5 mm)	FEM	Experimental
MPa	+37	58

Strain gauge n.16B (lower skin @ root, y=35.5 mm)	FEM	Experimental
MPa	+26	44



TEST RESULTS. Strain and stress measurement , design condition V=40 m/s N=60 Kg

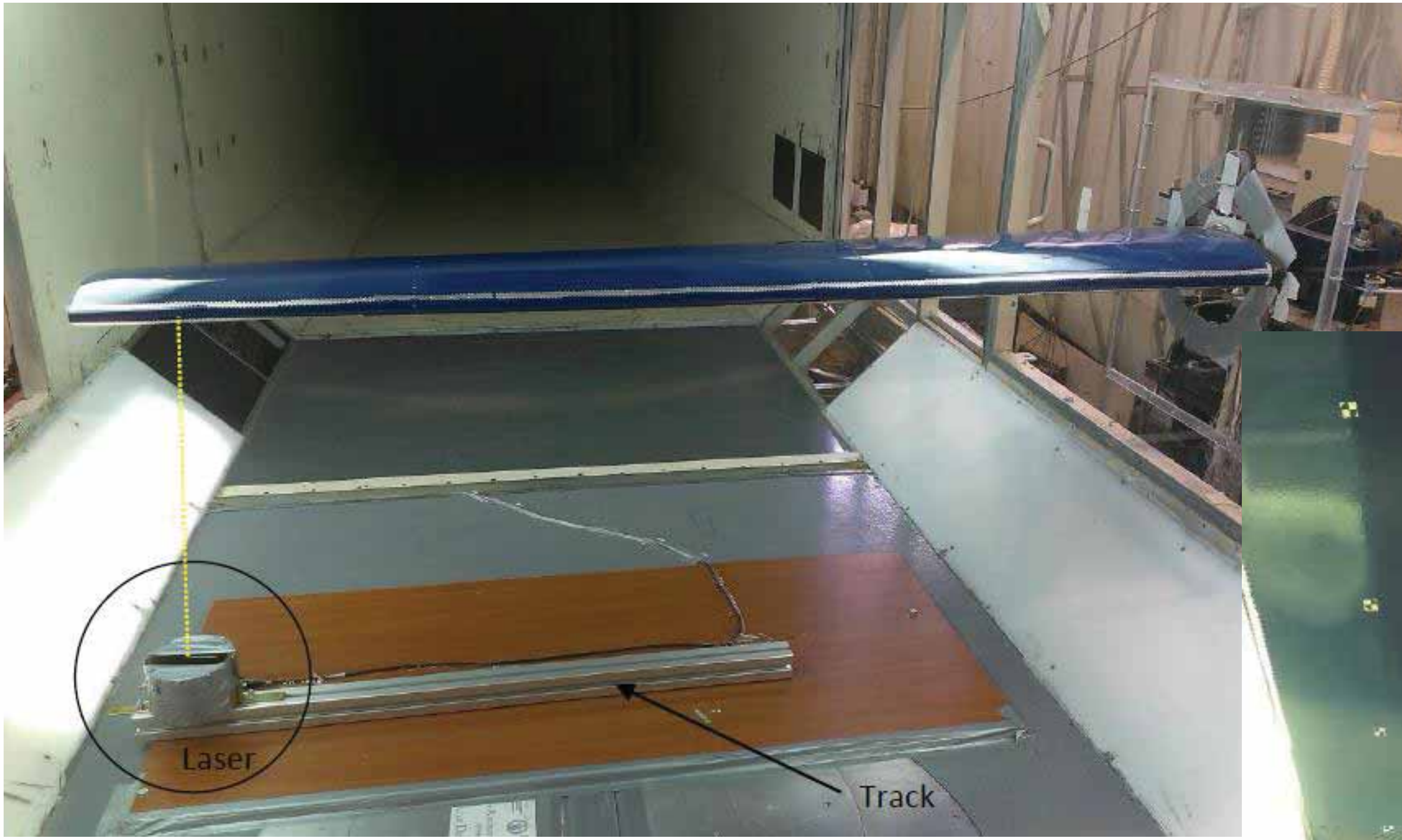


	FEM	Experimental
Strain gauge n.5 (front spar upper cap @ y=300 mm)	-16 Mpa	-17.5 Mpa
Strain gauge n.6 (front spar lower cap @ y=300 mm)	+15 MPa	18.2 MPa

	FEM	Experimental
Strain gauge n.9 (front spar upper cap @ y=600 mm)	-10 Mpa	-12.2 Mpa
Strain gauge n.10 (front spar lower cap @ y=600 mm)	+11 MPa	12.3 MPa

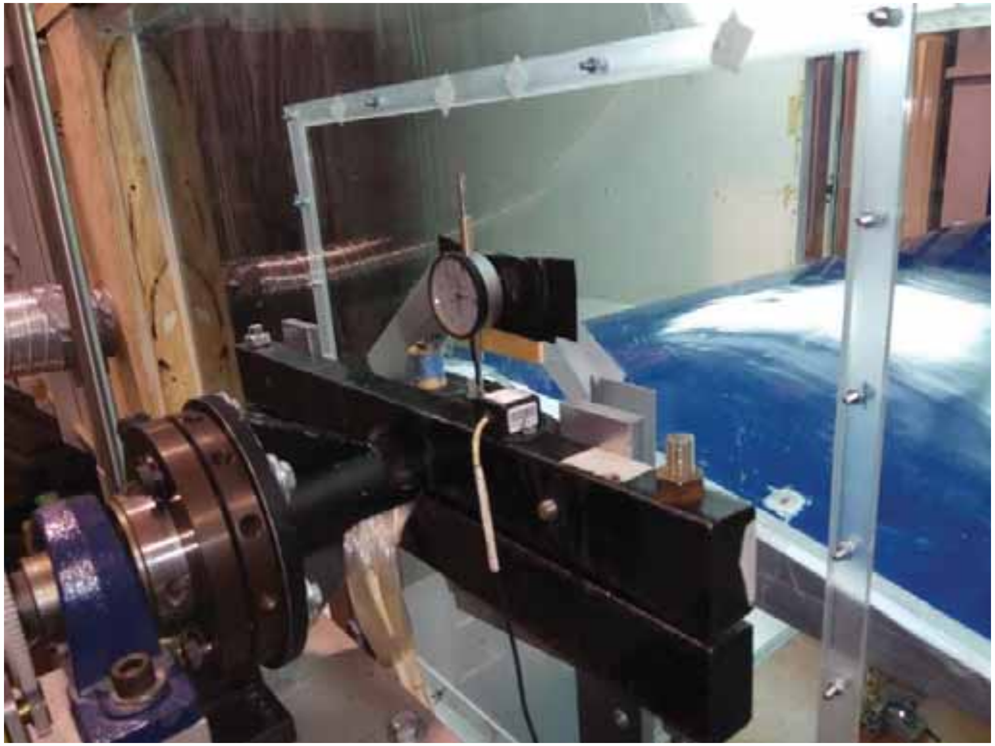
TEST RESULTS. Deformation measurement

V=40 m/s, alpha_g=6°, alpha_c= 7° N=60 Kg



TEST RESULTS. Deformation measurement

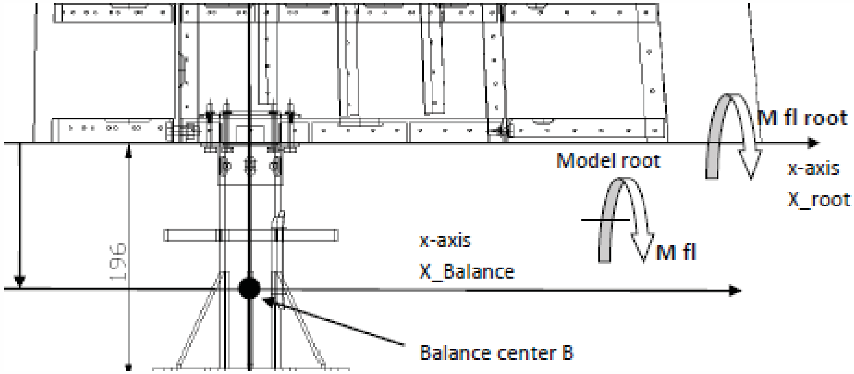
V=40 m/s, alpha_g=6°, alpha_c= 7° N=60 Kg

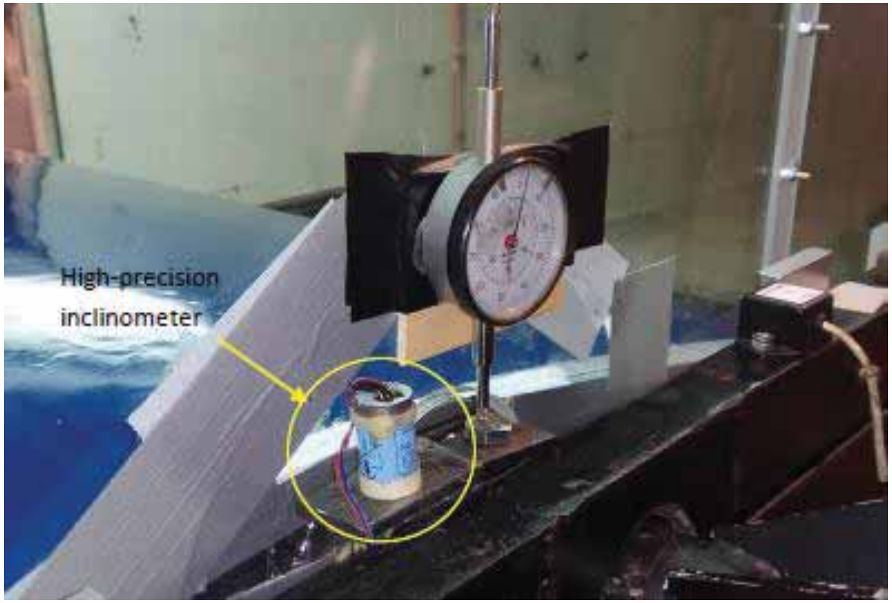


Highly accurate tilt sensor

On the wing root

Measure model rotation @ root





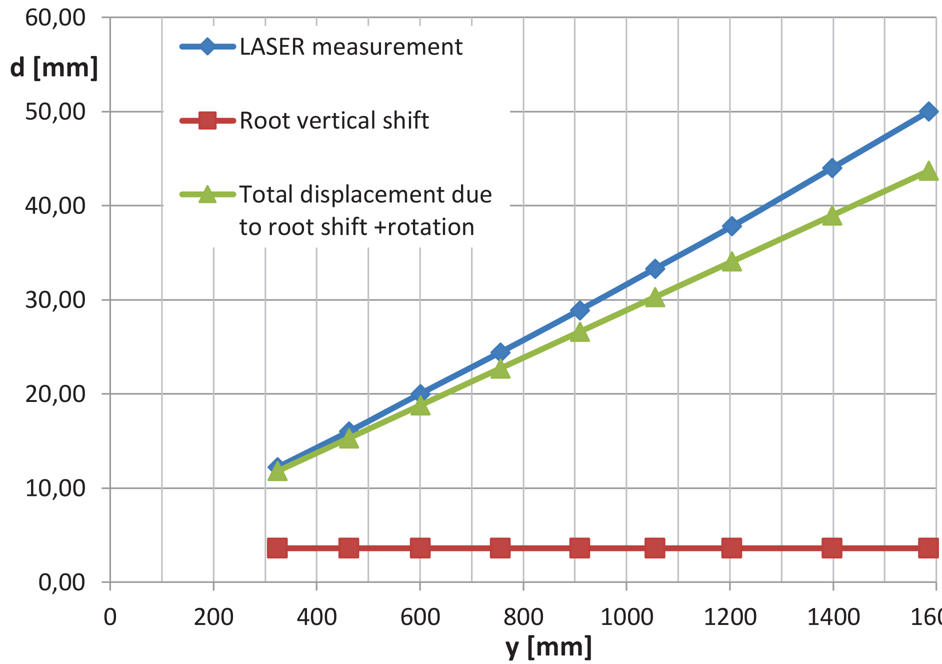
TEST RESULTS. Deformation measurement
V=40 m/s, alpha_g=6°, alpha_c= 7° N=60 Kg

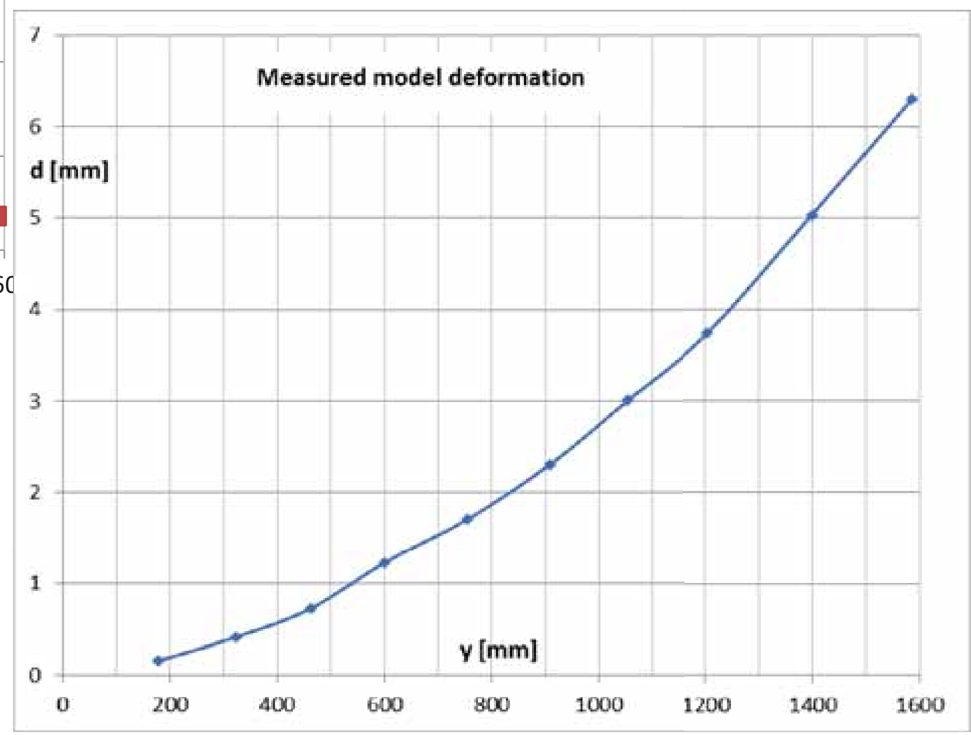
MARK	y [mm]	V	Normal Force	Root Inclinom Midori	LASER Measurem	Vertical root displacement (micro-meter comparator)	Total vertical shift	Shift due to only Root ROT	Deformation
		[m/s]	[Kgf]	[deg]	[mm]	[mm]	[mm]	[mm]	[mm]
11	1585	39.20	60.3	1.45	50.00	3.594	43.70	40.10	6.30
10	1398	39.20	60.3	1.45	44.00	3.590	38.96	35.37	5.04
9	1204	39.20	60.3	1.45	37.8	3.590	34.05	30.46	3.75
8	1055	39.20	60.3	1.45	33.30	3.590	30.28	26.69	3.02
7	909	39.20	60.3	1.45	28.90	3.590	26.59	23.00	2.31
6	755	39.20	60.3	1.45	24.40	3.590	22.69	19.10	1.71
5	600	39.20	60.3	1.45	20.00	3.590	18.77	15.18	1.23
4	462	39.20	60.3	1.45	16.00	3.590	15.28	11.69	0.72
3	324	39.20	60.3	1.45	12.20	3.590	11.79	8.20	0.41
2	178	39.20	60.3	1.45	8.25	3.590	8.09	4.50	0.16
1	35	39.20	60.3	1.45		3.590	4.48	0.89	

From measurements of point 11 and 11P(Posteriore) at different chord position, also the torsion at wing tip has been measured:
The torsional deformation at wing tip has been measured and is equal to 0.82 deg. (positive, twist up).

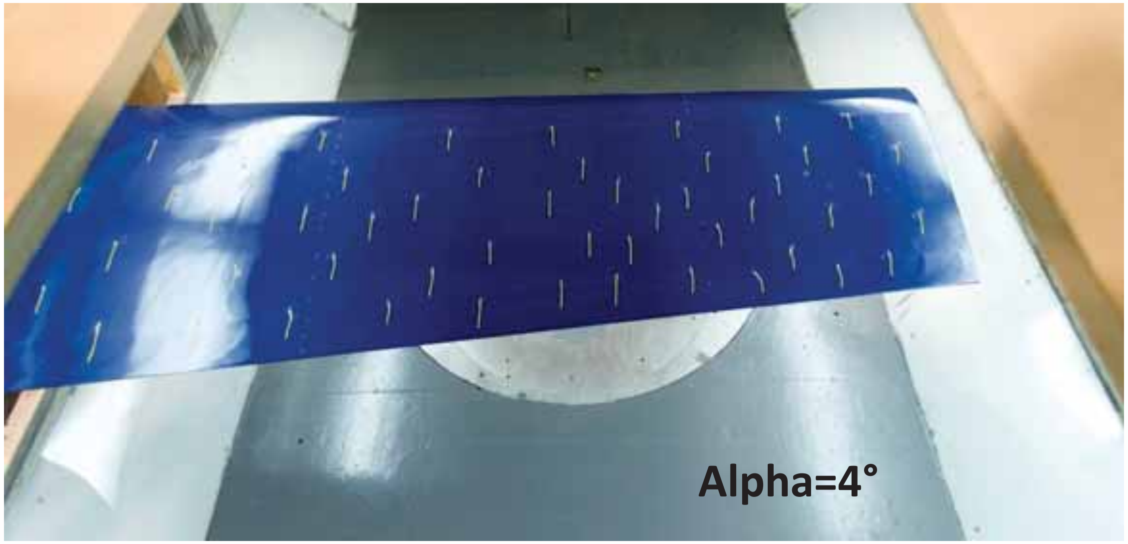
TEST RESULTS. Deformation measurement

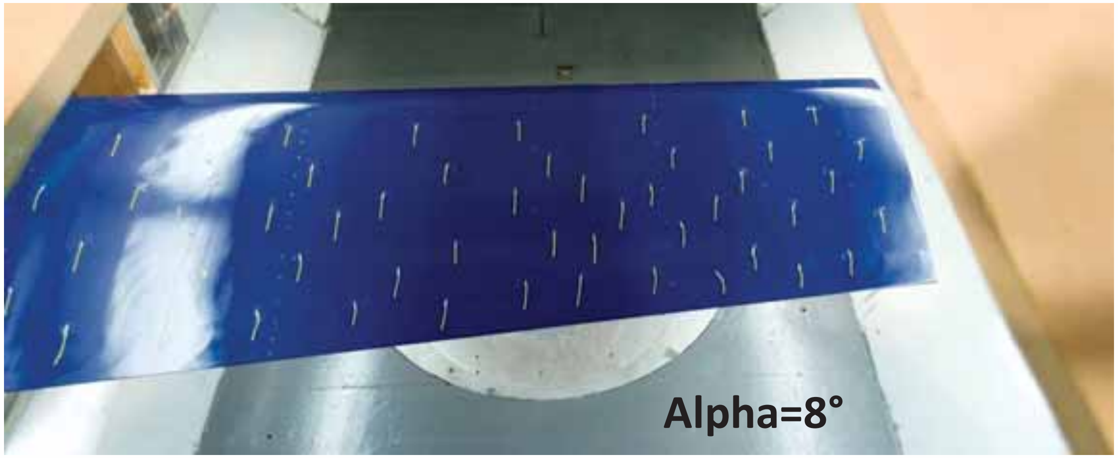
V=40 m/s, alpha_g=6°, alpha_c= 7° N=60 Kg



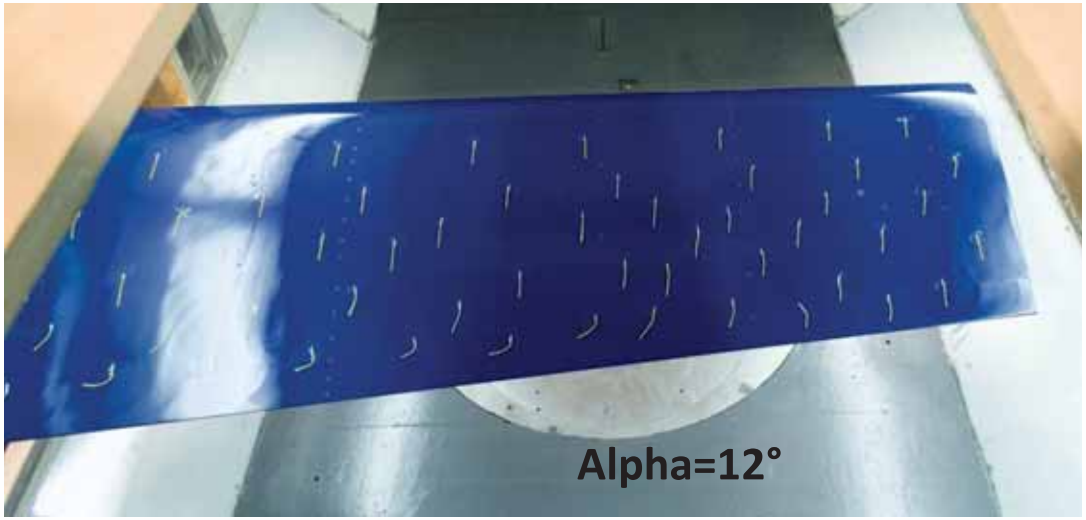


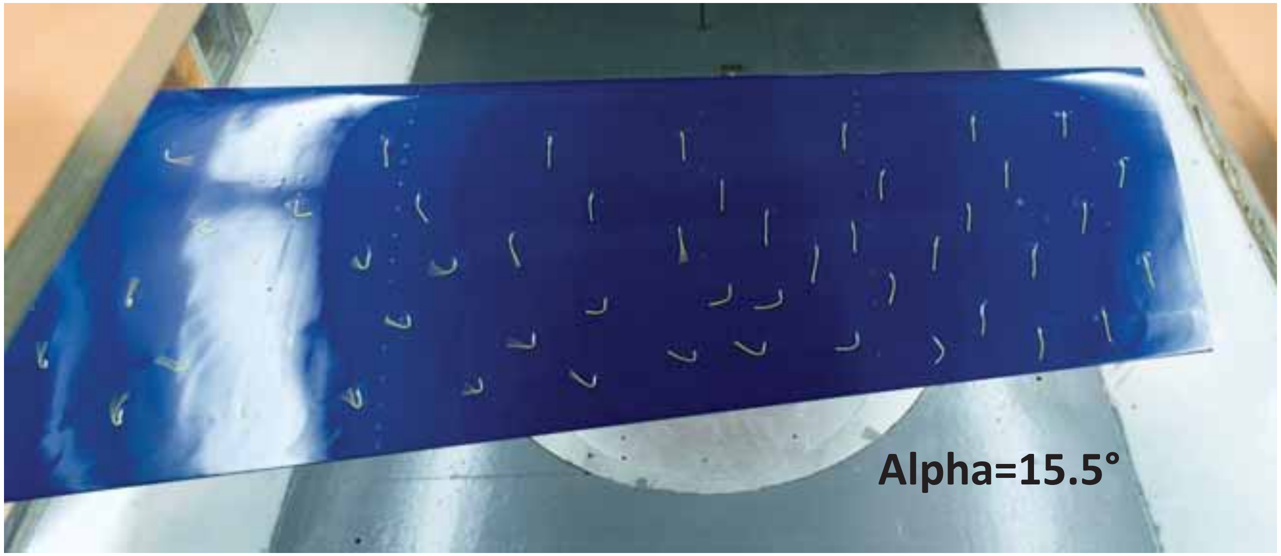
TEST RESULTS. Visualization with tufts





TEST RESULTS. Visualization with tufts





CONCLUSIONS

- Model design and building
- Force and pressure measurement
- Only small discrepancies at l.e. in a section
- Good comparison with numerical results

Further considerations (concerning stress and deformation) :

- It is difficult with a typical airplane structure and small dimensions to:
  - have very accurate reproduction of shape (especially at l.e.)
  - ensure reasonable deformations (especially torsional)
- Difficult to model constraint at root with connections through bolts